Petition

Before the United States Fish and Wildlife Service
United States Department of the Interior

April 12, 2023

Requesting Rulemaking to List the Southern Pig-Tailed Macaque (*Macaca nemestrina*) as a Threatened or Endangered Species Under the Endangered Species Act

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Research analyzing wild populations of southern pig-tailed macaques "paints a concerning outlook for the long-term survival of this species."[1] Data evidencing a population decline of at least fifty percent over the past thirty-three years (or three generations) led the International Union for Conservation of Nature (IUCN) to elevate the species' status from "vulnerable" to "endangered" on the IUCN Red List of Threatened Species in 2022. Primatologists expect that the population will continue to decline if threats to the species are not addressed.

The Endangered Species Act (ESA) requires the U.S. Fish and Wildlife Service (FWS or "Service") to list southern pig-tailed macaques as "endangered" or "threatened" if, throughout all or a significant part of their range, the species is in danger of extinction or is likely to become endangered within the foreseeable future. A single threatening factor can be sufficient to trigger listing status. But, here, the southern pig-tailed macaque is seriously threatened by multiple factors: (1) declining native habitats; (2) overutilization for scientific, commercial, and recreational purposes; (3) predation; and (4) inadequate regulatory mechanisms.

Records revealing high mean infant mortality dislodge the once-held perception that the southern pig-tailed macaque is adaptable to anthropogenic landscapes and less impacted by severe habitat disturbance and clear-cutting. As a species sensitive to these environmental transformations, as well as the threats posed by rampant trading (both legal and illegal), the outlook for the long-term survival of southern pig-tailed macaques is ominous.[2] Based on the petition herein, which summarizes, supplements, and incorporates by reference the IUCN's detailed 2022 Assessment, the petitioners urge the Service to list the southern pig-tailed macaque as an endangered or threatened species under the ESA.

II. INTRODUCTION

A. Petitioners

People for the Ethical Treatment of Animals (PETA) is a non-profit organization dedicated to protecting animals from abuse, neglect, and cruelty, and undertakes these efforts through public education, cruelty investigations, research, animal rescue, legislation, special events, celebrity involvement, protest campaigns, and lawsuits to enforce laws enacted to protect animals. Beginning in 1981 with an investigation that uncovered primates suffering in a Maryland research facility, PETA has spent decades exposing abusive and deadly experiments on primates and persistently champions ending the use of animals in experiments. For example, to further its work to end the importation of primates into the United States for experiments, PETA launched a campaign that persuaded major airlines to stop transporting primates, including southern pig-tailed macaques, into the United States for use in experiments. And, when the biomedical research community petitioned the Department of Transportation to take enforcement action against the airlines, PETA submitted extensive comments in opposition. In 2022, PETA's investigation of the Thai coconut industry's abusive use of captive primates—particularly southern pig-tailed

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[1] N. Ruppert et al., *Macaca nemestrina*, THE IUCN RED LIST OF THREATENED SPECIES 1 (2022), https://dx.doi.org/10.2305/IUCN.UK.2022-1.RLTS.T12555A215350982.en [hereinafter "IUCN 2022 Assessment"] [Ex. 1].

[2] *Id.* at 2.

macaques reportedly illegally abducted from their families and forced to pick coconuts—furthered its ongoing campaign to stop companies from sourcing canned coconut milk products from Thailand.[3]

Primatologist **Lisa Jones-Engel, Ph.D**. has studied the interface between humans and long-tailed and pig-tailed macaques in Indonesia, Singapore, Cambodia, Thailand, Myanmar and Bangladesh as well as in the primate biomedical facilities of the United States since the 1980s. Her scientific career has included field studies, research in the laboratory setting (most recently, the Washington National Primate Research Center), and teaching assignments. She has authored over 100 peer-reviewed articles, covering the fields of primatology, virology, epidemiology, microbiology, and conservation, and co-authored the IUCN 2022 Assessment. Dr. Jones-Engel currently serves as senior science advisor on primate experimentation with PETA's Laboratory Investigations Department.

Primatologist **Birutė Mary Galdikas, Ph.D**. has committed five decades to the conservation and study of primates in Indonesia. She is the world's authority on orangutans. Her field site in Indonesia is home to wild populations of long-tailed and pig-tailed macaques who share the rainforest with the orangutans. The Orangutan Foundation International, founded by Dr. Galdikas, takes a holistic and comprehensive approach with multiple complementary strategies to combat the complex challenges of conserving and protecting the animals and forests.

Dr. Jane Goodall, DBE, founder of the Jane Goodall Institute and UN Messenger of Peace, has for decades been a global champion for animal welfare and conservation. She travels the world asking each of us to take action on behalf of all living things and the planet we share.

Action for Primates is a UK-based project that advocates globally on behalf of non-human primates. Action for Primates recognizes that all animals, not just non-human primates, deserve respect and protection from harm by people.

Born Free USA is a leading wildlife charity, working for decades to end the exploitation of macaques and to enhance the survival of threatened species in the wild and protect natural habitats while respecting the needs and safeguarding the welfare of individual animals. They seek to have a positive impact on animals in the wild and protect their ecosystems in perpetuity, for their own intrinsic value and for the critical roles they play within the natural world.

Sarah Kite is co-founder of Action for Primates. She has spent decades working to bring awareness of the international trade and use of non-human primates, in particular macaques, for the global research and toxicity testing industries.

Dr Nedim Buyukmihci is Emeritus Professor of Veterinary Medicine at the School of Veterinary Medicine, University of California-Davis and co-founder of Action for Primates. His decades of non-human animal advocacy have included working on behalf of a wide range of

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[3] *See, e.g.*, Rebecca Ratcliffe, *HelloFresh Drops Thai Coconut Milk After PETA Monkey Labour Campaign*, THE GUARDIAN (Mar. 7, 2023), https://www.theguardian.com/us-news/2023/mar/07/hellofresh-drops-thai-coconut-milk-after-peta-monkey-labour-campaign [Ex. 2].

species, in particular macaques and other non-human primates. He has many years of experience co-managing sanctuaries, including for farmed animals and non-human primates, and a wildlife refuge.

Angela Grimes is Chief Executive Officer of Born Free USA, a wildlife conservation and animal welfare organization. For the past decade Angela has campaigned to ensure that long-tailed and pig-tailed macaques caught up in the wildlife, pet or laboratory trade are provided with sanctuary.

Dr. Liz Tyler-Griffin has worked in animal protection and conservation, with a particular focus on primates, for twenty years. She currently works as Programs Director for Born Free USA and runs one of the largest long-tailed and pig-tailed macaque sanctuaries in the United States.

The Macaque Coalition (MACC) was initiated in 2020 and is a working group of the Asia for Animals Coalition**.** MACC aims to collate and share information on the many welfare issues faced by macaques, and to facilitate networking and collaboration geared towards promoting respectful coexistence, alleviating their suffering, and protecting them at both the individual level and the species level. MACC produced the 2022 Macaque Report: Indonesia's Unprotected Macaques.

Ecoflix is a not-for-profit media group that educates, inspires and supports meaningful actions which will deliver a tangible, measurable difference in saving animals and restoring the planet. Dr. Ian Redmond**,** Head of Conservation for Ecoflix has spent decades raising awareness, through advocacy and research, about the trade in wildlife, including long-tailed and pig-tailed macaques.

Wildlife biologist and conservationist, **Dr. Ian Redmond** has devoted decades to protecting and advocating for conservation. He is the founder and chairman of the Ape Alliance, a coalition of organizations and individuals dedicated to the conservation and welfare of apes and other primates. The Ape Alliance Primate Trade Working Group publicize cases of illegal trade, and support efforts to repatriate confiscated live animals to the nearest suitable sanctuary to the point of origin.

Since 1973, under the leadership of our founder, Dr. Shirley McGreal, **International Primate Protection League** has spent decades fighting to protect and save macaques around the world. These significant efforts included fighting smugglers, exposing the fate of long-tailed and pig-tailed macaques in research labs, establishing a gibbon sanctuary and much more.

For decades, **Wildlife Alliance** has worked with stakeholders around the globe to combat the illegal wildlife trade in long-tailed macaques and other species.

Through lobbying, publishing research, training scientists, and attending and conducting scientific meetings, the **Physicians Committee for Responsible Medicine** is dedicated to the goal of eliminating the exploitation and use of macaques in testing across the globe.

Dr. Michael Schillaci is a Professor of Anthropology, University of Toronto Scarborough. Dr. Schillaci has spent two decades studying macaque morphology, growth, hybridization and evolution, including *Macaca fascicularis,* in addition to other macaque species. He has also been involved in research examining the consequences of human macaque interactions in Southeast Asia.

One Voice has been involved in the fight against animal experiments since its foundation about 30 years ago. With regard to macaques in particular, OneVoice fights against the fact that they are still being captured in the wild and bred, transported, and experimented. One Voice investigates, petitions, goes to court, analyses data and advocates on their behalf. The organization is also a member of the macaque coalition at an international level, in Asia for Animals.

Abolición Vivisección is a Spanish NGO born in 2021. Their activities started exposing the terrible conditions of the macaques imported and held in Camarney (Spain), the largest macaque farm for experimentation in Europe. Currently, their work focuses on raising awareness about the trafficking of macaques, the suffering of animals, and the futility of vivisection as a valid scientific method.

Dr. Sam Shanee is a conservation biologist/conservationist who has worked in Asia and South America for over 20 years. Much of his work is centered on the illegal wildlife trade and human-wildlife conflict resolution, and as such he has observed first-hand the multiple threats faced by both long-tailed and pig-tailed macaques.

Gemunu de Silva is the co-founder of Tracks Investigations, an ethical investigations agency providing investigative content to the animal protection sector world-wide. He has been an advocate for animals for over 35 years and has worked on a variety of global projects and campaigns, most notably his work investigating the international trade of primates for research in Vietnam, Cambodia and Mauritius for which he was awarded the special investigation prize by the RSPCA.

Northwest Animal Rights Network (NARN) is an animal rights organization based in the Pacific Northwest (PNW). NARN monitors the use of macaques in the PNW, and campaigns for those used in research in facilities around the PNW.

Pam Mendosa has worked with many primate species in the US and Africa, specializing in research protocols and wildlife rehabilitation. She is active in campaigning and activism and heads the current board of International Primate Protection League, supporting work to end the illegal pet trade and conserve primates in their native habitat.

Phoenix Zones Initiative (PZI) advocates for global and local policy changes that safeguard people, animals, and the environment against exploitation. PZI continues to promote dialogue about the importance of moving away from the use of long-tailed and pig-tailed macaques in biomedical research.

Dr. Hope Ferdowsian is a double-board certified internal medicine, preventive medicine, and public health physician, and co-founder and president of Phoenix Zones Initiative, a global nonprofit organization that advances the interdependent rights, health, and wellbeing of people, animals, and the planet through education, research, and advocacy. Over two decades, she has worked across six continents on policy to address human, animal, and environmental exploitation.

Dr. Nikhil Kulkarni is a board certified anesthesiologist and cofounder of Phoenix Zones Initiative, a global nonprofit organization that advances the interdependent rights, health, and wellbeing of people, animals, and the planet through education, research, and advocacy. Over the years, Dr. Kulkarni has worked with a number of organizations focused on the promotion of animal and environmental protection.

Neotropical Primate Conservation has been using primates as "flagship species" for community conservation projects for decades ensuring long term habitat protection for our flagship species and all wildlife that shares their habitats. Through this work they help local communities strengthen their stewardship of nature as well as protect their traditional and cultural identities, benefiting both humans and the environment.

The **EMS Foundation** is a not for profit organization based in South Africa, we believe that there is a need to conserve and protect non-human primate populations that are living in the wild because of land transformation and persecution by humans and the resultant fragmentation of populations and decline in numbers. The existential crisis non-human primates find themselves in, whether they are taken from the wild or bred in captivity, is closely tied to the insatiable and ever-proliferating demand to own and kill rare and exotic wild animals.

Tim Ajax, Executive Director of the **Oklahoma Primate Sanctuary**, has spent the last three decades working with captive non-human primates including many species of macaques such as long-tailed and pig-tailed macaques. Whether retired from research or rehomed from the exotic pet trade, Tim has worked tirelessly to provide a high-quality level of care with a focus on large enclosures where these intelligent primates can engage in normal behaviors.

Rise for Animals is a national animal rights organization on a mission to end animal experimentation. Their efforts to expose cruelty in labs, rescue animals, mobilize support, get laws passed, and advocate for innovative, humane, and effective research will end an outdated industry and free animals from cruelty. Founded as New England Anti-Vivisection Society, Rise for Animals has been working to free macaques and other non-human primates from biomedical research for decades. Ed Butler is the Executive Director at Rise for Animals. For more than twenty years he has worked on campaigns to save animals—including macaques.

Wildlife Friends Foundation Thailand is a registered foundation under Thai law. They campaign against all forms of animal abuse and exploitation in Thailand. WFFT actively seeks to combat the illegal wildlife trade in macaques and to rescue animals from poor conditions or exploitation from human entertainment.

The **Douc Langur Foundation**, headed by Dr. Lois Lippold, focuses on exposing and mitigating the poaching, trapping and illegal trade of primates from the forests of Southeast Asia.

Fundacion Entropika works closely with local stakeholders in South America, in community-led projects, educational and social programs, capacity building and empowerment of civil society, enforcing environmental and primate welfare laws and cooperative research.

Dr. Angela Maldonado, Project Director of Fundacion Entropika, is a primatologist, ecologist and conservationist working for over 20 years in the Colombian Amazon. Her work focuses on fighting the illegal wildlife trade and in helping local communities. She has been the recipient of multiple awards in recognition of her dedication to conservation.

Animal Defenders International, headed by Jan Creamer, has worked for decades to expose the violence and death that is associated with the capture, transport and use of long-tailed and pigtailed macaques destined for use in experiments.

World Animal Protection and Lindsay Oliver, World Animal Protection's Executive Director, fights to keep animals in the wild, where they belong.

Paula Pebsworth works in the area of human-primate coexistence and is currently the Head Scientist on a project run by the National Center for Wildlife in the Kingdom of Saudi Arabia to reduce human-baboon conflict. She has worked in India on projects to reduce human-macaque conflict.

Yuichi Hasegawa is the Executive Director of the **Japan Anti-Vivisection Association (JAVA)** which has been working for many years to eliminate the use of macaque monkeys, especially Japanese macaques, for animal experiments, entertainment, and culling.

The petitioners submit this petition with an interest in ensuring the protection of southern pig-tailed macaques under the ESA.

B. Endangered Species Act

Congress enacted the ESA of 1973, 16 U.S.C. §§ 1531−1544, "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved [and] to provide a program for the conservation of such endangered species and threatened species." 16 U.S.C. § 1531(b). An "endangered species" means "any species which is in danger of extinction throughout all or a significant portion of its range." *Id.* § 1532(6). A "threatened species" is one "which is likely to become an endangered species within the foreseeable future throughout all of or a significant portion of its range." *Id.* § 1532(20). Only those species listed as endangered or threatened receive the ESA's protection. The FWS, through the authority delegated to it by the Secretary of the Interior ("Secretary"), must list a species if the species qualifies as endangered or threatened because of any one of the following factors:

(A) the present or threatened destruction, modification, or curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;

> (C) disease or predation;
> (D) the inadequacy of existing regulatory mechanisms; or
> (E) other natural or manmade factors affecting its continued existence.

50 C.F.R. § 424.11(c); *see* 16 U.S.C. § 1533(a)(1); 50 C.F.R. § 402.01(b).

To prevent the Secretary from implementing the ESA haphazardly (i.e., "on the basis of speculation or surmise"), *Bennett v. Spear*, 520 U.S. 154, 176 (1997), the statute requires the listing determination to be made "solely on the basis of the best available scientific and commercial information regarding the species' status." 16 U.S.C. § 1533(b)(1)(A); 50 C.F.R. § 424.11(b).

Within ninety days after receiving a petition to list a species, the Secretary must determine "whether the petition presents substantial scientific or commercial information indicating that the petitioned action may be warranted." 16 U.S.C. § 1533(b)(3)(A). In other words, there must be "credible scientific or commercial information in support of the petition's claims such that a reasonable person conducting an impartial scientific review would conclude that the action proposed in the petition may be warranted." 50 C.F.R. § 424.14(h)(i).

The "reasonable person" standard is a "lesser standard"; a petition does not need to contain "conclusive evidence of a high probability of species extinction to warrant further consideration of listing that species." *Ctr. for Biological Diversity v. Morgenwreck*, 351 F. Supp. 2d 1137, 1141 (D. Colo. 2004). Rather, a petitioner must "simply show that the substantial information in the Petition demonstrates that listing of the species *may* be warranted." *Id.* (emphasis added). As described in 50 C.F.R. section 424.14(d), whether a particular listing petition provides "substantial" information depends on:

> (1) Information on current population status and trends and estimates of current population sizes and distributions, both in captivity and the wild, if available;
> (2) Identification of the factors under [16 U.S.C. § 1533(a)(1)] that may affect the species and where these factors are acting upon the species;
> (3) Whether and to what extent any or all of the factors alone or in combination identified in [16 U.S.C. § 1533(a)(1)] may cause the species to be an endangered species or threatened species . . . and, if so, how high in magnitude and how imminent the threats to the species and its habitat are;
> (4) Information on adequacy of regulatory protections and effectiveness of conservation activities by States as well as other parties, that have been initiated or that are ongoing, that may protect the species or its habitat.

If the Secretary finds that substantial information exists then, within twelve months after receiving the petition, the Secretary must review the species status and determine whether the species should be listed. *See* 16 U.S.C. § 1533(b)(3)(B). If the finding demonstrates that the petition is not warranted, the listing process ends but the negative finding may be judicially reviewed. *See* 16 U.S.C. § 1533(b)(3)(C)(ii).

III. NATURAL HISTORY[4]

A. Common Name

The common names for *Macaca nemestrina* are Southern Pig-tailed Macaque, Pig-tailed Macaque, Sunda Pig-tailed Macaque, and Sundaland Pigtail Macaque.[5] Throughout this petition, the species is referred to as "southern pig-tailed macaque."

B. Taxonomy

Kingdom	Animalia
Phylum	Chordata
Class	Mammalia
Order	Primates
Family	Cercopithecidae
Genus	*Macaca*
Species	*nemestrina*

Table 1. Taxonomy of *Macaca nemestrina*.[6]

C. Description

With a tail that has a pig-like appearance—short (i.e., 5−10 inches in length) and held semi-erect—southern pig-tailed macaques are light-brown in color but have darker hair on top of their heads and back.[7] Females measure between 15−19 inches in length and 10−13 pounds in weight.[8] Males measure between 20−23 inches in length, weigh between 12−26 pounds, and have mane-like hair framing their faces.[9] Fruits, supplemented by leaves, buds, flowers, and invertebrates comprise the majority of their diet.[10] The species is quadrupedal and generally remains on the ground except for when foraging and sleeping in trees.[11]

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[4] Refer to the IUCN 2022 Assessment [Ex. 1], pages 1, 6−7, for detailed notes on the species' natural history.

[5] IUCN Assessment, *supra* note 1, at 1; *Macaca nemestrina*, INTEGRATED TAXONOMIC INFO. SYS., https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=573021#null (last visited Mar. 31, 2023) [hereinafter "ITIS Report"] [Ex. 3].

[6] ITIS Report, *supra* note 5.

[7] K. Clare Quinlan, *Southern Pig-Tailed Macaque*, NEW ENGLAND PRIMATE CONSERVANCY (July 2022), https://neprimateconservancy.org/southern-pig-tailed-macaque/ [Ex. 4].

[8] *Id.*

[9] *Id.*

[10] *Id.*; IUCN 2022 Assessment, *supra* note 1, at 7.

[11] Quinlan, *supra* note 7; *see* IUCN 2022 Assessment, *supra* note 1, at 7 (citing Ruppert et al. 2018 [Ex. 5]).

D. Habitat

Southern pig-tailed macaques live in Southeast Asia’s dense tropical rainforests and occupy swamp, coastal, montane, and lowland forests.[12] Population densities are highest in primary forests, but the species also lives in secondary forests and agricultural areas (e.g., oil palm plantations).[13] The species’ habitat-elevation threshold is 1,900 m. above sea level but they are “best adapted to lowland and hill dipterocarp forests up to 900 m (Crockett and Wilson, 1980, Yanuar et al. 2009) and prefer dry forested grounds on the foot of hills and slopes (Bersacola et al. 2019).”[14]

IV. GEOGRAPHIC RANGE[15]

Southern pig-tailed macaques are native to Brunei Darussalam, Indonesia (Kalimantan, Sumatra), Malaysia (Peninsular Malaysia, Sabah, Sarawak), and Thailand.[16] Although the overall geographic area with reported presence of the species is large, the area occupied by the species is small in comparison.[17]

> For example, calculations for Peninsular Malaysia show that of the 131,600 km² available land area, only approximately half of it constitutes potential *Macaca nemestrina* habitat, with ca 68,000 km² lying in natural habitat sites such as primary and secondary forest (of which some lies above the 1,900 m elevation threshold beyond which the habitat is not suitable for this species), and ca 2,000 km² lying in oil palm plantations adjacent to forest (i.e., area calculated as a 500 m buffer zone from the forest edge into the plantation that macaques can potentially use to forage; B. Galea and N. Ruppert, unpublished data).[18]

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[12] Quinlan, *supra* note 7; IUCN 2022 Assessment, *supra* note 1, at 6.

[13] Quinlan, *supra* note 7.

[14] IUCN 2022 Assessment, *supra* note 1, at 6 (citing Crockett and Wilson 1980, Yanuar et al. 2009 [Ex. 6], Bersacola et al 2019).

[15] Refer to the IUCN 2022 Assessment [Ex. 1], pages 3–4, for detailed notes on the species’ geographic range.

[16] IUCN 2022 Assessment, *supra* note 1, at 3 (citing Groves 2001, Roos et al. 2014 [Ex. 7]).

[17] *Id.*

[18] *Id.*

Figure 1. Southern pig-tailed macaque distribution map.[19]

V. POPULATION STATUS AND TRENDS[20]

The IUCN documents a decreasing population trend.[21] Obtaining current, conclusive, population-size estimates has been fraught with difficulty given the challenges of encountering and counting wild macaques in the dense rainforest environment.[22] However, it is estimated that, between 1957 and 1975, the species' population in Peninsular Malaysia declined 43.7% (from 80,000 individuals to 45,000).[23] Further population decline has likely occurred given the magnitude and rate of forest conversion to other land use forms since 1975.[24] Across the broader distribution range, the IUCN suspects that the population decreased by at least fifty percent between 1989 and 2022 and that the rate will not improve in the next three generations (from 2022 to 2055),[25] based on the following:

> 1) ongoing habitat degradation across [the species'] range from 2001 to 2020 (e.g., 29% of tree cover loss in Malaysia; 16% to 41%

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[19] *Distribution Map*, IUCN (2022), https://www.iucnredlist.org/api/v4/assessments/215350982/distribution_map/jpg [Ex. 8].

[20] Refer to the IUCN 2022 Assessment [Ex. 1], pages 5–6, for detailed notes on the species' population status and trends.

[21] IUCN 2022 Assessment, *supra* note 1, at 6; *Southern Pig-Tailed Macaque*, IUCN, https://www.iucnredlist.org/species/12555/215350982 (last visited Mar. 31, 2023) [Ex. 9].

[22] *See* IUCN 2022 Assessment, *supra* note 1, at 5 (citing Bernstein 1967) (stating that there are "no conclusive reports about the current overall estimated population size of this species within their distribution range").

[23] *Id.* (citing IUCN SSC 1982 [Ex. 10]).

[24] *Id.*

[25] *Id.*

> tree cover loss across its range in Indonesia; Global Forest Watch 2022) which will certainly continue into the future;
>
> 2) evidence of local extirpation in former habitat sites (Holzner et al. 2021b);
>
> 3) evidence from the Pasoh Forest Reserve that highly degraded areas had a 10% decline in macaque site occupancy [between 2013 and 2017] (Holzner et al. 2021b); and
>
> [4]) a mean infant mortality rate of 66% (ranging from 30% to 100%) over an 8-year period (2014–2021) in/near oil palm plantations which already constitute a not-insignificant portion of the species' potential habitat [(A. Holzner and N. Ruppert, unpublished data)].[26]

These threats are in addition to other threats (discussed below), including trade, human-wildlife conflicts, and potential hybridization.

VI. THREATS[27]

Although this species is common in some parts of its range, the population size has been severely reduced in many other places due to habitat loss and degradation, capture for the increased demand for use in biomedical research, the pet trade, and subsistence hunting.[28] All of the statutory listing factors described in 16 U.S.C. § 1533(a)(1) threaten the species. While many of the factors are threats independent of other factors (e.g., overutilization), the severity is exacerbated when the factors work in combination (e.g., overutilization and inadequate regulatory mechanisms).

A. Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

Habitat loss and fragmentation in many parts of the southern pig-tailed macaque's range presents a serious threat. Natural forces (e.g., forest fires and droughts) and human activity (e.g., clear felling conducted to "expand monocultures, such as oil palm plantations, durian and rubber, for mining activities and urban and industrial expansion," and selective logging for timber extraction) threaten permanent loss to the species' prime habitat in lowland tropical rainforest.[29] Malaysia

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[26] *Id.* at 5, 6 (citing Global Forest Watch 2022, Holzner et al. 2021b [Ex. 11], Zainol et al. 2018 [Ex. 12]; *see also Malaysia*, GLOBAL FOREST WATCH, https://www.globalforestwatch.org/ (last visited Mar. 30, 2023) (click on "Dashboard" and select Malaysia) ("From 2001 to 2021, Malaysia lost 8.67Mha of tree cover, equivalent to a 29% decrease in tree cover since 2000."); *Indonesia*, GLOBAL FOREST WATCH, https://www.globalforestwatch.org/ (last visited Mar. 30, 2023) (click on "Dashboard" and select Indonesia (Kalimantan) and Indonesia (Sumatera) (indicating 17% to 42% tree cover loss across these regions from 2001 to 2021).

[27] Refer to the IUCN 2022 Assessment [Ex. 1], pages 1, 8−10, for detailed notes on threats to the species.

[28] IUCN 2022 Assessment, *supra* note 1, at 5.

[29] *Id.* at 8 (citing Global Forest Watch 2020, Global Forest Watch 2022, Meijaard et al. 2007, ASMC 2022).

reported the following loss in primary forest and tree cover between 2009 and 2019; the breakdown evidences a significant uptick in loss in more recent years.

Primary Forest Loss	
2002–2009	2010–2019
M ha (%)	
-.98 (-6.2%)	-1.65 (-11.0%)

Tree Cover Loss	
2002–2009	2010–2019
M ha (%)	
-0.47 (-1.6%)	-4.84 (-16.9%)

Table 2. Primary forest and tree cover loss in Malaysia 2002–2019.[30]

Between 2013 and 2017, the species "experienced a 10% decline in local site occupancy in heavily disturbed and clear-cut forest sites."[31]

The spread of African oil palm (*Elaeis guinees*) has been identified as the greatest threat to the populations in Indonesia and Malaysia.

> From 1967 to 2000, the area under oil palm cultivation [in Indonesia and Malaysia] increased from less than 2000 km^2 to more than 30,000 km^2. In 2011, 83,000 km^2 were planted with oil palm, including 20,000 km^2 in Peninsular Malaysia, 24,000 km^2 on Borneo, and 39,000 km^2 in Sumatra (Koh et al. 2011). In 2013, this number had grown to 116,000 km^2 (71,000 km^2 in Indonesia and 45,000 km^2 in Malaysia; Vijay et al. 2016), and the area planted with oil palm continues to increase rapidly (Meijaard and Sheil 2013). The establishment of oil palm monocultures does not only lead to loss of biodiversity but also contributes to habitat fragmentation and environmental pollution through chemical fertilizers or pesticide runoffs (reviewed in Fitzherbert et al. 2008), which directly affects *M. nemestrina*, who frequently uses plantations for short foraging bouts (Holzner et al. 2019, 2021a), and may thus get in direct and prolonged contact with dangerous chemicals, such as paraquat, which is a reportedly harmful herbicide (CDC 2018) still commonly used in Peninsular Malaysia (N. Ruppert, pers. obs.).[32]

The southern pig-tailed macaque's heavy dependence on intact forests "confirm[s] previous doubts on their ability to permanently persist in highly disturbed habitats."[33] Southern pig-tailed macaques frequently use oil palm plantations as a foraging ground but exclusively choose mature trees in the forest as the place for sleeping and conducting most social behaviors (e.g., grooming).[34] Notably, "no populations are reported that thrive in oil palm plantations far from natural forests."[35]

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[30] Rhett A Butler, *Rainforest Information*, MONGABAY (Aug. 14, 2020), https://rainforests.mongabay.com/ [Ex. 13].

[31] IUCN 2022 Assessment, *supra* note 1, at 8 (citing Holzner et al. 2021b [Ex. 11]).

[32] *Id.* (citing Koh et al. 2011 [Ex. 14], Vijay et al. 2016 [Ex. 15]; Meijaard and Sheil 2013 [Ex. 16], Fitzherbert et al. 2008 [Ex.17]; Holzner et al. 2019 [Ex. 18], Holzner et al. 2021a [Ex. 11]; CDC 2018 [Ex. 19]).

[33] *See id.* at 7 (citing Caldecott 1986).

[34] *See id.* 7 (citing Ruppert et al. 2018 [Ex. 5]).

[35] *See id.* (citing A. Holzner and N. Ruppert, unpublished data).

Furthermore, the infant mortality rate averages sixty-six percent in oil palm plantation habitats, confirming the unsuitability of this habitat for the species.[36]

B. Overutilization

Overutilization for scientific, commercial, and recreational purposes threatens the species. Between 53 and 136 individual southern pig-tailed macaques were exported annually from 2013−2018.[37] In 2017 and 2018, Indonesia led exportation and the United States led importation.[38] Southern pig-tailed macaques are bred (locally and internationally) in colonies for biomedical and behavioral research.[39] Specifically, they are sought for use in HIV/AIDS and other infectious disease research.[40]

Commercially, farmers exploit the species for coconut harvesting. Juvenile southern pig-tailed macaques begin "commerce training" at one or two years of age after farmers remove them from the wild.[41] While "extraction from the wild to meet the demand for coconut harvesting is perhaps the least documented," primatologists estimate that farmers in southern Thailand alone keep several thousand pig-tailed macaques (southern and northern pig-tailed macaques) for coconut harvesting.[42] The use of southern pig-tailed macaques in the coconut-plucking industry occurs in all range countries.[43]

Domestic trade for pets and entertainment and the influence of social media platforms further threaten the species.[44] As examples, in venues in Thailand, southern pig-tailed macaques perform "circus-like tricks" (e.g., ride bicycles, shoot basketballs, and perform push-ups), for paying customers.[45] In Indonesia, "1,274 individuals were offered for sale on Facebook in 2020/21 alone."[46] Malaysia has been a hot spot for illegal online pet trading.[47] An online search conducted in 2017/2018 of social media platforms in Malaysia showed consumer demand dictating a market

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[36] *See id.* at 6−7 (citing A. Holzner and N. Ruppert, unpublished data).

[37] *CITES Trade Database*, CITES (2022), https://trade.cites.org/ (last visited Apr. 3, 2023) (comparing gross imports and gross exports of live *Macaca nemestrina* from 2013–2018 for "all countries"). The IUCN 2022 Assessment cited to the CITES Trade Database (2022) as reporting "approximately 50–150 individuals exported per year between 2013–2020." IUCN 2022 Assessment, *supra* note 1, at 8.

[38] *See* IUCN 2022 Assessment, *supra* note 1, at 8; *CITES Trade Database*, *supra* note 37. Data describing the United States' importing numbers after 2018 does not appear in the CITES Trade Database. *See CITES Trade Database*, *supra* note 37.

[39] IUCN 2022 Assessment, *supra* note 1, at 8 (citing Sari et al. 2013 [Ex. 20]); *see also Primate Experimentation in Australia*, HUMAN RSCH. AUSTRALIA (Oct. 1, 2019), https://www.humaneresearch.org.au/primate-experimentation-in-australia/ [Ex. 21]; *Nonhuman Primate Resources*, ORIP 2 (2023), https://orip nih.gov/sites/default/files/ORIP_Nonhuman_Primate_Resources_Fact_Sheet.pdf [Ex. 22] (describing the breeding colonies maintained in the United States).

[40] IUCN 2022 Assessment, *supra* note 1, at 9 (citing as examples, Ha et al. 2000 [Ex. 23], Lee et al. 2021 [Ex. 24], Ritter et al 2013 [Ex. 25]).

[41] Devan Schowe et al., *Assessing the Welfare of Coconut-Harvesting Macaques in Thailand*, 242 APPLIED ANIMAL BEHAVIOR SCI. 2 (2021) https://www.sciencedirect.com/science/article/pii/S0168159121002021 [Ex. 26].

[42] *Id.*

[43] IUCN 2022 Assessment, *supra* note 1, at 9 (citing as an example, Bangkok Post 2015 [Ex. 27]).

[44] *See* IUCN 2022 Assessment, *supra* note 1, at 9.

[45] Nanchanok Wongsamuth, *Pay Coconuts, Get Monkeys*, BANGKOK POST (Sept. 6, 2015), https://www.bangkokpost.com/thailand/special-reports/681936/paycoconuts-get-monkeys [Ex. 27].

[46] IUCN 2022 Assessment, *supra* note 1, at 9 (citing "Anonymous, unpublished results").

[47] *See id.* (citing Zainol et al. 2018 [Ex. 12]).

price of $98 for a southern pig-tailed macaque—which was less than the range for the most frequently traded species (i.e., the dusky leaf monkey price ranged from $129 to $195) but more than the $61 price for the slow loris, another frequently traded species.[48]

C. Disease or Predation

Humans hunt and kill southern pig-tailed macaques for research, medicinal purposes, and food.[49] Human-wildlife conflict and the negative public perception of the species as "crop pests" have been described as "quite severe."[50] For example, between 2015 and 2020, the southern pig-tailed macaque repeatedly placed among the top five most complained about wildlife species to the Department of Wildlife and National Parks (DWNP) Peninsular Malaysia.[51]

D. Inadequacy of Existing Regulatory Mechanisms

This species is listed under Convention on International Trade in Endangered Species (CITES) Appendix II and thus is monitored and requires permits for international trade of live specimens and parts.[52] Only an export permit or re-export certificate is required; an import permit is not needed unless required by national law.[53] The IUCN 2022 Assessment acknowledges the protections already conferred in the species' geographic range.

> *Brunei*. The species is not protected but export is not allowed pursuant to the Brunei Wildlife Act 1978, updated 1984.[54]
>
> *Indonesia*. Although *Macaca nemestrina* is not listed as a protected species, the species is also not featured on the wildlife capture quota list.[55] Thus, "its capture from the wild is not

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[48] Muhammad Zaki Zainol et al., *Assessment of Illegal Online Primate Trade in Malaysia*, SCH. OF BIOLOGICAL SCIS. (August 2018), https://www.researchgate.net/publication/327933004_Assessment_of_illegal_online_primate_trade_in_Malaysia [Ex. 12].

[49] Kayla Ayers & Candace Vanderpoel, *Macaca nemestrina*, ANIMAL DIVERSITY (2009), https://animaldiversity.org/accounts/Macaca_nemestrina/ [Ex. 28].

[50] IUCN 2022 Assessment, *supra* note 1, at 8.

[51] *See, e.g.*, 2015 Annual Report 2015, PERHILITAN 166 (2015), https://www.wildlife.gov my/images/stories/penerbitan/laporan_tahunan/%5BSOFTCOPY%5DPERHILITAN-annual-report-2015.pdf [Ex. 29] (reporting 320 annual complaints); 2016 Annual Report, PERHILITAN (2016), at Appendix D, https://www.wildlife.gov.my/images/document/penerbitan/laporantahunan/LP2016%20-%2020022018.pdf [Ex. 30] (reporting 330 annual complaints); 2017 Annual Report, PERHILITAN 182 (2017), https://www.wildlife.gov.my/images/document/penerbitan/laporantahunan/LT2017.pdf [Ex. 31] (reporting 320 annual complaints); 2020 Annual Report, PERHILITAN 153 (2020), https://www.wildlife.gov my/images/document/penerbitan/laporantahunan/LT2020.pdf [Ex. 32] (reporting 363 annual complaints).

[52] *Macaca nemestrina*, CITES, https://cites.org/eng/taxonomy/term/1139 (last visited Mar. 22, 2023) [Ex. 33]; *Appendices*, CITES (Feb. 23, 2023), https://cites.org/eng/app/appendices.php [Ex. 34] (explaining that, when a species is included in Appendix II, "all parts and derivatives thereof are also included in the same Appendix); *How CITES Works*, CITES, https://cites.org/eng/disc/how.php (last visited Mar. 22, 2023) [Ex. 35].

[53] *How CITES Works*, *supra* note 52.

[54] IUCN 2022 Assessment, *supra* note 1, at 9.

[55] *Id.* (citing MOEF 2018 [Ex. 36], KLHK 2021); *see also* Malene F. Hansen et al., *Conservation of Long-Tailed Macaques: Implications of the Updated IUCN Status and the CoVID-19 Pandemic*, 35 PRIMATE CONSERVATION 5 (2021), https://www.researchgate.net/profile/Malene-Friis-Hansen-2/publication/349338354_Conservation_of_Long-tailed_Macaques_Implications_of_the_Updated_IUCN_Status_and_the_CoVID-19_Pandemic/links/602b825392851c4ed5752da6/Conservation-of-Long-tailed-Macaques-Implications-of-the-Updated-IUCN-Status-

> allowed."[56] Nonetheless, the rampant online pet trade of this species suggests that the zero harvest quota lacks stringent enforcement.[57]
>
> *Malaysia*. The species receives "protected" status—meaning a license is required for hunting, keeping, or trading—in Peninsular Malaysia under the Wildlife Conservation Act of 2010 (Act 716), in Sabah under the Wildlife Conservation Enactment of 1997 (Act 6 of 1997), and in Sarawak under the Wildlife Protection Ordinance of 1998.[58] The Wildlife Conservation Act of 2010 carves out subsistence hunting of the species by indigenous Malaysians in Peninsular Malaysia from the requirement.[59]
>
> *Thailand*. The southern pig-tailed macaque is not specifically listed on the Wild Animal Preservation and Protection Act, B.E. 2562 (2019), but the species "is given the general protection of wildlife, which restricts hunting and capture in all protected areas and forest lands."[60]

Yet, although *Macaca nemestrina* has been listed in CITES Appendix II since 1977,[61] the population has declined and is now considered endangered by the IUCN based on the levels of exploitation driven, in part, by trade. CITES' regulations have not adequately controlled the species trade.

E. Other Factors

Hybridization with other primates threatens the genetic integrity of the species. Hybridization with *Macaca fascicularis* has been observed in Sepilok, Sabah, and other parts of Malaysia.[62] And, where the southern pig-tailed macaque's range overlaps with *Macaca leonine* at the Surat Thani-Krabi depression, hybridization is expected.[63]

VII. CONCLUSION

The petitioners urge the Service to list the southern pig-tailed macaque (*Macaca nemestrina*) as an "endangered" or "threatened" species under the ESA. The species has experienced catastrophic population decline for decades, and primatologists expect this decline to continue without mitigating action. Southern pig-tailed macaques continue to lose significant portions of their habitat across their range, and this loss has been associated with "lower site occupancy, higher

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and-the-CoVID-19-Pandemic.pdf [Ex. 37] ("Since 2016, the quota for wild-caught macaques in Indonesia has been zero . . . .").

[56] IUCN 2022 Assessment, *supra* note 1, at 9.

[57] *See id.* at 8.

[58] *Id.* at 9.

[59] *Id.* (referring to Schedule 6 of the Wildlife Conservation Act of 2010 and citing Lappan and Ruppert 2019 [Ex. 38]).

[60] *Id.*

[61] *Taxon: Macaca nemestrina (Animalia)*, CITES, https://cites.application.developpement-durable.gouv.fr/viewtaxon.do?id=2570 [Ex. 39] (last visited Mar. 31, 2023).

[62] IUCN 2022 Assessment, *supra* note 1, at 1 (citing Gilhooly et al. 2021 [Ex. 40], N. Ruppert (pers. obs.)).

[63] *Id.* at 1, 5 (citing Malaivijitnond et al. 2012 [Ex. 41]).

infant mortality, and local extirpation."[64] Additional threats from the current levels of trade for scientific, commercial, and recreational purposes, and a general lack of protection (despite the laws in several habitat countries), are contributing to the species' disappearance. As a major importer of the species for experimentation, the United States adds pressure to the stressed population. The FWS has the authority and obligation to act swiftly and add the southern pig-tailed macaque to the list of animals protected under the ESA.

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[64] *See id.* at 5.

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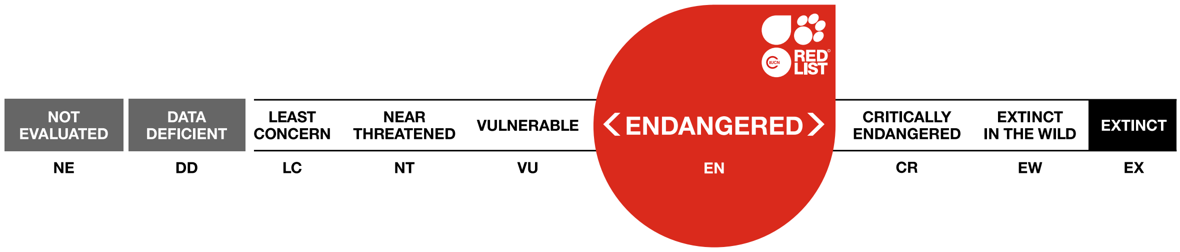
Exhibit 1

The IUCN Red List of Threatened Species™
ISSN 2307-8235 (online)
IUCN 2022: T12555A215350982
Scope(s): Global
Language: English

Macaca nemestrina, Southern Pig-tailed Macaque

Assessment by: Ruppert, N., Holzner, A., Hansen, M.F., Ang, A. & Jones-Engel, L.



View on www.iucnredlist.org

Citation: Ruppert, N., Holzner, A., Hansen, M.F., Ang, A. & Jones-Engel, L. 2022. *Macaca nemestrina*. *The IUCN Red List of Threatened Species* 2022: e.T12555A215350982. https://dx.doi.org/10.2305/IUCN.UK.2022-1.RLTS.T12555A215350982.en

Taxonomy

Kingdom	Phylum	Class	Order	Family
Animalia	Chordata	Mammalia	Primates	Cercopithecidae

Scientific Name: *Macaca nemestrina* (Linnaeus, 1766)

Synonym(s):

- *Macaca brachyurus* (Hamilton Smith, 1842)
- *Macaca broca* Miller, 1906
- *Macaca carpolegus* (Raffles, 1821)
- *Macaca fusca* (Shaw, 1800)
- *Macaca libidinosus* I. Geoffroy, 1826
- *Macaca longicruris* (Link, 1795)
- *Macaca maimon* (de Blainville, 1839)
- *Macaca nucifera* Sody, 1936
- *Macaca platypygos* (Schreber, 1774)

Common Name(s):

• English:	Southern Pig-tailed Macaque, Pig-tailed Macaque, Pigtail Macaque, Sunda Pig-tailed Macaque, Sundaland Pigtail Macaque
• French:	Macaque À Queue De Cochon
• Spanish; Castilian:	Macaca Cola De Cerdo
• German:	Südlicher Schweinsaffe
• Indonesian:	beruk

Taxonomic Notes:

This taxon was formerly treated as a subspecies of the *Macaca nemestrina* group, which comprised *M. n. nemestrina*, *M. n. leonina*, and *M. n. pagensis* (Fooden 1975, Rosenblum *et al.* 1997).

The boundary zone between *M. leonina* and *M. nemestrina* is not well defined and lies at the Surat Thani-Krabi depression (8-9°30'N) where ranges overlap and hybridization is likely to occur (Malaivijitnond *et al.* 2012). Formerly, there were reports of hybridization with *M. leonina* in a small area in southern mainland Thailand and on the islands of Phuket and Yao Yai (Fooden 1975, in Groves 2001), however more recent reports do not provide conclusive evidence of presence of a *M. nemestrina* population on Phuket (iNaturalist 2022, S. Malaivijitnond, pers. comm.). Hybridization of *M. nemestrina* with *M. fascicularis* also occurs in Sepilok, Sabah (Gilhooly *et al.* 2021) and is occasionally observed in other parts of Malaysia (N. Ruppert, pers. obs.).

Molecular clock analysis suggests that *M. nemestrina* arrived in the Malay Peninsula about 0.32 million years ago; and the Bornean populations are suggested to be the first extant lineages to have separated from the other examined lineages of *M. nemestrina*, *M. leonina*, *M. pagensis*, and *M. siberu* in Southeast Asia (Abdul-Latiff and Md-Zain 2021).

The population from Perak (west Peninsular Malaysia) is reported to differ genetically from other extant populations based on phylogenetic and population genetic analyses, indicating a possible subspecies distributed in the state of Perak (Abdul-Latiff and Md-Zain 2021).

Assessment Information

Red List Category & Criteria: Endangered A2cde+3cde ver 3.1

Year Published: 2022

Date Assessed: March 13, 2022

Justification:

This species is assessed as Endangered based on a suspected ongoing population reduction of at least 50% in the past three generations (approximately 33 years for this species), which is likely to continue into the future if the threats are not addressed. This population reduction is suspected due to the ongoing conversion of their prime habitat to other land use forms, leading to permanent habitat loss and degradation. This includes conversion of lowland tropical rainforest to large-scale oil palm monocultures and other crops (e.g., durian, rubber) and for mining activities through clear felling; habitat degradation due to selective logging for timber extraction and the construction of roads and linear infrastructure, and other large-scale urban and industrial development projects (e.g., the establishment of Indonesia's new capital city Nusantara in Kalimantan), draining of peat swamps, and seasonal forest burning that will likely become more severe due to predicted extreme weather events in the region. The incidences of road casualties have also steadily increased over the past years.

Although this species is reported to be able to make use of anthropogenically-impacted habitats such as agricultural landscapes and urban areas, it is sensitive to severe habitat disturbance and clear-cutting, leading to a local decline in site occupancy of 10% over four years from 2013 to 2017. A high recorded mean infant mortality of 66% (range 30–100% between 2014–2021) within the first year in disturbed habitat indicates that this species is not as adaptable to anthropogenic landscapes as previously thought.

Where the species persists, there is hunting and trapping for the illegal pet trade, for biomedical research and export, and for human consumption. They are often persecuted as crop pests and during other frequent human-macaque conflicts, leading to continued negative public perception of the species. Together with the observed extremely high annual infant mortality rate in human-impacted areas, possibly due to pollutants, and the inferred likely decrease in genetic diversity of populations in highly fragmented landscapes, this paints a concerning outlook for the long-term survival of this species.

Previously Published Red List Assessments

2020 – Vulnerable (VU)
https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T12555A181324867.en

2020 – Endangered (EN)
https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T12555A17950602.en

2008 – Vulnerable (VU)
https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T12555A3356892.en

2000 – Vulnerable (VU)

1996 – Vulnerable (VU)

1994 – Commercially Threatened (CT)

Geographic Range

Range Description:

This species is found in Brunei, Indonesia (Bangka, Kalimantan Borneo, and Sumatra), Malaysia (Peninsular Malaysia; Sabah and Sarawak in Borneo), and southern Thailand (from Surat Thani-Krabi depression N8–9° to the Malaysian border) (Groves 2001, Roos *et al*. 2014). It is apparently native to a few offshore islands such as Pulau Tioman (east coast of Peninsular Malaysia) and Batam (Riau Archipelago off the southern tip of the Malay peninsula) (Roos *et al*. 2014). There were small, introduced populations in the Natuna Islands (Groves 2001) and a few released individuals in Pulau Pinang and Singapore in the past that did not establish a viable population (N. Ruppert, A. Ang, pers. obs.).

The precise geographic boundary between *M. nemestrina* and *M. leonina* is not well-defined. There were previous reports of the two taxa found on either side of the assumed distribution limit in the Isthmus of Kra, but many of these small populations may have been the result of release by humans and the natural species boundary may lie further south at the Surat Thani–Krabi depression (N8–9°) as no recent reports of *M. nemestrina* indicate their presence further north of this area (iNaturalist 2022).

While the extent of occurrence (EOO) for this species is quite large (the overall geographical area with reported presence of this species sums up to *ca* 1.3 million km²) the actual area of occupancy (AOO) is likely much smaller and likely heavily fragmented. For example, calculations for Peninsular Malaysia show that of the 131,600 km² available land area, only approximately half of it constitutes potential *Macaca nemestrina* habitat, with *ca* 68,000 km² lying in natural habitat sites such as primary and secondary forest (of which some lies above the 1,900 m elevation threshold beyond which the habitat is not suitable for this species), and *ca* 2,000 km² lying in oil palm plantations adjacent to forest (i.e., area calculated as a 500 m buffer zone from the forest edge into the plantation that macaques can potentially use to forage; B. Galea and N. Ruppert, unpublished data).

The EOO, AOO, and habitat quality for this species continues to decline rapidly due to habitat degradation and loss, which are happening in Thailand, Peninsular Malaysia, Sumatra, and all parts of Borneo (Global Forest Watch 2020).

Country Occurrence:

Native, Extant (resident): Brunei Darussalam; Indonesia (Kalimantan, Sumatera); Malaysia (Peninsular Malaysia, Sabah, Sarawak); Thailand

Distribution Map

Legend

🟧 EXTANT (RESIDENT)

🟪 EXTANT & INTRODUCED (RESIDENT)

Compiled by:

IUCN (International Union for Conservation of Nature) 2022

Population

This species is common in some parts of its range, but numbers have been severely reduced in many other places due to habitat loss and degradation (e.g., IUCN SSC 1982, Meijaard *et al.* 2007), capture for the increased demand for use in biomedical research (e.g., Ha *et al.* 2000, Johnson *et al.* 2013, Ritter *et al.* 2013, Lee *et al.* 2021), the illegal pet trade (Zainol *et al.* 2018), and subsistence hunting (Bernstein 1967, Lappan and Ruppert 2019).

It is suspected that there has been at least a 50% reduction in population of the species in the last three generations (*ca* 33 years from 1989 to date) and that there will continue to be a 50% reduction in the population in the next three generations (*ca* 33 years from present day to 2055) if business-as-usual continues. This is suspected based on a range of data including: 1) ongoing habitat degradation across its range from 2001 to 2020 (e.g., 29% of tree cover loss in Malaysia; 16% to 41% tree cover loss across its range in Indonesia; Global Forest Watch 2022) which will certainly continue into the future; 2) evidence of local extirpation in former habitat sites (Holzner *et al.* 2021b); 3) evidence from the Pasoh Forest Reserve that highly degraded areas had a 10% decline in macaque site occupancy over a four-year period (Holzner *et al.* 2021b); and 3) a mean infant mortality rate of 66% (ranging from 30% to 100%) over an 8-year period (2014–2021) in/near oil palm plantations which already constitute a not-insignificant portion of the species' potential habitat. In summary, it is known that the species is losing (and has lost) significant portions of its habitat across its range and that where this has occurred, we have seen lower site occupancy, higher infant mortality, and local extirpation. There are additional threats to consider as well, including human-wildlife conflict, the ongoing live trade of the species (it is one of the top five primate species illegally traded online in Malaysia, Zainol *et al.* 2018), and potential hybridization (at the boundary zone between *M. leonina* and *M. nemestrina*; with *M. leonina* in a small area in southern mainland Thailand; and with *M. fascicularis* in Sepilok, Sabah and is occasionally observed in other parts of Malaysia; please see 'taxonomy' section for more information).

Additional supporting information is provided, below:

There are no conclusive reports about the current overall estimated population size of this species within their distribution range, as wild macaques are extremely elusive and difficult to encounter and count in a dense rainforest environment (Bernstein 1967). In Peninsular Malaysia, *M. nemestrina* is reported to have already experienced an estimated 43.7% population decline from 80,000 individuals in 1957 to 45,000 in 1975 (IUCN SSC 1982). Given the magnitude and rate of forest conversion to other land use forms since 1975, we suspect a substantial further population decline to have happened.

The species can persist in selectively-logged forests but is sensitive to severe habitat disturbance and clear-cutting, leading to a decline in site occupancy of 10% between 2013-2017 and local extirpation in former habitat sites (Holzner *et al.* 2021b).

A former census in west-central Sumatra (1996-1999) yielded density estimates of 1.7 groups/km^2 in lowland forest, 1.5 groups/km^2 in hill dipterocarp forest, 0.7 groups/km^2 in montane forest and 0.8 groups/km^2 in sub-montane forest (Yanuar *et al.* ^{2}2009). An assessment of habituated study groups in a mixed lowland dipterocarp forest-oil palm landscape in Perak, Peninsular Malaysia indicated approximately 1.5 groups/km^2 with group home range sizes of *ca*. 1 km^2 that partially overlap (Holzner *et al.* 2021a).

Group sizes appear to starkly vary between habitat types and study sites. In West Sumatra, the average group size of wild, unprovisioned *M. nemestrina* was assessed at 10–11 individuals (range 1–20) in hill dipterocarp forest, seven individuals (range 6–8) in montane forest, 9–10 individuals in sub-montane forest, and 8–9 individuals (range 1–13) in lowland forest (Yanuar *et al.* 2009), and ranged between 16–21 individuals (mean 18.3) for a Sumatran-wide survey (Crockett and Wilson 1980). However, Oi (1990) reported larger group sizes between 21 and 81 individuals in Sumatra, where animals were provisioned and observed at baiting sites. Numbers from wild, unprovisioned macaques reported from Peninsular Malaysia range between 15-50 individuals with mean group sizes estimated to fluctuate around 30 individuals of all sex-age classes (Caldecott 1986, Bernstein 1967, Ruppert *et al.* 2018, Holzner *et al.* 2021a). Temporary encounters of neighbouring groups may suggest the existence of large groups of over 80 individuals, but these aggregations are rare and usually only last for a few hours, as most inter-groups encounters are agonistic (N. Ruppert, pers. obs.). This may have also led to higher reported group sizes from baiting sites in Sumatra (Oi 1990).

It is estimated that in Peninsular Malaysia alone, oil palm plantations now constitute *ca* 3% of *M. nemestrina*'s potential habitat (B. Galea and N. Ruppert, unpublished data) that they enter from nearby forests for short foraging bouts (Ruppert *et al.* 2018). The conversion of their natural forest habitat into oil palm monocultures leads to changes in the activity budgets of *M. nemestrina*, with reduced sociality/affiliative social interactions and prolonged infant care in oil palm plantation habitat (compared to the forest). Ultimately, this may induce long-term changes in survival and fitness of these populations (Holzner *et al.* 2021a). The mean annual infant mortality rate (2014-2021) in this habitat type was estimated to be *ca* 66% within the first year of infant life, fluctuating from 30% in 2014 to 100% in 2019 (A. Holzner and N. Ruppert, unpublished data). This indicates a very low recruitment in anthropogenically-shaped landscapes, possibly due to the exposure to anthropogenic stressors, such as the presence of humans and agricultural pollution through large-scale pesticide and fertilizer use (N. Ruppert, pers. obs.). This high infant mortality is similar to wild macaques that are heavily exposed to tourism (e.g., *M. thibetana*: Berman *et al.* 2007), but much higher than in other wild species (e.g., ca. 17% in *M. maura*: Okamoto *et al.* 2000; *ca* 8% in *M. mulatta*: Southwick *et al.* 1980); and much higher than for this and other macaque species in captivity (e.g., *ca* 15% for captive *M. nemestrina*: Dazey and Erwin 1976; *ca* 13% for captive *M. fascicularis*: Erwin, 1977). An infant mortality rate of 66% is not assumed to be sustainable for this species.

Current Population Trend: Decreasing

Habitat and Ecology (see Appendix for additional information)

Macaca nemestrina occupies lowland primary and secondary forest, as well as coastal, swamp and montane forest. Although this species is known to occur from sea level up to ca. 1,900 m above sea level, they are best adapted to lowland and hill dipterocarp forests up to 900 m (Crockett and Wilson, 1980, Yanuar *et al.* 2009) and prefer dry forested grounds on the foot of hills and slopes (Bersacola *et al*. 2019). In Peninsular Malaysia, *M. nemestrina* occasionally visits lowland alluvial freshwater swamps (Ruppert *et al.* 2018) in search of fruits, such as *Salacca* and rattan (G. Villa and N. Ruppert, unpublished data).

This species is also frequently found around agricultural areas, hillside farms, and fringes of urban environments. Moreover, it has been reported in oil palm plantations (especially in Peninsular Malaysia and Borneo), both near to the forest edge and further inside the plantations (up to *ca* 500 m from the forest edge, Ruppert *et al.* 2018, Holzner *et al.* 2019, 2021a).

Macaca nemestrina lives in multi-male multi female groups and is often seen in association with long-tailed macaques (*M. fascicularis*). Interspecies interactions are common (N. Ruppert, pers. obs.) and hybridization can occur (Gilhooly *et al.* 2020). The species is diurnal and uses both terrestrial and arboreal habitat to travel and forage during the day. Adult males and females of a wild, habituated group of macaques spend most of their activity time (>50%; Ruppert *et al.* 2018) on the ground, but all individuals readily climb and forage in the trees. Previously, Caldecott (1986) reported *M. nemestrina* to spend only 8-10% of their activity time on the ground and 58–64% in the middle and upper canopy. The discrepancy from the above study may be explained by the lower habituation level of the animals observed by Caldecott (1986).

Although this species frequently uses oil palm plantations as a foraging ground, they exclusively choose mature trees in the forest as their sleeping sites (Ruppert *et al.* 2018). Similarly, resting and most social behaviours (e.g., grooming) are conducted mostly in the forest, even when their home ranges span over forest and oil palm plantation habitat, indicating that *M. nemestrina* heavily depends on intact nearby forest (Holzner *et al.* 2021a) and confirming previous doubts on their ability to permanently persist in highly disturbed habitats (Caldecott 1986). In this mixed habitat type, habituated groups exhibit different activity budgets in forest and oil palm plantation, spending most of their activity time in plantations on feeding and foraging (*ca* 70%) but most of their activity time in the forest on resting (*ca* 40%) (Holzner *et al.* 2021a). An adjusted overall activity budget assessed locomotion (*ca* 35%), feeding (*ca* 30%), resting (*ca* 15%) and foraging (*ca* 12%), social behaviour (*ca* 7%) and other behaviours during an 18-month study of this species in forest and oil palm plantation (Ruppert *et al.* 2018).

Macaca nemestrina is omnivorous. In Peninsular Malaysia, its diet in the forest consists of ripe and unripe fruits (32%), arthropods and invertebrates (32%), plant shoots and stems (15%), leaves (11%), and other items including small vertebrates, flowers, fungi and tree bark (Ruppert *et al.* 2018). Swarming termites, grasshoppers, other insects, spiders, fruits, seeds, young leaves, leaf stems, and fungi were also consumed elsewhere in the same region (Bernstein 1967). The macaques were found to act as key seed dispersers for non-climbing rattan species in a lowland dipterocarp forest in Malaysia (Ruppert *et al.* 2014).

In agricultural lands, they are known to feed on crops of oil palm (Holzner *et al.* 2019), corn, eggplants, chili pepper, and tapioca, reportedly able to forage on crops until a favourite crop such as corn is completely consumed (Crockett and Wilson 1980). They are also reported to crop forage on rice, papaya and banana crops, causing more damage compared to other crop-foraging species in Sumatra (Linkie *et al.* 2007). In Peninsular Malaysia, *M. nemestrina* was found to regularly feed on rats that they actively hunt in oil palm plantations, indicating a potential role as a biological pest control agent (as one group of macaques kills *ca* 3,000 rats per year, Holzner *et al.* 2019). However, this does not necessarily indicate healthy populations in monocultural landscapes as the very high infant mortality in this habitat type does not deem it suitable for the species and no populations are reported that thrive in oil palm plantations far from natural forests (A. Holzner and N. Ruppert, unpublished data).

Systems: Terrestrial

Use and Trade

The species is trapped for use in biomedical research (e.g., Ha *et al.* 2000, Ritter *et al.* 2013, Lee *et al.* 2021), hunted for food (Lappan and Ruppert 2019) and the illegal pet trade (Zainol *et al.* 2018), and as working animals in the coconut-plucking industry (e.g., Bernstein 1976, Choong 2019). Pet trade occurs in local markets and has also moved online to social media platforms such as Facebook. For example, in Indonesia, 1,274 individuals were offered for online sale from 2020 to 2021 alone (Anonymous, unpublished data). The legality of this is questionable, as the species is not protected in Indonesia (MOEF, 2018), however, the wild harvest quota for the species is zero and therefore capture from the wild is illegal (KLHK, 2021). In Malaysia, this species belongs to the Top-5 primate species illegally traded as pets on online platforms, reaching a trading value of *ca* 100 USD per infant (Zainol *et al.* 2018).

Locally and internationally, this species is bred in colonies for biomedical and behavioural research, for example in Bogor, Indonesia (Sari *et al*. 2013), Australia (HRA 2022) and the USA (e.g., ORIP 2021). It is traded with approximately 50–150 individuals exported per year between 2013–2020 (CITES Trade Database 2022). Indonesia used to be a main exporter, but there is currently no trade quota on the species.

Threats **(see Appendix for additional information)**

This species is threatened by habitat loss, which is very serious in many parts of its range. There has been extensive loss and degradation of lowland forest in Malaysia and Indonesia through clear felling to expand monocultures such as oil palm plantations, durian and rubber, for mining activities and urban and industrial expansion (Global Forest Watch 2020, 2022), as well as habitat loss/degradation through selective logging for timber extraction and forest fires/drought (Meijaard *et al.* 2007, ASMC 2022).

Habitat loss and fragmentation through the spread of African oil palm (*Elaeis guineens*) seems the greatest threat to its populations, both in Indonesia and Malaysia. From 1967 to 2000, the area under oil palm cultivation here increased from less than 2000 km² to more than 30,000 km². In 2011, 83,000 km² were planted with oil palm, including 20,000 km² in Peninsular Malaysia, 24,000 km² on Borneo, and 39,000 km² in Sumatra (Koh *et al.* 2011). In 2013, this number had grown to 116,000 km² (71,000 km² in Indonesia and 45,000 km² in Malaysia; Vijay *et al.* 2016), and the area planted with oil palm continues to increase rapidly (Meijaard and Sheil 2013). The establishment of oil palm monocultures does not only lead to loss of biodiversity but also contributes to habitat fragmentation and environmental pollution through chemical fertilizers or pesticide runoffs (reviewed in Fitzherbert *et al.* 2008), which directly affects *M. nemestrina,* who frequently uses plantations for short foraging bouts (Holzner *et al.* 2019, 2021a), and may thus get in direct and prolonged contact with dangerous chemicals, such as paraquat, which is a reportedly harmful herbicide (CDC 2018) still commonly used in Peninsular Malaysia (N. Ruppert, pers. obs.).

During the past decade, Malaysia alone has lost 11.3% of its primary forest and 16.8% of tree cover (Mongabay, 2021) and *Macaca nemestrina* is reported to be sensitive to timber harvest (Meijaard *et al.* 2007), and has experienced a 10% decline in local site occupancy in heavily disturbed and clear-cut forest sites over a period of only four years, recently (2013-2017; Holzner *et al.* 2021b).

Human-wildlife conflict and a generally negative public perception of this species is quite severe. *Macaca nemestrina* has consistently been in the Top-5 list of public complaints about wildlife filed to the

Department of Wildlife and National Parks Peninsular Malaysia (mean 298 annual complaints between 2013-2018 for Peninsular Malaysia alone; DWNP 2018). Negative public perceptions also occur due to crop foraging, which results in the macaques being perceived as pests. A study on crop foraging by Linkie *et al.* (2007) in Sumatra found that *M. nemestrina* was one of the most frequently reported crop foragers for rice, banana and papaya here. However, in Peninsular Malaysia, it was shown that *M. nemestrina* frequently forages in oil palm plantations but causes little damage to ripe oil palm fruits (<0.6%); it instead contributes to increasing oil palm yield by foraging on pest rodents in plantations (Holzner *et al.* 2019). However, due to the high infant mortality, palm oil plantations are not suitable habitats for the species, and it needs healthy forest adjacent to the plantations. Also, the publication by Holzner *et al.* (2019) led to a misunderstanding regarding the role of the species in oil palm plantations and its habitat needs, with the public assuming the species would thrive in oil palm plantations alone, which is not the case (N. Ruppert, pers. obs.).

In all range countries, the species along with *M. leonina* is used in the coconut plucking industry and the entertainment industry, which further threatens its survival (e.g., Bangkok Post 2015).

There is ongoing and active trade of the species, especially in Indonesia, where the species is still offered for sale in markets, and 1,274 individuals were offered for sale on Facebook in 2020/21 alone (Anonymous, unpublished results). The illegal online pet trade of this species is also rampant in Malaysia (Zainol *et al.* 2018). *Macaca nemestrina* is increasingly sought for use in biomedical science studies for HIV/AIDS and other infectious disease research (e.g., Ha *et al.* 2000, Lee *et al.* 2021, Ritter *et al.* 2013), and hunted for food (Bernstein 1967, Lappan and Ruppert 2019).

Conservation Actions **(see Appendix for additional information)**

This species is listed under CITES Appendix II. It is not listed as a protected species in Indonesia (MOEF, 2018), but as it does not currently feature on the wildlife capture quota list, its capture from the wild is not allowed (KLHK 2021).

Protected status of *Macaca nemestrina* is warranted in Peninsular Malaysia under the Wildlife Conservation Act of 2010 (Act 716), in Sabah under the Wildlife Conservation Enactment of 1997 (Act 6 of 1997), and in Sarawak under the Wildlife Protection Ordinance of 1998. “Protected” indicates that no hunting, keeping, or trade is permitted without a licence, which can be obtained from the relevant wildlife authority in each jurisdiction. Hunting for food is a traditional practice among indigenous hunter-gatherers in Malaysia and Schedule 6 of the Wildlife Conservation Act of 2010 provides for an exception for subsistence hunting of *M. nemestrina* by indigenous Malaysians in Peninsular Malaysia (Lappan and Ruppert, 2019).

In Thailand, it is not specifically listed on the Wild Animal Preservation and Protection Act, B.E. 2562 (2019), but it is given the general protection of wildlife, which restricts hunting and capture in all protected areas and forest lands.

The species is not protected in Brunei, however no export is allowed (Brunei Wildlife Act 1978, updated 1984).

Finally, the effectiveness of protected areas should be assessed for this species, as these areas seem to be strongholds for *M. nemestrina*. The majority land-use classification for remnant habitat is logging concession, and the selective extraction of mature trees may further negatively impact their persistence, given their reliance on trees as foraging and sleeping sites in the forest.

Further studies are needed into the distribution, abundance, ecology and threats to this species.

Credits

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Authority/Authorities:	IUCN SSC Primate Specialist Group

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External Resources

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Appendix

Habitats

(http://www.iucnredlist.org/technical-documents/classification-schemes)

Habitat	Season	Suitability	Major Importance?
1. Forest -> 1.6. Forest - Subtropical/Tropical Moist Lowland	-	Suitable	Yes
1. Forest -> 1.7. Forest - Subtropical/Tropical Mangrove Vegetation Above High Tide Level	-	Suitable	No
1. Forest -> 1.8. Forest - Subtropical/Tropical Swamp	-	Suitable	No
1. Forest -> 1.9. Forest - Subtropical/Tropical Moist Montane	-	Suitable	Yes
3. Shrubland -> 3.6. Shrubland - Subtropical/Tropical Moist	-	Marginal	-
14. Artificial/Terrestrial -> 14.1. Artificial/Terrestrial - Arable Land	-	Marginal	-
14. Artificial/Terrestrial -> 14.3. Artificial/Terrestrial - Plantations	-	Marginal	-
14. Artificial/Terrestrial -> 14.4. Artificial/Terrestrial - Rural Gardens	-	Marginal	-
14. Artificial/Terrestrial -> 14.5. Artificial/Terrestrial - Urban Areas	-	Marginal	-
14. Artificial/Terrestrial -> 14.6. Artificial/Terrestrial - Subtropical/Tropical Heavily Degraded Former Forest	-	Marginal	-

Use and Trade

(http://www.iucnredlist.org/technical-documents/classification-schemes)

End Use	Local	National	International
1. Food - human	Yes	Yes	No
13. Pets/display animals, horticulture	Yes	Yes	No
14. Research	Yes	No	Yes
17. Other (free text)	Yes	Yes	No

Threats

(http://www.iucnredlist.org/technical-documents/classification-schemes)

Threat	Timing	Scope	Severity	Impact Score
1. Residential & commercial development -> 1.1. Housing & urban areas	Ongoing	Majority (50-90%)	Causing/could cause fluctuations	Medium impact: 6
	Stresses:	1. Ecosystem stresses -> 1.1. Ecosystem conversion 1. Ecosystem stresses -> 1.2. Ecosystem degradation		

1. Residential & commercial development -> 1.2. Commercial & industrial areas	Ongoing	Majority (50-90%)	Causing/could cause fluctuations	Medium impact: 6
1. Residential & commercial development -> 1.3. Tourism & recreation areas	Ongoing	Majority (50-90%)	Causing/could cause fluctuations	Medium impact: 6
2. Agriculture & aquaculture -> 2.1. Annual & perennial non-timber crops -> 2.1.1. Shifting agriculture	Ongoing	Majority (50-90%)	Slow, significant declines	Medium impact: 6
	Stresses:	1. Ecosystem stresses -> 1.1. Ecosystem conversion 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
2. Agriculture & aquaculture -> 2.1. Annual & perennial non-timber crops -> 2.1.2. Small-holder farming	Ongoing	Majority (50-90%)	Slow, significant declines	Medium impact: 6
	Stresses:	1. Ecosystem stresses -> 1.1. Ecosystem conversion 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
2. Agriculture & aquaculture -> 2.1. Annual & perennial non-timber crops -> 2.1.3. Agro-industry farming	Ongoing	Majority (50-90%)	Very rapid declines	High impact: 8
	Stresses:	1. Ecosystem stresses -> 1.1. Ecosystem conversion 1. Ecosystem stresses -> 1.2. Ecosystem degradation		
2. Agriculture & aquaculture -> 2.2. Wood & pulp plantations -> 2.2.2. Agro-industry plantations	Ongoing	Majority (50-90%)	Very rapid declines	High impact: 8
2. Agriculture & aquaculture -> 2.3. Livestock farming & ranching -> 2.3.3. Agro-industry grazing, ranching or farming	Ongoing	Majority (50-90%)	Causing/could cause fluctuations	Medium impact: 6
3. Energy production & mining -> 3.1. Oil & gas drilling	Ongoing	Minority (50%)	Rapid declines	Medium impact: 6
4. Transportation & service corridors -> 4.1. Roads & railroads	Ongoing	Minority (50%)	Rapid declines	Medium impact: 6
5. Biological resource use -> 5.1. Hunting & trapping terrestrial animals -> 5.1.1. Intentional use (species is the target)	Ongoing	Majority (50-90%)	Causing/could cause fluctuations	Medium impact: 6
	Stresses:	2. Species Stresses -> 2.1. Species mortality		
5. Biological resource use -> 5.1. Hunting & trapping terrestrial animals -> 5.1.3. Persecution/control	Ongoing	Minority (50%)	Slow, significant declines	Low impact: 5
	Stresses:	2. Species Stresses -> 2.1. Species mortality		
6. Human intrusions & disturbance -> 6.1. Recreational activities	Ongoing	Majority (50-90%)	Slow, significant declines	Medium impact: 6
7. Natural system modifications -> 7.1. Fire & fire suppression -> 7.1.1. Increase in fire frequency/intensity	Ongoing	Minority (50%)	Causing/could cause fluctuations	Low impact: 5
7. Natural system modifications -> 7.3. Other ecosystem modifications	Ongoing	Minority (50%)	Causing/could cause fluctuations	Low impact: 5
9. Pollution -> 9.3. Agricultural & forestry effluents -> 9.3.3. Herbicides and pesticides	Ongoing	Majority (50-90%)	Slow, significant declines	Medium impact: 6

10. Geological events -> 10.2. Earthquakes/tsunamis	Ongoing	Minority (50%)	Causing/could cause fluctuations	Low impact: 5
11. Climate change & severe weather -> 11.2. Droughts	Ongoing	Majority (50-90%)	Slow, significant declines	Medium impact: 6
11. Climate change & severe weather -> 11.4. Storms & flooding	Ongoing	Majority (50-90%)	Slow, significant declines	Medium impact: 6

Conservation Actions in Place

(http://www.iucnredlist.org/technical-documents/classification-schemes)

Conservation Action in Place
In-place research and monitoring
Action Recovery Plan: No
Systematic monitoring scheme: No
In-place land/water protection
Conservation sites identified: No
Area based regional management plan: No
Occurs in at least one protected area: Yes
Invasive species control or prevention: Not Applicable
In-place species management
Harvest management plan: No
Successfully reintroduced or introduced benignly: No
Subject to ex-situ conservation: No
In-place education
Subject to recent education and awareness programmes: Yes
Included in international legislation: Yes
Subject to any international management / trade controls: Yes

Conservation Actions Needed

(http://www.iucnredlist.org/technical-documents/classification-schemes)

Conservation Action Needed
1. Land/water protection -> 1.1. Site/area protection
1. Land/water protection -> 1.2. Resource & habitat protection
2. Land/water management -> 2.1. Site/area management

Conservation Action Needed
2. Land/water management -> 2.3. Habitat & natural process restoration
3. Species management -> 3.1. Species management -> 3.1.2. Trade management
5. Law & policy -> 5.1. Legislation -> 5.1.2. National level
5. Law & policy -> 5.4. Compliance and enforcement -> 5.4.2. National level

Research Needed

(http://www.iucnredlist.org/technical-documents/classification-schemes)

Research Needed
1. Research -> 1.2. Population size, distribution & trends
1. Research -> 1.3. Life history & ecology
1. Research -> 1.4. Harvest, use & livelihoods
1. Research -> 1.5. Threats
1. Research -> 1.6. Actions
3. Monitoring -> 3.1. Population trends
3. Monitoring -> 3.3. Trade trends
3. Monitoring -> 3.4. Habitat trends

Additional Data Fields

Distribution
Continuing decline in area of occupancy (AOO): Yes
Continuing decline in extent of occurrence (EOO): Yes
Upper elevation limit (m): 1,900
Population
Continuing decline of mature individuals: Yes
Extreme fluctuations: Unknown
Population severely fragmented: Yes
Habitats and Ecology
Continuing decline in area, extent and/or quality of habitat: Yes
Generation Length (years): 11

The IUCN Red List Partnership

The IUCN Red List of Threatened Species™ is produced and managed by the IUCN Global Species Programme, the IUCN Species Survival Commission (SSC) and The IUCN Red List Partnership.

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Exhibit 2

Peta

HelloFresh drops Thai coconut milk after Peta monkey labour campaign

Thai government rejects Peta's claims, saying the practice of using monkeys to harvest is rarely used in industry

Rebecca Ratcliffe *in Bangkok*

Tue 7 Mar 2023 12.36 EST

The meal kit provider HelloFresh has said it will no longer sell coconut milk sourced from Thailand, after campaigning by an animal rights group that accused coconut farms in the country of using monkey labour.

The company confirmed to Axios that it does not tolerate "any form of animal abuse in our supply chain" and "out of an abundance of caution" will not be placing orders for coconut milk from Thailand. HelloFresh has not yet responded to the Guardian's request for comment.

Several companies have stopped selling some Thai coconut products over recent years after campaigning by Peta, which said that it had investigated Thai coconut farms and found chained monkeys that were forced to spend long hours climbing trees and picking coconut. Abuse of primates was "rampant", the group has said.

The Thai government has rejected the Peta's claims of widespread abuse, saying the traditional practice of using monkeys to harvest coconuts is almost nonexistent in industry, which, due to its scale, instead depends upon human labour and machinery.

In 2021, Thailand exported 236,323 metric tonnes of coconut milk, worth 12,800 million baht, according to the department of agriculture. It has begun issuing certificates to farms to verify that they are monkey-free to address concerns over animal cruelty.

Vincent Nijman, anthropology professor and head of the Oxford Wildlife Trade Research Group at Oxford Brookes University, who has researched the welfare of coconut-harvesting macaques in Thailand, said the practice is largely confined to the southernmost part of Thailand and involves the northern and southern pig-tailed macaques. The former is listed as vulnerable on the International Union for Conservation of Nature red list, while the latter is endangered.

A recent study co-authored by Nijman found that the needs of the pig-tailed macaques kept for coconut-harvesting - such as the ability to move freely and unrestrained, and to hide from stressors - were largely not met in such contexts.

It is probably the case that such monkeys are based on small farms catering to local consumption, he said, rather than farms that produce coconuts for exports.

A training session at a monkey school for coconut harvesting in Thailand. Photograph: Athit Perawongmetha/Reuters

“The total volume that potentially could be picked by macaques is small, certainly in light of the total number of coconuts that are being picked,” said Nijman. “The vast majority of coconut and coconut products do not come from farms where pig-tailed macaques are employed.”

Estimates regarding the numbers of macaques picking coconuts on farms vary, with some suggesting up to 3,000 pig-tailed macaques are involved, said Nijman. “Given that you cannot use animals that are too young, and once [they], especially the males, become fully grown they become more difficult to work with, there is only a few years’ window during which you can work with the macaques,” he said, adding that, because of this turnover, it is estimated that the number of pig-tailed macaques that need to be extracted from the wild is in the low hundreds each year.

The main export market for Thai coconuts is China, he added.

Responding to HelloFresh’s decision to stop sourcing from Thailand, Peta’s senior vice-president, Jason Baker, said: “HelloFresh’s decision will help protect monkeys from being kidnapped, chained, and whipped in the coconut trade. HelloFresh is helping Peta push the Thai coconut industry and government away from using and abusing monkeys.”

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Exhibit 3

ITIS

Integrated Taxonomic Information System - Report

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Macaca nemestrina (Linnaeus, 1766)

Taxonomic Serial No.: 573021

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Taxonomy and Nomenclature

Kingdom:	Animalia
Taxonomic Rank:	Species
Synonym(s):	Macacus brachyurus (Hamilton Smith, 1842) Macaca broca Miller, 1906 Simia carpolegus Raffles, 1821 Simia fusca Shaw, 1800 Macaca libidinosus I. Geoffroy Saint-Hilaire, 1826 Simia longicruris Link, 1795 Pithecus maimon de Blainville, 1839 Simia platypygos Schreber, 1774 Macaca nemestrina nucifera Sody, 1936
Common Name(s):	Sunda Pig-tailed Macaque [English] Southern Pig-tailed Macaque [English]

Taxonomic Status:

Current Standing:	valid

Data Quality Indicators:

Record Credibility Rating:	verified - standards met

Taxonomic Hierarchy

Kingdom	Animalia – Animal, animaux, animals
Subkingdom	Bilateria
Infrakingdom	Deuterostomia
Phylum	Chordata – cordés, cordado, chordates
Subphylum	Vertebrata – vertebrado, vertébrés, vertebrates
Infraphylum	Gnathostomata
Superclass	Tetrapoda
Class	Mammalia Linnaeus, 1758 – mammifères, mamífero, mammals
Subclass	Theria Parker and Haswell, 1897
Infraclass	Eutheria Gill, 1872
Order	Primates Linnaeus, 1758 – homem, macaco, primata, sagui, primates, primates
Suborder	Haplorrhini Pocock, 1918
Infraorder	Simiiformes Haeckel, 1866
Superfamily	Cercopithecoidea Gray, 1821
Family	Cercopithecidae Gray, 1821 – Old World monkeys
Subfamily	Cercopithecinae Gray, 1821 – cercopithecines
Tribe	Papionini – papionins
Genus	Macaca Lacépède, 1799 – macaques
Species	Macaca nemestrina (Linnaeus, 1766) – Sunda Pig-tailed Macaque, Southern Pig-tailed Macaque

References

Expert(s):

Expert: Anthony B. Rylands
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Other Source(s):

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Acquired:
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Article/Chapter Title:
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Page(s): xxxv + 743
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Geographic Information

Geographic Division:	Southern Asia
Jurisdiction/Origin:	

Comments

Comment:	Status: CITES - Appendix II; IUCN - Vulnerable Comments: M. nemestrina species group. Includes pagensis according to Fooden (1975:67, 1980:7) and Szalay and Delson (1979); but Wilson and Wilson (1977:216) considered pagensis a distinct species, and this was followed by Groves (2001c)

Species *Macaca nemestrina* (Linnaeus, 1766) contains:

Subordinate Taxa	Rank	Verified Standards Met	Verified Min Standards Met	Unverified	Percent Standards Met

Search on: ● Any Name or TSN ○ Common Name ○ Scientific Name ○ TSN

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Exhibit 4

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SOUTHERN PIG-TAILED MACAQUE

Macaca nemestrina

Southern Pig-Tailed Macaque

Macaca nemestrina

CONSERVATION STATUS: ENDANGERED

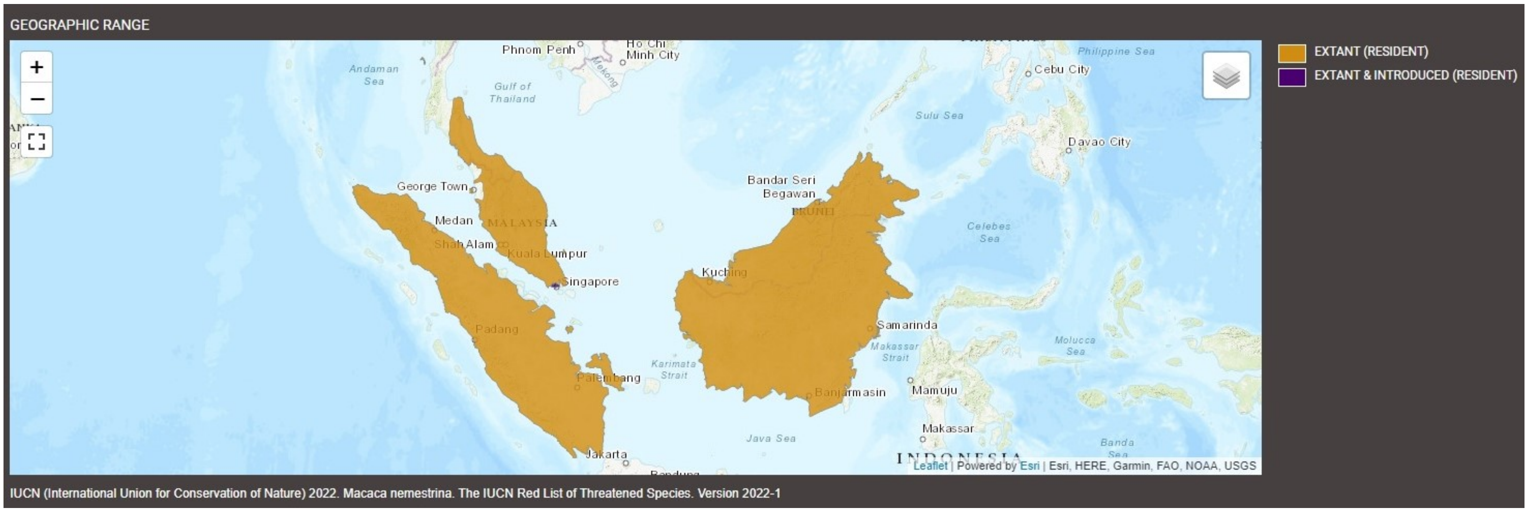
- Also called Sunda or Sundaland pig-tailed macaques
- Native to Brunei, Indonesia, Malaysia, and Thailand, with introduced populations in Singapore and the Natuna Islands
- They are at home in a variety of habitats from dense tropical forests to agricultural sites
- Threatened by on-going habitat loss due to conversion of their forests to other land-use forms, as well as hunting, collection for the pet trade and biomedical research, and they are persecuted as pests

Geographic Distribution and Habitat

Southern pig-tailed macaques (*Macaca nemestrina*), also known as Sunda or Sundaland pig-tailed macaques, are native to Brunei, Indonesia, Malaysia, and Thailand, and have also been introduced to areas of Singapore and the Natuna Islands. They are well at home in the dense tropical rainforests of southeast Asia, usually occupying lowland, coastal, swamp, and montane forests. While they are found in the highest population densities in primary forests, they can also live in secondary forests, and are even found living in agricultural areas, such as oil palm plantations. While they are found from sea level to 6,200 feet (1,900 m) in elevation, they tend to prefer the higher elevations and dry grounds of hills and slopes.

TAXONOMIC NOTES

The closely related northern pig-tailed macaque species, *M. leonina* (https://www.neprimateconservancy.org/northern-pig-tailed-macaque/), used to be considered a subspecies of the southern pig-tailed macaque, *M. nemestrina*, but they were only recently widely considered to be two distinct species. Much research prior to this taxonomic change refers only to "pig-tailed macaques," without specifying southern or northern populations, so the differences between the two species' ecology and behavior are not well understood. There is also no well-defined, precise geographic boundary between the two species, and they are in fact known to hybridize in a small area of southern Thailand and several nearby islands.



IUCN (International Union for Conservation of Nature) 2022. Macaca nemestrina. The IUCN Red List of Threatened Species. Version 2022-1

Southern pig-tailed macaque range, IUCN 2022

Size, Weight, and Lifespan

Males are larger than females, about 20–23 inches (50–58 cm) in length compared to the females' 15–19 inches (38–48 cm). The tail adds another 5–10 inches (13–25 cm) in length, which is quite short compared to most primates. Males weigh between 12 and

26 lbs (5–12 kg), and females weigh 10–13 lbs (4.5–6 kg). They can live upwards of 26 years in the wild and 35 in captivity.

Appearance

Southern pig-tailed macaques are buff-brown in color, with a darker back and crown. Their eyes are a light amber. A red streak of hair extends from the corner of each eye, appearing almost like eyeliner. Males have mane-like hair framing their faces that the females lack. Males also have larger canine teeth, usually almost twice as long as females'. Their face and belly are a light cream color, and they often have a yellow-ish tinge. They have short, hairless or nearly-hairless tails that they carry half-erect, giving them a pig-like appearance, hence their name. Infants are born with a solid black coat but begin to develop their adult coloring when they are about three months of age.

Diet

Southern pig-tailed macaques are frugivorous, with fruits making up about 74% of their diet. They supplement their diet with leaves and buds (11%), flowers (1%), invertebrates (12%), and other items. Some favorite foods of the macaques are figs, tapioca roots, corn, durian fruit, and papaya. Their diet can sometimes render them agricultural pests, as they have been known to raid farms until a favorite crop, such as corn, is completely consumed and the crop ruined. They have been observed cooperatively raiding gardens and fields, with one monkey acting as "lookout," raising an alarm call if a human is seen.

Behavior and Lifestyle

Southern pig-tailed macaques are quadrupedal (walking on all fours) and mostly terrestrial, tending to stick to the ground and even fleeing on the ground instead of in the trees. The main exception is foraging, as they tend to do this in the trees. Unlike most primates, they love water and swim readily. They spend most of their waking time moving (61%, based on one study), followed by resting (19%), foraging (16%), and social behavior (4%). Southern pig-tailed macaques like to sleep in tall trees (more than 66 feet, or 20 meters, tall on average), as a way to evade predators. They usually sleep in trees close to their last feeding site, so as to minimize the risk of predation while traveling from feeding to sleeping sites.

FUN FACTS

The southern pig-tailed macaque's Latin name, *nemestrina*, is based on the Latin Nemestrinus: "the god of groves."

Daily Life and Group Dynamics

Southern pig-tailed macaques have a home range size of 250–740 acres (100–300 hectares), although they don't use all parts of their range equally. In fact, their home range can overlap by as much as 50% with other group's, indicating that the entire area is not constantly defended. However, if two groups are in the same place at the same time, they attempt to drive the other group out. Daily movement ranges from about half a mile to two miles (0.8–3 km) per day, depending on weather and fruit availability.

They live in multi-male multi-female groups, with the male to female sex ratio varying from about 1:3 to 1:8. Total group size can vary wildly, with observed groups having varied from 15 to 81 individuals in size, although they tend to have between 15 and 40 individuals on average. Group size seems to be correlated with habitat, with hill forests groups having the largest sizes and lowland forest groups having the smallest. However, data about group sizes are based on a limited number of populations. Large groups sometimes split up into small sub-groups of about two to six individuals while foraging, to reduce competition. The subgroups stay relatively close to one another, and stay in contact through vocalizations.

Southern pig-tailed macaque groups have a dominance hierarchy, with male hierarchies being determined by strength and female hierarchies by genetic lineage. When a new male joins the group, he enters it as the lowest-ranking male, and has to improve his rank through competition. Generally speaking, the alpha female leads the group, while the alpha male manages conflict in the group and defends it. Males are socially dominant over females. This dominance hierarchy results in a fair amount of aggression within a group. Higher-ranking males often display aggression to lower-ranking males, and to new males seeking to join their groups. Females sometimes band together to attack lower-ranking males.

Communication

Southern pig-tailed macaques communicate through a huge variety of vocal calls, body postures, facial gestures, chemical cues, and touches. Interestingly, while very much capable of vocalizations and using them extensively, they are often silent in situations when other primates would usually be vocalizing, such as when fleeing. When they do vocalize, they can be heard at distances of up to 260 feet (80 m), and their vocalizations come in forms such as coos, squeals, barks, and growls.

Two individuals can display their tolerance of each other by grooming each other, kissing, and feeding together, behavior that is commonly displayed between high-ranking females, who are usually sisters. Southern pig-tailed macaques also have a unique set of social cues used to reconcile after an aggressive encounter. Dominant females mount subordinate ones, and in males, the subordinate male mounts the dominant one. Dominant females also reconcile by kissing subordinate females.

Reproduction and Family

Estrus is very apparent in female southern pig-tailed macaques, because their anogenital region swells and turns bright pink when they are receptive to breeding. When she is ready, a receptive female presents her backside to a male, who responds by pushing his lips out and flattening his ears before mounting her. The highest-ranking males tend to monopolize receptive females, acting aggressively to lower ranking males who attempt to breed. If there are multiple females in estrus at the same time, however, the highest-ranking males cannot effectively control all copulation, and lower-ranking males get their chance to breed.

Interestingly, despite this dynamic, studies show that higher-ranking males do not tend to produce more offspring than lower-ranking males, and female rank is actually the more important predictor of reproductive success. Female rank also tends to determine the sex of the offspring: higher-ranking females produce more female offspring and lower-ranking females tend to produce male offspring. Because females inherit their rank and males fight for it, it is more beneficial for a low-ranking female to produce a son who has a chance of improving his rank, rather than a daughter who will inherit her mother’s low rank. Conversely, high-ranking females are more likely to produce a daughter who will inherit her mother’s high rank, rather than a son who will become low-rank when he joins a new group.

Breeding happens year-round, although prime breeding time seems to be between January and May. Gestation averages 172 days long, or almost six months. Females give birth every year or two, and continue to nurse their offspring for four or five months. Females become sexually mature around age three while males become mature at about 4–5 years of age. Males leave the group upon reaching maturity, while females stay with their natal groups. Their generation length is about 10–12 years.

In their first month, offspring are virtually attached to their mothers. After a month, they begin to explore their surroundings. It is at this time when they are most at risk: they may die of starvation or dehydration if separated for too long, or they may be kidnapped by other adult females. If they survive their first month, their mothers continue to provide most of their care by nursing, carrying, and protecting them through their first year of life. After that, their mothers continue to provide care as needed, such as through grooming and social support, either for their whole lives for female offspring, or until they leave the group for males.

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Ecological Role

Southern pig-tailed macaques live in the same forests as gibbons and siamangs (https://www.neprimateconservancy.org/siamang/), and white-handed gibbons (*Hylobates lar*) (https://www.neprimateconservancy.org/white-handed-gibbon/) in particular compete with southern pig-tailed macaques for food and seem to be a nuisance to them. Natural predators are not documented but likely include large cats and snakes. While exact figures are not known, it is likely that, as frugivores, southern pig-tailed macaques are important seed dispersers for the plants they consume.

Conservation Status and Threats

The International Union for Conservation of Nature (IUCN) assesses the southern pig-tailed macaque as Endangered (IUCN 2022) based on an ongoing population reduction of at least 50% in the past 33 years, which is likely to continue into the future if threats are not addressed. This population reduction is due to the ongoing conversion of their prime habitat to other land use forms, leading to permanent habitat loss and degradation. This includes conversion of lowland tropical rainforest to large-scale oil palm monocultures and other crops (e.g., durian, rubber), and for mining activities through clear felling; habitat degradation due to selective logging for timber extraction and the construction of roads and linear infrastructure, and other large-scale urban and industrial development projects, draining of peat swamps, and seasonal forest burning that will likely become more severe due to predicted extreme weather events in the region. The incidences of road casualties have also steadily increased over the past years.

Although the species is able to adapt to agricultural landscapes and urban areas, it is sensitive to severe habitat disturbance and clear-cutting. Where the species persists, so too does hunting and trapping for the illegal pet trade, for biomedical research and export, and for human consumption. Southern pig-tailed macaques are often persecuted as crop pests and other frequent human-macaque conflicts, leading to continued negative public perception of the species. Together with the observed extremely high annual infant mortality rate in human-impacted areas, possibly due to pollutants, and the inferred likely decrease in genetic diversity of populations in highly fragmented landscapes, this paints a concerning outlook for the long-term survival of this species.

Conservation Efforts

Southern pig-tailed macaques are listed under Appendix II of the Convention on International Trade in Endangered Species (CITES), limiting their international trade. One promising 2006 study involved leading workshops in villages in southeast Asia, educating local people about endangered species, including pig-tailed macaques. The communities involved in the study made changes that resulted in reduced human-wildlife conflict, and thus less killing of the macaques. It is clear that in addition to widespread habitat protection, it is imperative that local people receive support in dealing with the sometimes nuisance southern pig-tailed macaques, improving the lives of both the humans and monkeys.

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Written by K. Clare Quinlan, September 2020. Conservation status updated July 2022.

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Exhibit 5

Int J Primatol (2018) 39:237 251
https://doi.org/10.1007/s10764 018 0032 z

Activity Budgets and Habitat Use of Wild Southern Pig-Tailed Macaques (*Macaca nemestrina*) in Oil Palm Plantation and Forest

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Received: 1 June 2017 / Accepted: 21 December 2017 /

Abstract Conversion of primary rainforest to agricultural land causes habitat loss and fragmentation and is a major threat to wild primates worldwide. Conversion of forest to oil palm plantations (*Elaeis guineensis*) is a particular problem, so it is important to understand whether and how primates use such plantations. Populations of southern pig-tailed macaques (*Macaca nemestrina*) are declining in Peninsular Malaysia due, in large part, to conversion of primary forests to oil palm plantations. Researchers have observed macaques foraging in plantations but little information is available about how macaques cope with the expansion of plantations into their habitat. We collected GPS data on the home range of a group of wild pig-tailed macaques that foraged in both habitat types in May 2013–May 2015, and compared their use of oil palm plantation and primary rainforest by recording their activity budgets and analyzing their habitat use and diet in both habitat types 4–6 days per week in October 2014–December 2015. The group visited the plantations daily. In 2013–2014, 17% of the group's overall home range core area (0.6 km^2) was in oil palm plantations and in 2014–2015, this increased to 28%. However, the macaques spent most of the day time in the forest and always used a sleeping tree in the forest. Macaque activity budgets in the plantation were significantly different from those in the forest. Feeding and foraging comprised a significantly larger proportion of their activity budget in the plantation, while locomotion, resting, and social behaviors occurred significantly more often in the

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forest. In both habitats, macaques spent most of their time on the ground and foraged primarily on the ground in the plantation. Of food items eaten in the plantation 85% were oil palm parts, including attached and fallen oil palm fruits and seeds, and flowers. Oil palm plantations serve as additional foraging ground for these macaques, but our results also show that the forest is essential, providing a greater dietary diversity and sleeping sites and allowing resting and social activities. It is not clear to what degree pig-tailed macaque populations can adapt to human-altered environments in the long term. Although our study group used oil palm plantations as regular foraging and feeding ground, pig-tailed macaques are also closely associated with the rainforest habitat, and the protection of natural forest is essential for their conservation.

Keywords Cercopithecidae · *Elaeis guineensis* · Home range · Human–primate interface · Peninsular Malaysia

Introduction

Anthropogenic habitat loss and fragmentation are the main threats to wild primates worldwide (Benchimol and Peres 2013; Chapman and Peres 2001; Estrada 2013; Johns and Skorupa 1987; Laurance *et al.* 2013; Schwitzer *et al.* 2011), threatening 60% of species (Estrada *et al.* 2017). Conversion of primary rainforest to agricultural land has occurred at a particularly rapid rate in Southeast Asia, one of the world's most biodiverse regions (Myers *et al.* 2000; Sodhi *et al.* 2010; Vijay *et al.* 2016) and an important region for primate endemism, leading to what some have called a "biodiversity crisis" (Bradshaw *et al.* 2008). In Indonesia and Malaysia, the world leaders in palm oil production (FAO 2007), the establishment of new oil palm (*Elaeis guineensis*) plantations has been the major cause of deforestation in the past few decades (Koh and Wilcove 2008; Vijay *et al.* 2016). In 2011, 8.3 million ha were planted with oil palm, including 2 million ha in Peninsular Malaysia, 2.4 million ha on Borneo, and 3.9 million ha on Sumatra (Koh *et al.* 2011). In 2013, this number had grown to 11.6 million ha (7.1 million ha in Indonesia and 4.5 million ha in Malaysia; Vijay *et al.* 2016), and the area planted with oil palm continues to increase rapidly (Meijaard and Sheil 2013). As these major palm oil producing countries are also important world biodiversity hotspots, the associated loss of tropical lowland forests represents a major threat to global biodiversity.

Animal biodiversity in oil plam plantations is considerably reduced compared to that in natural forests (Donald 2004), with an almost complete loss of most vertebrate taxa (Danielsen and Heegaard 1995; Fitzherbert *et al.* 2008). Only 27% of mammal species sampled in the primary forests of Malaysia have also been observed in oil palm plantations (Palm Oil Research Institute Malaysia 1994). Some larger mammal species may occasionally use oil palm plantations as corridors between habitats (e.g., elephants [*Elephas maximus*]) or to hunt for livestock cattle roaming in the plantations (e.g., tigers [*Panthera tigris*]: Azlan and Sharma 2006). However, few species (e.g., wild boar [*Sus scrofa*]) can adapt permanently to living in this monocultural landscape (Meijaard and Sheil 2013), and oil palm is a very poor habitat for most larger mammals (Maddox *et al.* 2007). In general, mammalian species assessments in oil palm plantations are scarce (reviewed in Harich and Treydte 2016) and there are no studies of the temporal or spatial use of oil palm plantations by mammals.

Rats of the genus *Rattus* are the main predators of oil palm fruits (Wood 2001), but primates such as orangutans (*Pongo* spp.: Meijaard and Sheil 2013) and macaques (*Macaca fascicularis*, *M. Nemestrina*: Linkie *et al.* 2007) also forage on oil palm. Macaques commonly feed on crops (Lee and Priston 2005; Linkie *et al.* 2007) but there are almost no quantitative data on the use of oil palm plantations by wild primates in Southeast Asia. Visiting oil palm plantations exposes primates to increased risk from predators, human hunting pressure, disease exposure, and road accidents, which can negatively affect their populations (Azhar *et al.* 2012; Estrada *et al.* 2012).

Southern pig-tailed macaques (*Macaca nemestrina*) are found on Borneo, Sumatra, and the Malay Peninsula, including southern Thailand (Choudhury 2003; Richardson *et al.* 2008). They inhabit lowland and hilly primary rainforests, and are also occasionally found in swamp and secondary forests (Crockett and Wilson 1980). The highest macaque densities are found in unfragmented rainforest landscapes (Lang 2005). Southern pig-tailed macaques are classified as Vulnerable (IUCN Red List; Richardson *et al.* 2008) because of recent substantial declines in their populations in some parts of their range due to conversion of lowland forest to oil palm plantations (Richardson *et al.* 2008). Several species of macaques, including southern pig-tailed macaques, enter oil palm plantations, presumably to feed on crops (Caldecott 1986a, b; Lee and Priston 2005; Linkie *et al.* 2007). Southern pig-tailed macaques are frequently shot as crop “pests” and hunted for food (Richardson *et al.* 2008). Moreover, pig-tailed macaques are the only primates in the region that are regularly captured to use for work (Bertrand 1967). They are caught in all range countries and trained to do chores such as picking coconuts and other crops that grow high in the trees (e.g., bitter beans [*Parkia speciosa*]) or kept as pets. Southern pig-tailed macaques live in multimale multifemale groups of *ca.* 80 individuals (Caldecott 1986a). Groups often split into smaller subgroups while foraging and then fuse again in the evening when they reach the sleeping site (Albert *et al.* 2013b; Bernstein 1967; Caldecott 1986a; Oi 1990a). These diurnal primates are semiterrestrial (Caldecott 1986a) and spend most of their day on the ground in search of food (Bernstein 1967; Malaivijitnond *et al.* 2012), such as fallen fruits, invertebrates, ground vegetation, and fungi (Caldecott *et al.* 1996).

Considering the extreme environmental pressures southern pig-tailed macaques now face, it is important to understand their behavior and adaptability to human-modified habitats, and especially oil palm, to facilitate long-term conservation actions. Although most cercopithecine species are characterized by high ecological flexibility and can persist in disturbed habitats (Albert *et al.* 2014), detailed information about this species, especially about its current distribution, abundance, and responses to human activities, is not yet available (Richardson *et al.* 2008).

We assessed the activity budgets of a group of southern pig-tailed macaques in a forest–oil palm habitat matrix and compared their spatial (proportion of home range and stratum use in each habitat type) and temporal (frequency and duration of visits) use of plantations to their use of adjacent forested habitat. Based on the observation that macaques enter oil palm plantations and the hypothesis that they are ecologically flexible crop feeders, we predicted that the macaques would use the oil palm plantations near the forest as an integral component of their home range. We tested this prediction by mapping the group’s home range and core area throughout an annual cycle. Because oil palm plantation is structurally very different from intact forest, we also predicted that the macaques would use the plantations primarily as a source of supplementary food and accordingly that the macaques' main activities differ between habitat types, with a greater proportion of time allocated to feeding and foraging and less time allocated to resting and social behavior in the plantation than in the forest. We tested that prediction by comparing macaque time budgets in forest and plantation habitats.

Methods

Study Site

We conducted this study in Segari Melintang Forest Reserve, Perak, Peninsular Malaysia and in the oil palm plantations bordering the southwestern part of the forest reserve near Hutan Lipur Pasir Panjang, Segari (4°19–20′N, 100°34–36′E). The 2720-ha permanent forest reserve consists mainly of dipterocarp forest and freshwater swamp forest (Ruppert *et al.* 2014). The oil palm plantations near Pasir Panjang are managed by a federal authority. The forest is home to five other primate species: long-tailed macaques (*Macaca fascicularis*), dusky leaf monkeys (*Trachypithecus obscurus*), banded leaf monkeys (*Presbytis femoralis*), agile gibbons (*Hylobates agilis*), and Sunda slow lorises (*Nycticebus coucang*). The mean annual temperature at the study site is 27.2 °C and mean annual rainfall is 1941 mm, with the highest rainfall (>200 mm/mo) usually occurring in October and November (Malaysian Meteorological Department 2016).

Study Group

We collected data on one group of wild southern pig-tailed macaques from June 2014 to October 2015. We recorded group composition several times on each sampling day. The study group comprised 53 ± SD 4 individuals ($N = 897$ group counts). We defined infants as small individuals nursed by females; juveniles as small individuals that were weaned, but still ranged in frequent proximity to a female; subadults of both sexes as individuals of almost adult size but that did not exhibit secondary sexual characters; and adults as fully grown with adult morphology (e.g., anogenital swelling or elongated nipples in females, pink scrotum and prominent testes in males). The mean monthly number of adult males was 8.8 ± SD 1.4 individuals (17%), the number of adult females was 19.6 ± SD 0.7 (37%), the number of infants was 9.2 ± SD 2.7 (17%), and the number of juveniles and subadults was 15.2 ± SD 0.4 (29%). Some adult males emigrated and new males immigrated into the group during the study. In addition, some females and infants died, and some individuals transitioned between age classes (e.g., juveniles reached subadulthood and subadults reached adulthood) during the study.

Group Scan Sampling

We conducted the research reported here during the habituation of the study group. In the pilot phase of this project, we located and followed the group by tracking one collared adult female (MOD-315, Telonics Inc., Mesa, AZ, USA). We (two observers at a time) tracked the group daily 11:00–15:00 h using a TR-4 receiver and H-antenna (Telonics Inc., Mesa, AZ, USA) but made prolonged and frequent visual contacts only in May 2013. From then on, the habituation process continued very slowly, and most individuals fled the observers on sight for another 6 mo. While we could follow the group without technical aid and take scan data during the study, the group was not yet completely habituated to human observers (we could approach individuals, but not to <10 m). At the end of the study, a few individuals allowed us to approach them to within 5 m, while the rest kept a horizontal distance of >10 m, and we could identify the adult males and females, but not all the subadults and juveniles.

We used scan sampling to collect behavioral data (08:00–19:00 h, 4–6 days per week). We used a standardized protocol and ethogram (adapted from Kaufman and Rosenblum 1966; Thierry *et al.* 2000). We scanned the group every hour to record its main activities in either forest or oil palm plantations (Table I), and recorded the behavior of the first three adult males, first three adult females, and the first three juveniles or subadults we encountered during a 10-min observation period. If we did not observe nine target individuals within 10 min, we included the data in analysis and stopped recording data until the next scan.

During the early stages of the project, when habituation levels were low, it was often hard to recognize specific food items because the macaques would not allow observers to approach them. Therefore, we conducted additional feeding scans in both forest and oil palm plantation from January 2016 until April 2016 to complement our behavioral data set. We conducted 15-min feeding scans one day per week, every 30 min, 09:00–18:00 h. During each feeding scan, we recorded all food items handled by the first three feeding adult males, the first three feeding adult females and the first three feeding juveniles or subadults.

Table I Activities recorded during group scan sampling of southern pig tailed macaques (*Macaca nemestrina*) at Segari, Malaysia, October 2014 to December 2015

Activity	Definition
Feeding	Eating, i.e., chewing and swallowing food items
Food processing	Manipulating food, e.g. opening a fruit, rubbing and cleaning fruits, cracking seeds with teeth
Foraging	Searching for food, i.e., locomotion or standing while looking around and/or handling leaves/ branches/ soil and other material with the hands to obtain food
Cheek pouch feeding	Eating food previously stored in cheek pouches
Drinking	Bringing water to the mouth, swallowing water, licking water from leaves
Locomotion	Walking, running, jumping, or climbing without any other behavior
Resting	Sitting, standing, or lying down without any other behavior
Allogrooming	One individual cleans the fur of another
Affiliative behaviors	All positive social interactions except for grooming and mating, e.g., touch, play, mount
Mating	Male mounts a female with intromission of penis
Aggression	All agonistic behaviors, including chase, attack, teeth display

Use of Habitat Types

We collected location data with a Garmin GPSMAP62s from May 2013, when we started habituating the study group, and used these data to determine the annual home ranges for 2 yr. (May 2013 to April 2014 and May 2014 to April 2015). We used point kernel density estimation (Silverman 1986) using the Home Range Analysis and Estimation (HoRAE) toolbox for the free GIS software OpenJUMP (Steiniger and Hunter 2013). We conducted an asymptote analysis in steps of 10 points with a fixed h-reference layer before the calculation to test whether the number of locations collected was sufficient for home range calculation (Steiniger and Hunter 2012). For the kernel density estimation (KDE), we set the cell size to 25, and used the bandwidth h-reference method, which delivers the optimal bandwidth value assuming a normal distributed point cloud within the data and a unimodal probability distribution. We obtained the smallest h-reference value when we applied the Normal Gaussian kernel function (Steiniger and Hunter 2013). We estimated the probability of use of the core area with a contour-based method, by generating areas for different probability values (Harris *et al.* 1990). We chose the probability p-core to determine the probability at which the calculated area sizes of the random space use and of the given point data set differed most (Seaman and Powell 1990). We determined the size of the plantation area used by the macaques by calculating the overlay of the home range area polygon with the plantation polygon. We chose the home range polygon of the reference KDE method with 95% probability.

During scans, we recorded the stratum used by the scanned individuals in forest and plantation to examine habitat use and level of terrestriality. The plantation does not have the complex stratification and height of the forest. Palm trees in the home range ranged 5–15 m in height, while the mean canopy height in the forest was 30 m. The spaces between the palms were empty without undergrowth or any vegetation other than short grass. Thus, we assessed the space use during the scans in the plantation by counting individuals on the ground, on the lower parts of a palm (i.e., trunk or lower fronds), on the higher growing fronds of a palm but not near the fruits, and in the palm crown at the fruit bunches. In the forest, we classified space use as forest stratum heights: on the ground (0–1 m), above ground (1–5 m), lower stratum (5–15 m), and high stratum (>15 m and in canopy).

Statistical Analysis

We tested data sets for normality using Kolmogorov–Smirnoff test. We used a two-step process to determine whether activity budgets differed in forest vs. plantation habitats. First, we conducted a chi-squared test using all observations for each habitat type to determine whether the observed frequencies of behaviors differed across habitat types. Then, we calculated mean monthly proportions of time that the macaques spent engaging in each behavior in each habitat type, and used paired *t*-tests (significance level $P \leq 0.05$, two tailed) to make more detailed comparisons for the specific behaviors in forest and plantation. We used GraphPad Software© for all statistical analyses (GraphPad 2017).

Ethical Note

We adhered to institutional and national guidelines. For collar application, we captured an adult female macaque with inflated anogenital swelling (indicating that she was neither pregnant nor nursing). We set a wire mesh cage (dimensions: 80 cm × 50 cm × 50 cm) with a mixed-fruit bait (banana, jackfruit, and oil palm). We set the trap inside the forest near the forest edge where the group was previously recorded on our camera traps. A licensed veterinarian (registration number: 10847) applied the collar under anesthesia (Ketamine 0.5 mg/kg) at the site and carefully monitored the macaque until she had fully recovered from anesthesia (*ca*. 4 h); after she had recovered we immediately released her at the capture site. She joined the group the next day. The research and handling permit was issued by the Department of Wildlife and National Parks Peninsular Malysia; permit number: JPHL&TN(IP): 80–4/2 Jld19(2).

Data Availability The data sets analyzed in this study are available from the corresponding author on reasonable request.

Results

Annual Home Range

The mean daily group travel distance during the study was 1880 ± SD 583.5 m, with a mean speed of 0.34 ± SD 0.13 km/h. The annual home range of the group was 1.49 km^2 in 2013–2014 (KDE 95%, core 85.7%: 0.58 km^2). In 2014–2015 the group's home range expanded into the oil palm plantation, with a home range of 1.81 km^2, KDE 95%) and core area of 0.72 km^2 (Fig. 1). In 2013–2014, 17.3% of the overall core area was in palm plantations and in 2014–2015, this portion increased to 27.8%.

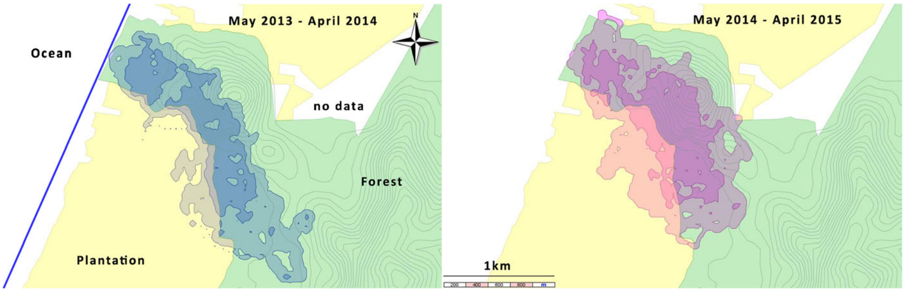

Fig. 1 Home ranges of southern pig tailed macaques (*Macaca nemestrina*) at Segari, Malaysia, based on GPS data taken from May 2013 to April 2015. **(Left)** May 2013 to April 2014; light shade: 95% KDE, dark shade: core area. **(Right)** May 2014 to April 2015; light shade: 95% KDE, dark shade: core area. White indicates no data (cleared private land with restricted access).

Activity Budgets in the Forest and Plantation

In the forest, the group spent almost three quarters of the observation time moving and one fifth of the observation time resting (Fig. 2). The macaques spent another fifth of the observation time in the forest feeding, and almost a tenth of their time foraging. In plantations, the macaques spent half as much time resting (−55.1%). Locomotion (−20.9%), affiliative interactions including allogrooming (−73.8%), and aggressive behaviors (−60.0%) were also reduced and the macaques spent twice as much time feeding (+48.3%) and foraging (+41.8%) as in the forest (Fig. 2). Macaque time budgets were significantly different in plantation and forest habitats (chi-squared test: $\chi^2 = 1574.19$, df = 6, $P \leq 0.001$). The group spent significantly more time feeding (paired *t*-test: $t = 10.21$, SE = 0.018, $P \leq 0.001$; df = 14 for all tests) and foraging ($\boldsymbol{t} =$ 4.78, SE = 0.013 $P \leq 0.001$) and significantly less time resting ($t = 9.33$, SE = 0.012, $P \leq 0.001$), locomoting ($t = 4.45$, SE = 0.019, $P \leq 0.001$), and in affiliative ($t = 7.09$, SE = 0.009, $P \leq 0.001$) and aggressive ($t = 2.40$, SE = 0.001, $P \leq 0.05$) behaviors in the plantation than in the forest (Fig. 2).

Spatial and Temporal Use of Forest and Oil Palm Plantation and Diet

The group used different forest strata at different times of day: in the morning (08:00–10:00 h) the macaques descended from their sleeping sites in the forest canopy near the forest edge (≤1 km away from the plantation), and used the lower strata in the forest and plantation, mainly the ground, during the late morning, midday, and afternoon (10:00–16:00 h) before ascending into the forest canopy again for the night. We never observed the group sleeping in the plantation.

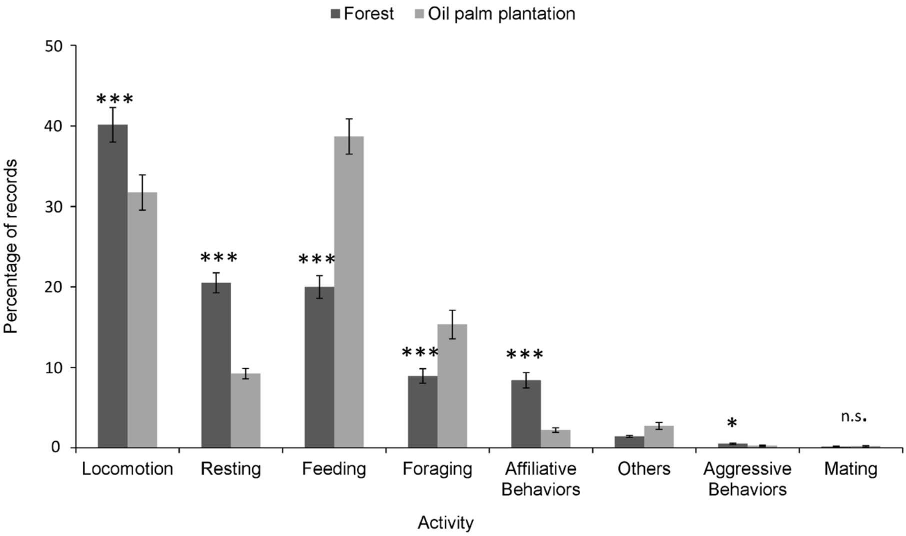

Fig. 2 Comparison of time budgets (mean ± SE) of southern pig tailed macaques (*Macaca nemestrina*) in forest and oil palm plantation at Segari, Malaysia, October 2014 to December 2015. ***$P \leq 0.001$; *$P \leq 0.05$; n.s. not significant based on paired two sample *t* tests.

In both forest and plantation, we recorded individuals on the ground more often (56.3% of forest stratum scans, *N* = 16,668; 50.3% of plantation stratum scans, *N* = 6711) than in higher strata. Adult males and females, but not juveniles, spent more time on the ground than in the trees in both habitat types. Adult males were on the ground during 66.9% of forest scans and 73.2% of plantation scans, and adult females were on the ground during 52.7% of forest scans and 56.5% of plantation scans. However, juveniles were on the ground in only 35.3% of forest scans and 41.2% of plantation scans. The group entered the oil palm plantations on all observation days and stayed in the plantation for a mean of 2.5 ± SD 1.4 h per day, usually between 12:00 h and 16:00 h (Fig. 3). They obtained most food items (52.1%; *N* = 102) from the ground in the plantation. Only about 10% of scanned individuals were in the palm crowns and within reach of attached oil palm fruit (Fig. 3).

Macaque diets varied with habitat type. In the forest (*N* = 521), the largest components of macaque diets were ripe and unripe fruits (32% of feeding scans), followed by arthropods not including ants (24%); nonflowering/fruiting plant parts, i.e., shoots and stems (15%); and leaves (11%). The rest of their diets consisted of ants (8%) (especially *Camponotus* spp.), fungi (6%), flowers (2%), and tree bark (2%). In the plantation (*N* = 196), the macaques ate mainly oil palm parts (85%), such as ripe attached fruits (30%), fallen fruits and seeds (29%), unripe attached fruits (18%), and oil palm flowers in anthesis (8%), which were heavily colonized by pollinating African oil palm weevils (*Elaeidobius kamerunicus*). Other food items in the plantation included fresh shoots (5%), ants (4%), palm bark (4%), and vertebrates (2%), including rats of the genus *Rattus* that the macaques chased out of the cavities of the palm bark.

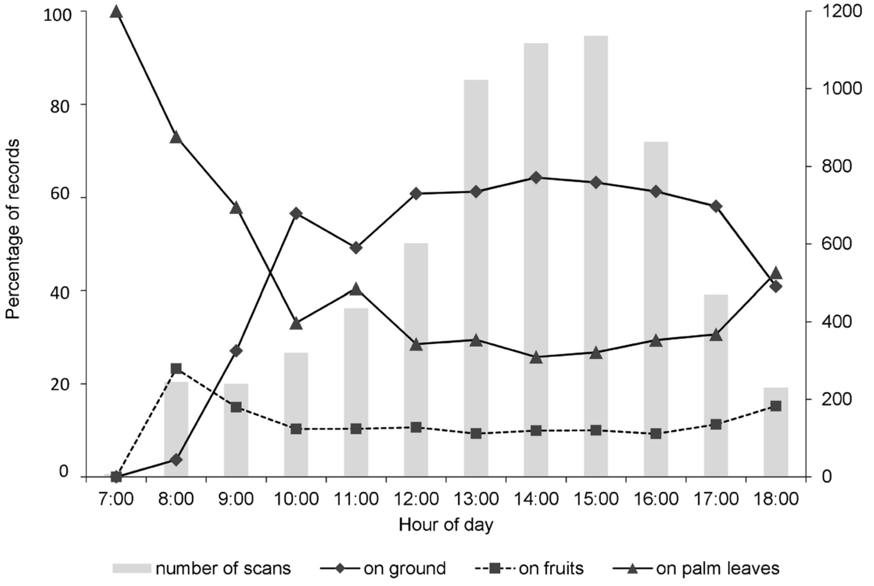

Fig. 3 Spatial and temporal use of oil palm plantations by southern pig tailed macaques (*Macaca nemestrina*) at Segari, Malaysia, October 2014 to December 2015: time budgets in each stratum of the plantation; and cumulative number of group scans during the study period according to day time (*N* 6711), representing macaque foraging times in the plantation.

Discussion

Oil palm plantations and activities in the plantations contributed considerably to the group's home range area and time budget. Macaques spent about one fifth of their daily activity time in the oil palm plantation and visited it on every observation day. Similar to observations from a forest patch surrounded by agricultural land at Lima Belas in Peninsular Malaysia (Caldecott 1986a), oil palm plantations were a substantial component of the study group's home range. A group of macaques at Pasoh in Peninsular Malaysia, however, had a substantially larger home range (8.3 km^2), and never visited oil palm plantations (Caldecott 1986a). Large (3.9–5.5 km^2) home ranges and medium-sized (0.8–1.3 km^2) home ranges have been reported for pig-tailed macaques at other sites (Albert *et al.* 2013a; Bernstein 1967; José-Domínguez *et al.* 2015a, b; Oi 1990b; Rodman 1978; Southwick and Cadigan 1972). Variation in home range size may arise from differences in food distribution and availability. In a fruit-rich habitat, pig-tailed macaques can survive in smaller areas, but in dipterocarp forests they need a much larger area (Caldecott 1986a; Caldecott *et al.* 1996). Our study site is a dipterocarp forest, so macaques should need a larger area than we observed. However, the plantation provided a year-round supply of accessible food.

Food items consumed in the plantation consisted mainly of oil palm parts. Oil palm produces fruits continuously, and the macaques consumed both ripe and unripe fruits, although we cracked open several unripe oil palm fruits and found that they contain water between the pulp and kernel and may thus serve for hydration rather than nutrition. Macaques also consumed overripe fallen palm fruits, seeds, and flowers, indicating the high value of oil palm plants as a source of food. Wild northern pig-tailed macaques (*Macaca leonina*) that were artifically provisioned reduced their monthly home range size while consuming human food (Albert *et al.* 2013a). Oil palm plantations may have had a similar effect on our study group. As the abundant and reliable food supply from oil palm plantations probably serves the same role as artificial food provisioning, our group probably needed a smaller foraging area than nonprovisioned pig-tailed groups in previous studies (Albert *et al.* 2013a; Bernstein 1967; José-Domínguez *et al.* 2015a; Oi 1990b; Rodman 1978; Southwick and Cadigan 1972). Other factors potentially affecting macaque home range sizes include troop size, degree of terrestriality, and study methodology (José-Domínguez *et al.* 2015b).

Macaques spent more time on the ground than in the trees in both the oil palm plantation and forest. Like northern pig-tailed macaques and other macaque species (Albert *et al.* 2011), our study group occupied the highest stratum of the forest canopy in the morning when they woke up. Whereas adults spent most of their time on the ground, juveniles spent more time in the trees throughout the day, perhaps to reduce their exposure to ground predators. Common predators of younger pig-tailed macaques in the area include feral dogs, reticulated pythons, monitor lizards, and raptors. We observed adult males in lower mean strata than females and juveniles throughout the day, in both the forest and the plantation, mostly at ground level. Southern pig-tailed macaques are semiterrestrial, unlike the other primarily arboreal primates in Malaysian forests (Bernstein 1967; Caldecott 1986a; Smith 1973). By foraging predominantly on the ground, pig-tailed macaques may reduce the costs of interspecific competition for arboreal food sources (Caldecott 1986a; José-Domínguez *et al.* 2015b) and the risk of arboreal predators (e.g., raptors). Movement on the ground is also less conspicuous than movement in the trees, although this is not true for the open habitat of plantations. The macaque's predominant use of the ground in plantations can be explained by the concentration of preferred food items, such as fallen oil palm fruits and seeds, and arthropods on the ground.

Macaques spent a greater proportion of their time feeding and foraging in the plantation than in the forest. We seldom observed the macaques resting or showing social behaviors in the plantation. Instead, they mostly foraged and fed and then left, usually after *ca.* 2.5 h. Oil palm plantations have a year-round production of accessible fruits and contain abundant high-quality food (Sha and Hanya 2013). Caldecott (1986a) suggested that an adult pig-tailed macaque consuming ripe oil palm fruits could access ≥10% of its daily energy requirements. However, only one third of food items recorded in the plantation were ripe oil palm fruits in our study. Future studies should assess the quantity of oil palm fruits consumed by macaques in oil palm plantations and their nutritional qualities.

We observed rest and social behaviors more frequently in the forest, where the group may be less exposed to predators than in plantations. As the plantations are more open and offer less cover, macaques may face higher exposure to predators, especially larger raptors, packs of feral dogs, and plantation workers or poachers. We observed several incidents in which villagers tried to capture infants from neighboring groups of macaques (both *Macaca nemestrina* and *M. fascicularis*) while they were foraging in the plantations, and sometimes macaques are chased, threatened, trapped, or killed by smallholder farmers in the area who fear for their crops (Ruppert, N. *pers. obs.*). Macaques (*M. nemestrina and M. fascicularis*) prefer non–oil palm habitats in Sumatra, where they generally exhibited a limited tolerance to the oil palm landscape (Maddox *et al.* 2007).

Many primate species feed on crops. Farmers in Sumatra believe long-tailed macaques (*Macaca fascicularis*), Thomas' leaf monkeys (*Presbytis thomasi*), and orangutans (*Pongo abelii*) to be the most destructive crop feeding species (Campbell-Smith *et al.* 2010; Machall and Hill 2009). Southern pig-tailed macaques are also considered as pests in oil palm plantations (Campbell-Smith *et al.* 2010; Linkie *et al.* 2007; Luskin *et al.* 2013; Richardson *et al.* 2008; Yanuar *et al.* 2009). However, very few data on primate foraging in oil palm plantations or oil palm fruit consumption by wild primates in Southeast Asia support this assumption. Although we found that one third of the macaque diet in the plantation consisted of ripe oil palm fruits, we do not know the effect of fruit consumption by pig-tailed macaques on the monthly harvest. The role of macaques in oil palm plantations should be investigated more thoroughly to assess their effect on oil palm harvest, mitigate human–macaque conflicts, and understand the effects of habitat fragmentation on their social behavior, population genetics, and dynamics.

Conservation Implications

Oil palm plantations seem to offer valuable and accessible food sources with year-round availability for our study group. As oil palm plantations are monocultures, they do not possess the complexity of the forest ecosystem. It is important that the primary forest, which provides more diverse foods, shelter that permits a full range of social activities, and appropriate sleeping sites, still exists nearby. It is not yet clear to what degree pig-tailed macaque populations can adapt to human-altered environments in the long term and how much intact forest they require within their home range to maintain a viable population. Furthermore, primates in plantations are more exposed to predators and poachers (Azhar *et al.* 2012; Estrada *et al.* 2012) and macaques feeding on plantation crops leads to human–macaque conflict (Linkie *et al.* 2007). Pressures on macaque populations will increase with further forest loss. The plantations in this study were unattended by humans most of the time and the company running the plantation employs mainly foreign workers who are paid daily wages. As their salaries are not affected by the harvest volume, the workers do not hunt or chase the macaques. The situation elsewhere, especially at small holder plantations or larger plantations run by other companies might be very different, with macaques being chased or killed (Ruppert, N. *pers. obs.*). Malaysian companies reported problems with pig-tailed macaque groups threatening plantation workers at their sites to us. As the pressure on this vulnerable species is already high, stricter enforcement of existing legal protections should be implemented to prevent the killing and capture of pig-tailed macaques. Based on our findings, there is reason to doubt the common belief that macaques are destructive crop pests in oil palm. The role of macaques in oil palm plantations should be investigated more thoroughly to assess their effect on oil palm plantations and to understand the effects of forest fragmentation by oil palm plantations on their social behavior, population genetics, and dynamics. Pig-tailed macaques are closely interlinked with the rainforest habitat, where they act as seed dispersers (*Macaca leonina*: Albert *et al.* 2013b; *M. nemestrina*: Ruppert *et al.* 2014); thus, conservation plans to protect primates and their natural habitats by minimizing the expansion of new oil palm plantations, enhancing the connectivity between forest patches, and applying best-management practices in existing oil palm plantations should be properly enforced. Only better protection for vulnerable species, coupled with increased awareness of the importance of these primates in their ecosystems, and stricter enforcement of existing laws on illegal land clearing and poaching can ensure their ability to coexist with humans in the future.

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Exhibit 6

THE POPULATION DISTRIBUTION OF PIG-TAILED MACAQUE (*Macaca nemestrina*) AND LONG-TAILED MACAQUE (*Macaca fascicularis*) IN WEST CENTRAL SUMATRA, INDONESIA

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ABSTRACT

Two macaque species, the Pig-tailed Macaque (*Macaca nemestrina*) and Long-tailed Macaque (*Macaca fascicularis*), occur sympatrically in and around the lowland and mountainous forests of the Barisan Range in the Kerinci-Seblat National Park in west-central Sumatra. We present and discuss line-transect data on the density, distribution and group size of the two macaques. *M. fascicularis* was the scarcer, found only in hill dipterocarp and lowland forests.

Keywords: *Macaca nemestrina, Macaca fascicularis*, population distribution, density, group size.

INTRODUCTION

The continuous and extensive conversion of tropical rainforests, home to the world's highest species diversity, is widely believed to be a key threat to the survival of wild populations of terrestrial and arboreal animals, including arboreal non-human primates (Eudey, 1987; Weisenseel *et al*., 1993; Laurance *et al*., 2002). It is also now believed that the local numbers of wild Pig-tailed Macaques (*Macaca nemestrina*) and Long-tailed Macaques (*Macaca fascicularis*) in Southeast Asia are continuing to decline due to habitat alteration and loss (MacKinnon, 1986). According to IUCN Red List of Threatened Species, *M. nemestrina* and *M. fascicularis* are respectively listed as Vulnerable and Least Concern (IUCN, 2008).

Both *M. nemestrina* and *M. fascicularis* have recently become seriously threatened and fragmented by human encroachment and habitat loss (from illegal and legal logging, traditional and modern crop plantations, land clearance for agriculture and new settlements/transmigration, forest fires and droughts), as well as hunting for the illegal pet trade. Trading for export by quota for both macaque species still occurs and Sumatra is the main supply source for biomedical research (MacKinnon, 1986; Bowden & Smith, 1992). Presently, there are many cases of land conflict use between macaques and humans and, as a result, both macaque species are regarded as crop pests by farmers. Furthermore, in Sumatra, primary tropical rainforest, especially in the lowlands, have disappeared rapidly (Achard *et al*., 2002; Kinnaird *et al*., 2003; Linkie *et al*., 2004), with most of the land being converted to commercial timber concessions, or cultivated lands and human settlements (FAO, 1981; Holmes, 2001; Jepson *et al*., 2001).

To protect and manage macaque populations and their habitats effectively, the status of macaque populations in protected and unprotected areas must be evaluated continuously (Struhsaker *et al*., 1975; Wilson & Wilson, 1975a & 1975b; MacKinnon, 1986). Unfortunately, in Sumatra, there has been little effort to date to survey or census primate species, which include gibbons, langurs, macaques, slow lorises, and western tarsiers, either inside or outside of protected areas.

The Kerinci-Seblat National Park (TNKS), in the extreme west central region of Sumatra (Figure 1), is one of the Indonesian "treasure houses" of faunal and floral diversity (MacKinnon & Suwelo, 1984). It covers about 1.3 million hectares (Mha) and is the largest national park on Sumatra, and among the largest protected areas in Southeast Asia (MacKinnon, 1986). The park spans four administrative provinces: Jambi, West Sumatra, Bengkulu, and South Sumatra. Primary and secondary rainforests in the national park are occupied by *M. nemestrina* and *M. fascicularis* and five other arboreal primate

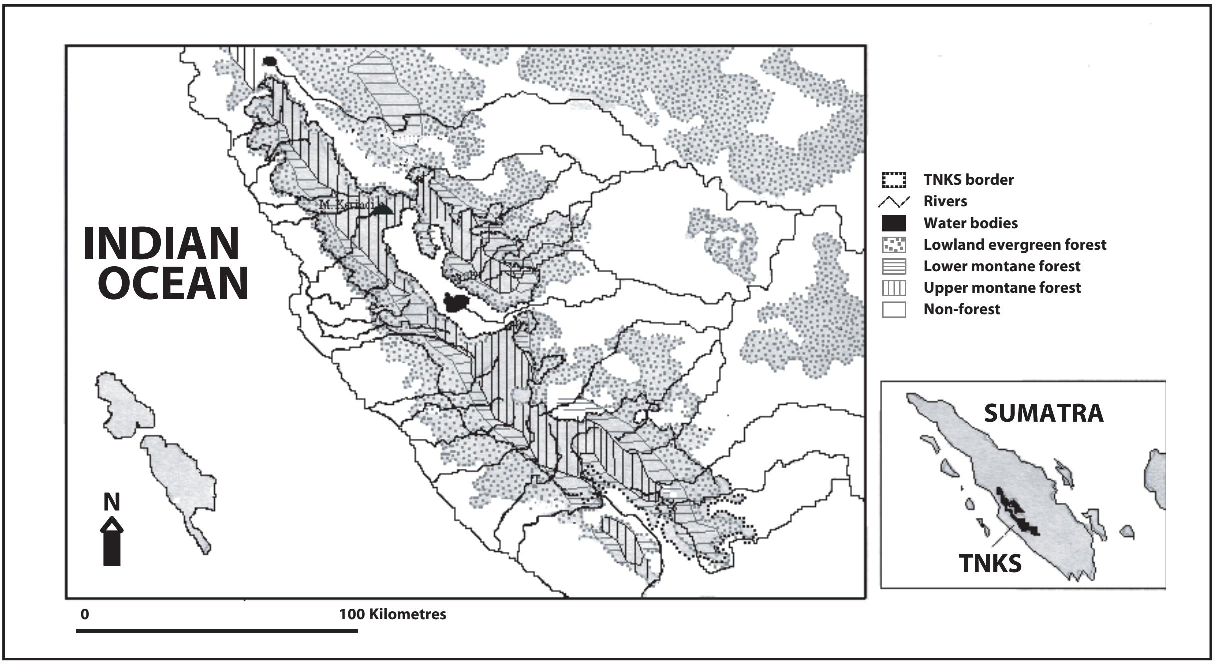

Figure 1. Map of Kerinci-Seblat National Park / Taman Nasional Kerinci-Seblat (TNKS) showing surveyed habitat types.

species (Siamang, *Symphalangus syndactylus*; Agile Gibbon, *Hylobates agilis*; Banded Langur, *Presbytis melalophos*; Silvered Langur, *Trachypithecus cristatus*; Slow Loris, *Nycticebus coucang*), in addition to being an important habitat for many other endangered species.

We examined the population status and distribution of macaques in TNKS by direct observation and line transect methods in four different habitat types (lowland, hill dipterocarp, sub-montane and montane forests), at varying elevations.

STUDY SITES AND METHODS

1. Study Sites

Survey routes were designed to cover a variety of habitat types inside and outside of TNKS. A total of 25 sites were surveyed (Figure 2, Table 1), of which most have never been visited by other researchers. Only 20% of the total area of TNKS is lowland forest <600 m above mean sea level (amsl). Nonetheless, most survey sites were within TNKS and in lowland evergreen forests, because lowland forest is currently believed to be the habitat type most seriously threatened by a variety of human activities. Several sites close to areas recently cleared for traditional and modern crop plantation as well as sites in selectively-logged forests within or near TNKS were also chosen as survey priorities.

2. Methods

We employed the line-transect method to estimate the density and population status of both macaque species through direct observation. We conducted these censuses from 1996 to 1999, while simultaneously surveying for other nonhuman primates.

We derived our methods for censusing macaques from published methods (Southwick & Cadigan, 1972; Wilson & Wilson, 1975a; Burnham *et al*., 1980; Marsh & Wilson, 1981; NRC, 1981; Peres, 1999), and adapted them to the field situation. Transects were established along existing trails on hill ridges, slopes and valleys in deep forest (85.9%) and old logged forest (8.4%) and along river banks (5.6%). Existing human or animal trails/paths were used; new trails were occasionally prepared by trimming small trees. We usually avoided steeper terrain due to difficulty in detecting animals. After the transect system was established, trail lengths were measured by pacing or using a pedometer calibrated to the observer's stride. Trails were an average of 0.5-1.0 m wide in dense forest

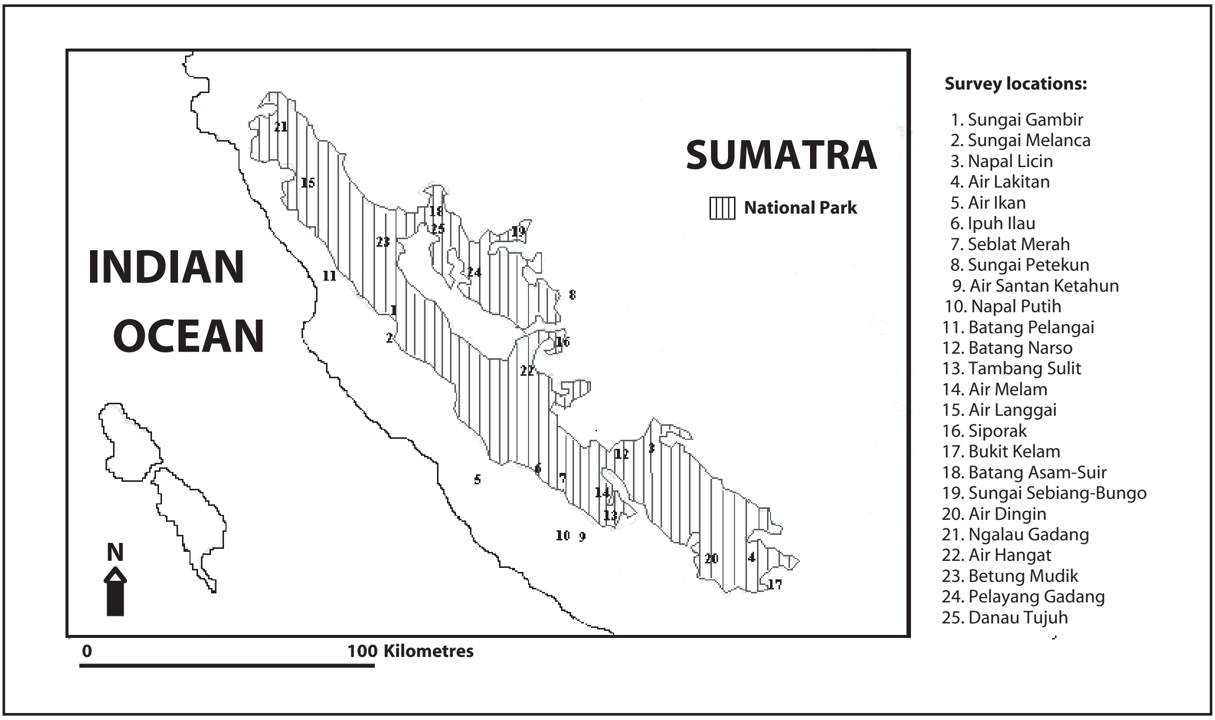

Figure 2. Map of TNKS showing survey sites.

Table 1. Site, elevation, and forest status for the 25 survey routes.

Site/habitat type	Province	Altitude (m)	Forest	Forest status
Lowland		**<450**		
Sungai Gambir	West Sumatra	250 medium	Disturbed	National Park
Sungai Melanca	West Sumatra	250 medium	Primary	Conversion
Napal Licin	South Sumatra	300 steep	Primary	National Park
Air Lakitan	South Sumatra	350 steep	Primary	National Park
Air Ikan	Bengkulu	250 medium	Disturbed	Production
Ipuh Ilau	Bengkulu	350 medium	Primary	National Park
Seblat Merah	Bengkulu	350 flat	Primary	National Park
Sungai Petekun	Jambi	250 steep	Primary	Protection
Air Santan Ketahun	Bengkulu	250 medium	Disturbed	Production
Napal Putih	Bengkulu	250 medium	Disturbed	Protection
Batang Pelangai	West Sumatra	250 medium	Disturbed	Protection
Hill		**450-900**		
B. Narso	Jambi	450 medium	Primary	Protection
Air Sulit	Bengkulu	450 steep	Primary	National Park
Air Melam	Bengkulu	450 steep	Primary	National Park
Air Langgai	West Sumatra	400 steep	Primary	National Park
Sungai Siporak	Jambi	450 medium	Primary	National Park
Bukit Kelam	South Sumatra	500 steep	Primary	National Park
B. Asam-Suir	West Sumatra	500 steep	Primary	National Park
Sungai Sebiang Bungo	Jambi	450 steep	Primary	National Park
Submontane		**900-1400**		
Air Dingin	Bengkulu	900 medium	Primary	National Park
Ngalau Gadang	West Sumatra	1100 steep	Primary	National Park
Air Hangat	Jambi	900 steep	Primary	National Park
Montane		**1400-2400**		
Betung Mudik	Jambi	1600 steep	Primary	National Park
Pelayang Gedang	Jambi	1500 steep	Primary	National Park
Danau Tujuh	Jambi	2100 steep	Primary	National Park

and 1.0-1.5 m wide in secondary forest, but trails were wider in recently logged forests as they followed old logging roads.

The average trail length surveyed on a given day was 2.6 km (range = 1.6-4.8 km). We walked slowly (average speed <1 km/h) with a local field assistant familiar with the terrain and the local wildlife. We frequently stopped for several minutes to listen for animal sounds, or when we encountered primates, to determine the group size and group spread. We started the census walk in the morning between 06:30 and 07:30 and finished by the middle of the day.

To estimate primate densities, it was first necessary to estimate the effective width of the strip surveyed (effective strip width, or ESW) (Marsh & Wilson, 1981; NRC, 1981; Peres, 1999). We estimated the maximum reliable detection distance (1/2 ESW) for density calculations for each species and habitat type using two methods: King's method, based on the "animal-to-observer", or direct distance, and Kelker's method, based on "animal-to-nearest trail", or perpendicular distance. In both methods, the maximum reliable distance is determined from the frequency-distribution curve of sightings, which generally shows an obvious plateau, followed by marked drop in frequency (Marsh & Wilson, 1981; NRC, 1981; Garcia, 1993; Brugiere & Fleury, 2000). We planned to estimate the maximum reliable detection distance as the last distance category before a drop of at least 50% in sighting frequency (NRC, 1981). Maximum reliable perpendicular, and the direct distance were then used to estimate the ESW.

RESULTS

1. Detection Distance and Effective Strip Width (ESW)

Because few sighting-distance data were collected for either macaque species, the cut-off cannot be shown in the histogram distribution of perpendicular distance (Figure 3a and b). Thus, we used the maximum distance at which they were sighted rather than maximum reliable distance to estimate ESW.

A. Maximum reliable animal-to-trail or perpendicular distance

The maximum perpendicular detection distance recorded for *M. nemestrina* was 20 m in montane forest (mean = 10.5, sd = 7.7, n = 2) thus ESW was computed as 40 m. In sub-montane (mean = 17.0, sd = 7.1, n = 2) and hill dipterocarp (mean = 13.5, sd = 8.0, n = 11) forests, the maximum distance was recorded as 30 m (Figure 3a) and the ESW was 60 m for both forest types (Table 2). In lowland forest, all groups of this species were recorded within 40 m as an effective distance and its ESW was 80 m (range = 0-45 m, mean = 15.8, sd = 8.3, n = 17). *M. fascicularis* was the scarcer species and was recorded only in hill dipterocarp and lowland forests. In both forest types, animal sightings were recorded within 35 m in hill dipterocarp forest (mean = 15.7, sd = 10.2) and lowland forest (mean = 14.9, sd = 9.0).

Table 2. Effective Strip Width (ESW) used for mean density calculations.

	Species	
ESW (m)	Pig-tailed Macaque	Long-tailed Macaque
Perpendicular distance		
Montane Forest	60	-
Sub-montane Forest	60	-
Hill Dipterocarp Forest	60	60
Lowland Forest	80	60
Direct distance		
Montane Forest	60	-
Sub-montane Forest	80	-
Hill Dipterocarp Forest	80	80
Lowland Forest	80	80

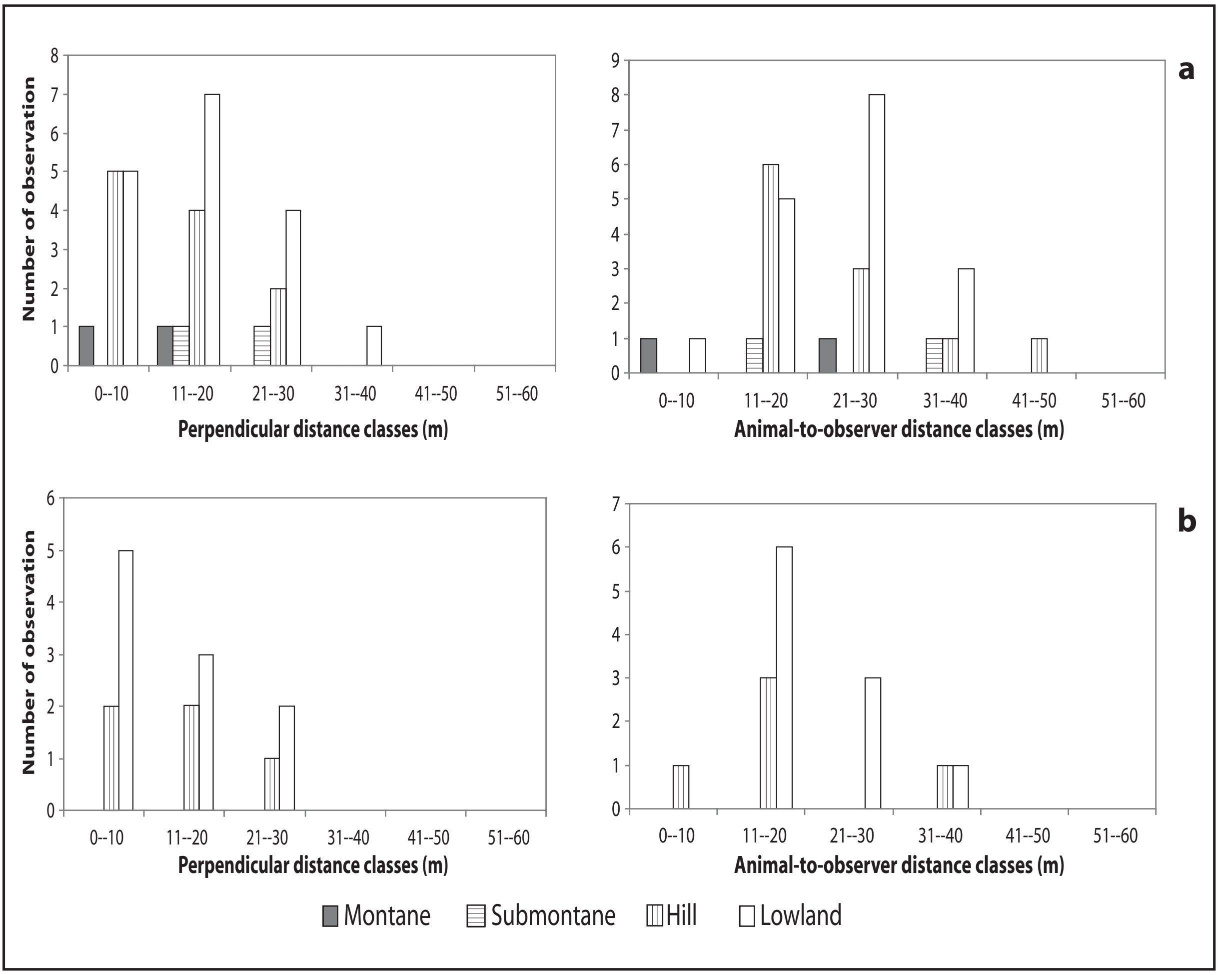

Figure 3. Observed perpendicular and animal-to-observer distance for Pig-tailed Macaque (a) and Long-tailed Macaque (b).

B. Maximum reliable animal-to-observer or direct distance

Sightings at a maximum distance of 30 m were recorded for *M. nemestrina* in montane forest (mean = 17.5, sd = 10.6). In three other forest types namely, sub-montane (mean = 22.5, sd = 10.6), hill dipterocarp (mean = 25.9, sd = 10.9), and lowland (mean = 25.6, sd = 8.1), sightings were recorded at a maximum distance within 40 m. *M. fascicularis* was recorded only in hill dipterocarp forest (mean = 19.0, sd = 9.6) and lowland forests (mean = 23.0, sd = 5.9) and had a maximum sighting of 40 m in both.

2. Pig-tailed Macaque and Long-tailed Macaque Densities

Group density estimates were calculated from data collected from a total of 311.2 km of line transects in four habitat types: lowland forests (eleven sites), hill dipterocarp forests (eight sites), sub-montane forests (three sites), and montane forests (three sites). Group densities calculated using perpendicular distance were higher than those produced using direct distance for *M. fascicularis* in lowland and for *M. nemestrina* in sub-montane and hill dipetrocarp forests (Table 3).

The estimated group densities (estimated by averaging the estimates produced using each method) for *M. nemestrina* had high densities in lowland forest (1.7 groups/km^2) and hill dipterocarp forest (1.5 groups/km^2); lower densities were found in montane (0.7 groups/km^2) and sub-montane forests (0.8 groups/km^2). *M. fascicularis* had lower densities and was found only in hill dipterocarp forests (0.5 groups/km^2) and lowland forests (1.1 groups/km^2).

3. The Distribution of Pig-tailed and Long-tailed Macaques in and around TNKS

We assessed the distribution of the two macaque species in censuses comprising 400 km of transects in 120 routes at 25 locations, ranging in altitude from 200 to 2,200 m amsl in and around TNKS forest complex. In montane forests, only *M. nemestrina* was observed. Like *S. syndactylus* and *P. melalophos*, they were observed at all elevations (from sea level to 1,900 m amsl) although seldom in montane and sub-montane forests, and most sightings in hill dipterocarp and lowland forests. The average elevation used by the Pig-tailed Macaques in and around TNKS was 477 m amsl (range = 225-1,900, n = 32), estimated from 25 survey sites.

Groups of Long-tailed Macaques were absent from montane forest and scarce at higher elevations such as sub-montane forest. In Kerinci-Seblat forest complex, groups were found only in lowland and hill dipterocarp forests (at six locations), and not above 800 m amsl. The maximum elevation for this species was at Air Hangat at 700 m amsl and its mean elevation was 382 m amsl.

4. Macaque Group Sizes

We recorded macaque group whenever they were sighted. The average group size of both macaque species was much larger than those found in *S. syndactylus*, *H. agilis* and *P. melalophos* in Kerinci-Seblat. In hill dipterocarp forest, *M. nemestrina* had an average group size of 10.5 individuals (range = 1-20 individuals, SE = 1.6, n = 11), larger than in montane, sub-montane and lowland forests (Figure 4). In montane forests, the average group size was 7 individuals (range = 6-8 individuals, SE = 10, n = 2), whilst in sub-montane forests the average group size was 9.5 individuals (SE = 0.5, n = 2). In lowland forest, the average group size of 8.5 individuals (range = 1-13, SE = 14, n = 17) being slightly smaller than in sub-montane forests and slightly larger than in the montane forests.

M. fascicularis had an average group size (9.6 individuals; range = 1-17 individuals, SE = 2.9, n= 5) that was slightly larger in the hill dipterocarp forests than in the lowland forests (9.0 individuals; range = 4-16 individuals, SE = 1.4, n = 10) (Figure 4).

DISCUSSION

Both *M. nemestrina* and *M. fascicularis* were rarely seen in any of the habitat types in and around Kerinci-Seblat National Park (TNKS) and, as a result, low densities were observed for both in this study. *M. fascicularis* is usually most abundant in swamp forest (Crocket & Wilson, 1980), and Chivers and Davies (1978) reported that this species has high densities in riverine and edge habitat in peninsular Malaysia. Furthermore, the densities of *M. nemestrina* were markedly lower in all habitats types than those reported for peninsular Malaysia (Chivers & Davies, 1978).

Table 3. Group density estimates for Pig-tailed Macaque and Long-tailed Macaque in and around Kerinci-Sablat National Park.

	N		km^2 surveyed		Density ± SE (groups/km^2)	
Habitat type	Pig-tailed Macaque	Long-tailed Macaque	Pig-tailed Macaque	Long-tailed Macaque	Pig-tailed Macaque	Long-tailed Macaque
Reliable primate-to-trail						
Montane	2	0	2.9	0	0.7 ± 0.8	-
Submontane	2	0	2.2	0	1.0 ± 1.0	-
Hill dipterocarp	11	4	6.3	6.3	1.7 ± 0.5	0.6 ± 0.3
Lowland	17	10	9.8	7.3	1.7 ± 0.9	1.3 ± 0.4
Reliable primate-to-observer						
Montane	2	0	2.9	0	0.7 ± 0.5	-
Submontane	2	0	2.9	0	0.7 ± 0.7	-
Hill dipterocarp	11	4	8.4	8.4	1.3 ± 0.3	0.4 ± 0.2
Lowland	17	10	9.8	9.8	1.7 ± 0.5	1.0 ± 0.3

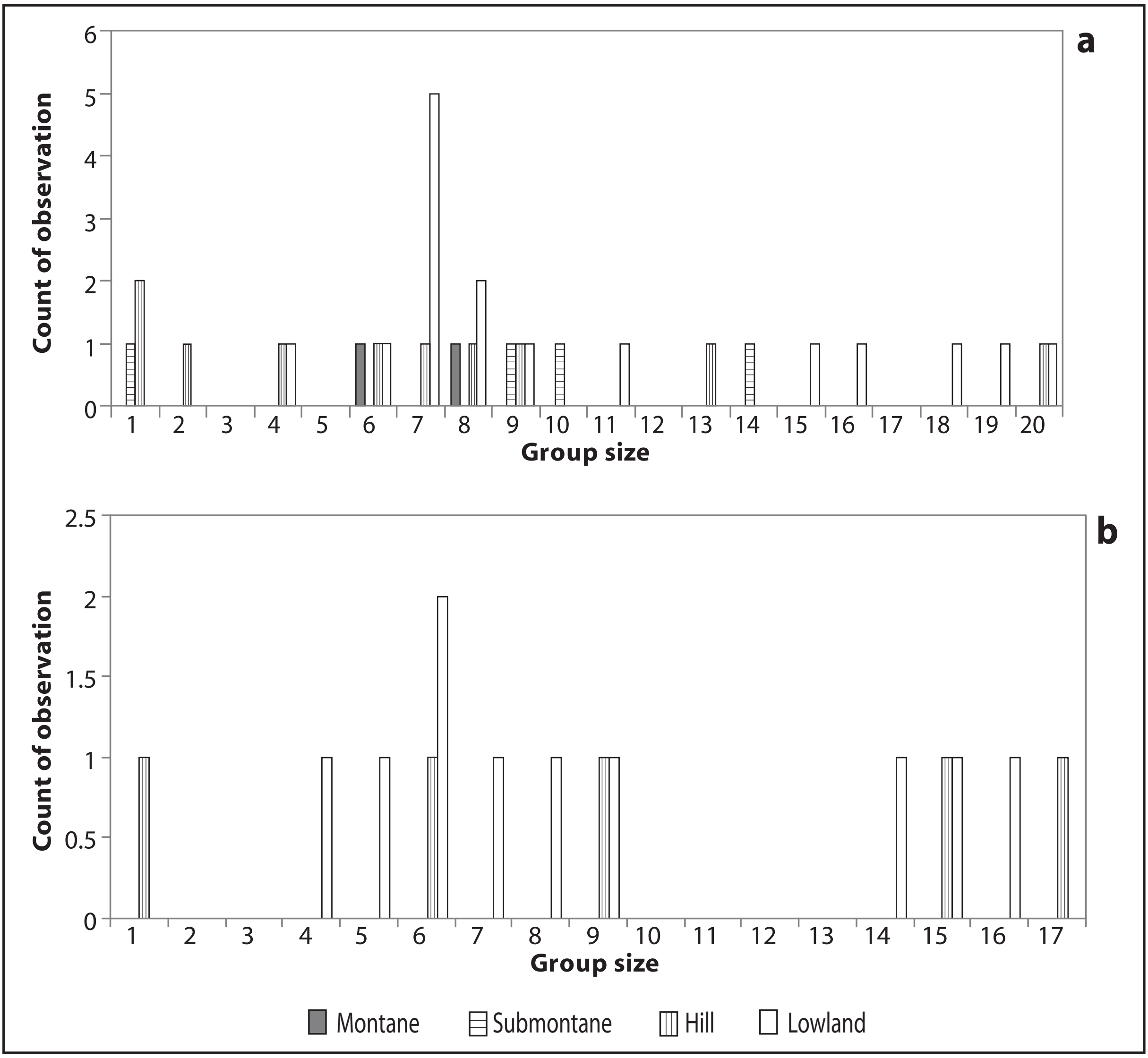

Figure 4. Group size for Pig-tailed Macaques (a) and Long-tailed Macaques (b) in montane, sub-montane, hill dipterocarp, and lowland forests.

Although semi-terrestrial, *M. nemestrina* is hard to study in the field (Marsh & Wilson, 1981; Robertson, 1986). The highest densities of this primate found at TNKS were in the lowland and hill dipterocarp forests (Table 4). The densities observed seemed less than those reported in 1970s by Rijksen (1978) at the Ketambe study area, Gunung Leuser National Park. Wilson and Wilson (1976) observed higher population densities of *M. nemestrina* throughout Sumatra than that observed in the TNKS' primary lowland forest, and at 25.5 range of group densities of *M. nemestrina* in the Krau Game Reserve in peninsular Malaysia, were similar in five different habitat types, i.e. at 0.1-0.3 groups/km^2. Meanwhile, Marsh and Wilson (1981), who also studied *M. nemestrina* in peninsular Malaysia, reported mean densities of 0.1 and 0.9 groups/km^2 in lowland and swamp forests, respectively.

Like other macaques, *M. nemestrina* lives in large groups with normally 15-40 individuals and an average 23 individuals (Caldecott, 1983; Robertson, 1986). Even larger groups were observed at Lima Belas, peninsular Malaysia (Caldecott, 1983) where the increase is associated with more immature in the group.

For *M. fascicularis* at Krau Game Reserve, the highest densities were found in riverine forest, while densities were reduced in lowland and disturbed forest (Chivers & Davies, 1978). On the other hand, Marsh and Wilson (1981) found that mean densities of *M. fascicularis* in lowland forest were higher than previously reported by Chivers and Davies (1978), but the highest densities found in peninsular Malaysia were in freshwater swamp forest (Marsh & Wilson, 1981) (Table 4). According to Crockett and Wilson (1980), who studied ecology and abundance of *M. fascicularis* and *M. nemestrina* in various habitat types in Sumatra, found that the highest group densities of *M. fascicularis* were in *Rhizophora* mangrove forest. The next favored habitat of this macaque was secondary hill dipterocarp forests, followed by mixed mangrove forest and riverine parts of the lowland forests.

In this study, group densities of *M. fascicularis* in the lowland forests were slightly higher than reported for the same habitats at the Krau Game Reserve (Chivers & Davies, 1978), but lower than those reported by Marsh and Wilson (1981) for peninsular Malaysia or for primary lowland forest in Sumatra (Crockett & Wilson, 1980). In hill dipterocarp forest, the density of *M. fascicularis* at TNKS was 85% less than that reported by Crockett and Wilson (1980) for throughout Sumatra. Crockett and Wilson (1980) found higher densities and group sizes of *M. fascicularis*, with the largest average group sizes in secondary lowland habitats. Yet, the group size average of this species in TNKS is still lower than those reported by Southwick and Cadigan (1972) in the urban areas of peninsular Malaysia.

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Table 4. Comparative densities and group size in Pig-tailed and Long-tailed macaques on Sumatra and in Malaysia.

	Density/km^2				**Group Size**		
Site	**Pig-tailed**		**Long-tailed**		**Pig-tailed**	**Long-tailed**	**Source**
	Group	**Individuals**	**Group**	**Individuals**			
TNKS							
Lowland	1.7	14.7	1.3	10.7	8.5(1-13)	9.6(1-17)	this study
Hill	1.5	15.7	0.6	6.6	10.5(1-20)	9.0(4-16)	this study
Sub-montane	1.0	5.9	-*)	-	9.5	-	this study
Montane	0.7	4.8	-	-	7.0(6-8)	-	this study
KETAMBE	-	19.0	-	-	4.04	6.4	Rijksen, 1978
SUMATRA							
Lowland	2.48	36.7	1.31	24.4	18.3(16-21)	46.0	Wilson & Wilson, 1976, Crockett & Wilson, 1980
Hill	2.24	33.2	5.26	97.8	16.0	-	Crockett & Wilson, 1980
Mangrove	-	-	6.47	120.3	21.0	13.0	Crockett & Wilson, 1980
MALAYSIA							
Swamp	0.9	-	4.8	-	-	-	Chivers & Davies, 1978; Marsh & Wilson, 1981
Lowland	0.1	-	1.4	-	-	29.8(14-70)	Bernstein, 1967; Chivers & Davies, 1978; Marsh & Wilson, 1981
Urban	-	-	-	-	-	24.0(7-44)	Southwick & Cadigan, 1972
KRAU GAME RESERVE							
Disturbed	0.1	-	0.6	-	-	-	Chivers & Davies, 1978
Riverine	0.3	-	1.4	-	-	-	Chivers & Davies, 1978
Lowland	0.3	-	0.2	-	20.0	24.0	Chivers & Davies, 1978
Hill	0.2	-	-	-	-	-	Chivers & Davies, 1978
Sub-montane	0.3	-	-	-	-	-	Chivers & Davies, 1978
LIMA BELAS ESTATES	-	15-40	-	-	50.0(45-55)	-	Caldecott, 1983

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Exhibit 7

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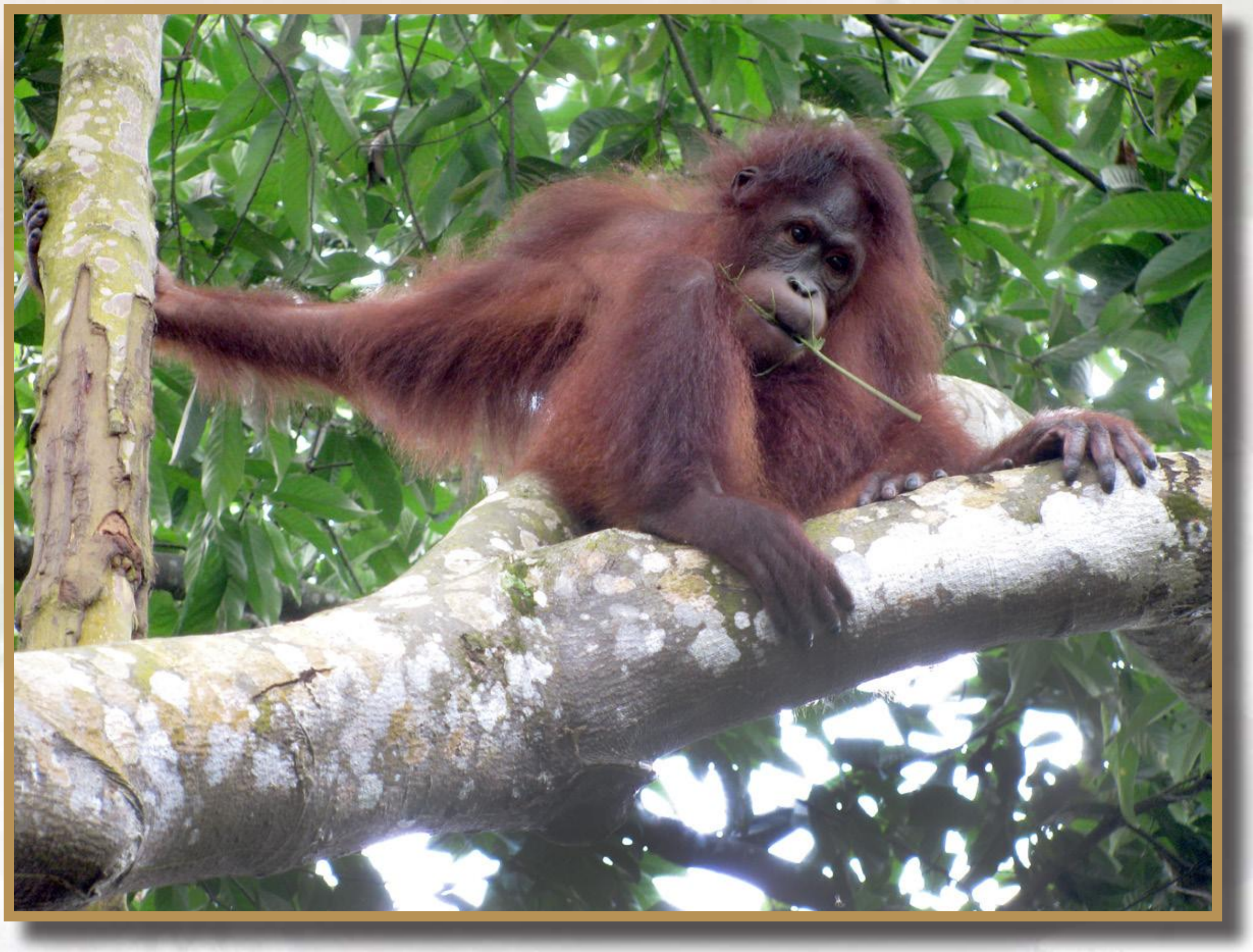

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Bornean Orangutan *Pongo pygmaeus*. Photo by Ramesh Boonratana.

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FOREWORD

The current issue comprises a single paper, but an important one.

The dynamic nature of mammal taxonomy is a great sign of the growth of our understanding, particularly since the wider application of genetic techniques. Still, these changes can make life difficult for those involved in studying and conserving mammals. Following years of work, 2013 saw the publication of the primate volume in the encyclopaedic series *"The Handbook of the Mammals of the World."* This brought the new findings together in one synthesis of the current primate taxa and their distributions and conservation status.

A downside of the comprehensive published format was that the results of the synthesis were inaccessible to many in Asia and elsewhere. The present paper seeks to make that synthesis more available for Asia's primates, whilst incorporating some further changes since the *Handbook* volume was published. It also adds greater consistency in the use of English common names. Supplementing the text are Stephen Nash's excellent illustrations.

The science will not stand still, but for the moment this paper summarises the state of knowledge on nomenclature, distribution and status of Asia's primates. It's a stirring reminder of the immense variety of these remarkable animals; and the precarious position so many of them are in.

Editors

AN UPDATED TAXONOMY AND CONSERVATION STATUS REVIEW OF ASIAN PRIMATES

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ABSTRACT

The present paper summarises and updates information on the taxonomy and status of Asian non-human primates from a new multi-author synthesis. For each species we include taxonomic authority, species type locality, subspecies, current distribution and conservation status. Including taxa described since the synthesis was published, the Asian non-human primate fauna comprises 119 species and 183 taxa, in 22 Asian countries. We give a breakdown of species by country, by conservation status category, and the number of species per status category in each family and genus. Of the 113 Asian primate species that have been assessed, 17 (15%) are Critically Endangered, 45 (40%) are Endangered and 25 (22%) are Vulnerable. The most endangered genera are *Rhinopithecus, Pygathrix, Nasalis, Simias, Hylobates, Nomascus, Symphalangus and Pongo*.

Keywords: Asian primates, taxonomy, conservation status, threatened fauna

INTRODUCTION

To conserve the non-human primate fauna of Asia, there has long been a need for an accessible, updated checklist of recognised taxa. Volume 3 (Primates) of *The Handbook of the Mammals of the World*, edited by Russell A. Mittermeier, Anthony B. Rylands and Don E. Wilson, was published in April 2013 (Mittermeier *et al*., 2013). The book integrates new information on primates, including data on morphology, behaviour, acoustics, and genetics. For each primate family, there is an introductory section with reviews of systematics, morphology, habitat, general habits, communication, food and feeding, breeding, movements, home range and social organization, relationship with humans, and conservation status, followed by species accounts with more detailed information, along with illustrations (by Stephen D. Nash) of each.

According to the book, the order Primates comprises 16 families, 78 genera, 480 species and 682 taxa. In Asia, this multi-author compilation recognizes five families, 19 genera, 116 species and 179 taxa of non-human primates. Since it went to press, the Bornean Slow Loris (*Nycticebus menagensis*) has been split into four species (Munds *et al*., 2013) and a new subspecies of Hoolock gibbon (*Hoolock hoolock mishmiensis* Choudhury, 2013) has been described; thus, non-human primates in Asia now comprise 119 species and 183 taxa.

There remained a need to make this information widely available. In the following, we give an overview of non-human primates in Asia, based on *The Handbook of the Mammals of the World* and the updated taxonomy on *Nycticebus* and *Hoolock*, including taxonomic authorities, type localities, subspecies, current distribution and conservation status. For consistency and clarity, we also suggest new common names for some taxa, mainly subspecies. We further list species in each country, species in each conservation status category (based on IUCN, 2013), and the number of species per status category in each family and genus. Although formal punctuation is retained for taxonomic purposes (scientific names and author initials), we have omitted this for general use (notably compass directions) for ease of reading. For place names, we have tried to standardise to English geographic terms (Island, River, Lake), with the exception of those in which the local term is part of its internationally familiar name; by way of explanation "Gunung" (Malay) = Mountain or Mt; "Batang" (Malay) = River"; "Shan" (Chinese) = Mountain; "Jiang" (Chinese) = River.

1. Family Lorisidae

1.1. Genus *Loris*

1.1.1. Red Slender Loris *Loris tardigradus* (Linnaeus, 1758)

Type locality: Ceylon [= Sri Lanka].

Subspecies/colour variants: 2 subspecies are recognized: Lowland Red Slender Loris *L. t. tardigradus* (Linnaeus, 1758); Horton Plains Red Slender Loris *L. t. nycticeboides* Hill, 1942, but this is in need of revision, and more species may exist; for example, the Horton Plains Slender Loris may be specifically distinct. In *L. t. tardigradus*,there are variants in coloration and head form.

Distribution: *L. t. tardigradus*: SW Sri Lanka (Western and Southern provinces), from the outskirts of Colombo in the N to Ranna in the S, up to 470 m; *L. t. nycticeboides*: Sri Lanka (Central Province highlands), 1650–2000 m.

Conservation status: Endangered (both subspecies).

1.1.2. Grey Slender Loris *Loris lydekkerianus* Cabrera, 1908

Type locality: India, Madras.

Subspecies/colour variants: 4 subspecies are recognized: Mysore Grey Slender Loris *L. l. lydekkerianus* Cabrera, 1908; Highland Grey Slender Loris *L. l. grandis* Hill & Phillips, 1932; Malabar Grey Slender Loris *L. l. malabaricus* Wroughton, 1917; Northern Sri Lankan Grey Slender Loris *L. l. nordicus* Hill, 1933. The two Indian taxa need reinvestigation; they may actually be distinct species. The nature and status of the Highland Grey Slender Loris needs to be investigated.

Distribution: *L. l. lydekkerianus*: S and E India (Andhra Pradesh, Karnataka and Tamil Nadu states), found in the dry forests of the Eastern Ghats; *L. l. grandis*: C Sri Lanka (Central Province); only known from the East Matale Hills, but probably occurs throughout the lower foothills at an average elevation of 900 m; *L. l. malabaricus*: SW India (Karnataka, Kerala and Tamil Nadu states), found in the wet forests of the Western Ghats up to 1200 m; *L. l. nordicus*: NC and E Sri Lanka throughout the lowland dry zone; the extent of its distribution to SE Sri Lanka is uncertain.

Conservation status: Least Concern; *L. l. lydekkerianus*, *L. l. malabaricus* Near Threatened; *L. l. grandis*, *L. l. nordicus* Endangered.

1.2. Genus *Nycticebus*

1.2.1. Bengal Slow Loris *Nycticebus bengalensis* (Lacépède, 1800)

Type locality: Bengal.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: E Bangladesh, NE India (Arunachal Pradesh, Assam, Meghalaya, Tripur, Nagaland, Manipur and Mizoram states), S China (S Yunnan Province from c. 25°N in Yunnan and the Pearl River in the E, and possibly S Guangxi Autonomous Region), Myanmar (including the Mergui Archipelago), N and C Vietnam, Laos, Cambodia, Thailand, and possibly N of peninsular Malaysia.

Conservation status: Vulnerable.

1.2.2. Sunda Slow Loris *Nycticebus coucang* (Boddaert, 1785)

Type locality: Malaysia, Malacca [= Melaka].

Subspecies/colour variants: No subspecies are recognized, but it has been claimed that there is morphological diversity in Sumatra, probably based on altitude.

Distribution: S Thailand, peninsular Malaysia (including Penang, Langkawi and Tioman islands), Singapore, and Sumatra, also Malacca Straits Islands and Riau Archipelago (Batam, Galang and Tebingtinggi islands), and Bunguran in the North Natuna Islands.

Conservation status: Vulnerable.

1.2.3. Javan Slow Loris *Nycticebus javanicus* É. Geoffroy Saint-Hilaire, 1812

Type locality: Java.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: W and C Java, with an isolated locality in the E.

Conservation status: Endangered.

1.2.4. East Bornean Slow Loris *Nycticebus menagensis* (Lydekker, 1893)

Type locality: Philippines, Tawitawi.

Subspecies/colour variants: None.

Distribution: N and E coastal Borneo (Brunei, Sabah and East Kalimantan) and the Southern Philippines.

Conservation status: Vulnerable; but assessment included *N. bancanus*, *N. borneanus* and *N. kayan*, which were recently separated from *N. menagensis*.

1.2.5. Bangka Slow Loris *Nycticebus bancanus* Lyon, 1906

Type locality: Klabat Bay, Bangka, Indonesia.

Subspecies/colour variants: None.

Distribution: Far SW of Borneo (West and South Kalimantan), S of the Kapuas River and E to the Barito River (appears not to extend all the way E to the Barito River), and on Bangka Island off Sumatra.

Conservation status: Not Evaluated.

1.2.6. Schwaner Mountains Slow Loris *Nycticebus borneanus* Lyon, 1906

Type locality: Sanggau District, Sakaiam River, Western Kalimantan, Borneo, Indonesia.

Subspecies/colour variants: None.

Distribution: SC Borneo (West, South and Central Kalimantan, but excluding the extreme SW), S of the Kapuas River, extending as far E as the Barito River.

Conservation status: Not Evaluated.

1.2.7. Kayan River Slow Loris *Nycticebus kayan* Munds *et al*., 2013

Type locality: Peleben, East Kalimantan, Borneo, Indonesia (S2°46’, E116°34’).

Subspecies/colour variants: None.

Distribution: Central and Northern Borneo (Sarawak, Sabah, East Kalimantan); S to the Mahakam River in East Kalimantan and the Rajang River in Sarawak, N to the southern part of Mt Kinabalu in Sabah, from E to W Borneo, but not along the coast.

Conservation status: Not Evaluated.

1.2.8. Pygmy Slow Loris *Nycticebus pygmaeus* Bonhote, 1907

Type locality: Nha Trang, Annam [= Vietnam].

Subspecies/colour variants: None.

Distribution: Laos, Vietnam and E Cambodia (E of the Mekong River). The precise W limit of the distribution is uncertain, but it appears to be absent (or at least very scarce) in the extreme W of the Mekong plain; records from S China (SE Yunnan Province) are uncertain and may be based merely on released captives brought in from elsewhere.

Conservation status: Vulnerable.

2. Family Tarsiidae

2.1. Genus *Tarsius*

2.1.1. Selayar Tarsier *Tarsius tarsier* (Erxleben, 1777)

Type locality: Unknown. Restricted to Selayar Island, off the South-western peninsula of Sulawesi, Indonesia, by C.P. Groves and M. Shekelle in 2010.

Subspecies/colour variants: None.

Distribution: Selayar Island, off the tip of the SW peninsula of Sulawesi.

Conservation status: Vulnerable.

2.1.2. Makassar Tarsier *Tarsius fuscus* Fischer, 1804

Type locality: “Madagascar”. Corrected and restricted to Makassar, South Sulawesi, Indonesia, by C.P. Groves and M. Shekelle in 2010.

Subspecies/colour variants: None.

Distribution: SW peninsula of Sulawesi, presumably S of the Lake Tempe Depression.

Conservation status: Not Evaluated.

2.1.3. Dian’s Tarsier *Tarsius dentatus* G.S. Miller & Hollister, 1921

Type locality: Indonesia, Labua Sore, North of Parigi, Sulawesi.

Subspecies/colour variants: None.

Distribution: E portion of the central core of Sulawesi to the tip of the E peninsula, the N boundary is the Isthmus of Palu (between Marantale, Ampibabo and Tomini Bay), the S boundary from Lore Lindu National Park to the E coast is unknown, but the W boundary appears to extend at least to the Palu River and S as far as Gimpu.

Conservation status: Vulnerable.

2.1.4. Peleng Tarsier *Tarsius pelengensis* Sody, 1949

Type locality: Indonesia, Peleng Island.

Subspecies/colour variants: None.

Distribution: Peleng Island, off the coast of the E peninsula of Sulawesi; it may also occur on other islands of the Banggai Archipelago.

Conservation status: Endangered.

2.1.5. Great Sangihe Tarsier *Tarsius sangirensis* Meyer, 1897

Type locality: Indonesia, Sanghir [= Sangihe] Island.

Subspecies/colour variants: None.

Distribution: Great Sangihe Island, c. 200 km N of Sulawesi; it may also occur on other islands in the Sangihe chain.

Conservation status: Endangered.

2.1.6. Siau Island Tarsier *Tarsius tumpara* Shekelle *et al*., 2008

Type locality: Siau Island, Indonesia, the southern end of the island c. 100 m from the N shore of a small lake (N2°39’, E125°23’).

Subspecies/colour variants: None.

Distribution: Siau Island, in the Sangihe Archipelago, c. 100 km N of Sulawesi; it may occur also on some small islands close to Siau.

Conservation status: Critically Endangered.

2.1.7. Sulawesi Mountain Tarsier *Tarsius pumilus* G.S. Miller & Hollister, 1921

Type locality: Indonesia, Rano Rano, Middle Celebes [= Sulawesi].

Subspecies/colour variants: None.

Distribution: S and C Sulawesi (known only from Rano Rano and the Latimojong Mts); distribution fragmented on isolated mountain tops.

Conservation status: Data Deficient.

2.1.8. Lariang Tarsier *Tarsius lariang* Merker & Groves, 2006

Type locality: Gimpu (S1°38’, E120°02’, 500 m), west of Lore-Lindu National Park, c. 5 km North of the River Lariang, Central Sulawesi, Indonesia.

Subspecies/colour variants: None.

Distribution: WC Sulawesi in the Lariang River Basin near the confluence with its tributary, the Meweh River, and extending N as far as Gimpu; the precise limits of its distribution may be much wider than those confirmed to date.

Conservation status: Data Deficient.

2.1.9. Wallace’s Tarsier *Tarsius wallacei* Merker *et al*., 2010

Type locality: Uwemanje, Central Sulawesi, Indonesia.

Subspecies/colour variants: None.

Distribution: NW Sulawesi (discontinuous range in Central Sulawesi Province); the N form occurs on the Isthmus of Palu from just W of the village of Tomini to the NE (c. E120°30’), the coastlines of the Isthmus of Palu to the E and to the W, to the villages of Ampibabo and Marantale in the S (c. S0°30’); the S form occurs in a very fragmented area W to SW of Palu, around the type locality Uwemanje (S0°58’, E119°50’).

Conservation status: Data Deficient.

2.2. Genus *Carlito*

2.2.1. Philippine Tarsier *Carlito syrichta* (Linnaeus, 1758)

Type locality: “Luzon”.

Subspecies/colour variants: 3 subspecies are conventionally recognized; they have not, however, been revised since their original descriptions, and it remains to be seen whether they are valid subspecies, or perhaps distinct species, or perhaps not valid at all. They are as follows: Philippine Tarsier *C. s. syrichta* (Linnaeus, 1758); Mindanao Tarsier *C. s. carbonarius* (Heude, 1898); Bohol Tarsier *C. s. fraterculus* (G.S. Miller, 1911). It may be that other taxa remain to be identified.

Distribution: *C. s. syrichta*: Eastern Visayas in SE Philippines (Leyte, Samar, Dinagat, Biliran and Maripipi islands), but by default, all other areas within the distribution of *C. syrichta*, except for Mindanao and Bohol islands; *C. s. carbonarius*: SE Philippines (Mindanao), some known locations in the N, C and SW provinces of Bukidnon, Davao del Norte, Davao del Sur, Misamis Occidental, Misamis Oriental, South Cotabato, Zamboanga del Norte, and Zamboanga del Sur, although presumably extirpated in many places today; also in Basilan Island; *C. s. fraterculus*: SE Philippines on Bohol Island.

Conservation status: Near Threatened (as *Tarsius syrichta*); individual subspecies have not been separately assessed.

2.3. Genus *Cephalopachus*

2.3.1. Western Tarsier *Cephalopachus bancanus* (Horsfield, 1821)

Type locality: Indonesia, South-east Sumatra, Bangka Island.

Subspecies/colour variants: 4 subspecies are conventionally recognized; they have not been revised since their original descriptions, and it remains to be seen whether they are valid subspecies, or distinct species; or perhaps not valid at all. They are: Horsfield's Tarsier *C. b. bancanus* (Horsfield, 1821); Bornean Tarsier *C. b. borneanus* (Elliot, 1910); Natuna Islands Tarsier *C. b. natunensis* (Chasen, 1940); and the Belitung Tarsier *C. b. saltator* (Elliot, 1910). The possibility of hitherto unidentified taxa, especially on Borneo, remains to be studied.

Distribution: *C. b. bancanus*: S Sumatra and Bangka Island; the precise distribution on Sumatra is unknown, but most likely delimited by the Musi River in the N; *C. b. borneanus*: Borneo and Karimata Island (off the SW coast of Borneo); *C. b. natunensis*: Serasan Island, one of the South Natuna Islands (just off the W coast of Borneo) and possibly nearby Subi Island; *C. b. saltator*: Belitung Island.

Conservation status: Vulnerable (as *Tarsius bancanus*); *C. b. borneanus* Vulnerable; *C. b. bancanus*, *C. b. saltator* Endangered; *C. b. natunensis* Critically Endangered.

3. Family Cercopithecidae

3.1. Genus *Papio*

3.1.1. Hamadryas baboon *Papio hamadryas* (Linnaeus, 1758)

Type locality: Egypt.

Subspecies/colour variants: None.

Distribution: SW Saudi Arabia (up to Jeddah), W Yemen, NE Sudan (Red Sea Hills), E Eritrea, Djibouti, NE Ethiopia, and NE Somalia.

Conservation status: Least Concern.

3.2. Genus *Macaca*

3.2.1. Lion-tailed Macaque *Macaca silenus* (Linnaeus, 1758)

Type locality: "Ceylon" [= Sri Lanka], corrected by J. Fooden in 1975 to India, Western Ghats, inland from Malabar Coast.

Subspecies/colour variants: None.

Distribution: SW India, endemic to the hills of the Western Ghats in the states of Karnataka, Kerala and Tamil Nadu, stretching from Anshi Ghats in the N to the Kalakkad Hills in the S, 800–1300 m.

Conservation status: Endangered.

3.2.2. Northern Pig-tailed Macaque *Macaca leonina* (Blyth, 1863)

Type locality: "Mountainous and rocky situation", Arakan District, South-eastern Burma [=Myanmar].

Subspecies/colour variants: None.

Distribution: NE India (S of the Brahmaputra River in the states of Assam, E Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland and Tripura), extending SE through E Bangladesh and Myanmar (including the Mergui Archipelago), SW China (SW Yunnan Province), Thailand, Laos, Vietnam and Cambodia; S to Surat Thani-Krabi Depression in peninsular Thailand (N8–9°). Lack of records in C and NE Myanmar between N20° and N25° suggests that this may be a natural gap in the distribution of the species.

Conservation status: Vulnerable.

3.2.3. Sunda Pig-tailed Macaque *Macaca nemestrina* (Linnaeus, 1766)

Type locality: Sumatra.

Subspecies/colour variants: None.

Distribution: Sunda area from Surat Thani-Krabi Depression in peninsular Thailand (N8–9°) SE through peninsular Malaysia, Sumatra, Bangka and Borneo; apparently native to offshore islets of Penang (W coast of peninsular Malaysia), Tioman (E coast of peninsular Malaysia) and Batam (Riau Archipelago off the S tip of peninsular Malaysia).

Conservation status: Vulnerable.

3.2.4. Siberut Macaque *Macaca siberu* Fuentes & Olson, 1995

Type locality: Indonesia, Siberut Island.

Subspecies/colour variants: None.

Distribution: Mentawai Archipelago, Siberut Island.

Conservation status: Vulnerable.

3.2.5. Pagai Macaque *Macaca pagensis* (G.S. Miller, 1903)

Type locality: Indonesia, South Pagai Island.

Subspecies/colour variants: None.

Distribution: Mentawai Archipelago (Sipora, North Pagai, South Pagai and on the Sinakak islet off the E coast of South Pagai).

Conservation status: Critically Endangered.

3.2.6. Crested Macaque *Macaca nigra* (Desmarest, 1822)

Type locality: "One of the islands of the Indian Archipelago".

Subspecies/colour variants: None.

Distribution: N Sulawesi (E tip of the N peninsula), Manado Tua and Talise islands. Introduced into the Moluccas Archipelago (Bacan Island).

Conservation status: Critically Endangered.

3.2.7. Gorontalo Macaque *Macaca nigrescens* (Temminck, 1849)

Type locality: Gorontalo, North Sulawesi Island, Indonesia.

Subspecies/colour variants: None.

Distribution: N Sulawesi, E of Gorontalo to Onggak Dumoga River in the N peninsula.

Conservation status: Vulnerable.

3.2.8. Tonkean Macaque *Macaca tonkeana* (Meyer, 1899)

Type locality: Indonesia, Sulawesi Tengah.

Subspecies/colour variants: Provisionally none are recognized, but this species may be divided into an eastern and a western species.

Distribution: C Sulawesi (S to Latimojong, SW to the base of the Toraja highlands at the Tempe Depression, SE toward, but not at, the lakes region of the SE peninsula, and NW to the isthmus between Palu and Parigi) and Togian Islands.

Conservation status: Vulnerable.

3.2.9. Booted Macaque *Macaca ochreata* (Ogilby, 1841)

Type locality: Unknown.

Subspecies/colour variants: 2 subspecies are recognized: Mainland Booted Macaque *M. o. ochreata* (Ogilby, 1841); Buton Macaque *M. o. brunnescens* (Matschie, 1901).

Distribution: *M. o. ochreata*: SE Sulawesi, through the entire SE peninsula, extending to the N of the lakes region; in the E, the border between this subspecies and *M. tonkeana* is the La River, while in the W it extends along the coast, across the Karaena River in its lower course, but not reaching into uplands further inland; *M. o. brunnescens*: Muna and Buton islands, and possibly the neighbouring islet of Labuan Blanda, off the coast of Sulawesi; it may no longer occur on Muna Island.

Conservation status: Vulnerable (both subspecies).

3.2.10. Heck's Macaque *Macaca hecki* (Matschie, 1901)

Type locality: Buol, Tengah, Sulawesi, Indonesia.

Subspecies/colour variants: None.

Distribution: NW Sulawesi from the base of the N peninsula (Isthmus of Palu) NE to just E of Gorontalo.

Conservation status: Vulnerable.

3.2.11. Moor Macaque *Macaca maura* (Schinz, 1825)

Type locality: Sulawesi Selatan, Indonesia.

Subspecies/colour variants: None.

Distribution: SW Sulawesi (from Bontobahari at the tip of the SW peninsula N to Tempe Depression).

Conservation status: Endangered.

3.2.12. Toque Macaque *Macaca sinica* (Linnaeus, 1771)

Type locality: Unknown.

Subspecies/colour variants: 3 subspecies are recognized: Dry-zone Toque Macaque *M. s. sinica* (Linnaeus, 1771); Wet-zone Toque Macaque *M. s. aurifrons* Pocock, 1931; Hill-zone Toque Macaque *M. s. opisthomelas* Hill, 1942.

Distribution: *M. s. sinica*: NE and SE Sri Lanka (Dry Zone); *M. s. aurifrons*: SW Sri Lanka (Wet Zone lowlands from the coast to c. 2000 m); *M. s. opisthomelas*: SC Sri Lanka (montane areas above 1800 m).

Conservation status: Endangered (all three subspecies).

3.2.13. Bonnet Macaque *Macaca radiata* (É. Geoffroy Saint-Hilaire, 1812)

Type locality: India.

Subspecies/colour variants: 2 subspecies are recognized; Dark-bellied Bonnet Macaque *M. r. radiata* (É. Geoffroy Saint-Hilaire, 1812); Pale-bellied Bonnet Macaque *M. r. diluta* Pocock, 1931.

Distribution: *M. r. radiata*: S and W India (states of Gujarat, Maharashtra, Andhra Pradesh, Goa, Karnataka, Kerala and Tamil Nadu), the N limit is the Tapti River, S to the Palni Hills and SE as far as Timbala, inland of Puducherry; introduced to the Mascarene Islands, including Mauritius and Réunion, probably in the 16th Century; *M. r. diluta*: SE India (states of Kerala and Tamil Nadu), from the S tip and the SE coast, N to Kambam at the SW foot of the Palni Hills and Puducherry on the E coast.

Conservation status: Least Concern (both subspecies).

3.2.14. Assamese Macaque *Macaca assamensis* (McClelland, 1839)

Type locality: India, Assam.

Subspecies/colour variants: 2 subspecies are recognized: Eastern Assamese Macaque *M. a. assamensis* (McClelland, 1839); Western Assamese Macaque *M. a. pelops* (Hodgson, 1840). *M. a. assamensis* may contain additional taxa.

Distribution: *M. a. assamensis*: SE Asia, 200–2750 m, E of the great bend of the Brahmaputra River, in SW China (SE Xizang, SW Guangxi, SW Yunnan and Guizhou provinces), NE India (E Arunachal Pradesh, E Assam, Nagaland, Meghalaya, Manipur, Mizoram and Tripura states), S and E through N and E Myanmar, N and W Thailand, Laos and N Vietnam; *M. a. pelops*: Himalayas up to 3100 m, from C Nepal (W limit Tipling, E83°36') E through NE India (N West Bengal, Sikkim and W Assam states), and Bhutan (E limit Manas River, E90°58'), with a widely disjunct record, of what may be a geographic relict, in coastal SW Bangladesh (Sundarbans).

Conservation status: Near Threatened (both subspecies).

3.2.15. Tibetan Macaque *Macaca thibetana* (Milne-Edwards, 1870)

Type locality: China, near Moupin [= Baoxing], Sichuan.

Subspecies/colour variants: Some subspecies have been described, but due to lack of information, provisionally none are recognized.

Distribution: E & C China (N25–33°, E102°30'–119°30') in E Xizang, Sichuan, S Gansu, S Shaanxi, Hubei, Anhui, Zhejiang, N Yunnan, Guizhou, Jiangxi, Fujian, N Guangxi and N Guangdong provinces; W limit in the Yangtze Gorge in W and NW Sichuan and S limit at N23°48', c. E110° in Guangxi. The species may range into NE India (Arunachal Pradesh, Assam and Meghalaya states), although some reports, at least, appear to be based on misidentifications.

Conservation status: Near Threatened.

3.2.16. Arunachal Macaque *Macaca munzala* Sinha *et al*., 2005

Type locality: Zemithang (N27°42', E91°43', 2180 m), Tawang District, Arunachal Pradesh, India.

Subspecies/colour variants: None.

Distribution: NE India (W Arunachal Pradesh State), in the districts of Tawang and West Kameng at elevations of 2000–3000 m; it possibly extends into Bhutan and Xizang [= Tibet] in W China. There are reports of its occurrence in Mouling National Park in the Upper Siang District of C Arunachal Pradesh, but they have yet to be confirmed.

Conservation status: Endangered.

3.2.17. Stump-tailed Macaque *Macaca arctoides* (I. Geoffroy Saint-Hilaire, 1831)

Type locality: Cochinchine [a region in southern Vietnam.] Based on the mounted skin of an adult male collected by P.M. Diard in June 1822; exact place of collection unknown.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: S and SE Asia, NE India S and E of the Brahmaputra River (Assam, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram and Tripura states), SW China S of N25° (Yunnan, Guizhou, Guangxi and Guangdong provinces), N Myanmar, Bangladesh, Thailand, Laos, Cambodia, Vietnam and N peninsular Malaysia where it could be a colonizer dispersed from S Thailand as recently as 1959; it may be now extirpated in Bangladesh where it was last recorded in 1982 and 1989. Known records are, at presenit, concentrated along N and S margins of its distribution, and it is rare or absent in C Indochinese peninsula, where deciduous forests predominate.

Conservation status: Vulnerable.

3.2.18. Long-tailed Macaque *Macaca fascicularis* (Raffles, 1821)

Type locality: Indonesia, Sumatra (Bengkulu).

Subspecies/colour variants: 10 subspecies are recognized: Common Long-tailed Macaque *M. f. fascicularis* (Raffles, 1821); Dark-crowned Long-tailed Macaque *M. f. atriceps* Kloss, 1919; Burmese Long-tailed Macaque *M. f. aureus* É. Geoffroy Saint-Hilaire, 1831; Con Song Long-tailed Macaque *M. f. condorensis* Kloss, 1926; Simeulue Long-tailed Macaque *M. f. fuscus* (G.S. Miller, 1903); Kemujan Long-tailed Macaque *M. f. karimondjawae* Sody, 1949; Lasia Long-tailed Macaque *M. f. lasiae* (Lyon, 1916); Philippine Long-tailed Macaque *M. f. philippinensis* (I. Geoffroy Saint-Hilaire, 1843); Maratua Long-tailed Macaque *M. f. tua* Kellogg, 1944; Nicobar Long-tailed Macaque *M. f. umbrosus* (G.S. Miller, 1902).

Distribution: *M. f. fascicularis*: S Laos, S Vietnam, Cambodia, E and S Thailand (and offshore islands), S to the Malay peninsula, Borneo, Sumatra, Java, Bali and most but not all offshore islands, also extending into the Sulu Archipelago and Zamboanga peninsula of W Mindanao in the Philippines; probably artificially introduced in the Nusa Penida-Timor Islands chain; *M. f. atriceps*: Khram Island [= Khram Yai], in Bight of Bangkok, off SE coast of Thailand; *M. f. aureus*: SW Bangladesh (Teknaaf peninsula), S Myanmar (including the Mergui Archipelago), and WC Thailand (S to c. N10°); *M. f. condorensis*: SE Vietnam (Con Son and Hon Ba islands in the South China Sea); *M. f. fuscus*: Simeulue Island in Banyak Archipelago, off NW Sumatra; *M. f. karimondjawae*: Karimunjawa Island and presumably nearby Kemujan Island, N of Java; *M. f. lasiae*: Lasia Island in Banyak Archipelago, off NW Sumatra; *M. f. philippinensis*: Philippine Archipelago N of c. N10°; *M. f. tua*: Maratua Island, off E Borneo; *M. f. umbrosus*: Nicobar Islands (Katchall, Little Nicobar and Great Nicobar islands).

Conservation status: Least Concern; *M. f. fascicularis* Least Concern; *M. f. condorensis*, *M. f. umbrosus* Vulnerable; *M. f. philippinensis* Near Threatened; *M. f. atriceps*, *M. f. aureus*, *M. f. fuscus*, *M. f. karimondjawae*, *M. f. lasiae*, *M. f. tua* Data Deficient.

3.2.19. Rhesus Macaque *Macaca mulatta* (Zimmermann, 1780)

Type locality: India. Based solely on Tawny Monkey, a menagerie animal (presumably observed in London), not preserved, identified by Pennant in 1771. Restricted by R. Pocock in 1932 to “Nepal Tarai” [= Terai], the narrow plain that extends along the southern border of Nepal.

Subspecies/colour variants: Many subspecies have been described, but due lack of information, provisionally none are recognized.

Distribution: S and SE Asia from c. N36° (in Afghanistan, Pakistan, India and China) S to c. N15° (in India, Thailand, Laos and Vietnam), also in Nepal, Bhutan, Bangladesh, Myanmar and Hainan Island. An isolated population at N40°24’ in NE China was extirpated in 1987.

Conservation status: Least Concern.

3.2.20. Japanese Macaque *Macaca fuscata* (Blyth, 1875)

Type locality: Japan.

Subspecies/colour variants: 2 subspecies are recognized: Mainland Japanese Macaque *M. f. fuscata* (Blyth, 1875); Yakushima Macaque *M. f. yakui* Kuroda, 1941.

Distribution: *M. f. fuscata*: Japanese Archipelago S of the Tsugaru Strait (N41°30’) in Honshu, Shikoku and Kyushu islands, and the nearby Kojima [= Koshima], Kashima, Awajishima, Shodoshima and Kinkazan islets; *M. f. yakui*: Japanese Archipelago (Yakushima Island, c. 60 km S of Kyushu).

Conservation status: Least Concern (both subspecies).

3.2.21. Taiwanese Macaque *Macaca cyclopis* (Swinhoe, 1863)

Type locality: Formosa [= Taiwan]. Restricted by R. Kellogg in 1945 to “Jusan (Ape’s Hill), Takao prefecture, Formosa” [= Shou Shan, Kaohsiung, Hsien, Taiwan].

Subspecies/colour variants: None.

Distribution: Taiwan Island, where it is widely distributed in the E mountains.

Conservation status: Least Concern.

3.3. Genus *Presbytis*

3.3.1. Thomas’s langur *Presbytis thomasi* (Collett, 1893)

Type locality: Indonesia, Sumatra, Aceh, Langkat.

Subspecies/colour variants: None.

Distribution: N Sumatra (Aceh Province), mostly N of the Wampu and Alas [= Simpang Kiri] rivers; a population has also been discovered S of the Alas at c. N3°50’.

Conservation status: Vulnerable.

3.3.2. Black-crested Sumatran Langur *Presbytis melalophos* (Raffles, 1821)

Type locality: Indonesia, Bencoolen [= Bengkulu], Sumatra.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: W Sumatra, from the upper Rokan River (Tanangtalu, N0°20’, E99°59’), just N of Gunung Talakmau, S to the upper Batang Hari and beyond along the Barisan Range, W of Lampung Province.

Conservation status: Near Threatened (as *P. melalophos melalophos*).

3.3.3. Black Sumatran Langur *Presbytis sumatrana* (Müller & Schlegel, 1841)

Type locality: “Mt Ophir” [= Gunung Talakmau], North of Padang.

Subspecies/colour variants: None.

Distribution: W and NC Sumatra (N highlands and W coast S of the Simpang Kiri River, N of Gunung Talakmau, and on the E coast from the Wampu River to the Barumun River, and SE to the Rokan River), and

Batu Islands (Pini Island).
Conservation status: Endangered (as *P. melalophos sumatranus*).

3.3.4. Black-and-white Langur *Presbytis bicolor* Aimi & Bakar, 1992
Type locality: Batang Kering, S0°50', E101°23', 14 km North of Kiliranjao, West Sumatra.
Subspecies/colour variants: None.
Distribution: EC Sumatra, from the Inderagiri River in the N to the Batang Hari in the S, mainly in highlands.
Conservation status: Data Deficient (as *P. melalophos bicolor*).

3.3.5. Mitred Langur *Presbytis mitrata* Eschscholtz, 1821
Type locality: Indonesia, Sumatra, mainland opposite Zutphen Islands.
Subspecies/colour variants: None.
Distribution: SE Sumatra E of the Barisan Range, from the Batang Hari, SW to the upper Musi River drainage, and S to Lampung Province.
Conservation status: Endangered (as *P. melalophos mitrata*).

3.3.6. Javan Langur *Presbytis comata* (Desmarest, 1822)
Type locality: Indonesia, Western Java.
Subspecies/colour variants: 2 subspecies are recognized; Grizzled Javan Langur *P. c. comata* (Desmarest, 1822); Fuscous Javan Langur *P. c. fredericae* (Sody, 1930).
Distribution: *P. c. comata*: W Java, from Ujung Kulno to Mt Lawu; E limit unknown; *P. c. fredericae*: C Java, around slopes of the volcanoes Gunung Slamet, Gunung Cupu and Diyeng; extent of its distribution to the W unknown.
Conservation status: Endangered (both under *P. comata*).

3.3.7. Pagai Langur *Presbytis potenziani* (Bonaparte, 1856)
Type locality: Tenasserim (corrected by O. Thomas in 1895 to Mentawai Islands, restricted by F.N. Chasen and C.B. Kloss in 1927 to Sipora Island).
Subspecies/colour variants: None.
Distribution: Mentawai Islands (Sipora, North Pagai, South Pagai and nearby Sinakak Island).
Conservation status: Critically Endangered (as *P. potenziani potenziani*).

3.3.8. Siberut Langur *Presbytis siberu* (Chasen & Kloss, 1928)
Type locality: Siberut Island, Indonesia.
Subspecies/colour variants: None.
Distribution: Mentawai Islands (Siberut Island).
Conservation status: Endangered (as *P. potenziani siberu*).

3.3.9. Banded Langur *Presbytis femoralis* (Martin, 1838)
Type locality: Singapore.
Subspecies/colour variants: 3 subspecies are recognized: Raffles' Banded Langur *P. f. femoralis* (Martin, 1838); East Sumatran Banded Langur *P. f. percura* Lyon, 1908; Robinson's Banded Langur *P. f. robinsoni* Thomas, 1910. In *P. f. femoralis*, colour variants occur.
Distribution: *P. f. femoralis*: S peninsular Malaysia (extreme S of Pahang and Johor states) and Singapore; *P. f. percura*: CE Sumatra, in a small area between the Rokan and Siak rivers; *P. f. robinsoni*: S Myanmar, S Thailand (from N13°50' in Phetchaburi Province), and NW peninsular Malaysia (S to Larut Hills, Perak State).
Conservation status: Near Threatened; *P. f. femoralis* Vulnerable; *P. f. robinsoni* Near Threatened; *P. f. percura* Data Deficient.

3.3.10. Pale-thighed Langur *Presbytis siamensis* (S. Müller & Schlegel, 1841)
Type locality: Malaya, Malacca [= Melaka].
Subspecies/colour variants: 4 subspecies are recognized: Malaysian Pale-thighed Langur *P. s. siamensis* (Müller & Schlegel, 1841); Riau-coast Pale-thighed Langur *P. s. cana* G.S. Miller, 1906; Mantled Pale-thighed Langur *P. s. paenulata* (Chasen, 1940); Bintan Pale-thighed Langur *P. s. rhionis* G.S. Miller, 1903.
Distribution: *P. s. siamensis*: peninsular Malaysia, in S Thailand (population isolate reported at N6°22', E101°08', well within the distribution of *P. femoralis robinsoni*) and most of peninsular Malaysia (it is absent in the NW to the N to the Piah Valley in Perak State, and in the S); *P. s. cana*: CE Sumatra (between the Siak and Indragiri rivers) and the Riau Archipelago (Kundur Island); *P. s. paenulata*: CE Sumatra (confined to a small wedge of coastal forest, with a population isolate reported from near Lake Toba); separated from *P. femoralis percura* by the Rokan River; *P. s. rhionis*: Riau Archipelago (for certain only from Bintan but may also occur on Batam and Galang islands).

Conservation status: Near Threatened; *P. s. siamensis*, *P. s. cana*, *P. s. paenulata* Near Threatened; *P. s. rhionis* Data Deficient.

3.3.11. Natuna Islands Langur *Presbytis natunae* (Thomas & Hartert, 1894)

Type locality: Indonesia, Bunguran Island, North Natuna Islands.

Subspecies/colour variants: None.

Distribution: Natuna Islands (Bunguran Island), N of the W coast of Borneo.

Conservation status: Vulnerable.

3.3.12. Cross-marked Langur *Presbytis chrysomelas* (Müller, 1838)

Type locality: Indonesia, Pontianak, West Borneo.

Subspecies/colour variants: 2 subspecies are recognized: Western Cross-marked Langur *P. c. chrysomelas* (Müller, 1838); Eastern Cross-marked Langur *P. c. cruciger* (Thomas, 1892). In both subspecies, colour variants occur.

Distribution: *P. c. chrysomelas*: W Borneo, from the IV Division in W Sarawak, S to the Kapuas River in West Kalimantan Province, also in W Brunei; *P. c. cruciger*: N Borneo, from Melalap in Sabah State to the Baram District in N Sarawak.

Conservation status: Critically Endangered (both subspecies).

3.3.13. Maroon Langur *Presbytis rubicunda* (Müller, 1838)

Type locality: Indonesia, Mt Sekumbang, South-east of Banjermasin, South Kalimantan.

Subspecies/colour variants: 5 subspecies are recognized; Southeast Bornean Maroon Langur *P. r. rubicunda* (Müller, 1838); Red-naped Maroon Langur *P. r. carimatae* G.S. Miller, 1906; Orange-backed Maroon Langur *P. r. chrysea* Davis, 1962; Orange-naped Maroon Langur *P. r. ignita* Dollman, 1909; Southwest Bornean Maroon Langur *P. r. rubida* (Lyon, 1911). In *P. r. rubicunda*, colour variants occur.

Distribution: *P. r. rubicunda*: Borneo (SE Kalimantan, roughly S of the Mahakam River and E of the Barito River); *P. r. carimatae*: Karimata Island, off W Borneo; *P. r. chrysea*: NE Borneo, confined to a very small area in E Sabah State near Kinabatangan; *P. r. ignita*: Borneo, in Sarawak State, from the Baram River at the border with Brunei, and in Kalimantan S to the Kapuas River; possibly in Brunei; *P. r. rubida*: Borneo (SW Kalimantan, roughly S of the Kapuas River and W of the Barito River).

Conservation status: Least Concern; *P. r. rubicunda*, *P. r. rubida*, *P. r. ignita* Least Concern; *P. r. chrysea*, *P. r. carimatae* Data Deficient.

3.3.14. Hose's Langur *Presbytis hosei* (Thomas, 1889)

Type locality: Malaysia, Sarawak, Niah.

Subspecies/colour variants: None.

Distribution: NW Borneo, W Sabah State (along W coast N to Mt Kinabalu), NE Brunei, and N Sarawak State (from its type locality Niah and the lower Baram River, E inland to N2°40', and the border with N Kalimantan).

Conservation status: Data Deficient (as *P. hosei hosei*).

3.3.15. Miller's Grizzled Langur *Presbytis canicrus* G.S. Miller, 1934

Type locality: Indonesia, East Kalimantan (Dutch North-east Borneo).

Subspecies/colour variants: None.

Distribution: Borneo, confined to an area of E Kalimantan, from the Kayan and Sembakung [= Sebuku] rivers in the N, S and SW to the Mahakam River, the W boundary is not well known but certainly E of the Apau Kayan and the Kayan Mentarang National Park.

Conservation status: Endangered (as *P. hosei canicrus*).

3.3.16. Sabah Grizzled Langur *Presbytis sabana* (Thomas, 1893)

Type locality: Malaysia, Sabah, Paitan.

Subspecies/colour variants: None.

Distribution: N Borneo in most of Sabah State, as far SW as Kalabakan (N4°26', E117°29'); its occurrence in N Kalimantan is not confirmed.

Conservation status: Endangered (as *P. hosei sabana*).

3.3.17. White-fronted Langur *Presbytis frontata* (Müller, 1838)

Type locality: Indonesia, South-eastern Borneo (restricted by Lord Medway in 1965 to South-eastern Kalimantan, Murung and "Pulu Lampy", near Banjarmasin, Pematang, Kuala).

Subspecies/colour variants: None.

Distribution: Found patchily in C and E Borneo, from C Sarawak State (absent from coastal areas and possibly occurs only between upper Rajang and upper Lupar rivers) to most of E Kalimantan and a few areas in the W (in the SE restricted to the E of the Barito River, there is a population in Gunung Palung in the SW, but it is not known whether it is isolated or continuous with other populations in the W).

Conservation status: Vulnerable.

3.4. Genus *Trachypithecus*

3.4.1. Golden Langur *Trachypithecus geei* Khajuria, 1956

Type locality: India, Assam, Goalpara District, Jamduar Forest Rest House, East bank of Sankosh River.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: NE India (Himalayan foothills of NW Assam State between the Manas and Sankosh rivers, and in the area immediately to the S, nearly to the Brahmaputra River) and Bhutan (as far N as Black Mt, c. N27°30', E of the Sankosh River; also extends E of the Mangde River along either side of the main stream).

Conservation status: Endangered.

3.4.2. Capped Langur *Trachypithecus pileatus* (Blyth, 1843)

Type locality: Type received from Barrackpore (menagerie), stated to be Malayan (corrected and restricted by C.P. Groves in 2005 to India, Assam).

Subspecies/colour variants: 4 subspecies are recognized: Blond-bellied Capped Langur *T. p. pileatus* (Blyth, 1843); Buff-bellied Capped Langur *T. p. brahma* (Wroughton, 1916); Orange-bellied Capped Langur *T. p. durga* (Wroughton, 1916); Dusky Capped Langur *T. p. tenebricus* (Hinton, 1923).

Distribution: *T. p. pileatus*: NE India highlands S and E of the Brahmaputra River, in the states of Arunachal Pradesh, Assam, Meghalaya, and Nagaland (Karbi Anglong Plateau, Barail Range, and Khasi, Garo, Naga, and Jaintia Hills), and in NW Myanmar (W of the Chindwin River, S to Chin Hills range and Mt Victoria), 600–3000 m; *T. p. brahma*: NE India, known only from the Dafla Hills, N of the Brahmaputra River, in Arunachal Pradesh State; *T. p. durga*: E Bangladesh and NE India in the states of Assam, Mizoram, and Tripura (Naga Hills, Lakhimpur, Golaghat, Cachar Hills, Samaguting, and Sibsagar), adjoining the distribution of *T. p. pileatus* to the N, but at lower elevations (from nearly sea level up to 600 m); *T. p. tenebricus*: NE India (Assam State) and Bhutan, in the Manas region N of the Brahmaputra River, 100–2000 m.

Conservation status: Vulnerable; *T. p. pileatus*, *T. p. durga*, *T. p. tenebricus* Endangered; *T. p. brahma* Data Deficient.

3.4.3. Shortridge's Langur *Trachypithecus shortridgei* (Wroughton, 1915)

Type locality: Burma [= Myanmar], Homalin, upper Chindwin.

Subspecies/colour variants: None.

Distribution: NE Myanmar, E of the Chindwin River (Kachin State N to Myitkyina District) and SW China (Dulong River Valley in Gongshan County, NW Yunnan Province).

Conservation status: Endangered.

3.4.4. East Javan Langur *Trachypithecus auratus* (É. Geoffroy Saint-Hilaire, 1812)

Type locality: Indonesia, Semarang (restricted by D. Brandon-Jones in 1995 to Batu District).

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: E Java (NW to the vicinity of Jakarta, and E of c. E109° in the S coast), Bali and Lombok islands, and Sempu and Nusa Barung islands, off the S coast of Java.

Conservation status: Vulnerable (as *T. auratus auratus*).

3.4.5. West Javan Langur *Trachypithecus mauritius* (Griffith, 1821)

Type locality: "Mauritius", probably W Java (restricted by D. Brandon-Jones in 1995 to Jasinga).

Subspecies/colour variants: None.

Distribution: W Java (restricted to the N coast W of Jakarta, and inland to Bogor, Cisalak, and Jasinga, SW to Ujung Kulon, then along the S coast as far E as Cikaso and possibly Ciwangi).

Conservation status: Vulnerable (as *T. auratus mauritius*).

3.4.6. Silvered Langur *Trachypithecus cristatus* (Raffles, 1821)

Type locality: Indonesia, Sumatra, Bencoolen [= Bengkulu].

Subspecies/colour variants: 2 subspecies are recognized: Sunda Silvered Langur *T. c. cristatus* (Raffles, 1821); Natuna Islands Silvered Langur *T. c. vigilans* (G.S. Miller, 1913). In *T. c. cristatus*, colour variants occur.

Distribution: *T. c. cristatus*: Borneo, Sumatra, Bangka, Belitung, and Riau (Bintan, Combol, Sugi, and perhaps Batam) and Lingga (Bakung, Lingga) archipelagos, off E Sumatra; *T. c. vigilans*: Natuna Islands (Serasan Island), off W Borneo.

Conservation status: Near Threatened; *T. c. cristatus* Near Threatened; *T. c. vigilans* Critically Endangered.

3.4.7. Selangor Silvered Langur *Trachypithecus selangorensis* Roos *et al*., 2008

Type locality: West Malaysia, Selangor Province, Kuala Selangor (N3°20', E101°20').

Subspecies/colour variants: None.

Distribution: W peninsular Malaysia, confined to a strip along the W coast from N6° to N1°30' in the states of Kedah, Perak, Selangor, Negeri Sembilan, Melaka, and Johor.

Conservation status: Not Evaluated.

3.4.8. Germain's Langur *Trachypithecus germaini* (Milne-Edwards, 1876)

Type locality: Cochin-China [= S Vietnam] and Cambodia.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: Mainland SE Asia in S Myanmar, S Thailand, S Laos, Cambodia (W of Mekong River), and the S tip of Vietnam; Mekong River as E limit not yet confirmed.

Conservation status: Endangered, but assessment included *T. margarita.*

3.4.9. Annamese Langur *Trachypithecus margarita* (Elliot, 1909)

Type locality: Vietnam, Langbian.

Subspecies/colour variants: None.

Distribution: S Laos (N limit is N16°23'), SC Vietnam (N limit is N14°30'), and E Cambodia (Ratanakiri and Mondulkiri provinces); most likely the W limit is the Mekong River, but further studies are needed to confirm this. Records in Vietnam N to N16°37' are questionable.

Conservation status: Endangered (but as a synonym of *T. germaini*).

3.4.10. Dusky Langur *Trachypithecus obscurus* (Reid, 1837)

Type locality: Malaysia (restricted by F.N. Chasen in 1940 to Malacca). [Melaka]

Subspecies/colour variants: 7 subspecies are recognized: Reid's Dusky Langur *T. o. obscurus* (Reid, 1837); Terutau Island Dusky Langur *T. o. carbo* (Thomas & Wroughton, 1909); Blond-tailed Dusky Langur *T. o. flavicauda* (Elliot, 1910); Cantor's Dusky Langur *T. o. halonifer* (Cantor, 1845); St Matthew Island Dusky Langur *T. o. sanctorum* (Elliot, 1910); Phangan Dusky Langur *T. o. seimundi* (Chasen, 1940); Perhentian Dusky Langur *T. o. styx* (Kloss, 1911).

Distribution: *T. o. obscurus*: peninsular Malaysia (S from about Perlis); *T. o. carbo*: Langkawi, Terutau and Dayang Bunting islands, off the W coast of the Thai-Malay Peninsula; *T. o. flavicauda*: S Myanmar (S of c. N15°10', and including James, Kisseraing and King islands in the Mergui Archipelago), SW Thailand (including Khao Lak Island), and N peninsular Malaysia (S to Perlis); *T. o. halonifer*: Penang Island, off W peninsular Malaysia; *T. o. sanctorum*: Mergui Archipelago (Zadetkyi Island), off W Myanmar; *T. o. seimundi*: Phangan Island; probably also on the adjacent E coast of the Thai-Malay Peninsula; *T. o. styx*: East Perhentian Island; probably also on the adjacent E coast of the Thai-Malay Peninsula.

Conservation status: Near Threatened; *T. o. obscurus*, *T. o. flavicauda*, *T. o. halonifer*, *T. o. carbo* Least Concern; *T. o. styx*, *T. o. seimundi*, *T. o. sanctorum* Vulnerable.

3.4.11. Phayre's Langur *Trachypithecus phayrei* (Blyth, 1847)

Type locality: Burma [= Myanmar], Arakan.

Subspecies/colour variants: 2 subspecies are recognized: Bengal Phayre's Langur *T. p. phayrei* (Blyth, 1847); Shan States Phayre's Langur *T. p. shanicus* (Wroughton, 1917).

Distribution: *T. p. phayrei*: E Bangladesh, NE India (Assam, Mizoram and Tripura states), and W Myanmar (SE through Arakan to Pegu); *T. p. shanicus*: SW China (Yingjiang-Namting River and Tunchong-Homushu Pass districts in W Yunnan Province), and N and E Myanmar (Shan State and neighbouring dry zone of N Myanmar).

Conservation status: Endangered (both subspecies).

3.4.12. Tenasserim Langur *Trachypithecus barbei* (Blyth, 1847)

Type locality: Burma [= Myanmar], Ye, South of Moulmein.

Subspecies/colour variants: None.

Distribution: E Myanmar and W Thailand, confined to a small region N of the Thai-Malay Peninsula (N14°20'–15°10', E98°30'–98°55').

Conservation status: Data Deficient.

3.4.13. Indochinese Grey Langur *Trachypithecus crepusculus* (Elliot, 1909)

Type locality: Burma [= Myanmar], Mt Muleiyit, 1500 m.

Subspecies/colour variants: None.

Distribution: SW China (E of Salween River and S of Xishuangbanna, S Yunnan Province), S Myanmar, N Thailand (S to Raheng, and W to the coast of the Bay of Bengal), N and C Laos, and N Vietnam; the W limit is most likely the Salween River; S of the distribution of Phayre's Langur (*T. phayrei*).

Conservation status: Endangered (as *T. phayrei crepuscula*).

3.4.14. Francois' Langur *Trachypithecus francoisi* (Pousarges, 1898)

Type locality: Longzhou, China.

Subspecies/colour variants: None.

Distribution: SW China (Chongqing, Guizhou and Guangxi provinces) and N Vietnam (Ha Giang, Cao Bang, Tuyen Quang, Bac Kan and Thai Nguyen provinces).

Conservation status: Endangered.

3.4.15. Cat Ba Langur *Trachypithecus poliocephalus* (Trouessart, 1911)

Type locality: The type locality is supposed to be the village Cai Kien (N21°19', E107°44') or the Cai Kinh limestone massif (N21°45', E107°30').

Subspecies/colour variants: None.

Distribution: Cat Ba Island, Ha Long Bay, off N Vietnam.

Conservation status: Critically Endangered (as *T. poliocephalus poliocephalus*).

3.4.16. White-headed Langur *Trachypithecus leucocephalus* Tan, 1957

Type locality: Fusui County, Guangxi, China.

Subspecies/colour variants: None.

Distribution: S China, restricted to the counties of Fusui, Chongzuo, Ningming and Longzhou in SW Guangxi Autonomous Region; it is bordered in the NW and N by the Zuo River, in the SW and S by the Ming River, and to the SE by the Shiwan Mts.

Conservation status: Critically Endangered (as *T. poliocephalus leucocephalus*).

3.4.17. Delacour's Langur *Trachypithecus delacouri* (Osgood, 1932)

Type locality: Hoi Xuan, Vietnam.

Subspecies/colour variants: None.

Distribution: NC Vietnam (Hoa Binh, Ha Nam, Ninh Binh and Thanh Hoa provinces).

Conservation status: Critically Endangered.

3.4.18. Laotian Langur *Trachypithecus laotum* (Thomas, 1921)

Type locality: Ban Na Sao, South-west French Laos, on the French side of the Mekong, c. N17°30'.

Subspecies/colour variants: None.

Distribution: WC Laos, from S Bolikhamsai Province, probably with the Nam Kading River as N barrier of the distribution, S to C Khammouane Province, at c. N17°40'; there are also reports from the corridor to Nakai-Nam Theun National Protected Area, and from Khamkeut District, close to Lak Sao (N18°13', E104°47').

Conservation status: Vulnerable.

3.4.19. Hatinh Langur *Trachypithecus hatinhensis* (Dao Van Tien, 1970)

Type locality: Xom Cuc (N17°56', E105°47'), Ha Tinh Province [now Tuyen Hoa District, Quang Binh Province], Vietnam.

Subspecies/colour variants: None.

Distribution: NC Vietnam (Quang Binh and Quang Tri provinces), and EC Laos (Khammouane Province). The records in other Vietnamese provinces (Nghe An, Thu Thien Hue, Gia Lai, Phu Yen) are errors.

Conservation status: Endangered.

3.4.20. Black Langur *Trachypithecus ebenus* (Brandon-Jones, 1995)

Type locality: "Indo China"; probably either Lai Chau or Fan Si Pan mountain chain (c. N22°30', E103°50'), Vietnam.

Subspecies/colour variants: None.

Distribution: EC Laos, in S Khammouane Province, close to the border with Vietnam and in scattered limestone blocks to the S into N Savannakhet Province to c. N16°50'; the species is also recorded in C Vietnam, Quang Binh Province (N17°59', E105°40').

Conservation status: Endangered (as synonym of *T. hatinhensis*).

3.5. Genus *Semnopithecus*

3.5.1. Northern Plains Sacred Langur *Semnopithecus entellus* (Dufresne, 1797)

Type locality: India, Bengal.

Subspecies/colour variants: None.

Distribution: India: the species' range extends 1900 km W to E, and includes all populations with the northern-type tail carriage between the Tapti River in Gujarat State and Krishna River in Andhra Pradesh State to the foothills of the Himalayas. Introduced into SW Bangladesh, where the population may have arisen from descendents of a pair introduced by Hindu pilgrims on banks of the Jalangi River.

Conservation status: Least Concern.

3.5.2. Chamba Sacred Langur *Semnopithecus ajax* (Pocock, 1928)

Type locality: India, Chamba, Deolah, 1800 m.

Subspecies/colour variants: None.

Distribution: NW India, confined to the Chamba Valley of Himachal Pradesh State; it may also occur in the Kishtwar Valley of Jammu and Kashmir State.

Conservation status: Endangered.

3.5.3. Terai Sacred Langur *Semnopithecus hector* (Pocock, 1928)

Type locality: India, Sitabani, Ramnagar, Kumaon, 600 m.

Subspecies/colour variants: None.

Distribution: Himalayan foothills in N India (states of Uttarakhand, Uttar Pradesh, and W Bengal), and W and C Nepal; it also probably occurs in SW Bhutan near Pankhabari.

Conservation status: Near Threatened.

3.5.4. Central Himalayan Sacred Langur *Semnopithecus schistaceus* Hodgson, 1840

Type locality: Nepal.

Subspecies/colour variants: None.

Distribution: NW Pakistan, N India (Jammu and Kashmir, Himachal Pradesh, Uttarakhand, and NW Bengal states, and Sikkim), S China (Tibetan regions of Bo Qu, Ji Long Zang Bu and Chumbi Valleys in Xizang Autonomous Region), Nepal, and W Bhutan (E to Sankosh River); its presence in E Afghanistan is uncertain.

Conservation status: Least Concern.

3.5.5. Malabar Sacred Langur *Semnopithecus hypoleucos* Blyth, 1841

Type locality: India, Travancore.

Subspecies/colour variants: 3 subspecies are provisionally recognized: Southern Malabar Sacred Langur *S. h. hypoleucos* Blyth, 1841; Northern Malabar Sacred Langur *S. h. achates* (Pocock, 1928); Black-legged Malabar Sacred Langur *S. h. iulus* (Pocock, 1928).

Distribution: *S. h. hypoleucos*: SW India (S Western Ghats), from around Brahmagiri Hills in Karnataka State S to the N of Silent Valley in Kerala State; *S. h. achates*: W India (W Deccan Plateau and E slopes of Western Ghats) up to the Roonwal line that follows the Tapti and Godavari rivers in the N; limited by the distribution of *S. entellus* in the NE and *S. priam priam* in the E; *S. h. iulus*: SW India (Western Ghats), from Jog Falls in Karnataka State, at 440 m, and S along the hilly wet zones to the Brahmagiri Hills.

Conservation status: Vulnerable; *S. h. hypoleucos* (as *S. hypoleucos*) Vulnerable; *S. h. achates*, *S. h. iulus* (both as synonyms of *S. dussumieri*) Least Concern.

3.5.6. Tufted Sacred Langur *Semnopithecus priam* Blyth, 1844

Type locality: India, Coromandel Coast.

Subspecies/colour variants: 3 subspecies are recognized: Madras Tufted Sacred Langur *S. p. priam* Blyth, 1844; Central Indian Tufted Sacred Langur *S. p. anchises* Blyth, 1844; Sri Lankan Tufted Sacred Langur *S. p. thersites* (Blyth, 1847) (described as *Presbytis*).

Distribution: *S. p. priam*: S and SE India (Andhra Pradesh, Karnataka, Kerala and Tamil Nadu states), a highly fragmented distribution ranging from the Krishna River in Andhra Pradesh S to Tirunelveli in Tamil Nadu; *S. p. anchises*: SC India (S Deccan Plateau), found in the districts of Kurnool, Andhra Pradesh, and in Pavagada in the district of Tumkur, Karnataka; *S. p. thersites*: Dry Zone of Sri Lanka, ranging from Jaffna in the N to the S coast.

Conservation status: Near Threatened; *S. p. priam* Near Threatened; *S. p. anchises* (as synonym of *S. dussumieri*) Least Concern; *S. p. thersites* Endangered.

3.5.7. Purple-faced Langur *Semnopithecus vetulus* (Erxleben, 1777)

Type locality: Ceylon [= Sri Lanka].

Subspecies/colour variants: 4 subspecies are recognized: Southern Purple-faced Langur *S. v. vetulus* (Erxleben, 1777); Highland Purple-faced Langur *S. v. monticola* (Kelaart, 1850); Western Purple-faced Langur *S. v. nestor* Bennett, 1833; Northern Purple-faced Langur *S. v. philbricki* (Phillips, 1927).

Distribution: *S. v. vetulus*: SW Sri Lanka (Wet Zone), from Kalu River S to Rama, up to 1000 m; the distribution is less than 5000 km^2; *S. v. monticola*: mountains of C Sri Lanka 1000–2200 m; *S. v. nestor*: W Sri Lanka (Wet Zone), N of the Kalu River up to 1000 m; *S. v. philbricki*: N & E Sri Lanka (Dry Zone) up to 1500 m in E Matale and Madulkele Hills.

Conservation status: Endangered (as *Trachypithecus vetulus*); *S. v. vetulus*, *S. v. monticola*, *S. v. philbricki* Endangered; *S. v. nestor* Critically Endangered.

3.5.8. Nilgiri Langur *Semnopithecus johnii* (Fischer, 1829)

Type locality: India, Tellicherry.

Subspecies/colour variants: None.

Distribution: SW India (Karnataka, Kerala, and Tamil Nadu states); it occurs sporadically in montane forests of the Western Ghats from Srimangala (N12°01’, E75°58’) in Karnataka S to the Aramboli Pass (N8°16’) in Kerala.

Conservation status: Vulnerable (as *Trachypithecus johnii*).

3.6. Genus *Rhinopithecus*

3.6.1. Tonkin Snub-nosed Monkey *Rhinopithecus avunculus* Dollman, 1912

Type locality: Yen Bay, Songkoi River, Vietnam.

Subspecies/colour variants: None.

Distribution: NW Vietnam, known only from small forest patches in Ha Giang, Tuyen Quang, Bac Kan, and Thai Nguyen provinces. Most likely also present in neighbouring China.

Conservation status: Critically Endangered.

3.6.2. Yunnan Snub-nosed Monkey *Rhinopithecus bieti* Milne-Edwards, 1897

Type locality: China, Yunnan, left bank of upper Mekong, Kiape, a day’s journey South of Atuntze (N28°25’, E98°55’).

Subspecies/colour variants: None.

Distribution: SW China, in SE Xizang Autonomous Region [= Tibet] and NW Yunnan Province (fragmented populations in the Yun Ling Mts), W of the Yangtze River and E of the Mekong River.

Conservation status: Endangered.

3.6.3. Guizhou Snub-nosed Monkey *Rhinopithecus brelichi* Thomas, 1903

Type locality: China, Van Gin Shan [= Fanjingshan], Guizhou.

Subspecies/colour variants: None.

Distribution: SC China, Guizhou Province, Fanjingshan in the Wuling Mts.

Conservation status: Endangered.

3.6.4. Golden Snub-nosed Monkey *Rhinopithecus roxellana* (Milne-Edwards, 1870)

Type locality: China, Sichuan, near Moupin [= Baoxing] (N30°26’, E102°50’).

Subspecies/colour variants: 3 subspecies are recognized: Moupin Golden Snub-nosed Monkey *R. r. roxellana* (Milne-Edwards, 1870); Hubei Golden Snub-nosed Monkey *R. r. hubeiensis* Wang *et al*., 1998; Qinling Golden Snub-nosed Monkey *R. r. qinlingensis* Wang *et al*., 1998.

Distribution: *R. r. roxellana*: WC China (S Gansu, S Shaanxi, and W Sichuan provinces); *R. r. hubeiensis*: WC China (Shennongjia in W Hubei Province and NW Sichuan Province); *R. r. qinlingensis*: WC China (Qinling Mts, S Shaanxi Province).

Conservation status: Endangered (all three subspecies).

3.6.5. Myanmar Snub-nosed Monkey *Rhinopithecus strykeri* Geissmann *et al*., 2011

Type locality: N26.43101°, E98.38894° [= N26°26’, E98°23’] (2815 m), Maw River area, North-eastern Kachin State, North-east Myanmar.

Subspecies/colour variants: None.

Distribution: NE Myanmar (Salween–N’mai Hka divide in NE Kachin State, only around the Maw River, as far E as the mountains above the village of Chichitago, N26.31°–26.51° and E98.34°–98.61°) and SW China (Gaoligongshan Nature Reserve, Yunnan Province).

Conservation status: Critically Endangered.

3.7. Genus *Pygathrix*

3.7.1. Grey-shanked Douc *Pygathrix cinerea* Nadler, 1997

Type locality: Vietnam, Gia Lai Province, Play Ku.

Subspecies/colour variants: None.

Distribution: C Vietnam between N16° and N13°38’ (Quang Nam, Kon Tum, Quang Ngai, Gia Lai, and Binh Dinh provinces), and a small part of NE Cambodia. Probably also S Laos.

Conservation status: Critically Endangered.

3.7.2. Red-shanked Douc *Pygathrix nemaeus* (Linnaeus, 1771)

Type locality: Vietnam, “Cochin-China”.

Subspecies/colour variants: None.

Distribution: EC and SE Laos, N and C Vietnam (but very fragmented), and a small area in NE Cambodia (Voensei, Ratanakkiri Province).

Conservation status: Endangered.

3.7.3. Black-shanked Douc *Pygathrix nigripes* (Milne-Edwards, 1871)

Type locality: Vietnam, Saigon [= Ho Chi Minh City].

Subspecies/colour variants: None.

Distribution: E Cambodia (E of the Mekong River and S of the Srepok River) and SW Vietnam from c. N14° to S Cat Tien National Park. The presence of this species in S Laos is suspected but not confirmed.

Conservation status: Endangered.

3.8. Genus *Nasalis*

3.8.1. Proboscis Monkey *Nasalis larvatus* (van Wurmb, 1787)

Type locality: Pontiana [= Pontianak], Borneo.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: Borneo (Sabah and Sarawak states, Brunei, and Kalimantan), also on Berhala, Sebatik and Laut islands.

Conservation status: Endangered.

3.9. Genus *Simias*

3.9.1. Pig-tailed Langur *Simias concolor* G.S. Miller, 1903

Type locality: Indonesia, West Sumatra, South Pagai Island.

Subspecies/colour variants: 2 subspecies are recognized: Pagai Pig-tailed Langur *S. c. concolor* G.S. Miller, 1903; Siberut Pig-tailed Langur *S. c. siberu* Chasen & Kloss, 1928. In both subspecies, colour variants occur.

Distribution: *S. c. concolor*: Mentawai Islands (Sipora, North Pagai, South Pagai and nearby Simalegu, Simatapi and Sinakak islands); *S. c. siberu*: Mentawai Islands (Siberut).

Conservation status: Critically Endangered (both subspecies).

4. Hylobatidae

4.1. Genus *Hoolock*

4.1.1. Western Hoolock Gibbon *Hoolock hoolock* (Harlan, 1834)

Type locality: India, Garo Hills, Assam.

Subspecies/colour variants: 2 subspecies are recognized: Common Western Hoolock Gibbon *H. h. hoolock* (Harlan, 1834); Mishmi Hills Western Hoolock Gibbon *H. h. mishmiensis* Choudhury, 2013.

Distribution: *H. h. hoolock*: Bangladesh and NE India (states of Assam, Arunachal Pradesh, Nagaland, Meghalaya, Manipur, Mizoram and Tripura), S of the Brahmaputra and Lohit rivers, extending into W Myanmar, W of the Chindwin River. *H. h. mishmiensis*: NE India (states of Assam and Arunachal Pradesh) between the Dibang and Lohit rivers, and to the S of the Ithun River. The identity of a population in the Medog Nature Reserve in SE Tibet, across the border from Arunachal Pradesh, is unknown.

Conservation status: Endangered; subspecies not separately evaluated.

4.1.2. Eastern Hoolock Gibbon *Hoolock leuconedys* (Groves, 1967)

Type locality: Burma [= Myanmar], Sumprabum, 1200 m.

Subspecies/colour variants: None.

Distribution: E Myanmar (E of the Chindwin River), and SW China in W Yunnan Province.

Conservation status: Vulnerable.

4.2. Genus *Hylobates*

4.2.1. Pileated Gibbon *Hylobates pileatus* Gray, 1861

Type locality: Cambodia.

Subspecies/colour variants: None.

Distribution: SE Thailand (E and S of the Mun and Takhong rivers; W limit may have formerly been the Bang Pakong River), SW Laos (W of the Mekong River), and N and W Cambodia (W of the Mekong River); may have formerly occurred in S Vietnam (W of the Mekong River).

Conservation status: Endangered.

4.2.2. Lar Gibbon *Hylobates lar* (Linnaeus, 1771)

Type locality: None. Malaysia, Malacca [= Melaka] (restricted by C.B. Kloss in 1929).

Subspecies/colour variants: 5 subspecies are recognized: Malaysian Lar Gibbon *H. l. lar* (Linnaeus, 1771); Carpenter's Lar Gibbon *H. l. carpenteri* Groves, 1968; Central Lar Gibbon *H. l. entelloides* I. Geoffroy Saint-Hilaire, 1842; Sumatran Lar Gibbon *H. l. vestitus* G.S. Miller, 1942; Yunnan Lar Gibbon *H. l. yunnanensis* Ma & Wang, 1986. In *H. l. lar*, *H. l. carpenteri* and *H. l. entelloides*, colour variants occur.

Distribution: *H. l. lar*: peninsular Malaysia, from N9° to the Mudah River and S of the Perak River; *H. l. carpenteri*: E Myanmar, NW Laos, and NW Thailand, from Chieng Dao at N19°22' to c. N16°; *H. l. entelloides*: S Myanmar and SW Thailand, from c. N15° to N10°; *H. l. vestitus*: N Sumatra, NW of Lake Toba and the Singkil River; *H. l. yunnanensis*: SW China (SW Yunnan Province), originally between the Salween and Mekong rivers in the counties of Cangyuan, Menglian and Ximeng, but probably now extirpated.

Conservation status: Endangered; *H. l. lar*, *H. l. vestitus*, *H. l. carpenteri* Endangered; *H. l. entelloides* Vulnerable; *H. l. yunnanensis* Data Deficient.

4.2.3. Agile Gibbon *Hylobates agilis* F. Cuvier, 1821

Type locality: Indonesia, West Sumatra.

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: S Thailand (near the Malaysian border, E of the Thepha River watershed), N peninsular Malaysia (from Mudah and Thepha rivers in the N to the Perak and Kelantan rivers in the S), and most of Sumatra (from SE of Lake Toba and the Singkil River to the S).

Conservation status: Endangered.

4.2.4. Bornean White-bearded Gibbon *Hylobates albibarbis* Lyon, 1911

Type locality: Indonesia, near Sukadana, South-west Borneo.

Subspecies/colour variants: None.

Distribution: SW Borneo (West and Central Kalimantan provinces), S of the Kapuas River and W of the Barito River.

Conservation status: Endangered.

4.2.5. Müller's Gibbon *Hylobates muelleri* Martin, 1841

Type locality: Indonesia, Kalimantan (restricted by M. Lyon in 1911 to South-eastern Borneo).

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: Borneo, SE Kalimantan, c. S of the Mahakam River and E of the Barito River.

Conservation status: Endangered (as *H. m. muelleri*).

4.2.6. Abbott's Grey Gibbon *Hylobates abbotti* Kloss, 1929

Type locality: Indonesia, Pontianak, South-western Borneo.

Subspecies/colour variants: None.

Distribution: SW Borneo (S Sarawak State and West Kalimantan Province), N of the Kapuas River and as far E as the Spaok [= Saribas], District of Sarawak.

Conservation status: Endangered (as *H. muelleri abbotti*).

4.2.7. East Bornean Grey Gibbon *Hylobates funereus* I. Geoffroy Saint-Hilaire, 1850

Type locality: Philippines, Sulu Islands.

Subspecies/colour variants: None.

Distribution: N & NE Borneo, from Sabah State S to the Mahakam River in East Kalimantan and perhaps W to the Baram District and the IV Division of Sarawak State.

Conservation status: Endangered (as *H. muelleri funereus*).

4.2.8. Kloss's Gibbon *Hylobates klossii* (G.S. Miller, 1903)

Type locality: Indonesia, West Sumatra, South Pagai Island.

Subspecies/colour variants: None.

Distribution: Mentawai Islands (Siberut, Sipora, North Pagai, South Pagai, and Sinakak) off the W coast of Sumatra.

Conservation status: Endangered.

4.2.9. Moloch Gibbon *Hylobates moloch* (Audebert, 1798)

Type locality: Indonesia, Java (restricted by H. Sody in 1949 to W Java, Mt Salak).

Subspecies/colour variants: No subspecies are recognized, but colour variants occur.

Distribution: Java, mainly in the W provinces (Banten and West Java), with an additional population in a small area in the C as far E as the Dieng Mts.

Conservation status: Endangered.

4.3. Genus *Nomascus*

4.3.1. Hainan Crested Gibbon *Nomascus hainanus* (Thomas, 1892)

Type locality: China, Hainan.

Subspecies/colour variants: None.

Distribution: China, Hainan Island. Formerly widespread, but today restricted to Bawangling Nature Reserve in the W of the island.

Conservation status: Critically Endangered.

4.3.2. Eastern Black Crested Gibbon *Nomascus nasutus* (Milne Edwards, 1884)

Type locality: Vietnam, Along [= Halong] Bay.

Subspecies/colour variants: None.

Distribution: Formerly S China to N Vietnam as far S and W as the Red River, but now restricted to a small area along the Sino-Vietnamese border in Trung Khanh District (Cao Bang Province, NE Vietnam) and Jingxi County (Guangxi Autonomous Region, SW China).

Conservation status: Critically Endangered.

4.3.3. Western Black Crested Gibbon *Nomascus concolor* (Harlan, 1826)

Type locality: Vietnam, Tonkin.

Subspecies/colour variants: 2 subspecies are recognized: Tonkin Western Black Crested Gibbon

N. c. concolor (Harlan, 1826); Laotian Western Black Crested Gibbon *N. c. lu* (Delacour, 1951).

Distribution: *N. c. concolor*: SW China (C & SW Yunnan Province) including a small population W of the Mekong River near the Myanmar border, and N Vietnam (Lao Cai, Son La, and Yen Bai provinces) between the Black and Red rivers from c. N20° to N23°45'; *N. c. lu*: NW Laos (Bokeo and Luang Namtha provinces) in an isolated population E of the Mekong River at c. N20°17'–N20°25'.

Conservation status: Critically Endangered (both subspecies).

4.3.4. Northern White-cheeked Crested Gibbon *Nomascus leucogenys* (Ogilby, 1841)

Type locality: Siam (restricted by J. Fooden in 1987 to Laos, Muang Khi).

Subspecies/colour variants: None.

Distribution: S China (extreme S Yunnan Province but probably extirpated, N Laos, and NW Vietnam between the Mekong and Black rivers, to the S possibly limited by the Khading River in Laos and the Rao Nay River in Ha Tinh Province in Vietnam.

Conservation status: Critically Endangered.

4.3.5. Southern White-cheeked Crested Gibbon *Nomascus siki* (Delacour, 1951)

Type locality: Vietnam, Thua Luu.

Subspecies/colour variants: None.

Distribution: C Laos and C Vietnam, restricted by the Rao Nay River in Vietnam and the Khading River in Laos in the N, the Mekong River in the W, the Vietnamese coastal agricultural areas in the E, and around the Thach Han River (N16°40'–N16°50') in Quang Tri Province, Vietnam, and Savannakhet Province in Laos, to the S.

Conservation status: Endangered.

4.3.6. Northern Yellow-cheeked Crested Gibbon *Nomascus annamensis* Van Ngoc Thinh *et al*., 2010

Type locality: Vietnam, Ja Boc, Sa Thay District, Kon Tum Province (c. N14°25', E107°35', Chu Mom Ray National Park).

Subspecies/colour variants: None.

Distribution: S Laos (E of Mekong River, up to approximately the Banhiang River, N16°00'–N16°03', in Savannakhet Province), C Vietnam (from the Thach Han River, N16°40'–N16°50', in Quang Tri Province in the N to approximately the Ba River, N13°00'–N13°10', in Gia Lai and Phu Yen provinces in the S), and NE Cambodia (Ratanakiri and Stung Treng provinces, E of the Mekong River and N of the Srepok River, N13°30').

Conservation status: Not Evaluated.

4.3.7. Southern Yellow-cheeked Crested Gibbon *Nomascus gabriellae* (Thomas, 1909)

Type locality: Vietnam, Langbian, 460 m.

Subspecies/colour variants: None.

Distribution: S Vietnam (from Ba River, N13°00'–N13°10', in Gia Lai and Phu Yen provinces in the N to the Nui Ong Nature Reserve, N11°01', in Binh Thuan Province in the S) and SE Cambodia (E of the Mekong River and S of the Srepok River).

Conservation status: Endangered.

4.4. Genus *Symphalangus*

4.4.1. Siamang *Symphalangus syndactylus* (Raffles, 1821)

Type locality: Indonesia, West Sumatra, Bencoolen [= Bengkulu].

Subspecies/colour variants: None.

Distribution: S Thailand on the west coast in Hala Bala Wildlife Sanctuary (on the border with Malaysia), and NW & C peninsular Malaysia (largely restricted to mountainous areas in the W of the country, S of the Perak River and N of the Muar River, and Lake Bera across to the Pahang River), and W Sumatra confined to the Barisan Mts; it may have formerly occurred on Bangka Island.

Conservation status: Endangered.

5. Family Hominidae

5.1. Genus *Pongo*

5.1.1. Sumatran Orangutan *Pongo abelii* Lesson, 1827

Type locality: Indonesia, Sumatra.

Subspecies/colour variants: None. The identity of the population in the Batang Toru region, on the west coast S of Lake Toba, remains to be studied.

Distribution: NW Sumatra (Aceh and North Sumatra provinces).

Conservation status: Critically Endangered.

5.1.2. Bornean Orangutan *Pongo pygmaeus* (Linnaeus, 1760)

Type locality: Indonesia, Kalimantan, Landak River.

Subspecies/colour variants: 3 subspecies are recognized: North-west Bornean Orangutan *P. p. pygmaeus* (Linnaeus, 1760); North-east Bornean Orangutan *P. p. morio* (Owen, 1837); South-west Bornean Orangutan *P. p. wurmbii* (Tiedemann, 1808).

Distribution: *P. p. pygmaeus*: W Borneo in Malaysia (S Sarawak State) and Indonesia (N West Kalimantan Province); *P. p. morio*: N & E Borneo in Malaysia (Sabah State) and Indonesia (East Kalimantan Province); possibly in N Sarawak; *P. p. wurmbii*: S Indonesian Borneo (S West and Central Kalimantan provinces).

Conservation status: Endangered (all three subspecies).

DISCUSSION

Non-human primates occur in 22 Asian countries (Table 1, Fig. 1). The countries with the highest number of species are Indonesia (58–59 species), Vietnam (25), Malaysia (24–25), China (22–26), India (21–22), Laos (20–22), Myanmar (18) and Thailand (18).

Of the 113 Asian non-human primate species that have been assessed, 87 (77%) are threatened with extinction, and over half are Endangered or Critically Endangered (Table 2). Seventeen species (15%) are Critically Endangered, 45 (40%) are Endangered, 25 (22%) are Vulnerable and 10 (9%) are Near Threatened. Thus Asia has the world's most threatened primate fauna after Madagascar.

The most endangered primate families, based on proportion of assessed species that are either Critically Endangered (CR) or Endangered (EN), are Hominidae (2 out of 2 = 100%), Hylobatidae (17/18 = 94%), Cercopithecidae (38/73 = 52%), Tarsiidae (3/10 = 30%) and Lorisidae (2/7 = 29%) (Table 3). The most endangered genera are *Rhinopithecus*, *Pygathrix*, *Nasalis*, *Simias*, *Hylobates*, *Nomascus*, *Symphalangus*, and *Pongo*. All species in these genera are CR or EN. Other highly endangered genera include *Trachypithecus* (12/19 = 63% CR or EN), *Loris* (1/2 = 50%), *Hoolock* (1/2 = 50%) and *Presbytis* (8/17 = 47%).

ACKNOWLEDGEMENTS

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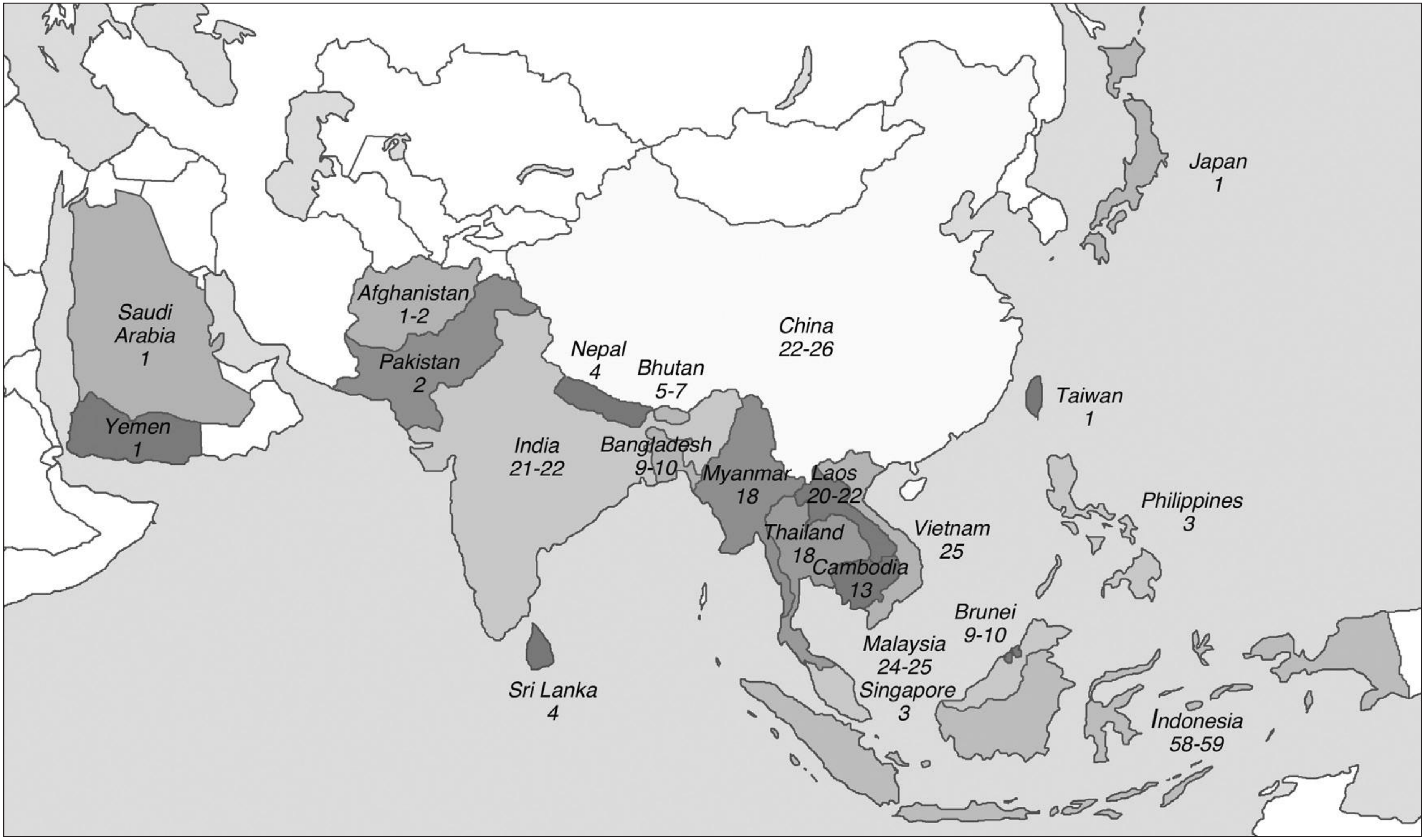


Fig. 1. Asian countries inhabited by non-human primates along with the number of confirmed/unconfirmed species.

Table 1. Asian non-human primates by country

Country	Species
Afghanistan (1–2 species)	*Macaca mulatta, (Semnopithecus schistaceus)*
Bangladesh (9–10 species)	*Nycticebus bengalensis, Macaca leonina, M. assamensis, (M. arctoides), M. fascicularis, M. mulatta, Trachypithecus pileatus, T. phayrei, Semnopithecus entellus, Hoolock hoolock*
Bhutan (5–7 species)	*Macaca assamensis, (M. munzala), M. mulatta, Trachypithecus geei, T. pileatus, (Semnopithecus hector), S. schistaceus*
Brunei (9–10 species)	*Nycticebus menagensis, Cephalopachus bancanus, Macaca nemestrina, M. fascicularis, Presbytis chrysomelas, (P. rubicunda), P. hosei, Trachypithecus cristatus, Nasalis larvatus, Hylobates funereus*
Cambodia (13 species)	*Nycticebus bengalensis, N. pygmaeus, Macaca leonina, M. arctoides, M. fascicularis, Trachypithecus germaini, T. margarita, Pygathrix cinerea, P. nemaeus, P. nigripes, Hylobates pileatus, Nomascus annamensis, N. gabriellae*
China (22–26 species)	*Nycticebus bengalensis, (N. pygmaeus), Macaca leonina, M. assamensis, M. thibetana, (M. munzala), M. arctoides, M. mulatta, Trachypithecus shortridgei, T. phayrei, T. crepusculus, T. francoisi, T. leucocephalus, Semnopithecus schistaceus, (Rhinopithecus avunculus), R. bieti, R. brelichi, R. roxellana, R. strykeri, (Hoolock hoolock), H. leuconedys, Hylobates lar, Nomascus hainanus, N. nasutus, N. concolor, N. leucogenys*
India (21–22 species)	*Loris tardigradus, L. lydekkerianus, Nycticebus bengalensis, Macaca silenus, M. leonina, M. radiata, M. assamensis, (M. thibetana), M. munzala, M. arctoides, M. mulatta, Trachypithecus geei, T. pileatus, T. phayrei, Semnopithecus entellus, S. ajax, S. hector, S. schistaceus, S. hypoleucos, S. priam, S. johnii, Hoolock hoolock.*
Indonesia (58–59 species)	*Nycticebus coucang, N. javanicus, N. menagensis, N. bancanus, N. borneanus, N. kayan, Tarsius tarsier, T. fuscus, T. dentatus, T. pelengensis, T. sangirensis, T. tumpara, T. pumilus, T. lariang, T. wallacei, Cephalopachus bancanus, Macaca nemestrina, M. siberu, M. pagensis, M. nigra, M. nigrescens, M. tonkeana, M. ochreata, M. hecki, M. maura, M. fascicularis, Presbytis thomasi, P. melalophos, P. sumatrana, P. bicolor, P. mitrata, P. comata, P. potenziani, P. siberu, P. femoralis, P. siamensis, P. natunae, P. chrysomelas, P. rubicunda, P. hosei, P. canicrus, (P. sabana), P. frontata, Trachypithecus auratus, T. mauritius, T. cristatus, Nasalis larvatus, Simias concolor, Hylobates lar, H. agilis, H. albibarbis, H. muelleri, H. abbotti, H. funereus, H. klossii, H. moloch, Symphalangus syndactylus, Pongo abelii, P. pygmaeus*
Japan (1 species)	*Macaca fuscata*
Laos (20–22 species)	*Nycticebus bengalensis, N. pygmaeus, Macaca leonina, M. assamensis, M. arctoides, M. fascicularis, M. mulatta, Trachypithecus germaini, T. margarita, T. crepusculus, T. laotum, T. hatinhensis, T. ebenus, (Pygathrix cinerea), P. nemaeus, (P. nigripes), Hylobates lar, H. pileatus, Nomascus concolor, N. leucogenys, N. siki, N. annamensis*

Country	Species
Malaysia (24–25 species)	*(Nycticebus bengalensis), N. coucang, N. menagensis, N. kayan, Cephalopachus bancanus, Macaca nemestrina, M. arctoides, M. fascicularis, Presbytis femoralis, P. siamensis, P. chrysomelas, P. rubicunda, P. hosei, P. sabana, P. frontata, Trachypithecus cristatus, T. selangorensis, T. obscurus, Nasalis larvatus, Hylobates lar, H. agilis, H. abbotti, H. funereus, Symphalangus syndactylus, Pongo pygmaeus*
Myanmar (18 species)	*Nycticebus bengalensis, Macaca leonina, M. assamensis, M. arctoides, M. fascicularis, M. mulatta, Presbytis femoralis, Trachypithecus pileatus, T. shortridgei, T. germaini, T. obscurus, T. phayrei, T. barbei, T. crepusculus, Rhinopithecus strykeri, Hoolock hoolock, H. leuconedys, Hylobates lar*
Nepal (4 species)	*Macaca assamensis, M. mulatta, Semnopithecus hector, S. schistaceus*
Pakistan (2 species)	*Macaca mulatta, Semnopithecus schistaceus*
Philippines (3 species)	*Nycticebus menagensis, Carlito syrichta, Macaca fascicularis*
Saudi Arabia (1 species)	*Papio hamadryas*
Singapore (3 species)	*Nycticebus coucang, Macaca fascicularis, Presbytis femoralis*
Sri Lanka (4 species)	*Loris tardigradus, Macaca sinica, Semnopithecus priam, S. vetulus*
Taiwan (1 species)	*Macaca cyclopis*
Thailand (18 species)	*Nycticebus bengalensis, N. coucang, Macaca leonina, M. nemestrina, M. assamensis, M. arctoides, M. fascicularis, M. mulatta, Presbytis femoralis, P. siamensis, Trachypithecus germaini, T. obscurus, T. barbei, T. crepusculus, Hylobates pileatus, H. lar, H. agilis, Symphalangus syndactylus*
Vietnam (25 species)	*Nycticebus bengalensis, N. pygmaeus, Macaca leonina, M. assamensis, M. arctoides, M. fascicularis, M. mulatta, Trachypithecus germaini, T. margarita, T. crepusculus, T. francoisi, T. poliocephalus, T. delacouri, T. hatinhensis, T. ebenus, Rhinopithecus avunculus, Pygathrix cinerea, P. nemaeus, P. nigripes, Nomascus nasutus, N. concolor, N. leucogenys, N. siki, N. annamensis, N. gabriellae*
Yemen (1 species)	*Papio hamadryas*

Note: Species records in brackets are those whose presence is unconfirmed

Table 2. IUCN Red List of threatened Asian non-human primates by category

Threatened Status	Species
Critically Endangered (17 species)	*Tarsius tumpara, Macaca pagensis, M. nigra, Presbytis potenziani, P. chrysomelas, Trachypithecus poliocephalus, T. leucocephalus, T. delacouri, Rhinopithecus avunculus, R. strykeri, Pygathrix cinerea, Simias concolor, Nomascus hainanus, N. nasutus, N. concolor, N. leucogenys, Pongo abelii*
Endangered (45 species)	*Loris tardigradus, Nycticebus javanicus, Tarsius pelengensis, T. sangirensis, Macaca silenus, M. maura, M. sinica, M. munzala, Presbytis sumatrana, P. mitrata, P. comata, P. siberu, P. canicrus, P. sabana, Trachypithecus geei, T. shortridgei, T. germaini, T. margarita, T. phayrei, T. crepusculus, T. francoisi, T. hatinhensis, T. ebenus, Semnopithecus ajax, S. vetulus, Rhinopithecus bieti, R. brelichi, R. roxellana, Pygathrix nemaeus, P. nigripes, Nasalis larvatus, Hoolock hoolock, Hylobates pileatus, H. lar, H. agilis, H. albibarbis, H. muelleri, H. abbotti, H. funereus, H. klossii, H. moloch, Nomascus siki, N. gabriellae, Symphalangus syndactylus, Pongo pygmaeus*
Vulnerable (25 species)	*Nycticebus bengalensis, N. coucang, N. menagensis, N. pygmaeus, Tarsius tarsier, T. dentatus, Cephalopachus bancanus, Macaca leonina, M. nemestrina, M. siberu, M. nigrescens, M. tonkeana, M. ochreata, M. hecki, M. arctoides, Presbytis thomasi, P. natunae, P. frontata, Trachypithecus pileatus, T. auratus, T. mauritius, T. laotum, Semnopithecus hypoleucos, S. johnii, Hoolock leuconedys*
Near Threatened (10 species)	*Carlito syrichta, Macaca assamensis, M. thibetana, Presbytis melalophos, P. femoralis, P. siamensis, Trachypithecus cristatus, T. obscurus, Semnopithecus hector, S. priam*
Least Concern (10 species)	*Loris lydekkerianus, Macaca radiata, M. fascicularis, M. mulatta, M. fuscata, M. cyclopis, Papio hamadryas, Presbytis rubicunda, Semnopithecus entellus, S. schistaceus*
Data Deficient (6 species)	*Tarsius pumilus, T. lariang, T. wallacei, Presbytis bicolor, P. hosei, Trachypithecus barbei*
Not Evaluated (6 species)	*Nycticebus bancanus, N. borneanus, N. kayan, Tarsius fuscus, Trachypithecus selangorensis, Nomascus annamensis*

Table 3. IUCN Red List of threatened Asian non-human primates by family and genus

Family	CR	EN	VU	NT	LC	DD	NE
Lorisidae		2	4		1		3
Loris		1			1		
Nycticebus		1	4				3
Tarsiidae	1	2	3	1		3	1
Tarsius	1	2	2			3	1
Carlito				1			
Cephalopachus			1				
Cercopithecidae	11	27	17	9	9	3	1
Papio					1		
Macaca	2	4	8	2	5		
Presbytis	2	6	3	3	1	2	
Trachypithecus	3	9	4	2		1	1
Semnopithecus		2	2	2	2		
Rhinopithecus	2	3					
Pygathrix	1	2					
Nasalis		1					
Simias	1						
Hylobatidae	4	13	1				1
Hoolock		1	1				
Hylobates		9					
Nomascus	4	2					1
Symphalangus		1					
Hominidae	1	1					
Pongo	1	1					

Plate 1: Genus *Loris & Nycticebus*

Plate 2: Genus *Tarsius, Carlito & Cephalopachus*

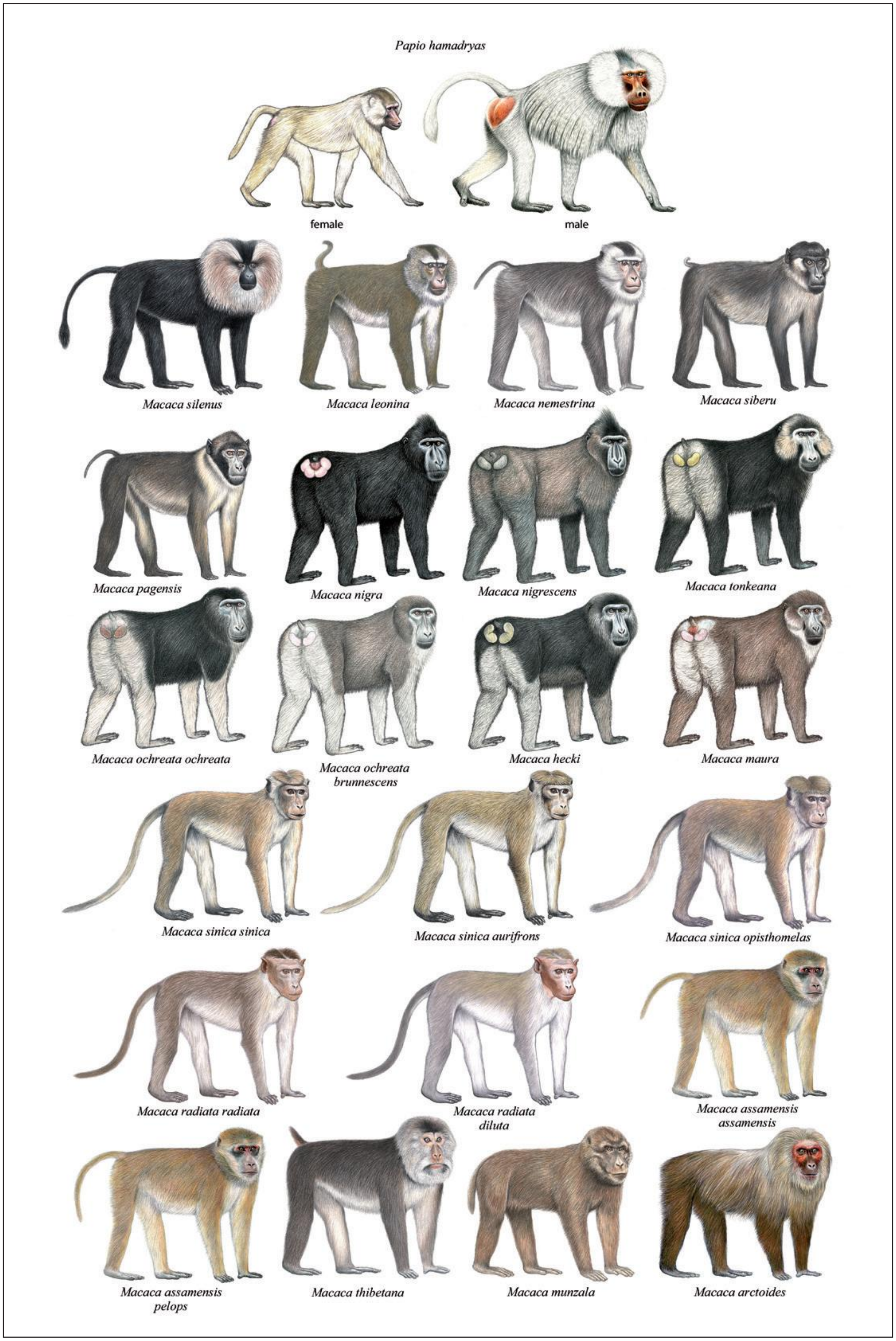
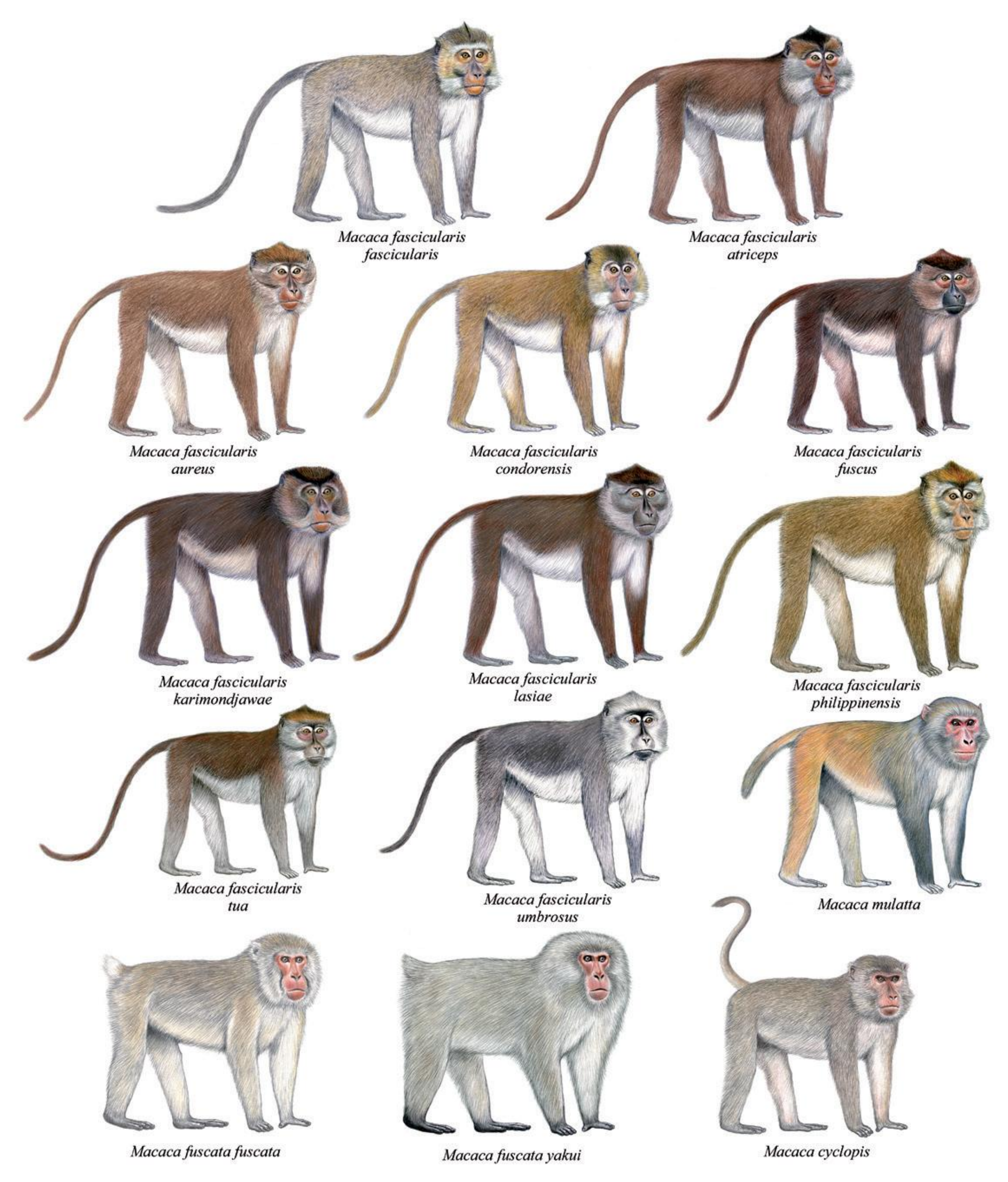


Plate 3: Genus *Papio* & *Macaca*



Macaca fascicularis fascicularis

Macaca fascicularis atriceps

Macaca fascicularis aureus

Macaca fascicularis condorensis

Macaca fascicularis fuscus

Macaca fascicularis karimondjawae

Macaca fascicularis lasiae

Macaca fascicularis philippinensis

Macaca fascicularis tua

Macaca fascicularis umbrosus

Macaca mulatta

Macaca fuscata fuscata

Macaca fuscata yakui

Macaca cyclopis

Plate 4: Genus *Macaca*

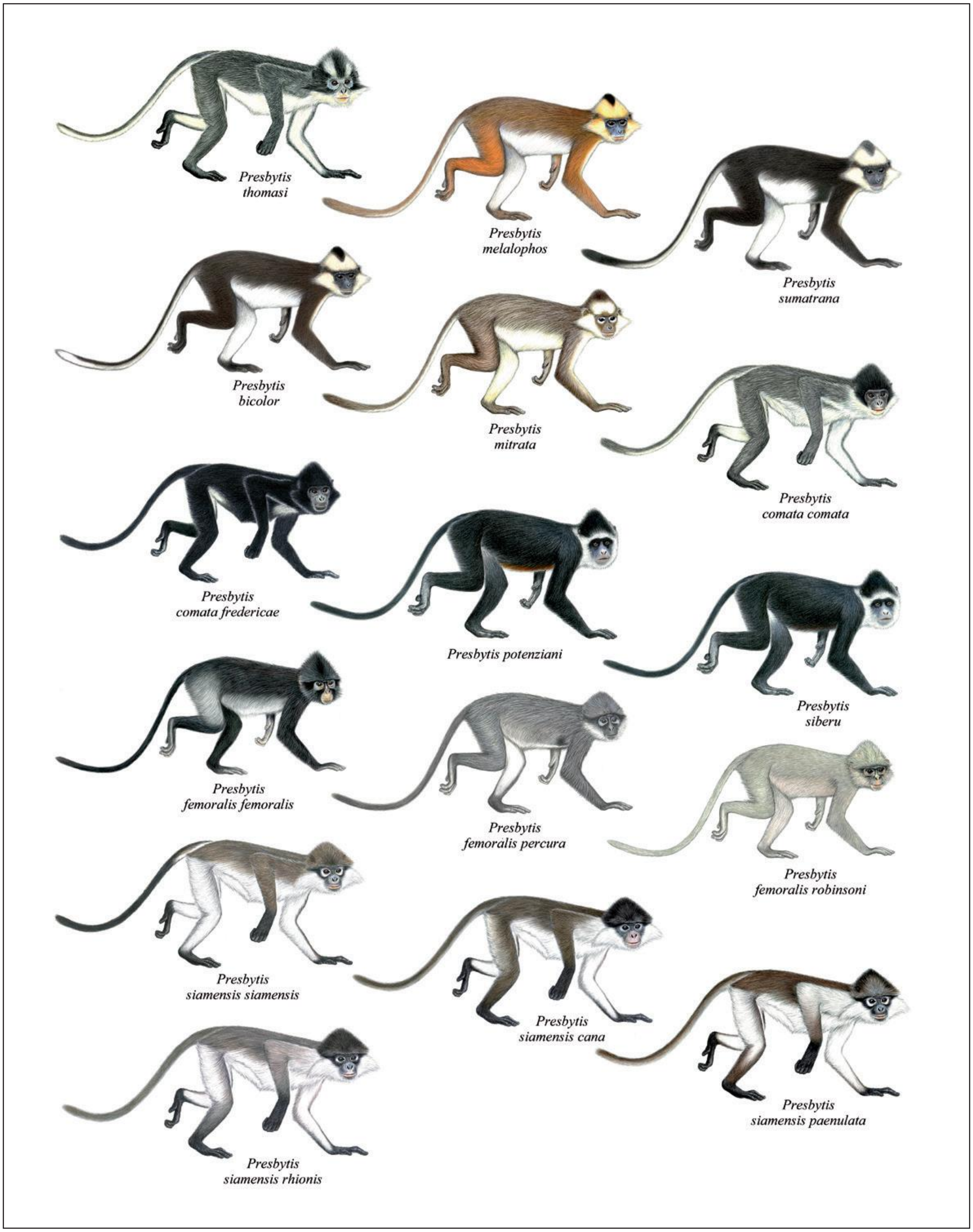


Plate 5: Genus *Presbytis*

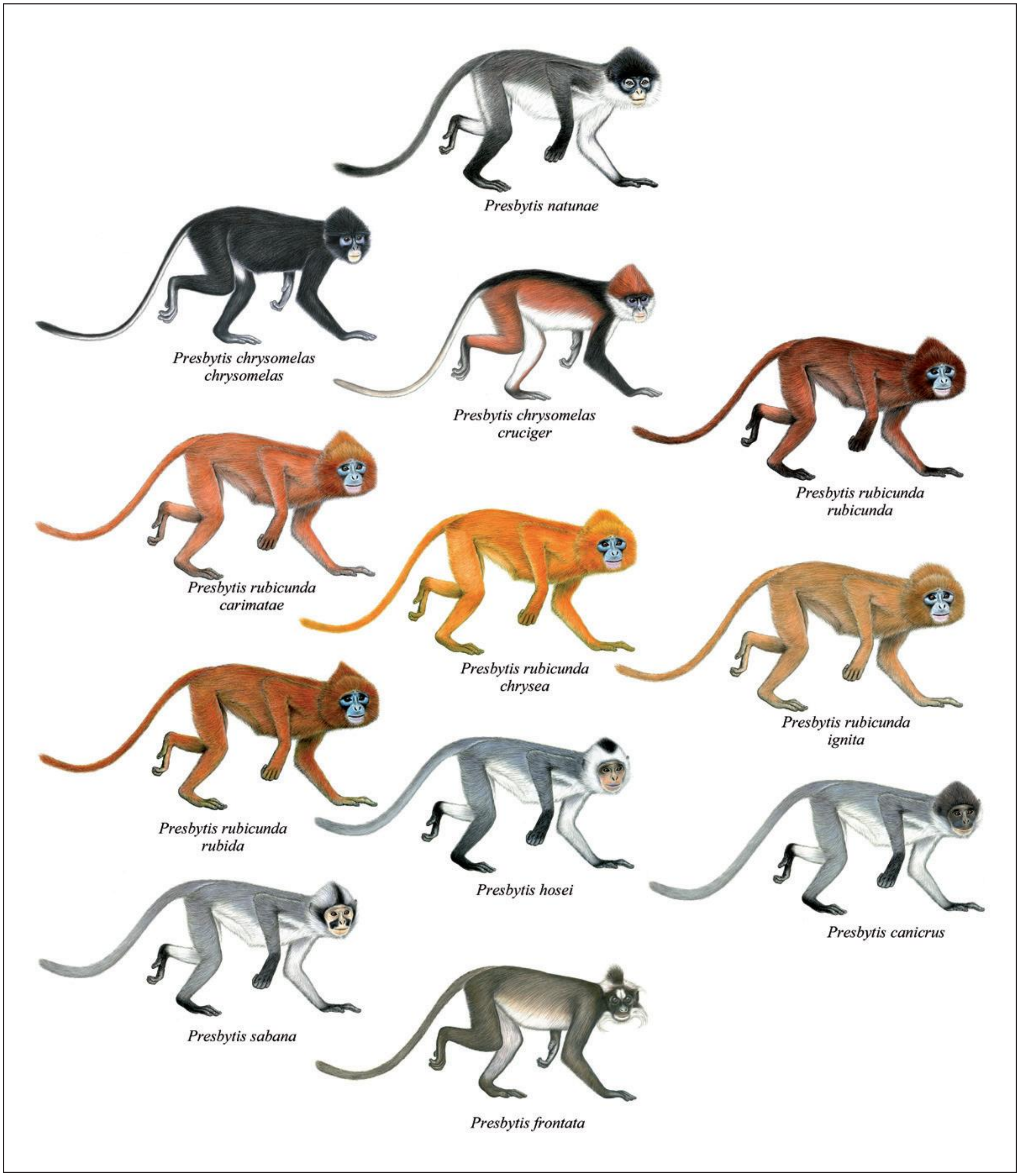


Plate 6: Genus *Presbytis*

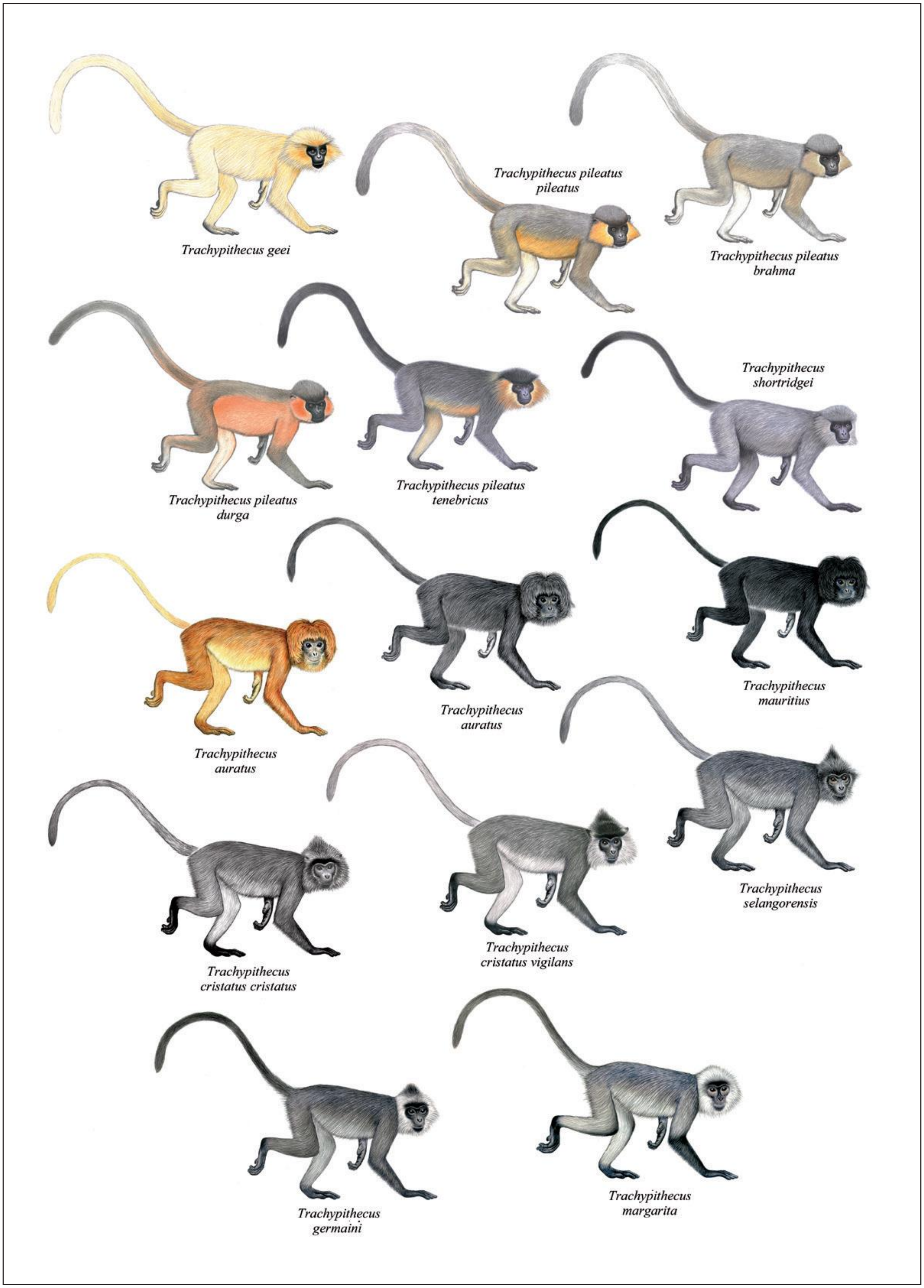


Plate 7: Genus *Trachypithecus*

Plate 8: Genus *Trachypithecus*

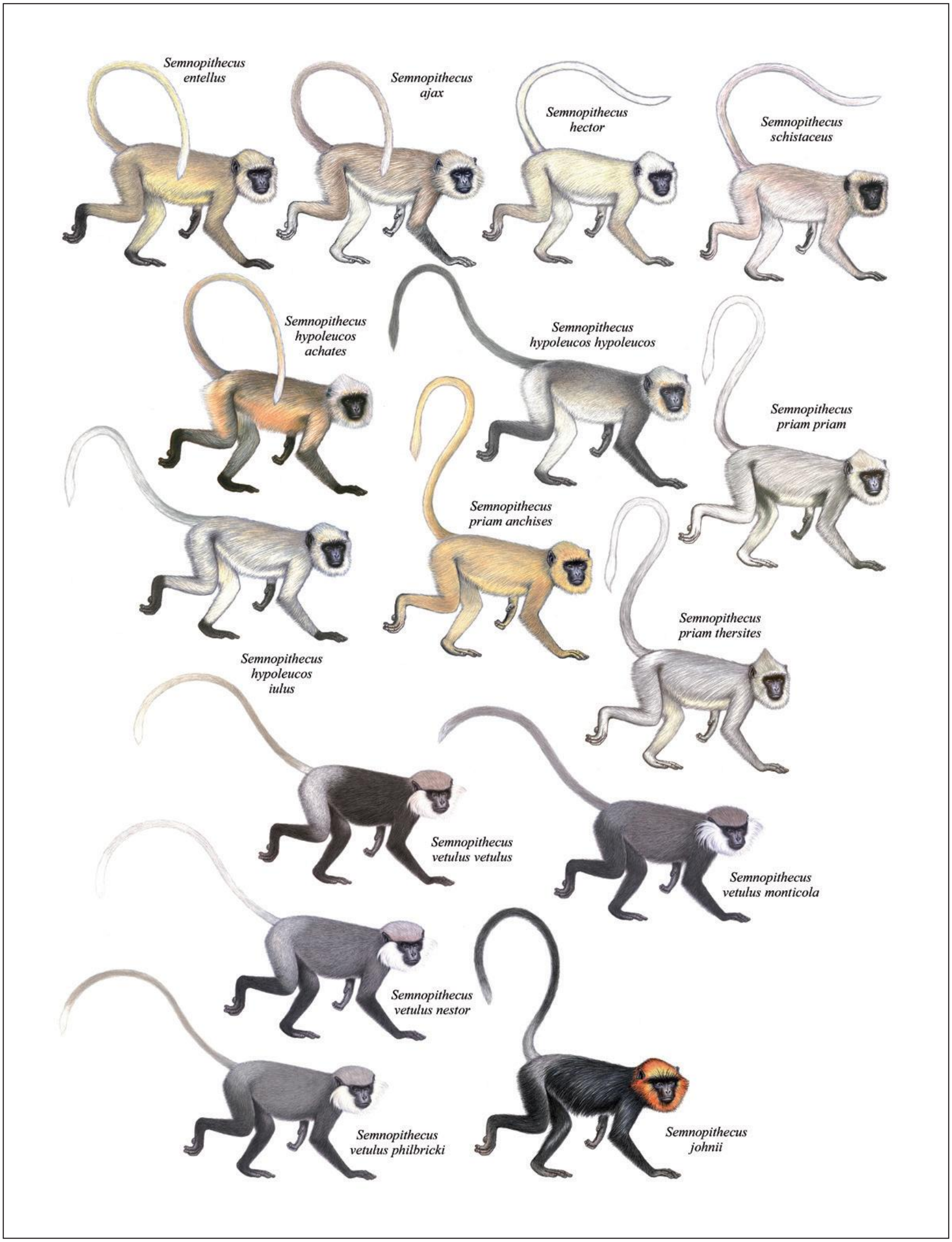


Plate 9: Genus *Semnopithecus*

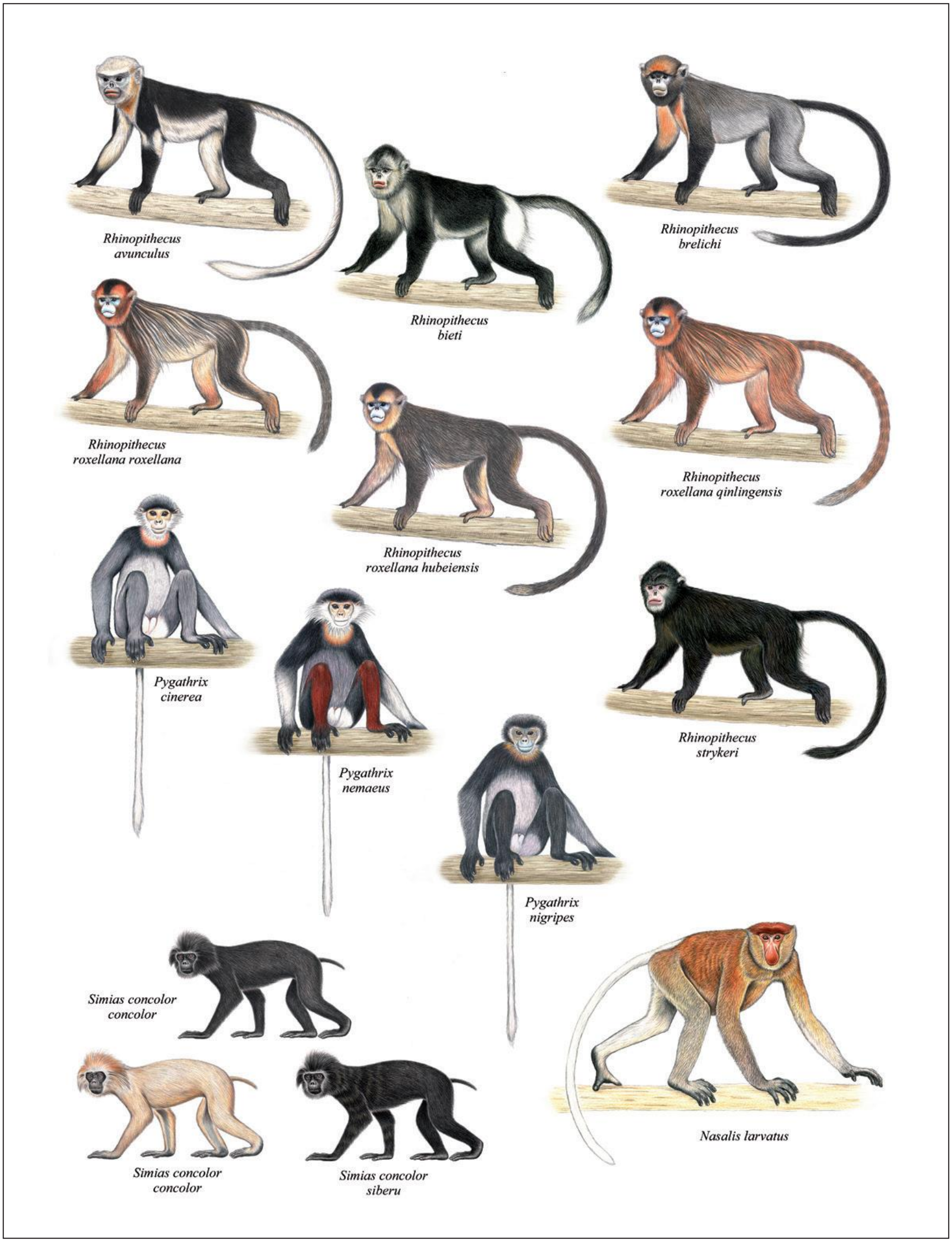


Plate 10: Genus *Rhinopithecus, Pygathrix, Simias & Nasalis*

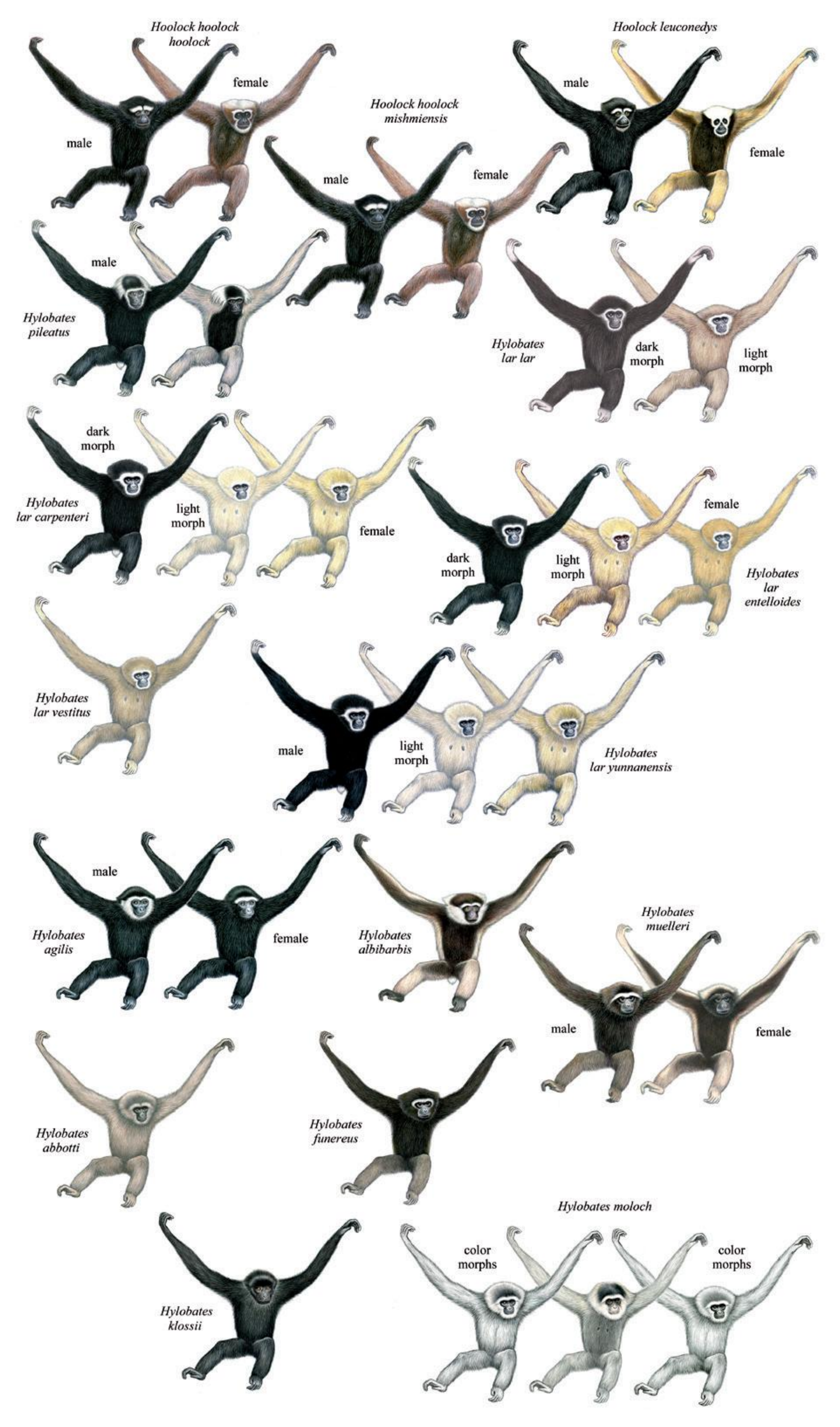


Plate 11: Genus *Hoolock & Hylobates*

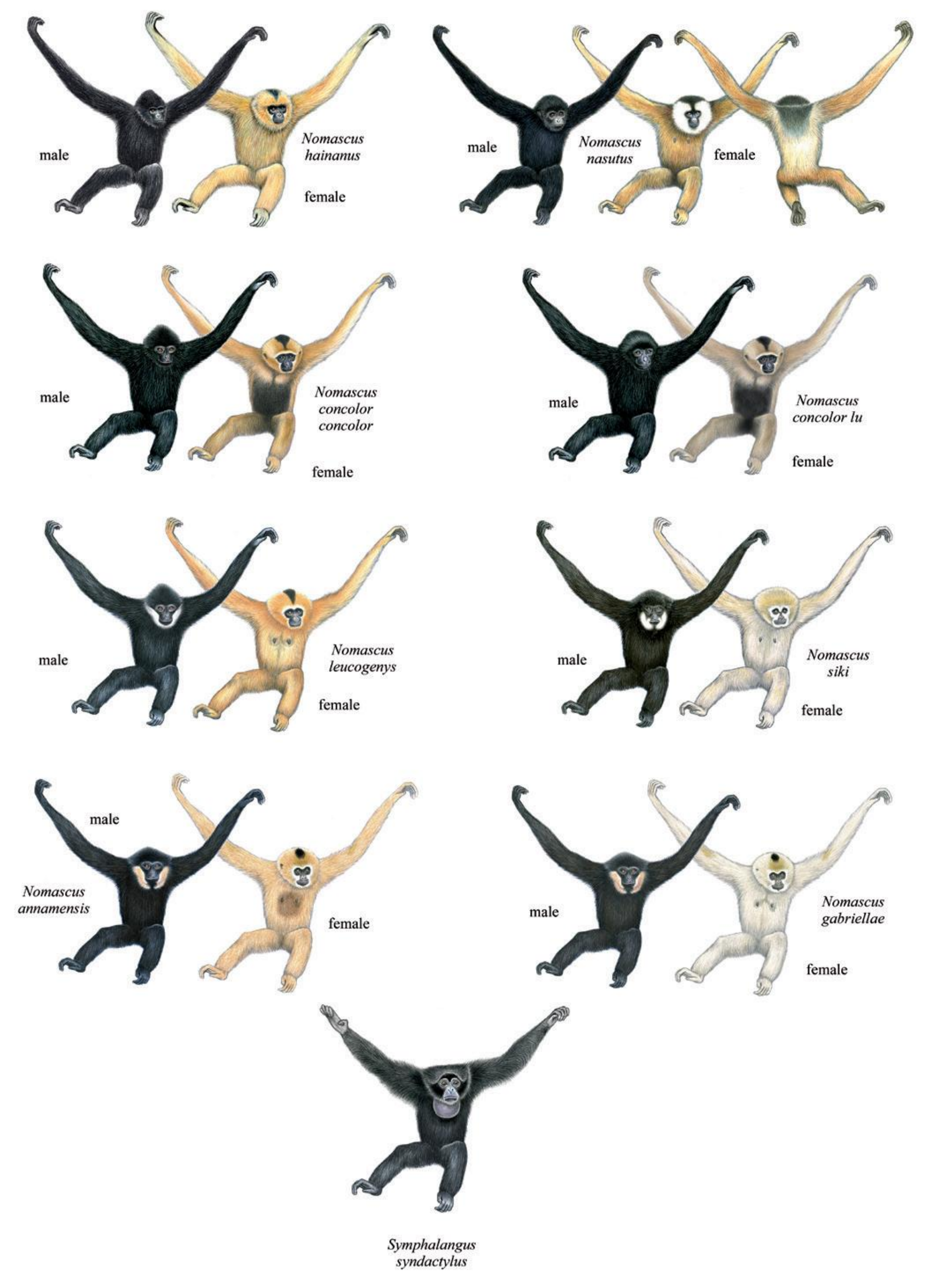


Plate 12: Genus *Nomascus* & *Symphalangus*

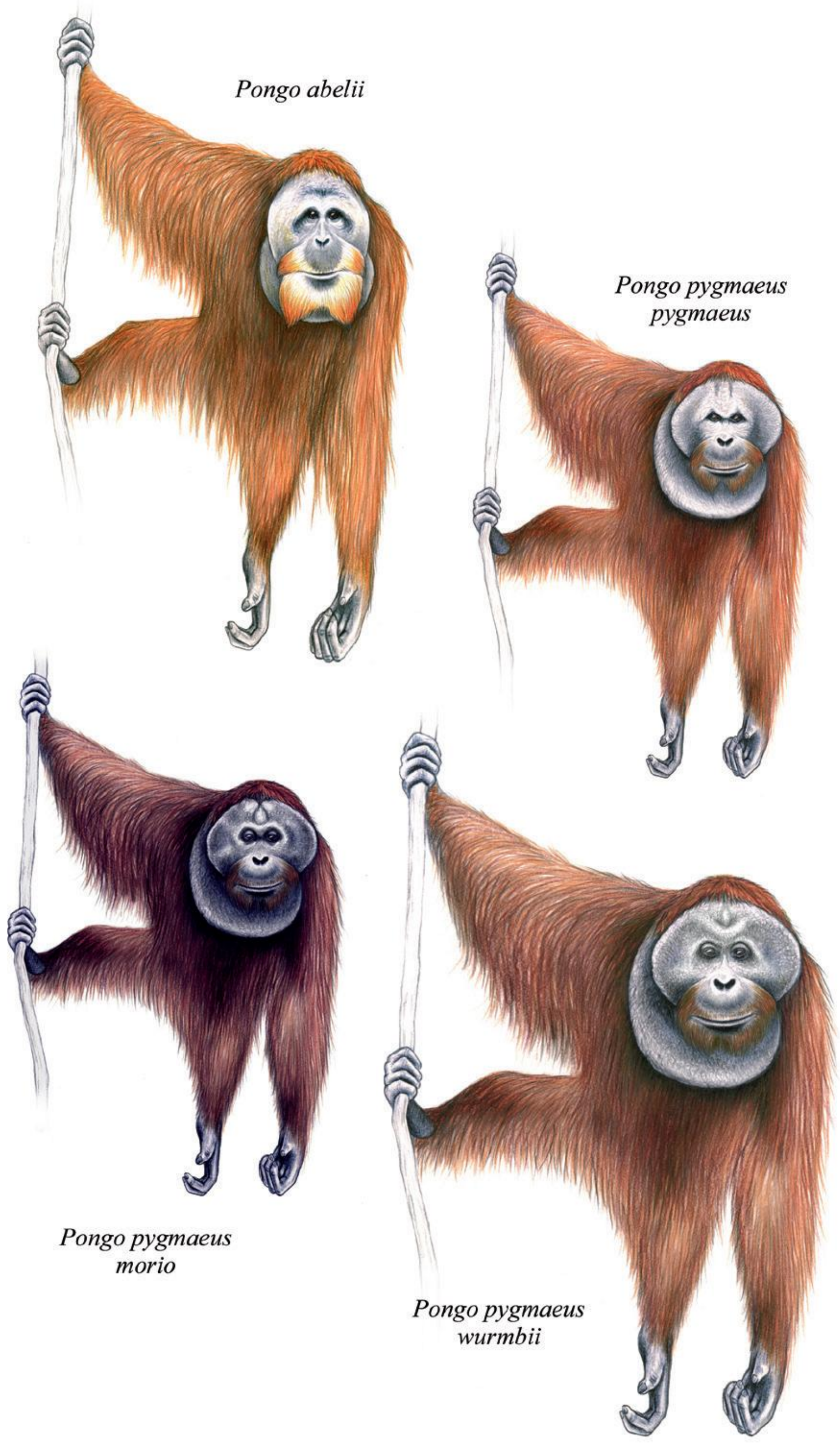


Plate 13: Genus *Pongo*

Instructions to Contributors

Scope

This journal aims to provide information relating to conservation of the primates of Asia. We welcome manuscripts on any relevant subject, including taxonomy and genetics, biogeography and distribution, ecology and behaviour, active threats and primate-human interactions. Submissions may include full articles, short articles and book reviews.

Submissions

Manuscripts and all editorial correspondence should be directed to Dr Ramesh Boonratana (rbz@loxinfo.co.th). Manuscripts are to be submitted to the journal on the understanding that they have not been published previously and are not being considered for publication elsewhere. The corresponding author is responsible for ensuring that the submitted manuscript has been seen and approved by all co-contributors, and the covering letter accompanying it should be signed to this effect. It is also the responsibility of the contributor to ensure that manuscripts emanating from a particular institution are submitted with the approval of the necessary authority. The editors retain the right to modify the style and the length of a contribution and to decide the time of publication; they will endeavour to communicate any changes to the contributors. The full name and address of each contributor should be included. Please avoid the use of unexplained abbreviations and acronyms.

Contributions

Manuscripts should be submitted in UK English. Manuscripts must be in electronic format in MS-Word or a compatible program, double-spaced and left-justified. The first page should include a concise title, up to seven keywords not found in the title, full names and addresses of all authors, current addresses if different, e-mail addresses, and indication to whom queries and proofs should be sent. In-text citations should use comma and ampersand and follow first chronological, then alphabetical, sequence: (Matsuzawa & MacKinnon, 1980; Marsh, 1998; Matsuzawa, 1998a, 1998b). All pages including tables should be numbered. Footnotes should be avoided.

Full articles will be sent out for peer-review and should contain significant new findings. They should not exceed about 20 pages in length (double-spaced), including references. Please include an abstract of no more than 200 words, placing the work in conservation context and summarising what it has contributed, and subheadings (e.g. Introduction, Methods, Results, Discussion, Acknowledgements, References) as appropriate.

Taxonomy

Scientific nomenclature should be used at first mention of any species or subspecies. Nomenclature should include taxonomic authority (at first mention) as currently recognised by IUCN, e.g. Northern Pigtailed Macaque *Macaca leonina* (Blyth) (see www.iucnredlist.org). Authors are referred to The Plant List (www.theplantlist.org) for up-to-date plant nomenclature.

Numbers

Measurements should always be metric, or where this is inappropriate, the metric equivalents given in parentheses. Time should be designated in the 24-hour system (as e.g. 17:30 h) and date in the European system (e.g. 7 December 2011). Summary statistics should include measures of both central tendency and dispersion where appropriate, e.g. means and standard deviations (SD). Reports of all statistical tests should include the name of the statistical test, the name and value of the test statistic, the degrees of freedom, the probability value used to determine significance and the authors' interpretation. Probabilities should be reported as exact values if not significant, otherwise rounded off to either $p<0.05$, 0.01 or 0.001.

Figures, maps and tables

Articles may include photographs, high-quality figures, high-quality maps and tables. Please keep these to a minimum. We stress the importance of providing maps which are *publishable*, with clear explanation of features shown, scale and orientation. Please number tables and figures (as Table 1, Fig. 1 etc.) and provide clear concise captions.

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Chapter in book

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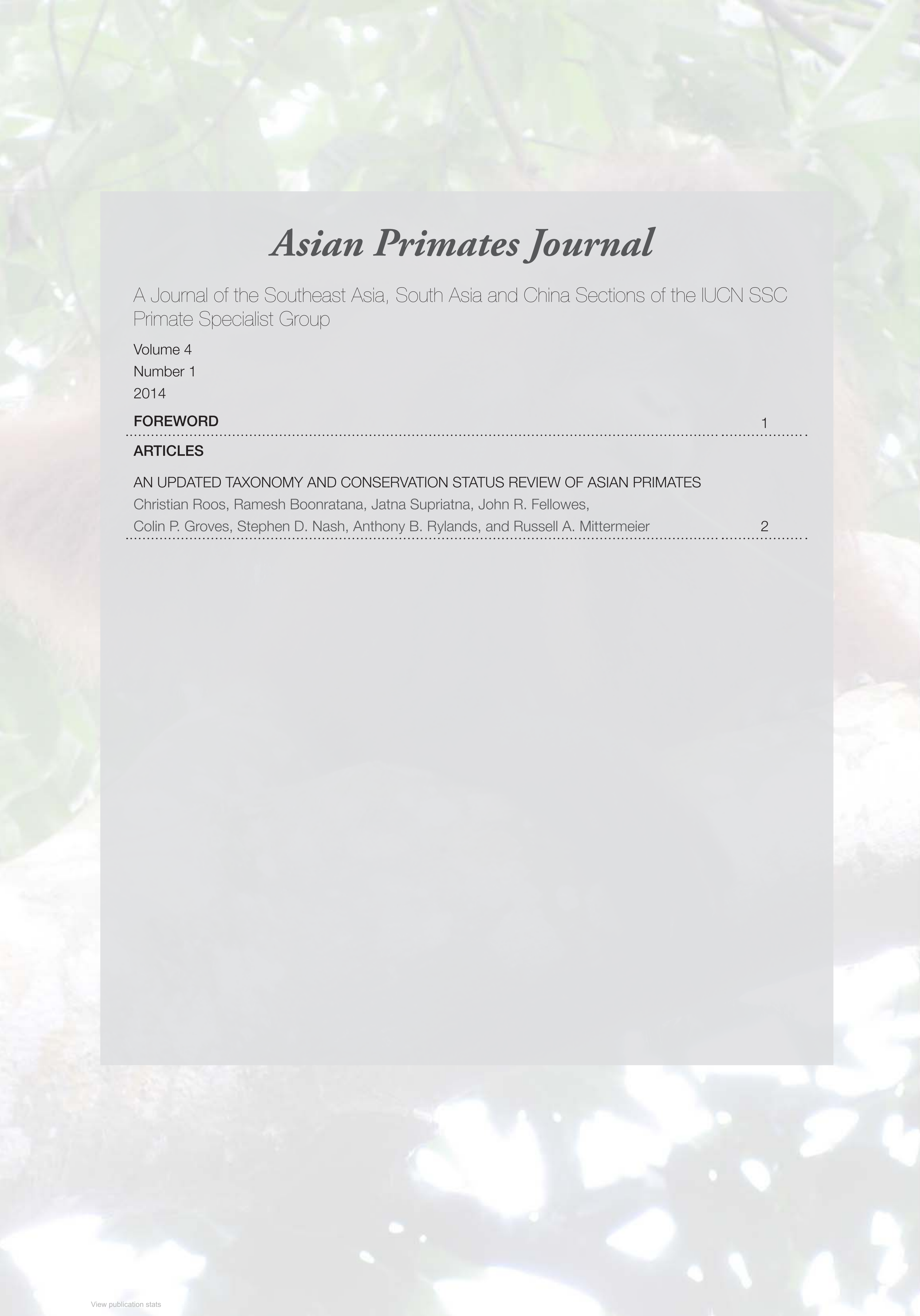

Asian Primates Journal

A Journal of the Southeast Asia, South Asia and China Sections of the IUCN SSC Primate Specialist Group

Volume 4
Number 1
2014

ARTICLES

Exhibit 8

Distribution Map

Macaca nemestrina

Legend

🟧 EXTANT (RESIDENT)

🟪 EXTANT & INTRODUCED (RESIDENT)

Compiled by:

IUCN (International Union for Conservation of Nature) 2022

Exhibit 9

Jump to Southern Pig-tailed Macaque: In detail

ⓘ Translate page

Select Language ▼

Southern Pig-tailed Macaque

Macaca nemestrina

ABSTRACT

Southern Pig-tailed Macaque *Macaca nemestrina* has most recently been assessed for *The IUCN Red List of Threatened Species* in 2022. *Macaca nemestrina* is listed as Endangered under criteria A2cde+3cde.

feedback

Download Text Overview

THE RED LIST ASSESSMENT ⓘ

▶ Ruppert, N., Holzner, A., Hansen, M.F., Ang, A. & Jones-Engel, L. 2022. *Macaca ne...*

LAST ASSESSED

13 March 2022

SCOPE OF ASSESSMENT

Global

Assessment in detail

POPULATION TREND

↓ Decreasing

NUMBER OF MATURE INDIVIDUALS

Population in detail

HABITAT AND ECOLOGY

Forest, Shrubland, Artificial/Terrestrial

Habitat and ecology in detail

GEOGRAPHIC RANGE

🟧 EXTANT (RESIDENT)

🟪 EXTANT & INTRODUCED (RESIDENT)

IUCN (International Union for Conservation of Nature) 2022. Macaca nemestrina. The IUCN Red List of Threatened Species. Version 2022-2

Geographic range in detail

Taxonomy

Assessment Information

Taxonomy

KINGDOM
Animalia

PHYLUM
Chordata

CLASS
Mammalia

ORDER
Primates

FAMILY
Cercopithecidae

GENUS
Macaca

▶ Taxonomy in detail

feedback

Assessment Information

IUCN RED LIST CATEGORY AND CRITERIA

Endangered A2cde+3cde

ver 3.1

DATE ASSESSED

13 March 2022

YEAR PUBLISHED

2022

▸ **Assessment Information in detail**

feedback

Geographic Range

NATIVE

Extant (resident)

Brunei Darussalam; Indonesia (Kalimantan, Sumatera); Malaysia (Sabah, Peninsular Malaysia, Sarawak); Thailand

NUMBER OF LOCATIONS

UPPER ELEVATION LIMIT

1,900 metres

LOWER ELEVATION LIMIT

▸ **Geographic Range in detail**

Population

CURRENT POPULATION TREND

Decreasing

NUMBER OF MATURE INDIVIDUALS

POPULATION SEVERELY FRAGMENTED

Yes

CONTINUING DECLINE OF MATURE INDIVIDUALS

Yes

▶ **Population in detail**

Habitat and Ecology

SYSTEM

Terrestrial

HABITAT TYPE

Forest, Shrubland, Artificial/Terrestrial

GENERATION LENGTH (YEARS)

11 years

CONGREGATORY

MOVEMENT PATTERNS

CONTINUING DECLINE IN AREA, EXTENT AND/OR QUALITY OF HABITAT

Yes

▶ **Habitat and Ecology in detail**

Threats

feedback

Residential & commercial development

- Housing & urban areas
- Commercial & industrial areas
- Tourism & recreation areas

Agriculture & aquaculture

- Annual & perennial non-timber crops
- Wood & pulp plantations
- Livestock farming & ranching

Energy production & mining

- Oil & gas drilling

Transportation & service corridors

- Roads & railroads

Biological resource use

- Hunting & trapping terrestrial animals

Human intrusions & disturbance

- Recreational activities

Natural system modifications

- Fire & fire suppression
- Other ecosystem modifications

Pollution

- Agricultural & forestry effluents

Geological events

- Earthquakes/tsunamis

Climate change & severe weather

- Droughts
- Storms & flooding

▸ **Threats in detail**

Use and Trade

Food - human

Local: ✓

National: ✓

International: ✗

Pets/display animals, horticulture

Local: ✓

National: ✓

International: ✗

Research

Local: ✓

National: ✗

International: ✓

Other (free text)

Local: ✓

National: ✓

International: ✗

▸ **Use and Trade in detail**

feedback

Conservation Actions

In-place research and monitoring

- Action Recovery Plan : No
- Systematic monitoring scheme : No

In-place land/water protection

- Conservation sites identified : No
- Area based regional management plan : No
- Occurs in at least one protected area : Yes
- Invasive species control or prevention : Not Applicable

In-place species management

- Harvest management plan : No
- Successfully reintroduced or introduced benignly : No
- Subject to ex-situ conservation : No

In-place education

- Subject to recent education and awareness programmes : Yes
- Included in international legislation : Yes
- Subject to any international management / trade controls : Yes

feedback

▶ **Conservation Actions in detail**

Bibliography

▶ **Red List Bibliography**

EXTERNAL DATA

Images and External Links

▶ Images and External Links in detail

CITES Legislation from Species+

DATA SOURCE

The information below is from the Species+ website.

▶ CITES Legislation from Species+ in detail

Studies and Actions from Conservation Evidence

DATA SOURCE

The information below is from the Conservation Evidence website.

▶ Studies and Actions from Conservation Evidence in detail

THE RED LIST PARTNERSHIP

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IUCN 2023. The IUCN Red List of Threatened Species. Version 2022-2.
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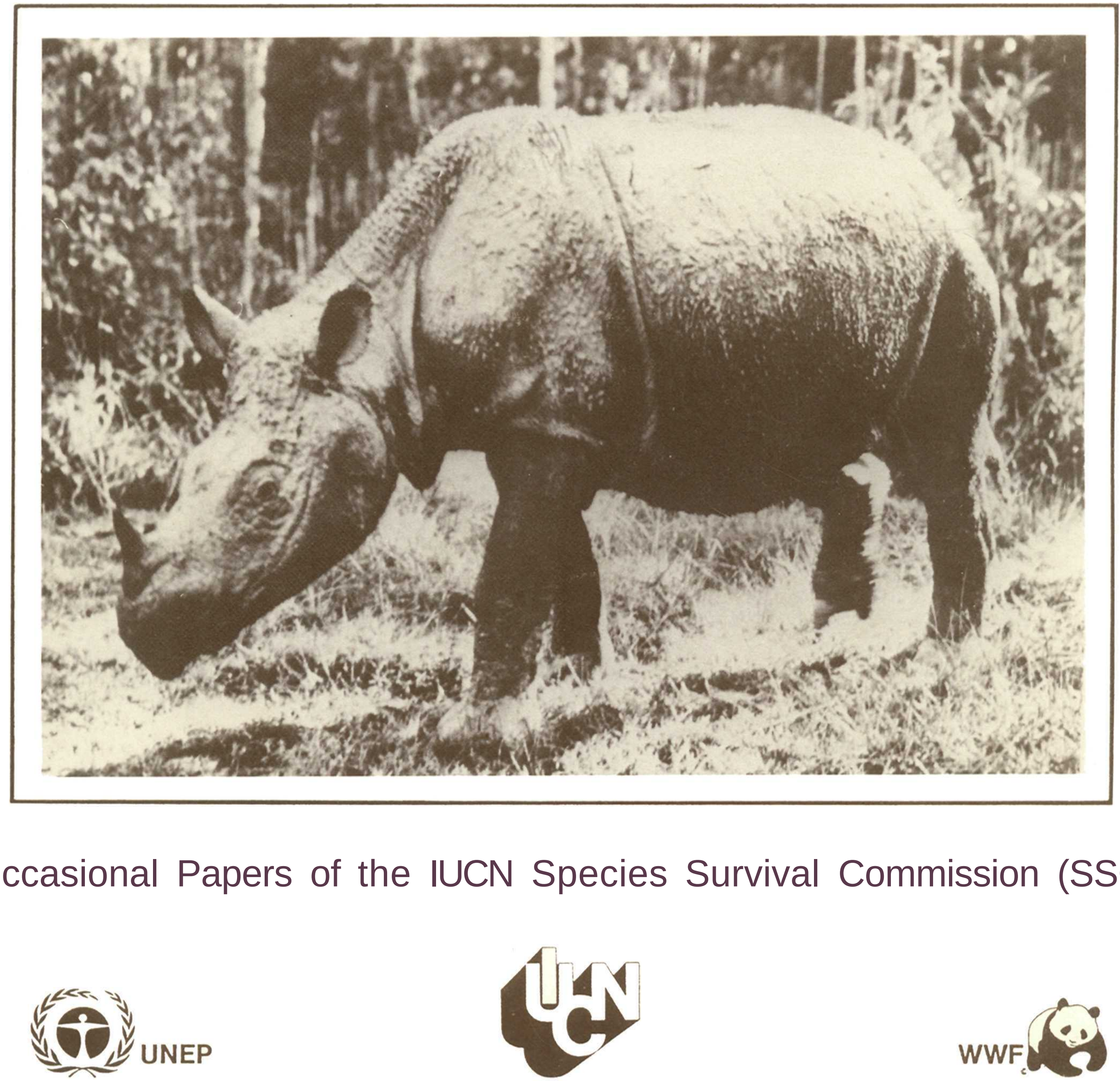
Exhibit 10

SPECIES CONSERVATION PRIORITIES IN THE TROPICAL FORESTS OF SOUTHEAST ASIA



Occasional Papers of the IUCN Species Survival Commission (SSC)

UNEP IUCN WWF

International Union for Conservation of Nature
and Natural Resources

INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES

SPECIES SURVIVAL COMMISSION

ROLE OF THE SSC

The Species Survival Commission (SSC) is composed of about 150 full members and over a thousand scientists and other experts organized into more than 75 specialist groups. This volunteer network serves as a primary source of the scientific and technical information required for the conservation of endangered and vulnerable flora and fauna, and recommends and promotes measures for their conservation.

OBJECTIVES OF THE SSC

To insure the maintenance of biological diversity by monitoring the status of species and populations, by developing action plans and promoting and implementing such plans, by interacting with a network of volunteers devoted to conservation concerns, and by advising and making policy recommendations to governments, other agencies and organizations.

Subobjective no. 1: To maintain an international network of volunteers and a forum for the exchange of views and scientific information on species and populations of conservation concern.

Subobjective no. 2: To cooperate with the IUCN Conservation Monitoring Centre (CMC) in developing a data base on the status of, and trade in, wild flora and fauna and in assessing and disseminating such information to CITES and elsewhere for conservation action.

Subobjective no. 3: To develop and review conservation action plans and priorities for species and populations.

Subobjective no. 4: To promote implementation of conservation action plans and to respond to related issues.

Subobjective no. 5: To provide studies, advice and policy recommendations to governments, other agencies and organizations in respect to conservation and management of species and populations.

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Cover Photo

The Sumatran rhinoceros *(Dicerorhinus sumatrensis)* is symbolic of species conservation priorities in the tropical forests of southeast Asia. The smallest and most distinctive of the five rhinoceros species, it survives in tiny remnant populations in a number of countries and is perhaps the most endangered large mammal in the region.

SPECIES CONSERVATION PRIORITIES IN THE TROPICAL FORESTS OF SOUTHEAST ASIA

Proceedings of a Symposium held at the 58th Meeting of
the IUCN Species Survival Commission (SSC)

October 4, 1982

Kuala Lumpur, Malaysia

Edited by
RUSSELL A. MITTERMEIER
and
WILLIAM R. KONSTANT

Editorial Assistant: Isabel Constable
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Occasional Papers of the IUCN Species Survival Commission (SSC)
Number 1

UNEP

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International Union for Conservation of Nature
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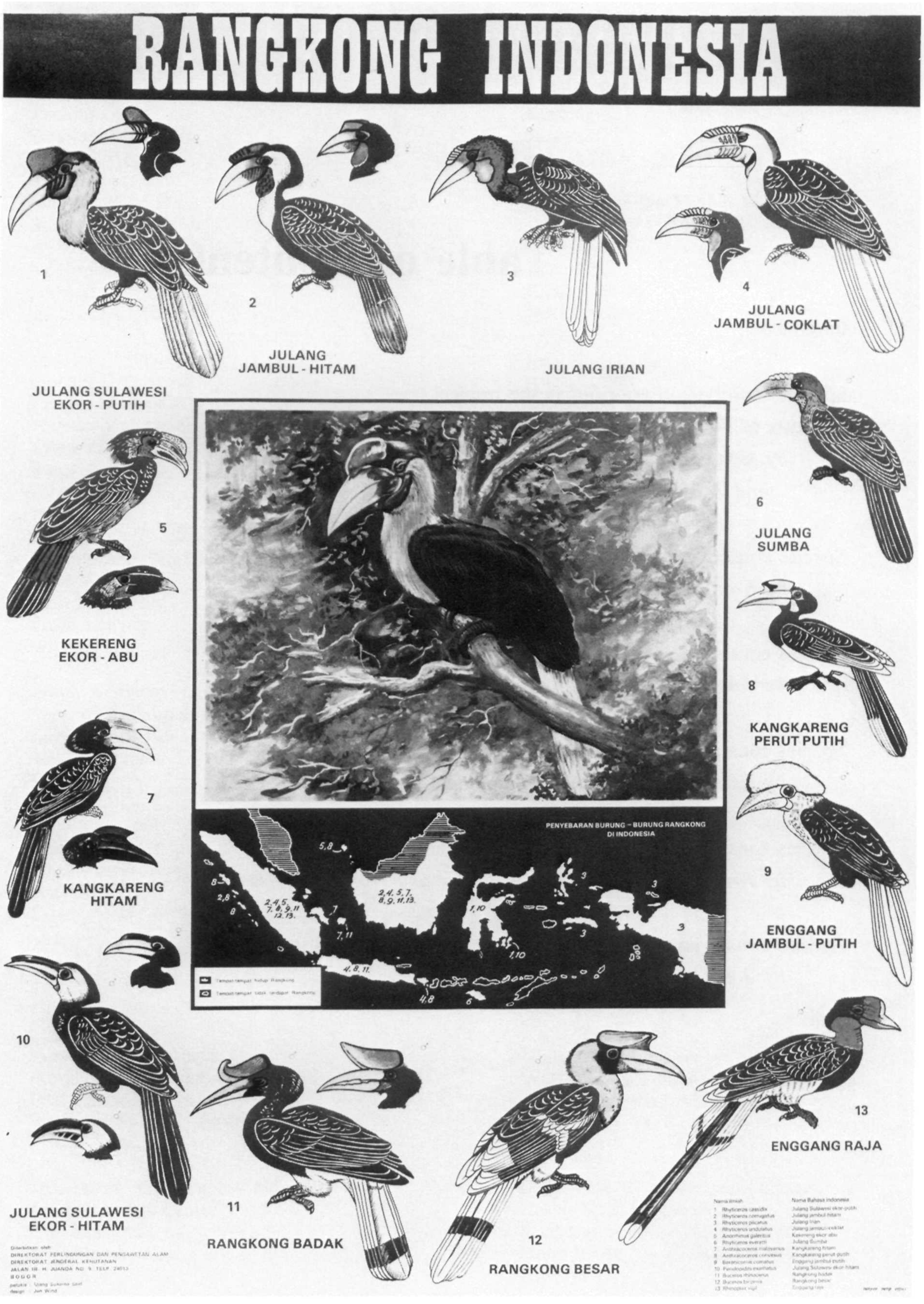


Poster producted by the Indonesia Directorate of Nature Conservation (PPA) depicting the hornbili species found in the country (designed by J. Wind).

Introduction

This contribution on Species Conservation Priorities in the Tropical Forests of Southeast Asia is the first in a new series entitled *Occasional Papers of the IUCN Species Survival Commission (SSC).* These papers are intended to provide an outlet for special reports on issues of concern to SSC, and for the proceedings of symposia held at regional SSC or related meetings. This booklet falls into the latter category, and represents the results of a symposium held on October 4, 1982 at the 58th SSC Meeting in Kuala Lumpur, Malaysia. It includes six chapters on species conservation in the tropical forests of Peninsular Malaysia, the Malaysian states of Sarawak and Sabah, and Indonesia, Thailand and Burma, and places special emphasis on key endangered species occurring in this region. As it turns out, the four countries in question are the best known in southeast Asia, and the absence of other southeast Asian countries from this report (e.g., Vietnam, Laos, Kampuchea) points to some of the gaps in our knowledge of this region and the need for further investigation and basic survey work.

It is clear from these six chapters that the problems facing wildlife in southeast Asia are similar to those in most other parts of the developing world. Loss of habitat is the primary concern, with poaching a serious factor for certain species as well. Conflicts with local human populations are also an issue, especially for species like the elephant, which can do substantial damage in agricultural areas.

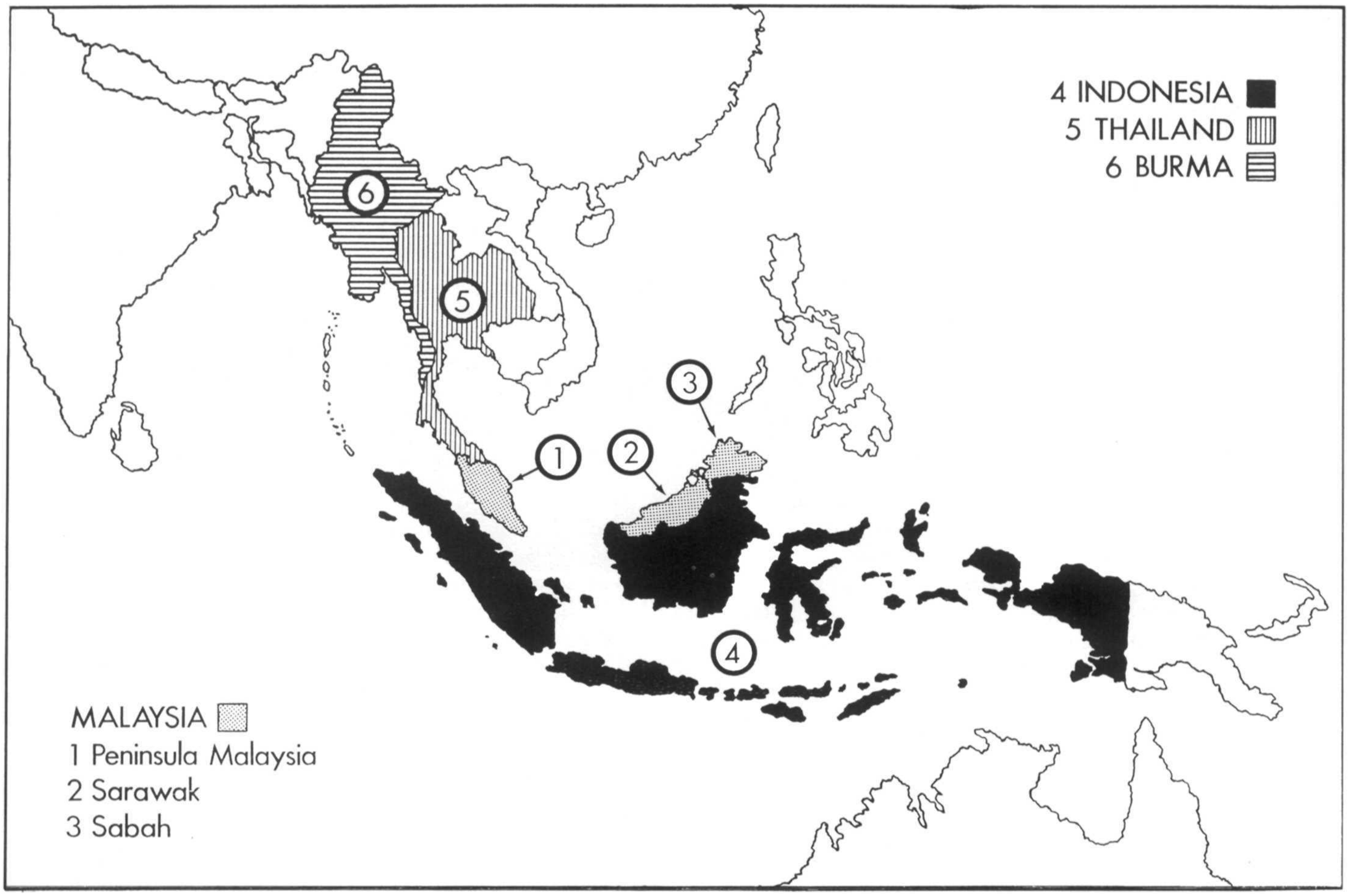
It is also obvious that our view of species conservation still focuses on the large, conspicuous and spectacular species, and especially on large mammals such as the elephant, the tiger, the orang-utan and the rhinos. Although this may seem limited in scope given the great diversity of life in this region, these animals are frequently among the most endangered and their symbolic value cannot be overestimated. Indeed, many of the species discussed in these articles have great value as symbols of the natural heritage of the countries in which they occur, and are worthy of protection on aesthetic grounds alone. It is also important to note that if these species can be protected in areas of suitable tropical forest habitat, many other smaller, less conspicuous species occurring in these same protected areas will survive as well — and, more often than not, it is the large and spectacular species that are most effective in calling attention to the entire conservation issue.

A number of these species also have great economic value, and are important resources to local people. The elephant is essential for the timber industry in Burma, the marine turtles provide a source of protein for many coastal peoples, and wild cattle represent a reservoir of genetic diversity for domestic stock. The economic importance of a growing tourist industry aimed at observing the fauna and flora of the world's tropical forests is also worthy of note, and it is usually the large and spectacular species that attract the most tourists.

Finally, it should be clear from the papers in this volume that all of the species discussed are integral components of the tropical forest ecosystems in which they occur, and that species and habitat conservation must always go hand in hand.

On behalf of the SSC Chairman, Mr. Grenville Lucas, we take great pleasure in launching this new SSC series, and hope that it will make a significant contribution to saving the species diversity of southeast Asia and our entire planet. We would also like to take this opportunity to extend our thanks to Department of Wildlife and National Parks of Malaysia, and especially to the Director General, Dr. Mohd. Khan bin Momin Khan for his outstanding efforts in organizing and hosting the 58th SSC Meeting.

Russell A. Mittermeier
William R. Konstant


4 INDONESIA ■
5 THAILAND ▥
6 BURMA ▤
MALAYSIA ▨
1 Peninsula Malaysia
2 Sarawak
3 Sabah
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5
6

Peninsula Malaysia

Species Conservation Priorities in the Tropical Rain Forests of Peninsula Malaysia

Mohd. Khan B. Motnin Khan
Sivananthan T. Elagupillay
and Zolkifli Bin Zainal

Introduction

Peninsula Malaysia (131,582 km^2) has some of the oldest rainforests in the world and is home to some of the world's richest and most unique animal and plant treasures. There are some 200 species of mammals, 600 species of birds, 130 species of snakes, 3,000 species of trees, 8,000 species of flowering plants, scores of amphibians and reptiles, and thousands of insects and invertebrate species.

Conservation in Peninsula Malaysia has evolved over periods of plenty and periods of scarcity of natural resources. During periods of plenty laws were lax, resulting in wasteful utilization of wildlife. Up to the time of the first salaried game warden in 1927, wildlife laws were enforced by volunteers or officers of the land office who were involved mainly in the issue of game licenses.

The incredibly low value put on the lives of animals contributed to the tragic extinction of the Javan rhinoceros in 1932 and the precarious situation of the Sumatran rhinoceros, which is still listed as an endangered species together with the tiger and the seladang. Strong and effective conservation legislation was slow in coming into force. Although current laws appear satisfactory to curb losses from poaching and trade in wildlife, the effects of habitat loss have proved to be a very serious cause of mortality. Approaches to the problems have changed from simple emphasis on law enforcement to a combination of research and management, extension programs, and establishment of national parks and wildlife reserves.

The need to expand and strengthen the developing economy has resulted in the clearance of vast stretches of virgin forest. In the last two decades Malaysia's forests have rapidly diminished and been replaced by agriculture and human settlements. Still, approximately 49 % of the total land area in Peninsula Malaysia remains forested.

Steven (1968) spent two years in Peninsula Malaysia collecting data for a report on wildlife conservation. He noted the occurrence of mammals at different elevations and concluded that 52% are found below 330 meters, 81 % are restricted to altitudes of less than 660 meters, 10% occur at higher elevations, and only 9% appear able to exist at all altitudes. Fifty-three per cent of all mammals are confined to primary forest, 25% live in primary or tall secondary forest, 12% live in primary or secondary forest or can subsist in cultivated areas, and 10% live in cultivated or urban areas.

Burgess (1971) described the effects of logging on hill dipterocarp forests in his study of approximately 40 hectares of average lower hill forest in the state of Trengganu. It was found that in this area only 35% of the stand disturbed by logging activity remained undamaged. Of the rest, 10% was felled for timber and 55% was destroyed in the extraction operation.

The effects of forest clearance on Malaysian mammals were studied by Harrison (1969), who found that the number of species decreased markedly in the transition from primary to secondary forest to scrub to grassland. The decrease in native mammalian diversity was on the order of 30 to 10 to 4 species, respectively.

Species Conservation in Peninsula Malaysia

Sumatran Rhinoceros (Dicerorhinus sumatrensis). Although numbers of Sumatran rhinos appear to have increased by about 30 individuals within Peninsula Malaysia between 1979 and 1982 (Table 1), only two areas, namely Endau Rompin and Tamara Negara (Fig. 1), have large and contiguous populations. It should be noted that the rhinos in Endau Rompin are reproducing, though at a slow rate of one animal every two years. The population has produced at least 3 young during the period 1975-1981. In other areas, rhino populations remain isolated and are threatened with extinction unless they can be translocated to safer areas.

Table 1. Estimated numbers of Sumatran rhinos in Peninsula Malaysia

Region	***Numbers***	
South	***1979***	***1982***
Endau-Rompin	8-15	20-25
G. Belmut	—	2-3
Mersing Coast	—	2-3
North Central		
Taman Negara	4-6	8-13
Ulu Lepar	2-4	3-5
Sg. Depak	2-4	3-5
Kuala Bolah	2-4	3-5
Krau Reserve	—	0-2
Bkt. Gebok	—	1-2
West Coast		
Sg. Dusun	2-4	4-6
Northwest		
Ulu Selama	—	3-5
Ulu Belum	2-4	3-5
Kedah Boarder	—	0-1
	30-50	52-80

Malayan Tiger (Panthera tigris). In 1954, Locke estimated the Malayan tiger (Fig. 2) population to be about 3,500, but it has

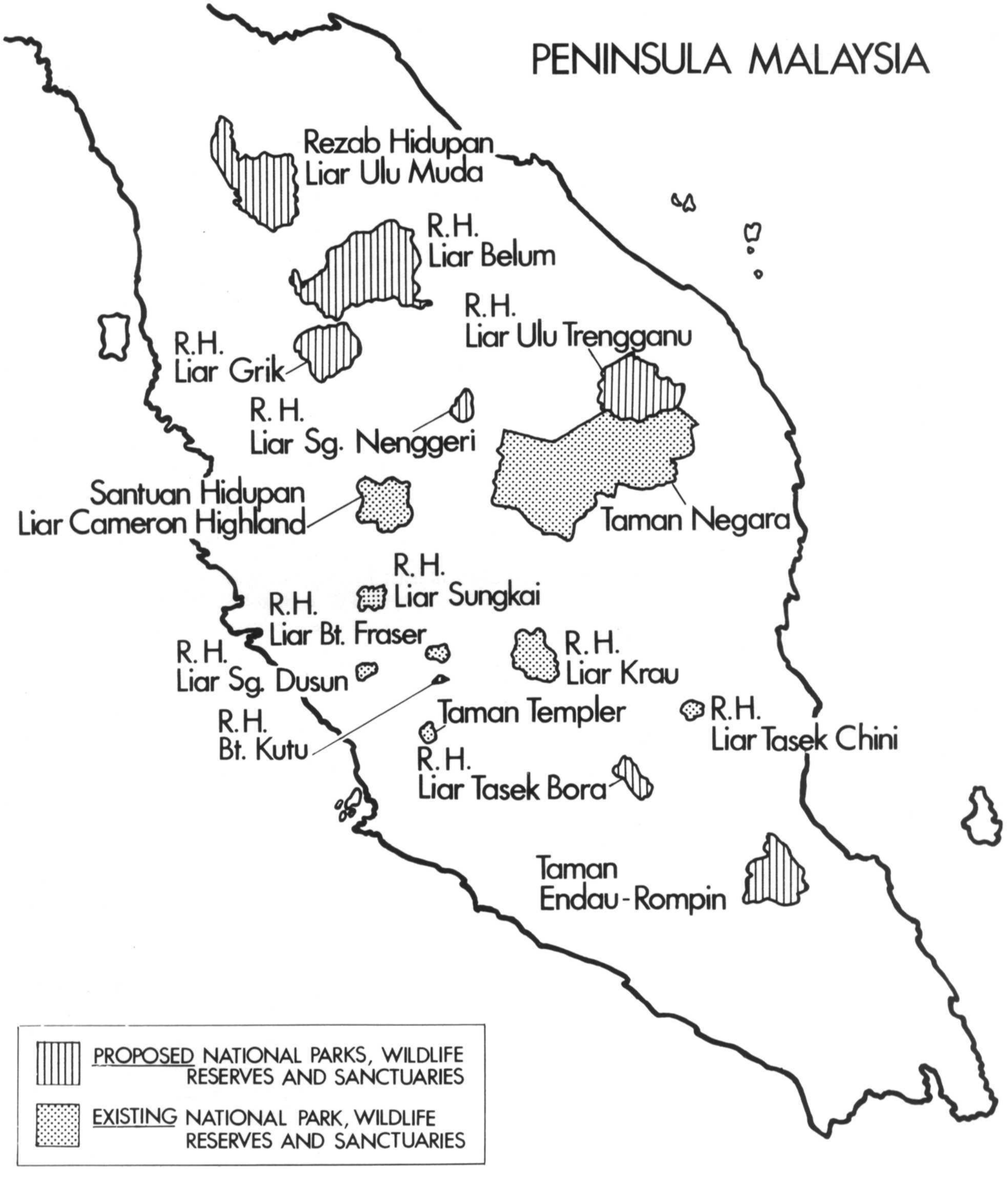

Fig. 1: Map of Peninsula Malaysia showing the location of existing and proposed national parks, wildlife reserves and sanctuaries.

now dwindled to about 250, based on work carried out by the Wildlife Department over the last four years. The tiger, which once inhabited the whole of Peninsula Malaysia, is now mainly found in the existing primary and secondary forest of Perak, Kelantan, Trengganu and Pahang.

Seladang (Bos gaurus). While it is difficult to manage populations of Sumatran rhinoceros and tiger, the situation for the seladang (gaur or wild cattle, Fig. 3) appears more hopeful. Its requirements are relatively simple: pasture, water, minerals and cover. In the last survey by the Wildlife Department in 1980, there was evidence of an increase in the seladang population (Table 2).

Table 2. Seladang population in Peninsula Malaysia as of 1980

	Numbers	
Areas	***1977***	***1980***
National Parks and Reserves	150	150
Ulu Tengganu	25	29
Sungai Nenggiri	40	53
Ulu Lepar	56	96
Maran	–	5
Lepar Hilir	–	10
Endau Rompin	25	25
Ulu Serting	10-12	10-12
Grik Wildlife Reserve	40	40
Belum Wildlife Reserve	60	60
	400	472

A detailed study in Ulu Lepar showed that the seladang preferred riverine habitat, with 70% being found at 0-7 m.

Elephant (Elaphas maximus). Like the tiger, the elephant (Figs. 4-5) once roamed freely throughout Peninsula Malaysia, but is now restricted to remaining forests in the states of Kelantan, Trengganu, Pahang, Perak, Johore and a few areas in Negari Sembilan and Kedah. There are now about 700 elephants distributed in these states, including Taman Negara (Table 3).

Table 3. The elephant populations of Peninsula Malaysia

States	***Numbers***
Kelantan	134
Trengganu	54
Johore	77
Pahang	175
Perak	126
Negeri Sembilan	5
Taman Negara	100
	671

Primates. Southwick and Cadigan (1972) reported on the abundance of non-human primates (Figs. 6-9) in primary and secondary forests of Peninsula Malaysia. An assessment was made of group densities (animal/km^2) of each species except the dark-handed gibbon (Table 4). Other source material includes Bernstein (1968), MacKinnon and Mackinnon (1978), Fleagle (1978) and Olivers (1980). The total area of forest still remaining in 1958 was 84%, or 110,308 km^2.

Table 4. Total population estimates of primates in Peninsula Malaysia in 1958

	Density of species		
Species	***2° Forest***	***1° Forest***	***Total Population***
Macaca fascicularis	1.54	0.37	415,000
M. nemestrina	0.13	- 1	80,000
Presbytis cristata	0.26	- 1	6,000
P. melalophos	2.95	2.22	962,000
P. obscura	0.64	0.74	305,000
Hylobates lar	0.89	1.11	144,000
H. syndactylus	0.51	1.11	111,000

Based on the same densities provided by Southwick and Cadigan (1972), Khan (1978) estimated the populations of the various species and indicated losses in numbers between 1958 and 1975 (Table 5). These estimates are based on 51 % of the total land area still being under forest cover at that time.

Table 5. Total losses in non-human primate populations between 1957 and 1975

Species	***Population in 1957***	***Population in 1975***	***Population loss***	***% loss***
Macaca fascicularis	415,000	318,000	97,000	23.37
M. nemestrina	80,000	45,000	35,000	43.75
Presbytis cristata	6,000	4,000	2,000	33.33
P. melalophos	962,000	554,000	408,000	42.41
P. obscura	305,000	155,000	150,000	49.18
Hylobates lar	144,000	71,000	73,000	50.09
H. syndactylus	111,000	48,000	63,000	56.75

Recent studies by Marsh and Wilson (1981) indicate that the distribution of primates in Peninsula Malaysia is similar to that reported in earlier studies by Lim (1962), Medway (1969, 1970), Khan (1970) and Chivers (1974). Langurs (*Presbytis* spp.), macaques *(Macaca* spp.) and gibbons *(Hylobates* spp.) are still widely distributed all over Peninsula Malaysia. Only the slow loris *(Nycticebus coucang)* is thought to be rare.

Birds. An attempt was made to estimate minimum bird populations in 6 different habitats: urban gardens, coconut plantations, mangrove forest, secondary lowland forest, extraction tracks in logged forest and virgin jungle in reserves in Selangor (McClure, 1969; Table 6).

The rich diversity of the forest bird fauna of Peninsula Malaysia was surveyed (Wells, 1971) in Pasoh, Negeri Sembilan, Kuala Lompat, Pahang and Sg. Sat and Sg. Sepia of Taman Negara (Table 7).

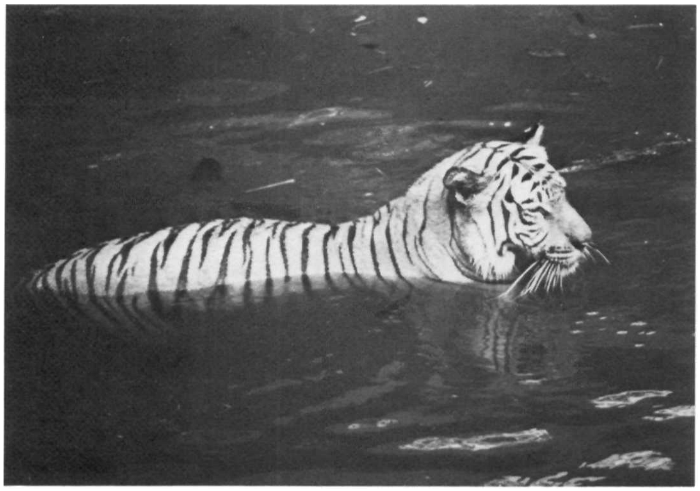

Fig. 2: The tiger, which once numbered about 3500, has now dwindled to about 250 (photo by R. A. Mittermeier).

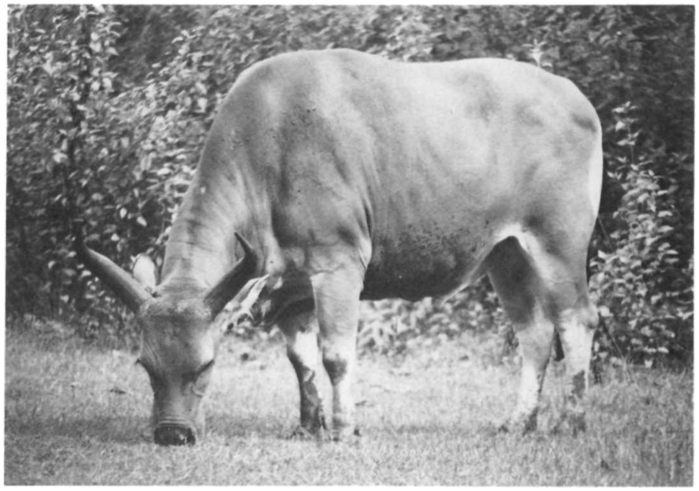

Fig. 3: The seladang, largest of the wild cattle and one of Malaysia's priority species (photo by R. A. Mittermeier). The individual shown is a female.

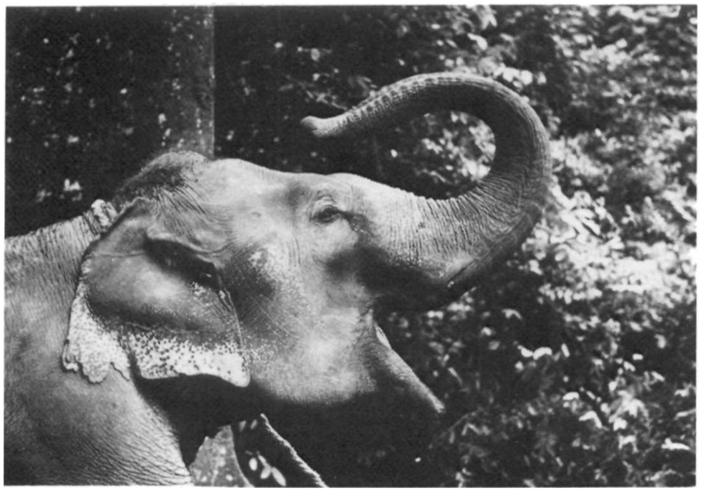

Fig. 4: The Malaysian elephant population is now thought to number about 700 individuals (photo by R. A. Mittermeier).

Fig. 5: The elephant catching unit of the Dept. of Wildlife and National Parks at work (photo by R. A. Mittermeier).

Table 6. Population estimates of birds according to habitat type (from McClure, 1969)

Location	*Habitat Type*	*Birds per 40 hectares*
Kuala Lumpur	Urban garden	1100
Subang	Secondary forest	450
Rantang Panjang	Coconut plantation, mangrove	800
Ulu Gombak Forest Reserve	Extraction track in logged forest	400
Ulu Gombak	Virgin Jungle reserve	400

Table 7. Record of species abundance of birds in each area (Wells, 1971)

Location	*Area Size (km^2)*	*Study Duration*	*# Species*
Pasoh, Negeri Sembilan	10	2 years	175
Kuala Lompat, Pahang	2	3 days	141
Sg. Sat and Sg. Sepia, Taman Negara	3	6 days	127

Table 8. Density and area needs of hornbills

Species	*Number of birds supported/200 ha (Kuala Lompat)*	*Estimated area needed to support 500 individuals (hectares)*
Helmeted hornbill *(Rhinoplax vigil)*	1	10,000±
Rhinoceros hornbill *(Buceros rhinoceros)*	c. 1	10,000
Southern Pied hornbill *(Anthracoceros convexus)*	2	5,000
Black hornbill *(Anthracoceros malayanus)*	4	2,500
Bushy-crested hornbill *(Anorrhinus galeritus)*	5	2,000

The total number of known lowland forest birds is 241 species. Observations at Kuala Lompat, Pahang, taken over an area of 194 hectares, provided data for estimates of the density of hornbills and of the area needed to support 5,000 individuals (Medway and Wells, 1971; Table 8).

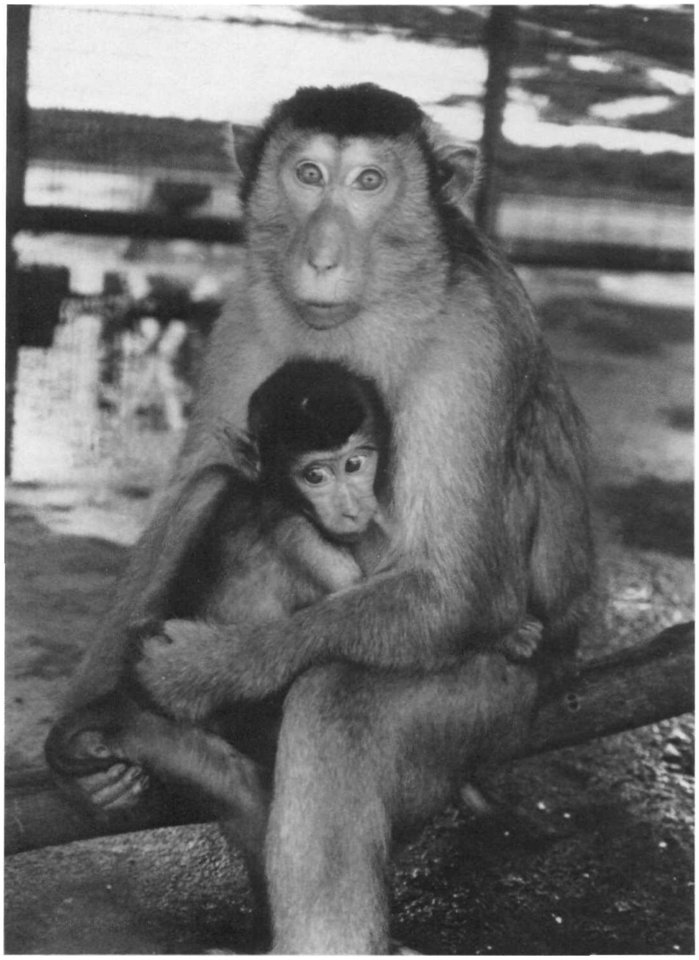

Fig. 6: One of Peninsula Malaysia's two macaque species, the pig-tailed macaque (*Macaca nemestrina*) (photo by R. A. Mittermeier).

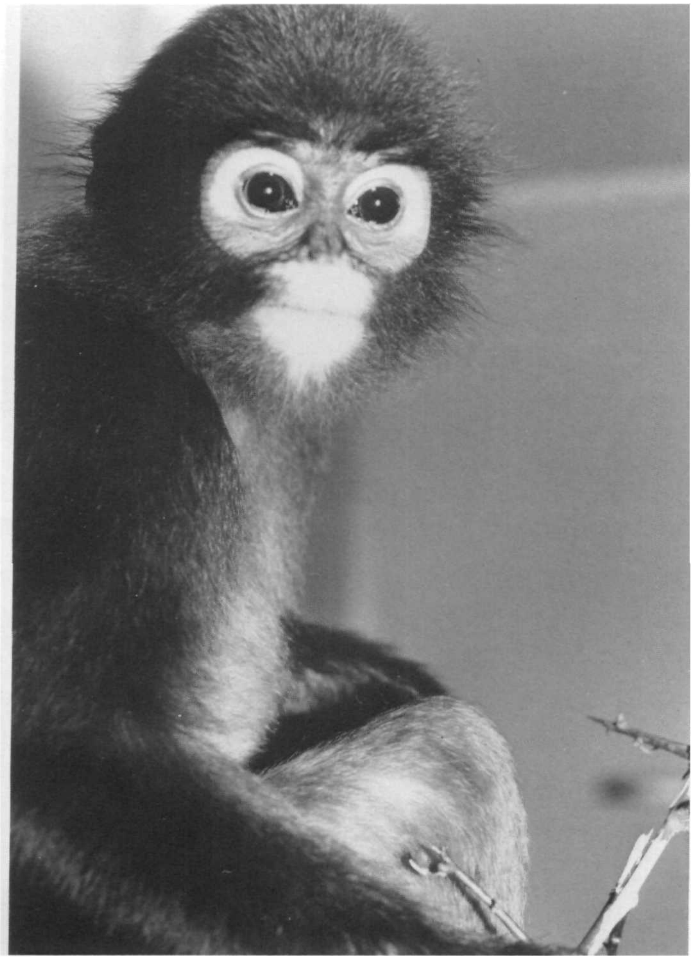

Fig. 7: One of Peninsula Malaysia's three langur species, the spectacled langur (*Presbytis obscura*) (photo by R. A. Mittermeier).

Fig. 8: The siamang *(Hylobates syndactylus),* largest of Peninsula Malaysia's nonhuman primate species (photo by D. J. Chivers).

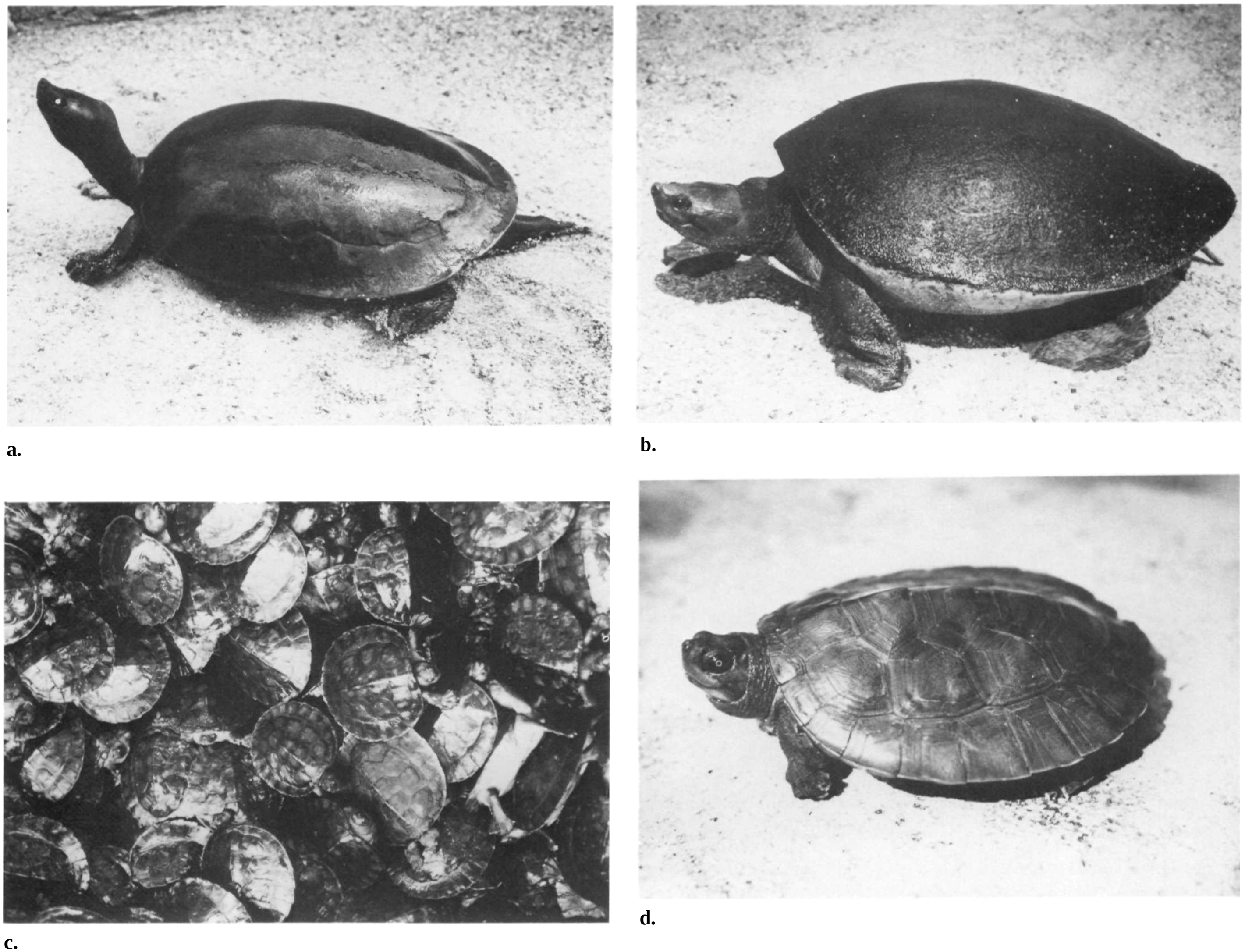

Fig. 9. The river terrapin *(Batagur baska)* is one of Malaysia's most endangered reptiles. Special hatcheries have been established in Kedah, Perk and Trengganu. These animals were photographed in the hatchery at Bota Kanan. (Photos by R. A. Mittermeier). a. Adult male *Batagur baska* (note the striking white eye). b. Adult female *Batagur baska.* c. Hatchling *Batagur baska. A.* Hatchlings awaiting release. e. Personnel of the Dept. of Wildlife and National Parks with a number of *Batagur baska* hatchlings to be released in the Perak River.

River Terrapin (Batagur baska). Three river terrapin hatcheries were started in the states of Kedah, Perak and Trengganu at a total cost of one million dollars (Figs. 10-14). These projects will hopefully counter the declining numbers of river terrapins due to poaching of adults and the extensive collection of their eggs. More than 20,000 one year old terrapins have been released from such hatcheries since 1967.

Deer. Two deer farms are now also being developed in the Sungkai Game Reserve, Perak and the Krau Game Reserve, Pahang, like the river terrapin hatcheries at a cost of about one million dollars. The deer are raised in a semi-wild state in an effort to produce good breeding stock. From a few locally obtained animals the breeding stock has now increased to about 100 individuals.

Conservation Action Priorities

Wildlife management in a strict sense is a relatively recent phenomenon in Peninsula Malaysia. Formerly, game departments functioned primarily as licensing agencies, while control of hunting and trade in wildlife was given low priority. Wildlife was shot and killed indiscriminately and the incidence of licensees taking more game than the allowed bag limits was high. A number of species have become endangered or extinct, and this is evidence of the absence of sustained conservation efforts.

The large number of firearms in the hands of hunters presents a serious problem for wildlife conservation. In Peninsula Malaysia, wildlife species may be killed in defense of crops, life or property. Illegal possession of firearms carries the death penalty, but far too many people are currently licensed to carry firearms.

Corruption among enforcement officials is a serious problem. It must be corrected by better income and more attractive prospects in the wildlife service. In addition, close supervision of and legal action against corrupt officers is essential. Violations, no matter how small, should be acted upon. To speed up action, minor offenses may be settled out of court, whereas serious offenses should all go to court and be dealt with accordingly.

Smuggling is serious because of the demand and the high commercial value of many species of wildlife. To curb smuggling, Malaysia became a party to CITES in 1978.

Apart from legislation directly pertaining to the protection of wildlife and national parks there are numerous laws that are not effectively enforced. In Peninsula Malaysia, river terrapins are governed by the river rights laws of each state. In pre-war days, when these laws were strictly enforced, terrapins were abundant. Nowadays, these laws are hardly enforced, which explains why the river terrapin is endangered.

We believe support for conservation to be a top priority. A variety of conservation-oriented programs already exist on radio and television networks, but films on conservation are mainly products of foreign countries. A more direct approach is necessary to illustrate local problems and what is being done in the field of conservation.

A special effort to gain the support of decision makers and politicians is the utmost priority in solving wildlife management problems. This approach is unfortunately slow, short-term results not being easily achieved. The support of the judiciary is indispensable, as it would be meaningless to impose fines which do not deter offenders. An effective system with adequate law enforcement officers equipped to perform their duties with confidence is essential.

The need for political stability routinely takes precedence over the need for wildlife reserves in developing nations. In the face of a rapidly expanding population there is no alternative but to exploit both renewable and non-renewable natural resources, since leaders perceive constraint on raising the standard of living unacceptable. Despite this, the concept of conservation is included in the ASEAN (Association of Southeast Asian Nations) program for the environment, through the actions of high-ranking government officials and ministers. Under conservation the importance of national parks, trade in wildlife, legislation, training, information exchange and wildlife management research are given prominence. Representatives from the Department of Wildlife and National Parks of each country participate in meetings, workshops and field trips, and assistance and advice from international organizations like UNEP and IUCN are sought when needed. In the past, a lack of sound management research has resulted in undesirable decisions, based on incomplete data analyses. This has often had a serious effect on wildlife. For example, improperly scheduled hunting seasons have resulted in heavy mortality of pregnant animals and their young. It is important that management research be increased as most, if not all, conservation action must be based on a thorough knowledge of the biology of animals and their roles in the ecosystems.

Mining activities presently occur in about 1 % of the total land area of Peninsula Malaysia, but are not regulated under a general landscape quality program for the entire country due to the prohibitive costs of establishing such a program.

Shifting cultivation presents a serious problem in wildlife management. While it is beneficial to some species of wildlife, it is detrimental to most because of habitat loss. Shifting cultivation, of necessity, is quite extensive in this region. In practice, the first few crops provide good harvests, but declining fertility within only a few years necessitates relocation. It takes several years before an abandoned cultivated area becomes naturally fertile again; which explains why extensive areas are needed for shifting cultivation. While waiting for the crops to be harvested, wildlife and wild plant products take their place.

The elephant problem in Peninsula Malaysia was tolerable before palm oil became a major industry. Continuing loss of habitat, coupled with the elephants' preference for oil palm have resulted in a serious confrontation between this species and man. More research is required to produce an effective means of elephant control. A trapping scheme solved the Bengka crop depredation problem, which at the time was very serious. The scheme is applied in places where there is no available forest for elephants. Electric fences are also being widely used by planters and have proven an effective deterrent.

Wildlife Plan. A Wildlife Plan is essential for Malaysia. Such a plan must consider the variety of species present, their habitat and their potential uses. The species currently being managed are important by virtue of their status as endangered species, economically important species or serious pests. A more comprehensive Wildlife Plan is currently being prepared, aimed at conserving a representative cross-section of the diverse Malaysian flora and fauna. This comprehensive plan will be dependent upon existing governmental policies, yet will allow for appropriate action to be taken promptly in critical situations.

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Fig. 10: The white-handed gibbon *(Hylobates lar)*, one of Malaysia's three gibbon species (photo by D. J. Chivers).

Sarawak

Species Conservation Priorities in the Tropical Forests of Sarawak, Malaysia

Kron Mide Aken
and Michael Kavanagh

Introduction

Sarawak is the largest of Malaysia's 13 states, occupying 124,450 km^2 of northwestern Borneo, approximately between 1 ° and 5 ° N latitude (Fig. 1). It is bounded to the north by the double enclave of Brunei (5,763 km^2) and approximately 2,000 km of coastline. In the south and east it shares roughly 2,250 km of frontier with the Indonesian states of West and East Kalimantan, and a further 125 km with the Malaysian state of Sabah.

Geologically, Sarawak consists largely of relatively young, very deep sedimentary rocks that have been subjected to complex and localized folding; although more ancient formations, even pre-Permian, are found in the extreme west (Fitch, 1960).

Approximately 28,900 km^2 of the state (23%) lies below the 30 m above sea level contour, forming a coastal plain of varying width, with a number of isolated outcrops. The soils here are mainly gley and peat formations, most of which are poorly drained and naturally covered with various types of swamp forest (Anon., 1968). Above the 30 m contour, skeletal and podzolic soils predominate, being loamy sands to clays and typically very shallow where the land is steep. Much of this area is very rugged hill country, even steeply mountainous in places. The vegetation is chiefly mixed dipterocarp forest, with *kerangas* (heath forest) occurring in areas of coarse, sandy soils (see Whitmore, 1975 and Table 1).

Land above 610 m, with more montane forest formations (20% of the state), is mainly to be found in northeastern Sarawak, culminating in the Kelabit Uplands and the state's highest peak, 2,425 m, named Gunung Murud. Nearby, Gunung Mulu rises to 2,378 m.

In Sarawak's 1980 census 1,294,753 people were counted (Dept. of Statistics Information, Sarawak). The most recent ethnic breakdown of 1970 gives the Malay/Melanau people as comprising 24 % of the population, other native peoples as 45 %, and the Chinese and non-natives as 31%. The significance of these figures is that the Malay/Melanau and non-native 55 % of the population are mainly urban and coastal peoples who do not depend on hunting as a source of protein. The remaining 45%, sometimes referred to as *Dyaks,* are mainly rural people, many of whom practice hunting for food and cultural purposes (e.g., to collect feathers) with shotguns, spears and blowpipes (Figs. 2-3). They include the Bidayuhs of western Sarawak, the Ibans, Kayans and Kenyahs of the center of the state, and smaller tribes from the north, such as the Kelabits, Muruts, Punans and Penans. Many of these people dwell in traditional longhouses and practice shift-

Fig. 1: A penan man using a blowpipe and poison darts to hunt for small game (photo by M. Kavanagh).

Fig. 2: Two Kelabit hunters of Sarawak's Fourth Division skinning a freshly shot Hose's langur (*Presbytis hosei*) (photo by M. Kavanagh).

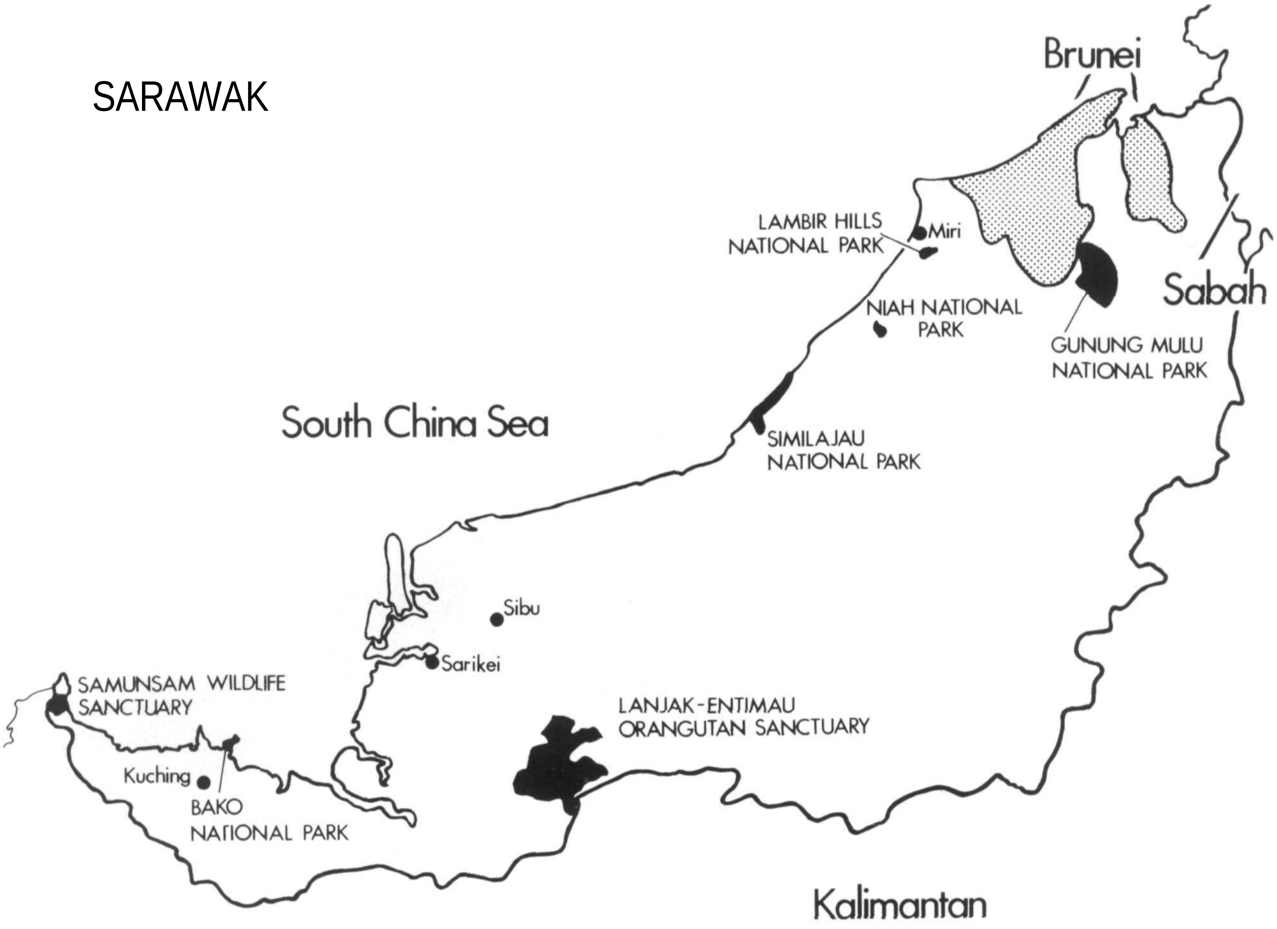

Fig. 3: Map of Sarawak showing the location of National Parks and Wildlife Sanctuaries.

ing cultivation of hill *padi* (with other crops) over wide areas. Nomadic hunter-gatherer groups may still be found among the Punans and Penans.

Throughout the state, the "Dyaks" have the right to practice their shifting cultivation wherever the land is neither specifically owned by some person or organization, nor gazetted as a government reserve. This means that they can farm in more than half of the area of Sarawak. Apart from their right to farm, they also enjoy "native customary rights," whereby they may hunt, fish and collect such forest products as rattan, fruit and timber for their housing. Generally, this is done in the forests fairly close to the longhouses, but it also occurs as much as three or four days journey upriver by non-motorized boat.

The net result of all this is that wildlife conservation is not an easy task. Shifting cultivation and wildlife conservation are often in competition for land; and the government usually has to abrogate or reduce native customary rights — often with extensive compensation — in order to obtain areas for national parks or wildlife sanctuaries. Once an area is gazetted as a park or sanctuary, constant patrolling is necessary against both poachers and encroachment by shifting cultivators.

Sarawak has a very limited road system. A single, largely unpaved trunk road from the extreme west to Brunei is scheduled for completion during 1983. However, the rivers will continue to form the basis of the transportation network for many years to come. A regular air service is available and air travel into the interior is subsidized by the government.

Table 1. Principal forest types and other land use in Sarawak

	Sq. Km.	*% of land area*
Forested land		
Mangrove & nipah swamp	1,738	1.4
Other swamp forests	14,738	12.0
Mixed dipterocarp forests	74,189	60.2
Kerangas (heath forest)	3,660	2.9
	94,325	76.5
Non-forest land		
Settled agricultural & non-agricultural	4,730	3.8
Shifting cultivation & unused land	24,198	19.7
	28,928	23.5
Total land area	123,253	100.0
(Water	1,197	)

Source Anon. (1982).

Under the Forest Ordinance of 1954 and its subsequent amendments, the Sarawak Forest Department administers 24.3% of the state as permanent forest in the form of forest reserves, protected forests and communal forests (Table 1). All are intended to be managed on a sustained yield basis. Forest reserves and protected forests, and all that they contain, are the property of the state government and may be exploited for timber under a licensing system. In addition, any inhabitant of Sarawak may enter any protected forest (subject to the control of the Director of Forests) to hunt, fish and collect minor forest products. Communal forests are specifically intended for more local exploitation by the people of the immediately surrounding area. These people have the sole right to utilize the forest, which they normally maintain and control, and which cannot be licensed for commercial timber extraction. It is the case, however, that "minor forest produce" is invariably understood to include wood for domestic use only.

National parks and wildlife sanctuaries are also controlled by the Director of Forests (who doubles as the Chief Game Warden), being administered on his behalf by the National Parks and Wildlife Office of the Sarawak Forest Department. They are the most fully protected areas in the state, the main practical difference between them being that parks are intended to include recreation and tourism. These protected areas, constituted under the National Parks Ordinance of 1956, the Wild Life Protection Ordinance of 1958 and their subsequent amendments, provide for certain hunting and collecting rights to be exercised, if so specified in the Government Gazette. Since there is no legal provision for buffer zones, these must be located within the protected area boundaries if they are to be managed as part of the area. The Wild Life Protection Ordinance also makes provision for the legal protection of listed species (see Table), to be enforced by means of fines and jail sentences.

Fig. 4: The proboscis monkey *(Nasalis larvatus),* a large and striking primate restricted to Borneo (photo by R. A. Mittermeier).

Species Conservation in Sarawak

The National Parks and Wildlife Office (NPWO) has a **staff** of 57, of whom only 6 are graduates, plus 3 foreign volunteers. The current emphasis of the office is to administer the existing

Fig. 5: The probiscis monkey *Nasalis larvatus),* a large and striking primate restricted to Borneo (photo by R. A. Mittermeier).

Fig. 6: Nipa-mangrove association in the Samunsam Wildlife Sanctuary, one of the main strongholds of the proboscis monkey in Sarawak (photo by R. A. Mittermeier).

Fig. 7: Bako National Park, an attractive national park located near the capital city of Kuching (photo by R.A. Mittermeier).

parks and sanctuaries and to gazette more land under these categories. It is therefore not surprising that a relatively small amount of survey information is available, much of it emanating from joint projects with scientists outside the department (e.g., Anderson, et al., 1982; Kemp and Kemp, 1974; WWF, 1982). Consequently, data on the effects of widespread shifting cultivation are usually conspicuously lacking in wildlife sanctuaries, even in comparison with settled land in Peninsula Malaysia.

Survey information does exist for hornbills *(Bucerotidae;* Kemp and Kemp, 1974) and the proboscis monkey *(Nasalis larvatus;* Salter and MacKenzie, 1981). Of the 8 hornbill species in Sarawak, only the pied hornbill *(Anthracoceros coronatus)* is regarded as vulnerable, as it prefers the coastal habitat. The coastal part of the state is precisely that which has been most cleared for agricultural development. The proboscis monkey (Figs. 4-7) has a disjunct distribution along the coast and a total population that is estimated at about 2,000 animals, far fewer than previously thought (IUCN, 1978), 90% of which are found in areas that are open to human exploitation.

Of the other species listed in the *Red Data Books* (ICBP, 1981; IUCN, 1978, 1982), orangutans *(Pongo pygmaeus)* are found in and around Lanjak-Entimau Orangutan Sanctuary. Although they have yet to be quantitatively surveyed, the available evidence shows that they cover a wide area and suggests that they are present in good numbers (WWF, 1982; NPWO unpublished reports, 1983; *contra* Davies, 1983). Elsewhere, they are found only in highly accessible, disjunct pockets of unprotected forest where they are unlikely to survive for very long. The Bornean tarsier *(Tarsius bancanus borneanus)* appears to be more widespread than previously thought (e.g., Medway, 1977), being present in Gunung Mulu National Park and Lamjak-Entimau (Anderson, et al., 1982; WWF, 1982), as well as, for example, Semenggoh Forest Reserve, Bako National Park and Niah National Park (Niemitz, 1979).

Very little is known about the distributions of the clouded leopard *(Neofelis nebulosa),* marbled cats *(Felis marmorata* and *F. badia),* or the flat-headed cat *(F. planiceps).* The Sumatran rhinoceros *(Dicerorhinus sumatrensis),* relatively common in the 1930's, may well be extinct in Sarawak, and the banteng *(Bos javanicus)* persists only in remote parts of the north and east, if at all.

The most up-to-date information for Sarawak's eight bird species that are listed in the *Red Data Book* may be found in ICBP (1981) and Smythies (1981). Likewise, up-to-date information about threatened reptiles may be found in IUCN (1982), to which it may be added that the false gharial *(Tomistoma schlegelii)* is still hunted, quite legally. A population of false gharials, as yet unsurveyed in detail, would be protected if current plans to establish Sarawak's only lake, Loagan Bunut, as a national park are successful. The first steps in this direction have been taken by the Forest Department.

Conservation education is in its early stages at all levels of Sarawakian society. However, certain species may be occasionally protected by specific customs and taboos. For example, orangutans are not hunted by most of the people of the upper Batang Ai river basin immediately to the south of Lanjak-Entimau. In consequence, they persist there, even in areas of secondary forest adjacent to cultivation where other primary forest species are almost totally absent. The same is not true in nearby areas where orangutans are equally protected by law, but not by tradition (unpublished survey information, NPO/WWF, 1983). For the majority of the people of Sarawak, wildlife conservation is of little or no interest, except where declining yields have become a matter for regret (see Aken, 1982).

With three-quarters of the state still forested, habitat destruction is not the immediate problem that it is in some other parts of southeast Asia, but this situation is unlikely to persist for long. At the present time, rural people and several development agencies are competing to use forested land, with many legitimate claims that can result in forest degradation and destruction.

Table 2. Protected areas in Sarawak

	Sq. Km.	*% of the area of the state*
Production forests		
Forest reserves	7,602	6.1
Protected forests	22,536	18.1
Communal forests	55	<.1
	30,193	24.3
Parks & Sanctuaries		
(with dates of gazettement)		
1. Bako National Park (1957)	27	<.1
2. Gunung Mulu National Park (1974)	529	0.4
3. Niah National Park (1974)	31	<.1
4. Lambir Hills National Park (1975)	69	<.1
5. Similajau National Park (1979)	71	<.1
6. Samunsam Wildlife Sanctuary (1979)	61	<.1
7. Lanjak-Entimau Orang-utan Sanctuary (1983)	1,688	1.4
8. Gunung Gading National Park (1983)	54	<.1
	2,530	2.0

Source Anon. (1982); WWF (1982).

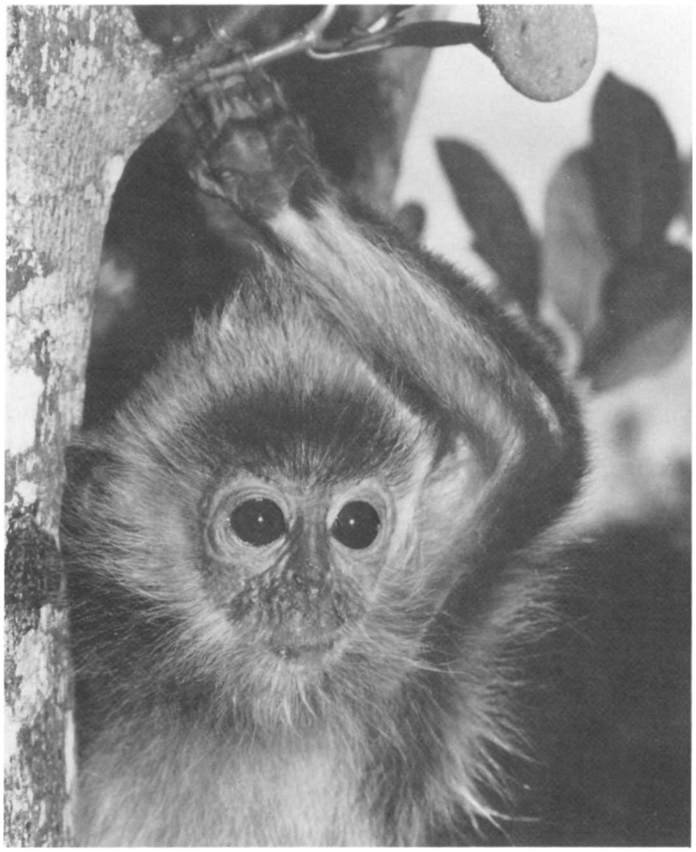

Fig. 8: Juvenile silver leaf monkey *(Presbytis cristata)* from Sarawak (photo by R. A. Mittermeier).

National parks and wildlife sanctuaries cover only *2%* of the state and of those, only one exceeds 1,000 km^2 (Table 2). Should the existing parks and sanctuaries ever become completely isolated from the surrounding forests, they will certainly be inadequate to conserve more than a small proportion of Sarawak's plant and animal species. Species that naturally occur at low densities (such as many forest trees and large animals) and those which normally experience severe population fluctuations will be most at risk (Diamond, 1975). An additional problem for Sarawak is that swamp forests (about 17.5% of current forest cover) are effectively unrepresented among the existing parks and sanctuaries.

Finally, the state presently lacks appropriate regulations for the enforcement of CITES, to which Malaysia is a party, although the Wild Life Protection Ordinance (Table 3) provides the necessary enabling legislation. Specific proclamations must be gazetted before, for example, the trades in crocodile or pangolin derivatives can be controlled.

Conservation Action Priorities

It is recognized that the management plans for Gunung Mulu National Park and Lanjak-Entimau Orangutan Sanctuary require implementation, and that similar management work is required for the remaining parks and sanctuaries. Work is proceeding in these areas, but an equal priority is to develop a master plan for the statewide conservation of representative habitat types. This will result in recommendations for more protected areas and for the incorporation of other types of permanent forest estate into the system to minimize fragmentation.

Table 3. Animals listed on the First Schedule of the Wild Life Protection Ordinance

Protected animals:

1.	*Nasalis larvatus*	proboscis monkey
2.	*Pongo pygmaeus*	orang-utan
3.	*Dicerorhinus sumatrensis*	Sumatran rhinoceros
4.	*Egretta sacra*	reef egret
5.	*Bulbulcus coromandus*	cattle egret
6.	*Ciconia stormi*	Storm's stork
7.	*Leptoptilos javanicus*	lesser adjutant
8.	*Haliaeetus leucogaster*	white-bellied sea-eagle
9.	*Ichthyophaga ichthyaetus*	grey-headed fishing eagle
10.	*Sterna sumatrana*	black-naped tern
11.	*Sterna anaethetus*	bridled tern
12.	*Ducula bicolor*	pied imperial pigeon
13.	*Chelonia mydas*	green turtle
14.	*Eretmochelys imbricita*	hawksbill turtle
15.	*Dermochelys coriacea*	leatherback turtle
16.	*Berenicornis comatus*	white-crested hornbill
17.	*Anorrhinus galeritus*	bushy-crested hornbill
18.	*Rhyticeros corrugatus*	wrinkled hornbill
19.	*Rhyticeros undulatus*	wreathed hombill
20.	*Anthrococeros malayanus*	black hornbill
21.	*Anthrococeros coronatus*	pied hombill
22.	*Buceros rhinoceros*	rhinoceros hornbill
23.	*Rhinoplax vigil*	helmeted hornbill
24.	*Polyplectron malacense*	Malaysian peacock pheasant
25.	*Argusianus argus*	great argus pheasant
26.	*Dugong dugon*	dugong
27.	*Lanthanotus borneensis*	earless monitor lizard
28.	*Tarsius bancanus*	Horsfield's tarsier
29.	*Neofelis nebulosa*	clouded leopard
30.	*Nycticebus coucang*	slow loris
31.	*Hylobates muelleri funereus*	Bornean gibbon
32.	*Hylobates muelleri muelleri*	Bornean gibbon
33.	*Hylobates muelleri abbotti*	Bornean gibbon

Other animals the export of which is forbidden except under licence:

1. Apes and monkeys
2. Bears
3. Deer

n.b. The numbering of the listed animals follows that of the Ordinance but the scientific names have been up-dated where necessary.

In this connection, NPWO is pursuing several concurrent lines of approach, partly in conjunction with WWF Malaysia (Project 3212). Firstly, potential protected areas are being surveyed on an opportunistic basis and proposed, if appropriate. Secondly, work has begun on the overall master plan as a basis for strategy. Thirdly, NPWO is encouraging greater integration of wildlife management practices with production forestry in forest reserves and protected forests (Aken, 1982).

Limited faunal surveys are being conducted as part of the above approach, but large parts of the interior, especially in the almost uninhabited east-central highlands, have yet to be tackled. A habitat-oriented, rather than species-oriented approach is currently most appropriate overall, but Lanjak-Entimau Orangutan Sanctuary was created largely to provide for that particular species, and the need for an area of deltaic mangrove for proboscis monkey protection is an immediate priority. Should a viable population of banteng or even rhinoceros be found in the state, NPWO would take steps to meet the species' conservation requirements, as necessary.

In addition, certain species are widely hunted and require management on a sustained yield basis over as big an area as possible. In effect, this will mean the implementation of closed seasons and perhaps certain hunting and trapping restrictions. NPWO is therefore taking steps to collect the relevant basic information, including quantified data on hunting practices, yields and the reproductive patterns and demography of the species concerned. It is anticipated that the studies will confirm the bearded pig *(Sus barbatus)* as the most hunted animal, with deer (Tragulidae and Cervidae) also being very important sources of protein in the rural areas.

Revision of the regulations gazetted under the Wild Life Protection Ordinance, especially for the purpose of controlling the wildlife trade, is also a current priority for NPWO, but for technical and constitutional reasons, this may take some time.

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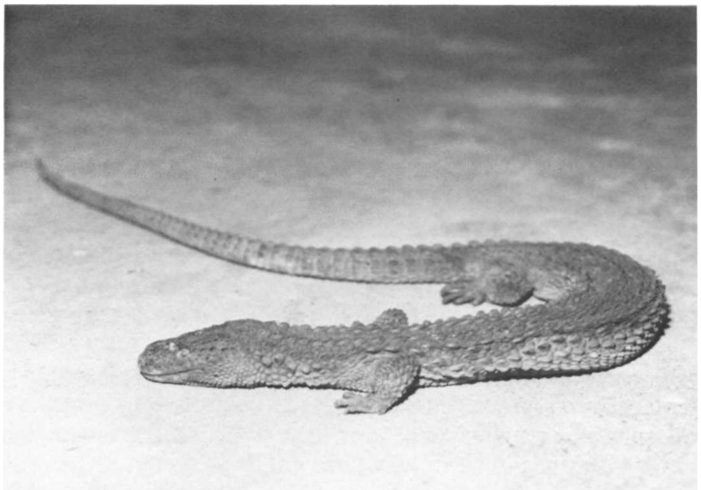

Fig. 9: The Bornean earless monitor (*Lanthanotis borneensis*), a very rare lizard first discovered in Sarawak (photo by R. A. Mittermeier).

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Sabah

Species Conservation Priorities in the Tropical Forests of Sabah, East Malaysia

John Payne

Introduction

Sabah (Fig. 1), occupying 76,000 km^2 of the northern part of the island of Borneo, is the second largest of the thirteen states in the federation of Malaysia. Geologically, Sabah consists largely of relatively young sedimentary formations. The terrain is hilly throughout the interior and western regions, and Mount Kinabalu, which rises to 4101 m above sea level, is the highest peak in southeast Asia.

Sabah can be divided broadly into five regions. In western Sabah there are high hill ranges divided by fertile valleys and plains which are cultivated by the oldest indigenous inhabitants of Sabah. Central Sabah is dominated by rugged, sparsely inhabited highlands 300-1,000 m in altitude. Most of Sabah's remaining primary forest with high timber stands occurs here. In the northeast are plains and low hills with predominantly poor, sandy soils. There are old indigenous communities along all major rivers.

In the southeast is an area of mixed topography on old volcanic rocks with fertile soils. This was the region to undergo the first extensive, large-scale plantation fanning in Sabah. The eastern central part of Sabah consists mostly of flat or rolling terrain less than 300 m in altitude. Almost all of this region, previously uninhabited by man, was logged during the 1960's and 1970's, and is now the region of rapid, large-scale agricultural development. All major towns and settlements are in the western valleys and plains, with the exception of three on the east coast. Public roads link all the main western communities. There is one east-west road from Kota Kinabalu to Sandakan, and a second road will soon be completed in the southern part of the state. There is an extensive road network in eastern Sabah, built and maintained largely by logging companies and agricultural estates.

Natural habitats in Sabah can be divided very broadly into three main classes: mangrove and fresh water swamps, evergreen dipterocarp forest, and montane forest. Along most of the east coast and parts of the west coast are swamps, mostly mangrove, and, further inland, permanent or seasonal fresh water swamps. Apart from the locally distinct floral communities in freshwater swamps, animals of interest here are the proboscis monkey *(Nasalis larvatus)*, a Bornean endemic, and the estuarine crocodile *(Crocodylus porosus)*. Only a very small fraction of the mangrove is afforded total protection in the form of "Virgin Jungle Reserve," a class of protected forest reserve intended primarily to preserve representative samples of forest formations. Local people traditionally cut mangrove trees for domestic purposes and for sale, but this is a localized activity. Extensive areas are now cut under license primarily for chip or particle board. (Fig. 2)

The natural vegetation on land from sea level to about 1,000 m is evergreen dipterocarp forest. The majority of the largest trees present (more than 180 cm in girth and 30 m tall) belong to the family Dipterocarpaceae. There is great diversity both within and between the various dipterocarp formations. It is these forests which yield timber and which have been the major sources of Sabah's wealth over the past three decades. Logging is "selective," unless the land is designated for agricultural development, in which case all growth is felled and burnt. In practice, selective logging involves removal of approximately 10 big trees from each hectare (the actual number is highly variable), with accompanying, unintentional destruction of about half of the remaining plants.

Fig. 1: Clear cutting of mangroves in Sabah chip wood production (photo by R. A. Mittermeier).

In Silabukan Forest Reserve, eastern Sabah, a 0.5 hectare plot of primary forest was found to contain about 118 tree species (more than 30 cm in girth). An equivalent area of forest investigated 20 years after logging contained 43 species, of which 18 were secondary species which grew up after logging had opened the tree canopy. Some tree species may go extinct over wide areas after logging, unless sufficient seedlings remain and grow into productive trees. At present, the only studies of forest regeneration refer to common, commercially valuable species. According to Forest Department estimates, more than 30% of Sabah's forests were logged in the period 1971-1980. There is no doubt that, ultimately, the great majority of Sabah's forest cover will consist of logged dipterocarp forest. Thus, a conservation priority is investigation of the effects of logging on the survival of the flora of dipterocarp forests. It is heartening to find that logging in itself does not seem to lead to the extinction of any mammal or bird species; it is the pattern and extent of logging which are important. Animals are mobile, however, whereas plants are not and it is likely that at least some plants are highly sensitive to the changes in microclimate occurring after logging.

On the hills and mountains higher than 1,000 m in altitude are montane forests which contain few or no big trees of the family Dipterocarpaceae. Most montane forests occur in western Sabah, where two fine conservation areas provide protection for most, if not all of the montane flora and fauna characteristic of northwestern Borneo. Kinabalu National Park (76,800 ha.) contains two separate major peaks (Kinabalu, 4,101 m; Tambuyukan, 2,580 m), dipterocarp forest, both sedimentary and ultrabasio-derived rocks, and an astoundingly diverse flora and fauna, with many species endemic to the Park region. The Crocker Range Protection Forest Reserve (129,815 ha) consists of a long, narrow range of hills rising to a maximum of about 1,500 m.

There are two authorities in Sabah whose policies include a commitment to conservation of the native flora and fauna. The Sabah Forest Department is responsible for management of forest reserves, which cover nearly 50% of Sabah's land area. All but 5% of the Forest Reserve area is classed as "commercial"; liable to be logged. The Wildlife Section (officially still known by the rather dated name of Game Branch) of the Sabah Forest Department is responsible for conservation of mammals, birds and other large vertebrate animals throughout Sabah, except in the national parks (see below). The most important existing law referring to protection of wild animals outside national parks is the Fauna Conservation Ordinance of 1963, and its amendments. It is concerned mainly with rules for hunting and collecting wild animals. With a total staff of just over 30 expected to cover 98.5% of Sabah, it is difficult for the Wildlife Section to carry out much more work than its three main long-standing obligations: (1) enforcement of the law, (2) maintenance of the orangutan rehabilitation center (and more recently, a new conservation education center) at Sepilok Forest Reserve, and (3) protection of agriculture from damage by elephants.

A separate organization, Sabah National Parks, is responsible for management of five parks, two on the mainland (Kinabalu and Tawau Hills National Parks) and three island parks (Tunku Abdul Rahman, Palau Tiga and Turtle Islands National Parks; Fig. 1).

Species Conservation in Sabah

Without detracting from the value of national parks in protecting montane, island and marine communities, it should be apparent that the policies and actions of the Forest Department are of prime importance in the conservation of the dipterocarp forests, and therefore their fauna. In Sabah, it is primarily the Assistant Chief Game Warden who recommends conservation measures for the fauna of the dipterocarp forests. In 1978, the newly appointed Warden, Patrick Andau, initiated a survey of the status of mammals and birds throughout Sabah. With sponsorship from WWF Malaysia in providing technical assistance, a faunal survey of Sabah was carried out between 1979-81 (Davies and Payne, 1982). A major, but not unexpected finding of the survey was that four large mammal species — Sumatran rhinoceros *(Dicerorhinus sumatrensis;),* elephant *(Elephas maximus;* Fig. 3), banteng *(Bos javanicus),* and orangutan *(Pongo pygmaeus;* Fig. 4) — require special conservation measures if they are to survive in the long-term. It also became apparent that it is the pattern of planned agricultural development, rather than selective logging, which will have the most adverse effects on these, as well as some other species. The current status of each of the four threatened species (all but the elephant protected by law) is presented below.

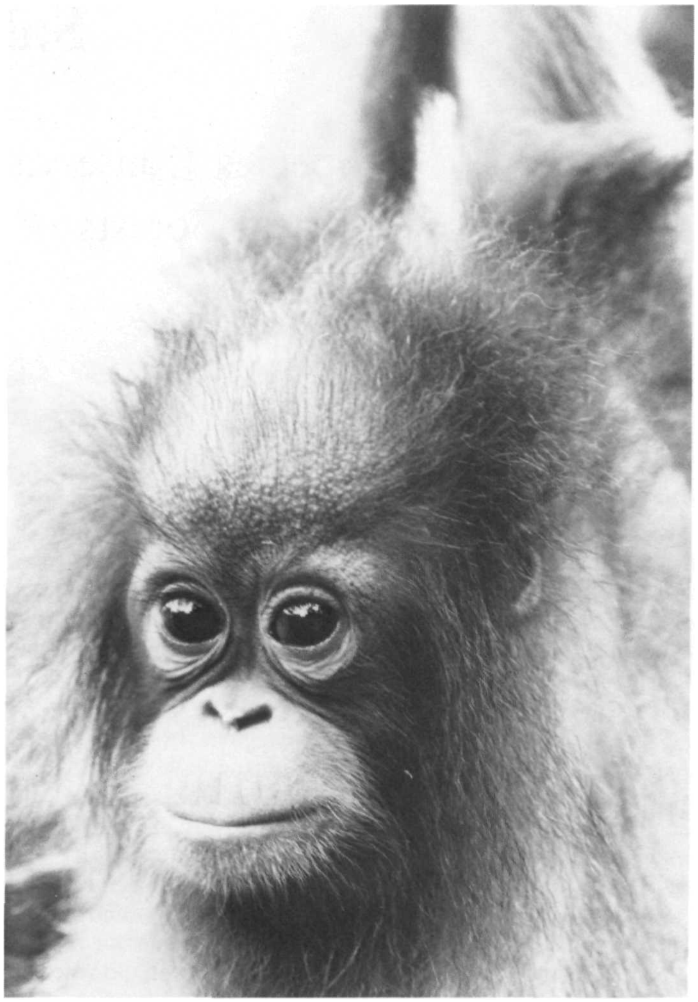

Fig. 3: A young orang kept at the Sepilok Forest Reserve rehabilitation station outside Sandakan. The orang is a major tourist attraction for Sabah, and the Sepilok Forest Reserve serves as both a home for displaced orangs and a focus for conservation education. Surveys are needed to identify areas with good orang populations in permanent forest reserves. Danum Valley may prove to be the most important long-term conservation area for the species (photo by R. A. Mittermeier).

Fig. 2: A group of elephants from Sabah charging the Faunal Survey of Sabah vehicle (photo by John Payne/WWF - Malaysia). The elephant is Sabah's problem species. Hundreds of elephants are in areas designated for agriculture. Ultimately, Silabukan-Lumerau will probably be the most important conservation area for elephants in Borneo.

Fig. 4: Map of Sabah showing the location of National Parks and Forest Reserves.

Sumatran Rhinoceros. There are scattered relics of a once widespread rhinoceros population in several parts of Sabah, mostly in the eastern half of the country. The southern-central part of Sabah has never been adequately investigated, so the rhino situation there remains unknown, but for the remainder of Sabah only one area still supports a potentially viable breeding population. This is the area represented by the Silabukan and Lumerau Commercial Forest Reserves. Adjacent areas contain some rhinos, but all such areas are to be converted to cocoa and oil palm plantations.

Elephants. Elephants have a restricted distribution in Sabah, occurring in the southern and eastern portions of central Sabah. They have not existed in northern or western Sabah in recent times, and have been virtually exterminated in the southeast during this century as a result of agricultural development. Current agricultural development policy is such that by the end of this century there will be only two separate blocks of forest large enough to support viable elephant populations. These are the Silabukan-Lumerau Forest Reserve block and the vast area of forest on predominantly rugged terrain in central Sabah. It is expected that the Permanent Forest Reserves will remain as protected areas. The current estimate of the total Sabah elephant population is between 500 and 2,000 individuals, and of these more than half live in areas designated for agricultural development. Logged forest contains many more known elephant food plants than primary forest, so there is reason to hope that some of the elephants displaced by agriculture will move from their traditional ranges into the Silabukan-Lumerau Forest Reserve block and those areas which reportedly will remain as permanent forest preserves. The distribution of elephants in these latter areas appears to be very sparse and patchy, however, and mainly along the larger rivers.

Banteng. The banteng, widely known as *tembadau* in Sabah, occurs in scattered concentrations throughout much of eastern Sabah; the species has been almost exterminated in the western half of the country. Discounting the threat of illegal hunting, banteng usually thrive in areas of traditional shifting cultivation and logging, as a result of the great increase in the abundance of grasses. But, like elephants, they are only abundant in the flatter, fertile areas designated for agriculture.

Orangutan. The Faunal Survey of Sabah indicated that population densities of orangutans are high (1 or more individuals/km^2) only in primary dipterocarp forests at less than about 400 meters above sea level. Unfortunately, it is these forests which have been logged most heavily, and much is due to be converted to agriculture. The situation in the better protected areas is either precarious or unknown. For example, orangutans exist in parts of Kinabalu National Park and Crocker Range Protection Forest Reserve, but at extremely low population densities, and they are hunted in some areas for food. Equally alarming is that they are unaccountably scarce or absent in certain regions; they appear to be completely absent from Tawau Hills National Park and are very rare throughout much of Silabukan-Lumerau Forest Reserve.

Before finally summarizing recent conservation achievements and suggesting future plans, a note on the importance of hunting to the survival of the above-mentioned species is important. The rhinoceros is now so rare in Sabah as a result of hunting, that any further deaths due to poaching will significantly reduce any chance for its survival in Borneo. The only known breeding population in all of Borneo is in the Silabukan-Lumerau Forest Reserve, yet this area is relatively accessible, and logging commitments made before the importance of the area was recognized in 1980 mean that roads will reach its core sometime this decade. Two rhinos are known to have been poached in Sabah in 1981 and one shot in 1982 (only one of these in the Silabukan-Lumerau Forest Reserve). For elephant conservation, in contrast, hunting has no significance. More elephants lose their habitat as a result of planned agricultural development than are shot annually for crop protection. According to available records over the past ten years, an average of 10 elephants are shot legally per year and perhaps one illegally.

For banteng also, loss of habitat will be the most important factor in population decline. However, illegal hunting is a major threat as well, and has the potential to exterminate populations from proposed conservation areas (see below).

Twenty years ago, hunting was correctly judged to be a major drain on the then existing orangutan population in Sabah. Since then, logging and habitat loss have replaced hunting as the most significant threats for this species.

Conservation Action Priorities

Sabah's existing national parks make a fine contribution to the conservation of montane and island communities. However, the prevailing opinion in Sabah, outside the national parks organization, is that parks are for recreation and not for conservation. For a long time to come, therefore, the onus will be on the Forest Department to manage and conserve dipterocarp forests where so much of the native flora and fauna occur.

Not surprisingly, our knowledge of the distribution and ecological requirements of northern Borneo's lowland flora is inadequate to assess which species may be endangered. With regard to trees, available data would suggest that very few and possibly no species occur exclusively in east central and southeast Sabah where agriculture will replace forest. There are three areas which are expected to be most important for conservation of the lowland dipterocarp communities:

1. *Sepilok Forest Reserve* (4,000 ha) is the best investigated lowland forest in Sabah.

2. *Silabukan-Lumerau Forest Reserves block.* Negotiations are underway to reserve 9,300 ha of primary forest in the middle of this block. This would provide for the conservation of a total plant community and also serve as a temporary holding area for Sumatran rhinos displaced by intensive logging in the surrounding forest. If the plan is successful, this would form the core of a single 123,000 ha block of forest reserve.

3. *Danum Valley.* This area of primary forest has in the past been proposed as a game sanctuary (permissible under current legislation, although no sanctuaries yet exist) and as a national park. Along with a substantial portion of Sabah's remaining dipterocarp forest, this area lies within the 100-year logging concession of the Sabah Foundation. This organization has a unique advantage, from the conservation viewpoint, over all other governmental and non-governmental organizations in Sabah, in that it can plan for decades in advance, rather than the usual period of 5 years maximum. Sabah Foundation has agreed to retain an area of 42,755 ha of primary forest in the Danum Valley region for wildlife conservation and water catchment protection. An important feature of the Danum Valley conservation area is that it contains several different primary forest formations within a huge surrounding buffer zone of logged forest.

Silabukan-Lumerau Forest Reserve is vital to the conservation of both rhinoceros and elephant in Borneo. In August 1982, the Forest Department allotted 122,980 ha of the existing commercial forest reserve for rhino conservation. This means that logging licenses can still be issued but that there is a stronger case than previously to disallow extensions of land for agriculture.

The large block of permanent forest reserves (Fig. 1) will form an extremely important conservation area, mainly because of its vast size. If present plans are successfully carried out, there will be two large cores of primary forest within the block: Danum Valley and a steep, remote area further west known as Gunung Letung ("the slow loris mountain"; about 50,000 ha), which also lies within Sabah Foundation's concession. It is necessary that more wildlife surveys be carried out in this region, with the highest priority being to investigate the distribution and population status of orangutans.

Two more conservation areas have been proposed for Sabah. The first is about 5,000 ha of coastal swamp and mangrove forest containing proboscis monkeys and crocodiles. The second is 510 ha of logged lowland forest which contains a high density of banteng.

Hopefully, this complex of protected areas will ensure the survival of Sabah's superb wildlife heritage.

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Fig. 5: A bornean gibbon (*Hylobates muelleri*) in the Sepilok Forest Reserve (photo by R. A. Mittermeier).

Indonesia

Species Conservation Priorities in the Tropical Forests of Indonesia

John Mackinnon
Ismu Sutanto Suwelo

Introduction

Indonesia (Fig. 1) is one of the world's treasure houses of species diversity. Made up of some 13,000 islands stretching 6000 km, the country covers a total land area of 1,919,443 km^2 and spans two major biogeographical regions, the Oriental and the Australasian. The human population is the fifth highest in the world, with more than 150,000,000 inhabitants, and some of the islands such as Java, Bali and Madura are quite densely populated. On the other hand, the large islands of Sumatra, Kalimantan and Irian Jaya, which constitute about 75% of the land area of the country, are still relatively sparsely populated.

Over 1500 species of birds, 500 mammals and several thousand tree species occur in Indonesia, and the country has within its borders perhaps the most unusual mix of faunal elements anywhere on earth. The islands of Sumatra, Kalimantan (the Indonesian part of Borneo), Java and Bali are known collectively as the Sunda Islands or Great Sunda because of their shared position on the shallow Sunda Continental Shelf, which is no more than 200 m in depth and connects them with the Asian mainland. This connection was above water during the last glacial age and consequently the fauna of these islands is largely Asiatic, consisting of monkeys, apes, rhinos, tigers and sambar deer. The climate is also hot and humid, with the original vegetation being mainly rain forest. To the east of Bali are the Lesser Sundas or Nusa Tenggara, which are under the influence of Australia, both in terms of fauna and flora and in climate. The first marsupials appear in Sulawesi and the Malukus, apes and big cats are absent, and birds such as lories and cockatoos begin to replace the Asian species. The climate has a pronounced dry season and overall is generally drier than in the Greater Sundas (Veevers-Carter, 1978).

The survival of Indonesia's great species diversity is a matter of world as well as national concern, and with Indonesia's rapid population growth and speedy loss of forest and marine habitat, these valuable genetic resources, many of which are or could be used by man, are severely threatened.

The Government of Indonesia has recognized the need for conservation in order to promote the cultural and economic development of the Indonesian people in harmony with their natural environment. Government policy states that all forms of natural life and examples of all Indonesian ecosystems must be preserved for the benefit of future generations, with special emphasis on protection of the air, water, soil, plant, fish and animal resources upon which people depend (Sumardja, et al., 1984).

Conservation in Indonesia is under the jurisdiction of the Directorate of Nature Conservation and Wildlife Management (PPA), which was established within the Ministry of Agriculture in 1971 and is based in Bogor. Conservation has been achieved through the maintenance of a system of protection forests to protect water sources and soils on steep or high land, the maintenance of the system of strict nature reserves (*Cagar Alam*) and game reserves (*Suaka Margasatwa*), and the adoption of a number of laws and regulations controlling the exploitation of living resources including logging regulations, game laws, protected species laws and others (Sumardja, et al., 1984).

Faced with a multitude of conservation problems, and especially with the immediate need to preserve fuelwood and timber supplies and safeguard important river catchments, the Government of Indonesia has approved a major increase in conservation areas and protection forests. It is now planned that 30% of the land surface of Indonesia will be retained under permanent forest cover and that nearly half of this forest will be in nature reserves. Already the total area protected has risen dramatically from 4 million hectares in 1977 to a total of 11,267,540 hectares in 299 locations as of March, 1982 (Sumardja et al., 1984). Some of the most important protected areas in Indonesia are indicated in Fig. 1, and a more detailed look at protected areas on the island of Java is provided in Fig. 3.

Species Conservation in Indonesia

Selection of new reserves is done with the intention of including viable large areas of all distinct habitat types in the country. Thus, species will be conserved *in situ* by protection of their habitat. Geographical distribution and habitat preference data have been compiled for all mammal and bird species occurring in Indonesia, and there is not a single species of bird or mammal which does not have a major reserve planned within its estimated distribution. The distribution ranges of plants are not so accurately known but it is thought that here too all species will be present in at least one reserve. Most species will be contained within more than one reserve. The needs for species specific management projects are in this way greatly reduced. Eventually when island biogeographical effects play their part in trimming down the number of species surviving in isolated reserves it will be necessary to monitor populations of indicator or extinction-prone species and where necessary introduce active management such as artificially maintaining high species immigration levels between neighbouring reserves. In the meantime, however, the priority is on getting the reserves declared and physically established, paying attention at the species level only to those species which are not adequately protected by the protection of their habitat in reserves. These species include:

1. *Migrating species* who spend only part of their time in Indonesia and whose survival therefore depends on many factors both outside Indonesia and its reserves - e.g. migratory birds, whales, turtles etc.
2. *Resident but wide ranging species with large home ranges* - e.g. elephants, tigers, eagles, fruit bats, waterbirds who often cannot be contained or restricted within reserve boundaries.
3. *Rare species* which are represented at such low densities or which have such restricted distributions as to survive at dangerously low population levels.
4. *Species endangered by changed ecological conditions* particularly by newly introduced competitors, predators or pests.
5. *Species endangered by overexploitation* such as hunting or trade which could be exterminated despite protection of their habitat because of the impossibility of adequately guarding all the reserves.
6. *Riverine species* endangered by changes in water condition resulting from human development.

The scale of these species specific needs for attention is still quite large and the Indonesian Government has established a special Subdirectorate of Species Conservation in the Directorate of Nature Conservation to deal with these problems.

Conservation Action Priorities

1. *Migrating Species*
   Migrating birds visiting Indonesia fall into 3 main categories.

   a. Montane passerines such as wagtails, warblers, thrushes

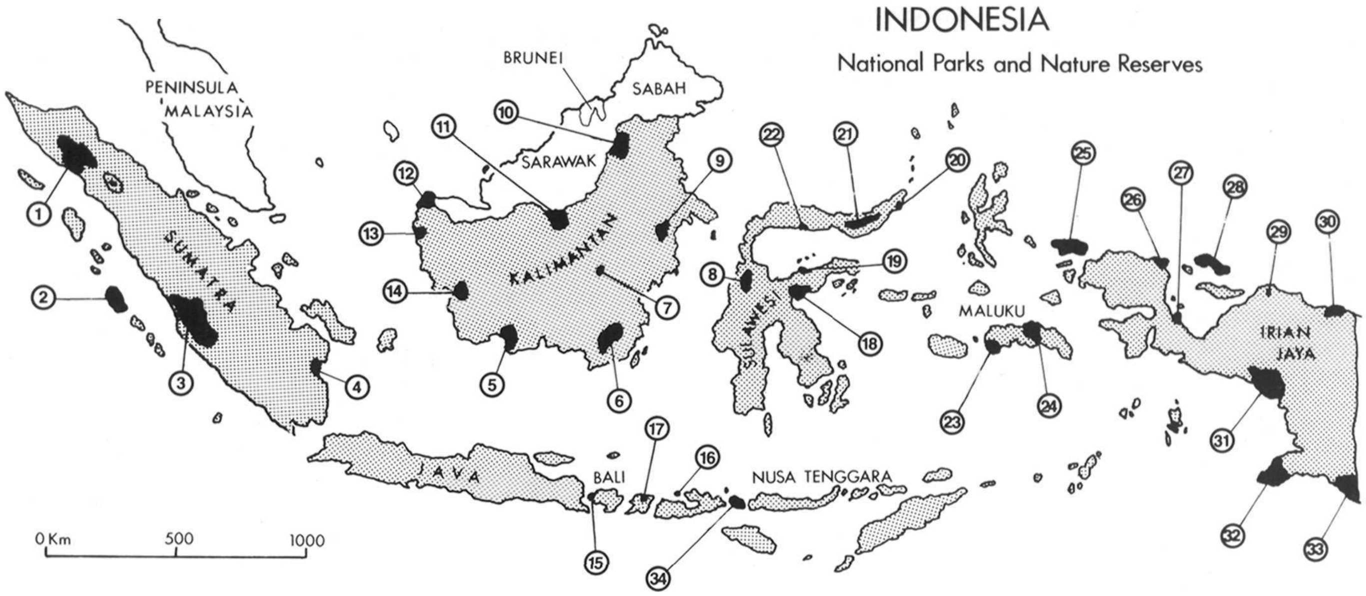

Figure 1: Map of Indonesia showing the location of national parks and nature reserves (modified from a publication by the Indonesian Directorate General of Tourism).

1. **Gunung Leuser National Park**
2. **Siberut Reserves**
3. **Kerinci Seblat Reserve**
4. **Way Kambas Reserve**
5. **Tanjung Puting Reserve**
6. **Pleihari-Martapura Reserve**
7. **Padang-Luwai Reserve**
8. **Lore Lindu Reserve**
9. **Kutai Reserve**
10. **Hulu-Bahau-Sungai Malinau Reserve**
11. **Bukit Raya Reserve**
12. **Hutan Sambas Reserve**
13. **Mandor Reserve**
14. **Gunung Palung Reserve**
15. **Bali Barat Reserve and Marine Reserve**
16. **Pulo Moyo Reserve**
17. **Gn. Rinjani Reserve**
18. **Morowali Reserve**
19. **Tanjung Api Reserve**
20. **Tangkoko-Batuangus-Dua Saudara Reserves**
21. **Dumoga Bone Reserves**
22. **Panua-Tanjung Panjang Reserves**
23. **Palau Kasa — Palau Pombo Marine Reserves**
24. **Manusela Reserve**
25. **Raja Ampat Island Reserves**
26. **Gunung Meja Reserve**
27. **Peg. Wandiwoi/Wandamen Reserve and Cendarawasih Marine Reserve**
28. **Palau Biak — Superiori Reserves**
29. **Memberamo Pegunungan Foja Rouffaer Reserves**
30. **Cyclops Mountains Reserves**
31. **Lorentz Reserve**
32. **Palau Dolok Reserve**
33. **Rawa Biru — Wasur Reserve**
34. **Komodo National Park**

etc. whose habitat needs in Indonesia are apparently adequate and no measures are being taken.

b. Waterbirds e.g. ducks, rails, pelicans etc. which are being heavily hunted in many riceland areas but for which some extensive water areas will be included in reserves and for which no other management is feasible beyond legal protected status for rare species e.g. pelicans.

c. Costal waders for which some areas of coastline are being included in reserves but many important estuaries are outside reserves and face the possibility of pollution etc. No management is at present envisaged but it would be worthwhile to plot out the main migration routes and identify the most important stopping and feeding areas to try and get these protected where necessary.

2. *Resident Species with Wide Ranges*

There are several species that fall into this category but in most cases these are common species which are often serious pests coming out of forests and reserves to eat agricultural crops e.g. some parrot species, macaque monkeys, commensal rats, wild pigs, fruit bats etc. In these cases attention for control or discouragement of these animals from coming into agricultural areas is needed but they do not constitute a species survival problem. In the case of elephants and tigers however, they do.

In Sumatra, elephant and tiger conflicts with the expanding rural population are increasing in frequency and the matter has been greatly published in news media to the point that the Minister of Agriculture is calling for control projects. This is a very difficult and sensitive area of conservation and several drafted project proposals have failed to reach the necessary support or funding to be implemented, but it is an area of high government priority, and some projects to help reduce the friction between these large, dangerous but very important species and rural human population are urgently needed.

3. *Rare Species*

Indonesia has a number of rare species - local endemics with very small distributions, for example the Javan rhinoceros, Bali starling, Bawean deer, Sumatran hare, the Mentawai primates and widespread species which occur at low population density, for example the Sumatran rhinoceros, and orang-utan.

In some cases large reserves have been established that contain all or most of surviving populations e.g. Bali Barat Reserve for the Bali starling, Siberut reserve for the endemic primates, Kerinci-Seblat for the Sumatran hare, Ujung Kulon for the Javan rhinoceros, and Bawean island for the Bawean deer but in addition some attempts are being made to foster rare species by captive breeding *ex situ* e.g. Bawean deer, and Bali starling. Also the formation of additional wild populations is currently planned by ranching of Bawean deer on Madura island, the possible reintroduction of Javan rhinoceros into Sumatra, and the rehabilitation and translocation schemes for orang-utans.

4. *Species Endangered by Changed Ecological Conditions*

Indonesian examples are the endemic fish in many lakes where exotic species (e.g. *Tilapia)* have been introduced or where water hyacinths are changing local conditions.

Seed eating birds face competition from introduced munias and sparrows. The warty pig of Java faces artificially enhanced competition from the wild boar. Wildlife on all small islands are threatened by rats and cats which have been introduced.

Such problems are often extremely difficult to tackle. It is not usually possible to remove the exotic species which is causing problems and the classic conservation method for such situations is to release the endangered species on a 'clean' island as a refuge and/or captive breeding. The Javan warty pig project currently in operation will be a good test case to see what can be done in such instances in Indonesia.

5. *Species Endangered by Over-Utilization*

There are several Indonesian species endangered by overhunting or trade such as rhinoceros, wild cats, the babirusa, the anoa, crowned pigeons, birds of paradise, megapodes, some parrot species, marine turtles, crocodiles, giant clams, butterflies and many species of trees and orchids. All these endangered species are already or could be put on the protected species lists, but law enforcement in Indonesia is so difficult that this is itself no guarantee of actual protection.

Improvements to the protected species lists, improvements to control, improvements to reserve guarding, improvements of game legislation, implementation of CITES, ratification of the migrating species convention etc., all play a part in tackling these problems as does conservation education and extension work. Some management or breeding projects can be effective and in many cases the development of wildlife based industries undertaken on a sustained yield basis can in fact help to save species by giving them a value and giving people a long-term interest in their survival. Thus plans are underway to promote primate ranching, crocodile rearing, butterfly farming and parrot breeding projects which will help satisfy demands for such products as well as provide badly needed income sources to rural peoples without placing undue strain on wild populations.

6. *Riverine Species*

It is extremely difficult to protect whole rivers in nature reserves as they are so heavily used as arteries of communication, sources of irrigation, fishing areas etc. by local people. Almost no attention has been paid so far to the plight freshwater species in Indonesia but there are undoubtedly many endangered reptiles, fish, molluscs and crustaceans in the river and lake systems. Pollution and dangerous fishing methods such as the use of poisons and explosives have decimated fish population in many rivers. As fresh water rivers have high levels of local endemism many species may be lost. There are few obvious solutions to these problems but it is as well to draw more attention to the problems of this neglected group of species. It would be worthwhile to collect more information or the distribution of fresh water species so that those with very limited distribution can be identified and at the same time monitor the levels of biotic degradation in the different waterways so that the scale of this threat can be assessed.

A number of conservation action projects are currently underway, planned or already completed in Indonesia, and these are summarized in the following list:

A	***General Programs of Sub-Directorate of Species Conservation***		
1	Inventorization of species distribution and status		continuing
2	Field monitoring of species status		continuing
3.	Revisions to protected species lists		continuing
4	Establishment of new reserves for rare species		continuing
B	***In Situ Management Activities***		
5	Maintenance of artificial grazing areas	Ujung Kulon, Meru Betiri, Pangandaran and Baluran	continuing

6	Cutting *Arenga* palms to promote tree sapling regeneration for rhinoceros	Ujung Kulon	planned
7	Thinning of teak forests for Bawean deer	Bawean Island	continuing
8	Clearing of brush from maleo nesting areas	Sulawesi	experiments completed
9	Control of egg predators at turtle nesting beaches	various	occasional
C	***Rehabilitation and Captive Breeding for release into Wild***		
10	Orang-utans	Ketambi (completed) Bohorok Kutai, Tanjung Puting	ongoing
11	Gibbons	Pangandaran Tanjung Puting	occasional
12	Bawean deer	Madura	ongoing
13	Bali mynah	Bali Barat	ongoing
14	False ghavials	Sekundur	started
D.	***Translocation Projects***		
15	Sumatran tigers	Sumatra	planned
16	Elephants	Way Kambas Sumatra	ongoing
17	Javan rhinoceros	Sumatra	feasibility study started
18	Orang-utans	Martapura Pleihari	planned
E.	*Captive Breeding/Rearing for Sustained Yield Harvest*		
19	Crocodiles	Irian Jaya	started
20	Marine turtles	Bali/Sukamade	started
21	Macaque monkeys	Jakarta	started
22	Maleo birds	N Sulawesi	feasibility study completed
23	Birdswing butterflies	Irian Jaya	planned
24	Cockatoos	Ambon	planned
25	Orchids	Bogor	started
F.	***Conservation-Oriented Research Projects on the Ecology of Rare Species***		
26	Orang-utan	Ranun, Kctambe Tanjung Puting	1971 ongoing
27	Javan rhinoceros	Ujung Kulon	1967 ongoing
28	Sumatran rhinoceros	Gn Leuser	1977 ongoing
29	Bawean deer	Bawean Island	1977-79
30	Marine turtles	various	ongoing
31	Crocodiles	Irian Jaya	1979-80
32	Javan gibbons	Ujung Kulon	1977-79
33	Sulawesi endemic fauna	Tangkoko-Batuangus	1977-79
34	Banteng	Ujung Kulon Pangandaran Baluran	various
35	Mentawai primates	Siberut island	various
36	Proboscis monkeys	Kalimantan	various
37	Rafflesia flowers	Sumatra Java	occasional
38	Komodo lizards	Komodo	1970-71
G	***Field Monitoring of Species Status***		
39	Bali tiger	Bali Barat	1978
40	Sumatran tiger	Sumatra	1977
41	Javan rhinoceros	Ujung Kulon	annual
42	Crocodiles	Irian Jaya	1979/80
43	Javan gibbon	W Java	1978
44	Proboscis monkeys	Kalimantan	occasional
45	Rafflesia flowers	Java/Sumatra	1981
46	Fresh water dolphins	Mahakam	c. 1980
47	Fresh water sawfish	Irian Jaya	1980
48	Sumatran rhinoceros	Sumatra	various
49	Bali starling	Bali Barat	regular
50	Timor monitor lizard	Timor	1981
51	Kelasa fish	Sumatra	c. 1981
52	Marine turtles	various	various
53	Banteng	Ujung Kulon	occasional
54	Javan warty pigs	Java	ongoing
55	Kangean leopards	Kangean	1982
56	Bandasea birds	Banda Sea	1981

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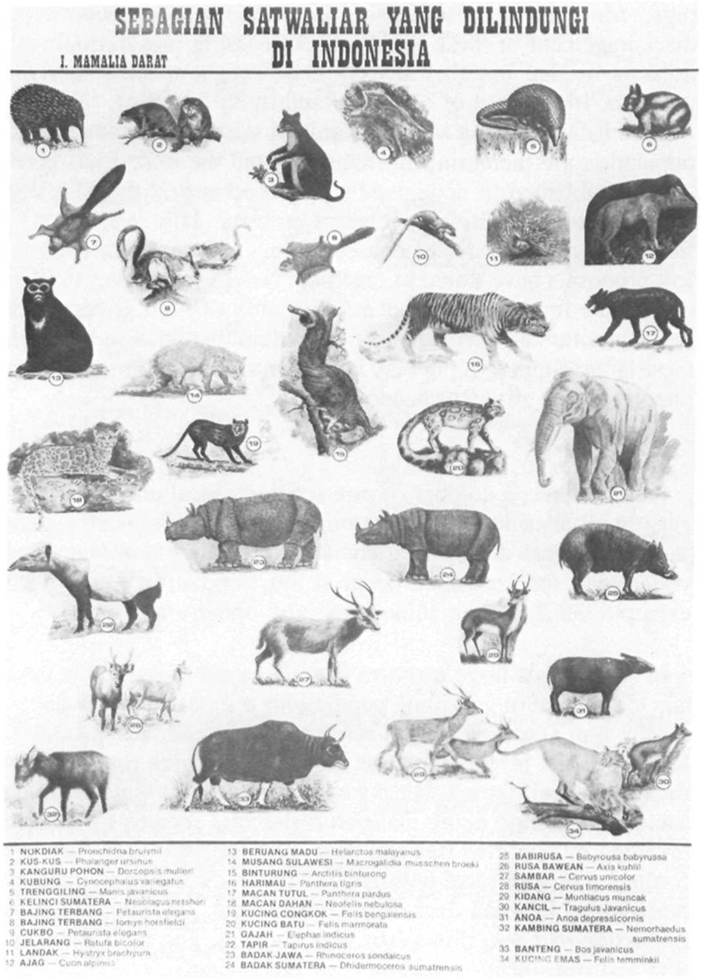
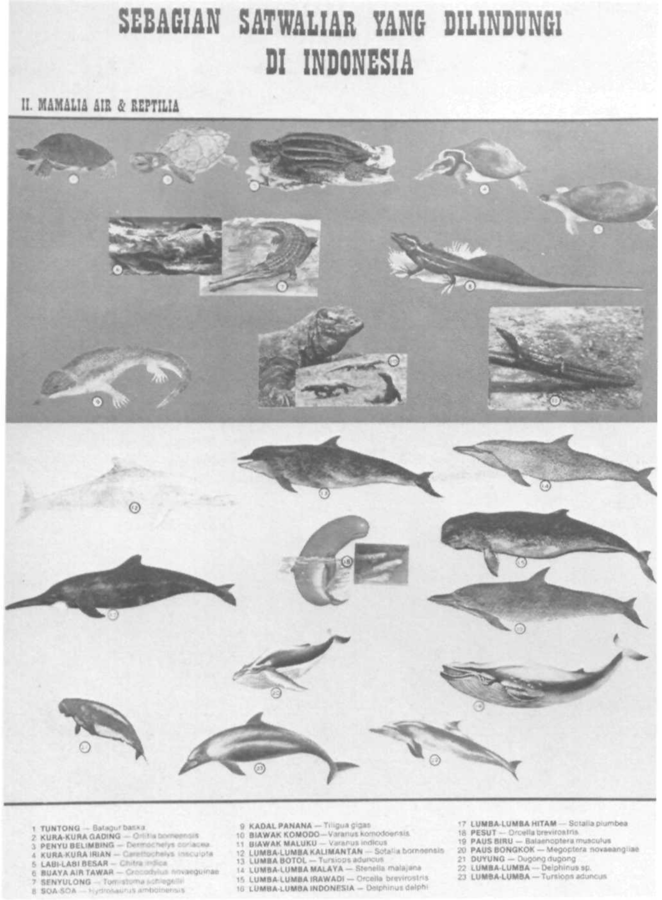


a.

Figure 2: A series of five posters depicting protected species of Indonesian wildlife. These posters also give a good impression of Indonesia's tremendous wildlife diversity. Included in the series as the following:

a. Land mammals
b. Reptiles and marine mammals
c. Land birds
d. Water birds
e. Primates



SEBAGIAN SATWALIAR YANG DILINDUNGI
DI INDONESIA

II. MAMALIA AIR & REPTILIA

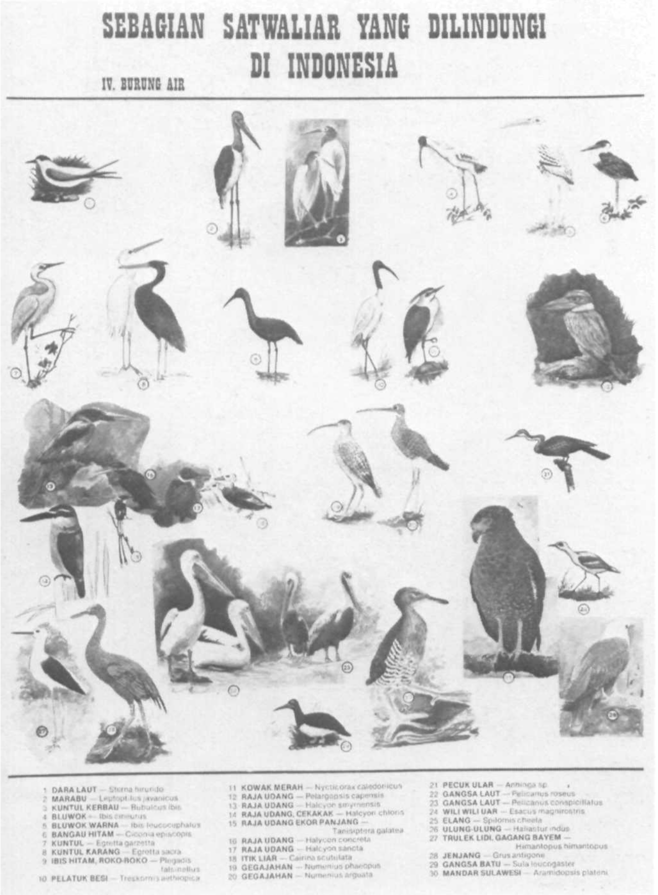
1 **TUNTONG** — Batagur baska
2 **KURA-KURA GADING** — Orlitia borneensis
3 **PENYU BELIMBING** — Dermochelys coriacea
4 **KURA-KURA IRIAN** — Carettochelys insculpta
5 **LABI-LABI BESAR** — Chitra indica
6 **BUAYA AIR TAWAR** — Crocodylus novaeguinae
7 **SENYULONG** — Tomistoma schlegelii
8 **SOA-SOA** — Hydrosaurus amboinensis
9 **KADAL PANANA** — Tiligua gigas
10 **BIAWAK KOMODO** — Varanus komodoensis
11 **BIAWAK MALUKU** — Varanus indicus
12 **LUMBA-LUMBA KALIMANTAN** — Sotalia borneensis
13 **LUMBA BOTOL** — Tursiops aduncus
14 **LUMBA-LUMBA MALAYA** — Stenella malajana
15 **LUMBA-LUMBA IRAWADI** — Orcella brevirostris
16 **LUMBA-LUMBA INDONESIA** — Delphinus delphi
17 **LUMBA-LUMBA HITAM** — Sotalia plumbea
18 **PESUT** — Orcella brevirostris
19 **PAUS BIRU** — Balaenoptera musculus
20 **PAUS BONGKOK** — Megoptera novaeangliae
21 **DUYUNG** — Dugong dugong
22 **LUMBA-LUMBA** — Delphinus sp.
23 **LUMBA-LUMBA** — Tursiops aduncus

b.

SEBAGIAN SATWALIAR YANG DILINDUNGI
III. BURUNG DARAT DI INDONESIA

1 **KASUARI** — Casuarius casuarius
2 **DARA MAHKOTA** — Goura cristata
3 **JUNAI** — Caloenas nicobarica
4 **KANGKARENG** — Anthracoceros coronatus
5 **JULANG, RANGKONG** — Aceros undulatus
6 **ENGGANG PAPAN** — Buceros rhinoceros
7 **BURUNG MALEO** — Macrocephalon maleo
8 **BURUNG GOSONG** — Megapodius reinwardtii
9 **MERAK** — Pavo muticus
10 **KUAU** — Argusianus argus
11 **NORI MERAH** — Domicella domicella
12 **NORI** — Domicella garrula
13 **NORI** — Domicella lory
14 **KAKATUA RAJA** — Probosciger atterimus
15 **KAKATUA PUTIH BESAR** — Cacatua galerita
16 **SERINDIT SULAWESI** — Loriculus exilis
17 **BEO NIAS** — Gracula religiosa robusta
18 **JALAK BALI** — Leucopsar rotschildi
19 **JALAK PUTIH** — Sturnus melanopterus
20 **CENDERAWASIH** — Diphyllodes magnificus
21 **CENDERAWASIH** — Paradisaea apoda
22 **CENDERAWASIH** — Paradisaea ragiana
23 **KIPAS BIRU** — Muscicapa rueckii
24 **TULUMTUMPUK** — Megalaema javensis
25 **KESUMBA** — Harpactes reinwardtii
26 **BURUNG MADU** — Leptocoma jugularis
27 **BURUNG MADU** — Aethopyga mystacalis
28 **BURUNG SESAP MADU** — Anthreptes malacensis
29 **BURUNG KEPENG** — Cicinnurus regius
30 **ALAP ALAP** — Elanus hypoleucus
31 **PITTA** — Pitta guajana
32 **PAOK CACING** — Pitta sordida
33 **KOAKIAU** — Philemon buceroides
34 **BRECET WERGAN** — Alcippe pyrrhoptera
35 **GLATIK GUNUNG** — Psaltria exilis
36 **TEPUS** — Stachyris melanothorax
37 **KIPAS MERAH** — Rhipidura phoenicura
38 **KIPAS GUNUNG** — Rhipidura euryura
39 **BURUNG KUDA** — Garrulax rufifrons
40 **KESTURI RAJA** — Psittrichas fulgidus

c.



SEBAGIAN SATWALIAR YANG DILINDUNGI
IV. BURUNG AIR DI INDONESIA

1 **DARA LAUT** — Sterna hirundo
2 **MARABU** — Leptoptilus javanicus
3 **KUNTUL KERBAU** — Bubulcus ibis
4 **BLUWOK** — Ibis cinnerus
5 **BLUWOK WARNA** — Ibis leucocephalus
6 **BANGAU HITAM** — Ciconia episcopis
7 **KUNTUL** — Egretta garzetta
8 **KUNTUL KARANG** — Egretta sacra
9 **IBIS HITAM, ROKO-ROKO** — Plegadis falcinellus
10 **PELATUK BESI** — Treskornis aethiopica
11 **KOWAK MERAH** — Nycticorax caledonicus
12 **RAJA UDANG** — Pelargopsis capensis
13 **RAJA UDANG** — Halcyon smyrnensis
14 **RAJA UDANG, CEKAKAK** — Halcyon chloris
15 **RAJA UDANG EKOR PANJANG** — Tanisiptera galatea
16 **RAJA UDANG** — Halycon concreta
17 **RAJA UDANG** — Halcyon sancta
18 **ITIK LIAR** — Cairina scutulata
19 **GEGAJAHAN** — Numenius phaeopus
20 **GEGAJAHAN** — Numenius arguata
21 **PECUK ULAR** — Anhinga sp.
22 **GANGSA LAUT** — Pelicanus roseus
23 **GANGSA LAUT** — Pelicanus conspicillatus
24 **WILI WILI UAR** — Esacus magnirostris
25 **ELANG** — Spilornis cheela
26 **ULUNG-ULUNG** — Haliastur indus
27 **TRULEK LIDI, GAGANG BAYEM** — Himantopus himantopus
28 **JENJANG** — Grus antigone
29 **GANGSA BATU** — Sula leucogaster
30 **MANDAR SULAWESI** — Aramidopsis plateni

d.

SEBAGIAN SATWALIAR YANG DILINDUNGI
DI INDONESIA

V. PRIMATA

1 **KUKANG** — Nycticebus coucang
2 **SINGAPUAR** — Tarsius tarsiur
3 **DARE** — Macaca maura
4 **DIHE** — Cynopithecus niger
5 **BEKANTAN** — Nasalis larvatus
6 **SURILI** — Presbytis aygula
7 **SIMAKOBU** — Simias concolor
8 **YOYA** — Presbytis potenziani
9 **KLOSSI** — Hylobates klossi
10 **BOKOI** — Macaca pagensis
11 **SIAMANG** — Hylobates syndactylus
12 **UNGKO** — Hylobates agilis
13 **OWA** — Hylobates moloch
14 **MAWAS** — Pongo pigmeaus

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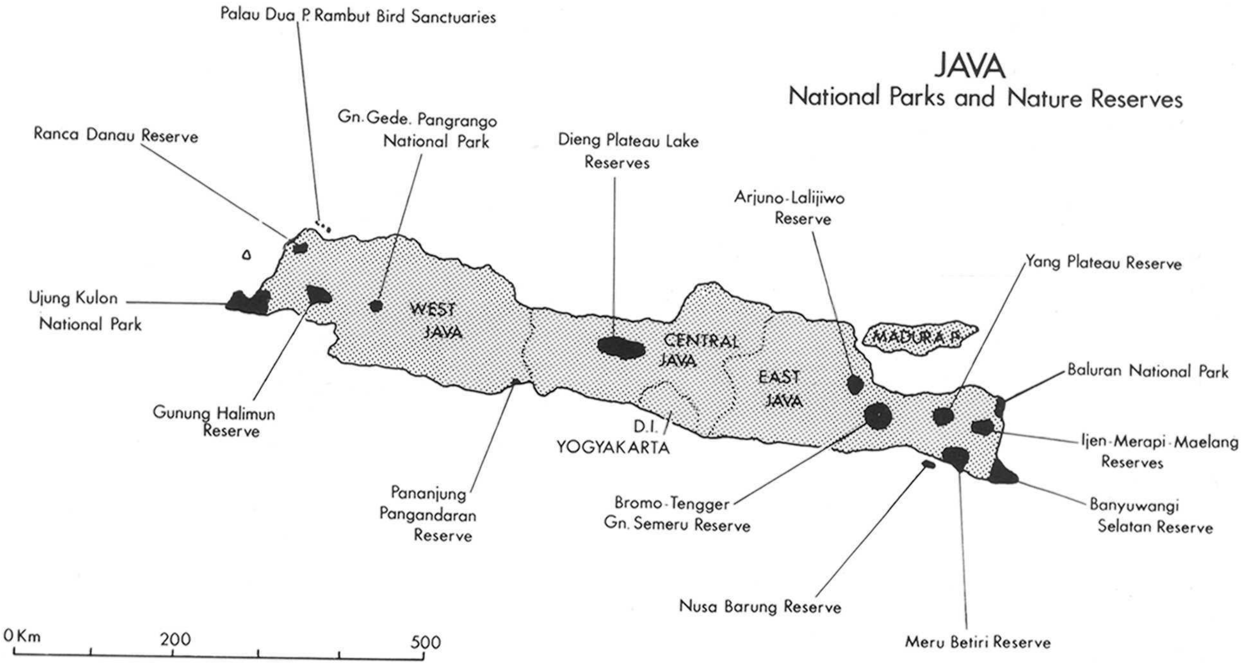
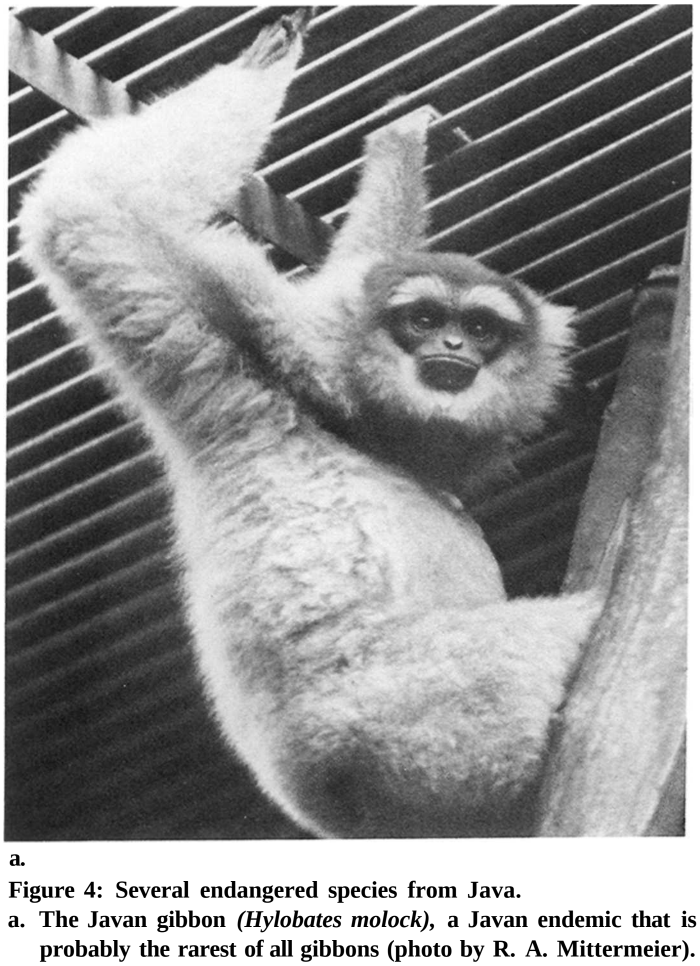


Figure 3: Map of the island of Java showing the location of national parks and reserves (modified from a publication by the Indonesian Directorate General of Tourism).



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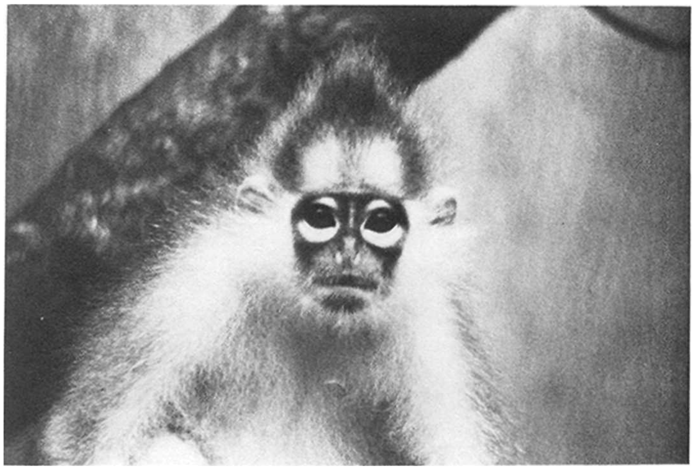

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Figure 4: Several endangered species from Java.

a. The Javan gibbon *(Hylobates molock),* a Javan endemic that is probably the rarest of all gibbons (photo by R. A. Mittermeier).

b. The Javan leaf monkey *(Presbytis aygula),* another primate species found only on Java (photo by R.A. Mittermeier).

c. Adult male Javan rhino *(Rhinoceros sondaicus)* from Ujung Kulon National Park at the extreme western tip of Java. Once found over a large area of southest Asia, this species now occurs with certainty only in this one park (photo by M. Kappeler).

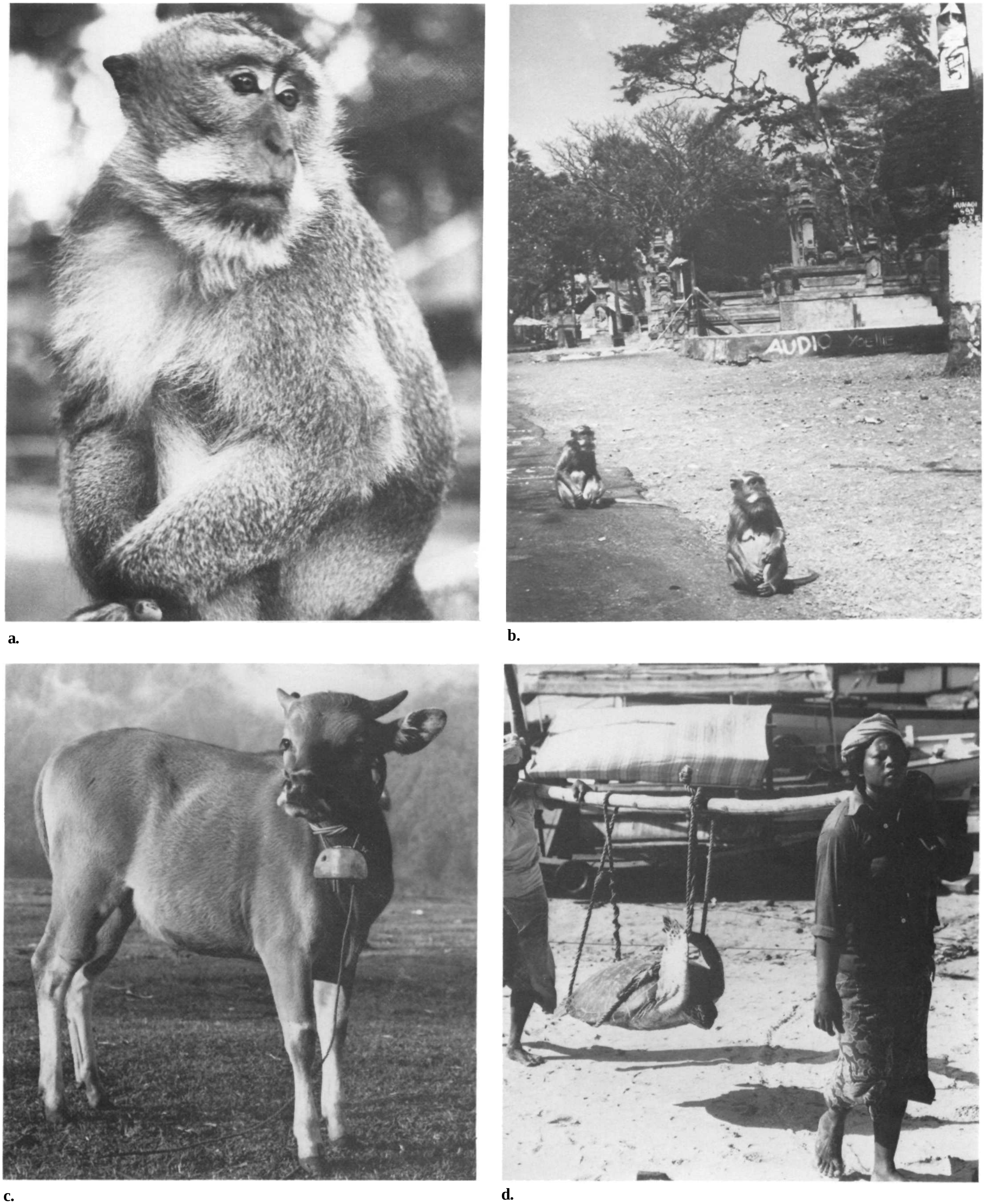
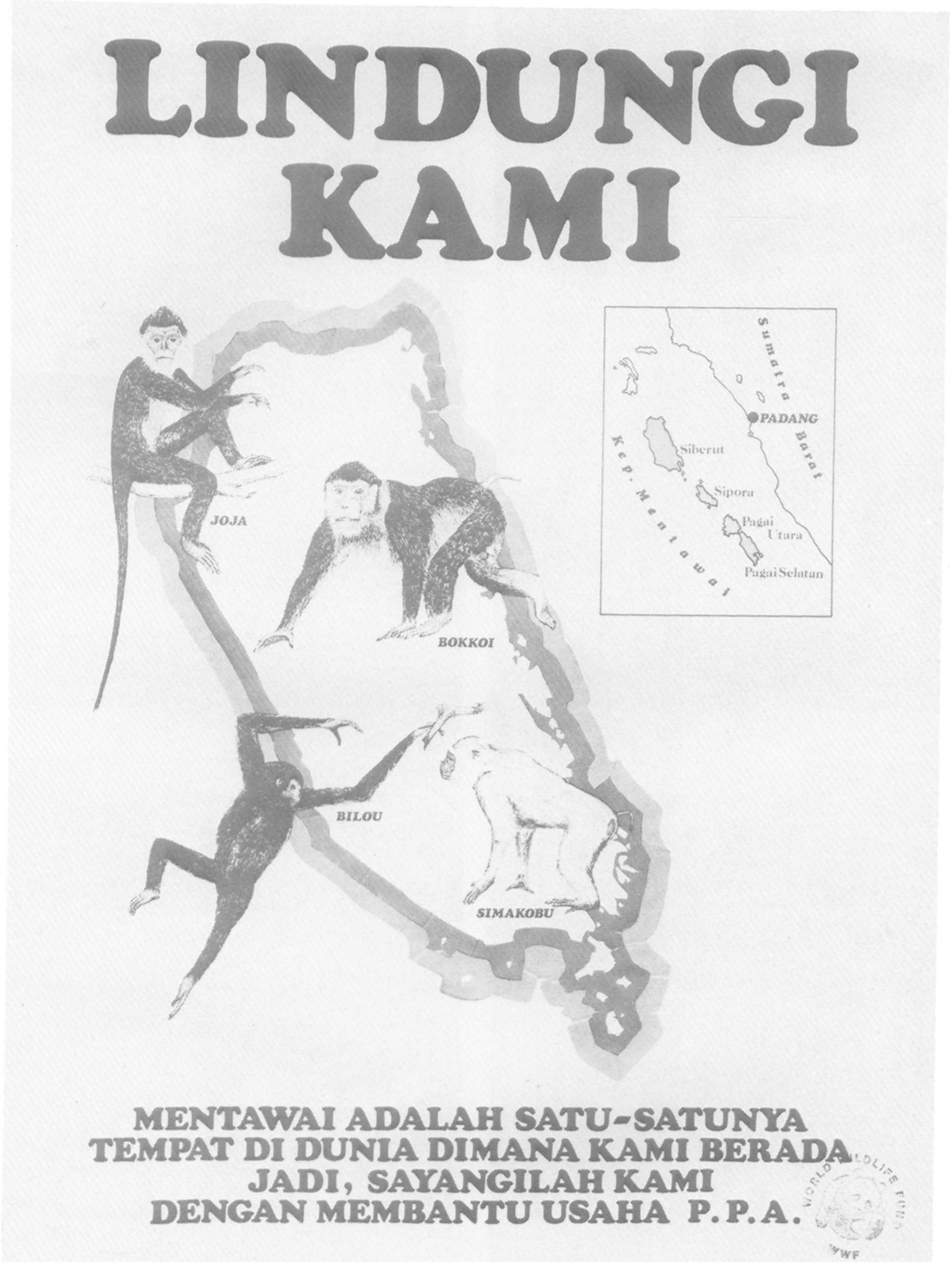


Figure 5: Animals from Bali.

a. & b. The wide-ranging crab-eating or long-tailed macaque *(Macaca fascicularis)* is common on the island of Bali, and is often found in close proximity to human habitations. Temple monkeys are a tourist attraction on the island (photos by R.A. Mittermeier).

c. A domesticated banteng *(Bos javanicus)* from Bali. This species is native to southeast Asia, and wild populations still occur in a number of countries (photo by R.A. Mittermeier).

d. Green turtle *(Chelonia mydas)* being carried to a holding pen on Bali. This species is sought after for its meat (photo by R.A. Mittermeier).



a.

Figure 6: Primates from the Mentawai Islands off the west coast of Sumatra. The Four Mentawai primate species are endemic to these islands, and ail are listed in the IUCN *Red Data Book.*

a. Poster produced by the Indonesian Directorate of Nature Conservation (PPA) and WWF depicting the four Mentawai primates: the *joja (Presbytis potenziani),* and *bokkoi (Macaca pagensis),* the *bilou (Hylobates klossii),* and the *simakobu (Simias concolor).*

b. The Mentawai Islands leaf monkey *(Presbytis potenziani).* Plate from the original description of the subspecies *Presbytis potenziani siberu* by Chasen and Kloss *(Proc. Zool. Soc. London,* 1927).

c. The pig-tailed langur or *simakobu (Simias concolor),* a *genus* endemic to the Mentawai Islands. This unusual species is most closely related to the proboscis monkey of Borneo, and is perhaps the most endangered Mentawai primate. Plate from the original description of the subspecies *Simias concolor siberu* by Chasen and Kloss *(Proc. Zool. Soc. London,* 1927).

d. Juvenile pig-tailed langur *(Simias concolor)* (photo by A. Mitchell).

e. Juvenile *bokkoi* or Mentawai macaque *(Macaca pagensis)* (photo by A. Mitchell).

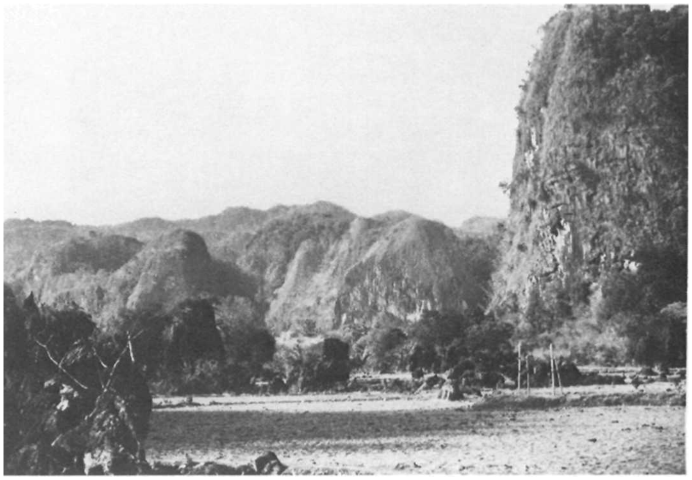
b.

c.

d.

e.

a.



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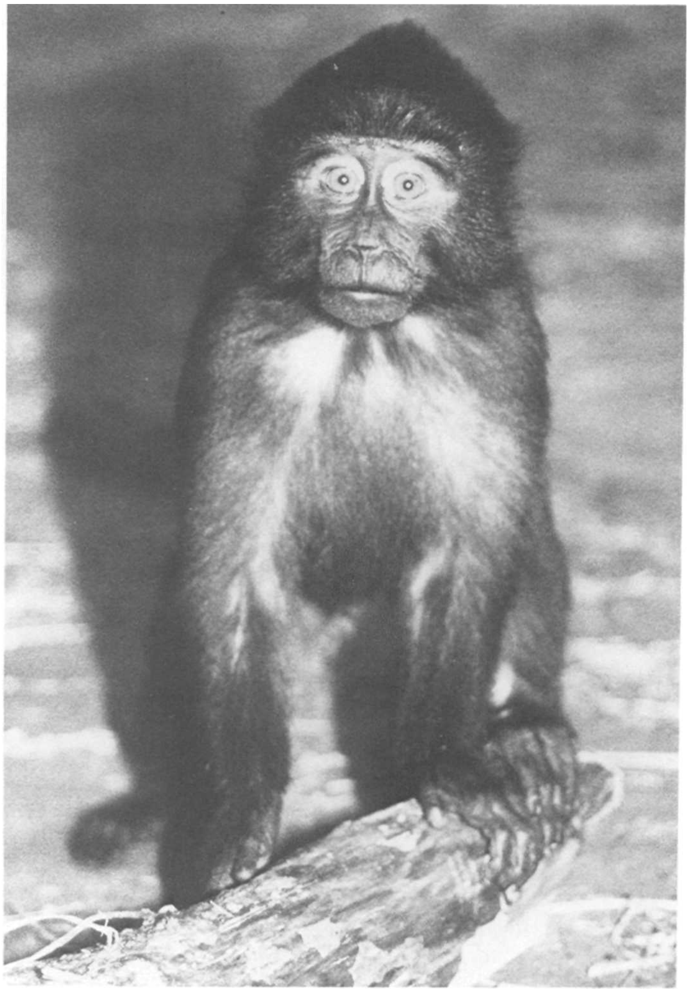

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Figure 7: Wildlife of Sulawesi, an island with a unique mix of Oriental and Australasian faunal elements.
a. The anoa *(Bubalus depressicornis),* a species of wild cattle endemic to Sulawesi (photo by R.A. Mittermeier).
b. Limestone cliffs near Ujungpandang in southeastern Sulawesi, habitat of the moor macaque *(Macaca maura),* one of seven macaques endemic of Sulawesi (photo by R.A. Mittermeier).
c. The crested macaque or "Celebes black ape" *(Macaca nigra),* from northeastern Sulawesi. This is the best known of the Sulawesi macaques and is often kept in captivity (photo by R.A. Mittermeier).
d. Juvenile *Macaca tonkeana,* another Sulawesi macaque species (photo by R.A. Mittermeier).
e. Poster produced by the Indonesian Directorate of Nature Conservation and WWF depicting the unique fauna of Sulawesi.

LESTARIKAN KHASANAH KHAS SULAWESI

Penerbit: Perlindungan & Pengawetan Alam, disponsori oleh; World Wildlife Fund   Disain: Yayasan Indonesia Hijau (M. Indradjit, Ujang SS).

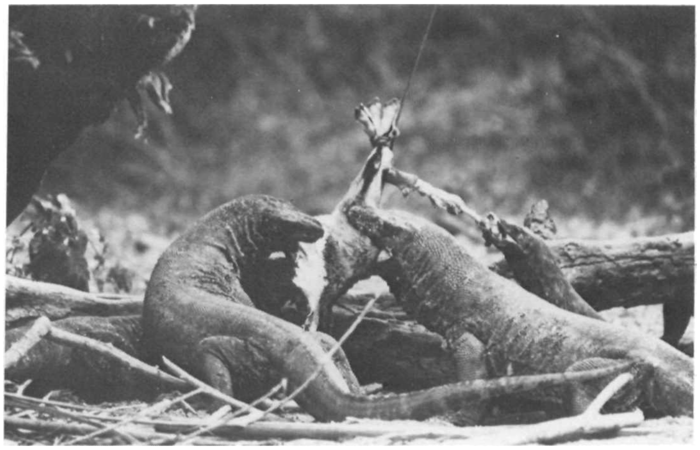
I	Cagar Alam Tangkoko Batuangus	4.446 Ha.
II	Suaka Margasatwa Manembo-nembo	6.500 Ha.
III	Cagar Alam Gunung Ambang	8.638 Ha.
IV	Suaka Margasatwa Dumoga	93.500 Ha.
V	Cagar Alam Pansa	1.500 Ha.
VI	Cagar Alam Paboya	1.000 Ha.
VII	Suaka Margasatwa Lore Lindu	
	(SM. Lore Kalamanta)	131.000 Ha.
	(TW. Danau Lindu)	31.000 Ha.
VIII	Cagar Alam Tanjung Api	4.246 Ha.
IX	Cagar Alam Morowali	200.000 Ha.
X	Suaka Margasatwa Lombuyan	3.665 Ha.
XI	Suaka Margasatwa Pati-pati	198 Ha.
XII	Cagar Alam Pegunungan Torohumpenai	90.000 Ha.
XIII	Taman Wisata Danau Matano/Mahalano	30.000 Ha.
XIV	Taman Wisata Danau Towuti	65.000 Ha.
XV	Suaka Margasatwa Lampoko dan Mampie	2.000 Ha.
XVI	Cagar Alam Lamedae	500 Ha.
XVII	Cagar Alam Bantimurong	18 Ha.
XVIII	Cagar Alam Karaenta	1.000 Ha.
XIX	Suaka Margasatwa Tanjung Amolengo	850 Ha.
XX	Cagar Alam Napabalano	9 Ha.
XXI	Taman Wisata Tirta Rimba/Air Jatuh	500 Ha.

e.

a.

b.

c.



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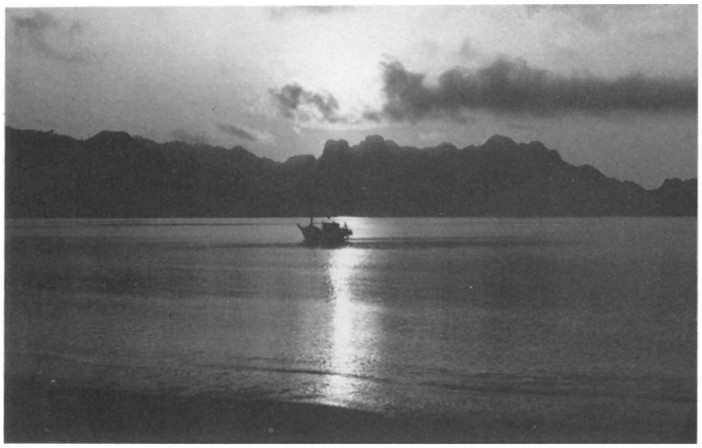

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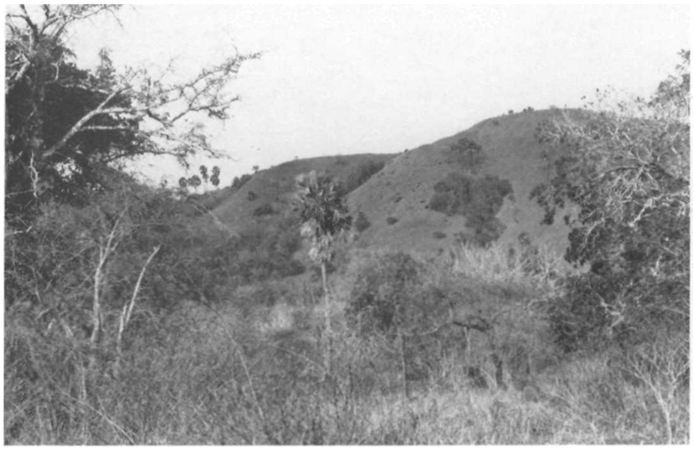

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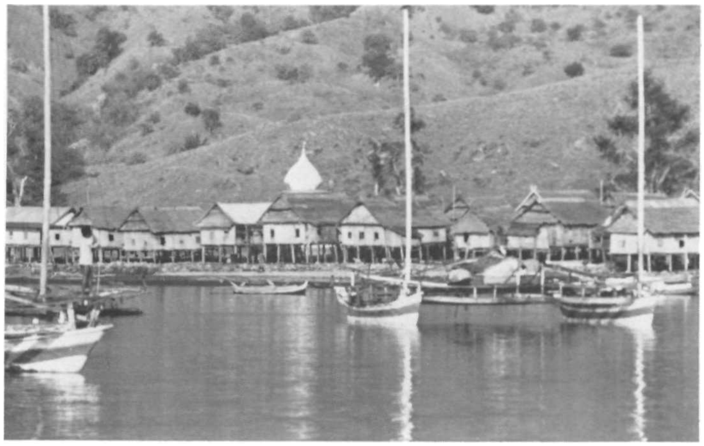

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Figure 8: The Komodo monitor *(Varanus komodoensis)*, world's largest living lizard. This species is found only on the islands of Komodo, Rintja, Padar, western Flores and a handful of tiny islands in the vicinity, and is protected in Komodo National Park (photos by R.A. Mittermeier).

a. b & c. Komodo monitors in the wild on the island of Komodo.
d. Komodo monitors feeding on a goat used to attract the lizards for tourist viewing.
e. View of Komodo monitor habitat on the island of Komodo.
f. View of Komodo at sunset showing the mountainous nature of the terrain.
g. The village of Komodo, part of the Komodo Biosphere Reserve.
h. Tourists climbing up from Komodo village in search of the giant lizards.

Thailand

Species Conservation Priorities in Thailand

Jira Jintanugool
Ardith A. Eudey
Warren Y. Brockelman

Introduction

Thailand covers an area of about 541,000 km^2 extending between 6 ° and 20 °N latitude in mainland Southeast Asia. The country encompasses diverse kinds of ecosystems and spans the Indo-Chinese, Indo-Malaysian, and Indo-Burmese subregions of the Oriental biogeographical region. The wildlife is diversified, but most species are not very abundant, which may be a consequence, in part, of their evolutionary history. The details of geographical distribution and habitat preference remain to be compiled for most vertebrates, including mammal and, to a lesser extent, bird species. Inventories of floristic communities are in progress, and efforts are being made to identify plants of potential use to the human population.

As is true of other developing countries in the tropics, Thailand is attempting to conserve its wildlife and forest habitats in the face of increasing exploitative pressures, both internal and external. According to government inventories, the forest cover of Thailand declined from more than 53% in 1961 to only 28% in 1981. The rate of forest destruction may have been nearly 10% a year during much of the last decade. Slash and burn agriculture and illegal logging, especially of teak and other tropical hardwoods, contributed significantly to this rate. In Thailand there are six major hilltribe populations, altogether consisting of more than 300,000 people, who practice shifting cultivation. Not only hilltribe peoples, but also ethnic Thais, have cleared large areas of forested land, which may be abandoned entirely after only a few years of use. A variety of timbering activities as well as irrigation and hydroelectric projects, highway construction, resettlement programs for hilltribe peoples and others, mineral exploration, and even recreation increase the pressure on forests and wildlife.

Illegal hunting or poaching of wildlife constitutes another serious problem. Traditional food hunting continues in areas near villages, but it is not nearly as detrimental to animal populations as the more modern type of hunting for sale. "Market hunting" is very difficult to control because of the sophistication of weapons available to hunters. The ready availability of modern forms of transportation and firearms results not only in wild animals being subjected to heavy slaughter, but also in forests being cleared and burned at an alarming rate to increase the area for cultivation as squatters do not hesitate to move in and settle down even in reserved forests.

Commercial exploitation for international trade also severely reduced certain populations of wild animals, for example, macaque monkeys, especially stumptail macaques *(Macaca arctoides).* A ban on the commercial export of all macaque species went into effect in 1976.

Pesticides and insecticides are used freely in Thailand. In some places the widespread use of insecticides on crops has caused the death of fish and other aquatic fauna, as well as birds. Such use also destroys predators and beneficial insects.

Species Conservation in Thailand

Early efforts in Thailand to protect wildlife were species-oriented. In 1921 a Wild Elephant Act was enacted, and in 1931 there were unsuccessful attempts to establish protection for the cows of wild water buffalo and some other large mammals. However, wild animals were reported to be still plentiful in every part of Thailand before World War II. Soon after the war, the impact of a rapidly expanding human population, declining economic wealth, and greater numbers of firearms and vehicles, as described above, resulted in both wildlife and their habitats being severely reduced. The Royal Forest Department and some societies, including the Siam Society, were responsible for the passage in 1960 of the Wild Animal Preservation and Protection Act B. E. 2503, which came into effect on January 1, 1961.

The Act established two major groups of wild animals: Reserved and Protected. These categories form the basis for the regulation of traffic in wildlife, to which a heavy commitment was made by private enterprise in Thailand, and are reflected in the schemes for captive breeding and restocking that are included within the Thai conservation strategy. These activities are under the jurisdiction of the Wildlife Conservation Division, Royal Forest Department-

Reserved wild animals are those considered to be rare or endangered, and are not permitted to be captured or hunted or even kept in possession except for educational or scientific purposes or for exhibition at zoological gardens. Nine species are included in this group: Javan rhinoceros *(Rhinoceros sondaicus),* Sumatran rhinoceros (*Dicerorhinus sumatrensis*), kouprey *(Bos sauveli),* wild water buffalo *(Bubalus bubalis),* Eld's deer *(Cervus eldi),* Schomburgk's deer *(Cervus schomburgki),* hog deer *(Axis porcinus),* goral *(Naemorhedus goral)* and serow *(Capricornis sumatraensis;* Table 1; Fig. 1).

Schomburgk's deer was endemic to Thailand and is now extinct; the last buck was shot in 1913. Of the rhinos, the Javan is believed to have been wiped out, while a few Sumatran are presently reported in some remote areas of the country. Villagers of Sisaket Province, in the northeast, reported having seen five kouprey near the Kampuchean border in August, 1982; it is believed that some animals moved to Thailand during the rainy season. Two subspecies of Eld's deer are found in Thailand, *Cervus eldi siamensis* and *Cervus eldi thamin.* The *siamensis* subspecies may have been extirpated in the wild, but small numbers of the *thamin* subspecies are reported to exist in areas near the Burmese border. The range of the goral is limited to remote parts of northern Thailand; a few goral were recently reported in Mae Tun Wildlife Sanctuary. It is doubtful if any hog deer still exist

Table 1. Reserved wild animals of Thailand

List of Reserved Wild Animals

1. Javan Rhinoceros *(Rhinoceros sondaicus)*
2. Sumatran Rhinoceros *(Dicerorhinus sumatrensis)*
3. Kouprey *(Bos sauveli)*
4. Wild Water Buffalo *(Bubalus bubalis)*
5. Eld's Deer *(Cervus eldi)*
6. Schomburgk's Deer *(Cervus schomburgki)*
7. Hog Deer *(Axis porcinus)*
8. Serow *(Capricornis sumatraensis)*
9. Goral *(Naemorhedus goral)*

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*Schedule of Reserved Wild Animals, the Wild Animals Reservation and Protection Act B.E 2503

within the former range of the species. However, a number of hog deer are being kept in captivity. The only known wild water buffalo population occurs in Huai Kha Khaeng Wildlife Sanctuary, where approximately 50-80 animals survive. Poaching is presently the main problem threatening this relict group of wild cattle. The least threatened species in the reserved category seems to be the serow, which ranges throughout every region of the country, mainly in limestone mountains and can be found in every wildlife sanctuary.

The Protected group of wild animals is composed of two categories (Table 2). The first category legally includes wild animals whose flesh is not usually used as human food, or which are not usually hunted for sport, or which destroy plant pests, or which should be protected for their natural beauty or for increasing their population numbers. Capturing live animals of this first category is permissible, but killing of these animals is not allowed except by collecting permit issued only for educational or scientific purposes. There are presently 184 vertebrate taxa declared as Protected Wild Animals of the First Category: 35 mammal, 131 bird, and 14 reptile (Table 2). Since venomous snakes pose a threat to the human population in agricultural areas, protection for reptiles is difficult to obtain, and, as a consequence, large numbers of snakes continue to be exported annually.

Protected wild animals of the second category are considered to be those that are palatable for human consumption or that are traditionally hunted for sport. Hunting of these animals can be done by securing a license. There are presently 35 vertebrate taxa declared as Protected Wild Animals of the Second Category: 12 mammal, 22 bird, and one amphibian (Table 3). Gaur *(Bos gaurus)* and banteng *(Bos banteng)*, sambar deer *(Cervus unicolor)* and barking deer *(Muntiacus muntjak)*, tiger *(Panthera tigris)* and leopard *(Panthera pardus)* are among the mammals historically included in the second category.

In Thailand the breeding program for wild animals has two objectives. Some species of rare animals, for example, Eld's deer, banteng and fireback pheasant *(Lophura diardi)*, are being bred in captivity for restocking in areas where they have been depleted; no release has yet been made. A number of hog deer are being kept in captivity for study and breeding purposes; some animals introduced onto an island in the southeast are breeding successfully. Likewise, reports of sightings of kouprey on the Thai-Kampuchean border have resulted in expeditions by the Wildlife Conservation Division to capture for propagation and study individuals of this wild cattle species which was believed to have been hunted to extinction in Thailand during this century. No capture has yet been made. In contrast, animals such as sambar deer and peafowl *(Pavo muticus)* are being maintained in captivity to increase their numbers and to study the requirements for commercially farming them.

Table 2. Protected wild animals of Thailand

***Schedule 1.* List of Protected Wild Animals of the first category**

No.	***Protected Wild Animals of the first category***
	MAMMALIA
1	Flying Squirrels of genera *Hylopetes* and *Pteromyscus*
2	Giant Flying Squirrels of genus *Petaurista*
3	Prevost's Squirrel *(Callosciurus prevostii)*
4	Langurs of genus *Presbytis*
5	Kitti's Hog-nosed Bat *(Craseonycteris thonglongyai)*
6	Wrinkled-lipped Bat *(Tararida plicata)*
7	Large Indian Civet *(Viverra zibetha)*
8	Small Indian Civet *(Viverricula malaccensis)*
9	Large Spotted Civet *(Viverra megaspila)*
10	Otter Civet *(Cynogale bennetti)*
11	Gibbons of genus *Hylobates*
12	Asiatic Wild Elephant *(Elephas maximus)*
13	Otters of genera *Lutra*, *Lutrogale* and *Amblonyx*
14	Flying Lemur *(Cynocephalus variegatus)*
15	Giant Squirrels of genus *Ratufa*
16	Mongooses of genus *Herpestes*
17	Back-striped Weasel *(Mustela strigidorsa)*
18	Siberian Weasel *(Mustela sibirica)*
19	Malaysian Weasel *(Mustela nudipes)*
20	Asiatic Brush-tailed Porcupine *(Atherurus macrourus)*
21	Common Porcupine *(Hystrix brachyura)*
22	Brush-tailed Porcupine *(Atherurus angustiramus)*
23	Marbled Cat *(Felis marmorata)*
24	Leopard Cat *(Felis bengalensis)*
25	Flat-headed Cat *(Felis planiceps)*
26	Jungle Cat *(Felis chaus)*
27	Slow Loris *(Nycticebus coucang)*
28	Macaques of genus *Macaca*
29	Pangolins of genus *Manis*
30	Malayan Tapir *(Tapirus indicus)*
31	Clouded Leopard *(Neofelis nebulosa)*
32	Golden Cat *(Felis temmincki)*
33	Fishing Cat *(Felis viverrina)*
34	Binturong Bear Cat *(Arctictis binturong)*
35	Hog Badger *(Arctonyx collaris)*
36	Ferret Badger *(Melogale personata)*
37	Yellow-throated Marten *(Martes flavigula)*
38	Banded Linsang *(Prionodon linsang)*
39	Spotted Linsang *(Prionodon pardicotor)*
40	Banded Palm Civet *(Hemigalus derbyanus)*

	AVES
1	Cormorants of family Phalacrocoracidae
2	Spot-billed Pelican *(Pelecanus philippensis)*
3	Painted Stork *(Ibis leucocephalus)*
4	Black Stork *(Ciconia nigra)*
5	White-necked Stork *(Ciconia episcopus)*
6	Black-necked Stork *(Xenorhynchus asiaticus)*
7	Ibises of family Threskiornithidae
8	Hill Partridges of genus *Arborophila*
9	Long-billed Partridge *(Rhizothera longirostris)*
10	Ferruginous Wood Partridge *(Caloperdix oculea)*
11	Bamboo Partridge *(Bambusicola fytchii)*
12	Roulroul *(Rollulus roulroul)*
13	Pheasants of genus *Lophura*
14	Hume's Pheasant *(Syrmaticus humiae)*
15	White-breasted Waterhen *(Amaurornis phoenicurus)*

No. ***Protected Wild Animals of the first category***

AVES (Continued)

16 Sarus Crane *(Grus antigone)*
17 Lapwings of genus *Vanellus*
18 Thick-knees of family Burhinidae
19 Munias and Weavers of family Ploceidae
20 Red-billed Ground Cuckoo *(Carpococcyx renauldi)*
21 Coucak or Crow Pheasant of genus *Centropus*
22 Kingfishers of family Alcedinidae
23 Laughing Thrushes of genus *Garrulax*
24 Hoopoe *(Upupa epops)*
25 Silver-eared mesia *(Leiothrix argentauris)*
26 Grey-headed Parakeet *(Psittacula finschii)*
27 Treepies of genus *Dendrocitta*
28 Great Hornbill *(Buceros bicornis)*
29 Indian Pied Hornbill *(Anthracoceros albirostris)*
30 Black Hornbill *(Anthracoceros malayanus)*
31 Racket-tailed Treepies *(Crypsirina temia)*
32 Babblers, Thrushes, Mesia, Cutia, Barwing, Sivas, Yuhinas, and Sibias of genera *Pellorneum, Trichastoma, Malacopteron, Stachyris, Macronous,* and *Chrysomma*
33 Parrots of genus *Psittacula*
34 Magpie Robin *(Copsychus saularis)*
35 White-rumped Shama *(Copsychus malabaricus)*
36 Forktails of genus *Enicurus*
37 Rock Thrush of genus *Monticola*
38 Warblers of subfamily Sylviinae
39 Black-collared Starling *(Sturnus nigricollis)*
40 Sunbirds of family Nectariniidae
41 Crested Jay *(Platylophus galericulatus)*
42 White-winged Black Jay *(Platysmurus leucopterus)*
43 Flowerpeckers of family Dicaeidae
44 Robins of genera *Phoenicurus, Rhyacornis, Thamnolaea, Hodgsonius*, and *Cinclidium*
45 Red-breasted Parakeet *(Psittacula alexandri)*
46 Cuckoo Dove of genus *Macropygia*
47 Red Turtle Dove *(Streptoplia tranquebarica)*
48 Spotted-necked Dove *(Streptopelia chinensis)*
49 Zebra Dove *(Geopelia striata)*
50 Emerald Dove *(Chalcophaps indica)*
51 Rufous Dove *(Streptopelia orientalis)*
52 Cutia *(Cutia nipalensis)*
53 Trogons of family Trogonidae
54 Ioras and Leafbirds of family Chloropscidae
55 Hill Myna *(Gracula religiosa)*
56 White-eyes of family Zosteropidae
57 Orioles and Bluebirds of family Oriolidae
58 Sanderling *(Crocethia alba)*
59 Rail Babbler *(Eupetes macrocerus)*
60 Red-winged Crested Cuckoo *(Clamator coromandus)*
61 Cuckoos of genus *Cacomantis*
62 Cuckoos of genus *Cuculus*
63 Cuckoos of genus *Chrysococcyx*
64 Drongo Cuckoo *(Surniculus lugubris)*
65 Owls of family Strigidae
66 Anhinga *(Anhinga anhinga)*
67 Hornbills of family Bucerotidae
68 White-eyed River Martin *(Pseudochelidon sirintarae)*
69 Bee-eaters of family Meropidae
70 Larks of family Alaudidae
71 Flycatchers and Niltavas of subfamily Muscicapinae
72 Brown Barbet *(Calorhamphus fuliginosus)*
73 Nicobar Pigeon *(Caloenas nicobarica)*
74 Sandpipers and Shanks of genus *Tringa*
75 Broad-billed Sandpiper *(Limicola falcinellus)*
76 Curlew Sandpiper *(Calidris furruginea)*
77 Asian Dowitcher *(Limnodromus semipalmatus)*
78 Drongos of family Dicruridae
79 Koel *(Eudynamys scolopacea)*
80 Thrushes of genera *Zoothera* and *Turdus*
81 Common Sandpiper *(Actitis hypoleucos)*
82 Wagtails and Pipits of family Motacillidae
83 Greater Adjutant Stork *(Leptoptilos dubius)*
84 Lesser Adjutant Stork *(Leptoptilos javanicus)*
85 Great Barbet *(Megalaima virens)*
86 Tits of family Paridae
87 Coppersmith Barbet *(Megalaima haemacephala)*
88 Wandering Tattler *(Heteroscelus incanus)*
89 Night Jars of family Caprimulgidae
90 Black-billed Roller *(Coracias benghalensis)*
91 Dollar Bird *(Eurystomus orientalis)*
92 Nuthatches of family Sittidae
93 Pittas of family Pittidae
94 Knots and Stints of genus *Calidris*
95 Swifts, Tree Swifts, Swallows, and Martins of family Apodidae, Hemiprocnidae, and Hirundinidae
96 Gulls and Terns of family Laridae
97 Malkohas of genus *Phaenicopheus*
98 Bulbuls of family Pycnonotidae
99 Little Grebe *(Podiceps ruficollis)*
100 Open-billed Stork *(Anastomus oscitans)*
101 Parrotbills of genus *Paradoxomis*
102 Black-tailed godwit *(Limosa limosa)*
103 Bar-tailed godwit *(Limosa lapponica)*
104 Comb Duck *(Sarkidiornis melanotos)*
105 White-winged Wood Duck *(Cairina scutulata)*
106 Pigeons of genus *Treron*
107 Jambu Fruit Pigeon *(Ptilinopus jambu)*
108 Brown-throated Tree Creeper *(Certhia discolor)*
109 Frogmouths of family Podargidae
110 Spectacled Barwing *(Actinodura ramsayi)*
111 Cochoas of genus *Cochoa*
112 Pintail Parrot Finch *(Erythrura prasina)*
113 Broadbills of family Eurylaimidae
114 Minivets of family Campophagidae
115 Turnstone *(Arenaria interpres)*
116 Barbets of genus *Megalaima*
117 Brown Dipper *(Cinclus pallasii)*
118 Herons, Bitterns, and Egrets of family Ardeidae
119 Green Peafowl *(Pavo muticus)*
120 Scimitar of genus *Pomatorhinus*
121 Ruff and Reeve *(Philomachus pugnax)*
122 Pied Imperial Pigeon *(Ducula bicolor)*
123 Peacock pheasants of genus *Polyplectron*
124 Sivas of genus *Minla*
125 Barn Owl *(Tyto alba)*
126 Greenpies of genus *Cissa*
127 Golden-crested Myna *(Ampelicens coronatus)*
128 Shrike babblers of genera *Pteruthius* and *Gampsorhynchus*
129 Blue-rumped Parrot *(Psittinus cyanurus)*
130 Hanging lorikeets of genera *Loriculus*
131 Helmeted Hornbill *(Rhinoplax vigil)*
132 Great Argus Pheasant *(Argusianus argus)*
133 Hawks, Kites, Buzzards, Goshawk, Shikra, Eagles, Vultures, Harriers, Ospreys, Falconats, Falcons, Hobby and Kestrels of Order Falconiformes
134 Woodpeckers of family Picidae
135 Plovers in genera *Charadrius* and *Pluvialis*
136 Blue Whistling Thrush *(Myophonus caeruleus)*

No.	*Protected Wild Animals of the first category*
	AVES (Continued)
137	Ashy Wood Swallow *(Artamus fuscus)*
138	House Crow *(Corvus splendens)*
139	Large-billed Crow *(Corvus macrorhynchus)*
140	Black-headed Shrike *(Lanius schach)*
141	Pied Starling *(Sturnus contra)*
142	Jerdon's Starling *(Sturnus burmannicus)*
143	Common Myna *(Acridotheres tristis)*
144	Crested Myna *(Sturnus javanicus)*
145	Owls of genera *Ketupa* and *Bubo*
	REPTILIA
1	Flying Lizard of genus *Draco*
2	Garden Lizard of genus *Calotes*
3	Spiny Lizard of genus *Acanthosaura*
4	Angle-headed Lizard of genus *Goniocephalus*
5	Oriental Water Lizard *(Physignathus cocincinus)*
6	False Gavial *(Tomistoma schlegelii)*
7	Gecko of genus *Cyrtodactyllus*
8	Flying Gecko of genus *Ptychozoon*
9	Hawksbill Turtle *(Eretmochelys imbricata)*
10	River Turtle or Four-toed Turtle *(Batagur baska)*
11	Spiny Hill Turtle *(Geoemyda spinosa)*
12	Impressed Tortoise *(Testudo impressa)*
13	Green Turtle *(Chelonia mydas)*
14	Loggerhead Turtle *(Caretta caretta)*
15	Big-headed Turtle *(Platysternum megacephalum)*
16	Leathery Turtle *(Dermochelys coriacea)*
17	Giant Asiatic Tortoise *(**Testudo** emys)*
18	Pacific Ridley's Turtle *(Lepidochelys **olivacea**)*
19	Elongate Tortoise *(Testudo elongata)*
20	Roughneck Monitor ***(Varanus rudicollis)***
	AMPHIBIA
1	Crocodile Salamander *(Tylototriton versucosus)*

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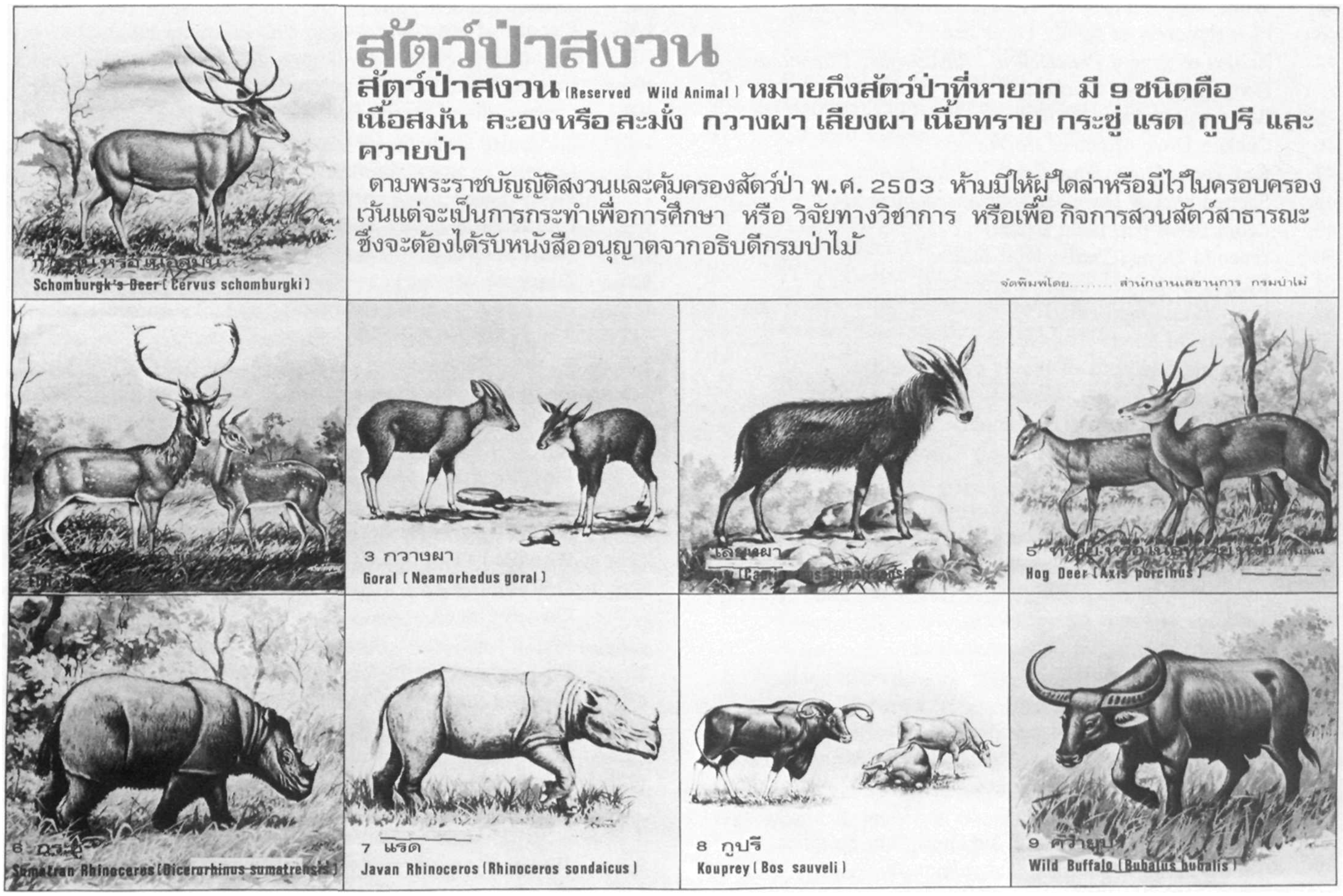
*Ministerial Regulation No. 14 (B.E. 2525) Issued according to the Wild Animals Reservation and Protection Act B.E 2503

Table 3. Protected Wild Animals of Thailand

Schedule 2. **List of Protected Wild Animals of the second category**

No.	*Protected Wild Animals of the second category*
	A. MAMMALIA
1	Gaur *(Bos gaurus)*
2	Mouse Deer of genus *Tragulus*
3	Siamese Hare *(Lepus siamensis)*
4	Sambar Deer *(Cervus unicolor)*
5	Dugong *(Dugong dugong)*
6	Banteng *(Bos banteng)*
7	Tiger *(Panthera tigris)*
8	Leopard or Panther *(Panthera pardus)*
9	Asiatic Black Bear *(Selenarctos thibetanus)*
10	Malayan Sun Bear *(Helarctos malayanus)*



สัตว์ป่าสงวน (Reserved Wild Animal) หมายถึงสัตว์ป่าที่หายาก มี ๙ ชนิดคือ เนื้อสมัน ละองหรือ ละมั่ง กวางผา เลียงผา เนื้อทราย กระซู่ แรด กูปรี และ ควายป่า

ตามพระราชบัญญัติสงวนและคุ้มครองสัตว์ป่า พ.ศ. 2503 ห้ามมิให้ผู้ใดล่าหรือมีไว้ในครอบครอง เว้นแต่จะเป็นการกระทำเพื่อการศึกษา หรือ วิจัยทางวิชาการ หรือเพื่อ กิจการสวนสัตว์สาธารณะ ซึ่งจะต้องได้รับหนังสืออนุญาตจากอธิบดีกรมป่าไม้

Fig. 1: Poster produced in Thailand depicting the country's nine Reserved Wild Animals. These include Schomburgk's deer, Eld's deer, goral, serow, hog deer, Sumatran rhinoceros, Javan rhinoceros, kouprey and wild buffalo.

No.	*Protected Wild Animals of the first category*
	MAMMALIA (Continued)
11	Barking Deer *(Muntiacus muntjak)*
12	Fea's Barking Deer *(Muntiacus feae)*
	B. AVES
1	Grey Heron *(Ardea cinerea)*
2	Purple Heron *(Ardea pupurea)*
3	Dusky Grey Heron *(Ardea sumatrana)*
4	Francolin *(Francolinus pintadeanus)*
5	Green-legged Tree Partridge *(Arborophila charltonii)*
6	Finches and Buntings of family Fringillidae
7	Red Jungle Fowl *(Gallus gallus)*
8	Night Heron *(Nycticorax nycticorax)*
9	Ducks, Garganeys, Pintails, Pochards, Shelducks, Shovellers, Teals, and Wigeon of family Antidae
10	Painted Snipe *(Rostratula benghalensis)*
11	Snipes of genus *Capella*
12	Thick-billed Green Pigeon *(Treron curvirostra)*
13	Bronze-winged Jacana *(Metopidius indicus)*
14	Mountain Imperial Pigeon *(Ducula badia)*
15	Pale-capped Pigeon *(Columba punicea)*
16	Green Imperial Pigeon *(Ducula aenea)*
17	Rails and Crakes of family Rallidae
18	Curlews and Whimbrel of genus *Numenius*
19	Watercock *(Gallicrex cinerea)*
20	Moorhen *(Gallinula chloropus)*
21	Purple Gallinule *(Porphyrio poliocephalus)*
22	Pheasant-tailed Jacana *(Hydrophasianus chirurgus)*
	C. AMPHIBIA
1	Asiatic Giant Frog *(Rana blythii)*

Each year a quota is set for the numbers and species of Protected wild animals to be hunted and traded. In 1981, 12 bird taxa of the first category and six bird taxa of the second category were so listed, (Table 3), but no mammals or reptiles.

In January 1983, Thailand ratified CITES and became the 79th member country effective as of April 21, 1983. In order to guard against the smuggling of wildlife from Thailand to non-CITES countries, which continues to be a serious problem, the Wildlife Conservation Division maintains two checkpoints, at the airport and at the harbor in Bangkok. Three more checkpoints will be established, at the borders with Laos and with Malaysia, and at Chiengmai International Airport.

TABLE 3. HUNTING AND TRADING QUOTA OF PROTECTED WILD ANIMALS FOR 1982

The Wildlife Conservation Committee has determined the limit for numbers of protected wild animals to be hunted and traded per licensee for 1982. The export of these protected animals will, therefore, not exceed these limited numbers.

A. Hunting and Trading Quota of Protected Wild Animals of the First Category.

No.	Animal Taxon	Bag Limits	Trading Limits
1	White-breasted waterhen (*Amaurornis phoenicurus*)	5	30
2	Laughing thrushes of genus *Garrulax*	5	20
3	Parrots of genus *Psittacula* excluding Red-breasted parakeet (*Psittacula alexandri*) and Large parakeet (*Psittacula eupatria*)	15	60
4	White-rumped shama (*Copsychus malabaricus*)	5	10
5	Spotted-necked dove (*Streptopelia tranquebarica*)	10	20
6	Zebra dove (*Geopelia striata*)	10	50
7	Hill myna (*Gracula religiosa*)	5	30
8	Koel (*Eudynamys scolopacea*)	2	10
9	Great barbet (*Megalaima virens*)	2	10
10	Pintail parrot finch (*Erythrura prasina*)	10	50

B. Hunting and Trading Quota of Protected Wild Animals of the Second Category.

No.	Animal Taxon	Bag Limits	Trading Limits
1	Francolin *(Francolinus pintadeanus)*	5	10
2	Snipes of genus *Capella*	10	20
3	Thick-billed green pigeon *(Treron curvirostra)*	10	30
4	Watercock *(Gallicrex cinerea)*	20	50
5	Moorhen *(Gallinula chloropus)*	20	50
6	Purple gallinule *(Porphyrio poliocephalus)*	10	40

Habitat-Oriented Conservation Activities

The Wildlife Act of 1960, in recognition of the need to maintain critical habitat for species survival, also provided for the creation of protected areas for wild animals (wildlife sanctuaries). The Wildlife Conservation Division has jurisdiction over the sanctuaries. The first sanctuary, Salak Phra, in the province of Kanchanaburi in west-central Thailand, was established in 1965. Since then, 23 more sanctuaries have been set up. The total area included within the sanctuaries is somewhat less than 2 million hectares, or almost *4%* of the country's area (Figure 1).

The first national park of Thailand, Khao Yai, spanning the provinces of Nakhon Rachasima, Saraburi, Nakhon Nayak and Prachinburi in central Thailand, was declared in 1963, following enactment of the National Parks Act of the previous year. The national parks, which are under the jurisdiction of the National Parks Division, Royal Forest Department, are intended, in contrast to the wildlife sanctuaries, to provide a place for recreation in addition to protecting local flora and fauna. At present there are 42 national parks, including several marine parks, encompassing a total of more than 2.3 million hectares, or about 4.5% of Thailand's area (Figure 2).

Many of the protected areas contain excellent forest and other habitats for wild animals. The survival of relatively intact ecosystems frequently can be attributed to the location of these areas in regions peripheral to human development. All efforts are be-

Fig. 2: Map of Thailand showing the location of existing Wildlife Sanctuaries and Nature and Wildlife Education Centers.

ing made by the Royal Forest Department to protect the sanctuaries and national parks, but each area appears to have its own set of conservation problems, as discussed below. Based on surveys conducted by the Royal Forest Department, there seem to be good forests and other habitats for wild animals remaining, that if brought under the jurisdiction of the sanctuaries or national parks would increase the reserved areas to about 10% of the total area of Thailand. Within the Royal Forest Department there is some debate over whether the more effective conservation strategy involves strengthening protection for already existing reserves or declaring as much remaining area as possible part of the reserve system before human encroachment occurs.

Within the wildlife sanctuaries and national parks, hunting, timbering and mining are prohibited. Other activities are strictly regulated. However, hydroelectric and irrigation projects increasingly are threatening protected areas. Salak Phra, the first sanctuary, lost much of its wildlife richness as a consequence of the construction of Srinakarin Dam. Elsewhere in western Thailand, the proposed Nam Choan Dam, to be financed with the assistance of the World Bank, threatens to disrupt the migrations of large mammals such as elephant between Huai Kha Khaeng and Thung Yai sanctuaries and open up the latter to human exploitation.

Research on wildlife in Thailand is aimed at producing management techniques or at adding to our general knowledge about species. Several projects to identify species and numbers of animals and habitat requirements have been initiated in protected areas. Both Thai scientists and foreign scientists are involved in these activities. Thai researchers have concentrated on the study of bird populations, including the shore birds found at Songkhla Lake in southern Thailand. Foreign researchers, in cooperation with Thai students or Thai counterparts in the Royal Forest Department, have concentrated on the study of primate populations (see below).

Many efforts are being made to make the Thai public aware of the value of their natural heritage and of how to enjoy nature. The Wildlife Conservation Division has set up Nature and Wildlife Education Centers in seven sanctuaries, representing every part of Thailand (Figure 1). The National Parks Division also is improving its visitor centers in the national parks.

Conservation Action Priorities

The comments which follow address the problem of developing effective local conservation strategies and were prepared by Brockelman and Eudey as a consequence of their field work on primates in Khao Soi Dao and Huai Kha Khaeng Wildlife Sanctuaries, respectively.

As in neighboring countries, there are a large number of endangered species in Thailand, some of which have been identified above. The Species Survival Commission (SSC) has the same ultimate goal as the other IUCN Commissions. Our particular responsibility is to help identify the species and habitats in need of urgent attention and establish some priorities for action. This should be followed up with project proposals. We are now rethinking how species and project priorities should be set to arrive at some useful recommendations for Thailand. What should be the criteria?

The first and most obvious criterion for the SSC is the *degree of endangerment of the species.* Critically endangered species should receive more attention than vulnerable species.

A second criterion is the *probable effect of the proposed action.* Is the anticipated effect small or large, localized or widespread, measurable or highly diffuse? Is the probable effect high per dollar spent? This is clearly important. For example, the Sumatran rhinoceros is highly endangered in Thailand; as such, it is classified as a Reserved Animal, and its survival is problematical. It is doubtful if $50,000 spent on this species would have any effect; spending a comparable amount to conserve elephants, which are also endangered but more abundant, would seem to hold more promise.

A third criterion is the *feasibility of the project* — can it, in fact, be carried out? Feasibility depends on many factors, such as:

1. Available infrastructure, for administrative and managerial support.
2. Local enthusiasm and cooperation.
3. Availability of capable principal investigators.
4. Logistical and/or scientific feasibility.

The probable effect of the project and its feasibility, to a large degree, depend on another consideration, the *strategy of conservation.* By this, we refer to areas of action such as the following:

1. Protection: creation of guard stations or procurement of equipment.
2. Field information: population inventory and habitat survey.
3. Research: ecological study.
4. Management and technical training assistance.
5. Education: dissemination of information on population and habitat significance on appropriate levels.
6. Socioeconomic action involving local residents near reserved areas.

Each of these areas of action has probable effect on, and a feasibility for, a given population or ecosystem. The efficacy of each action depends heavily on local circumstances and may vary even from one protected area to another within the same region. We can make some generalizations for Thailand. Equipment for protection is budgeted by the Thai government and, at this point in time, is not lacking; we do not feel that WWF or other outside agencies normally need assume this responsibility as it is not really efficient use of limited funds. Population inventory and habitat survey are badly needed in the greatly expanding system of sanctuaries and parks in Thailand, and some assistance in planning and actual execution of such activities may be essential. Research assistance may be useful in breeding or managing a few species, such as deer for rural economic development, or sea turtles. Education of persons living near sanctuaries and parks, especially children, is a valuable long-term investment, but it is doubtful if it will modify the immediate poaching and problems attendant upon shifting cultivation, which have largely socioeconomic causes and solutions. Education of high government officials is not such a priority in Thailand because conservation and protection are well supported by the law and the bureaucracy, but education of politicians may be critical because of the potential destruction of species and habitat by rapid technological development.

Nearly 10% of the territory of Thailand, as indicated above, may soon be included in the expanding protected area system. The problem now is how to most effectively maintain and strengthen this area. Socioeconomic action to us seems to be a neglected concern. We will illustrate our concept of the need for action in this area with experiences in two major reserved areas, both of which contain a diversity of endangered species.

Khao Soi Dao Wildlife Sanctuary. This area, which includes over 1,000 km^2 in southeast Thailand not far from the Kampuchean border, contains elephant, gaur, tiger, wild dog, silvered leaf monkey *(Presbytis cristatus)* and many other species. The very lush rain forests covering its mountains, valleys, and hills contain probably the most dense and extensive population of the pileated gibbon *(Hylobates pileatus* Figs. 4 & *5),* making it a top priority for action for this reason alone. Although deforestation has been largely halted, poaching by local farmers continues in

Fig. 3: Map of Thailand showing the location of existing National Parks.

nearly all parts of the sanctuary, and the guards are unable to stop it anywhere except near the three or four stations at the edge of the sanctuary (and usually away from the forest). The forest is not patrolled.

What actions could further conserve the species in this sanctuary since existing protection is insufficient to do the job? Management planners might say that the first priority is more protection, i.e., more jeeps, guns, guard stations, radios and motorcycles. But researchers with several years' experience in Khao Soi Dao have concluded that a project oriented toward more protection capability would probably have little positive effect and might actually have adverse effects. The approximately 30 men stationed there are reasonably well-equipped, but there are too few men to man the existing stations and patrol the forest. It is not likely that their numbers will be increased because the budget is limited for manpower, and an increase cannot be affected by outside financial help. The critical factor may be relations with the local residents, who harvest plant and animal products within the forest. Experience over the years has shown that if strict enforcement is attempted, the local residents resist with a variety of tactics: appeal to local politicians or police to pressure the sanctuary officials, threats on the sanctuary headquarters, and actual shooting at the guards. What is to be done? To advocate that the Royal Forest Department become an occupying army would only worsen an existing insurgency problem in the region. Khao Soi Dao is now nearly a forest island surrounded by several thousand relatively poor farm families (and some not-so-poor rambutan orchards) that cannot be managed or regulated by force. What may be needed is a change in the concept of wildlife sanctuary. Every effort must be made to realize the considerable value of the sanctuary to science, education, and the benefit of the local residents who must make economic sacrifices to preserve it. No such effort is being made now, and we see little hope that local poaching will stop. There is no ethical mandate to stop it.

Fig. 4: Juvenile pileated gibbon (*Hylobates pileatus*) in Khao Soi Dao Wildlife Sanctuary (photo by W. Y. Brockelman).

Fig. 5: Adult male pileated gibbon (*Hylobates pileatus*) in Khao Soi Dao Wildlife Sanctuary (photo by W. Y. Brockelman).

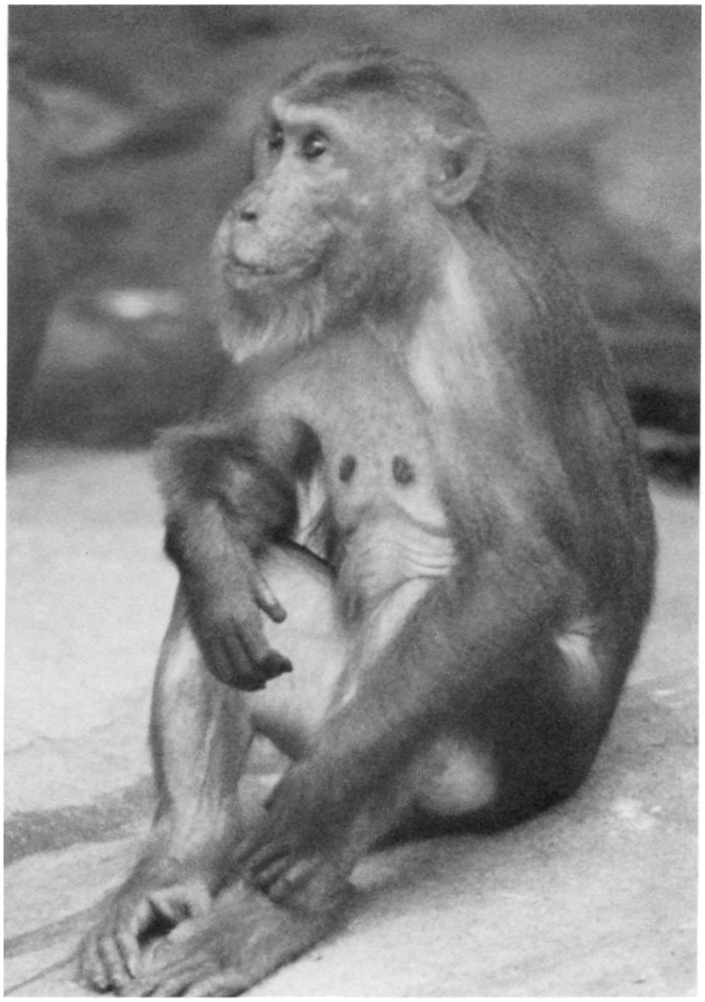


Fig. 6: The stumptail macaque (*Macaca arctoides*), probably the most endangered of Thailand's macaque species (photo by R. A. Mittermeier).

Fig. 7: Forest destruction caused by shifting cultivation to the east of Huay Kha Khaeng Wildlife Sanctuary, Uthaithani Provice. The area was covered with dry evergreen forest until about 200 years ago (photo by A. A. Eudey).

Huai Kha Khaeng Wildlife Sanctuary. This area is more than twice as large as Khao Soi Dao and encompasses monsoon deciduous and evergreen forest in lowland and mountain regions in the Dwana Range in west-central Thailand near Burma. Huai Kha Khaeng and the contiguous sanctuary of Thung Yai to the west total about 4,830 km^2 and constitute one of the largest remaining forested areas in Thailand. In the former the mammal fauna includes elephant, wild water buffalo, tapir *(Tapirus indicus),* serow, and many congeneric species, for example, banteng and gaur, tiger and leopard, Phayre's leaf monkey *(Presbytis phayrei)* and silvered leaf monkey, and five species of macaques, including the stumptail macaque *)Macaca arctoides,* Fig. *6),* which appears to be endangered throughout its disjunct distribution in Asia. Only the lar or white-handed gibbon *(Hylobates lar)* is found in the region. Although research or conservation efforts may be based on a species approach (Eudey, for example, has been studying the ecology of sympatric macaques in Huai Kha Khaeng since 1973), the importance of this protected area, with an extremely patchy environment, lies in the complexity of its ecosystem. The area may have been a forest refuge or refugium in the Pleistocene during periods of decreasing temperature and precipitation induced by glacial advances at more northern latitudes.

The region is remote (few Thais in Bangkok have ever visited the province of Uthaithani in which most of the sanctuary is found), yet easily accessible for research (and for poaching). Although the presence of human occupation in the general area and hunting of wildlife can be documented in the archaeological record to about 14,000 years ago, contemporary encroachment by the human population is recent.

Since its declaration in 1972, some effort has been made to employ local residents in the actual running of the sanctuary; a settlement of former hunters even has been incorporated into sanctuary headquarters. Initially Karen hilltribe men, the local people most knowledgeable of the forest and animals, were employed as guides and general assistants, but their numbers have dwindled and no effort is being made to recruit them now. A resettlement scheme for Karen south of the sanctuary may even increase the amount of poaching done by these people. Meo villages occur within the sanctuary. Some of the villages engage in insurgency and some in opium-growing. Throughout the Meo area shifting agriculture is destroying primary forest and wildlife is being threatened by subsistence hunting (Fig. 7 & 8). Increasing communication and cooperation with hilltribe peoples seem essential for strengthening of the sanctuary.

Patrol of the forest against hunting does occur, and this is one sanctuary where, because of its size, an increase in guard stations and acquisition of more sophisticated weapons is necessary. Hunting may be commercially motivated or for sport by people equipped with modern weapons.

Expansion of the boundaries of the sanctuary to the east and south is essential to include habitat critical for bovids. A plywood concession to the east makes the boundary artificial and excludes an area of important salt licks from legal protection. Habitat of wild water buffalo is outside the present boundary in the south. Minor and major irrigation and hydroelectric projects, if executed, will increase the accessibility of the sanctuary to the human population, necessitating more protection. In this context, educa-

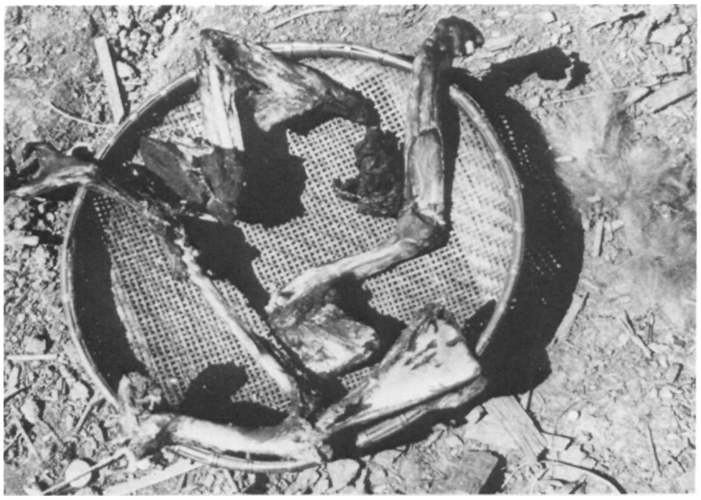


Fig. 8: Signs of subsistence hunting of protected wild animals by Meo hilltribe peoples. In the basket are limb bones of a colobine monkey, probably Phayre's leaf monkey (*Presbytis phayrei*), which has been smoked over a fire, and on the ground is the hair of a white-handed gibbon (*Hylobates lar*) (photo by A. A. Eudey).

tion of politicians as to the consequences for conservation of their decisions about technological development seems critical.

These two examples illustrate that the local conditions that determine an appropriate conservation strategy may vary greatly from place to place. Intimate knowledge of how each system works appears essential. Only persons with local field and cultural experience, including many on our commission, have the knowledge necessary to formulate effective proposals. Thus, we must concern ourselves not merely with deciding on species priorities, but also with helping to formulate and decide on new strategies. All too often strategies are formulated and evaluated on the basis of abstract philosophy or theories currently in vogue.

In Thailand, virtually every visiting consultant and expert in conservation has noted the difficulty of conserving protected areas and recommended, with the best of intentions, increased training, management planning, administration, and equipment for protection. These are, of course, all important. With the best possible management planning, the limiting factors early on should be identified and remedied in the plans, but in practice planners seem to advocate more of the same — guard stations, guns, and other equipment. The needed fundamental changes are seldom recommended except as a very low priority. The scope of conservation management planning, as it has grown largely out of Western experience, is not broad enough to include the needed solutions.

In Thailand, we advocate re-examining the objectives of wildlife conservation and the uses of reserved areas. We feel it is time to address the socioeconomic problems that appear to be worsening and that are limiting progress in conservation.

In conclusion, we advocate that the SSC, while using species and habitats as starting points, broaden the scope of concern to include the identification of locally limiting problems and the most promising and effective strategies to overcome them. In this, the collaboration of other commissions in designing proposals will be of critical importance.

Fig. 9: The slow loris *(Nycticebus coucang),* a nocturnal prosimian found in Thailand and a number of other Southest Asian countries (photo by R. A. Mittermeier).

Burma

Species Conservation Priorities in Burma

John Blower

Introduction

Burma (Fig. 1), with a total area of 676,756 km^2, extends from latitude 10° N in the extreme south, to latitude 28 ° N on the northern border with Tibet, a total distance of some 2093 km. Between these two extremes there exists an ecological spectrum of almost unique variety, ranging from tropical rainforest and coral reefs in the south to temperate forests of conifers, oaks and rhododendrons in the far north, where snow-capped mountains up to 5792 m mark the eastern extremity of the Himalayas.

High mountain ranges form a continuous barrier along the western border with India and Bangladesh, extending southward parallel with the coast nearly to the Irrawaddy Delta. In the northeast the border with China follows the high crest of the Irrawaddy-Salween divide, then bulges out eastward to enclose the Shan Plateau, a vast area of rugged mountain country bordering with Laos and Thailand. Between these mountain barriers to the west and east lies the fertile, heavily populated basin of the Irrawaddy, with its largest tributary, the Chindwin, joining it from the northwest. Burma's other great river, the Salween, flows south through neighboring Yunnan and then cuts through the Shan Plateau in deep, heavily forested gorges before finally reaching the sea in the Gulf of Martaban. Further south, Tenasserim extends in a long mountainous arm bordering with Thailand down to the Kra Isthmus.

Apart from the northern uplands of Kachin State, the climate of Burma is tropical monsoonal, with a rainy season coinciding with the southwest monsoon from May to October and a generally well marked dry season from November to April. There are, however, important local variations, with mean annual rainfall ranging from as little as 762 mm in parts of the central Dry Zone to over 6350 mm in Tenasserim.

The population is about 33 million with an average density ranging from less than 10 per km^2 in some of the peripheral mountain areas to nearly 350 in the very heavily populated Rangoon Division, and over 116 in the Irrawaddy Delta, giving an overall density of about 46 per km^2, which is well below the average for southeast Asia. The annual population growth rate has been fairly constant in recent years at about 2.2%. Agriculture, including timber production, employs two-thirds of the work force and 76% of the population still lives in rural areas.

The officially quoted figure of 57% overall forest cover in Burma is somewhat out of date. The report of the FAO/UNEP Tropical Forest Resources Assessment Project (FAO/UNEP, 1981), based on analysis of Landsat satellite imagery, estimated about 47% forest cover in 1980, including all types of woody growth such as scrub woodland and bamboo in addition to high forest. The annual rate of deforestation through shifting cultivation and other causes was estimated at around 101,175 hectares per year.

Forests may be broadly divided into four main categories:

1. *Tropical moist forest,* which includes the evergreen dipterocarp rainforest) of the high rainfall areas in Tenasserim, Kachin State, and Upper Chindwin; the semi-evergreen forests of Arakan and parts of North Burma, and the extensive moist deciduous forests, which are of great importance for production of teak and other commercial hardwoods. It also includes the various types of tidal and fresh water swamp forests.
2. *Tropical dry forest;* mixed deciduous forests including *indexing* — characterized by the presence of *Dipterocarpus tuberculatus,* dry teak forest and other types of rather open, stunted woodland found in the drier areas.
3. *Montane sub-tropical forests;* typically including *Quercus, Castanopsis* and pines *(Pinus merkusii* and *P. insularis)* in mountain areas from 915-1524 m, and sometimes higher.
4. *Montane temperate forests;* occurring between 1524 and 3659 m, and characterized by *Quercus, Castanopsis, Schima,* pines *(P. excelsa* and *P. wallichiana),* and at highest elevations in north Burma, *Tsuga, Abies, Betula* and rhododendrons.

Species Conservation in Burma

Most of Burma lies within the Indochinese Zoogeographic subregion of the Oriental region, with the Arakan and Chin Hills in the Indian sub-region, and the high mountains of the extreme north, with their typically Himalayan species, in the Palearctic region.

Large mammals such as elephant *(Elaphas maximus),* gaur *(Bos gaurus),* banteng *(Bos javanicus),* sambar *(Cervus unicolor),* barking deer *(Muntiacus muntjak),* tiger *(Panthera tigris)* and leopard *(P. pardus)* are widely distributed in the less disturbed forested regions of most of Burma apart from the far north. But in the absence of factual data their status is uncertain. Two species of rhinoceros formerly occurred in Burma, of which the Javan rhinoceros *(Rhinoceros sondaicus)* is already extinct and the Sumatran *(Dicerorhinus sumatrensis)* probably so.

Among other larger mammals, the distributions of which are more localized, are hog deer *(Cervus porcinus),* musk deer *(Moschus moschiferus),* thamin *(Cervus eldi)* — in the drier areas of central Burma, tufted deer *(Elaphodus cephalophus)* from the northeast border with Yunnan, and two species of mouse deer *(Tragulus napu* and *T. javanicus)* in Tenasserim. There are also three species of goat-antelope; takin *(Budorcas taxicolor)* — which occurs only in the north of Kachin State, serow *(Capricornis sumatraensis)* and goral *(Nemorhaedus goral).* Tapir *(Tapirus indicus* Fig. 2) were formerly found in mainland Tenasserim ap-

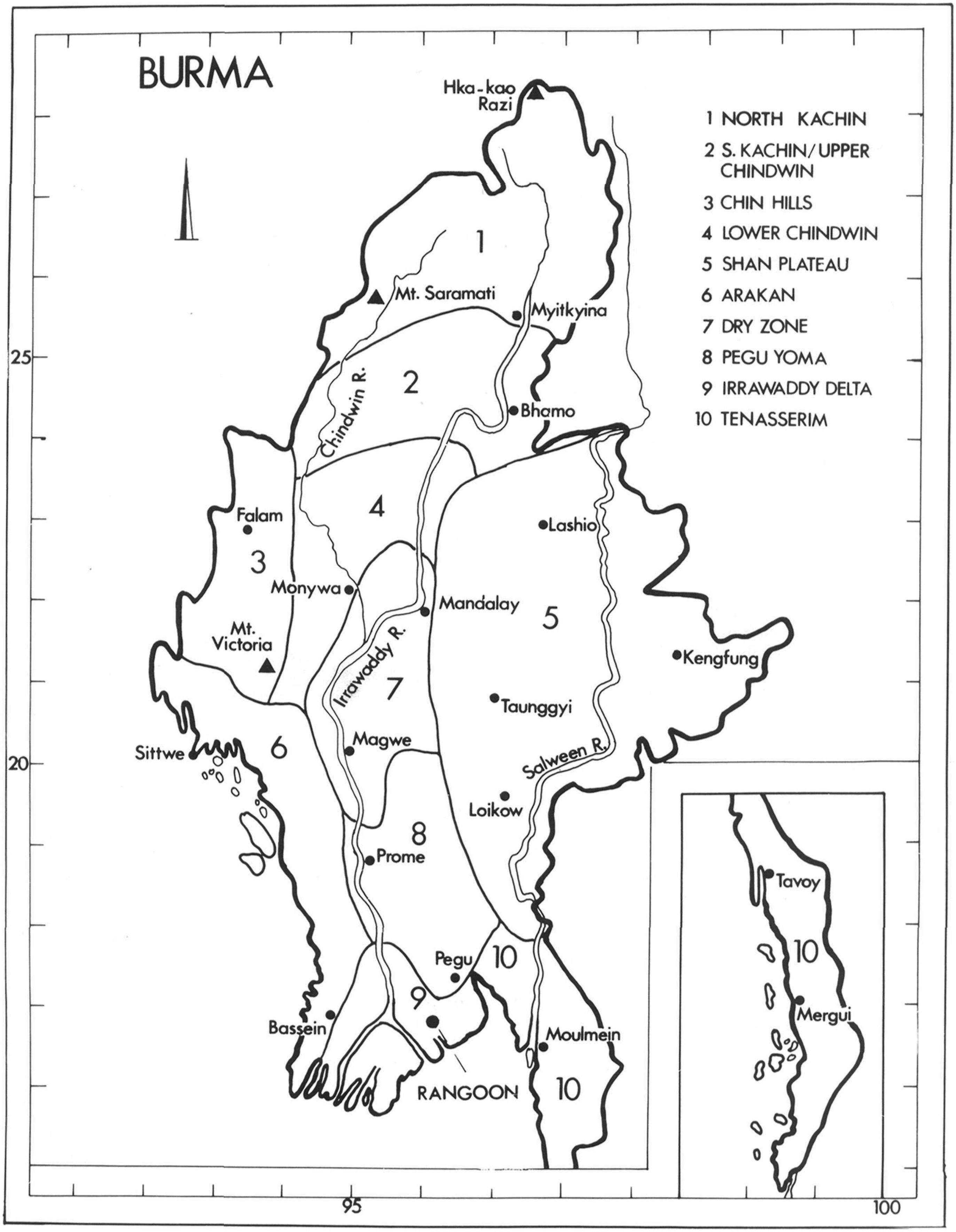


Fig. 1: Map of Burma showing major geographical subdivisions, towns and rivers.

proximately as far north as latitude 18° N, but whether their present range extends so far north is uncertain.

Carnivores include two species of bear *(Helarctos malayanus;* Fig. 3) and *Selenarctos thibetanus),* clouded leopard *(Neofelis nebulosa),* wild dog *(Cuon alpinus),* Asiatic jackal *(Canis aureus)* and, in northern Kachin State, red panda *(Ailurus fulgens),* and possibly wolf *(Canis lupus).*

Among primates, several species of *Macaca* and *Presbytis* are fairly widely distributed, and there are also two gibbons, the hoolock *(Hylobates hoolock)* of Upper Burma and the white-handed gibbon *(H. lar)* of Tenasserim.

Marine mammals and reptiles occurring in coastal waters and riverine estuaries include the now very rare dugong *(Dugong dugon* Fig. 4), the salt water crocodile *(Crocodilus porosus)* and possibly five species of marine turtle, of which the commonest are the green turtle *(Chelonia mydas)* and probably the olive ridley ***(Lepidochelys olivacea)*** (although the latter has in the past been confused with the loggerhead *(Caretta caretta)* and the relative status of the two species is unclear).

About one thousand bird species have been recorded from Burma (Smythies, 1953), this relatively high species diversity being due to the fact that the country extends into two zoogeographic regions, each with different bird faunas. The forests of Tenasserim contain many Malesian species, whereas in the central and northern part of the country the bird fauna has Indian and Chinese affinities. A large number of Himalayan species occur in the montane forests of north and west Burma. There are relatively few endemic species (Sayer, 1983).

There is, as yet, little information on the status, distribution and ecology of individual species, though there is no evidence that any major species is seriously endangered, apart from vultures, which have practically disappeared from most of Burma in recent years.

The main threats to bird life are the conversion of wetlands to agriculture, the habitat of waterfowl and waders including the large numbers of migratory species which winter in Burma, hunting and trapping, especially of pheasants and peafowl, and the use of agricultural pesticides such as Endrin, which is a serious threat to scavengers and seed-eaters. The principal conservation needs for birds are the protection of sufficient areas of natural habitat, especially wetlands, and research to obtain data on the status and distribution of individual species, particularly those which are either rare or endemic to Burma.

Wildlife conservation has hitherto been the responsibility of the Forest Department. Apart from the Reserved Forests which total 90,673 km^2, or approximately 13.5% of the total land area, there are 14 wildlife sanctuaries. However, most are relatively small, their aggregate area being only 4,728 km^2, or approximately 0.7% of the total land area.

Apart from the inadequate size of existing protected areas, both individually and in aggregate, they also fail to provide representative coverage of several important biota, including the northern temperate forests, the evergreen dipterocarp forests of Tenasserim, and coastal areas including the Irrawaddy Delta and the Mergui Archipelago with its coral reefs.

Under existing legislation, which dates from the pre-World War II colonial era, the fauna in wildlife sanctuaries is protected but the habitat is not, with the result that many areas and species have suffered serious damage. Moreover, in most cases effective protection of wildlife has not been possible due to shortage of Forest Department staff.

Wildlife in Reserved Forests enjoys a certain degree of legal protection and may not be hunted without a special permit. But here again, effective law enforcement is difficult due to staff shortages and the large numbers of firearms in the hands of the military and para-military People's Militia.

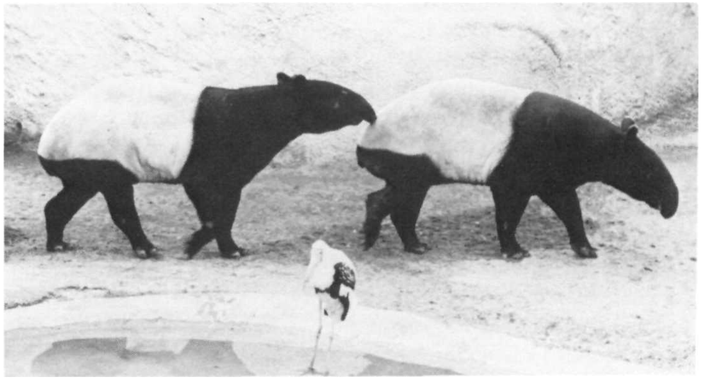


Fig. 2: The Malayan tapir *(Tapirus indicus)* an endangered species from Burma (photo by R. A. Mittermeier).

Fig. 3: The sun bear *(Helarctos malayanus),* one of two bear species found in Burma (photo by R. A. Mittermeier).

In 1981, the Government, with assistance from FAO/UNEP, introduced a new Nature Conservation and National Parks project with the object of ensuring more effective protection of flora, fauna and natural landscapes, including establishment of national parks and other protected areas. Preliminary surveys of over twenty potential sites have been completed (June, 1983), and several have been identified as suitable for establishing national parks, nature reserves or sanctuaries. Other areas, particularly in northern Burma, still remain to be surveyed.

Species Conservation Action Priorities

The most urgent priorities are the conservation of large mammals, particularly elephants, marine turtles and the saltwater crocodile. In the almost total absence of reliable data on the present status of wildlife populations in Burma it is impossible to give anything other than a very subjective impression of the degree to which individual species may or may not be endangered.

Elephant (Elaphas maximus). The elephant is of major economic importance to Burma for extraction of teak and other hardwoods, which are one of the country's main sources of foreign exchange. There are approximately 5,400 captive elephants in Burma, most of which are employed in the timber industry. However, the annual reproductive rate among timber elephants is only about 5.3 per 100 breeding females, which, allowing for mortality, is insufficient to maintain this population without influx from the wild. Consequently, it is necessary to continue the capture of wild elephants at an average rate of about 120 per year.

Estimates of the wild elephant population in Burma range from 3,000 to 6,000, but observations in the limited areas covered so far by our surveys indicate that the lower figure is probably the more realistic. Mortality in capture operations is officially admitted to be about 20%, and may even be higher. There is also a significant amount of illegal capture and smuggling of elephants to Thailand, and also poaching for ivory (38 animals are known to have been successfully smuggled to Thailand in recent months and a further 11 were intercepted en route and confiscated). Therefore, while it is not yet possible to give any reasonably accurate estimate of actual numbers, it is certain that the overall annual offtake from legal and illegal capture and poaching is appreciable.

In nearly all the areas so far surveyed the elephant population has been found to be appreciably lower than previous official estimates. It is therefore reasonable to assume that the overall population is also considerably lower than the official figure of about 6,000, and that with continuing offtake, known and unknown, numbers are steadily declining.

ACTION REQUIRED:

1. Field research to obtain data on the present status and distribution of wild elephants and to monitor future trends;
2. Based on results of the above, to establish elephant ranges or nature reserves of sufficient size wherein viable populations can be effectively protected;
3. Study of the management of captive elephants, with a view to increasing the birth rate to a level where the population can be self-sustaining;
4. Progressive reduction in numbers of capture permits issued, combined with law enforcement to control poaching, illegal capture and smuggling.

Rhinoceros (Dicerorhinus sumatrensis). This species formerly occurred in Kachin State, Upper Chindwin, Arakan, Mongmit/Mandalay Division, Kayah State and Tenasserim, but there have been no recent confirmed reports of its survival in any of these areas and it may already be extinct.

The only areas where it has been reported to occur during the past 20 years are the Tamanthi Wildlife Sanctuary in Upper Chindwin and Shwe-u-daung Sanctuary on the border between Mongmit and Mandalay Divisions. However, both these areas have been subject to extensive insurgent activity, and it is doubtful that any rhino still survive. Surveys of both areas are planned for the 1983/84 dry season.

ACTION REQUIRED:

1. Surveys of Tamanthi and Shwe-u-daung Wildlife Sanctuaries and any other appropriate areas to determine whether or not any rhinoceros survive;
2. Subject to confirmation of their survival in any area, to plan and implement effective conservation measures without delay (including possible upgrading of the area concerned to National Park or Nature Reserve status).

Thamin (Cervus eldi thamin). The Burmese subspecies of this deer is confined to the drier areas of central Burma, and there have also been unconfirmed reports of its occurrence in Paan Division to the east of the Salween, near the Thai border. Although fully protected by law, thamin are widely hunted, but fortunately appear able to withstand hunting pressure moderately well and also to adapt to habitat changes. However, their range has been considerably reduced, and although they are spottily distributed throughout much of Shwebo Division and elsewhere in central Burma, the only population which can be regarded as truly viable is in the Kyatthin Wildlife Sanctuary in Shwebo Division. There are believed to be about 2,000 thamin there and a few hundred in the somewhat larger, but much degraded Shwezettaw Wildlife Sanctuary to the west of the Irrawaddy in Minbu Division.

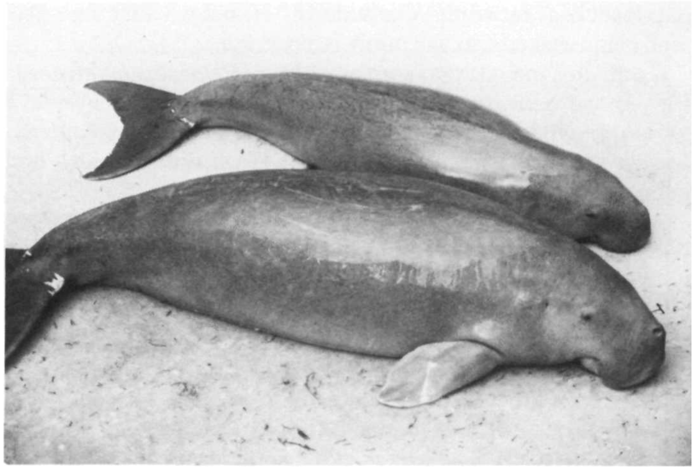


Fig. 4: The dugong (*Dugong dugon*), now very rare in Burman coastal waters (photo by R. A. Mittermeier).

Thamin are vulnerable, but not yet endangered, though conservation measures are needed if they are to survive in the long-term.

ACTION REQUIRED:

1. Enlargement of the Kyatthin Wildlife Sanctuary with realignment of boundaries to exclude villages presently contained within;
2. Upgrade the status of Kyatthin to Nature Reserve with provision of sufficient staff to protect it;
3. Full protection of thamin elsewhere, with severe penalties for illegal hunting; and
4. A research program on thamin ecology.

Wild Cattle (Bos spp.). Gaur *(Bos gaurus)* and banteng *(Bos javanicus)* occur throughout much of Burma in areas where there is still good forest cover and little human disturbance, gaur generally preferring more hilly country than the banteng. Although theoretically protected, both species are heavily hunted and are becoming increasingly scarce. Both are vulnerable, if not endangered.

ACTION PRIORITIES:

1. Establish one or more national parks or nature reserves of adequate size wherein there are viable populations of these species and provide sufficient staff to protect them (the proposed Alaungdaw Kathapa and Pegu Yoma National Parks would be very suitable for this purpose);
2. Enforce the law to stop the killing of these animals for meat, especially by the Army and the People's Militia;
3. Survey to ascertain status and distribution as a basis for further conservation planning.

Tiger (Panthera tigris). Burma is the only country where the tiger occurs that it is not protected by law. When the present law was introduced (1936), tiger were still plentiful in Burma, causing considerable damage to domestic livestock and constituting a serious menace to human life in certain areas. Consequently, they were at that time regarded as "vermin" and were not placed on the protected list.

The situation today is very different. There are a few isolated areas such as the proposed Alaungdaw Kathapa National Park where tiger are still relatively plentiful. But in most areas they are now rare, as has been clearly shown by recent field surveys, which revealed very few signs of tigers. This is probably due both to scarcity of prey species such as the heavily hunted sambar, and also to hunting, trapping and poisoning of the tigers themselves. Tiger skins are readily obtainable in Bangkok where they fetch as much as US $1,000 apiece. Most of these have come from Burma where they have been trapped, shot or poisoned with the highly toxic and widely available agricultural pesticide Endrin.*

Tiger in Burma are not yet seriously endangered, but they will be, as elsewhere in southeast Asia, unless positive steps are taken for their conservation.

ACTION PRIORITIES:

1. Place the tiger on the fully protected list of wildlife, except in cases of proven man-killing, with severe penalties for hunting or possession of skins;
2. Establish national parks or reserves in areas where there are still good populations of tigers and prey species;
3. Conduct an education campaign to convince the public that tigers are a beautiful and increasingly rare species, important in Burmese culture and tradition, and that they will inevitably disappear unless protected.

Saltwater Crocodile (Crocodilus porosus). Formerly widely distributed in estuaries and tidal swamps of Arakan, the Irrawaddy Delta and Tenasserim, crocodiles have been heavily hunted for skins and are now very seldom seen. Another major factor in their decline has been the loss of habitat due to extensive clearing of mangroves for rice cultivation. There are, however, apparently still viable populations in the Irrawaddy Delta where the People's Pearl and Fisheries Corporation (PPFC) collects an average of about 500 hatchlings a year for their crocodile farm in Rangoon. Also, there are still possibly viable populations in less disturbed coastal areas of Arakan and Tenasserim where there are still extensive areas of suitable habitat among the tidal creeks and mangrove swamps.

The PPFC has proposed that Meinmahla Kyun, an estuarine island about 130 km^2 in area in the Irrawaddy Delta, be declared a sanctuary for this species. The crocodile population is, however, very small with no sign of breeding. Restocking from the crocodile farm will therefore probably be necessary.

ACTION PRIORITIES:

1. Full legal protection for this species, except for the collection of a limited number of hatchlings by PPFC under permit;
2. Heavy penalties for possession of crocodile skins;
3. Establishment of Meinmahla Kyun as a sanctuary for protection of crocodiles with restocking as necessary;
4. Surveys in Arakan and Tenasserim to obtain data on status and distribution, and identify suitable conservation areas.

Marine Turtles. The five species of marine turtles reportedly occurring in Burmese coastal waters are as follows:

— Green turtle *(Chelonia mydas)* — Commonest species on Thamihla Kyun.
— Olive ridley *(Lepidochelys olivacea)* — Fairly common off the Irrawaddy Delta.
— Loggerhead *(Caretta caretta)* — Status uncertain, but reported to be fairly common in the Delta region.
— Hawksbill *(Eretmochelys imbricata)* — Rare.
— Leatherback *(Dermochelys coriacea)* — Very rare.

There are turtle nesting beaches along the coast and on certain offshore islands in Arakan, the Irrawaddy Delta and Tenasserim, of which the most important appear to be Thamihla Kyun (Diamond Island) off the mouth of the Bassein River, Kadonly and Gayedgyi Islands off the mouth of the Bogale River, and Aung Bok in the South Moscos Islands (Tenasserim).

Both Thamihla Kyun and the Moscos Islands are legally established Wildlife Sanctuaries, but nearly all the turtle eggs laid are taken from the former by the PPFC and from the latter by a local contractor with a Forest Dept. license. Eggs are also taken from all other known nesting sites.

Past records show that at the beginning of this century 1.5-2 million eggs a year were being harvested from Thamihla Kyun. The average annual offtake today is only about 150,000, a 90% reduction. Many former nesting beaches are no longer visited by any turtles. Apart from egg collection, mature turtles are taken by fishermen, reportedly including PPFC trawlers which catch them in their nets. Hawksbill turtles are killed for their "tortoise shell".

From the enormous reduction in the number of eggs collected from Thamihla Kyun and elsewhere and the fact that many of the formerly well known nesting beaches are now unused, it is clear that turtle populations have declined markedly and that two species, the leatherback and the hawksbill, are endangered while the other three species must be considered seriously threatened. Leatherbacks are so rare that their occurrence should perhaps be considered accidental.

ACTION REQUIRED:

1. Establish Thamihla Kyun and South Moscos as effective wildlife sanctuaries and stop all collection of turtle eggs. South Moscos has been proposed as a future national park and has been approved in principle. Its designation as a park will, however, have to wait introduction of new legislation;
2. Declare Kadonly Kyun a wildlife sanctuary and provide sufficient staff, boats, etc., to protect it and the other two sanctuaries mentioned above. It appears that Kadonly Kyun attracts mainly olive ridley and the other two islands mainly green turtle;
3. Enlist cooperation of PPFC in not trawling in areas immediately seaward of sanctuaries and in releasing any turtles accidentally caught in nets; and
4. Survey by experienced marine biologist to determine the status and distribution of marine turtles in Burmese waters and to recommend further conservation action.

River Terrapin (Batagur baska). This endangered species still occurs in the Irrawaddy Delta and is reported to nest on certain of the offshore islands and sandbanks, including Kadonly Kyun, which has been proposed as a wildlife sanctuary. However, both the terrapin itself and the eggs are taken wherever they are found. The species is now very rare in Burmese waters and without effective conservation measures is likely to become extinct within the foreseeable future.

ACTION REQUIRED:

1. Full protection of both the terrapin and its eggs;
2. Establishment of Kadonly Kyun as a wildlife sanctuary;
3. Survey by a marine biologist to determine status and distribu-

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*Note: The Government of Burma has recently prohibited further importation of Endrin and less toxic pesticides are being introduced in its place.

tion (combined with a marine turtle survey) and to recommend further conservation action, including a possible hatchery on Kadonly Kyun or elsewhere.

Conclusion

Burma is a country of unusual ecological diversity, rich in a wide variety of flora and fauna. But, as elsewhere, the natural environment is increasingly threatened by shifting cultivation, illegal hunting, uncontrolled use of highly toxic pesticides and other harmful influences resulting from steady growth of the human population. Satellite monitoring shows that forest cover, though still greater in proportion to the total land area than in most southeast Asian countries, is diminishing at a steady rate. The Javan rhinoceros has already become extinct here, and other species, including the economically important elephant, marine turtles and saltwater crocodile, are seriously threatened.

The Government, having realized that effective conservation action is urgently needed, has, with UNDP/FAO assistance, initiated a nature conservation program which will include new legislation and establishment of national parks and other protected areas. Several suitable sites have already been identified in addition to the 14 wildlife sanctuaries already in existence.

Provided that viable populations of those species known to be threatened or endangered are effectively protected, together with sufficiently extensive areas of their habitat, their survival should be assured. Otherwise, they will inevitably go the same way as the Javan rhinoceros.

Though much work yet remains to be done, particularly in field research to determine the status and distribution of individual species, the broad basis for an effective nature conservation program now exists. Continued external assistance will be needed for some years, but ultimate responsibility for implementation of this program necessarily rests with the Burmese government.

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Table 1. Burma
Biogeographical Subdivisions Showing Distribution of Protected Areas, Existing and Proposed

Map Ref. No.	*Designation*	*Major rare, vulnerable or endangered species*	*Protected Areas*			
			Existing	*Area (km^2)*	*Proposed*	*Area (km^2)*
1.	NORTH KACHIN	Takin, musk deer, wolf, red panda. elephant, rhinoceros (?), tiger. several pheasant species	Nil		Nil	
2.	SOUTH KACHIN/ UPPER CHINDWIN	Elephant, gaur, tiger, rhinoceros (?), Sarus crane	TAMANTHI W.S. PIDAUNG W.S.	2150 705	Nil	
3.	CHIN HILLS	Elephant (scarce), gaur, tiger	Nil		NAIMI TAUNG (Mt. Victoria) N.P. KYAUKPANDAUNG N.P.	303 132
4.	LOWER CHINDWIN	Elephant, thamin, gaur, banteng, tiger, wild dog	KYATTHIN W.S.	268	ALAUNGDAW KATHAPA N.P.	1606
5.	SHAN PLATEAU	Elephant, gaur, banteng, tiger, wild dog, Sarus crane	MAYMYO W.S. SHWE-U-DAUNG W.S. TAUNGGYI W.S.	127 207 16	INLE AND MONGPAI N.R.	41
6.	ARAKAN (RHAKINE)	Elephant, gaur, banteng, tiger, wild dog, salt-water crocodile	Nil		Nil	
7.	DRY ZONE	Thamin, gaur, banteng (in foothills), wild dog	SHWEZETTAW W.S. WETHTIGAN W.S. MINWUN TAUNG W.S.	552 5 206	POPA MOUNTAIN PARK	96
8.	PEGU YOMA	Elephant, gaur, banteng, tiger, wild dog	Nil		PEGU YOMA N.P. MOHINGYI N.R. GYOBYU RECREATIONAL AREA	1461 104 34
9.	IRRAWADDY DELTA	Marine turtle, saltwater crocodile. river terrapin, Irrawaddy dolphin (?)	THAMIHLA W.S. (Diamond I.)	1	MEINMAHLA KYUN W.S. KADONLAY KYUN W.S.	130 3
10.	TENASSERIM	Elephant, gaur, banteng, Fea's muntjak, marine turtle, salt-water crocodile, Argus pheasant	KAHILU W.S. KELATHA W.S. MULAYIT W.S. MOSCOS W.S.	161 25 139 49	LAMPI N.P. PAKCHAN N.R.	233 1451

Note N.P. = National Park. N.R. = Nature Reserve. W.S. = Wildlife Sanctuary.

Exhibit 11

Occupancy of wild southern pig-tailed macaques in intact and degraded forests in Peninsular Malaysia

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ABSTRACT

Deforestation is a major threat to terrestrial tropical ecosystems, particularly in Southeast Asia where human activities have dramatic consequences for the survival of many species. However, responses of species to anthropogenic impact are highly variable. In order to establish effective conservation strategies, it is critical to determine a species' ability to persist in degraded habitats. Here, we used camera trapping data to provide the first insights into the temporal and spatial distribution of southern pig-tailed macaques (*Macaca nemestrina*, listed as 'Vulnerable' by the IUCN) across intact and degraded forest habitats in Peninsular Malaysia, with a particular focus on the effects of clear-cutting and selective logging on macaque occupancy. Specifically, we found a 10% decline in macaque site occupancy in the highly degraded Pasoh Forest Reserve from 2013 to 2017. This may be strongly linked to the macaques' sensitivity to intensive disturbance through clear-cutting, which significantly increased the probability that *M. nemestrina* became locally extinct at a previously occupied site. However, we found no clear relationship between moderate disturbance, *i.e.*, selective logging, and the macaques' local extinction probability or site occupancy in the Pasoh Forest Reserve and Belum-Temengor Forest Complex. Further, an identical age and sex structure of macaques in selectively logged and completely undisturbed habitat types within the Belum-Temengor Forest Complex indicated that the macaques did not show increased mortality or declining birth rates when exposed to selective logging. Overall, this suggests that low to moderately disturbed forests may still constitute valuable habitats that support viable populations of *M. nemestrina*, and thus need to

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be protected against further degradation. Our results emphasize the significance of population monitoring through camera trapping for understanding the ability of threatened species to cope with anthropogenic disturbance. This can inform species management plans and facilitate the development of effective conservation measures to protect biodiversity.

Subjects Conservation Biology, Ecology, Zoology
Keywords Camera trapping, Deforestation, Imperfect detection, *Macaca nemestrina*, Southern pig-tailed macaques, Occupancy, Peninsular Malaysia, Selective logging

INTRODUCTION

Tropical rainforests are highly complex ecosystems that exhibit exceptional biodiversity (*Gallery, 2014*). Yet, continuing human population growth, expanding infrastructure and the intensive cultivation of crops lead to dramatically increasing deforestation rates, which are the major threat to these remarkable habitats (*Rosa et al., 2016*). Southeast Asia, for example, one of the world's most biodiverse regions and home to many charismatic primate species (*Myers et al., 2000*; *Sodhi et al., 2010*), has lost about 80 million hectares of forest between 2005 and 2015 (*Estoque et al., 2019*).

It is well known that human land use drastically reduces biodiversity and important ecosystem functions of primary forests (*Marques et al., 2019*; *Alroy, 2017*; *Barnes et al., 2014*). Degraded habitats, such as forest fragments, monocultures or urban environments, were shown to include on average 41% fewer species than undisturbed forests (*Alroy, 2017*). Numerous studies have highlighted the negative impact of forest clear-cutting on biodiversity, with the conversion of tropical forests into oil palm plantations being the main driver of deforestation in many Southeast Asian countries (*Koh & Wilcove, 2007*; *Fitzherbert et al., 2008*). The establishment of oil palm monocultures does not only imply severe losses in species richness but also substantially contributes to habitat fragmentation and environmental pollution through chemical fertilizers or pesticide runoffs (reviewed in *Fitzherbert et al., 2008*). Particularly, larger mammals and specialized bird species that have a narrow dietary spectrum may have difficulties in permanently adapting to and surviving in these monocultural landscapes (*Danielsen & Heegaard, 1995*; *Fitzherbert et al., 2008*). The negative effects of habitat degradation on animal populations may further be reinforced by the increase of so-called 'edge effects', describing ecological alterations that result from the development of abrupt, artificial edges of forest fragments (*Didham et al., 1998*). Forest edges open the canopy and dry out the wood, which increases the susceptibility of forests to fire (*Cochrane, 2003*).

Selective logging is one of the most widespread, albeit less intensive, forms of habitat degradation (*Asner et al., 2005*). It refers to the removal of a limited number of economically valuable tree species of a given age in a particular area and/or during a distinct logging cycle (*Johns, 1985*). However, it also implies secondary threats, such as an increased hunting pressure from local communities, as logging roads facilitate human access to forests (*Robinson, Redford & Bennett, 1999*; *Milner-Gulland & Bennett, 2003*). Previous research suggested that selective timber extraction may have less severe effects on species diversity and abundance than more intensive forms of land use change, *e.g.*, through clear-cutting (*Ibarra et al., 2017*; *Gibson et al., 2011*). However, *Tobias (2015)* highlighted the high variability in the reaction of different species to habitat degradation, with both logging practices as well as species traits, such as diet and body mass, being important factors in determining the effects of selective timber harvesting on wildlife abundance. This is in line with other studies suggesting that generalist feeding tendencies in particular are indicative of the ability of a species to persist in selectively logged habitats (*Vetter et al., 2011*; *Burivalova et al., 2015*). Indeed, some species were found to have a higher abundance in moderately disturbed compared to primary forest habitats, including several ungulates (*Brodie, Giordano & Ambu, 2015*), rodents, and granivorous bird species (*Bicknell & Peres, 2010*). Carnivores, as well as frugivorous forest specialists, on the other hand, were often reported to be confined to undisturbed primary forests (*Brodie, Giordano & Ambu, 2015*; *Tobias, 2015*). In this context, caution is needed when inferring the adaptive capacity of one species from the response of another.

Malaysia is a biodiversity hotspot with high primate diversity but much of its primary forest is being converted into new oil palm plantations, quarries and urban areas (*Vijay et al., 2016*; *Omran & Schwarz-Herion, 2020*). During the past decade, the country has lost 11.3% of its primary forest and 16.8% of tree cover (*Mongabay, 2021*). As reported by the International Union for Conservation of Nature (*IUCN, 2020*), more than one fourth of Malaysia's mammals are threatened with extinction. Among them are 25 non-human primates (hereafter 'primates'; *Roos et al., 2014*), one of which is the southern pig-tailed macaque (*Macaca nemestrina*), a little-studied, predominantly terrestrial species native to the tropical rainforests of Malaysia, Indonesia and southern Thailand (*Ang et al., 2020*). The macaques' diet consists primarily of fruits (*Caldecott, 1986*), indicating their value as seed dispersers (*Ruppert, Mansor & Anuar, 2014*) and, consequently, their potential role in forest regeneration (*Albert et al., 2014*). However, it also suggests that they are frugivorous forest specialists with limited ecological flexibility. The dramatic decline of primary forest habitat in the primates' range, human hunting of macaques for food and the pet trade, and their widespread perception as crop pests have contributed to rapidly decreasing populations during the past few decades (*Linkie et al., 2007*; *Ang et al., 2020*). Only recently, *Ang et al. (2020)* confirmed the macaques' negative population trend and its current status as 'Vulnerable' (*IUCN, 2020*). *Meijaard et al. (2007)* reported a generally high sensitivity of this species to logging, yet the macaques' response to human disturbance remains poorly understood (*Ang et al., 2020*). To date, we lack detailed knowledge on *M. nemestrina*'s distribution, their abundance as well as their ability to cope in anthropogenically impacted habitats. However, these issues are crucial to understand in order to establish effective protection measures ensuring the long-term survival of this and other threatened wildlife species affected by human activities.

Using available camera trapping data, we provide the first insights into the impact of forest degradation through tree felling on the occupancy of *M. nemestrina* in Peninsular Malaysia. In order to obtain a broad picture of the effects of human activities on this species, the study comprised two sites that are characterized by different degrees of human disturbance. Firstly, we used a dynamic occupancy modelling approach

(*MacKenzie et al., 2003*) to assess temporal changes in the macaques' distribution as well as factors potentially impacting dynamics in site occupancy in the highly disturbed Pasoh Forest Reserve (PFR), which was affected by partial clear-cutting and selective logging from 2013 to 2017. Secondly, we investigated the macaques' spatial distribution within the Belum-Temengor Forest Complex (BTFC) from 2011 to 2013, focusing on differences between the undisturbed, strictly protected Royal Belum State Park and the selectively logged Temengor Forest Reserve. This direct comparison enables a better understanding of the immediate effects of selective timber extraction on the site occupancy of *M. nemestrina*. Finally, we assessed potential differences in the macaques' age and sex structure in undisturbed as well as selectively logged forests within BTFC. This can inform about vital parameters of population dynamics, particularly breeding success and survival, and therefore be indicative of population health.

Although *M. nemestrina* readily leaves its natural forest habitat to enter oil palm plantations in search of food (*Ruppert et al., 2018*; *Holzner et al., 2019*), it is described as a shy and elusive macaque species that tends to avoid human-dominated areas (*Bernstein, 1967*; *Oi, 1990*). Recent studies highlighted the macaques' dependency on primary forest habitat as a safe retreat to sleep and socialize (*Ruppert, Mansor & Anuar, 2014*; *Holzner et al., 2021*), confirming previous doubts on their ability to permanently persist in highly disturbed habitats (*Caldecott, 1986*). Accordingly, we predicted that forest clearance negatively affects the macaques' ability to occupy a specific habitat, and hence a general decline in site occupancy in PFR during the sampling period. As a predominantly frugivorous species, *M. nemestrina* may also be sensitive to less intensive forms of habitat degradation, such as selective timber harvesting. Thus, we predicted macaques site occupancy to be lower in selectively logged compared to undisturbed forests within BTFC. In line with this, we predicted measures describing the accessibility of a site to humans, such as the distance to the nearest human settlement or the forest edge, to negatively affect macaque site occupancy. These may serve as a proxy for hunting pressure, which has been suggested to be one of the major risks to wildlife in disturbed habitats (*Milner-Gulland & Bennett, 2003*; *Tilker et al., 2019*). In addition, environmental factors may influence macaque site occupancy. Based on previous studies (*Yanuar et al., 2009*; *McCain & Grytnes, 2010*; *Ang et al., 2020*), we predicted elevation, defining different floristic zones and thus food availability, to be an indicator of the suitability of a site for *M. nemestrina*. *Yanuar et al. (2009)* reported that this species is best adapted to lowland and hill dipterocarp forests up to 900 m above sea level. Importantly, anthropogenic impact on animals' natural habitats may further be associated with demographic changes in wildlife populations (*Klass, Belle & Estrada, 2020*; *Shil, Biswas & Kumara, 2020*). Particularly, a proportionally low number of juveniles resulting from low birth rates can be indicative for a declining population (*Rudran & Fernandez-Duque, 2003*; *Shil, Biswas & Kumara, 2020*). Moreover, skewed adult sex ratios have previously been linked to increased mortality within the dispersing sex in animal populations, owing to the risk of migration (*Zunino et al., 2007*; *Klass, Belle & Estrada, 2020*). Accordingly, we finally predicted differences in the macaques' age and sex structure between habitats with varying degrees of disturbance. Specifically, we hypothesized the ratio of immature to adult individuals to be lower and the adult sex ratio to be less balanced, potentially with a surplus of females, in disturbed, *i.e.*, selectively logged, forests compared to undisturbed primary forests within the BTFC. As is true for most Cercopithecine primates, female southern pig-tailed macaques are philopatric and form the core of social groups, while male individuals leave their natal group at sexual maturity to breed elsewhere (*Cords, 2012*).

METHODS

Study sites

Our study was conducted at two different sites in Peninsular Malaysia, which are characterized by different degrees of human impact. One site is located within the highly disturbed Pasoh Forest Reserve (PFR) in the state of Negeri Sembilan (102°31′0″E, 2°98′0″N). Large parts of the 140 km^2 sized PFR were logged between the 1950s and 1970s, today comprising regenerating lowland forest. Only its 4 km^2 core area still consists of virgin primary forest (*Fletcher et al., 2012*). Also today, PFR is subject to clear-cutting and selective logging. It is surrounded by oil palm plantations. The second study site is located within the Belum-Temengor Forest Complex (BTFC) in the state of Perak (101°15′0″-101°46′0″E, 5°55′0″-5°0′0″N). BTFC is less intensively impacted by human activities than PFR. With a size of approximately 3,000 km^2, it forms part of the second-largest contiguous forest complex in Peninsular Malaysia, comprising lowland, hill and upper dipterocarp, as well as montane forest (*Rayan & Linkie, 2016*). The Gerik-Jeli Highway divides the forest complex into two areas, *i.e.*, the strictly protected Royal Belum State Park (hereafter 'Belum') in the north, and the Temengor Forest Reserve (hereafter 'Temengor'), where selective logging has been ongoing since the 1970s, in the south (*Rayan & Linkie, 2016*).

Camera trap setup

This study is based on camera trap data originally collected to assess habitat use of mainland clouded leopards (*Neofelis nebulosa*) in PFR (*Tan et al., 2017*) as well as density and habitat use of Malayan tigers (*Panthera tigris jacksoni*), occupancy of ungulates and interactions between large carnivores in BTFC (*Rayan & Linkie, 2015*, *2016*, *2020*). All necessary permits and support letters from the Perak State Parks Corporation, the Department of Wildlife and National Parks and the Forestry Department of Perak were acquired prior to data collection. Due to the non-invasive nature of observational studies based on camera trapping, no institutional ethical approval was required.

Detection data of *M. nemestrina* from PFR were provided by the Tropical Ecology Assessment and Monitoring (TEAM) Network (*Fletcher & Campos-Arceiz, 2011*). In PFR, camera trapping was conducted from 2013 to 2017. Each camera trap was active for an average of 32 (standard deviation SD 5) consecutive days per year. The camera setup covered an area of 120 km^2, including a grid of 60 cameras. The spacing between cameras was approximately 1.5 km. Camera images of macaques detected in BTFC were provided by D. Mark Rayan and WWF Malaysia. Here, camera trapping was conducted from 2009 to 2011. Camera traps were active for an average of 87 (SD 32) consecutive days between August 2009 and May 2010 in Temengor, and 82 (SD 19) consecutive days between August 2010 and April 2011 in Belum. The camera setup covered an area of approximately 400 km^2 in each habitat (Rayan & Linkie, 2015). A grid of 70 cameras was created in Belum and Temengor, respectively, with each grid cell covering 2 × 2 km. To increase spatial coverage, the cameras were moved within the grid after 3 to 4 months of operation, resulting in 140 distinct camera locations. The sampling blocks within Belum and Temengor were selected to represent the entire forest by taking into account the proportion of different vegetation types (Rayan & Linkie, 2015).

The placement of camera traps (RECONYX and SONY P41) in PFR and BTFC was chosen to ensure an average distance of about 1 km between traps (Fig. 1). As the approximate home range size of *M. nemestrina* is 1 km^2 (Ruppert et al., 2018; Holzner et al., 2019), a macaque group was unlikely to be detected by two different cameras, ensuring spatial independence between sites. Camera traps were active for 24 h per day and set to take photos at 10-s intervals. They were fixed to trees at a height of approximately 50 cm above the ground. Ground trapping (as opposed to placing cameras higher up in the trees) was reasonable for this species, as *M. nemestrina* has previously been described as a predominantly terrestrial primate, spending on average 56% of its active time on the forest ground (Ruppert et al., 2018). GPS locations of the cameras were recorded using Garmin GPSMAP® 60CSX hand-held GPS units.

The rationale behind including data from two different sites, *i.e*., PFR and BTFC, despite methodological differences was to provide a broader perspective on how distinct forms of human disturbance may differentially affect macaque site occupancy, and thus to increase the analytical power of this study. While PFR represents a highly degraded habitat that is affected by partial clear-cutting, data from BTFC may specifically inform about the potential impact of selective logging. Further, the analysis of PFR was specifically focused on describing dynamics in pig-tailed macaque site occupancy over time, whereas the analysis of BTFC focused on providing thorough insight into spatial differences between undisturbed and selectively logged forests.

Detection histories

Based on presence and absence data obtained from photographic records, we constructed detection histories for each camera site in PFR and BTFC. For repeated sampling occasions, we recorded a '1' when macaques were detected and a '0' when no macaques were detected even though a camera trap was active, either because they were truly absent from a particular site or because they were outside the detection range of a camera trap. Referring to previous studies (Tan et al., 2017; Semper-Pascual et al., 2020), we pooled daily detection/non-detection records for each camera site into sampling occasions of seven (PFR) and 14 (BTFC) consecutive days, respectively, in order to minimize the risk of temporal interdependence among occasions and to increase the overall detection probability. The periods of 1 and 2 weeks, respectively, were chosen to maximize the model fit according to the different data collection methods used across sites, as low probabilities of detection can prevent model convergence (Dillon & Kelly, 2007; Tan et al., 2017). As several camera traps within BTFC intermittently failed to record data for at least two sampling occasions and thus were excluded from analysis, the final datasets of Belum

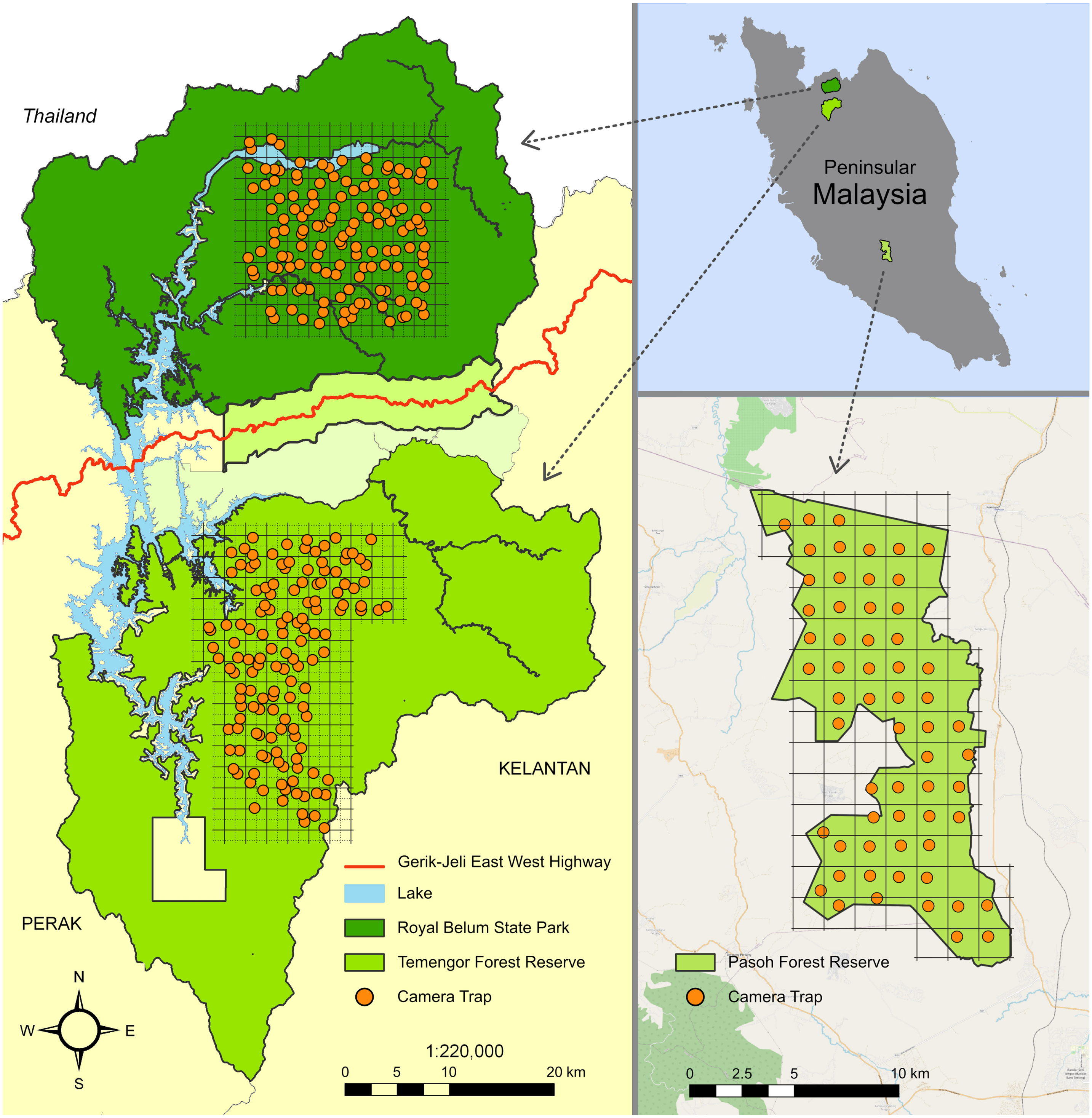

Figure 1 **Study sites in Peninsular Malaysia.** The maps indicate the camera trap distribution in the Belum Temengor Forest Complex (left) and Pasoh Forest Reserve (right). Adapted from *Darmaraj (2012)*. Full size DOI: 10.7717/peerj.12462/fig 1

and Temengor included 129 and 125 camera sites, respectively. In PFR, all 60 camera traps were functioning. The total number of sampling occasions per year ranged between two and nine (mean ± SD 5.5 ± 2.0) in PFR and between two and eleven (mean ± SD 7.0 ± 1.9) in BTFC.

Occupancy modelling

Using a maximum likelihood approach, occupancy models account for imperfect detection by linking a state model determining occupancy (ψ, *i.e.*, the probability with which a species occurs at a specific site) with an observation model determining detection probability (p, *i.e.*, the ability to detect a species when it is present) based on repeated samples from the same site (*MacKenzie et al., 2002*). Variation in probabilities across sampling sites and observation periods can be modelled using site-specific (*e.g.*, habitat variables) and observation-specific (*e.g.*, the sampling effort) covariates.

Firstly, to assess temporal changes in the macaques' distribution in the PFR, we fit the dynamic occupancy model described by *MacKenzie et al. (2003)*. This assesses site occupancy dynamics over multiple seasons by estimating, besides detection (p) and first year occupancy (ψ), the probabilities of colonization (γ, *i.e.*, the probability that a species is present at a previously unoccupied site) and extinction (ε, *i.e.*, the probability that a species is absent at a previously occupied site, *MacKenzie et al., 2003*). We included the mean elevation per camera grid cell (range 94–664 m, mean ± SD 295 ± 156 m) and the shortest distance to the forest edge (range 5–2,865 m, mean ± SD 1,076 ± 695 m) as potential predictors for first year ψ. Both altitude, as well as edge effects, which are likely to affect microclimate and tree communities in areas near the forest border, are known to be important factors in predicting the distribution of wildlife species, including primates (*McCain & Grytnes, 2010*; *Brodie, Giordano & Ambu, 2015*). Further, a shorter distance of a camera site from the forest edge may facilitate human access and thus increase the hunting pressure (*Milner-Gulland & Bennett, 2003*). Additionally, we modelled variation in γ and ε using a yearly site-specific categorial covariate describing differences in the occurrence and intensity of forest degradation through tree felling between camera sites and sampling years. Based on previous studies reporting a high variation in species' responses depending on the severity of human activity (*Gibson et al., 2011*; *Tobias, 2015*), we distinguished between clear-cutting, *i.e.*, land use change resulting in the loss of the entire forest cover in a specific area, selective logging, *i.e.*, the removal of a limited number of economically valuable trees for the timber industry, and no disturbance/tree felling. As previous research highlighted that primate populations may still be critically affected several years after tree felling took place (*Shelton, 1985*; *Rao & Schaik, 1997*), we classified a site as clear-cut or selectively logged if the respective type of forest degradation occurred during the past 5 years. Finally, we included the survey effort, *i.e.*, the number of days a camera trap was active during a sampling occasion (range 1–7, mean ± SD 6.0 ± 1.8 days), the sampling month (Jan, Feb, May–Dec), and the sampling year (2013–2017) as predictors for p in order to account for seasonal variation and the effects of abiotic factors on the macaques' activity (*Takemoto, 2004*;

Hanya et al., 2018). Based on the six predictor variables, we constructed the full model and subsequently built candidate models with all possible combinations of predictor sets.

Secondly, to assess the macaques' spatial distribution within the BTFC, we fit a single-season occupancy model (*MacKenzie et al., 2002*). We are confident that our dataset, including sampling periods of a maximum length of 5 months, meets the closure assumption of occupancy modelling (*i.e.*, that the occupancy status of a site does not change during the sampling, *MacKenzie et al., 2002*), as previous studies suggested home range areas of *M. nemestrina* to be stable even over several years (*Ruppert et al., 2018*; *Holzner et al., 2019*). As above, we included the mean elevation per grid cell (range 323–1,664 m, mean ± SD 737 ± 302 m) as a potential predictor for ψ. To account for the effects of habitat degradation on ψ, we further modelled the habitat type (undisturbed Belum or selectively logged Temengor) and the mean Normalized Difference Vegetation Index (NDVI, range 0.45–0.85, mean ± SD 0.78 ± 0.05). The NDVI estimates the density of green on a patch of land by measuring differences between visible and near-infrared reflectance of vegetation cover, thus having frequently been used as a proxy to describe the bio-structural changes in vegetation caused by land clearing and logging (*Weier & Herring, 2000*; *Rayan & Linkie, 2015*; *Hamel et al., 2009*). It was computed using ASTER satellite images from 2008 to 2011 with a 15-m spatial resolution (*Rayan & Linkie, 2015*). Additionally, we included the distance to the nearest human settlement, including indigenous villages and logging camps in the forest (range 662–20,643 m, mean ± SD 8,099 ± 4,756 m), as this may be indicative of the intensity of human hunting of macaques at a camera site (*Milner-Gulland & Bennett, 2003*). Unlike in PFR, we did not expect pronounced edge effects in BTFC, as it comprises huge areas of continuous forest habitat, with the majority of camera traps being located several kilometres from the forest border. The approximate home range area of *M. nemestrina*, on the other hand, is only 1 km^2. Finally, to account for variation in p, we included the survey effort (range 1–14 days, mean ± SD 12.1 ± 3.6 days) and the sampling month (Jan–May, Aug–Dec) as observation-specific predictors into the model. As described above, we constructed the full model based on all six predictor variables and then built candidate models with all possible combinations of these predictors.

We fitted the occupancy models for PFR and BTFC, respectively, using the functions *colext* and *occu* from the package 'unmarked' (version 1.0.1, *Fiske & Chandler, 2011*) in R (version 3.4.4, *R Core Team, 2018*). To facilitate model interpretation and convergence, we standardized all continuous predictors before model fitting to a mean of zero and a standard deviation of one (*Schielzeth, 2010*). We checked for collinearity between continuous covariates using Spearman's rank correlation. Covariates were considered independent if their correlation coefficient $|r_s| \leq 0.7$ (*Dormann et al., 2013*). This was the case for all covariate pairs included in the same model. We drew inference using multi model inference based on Akaike's information criterion (AIC, *Burnham & Anderson, 2002*). Following recommendations of *MacKenzie (2006)*, we first modelled detection, identifying a suitable covariate structure for p while holding ψ and, in the dynamic model of PFR, γ and ε at the most general model including all covariates. Having identified the most parsimonious model structure for p, we kept this constant and modelled occupancy, colonization, and extinction, respectively. This two-step approach may be advantageous over maintaining a general model for p, as it reduces the number of parameters being estimated (*MacKenzie, 2006*). We assessed the role of our covariates on ψ, γ and ε by ranking all candidate models according to their AIC corrected for small sample sizes (AIC_c, *Burnham & Anderson, 2002*). We considered top-ranked models as those with $\Delta AIC_c \leq 2$ (*Burnham & Anderson, 2002*). Model estimates were obtained by averaging over all candidate models using the zero method (*Nakagawa & Hauber, 2011*). We tested the goodness of fit of the global models by comparing the observed Chi-square statistics to respective reference distributions calculated from 1,000 parametric bootstraps (*MacKenzie & Bailey, 2004*). This indicated no lack of fit for both models (both $P > 0.05$, further details and R functions used in Supplemental Methods).

Assessment of the macaques' age and sex structure

To gain a deeper insight into the viability of *M. nemestrina* in selectively logged forests, we compared age and sex ratios in the macaque populations in Belum and Temengor, respectively, based on camera trap images. Due to a combination of time constraints for completing analyses, and the fact that images were not immediately accessible from PFR, which would have required time to individually download, organise and review before age and sex classifications could be established, this assessment was restricted to BTFC.

Each individual detected was identified as adult male, adult female, subadult, juvenile, or infant according to its body size, sexual characteristics (*e.g.*, anogenital swelling and elongated nipples in females or prominent testes in males, *Bullock, Paris & Goy, 1972*), or individual behaviour (*e.g.*, juveniles ranging in frequent proximity to their mother or infants nipple holding). Individuals that were partly hidden from view and thus could not be clearly assigned to either of these categories were marked as 'unknown'. We then summed the number of independent detections in each age and sex class, separately for each of the two habitats. Following *O'Brien, Kinnaird & Wibisono (2003)* and *Kafley et al. (2019)*, we defined independent detections as (1) consecutive photographs of identifiable different individuals based on their unique characteristics, (2) consecutive photographs of individually unrecognizable macaques of the same age and sex class taken more than 30 min apart, or (3) non-consecutive photographs of individuals of the same age and sex class. As described above, spatial independence between camera sites was assumed due to the generally small home range size of approximately 1 km^2 of *M. nemestrina* (*Ruppert et al., 2018*; *Holzner et al., 2019*). The identification of individuals in images across cameras was not possible in the framework of this study. We assessed differences in the macaques' age and sex structure between Belum and Temengor using a Chi-square test for independence.

RESULTS

Detection of macaques in PFR and BTFC

Within PFR, we detected *M. nemestrina* during 42.3% of in total 1,636 independent sampling occasions. The naïve occupancy, *i.e.*, the proportion of camera sites with at least

Table 1 Top ranked *Macaca nemestrina* detection models ($\Delta AIC_c \leq 2$) for Pasoh Forest Reserve (PFR) and Belum Temengor Forest Complex (BTFC) with global occupancy models. Shown are Akaike's Information Criterion corrected for small samples (AIC_c), differences in AIC_c between each model and the respective best model (ΔAIC_c), the probability of each model to the best model, *i.e.*, the Akaike weights (wAIC), and the number of parameters (K, details on model selection and model averaged estimates for all covariates in Tables S1 and S2).

Site	Top ranked models	AIC_c	ΔAIC_c	wAIC	K
PFR	*p* (effort + sampling year)	2,069.5	0	1	15
BTFC	*p* (effort + sampling month)	1,238.6	0	0.995	16

one detection (*MacKenzie et al., 2006*), ranged between 0.80 and 0.93 during the 5-year sampling period, with the highest rate recorded in 2013. In the BTFC, macaques were present during 13.3% of 1,774 sampling occasions. The naïve occupancy was 0.53 in the undisturbed forest of Belum and 0.39 in the selectively logged forest of Temengor.

Based on AIC_c, camera trapping effort and the sampling date significantly contributed to explaining the variation in the detection probability of *M. nemestrina* (Table 1). Specifically, detection was positively correlated with the number of trapping days at both study sites, *i.e.*, PFR and BTFC (model estimate ± standard error (PFR/BTFC) 0.51 ± 0.06/0.61 ± 0.12), and varied between sampling year and sampling month, respectively, indicating the presence of seasonal effects (details in Table S2). The mean estimated detection probability across all camera sites was 0.48 (SD 0.15) in PFR and 0.23 (SD 0.11) in BTFC.

Temporal changes in macaque site occupancy in the highly disturbed PFR

Using a dynamic occupancy modelling approach, we aimed at predicting temporal changes in macaque site occupancy as well as their potential causes in PFR. The initial occupancy probability of *M. nemestrina* in PFR was estimated to be 0.95 (standard error (SE) 0.03), when fixing elevation and the distance to the forest edge at their mean values. Macaque site occupancy in subsequent years was found to decrease by 10% from 0.95 in 2013 to 0.85 in 2017 (Fig. 2).

Further, we assessed the role of environmental and anthropogenic factors in predicting occupancy, colonization and extinction in PFR. Accordingly, only the top-ranked model, including forest degradation (arising from tree felling through clear-cutting or selective logging) as a predictor for extinction, received substantial support ($\Delta AIC_c \leq 2$, Table 2). In line with this, model-averaged coefficients corroborated the effect of forest degradation on the local extinction probability of *M. nemestrina* in PFR (Table 3). Specifically, we found that the macaques were approximately 6 times more likely to be absent at a previously occupied camera site in areas affected by clear-cutting compared to undisturbed forest patches (Fig. 3). No significant effect could be found for selective logging, yet large confidence intervals indicate a high variability in the response of *M. nemestrina* to this less intensive form of habitat degradation, potentially relating to small sample sizes as well as different practices and intensities of selective timber

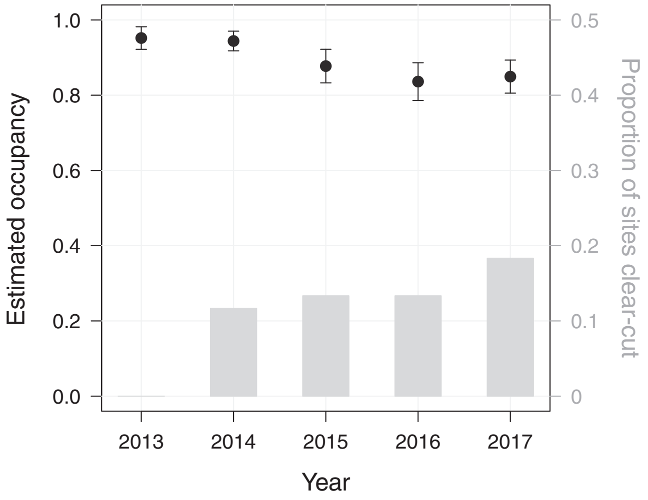

Figure 2 **Dynamics in *Macaca nemestrina* occupancy in the Pasoh Forest Reserve from 2013 to 2017.** Shown are site occupancy estimates, *i.e.*, the predicted proportion of sampled sites that are occupied, and their standard errors ($N = 60$). The bars indicate the cumulative proportion of sites at which clear cutting occurred.

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Table 2 **Top ranked *Macaca nemestrina* occupancy models ($\Delta AIC_c \leq 2$) for Pasoh Forest Reserve (PFR) and Belum Temengor Forest Complex (BTFC) with best respective detection models.** Shown are Akaike's Information Criterion corrected for small samples (AIC_c), differences in AIC_c between each model and the respective best model (ΔAIC_c), the probability of each model to the best model, *i.e.*, the Akaike weights (wAIC), and the number of parameters (K, details on model selection in Table S3).

Site	Top ranked models	AIC_c	ΔAIC_c	wAIC	K
PFR	ψ (.) γ (.) ε (forest degradation)	2,056.4	0	0.633	11
BTFR	ψ (elevation)	1,232.1	0	0.415	13

harvesting (Fig. 3). Further, low model-averaged coefficients and 95% confidence intervals including zero suggest that both elevation and the distance of a camera site to the forest edge did not significantly affect macaque site occupancy in PFR (Table 3).

Macaques' spatial distribution in undisturbed and selectively logged forests within BTFC

To better understand the effects of selective logging on *M. nemestrina*, we assessed the macaque distribution as well as the covariate structure that best explains variation in occupancy probabilities within BTFC. Unlike in PFR, we found evidence that elevation had a strong effect on site occupancy in BTFC, as indicated by its inclusion in the top-ranked model ($\Delta AIC_c \leq 2$, Table 2). Specifically, occupancy probability was found to significantly decrease with increasing elevation (Table 3, Fig. 4). Further, low model-averaged coefficients and comparatively large 95% confidence intervals suggest that occupancy did not significantly differ between habitats. Predicted occupancy probabilities in the strictly protected forest of Belum and the selectively logged forest of Temengor were 0.59 (SE 0.08) and 0.58 (SE 0.09), respectively, when fixing all other covariates at

Table 3 Effect of covariates on *Macaca nemestrina* occupancy, colonization and extinction in the Pasoh Forest Reserve (PFR) and Belum Temengor Forest Complex (BTFC). Shown are model averaged estimates (zero method), standard errors (SE) and lower and upper 95% confidence intervals (CI). Predictors included into the respective top models ($\Delta AIC_c \leq 2$) are indicated in bold.

Site	Parameter	Covariate	Estimate	SE	lower CI	upper CI
PFR	Occupancy ψ	distance to edge[a]	−0.03	0.29	−1.47	1.14
		elevation[a]	−0.04	0.29	−1.51	1.12
	Colonization γ	forest degradation (no *vs.* clear cut)[b]	0.02	0.33	−2.58	3.58
		forest degradation (no *vs.* selective)[b]	−0.01	0.34	−3.52	2.81
	Extinction ε	**forest degradation (no *vs.* clear cut)**[b]	**2.25**	**0.69**	**1.13**	**3.48**
		forest degradation (no *vs.* selective)[b]	**0.60**	**1.06**	**−1.47**	**2.70**
BTFC	Occupancy ψ	habitat (Belum = 0, Temengor = 1)	−0.001	0.23	−0.90	0.90
		NDVI[a]	0.02	0.10	−0.28	0.45
		distance to settlement[a]	−0.01	0.11	−0.46	0.35
		elevation[a]	**−1.17**	**0.23**	**−1.62**	**−0.73**

Notes:

[a] z transformed to mean 0 and SD 1 prior to model fitting; original means ± SDs were: distance to edge: 1,076 ± 695 m, elevation (*PFR*): 295 ± 156 m, NDVI: 0.78 ± 0.05, distance to settlement: 8,099 ± 4,756 m, elevation (*BTFC*): 737 ± 302 m.

[b] Reference level is 'no tree felling'.

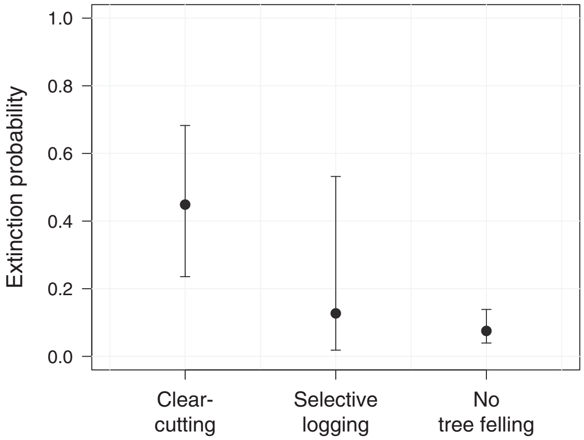

Figure 3 Effect of forest degradation on the local extinction probability of *Macaca nemestrina* in the Pasoh Forest Reserve. The filled circles show the fitted model and the whiskers its 95% confidence interval, conditional on all other predictors being fixed at their mean values. Clear cutting occurred at a total of 11 sites during the study period, while five sites were selectively logged and 44 sites remained undisturbed ($N = 60$). Full size DOI: 10.7717/peerj.12462/fig 3

their mean values. Similarly, the NDVI and distance to the closest human settlement had no effect on macaque site occupancy (Table 3).

Macaques' age and sex structure in BTFC

To explicitly examine the viability of *M. nemestrina* in selectively logged forests, we investigated whether the macaques' age and sex structure differed between intact and partially degraded habitats within BTFC. We detected a total of 614 and 695 individual macaques in Belum and Temengor, respectively, 96% of which could be unambiguously

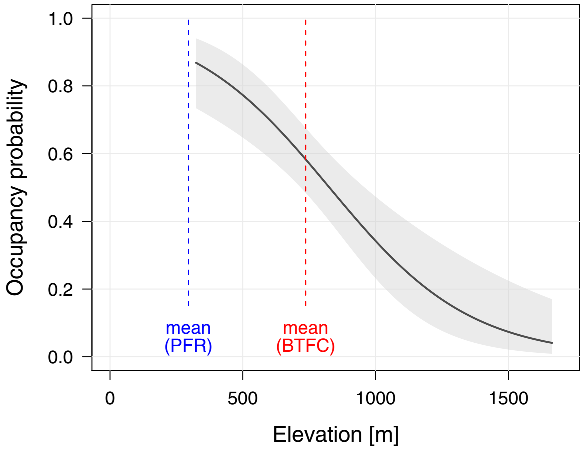

Figure 4 **Effect of elevation on site occupancy of *Macaca nemestrina* in the Belum Temengor Forest Complex.** The solid line shows the fitted model and the shaded areas its 95% confidence interval, conditional on all other predictors being fixed at their mean values ($N = 254$). The dashed lines indicate the mean elevation at the two study sites, *i.e.*, the Belum Temengor Forest Complex (BTFC) and Pasoh Forest Reserve (PFR). Full size DOI: 10.7717/peerj.12462/fig 4

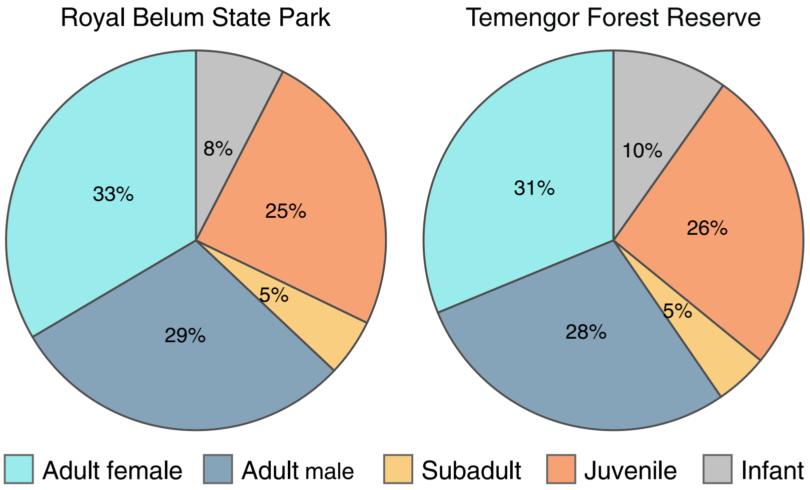

Figure 5 **Age sex structure of *Macaca nemestrina* in the Belum Temengor Forest Complex.** The pie charts indicate the proportion of independent detections of each age sex category, separately for the Royal Belum State Park (Belum, $N = 594$) and Temengor Forest Reserve (Temengor, $N = 663$). Full size DOI: 10.7717/peerj.12462/fig 5

assigned to an age and sex class. Chi-square test of independence did not reveal significant differences in the age and sex ratio between the undisturbed forest of Belum and the selectively logged forest of Temengor ($\chi^2 = 0.45$, df = 4, $p = 0.98$). In both habitats, approximately 60% of detected individuals were adults, while 40% of detections were immatures including subadults, juveniles and infants (Fig. 5).

DISCUSSION

Globally, increasing human encroachment into natural habitats is a major cause of biodiversity loss (*Marques et al., 2019*), yet previous studies have highlighted the high variability in species' ability to cope with anthropogenic impact (*Brodie, Giordano & Ambu, 2015*). This study provides the first insights into the distribution of *M. nemestrina* across intact and degraded forest habitats in Peninsular Malaysia, focusing on the effects of tree felling on macaque occupancy over time and space. Specifically, clear-cutting significantly increased the probability that *M. nemestrina* became locally extinct at a previously occupied site as compared to a site without tree felling, likely accounting for the considerable decline in site occupancy observed in PFR during the 5-year study period from 2013 to 2017. However, there was no difference in the extinction probability of *M. nemestrina* between selectively logged and undisturbed sites within PFR, which is consistent with our findings from BTFC where occupancy probabilities did not depend on whether a site was located in the strictly protected forest of Belum or the selectively logged forest of Temengor. Importantly, all occupancy measures were obtained while controlling for differences in the detection probability of *M. nemestrina* between the study sites. Finally, there were no differences in the macaques' age and sex structure between Belum and Temengor, suggesting that low to moderate habitat degradation, such as selective logging, is not necessarily linked to declining populations, as would be indicated by an increased ratio of adults to immatures (*Rudran & Fernandez-Duque, 2003*; *Shil, Biswas & Kumara, 2020*). Rather, this species may be able to maintain viable populations in selectively logged forests. Further, similar sex ratios do not imply negative effects of selective timber harvesting on the survival of dispersing males (*Rudran & Fernandez-Duque, 2003*; *Zunino et al., 2007*; *Klass, Belle & Estrada, 2020*).

As one of the world's leading palm oil producers, Malaysia continues to be affected by deforestation, which has dramatic consequences for many tropical species that rely on primary rainforest (*Vijay et al., 2016*; *Estrada et al., 2017*). Our results provide evidence that southern pig-tailed macaques are particularly threatened by intensive forest clearance. Clear-cutting for the purpose of converting natural forest, whether undisturbed or previously selectively logged, into other land use forms, including agricultural land, is likely to dramatically reduce the suitability of a habitat for this species. In degraded forests, wildlife may suffer from habitat fragmentation, reduced availability of natural food sources, and a high human hunting pressure facilitated by the increased accessibility to the remaining forest patches (*Johns, 1985*; *Tilker et al., 2019*). Previous studies emphasized the primates' dependency on preserved natural forests in and around these highly disturbed landscapes to successfully disperse and reproduce (*Ancrenaz et al., 2021*), as well as to perform the full range of their natural behavioural repertoire (*Holzner et al., 2021*). The latter includes the formation of strong social relationships, which are critical characteristics of group-living animals owing to their crucial link to individual fitness (*Cameron, Setsaas & Linklater, 2009*; *Schülke et al., 2010*; *Ellis et al., 2019*) and offspring survival (*Silk, Alberts & Altmann, 2003*).

In the light of the rising global demand for palm oil, it is inevitable to focus conservation actions on reducing the negative environmental impacts of oil palm monocultures. Recent research has assessed the viability of potential palm oil substitutes, such as sunflower and coconut oil or single cell oil from yeast and microalgae (*Parsons, Raikova & Chuck, 2020*). Yet, due to its high-per hectare yield and unique lipid profile, palm oil still outweighs the available alternatives (*Parsons, Raikova & Chuck, 2020*). Therefore, the promotion of sustainable practices in the palm oil sector, including the avoidance of further deforestation, the refrainment from the use of chemical fertilizer and pesticides, as well as the establishment of green corridors and buffer zones, is of utmost importance to allow animals to pertain and survive in the forest-plantation matrix, and thus to prevent further loss of wildlife biodiversity.

Unlike clear-cut habitats, less intensively disturbed, selectively logged forests, may indeed sustain viable macaque populations under certain conditions. In this context, elevation in particular appears to be an important factor in predicting whether macaques occur at a given site. This is unsurprising, as elevation defines different floristic zones and thus determines food availability for a variety of species, such as the predominantly frugivorous southern pig-tailed macaque (*Saw, 2010*). Previous studies have highlighted the impact of elevation on the occurrence and abundance of wildlife. *McCain & Grytnes (2010)*, for example, found a general trend of declining species richness with increasing elevation across multiple taxa, including small mammals, reptiles, and amphibians. Further, *Campera et al. (2020)* reported a strong negative correlation between lemur abundance and elevation in the Malagasy rainforests. As predicted, we found macaque site occupancy to decrease with increasing elevation in BTFC. However, PFR lacks this correlation, likely due to low variation between camera sites and generally low altitudes not exceeding 670 m (range 94–664 m). In BTFC, on the other hand, altitudes reached up to 1,600 m (range 323–1,664 m). Importantly, this difference in altitude between the study sites may explain the general discrepancy between occupancy estimates in PFR and BTFC. While large parts of the BTFC comprise hill and upper dipterocarp forest of mid altitude as well as montane forest (*Rayan & Linkie, 2016*), PFR is a lowland rainforest (*Fletcher et al., 2012*), which was previously reported to be the preferred habitat type of *M. nemestrina* (*Yanuar et al., 2009*). This is in line with findings by *Goodman & Ganzhorn (2004)* who suggested that the average elevation used by primates in Asia is around 400 m.

Another important determinant of the ability of a species to occupy and persist in a habitat is the intensity of human activity, such as the hunting pressure. As demonstrated by *Tilker et al. (2019)*, intensive hunting by humans may be an even more immediate threat to tropical wildlife than moderate habitat degradation. Both the distance to human settlements and the distance to the forest edge were not included in our top-ranked occupancy models, indicating that hunting activities by indigenous tribes, local communities, and logging workers may have been rather low at our study sites. In BTFC, this may be closely linked to low densities of settlements, which entail greater distances averaging 8 km to camera sites.

Earlier studies suggested that species characterized by a more generalist diet, and thus a lower degree of frugivory, may thrive in partially logged habitats (*Johns & Skorupa, 1987*; *Vetter et al., 2011*). Some of these were found to even prefer disturbed environments to primary forest. Ungulates, small mammals or omnivorous and granivorous birds, for example, exhibit higher abundances in disturbed or edge-affected habitats compared to undisturbed forests (*Lambert, Malcolm & Zimmerman, 2006*; *Brodie, Giordano &*

Ambu, 2015; *Burivalova et al., 2015*). Although the main component of *M. nemestrina*'s natural diet are fruits (ca. 75%, *Caldecott, 1986*), they feed on a wide range of other foods, such as insects, leaves, mushrooms and small mammals (*Ang et al., 2020*). Southern pig-tailed macaques inhabiting a forest-oil palm matrix at the west coast of Peninsular Malaysia were reported to complement their natural forest diet with cultivated oil palm fruits and plantation rats (*Ruppert et al., 2018*; *Holzner et al., 2019*), suggesting that macaques may indeed be able to adapt their diet to changing environmental conditions, as also found for other Malaysian primates (*Johns, 1985*).

Previous findings stressed the importance of accounting for imperfect detection during data collection when studying the occurrence or distribution of wild animals (*MacKenzie, 2006*). This proved to be relevant also in our study, as the detection probability, *i.e.*, the probability to detect a species when it is present, varied across study sites. Camera sites in BTFC in particular showed a low probability to detect macaques when present, even after increasing the interval of sampling occasions from 7 to 14 days. In PFR, on the other hand, the probability of detection was considerably higher. One crucial factor in explaining this discrepancy in the detection of wildlife may be seasonality. Based on our results, the date of sampling was identified as an important predictor of the detection probability. Prolonged rainfall during the monsoon season may decrease the macaques' overall activity and/or terrestriality (*Takemoto, 2004*; *Hanya et al., 2018*), thus resulting in a lower probability of being detected by the camera traps on the ground. While camera trapping in BTFC was performed from August until May, including the rainy season from November until January, in PFR more than 87% of sampling days took place during the commonly dryer period between May and August, likely resulting in a higher detection probability in PFR compared to BTFC. This effect may be reinforced, as PFR is a relatively small, highly degraded forest surrounded by oil palm plantation, with canopy gaps likely promoting movement of macaques on the ground (*Ancrenaz et al., 2014*). As pointed out by previous research, small home range areas frequently reported for primate groups ranging in anthropogenic environments, as well as high group densities may also lead to increased detection probabilities (*McLennan, Spagnoletti & Hockings, 2017*; *Parsons et al., 2017*; *Neilson et al., 2018*), although the available dataset did not allow us to verify this. Furthermore, it is important to note here that, based on our analyses, we can infer macaque occupancy but not necessarily abundance. In order to provide in-depth information on whether or not selective logging affects the long-term viability of *M. nemestrina*, more detailed studies including larger data sets are needed. However, *MacKenzie & Nichols (2004)* proposed that occupancy may serve as a surrogate for abundance estimation and some earlier studies found strong associations between occupancy and density in carnivorous species (*Clare, Anderson & MacFarland, 2015*; *Linden et al., 2017*).

CONCLUSIONS

There are no population assessments of *M. nemestrina* in its species range, but general estimates are primarily based on assumptions inferred from knowledge available from other primates occupying the same or similar habitats (*Ang et al., 2020*). Here, we add to these findings by providing thorough insight into the macaques' ability to persist in human-impacted habitats and quantifying the effect of tree felling activities on the distribution of *M. nemestrina*. We confirm how population monitoring through camera trapping can contribute to understanding the response of an elusive and threatened Malaysian primate to ecological and anthropogenic factors, and hence to informing conservation efforts. The present study stresses the high sensitivity of *M. nemestrina* to clear-cutting. At the same time, it demonstrates that not only primary forest but also moderately disturbed habitats may play a key role for the protection of this species. Overall, our data indicate that previously selectively logged forests may constitute a valuable habitat for the macaques and therefore should be protected and regenerated instead of opened for more land development. Ultimately, it is imperative to clearly differentiate between these partially degraded, but for the protection of biodiversity, very important forests (*Johns, 1985*; *Lee, Powell & Lindsell, 2015*) and vast areas of monoculture timber plantations. Frequently, the latter are also defined as 'forest' (*e.g.*, Peninsular Malaysia's National Forestry Act of 1984) and thus continue to legally replace selectively logged areas, *i.e.*, potential primate habitats, in many forest reserves after the high-value forest timber had been extracted (*Aziz, Laurance & Clements, 2010*). To counteract population declines at accelerated rates, conservation actions need to focus on the maintenance (and if necessary, restoration) of primary and secondary forest habitats (*WWF, 2020*), including partially degraded forest that can provide valuable habitat for various species, such as *M. nemestrina*. Specifically, the protection of selectively logged forest against conversion into other land use forms, *e.g.*, monoculture plantations, targeted restoration efforts of degraded habitats, and the reconnection of isolated forests through the establishment of wildlife corridors in fragmented habitats are important conservation measures. This may facilitate natural dispersal between wildlife populations, which is inevitable to ensure the long-term survival of this and other species.

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ADDITIONAL INFORMATION AND DECLARATIONS

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Competing Interests

Anja Widdig is an Academic Editor for PeerJ.

Author Contributions

- Anna Holzner conceived and designed the experiments, analyzed the data, prepared figures and/or tables, authored or reviewed drafts of the paper, and approved the final draft.
- D. Mark Rayan performed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Jonathan Moore performed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Cedric Kai Wei Tan performed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Laura Clart conceived and designed the experiments, analyzed the data, authored or reviewed drafts of the paper, and approved the final draft.
- Lars Kulik analyzed the data, authored or reviewed drafts of the paper, and approved the final draft.
- Hjalmar Kühl conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.

- Nadine Ruppert conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.
- Anja Widdig conceived and designed the experiments, authored or reviewed drafts of the paper, and approved the final draft.

Animal Ethics

The following information was supplied relating to ethical approvals (*i.e.*, approving body and any reference numbers):

Due to the non-invasive nature of the data collection through camera trapping, which formed the basis of the present study, no ethical approval was required.

Field Study Permissions

The following information was supplied relating to field study approvals (*i.e.*, approving body and any reference numbers):

For Temengor Forest Reserve, the forest entry permit was given to WWF Malaysia by the district Hulu Perak Forestry Department (through the Perak State Forestry Department), and for Royal Belum State Park, this was given by the Perak State Parks Corporation in 2007.

In addition, for the camera trapping research in Belum-Temengor in 2011, WWF-Malaysia had clarified on the need for a wildlife research permit and received the response from the Department of Wildlife and National Parks (DWNP) stating that they had no objection to conduct a noninvasive wildlife study if it is carried out in areas not governed by DWNP.

Data Availability

The following information was supplied regarding data availability:

Full datasets cannot be shared publicly because they contain location data of protected mammal species of Peninsular Malaysia. Basic detection data are available in the Supplemental Files. Data from Belum-Temengor are co-owned by WWF-Malaysia and one of the co-authors (D. Mark Rayan) who, at the time of data collection, was formally affiliated with WWF-Malaysia. Upon reasonable request, these data can be made available through an alternative contact from WWF-Malaysia (Christopher Wong, christopher.wong@wwf.org.my). Data from Pasoh were obtained as part of the Tropical Ecological Assessment and Monitoring (TEAM) Network work, conducted in collaboration with the Forest Research Institute Malaysia (FRIM), and can be made available upon reasonable request through one of the co-authors (Jonathan Moore, jonathan.moore03@gmail.com). Statistical analyses were done using the software R (version 3.4.4). R scripts are available in the Supplemental Files.

Supplemental Information

Supplemental information for this article can be found online at http://dx.doi.org/10.7717/peerj.12462#supplemental-information.

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Exhibit 12

Assessment of illegal online primate trade in Malaysia

Poster August 2018

DOI: 10.13140/RG.2.2.12016.92168

Zaki Zainol
Universiti Sains Malaysia
1 PUBLICATION **1** CITATION
SEE PROFILE

Nadine Ruppert
Universiti Sains Malaysia
67 PUBLICATIONS **357** CITATIONS
SEE PROFILE

Nik Fadzly
Universiti Sains Malaysia
60 PUBLICATIONS **514** CITATIONS
SEE PROFILE

ASSESSMENT OF ILLEGAL ONLINE PRIMATE TRADE IN MALAYSIA

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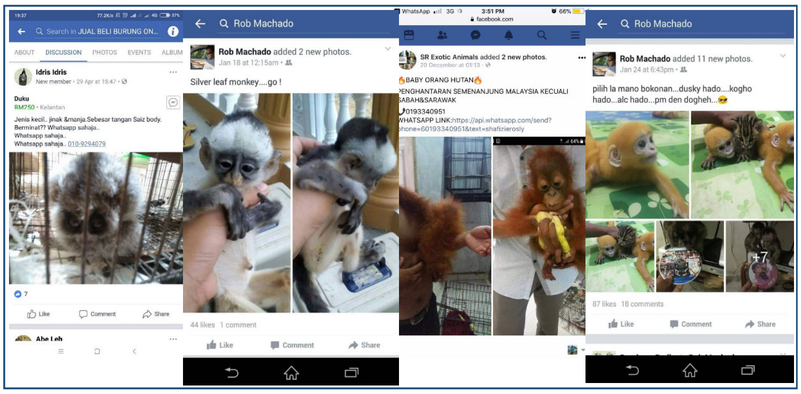
INTRODUCTION

The illegal online wildlife trade is widespread in Malaysia and primates are dominating the market. Globally, 60% of primates are considered endangered (Estrada et al. 2017). Totally protected species, like Dusky leaf monkeys (*Trachypithecus obscurus*) and Sunda slow lorises (*Nycticebus coucang*) are advertised openly, which has recently led to a series of confiscations and arrests by the Department of Wildlife and National Parks Peninsular Malaysia (2015, 2017). Yet, consumers continued to request primates as pets in 2016 through January 2018 and almost daily, new advertisements of protected species are uploaded on social media.



Idris Idris
New member · 29 Apr at 15:47

Duku
RM250 · Kelantan
Jenis kecil.. jinak &manja.Sebesar tangan Saiz body.
Berminat?? Whatsapp sahaja..
Whatsapp sahaja..
Whatsapp sahaja.. 010-9294079

Rob Machado added 2 new photos.
Jan 18 at 12:15am
Silver leaf monkey....go !
44 likes 1 comment

SR Exotic Animals added 2 new photos.
20 December at 01:13
BABY ORANG HUTAN
PENGHANTARAN SEMENANJUNG MALAYSIA KECUALI SABAH&SARAWAK
0193340951
WHATSAPP LINK:https://api.whatsapp.com/send?phone=60193340951&text=shafizierosly

Rob Machado added 11 new photos.
Jan 24 at 6:43pm
pilih la mano bokonan...dusky hado....kogho hado...alc hado...pm den dogheh...
87 likes 18 comments

OBJECTIVES

- Assessing the general pattern of online primate trade in Malaysia.
- Determining the main online channels for sellers and buyers.
- Assessing which species are most traded and at what value.

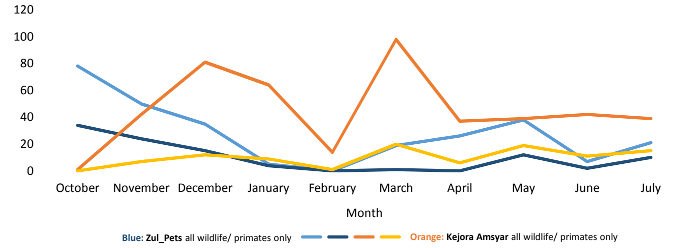
zul_pets2 Slow lorris / kongkang
Female
Jinak n cute

METHODS

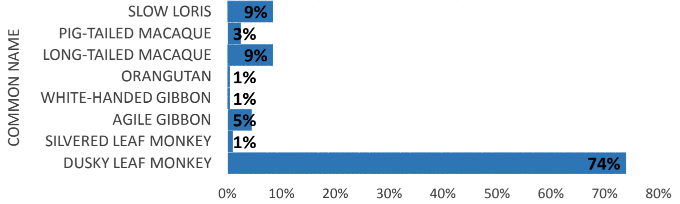
Phase 1: Online search (October 2017 – July 2018) by using common search engines (e.g. Google) to locate websites (incl. social media) that contain publicly accessible primate advertisements.
Keywords chosen based on species' common names in Malay and English.
Phase 2: Detailed search for live primates and primate products on all identified websites. Recording data of each advertisement, including species, age, state/region, listing price, shipping range, website policy, product type, keywords and final sale status (following Lawson & Vines 2014).

RESULTS

Number of online primate advertisements from TWO Facebook pages
(Zul_Pets2 and Kejora Amsyar)

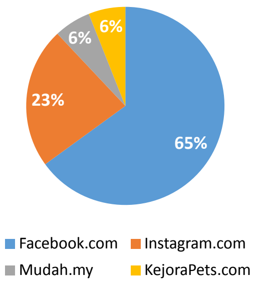


Frequency of traded species (N=736)



PRIMATE SPECIES	PRICE RANGE 1USD= RM4.1
Dusky leaf monkey *Trachypithecus obscurus*	RM530-RM800
Silvered leaf monkey *Trachypithecus cristatus*	RM750
Agile gibbon *Hylobates agilis*	RM800- RM3000
White-handed gibbon *Hylobates lar*	Not specified
Orangutan *Pongo pygmaeus*	Not specified
Long-tailed macaque *Macaca fascicularis*	Not specified
Pig-tailed macaque *Macaca nemestrina*	RM400
Slow loris *Nycticebus coucang*	RM250

Frequency of online primate posts by website (N=736)



DISCUSSION

- Facebook had most posts overall probably due to its heavy traffic with more than 12 million users in Malaysia.
- Dusky leaf monkey babies (*Trachypithecus obscurus*) are the most traded primates in Malaysia probably because of their orange fur, relatively high abundance and docile behavior.
- Agile gibbon (*Hylobates agilis*) is the most expensive species traded in Malaysia, which is a concerning trend as these small apes are listed as Endangered (IUCN).
- Indirect promotion of primates as pets by famous local celebrities may impact the business as they set this popular trend among their followers.

CONCLUSION

Social media platforms in Malaysia commonly advertise primates as pets. High consumer demand dictates the considerably high market prices. Due to a loophole in the Malaysian Wildlife Conservation Act (2010), the brokering of totally protected species online is not yet prohibited, thus brokers/ traders continue their business. We suspect that many buyers lack awareness that possessing (not brokering) primates in Malaysia is illegal. Thus, we need to conduct more environmental education and outreach programs to inform the public and stricter laws and enforcement to prosecute the sellers.

This project is supported by MALAYSIAN PRIMATOLOGICAL SOCIETY MPS and its outreach projects PRIMATE WATCH, MNeP, LANGUR PROJECT PENANG, GIBBONS OF MALAYSIA, Night Spotting Project NSP

Contact: zainolmzaki@gmail.com

Exhibit 13

☰

RAINFOREST INFORMATION

By **Rhett A. Butler** Last updated Aug 14, 2020

A Place Out of Time: Tropical Rainforests and the Perils They Face - information on tropical forests, deforestation, and biodiversity

RAINFOREST FACTS

- Tropical forests presently cover about 1.84 billion hectares or about 12 percent of Earth's land surface (3.6% of Earth's surface).
- The world's largest rainforest is the Amazon rainforest
- Brazil has the largest extent of rainforest cover, including nearly two-thirds of the Amazon.
- Rainforests also exist outside the tropics, including temperate North America, South America, Australia, and Russia.
- An estimated 50 percent of terrestrial biodiversity is found in rainforests
- Rainforests are thought to store at least 250 billion tons of carbon
- Deforestation and degradation of tropical forests account for roughly 10 percent of global greenhouse emissions from human activities

Sections:

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Rainforest biodiversity

Rainforest canopy

Rainforest floor

Rainforest waters

Rainforest peoples

Deforestation

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The Amazon

The Congo

Rainforest Facts

For kids

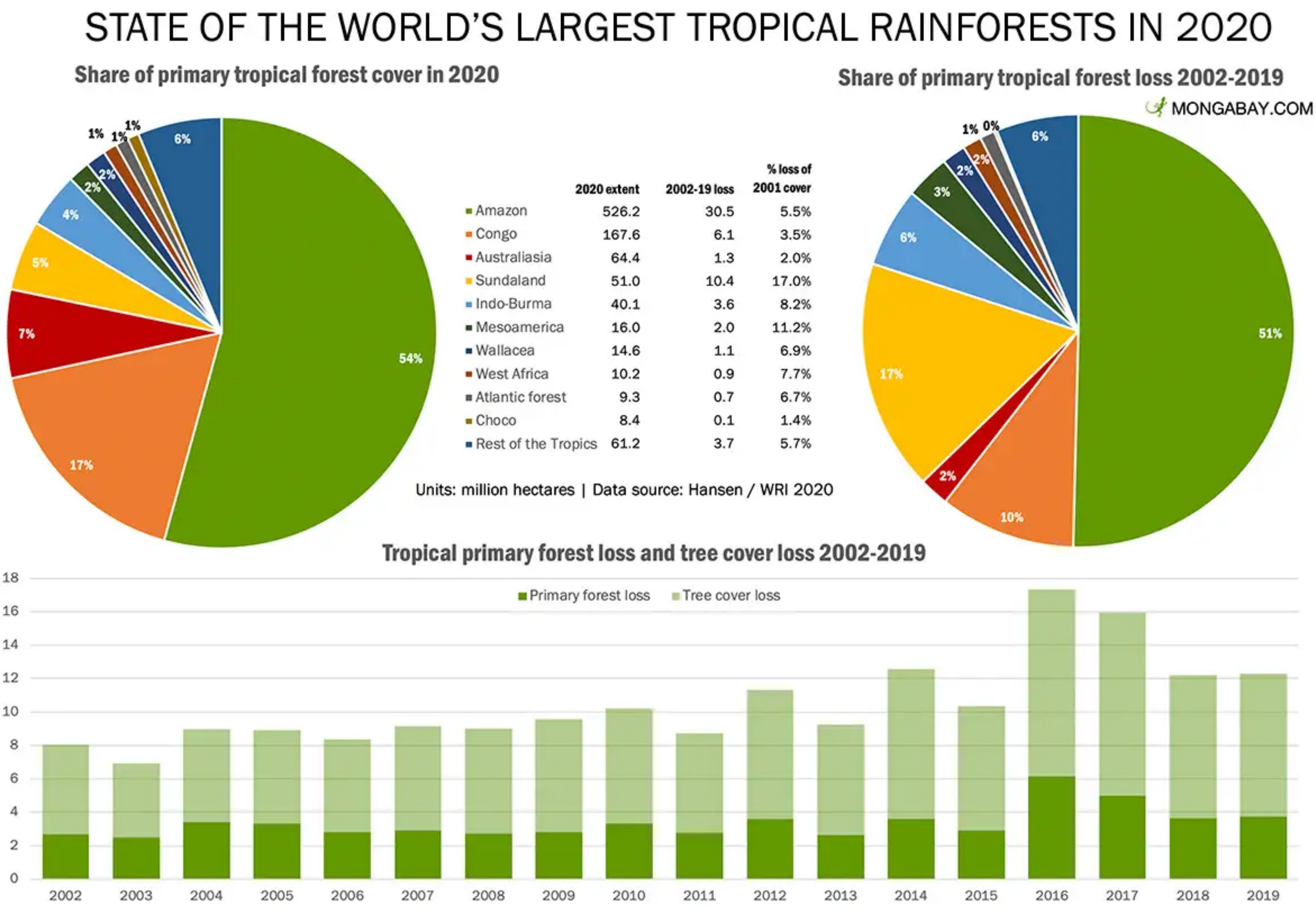
Rainforest photos

BACKGROUND INFORMATION ON THE RAINFOREST

section of the web site, rainforests are actually found widely around the world, including temperate regions in Canada, the United States, and the former Soviet Union.

Tropical rainforests typically occur in the equatorial zone between the Tropic of Cancer and Tropic of Capricorn, latitudes that have warm temperatures and relatively constant year-round sunlight. Tropical rainforests merge into other types of forest depending on the altitude, latitude, and various soil, flooding, and climate conditions. These forest types form a mosaic of vegetation types which contribute to the incredible diversity of the tropics.

The bulk of the world's tropical rainforest occurs in the Amazon Basin in South America. The Congo Basin and Southeast Asia, respectively, have the second and third largest areas of tropical rainforest. Rainforests also exist on some the Caribbean islands, in Central America, in India, on scattered islands in the South Pacific, in Madagascar, in West and East Africa outside the Congo Basin, in Central America and Mexico, and in parts of South America outside the Amazon. Brazil has the largest extent of rainforest of any country on Earth.



	2020 extent	2002-19 loss	% loss of 2001 cover
Amazon	526.2	30.5	5.5%
Congo	167.6	6.1	3.5%
Australiasia	64.4	1.3	2.0%
Sundaland	51.0	10.4	17.0%
Indo-Burma	40.1	3.6	8.2%
Mesoamerica	16.0	2.0	11.2%
Wallacea	14.6	1.1	6.9%
West Africa	10.2	0.9	7.7%
Atlantic forest	9.3	0.7	6.7%
Choco	8.4	0.1	1.4%
Rest of the Tropics	61.2	3.7	5.7%

Units: million hectares | Data source: Hansen / WRI 2020

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a home to wildlife and Indigenous people. Rainforests are also the source of many useful products upon which local communities depend.

While rainforests are critically important to humanity, they are rapidly being destroyed by human activities. The biggest cause of deforestation is conversion of forest land for agriculture. In the past subsistence agriculture was the primary driver of rainforest conversion, but today industrial agriculture — especially monoculture and livestock production — is the dominant driver of rainforest loss worldwide. Logging is the biggest cause of forest degradation and usually proceeds deforestation for agriculture.

Organization of this site

The rainforest section of Mongabay is divided into ten "chapters" (the original text for the site was a book, but has since been adapted for the web), with add-on content in the form of special focal sections (e.g. The Amazon, the Congo, REDD, New Guinea, Sulawesi, Forests in Brazil, etc), appendices, and other resources.

There is also a version of the site geared toward younger readers at kids.mongabay.com.

ABOUT THE RAINFOREST (SUMMARY)

Chapter 1:

RAINFOREST DISTRIBUTION AND CHARACTERISTICS

Each rainforest is unique, but there are certain features common to all tropical rainforests.

- Location: rainforests lie in the tropics.
- Rainfall: rainforests receive at least 80 inches (200 cm) of rain per year.
- Canopy: rainforests have a canopy, which is the layer of branches and leaves formed by closely spaced rainforest trees some 30 meters (100 feet) off the ground. A large proportion of the plants and animals in the rainforest live in the canopy.
- Biodiversity: rainforests have extraordinarily highs level of biological diversity or “biodiversity”. Scientists estimate that about half of Earth's terrestrial species live in rainforests.
- Ecosystem services: rainforests provide a critical ecosystem services at local, regional, and global scales, including producing oxygen (tropical forests are responsible for 25-30 percent of the world's oxygen turnover) and storing carbon (tropical forests store an estimated 229-247 billion tons of carbon) through photosynthesis; influencing precipitation patterns and weather; moderating flood and drought cycles; and facilitating nutrient cycling; among others.

The global distribution of tropical rainforests can be broken up into four biogeographical realms based roughly on four forested continental regions: the Afrotropical, the Australiasian, the Indomalayan/Asian, and the Neotropical. Just over half the world's rainforests lie in the Neotropical realm, roughly a quarter are in Africa, and a fifth in Asia.

Map showing the world's rainforests, defined as primary forests in the tropics. Click to enlarge.

These realms can be further divided into major tropical forest regions based on biodiversity hotspots, including:

1. **Amazon**: Includes parts of Bolivia, Brazil, Colombia, Ecuador, French Guiana, Guyana, Peru, Suriname, Venezuela

3. **Australiasia**: Includes parts of Australia, Indonesian half of New Guinea, Papua New Guinea
4. **Sundaland**: Includes parts of Brunei, Indonesia, Malaysia, Singapore
5. **Indo-Burma**: Includes parts of Bangladesh, Cambodia, China, India, Laos, Myanmar, Thailand, Vietnam
6. **Mesoamerica**: Includes parts of Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama
7. **Wallacea**: Sulawesi and the Maluku islands in Indonesia
8. **West Africa**: Includes parts of Benin, Cameroon, Côte d'Ivoire, Ghana, Guinea, Liberia, Nigeria, Sierra Leone, Togo
9. **Atlantic forest**: Includes parts of Argentina, Brazil, Paraguay
10. **Choco**: Includes parts of Colombia, Ecuador, Panama

Dozens of countries have tropical forests. The countries with the largest areas of tropical forest are:

- Brazil
- Democratic Republic of Congo (DRC)
- Indonesia
- Peru
- Colombia

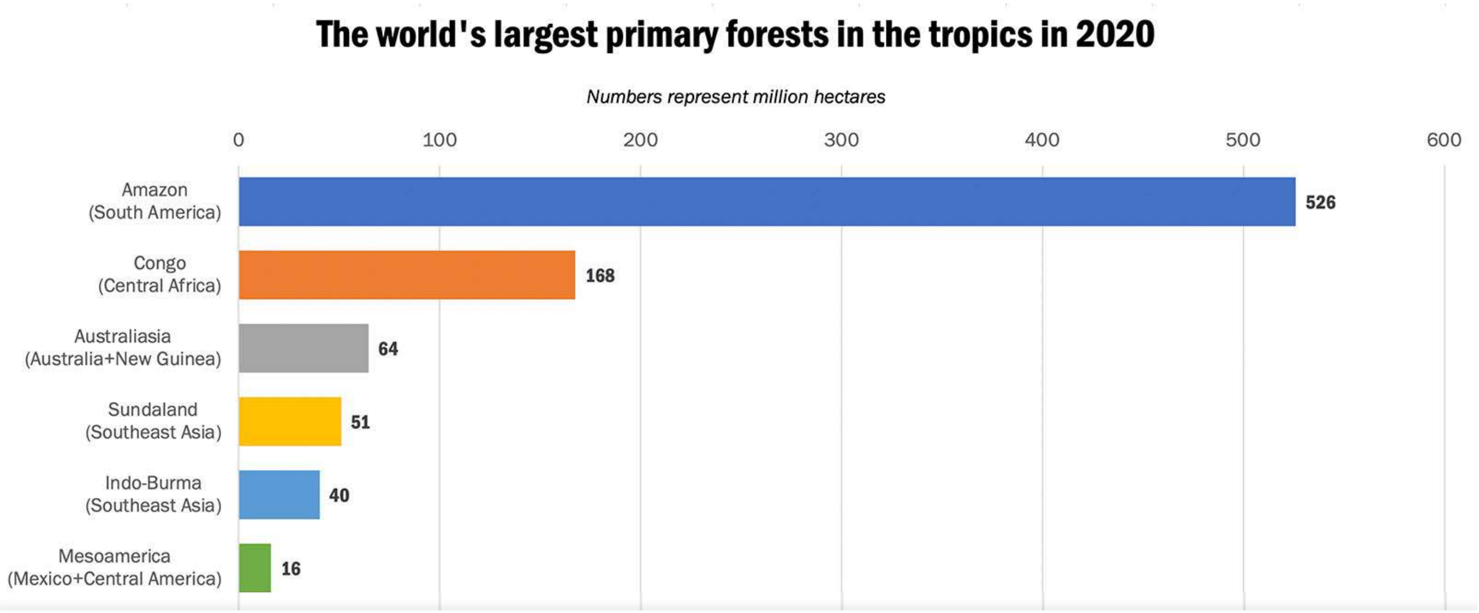
Other countries that have large areas of rainforest include Bolivia, Cameroon, Central African Republic, Ecuador, Gabon, Guyana, India, Laos, Malaysia, Mexico, Myanmar, Papua New Guinea, Republic of Congo, Suriname, and Venezuela.

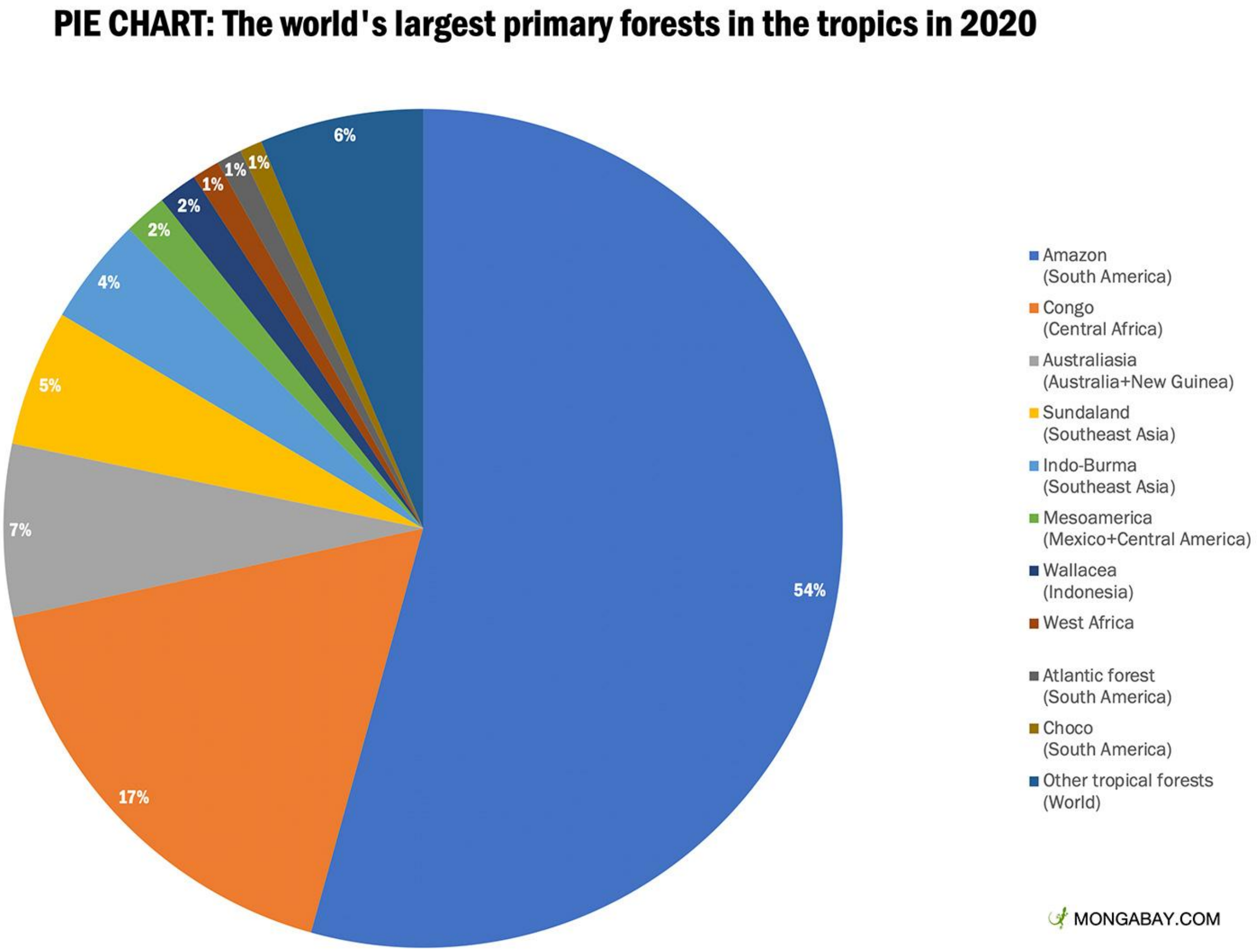
Cover and loss by rainforest region

	Primary forest extent			Tree cover extent		
Rainforest region	**2001**	**2010**	**2020**	**2001**	**2010**	**2020**
Amazon	556.7	543.5	526.2	673.4	658.6	628.9
Congo	173.7	172.2	167.6	301.2	300.3	287.7
Australiasia	61.8	65.4	64.4	76.3	91.3	89.1
Sundaland	39.9	57.3	51.0	67.7	121.6	103.1
Indo-Burma	15.3	42.6	40.1	37.8	153.0	139.1
Mesoamerica	43.7	17.4	16.0	160.3	54.3	49.8
Wallacea	18.1	15.2	14.6	56.2	26.1	24.5

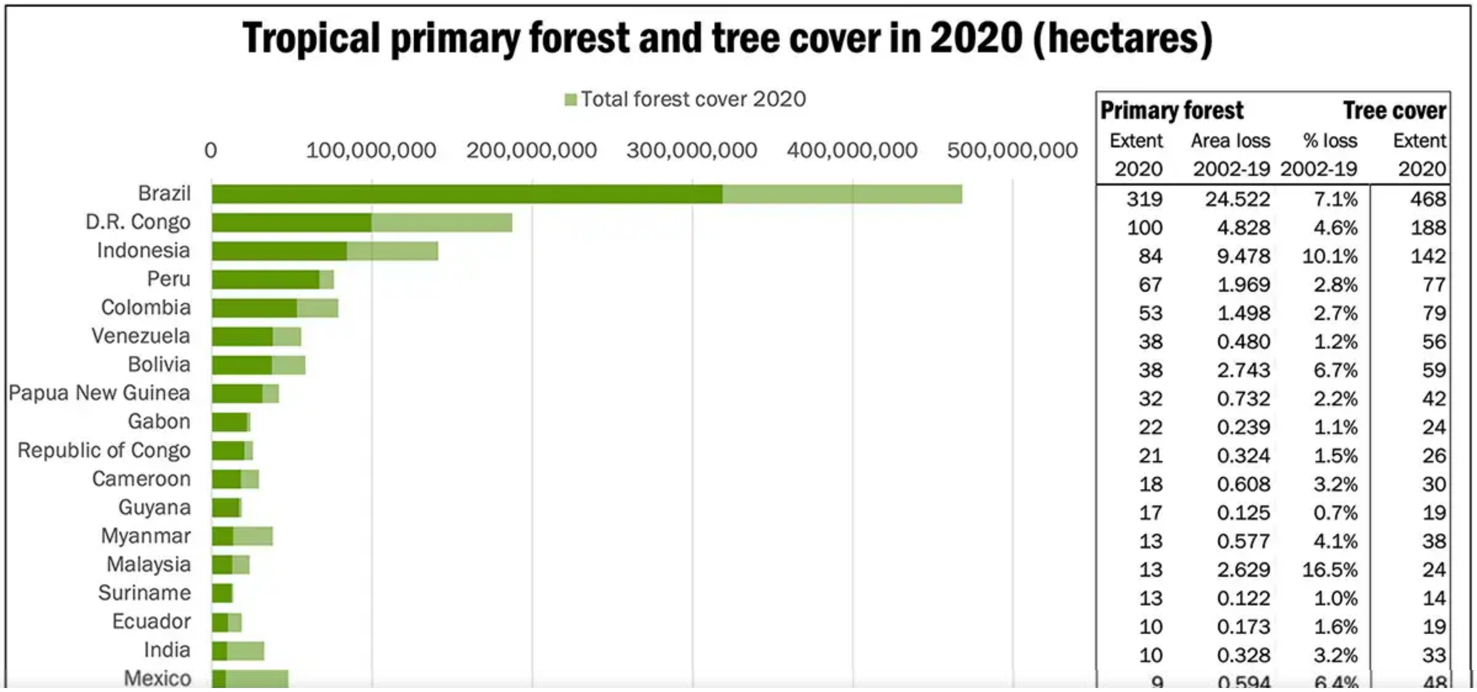
Choco	10.0	8.5	8.4	99.8	15.9	15.6
PAN-TROPICS	1,029.6	1,006.5	969.1	2,028.3	1,959.4	1,839.1

	Primary forest loss		**Tree cover change**	
	2002-09	**2010-19**	**2002-09**	**2010-19**
Rainforest region	**M ha (%)**	**M ha (%)**	**M ha (%)**	**M ha (%)**
Amazon	-13.18 (-2.4%)	-17.28 (-3.2%)	-14.7 (-2.2%)	-29.8 (-4.5%)
Congo	-1.46 (-0.8%)	-4.68 (-2.7%)	-0.8 (-0.3%)	-12.7 (-4.2%)
Australiasia	-0.29 (-0.5%)	-0.86 (-1.3%)	0.2 (0.2%)	-1.4 (-1.5%)
Sundaland	-2.22 (-5.5%)	-3.67 (-6.4%)	-1.5 (-2.3%)	-9.5 (-7.8%)
Indo-Burma	-1.62 (-10.5%)	-2.14 (-5.0%)	-0.6 (-1.6%)	-6.4 (-4.2%)
Mesoamerica	-1.10 (-2.5%)	-2.51 (-14.4%)	-7.3 (-4.6%)	-13.9 (-25.6%)
Wallacea	-0.66 (-3.6%)	-1.36 (-8.9%)	-1.9 (-3.3%)	-4.6 (-17.5%)
West Africa	-0.30 (-3.1%)	-0.50 (-4.6%)	-0.1 (-0.8%)	-1.2 (-2.4%)
Atlantic forest	-0.24 (-2.1%)	-0.62 (-6.4%)	-0.7 (-1.5%)	-6.8 (-7.0%)
Choco	-0.33 (-3.3%)	-0.35 (-4.1%)	-3.5 (-3.5%)	-7.3 (-46.0%)
PAN-TROPICS	-23.11 (-2.2%)	-37.34 (-3.7%)	-68.9 (-3.4%)	-120.3 (-6.1%)





Bar chart showing the world's largest rainforests as defined by the area of primary forest cover according to Hansen / WRI 2020.



	Primary forest			Tree cover
	Extent 2020	Area loss 2002-19	% loss 2002-19	Extent 2020
Brazil	319	24.522	7.1%	468
D.R. Congo	100	4.828	4.6%	188
Indonesia	84	9.478	10.1%	142
Peru	67	1.969	2.8%	77
Colombia	53	1.498	2.7%	79
Venezuela	38	0.480	1.2%	56
Bolivia	38	2.743	6.7%	59
Papua New Guinea	32	0.732	2.2%	42
Gabon	22	0.239	1.1%	24
Republic of Congo	21	0.324	1.5%	26
Cameroon	18	0.608	3.2%	30
Guyana	17	0.125	0.7%	19
Myanmar	13	0.577	4.1%	38
Malaysia	13	2.629	16.5%	24
Suriname	13	0.122	1.0%	14
Ecuador	10	0.173	1.6%	19
India	10	0.328	3.2%	33
Mexico	9	0.594	6.4%	48

Data source: Mongabay using WRI / Hansen 2020

Country	2001	2010	2020	2001	2010	2020
Brazil	343.2	331.9	318.7	516.4	498.1	468.2
DR Congo	104.6	103.4	99.8	198.8	198.5	188.0
Indonesia	93.8	90.2	84.4	159.8	157.7	141.7
Colombia	54.8	54.2	53.3	81.6	81.7	79.3
Peru	69.1	68.5	67.2	77.9	78.6	76.5
Bolivia	40.8	39.9	38.1	64.4	62.7	58.9
Venezuela	38.6	38.5	38.1	56.4	57.3	56.1
Angola	2.5	2.4	2.3	49.7	48.3	46.8
Central African Republic	7.4	7.3	7.2	46.9	47.1	46.6
Papua New Guinea	32.6	32.4	31.9	42.9	42.9	41.9
Mexico	9.2	9.0	8.6	43.3	42.5	40.3
China	1.7	1.7	1.7	42.8	41.1	38.5
Myanmar	14.0	13.8	13.5	42.8	40.9	38.2
India	10.2	10.1	9.9	35.1	31.4	30.2
Cameroon	19.1	19.0	18.5	30.6	29.7	28.7
Republic of Congo	21.2	21.1	20.8	26.4	26.6	26.0
Argentina	4.4	4.2	4.0	30.9	27.6	24.9
Gabon	22.7	22.6	22.4	24.7	24.7	24.4
Malaysia	15.9	15.0	13.3	29.1	28.6	23.8
Mozambique	0.1	0.1	0.1	26.6	25.0	23.1
Tanzania	0.7	0.7	0.7	21.8	20.6	19.3
Guyana	17.3	17.3	17.2	19.0	19.1	18.9
Ecuador	10.6	10.6	10.5	18.3	18.5	18.1

Paraguay	3.5	3.0	2.5	23.9	20.2	16.6
Zambia	0.3	0.3	0.3	18.5	17.4	16.6
Laos	8.3	8.1	7.5	19.1	17.9	15.4
Suriname	12.8	12.7	12.6	13.9	14.0	13.9
Rest of the tropics	59.6	58.0	53.9	210.1	203.5	183.3
Grand Total	1,029.6	1,006.5	969.1	2,009.7	1,959.4	1,839.1

	Primary forest loss		**Tree cover change**	
	2002-09	**2010-2019**	**2002-09**	**2010-2019**
Country	**M ha (%)**	**M ha (%)**	**M ha (%)**	**M ha (%)**
Brazil	-11.37 (-3.3%)	-13.15 (-4.0%)	-18.25 (-3.5%)	-29.93 (-6.0%)
DR Congo	-1.16 (-1.1%)	-3.67 (-3.5%)	-0.37 (-0.2%)	-10.50 (-5.3%)
Indonesia	-3.63 (-3.9%)	-5.85 (-6.5%)	-2.09 (-1.3%)	-15.98 (-10.1%)
Colombia	-0.54 (-1.0%)	-0.96 (-1.8%)	0.17 (0.2%)	-2.43 (-3.0%)
Peru	-0.60 (-0.9%)	-1.37 (-2.0%)	0.68 (0.9%)	-2.10 (-2.7%)
Bolivia	-0.90 (-2.2%)	-1.84 (-4.6%)	-1.67 (-2.6%)	-3.75 (-6.0%)
Venezuela	-0.15 (-0.4%)	-0.33 (-0.9%)	0.86 (1.5%)	-1.14 (-2.0%)
Angola	-0.03 (-1.2%)	-0.09 (-3.8%)	-1.37 (-2.8%)	-1.51 (-3.1%)
Central African Republic	-0.05 (-0.6%)	-0.11 (-1.5%)	0.15 (0.3%)	-0.49 (-1.0%)
Papua New Guinea	-0.19 (-0.6%)	-0.55 (-1.7%)	0.04 (0.1%)	-1.05 (-2.4%)
Mexico	-0.20 (-2.1%)	-0.40 (-4.4%)	-0.81 (-1.9%)	-2.22 (-5.2%)
China	-0.03 (-1.9%)	-0.04 (-2.4%)	-1.67 (-3.9%)	-2.66 (-6.5%)
Myanmar	-0.19 (-1.4%)	-0.38 (-2.8%)	-1.90 (-4.4%)	-2.70 (-6.6%)
India	-0.13 (-1.2%)	-0.20 (-2.0%)	-3.67 (-10.5%)	-1.18 (-3.8%)
Cameroon	-0.11 (-0.6%)	-0.50 (-2.6%)	-0.96 (-3.1%)	-1.02 (-3.4%)
Republic of Congo	-0.07 (-0.3%)	-0.25 (-1.2%)	0.28 (1.0%)	-0.60 (-2.2%)

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Malaysia	-0.98 (-6.2%)	-1.65 (-11.0%)	-0.47 (-1.6%)	-4.84 (-16.9%)
Mozambique	0.00 (-1.6%)	-0.01 (-7.5%)	-1.60 (-6.0%)	-1.95 (-7.8%)
Tanzania	-0.01 (-0.9%)	-0.02 (-2.8%)	-1.21 (-5.5%)	-1.31 (-6.3%)
Guyana	-0.03 (-0.2%)	-0.09 (-0.5%)	0.07 (0.3%)	-0.14 (-0.8%)
Ecuador	-0.05 (-0.5%)	-0.12 (-1.2%)	0.20 (1.1%)	-0.43 (-2.3%)
Thailand	-0.07 (-1.2%)	-0.05 (-0.9%)	-0.75 (-3.8%)	-1.31 (-6.9%)
Philippines	-0.05 (-1.1%)	-0.09 (-2.1%)	-0.18 (-1.0%)	-0.80 (-4.4%)
Paraguay	-0.46 (-13.3%)	-0.53 (-17.7%)	-3.69 (-15.4%)	-3.60 (-17.8%)
Zambia	0.00 (-1.0%)	-0.02 (-6.5%)	-1.07 (-5.8%)	-0.77 (-4.4%)
Laos	-0.23 (-2.7%)	-0.55 (-6.8%)	-1.15 (-6.0%)	-2.58 (-14.4%)
Suriname	-0.02 (-0.2%)	-0.10 (-0.8%)	0.05 (0.4%)	-0.14 (-1.0%)
Rest of the tropics	-1.59 (-2.7%)	-4.04 (-7.0%)	-6.59 (-3.1%)	-20.17 (-9.9%)
Grand Total	-23.11 (-2.2%)	-37.34 (-3.7%)	-50.27 (-2.5%)	-120.27 (-6.1%)

Chapter 2:

RAINFOREST STRUCTURE

Rainforests are characterized by a unique vegetative structure consisting of several vertical layers including the overstory, canopy, understory, shrub layer, and ground level. The canopy refers to the dense ceiling of leaves and tree branches formed by closely spaced forest trees. The upper canopy is 100-130 feet above the forest floor, penetrated by scattered emergent trees, 130 feet or higher, that make up the level known as the overstory. Below the canopy ceiling are multiple leaf and branch levels known collectively as the understory. The lowest part of the understory, 5-20 feet (1.5-6 meters) above the floor, is known as the shrub layer, made up of shrubby plants and tree saplings.

Chapter 3:

RAINFOREST BIODIVERSITY

Tropical rainforests support the greatest diversity of living organisms on Earth. Although they cover less than 2 percent of Earth’s surface, rainforests house more than 50 percent of the plants and animals on the planet.

- Climate: because rainforests are located in tropical regions, they receive a lot of sunlight. The sunlight is converted to energy by plants through the process of photosynthesis. Since there is a lot of sunlight, there is a lot of energy in the rainforest. This energy is stored in plant vegetation, which is eaten by animals. The abundance of energy supports an abundance of plant and animal species.
- Canopy: the canopy structure of the rainforest provides an abundance of places for plants to grow and animals to live. The canopy offers sources of food, shelter, and hiding places, providing for interaction between different species. For example, there are plants in the canopy called bromeliads that store water in their leaves. Frogs and other animals use these pockets of water for hunting and laying their eggs.
- Competition: while there is lots of energy in the rainforest system, life is not easy for most species that inhabit the biome. In fact, the rainforest is an intensively competitive place, with species developing incredible strategies and innovations to survive, encouraging specialization.

While species everywhere are known for utilizing symbiotic relationships with other species to survive, the biological phenomenon is particularly abundant in rainforests.

Chapter 4:

THE RAINFOREST CANOPY

In the rainforest most plant and animal life is not found on the forest floor, but in the leafy world known as the canopy. The canopy, which may be over 100 feet (30 m) above the ground, is made up of the overlapping branches and leaves of rainforest trees. Scientists estimate that more than half of life in the rainforest is found in the trees, making this the richest habitat for plant and animal life.

The conditions of the canopy are markedly different from the conditions of the forest floor. During the day, the canopy is drier and hotter than other parts of the forest, and the plants and animals that live there have adapted accordingly. For example, because the amount of leaves in the canopy can make it difficult to see more than a few feet, many canopy animals rely on loud calls or lyrical songs for communication. Gaps between trees mean that some canopy animals fly, glide, or jump to move about in the treetops. Meanwhile plants have evolved water-retention mechanisms like waxy leaves.

Scientists have long been interested in studying the canopy, but the height of trees made research difficult until recently. Today the canopy is commonly accessed using climbing gear, rope bridges, ladders, and towers. Researchers are even using model airplanes and quadcopters outfitted with special sensors — conservation drones — to study the canopy.

Chapter 5:

The rainforest floor

The rainforest floor is often dark and humid due to constant shade from the leaves of canopy trees. The canopy not only blocks out sunlight, but dampens wind and rain, and limits shrub growth.

Despite its constant shade, the ground floor of the rainforest is the site for important interactions and complex relationships. The forest floor is one of the principal sites of decomposition, a process paramount for the continuance of the forest as a whole. It provides support for trees responsible for the formation of the canopy and is also home to some of the rainforest's best-known species, including gorillas, tigers, tapirs, and elephants, among others.

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Chapter 6:

Rainforest waters

Tropical rainforests support some of the largest rivers in the world, like the Amazon, Mekong, Negro, Orinoco, and Congo. These mega-rivers are fed by countless smaller tributaries, streams, and creeks. For example, the Amazon alone has some 1,100 tributaries, 17 of which are over 1,000 miles long. Although large tropical rivers are fairly uniform in appearance and water composition, their tributaries vary greatly.

Rainforest waters are home to a wealth of wildlife that is nearly as diverse as the biota on land. For example, more than 5,600 species of fish have been identified in the Amazon Basin alone.

But like rainforests, tropical ecosystems are also threatened. Dams, deforestation, channelization and dredging, pollution, mining, and overfishing are chief dangers.

Chapter 7:

Rainforest people

Tropical rainforests have long been home to tribal peoples who rely on their surroundings for food, shelter, and medicines. Today very few forest people live in traditional ways; most have been displaced by outside settlers, have been forced to give up their lifestyles by governments, or have chosen to adopt outside customs.

Of the remaining forest people, the Amazon supports the largest number of Indigenous people living in traditional ways, although these people, too, have been impacted by the modern world. Nonetheless, Indigenous peoples' knowledge of medicinal plants remains unmatched and they have a great understanding of the ecology of the Amazon rainforest.

In Africa there are native forest dwellers sometimes known as pygmies. The tallest of these people, also called the Mbuti, rarely exceed 5 feet in height. Their small size enables them to move about the forest more efficiently than taller people.

There are few forest peoples in Asia living in fully traditional ways. The last nomadic people in Borneo are thought to have settled in the late 2000's. New Guinea and the Andaman Islands are generally viewed as the last frontiers for forest people in Asia and the Pacific.

Chapter 8:

Every year an area of rainforest the size of New Jersey is cut down and destroyed, mostly the result of human activities. We are cutting down rainforests for many reasons, including:

- wood for both timber and making fires;
- agriculture for both small and large farms;
- land for poor farmers who don’t have anywhere else to live;
- grazing land for cattle (the single biggest driver of deforestation in the Amazon);
- plantations, including wood-pulp for making paper, oil palm for making palm oil, and rubber;
- road construction; and
- extraction of minerals and energy.

In recent decades there has been an important shift in deforestation trends. Today export-driven industries are driving a bigger share of deforestation than ever before, marking a shift from previous decades, when most tropical deforestation was the product of poor farmers trying to put food on the table for their families. There are important implications from this change. While companies have a greater capacity to chop down forests than small farmers, they are more sensitive to pressure from environmentalists. Thus in recent years, it has become easier—and more ethical—for green groups to go after corporations than after poor farmers.

Rainforests are also threatened by climate change, which is contributing to droughts in parts of the Amazon and Southeast Asia. Drought causes die-offs of trees and dries out leaf litter, increasing the risk of forest fires, which are often set by land developers, ranchers, plantation owners, and loggers.

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Chapter 9:

Rainforest importance

While rainforests may seem like a distant concern, they are critically important for our well-being. Rainforests are often called the lungs of the planet for their role in absorbing carbon dioxide, a greenhouse gas, and producing oxygen, upon which all animals depend for survival. Rainforests also stabilize climate, house incredible amounts of plants and wildlife, and produce nourishing rainfall all around the planet.

Rainforests:

- Help stabilize the world’s climate: Rainforests help stabilize the world’s climate by absorbing carbon dioxide from the atmosphere. Scientists have shown that excess carbon dioxide in the atmosphere from human activities is contributing to climate change. Therefore, living rainforests have an important role in mitigating climate change, but when rainforests are chopped down and burned, the carbon stored in their wood and leaves is released into the atmosphere, contributing to climate change.
- Provide a home to many plants and animals: Rainforests are home to a large number of the world’s plant and animals species, including many endangered species. As forests are cut down, many species are doomed to extinction.
- Help maintain the water cycle: The role of rainforests in the water cycle is to add water to the atmosphere through the process of transpiration (in which plants release water from their leaves during photosynthesis). This moisture contributes to the formation of rain clouds, which release the water back onto the rainforest. In the Amazon, 50-80 percent of moisture remains in the ecosystem’s water cycle. When forests are cut down, less moisture goes into the atmosphere and rainfall declines, sometimes leading to drought. Rainforests also have a role in global weather patterns. For example researchers have shown that forests in South America affect rainfall in the United States, while forests in Southeast Asia influence rain patterns in southeastern Europe and China. Distant rainforests are therefore important to farmers everywhere.
- Protect against flood, drought, and erosion: Rainforests have been compared to natural sponges, moderating flood and drought cycles by slowing run-off and contributing moisture to the local atmosphere. Rainforests are also important in reducing soil erosion by anchoring the ground with their roots. When trees are cut down there is no longer anything to protect the ground, and soils are quickly washed away with rain. On steep hillsides, loss of forest can trigger landslides.
- Are a source for medicines and foods and support forest-dependent people: People have long used forests as a source of food, wood, medicine, and recreation. When forests are lost, they can no longer provide these resources. Instead people must find other places to get these goods and services. They also must find ways to pay for the things they once got for free from the forest.

Rainforests are disappearing very quickly. The good news is there are a lot of people who want to save rainforests. The bad news is that saving rainforests will be a challenge as it means humanity will need to shift away from business-as-usual practices by developing new policies and economic measures to creative incentives for preserving forests as healthy and productive ecosystems.

Over the past decade there has been considerable progress on several conservation fronts. Policymakers and companies are increasingly valuing rainforests for the services they afford, setting aside large blocks of forests in protected areas and setting up new financial mechanisms that compensate communities, state and local governments, and countries for conserving forests. Meanwhile, forest-dependent people are gaining more management control over the forests they have long stewarded. Large international companies are finally establishing policies that exclude materials sourced via deforestation. People are abandoning rural areas, leading to forest recovery in some planes.

But the battle is far from over. Growing population and consumption means that rainforests will continue to face intense pressures. At the same time, climate change threatens to dramatically alter temperatures and precipitation patterns, potentially pushing some forests toward critical tipping points.

Thus the future of the world's rainforests in very much in our hands. The actions we take in the next 20 years will determine whether rainforests, as we currently know them, are around to sustain and nourish future generations of people and wildlife.

The Latest News on Rainforests

Tropical forest regeneration offsets 26% of carbon emissions from deforestation (Mar 23 2023)
- A new study published in the journal Nature analyzed satellite images from three major regions of tropical forest on Earth — Amazon, Central Africa and Borneo — and showed recovering forests offset just 26% of carbon emissions from new tropical deforestation and forest degradation in the past three decades.
- Secondary forests have a good potential to absorb carbon dioxide from the atmosphere and could be an ally in addressing the climate crisis, but emissions generated from deforestation and forests lost or damaged due to human activity currently far outpace regrowth.
- The study provides information to guide debates and decisions around the recovery of secondary forests and degraded areas of the Brazilian Amazon — around 17% of the ecosystem is in various stages of degradation and another 17% is already deforested.
- Since Brazil’s new President Luiz Inácio Lula da Silva took office, projects to curb deforestation are in place, but plans to protect recovering areas remain unclear.

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high in 2022, according to various analyses.
- The forest loss was driven by clearing for oil palm plantations by well-connected local elites, rather than smallholders, according to advocacy group Rainforest Action Network (RAN).
- RAN's investigation found that palm oil from these illegal plantations had wound up in the global supply chains of major brands like Procter & Gamble, Nestlé, PepsiCo and Unilever, among others.

Indonesian campaigns getting money from illegal logging, mining, watchdog says (Mar 21 2023)
- As Indonesia gears up for legislative and presidential elections in less than a year, authorities have warned of the pattern of dirty money from illegal logging, mining and fishing flowing into past campaigns.
- Experts say the practice of candidates taking this money from companies that exploit natural resources is common, given the high cost of running a campaign.
- This then perpetuates a tit-for-tat cycle that sees the winning candidate pay back their funders in the form of land concessions and favorable regulations.

Bearded pigs a 'cultural keystone species' for Borneo's Indigenous groups: Study (Mar 20 2023)
- A recent study examined the impacts of ecological and sociocultural influences on bearded pig populations in Malaysian Borneo.
- The researchers found that the presence of pigs is "compatible" with Indigenous hunting in certain areas.
- The team's findings point to the importance of a nuanced understanding of nearby human cultural values and local ecology in determining policies toward hunting.

Deforestation on the rise in Quintana Roo, Mexico, as Mennonite communities move in (Mar 15 2023)
- Mennonite families began to arrive in the southern Mexican municipality of Bacalar in 2001.
- They swiftly bought land, became members of the local ejido — an area of communally owned agricultural land — and then founded their own.
- Their presence in the region has continued to grow, along with the level of deforestation.
- Satellite imagery and field visits reveal vast swaths of rainforest have been cleared for large-scale agriculture.

Make it local: Deforestation link to less Amazon rainfall tips activism shift (Mar 14 2023)
- A new study supports mounting evidence that deforestation in the Amazon Rainforest correlates with a reduction in regional rainfall.
- Experts say this research reinforces the findings of other studies that claim the Amazon is leaning toward its "tipping point" and the southern regions are gradually becoming drier.

Global ecosystems are at risk of losing carbon storage ability, study says (Mar 14 2023)
- Landscapes are showing signs of losing their ability to absorb the amount of carbon they once could, a new study revealed. That would pose serious obstacles to the fight against climate change.
- The study reviewed the productivity of carbon storage of different ecosystems between 1981 and 2018, finding that many fluctuated greatly and were at risk of turning into permanent scrubland.
- Researchers identified a concerning “spiraling” effect, in which landscapes absorb less carbon that in turn worsens climate change, which then destabilizes additional landscapes and puts them at higher risk of turning into scrubland.

Mobilizing Amazon societies to reduce forest carbon emissions and unlock the carbon market (commentary) (Mar 13 2023)
- Brazil could generate $10 billion or more from the global voluntary carbon market over the next four years through the sale of credits from Amazon states’ jurisdictional REDD+ programs; some states are already finalizing long-term purchase agreements.
- This funding would flow to those who are protecting the forest – Indigenous peoples and traditional communities, farmers, businesses, and government agencies – and the prospect of this funding could mobilize collective action to reduce emissions from illegal deforestation and degradation.
- Rapid progress in reducing emissions from Amazon deforestation and forest degradation – which represent half of Brazil’s nation-wide emissions – would also position Brazil to capture significant international funding for its national decarbonization process through the regulated carbon market that is under development through the UN Paris Agreement.
- This post is a commentary. The views expressed are those of the authors, not necessarily of Mongabay.

Most of ‘top ten’ hotspots for jaguar conservation are in Brazil’s Indigenous territories (Mar 10 2023)
- Jaguars are essential to healthy ecosystems but have been eradicated from almost 50% of their historical range, and by some estimates, only 64,000 individuals remain.
- Brazil is home to half of the world’s jaguars, and a group of researchers has identified the highest-priority protected areas in the Brazilian Amazon for jaguar conservation.
- The top 10 highest-priority protected areas fall primarily across the arc of deforestation in southern and western Brazil, and eight of these are Indigenous territories.
- Researchers say conservation efforts must include strengthened participation of Indigenous peoples and local communities, increased funding and support for protected areas and environmental agencies, and the implementation of more robust environmental policies.

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- Colombia and Ecuador are implementing a system designed to alert about risks of violence against residents who live near the border, many of whom are Awá Indigenous people.
- Since last August, thousands of Awá have been forcibly displaced or suffered threats, intimidation, torture or forced recruitment by organized crime groups participating in drug trafficking and illegal mining.
- Many Awá live in extremely biodiverse areas that serve as corridors to other parts of the Amazon. But they've struggled to protect their ancestral land.

Struggles loom as Bolivia prepares new plan to clean up its mercury problem (Mar 9 2023)
- Bolivia's failure to combat illegal gold mining led to international outcry last year, as deforestation and mercury pollution continued to run rampant.
- Earlier this month, the government announced two plans to formalize small-scale and illegal gold mining operations and introduce technology that could help replace mercury.
- However, some critics say the government has a bad track record for implementing sweeping industry regulations, which might look good on paper but fall flat in practice.
- Major road investments in mining areas could also increase illegal activity at the same time the government is implementing regulations, as it will be easier for heavy machinery to access rural areas.

As Indonesia's new capital takes shape, risks to wider Borneo come into focus (Mar 8 2023)
- Indonesia's plan to build its new capital city on an expiring logging concession in eastern Borneo has sparked concerns among environmental and human rights observers about the larger eco-social impacts to the rest of the island.
- The administration of President Joko Widodo, who made the decision and will leave office next year, has made glowing promises of a green and sustainable development: claiming minimal forest clearance, respect for Indigenous and local communities' rights, and a net-zero carbon emission design.
- Mongabay visited the site of the project last October to see its progress, observe firsthand some of the earliest impacts from the construction of the city and supporting infrastructure, and speak with the people most likely to be affected.
- Clearing of mangroves and high-conservation forest areas, land conflicts with Indigenous communities, and potentially large-scale displacements are already happening, calling into question whether the $34 billion project's benefits will outweigh its downsides.

Logged and loaded: Cambodian prison official suspected in massive legalized logging operation (Mar 8 2023)
- A Mongabay investigation indicates that a three-star military general who also serves as a top interior ministry official appears to be the notorious illegal logger known as Oknha Chey.
- Family and business ties link Meuk Saphannareth to logging operations in northern Cambodia that

been awarded to Oknha Chey, while the interior ministry ignored Mongabay's questions about the allegations against Saphannareth.
- Some names have been changed to protect sources who said they feared reprisals from the authorities.

Amazon deforestation linked to reduced Tibetan snows, Antarctic ice loss: Study (Mar 8 2023)
- Earth's climate is controlled by a complex network of interactions between the atmosphere, oceans, lands, ice and biosphere. Many elements in this system are now being pushed toward tipping points, beyond which changes become self-sustaining, with the whole Earth system potentially shifting to a new steady state.
- A recent study analyzed 40 years of air temperature measurements at more than 65,000 locations to investigate how changes in one region rippled through the climate system to affect temperatures in other parts of the globe. Computer models then simulated how these links may be affected by future climate change.
- Researchers identified a strong correlation between high temperatures in the Amazon Rainforest and on the Tibetan Plateau. They found a similar relationship between temperatures in the Amazon and the West Antarctic Ice Sheet.
- Deforestation in the Amazon likely influences the Tibetan Plateau via a convoluted 20,000-kilometer (12,400-mile) pathway driven by atmospheric and oceanic circulation patterns. The study suggests that a healthy, functioning Amazon is crucial not only for the regional climate in Brazil, but for the whole Earth system.

Lost bird found: Dusky tetraka seen in Madagascar after 24-year absence (Mar 7 2023)
- The dusky tetraka, a small yellow songbird that had eluded ornithologists for 24 years, has been found again in the tropical forests of northeastern Madagascar.
- The bird was found at a lower elevation than expected, in thick underbrush near a river. The team plans to search for the dusky tetraka again during the breeding season to learn more about its ecology and biology.
- The dusky tetraka is listed as one of the top 10 most-wanted lost birds, an initiative that aims to locate bird species that have not been seen and recorded for a minimum of 10 years.
- More than 90% of the species found in Madagascar are endemic, with the island yielding at least 150 new-to-science species in the last 30 years.

NEXT

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Exhibit 14

Remotely sensed evidence of tropical peatland conversion to oil palm

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Rising global demands for food and biofuels are driving forest clearance in the tropics. Oil-palm expansion contributes to biodiversity declines and carbon emissions in Southeast Asia. However, the magnitudes of these impacts remain largely unquantified until now. We produce a 250-m spatial resolution map of closed canopy oil-palm plantations in the lowlands of Peninsular Malaysia (2 million ha), Borneo (2.4 million ha), and Sumatra (3.9 million ha). We demonstrate that 6% (or ≈880,000 ha) of tropical peatlands in the region had been converted to oil-palm plantations by the early 2000s. Conversion of peatswamp forests to oil palm led to biodiversity declines of 1% in Borneo (equivalent to four species of forest-dwelling birds), 3.4% in Sumatra (16 species), and 12.1% in Peninsular Malaysia (46 species). This land-use change also contributed to the loss of ≈140 million Mg of aboveground biomass carbon, and annual emissions of ≈4.6 million Mg of belowground carbon from peat oxidation. Additionally, the loss of peatswamp forests implies the loss of carbon sequestration service through peat accumulation, which amounts to ≈660,000 Mg of carbon annually. By 2010, 2.3 million ha of peatswamp forests were clear-felled, and currently occur as degraded lands. Reforestation of these clearings could enhance biodiversity by up to ≈20%, whereas oil-palm establishment would exacerbate species losses by up to ≈12%. To safeguard the region's biodiversity and carbon stocks, conservation and reforestation efforts should target Central Kalimantan, Riau, and West Kalimantan, which retain three-quarters (3.9 million ha) of the remaining peatswamp forests in Southeast Asia.

carbon payment | climate change | Reducing Emissions from Deforestation and Forest Degradation | rural livelihoods | tropical ecology

Global deforestation rates have remained worryingly high over the past decade, although forest loss might be slowing down in some areas such as the Amazon (1, 2). The top five countries with highest rates of primary forest loss–Brazil, Papua New Guinea, Gabon, Indonesia, and Peru–lost a total of 3.6 million ha of primary forests annually, due largely to agricultural and forestry expansion (3, 4). A case in point is oil palm agriculture in Southeast Asia (5 9). Indonesia and Malaysia are the world's top producers of palm oil (≈43 million Mg/y), accounting for 87% of global production (10). Since 1990, the combined harvested area for oil palm in both countries have expanded by 6.5 million ha, or almost fourfold (11). Even if only half of oil palm expansion resulted in forest loss (4, 8), this single crop would have contributed to >10% of total deforestation in Indonesia and Malaysia between 1990 and 2010 (1).

Indonesia and Malaysia harbor 80% (or ≈51 million ha) of Southeast Asia's remaining primary forests (1). These forests provide important ecosystem services, including biodiversity conservation, pest control, water filtration, and carbon storage and sequestration (6, 12, 13). In particular, the region's peatswamp forests (i.e., primary forests on tropical peatlands) both contain high concentrations of region endemic species and are important reservoirs of peat and biomass carbon (14). The conversion of peatlands to oil palm has purportedly contributed to substantial biodiversity declines and carbon emissions (5, 6, 14). However, surprisingly, scientists have little understanding of the historical pathways of land use change leading to oil palm development in Southeast Asia (4, 8, 15). Consequently, any environmental impact due to oil palm expansion remains largely unquantified, especially at the regional scale (4, 8, 16). The need to fill this gap in knowledge is acquiring urgency because oil palm agriculture continues to expand not only in Southeast Asia but also in other forest rich nations such as Papua New Guinea, Colombia, and Liberia (9, 17).

Our main objectives are (*i*) to produce a 250 m spatial resolution map of closed canopy oil palm plantations in the lowlands of Peninsular Malaysia, Borneo, and Sumatra for 2010; (*ii*) to quantify the extent of oil palm expansion in tropical peatlands by the early 2000s; (*iii*) to model the biodiversity impacts of converting peatswamp forests to oil palm, based on a matrix calibrated species area model; (*iv*) to estimate the magnitudes of above and belowground carbon emissions and forfeited carbon sequestration service due to peatland deforestation; and (*v*) to project the environmental impacts of alternative future land use scenarios for the region's peatlands.

Results

A total of 8.3 million ha of closed canopy oil palm plantations occur in Peninsular Malaysia (2 million ha), Borneo (2.4 million ha), and Sumatra (3.9 million ha) (Fig. 1 and Table S1). Approximately one tenth of these plantations are established on peatlands (≈880,000 ha, or 6% of total peatland area) (Table S2). The five subregions that suffered the most severe losses of peatswamp forests to oil palm are Riau (≈240,000 ha), Peninsular Malaysia (≈240,000 ha), North Sumatra (≈110,000 ha), Sarawak (≈100,000 ha), and West Sumatra (≈32,000 ha) (Fig. 2 and Table S2).

By the early 2000s, conversion of peatswamp forests to oil palm likely led to the local extinction of ≈3% of forest dwelling birds across our three study regions: 1% in Borneo (or four species), 3.4% in Sumatra (16 species), and 12.1% in Peninsular Malaysia (46 species) (Table 1). At the subregional level, projected biodiversity losses range from 0.2% in Central Kalimantan to ≈35% in Bengkulu (Table 1; discounting South and East Kalimantan, which have negligible oil palm area). Furthermore, this land use change potentially contributed to a net loss of ≈140 million Mg of aboveground biomass carbon, and annual emissions of ≈4.6 million Mg of belowground carbon from peat oxidation (Table 1). The loss of these peatswamp forests also implies the loss of associated carbon sequestration service through peat accumulation, which amounts to ≈660,000 Mg of carbon annually.

By 2010, a total of 2.3 million ha (roughly equivalent to the land area of New Jersey) of peatswamp forests have been clear-felled, although the fate of these clearings remains to be de

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Author contributions: L.P.K., J.M., S.C.L., and J.G. designed research, performed research, contributed new reagents/analytic tools, analyzed data, and wrote the paper.

The authors declare no conflict of interest.

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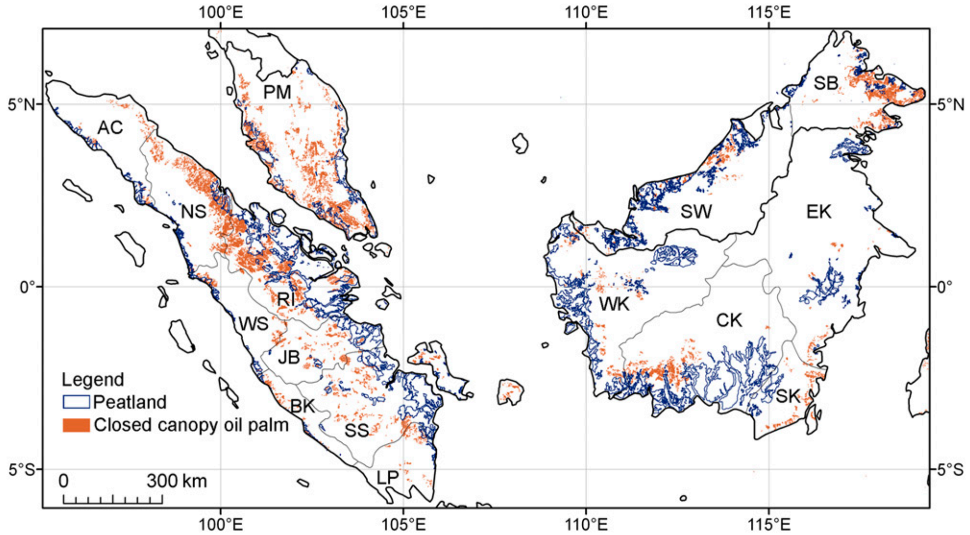

Fig. 1. Distribution of closed canopy oil palm plantations and tropical peatlands in the lowlands of Peninsular Malaysia, Borneo and Sumatra (PM, Peninsular Malaysia; SW, Sarawak; SB, Sabah; WK, West Kalimantan; CK, Central Kalimantan; SK, South Kalimantan; EK, East Kalimantan; AC, Aceh; NS, North Sumatra; RI, Riau; WS, West Sumatra; JB, Jambi; BK, Bengkulu; SS, South Sumatra; LP, Lampung).

termined (Fig. 2 and Table S2). The most extensive areas of cleared peatlands are found in Riau (≈450,000 ha), Central Kalimantan (≈400,000 ha), South Sumatra (≈320,000 ha), and Sarawak (≈290,000 ha) (Fig. 2 and Table S2). The recovery of mosaic vegetation on these clearings could enhance bird diversity by at least 0.2% (Aceh), whereas the reforestation of these lands could boost biodiversity by up to ≈20% (South Kalimantan) (Fig. 3 and Table S3). In contrast, the planting of oil palm on cleared peatlands would result in further losses of biodiversity by between 0.6% (Aceh) and ≈12% (South Kalimantan).

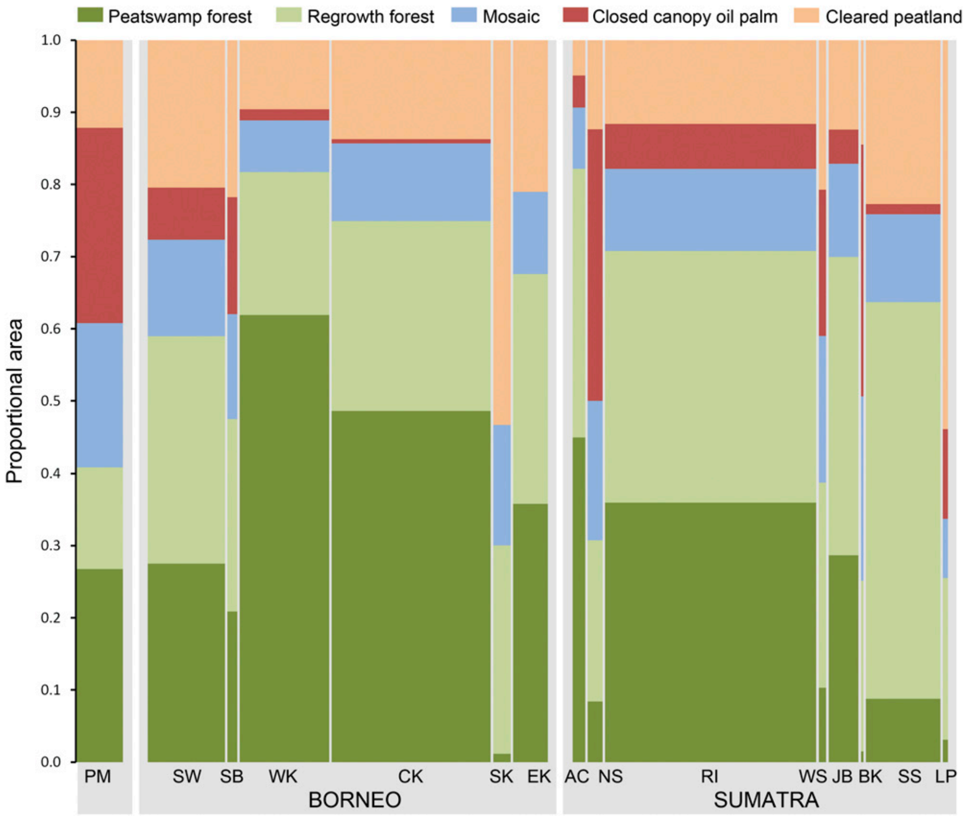

Fig. 2. Peatland composition in the lowlands of Peninsular Malaysia, Borneo, and Sumatra. Column widths reflect relative areas of peatland among sub regions. Refer to *Materials and Methods* for detailed definition of each land cover class; see also Table S2 (PM, Peninsular Malaysia; SW, Sarawak; SB, Sabah; WK, West Kalimantan; CK, Central Kalimantan; SK, South Kalimantan; EK, East Kalimantan; AC, Aceh; NS, North Sumatra; RI, Riau; WS, West Sumatra; JB, Jambi; BK, Bengkulu; SS, South Sumatra; LP, Lampung).

Table 1. Biodiversity and carbon losses from conversion of peatswamp forests to oil-palm plantations in the lowlands of Peninsular Malaysia, Borneo, and Sumatra

Region/subregion	Biodiversity loss,* %	Net biomass carbon loss,† Mg	Net peat carbon loss,‡ Mg/y	Forfeited carbon sequestration,§ Mg/y
Peninsular Malaysia	12.1 (±0.015)¶	36,825,473 (±9,283,335)	1,241,883 (±267,133)	178,088 (±59,679)
Borneo	1 (±0.001)	27,553,214 (±6,945,891)	929,190 (±199,872)	133,248 (±44,652)
Sarawak	3.6 (±0.005)	16,147,240 (±4,070,558)	544,541 (±117,132)	78,088 (±26,168)
Sabah	8.7 (±0.011)	4,690,878 (±1,182,524)	158,193 (±34,028)	22,685 (±7,602)
West Kalimantan	0.5 (±0.001)	3,982,546 (±1,003,960)	134,305 (±28,889)	19,260 (±6,454)
Central Kalimantan	0.2 (±<0.001)	2,727,705 (±687,627)	91,988 (±19,787)	13,191 (±4,420)
South Kalimantan	0	0	0	0
East Kalimantan	<0.01 (±<0.001)	4,845 (±1,221)	163 (±35)	23 (±8)
Sumatra	3.4 (±0.004)	72,238,161 (±18,210,520)	2,436,122 (±524,017)	349,345 (±117,068)
Aceh	1.7 (±0.002)	1,507,748 (±380,088)	50,847 (±10,937)	7,291 (±2,443)
North Sumatra	24.2 (±0.028)	16,922,431 (±4,265,976)	570,683 (±122,756)	81,837 (±27,424)
Riau	2.6 (±0.003)	37,604,540 (±9,479,730)	1,268,156 (±272,784)	181,856 (±60,941)
West Sumatra	14.3 (±0.017)	4,979,637 (±1,255,317)	167,931 (±36,122)	24,082 (±8,070)
Jambi	2.3 (±0.003)	4,207,353 (±1,060,632)	141,887 (±30,520)	20,347 (±6,818)
Bengkulu	35.1 (±0.037)	2,509,683 (±632,666)	84,635 (±18,205)	12,137 (±4,067)
South Sumatra	1.4 (±0.002)	3,107,549 (±783,382)	104,797 (±22,542)	15,028 (±5,036)
Lampung	16.3 (±0.018)	1,399,220 (±352,729)	47,187 (±10,150)	6,767 (±2,268)
Total study region	2.6 (±0.003)	136,616,848 (±34,439,746)	4,607,195 (±991,021)	660,681 (±221,398)

*Refers to the local extinction of bird species within the peatland landscape of each region/subregion that is attributable to the conversion of peatswamp forests to oil palm; modeled based on a matrix calibrated species area model (34, 35).

†Derived from the difference in aboveground biomass carbon between peatswamp forest (179.7 ± 38.2 Mg/ha) and oil palm (24.2 ± 8.1 Mg/ha) (39).

‡Derived from belowground carbon flux between heterotrophic soil respiration in oil palm and soluble and physical removal (i.e., carbon output; 10.3 ± 2.8 Mg/ha·y^{-1}), and oil palm litterfall and root mortality (i.e., carbon input; 5.1 ± 1.1 Mg/ha·y^{-1}) (39).

§Derived from rate of peat accumulation in peatswamp forest (0.75 ± 0.25 Mg/ha·y^{-1}) (39).

¶Number in parentheses indicates SE.

Discussion

Indonesia recently announced plans to double oil palm production by 2020 (18). Our analytical approach can be used for qualitative and quantitative monitoring of future land use change driven by oil palm expansion. This approach could facilitate more environmentally sustainable development in the country. An accuracy assessment of our oil palm map reveals that 98% of areas we identified to be oil palm is verified to be planted with oil palm; and 85% of areas covered by closed canopy oil palm plantations could be identified by our mapping approach. In practice, this assessment implies that our approach produced a highly reliable, albeit slightly conservative, map of closed canopy oil palm plantations within our study region.

Our results suggest that almost 90% of oil palm development, before the early 2000s, had occurred on nonpeat areas, and that only 6% of total peatlands within our study region had been planted with oil palm (Table S1). These findings imply that, from a regional perspective, the oil palm industry was not the main perpetrator of peatland deforestation. At the subregional level, however, substantial proportions of peatswamp forests in North Sumatra (≈38%), Bengkulu (≈35%), and Peninsular Malaysia (≈27%) were lost to oil palm (Fig. 2 and Table S2). These subregions also experienced the greatest biodiversity losses (Table 1). Furthermore, in absolute terms, the Indonesian province of Riau suffered the most severe deforestation due to oil palm expansion (≈240,000 ha) (Table S2). This deforestation resulted in a net loss of ≈38 million Mg of biomass carbon (roughly equivalent to annual greenhouse gas emissions from Britain's transportation sector) (19), which accounts for ≈28% of total carbon emissions attributable to oil palm conversion within our study region (Table 1). Therefore, oil palm development did result in substantial, albeit variable, biodiversity and carbon impacts across parts of Southeast Asia.

A recent analysis of agricultural and deforestation statistics for the period 1990 2005 shows that more than half of oil palm development in Malaysia and Indonesia had resulted in deforestation (8). These findings were subsequently confirmed by a remote sensing based analysis of land use change (4), which demonstrates that primary forests were the source of nearly 60% of new plantations established in Southeast Asia between 1980 and 2000, although that study did not distinguish unique expansion pathways for different types of commercial plantations (e.g., oil palm or rubber). Thus, the results of our analysis are consistent with previous estimates of land conversion. Additionally, our study reveals that the proportion of peatswamp forests destroyed by oil palm development (up to ≈38% in North Sumatra) is lower than the proportion of forests, in general, that was lost to oil palm (at least 50%). This finding is likely due to the higher financial costs of establishing oil palm plantations on peatlands than on mineral soils. Such additional costs derive largely from land preparation requirements before a new planting, including the drainage of the peat swamp (20). Nevertheless, as productive and profitable lands for oil palm become scarcer, and if global demands for palm oil continues to increase as predicted (5), future oil palm development will likely encroach more extensively on peatlands and other marginal areas.

In fact, our study shows that the extent of cleared peatlands (2.3 million ha) is more than double the land area under oil palm cultivation (≈880,000 ha) (Table S2). Some of these clearings might already be planted with oil palm (e.g., young palms lacking a closed canopy, and/or smallholder plantations <200 ha), but have not been so identified because of the limitations of our mapping approach (*Materials and Methods*). The remaining unplanted clearings are under increasing threat of conversion, particularly if cleared peatlands were to be considered "degraded lands" by land use policymakers. Recent international negotiations on climate change mitigation and forest protection have emphasized the diversion of future agricultural expansion to degraded lands (21 23). However, without a clear and transparent definition of degraded lands, any form of secondary vegetation, including cleared peatlands, will be exposed to future development risks, despite forest protection schemes such as Reducing Emissions from Deforestation and Forest Degradation (21 24). Our analysis shows that the conversion of cleared peatlands to oil palm would further threaten biodiversity and carbon

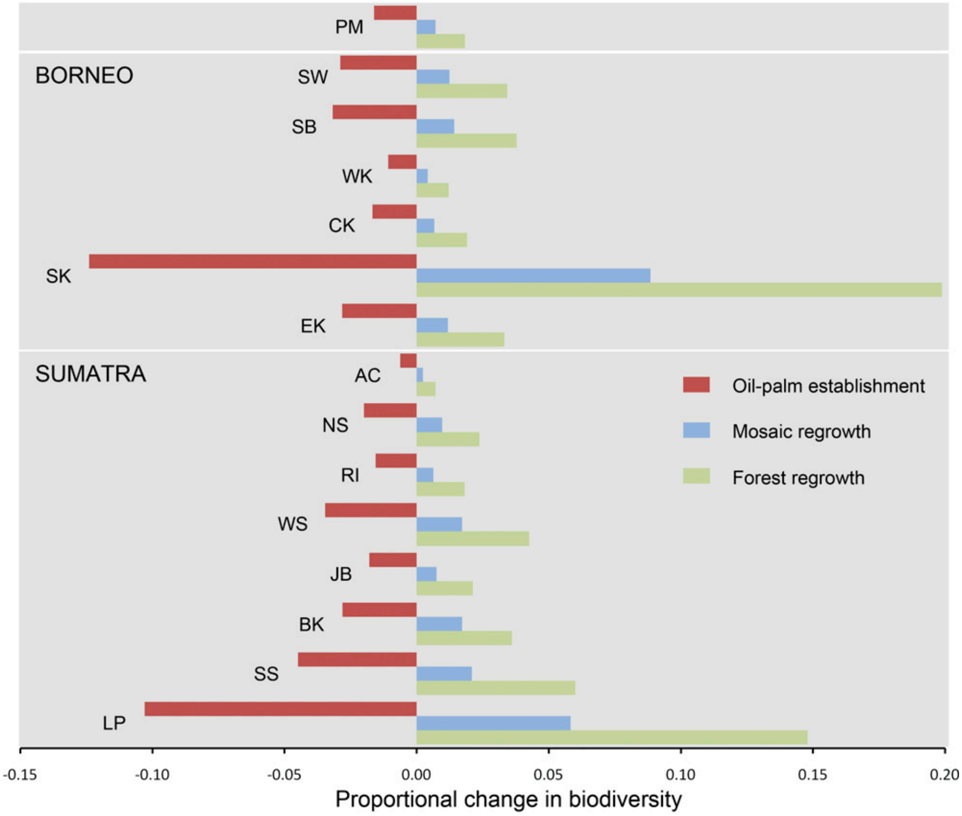

Fig. 3. Biodiversity outcomes of land use transition scenarios for cleared peatlands. Land use transition scenarios are oil palm establishment (cleared peatland to oil palm), mosaic regrowth (cleared peatland to mosaic), and forest regrowth (cleared peatland to regrowth forest). See also Table S3 (PM, Peninsular Malaysia; SW, Sarawak; SB, Sabah; WK, West Kalimantan; CK, Central Kalimantan; SK, South Kalimantan; EK, East Kalimantan; AC, Aceh; NS, North Sumatra; RI, Riau; WS, West Sumatra; JB, Jambi; BK, Bengkulu; SS, South Sumatra; LP, Lampung).

stocks, whereas the reforestation of such lands could reap substantial environmental benefits (Fig. 3 and Table S3). Therefore, we argue that cleared peatlands must be distinguished from degraded lands and be accorded a high priority for conservation and forest restoration efforts.

It is striking that more than half of peatswamp forests have been lost in all, except one (West Kalimantan), of the subregions (Fig. 2 and Table S2). Fortunately, subregions that contain the largest peatland areas are also those that still retain a third or more of their peatswamp forests: West Kalimantan (1 million ha), Central Kalimantan (1.4 million ha), and Riau (1.4 million ha). To safeguard the region's biodiversity and carbon stocks, forest protection efforts should be targeted at these three Indonesian provinces, which account for ≈74% of remaining peatswamp forests in our study region.

Materials and Methods

Mapping Oil Palm. The extent and distribution of oil palm plantations were derived from a 250 m spatial resolution land cover map of insular Southeast Asia, which was based on Moderate Resolution Imaging Spectroradiometer (MODIS) images acquired from the Earth Observing System Data Service (25, 26). A total of 490 daily MODIS images captured between January 2 and July 3, 2010, were used to create composite images of the study region. In addition, other data sources used in our analysis include 90 m spatial resolution digital elevation data from the Shuttle Radar Topography Mission (27), regional peatland distribution maps (28 30), and Daichi Advanced Land Observing Satellite (ALOS) data (31).

We adopted a three step approach to mapping oil palm plantations. First, we performed unsupervised land cover classification based on the ISODATA clustering algorithm (32), which produced 100 land cover clusters from the MODIS composite images we compiled. These clusters were visually inspected and assigned to one of five basic land cover types (water, forest, plantation/regrowth, mosaic, or open). Second, based on further visual inspection and manual delineation, the five basic land cover types were split into 12 land cover classes, including a "plantation/regrowth" class, which encompasses closed canopy vegetation ranging from tree crop plantations to dense shrubland and young secondary forests. Third, from this plantation/regrowth class, we identified closed canopy oil palm plantations based on the ALOS Phased Array type L band Synthetic Aperture Radar mosaic data (31). All areas within the plantation/regrowth land cover class with >6.5 dB difference in the HH (horizontal horizontal) and HV (horizontal vertical) backscatter values were identified as oil palm plantations (33). Given that only closed canopy (>80%) oil palm plantations could be identified by using this method, our mapping of oil palm was limited to mature plantations, estimated to be established in 2002 or earlier. Furthermore, because of the difficulty of distinguishing small patches of oil palm, we imposed a minimum threshold area of 200 ha for mapping oil palm plantations. Current satellite image resolution and our method of identifying oil palm plantations do not allow us to identify plantations smaller than this minimum threshold area. Thus, our analysis is limited to large scale monoculture plantations, which would typically be operated by oil palm corporations, aggregates of smallholder oil palm farmers, or government supported smallholder schemes. Subsequently, all areas classified as oil palm were visually inspected on the MODIS composite and ALOS mosaic images; clearly misclassified areas were excluded (mainly shrublands on peat soil, narrow stretches of coastal vegetation, and known rubber plantations).

To assess the accuracy of our mapping method, we acquired 100 pan sharpened IKONOS satellite images (natural color, 1 m spatial resolution) over southern Peninsular Malaysia (south of 3°N on the peninsula). We overlaid our newly generated land cover map on these IKONOS images. On cloud free portions of the IKONOS images, we randomly selected 100 sample pixels, comprising 50 pixels each of the plantation/regrowth land cover class and the oil palm areas we identified by using the method described above. Each sample pixel was then visually inspected and determined to be either a closed canopy oil palm plantation or not, using the IKONOS images for verification. Finally, we quantified the proportion of incorrectly identified oil palm samples, as well as the proportion of oil palm samples that our method failed to identify.

The land cover classes relevant to this study are defined as follows: (*i*) peatswamp forest: forest growing on peat soil; (*ii*) regrowth forest: closed canopy plantations (excluding oil palm) and natural secondary forests; (*iii*) mosaic: mosaic of closed canopy vegetation and open areas comprising croplands, agroforests, and small forest patches; (*iv*) closed canopy oil palm: large scale, mature oil palm monoculture; (*v*) cleared peatland: open areas covered by remnants of original vegetation, sparse grass/shrublands, and transitional agricultural areas.

Modeling Biodiversity Change. We modeled change in biodiversity based on a matrix calibrated species area model (34, 35). This model accounts for both changes in primary forest cover and taxon specific responses to each component of a heterogeneous landscape matrix. By accounting for difference in matrix composition between landscape scenarios, the model allows the attribution of any changes in biodiversity to specific land use transitions. The matrix calibrated species area model partitions the *z* value (i.e., slope) of species area models, into two components: γ, a constant, and σ, a measure of the sensitivity of the taxon to the transformed habitat [quantified as the proportional decrease in the number of species ($0 < \sigma < 1$)]. The model accounts for situations whereby land use change results in a mosaic of several habitat types of varying quality for the taxon, by incorporating an area weighted average of the taxon's response to each component of the heterogeneous transformed landscape. The matrix calibrated species area model is expressed as:

$$\frac{S_{\text{new}}}{S_{\text{org}}} = \left(\frac{A_{\text{new}}}{A_{\text{org}}}\right)^{\gamma\cdot\sum_i^n p_i\sigma_i}$$

where *S* and *A* represent species richness and primary forest area, respectively; and the subscripts "new" and "org" represent the transformed and original landscapes, respectively. Additionally, *p* is the proportional area of the *i*th habitat type relative to the total converted land area (matrix), and n represents the total number of habitat types. We focused our analysis on forest dwelling birds defined as those species that might occur in non forested habitats but require forests for long term persistence as an indicator of potential change in forest biodiversity. Birds are arguably the best studied tropical taxon in terms of the effects of land use change on biodiversity (16). Based on data on *z* values compiled by Watling and Donnelly (36), we calculated the mean slope of species area relationships of birds on land bridge archipelagos and used this value, $z = 0.35 \pm 0.06$ (±SEM), as the γ value in the matrix calibrated model. Additionally, based on the data compiled by Sodhi et al. (16), we determined the sensitivity (i.e., the σ value) of birds to cleared peatland ($\sigma = 0.43 \pm 0.06$), closed canopy oil palm ($\sigma = 0.70 \pm 0.04$), regrowth mosaic ($\sigma = 0.33 \pm 0.05$), and regrowth forests ($\sigma = 0.14 \pm 0.03$).

For each region/subregion, we modeled biodiversity loss due to oil palm conversion by comparing projected biodiversity outcomes between two landscape scenarios: pre oil palm and post oil palm development. Under the post oil palm development scenario, we projected the percentage biodiversity remaining in the peatland landscape by applying the matrix calibrated species area model, based on the above γ and σ parameters, on current peatland composition (Table S2). Under the pre oil palm development scenario, we did the same except that we assumed all current oil palm planted areas were occupied by peatswamp forests. We quantified the percentage biodiversity loss attributable to oil palm conversion as the difference in biodiversity projections between these two scenarios. To calculate absolute biodiversity loss, these predictions of percentage biodiversity loss were applied to the known number of species of birds occurring within regional peatswamp forests (Peninsular Malaysia: 381 species; Sumatra: 463 species; Borneo: 396 species) (37).

In this study, biodiversity loss refers to local species extinctions (i.e., population extinctions). Furthermore, because of the lag effects of species "extinction debts" (38), our projections of species losses would include persistent species that are consigned to extinction.

Additionally, we modeled biodiversity change under three alternative land use transition scenarios for cleared peatlands: (*i*) oil palm establishment (cleared peatland to oil palm), (*ii*) mosaic regrowth (cleared peatland to mosaic), and (*iii*) forest regrowth (cleared peatland to regrowth forest). We applied the matrix calibrated species area model, as described above, to calculate the potential change in species richness of birds resulting from each alternative land use transition scenario.

We performed Monte Carlo simulations to account for variability in both the slope of species area relationships (γ value) and the sensitivity of birds to each land cover class (σ value). For a total of 100,000 simulation runs, we entered randomized γ and σ values derived from their mean and SD (assuming normal distribution of errors) to the species area model to calculate the mean biodiversity remaining (and SE) under each landscape/land use transition scenario.

Estimating Carbon Emissions due to Oil Palm Conversion. We assumed that all oil palm plantations on peatlands were converted from peatswamp forests (i.e., there was no intermediate land use). We calculated potential biomass carbon loss as the difference in aboveground biomass carbon between peatswamp forest (179.7 ± 38.2 Mg/ha) (±SEM) and oil palm (24.2 ± 8.1 Mg/ha) (39). Hence, conversion of peatswamp forest to oil palm would result in net carbon loss of 155.5 ± 39.2 Mg/ha. We derived potential peat carbon emissions based on the belowground carbon flux between heterotrophic soil respiration in oil palm and soluble and physical removal (i.e., carbon output; 10.3 ± 2.8 Mg/ha·y^{1}), and oil palm litterfall and root mortality (i.e., carbon input; 5.1 ± 1.1 Mg/ha·y^{1}) (39). Therefore, conversion of peatswamp forest to oil palm would lead to net peat carbon emissions of 5.2 ± 1.1 Mg/ha·y^{1}. We quantified forfeiture in carbon sequestration service as the rate of peat accumulation in peatswamp forests (0.75 ± 0.25 Mg/ha·y^{1}) (39).

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Exhibit 15

PLOS | ONE

RESEARCH ARTICLE

The Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss

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Abstract

Palm oil is the most widely traded vegetable oil globally, with demand projected to increase substantially in the future. Almost all oil palm grows in areas that were once tropical moist forests, some of them quite recently. The conversion to date, and future expansion, threatens biodiversity and increases greenhouse gas emissions. Today, consumer pressure is pushing companies toward deforestation-free sources of palm oil. To guide interventions aimed at reducing tropical deforestation due to oil palm, we analysed recent expansions and modelled likely future ones. We assessed sample areas to find where oil palm plantations have recently replaced forests in 20 countries, using a combination of high-resolution imagery from Google Earth and Landsat. We then compared these trends to countrywide trends in FAO data for oil palm planted area. Finally, we assessed which forests have high agricultural suitability for future oil palm development, which we refer to as vulnerable forests, and identified critical areas for biodiversity that oil palm expansion threatens. Our analysis reveals regional trends in deforestation associated with oil palm agriculture. In Southeast Asia, 45% of sampled oil palm plantations came from areas that were forests in 1989. For South America, the percentage was 31%. By contrast, in Mesoamerica and Africa, we observed only 2% and 7% of oil palm plantations coming from areas that were forest in 1989. The largest areas of vulnerable forest are in Africa and South America. Vulnerable forests in all four regions of production contain globally high concentrations of mammal and bird species at risk of extinction. However, priority areas for biodiversity conservation differ based on taxa and criteria used. Government regulation and voluntary market interventions can help incentivize the expansion of oil palm plantations in ways that protect biodiversity-rich ecosystems.

Introduction

African oil palm (*Elaeis guineensis* Jacq.) is a tropical crop grown primarily for the production of palm oil. It is the world's highest yielding and least expensive vegetable oil, making it the preferred cooking oil for millions of people globally and a source of biodiesel. Palm oil and its derivatives are also common ingredients in many packaged and fast foods, personal care and

Competing Interests: The authors have declared that no competing interests exist.

cosmetic products, and household cleaners. Driven by demand for these products, palm oil production nearly doubled between 2003 and 2013 [1] and is projected to continue increasing [2, 3]. Palm oil is the most important tropical vegetable oil globally when measured in terms of both production and its importance to trade, accounting for one-third of vegetable oil production in 2009 [4, 5]. The dominance of palm oil may be explained by the yield of the oil palm crop, over four times that of other oil crops [6], as well as its low price and versatility as an ingredient in many processed goods [7].

In this study, we seek to identify where oil palm has recently replaced tropical forests because this may best anticipate where future deforestation may occur. Furthermore, we wish to understand where future deforestation may cause the most harm to biodiversity.

The growth in demand for palm oil has led to a large expansion of the land used to produce it. Because the oil palm's range is limited to the humid tropics, much of this expansion has come at the expense of species-rich and carbon-rich tropical forests. Oil palm was responsible for an average of 270,000 ha of forest conversion annually from 2000–2011 in major palm oil exporting countries [8]. One study found that >50% of Indonesian and Malaysian oil palm plantations in 2005 were on land that was forest in 1990 [9].

Cutting carbon emissions from tropical deforestation could play a critical role in limiting the impacts of climate change and contribute toward global mitigation efforts aimed at reaching the agreed goal of <2 degree C global temperature increase [10]. Annual carbon emissions from gross tropical deforestation are estimated at 2.270 Gt CO_2 from 2001–2013 [10], contributing nearly 10% of the global total of anthropogenic greenhouse gas emissions. There is growing recognition of the need to limit or end such deforestation. More than 180 governments, companies, indigenous people's organizations, and non-governmental organizations have signed the New York Declaration on Forests (NYDF). It calls for ending deforestation from the production of agricultural commodities such as palm oil by no later than 2020 as part of a broader goal of reducing deforestation 50% by 2020 and eliminating it by 2030. The Consumer Goods Forum, representing more than 400 retailers and manufacturers, has taken up this goal and pledged to help eliminate deforestation in member companies' supply chains by 2020.

Different scenarios of oil palm development will lead to very different outcomes in terms of deforestation and carbon emissions, such as the development of degraded land versus peatlands in Indonesia [11]. In recent years, consumers and non-governmental organizations (NGOs) have increasingly called on consumer goods companies to buy responsibly produced palm oil and companies have begun to adopt voluntary measures [12]. The main organization responsible for the certification of sustainable palm oil is the Roundtable on Sustainable Palm Oil (RSPO), a group composed of oil palm producers, palm oil processors and traders, manufacturers, retailers, investors and NGOs. This certification system requires the producers to follow several criteria including transparency of management, conservation of natural resources and the execution of social and environmental impact assessments [13].

Currently, there are 3.51 million hectares of RSPO certified oil palm plantations producing 13.18 million tonnes of palm oil, making up 21% of global palm oil production [14]. NGOs have raised concerns about the monitoring and enforcement of standards for certification [15, 16, 17]. Furthermore, while primary forests and High Conservation Value forests (those deemed to have significant biodiversity or cultural value, or that provide ecosystem services) are protected under RSPO regulations, secondary, disturbed or regenerating forests are unprotected. RSPO certification has been criticized as insufficient from an environmental perspective [18]. Finally, there are concerns about the sources of palm oil that lacks certification, much of which is processed or traded by RSPO member companies and sold in the global marketplace [19].

Because Indonesia and Malaysia together account for approximately 80% of global oil palm fruit production [1], many studies focus solely on these countries [9, 20]. As area for expansion in this region is limited, however, future expansion of oil palm plantations is likely to occur in other areas. Oil palm is currently grown in 43 countries (Fig 1A) so understanding the environmental impacts at a global level may help in understanding differences in development patterns that have led to deforestation. Fig 1B shows the percent growth in oil palm harvested area from 2003–2013. Despite having little plantation area currently, some countries in Latin America and Africa experienced greater percent growth during this period than did either Indonesia or Malaysia. If these growth rates continue, oil palm plantation expansion in these countries will likely have increased impacts.

Other reasons past assessments may have focused on only one or two countries are the many obstacles that face regional and global assessments of land cover changes and land use history. Assembling imagery across many countries using local resources is prohibitively labour intensive. While global satellite datasets are available, such as Landsat Thematic Mapper (TM) imagery from 1984 to the present, identifying land cover transitions from these images can be difficult, especially in humid tropical areas with frequent cloud cover. This means that transitions between distinct cover types (e.g. forest and row crops) are more reliably identified than those between similar cover types (e.g. fragmented forests and shifting cultivation). Thus, while availability of high-resolution imagery over much of the globe makes it possible to identify current land cover with great accuracy, sometimes even specific crops such as oil palm, the assessment of historical land cover is limited to broad categories in global assessments. For example, when Gibbs et al. [21] made a global assessment of land cover changes for the expansion of agriculture in the tropics, they decided to classify using only five land cover types to reduce these types of errors.

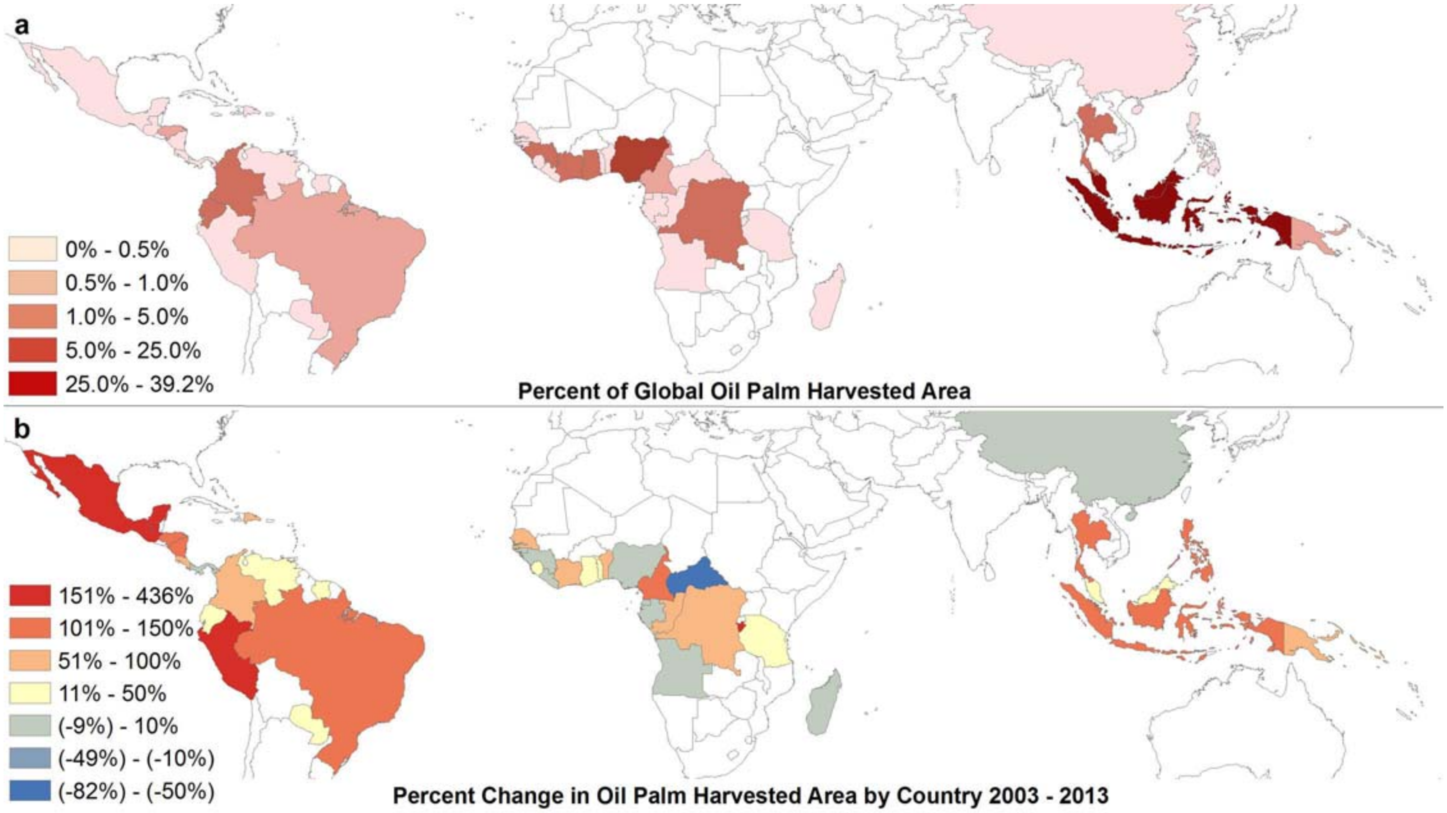

Fig 1. World production of palm oil. (a) Percent of FAO reported total global oil palm harvested area in 2013. (b) Percent changes in FAO reported oil palm harvested area by country from 2003–2013.

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We adopted a new approach. First, we identified current oil palm plantations in 20 countries using high-resolution imagery. Second, we examined what proportion of these sites were recently deforested and compared this to trends in the FAO's estimates of the total area planted in oil palm. Third, we mapped where forests are vulnerable to deforestation for oil palm based on an FAO crop suitability model and the location of current IUCN category I and II protected areas. We did so for both current climatic conditions and those projected for 2080. Finally, we mapped the biodiversity of mammals and birds in these vulnerable forests to attempt to identify where future oil palm expansion may be most damaging.

Materials and Methods

Site Analysis

We studied oil palm plantations in 20 countries in four regions of interest: 1.) South America; 2.) Central America, Mexico and Caribbean (which we will refer to as Mesoamerica); 3.) Africa; and 4.) Southeast Asia. In each region, we selected the five countries with the largest values of FAO 2013 palm oil production.

We selected individual sample sites with oil palm monoculture using high-resolution imagery available from Google Earth of sufficient resolution to identify visually the pattern of individual oil palm trees. Whenever possible, we verified sample sites using corroborating news articles, geotagged photos, government and company records, or scholarly articles. We also used these sources to identify regions within each country (e.g. states and provinces) where oil palm is produced and examined each for oil palm to improve the spatial distribution of such sites within each country. A fully random selection of sites based on age would have been prohibitively time consuming, if even possible with available satellite imagery and mapping algorithms. The sampled oil palm areas covered at least 3% of the FAO 2013 total oil palm harvested area for each sample country. The percentage of sampled area was much higher for many lower production countries (Table 1).

Table 1. Percent of Total Oil Palm Planted Area Sampled by Country.

Producer Country	FAO Total Oil Palm Harvested Area 2013(km^2)	Sample Area (km^2)	Percent FAO Sampled(2013)
Indonesia	70,800	2,258.5	3.2
Malaysia	45,500	2,289.9	5.0
Nigeria	20,000	609.8	3.0
Thailand	6,264	203.6	3.3
Ghana	3,600	140.1	3.9
Ivory Coast	2,700	315.3	11.7
Colombia	2,500	766.5	30.7
Ecuador	2,188	189.1	8.6
Dem. Rep. of Congo	2,100	105.2	5.0
Papua New Guinea	1,500	162.5	10.8
Cameroon	1,350	161.3	11.9
Honduras	1,250	243.9	19.5
Brazil	1,220	513.2	42.1
Costa Rica	745	166.8	22.4
Guatemala	650	137.9	21.2
Philippines	500	70.9	14.2
Peru	475	280.2	59.0
Mexico	461	25.1	5.5
Venezuela	270	58.3	21.6
Dominican Republic	170	78.1	46.0

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We used Landsat 8 imagery for 2013–2014 along with the high-resolution imagery from Google Earth to digitize sample plantation areas. For change analysis at each sample site, we acquired Landsat 4–5 TM and Landsat 7 ETM (SLC-on) images for three periods: 1984–1990, 1994–2000, 2004–2010 with some variation based on the availability of cloud-free imagery. We digitized deforested land within each sample area from the satellite imagery using ArcMap 10.2 [22]. We identified forest within the sample using visual classification, comparing spectral characteristics to nearby forest areas outside the sample but within the same Landsat scene. These reference forest areas were verified using high-resolution imagery from Google Earth. In each of the 20 sample countries, we examined the deforestation since 1989 for sample areas identified as oil palm in 2013. Fig 2 shows an example. For 2013, (bottom right) we used high-resolution imagery to outline an oil palm planted area. Using lower resolution Landsat imagery, we have outlined in black the area deforested in 2004, 1997, and 1990. Because of the lower resolution, we cannot confirm whether the deforested areas are indeed early stage oil palm plantations or land cleared for other reasons.

We did not evaluate regrowth for this study because we were interested in the earliest identifiable deforestation events in areas currently occupied by oil palm. Finally, to facilitate analyses at larger spatial scales, we linearly interpolated annual deforested area between image dates to produce an annual time series of deforested area in each sample. We used 1989 as a start date for analysis since satellite imagery for the first sample point of most sites was available by that date (85%). The latest starting sample was 1991.

We estimated historical deforestation within current oil palm plantations (relative to the 2013 plantation area) by summing the annual deforested area estimates for all sample sites and normalizing by the total sample area within each country. To scale up from country to regional deforestation trends within areas currently occupied by oil palm, we calculated the weighted average of individual country trends with weights based on FAO 2013 total oil palm harvested area. The underlying assumption is that the trend we observed in each country is representative of all current oil palm planted area within that country. We also compared country deforestation trends with overall growth in oil palm plantation area by plotting each country deforestation trend with FAO oil palm planted area, normalized by the 2013 value. For clarity, we refer

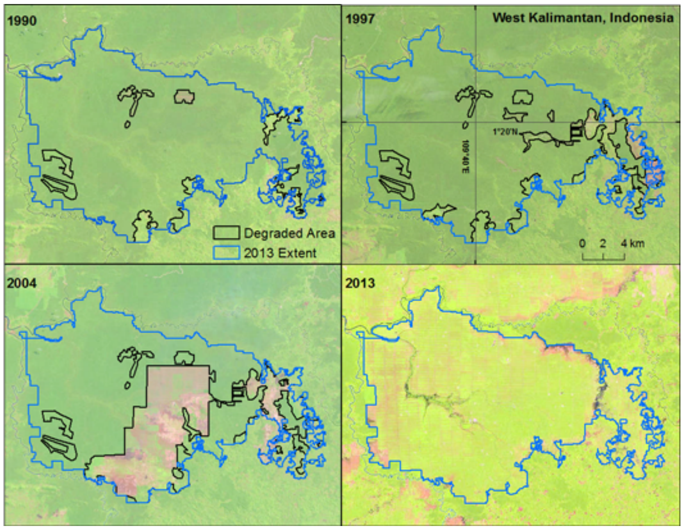

Fig 2. Example of deforestation site analysis within an oil palm plantation in Bawat, West Kalimantan, Indonesia. Each panel represents one sample year, with the deforested area in that year outlined in black and the 2013 oil palm planted area outlined in red. Imagery from Landsat 5 TM (1990, 1997 and 2004) and Landsat 8 (2013).

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to the FAO harvested area data as planted area in the rest of our analyses, since the time from planting until the first harvest is approximately 2.5 years [23], much shorter than the intervals of our measurement. We acknowledge that the accuracy of the FAO data may vary by country, but these data remain the best estimate of oil palm planted area available.

Oil Palm Vulnerable Forest Assessment

We determined the current suitable area for oil palm agriculture using the Food and Agriculture Organization of the United Nations (FAO) Global Agro-Ecological Zones (GAEZ) model for agricultural suitability of oil palm [24]. The GAEZ agricultural suitability model primarily incorporates knowledge of crop specific soil nutrient and climatic requirements to determine the suitability of crop planting under varying management regimes. We used the model for rain-fed high input (industrial scale) agriculture because it represents the primary method of oil palm cultivation globally.

To determine future suitable area for oil palm plantations, we used GAEZ model outputs of suitability for 2080. To represent "business as usual" and reduced emission scenarios, we used IPCC emission scenarios A2 and B2, respectively. We averaged all the GAEZ outputs for global climate models Canadian Centre for Climate Modelling and Analysis (CCCma), Coupled Global Climate Model(CGCM2), CSIRO Atmospheric Research Mark 2b (CSIRO MK2) and Max Plank Institute ECHAM4 (MPI ECHAM4) for both emission scenarios to produce an average estimate for crop suitability in 2080. We considered, but excluded, Hadley model projections from the estimates because they were divergent from other projections.

Values for the suitability models range from 0–100 with 100 representing areas most suited to oil palm cultivation. We used a threshold suitability value of 30, which we based on the lower bound of the 95% confidence interval of suitability for 200 random points inside sample plantations with a minimum distance of 1 km between points. Because the GAEZ suitability used represents high-input rain-fed agriculture, not all sample plantations fit the suitability criteria and we excluded 4 of the 200 points that had zero suitability.

Once we determined suitable areas for oil palm plantations, we estimated the forest area within these areas that may be vulnerable to oil palm development. The MODIS 250m Vegetation Continuous Fields (VCF) tree cover dataset Version 5 2010 [25] provided forest cover classification. To reduce the incidence of random errors in the data, we used the median of MODIS VCF layers from 2008 to 2010.

As an additional filter to remove cropland area from the vulnerable forest layer, we overlaid the 300m GlobCover 2009 Cropland data on a rescaled median MODIS VCF 300m layer [26]. To remove pixels with crop presence from the forest dataset, we set a threshold for both layers at 50% to create binary classifications. We also excluded International Union for Conservation of Nature (IUCN) category I and II protected areas, obtained from the World Database on Protected Areas (WDPA), from the forest layer [27]. Finally, we excluded the sample plantation sites from the Site Analysis above from the vulnerable forest area as oil palm plantations occupy these areas currently. Eliminating both the crop areas and sample plantation areas were intended as a correction to remove much of the tree plantation area from the forest cover data. It is likely that some plantation areas remained misclassified as forest.

Biodiversity Assessment for Vulnerable Forest Areas

To estimate the potential impact on biodiversity of oil palm related deforestation, we analysed species range data for mammals and birds [28, 29]. As these studies point out, the risk of extinction is more accurately determined by looking at impacts of development on small-ranged and threatened species rather than total number of species. Therefore, we overlaid the number of small-ranged and threatened species with baseline oil palm vulnerable forests, as determined by the analysis above. From the resulting maps, we attempted to identify areas of high conservation value within the forest vulnerable to oil palm in each region.

Results

Data associated with each of the analyses performed in this paper: site analysis, vulnerable forest analysis and biodiversity prioritization, are available through the Dryad data repository (doi:10.5061/dryad.2v77j) and Supporting Information.

Regional Trends

For each sample site, we determined the percent of forest area within the current oil palm plantation areas for three dates from 1984–2010, as well as in 2013. We interpolated these data for each year and then aggregated them at the country scale relative to the plantation area of the sites in 2013 (S1 Table). Fig 3 shows percent forest within sample oil palm plantations for the four regions. Note that the absolute area of oil palm plantations in 2013 varied greatly by country (Table 1) and country trends were weighted by each country's total FAO plantation area for 2013 to calculate regional trends. All regions reach 0% forest in 2013 when the sample areas were fully converted to oil palm plantation.

Mesoamerican and African oil palm plantations had the lowest percent forest in 1989. Only 2% and 7%, respectively, of sample plantation area was forest at the beginning of the study.

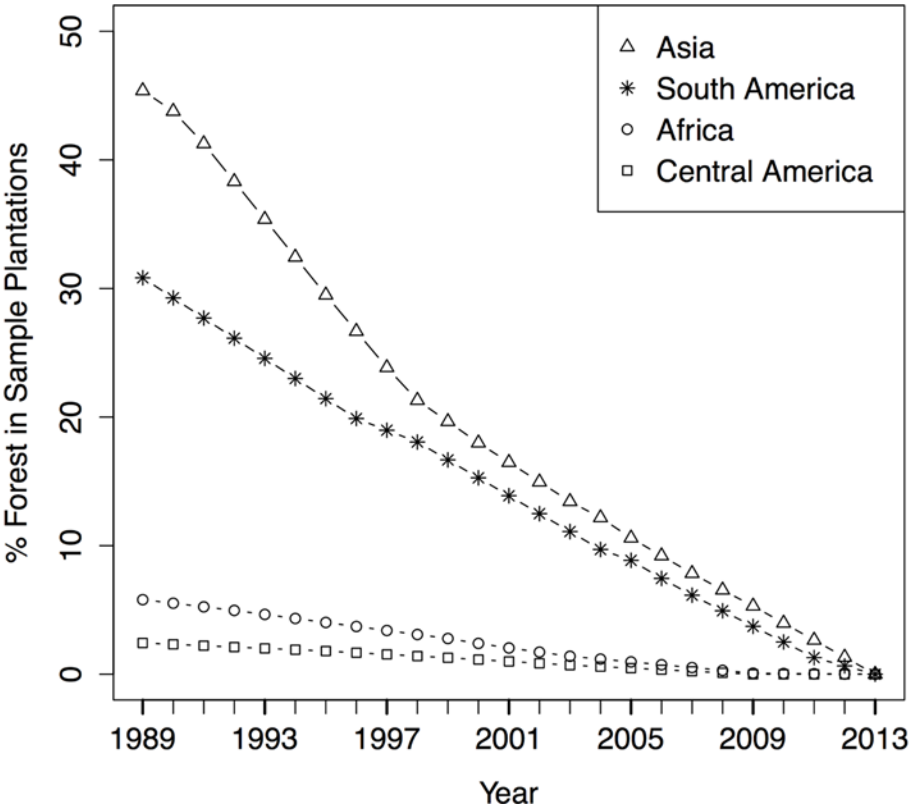

Fig 3. Annual percent change in forest areas within oil palm plantations by region. Values are an average of the proportion of sampled 2013 oil palm plantation area classified as forest each year in five countries within each region, weighted by each country's 2013 FAO-reported oil palm planted area.

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This need not necessarily indicate continuous production of oil palm on these sites. It may indicate other uses such as pasture or annual row crops before conversion to oil palm.

In contrast, Asian plantations had the highest estimated percent forest in 1989 (45%), while South American plantations were intermediate between the other regions (31%). Thus, a greater percentage of oil palm expansion in these countries came at the expense of intact forest since 1989. Examination of the deforestation trend in Southeast Asia shows that deforestation within plantations occurred more rapidly between 1989 and 1998, whereas in South America, the deforestation trend appeared to be linear during the study period.

Country Trends

For each sample country, we examined the recent history (1989–2013) of expansion in oil palm plantation area and the degree to which it was associated with deforestation for oil palm plantations. Fig 4 shows the trends in two metrics relative to their 2013 value: the total area of oil palm plantation FAO reports (open circle) and the percent deforested in our sample plantation (solid triangle). Note that all percentages reported in this section are relative to the 2013 values. Due to this rescaling, both values are 100% in 2013. The figure highlights two countries selected from the five sample countries in each region that either exemplify or show distinct trends from the rest of the region (see S1 Fig). The percent changes in these quantities over the study period are given in Table 2 for all countries.

In Mesoamerica, all five countries showed large percent increases in the FAO estimates of oil palm area. All five countries also had little to no deforestation within the sample areas during the study period. Guatemala (Fig 4A) and Mexico (Fig 4B) are typical. In contrast, in Africa the total area of oil palm plantations has fluctuated considerably in the sample countries. The area of oil palm plantations increased from 1989 to 2013 in all five countries, but experienced some years without growth or with declines. The net increase was lowest for DRC (Fig 4C) and Nigeria (Fig 4D) with periods of dramatic decline in the area planted for both. In Cameroon, Ghana, and the Ivory, the increase in planted area was higher. As in Mesoamerica, sample countries in Africa were mostly deforested at the beginning of the study period. Of the five countries, we observed the largest amount of deforestation from 1989 to 2013 in Cameroon (16.9%).

All sample countries in South America showed large increases in the total area of oil palm. For some, the patterns of increase mirrored the patterns of deforestation, as seen in Ecuador (Fig 4E) and Peru (Fig 4F). Brazil also experienced large increases in FAO planted area accompanied by large increases in area deforested in the samples. Only for two countries, Venezuela and Colombia (S1 Fig), did we find sample sites 100% deforested by 1989 despite large increases in the FAO planted area (Table 2). In Venezuela, the rapid increase in planted area occurred from about 1989 to 1995, after which the recorded planted area remained static (S1 Fig).

In Asia, all countries showed large increases in area planted for oil palm. Indonesia (Fig 4G) and Malaysia (Fig 4H) are typical of countries where deforestation mirrors increases in planted area. Papua New Guinea, to a lesser degree, was consistent with the trend of deforestation mirroring increases in oil palm planted area. In contrast, in the Philippines and Thailand, the sample sites had been 100% deforested in1989, despite marked increases in FAO planted area (Table 2).

In summary, we observe two main trends in deforestation within sample countries. One is the conversion of previously deforested land to oil palm, resulting in low levels of deforestation during the study period. We observed this scenario in the sample countries in Mesoamerica and Africa, as well as in Colombia, Venezuela, Philippines and Thailand. Data from the other

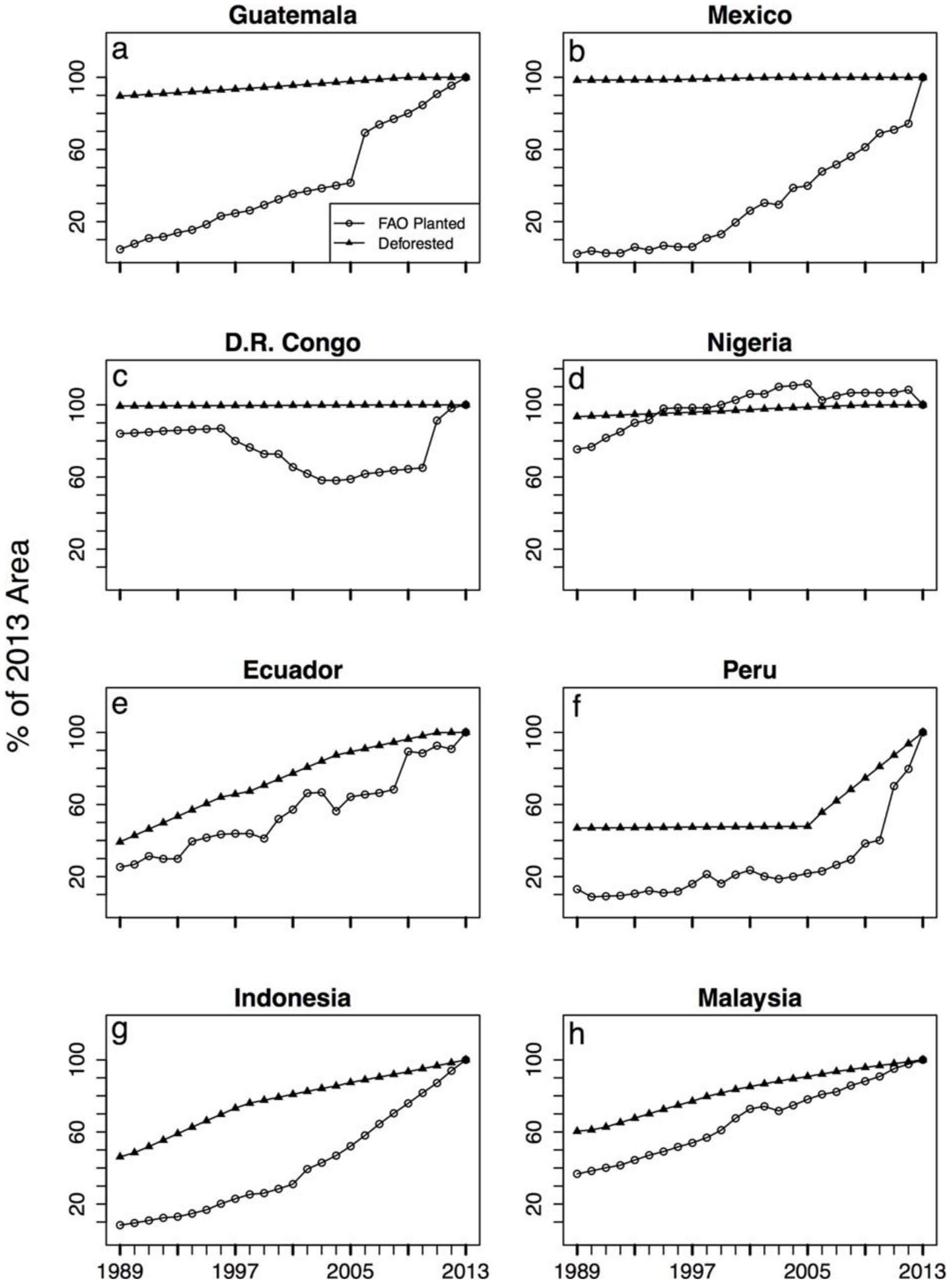
% of 2013 Area
Guatemala
a
Mexico
b
D.R. Congo
c
Nigeria
d
Ecuador
e
Peru
f
Indonesia
g
Malaysia
h
FAO Planted
Deforested
20
60
100
1989
1997
2005
2013

Fig 4. Trends of deforestation and oil palm planted area. Trends of deforestation inside sampled oil palm plantations (solid triangle) and total FAO oil palm planted area for eight countries (open circle). Both trends are relative to 2013 values, thus both reach 100% in 2013. Countries represented are either representative of regional trends or distinct from regional trends for sample countries. (a, b) Mesoamerica, (c, d) Africa, (e, f) South America, (g, h) Southeast Asia.

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countries in South America and Asia suggest a second scenario, where deforestation in sample sites mirrors oil palm plantation expansion. We observed this trend in a majority of countries in South America (Ecuador, Peru, and Brazil) and Asia (Indonesia, Malaysia and Papua New Guinea). This scenario suggests a rapid transition from forest to plantation, resulting in higher levels of deforestation during the study period.

Vulnerable Forest Assessment

Fig 5 shows the area that is suitable for oil palm that is forested (green) and deforested (blue), current IUCN category I and II protected areas (orange), and vulnerable forest area (current in dark and forecasted for 2080 in light green). We define vulnerable forest area as forest located inside suitable area for oil palm, but outside IUCN I and II protected areas, with total areas listed in Table 3 for both present and 2080. Though we excluded IUCN category I and II protected areas from the vulnerable forest areas, we determined that present rates of coverage of vulnerable forest by these categories of protected area were low in all regions, ranging from 4.4% of oil palm suitable forests in Southeast Asia to 11% in Mesoamerica.

We predict decreases in vulnerable forest area in three of the four study regions, based on the mean climate model projection for 2080 (excluding the Hadley model) and the resulting shifts in climatic suitability for oil palm cultivation. Only Africa shows an increase in total vulnerable forest area in 2080. However, even though some forested areas may become unsuitable

Table 2. Percent increase in FAO total oil palm planted area from 1989–2013 by country and estimated percent of oil palm planted area coming from deforestation since 1989.

Producer Country	Percent increase in planted area	Percent of area from deforestation
Indonesia	91.7	53.8
Malaysia	63.3	39.6
Nigeria	24.7	6.6
Thailand	85.5	0.0
Ghana	63.9	0.4
Ivory Coast	62.0	4.1
Colombia	69.5	0.0
Ecuador	74.7	60.8
Dem, Rep, of Congo	16.0	0.7
Papua New Guinea	72.3	25.3
Cameroon	59.3	16.9
Honduras	81.0	0.4
Brazil	77.0	39.4
Costa Rica	73.2	0.0
Guatemala	95.4	10.4
Philippines	72.1	0.0
Peru	87.0	53.1
Mexico	97.8	1.6
Venezuela	90.0	0.0
Dominican Republic	94.1	0.0

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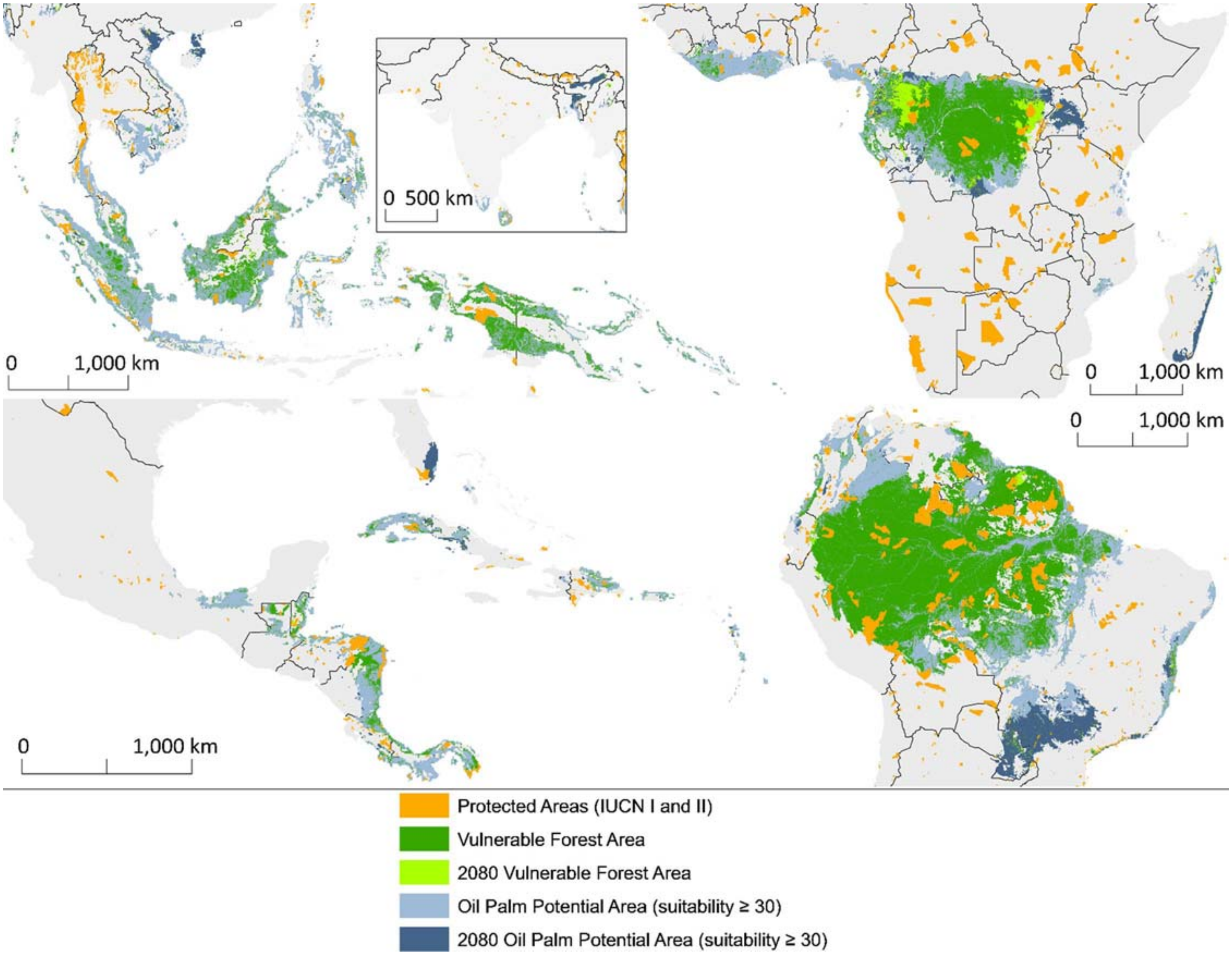

Fig 5. Vulnerable forest area. Present (dark green) vulnerable forest area and predicted vulnerable forest area in 2080 (light green). Vulnerable forest is MODIS VCF forest inside GAEZ suitable oil palm land, minus croplands and IUCN category I and II protected areas (orange). Deforested area suitable for oil palm is shown in each region at two times, present (light blue) and projected for 2080 (dark blue).

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Table 3. Percent Vulnerable Forest by Region (Present and 2080).

Region	Time Period	Total Vulnerable Forest (km^2)	Percent Protected Forest (IUCN I and II)
Africa	Present	1,319,737	4.7
	2080	1,538,038	6.3
Asia	Present	637,662	4.4
	2080	618,498	4.3
Mesoamerica	Present	75,359	11.5
	2080	71,709	11.7
South America	Present	4,418,443	9.4
	2080	3,669,858	9.3

doi:10.1371/journal.pone.0159668.t003

in the long-term, they will remain vulnerable to development in the coming decades. Additionally, areas in both South America and Africa that were not suitable for oil palm growth become suitable in these climate scenarios. This result changes not only the amount of vulnerable forest, but also adds new areas that need monitoring (Fig 5). The vulnerable forest areas in South America and Mesoamerica lie mostly within countries that have some of the highest recent rates of increase in planted area of oil palm in the world (Fig 1B).

All countries with high percentage of current plantation areas coming from recent deforestation (1989–2013) had vulnerable forest comprising more than 30% of their present suitable areas for oil palm (dashed line in Fig 6). Countries that exemplify this trend are Indonesia, Ecuador, and Peru. Not all countries with large percentage of vulnerable forest had high deforestation rates within plantations. Examples include Democratic Republic of Congo, Colombia and Venezuela. All countries with low percentage of vulnerable forest had low deforestation rates, likely a consequence of prior deforestation.

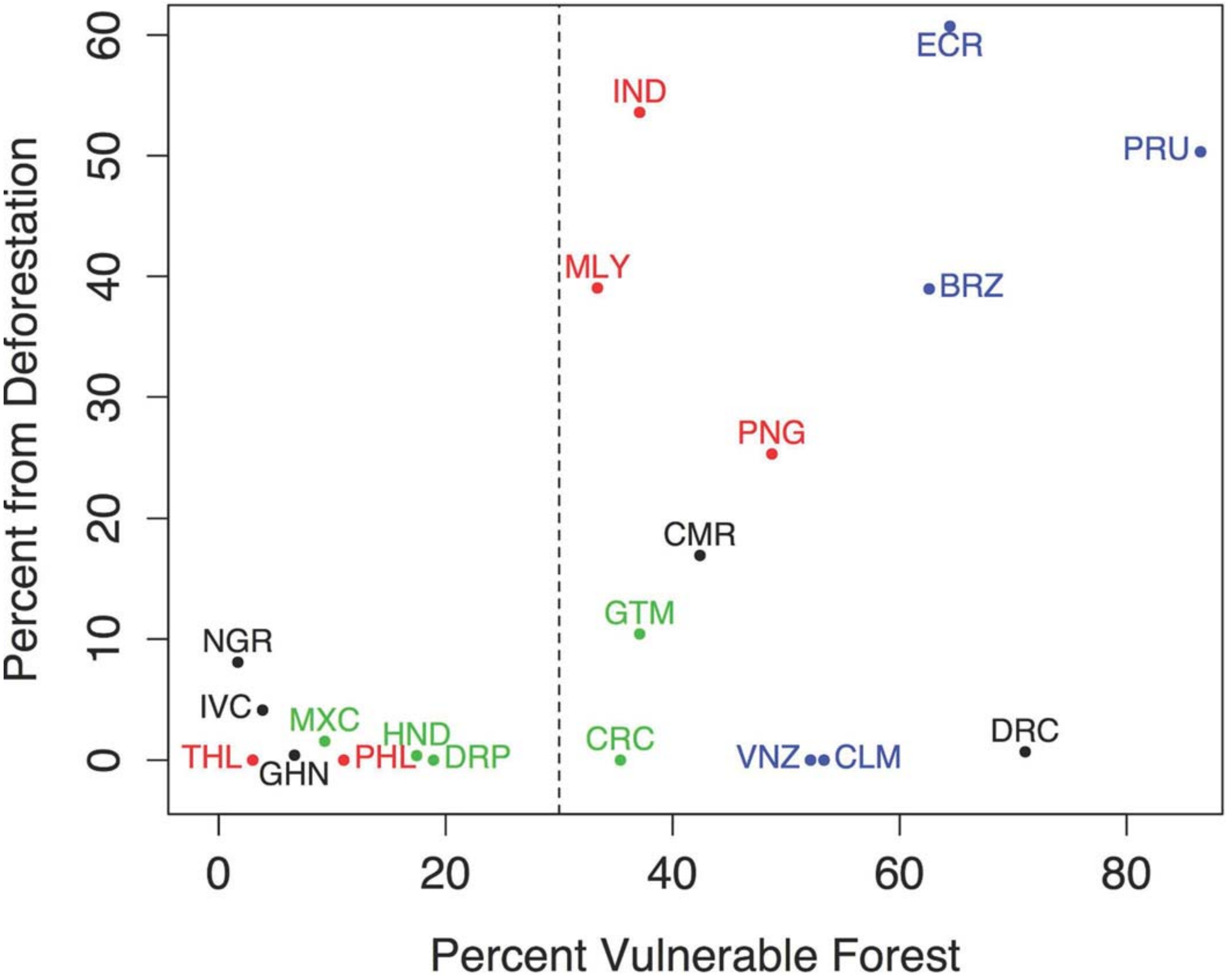

Fig 6. Percent deforestation versus percent vulnerable forest. Percent deforestation in sampled oil palm plantations (1989–2013) versus percent vulnerable forest within suitable area for oil palm (2013). Shown for all 20 sample countries. Colours indicate region: Blue-South America, Green-Mesoamerica, Black-Africa, and Red-Asia. Country name abbreviations: BRZ-Brazil, CMR-Cameroon, CRC-Costa Rica, DRC-Democratic Republic of Congo, DRP-Dominican Republic, ECR-Ecuador, GHN-Ghana, GTM-Guatemala, HND-Honduras, IND-Indonesia, IVC-Ivory Coast, MLY-Malaysia, MXC-Mexico, NGR-Nigeria, PNG-Papua New Guinea, PRU-Peru, PHL-Philippines, THL-Thailand, VNZ-Venezuela.

doi:10.1371/journal.pone.0159668.g006

Biodiversity Analysis

Having identified areas presently vulnerable to oil palm, we explored conservation prioritization based on the richness of threatened and small-range species of birds and mammals. We identified the vulnerable forest areas that were within the 10 percent richest global land area for threatened (blue), small-ranged (red), or both (purple) species within each taxon (Fig 7A and 7B).

For mammal species (Fig 7A), we would prioritize different areas for conservation depending on the richness criterion selected. A combination of small-range and threatened mammal species would prioritize areas of the Amazon, Brazilian Atlantic Forest, Liberia, Cameroon, Malaysia, and western Indonesia. Prioritizing for only threatened mammals would greatly increase the area targeted for conservation in the Amazon and Indonesia. On the other hand, prioritizing for only small-ranged mammals would target more areas of Mesoamerica, coastal Colombia and Ecuador, the Congo Basin, eastern Indonesia, the Philippines and Papua New Guinea.

Looking at a combination of small-range and threatened bird species (Fig 7B), we would prioritize different areas than for mammals. As found for mammals, the prioritization also differs based on richness criteria used. Priorities for both small range and threatened birds include areas in Cuba, coastal forests of Colombia and Ecuador, Western Amazon, Brazilian Atlantic Forest, the Philippines, Sulawesi, and eastern Papua New Guinea. Prioritizing for only threatened birds, like for mammals, would target large areas of the Amazon and Indonesia. It would also include areas of Brazilian Atlantic Forest, Liberia and Malaysia. Also similar to mammals, prioritizing for small-range birds would target areas of Mesoamerica, coastal Colombia, eastern Indonesia and Papua New Guinea.

Discussion

Deforestation of tropical moist forests increases carbon emissions. The replacement of natural forests with monoculture palm plantations reduces overall plant diversity and eliminates the many animal species that depend on natural forests [30, 31, 32]. Understanding the recent trends in deforestation related to oil palm production requires an understanding of both the use of satellite data and the longer history of plantation agriculture in the four major oil palm producing regions. We followed this by an assessment of the vulnerabilities of tropical moist forests and the vertebrate species living in them to future development for oil palm. While this exercise highlights some critical areas for future monitoring efforts, it also highlights the need for closer study of the drivers of oil palm development in each region and the need for clearly defined conservation goals in prioritizing areas for protection.

Monitoring using satellite imagery

In monitoring oil palm's impacts, we must look to the past as well as predict future expansions. Our estimates of recent rates of deforestation inside oil palm plantations differed by region. Asia and South America experienced high rates of deforestation while Mesoamerica and Africa had low ones. While Southeast Asia is currently responsible for ~68% of the area planted in oil palm, there is rapid expansion in other regions (FAOSTAT, Fig 1B).

Our estimate for Indonesia (54% from deforestation) is similar to a previous study (56%) [9], while our estimate for Malaysia (39% from deforestation) was lower than the 55–59% in their study. Differences in data, methodology, and period of study may explain this. Another estimate of deforestation (49%), for oil palm plantations in Ketapang District, West Kalimantan, Indonesia, was similar to our estimates at the country scale [33]. A related study found reported that 47% of lands converted to oil palm across Kalimantan from 1990–2010 were

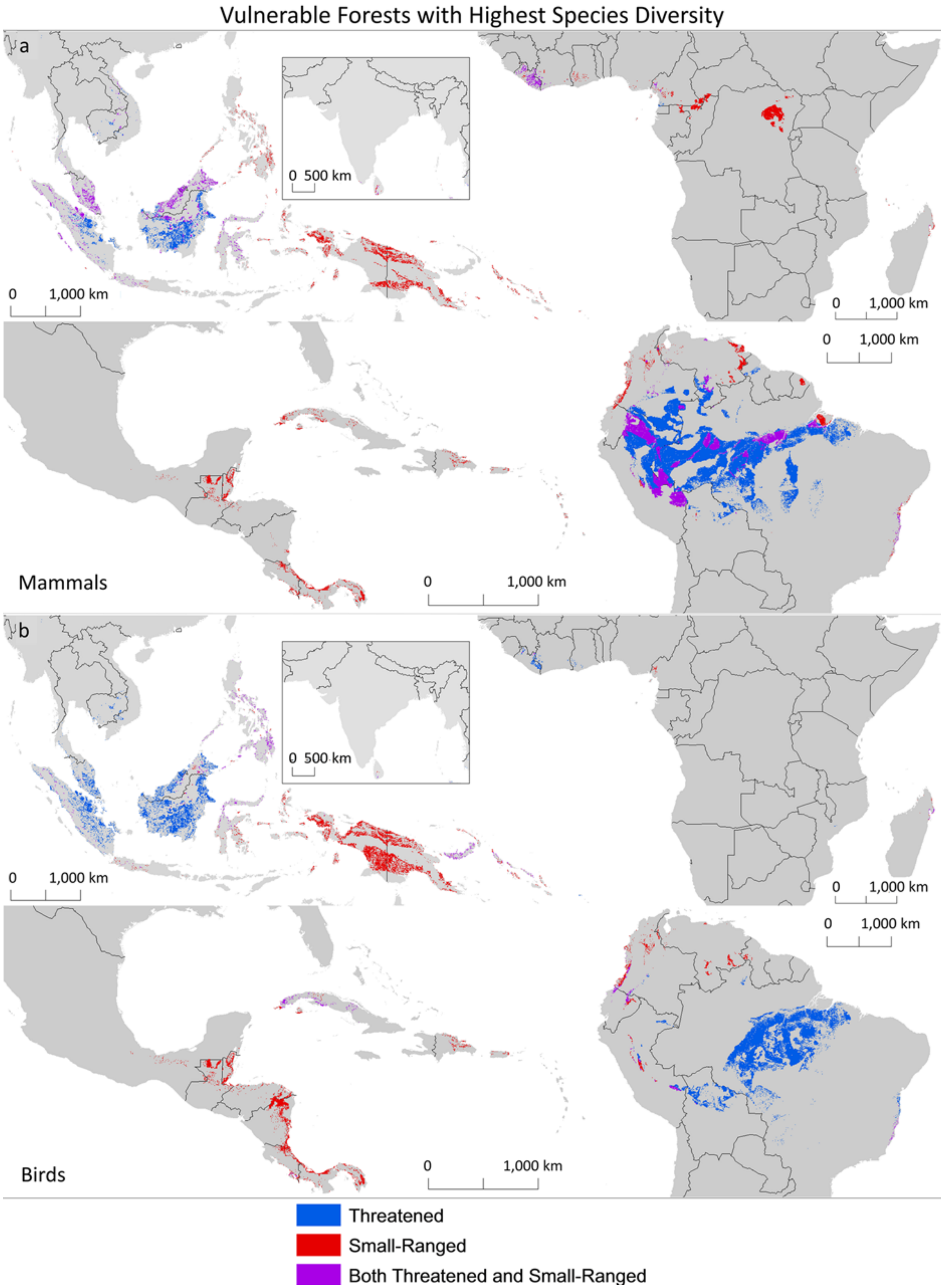
Vulnerable Forests with Highest Species Diversity
a
0 500 km
0 1,000 km
0 1,000 km
0 1,000 km
Mammals
0 1,000 km
b
0 500 km
0 1,000 km
0 1,000 km
0 1,000 km
Birds
0 1,000 km
Threatened
Small-Ranged
Both Threatened and Small-Ranged

Fig 7. High biodiversity vulnerable forests. Vulnerable forest areas for (a) mammals and (b) birds within the 10 percent richest global land area for threatened (blue), small-ranged (red), or both (purple) mammal and bird species (Jenkins et al. 2013, Pimm et al. 2014).

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intact forests [34]. These distinct regional trends suggest that studying only Southeast Asia would give a skewed perspective of the patterns of deforestation that have occurred and might occur in the future.

While the country trends mostly match the regional deforestation trends, some individual countries deviate. For example, in Cameroon 17% of sampled plantation area came from deforestation, in contrast to 2% of sample plantation areas at a regional level in Africa. In Thailand and the Philippines, none of the sample plantation sites came from deforested areas, while Asia overall had the highest net deforestation for sample oil palm plantation areas (45%). There is also the caveat that the weight we give each country in calculating regional trends is based on FAOstat data, the accuracy of which may vary due to differences in reporting among countries.

In areas where we observed low levels of deforestation for oil palm, we suspect that cropland or previously degraded land was converted to plantation area. Depending on patterns of displacement of crops and farmers, cropland conversion for oil palm expansion may be less damaging for biodiversity than forest conversion. However, even when it is, concerns may arise from conflicts over land seizure and violence in some areas [35, 36]. Areas classified as having low deforestation rates were cleared before our starting date of 1989, a date we set based solely on the availability of global satellite datasets. There is little "deforestation-free" oil palm. The real question is *when* landowners cleared the forests on which oil palm now grows.

Our methods reflect the limited availability of historical high-resolution imagery. We cannot determine the specific land cover transitions leading up to the planting of oil palm. Such data are needed to decide whether oil palm expansion was directly responsible for deforestation or whether the land was converted for another use first before planting in oil palm. Even if we had data on such transitions, land conversion for other purposes could simply be a pretext for deforestation followed by a rapid transition to oil palm. While high-resolution satellite imagery should be useful in future monitoring efforts such as those associated with RSPO certification, the limitations of our approach highlight that such approaches should supplement, not replace, ground-based data collection, case studies [37], and economic projections [38, 39].

Impact of historic land use

The lack of Landsat TM imagery before 1984 restricts what we know about prior changes in land use. Our study period began later than this, in 1989, due to cloud cover issues and gaps in the Landsat TM data. Other sources suggest that significant land clearing occurred historically in the two regions with low observed deforestation in our study: Africa and Mesoamerica.

In Mesoamerica, oil palm area increased after 1989, but deforestation was still low. The history of export monoculture in the region may explain this. Plantation agriculture, including coffee, sugar and bananas drove deforestation of moist forest areas beginning in the late 1800s [40]. By the mid-twentieth century, the expansion of cattle ranching areas emerged as a significant driver of deforestation [40, 41]. While our data only reveal when deforestation in current oil palm plantation area first occurred in the Landsat record and do not reveal intervening land uses, it seems likely that many areas that are now oil palm plantations were previously used for other plantation agriculture or pasture.

In Africa, there was no consistent expansion of oil palm area since 1989. Indeed, all surveyed countries experienced some declines during the study period. We also observed low levels of recent deforestation for oil palm. These trends may be explained by historical land use in the region. There is a long history of oil palm agriculture in Africa with semi-wild groves established by the time of European exploration [42]. During the colonial era in West and Central Africa, industrial plantations of crops like cacao, sugar cane, oil palm and rubber greatly expanded, in part through deforestation [43,44].

In both of these regions, this past agricultural history shapes the current forest cover within oil palm suitable zones and, consequently, the availability of prior agricultural land for conversion to oil palm plantation.

Vulnerability of forests to future oil palm development

The largest forested areas that future oil palm development threatens are in South America and Africa (Fig 5). Countries with less than 30% vulnerable forest (forest without IUCN I and II protection) in suitable areas for oil palm had little of their plantation areas coming from recently deforested areas (Fig 6). Possibly, the same factors that have prevented the conversion of these forests to other forms of agriculture—such as relative inaccessibility and steep slopes—also make them unsuitable for oil palm. In our samples, countries with>30% vulnerable forest either established the majority of their oil palm plantations on recently deforested land (like Indonesia and Ecuador) or, in contrast, they established very few of their plantations on recently deforested land (such as the Democratic Republic of Congo, Costa Rica, or Colombia).

The discrepancy in observed deforestation trends for countries with >30% vulnerable forest we might explain by country-level variation in production, land clearing policies, or other barriers to development, such as political instability or the accessibility of forested areas. In the Democratic Republic of Congo, there has been little expansion in oil palm planting over the last 25 years (Fig 4). In Costa Rica, deforestation for plantation establishment may be low because of high coverage of protected areas or because of the conversion of other plantation types, like banana, to oil palm. Protected areas cover one-fifth of the country [45]. Moreover, the 1996 ban on deforestation reduced deforestation for crop expansion [46]. Similar to our study, another study also found under 15% deforestation for oil palm plantation establishment in Colombia, mostly in small fragmented patches [47]. This may be attributed to high costs of land clearing and the inaccessibility of the contiguous forest areas.

A better way to characterize the expansion of oil palm may be to include proximity to infrastructure rather than relying solely on the biophysical requirements for the crop. More localized studies could accomplish this by including distance to population centres or road networks as factors that may determine oil palm development. For example, in Indonesia, village areas suitable for oil palm remained undeveloped because of low accessibility, a circumstance that changes with added infrastructure [48]. For monitoring purposes, we need to understand the factors associated with likelihood of oil palm development in other regions as well. However, it is possible that outside of Southeast Asia or for larger plantations, likelihood of development is determined by factors other than accessibility. Our observation of sites in South America showed oil palm plantation establishment in areas far from roads or population centres, with some infrastructure built specifically for the palm plantations.

Prioritizing vulnerable forests for conservation

Within forests vulnerable to oil palm development, there is relatively low protection by IUCN category I and II protected areas (4.4% in Southeast Asia to 11.5% in Mesoamerica). In our assessment of vulnerable forest areas, we excluded the IUCN category I and II areas but did not exclude other protected areas and indigenous areas. Therefore, it is possible that some of the areas identified have such designations, some of which may lend a similar degree of protection as IUCN category I and II areas.

Protected areas are a primary strategy for species conservation, but there remain questions about which places to protect. One strategy is the protection of high biodiversity areas, specifically focusing on the places with highest concentration of species with the greatest vulnerability to extinction: those with small ranges or deemed threatened by the IUCN. Applying this strategy, our results indicate that, even if biodiversity of vertebrate taxa were an agreed upon priority, the areas selected for conservation would depend on the specific taxa and vulnerability criteria. In a larger view across taxa and vulnerability criteria, it is clear that expansion of oil palm plantations at the expense of existing tropical forests threatens biodiversity (Fig 7).

Another strategy is the protection of the most accessible forests, those closer to roads and cities and on flatter land. Protecting areas of high accessibility prevents deforestation more effectively than protecting remote and high slope areas [49]. As we stated in the previous section, accessibility may be a factor important in determining the areas most likely to be developed for oil palm. If this is the case for all regions of production, the two approaches could be combined to address both likelihood of development and biodiversity conservation.

Conclusions

Our findings show high rates of forest loss for palm oil production across a range of countries and continents, raising concerns about future expansions of oil palm plantations. This legacy of forest loss points to the need for increased monitoring and interventions with a particular emphasis in Indonesia, Malaysia and Papua New Guinea in Southeast Asia, Peru, Ecuador, and Brazil in South America, and Cameroon in Africa. We also find that conservation priorities depend on taxa and selection criteria. By one criterion or another, almost all of the forests vulnerable to oil palm development have high biodiversity. Expansion of oil palm at the expense of natural forest is a conservation concern in all regions. We propose that government regulations, enforcement, and monitoring, combined with voluntary market initiatives by the largest buyers and sellers of palm oil, hold promise for stemming oil palm driven deforestation.

Supporting Information

S1 Fig. Additional Country Trends. Trends of deforestation inside sampled oil palm plantations (red) and total FAO oil palm planted area for twelve countries (black). Both trends are relative to 2013 values, thus both reach 100% in 2013.
(PDF)

S1 Table. Interpolated Annual Percent of Sample Area Deforested by Country
(CSV)

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Author Contributions

Conceived and designed the experiments: VV SLP CNJ. Performed the experiments: VV. Analyzed the data: VV. Wrote the paper: VV SLP CNJ SS.

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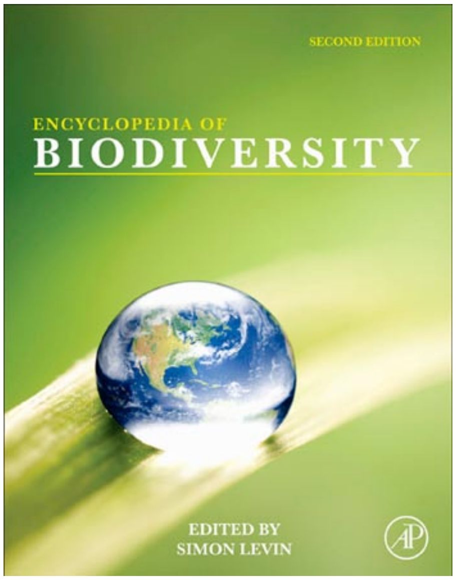
Exhibit 16



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Oil-Palm Plantations in the Context of Biodiversity Conservation

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Glossary

Biofuel	Wide range of fuels that are in some way derived from biomass.
Endosperm	Nutritive storage tissue in the seeds of most angiosperms.
Epiphyte	Plant that grows on another plant nonparasitically or sometimes on some other object.
Hectare (ha)	Area equal to 2.47 acres.
Mesocarp	Botanical term for the middle layer of the pericarp for example, comprising the flesh of fruits such as plums and cherries.
Monoecious	In the current context, having male and female flowers on the same plant.

Oil Palm: Green Gold or Great Evil?

An Introduction to the Green Gold

Few topics provide as much controversy in tropical forest and wildlife conservation as the rapid expansion of oil palm (*Elaeis guineensis*) plantations. On the one hand, oil palm has been linked to deforestation, peat degradation, biodiversity loss, forest fires, and a range of social issues (Danielsen *et al.*, 2009; Koh and Wilcove, 2008, 2009; Sheil *et al.*, 2009; Sodhi *et al.*, 2010). On the other hand, oil palm expansion is considered a powerful driver of economic development in tropical countries with low levels of welfare (Casson, 2000; McCarthy and Zen, 2010; Sheil *et al.*, 2009; World Growth, 2011), and it has been referred to as "green gold" (Friends of the Earth, 2008). Economic development can lead to reduced levels of forest loss, and biofuels from oil palm can reduce global carbon emissions, but the unanswered question is whether, at a global scale, do the benefits of oil palm outweigh the environmental costs? With much of Earth's species diversity residing in tropical areas where oil palm thrives, there seems ample reason to closely assess the role that oil palm has played in tropical deforestation and loss of wildlife. Here the authors review the role of oil palm in biodiversity loss and conservation by assessing its impacts over a range of different spatial scales and in different socioecological contexts.

Basics

The origin of oil palm lies in the tropical rain forest region of West Africa in a region about 200–300 km wide along the coastal belt from Liberia to Angola (Duke, 1983). It has been described as "probably the most useful tree in West Africa" (Irvine, 1961). In prehistory, the palm was likely spread by people to a much larger area in Africa, ranging from 16° N latitude in Senegal to 15° S in Angola and eastward to the Indian Ocean, Zanzibar, and Madagascar. It has also been introduced and cultivated outside Africa and now occurs throughout the tropics between 16° N and 16° S latitudes. A distinct, closely related species of the oil palm, *Elaeis oleifera* (also known as *Elaeis melanococca*), is indigenous to Latin America. We will limit our discussion to the African species and refer to it as "oil palm."

Oil palm is a pioneer species that historically appears to replace evergreen rain forest under drier climatic conditions. For example, during the mid Holocene in western Africa, changes in African monsoon conditions, decreased humidity, and increased fire led to the contraction of wet, evergreen rain forest and the expansion of woodland savannas. On these more open savanna type lands, oil palms were the dominating species (Maley, 2002; Ngomanda *et al.*, 2009; Salzmann and Hoelzmann, 2005). These vegetation shifts occurred alongside relatively "warm" regional and global conditions and could be an "analog" to events that might occur under global warming (Maley, 2002). Land clearance and burning act to increase the conditions under which oil palm thrives (Sowumni, 1999).

When fully grown, oil palms are tall, erect, single stemmed trees that vary in heights from 8 to 20 m, with a stem diameter of as much as 50 cm. The tree is monoecious, with male and female flowers in separate clusters but on the same tree. Ecologically, this is a species of riverine forests and freshwater swamps that can tolerate temporary flooding and a fluctuating water table. The species does not do well in closed forest conditions and requires adequate light and generally open canopy conditions. It grows best in lowland areas with 1780 to 2280 mm rainfall per year, with a 2–4 month dry period, and a mean minimum temperature of 21–24 °C, but the species is adaptable and with proper care can be grown in climatic conditions outside these ranges (Duke, 1983). Its ecological adaptability is also clear from the wide range of tropical soils on which the species grows and thrives, with only waterlogged, highly lateritic, extremely sandy, stony, or peaty soils providing suboptimal growth conditions. Considering the rapid expansion of oil palm into Indonesian and Malaysian peat swamp areas (Koh *et al.*, 2011), it seems clear that even these acidic and often waterlogged conditions under appropriate silvicultural care provide suitable growing conditions for oil palm (Sheil *et al.*, 2009).

The use of oil palm by early humans is well known from the archeological record. Such uses date back to at least 4000

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years BP (Logan and D'Andrea, 2012), and it appears that people in West Africa were actively cultivating oil palm as early as 3600 3200 BP (D'Andrea *et al.*, 2007). These early people were likely encouraging the growth of oil palms and achieving higher yields by clearing land (Logan and D'Andrea, 2012). Oil palm was a "camp follower" because of its ability to regenerate from discarded seeds without any particular horticultural treatment (Zeven, 1972). It was also traded widely, as indicated by finds of palm oil residues in 5000 year old Egyptian tombs (Friedel, 1897) far from where the oil was likely produced.

In Africa, palm oil has many traditional uses (Maley and Chepstow Lusty, 2001). A few written records of the local food use of a palm oil (presumably from *Ela. guineensis*) are available in accounts of European travelers to West Africa from the middle of the fifteenth century (Hartley, 1988). One source describes how oil is produced from seeds by boiling, as well as how the oil palm kernels are roasted and either eaten directly or made into flour (De Hondt, 1749). Palm oil later became an important item in the provisioning trade supplying the caravans and ships of the Atlantic slave trade, and it apparently remains a popular foodstuff among people of African descent in the Bahia region of Brazil (Northrup, 1978). Palm oil also found its way to Europe. James Welsh first brought 32 barrels of palm oil to England in 1590, and use grew rapidly after that. By the early nineteenth century, palm oil was being used to make soap and candles; later it was used for heating and cooking and in many other products from dynamite to margarine (Henderson and Osborne, 2000).

The increasing commercial use of palm oil is shown in early trade data. In the 1840s, the West African regions of Dahomey and the Niger delta exported approximately 1000 and 13,000 tons per year, respectively; by the 1880s these totals had risen to 5000 and 20,000 (Kiple and Ornelas, 2011). After 1900, European run plantations were established in Central Africa and Southeast Asia, and the world trade in palm oil continued to grow slowly, reaching a level of 250,000 tons per year by 1930 (Hartley, 1988), still only about 0.5% of what was produced in the early twenty first century (*see* The Modern Expansion).

The Modern Expansion

Plantations throughout Southeast Asia originate from the seeds of only four trees planted in Java, in present day Indonesia, in 1848 (Henderson and Osborne, 2000). In 1905, a Belgian agricultural engineer, Adrien Hallet, arrived in Sumatra, another Indonesian island, and noticed that local palms that had originated from the small Javan gene pool grew more quickly and bore a richer fruit than counterparts in the Congo, where he had previously worked (Leplae, 1939). It was obvious that under Asian equatorial conditions, the locally cultured palms held a distinct advantage over the ordinary palms of Africa (Kiple and Ornelas, 2011). Reduced seasonality in island Southeast Asia compared to west Africa has a big impact on yield, with any drought (or even loss of humidity) reducing fruit set. Also, the fact that all the Asian palms were descended from so few parents meant that the early planters could expect fairly uniform results (Kiple and Ornelas, 2011), ensuing easier management. This lowered the risks associated with plantation cultivation, an effect reinforced by the absence of the palm's usual pests and diseases in its new geographic setting. The success of oil palm was quickly noted in neighboring Malaysia, and the first plantations were established in peninsular Malaysia in 1917. By 1919, more than 6000 ha had been planted in Sumatra, rising to 32,000 in 1925, by which time 3400 ha had come under cultivation in Malaysia. Over the next 5 years, a further 17,000 ha were planted in Malaysia, whereas the Sumatran area doubled (Kiple and Ornelas, 2011). By 1998, palm oil contributed more than 5% to Malaysia's gross domestic product (Yusoff, 2006).

Oil palm seeds were introduced to Central America by the United Fruit Company, which brought seeds from Sierra Leone to Guatemala in 1920, and from Malaysia to Panama in 1926 and Honduras in 1927 (Kiple and Ornelas, 2011). Other introductions from Java and the Belgian Congo followed, but the first commercial planting of 250 ha only took place in Guatemala in 1940. In its tropical American setting, the oil palm, however, proved vulnerable to disease possibly due to the native American species being almost the same and difficulties were encountered in identifying suitable growing conditions (Hartley, 1988). By 1992, the total area of oil palm planted in Latin America had grown to 390,000 ha. This is a small fraction of the area in Africa and Southeast Asia (Kiple and Ornelas, 2011), but oil palm production in the neotropics is viewed by many as a major new force for land use change and forest conversion in that region.

Production of palm oil in Indonesia rose from 168,000 tons grown on 105,808 ha in 1967, to roughly 16.4 million tons grown on 6.2 million ha in 2006 (Sheil *et al.*, 2009). By 2011, an annual production of 25.4 million tons was estimated for Indonesia, 18.4 million tons for Malaysia, 1450 tons for Thailand, 880 tons for Colombia, and 850 tons for Nigeria, with an additional 3281 tons from a range of countries, adding up to a global production of 50.3 million tons (USDA, 2011). Palm oil takes up about 10% of the global production of vegetable oils, which remains dominated by soybean oil (USDA, 2011). These figures suggest that Indonesia alone underwent a 150 fold increase in palm oil production in 34 years.

Currently, Indonesia is the world's largest and most rapidly growing producer. Indonesia's wet tropical climate provides ideal growing conditions for oil palm. Land is abundant, and labor is cheap (Sheil *et al.*, 2009). About 10% of Indonesia's palm oil production comes from government plantations, 40% from small holders, and 50% from private plantations (IPOC, 2006). Malaysia is the world's second largest individual palm oil producing nation. Together, Indonesia and Malaysia account for about 90% of crude palm oil produced globally per annum (Sheil *et al.*, 2009). In the Southeast Asian region, a total of 8.3 million ha of closed canopy oil palm plantations occur in peninsular Malaysia (2 million ha), Borneo (2.4 million ha), and Sumatra (3.9 million ha) (Koh *et al.*, 2011), suggesting that oil palm takes up about 6.2% of the total landmass of these three regions. We note that the study by Koh and colleagues was unable to detect newly planted oil palm, so that total area of oil palm may be larger.

As a region, Africa is the second largest producer of oil palm in the world. Data from the Food and Agricultural Organization's FAOSTAT database indicate that about 4.5 million ha of productive oil palm plantation existed on the continent in 2009. Some 71% of African oil palm is produced in Nigeria, with Ghana, Guinea, Côte d'Ivoire, and the Democratic Republic of the Congo being other important producers.

In addition to Africa and Asia, oil palm production is also rapidly expanding in the neotropics, with some 700,000 ha of productive plantation in 2009 (FAOSTAT data). Nearly half of the Amazon basin, around 2.3 million km^2, appears suited in terms of climate and soils for oil palm cultivation (Stickler *et al.*, 2008). Even though the total oil palm area remains small compared to Asia, the mean annual rate of expansion was an astonishing 7.9% between 1991 and 2001 (Bolivar and Cuellar Mejia, 2003). Large scale plantations are already established in Colombia, Ecuador, and Brazil, although the latter was only the world's 14th biggest producer of palm oil in 2009. If the full potential of the Amazon basin was utilized, however, Brazil alone could dwarf the current production of Asia (Butler and Laurance, 2009). Oil palm planting has been promoted in Colombia, where it is seen as a relatively profitable alternative to cocaine (Gómez *et al.*, 2005). To differentiate it from the less productive but similar native species *Ela. oleifera* (*see* Uses) *Ela. guineensis* is commonly referred to as the "African palm" or "dendezeiro" (Lopes and Steidle Neto, 2011). As in Asia, oil palm is viewed as a crop that can be profitable under many different levels of management intensity (including smallholders) in a wide range of contexts (Wolff, 1999). However, there are concerns over disease though it is likely that breeders will be able to develop healthier and more resistant varieties and hybrids (de Franqueville, 2003).

Uses

In well managed plantations, oil palm produces 3 8 times more oil from a given area than any other tropical or temperate oil crop (Sheil *et al.*, 2009; Yusoff, 2006). Oil can be extracted from fruit and seed, palm fruit oil from the outer mesocarp, and palm kernel oil from the endosperm. Most palm fruit oil is used in foods. In contrast, most palm kernel oil is used in various nonedible products such as detergents, cosmetics, plastics, surfactants, and herbicides, as well as in industrial and agricultural chemicals (Wahid *et al.*, 2005). The use of palm oil as a biofuel is also increasing (Persson and Azar, 2010), giving oil palm an aura of environmental sustainability. In fact, if biodiversity losses from land use changes are disregarded, oil palm is one of the most environmentally sustainable among a range of global biodiesel and ethanol crops (de Vries *et al.*, 2010). Together with sugarcane grown in Brazil and sweet sorghum grown in China, oil palms makes the most efficient use of land, water, nitrogen, and energy resources, whereas pesticide applications are relatively low in relation to the net energy per hectare produced (de Vries *et al.*, 2010).

The traditional red palm oil produced by West African village methods has a wide range of applications. It is mostly used for food (Kiple and Ornelas, 2011). This type of oil, however, has not proved suitable for food use in the importing countries of the West, where consumers require a bland, nearly white cooking fat. Today's plantation produced palm oil can be treated to meet Western requirements, but this was not possible before the early twentieth century (Vanneck and Loncin, 1951). Once technology had advanced enough, European food manufacturers could exploit palm oil, replacing more expensive fats such as butter, beef tallow, and lard in central and northern Europe and olive oil in southern Europe (Kiple and Ornelas, 2011). Palm oil was suitable as both liquid oil and solid fat.

Since the late 1960s, plant breeders have taken an interest in the American oil palm *Ela. oleifera* because its oil has a high iodine value and unsaturated fatty acid content, making it especially suitable for food use (Kiple and Ornelas, 2011). However, the fruit is often small, with a thin, oil yielding mesocarp surrounding a large, thick shelled kernel. Harvested bunches often contain a low proportion of fruit of quite variable quality. Hybrids between *Ela. guineensis* and *Ela. oleifera* have been trialed and show some advantages over *Ela. guineensis*, despite higher production costs (Amblard *et al.*, 1995).

Concern over greenhouse gases and high prices for fossil fuel have spurred interest in biofuels and alternative sources of energy. Biodiesel from palm oil (palm oil methylester) is currently leading the pack, and major investments are already planned to convert millions of hectares of tropical forests and other land types to oil palm plantations (Sheil *et al.*, 2009).

Biofuels may have major positive or negative effects on natural forests, forest dwellers, and owners. On the one hand, biofuel from oil palm plantations could help to promote economic prosperity and alleviate poverty (World Growth, 2011). On the other hand, demand for biofuels could increase competition for land, threaten food production, and exacerbate inequities between rich and poor (Astyk, 2006). Whether or not the use of palm oil as biodiesel yields a net reduction of greenhouse gas emissions remains debated (de Souza *et al.*, 2010; Gibbs *et al.*, 2008) but depends a lot on the type of vegetation that existed prior to oil palm development.

High global demand feeds the current oil palm boom. Despite many anti oil palm campaigns targeting palm oil consumers and importing countries, it is likely that the sector will expand further, either in Southeast Asia or, if the land bank becomes limited there, in the African and American tropics. At current prices, it has recently been estimated that the opportunity costs of conserving forests in Southeast Asia are US $9860 12,750 ha^{-1} from logging and a further US $11,240 ha^{-1} from subsequent conversion into oil palm plantations (Fisher *et al.*, 2011). Others have argued that these figures are overly pessimistic (from a forest conservation point of view) and that payments for carbon sequestration and other environmental services such as clean water supply from forests could realistically offset the opportunity costs of forest development (Ruslandi *et al.*, 2011; Venter *et al.*, 2009).

Production in Small-Holder and Large-Scale Contexts

Oil palm seedlings are typically raised in a nursery for 1 year before planting out. Planting densities range from 110 to 150 stems per ha (Basiron, 2007). In small holder settings in Africa, planting densities can be considerably higher; densities of 200 palms per ha were common in the late 1940s, and densities of more than 300 palms per ha were not unknown (Hartley, 1988). Most commercially used oil palms mature rapidly, and fruit can be harvested only 2 3 years after planting (Basiron, 2007) although 9 15 year old trees are most productive (BisInFocus, 2006). After 25 30 years, trees become too tall to harvest and are replaced. Some long established plantations in Malaysia have already been replanted for the third time (Basiron, 2007).

Labor input over the life of an oil palm project is about 1397 person day per ha in Southeast Asia; divided by 25 years, this suggests that on average each hectare of oil palm has someone working on it and thus earning income 56 days of the year (Ginoga *et al.*, 1999). Unlike most other crops, oil palm production is not very seasonal, allowing more efficient, year round use of labor.

Once harvested, fruit deteriorates rapidly and must be processed within 24 h (Vermeulen and Goad, 2006), so access to a mill is a major factor in determining where commercial plantations can be established. Palm oil production is therefore most efficient when the crop is grown in a large monoculture around a central processing mill rather than in small holdings interspersed with other vegetation (Maddox *et al.*, 2007). The development of small scale floating mills may allow companies to plant and process oil palm fruits in remote areas at smaller scales, but such initiatives have not been taken up yet and are presumably less cost effective than large scale plantations.

Public Perceptions

Oil palm is hotly debated. Any internet search on keywords "orangutan" and "oil palm" reveals a plethora of mostly negative attitudes toward this palm and the people behind its boom. Internet titles such as "Palm oil costs the lives of about 50 orangutans every week and its cultivation is a major cause of global warming" and "Orangutans struggle to survive as palm oil booms" further suggests that conservation and oil palm are not happy bed fellows (EIA, 1998; Robertson and van Schaik, 2001; World Growth, 2009). Oil palm has its proponents too, however. These proponents not only include obvious ones such as palm oil producers and their support organizations but also the national governments of Indonesia and Malaysia, which earn significant revenues from palm oil production. It is becoming increasingly clear that small scale farmers in these countries prefer oil palm to other crops because of high relative returns (Feintrenie *et al.*, 2010; Rist *et al.*, 2010). The strongly divergent viewpoints about the environmental and social costs of oil palm versus its benefits (Koh *et al.*, 2009; Meijaard and Sheil, 2011) has resulted in a situation in which middle ground solutions of minimizing oil palm's impact have become increasingly difficult (Meijaard, 2010). The situation is not helped by the significant disinformation created on both sides of the debate (Koh and Wilcove, 2009; Sheil *et al.*, 2009). Better science based information about the positive and negative impacts of oil palm over different temporal and spatial scales is urgently needed for more informed discussion on the impact of this palm on global biodiversity (Sheil *et al.*, 2009).

Oil Palm and Biodiversity

Value as Wildlife Habitat

Not all aspects of biodiversity are negatively impacted by oil palm, and oil palm plantations have some conservation benefits. Similar to fig and nectar, palm nuts are considered to be keystone ecological resources, providing crucial links between plant and animal communities (Terborgh, 1986). For example, in its native West Africa, oil palm provides important resources to the chimpanzee (*Pan troglodytes verus*) (Humle and Matsuzawa, 2004; Leciak *et al.*, 2005; Sousa *et al.*, 2011). This mostly occurs in patchy oil palm groves in a matrix of agricultural land and forests rather than the extensive areas of single species oil palm plantation generally found in Asia. Chimpanzees seem to prefer oil palms for building their sleeping platforms or "nests," even when they have access to natural forests; they also use palm fruits as fallback resources (Sousa *et al.*, 2011).

Other African species that feed on oil palm include Thomas's rope squirrels (*Funisciurus anerythrus*) (Pettet, 1969); white throated bee eaters (*Merops albicollis*), which catch and eat the epicarp of the fruit dropped by the squirrels (Fry, 1964); southern yellow billed hornbills (*Tockus leucomelas*); and the aptly named oil palm vulture (*Gypohierax angolensis*) (Landsborough and Moreau, 1957). Black vultures (*Coragyps stratus*) in northwestern Colombia feed heavily on oil palm fruit and appear to prefer it to carrion (Elias and Dubost, 1982), whereas several raptor species that feed on rats thrive in oil palm in Honduras (Padilla *et al.*, 1995). In Central America, the white faced capuchins (*Cebus capucinus*) are well known users of oil palm areas (McKinney, 2010; Williams and Vaughan, 2001).

Southeast Asian oil palm areas also provide resources to certain species, and many species use the oil palm matrix to move between forest patches, something they might not do in plantings of annual crops or grasslands. A study in Sumatra showed a wide range of species inhabiting the area of an oil palm plantation, with 40 mammals listed in total (38, not including domestic species) (Maddox *et al.*, 2007). Of these, 63% have an important conservation value or are protected under national law, and 25% are listed as vulnerable or higher on IUCN red lists. The tiger was the most endangered species recorded on site, rated as critically endangered. Asian elephants (*Elephas maximus*) and dhole or wild dog (*Cuon alpinus*) are the next most endangered. Tigers (*Panthera tigris*) and leopards (*Panthera pardus*) in peninsular Malaysia frequently move into oil palm estates from surrounding forest areas to prey on wild ungulates such as pigs and deer or on domestic cattle (Azlan and Sharma, 2006). In fact, a study in peninsular Malaysia suggested that a hyperabundance of the banded pig (*Sus scrofa vittatus*) in a forest reserve surrounded by oil palm was caused by abundant year round food supply of oil palm fruits from the extensive plantations bordering the reserve (Ickes, 2001). The presence of prey species in oil palm is both a benefit and threat to large predators (*see* Charismatic Species).

Considering that oil palm produces highly nutritious nuts, it is surprising that few records exist of Southeast Asian species feeding on oil palm. There are indications that orangutans occasionally eat oil palm nuts (M. Ancrenaz, pers. comm.), but such use is not extensively documented. Considering that chimpanzees use these fruits extensively, it may just be a matter of time until orangutans similarly learn to do so. Observations in Sumatra suggest that both long tailed (*Macaca fascicularis*) and pig tailed (*Macaca. nemestrina*) macaques feed extensively on fallen palm fruit, as do pig species (both *S. scrofa* and *Sus barbatus*) (EM, pers. obs.). A lot more records of species feeding on oil palm are available in the literature on pest species. A book on pest species that affect oil palm globally (Hill, 2008) lists squirrels (*Callosciurus* spp.), rats (*Rattus* spp.), various parrots and parakeets, porcupines (*Hystrix* sp.), and a host of invertebrate species, such as the coconut case caterpillar (*Mahasena corbetti*), the African rhinoceros beetle (*Oryctes boas*), the coconut palm borer (*Melittomma insulare*), the palm leafminer (*Promecotheca cumingii*), the South American palm weevil (*Rhynchophorus palmarum*), and the African palm weevil (*Rhynchophorus phoenicis*). As documented in Southeast Asia, these invertebrates in turn attract bird species such as *Pycnonotus goiavier*, *Prinia* spp., *Parus major*, *Copsychus saularis*, and *Halcyon smyrnensis*, all species feeding primarily on insects and normally common outside forests (Desmier de Chenon and Susanto, 2006).

The obvious issue with some species in an oil palm plantation context is that they cause damage to plants and palm nuts. For example, population densities of *Rattus tiomanicus* are between 100 and 600 animals per ha in Southeast Asian plantings of a range of ages and localities (Wood and Fee, 2003), and losses in Malaysian palm oil caused by these rodents were valued at US $32 million annually in the 1980s (Basri and Halim, 1985). This benefits threatened species such as blood pythons (*Python brongersmai*) and short tailed pythons (*Python curtus*) that feed on these rats, and which in Sumatra have increased in abundance because of the establishment of oil palm plantations (Shine *et al.*, 1999).

Impact on Species Diversity

Most of the world's species diversity is concentrated in humid tropical forest (Hoffmann *et al.*, 2010; Leadley *et al.*, 2010), the ideal habitat for oil palm fruit production. The expansion of oil palm is therefore most likely to directly impact tropical biodiversity. The same tropical region is also an area where the majority of people are primarily concerned with meeting their basic needs (Kaimowitz and Sheil, 2007; Millennium Ecosystem Assessment, 2005). Economic development in many countries in this region is driven by natural resource exploitation, adding to the pressure on remaining forest areas. With regard to oil palm, this is especially evident in Southeast Asia, where the largest areas have so far been developed. Indonesia and Malaysia's lowland forests are among Earth's most species rich terrestrial habitats (Sodhi *et al.*, 2004; Whitten *et al.*, 2004). The loss of Southeast Asia's lowland forests threatens the region's exceptional conservation value (Curran *et al.*, 2004; Tinker, 1997) and has long been the principal conservation concern in the region (Jepson *et al.*, 2001).

Surprisingly, despite the apparent impact of oil palm on biodiversity, conservation science is a relative newcomer to this topic. A 2008 review of 678 publications on oil palm published over 35 years found that only six of the publications specifically addressed the biodiversity and species conservation aspects of oil palm (Turner *et al.*, 2008). Since that time, there have been many more scientific study of species diversity and abundance in oil palm.

Because of oil palm's light requirements, plantation development generally requires that all other vegetation is removed. Oil palm plantations are thus dominated by only one plant species (Danielsen *et al.*, 2009; Fitzherbert *et al.*, 2008; Gillison and Liswanti, 1999). Oil palm plantations are also structurally less complex than natural forests, with a uniform tree age structure, lower canopy, sparse undergrowth, less stable microclimate, and greater human disturbance (Danielsen and Heegaard, 1994; Fitzherbert *et al.*, 2008; Peh *et al.*, 2006), and they are cleared and replanted on a 25 30 year rotation (Sheil *et al.*, 2009). It is therefore not surprising that the floral and faunal diversity of these plantations is very low when compared to tropical lowland rain forests.

To give examples, researchers in the province of Jambi recorded 75% less plant diversity in oil palm plantations than in natural forest (Gillison and Liswanti, 1999). Mammals are also affected, and a 4 year study of terrestrial mammals living in and around an oil palm plantation concession in Jambi concluded that oil palm monocultures are very poor habitats for most terrestrial mammal species (Maddox, 2007). Only four mammal species (10% of the number detected within the approximately 80,000 ha landscape) were regularly detected in the oil palm itself, and none of these species had a high conservation value. Some species, including deer (*Cervus unicolor*), macaques (*Macaca* spp.), and pangolin (*Manis javanica*) showed limited tolerance, but, with the exception of pigs (*Sus* spp.), all species showed a general preference for non oil palm habitats even heavily degraded forests (Maddox, 2007). In fact, the study highlighted the conservation importance of marginal or degraded habitats often found within palm oil concessions and highlighted that these areas can retain high conservation values (Maddox, 2007).

Most studies of oil palm biodiversity show large differences in faunal species composition between oil palm and forests (Fitzherbert *et al.*, 2008). The animal species lost tended to include species with specialized diets and reliance on habitat features not found in plantations (such as large trees for cavity dwelling species) and also species with the smallest range sizes and those of highest conservation concern (Fitzherbert *et al.*, 2008). Plantation assemblages were typically dominated by a few abundant generalists, nonforest species (including alien invasives), and pests.

These findings of reduced species diversity in oil palm correspond with studies elsewhere. In Malaysia, researchers found that fewer than 20 of 75 mammal species encountered in primary forest also used oil palm (PORIM, 1994). Birds are also negatively affected, with one study in a 5000 ha study site of forests, oil palm, and agricultural lands reporting that conversion of forest to plantations resulted in reduced species richness of at least 60%, which especially affected threatened forest dependent birds (Aratrakorn *et al.*, 2006). A review study of bird faunas in oil palms and forests found that although bird species richness is lower in oil palm than in forests, bird abundance does not appear to be. Species found in plantations are generally of lower conservation concern than those from forests (Najera and Simonetti, 2010).

Invertebrate communities in oil palm plantations seem to be similarly influenced. Beetle assemblages in habitat types in Sabah, Malaysia, ranging from primary forest, logged forest, and acacia plantation to oil palm plantation, had the lowest species diversity in oil palm, with a few species becoming numerically dominant (Chung *et al.*, 2000). Ant species richness in Malaysian Borneo decreased from 309 to 110 species (−64%) between a 43,800 ha primary forest areas and a 2576 ha oil palm plantation (Fayle *et al.*, 2010), and oil palm can sustain only about 5% of the ground dwelling ant species of the forest interior (Bruhl and Eltz, 2010). However, the impact of oil palm on species diversity was not the same across all microhabitats that were investigated, with bird's nest ferns occurring in both forests and oil palm maintaining almost the same number of ant species in both vegetation types. Species losses were much more pronounced in canopy and leaf litter faunas (Fayle *et al.*, 2010). Also, ant communities in oil palm are dominated by nonforest species, with nine of the 23 ant species baited in the plantations never having been recorded inside the forest (Bruhl and Eltz, 2010).

Species diversity *per se* may not always be a relevant measure for ecosystem health. A study of bee diversity in a range of vegetation types, including oil palm, in peninsular Malaysia found that the diversity in oil palm, as measured by a wide range of diversity and evenness indices, was considerably higher than in primary forest, although the absolute abundance of bees was much lower (Liow *et al.*, 2001). The 2500 ha monocultural oil palm plantation had 17 species of bee, whereas the two natural forest sites (each >2000 ha) had nine and seven, respectively. The absolute number collected, however, was 64 for the oil palm site and 419 and 444 for the natural forest sites. The authors suggest that absolute numbers of bees rather than species diversity may be more important for maintaining the ecosystem and ecological processes than the absolute number of species, because of their role in pollination.

A recent review of 13 studies summarized how species diversity in oil palm compared to that in other plantation crops (Fitzherbert *et al.*, 2008). Because of the small sample size, control for locations and context was not possible, and the review findings need to be interpreted with caution. Rubber (*Hevea brasiliensis*) supported as many or more species as oil palm and more forest species. Cocoa (*Theobroma cacao*) had similar or higher species richness but not always more forest species. Coffee (*Coffea canephora*) supported higher ant species richness and more forest species than oil palm. Rubber, cocoa, and coffee are often grown in small holder settings or agroforestry landscapes. Compared to oil palm, their scale of development is generally smaller, and these crops often occur in a matrix of secondary forest regrowth. This might at least partly explain why their species richness is higher than in oil palm. *Acacia mangium* plantations, which are planted for pulp and paper, are generally developed as large (>10,000 ha) industrial plantations. In Indonesia, oil palm is established in monoculture plantations ranging in size from 4000 to more than 20,000 ha (Sheil *et al.*, 2009), which is on a scale similar to industrial tree plantations. Still, acacia plantations have higher beetle species richness than oil palm, and species composition is closer to that in forest (Chung *et al.*, 2000). Similar results were found for studies of birds, which in acacia and albizia (*Paraserianthes falcataria*) plantations resembled the avifauna of secondary forest regrowth, whereas oil palm attracted few bird species (Sheldon *et al.*, 2010).

Fitzherbert *et al.*'s (2008) review suggested that only pasture and urban mown grassland had lower species diversity than oil palm, whereas gardens of mixed crops had similar or higher species richness, and abandoned pasture had more species than oil palm. *Imperata cylindrica* grasslands, a fire induced vegetation type that commonly replaces deforested land, had more species of ants but fewer forest ant species than oil palm (Fitzherbert *et al.*, 2008). Compared to other monocultural plantation species that harbor significant native species diversity (Hobbs *et al.*, 2006; Lugo, 1992), oil palm plantations appear to resemble the other extreme of exotic plantation species that have limited value to native biodiversity conservation (Mascaro *et al.*, 2008). The overall conclusion about biodiversity in oil palm plantations is that, at a local scale, it is as low as the most degraded and human altered tropical vegetation types and therefore has limited local conservation importance.

Charismatic Species

A number of species, including orangutans (*Pongo* spp.) and the Sumatran tiger (*P. tigris sumatrae*) are the focus of international concern. The conservation of these species is often mentioned in relation to the expansion of oil palm (Linkie *et al.*, 2003; Nantha and Tisdell, 2009; WWF, 2011), and these species have played an important role in shaping the public attitude toward oil palm. Although industrial oil palm development has been ongoing for decades, it was not until the 1990s when environmental campaigns started to focus on the role that oil palm plays in the demise of iconic conservation species and their forest habitats that the public mood began to change. These campaigns initially focused on the impacts on orangutans (Buckland, 2006; EIA, 1998) but also addressed other species, primarily tigers and elephants (Friends of the Earth, 2005). The authors discuss the impacts of oil palm on these species relative to other threats.

Orangutans

The main impact of oil palm on orangutans is habitat loss, with human orangutan conflicts associated with oil palm development a secondary threat (Meijaard *et al.*, 2011, 2012). Orangutans are primarily arboreal creatures, using relatively large territories and mostly feeding on fruits, leaves, and barks originating from hundreds of plant species (Rijksen and Meijaard, 1999). In 2008 in Kalimantan, oil palm threatened 750,000 ha of orangutan forest, representing 5.5% of the Bornean orangutan distribution (Venter *et al.*, 2009).

Recent studies have shown unexpected ecological resilience in orangutans in selectively harvested timber concessions and plantations of *Acacia mangium* (Ancrenaz *et al.*, 2010; Meijaard *et al.*, 2010). Surprisingly, very few studies exist of orangutan use of oil palm habitats. One report focuses on management and the avoidance of human orangutan conflict in oil palm areas (Yuwono *et al.*, 2007), but it does not clarify how orangutans are affected. A recent study in Sumatra investigated crop raiding by a population of Sumatran orangutans (*Pongo abelii*) that had become isolated from natural forest in an agricultural landscape, including oil palm plantations (Campbell Smith *et al.*, 2011). This study showed that the oil palm patches in this landscape offered few, if any, benefits to orangutans.

Aerial surveys in eastern Sabah, Malaysian Borneo (M. Ancrenaz, unpublished data), identified large numbers of orangutan nests in oil palm plantations, especially in small forest patches within the oil palm matrix. The size of these patches fluctuated from a single tree to a few hectares and the forest was highly degraded and lacked the typical forest structure. It was estimated that at least a couple of hundred individuals were using the oil palm landscape at the time of the surveys.

As long as oil palm does not offer a food resource to orangutans and forest fragments within the oil palm are small, degraded, and few, it is doubtful that an oil palm landscape can sustain a viable resident orangutan population in the long term. The nests seen during aerial surveys were most probably built by "transient" orangutans that are roaming through the oil palm estates in search of forest during their dispersal phase. Indeed, young males leave their native community when they become mature and establish their own territory in a new forest area (Goossens *et al.*, 2006). These orangutans are "connectors" in fragmented metapopulations, and oil palm could therefore have some benefits in maintaining overall connectivity.

Tigers

Tigers are threatened worldwide by habitat loss, reduction in prey, and hunting (Chundawat *et al.*, 2010) and in Malaysia and Indonesia also by expansion of oil palm (Linkie *et al.*, 2003). Like orangutans, tigers do reasonably well in selectively logged or otherwise degraded forests, but they favor areas with little human use (Linkie *et al.*, 2008). Compared to natural forests, oil palm estates have relatively high human use. It is therefore not surprising that tigers have much higher densities in forest than in oil palm (Maddox *et al.*, 2007).

Tigers do use oil palm areas, however, especially when these are adjacent to good quality forest. The attraction is in the food resources such as deer, pigs, and also domestic animals. For example, tigers killed at least 60 cattle in a 27 month period in an oil palm estate in peninsular Malaysia (Azlan and Sharma, 2006). Where large predators and oil palm coincide, this often leads to conflict and there are regular reports in Malaysian and Indonesian newspapers of oil palm workers having been killed. Generally, tigers are unwelcome in oil palm and are often killed if they threaten workers (Brown and Jacobson, 2005). Also, crop predation by wild ungulates such as pigs and deer leads to crop protection measures, which often include nonselective techniques such as snaring, poisoning, and drive netting. These, in turn, harm or kill tigers and reduce their prey (Wibisono, 2005). In fact, it is thought that one of the main threats to the conservation of Sumatran tigers is the response to crop depredation by large ungulates in agricultural lands, including oil palm plantations, near protected areas (Wibisono and Pusparini, 2010).

A recent study modeled extinction risk of Sumatran tiger in a landscape containing a protected area, logging concessions, pulp wood plantations, agroforestry, oil palm, and settlements (Imron *et al.*, 2011). The study used information on tiger hunting and breeding behavior and found that the longest survival times occurred in mixed landscapes of protected areas, logging concessions, and pulp wood plantations rather than models based on a single land use. Selectively logged forests contributed most to the survival chances of tigers in the protected area, concurring what was found by Meijaard and Sheil (2008) elsewhere. The settlement and oil palm plantation scenarios clearly showed the detrimental effect of these land uses on tiger persistence. Both single land use and combined scenarios resulted in extinction within a relatively short period of time, confirming that oil palm plantations do not provide good habitat for tiger prey, provide poor tiger habitat, and experience high human pressure, which lead to the absence of tigers (Imron *et al.*, 2011).

Asian Elephants

Asian elephants (*Ele. maximus*) are primarily a forest edge species (Rood *et al.*, 2011), suggesting they prefer to feed on the type of vegetation found in disturbed areas. Potentially, this could include oil palm areas, but the evidence for this is unclear. On the one hand, they are reported to avoid oil palm. In a study in Sumatra, elephants were only ever recorded once on the fringes of the oil palm (Maddox *et al.*, 2007). On the other hand, another study reported that elephants are considered to pose a risk to oil palm plantations because they often destroy palms and feed on the oil rich palm nuts (Susanto and Ardiansyah, 2003). In fact, it has been suggested that such agricultural conflicts may pose as big a threat to Asian elephants as habitat loss (Hedges *et al.*, 2005; Linkie *et al.*, 2007). An internet search reveals many stories of elephants causing damage to oil palm and dead elephants being found in or close to oil palm plantations, several reportedly killed by poisoning. Often the conservation authorities assist local farmers and oil palm companies by capturing elephants and either moving them to other areas or keeping them in captivity. Trials in Malaysian Borneo, where the tamer Bornean subspecies of *Ele. maximus* uses oil palm areas to move between forest patches, show that the use of electrical fencing to protect small holder crops combined with the replanting of forest corridors provides an effective means to reduce elephant conflict (Ancrenaz and Lackman, 2011). This is expensive, however, and may only work in small plots. Chili grease covered fences may be a cheaper alternative (Hedges and Giunaryadi, 2010).

Beneficial Wildlife

Oil palm estate managers actively promote the presence of some species because they increase the production of oil palm or at least make it cheaper. Owls and snakes are the most important among these beneficial species. Barn owls (*Tyto alba javanica*) have been widely encouraged in Malaysian oil palm plantations to control rodent pests. They were formerly considered vagrants in peninsular Malaysia, but they became established following the increase in rats with the advent of oil palm plantations (Lenton, 1984). It is estimated that a pair of barn owls together with their chicks consume around 1300 rats per year (Duckett and Karuppuah, 1989), but it apparently remains doubtful whether these owls truly regulate rodent populations or whether rodent populations are more strongly affected by other factors such as food supply (Puan *et al.*, 2011).

Certain species of snakes are also attracted to the many rodents and other species feeding in oil palm areas (Akani *et al.*, 2008; Shine *et al.*, 1999), and some plantations actively use snakes to control rodents, although not as commonly as owls or baiting (Hafidzi and Saayon, 2001). How effective such pest control is remains unclear.

Exclosure studies in Sabah, Malaysia, show that insectivorous birds deliver a natural pest control service for oil palm agriculture (Koh, 2008a). Where birds were excluded from oil palm seedlings, herbivory rates from insects increased between 1.2 and 17.2 fold significantly higher than that in control treatments.

Koh (2008a) reports that many companies adopt an integrated pest management approach that favors the use of nonchemical pest control methods such as the establishment of ''beneficial plants'' (e.g., *Euphorbia heterophylla*) to attract the insect predators and parasitoids of oil palm pests such as the wasp *Dolichogenidea metesae* (Basri *et al.*, 1995).

Finally, the native pollinator of oil palm (the weevil *Elaeidobius kamerunicus*) did not originally occur in Asia. When it was introduced from Africa, production increased and the cost of artificial pollination was saved (Dhileepan, 1994; Southworth, 1985).

Notes of Caution

One of the constraints on interpreting research on species diversity in oil palm is that there are few scientific case studies (Fitzherbert *et al.*, 2008). For example, there are no scientific studies that address plant diversity in oil palm. This introduces confounding factors that often cannot be controlled for. Research is required that addresses questions such as, what is the effect of area on species diversity when one compares species in a 50,000 ha natural forest with those in a 2500 ha oil palm plantation? Would the species diversity of a 1000 ha oil palm plantation be the same as a 10,000 ha one? What is the effect of fragmentation when areas of natural forests to which oil palm diversity is compared are fragments themselves in a matrix of nonforests (Liow *et al.*, 2001)? How does species diversity vary in different oil palm contexts, from the mixed forest gardens settings often found in Africa to the large (>20,000 ha) monocultural plantings sometimes found in Indonesia?

Broader Environmental Impacts of Oil Palm

Oil Palm and Deforestation

Information on how much forest has been displaced by oil palm is hard to come by. Considering that oil palm is a crop of the humid tropics, one could argue that all planted oil palm has ultimately replaced tropical forest. Some forests, however, were cut down centuries ago and only recently planted with oil palm. Oil palm is developed under a wide range of field conditions, varying from old degraded grasslands, secondary scrubland, forest regrowth, degraded and overlogged forest, and relatively intact forests. In our experience, rarely has oil palm been established in areas that were primary forest (i.e., visually untouched by human activities) directly prior to oil palm development. Therefore, the more pertinent question regarding oil palm and forest wildlife is how much forest has recently been cut down and directly been replaced by oil palm? A recent analysis of agricultural and deforestation statistics for the period 1990 2005 suggested that more than half the area of oil palm developed in Malaysia and Indonesia had resulted in deforestation (Koh and Wilcove, 2008). Others, however, argue that the data are too poor to draw such conclusions and that these estimates do not account for other causes that triggered deforestation before oil palm plantations were established (Wicke *et al.*, 2011).

To estimate future impacts, we need to know how much of the oil palm expansion will be in forested areas. Future demand for edible oil is estimated at around 240 Mt in 2050, requiring an additional 12 million ha of palms, if average yields continue to rise as in the past (Corley, 2009). This demand could at least partly be met on existing nonforest lands (Wicke *et al.*, 2011). However, Corley (2009) also points out that biofuel demand might greatly exceed that for edible use, and the interchangeability of the major oils for edible and biofuel uses means that this demand will drive oil palm expansion, whether or not palm oil is actually used for biodiesel.

Without a clear definition of oil palm induced deforestation, better data on forest cover and the distribution of oil palm plantations, and future expansion potential of oil palm, it remains impossible to accurately quantify the impact of oil palm development on forest wildlife.

Some have argued that oil palm plantations are forests. Malaysia, for example, has considered (but ultimately rejected) including oil palm plantations in the country's national statistics on forest cover (Simamora, 2010). Many conservation bodies highlighted this as unacceptable (Biofuels Watch, 2010; World Rainforest Movement, 2010), and the Food and Agricultural Organization excludes oil palm from global forest estimates because it considers it an agricultural crop, not a planted forest (FAO, 2010). Meijaard and Sheil (2011) pointed out that in much of the temperate world pulpwood plantations are included as forests, and there is an obvious need to develop and agree on such definitions (Sasaki and Putz, 2009).

Broader Environmental Impacts of Oil-Palm Plantations

Palm oil production has environmental impacts that could potentially affect wildlife beyond the actual plantation. Extraction of palm oil results in large amounts of effluent that is often returned to natural water courses without treatment (Sheil *et al.*, 2009). Palm oil mill effluent is a colloidal suspension of water, oil, grease, and solids: it is fairly acidic (pH 4 5) and is typically discharged hot (80 90 °C) (Ahmad *et al.*, 2005). Although most mills have treatment areas, leaks of effluent can have significant negative impacts on water quality. How this affects the ecological functioning of waterways remains largely unstudied (Sheil *et al.*, 2009).

The oil palm industry is one of the largest consumers of mineral fertilizers in Southeast Asia (Hardter and Fairhurst, 2003). A typical oil palm plantation planted on both mineral and peat soils requires around 354 kg ha^{-1} of nitrogen over the first 5 years to increase and maintain yields (Guyon and

Simorangkir, 2002). Pesticides and herbicides also increase pollution, especially with repeated use (Hartemink, 2005). Most of the reports on impacts are generated by companies and may not be objective because they wish to be seen as minimizing damage to the environment (Sheil *et al.*, 2009).

The environmental impact of oil palm plantations could be less than most alternative crops if considered in terms of production more can be produced on less land. Given the necessary trade offs between conservation and economic growth, this is important. Better management, higher yields from improved varieties, and planting on land that is already degraded could improve yields significantly without further deforestation (Hardter *et al.*, 1997). Concentrating oil producing crops on those lands with the highest yields could reduce the need for land elsewhere, offering potential conservation benefits

Could Oil-Palm Development Reduce Biodiversity Impacts Elsewhere?

Large scale oil palm production has documented benefits. The plantation sector in Malaysia is one of the largest employers, providing income and employment for many rural people. Basiron (2007) comments that "involvement in cultivation or downstream activities has uplifted the quality of life of people." Decreasing rural poverty may reduce deforestation, although this is highly context specific (Sunderlin *et al.*, 2007; Wunder, 2001). Also, assuming a certain global demand for vegetable oil for food and biofuel producing it in areas with plant species that maximize yields could potentially reduce pressure on land elsewhere. The interactions between the various economic, trade, environment, and political factors remain too complex to reliably determine overall global impacts of oil palm on biodiversity compared to the alternative of producing oils with different crops. This is an important area of research to guide the different oil industries.

Enhancing the Biodiversity Values of Oil Palm

An important question regarding the biodiversity of oil palm plantations is whether this can be boosted by retaining patches of natural forest within the oil palm matrix, the so called wildlife friendly strategy (Edwards *et al.*, 2010; Fitzherbert *et al.*, 2008; Koh, 2008b). Oil palm developed in large estates can create monocultural stands of 50,000 ha or more. Such areas have very limited ecological variation and create large areas mostly devoid of wildlife. In a small holder setting, oil palm is planted on much finer scales, often in plantations of 1 or 2 ha. If such plantations are part of a broader multifunctional landscape with remaining forest stands and secondary regrowth, the overall species diversity is likely to be higher. If a certain total area of oil palm plantation is targeted to fulfill global demands, an important ecological question is whether for wildlife conservation purposes it is better to concentrate all oil palms into large monocultural stands (potentially leaving more space for natural forests) or to spread oil palm plantings over much larger multifunctional landscapes.

A study comparing bird diversity in oil palm, forest fragments within oil palm, and contiguous natural forest indicated that abundances of imperiled bird species in oil palm were 60 times lower in fragments and 200 times lower in oil palm than in contiguous forest. Forest fragments did not increase bird abundances in adjacent oil palm, and they had lower species richness than contiguous forest and an avifaunal composition that was more similar to oil palm than to contiguous forest. The study concluded that, from a perspective of maximizing biodiversity conservation, any investment in the retention of fragments would be better directed toward the protection of contiguous forest (Edwards *et al.*, 2010) that is, the land sparing strategy.

Increasing the productivity of existing oil palm plantations for example, by better management of harvesting to improve oil yield could potentially reduce the need for more land to be cleared. However, this will only generate a conservation gain if it is linked to the protection of natural habitats for example, through strategic land use planning and implementation (Fitzherbert *et al.*, 2008). Fitzherbert et al (2008) argue that with higher yields per unit area for both large and small scale enterprises, oil palm might provide a substitute for traditional subsistence agriculture and could reduce the area of land needed to support each household. They also point out that successful land sparing is contingent on inelasticity of demand for agricultural products (Green *et al.*, 2005). The substitutability of vegetable oils ensures that demand for any one oil is elastic and, although future global requirements for edible oils depending much on demand from China and India may be reasonably predictable, demand will become effectively limitless if driven by new biofuel markets. Proposals for nongovernmental organizations to use oil palm agriculture to acquire private reserves (Koh and Wilcove, 2007) are unlikely to be the most cost effective approach (Venter *et al.*, 2008).

Meanwhile, several new international and national initiatives are under way to improve practices in establishing oil palm plantations and using forests. One national initiative is Sawit Watch (*sawit* meaning oil palm), which campaigns for the rights of indigenous people in land disputes and highlights the social ramifications of oil palm developments in Indonesia (Sheil *et al.*, 2009). International initiatives include the Roundtable for Sustainable Palm Oil (RSPO), which was established in 2004 by Malaysian and Indonesian companies to ensure palm oil "contributes to a better world." The RSPO has developed a verifiable standard for sustainable palm oil and encourages oil palm companies to adopt more responsible practices. This standard consists of the RSPO Principles and Criteria (P&C) for Sustainable Palm Oil Production, which set out the requirements that must be met and against which certification assessments are made. To define sustainability in the oil palm sector, the RSPO has developed 39 sustainability criteria organized under eight general principles that are designed to limit environmental impacts of growing and processing palm oil (Laurance *et al.*, 2010). Of these, principle four is of direct relevance to biodiversity. Among others, it requires that growers maintain soil fertility, minimize and control erosion and degradation of soils, maintain the quality and availability of surface and groundwater, regulate the use of agrochemicals, and effectively manage pests, diseases, weeds, and invasive introduced species (RSPO, 2007). Most importantly for biodiversity in oil palm, however, is principle five, which concerns the environmental responsibility and conservation of natural resources and biodiversity. This focuses primarily on the design of plantations, most relevantly the clearing of natural vegetation and how this affects the status of rare, threatened, or endangered species and habitats of high conservation value. Specifically, if such species or habitats are present, the standard requires that any legal requirements relating to the protection of the species or habitat are met, damage to and deterioration of applicable habitats is avoided, and any illegal or inappropriate hunting, fishing, or collecting activities is controlled, including the development of responsible measures to resolve human wildlife conflicts. Such conflicts are frequent as has, for example, been indicated by the many reported cases of orangutan killing in association with oil palm development (Meijaard *et al.*, 2011).

Despite its ambitious environmental goals, the RSPO has been criticized for failing to stop clearing of natural forests and, more generally, for noncompliance by its members (Laurance *et al.*, 2010). Also, many companies have experimented with the RSPO standard since it was ratified in November 2005 but have found it to be complicated, costly, and hard to implement (Nikoloyuk *et al.*, 2010; Paoli *et al.*, 2010). Recently, RSPO has channeled activities toward developing a standard for smallholders because they cannot afford the additional oversight required for mainstream RSPO certification. Smallholders also struggle to adopt best practices, such as zero burning, because such practices require upfront capital and are more expensive at the onset. It remains to be seen whether the lofty goal of "sustainable" palm oil management can be attained through the RSPO process. Countries such as Indonesia that investigated ways of integrating RSPO principles into current policies (McCarthy and Zen, 2010) have apparently concluded that this was not possible and subsequently developed their own standards: the Indonesian Sustainable Palm Oil Foundation (ISPO).

Conclusions

The scientific evidence suggests that oil palm plantations in equatorial Asia have low biodiversity value compared to most other tropical land uses. A few species do well in oil palm, but these generally have little conservation value. Species that lose out in oil palm are forest dependent species with specific habitat requirements and low abundance, and many are of conservation significance (Persey, 2011).

It is possible to make the oil palm industry more biodiversity friendly. It is most important, however, that oil palm should be developed on already deforested or degraded lands rather than in areas of tropical forest. Oil palm itself can also be made more hospitable for biodiversity for example, by increasing structural and faunistic diversity (e.g., allowing the growth of epiphytic ferns and maintaining weed cover) and retaining as much natural forest in and around the planted areas as possible.

Ultimately, the global impact of oil palm on biodiversity can only be judged in relation to the alternatives. There is an increasing demand for vegetable oils for food and other uses, and demand for biofuels is growing. Oils and biofuels can be generated with different crops, and oil palm has the highest yield per unit land area and per unit of financial investments. If oil palm is not expanded further, then either the demand for oil will not be met or it will be fulfilled with other crops that require more land than would the oil palm.

See also: Agriculture, Sustainable. Agrobiodiversity. Biodiversity-Rich Countries. Deforestation and Land Clearing. Hotspots. Land-Use Issues. Mammals, Conservation Efforts for. Market Economy and Biodiversity. Poverty and Biodiversity. Primate Populations, Conservation of. Rainforest Ecosystems, Animal Diversity. Rainforest Ecosystems, Plant Diversity. Rainforest Loss and Change. Sustainability and Biodiversity

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Exhibit 17

How will oil palm expansion affect biodiversity?

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Oil palm is one of the world's most rapidly increasing crops. We assess its contribution to tropical deforestation and review its biodiversity value. Oil palm has replaced large areas of forest in Southeast Asia, but land-cover change statistics alone do not allow an assessment of where it has driven forest clearance and where it has simply followed it. Oil palm plantations support much fewer species than do forests and often also fewer than other tree crops. Further negative impacts include habitat fragmentation and pollution, including greenhouse gas emissions. With rising demand for vegetable oils and biofuels, and strong overlap between areas suitable for oil palm and those of most importance for biodiversity, substantial biodiversity losses will only be averted if future oil palm expansion is managed to avoid deforestation.

Oil palm: one of the world's most rapidly expanding crops

Expansion and intensification of agriculture is the greatest current threat to biodiversity [1 3]. Vegetable oils are among the most rapidly expanding agricultural sectors [4], and more palm oil is produced than any other vegetable oil [5]. Global palm oil production is increasing by 9% every year, prompted largely by expanding biofuel markets in the European Union [6] (Box 1) and by food demand in Indonesia, India and China [4].

Oil palm *Elaeis guineensis* is grown across more than 13.5 million ha of tropical, high-rainfall, low-lying areas, a zone naturally occupied by moist tropical forest, the most biologically diverse terrestrial ecosystem on Earth [7,8] (Figure 1a,b). Malaysia and Indonesia produce more than 80% of all palm oil [9] (Figure 1d). Together, they also hold more than 80% of Southeast Asia's remaining primary forests (mainly in Indonesia), where many endemic species are threatened with extinction by some of the highest global rates of deforestation [10 13] (Figure 1a). Environmental groups and industry representatives debate the extent to which oil palm has contributed to deforestation [14,15].

The ecological impact of oil palm depends crucially on the extent to which its expansion causes deforestation, and on the extent to which it is able to support biodiversity. Here we review the contribution of oil palm to deforestation, with a focus on Malaysia and Indonesia. We compare the biodiversity value of oil palm plantations with that of forest and alternative land uses to assess whether biodiversity loss can best be reduced by making plantations more wildlife friendly or by linking yield increases with habitat protection (Box 2). We review emerging opportunities to reduce the biodiversity impact of oil palm, identify obstacles to success and gaps in current knowledge and finally ask whether new initiatives are likely to reduce the ecological cost of oil palm expansion.

Contribution of oil palm expansion to deforestation

As with other crops [16], it is difficult to quantify the extent to which oil palm has been a direct cause of deforestation because of a lack of reliable data on land-cover change and incomplete understanding of its complex causes. The usefulness of the most widely cited land-cover data sets (those of the Food and Agriculture Organization of the United Nations, FAO [11]) is undermined by changing definitions of forest, minimal independent monitoring of government statistics and a lack of information on the subnational patterns and causes of land-cover change [17 19].

Oil palm expansion could in principle contribute to deforestation in four often indistinguishable ways: (i) as the primary motive for clearance of intact forests; (ii) by replacing forests previously degraded by logging or fire; (iii) as part of a combined economic enterprise, such as with timber, plywood or paper pulp profits used to offset the costs of plantation establishment; or (iv) indirectly, through generating improved road access to previously inaccessible forest or displacing other crops into forests. Land might also be deforested initially for other reasons and then subsequently be planted with oil palm. In such cases, oil palm could easily, but wrongly, be identified as a

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Box 1. Oil palm as a biofuel

Biofuels derived from palm oil and other biomass from plantations can be used as alternatives to fossil fuels such as diesel. As a substitute for diesel, palm oil is less suitable than other vegetable oils owing to its high viscosity, lower energy density and high flash point [66]. However, oil palm gives high yields at low prices, and hence is likely to be important in meeting biofuel demand [5,67].

Global palm oil production increased by 55% between 2001 and 2006 (see http://faostat.fao.org), and will be further promoted by increases in demand for biofuels generally. Given the substitutability of vegetable oils both for biodiesel production and most edible uses [4], targets such as those set by the European Union to promote biofuel use [6] will increasingly divert edible oils such as rapeseed *Brassica napus* toward biofuel production. An increase in the demand for any vegetable oil increases prices for all of them, and further drives expansion, such as for both oil palm in Southeast Asia and soybean *Glycine max* in Brazil. Even if the European Union sources its palm oil exclusively from certified 'sustainable' sources (such as producers signed up to the Principles and Criteria of the Roundtable on Sustainable Palm Oil; see Box 3), it will be indirectly supporting less responsible producers via higher prices.

The rationale for using biofuels is that they should be carbon neutral, unlike fossil fuels which when burned release carbon stored over millions of years. However, only if oil palm plantations are established on degraded grasslands with low carbon content are they likely to become net carbon sinks [35,68]. There are large greenhouse gas emissions associated with forest clearance, desiccation of peat soils and use of fossil fuels for plantation cropping, processing and transport [62,63,68,69]. It will take decades or centuries for the avoided carbon emissions from fossil fuels to compensate for emissions released when forest or peat soils are converted [35,69]. Until it is demonstrated that oil crops are no longer replacing forests, the use of palm and other vegetable oils as biofuel feedstock is likely to exacerbate climate change, drive up food prices and hasten biodiversity loss.

driver of deforestation. However, oil palm is also used as a pretext by companies to obtain permits to clear land for other purposes, and cannot easily be excluded as a contributing factor.

Malaysia

Oil palm was first planted commercially in Peninsular Malaysia in 1917, where it replaced rubber plantations and forest [7,20] (Figure 1d). As land became scarce, expansion shifted to Sabah and Sarawak, often in association with logging [18,21,22], and was facilitated by the reclassification of some state forest reserves to allow conversion to plantations [18,21]. Between 1990 and 2005 the area of oil palm in Malaysia increased by 1.8 million ha to 4.2 million ha (see http://www.mpob.gov.my), while 1.1 million ha of forest were lost [11] (Figure 1d). It has been estimated that at least 1.0 million ha of forest were replaced by oil palm over this period [23], but this estimate does not consider forest conversion into unproductive land, nor whether oil palm caused or simply followed deforestation.

Indonesia

Commercial oil palm cultivation started in Sumatra in 1911; expansion to other parts of Indonesia did not occur until the 1980s [7] (Figure 1d). Today, ambiguities in the land tenure system and corruption [13], combined with increased regional autonomy, have made it easier for timber, plywood and paper pulp companies to obtain permission to clear millions of hectares of forest under the pretext of plantation establishment, without later planting them, especially in Kalimantan [22,24,25]. Oil palm plantations often replace forests previously degraded by fire and logging [17,26], and illegal oil palm development has been reported inside protected areas [4,15]. Between 1990 and 2005 the area of oil palm increased by 4.4 million ha to 6.1 million ha (see http://www.deptan.go.id), while total forest loss was 28.1 million ha [11]. Hence, conversion to oil palm could account for at most 16% of recent deforestation. It has been estimated that 1.7 3.0 million ha of forest were lost to oil palm over this period [23]. The uncertainty surrounding these estimates is high and, as they exclude changes in unproductive land area and include only mature oil palm area, they could be over- or underestimates (see http://faostat.fao.org).

Elsewhere, oil palm has been documented as replacing forest in southern Thailand [27], Myanmar [28] and Papua New Guinea [29].

The future

Although the extent to which oil palm has been a direct cause of past deforestation is difficult to quantify, its potential as a future agent of deforestation is enormous. Demand for palm oil is predicted to continue increasing [5], and globally, most of the remaining areas suitable for planting are forested. At present, relatively little oil palm is grown outside Southeast Asia, but 410 570 million ha of currently forested land across Southeast Asia, Latin America and Central Africa are potentially suitable for oil palm cultivation (Figure 1c) (http://www.whrc.org/resources/published literature/pdf/WHRC REDD crop suitability.pdf) and might be increasingly utilised as demand rises and agronomic advances are made.

Effects of converting forests to oil palm plantations

An understanding of how much biodiversity oil palm plantations can support is essential to direct conservation action. If plantations are consistently depauperate relative to forests, the focus should be on stopping deforestation. Alternatively, if the management of plantations can be adapted so that they support a substantial proportion of forest species while maintaining high yields, conservation effort should focus on ways to enhance biodiversity in plantations [3].

The response of biodiversity to land-cover change depends upon the extent to which natural habitat features are replicated and upon variation in the sensitivities of species to change [30]. Oil palm plantations are structurally less complex than natural forests, with a uniform tree age structure, lower canopy, sparse undergrowth, less stable microclimate and greater human disturbance [31 33] and are cleared and replanted on a 25 30 year rotation [7].

To assess the effect of palm oil on biodiversity, we conducted a literature survey. Publications on biodiversity make up less than 1% of the scientific literature on oil palm since 1970 [34]; we could find no published studies of plants (but see Ref. [35]) and just 13 of animals [23,31 33,35 43] that compared biodiversity in oil palm plantations with that in forest.

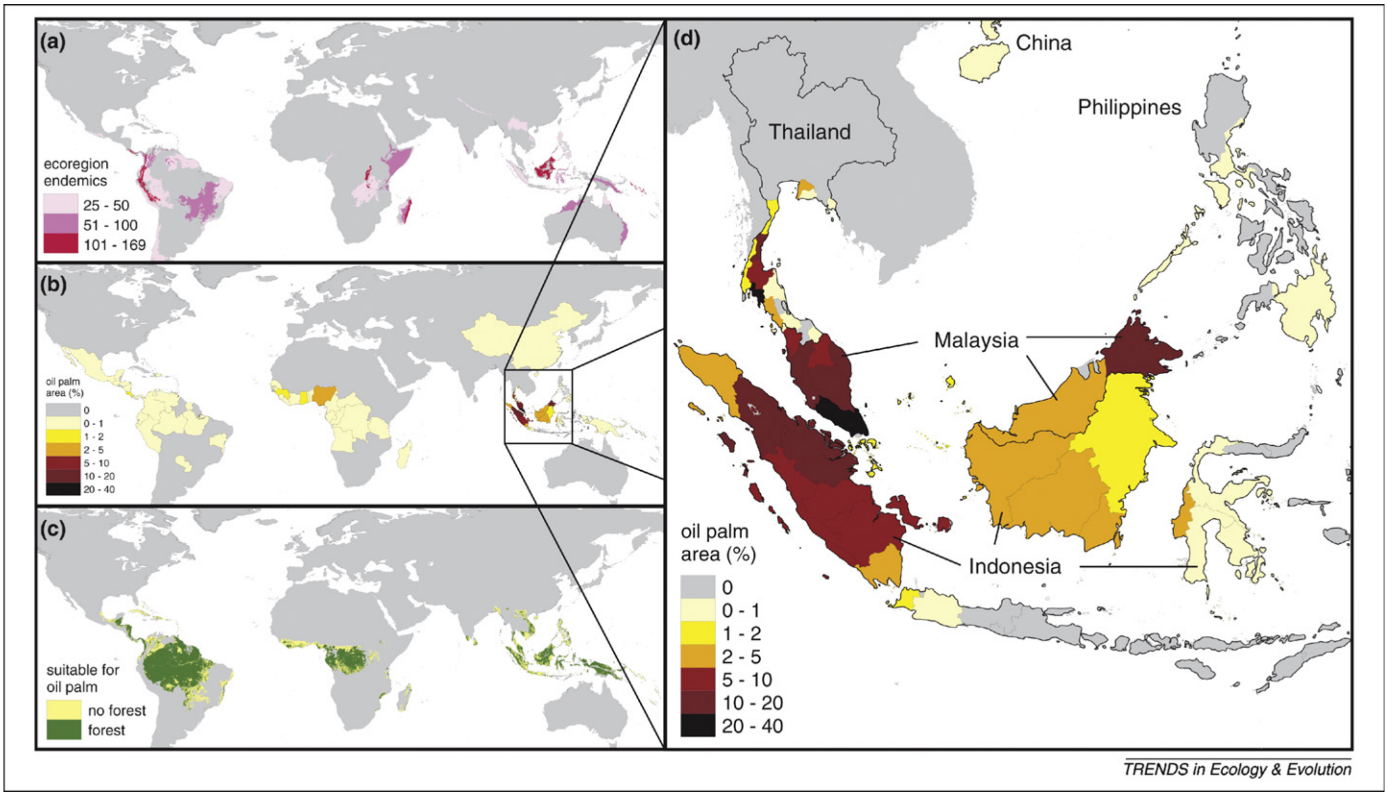

Figure 1. Global distribution of oil palm and potential conflicts with biodiversity: **(a)** areas of highest terrestrial vertebrate endemism (ecoregions with 25 or more endemics are shown); **(b)** global distribution of oil palm cultivation (harvested area as percentage of country area); **(c)** agriculturally suitable areas for oil palm (with and without forest); and **(d)** oil palm-harvested area in Southeast Asia. In (b) and (d), Brazil, Indonesia, Malaysia, the Philippines and Thailand are subdivided by province, but other countries are not. Data are for 2006, except for the Philippines and Thailand, where 2004 data are the most recent available. (Sources: [a] World Wildlife Fund (2006) WildFinder: online database of species distributions, version Jan-06, http://www.worldwildlife.org/wildfinder; [b,d] world: http://faostat.fao.org; Brazil: http://www.ibge.gov.br/estadosat; Indonesia: http://www.deptan.go.id; Malaysia: http://econ.mpob.gov.my/economy/annual/stat2006/Area1.7.htm; Philippines: http://www.bas.gov.ph/downloads_view.php?id=127; Thailand: http://www.oae.go.th/statistic/yearbook47/indexe.html; [c] forest area: European Commission Joint Research Centre [2003] Global Land Cover 2000 database, http://www-gem.jrc.it/glc2000; oil palm suitability: updated map from G. Fischer, first published in Fischer *et al.* [65], http://www.iiasa.ac.at/Research/LUC/SAEZ).

Species richness

Oil palm consistently held fewer than half as many vertebrate species as primary forests, whereas invertebrate taxa showed more variation [35] (Figure 2a). Oil palm also had much lower species richness than disturbed (logged or secondary) forests, although the differences were not so great (Figure 2b). One study of bees found more species in oil palm than in forests, but might have underestimated species richness in forests because the canopy was not sampled [39]. Across all taxa, a mean of only 15% of species recorded in primary forest was also found in oil palm plantations.

Box 2. Linking production to conservation

Increasing the productivity of existing oil palm plantations, for example by better management of harvesting to improve oil yield [7] (see Ref. [70]) could potentially reduce the need for more land to be cleared (the ‘land sparing’ option of Ref. [3]). However, this will only generate a conservation gain if it is linked to the protection of natural habitats, for example through strategic land use planning and implementation. Our review of the value of oil palm plantations for a wide range of taxa suggests that a land sparing approach that ensures the conservation of intact forests would be more beneficial than the promotion of wildlife friendly management practices within planted areas.

With higher yields per unit area for both large scale commercial enterprises and small holders than many alternatives, oil palm might provide a substitute for traditional subsistence agriculture and could reduce the area of land needed to support each household [7,25]. However, rural communities do not always welcome plantation development [17], and care must also be taken that labourers do not increase the pressure on natural habitats near plantations [25]. Successful land sparing is contingent upon inelasticity of demand for agricultural products [3]. The substitutability of vegetable oils ensures that demand for any one oil is elastic and, although future global requirements for edible oils are reasonably predictable, demand will become effectively limitless if driven by new biofuel markets. Estimated annual world biodiesel requirement by 2050 could be 277 million tons, twice current total vegetable oil production and seven times total palm oil production [67].

There are possibilities for conservation partnerships between oil palm producers, conservation practitioners and rural communities which would enable financial resources from oil palm to be channelled into forest conservation efforts, such as local capacity building in legal aspects of forest law and enforcement [50,71,72]. Recent proposals for nongovernmental organisations to use oil palm agriculture to acquire private reserves [9] are unlikely to be the most cost effective approach [72]. There might be more scope for producers to contribute to payments for environmental services schemes aimed at slowing deforestation [73], and to conserve forest remnants within their plantations. Strategic alliances between multiple stakeholders, such as oil palm producers, environmental organisations, rural communities, government agencies and carbon offsetters, have the largest chance of success [72].

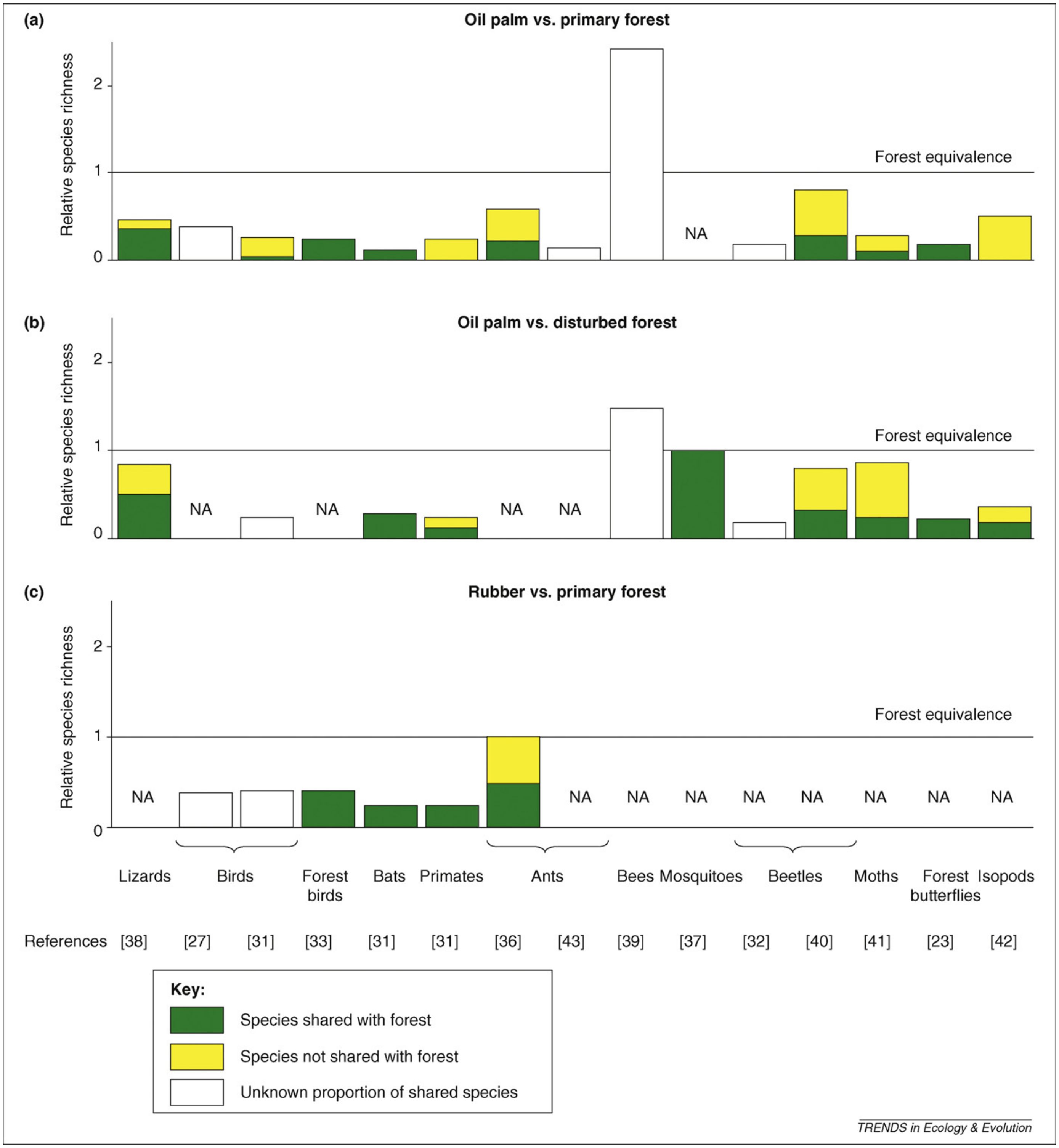

Figure 2. The biodiversity impact of converting forests to plantations is shown by comparing species richness and forest species richness in **(a)** oil palm relative to primary forests, **(b)** oil palm relative to degraded (logged and secondary) forests and **(c)** rubber relative to primary forests. Species richness is scaled so that forest richness in primary or degraded forests equals 1. Each vertical column contains a study of one taxon (NA = not applicable). In most taxa, the highest species richness is found in primary forests. There is a large reduction in species richness in oil palm compared with both primary and degraded forests, illustrated by the gap between the bars and the line of forest equivalence. The reduction in forest species richness is even more marked in most taxa. Rubber plantations show a similar loss of species richness compared with primary forests, but retain a higher species richness and/or forest species richness of some taxa. In no study does rubber have lower species richness than oil palm.

Species composition and abundance

Most studies found large differences in faunal species composition between oil palm and forests [27,32,35,36,39,40]. The species lost were not a random subset of the original forest fauna, but tended to include species with the most specialised diets, those reliant on habitat features not found in plantations (such as large trees for cavity-dwelling species), those with the smallest range sizes and those of highest conservation concern [27,31,33,41]. Plantation assemblages were typically dominated by a few abundant generalists, non-forest species (including alien invasives) and pests [27,32,41]. Forty percent of the ant species found in oil palm plantations in Malaysia were aliens, including the highly invasive crazy ant *Anoplolepis gracilipes* [43]. Densities of rats (e.g. *Rattus tiomanicus*) can reach 600 per ha [44], providing abundant food for predators such as blood pythons *Python brongersmai* [45], barn owls *Tyto alba* [44] and leopard cats *Prionailurus bengalensis* [46].

Caveats

Several methodological shortcomings are likely to reduce the apparent difference in biodiversity measures between forest and oil palm, so our estimates of biodiversity loss are likely to be conservative [35,47,48]. For example, it is more difficult to detect many taxa in rain forests, because rain forests have a taller canopy and more structural complexity than plantations [31]. Also, estimates of species richness from small areas of oil palm [32,36,38,42] or near forest edges [27,40] will be artificially inflated by the presence of transient species from nearby forests. Even standardising results based on effort (which was not done in most studies) does not fully remove these biases [27,48], especially when only a small number of species are sampled [31,37,38]. Finally, a time lag between habitat loss and extinction [10] might lead to the recording of some species in oil palm plantations that cannot ultimately persist there.

Comparison with other land uses

To understand the relative impacts of converting different prior land covers (forest and other crops) to oil palm, and of converting forest to oil palm rather than to other crops, we examined studies which made such comparisons. Rubber *Hevea brasiliensis* supported as many or more species as oil palm, and more forest species (Figure 2a,c). Cocoa *Theobroma cacao* had similar [38] or higher [36] species richness, but not always more forest species. Coffee *Coffea canephora* supported higher ant species richness and more forest species [36]. *Acacia mangium* plantations had higher beetle species richness than oil palm, and species composition was closer to that in forest [32]. There was greater overlap in species composition between oil palm and other tree crops than there was with forest [27,36,40]. Compared with oil palm, pasture and urban mown grassland had lower species richness, gardens of mixed crops had similar or higher species richness and abandoned pasture had more species [33,36,38]. *Imperata cylindrica* grasslands (which cover at least 8.5 million ha in Indonesia alone [49]) had more species of ants than oil palm, but fewer forest species [36].

In summary, oil palm is a particularly poor substitute for either primary or degraded forests, and whereas any conversion of natural forest is inevitably damaging to biodiversity, oil palm plantations support even fewer forest species than do most other agricultural options.

Landscape scale effects

Because oil palm and other tree crops are unsuitable habitats for most forest species, plantations, where they form part of the landscape matrix, can act as a barrier to animal movements [50,51]. Thus, forest fragments isolated within oil palm plantations supported fewer than half as many ant species as nearby continuous forests, and a greater number of invasive 'tramp' species were found in the smallest fragments [52]. Small, isolated forest fragments surrounded by oil palm had lower species richness and diversity of butterflies than larger, less isolated fragments [53].

As well as decreasing area and connectivity, fragmentation increases the length of forest edge exposed to harmful edge effects [30]. Abiotic edge effects include increased vulnerability to wind, desiccation and fire [30,54], although mature plantations of oil palm and other tree crops might provide more protection to forest edges than treeless habitats. Biotic edge effects include increased tree sapling mortality in forests where densities of wild pigs *Sus scrofa* are elevated by increased food availability in nearby oil palm plantations [55].

Box 3. Regulating development: the RSPO and public disclosure

Although increasing consumption of palm oil has promoted oil palm expansion, consumer concern has helped stimulate a movement toward more environmentally responsible practices within the industry. The most important initiative is the Roundtable on Sustainable Palm Oil (RSPO; see http://www.rspo.org), whose members manage more than one third of the global oil palm area, and which has developed a set of environmental and social Principles and Criteria for producers. Commitments to reduce impacts on biodiversity using the High Conservation Values approach to identify forests and other areas for preservation are included [74], but difficulties remain in defining and applying these values consistently. One area of concern is that forests degraded by logging are generally assumed to have low conservation value, when this is often not the case [47]. There are also challenges in ensuring compliance, and in certifying the activities of small holder farmers who supply palm fruits to RSPO producers. The auditing and certification system was only agreed to in November 2007, and thus RSPO certified palm oil will not be available before late 2008.

Governments are not directly involved in the RSPO, but have responsibility under international conventions to ensure that neither RSPO members nor other producers contribute to biodiversity loss [12]. It will take time for governments and legal institutions to become more effective and, in the meantime, voluntary or informal methods can be useful in providing some degree of regulation. To this end, 'public disclosure techniques' can help to provide effective environmental governance. A growing body of evidence suggests that in countries where regulatory agencies are weak, such as Indonesia, the regular collection and dissemination of information about the environmental performance of companies can lead to increased compliance with regulations, with minimal burden on regulators [75]. Disclosure works both by increasing external pressures on firms and by improving the access of managers to information about the impacts and mitigation opportunities of their companies. Disclosure for visible, well known attributes such as forest fire is likely to have the most impact (see e.g. http://www.eyesontheforest.or.id). Public disclosure programmes can quickly lose credibility if information is mishandled, so accurate reporting and independent auditing is essential [75].

Impacts of plantation development and management

As with other crops, the biodiversity impacts of oil palm depend on how the crop is developed and managed. Many of the greatest impacts result from the initial process of land clearance and preparation. Fire, whether used deliberately to clear forest or spreading accidentally from agricultural land, kills seeds and sedentary animals [54]. Many of the larger palm oil producers (Box 3) have committed to avoid using fire in land preparation and when mature, oil palm landscapes are probably less susceptible than *Imperata* grasslands to the spread of uncontrolled fires [17]. Initial land clearance exposes the soil to erosion. Sediment loads in streams increase dramatically after land clearance but return to baseline levels after plantation establishment [56]. Establishment of plantations on peat soils and where they replace forest contributes substantially to greenhouse gas emissions (Box 1), and thus to climate change, a growing global threat to biodiversity [35,57]. Despite these negative impacts, oil palm plantations might be better at providing some ecosystem services (such as carbon sequestration and soil protection) than annual crops or grassland, but not if they replace forest or peatland (Box 1).

Following plantation establishment, the greatest environmental impacts are likely to come from pollution. Water pollution from plantations and onsite mills is likely to affect aquatic biodiversity [58], but such impacts have not been assessed in relation to oil palm. Potential pollutants include palm oil mill effluent (POME), fertilisers, insecticides, rodenticides and herbicides [7,41,44]. Efforts to reduce the impacts of some of these pollutants are already in place in some plantations. POME is usually purified, so it can be harmlessly discharged into rivers; widespread use of integrated pest management and leguminous cover crops reduces use of insecticides and herbicides; and oil palm requires less fertiliser per unit of output than other oil crops [4,7].

There appear to be few biodiversity-friendly management practices which could enhance the value of oil palm plantations for native species. There are fewer animal species in planted areas because of reductions in habitat structural complexity and plant species diversity [27,32,38], and opportunities to increase these while maintaining agricultural productivity are limited [59]. Species richness of birds and butterflies was only marginally higher in oil palm plantations with more epiphytes or undergrowth [27,59]. Planting nonnative plants (such as *Euphorbia heterophylla* in Malaysia) to attract beneficial insects might help in pest control, but does not significantly improve the biodiversity value of plantations [59]. A trade-off might exist between enhancing the biodiversity value of plantations and minimising expansion into forested areas: if biodiversity-friendly management reduces yields, then more land will be needed to achieve production targets [3]. In this context, the limited available evidence suggests that the potential of biodiversity-friendly management is minimal (Box 2).

Of much greater value to biodiversity is the protection of fragments and corridors of native forest within and around plantations, including riverside buffers and remnants on steep slopes [59]. For species able to move through the oil palm matrix, forest fragments can act as ‘stepping stones’ for dispersal, and can be more beneficial than habitat ‘corridors’ [60], especially if they are large and not too isolated from other forests [53]. Although forested areas of tens of thousands of hectares will be needed to avert the extinction of many species [61], even small and degraded fragments can hold considerable biodiversity value and complement the species in larger reserves [50,51,53].

What can be done to mitigate the impacts?

Although there is value in protecting forest remnants, there seem to be few other opportunities to improve the biodiversity value of oil palm plantations, and the future ecological impact of oil palm will be determined largely by the extent to which it causes large-scale deforestation. Governments, environmental and social organisations, scientists, producers, financial institutions, buyers and consumers together have the capacity to soften the impact of palm oil production on biodiversity. Although the

Box 4. Outstanding questions

The value of conservation research depends upon its ability to stimulate informed action by policymakers and practitioners [76]. Robust answers to the following, often multidisciplinary, questions will help to inform policy and conservation action.

Preventing oil palm driven deforestation

Ensuring that the expansion of oil palm plantations does not occur at the expense of tropical forests is of the highest priority if ecological damage is to be minimised, and will be aided by well informed and effectively implemented strategic landscape planning.

(i) How can the contribution of oil palm development to land cover change be effectively determined and monitored?
(ii) How is oil palm development linked to other drivers of land cover change in different regions and at different scales?
(iii) Do current methods of determining High Conservation Value areas ensure the protection of areas of conservation importance?
(iv) Is it safe to assume that marginal non forest lands, for example *Imperata* grasslands, are of low conservation value?
(v) Where can oil palm expansion be directed to maximise agricultural yields and minimise impacts on biodiversity and climate?

Conservation strategies in an oil palm dominated landscape

There is now sufficient evidence to conclude that the biodiversity value of oil palm plantations is low in comparison with forest, but little is known about the influence of different plantation management strategies and landscape configurations on native species.

(i) What are the impacts of oil palm cultivation on freshwater and marine ecosystems?
(ii) Can oil palm yields be increased while limiting negative externalities such as aquatic pollution?
(iii) Are there economically acceptable ways to make oil palm dominated landscapes more biodiversity friendly (e.g. by increasing functional connectivity) without reducing yields?
(iv) What is the long term potential for species persistence within oil palm dominated landscapes?

Policy and markets

The applicability of conservation research depends upon the integration of biological, social, political and economic concerns.

(i) What are the barriers to the implementation of strategic landscape planning and how can they be overcome?
(ii) How can responsible oil palm development be best promoted, monitored and enforced?
(iii) How will the attitudes of consumers in developing palm oil markets (especially in Asia) affect future demand?
(iv) How will biofuel policies and markets affect oil palm expansion?

best strategies for impact mitigation will differ within and between countries, there are several emerging opportunities.

Governmental and nongovernmental organisations can work to develop national strategies for land allocation that integrate maps of conservation priorities and agricultural suitability. Such strategies give no assurance that impacts are being minimised unless they are integrated into land-use allocation and coupled with effective regulatory systems. Diverting oil palm expansion into areas of low conservation importance (e.g. degraded *Imperata* grasslands, not to be confused with degraded forests) would avert much ecological damage. However, current international policies are doing nothing to ensure that such areas are being used in preference to natural forests, and difficult issues such as governance and land tenure need to be tackled effectively in producer countries. A challenge for conservation scientists is to understand these issues and identify solutions (Box 4). Nongovernmental organisations can help increase transparency by disseminating information to plantation managers and other stakeholders (Box 3).

Producers must be given access to information that will allow them to locate new plantations in areas where they will cause the least ecological damage. There is considerable scope for more widespread use of comprehensive Environmental Impact Assessments of proposed plantations, including Life-Cycle Analyses, to identify and reduce impacts [62,63]. There are opportunities for identifying ways in which palm oil yield can be increased while minimising negative environmental externalities (Box 2). There might also be wildlife-friendly management practices that do not reduce yields (but sometimes even enhance them [64]), and opportunities for companies to promote awareness of biodiversity among their staff [34]. Some producers have made significant progress toward minimising the adverse impacts of palm oil production, but challenges remain (Box 3). Strategic alliances between producer companies, environmental organisations and other stakeholders will be needed for conservation efforts to be successful (Box 2).

Financial institutions, buyers and consumers can assist by continuing to demand detailed evidence that producers are doing all they can to minimise the negative impacts of palm oil production, and by denying finance and markets to those that are not. Such evidence will be most credible if independently audited, for instance by local nongovernmental organisations (Box 3). It is difficult to predict how quickly emerging markets (e.g. in India and China) will start to demand evidence of environmental responsibility, but this could be critical in determining whether irresponsible and unregulated producers continue to make a profit, and hence whether oil palm expansion comes at great cost to forests.

Conclusions

For biodiversity, oil palm plantations are a poor substitute for native tropical forests. They support few species of conservation importance, and affect biodiversity in adjacent habitats through fragmentation, edge effects and pollution. There is enough non-forested land suitable for plantation development to allow large increases in production without further deforestation, but political inertia, competing priorities and lack of capacity and understanding, not to mention high levels of demand for timber and palm oil from wealthy consumers, often make it cheaper and easier to clear forests. The efforts of some producers to reduce their environmental impacts, especially by avoiding forest conversion, must be commended. However, unless governments in producer countries become better at controlling logging, protecting forests and ensuring that crops are planted only in appropriate areas, the impacts of oil palm expansion on biodiversity will be substantial.

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Exhibit 18

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Macaques can contribute to greener practices in oil palm plantations when used as biological pest control

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Conversion of tropical forests into oil palm plantations reduces the habitats of many species, including primates, and frequently leads to human–wildlife conflicts. Contrary to the widespread belief that macaques foraging in the forest–oil palm matrix are detrimental crop pests, we show that the impact of macaques on oil palm yield is minor. More importantly, our data suggest that wild macaques have the potential to act as biological pest control by feeding on plantation rats, the major pest for oil palm crops, with each macaque group estimated to reduce rat populations by about 3,000 individuals per year (mitigating annual losses of 112 USD per hectare). If used for rodent control in place of the conventional method of poison, macaques could provide an important ecosystem service and enhance palm oil sustainability.

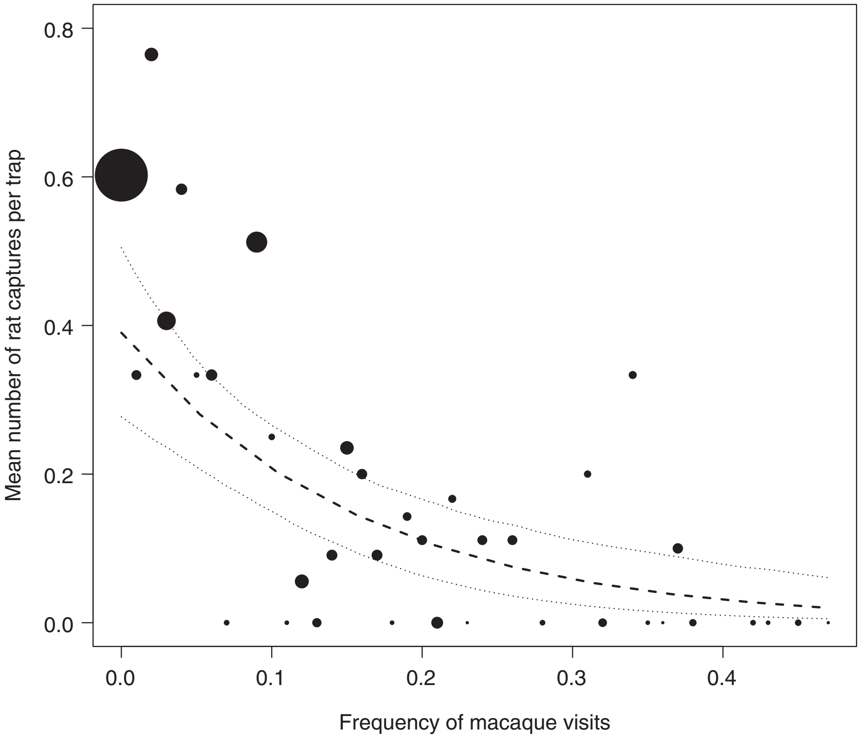

Figure 1. Mean number of rat captures per trap as a function of the frequency of macaque visits.
The frequency of macaque visits refers to the number of days the macaques were present at a trap site during the last 90 days prior to sampling. The area of the circles represents the sample size (total N = 575 traps). The dashed line shows the fitted model and the dotted lines its 95% confidence interval, conditional on continuous control predictors being on their average, and based on undergrowth and session manually dummy coded and then centered.

The area of primary rainforest converted into oil palm plantations has dramatically increased over the past decades. Today, oil palm plantations cover 18.7 million hectares of land worldwide [1]. Malaysia is ranked among the world's leading palm oil producers, reaching an annual production of approximately 19.5 million tons [2] (30% of world production). This expansion has had negative ecological impacts, as isolated forest fragments suffer from reduced species and genetic diversity, impaired climate regulation, and lower resilience [3]. At the same time, plantations offer habitat to a range of species, some of which negatively affect the plantations by eating or damaging oil palm fruits. Rats (*Rattus* spp.), for example, can cause losses of up to 10% of the yield [4], which in Malaysia alone is equal to crops grown over up to 580,000 hectares [2] (monetary loss of approximately 930 million USD per year). The use of rodenticides in pest control is not only expensive and largely inefficient [5] but has also proven to be harmful to non-target wildlife and the environment [6]. This highlights the global importance of improving sustainable palm oil production, including the use of efficient and environmentally friendly pest control. Southern pig-tailed macaques (*Macaca nemestrina*) are directly affected by the dramatic decline of forest habitat in Malaysia [7]. In fragmented forests they increasingly divert their foraging activities into oil palm plantations, where they are widely regarded as crop pests [8]. However, we observed pig-tailed macaques actively foraging for plantation rats, suggesting that macaques may in fact decrease crop damage by rats. Hence, we investigated both the role of macaques as crop pests and their potential utility as biological pest control. Here, we present the first data on macaques' net damage to oil palm crops and their effect on plantation rats.

Ranging and behavioral data (collected from January 2016 to September 2018) of two habituated groups of pig-tailed macaques inhabiting the Segari Melintang Forest Reserve in Peninsular Malaysia and the surrounding oil palm plantation showed that approximately one third of the macaques' home range includes the plantation (Figure S1). Macaques spent an average of 2.9 hours per day at the plantation, with their feeding time at the plantation representing 44% of the overall feeding time. Although 74% of the macaques' plantation diet consisted of oil palm fruits, our results question the common perception of macaques as crop pests. Based on individual consumption rates of fresh fruitlets, we estimated the annual oil palm fruit consumption by an average group of macaques ($N = 44$ individuals) to be approximately 12.4 tons, which is equal to 0.56% of the overall oil palm production in the macaques' home range (2,197.6 tons; see Supplemental Information). Hence, the damage by macaques is up to 17-fold lower than the crop damage reported for rats (10%) [4].

Further, an extrapolation of foraging data estimated a consumption rate of 3,135 rats per year per macaque group. Pig-tailed macaques seem to be particularly effective pest control agents due to their foraging behavior. They engage in multiple methods of actively foraging for rats. Removing persistent leaf bases (boots) from oil palm trunks to uncover rats that seek shelter in cavities under these boots during the day was the most successful strategy observed (90% of caught rats were found under boots, Figure S2A).This shows that macaques not only apply different hunting strategies (Figure S2B), but also occupy a different foraging niche than other rodent predators (such as barn owls [6] and leopard cats [9]) that hunt for rats on the plantation grounds during the night. A capture program on plantation rats, which related rat abundance to macaque presence, further corroborated the effect of macaques on pest rodents. We considered the actual number of rat captures as a proxy for rat abundance, which we found to be lower in plantation areas that had recently been visited more frequently by macaques. Controlling for other factors potentially impacting rat populations (specifically, rainfall, undergrowth, distance to the forest edge, trapping session and spatial autocorrelation between trap sites), this relationship was statistically highly significant (Generalized Linear Mixed Model estimate $\pm$ SE $= -0.72 \pm 0.18$, $p < 0.001$, $n = 575$ traps, see Supplemental Information). For example, an increase from 0 to 25% of days with macaque visits (that is, every fourth day) leads to a decrease in rat numbers by 79% (Figure 1). This suggests that, as compared to their absence, regular visits of pig-tailed macaques in Malaysia's oil palm plantations could reduce crop damage from 10% to less than 3% (2.1% by rats plus 0.56% by macaques), corresponding to a yield increase equal to crops grown over approximately 406,000 hectares (monetary gain of approximately 650 million USD per year).

Pig-tailed macaques were listed as Vulnerable in their most recent assessment by the International Union for Conservation of Nature in 2008, with habitat loss and human hunting being reported as their major threats [7]. However, given the dramatic decline of their natural habitat, macaque population size is assumed to have further decreased during the past decade. As umbrella species, macaques represent a wide range of species living in rainforest. However, appropriate management may allow them to also survive in multifunctional landscapes that include plantations [10]. Our results suggest important opportunities for mitigating human–wildlife conflicts: farmers and palm oil companies are encouraged to protect primates in their natural habitat via wildlife corridors between forest patches and viable interfaces between forests and plantations. This could maintain functional connectivity and gene flow between macaque populations while increasing environmental sustainability and productivity of existing oil palm plantations, promoting win-win solutions for palm oil producers and biodiversity.

SUPPLEMENTAL INFORMATION

Supplemental Information including two supplemental figures, experimental procedures and supplemental references can be found with this article online at https://doi.org/10.1016/j.cub.2019.09.011.

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DECLARATION OF INTERESTS

The authors declare no competing interests.

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Exhibit 19

Centers for Disease
Control and Prevention

Facts About Paraquat

Related Pages

Facts About Paraquat

Case Definition: Paraquat Poisoning

What paraquat is

- Paraquat is a toxic chemical that is widely used as an herbicide (plant killer), primarily for weed and grass control.
- In the United States, paraquat is available primarily as a liquid in various strengths. The US Environmental Protection Agency classifies paraquat as “restricted use.” This means that it can be used only by people who are licensed applicators.
- Because paraquat is highly poisonous, the form that is marketed in the United States has a blue dye to keep it from being confused with beverages such as coffee, a sharp odor to serve as a warning, and an added agent to cause vomiting if someone drinks it. Paraquat from outside the United States may not have these safeguards added.

Where paraquat is found and how it is used

- Paraquat was first produced for commercial purposes in 1961.
- Worldwide, paraquat is still one of the most commonly used herbicides.
- In the United States, due to its toxicity, paraquat is available for use only by commercially licensed users.

How you could be exposed to paraquat

- Paraquat is not known to have been used in any terrorist attacks or wars.
- The most likely route of exposure to paraquat that would lead to poisoning is ingestion (swallowing).
- Paraquat can be mixed easily with food, water, or other beverages. If the form of paraquat that is used does not contain the safeguard additives (dye, odor, and vomiting agent), people might not know that the food, water, or other beverages are contaminated. Eating or drinking paraquat-contaminated food or beverages could poison people.
- Paraquat poisoning is also possible after skin exposure. Poisoning is more likely to occur if the skin exposure lasts for a long time, involves a concentrated version of paraquat, or occurs through skin that is not intact (skin that has sores, cuts, or a severe rash).
- If it is inhaled, paraquat could cause poisoning leading to lung damage. In the past, some marijuana in the United States has been found to contain paraquat.
- Licensed applicators of paraquat are the people most at risk for exposure.

How paraquat works

- The extent of poisoning caused by paraquat depends on the amount, route, and duration of exposure and the person’s health condition at the time of the exposure.
- Paraquat causes direct damage when it comes into contact with the lining of the mouth, stomach, or intestines.

- After paraquat enters the body, it is distributed to all areas of the body. Paraquat causes toxic chemical reactions to occur throughout many parts of the body, primarily the lungs, liver, and kidneys.
- Cells in the lung selectively accumulate paraquat likely by active transport.

Immediate signs and symptoms of paraquat exposure

- After a person ingests a large amount of paraquat, he or she is immediately likely to have pain and swelling of the mouth and throat. The next signs of illness following ingestion are gastrointestinal (digestive tract) symptoms, such as nausea, vomiting, abdominal pain, and diarrhea (which may become bloody).
- Severe gastrointestinal symptoms may result in dehydration (not enough fluids in the body), electrolyte abnormalities (not enough sodium and potassium in the body), and low blood pressure.
- Ingestion of small to medium amounts of paraquat may lead to development of the following adverse health effects within several days to several weeks:
    - Heart failure
    - Kidney failure
    - Liver failure
    - Lung scarring
- In general, ingestion of large amounts of paraquat leads to the following signs/symptoms within a few hours to a few days:
    - Acute Kidney failure
    - Confusion
    - Coma
    - Fast heart rate
    - Injury to the heart
    - Liver failure
    - Lung scarring (evolves more quickly than when small to medium amounts have been ingested)
    - Muscle weakness
    - Pulmonary edema (fluid in the lungs)
    - Respiratory (breathing) failure, possibly leading to death
    - Seizures
- Showing these signs and symptoms does not necessarily mean that a person has been exposed to paraquat.

Long-term health effects

- If a person survives the toxic effects of paraquat poisoning, long-term lung damage (scarring) is highly likely. Other long-term effects may also occur, including kidney failure, heart failure, and esophageal strictures (scarring of the swallowing tube that makes it hard for a person to swallow).
- People with large ingestions of paraquat are not likely to survive.

How you can protect yourself, and what you should do if you are exposed to paraquat

- Because ingestion is likely to be the primary route of exposure, if poisoning is suspected, avoid any further ingestion and seek medical attention immediately.
- Pre-hospital therapy may include oral administration of activated charcoal or Fuller's earth in order to bind ingested paraquat.
- If you think you may have been exposed to liquid paraquat on your clothes or body, remove your clothing, rapidly wash your entire body with soap and water, and get medical care as quickly as possible.
    - **Removing your clothing:**

        - Quickly take off clothing that has liquid paraquat on it. Any clothing that has to be pulled over the head should be cut off the body instead of pulled over the head.
        - If you are helping other people remove their clothing, try to avoid touching any contaminated areas, and remove the clothing as quickly as possible.
    - **Washing yourself:**
        - As quickly as possible, wash any liquid paraquat from your skin with large amounts of soap and water. Washing with soap and water will help protect people from any chemicals on their bodies.
        - If your eyes are burning or your vision is blurred, rinse your eyes with plain water for 10 to 15 minutes. If you wear contacts, remove them and put them with the contaminated clothing. Do not put the contacts back in your eyes (even if they are not disposable contacts). If you wear eyeglasses, wash them with soap and water. You can put your eyeglasses back on after you wash them.
    - **Disposing of your clothes:**
        - After you have washed yourself, place your clothing inside a plastic bag. Avoid touching contaminated areas of the clothing. If you can't avoid touching contaminated areas, or you aren't sure where the contaminated areas are, wear rubber gloves or put the clothing in the bag using tongs, tool handles, sticks, or similar objects. Anything that touches the contaminated clothing should also be placed in the bag. If you wear contacts, put them in the plastic bag, too.
        - Seal the bag, and then seal that bag inside another plastic bag. Disposing of your clothing in this way will help protect you and other people from any chemicals that might be on your clothes.
        - When the local or state health department or emergency personnel arrive, tell them what you did with your clothes. The health department or emergency personnel will arrange for further disposal. Do not handle the plastic bags yourself.
- For more information about cleaning your body and disposing of your clothes after a chemical release, see "Chemical Agents: Facts About Personal Cleaning and Disposal of Contaminated Clothing".

How paraquat exposure is treated in the hospital

Initial therapy consists of removing the paraquat from the body (decontamination) and preventing further absorption for oral exposures by using activated charcoal or Fuller's earth. Nasogastric suction may be considered for ingestions that present within 1 hour. Supportive care measures such as intravenous fluids (fluids given through a needle inserted directly into a vein), medications to help with breathing and to raise low blood pressure, a ventilator to support breathing, and possibly dialysis for kidney failure should be provided. Administration of excessive oxygen should be avoided because it may worsen paraquat toxicity. No proven antidote or cure exists for paraquat poisoning.

How you can get more information about paraquat

You can contact one of the following:

- Regional poison control center: 1-800-222-1222
- Centers for Disease Control and Prevention
    - Public Response Hotline (CDC)
        - 800-CDC-INFO
        - 888-232-6348 (TTY)
    - E-mail inquiries: cdcinfo@cdc.gov

- Centers for Disease Control and Prevention (CDC), National Institute for Occupational Safety and Health (NIOSH), Pocket Guide to Chemical Hazards.

Page last reviewed: April 4, 2018

Exhibit 20

The isolation and molecular identification of papillomavirus in macaca fascicularis and macaca nemestrina at animal facility of primate research centre – Bogor Agricultural University.

Date
2013

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Iskandriati, Diah

Abstract

Cervical cancer is still regarded as a major cause of death in women world wide, hence research on papilloma viruses, their drugs and vaccines for the prevention are still continued. Papilloma virus is a DNA virus of the family papillomaviridae. Papilloma virions have no sheath, the diameter of 55 nm, and icosahedral capsid. The virus multiplies in the cell nucleus and causes chronic latent infection. The virus genome has a circular form, 8 kbp in length with 8 open reading frames. The genome is divided into early (E) and late (L) genes. The E gen synthesizes 6 E proteins, namely E1, E2, E4, E5, E6 and E7, which are linked into the process of viral replication and oncogenes. Meanwhile, the L gene synthesizes 2 proteins, the L1 and L2, which are related to the formation of the capsid (Hakim 2010). In order to obtain the best result of the cancer research, it is highly requested to obtain appropriate animal model that reflect aspects of human disease. Non-human primates have high similarity with humans, both in terms of the evolution of the genetic, anatomical, physiological, biochemical and organ systems, as well as in cancer genes. Non-human primates of the genus Macaca is a genus with the highest distribution worldwide, from Japan to Afghanistan. So far, there are 22 species are included in the genus Macaca. Originally rhesus monkeys or M. mulatta are widely used for biomedical research, but since the Indian government imposed a ban on importing these animals, then Macaca fascicularis (Long-tailed Macaque, cynomolgus) and Macaca nemestrina (Pig-tailed Macaque), which has high population in Southeast Asia, began to be used as research animal. Various medical aspects related to both species are commonly studied by many researchers as an animal model for human diseases. This study is using the polymerase chain reaction (PCR) method and nucleotide tracking to identify papillomavirus tipes that infect the genital tract of Macaca fascicularis and Macaca nemestrina, which is kept in breeding facilities of Primate Research Center, IPB. The analysis of nucleotide sequences were performed using the Clustal W 2.1 and 5.1 Mega program. The establishment of phylogenetic tree using neighbor joining with 1000 times bootstrap repetition. The results showed that the papillomavirus that infect Macaca fascicularis was 32.7% (78/238) and Macaca nemestrina 12%

(4/31). Both species were infected by Macaca fascicularis papillomavirus (MfPV) tipe 3, 4, 5, 7 and 9, belongs to the genus Alpha papillomavirus with homology of 80 - 100%. Papilloma virus that infected the pig-tailed macaque was the same tipe of papillomavirus that infected the cynomolgus with similarity between 82% - 99% based on L1 region. To further explain the tipes of papilloma viruses that infected the pig-tailed macaque, it is necessary to identify the entire genome of the virus. To determine the tipe of the virus, it requires the identification of a more complete nucleotide sequence. It is interesting because papillomavirus that infected the pigtail macaques has 76% homology with the HPV tipe 52. This is the first report on the incidence of papillomavirus infection in the pigtail macaque genome that further analysis needs to be done. The results also showed that the two species of non-human primates can be utilized as an animal model for the study of papillomavirus and cervical cancer in humans.

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MT - Multidiciplinary Program [1319]

Exhibit 21

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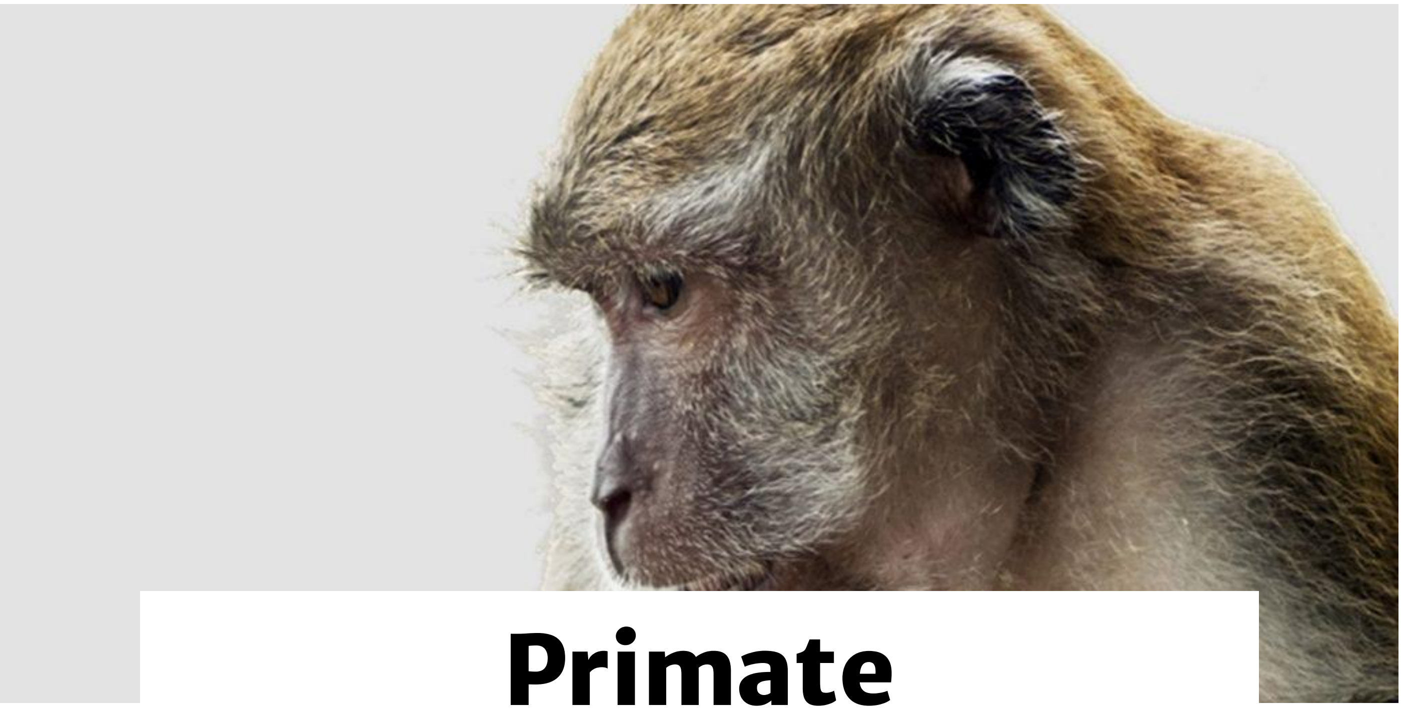

Primate Experimentation in Australia

October 1, 2019 (https://www.humaneresearch.org.au/primate-experimentation-in-australia/) Ban Primate Experiments (https://www.humaneresearch.org.au/ban-primate-experiments/)

Primates are used in a variety of research experiments in institutions around Australia – including macaques and marmosets in brain and vision studies and baboons in xenotransplantation research. You can find a list of HRA "case studies" involving primates here (http://www.humaneresearch.org.au/case-studies/case-studies-primates). Listen to the HRA podcast on primate research in Australia here (https://www.podomatic.com/podcasts/humaneresearchaustralia/episodes/2021-02-22T22_11_56-08_00).

> *(https://www.humaneresearch.org.au/wp-content/uploads/2019/10/jared-cooper-and-and-ned-2012-10-01.jpg)"As an expert on the welfare and well-being of non-human primates, I believe that using these individuals in research is inherently immoral. Social structure and the opportunity for normal interactions with not only conspecifics (members of their species) in general, but their family members in particular, are crucial for the physical and psychological well-being of non-human primates. The privation of captivity is compounded by the kinds of experiments imposed on these individuals, which often cause intense pain and suffering which cannot be alleviated until the individual is killed. Although they are similar to human beings in some ways, non-human primates are sufficiently different to make them poor surrogates. Only studies on people can provide us with unquestionably useful information about human structure, function and pathological conditions which will be invaluable in understanding and treating human disorders. We are an intelligent and capable species. If we use our intelligence compassionately, we can find ways to answer the questions we have without harming and killing non-human primates."*

– Nedim C. Buyukmihci, V.M.D.
Emeritus Professor of Veterinary Medicine

School of Veterinary Medicine
University of California-Davis

Suitability as models for human disease

(https://www.humaneresearch.org.au/wp-content/uploads/2019/10/BPE_chimp_canstockphoto.jpg)

Chimpanzees are the species most closely related to humans. The chimpanzee genome (complete genetic material) is 98.77 percent identical to that of humans, therefore, researchers argue that chimpanzees will be the species most likely to replicate human outcomes in scientific (biomedical and toxicity) testing. However this small genetic variation between human and chimpanzees accounts for very significant differences in the way diseases affect the two species.[12] Chimpanzees are not currently used in Australian research, and those primates that are used have even wider genetic variation to humans, meaning that the differences in results would be greater again.

Universally accepted in scientific experiments involving human and non-human animal subjects, is the principle that the benefits must exceed the costs. Between 1995 and 2004, 749 papers on biomedical testing on chimpanzees were published worldwide. Ninety-five of these were randomly selected and not even half were cited in subsequent papers. Of those that were cited, only 14.7 percent were mentioned in the abstracts indicating relevance to tackling human diseases.

The degree to which a journal is circulated within the scientific community affects citation rates, therefore, citation rates are not an entirely objective measure of the importance of that research.[13] However, if chimpanzee studies are published in lower impact journals, then the logical reflection is that they are not important in the studies themselves. This calls into question the value of chimpanzee experiments, the majority of which make little noticeable contribution to biomedical advancement. Of the original sample, no chimpanzee study made an essential contribution to papers which had well developed methods for combating human diseases. Brown stated, “It is always problematic to what extent such models reflect the human situation.”[14]

Despite chimpanzees being the most genetically similar animals to humans, experiments on them have not provided substantial contributions to biomedical research. Therefore, it is logical for us to question, that if the most genetically similar animal to humans is an ineffective model, then how can the use of more genetically distant animals assist us? Such concerns – both scientific and ethical – are being recognised around the world where their use in research is being phased out.

> *"Monkeys are very poorly representative of human biology and diseases, including crucial research areas such as HIV/AIDS, malaria, neurodegenerative diseases, cancer, and many others. They continue to be used in experiments due to their superficial similarity to humans, but it is increasingly clear that countless and important genetic differences exist, which combine to generate vastly different biologies, disease susceptibilities and pathologies. Monkey experiments are therefore inherently misleading, and can never reliably inform human medicine. The sooner science leaves them behind, the better – not just for monkeys, but also for billions of people relying on science for cures and treatments for diseases that blight their lives."*

– Jarrod Bailey, Ph.D.
Senior Research Scientist, BUAV

Statistics 2006–2017:

The following table shows the number of primates used in Australian research between 2006 and 2017 (the latest available). Not all states have provided annual returns showing the numbers of animals used in research, so the figures below could be considered to be conservative. The figures also do not include owl monkeys held by the Australian Defence Force (per below)

Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017

VIC	128	65	90	186	282	313	235	176	143	182	181	227
NSW	122	147	323	484	184	27	18	22	41	200	96	38
TAS	–	–	–	–	–	–	–	–	–	–	–	–
SA	–	–	32	30	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
NT	n/a	n/a	n/a	–	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
WA	33	–	n/a	n/a	n/a	n/a	n/a	21	18	23	28	7
QLD	n/a	n/a	n/a	58	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
ACT*	–	5	–	10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
TOTAL	283	217	445	768	466	340	253	219	202	405	305	272

NB: ACT figures are from ANU and CSIRO only. n/a = Statistics were not made available by the State or Territory Government.

Breeding Facilities

There are three NHMRC-funded non-human primate breeding facilities in Australia.

Despite this however, between 2000-2015, Australia imported:

- 331 pig-tailed macaques (Macaca nemestrina) listed on the International Union for Conservation of Nature (ICUN) Red List of Threatened Species as vulnerable to extinction (from Indonesia)
- 250 crab-eating macaques (Macaca fascicularis) listed on the IUCN Red List from Indonesia
- 46 owl monkeys (Aotus lemurinus grisembra) listed on the IUCN Red List from the US.[15] (71 are currently held at the Australian Defence Force Malaria and Infectious Diseases Institute and used for malaria research – personal email 4/4/18.) These animals are not included in the above statistics.

- 59 marmosets (Callithrix jacchus) from France
- 10 crab-eating macaques (Macaca fascicularis) from France.

(Numbers sourced from the CITES Trade Database, accessed July 2018)

The NHMRC supports the use of national breeding colonies (NBCs) for macaques, marmosets and baboons. In addition to the provision of research grants, the NHMRC makes annual contributions of $500,000 to the National Non-Human Primate Breeding and Research Facility and $195,000 to the National Baboon Colony.[16]

Over the period 2014-2017, the NHMRC awarded 26 grants to applicants who indicated they would involve non-human primates in their research:[17]

Grant Recipient	**No. of grants**	**Value of grants**	**Species**
Australian National University	2	$1.1 million	Macaque
La Trobe University	1	$0.9 million	Marmoset
Monash University	9	$6.2 million	Macaque, Marmoset
Murdoch Children's Research Institute	1	$1.1 million	Macaque
University of Adelaide	1	$0.8 million	Marmoset
University of Melbourne	8	$5.7 million	Macaque
University of Queensland	1	$0.8 million	Night Monkey
University of Sydney	3	$3.2 million	Baboon, Macaque

This research included studies into infectious diseases, sensory systems, nervous system disorders, immunology and vaccine development.

Furthermore, the NHMRC also funds research on primates overseas, such as inflicting heart attacks on macaques at University of Washington (http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4154594/).

Alternatives

The development of several international centres and university departments for the furtherance of non-animal alternatives in scientific testing around the world shows that there is interest in this option. The Fund for the Replacement of Animals In Medical Experiments in the United Kingdom has examined non primate alternatives in five areas of medical research[18]:

Malaria: There have been several in vitro (literally meaning, in a test tube) studies on human cells that have been used to examine the malarial parasite. These have included developing imaging technologies for visualisation of malaria molecules in living human cells, such as human liver cells. Human volunteers have been used to study the effects of specific genes, the product of which could be induced into a vaccine. Further, the human volunteer studies can be used to show gene expression in the malarial parasite, including the influences on the survival of the parasite.

Cognition: Human imaging is the keystone to understanding the human brain. It replaces primate experiments with ethical, human volunteer subjects. Different brain scans can produce impressive amounts of accurate data, without the need for invasive techniques. Where brain lesions are needed, fully reversible lesions can be created safely on people. Human subjects are also able to respond to verbal instructions. This is invaluable to scientific understanding within cognition research.

Stroke: Due to the failures in animal and primate models in current stroke research, there is more potential in the development of techniques to research strokes in humans. The techniques can include computer aided technology, brain imaging scans, in vitro studies, and the development of co-cultures using human cells and brain slices to study cell activity post mortem.

AIDS: Non-animal techniques can be used to provide insight into the HIV virus and AIDS, such as screening the genetic makeup of hundreds of HIV sufferers, to determine susceptibility to the virus. Mathematical analysis and statistical prediction can be used to map the acquisition of the infection, its viral state, and how the disease escapes immune control. In vivo (within a live organism) and in vitro studies, along with molecular research using tissues and cells, have also proved to be some of the most successful non-animal tests to date assisting with understanding the disease and subsequent drug production.

Hepatitis C (HCV): Mathematical modelling has been the most successful method for advancing the understanding of the HCV virus in human patients. In vitro systems have also proved effective.

Research on non-animal testing alternatives for these diseases has created a positive trajectory for the development of non-primate alternatives, should they be given the resources. Australia needs to step up to the mark and become a leader in this area – not continue with archaic and unethical research on primates.

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Exhibit 22

ORIP

OFFICE OF RESEARCH
INFRASTRUCTURE PROGRAMS

Photo by Kathy West, courtesy of the California National Primate Research Center.

NONHUMAN PRIMATE RESOURCES

2023

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ORIP'S MISSION

ORIP advances the NIH mission by supporting infrastructure for innovation. This support is focused on research resources, including animal models for human diseases, cutting-edge scientific instrumentation, construction and modernization of research facilities, and research training opportunities for veterinary scientists. Through continued engagement with NIH Institutes, Centers, and Offices and the biomedical research community, ORIP empowers and expands existing programs and develops new initiatives to support NIH research at the forefront of scientific progress.

National Institutes of Health
Office of Research Infrastructure Programs

OVERVIEW

The Division of Comparative Medicine (DCM) within the Office of Research Infrastructure Programs (ORIP), Division of Program Coordination, Planning, and Strategic Initiatives (DPCPSI), Office of the Director, National Institutes of Health (NIH), advances biomedical research by supporting research resources, such as those that provide animal models for human disease.

Because of their genetic, anatomical, physiological, and behavioral similarities to humans, nonhuman primates (NHPs) are one of the best models for human disease research when studies in humans are not ethical or feasible. Among other important medical advances, NHPs have played key roles in the understanding and treatment of a variety of infectious diseases, such as AIDS, tuberculosis, Zika virus disease and congenital Zika syndrome, Ebola, and, recently, COVID-19. Additionally, NHPs have been critical in advancing therapeutics for type 2 diabetes and other metabolic disorders, treatment of glioblastoma (brain cancer), deep brain stimulation to treat Parkinson's disease, neuroprosthetics (including the decoding of brain waves for brain–machine interfaces), pain management interventions, and organ transplantation. NHPs help determine the safety and efficacy of vaccines, devices, and therapies before they are used in humans. The COVID-19 pandemic demonstrated the pivotal role of NHPs in developing medical countermeasures for SARS-CoV-2, the virus that causes COVID-19; this included understanding infection progression and pathophysiology, preclinical development of vaccine candidates and therapeutics, and development of a variety of SARS-CoV-2-specific diagnostic assays.

Costs related to stringent breeding and housing requirements limit access to NHPs throughout the biomedical research community. To mitigate these issues, ORIP's DCM supports multiple NHP colonies and research-related resources that are available to the community of NIH-funded researchers. These NHP resources support biomedical research spanning scientific disciplines, with studies supported across almost all NIH Institutes, Centers, and Offices.

NONHUMAN PRIMATE RESOURCES

National Primate Research Centers

The National Primate Research Centers (NPRCs) are a national network of seven Centers that increase access to and promote sharing of valuable NHP-related resources among biomedical researchers. Additionally, the NPRCs advance the missions of NIH Institutes, Centers, and Offices by providing the animals, facilities, expertise, and resources required by investigators in disease-specific areas. ORIP's DCM funds NPRCs located in California, Georgia, Louisiana, Oregon, Texas, Washington, and Wisconsin. Collectively, the NPRCs maintain breeding colonies for rhesus, pigtail, and Japanese macaques; common marmosets; olive baboons; and titi monkeys.

Each Center provides expertise on the use of various NHP species as models for human disease to address specific research projects. Each provides a variety of services both individually and through inter-NPRC collaborations. The NPRCs provide services for research funded by NIH, other federal agencies, nonprofit foundations, and the private sector. Additionally, the program offers a Pilot Research Program for new investigators or exploratory research and a Visiting Scientist Program that offers advanced research training. The NPRCs have scientific programs addressing major research fields, such as infectious diseases, aging, cardiovascular disease, diabetes and metabolic disorders, neuroscience, pediatrics, regenerative medicine, reproductive health, and women's health. For detailed information on NPRC capabilities and programs, visit NPRCresearch.org. Recent advances by the NPRCs can be viewed at nprc.org.

① **Emory University**—Emory National Primate Research Center

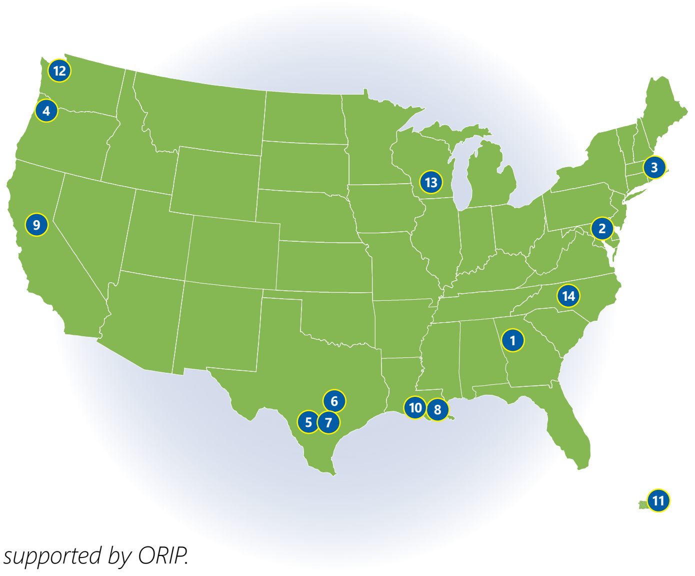
② **Johns Hopkins University School of Medicine**—Specific-Pathogen-Free Pigtail Macaque Breeding Colony for HIV Research Projects

③ **MassBiologics, University of Massachusetts Chan Medical School**—Nonhuman Primate Reagent Resource; Neotropical Primate Reagent Resource

④ **Oregon Health & Science University**—Oregon National Primate Research Center

⑤ **Texas Biomedical Research Institute**—Southwest National Primate Research Center

⑥ **The University of Texas MD Anderson Cancer Center**—Specific-Pathogen-Free Baboon Research Resource; Squirrel Monkey Breeding and Research Resource



⑦ **Trinity University**—New World Monkey Immunoreagent Resource

⑧ **Tulane University**—Tulane National Primate Research Center

⑨ **University of California, Davis**—California National Primate Research Center

⑩ **University of Louisiana at Lafayette**—Resource for Nonhuman Primate Immune Reagents

⑪ **University of Puerto Rico**—Caribbean Primate Research Center

⑫ **University of Washington**—Washington National Primate Research Center

⑬ **University of Wisconsin–Madison**—Wisconsin National Primate Research Center

⑭ **Wake Forest University School of Medicine**—Vervet Research Colony

Nonhuman primate research resources supported by ORIP.

NHP COVID-19 research being conducted in an Animal Biosafety Level 3 laboratory. Photo courtesy of the Southwest National Primate Research Center.

Specific-Pathogen-Free Macaque Colonies

Macaque monkeys are premier research models for HIV/AIDS. For example, macaques infected with the simian immunodeficiency virus (SIV)—the NHP analogue of HIV—are used to address basic research questions about viral infection routes, acute phases of infection, and latent viral reservoirs because these cannot be explored in humans. Likewise, SIV-infected macaques serve as models for developing HIV vaccines, infection prevention devices, new therapeutics, microbicides, and cure strategies prior to first-in-human trials.

The presence of specific viral pathogens in experimental animals can confound the results of HIV/AIDS-related investigations or pose a health risk to staff. Therefore, a consortium of colonies was developed to provide specific-pathogen-free (SPF) macaques for AIDS research that are negative for SIV, type D simian retrovirus, simian T-cell lymphotropic virus, and herpes B virus. Additionally, SPF macaques are characterized for major histocompatibility complex class I alleles, which are known to be associated with SIV viral load and rate of disease progression. ORIP supports SPF rhesus macaque colonies at the California, Oregon, Southwest, Tulane, and Emory NPRCs, as well as the Caribbean Primate Research Center in Puerto Rico. ORIP also supports SPF pigtail macaque colonies at the Washington NPRC and the Johns Hopkins University School of Medicine. Visit the ORIP website for more details on these critical SPF macaque resources.

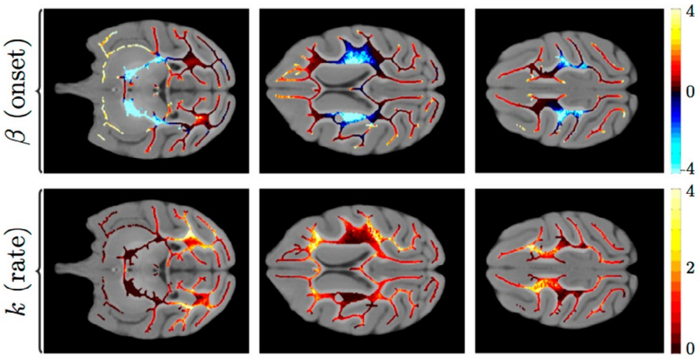
Other Nonhuman Primate Research Resources

Baboon Research Resources: Relative to most other NHP models, baboons share the greatest similarity to humans in terms of their larger size, year-round breeding, and placental biology. Because of similarities between the baboon and human immune systems, baboons are critical for vaccine development, xenotransplantation, and studies of infectious disease and bacterial sepsis. The baboon colony at MD Anderson Cancer Center's Michale E. Keeling Center for Comparative Medicine and Research (KCCMR) is maintained free of infection from an extensive list of at least 18 viruses, bacteria, and parasites and is a valuable research resource for studies requiring the unique similarities of baboons to humans without the complicating influences of coinfections. A baboon colony also exists at the Southwest NPRC.

Squirrel Monkey Breeding and Research Resource: Housed at KCCMR, this is the only national squirrel monkey breeding and research resource available for biomedical research and one of the few NIH-supported national research resources that specialize in a New World (neotropical) primate species. Squirrel monkeys are valuable for neuroscience research because of their small size and similarities to humans in brain structure, which makes them superior neuroscience models compared to small nonprimate mammals, such as rodents. Squirrel monkeys are used widely in neuroscience, vision, and hearing research; in studies of infectious diseases (malaria vaccine, polyoma virus disease, Zika virus); as a model of sporadic cerebral amyloid angiopathy; and in research on drug addiction and its behavioral and physiological consequences.

Caribbean Primate Research Center Program: The Caribbean Primate Research Center (CPRC) Program maintains conventional and SPF macaque colonies. Additionally, the CPRC maintains a free-ranging colony of rhesus macaques of purely Indian origin that was established over 80 years ago from a substantial founder population. This colony exhibits the lowest levels of genetic admixture with non-Indian-origin rhesus macaques among all rhesus monkey colonies surveyed in the United States, providing a unique resource for research in a naturalistic

Data on gait parameters as a common marmoset in the Wisconsin National Primate Research Center's Preclinical Parkinson's Research Program walks through a Noldus CatWalk XT10.6 (apparatus not shown).

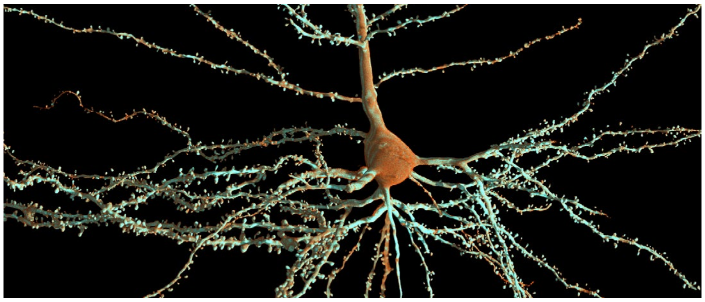


Postnatal brain structural maturation in infant rhesus macaques during the first 18 months of age. Top: White matter onset intensity at birth (β). Bottom: Median rate (k) of normalized white matter intensity change per day. Image courtesy of the Emory National Primate Research Center and collaborators, Drs. M. Styner and M. Niethammer.

setting. The CPRC supports researchers at other U.S. institutions, as well as collaborations onsite, and it has active programs in virology (especially SIV and West Nile, dengue, and Zika viruses), genetics, diabetes, parasitology, behavior, cognition, and anatomy.

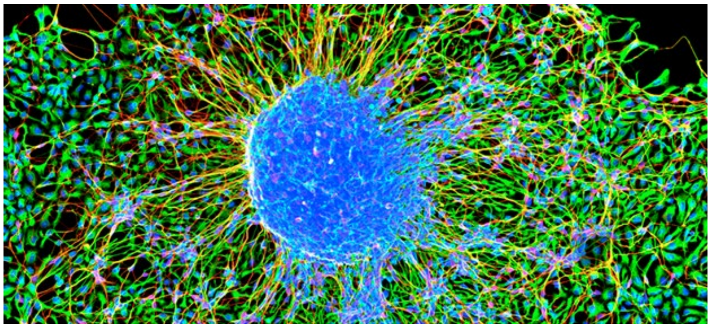
Vervet Research Colony: Vervets, or African green monkeys (AGMs), are critical research models owing to their similarities to humans in reproductive biology, development of cardiovascular disease and type 2 diabetes on a Western diet, and growth of amyloid plaques with age. The Vervet Research Colony (VRC) at Wake Forest School of Medicine maintains a multi-generational, pathogen-free, genotyped colony of Caribbean-origin AGMs. The colony consists of individuals ranging in age from newborns to geriatric animals over 27 years old. VRC animals, biospecimens, and data have contributed to research on diabetes, obesity, cardiovascular diseases, Alzheimer's disease, microbiome influences, metabolomics, and neuroscience. Additionally, VRC animals have supported vaccine research for SIV, neonatal influenza, respiratory syncytial virus, dengue virus, and SARS-CoV-2.

NHP Antibody Resources: The Nonhuman Primate Reagent Resource (NHPRR) and the Neotropical Primate Reagent Resource are located at Mass Biologics, a business unit of the University of Massachusetts Medical School. With ORIP support, the NHPRR develops, manufactures, and distributes immune cell–depleting antibody reagents to optimize the usefulness of Old World NHPs (e.g., rhesus and pigtail macaques) in biomedical research. These reagents support research on HIV and other infectious diseases, transplantation, cancer, and gene therapy. The Neotropical Primate Reagent Resource characterizes the immunoglobulin repertoire and antibody responses of New World NHPs (e.g., marmosets and squirrel monkeys) and uses this information to engineer species-matched lymphocyte-depleting and diagnostic antibodies for New World monkeys. Investigators may make inquiries of, and request reagents from, both resources via the NHPRR website.



Pyramidal cell from the prefrontal cortex of a rhesus macaque. The NPRCs offer a wide variety of resources for research with nonhuman primates, including advanced microscopy. Photo courtesy of John Morrison of the University of California, Davis.

The New World Monkey Immunoreagent Resource, located at Trinity University in San Antonio, Texas, develops mouse monoclonal antibodies to be used in novel immunoassays specific for biomarkers of inflammation and metabolic hormones in marmosets, squirrel monkeys, and owl monkeys. Immunoreagents for such biomarkers are useful in studies of aging, infectious diseases, neurodegenerative diseases, diabetes, metabolic syndrome, and obesity, all of which are being modeled in New World monkeys.



Common marmoset–derived embryonic stem cells differentiating into neurons in Marina Emborg's laboratory at the Wisconsin National Primate Research Center. A neurosphere was stained to visualize nuclei (blue) and immature neural progenitors (green) transitioning to neurons (red). Image by Scott Vermilyea, Ph.D.

NHP Centers of the Somatic Cell Genome Editing Program: The NIH Common Fund's Somatic Cell Genome Editing (SCGE) Program includes approaches for development and testing in NHPs to improve the efficacy and specificity of gene-editing approaches, with the ultimate aim of reducing the burden of common and rare genetic diseases in humans. Regulatory authorities currently require in-animal studies of safety, efficacy, and gene target specificity for nearly all genome-editing therapeutics under development for clinical use. With program management support from ORIP, the Oregon Health & Science University and Massachusetts Institute of Technology are generating genetically modified rhesus macaques and marmosets, respectively, to serve as reporter models to evaluate the efficiency of delivery and editing of CRISPR-based tools *in vivo*. These modified NHP models, as well as unmodified rhesus macaques and marmosets, will be used at the University of California, Davis, Nonhuman Primate Testing Center established through the SCGE Program. After validation, all new reporter animals created by the SCGE Program will be available for distribution to the wider biomedical community.

Visit the ORIP website for more details on other supported NHP research resources.

Exhibit 23

American Journal of Primatology 52:187–198 (2000)

Demographic Analysis of the Washington Regional Primate Research Center Pigtailed Macaque Colony, 1967–1996

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This work presents the results of a demographic analysis of 30 years of breeding records from the University of Washington's recently closed Primate Field Station at Medical Lake, Washington. Summaries of population growth, age-specific fertility and mortality rates, first-year survival, and seasonality of reproduction are presented, as well as an analysis of survival by decade. In addition, we present data on interbirth intervals in this population. In general, pigtailed macaques represent a typical Old World monkey pattern of age-specific fertility and mortality, with a few minor exceptions. We suggest that pigtailed macaques are most similar to rhesus and Barbary macaques, and that Japanese and bonnet macaques differ somewhat in their demographics. Am. J. Primatol. 52:187–198, 2000. © 2000 Wiley-Liss, Inc.

Key words: demography; mortality; fertility; vital statistics; pigtailed macaque; *Macaca nemestrina*

INTRODUCTION

Very little has been published on the demographics of pigtailed macaques in captivity. The Animal Records System at the University of Washington's Regional Primate Research Center (WaRPRC), which houses the largest captive-bred colony of pigtailed macaques in existence, contains a wealth of information which could contribute to the health and well-being of primates held in captivity. In addition, the pigtailed macaque is an important research species in the United States and around the world, and any additional information which might increase captive populations will aid in minimizing the need to draw animals from the wild. The pigtailed macaque is not an endangered primate species, and thus information gained from its larger population size may contribute to the development of methods to breed endangered and closely related species of macaques. Finally, from an evolutionary point of view, comparative information and comparisons among related species contribute to our understanding of the evolution of a taxon.

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Thus, we present a demographic analysis of 30 years of breeding records from a colony of pigtailed macaques (*Macaca nemestrina*) at the WaRPRC. These data include age-specific mortality and fertility. A similar report has been published on a captive population of rhesus macaques (*Macaca mulatta*) at the Wisconsin Regional Primate Research Center (WiRPRC) [Dyke et al., 1986], from which this study was modeled.

Demography of Macaques

Rhesus macaques give birth after the age of 2 years (usually at 4 years of age); their fertility peaks between 10 and 12 years of age, and declines gradually thereafter [Dyke et al., 1986; Johnson & Kapsalis, 1995; Smith, 1982]. The mean interbirth interval for rhesus macaques is about 15.6 months, with a tendency for slightly longer interbirth intervals in the middle of reproductive life, and slightly shorter interbirth intervals at the end of the reproductive life [Petto et al., 1995].

In comparison, Japanese macaques (*Macaca fuscata*) become reproductive later, after 4 years of age (generally at 5 or 6), with fertility gradually increasing until 20 years of age and then decreasing gradually with age [Itoigawa et al., 1992; Koyama et al., 1992; Watanabe et al., 1992]. Interbirth intervals in Japanese macaques on Koshima were approximately 24 months [Watanabe et al., 1992], and 19 months at Katsuyama [Itoigawa et al., 1992].

Bonnet macaques (*Macaca radiata*) produce their first infant at approximately 4 years of age, and there is no indication that fertility declines with age [Silk et al., 1981]. Interbirth intervals for bonnets are short compared to rhesus and Japanese macaques: 13 months after a surviving infant, and 11 months after a nonsurviving infant [Silk et al., 1981].

Barbary macaques (*Macaca sylvanus*) follow the typical macaque pattern of first-birth after 4 years of age: gradually increasing fertility until 8 years of age, and then experiencing stable fertility until after 20 years, when fertility declines [Kuester et al., 1995]. Interbirth intervals are approximately 22 months [Mehlman, 1989].

Reports of age-specific mortality in macaques are less prevalent in the literature than age-specific rates of fertility. Gage and Dyke [1988] summarized the literature on age-specific mortality in Old World monkeys by developing a model life table using statistical procedures to test for differences among populations, and then pooling all published information on age specific mortality in this group. This composite model of survivorship included data on *Macaca mulatta, M. fuscata*, and *Papio ssp*., all from captive or provisioned populations. In this model, as in most mammalian populations, mortality is highest in the first year of life, and then declines with age [Dyke et al., 1986; Smith, 1982; Tigges et al., 1988]. The maximum age of rhesus in captivity is 35 years [Tigges et al., 1988].

A number of reports have described the demographic characteristics of rhesus macaques (*Macaca mulatta*) [Drickamer, 1974; Sade et al., 1977; Smith, 1982; Rawlins et al., 1984; Dyke et al., 1986; Hendrie et al., 1996], Japanese macaques (*Macaca fuscata*) [Masui et al., 1975; Sugiyama & Ohsawa, 1982; Fedigan, 1991; Koyama et al., 1992], cynomologus macaques (*Macaca fasicularis*) [Hendrie et al., 1996], bonnet macaques (*Macaca radiata*) [Silk et al., 1981; Hendrie et al., 1996], and Taiwan macaques (*Macaca cyclopis*) [Petto et al., 1995]. Information on infant mortality for pigtailed macaques has been published [Dazey & Erwin, 1976; Bernstein & Gordon, 1977], but life tables have never been published. Captive pigtails begin perineal ("sex skin") swelling after 2 years of age, and animals become pregnant after 3 years of age [Erwin & Erwin, 1976]. Field work suggests that the interbirth interval for wild pigtailed macaques is approximately two years [Bernstein, 1967]. There is no reported seasonal birth effect in pigtails [Kuehn et al., 1965; Bernstein & Gordon, 1977].

Age-specific demographic data on pigtailed macaques is essential for comparative approaches, assessment of the health of pigtailed macaque captive populations, and for projections of future growth. This information is applicable to captive pigtailed macaques specifically, and to the colony management of macaques more generally.

METHODS

Population

Data were obtained from the WaRPRC's animal colony records on pigtailed macaques from 1967 to 1996. The animals were housed in indoor rooms (2.1 × 3.1 × 3 m high) under artificial lighting and on a 14 hr lights on:10 hr lights off photoperiod at the WaRPRC's Primate Field Station (PFS) at Medical Lake, Washington. The PFS was developed in 1965 by Theodore Ruch, director, and Orville Smith, assistant director, as an expanded breeding facility, and was established in a former state building on the grounds of the Eastern State Hospital [Dukelow, 1995]. It housed a large breeding colony of pigtailed macaques, as well as smaller colonies of long-tailed macaques (*M. fascicularis*) and baboons (*Papio cynocephalus*). In 1996–1997, this colony was moved to a new breeding facility on the grounds of the Tulane Regional Primate Research Center (Covington, Louisiana).

In general, animals were housed in social harem groups of approximately eight to 12 females and one breeding-age male. Infants were mother-reared, unless considered at risk for mortality, when they were moved to the University of Washington's Infant Primate Research Laboratory. In general, infants were weaned at 4–8 months of age. The monkeys were fed standard primate diet (chow) supplemented with fresh produce and grains [see Blakely et al., 1972, for other husbandry details].

Analysis

Our analysis was restricted to the records of 7,333 captive-born animals with known birth dates (3,528 males, 3,549 females, and 256 unknown sex) and 2,488 wild-caught animals with unknown birth dates (315 males and 2,173 females) housed in social groups generally containing a single breeding male or of all-female composition. There was a PFS husbandry policy of removing breeding males from harem groups after all females had conceived, and replacing males after the termination of conceptions. This was done in situations in which there was a shortage of breeding males, or to prevent male-initiated aggression towards pregnant females. These animals were assigned to our breeding colony, and thus every attempt was made to maximize breeding production. They did not experience experimental protocols immediately prior to, or during, the periods of data presented in this study. Standard life table analyses were performed using the Animal Colony Management Package software from the Southwest Foundation for Biomedical Research (SFBR)'s Population Genetics Laboratory [Dyke & Mamelka, 1989] following extraction from the WaRPRC's Animal Record System and conversion to SFBR's Pedsys format [Dyke, 1994]. In addition, we compared 30-day postnatal survival of infants born to wild-caught and captive-born dams born in social groups vs. single dam-with-infant caging, using Kaplan-Meier survival estimates and Tarone-Ware log-rank probabilities. Output was selected from these programs for presentation based on the literature so as to provide comparable measures for interspecific comparisons where possible.

RESULTS

Male and female population sizes and their growth over the 34-year existence of the WaRPRC PFS breeding colony are depicted in Fig. 1. The breeding colony population had a decade of rapid male and female growth (1967–1976), a period of female population expansion but slower growth in the male population (1977–1986), and a period of relatively stable existence before the move (1987–1996). The final downturn in population size in the mid-1990s is due to a PFS population reduction, through sales and moves to the Seattle colony, in anticipation of the move to Tulane.

Age-specific fertility rates for females showed an onset of fertility at 3 years of age, and significant fertility at 4 years of age (Table I). Age-specific fertility increased to a peak at 8–9 years of age. Following this peak, fertility decreased gradually to reproductive senescence at 19 years of age. In this data set, female births slightly, and nonsignificantly, outnumbered male births 50.6% to 49.4%. Overall gross reproductive rate (GRR: the average number of daughters born to females surviving the entire fertile period) was 3.41 (Table II), comparing favorably to 3.24 in rhesus macaques housed at the WiRPRC [Dyke et al., 1986]. Total fertility rate (TFR: the average number of offspring of both sexes) was 6.76 (Table II), again comparing favorably to 6.73 at the WiRPRC [Dyke et al., 1986]. Both GRR and TFR increased over the three decades that the PFS operated (Table II).

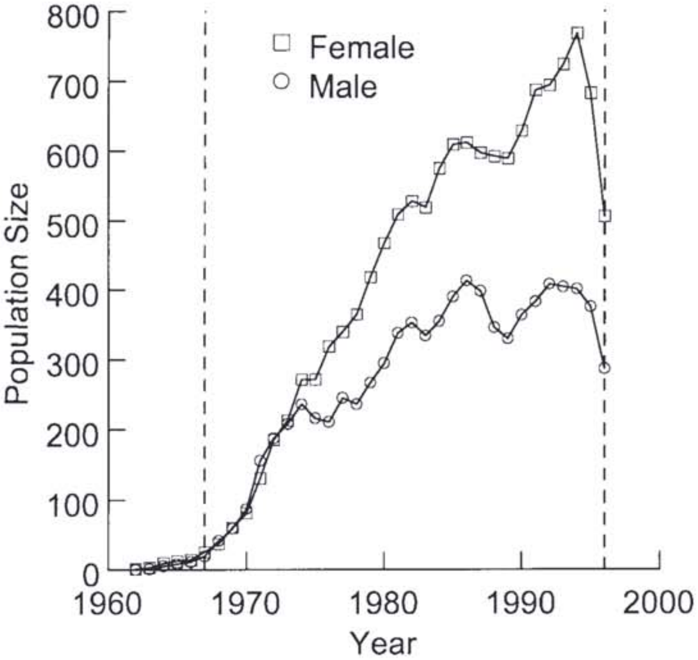

Fig. 1. Population sizes for the entire Washington Regional Primate Research Center Primate Field Station (WaRPRC PFS) breeding colony from its inception until its transfer to a new facility at the Tulane Regional Primate Research Center in Covington, Louisiana. Dashed lines indicate the period (30 years) analyzed in this study.

TABLE I. Age Specific Fertility Rates (ASFR) for Females at the Primate Field Station Colony From 1967 to 1996

Age	Animal-years	Female births	Female ASFR	Both sexes, births	Both sexes, ASFR
0–1	2368.0	0	0.00	0	0.00
1–2	1919.9	0	0.00	0	0.00
2–3	1569.4	0	0.00	0	0.00
3–4	1319.1	43	0.03	101	0.07
4–5	1122.3	300	0.26	594	0.51
5–6	978.4	292	0.29	590	0.58
6–7	841.7	229	0.26	486	0.56
7–8	689.6	215	0.30	405	0.57
8–9	565.0	163	0.28	298	0.51
9–10	463.9	116	0.25	224	0.47
10–11	381.9	88	0.24	192	0.52
11–12	288.6	77	0.26	141	0.48
12–13	232.4	54	0.23	100	0.43
13–14	184.0	37	0.20	71	0.38
14–15	134.3	21	0.15	37	0.27
15–16	99.3	24	0.24	39	0.39
16–17	74.8	7	0.09	15	0.20
17–18	52.0	7	0.13	12	0.23
18–19	38.0	2	0.05	3	0.08
19–20	21.3	0	0.00	2	0.09
20–21	12.6	0	0.00	2	0.16
21–22	8.1	0	0.00	1	0.12
22–23	7.2	1	0.14	1	0.14
23–24	4.8	0	0.00	0	0.00
24–25	3.8	0	0.00	0	0.00
25–26	2.2	0	0.00	0	0.00
26–27	2.0	0	0.00	0	0.00
27–28	1.8	0	0.00	0	0.00
28–29	1.0	0	0.00	0	0.00
29–30	0.2	0	0.00	0	0.00
Total		1676		3314	

Animal-years is the number of animsl over years exposed to risk of fertility in age interval x.

Interbirth intervals were measured only after the first birth, since husbandry procedures and lack of records prevented accurate calculation of the age of first exposure to a fertile male. Interbirth intervals following the first birth increased linearly with parity by 0.268 months per pregnancy (Table III; t(10) = 3.94, P = 0.0034, $R^2 = 0.63$). A stronger pattern showed that interbirth intervals were lower for the first seven pregnancies ($\overline{x}$ = 15.2 months, SE = 0.23), and increased sig-

TABLE II. Overall Gross Reproductvie Rate (Average Number of Daughters Born to Females Surviving the Entire Fertile Period) and Total Fertility Rate (Average Number of Offspring of Both Sexes) by Decade for the Primate Field Station Colony From 1967 to 1996

Decade	Gross reproductive rate	Total fertility rate
1967–74	2.03	5.65
1975–84	3.45	6.67
1985–94	3.73	7.30
Overall	3.41	6.76

TABLE III. Interbirth Intervals (Months) as a Function of Parity, Beginning Following the First Birth, for Pigtailed Macaques Housed at the Washington Regional Primate Research Center's Primate Field Station From 1967–1996

Parity	Mean interbirth interval (mo)	No. dams >=parity
1–2	14.6	562
2–3	15.3	404
3–4	15.3	287
4–5	15.1	208
5–6	16.3	139
6–7	15.0	91
7–8	14.8	54
8–9	16.9	35
9–10	16.4	19
10–11	16.9	13
11–12	18.1	4

nificantly for pregnancies 8–11 ($\bar{x}$ = 17.1 months, SE = 0.31, t(9) = –4.902, P = 0.00084, R^2 = 0.73). There was no seasonality in births or deaths (births: $X^2(11)$ = .409; deaths all: $X^2(11)$ = 0.517; deaths first year: X^2 = 0.573; all P = 1.000; Fig. 2).

Age-specific mortality rates (q_x) for males and females at the PFS were relatively constant from 2–16 years of age (Table IV). Mortality rates were highest for infants (< 1 year old), declined to a plateau, and then rose gradually from 17 years old through the maximum lifespan of about 26 years. In comparing the PFS results for males and females to the rhesus data from the WiRPRC [Dyke,

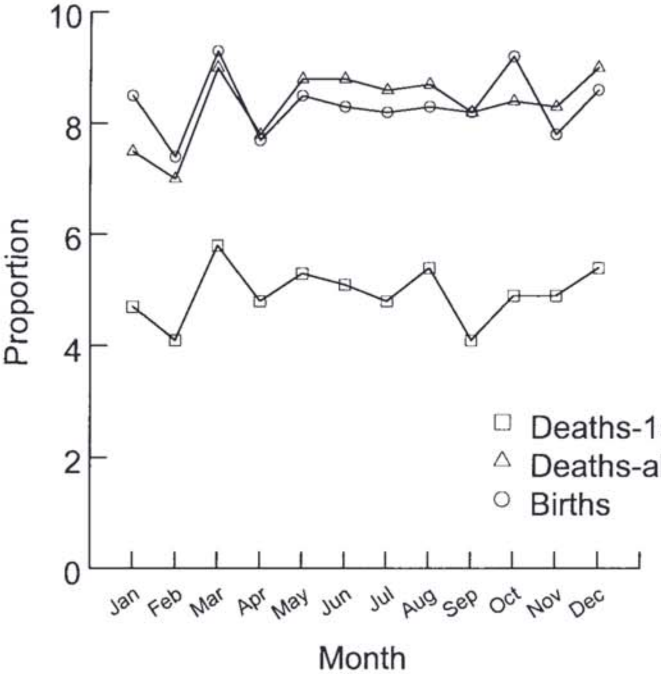

Fig. 2. Seasonality of births and deaths of captive pigtailed macaques housed at the WaRPRC PFS from 1967–1996.

TABLE IV. Age Specific Mortality of Males and Females at the Primate Field Station Colony From 1967 to 1996

	Males			Females		
Age	Exposed to risk	No. of deaths	q(x)	Exposed to risk	No. of deaths	q(x)
0–1	3161.1	1051	0.33	3261.4	1090	0.33
1–2	1818.9	256	0.14	2080.9	287	0.14
2–3	1302.6	107	0.08	1673.6	139	0.08
3–4	934.5	36	0.04	1409.5	89	0.06
4–5	648.1	26	0.04	1186.7	54	0.05
5–6	451.2	27	0.06	1035.7	48	0.05
6–7	320.8	14	0.04	891.0	44	0.05
7–8	238.5	14	0.06	734.7	46	0.06
8–9	181.5	8	0.04	590.2	20	0.03
9–10	146.4	7	0.05	489.3	30	0.06
10–11	125.1	6	0.05	381.1	22	0.06
11–12	103.6	6	0.06	305.4	18	0.06
12–13	88.1	8	0.09	240.7	14	0.06
13–14	68.8	9	0.13	194.4	16	0.08
14–15	52.9	5	0.09	144.1	14	0.10
15–16	46.5	4	0.09	106.7	10	0.09
16–17	40.8	2	0.05	82.8	13	0.16
17–18	36.4	5	0.14	58.5	10	0.17
18–19	30.1	6	0.20	40.1	7	0.17
19–20	21.3	4	0.19	25.0	7	0.28
20–21	14.9	2	0.13	13.8	3	0.22
21–22	12.0	3	0.25	8.1	0	0.00
22–23	9.0	2	0.22	7.7	1	0.13
23–24	6.4	1	0.16	6.0	2	0.33
24–25	4.2	2	0.48	3.8	0	0.00
25–26	2.0	1	0.50	2.2	0	0.00
26–27	1.0	0	0.00	2.0	0	0.00
27–28	0.9	0	0.00	2.0	1	0.50
28–29	0.0	0	0.00	1.0	0	0.00
29–30	0.0	0	0.00	0.2	0	0.00
Total	9867.5	1612	3.71	14978.5	1985	3.33

q(x) is the probability of dying in the interval.

et al., 1986], it was clear that first- and second-year mortality was much higher than in the WiRPRC rhesus colony, but that PFS mortality rates in subsequent years were more typical (Fig. 3). Overall, age-specific mortality was higher among captive-housed pigtailed macaques than for rhesus. Survivorship curves for males and females by decade showed no significant differences (Fig. 4).

Thirty-day infant survival was influenced by both origin (wild-caught dam vs. captive-born dam) and housing type at birth (social group vs. single cage). Survival of infants born to wild-caught dams was significantly better than that of infants born to captive-born dams (Table V). Housing type had no effect on 30-day survival of infants of wild-caught dams, but survival of single-cage-housed infants of captive-born dams was higher than that of socially-housed dams (Table V).

DISCUSSION

The demographic patterns of pigtailed macaque monkeys housed at the PFS from 1967 through 1996 follow the same basic patterns established for other

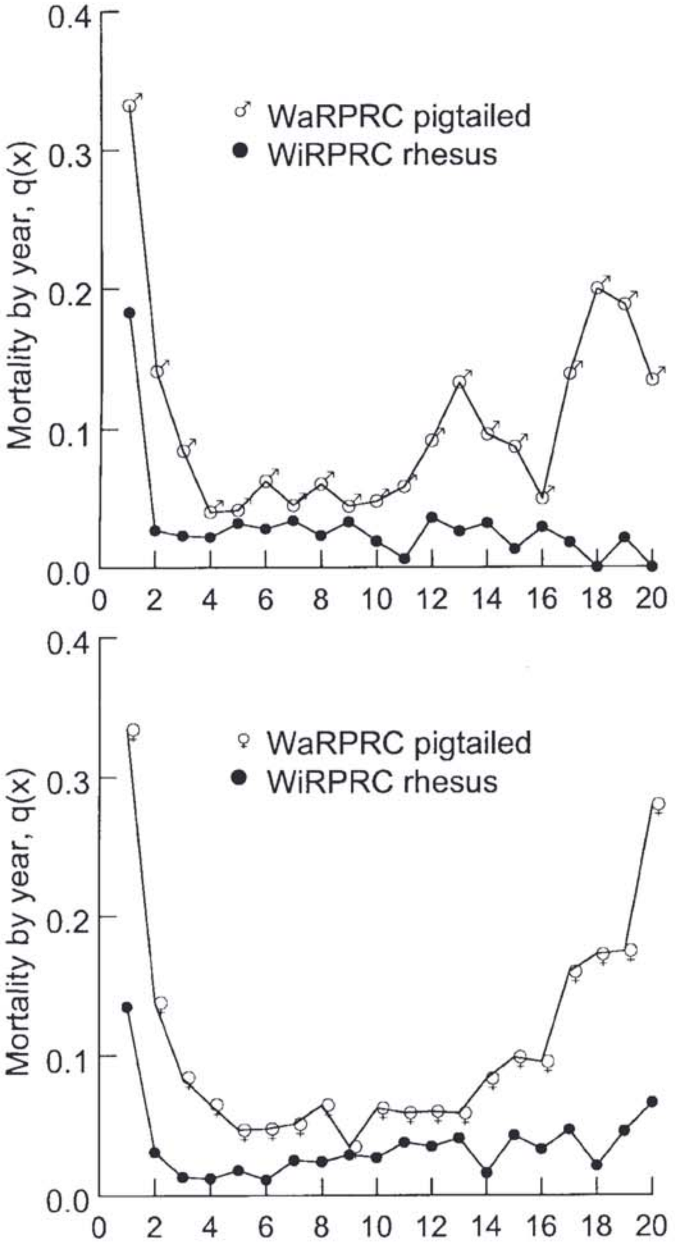

Fig. 3. A comparison of age-specific mortality rates (q_x) at the midpoint of the interval for (**a**) males and (**b**) females housed at the WaRPRC PFS from 1967–1996. The filled symbols represent the age-specific mortality rate for rhesus monkeys housed at the Wisconsin Regional Primate Research Center [Dyke et al., 1986]. The open symbols represent the age-specific mortality rates for the PFS population.

macaques. Fertility began about 4 years of age, peaked around 9 years of age, and declined gradually in later years. Interbirth intervals increased with age and number of pregnancies. Age-specific mortality was highest in infants, relatively constant in middle years, and then increased after about 20 years of age.

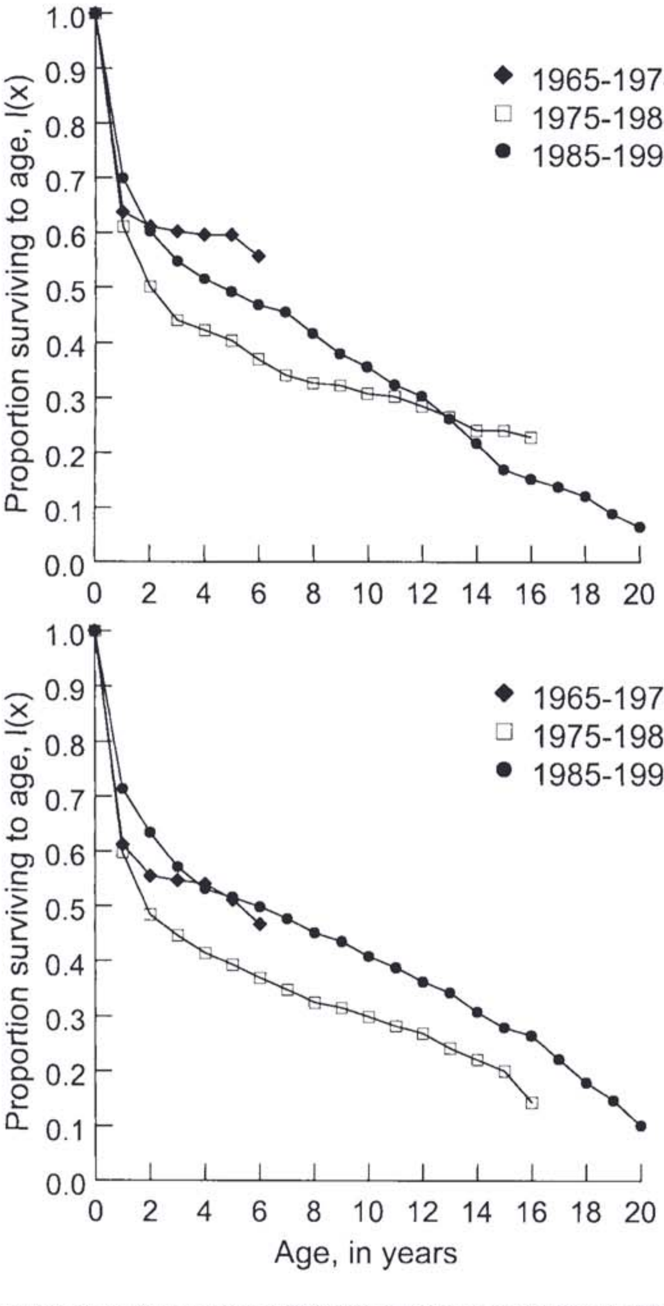

Fig. 4. Survival curves for (**a**) male and (**b**) female pigtailed macaques from the PFS by decade.

Some interspecific variation is apparent, however, and these data have been summarized in Table VI. Perhaps the pattern described above could be labeled a macaque-typical demographic pattern, and would include rhesus, Barbary, and pigtailed macaques. Japanese macaques seem to have a late reproductive onset, a late peak in fertility, and relatively long interbirth intervals. Bonnet macaques

TABLE V. Thirty Day Survival of New-Born Pigtailed Macaques, as a Function of Birth Location of the Dam (Wild-Caught vs. Captive-Born) and Housing Type at Birth (Social Group vs. Single Cage)

	Birth location		
Housing type	Wild-caught	Captive-born	
Social group	69.7%	47.1%	P<0.000001
Single cage	70.0%	59.4%	
	69.4%	53.7%	
	p<0.000001		

have no peak in fertility and short interbirth intervals. Of course, many factors influence these demographic patterns, including husbandry, social organization [Ha et al., 1999], environment, and nutrition. Therefore, further studies in many more populations are required before these patterns can be confirmed or rejected.

We found a notable departure from the WiRPRC rhesus findings [Dyke et al., 1986] in the mortality pattern of our pigtailed macaques, with our population showing significantly higher mortality during year 1. This increase in first-year mortality is driven by mortality in the neonatal (first 30 postnatal days) period [Bernstein & Gordon, 1977]. Our results suggest that a number of factors, such as origin of the stock and housing style, can significantly influence these mortality rates. In addition, other factors may be involved, including species differences, differences in birth experience (parity) between colonies, and differences in levels of captive breeding (generations in captivity). Our perception is that the WaRPRC breeding colony may contain more captive-born animals than some other colonies, and thus exhibits a higher infant mortality, particularly in social housing situations.

It should be noted that over the 30-year time period both husbandry and diet changed somewhat with changing knowledge of primate nutritional and breeding requirements. However, if reproductive or mortality measures were affected by nutrition (or other management changes not examined in this analysis), this would only contribute to the “unexplained” variance in our results and hence make it more difficult for us to find significant results for the measures in which we were interested.

Overall, pigtailed macaques seem to be fairly typical Old World monkeys in demographic patterns under captive breeding conditions. In general, their demographics improved over time at the PFS, probably due to greater experience in their husbandry and sophistication in veterinary and husbandry care. It is pos-

TABLE VI. A Review of Lifespan Fertility Patterns in Macaques

Species	Reproductive onset (years)	Peak age of fertility (years)	Decline in fertility with age	Interbirth interval (months)
Rhesus	4	10–12	Gradual	15.6
Japanese	5–6	20	Gradual	19–24
Bonnet	4	None	Stable	11–13
Barbary	4	8	Stable	22
Pigtailed	4	8–9	Gradual	16

For references, see Introduction.

sible that these demographic patterns were affected by selection-based changes in the population itself, as suggested by evidence from the move of these animals to their new quarters at the Tulane Regional Primate Research Center in Covington, Louisiana [Ha et al., 2000].

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Exhibit 24

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Anti-Drug Antibodies in Pigtailed Macaques Receiving HIV Broadly Neutralising Antibody PGT121

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Broadly neutralising antibodies (bNAbs) may play an important role in future strategies for HIV control. The development of anti-drug antibody (ADA) responses can reduce the efficacy of passively transferred bNAbs but the impact of ADA is imperfectly understood. We previously showed that therapeutic administration of the anti-HIV bNAb PGT121 (either WT or LALA version) controlled viraemia in pigtailed macaques with ongoing SHIV infection. We now report on 23 macaques that had multiple treatments with PGT121. We found that an increasing number of intravenous doses of PGT121 or human IgG1 isotype control antibodies (2-4 doses) results in anti-PGT121 ADA induction and low plasma concentrations of PGT121. ADA was associated with poor or absent suppression of SHIV viremia. Notably, ADA within macaque plasma recognised another human bNAb 10E8 but did not bind to the variable domains of PGT121, suggesting that ADA were primarily directed against the constant regions of the human antibodies. These findings have implications for the development of preclinical studies examining multiple infusions of human bNAbs.

Keywords: HIV, broadly neutralizing antibodies (bNAb), PGT121, anti-drug antibodies (ADA), pigtailed macaque

INTRODUCTION

Monoclonal antibodies to prevent or treat HIV infection are of increasing interest. Passive infusion of bNAbs effectively controls viremia in HIV infected subjects and SHIV infected macaques when the strain is sensitive to the bNAb (1 4). Control of HIV with bNAbs will require multiple treatments since the half life of standard IgG antibodies is commonly 2 3 weeks and the half life of IgG antibodies with mutations that extend half lives is commonly 8 12 weeks (5). Repeated treatment of humans with monoclonal antibodies can lead to anti drug (anti antibody) antibodies (commonly termed ADA) (6, 7). Anti HIV bNAbs are commonly heavily mutated away from the germline in the Fab region of the antibody (8), which could result in immunogenic epitopes. A disadvantage of macaque/SHIV studies of bNAbs is the foreign nature of the entire human bNAb (both the Fab and the Fc). Previous work has illustrated that ADA is common when human bNAbs are delivered to rhesus macaques since the entire antibody is foreign and ADA to both the Fab and Fc can occur (9 12).

Although ADA is an important issue in macaque studies of human bNAbs, several knowledge gaps remain. The number of human mAb treatments needed to induce ADA is not well studied. ADA is presumably effectively primed with a limited number of bNAb administrations, then when boosted to high levels by another administration, results in rapid clearance of the bNAb and consequent reduced antiviral efficacy. However, these precise relationships have not been widely studied.

PGT121 is a potent bNAb that binds to V3 glycans of HIV 1 Env and is effective against a majority of HIV 1 strains. PGT121 has been of great interest in cure related HIV trials, particularly in combination with a TLR7 agonist where partial control of SHIV in the absence of ART was observed (13). HIV cure studies are likely to need multiple bNAb administrations and robust evaluation in macaque pre clinical models to delineate a precise role. However, PGT121 has been reported to induce ADA in rhesus macaques (*Macaca mulatta*) by both subcutaneous administration and through delivery *via* an adeno associated vector (10, 14). Although SIV or SHIV infected pigtailed macaques (*Macaca nemestrina*) are an important and useful model of HIV 1, ADA to bNAbs in pigtailed macaques has not previously been studied. We analyzed ADA to the bNAb PGT121 in 23 SHIV infected pigtailed macaques, assessing the frequency and specificity of ADA generated to PGT121 and the relationship of ADA to loss of potency in controlling viremia. This work will help inform future studies of bNAbs in pigtailed macaques.

MATERIALS AND METHODS

Non-Human Primates

Juvenile pigtailed macaques were sourced from the Monash University Animal Research Platform, the Australian National macaque breeding facility. The Monash University and Australian Commonwealth Scientific and Industrial Research Organization Animal Health Animal Ethics Committees approved all macaque studies. The macaques described here were from three separate studies to assess (i) the efficacy of PGT121 in preventing cell free or cell associated SHIV$_{\text{SF162P3}}$ infection (3), (ii) the efficacy of WT or LALA PGT121 in preventing cell associated SHIV$_{\text{SF162P3}}$ infection and treating ongoing SHIV$_{\text{SF162P3}}$ infection (15) and (iii) the efficacy of PGT121 (16) or eCD4 Ig (unpublished) in preventing intrarectal SHIV$_{\text{SF162P3}}$ infection in the presence of seminal plasma. The number and type of human antibody exposures for all macaques in this study are listed in **Supplementary Table 1**.

PGT121 WT, PGT121 LALA, eCD4 Ig and the human IgG1 isotype control antibody were all administered intravenously at 1mg/kg one hour prior to challenge with SHIV$_{\text{SF162P3}}$. Both PGT121 WT and LALA were purchased from the Center for Antibody Development and Production (Scripps Research Institute) while the human IgG1 isotype control antibody (clone 52H5/TT1204) was provided by Keith Reimann (NIH Nonhuman Primate Reagent Resource). eCD4 Ig was kindly provided by Stuart Turville (Kirby Institute, University of New South Wales) and Michael Farzan (Scripps Research Institute). A pool of human seminal plasma was generated using samples obtained from the Opposites Attract cohort study (17).

Viral Load Quantification

Viral RNA in the plasma of SHIV$_{\text{SF162P3}}$ infected macaques was measured by digital droplet PCR (ddPCR) as described previously (15). The decay rates of plasma viral loads were estimated using an ordinary linear regression method on the log transformed values of the measurements using GraphPad Prism software.

ELISA to Measure ADA in Macaque Plasma

ELISAs were performed to measure the level of anti drug antibodies against full length PGT121, PGT121 scFv (Creative Biolabs) and 10E8 (NIH AIDS Reagent Program) in macaque plasma. 96 well Maxisorp plates (Thermo Fisher) were coated overnight at 4°C with 1μg/ml of PGT121, PGT121 scFv or 10E8 in PBS. After blocking with PBS containing 4% bovine serum albumin (BSA) and 0.1% Tween 20, duplicate wells of macaque plasma (1:100 dilution in PBS with 0.2% Tween 20, 0.1% BSA and 0.5% NP 40) were added and incubated for 1.5 hrs at 37°C. Next, plates were incubated with a HRP conjugated secondary antibody specific for macaque IgG (clone 1B3, Kerafast; 1:16,000 dilution) for 1 hr at 37°C. Plates were then developed with TMB substrate (Sigma), stopped with 0.16M sulphuric acid and read at 450nm using the FLUOstar Omega microplate reader. The absorbance values (OD$_{450}$) of macaque plasma samples were background subtracted with wells containing only PBS and normalised to a positive plasma control for ADA (sample from macaque NM08) by dividing the OD values of test samples with the OD values of the positive control. To validate the ELISA, we measured plasma endpoint titres for ADA and found that ADA measured at a 1:100 plasma dilution (normalised OD$_{450}$) correlated strongly with ADA measured by endpoint titre ($r = 0.91$, $p = 0.0001$; spearman correlation).

ELISA to Measure Plasma Concentration of PGT121

96 well Maxisorp plates (Thermo Fisher) were coated overnight at 4°C with 1μg/ml of HIV$_{\text{BaL}}$ gp120 (NIH AIDS Reagent Program). After blocking with PBS containing 4% BSA and 0.1% Tween 20, macaque plasma (1:50 and 1:250 dilutions in PBS with 0.2% Tween 20, 0.1% BSA and 0.5% NP 40) was added and incubated for 1.5 hrs at 37°C. Next, plates were incubated with a HRP conjugated anti human IgG secondary antibody that does not cross react with macaque IgG (#2049 05, Southern Biotech; 1:8,000 dilution) for 1 hr at 37°C. Plates were then developed with TMB substrate (Sigma), stopped with 0.16M sulphuric acid and read at 450nm using the FLUOstar Omega microplate reader. Serial dilutions of PGT121 were included on each plate to construct a standard curve, from which the concentration of PGT121 within macaque plasma was

calculated using non linear regression analysis (using the "Hyperbola (X is concentration)" option in GraphPad Prism).

Statistics

Statistical analyses were performed with Graphpad Prism 8. The correlation of ADA and viral load decay rate was assessed using the non parametric Spearman test.

RESULTS

Induction of Anti-PGT121 Antibodies in Macaques Following Exposure to Human Antibodies

As part of two previous studies (3, 15), a subset of pigtailed macaques were administered either 1mg/kg of PGT121 (with WT Fc) or a human IgG1 isotype control intravenously prior to challenge with cell free or cell associated simian HIV (SHIV). Animals receiving PGT121 were protected from viral challenge while animals receiving isotype control developed high levels of viraemia (**Figure 1** and **Supplementary Figure 1**). For a separate study, two animals (NM04 and NM05) were rectally challenged with SHIV following exposure to human seminal plasma and subsequently developed high levels of viraemia (16). The viraemic animals were then used to examine the therapeutic efficacy of PGT121 with either WT Fc or a LALA mutation to abrogate Fcγ receptor engagement (15). While the first therapeutic infusion of PGT121 WT and LALA successfully suppressed viraemia in three of five macaques, two animals (NM01 and NM04) did not exhibit a corresponding decline in plasma viral loads. Viral loads for NM02 and NM03 were suppressed following the first infusion of PGT121 but not after the second infusion. The lack of therapeutic efficacy for PGT121 WT and LALA in certain cases led us to examine whether these five macaques developed anti PGT121 anti drug IgG antibodies (ADA) following multiple exposures to antibodies of human origin. As shown in **Figure 1**, all four macaques that failed PGT121 therapy (NM01, NM02, NM03 and NM04) had high levels of PGT121 specific ADA at the time of failed PGT121 therapy (indicated by red text). Most animals developed PGT121 ADA only after 2 3 exposures to either PGT121 or the human IgG1 isotype control antibody. NM03 developed low levels of ADA 3 weeks after the first infusion of PGT121, which waned over time and were boosted to high levels two weeks after the third exposure to a human antibody. Interestingly, while macaque NM04 did not have any ADA following two intravenous infusions of PGT121, ADA were likely primed by the two infusions of human mAbs and the animal developed ADA 4 weeks following two subsequent intrarectal administrations of human seminal plasma (which contains IgG antibodies). PGT121 ADA began to wane in NM01 5 weeks after the last PGT121 exposure but remained high in all other animals.

Lack of PGT121 Therapeutic Efficacy Due to PGT121-Specific ADA

To examine the impact of ADA on the therapeutic efficacy of PGT121 more clearly, we measured the plasma concentration of PGT121 in three macaques that failed PGT121 therapy following the second infusion (**Figure 2**). After the first intravenous infusion, plasma PGT121 levels reached 11.2μg/ml, 3μg/ml and 6μg/ml in NM02, NM03 and NM08 respectively, resulting in a sharp decline in viral loads that eventually rebounded after plasma PGT121 dropped to undetectable levels. In all three animals, PGT121 ADA rose to high levels 2 4 weeks following first infusion of PGT121. ADA remained high at the time of second infusion, resulting in low plasma concentrations of PGT121 and no corresponding decline in plasma viraemia (**Supplementary Figure 2**). These results confirm that the lack of PGT121 therapeutic efficacy was caused by the low levels of bioavailable PGT121 in plasma, likely due to blocking or rapid clearance by PGT121 specific ADA.

An important measure of the potency of bNAbs and other HIV therapeutics is the rate at which virus decays in the days after administration. With the large number of animals studied, we were able to analyse whether ADA was associated with slower viral decay. We found that the level of PGT121 ADA at the time of infusion negatively correlated with the decay rate of viral loads within 72 hours of PGT121 infusion ($r = 0.41$, $p<0.05$; **Figure 3**). A stronger negative correlation between ADA and viral load decay rate is observed if animals without ADA at the time of infusion are excluded ($r = 0.62$, $p<0.05$).

PGT121-Specific ADA Increase With the Number of Exposures to Human Antibodies

To examine the number of exposures to human antibodies required for the induction of ADA within pigtailed macaques, we measured anti PGT121 ADA in macaques pre and 3 4 weeks post exposure to all sources of human antibodies (**Figure 4A**). Some macaques received two administrations of human seminal plasma (either intrarectally or both intrarectally and intravaginally) two weeks apart (**Supplementary Table 1**), in which case anti PGT121 ADA was only measured pre and post second administration. 23 macaques had been exposed to human antibodies at least twice, with 2 macaques developing very low levels of ADA after first exposure and 4 of 23 macaques developing ADA after second exposure. Following the third exposure, out of 10 macaques that had not seroconverted, a further 7 macaques developed ADA. Interestingly, 7 macaques did not develop ADA following four exposures to human antibodies, while all macaques that had five exposures developed high levels of ADA after the fifth exposure.

We then examined whether the different sources of human antibodies resulted in differential induction of ADA (**Figure 4B**). Intravenous infusions of PGT121 (WT and LALA) and the human IgG1 isotype control antibody all elicited high levels of ADA against PGT121 following 2 5 exposures. Only one animal developed low levels of ADA following intrarectal exposure to human seminal plasma (which contains IgG antibodies) on its fourth exposure to human antibodies. These results show that the elicitation of ADA depends more on the number of exposures to human antibodies rather than the type of antibody exposure.

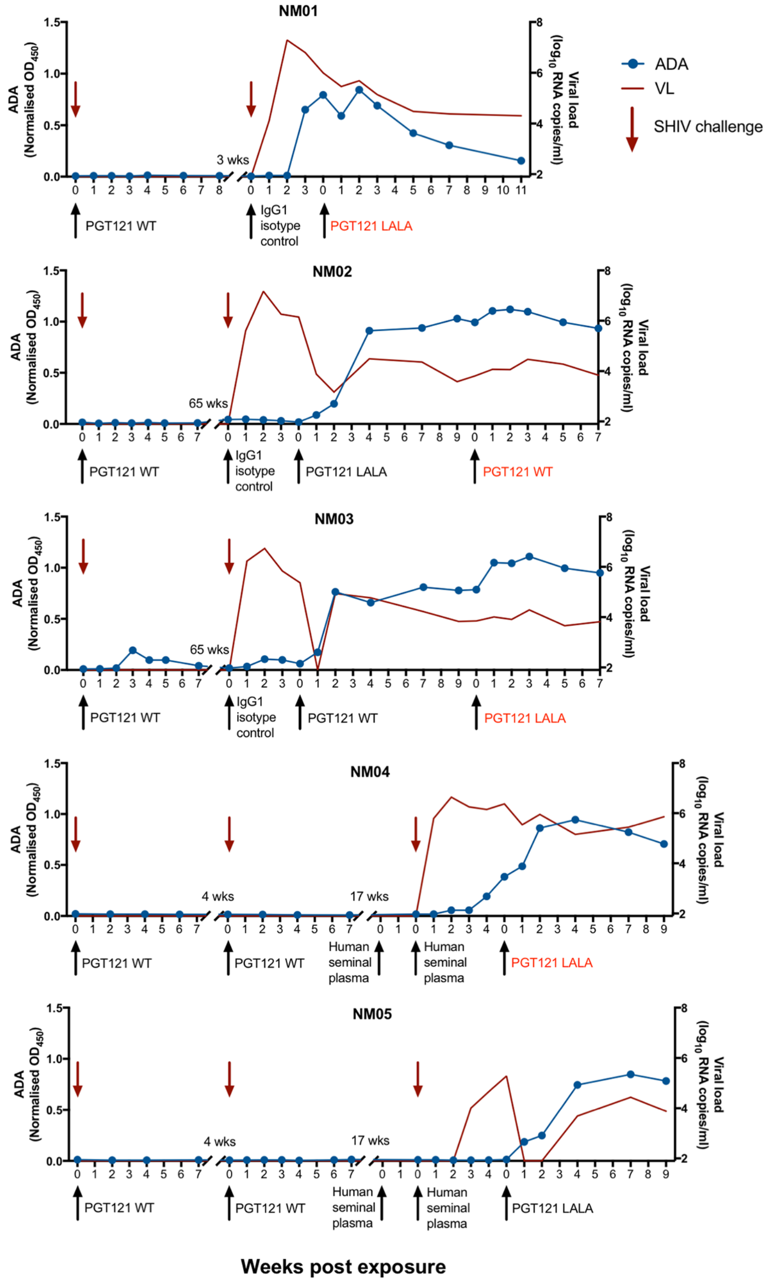

FIGURE 1 | Anti PGT121 antibodies develop in pigtailed macaques following exposure to human antibodies. Five pigtailed macaques were administered PGT121 or a human IgG1 isotype control antibody intravenously (1mg/kg) prior to challenge with cell free or cell associated SHIV. Macaques NM04 and NM05 were administered human seminal plasma either intrarectally or both intravaginally and intrarectally prior to intrarectal challenge with SHIV. Viraemic animals were then infused with PGT121 with either WT or LALA Fc. Macaque anti PGT121 ADA are shown in the blue line (left y axis) while SHIV viral loads are shown in the red line (right y axis). Black arrows indicate antibody administration while red arrows indicate SHIV challenge. The red text indicates failed therapy with PGT121 WT or LALA.

ADA Are Specific for the Constant but Not Variable Domains of PGT121

To interrogate the specificity of ADA within macaque plasma, we next measured the level of antibodies against PGT121 and the gp41 specific bNAb 10E8, which also uses a λ light chain. NM02 and NM03 both had antibodies against PGT121 and 10E8 (**Figure 5A**), implying that the ADA developed from exposure to PGT121 and the isotype control antibody were recognising the constant regions of IgG1 as they were not exclusively specific for PGT121. To confirm these results, we then examined whether

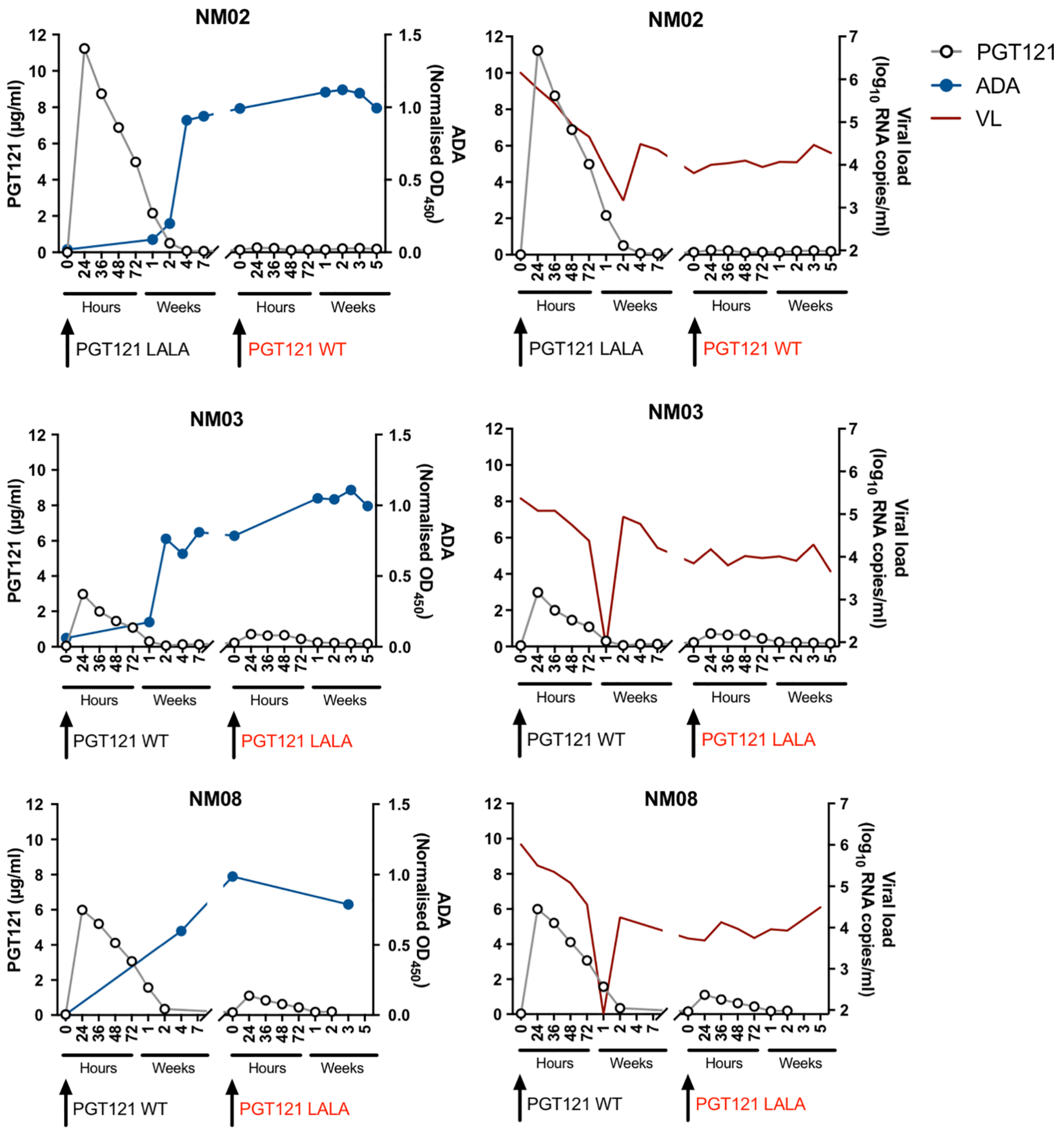

FIGURE 2 | Anti PGT121 antibodies limit the plasma concentration of PGT121 and diminish the therapeutic efficacy of PGT121 against SHIV. The plasma concentration of PGT121 WT or LALA post infusion (open circles, left y axis) is plotted with the level of anti PGT121 ADA (blue line, right y axis) or SHIV viral loads (red line, right y axis). Black arrows indicate antibody administration. The red text indicates failed therapy with PGT121 WT or LALA.

macaque ADA could recognise the single chain variable fragment (scFv) of PGT121, which contains only the variable domains of both heavy and light chains (V_H and V_L) without the constant domains (C_H1, C_H2, C_H3 and C_L). The three macaques tested (NM01, NM02 and NM03) did not have any antibodies recognising the scFv of PGT121 (**Figure 5B**), but had high levels of antibodies recognising full length PGT121, confirming that the ADA were indeed recognising the constant but not variable domains of PGT121.

DISCUSSION

The macaque SHIV challenge model of HIV exposure and infection has long been used to examine the protective and therapeutic efficacy of HIV 1 bNAbs isolated from people living with HIV (3, 12, 15, 18 20). bNAbs will generally need to be administered multiple times or delivered continuously *via* viral vectors to maintain efficacy but this poses risks of developing ADA. We describe herein that intravenous administration of human

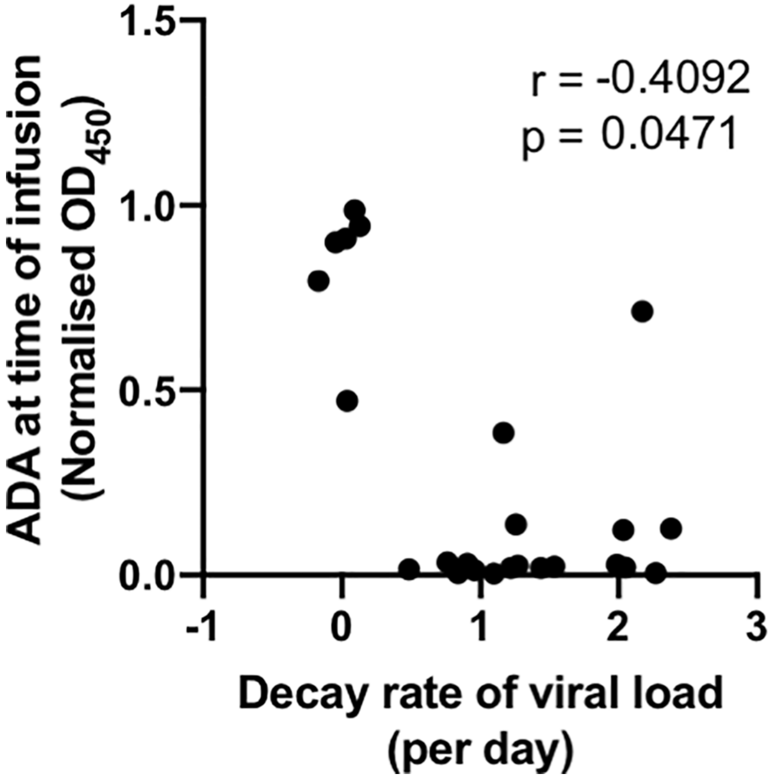

FIGURE 3 | ADA at time of infusion negatively correlates with viral suppression by PGT121. Macaques with active SHIV infection were administered PGT121 WT or LALA. Plasma viral loads were measured by digital droplet PCR at 0, 24, 36, 48 and 72 hours after PGT121 infusion and the decay rate within 72 hours was calculated using linear regression. The correlation was performed using a non parametric spearman test.

antibodies (1mg/kg) to macaques can lead to the development of anti PGT121 ADA responses, rising after 2 4 exposures with human antibodies. Interestingly, in an animal that had received two prior infusions of PGT121, anti PGT121 ADA were detected following two subsequent intrarectal exposures to human seminal plasma (which contains IgG antibodies), showing that mucosal exposure to human antibodies can also lead to the development of ADA. The high levels of anti PGT121 ADA in these animals resulted in low plasma concentrations of PGT121 following intravenous infusion, impacting the therapeutic efficacy of PGT121 in suppressing SHIV viraemia. The ADA responses did not recognise the variable domains of PGT121 and were therefore not anti idiotypic, but were directed against the constant domains of PGT121, cross reacting with a different bNAb, 10E8. While some macaques remained ADA naïve even after 4 exposures to human antibodies, we recommend that future studies limit the number of infusions of human antibodies to reduce the likelihood of ADA impairing the efficacy of infused antibodies.

The ADA we measured were directed against the constant domains of PGT121 instead of the variable domains. This presumably reflects dominant epitopes in the human IgG1 Fc recognized by the pigtailed macaques, but may also have been exacerbated in our studies as the macaques were exposed to multiple sources of human antibodies (PGT121, human IgG1 isotype control and/or human seminal plasma). The repeated exposures to human IgG1 could have focussed the ADA response to the conserved constant regions instead of the variable domains. A previous study detected PGT121 anti idiotypic responses in rhesus macaques following two homologous subcutaneous infusions at a higher dose (5mg/kg) (9, 10). A potential way to overcome the elicitation of anti human ADA in macaques is to "simianise" the bNAbs by grafting the complementarity determining regions (CDR) of bNAbs onto homologous macaque germline genes with macaque IgG constant regions. While this approach does remove a large portion of immunogenic human antibody epitopes, repeated passive transfer of simianised VRC01 and AAV delivery of simianised VRC07 still resulted in the development of anti idiotypic antibodies in macaques (21, 22), reducing the utility of the macaque model in testing repeated or sustained deliveries of HIV bNAbs.

Dosing interval may affect the induction of bNAb specific ADA, similar to that observed for some human mAbs in use such as TNF inhibitors where longer spaced episodic treatment results in higher induction of ADA compared to regular shorter intervals (23). For our PGT121 studies, we dosed our pigtailed macaques at widely spaced intervals (average 13 weeks, range 2 124) to allow for sufficient drug washout and for SHIV to recrudesce between antibody doses. This wide interval almost

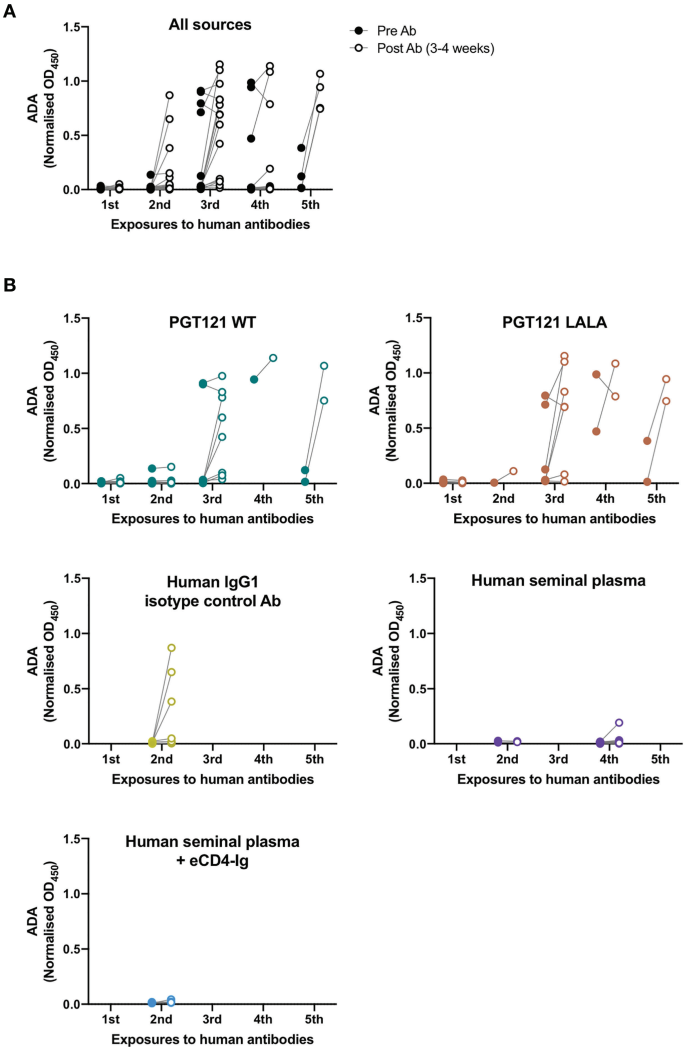

FIGURE 4 | Anti PGT121 ADA increases with the number of exposures to human antibodies. **(A)** The level of anti PGT121 ADA in macaques before (closed circles) and 3 4 weeks after (open circles) exposure to human antibodies. **(B)** The level of anti PGT121 ADA before and after exposure to different sources of human antibodies (intravenous administration of PGT121 WT, PGT121 LALA, eCD4 Ig and human IgG1 isotype control antibody or intrarectal/intravaginal administration of human seminal plasma).

uniformly generated ADA after 2 4 doses and thus it was not possible for us to dissect the relative roles of dosing interval or number of doses. One study in rhesus macaques dosed PGT121 at 2 weekly intervals, maintaining control of SHIV, and did not report ADA (13). Future studies of ADA to HIV bNAbs could consider designs to directly assess the role of interval in induction of ADA. Refinement of dosing intervals could be important to limit the generation of ADA responses.

While the elicitation of ADA in non human primates due to species differences does not translate to humans, bNAbs are typically highly somatically mutated from germline sequences and could potentially be immunogenic. A phase 1 trial of VRC01 administration in humans did not detect anti VRC01 ADA even after 6 intravenous infusions at 20mg/kg (24). Another phase 1 trial of 3BNC117 and 10 1074 infusion detected ADA in 4 of 18 participants, with one participant having treatment induced ADA to 3BNC117, one having treatment induced ADA to 10 1074 and two having anti 3BNC117 ADA at baseline (25). During the study, ADA were not at high enough concentrations to inhibit 3BNC117 or 10 1074 neutralisation of HIV although the ADA, if boosted by further doses of the bNAb, could ultimately limit the effectiveness of the bNAb. Thus, passive infusions of certain bNAbs can result in the generation of ADA responses in humans and should be monitored carefully in future clinical trials.

There is growing interest in utilising bNAbs to prevent or treat HIV infection. Macaque challenge models with SHIV have been a crucial model to test the efficacy of bNAbs preclinically, though the elicitation of ADA responses hampers the ability to

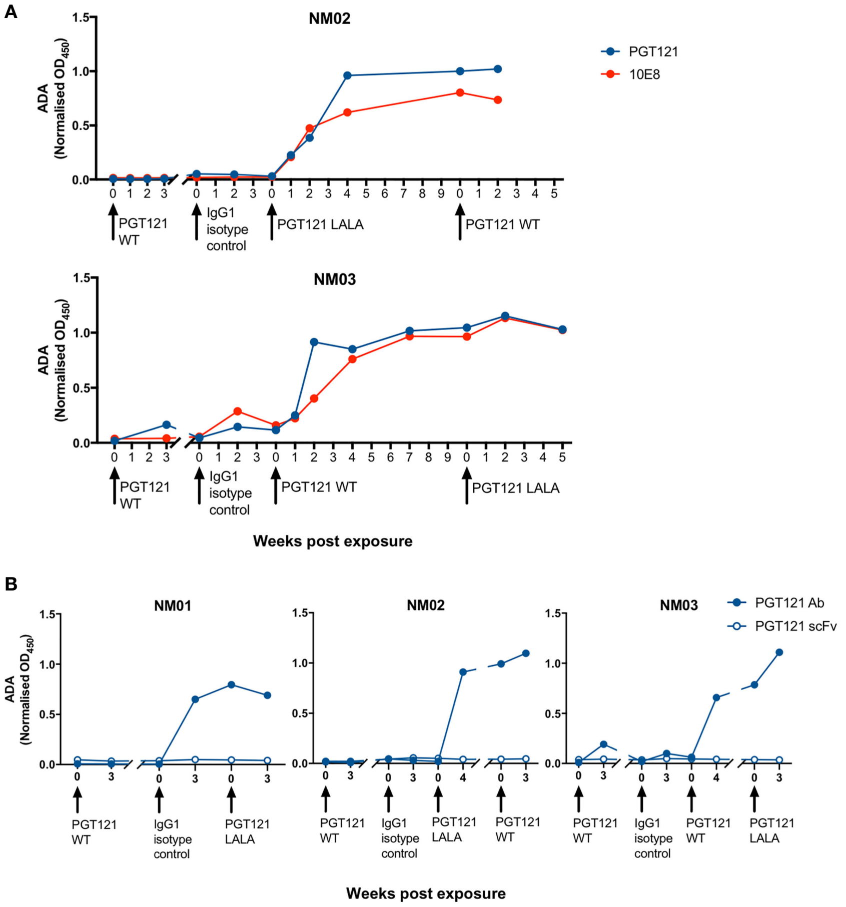

FIGURE 5 | The specificity of ADA responses in pigtailed macaques following multiple infusions of human antibodies. **(A)** Macaque anti PGT121 and anti 10E8 ADA are shown in blue and red respectively. **(B)** The level of macaque ADA against full length PGT121 (closed circles) and PGT121 scFv (open circles). Black arrows indicate antibody administration.

examine repeated or sustained deliveries of human antibodies. Our findings suggest that future preclinical studies of human antibodies in pigtailed macaques, similar to rhesus macaques, should limit the number of infusions to avoid generating ADA that can diminish the efficacy of the mAbs of interest.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by the Monash University and Australian Commonwealth Scientific and Industrial Research Organisation Animal Health Animal Ethics Committees.

AUTHOR CONTRIBUTIONS

Conceived and designed experiments: WL, MP, and SK. Performed experiments: WL and TA. Analysed the data: WL, AR, TA, and MP. Wrote the paper: WL and SK. Revised the paper: AR, TA, MP, and MD. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fimmu.2021.749891/full#supplementary material

Supplementary Figure 1 | The development of anti PGT121 ADA following multiple exposures to human antibodies in individual macaques. Macaque anti PGT121 ADA are shown in the blue line (left y axis) while SHIV viral loads are shown in the red line (right y axis). Black arrows indicate antibody administration while red arrows indicate SHIV challenge. The numbers in red indicate the viral load decay rate (per day) within 72 hours of therapeutic PGT121 WT or PGT121 LALA administration.

Supplementary Figure 2 | Mean levels of anti PGT121 ADA, plasma concentration of PGT121 and corresponding SHIV viral loads in macaques NM02, NM03 and NM08. The mean plasma concentrations of PGT121 WT or LALA post infusion (open circles, left y axis) are plotted with the mean levels of anti PGT121 ADA (blue line, right y axis) and mean SHIV viral loads (red line, right y axis). Black arrows indicate antibody administration. The red text indicates failed therapy with PGT121 WT or LALA. The data are depicted as the mean and standard error of the mean.

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Neurologic Melioidosis in an Imported Pigtail Macaque (*Macaca nemestrina*)

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Abstract

Burkholderia pseudomallei is the cause of melioidosis in humans and other animals. Disease occurs predominately in Asia and Australia. It is rare in North America, and affected people and animals typically have a history of travel to (in human cases) or importation from (in animal cases) endemic areas. We describe the gross and histopathologic features and the microbiologic, molecular, and immunohistochemical diagnoses of a case of acute meningoencephalomyelitis and focal pneumonia caused by *B. pseudomallei* infection in a pigtail macaque that was imported from Indonesia to the United States for research purposes. This bacterium has been classified as a Tier 1 overlap select agent and toxin; therefore, recognition of pathologic features, along with accurate and timely confirmatory diagnostic testing, in naturally infected research animals is imperative to protect animals and personnel in the laboratory animal setting.

Keywords

Burkholderia pseudomallei, immunohistochemistry, macaque, melioidosis, meningoencephalomyelitis, neurologic, PCR

Melioidosis is a multisystemic disease caused by the Gram-negative bacterium *Burkholderia pseudomallei*. The disease is endemic in parts of Southeast Asia, northern Australia, and the Indian subcontinent; sporadic cases have also been reported from Central and South America. The bacterium is a facultative anaerobe found in soil and water in these regions. It readily infects humans and many other animals, resulting in a wide range of outcomes, from asymptomatic infection to disseminated fatal disease in up to 40% of cases.[28] Infection may occur through a variety of means, including inhalation, contamination of skin wounds, or accidental ingestion from the environment.[5,17,18,25] Direct transmission from infected to naive individuals and sexual and vertical transmission are considered rare.[1,6,7,18,24,27] The incubation period is highly variable and may be days to decades long. Longer incubations are often associated with subclinical infections, with fulminant disease developing during periods of host immunosuppression.[2,12,17,19,28]

Clinical signs of melioidosis in all species are variable and depend on the route and dose of infection, virulence of the infecting bacterial strain, and perhaps most importantly, the immune status of the host and presence of concurrent chronic diseases.[6,11,12,28] The most common disease manifestations in people are pneumonia and septicemia with systemic abscess formation. Localized cutaneous abscesses at the site of bacterial inoculation, meningoencephalitis, osteomyelitis, and arthritis also occur commonly.[12] In nonhumans, the disease is best described in ruminants and swine. As with humans, the clinical signs vary depending on the site(s), severity, and stage of infection. Overall, they are similar to those in humans and are clinically indistinguishable from other disease entities, particularly bacterial septicemias.[24] Characteristic but nonspecific pathologic findings include abscesses with suppurative or caseous exudates in multiple tissues.[20,24,25]

Asian macaques are widely imported from melioidosis-endemic regions for use in biomedical research; therefore, subclinically infected macaques may represent a possible vector for the spread of this potentially deadly bacterium into research facilities in nonendemic areas. Given the bacterium's potential for rapid and easy transmission among many different species in contaminated environments, introduction of a single infected animal could have potentially devastating effects on an animal colony. Furthermore, it could result in introduction into the human population through interactions of animal caretakers with infected animals and/or their contaminated environments if personal protective equipment is not used.

Because the clinical presentation of melioidosis is highly variable and may mimic other infectious diseases, recognizing

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the characteristic pathology and following up with appropriate diagnostic testing at the time of necropsy are essential in identifying this disease within research animal colonies. Herein, we describe the gross and histopathologic features, along with the microbiologic, molecular, and immunohistochemical diagnoses, of *B. pseudomallei* meningoencephalomyelitis and pneumonia in a captive-bred pigtail macaque imported to the United States from Indonesia for research purposes.

Case Report

History

An adult female pigtail macaque (*Macaca nemestrina*) was humanely euthanized after a 2-day course of sudden-onset neurologic signs involving multiple cranial nerve deficits and generalized tremors and stiffness, which progressed despite supportive care. Clinical signs referable to organ systems other than the central nervous system were not observed. The animal had been captive-bred in Indonesia and imported via the Philippines to the United States for research use approximately 6 months prior to presentation. She had not yet been actively involved in any research studies at the time of euthanasia. Of note, at the time of introduction to the facility, she had a cutaneous abscess over the right stifle. Bacterial culture revealed coagulase-negative *Staphylococcus sp* and a Gram-negative bacillus that could not be identified. The abscess resolved with antibiotic treatment.

Necropsy

Gross findings were limited to the central nervous system and lungs. The meninges over the parietal and occipital lobes of the cerebrum were congested. Suppurative exudate was present between the ventral surface of the right rostral brainstem and underlying sphenoid bone. The brainstem, pons, and midbrain contained multiple poorly demarcated regions of malacia, cavitation, and yellow discoloration with scattered foci of hemorrhage (Fig. 1). The thoracolumbar spinal meninges were diffusely expanded by a highly viscous, tan suppurative exudate (Fig. 2). A 1-cm area of the right cranioventral lung lobe was firmly adhered to the thoracic wall; a small amount of suppurative exudate oozed from the cut surface. At the time of necropsy, no evidence of the previous stifle abscess remained, and all other tissues were grossly unremarkable. A complete set of tissues was collected and fixed in 10% neutral buffered formalin at room temperature for 7 days.

Histopathology

Tissues were processed for routine paraffin histology, sectioned at a thickness of 4 microns, and routinely stained with hematoxylin-eosin, Warthin-Starry, and Lillie-Twort Gram stains.

Histopathologic evaluation of the brain revealed bilateral lesions in the brainstem, pons, midbrain, and, to a lesser extent, thalamus. The cerebral cortex was spared. Lesions consisted of variably defined, nonencapsulated abscesses and microabscesses comprising necrotic foci with dense neutrophilic infiltrates. Acute hemorrhage was also multifocally present (Fig. 3). In multiple sections of thoracic and lumbar spinal cord, the leptomeninges were markedly thickened by a neutrophilic and lymphoplasmacytic infiltrate mixed with fibrinonecrotic debris and granulation tissue. The spinal cord itself was spared of notable inflammation or degenerative changes (Fig. 4). In distal lumbar sections, the inflammatory exudate extensively involved spinal nerves and those of the cauda equina and extended out into the epidural adipose tissue. In a section from the right cranioventral lung lobe from the site of gross pleural adhesion, there was a well-defined, nonencapsulated focus of acute pneumonia characterized by destruction of alveolar walls and pooling of viable and degenerate neutrophils, cellular debris, and hemorrhage. Numerous microabscesses with similar features to those in the brain were scattered throughout multiple sections of liver. Other than mild lymphoplasmacytic enterocolitis, other tissues (heart, thyroid gland, spleen, adrenal gland, kidney, urinary bladder, ovary, uterus, and stomach) were histologically unremarkable.

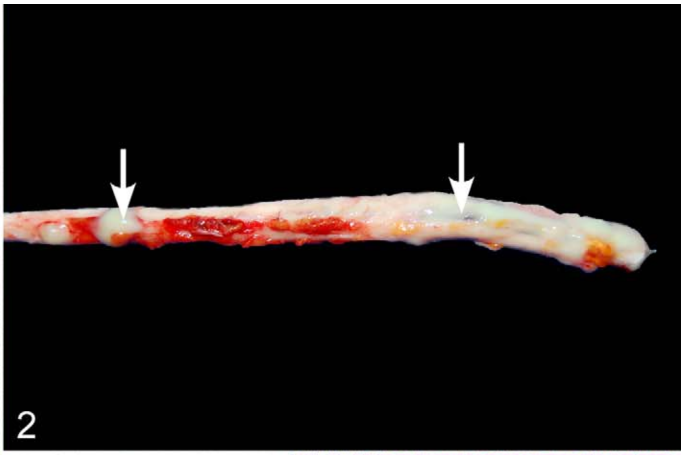
Warthin-Starry stain revealed numerous bacilli in the pneumonic lung, as well as moderate and low numbers of bacilli within the thoracolumbar meningeal exudate and microabscesses of the brain, respectively (Fig. 5). Bacilli were weakly Gram negative (Fig. 5, inset). Bacteria were not identified with special stains in liver sections.

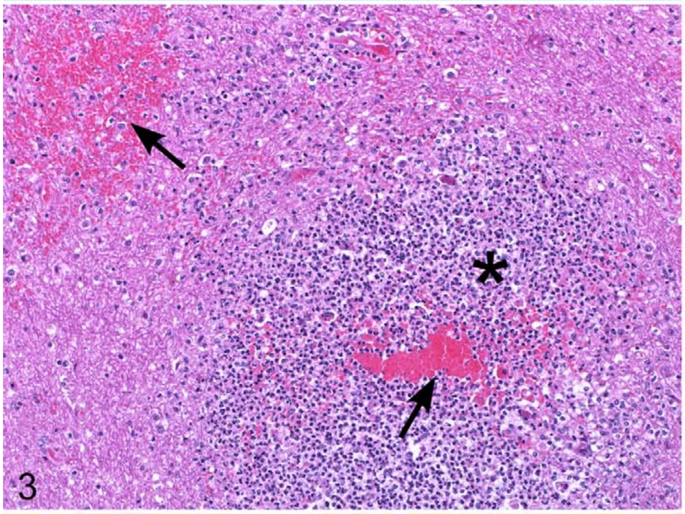
Bacterial Culture

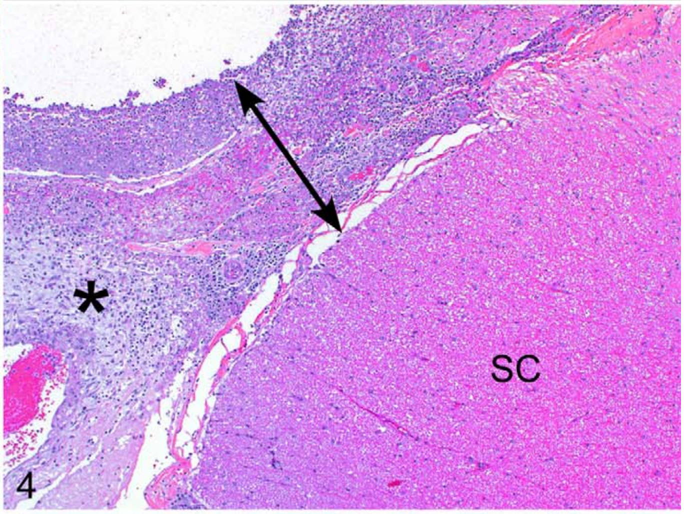
Swabs from brainstem abscesses and spinal meningeal exudates were submitted to the Georgia Laboratory Animal Diagnostic Service (GLADS) for bacterial aerobic culture. Inoculations were carried out in a biosafety cabinet. Blood and MacConkey agars (Remel; Thermo Scientific, Lenexa, KS) were inoculated and incubated at 35 ± 5°C overnight in a tight-sealed container. Pure growth of a non–lactose-fermenting, oxidase-positive, Gram-negative rod was observed. Identification was attempted using the BIOLOG (Gen III) system, which yielded an identification of *Burkholderia ambifaria*, 63% probability. This was considered below the limit of acceptability, and the isolate was recommended for 16S rRNA sequencing for definitive identification.

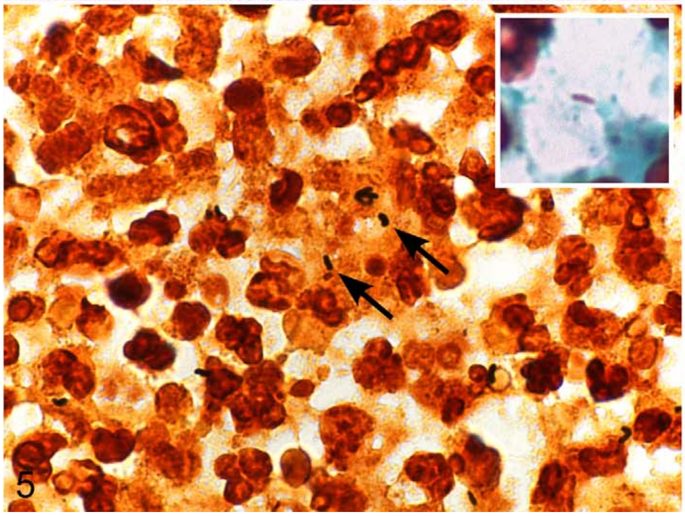
Polymerase Chain Reaction

Bacterial identification through nucleic acid sequencing is routinely carried out at GLADS, where 1500 bp of the 16S ribosomal RNA are amplified and sequenced using primers described by Relman.[23] DNA was extracted from whole-cell suspensions with the MoBio Ultraclean Microbial DNA Kit (MoBio, Carlsbad, CA). Each polymerase chain reaction (PCR; 10 µl total) contained 2 mM $MgCl_2$ PCR buffer (Idaho Technologies, Salt Lake City, UT), 0.05U Taq polymerase (Roche, Pleasanton, CA), 0.2 mM dNTPs (Roche), and 0.1 µM of each primer. The









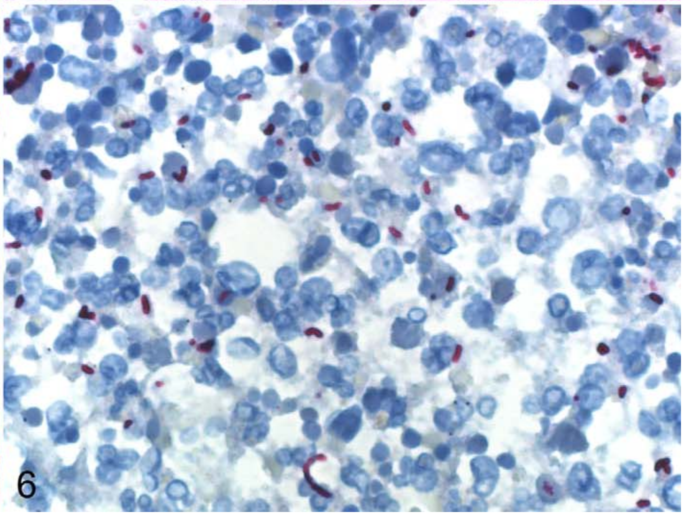


Figure 1. Brain; pigtail macaque. Multifocal areas of malacia and hemorrhage (arrows) throughout the brainstem. **Figure 2.** Spinal cord; pigtail macaque. Suppurative exudate (arrows) is present throughout the thoracolumbar meninges. **Figure 3.** Brainstem; pigtail macaque. Microabscess (*) with hemorrhages (arrows) in the brainstem. Hematoxylin and eosin (HE). **Figure 4.** Spinal cord; pigtail macaque. Fibrinocellular exudate (double headed arrow) with granulation tissue (*) expands the lumbar spinal meninges. The spinal cord (SC) itself is spared of inflammation or degenerative changes. HE. **Figure 5.** Spinal cord; pigtail macaque. Bacilli (arrows) within the spinal meningeal exudate are highlighted by Warthin Starry silver stain. Inset: a Gram negative bacillus is shown with Lillie Twort stain. **Figure 6.** Brainstem; pigtail macaque. Bacilli show positive immunoreactivity by immunohistochemistry using an anti–*Burkholderia pseudomallei* antibody, Fast Red chromogen with Mayer's Modified Hematoxylin counterstain.

PCR product was purified (Millipore Microcon, Billerica, MA) and sequencing was performed by Seqwrite (Houston, TX). A contiguous sequence of 1391 bp was generated and assembled using Sequencher 5.0 (Gene Codes Corporation, Ann Arbor, MI). The resulting sequence was found to have >99% similarity with *B. pseudomallei* (BLAST; National Center for Biotechnology Information, Bethesda, MD).

Immunohistochemistry

Specimens were evaluated by immunohistochemistry using 2 rabbit polyclonal anti–*B. pseudomallei* antibodies: one raised against the whole organism and one raised against the bacterial flagellum (National Kaohsiung Normal University, Kaohsiung City, Taiwan). Immunohistochemical testing was performed using an alkaline phosphatase (AP) polymer detection system (Thermo Scientific). Four-micron sections of formalin-fixed paraffin embedded tissue were deparaffinized and rehydrated using gradations (100%, 95%, and 70%) of ethanol. Proteinase K (Roche) digestion was performed for 15 minutes at room temperature (RT), after which Ultra V Block (Thermo Scientific) was applied for 10 minutes at RT. Tissues were then incubated with the rabbit polyclonal anti–*B. pseudomallei* antibody (30 minutes at RT), followed by Primary Antibody Enhancer (Thermo Scientific; 10 minutes at RT), AP Polymer (Thermo Scientific; 15 minutes at RT), and Naphthol Phosphate Substrate/Fast Red Tablet (Thermo Scientific; 20 minutes at RT). Sections were counterstained in Mayer's Modified Hematoxylin (Poly Scientific, Bay Shore, NY). Appropriate positive and negative controls were run in parallel. Tissues from previously diagnosed cases of human melioidosis were used as positive controls. For negative controls, the primary antibodies were replaced with normal rabbit serum (Centers for Disease Control and Prevention, Atlanta, GA).

For both anti–*B. pseudomallei* antibodies, extensive labeling of bacilli was observed within the spinal meningeal exudate, brain abscesses (Fig. 6), and the pneumonic lung. Scattered bacterial labeling was also seen within necrotic foci in the liver. Bacilli were not identified by immunohistochemistry in sections of spleen, kidney, adrenal gland, stomach, or intestine.

Discussion

Melioidosis has historically been identified in the tropical regions of Southeast Asia, northern Australia, the Indian subcontinent, and, to a lesser extent, Central and South America, but more recently has emerged in regions peripheral and distant to these areas.[8,17,25] The causative bacterium, *B. pseudomallei*, has been classified as a Tier 1 overlap select agent and toxin (formerly a category B bioterrorism agent) by the US Department of Health and Human Services, because of its intrinsic antibiotic resistance and potential for easy dissemination with high mortality among humans and many other animal species.[6,22]

Because Asian macaques are extensively used in biomedical research, they represent a potential portal of entry for melioidosis into nonendemic areas. Several cases of melioidosis have been reported in macaques and other nonhuman primate species associated with such facilities. These include rhesus macaques, pigtail macaques, stumptail macaques, a chimpanzee, and an orangutan. Among these species, infections have been associated with fight or puncture wounds or with surgical implantation of foreign materials during research procedures and have resulted in cutaneous and visceral abscesses, lymphadenitis, pneumonia, septicemia, and osteomyelitis. Disease was recognized in these animals ranging from 3 days to 10 years after importation.[3,4,13–15,19,21,26] The animal in this report had a stifle abscess at the time of arrival to our facility. Although *Burkholderia* was not definitively identified from this lesion, this may have been the initial site of infection, with progression to central nervous system and lung involvement 6 months later.

To the authors' knowledge, this is the first report of naturally acquired melioidosis predominately involving the central nervous system in a research monkey in the United States. In Australia but rarely in other endemic areas, 3% to 5% of human melioidosis cases have neurologic disease, which manifests as cranial nerve deficits and/or myelitis with peripheral motor weakness.[9,10,27,28] It is these patients who are at highest risk of fatal infection.[17] Lesions in such cases include meningoencephalitis with microabscesses in the brainstem and spinal cord, similar to those observed in this macaque.[6,17] Neurologic melioidosis primarily involving the brainstem has also been observed in naturally infected horses and experimentally infected mice and sheep.[9]

Because animal melioidosis is almost never encountered in the United States, it was not initially considered in the differential for this animal's clinical disease or pathologic findings. Routine laboratory testing initiated at the time of necropsy ultimately led to identification of the organism. This highlights the fact that lesions of melioidosis are nonspecific and cannot be distinguished clinically or by gross or histopathology from those of other bacterial infections. Identification of *B. pseudomallei* within lesions is therefore imperative for definitive diagnosis. The diagnosis was confirmed in this macaque by culture, 16S rRNA sequencing, and immunohistochemistry. Samples for culture should be handled under biosafety level 3 conditions when *Burkholderia* is suspected.[25] Furthermore, any fresh biologic sample from nonhuman primates should always be handled in a biosafety cabinet since these animals could be carriers of many other zoonotic diseases that may not be suspected at the time of sample submission. *B. pseudomallei* can reliably be isolated from abscess material and may also be cultured from feces or swabs from the throat, sputum, blood, or urine.[25] It grows readily on routine culture media within 24 to 48 hours at 37°C and selectively on Ashdown's medium, which contains crystal violet, glycerol, and gentamicin.[25,27]

Although biochemical tests and colony and cell morphology are used for diagnosis in countries where melioidosis is endemic, *B. pseudomallei* is not present in the identification database of most bacterial identification systems in nonendemic regions. Therefore, in countries where its isolation is very rare, reliance on such methods may result in misidentification of the organism if not isolated in a laboratory with appropriate expertise and knowledge of the agent. A complete history and country of origin for the submitted sample are crucial to aid the laboratory in its diagnosis.

16S rRNA sequencing is an effective way to determine bacterial genus and, in many cases, bacterial species and was used to confirm the identity of the causative agent in this case. As sequencing technology has become more economical and more widely accessible, its use has been increasing. Sequencing of nearly the full 16S ribosomal RNA is a reliable method to distinguish among the most common *Burkholderia spp*.[16] Immunohistochemistry using anti–*B. pseudomallei*–specific antibodies provides another means of diagnosis in formalin-fixed paraffin embedded tissues; however, because highly sensitive and specific antibodies are limited in their commercial availability, this testing often can be performed only at specialized reference laboratories.[25]

In conclusion, *B. pseudomallei* is an uncommon infection outside of endemic areas and is essentially always associated with travel to (in human cases) or importation from (in animal cases) endemic areas. Because nonhuman primates used in biomedical research are frequently imported from Asia, melioidosis should be considered in the differential diagnosis for these animals when they present with 1 or more abscesses or with nonspecific symptoms consistent with infectious disease, regardless of the time frame since importation. Necropsy and histopathology, coupled with microbiological, molecular, and immunohistochemical assays, aid in the rapid diagnosis of melioidosis and therefore can facilitate prompt implementation of appropriate biosecurity measures regarding reporting, containment, and elimination of the infection in research animal colonies.

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Exhibit 26

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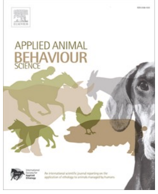

Assessing the welfare of coconut-harvesting macaques in Thailand

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ABSTRACT

Pig-tailed macaques are used by coconut farmers in Southeast Asia to harvest coconuts. We assessed the welfare of northern pig-tailed macaques *Macaca leonina* involved in coconut harvesting in southern Thailand. We interviewed 89 coconut farmers in three provinces focusing on quantifying basic demographics of this trade, i.e., species, where the macaques were sourced, diet, sex, and age. Independent from the interviews, we assessed the welfare of 158 working macaques through direct observations using the 'five domains' criteria. Based on our scoring system, the mean welfare score of 4.8 out of the maximum 12 points indicates a need for improvement. Overall, we found good agreement between the interviews data and the welfare assessments. The most important individual welfare modifications required for working macaques to obtain a good level of welfare that benefits both the farmers and macaques include: providing access to conspecifics, adding opportunities to hide from stressors, and increasing the freedom of movement. This study highlights the individual welfare concerns and necessity of legislative changes regarding working macaques and other working animals of wild origins.

1. Introduction

Evidence of humans reaping the benefits of employing animals to harvest food sources points to its beginning in the Neolithic period approximately 12,000 years ago (Driscoll et al., 2009). This arguably mutualistic relationship between working animals and humans largely facilitated the rapid growth of humankind (Wilson, 2003). By exploiting the harvesting power of working animals, humans achieve increased harvest rates, decreased time dedicated to labour, and increased nutrient acquisition (Driscoll et al., 2009). Research suggests that animals comprise about 50 % of the world's total agricultural harvesting power (Wilson, 2003). Most of these animals, including cattle, horses, goats, pigs, and sheep, have undergone the process of domestication via selective breeding for several thousands of years (Driscoll et al., 2009). However, some working animal species, despite working alongside humans on a daily basis for an extended period of time, do not demonstrate the same level of domestication (Chatkupt et al., 1999; Sponsel et al., 2009; Xaodie, 2005). Two of the oldest examples of training wild animals to harvest food sources include falconry (using birds of prey to capture small animals for recreational hunting) in China up to 3,000 years ago (Kenward, 2009; Xaodie, 2005) and fishing with cormorants in Southwest China 1,000 years ago (Hoh, 2000). By contrast, logging companies in Thailand originally began using Asian elephants *Elephas maximus* to extract timber from dense forests in the 1800s (Chatkupt et al., 1999), while coconut harvesting using macaques has occurred in Thailand for at least a century (Sponsel et al., 2009). Although some captive wild animals appear tolerant of humans and are thus deemed 'tame', it is important to note that without having their breeding controlled by humans, these animals are not truly domesticated (Driscoll et al., 2009). While the individual welfare of domesticated working animals has been previously investigated, analysed, and documented (Duncan, 2005; Pritchard et al., 2005; Swann, 2006), the impacts on the welfare of working animals of wild origins remains relatively unexplored.

Coconut harvesting using northern and southern pig-tailed macaques (*Macaca leonina* and *M. nemestrina*) occurs throughout Thailand, Malaysia, and Indonesia (Azis et al., 1980; La Rue, 1919; Sponsel et al., 2009; Winograd, 2015). Both species are considered globally threatened

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(northern pig-tailed macaques as Vulnerable and southern pig-tailed macaques as Endangered), with decreasing populations (Boonratana et al., 2020; Cheyne and Eudey, 2020). Within Thailand, the Wildlife Conservation and Protection Act B.E. 2562 (2019) provides domestic protection for both species of pig-tailed macaques. While removing macaques from the wild, trading, and possessing them without permits are illegal, macaques are kept in the open and farmers and owners speak freely about them. Of the current threats facing these two species, extraction from the wild to meet the demand for coconut harvesting is perhaps the least documented. Sponsel et al. (2009) estimated that several thousand pig-tailed macaques are kept for coconut harvesting in southern Thailand alone.

To obtain the macaques, coconut farmers extract juveniles from the wild between the ages of one to two years to commence training (Bertrand, 1967; Malaivijitnond et al., 2012). Collectors obtain them by either baiting a wooden box or shooting the mother (Sponsel et al., 2009). Training of coconut harvesting macaques is performed through positive punishment using tight leashes and whips (Bertrand, 1967). As a whole, the process of harvesting, training, working, and retiring macaques has serious and largely undocumented welfare implications. For instance, many macaques work for 6–8 hours per day, during which they harvest between 500 and 1000 coconuts (Sponsel et al., 2009; Malaivijitnond et al., 2012). Macaques are often aggressive towards their handlers and others. Owners chain macaques on short leashes to curtail high aggression when they are not working. When males reach full maturity, at the age of around seven, they reportedly are frequently too aggressive for their owners to continue handling them and they may be released back into the wild (Bertrand, 1967). In 2020, People for the Ethical Treatment of Animals in the United Kingdom (PETA UK) published a report detailing the poor welfare of pig-tailed macaques used to harvest coconuts in Thailand. The report summarised the inadequate living conditions, extremely demanding workdays, abusive training practises, and poor mental health of the monkeys observed, however, systematic studies providing quantitative and qualitative data on the topic to evaluate the present situations are lacking. While PETA provided a preliminary overview of the welfare violations occurring within this practise, we systematically quantify the number of macaques affected, describe the severity of these welfare violations, examine potential negative effects on wild populations, illustrate the cultural context, and offer solutions to improve the ethical shortcomings of using macaques for coconut harvesting.

Here, we report on the individual welfare status of pig-tailed macaques used to harvest coconuts in southern Thailand. We quantify the age, sex, numbers, origins from which macaques were sourced, diet, and housing. We assessed the welfare status using the ‘five domains’ of animal welfare approach (Mellor et al., 2009). The core considerations of this framework include: nutrition, environment, health, behaviour, and mental state; which primarily focuses on the freedom to express natural

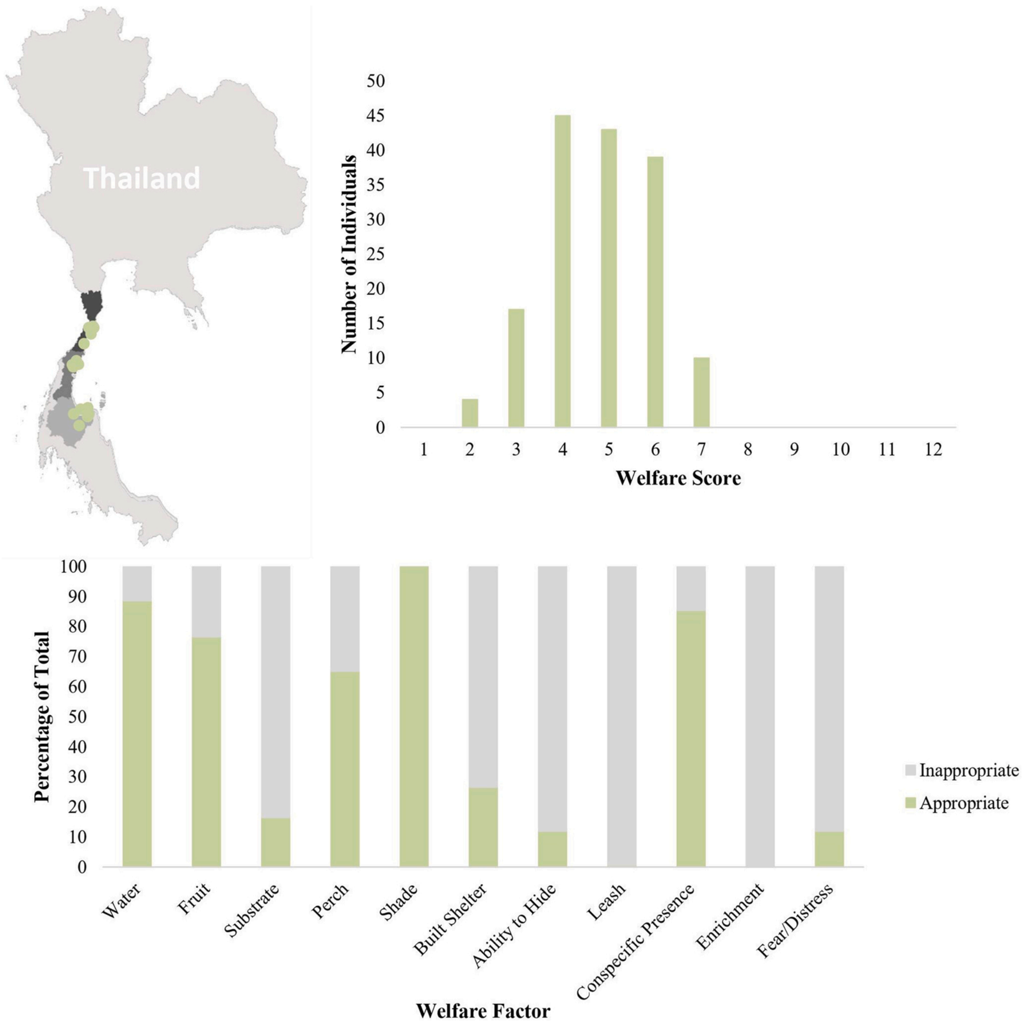

Fig. 1. From top left, clockwise: (1) Thailand with the study locations in Prachuap Khiri Khan (dark grey), Chumphon (medium grey) and Surat Thani (light grey) provinces; (2) distribution of welfare score frequencies (out of 12) observed in 158 northern pig-tailed macaques *Macaca leonina* used for coconut harvesting; (3) scores of eleven welfare factors.

behaviours and freedom from fear and distress (RSPCA, 2021).

2. Methods

2.1. Study site selection

We have worked on the ecology and conservation of northern and southern pig-tailed macaques in various parts of Thailand intermittently since 2011 (Malaivijitnond et al., 2012; José-Domínguez et al., 2015; Moyes et al., 2016; Siriwat et al., 2019). Coconut picking appears to be concentrated in the upper southern provinces, where the 62 % of all Thai coconuts plantations areas are located in 3 provinces; Surat Thani, Chumphon, and Prachuap Khiri Khan (Fig. 1; Wongsamuth, 2015). Therefore, we decided to conduct our research in these three provinces, specifically in districts where we have previous experience of working; Bang Bai Mai district in Surat Thani, Bang Mak district in Chumphon, and Bangsaphan district in Prachuap Khiri Khan (Fig. 1).

2.2. Data collection

We collected data in the first half of 2019. Because of our previous research in the area we knew of several coconut farmers that used macaques, and these were visited first. We then located additional coconut farmers by using snowball sampling (Newing, 2011). Interviews and observations were conducted at private residences and in coconut plantations. Interviews ranged from five to twenty minutes, and we did not provide monetary compensation for participating. At each farm we made observations on the pig-tailed macaques that were present, five minutes each for every macaque. We aged the macaques as follows; infants 0-1 years old, juveniles 1–4.5, adolescents 5–9, and adults 9 or older (Oi, 1990).

2.3. The five domains

We assessed and collected data on the following variables pertaining to the 'five domains' of animal welfare: Nutrition (diet), Environment (i.e., appropriate shelter), Behaviour (i.e., the ability to engage in species-specific behaviours) and Mental State (i.e., no evidence of abnormally high stress/fear), excluding Health (Botreau et al., 2007; Mellor et al., 2009). We did not assess Health (Mellor et al., 2009), but we did not observe any monkeys with obvious malnourishment, injury, or disease. We scored nutrition based on access to water and fruit, and we scored shelter according to the amount of coverage from environmental conditions, hiding opportunities, substrate composition, and opportunity to perch (Buchanan-Smith et al., 2004). Perches included any materials that allowed for raised sitting off the ground, including the following observed environmental items: wooden beams, tree stumps, tires, boxes, suspended ropes, trees, concrete fixtures, and barrels. The ability to engage in species-specific behaviours was scored by considering the allowance for freedom of movement, interaction with conspecifics, and the ability to engage in foraging behaviours. We assessed mental state by noting the presence of any stereotypic behaviours, including pacing, head-turning, abnormally high human-directed fear or aggression, self-biting, self-clasping, hair-plucking, self-masturbation, (Lopresti-Goodman et al., 2013; Mallapur and Choudhury, 2003) and back-flipping.

2.4. Welfare scoring system

To quantify the welfare status we developed an independent scoring system to create welfare scores for each individual macaque observed. We coded all variables as present (1) or absent (0) except substrate and diet. Substrate fell into six categories as observed: grass, dirt, metal, gravel, coconut husks, and concrete. Diet included the five most frequent interview responses, including rice, fruit, processed food, milk, and fresh vegetables. Human food included cooked or fried vegetables, snack foods, yogurt, stir fry noodles, and curry dishes as reported. We grouped each variable based on the following categories: housing (including the presence of a hiding spot, perch, grass substrate, shade, and a built shelter); diet (access to food and water); the ability to express natural behaviours (conspecific presence, no physical restraint due to a leash or chain, and the presence of enrichment); and mental condition (no evidence of abnormal repetitive behaviours).

We assigned an overall score for each individual based on the number of variables that met appropriate standards within each category. An individual could obtain a minimum score of 0 for all variables and a maximum of 12; 2 in diet (1 point for the presence of water, 1 point for fruit incorporated in the daily feeding regimen); 5 in housing (1 point for each of the following being present: acceptable substrate, perch, ability to hide, shade, and shelter); 4 in natural behaviours (1 point for each: acceptable freedom of movement (no leash), conspecific presence, opportunity for physical conspecific interaction, and daily provision of enrichment), and 1 in mental condition (1 point for the absence of stereotypic behaviours). Therefore, a case in which all welfare measures were appropriately met would achieve a maximum score of 12. We present means ± one standard deviation of the mean. We did not handle any animals and all procedures complied with the Oxford Brookes University Code of Practise for Research Ethics for Research Involving Human Participants. Permission to conduct this project was authorised by the National Research Council of Thailand (permit number: 6763113).

3. Results

We interviewed 89 people (26 in Surat Thani, 36 in Chumphon, 27 in Prachuap Khiri Khan). Collectively, the interviewees owned 266 male macaques (95 %) and 13 female macaques (5%). The mean number of macaques owned at one time per farmer was 3.0 ± 2.9 individuals (n = 88/89 owners). Most farmers commuted to coconut farms with their macaque(s).

All of the macaques were northern pig-tailed macaques, except one juvenile identified as a hybrid between northern and southern pig-tailed macaques. The species identification of northern and southern pig-tailed macaques and the hybrid followed Malaivijitnond et al. (2012). All macaques lived outside next to the owner's place of residence. The mean age of macaques when acquired by farmers was 2.6 ± 1.6 years old (n = 80), ranging from 4 months to 8 years. Macaques were purchased as juveniles (n = 43/80), as infants (n = 25/80), or as adolescents (n = 12/80). Farmers indicated that macaques work for 10–12 years and retire at around 14–15 years of age. When macaques are too old to work, farmers either keep them as pets (n = 51/84), sell or give them to others (n = 20/84) or simply release them (n = 13/84). Nine interviewees reported that their macaque died between 15–20 years of age.

Macaques were frequently reported as being aggressive (72/89 farmers) and only five explicitly stated their macaques were not aggressive (these were mostly young macaques or females). Four farmers had large scars from macaque bites on their forearms and ankles that had required medical intervention. Coconut farmers sourced macaques from other farmers (n = 56/86), from the wild (n = 19/86), or monkey schools or other captive facilities (n = 11/86). Farmers stated that macaques sourced from the wild are obtained by either baiting a large net or cage trap with food items. The farmers reported that macaque collectors typically only remove male macaques when they are between the ages of one to three years. Older males and females are released back into the wild.

We scored 158 out of the 279 macaques on individual welfare. The mean welfare score was 4.8 ± 1.2 (range from 2 to 7) out of the 12-point maximum (Fig. 1). Although we did not formally assess health, the majority of macaques observed demonstrated good body condition (not obese or emaciated) and did not suffer from visible wounds or physical debilitations. All the macaques had access to at least partial shade (n = 158), two-thirds had access to a perch (n = 103/158), a tree (n = 109/

158), and/or shelter (n 42/158). A barrel (n 19/158) was the only structure that offered an opportunity to hide (Fig. 2). We did not observe any macaques that were provided with enrichment, and many demonstrated fear and/or distress during observation (n 139/158). Almost all macaques were tethered on a leash (n 157/158) consisting of a metal ring around the neck with either a rope or chain attached that allowed limited movement. Leashes were short (typically 1 m or less), thus precluding physical interaction between macaques where farmers owned multiple individuals (n 135/158). A small number of farmers (n 23/89) had sliding leashes with a metal ring that moved along a horizontal rope, which allowed for a slightly increased range of movement. Most macaques were kept on the ground (bare ground n 105/158, grass n 26/158, concrete or gravel n 22/158). The remainder (n 5/158) were kept on metal bars or coconut husks. A majority of macaques showed signs of abnormal repetitive behavior. Most (n 139/158) were observed pacing, seven macaques showed signs of self-biting, self-clasping and hair-plucking, one was self-masturbating, and one was repetitively back-flipping. The diet was reported to be boiled rice (n 146/158), fruits (n 121/158), milk (n 64/158), fresh vegetables (n 19/158), or human food leftovers (n 42/158). Most had access to water (n 140/158).

Information provided by the farmers indicated that macaques worked seven days per week for ~6.5 h per day, taking breaks only at the same time of the farmers themselves. Each day, the macaques typically climbed more than 50 coconut trees and harvested between 500–1,000 coconuts. Many farmers reported that macaques got tired during the workday and the farmers that owned more than one macaque used one until the animal showed signs of exhaustion and then subsequently worked the other one(s). Farmers indicated that the macaques became too hyperactive or aggressive if they did not work every day. Ways to reduce aggression included physically beating or removing canines. Again, according to the farmers, macaques rarely attacked the owner, but attacks on other members of the community were frequent. Farmers used positive punishment to handle the macaques (i.e., the application of punishment to discourage undesired behaviours, including yanking the leash and shouting commands). We did not observe a single case of positive reinforcement (reinforcing desirable behaviours by administering rewards).

4. Discussion

Our study details the demographics and evaluates the welfare status of coconut harvesting northern pig-tailed macaques in southern Thailand. Overall, working macaques involved in the coconut trade achieved a welfare score of 4.8 out of 12 points. Similar to our findings, the PETA UK (2020) report mentioned the extraction of macaques from the wild, daily physical abuse and exploitation, constant restriction of movement via leashes, presence of abnormal repetitive behaviours, and barren housing conditions. The diet we observed was comprised mostly of inappropriate processed foods (Oftedal et al., 1991; Albert et al., 2013; Ruppert et al., 2018).

Factors including physical restraint, inability to interact with conspecific(s), demonstration of fear and distress, presence of enrichment, the ability to hide, and adequate shelter/substrate were among the lowest-rated variables on appropriateness. Additionally, the overall mental state of the macaques indicated a largely negative or neutral

Fig. 2. Housing for coconut-picking northern pig-tailed macaques *Macaca leonina* observed at coconut farmer residences in southern Thailand: A) barrel providing hiding opportunities; B) a single juvenile macaque in a small cage without water; C) juvenile macaque on a concrete substrate with no opportunities to hide or climb; D) juvenile macaque tied to a tyre without opportunities to hide or climb.

state, as no behaviours directly indicating a positive mental state were observed. The lack of social stimulation, sensory input, environmental complexity, and overall poor-quality diet likely increases frustration in these captive macaques and further contributes to the high incidence of abnormal repetitive behaviours observed in the present study. The presence of these behaviours often indicates extremely poor welfare. Similar to those demonstrated by pet primates removed from their mothers during infancy, these behaviours often manifest as abnormally high aggression, abnormally repetitive behaviours performed to decrease high levels of stress (i.e. pacing), and mental illness symptoms including PTSD (Lopresti-Goodman et al., 2013). While improving the welfare standards may be seen as in the best interest of both the macaques and the coconut farmers, as healthier macaques may increase agricultural output (Hemsworth and Coleman, 1998), it is ethically questionable using macaques in this manner to begin with.

While most macaques in our study were in the presence of conspecifics, none were able to physically interact. Infants comprised the second-largest age category (31 %) of the reported age when purchased, indicating that over 30 % of these individuals did not experience a normal maternal upbringing. For highly social animals like pig-tailed macaques, the absence of normal social interactions during infancy (i.e. grooming, play, and asserting/accepting dominance displays) often leads to an increase in self-directed aggression, aggression directed towards others, and the inability to behave normally in social situations (Rommeck et al., 2011). Depriving young macaques of social interactions during this critical learning period inhibits the development of skills necessary to survive independently, i.e. foraging and self-defence (Mallapur and Choudhury, 2003). Additionally, these aggressive behaviours may be further exacerbated by frequent human presence (Honess and Marin, 2006) or the psychological trauma associated with being captured from the wild at a young age (Mallonee and Joslin, 2004).

Almost all macaques observed interacting with their owners demonstrated an abnormally high level of fear, e.g. laying on their stomach, fear-grimacing, and frequent vocalising, presumably due to the fear-based style of establishing dominance and daily mistreatment. The training strategy itself may also contribute to the high rate of aggression in working macaques. Using positive punishment as a training strategy suppresses the undesired behaviour instead of eliminating it completely, which often creates a fear that becomes generalised to other undesirable behaviours. This response increases the tendency to use aggression as a coping mechanism (Skinner, 1938).

Achieving good animal welfare involves the incorporation of the following qualities: 1) mimicking the natural environment on a functional level to ensure proper opportunities for the expression of species-specific behaviours (Fraser, 2009; Kagan and Veasey, 2010) and 2) ensuring the individual has a good amount of control and choice in the environment (Boissy et al., 2007). None of these objectives were achieved in the macaques we observed. Notably, a few farmers acknowledged that preventing their macaques from engaging in species-specific behaviours had negative outcomes. For example, some stated that macaques exhibit increased aggression because they are denied mating opportunities and that they cannot be released into the wild due to a lack in the skills required to forage, defend themselves, and behave normally within a troop.

Pig-tailed macaques are protected under the Wildlife Conservation and Protection Act B.E. 2562 (2019) and the Cruelty Prevention and Welfare of Animal Act B.E. 2557 (2014) in Thailand. Despite these legislative texts, which state that the ‘type, kind, character, condition, and age’ of the animal must be taken into consideration upon ownership, no specific regulations regarding captive breeding or environmental requirements (e.g., housing, diet, and activity level for working animals) to own these animals in conditions that promote good welfare currently exist (Schmidt-Burbach et al., 2015). A similar legislative dissonance is also present for keeping working animals of other originally wild species in Thailand, e.g. working elephants. Driscoll et al. (2009) state that domestication occurs when a set of physiological and psychological qualities are met, including: high tolerance of close proximity to humans, adaptation to a poorer quality diet, more frequent reproductive cycles, and maintaining physical characteristics from infancy into adulthood. Although humans have a long history with working animals, coconut harvesting macaques have worked alongside humans for just 100 years (Sponsel et al., 2009), with only 13 % of all coconut farmers in the present study indicating sourcing macaques through captive breeding.

Although pig-tailed macaques harvest less coconuts per day than humans (according to several farmers interviewed, macaques harvest 1,000 coconuts whereas humans harvest 2,000 coconuts), using macaques is arguably safer (Sponsel et al., 2009). With the help of the macaques, who climb up each tree while attached to a long lead, the farmers can stand farther away from the tree to avoid falling coconuts. The trade-off between potential injury from falling coconuts or possible disease transmission and likely injury from aggressive macaques, however, is something to consider. Making adjustments to individual welfare at farmer residences and creating distinct categories of welfare criteria for both domesticated and wild working animals respectively are imperative to improve the welfare of working macaques kept in captivity. Promoting public awareness of the poor welfare of working pig-tailed macaques may also function as a successful strategy in reducing the economic profits obtained from using macaques to harvest coconuts or increasing incentive for farmers to improve working macaque welfare to appeal to the consumer concerned about poor animal welfare. With less economic value attributed to the macaques, fewer coconut farmers would ultimately choose to use macaques as their primary coconut collection method (or more coconut farmers would want to improve their macaques’ welfare).

5. Conclusions

We found that the species-specific needs of the pig-tailed macaques kept for coconut-harvesting purposes were largely not met. These needs, in short, primarily include: the ability to engage in social interactions with conspecifics, to move freely and unrestrained, and housing that provides the ability to hide from stressors. Additionally, no legislation currently exists to ensure that these needs are satisfied to promote a higher standard of living conditions and better animal welfare to occur while these animals stay in domestic care. From our work, it follows that at least three strategies must be enacted to improve the individual welfare of working pig-tailed macaques and other working non-domesticated animals: 1) adapting national legislation to include the specific needs of wild animals (cf. Dorloh, 2017), 2) making improvements that both enable and encourage the expression of species-specific behaviours in macaques, and 3) raising awareness of the inadequate welfare conditions of the macaques involved in coconut picking to instigate a debate on the necessity of this practice.

Declaration of Competing Interest

The authors report no declarations of interest.

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Exhibit 27

Bangkok Post

Pay coconuts, get monkeys

Training young macaques to work on plantations and perform in circus-style shows can be big business, but owners are under scrutiny over the way the animals are being treated.

PUBLISHED : 6 SEP 2015 AT 01:42

NEWSPAPER SECTION: SPECTRUM
WRITER: NANCHANOK WONGSAMUTH

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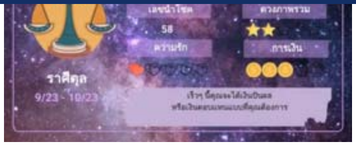
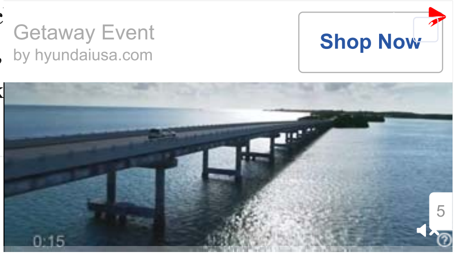
The next time you drink canned coconut milk, look at the label. If it's produced in Thailand, the coconuts have most likely been collected by monkeys — specifically, southern pig-tailed macaques.

Learning the ropes: Noi Petchpradab can make about 1,000 baht a day hiring out his monkeys, but the big money comes from selling the animals.

Those recruited for labour in the southern province of Prachuap Khiri Khan, the country's biggest coconut producer, work eight hours a day, six days a week.



In Bang Saphan district, Noi Petc
collect coconuts for four decades,
the ground, a signal for the monk



When all the coconuts are picked from a tree, Mr Noi tugs the rope attached to the monkey's neck, signalling it to climb down.

"I can't help but wonder: who was the first person to think of training monkeys this way?" asked Mr Noi. "A human being would be exhausted after climbing one or two trees. Monkeys can climb all day long."

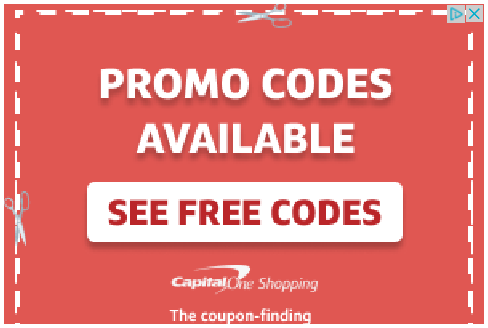
While a day of collecting coconuts can bring in up to 1,000 baht, trainers are increasingly turning their businesses into tourist attractions.

For owners who are willing to take the leap, monkey shows which mimic animal circuses can generate hundreds of thousands of baht per month.

But while locals argue the monkeys have been helping their human friends pick coconuts for hundreds of years and consider it part of Thai culture, wildlife experts question whether the practice and the use of animals for entertainment — many of which do not involve captive breeding — violate the country's new animal cruelty law.

LIVING MACHINES

Mr Noi's monkeys work from 8am to 5pm, stopping only for a short lunch break and on rainy days and Sundays.



Mr Noi said is due to their aggressiveness. They are given three daily meals, consisting of rice mixed with Lactasoy milk.

The monkeys start training at one to two years old. They begin by learning to spin coconuts attached to sticks and plastic ropes using their two legs and a hand, mimicking the process of picking a coconut from a tree.

“People prefer monkeys that use both their hands and legs. Ones that use only their hands won’t be resold at a good price,” Mr Noi said, adding that a well-trained monkey can fetch as much as 70,000 baht.

He said some monkeys can start picking coconuts as early as one month after they start training on the ground. Due to their aggressive nature, the monkeys wear a muzzle during training.

“These creatures don’t bite like dogs. If you get bitten by one, they can rip your veins apart,” Mr Noi said.

Due to their ability to work for long hours, the macaques are capable of collecting 600-1,000 coconuts per day, compared to only 100-200 for humans. On a few occasions, he admitted, the monkeys are so tired from picking coconuts that they faint.

Apart from Prachuap Khiri Khan, other southern provinces such as Surat Thani and Chumphon are also home to several monkey training schools for coconut collection.

On the website of one training centre, monkeys are branded as “efficient industrial agriculture labour” and provide income to both the coconut farmer and monkey owner.

According to the website, the use of pig-tailed macaques is more beneficial and safer than using human labour, as they are “strong, enjoy climbing, are not afraid of heights, do not complain, do not call for higher wages … and are not corrupt. They do not require social security and accident insurance. Monkeys are therefore considered a ‘living machine’ that is very valuable for coconut farmers.”

MONKEY BUSINESS

There were few monkey trainers in Bang Saphan district when Mr Noi started his career 38 years ago, at the age of 23. Now, hundreds of coconut farmers have their own monkeys, although not all provide training.

Mr Noi uses his four macaques to collect coconuts at his 14-rai plantation, but he also uses them to work at other plantations and offers training for those who already own monkeys.

He has about a dozen regular customers, with two or three large plantations which each produce 7,000-8,000 coconuts per harvest. The rest of the plantations generate between 500 and 3,000 per harvest.

Prachuap Khiri Khan province has more than 410,000 rai of coconut plantations, and last year produced 293,022 tonnes of coconuts, according to the Office of Agricultural Economics. That is roughly double the amount of Chumphon, the second-largest producer at 193,237 tonnes.

The two provinces, along with Surat Thani, account for 62% of Thailand's total coconut plantation area, according to 2012 data.

Coconuts are used as one of the main ingredients in many Thai dishes, and much of the crop produced in Prachuap Khiri Khan is sent to major canned coconut manufacturers.

Money earned from coconut-picking depends on market prices. In the high season, when prices can fetch up to 20 baht per coconut, Mr Noi can earn more than 1,000 baht per day by hiring out his monkeys. But with the current market price at seven baht, returns are lower.

The big profit lies in selling trained monkeys, said Mr Noi, who estimates he has sold 40-50 animals over the years. While he purchases the monkeys from a seller in Chumphon province for 6,000 baht, a well-trained monkey can be resold for tens of thousands of baht.

ENJOY THE SHOW

Sam, a 15-year-old pig-tailed macaque, is one of the main stars at a monkey show in Chiang Mai's Mae Rim district.

Unlike the coconut-harvesting monkeys, Sam is fatter and non-aggressive, although he is still required to be on a leash at all times.

Mae Rim district houses two venues which advertise themselves as monkey training schools but are in fact shows where circus-like tricks are

“Next the monkey will show you his amazing memory. Say a number and the monkey will pick it up for you,” says the MC in English.

Prasit Cheundang, the owner of the Monkey Training Centre in Mae Rim, said it takes years to train the monkeys to perform in shows, with all tasks being equally difficult.

“Some monkeys can be trained, but they just stop performing once they are in front of a large crowd,” he said.

Mr Prasit, 61, owns 30 monkeys, but only eight perform. The rest are “retired” at an average age of 20.

The native of Chumphon province’s Ta Sae district started his career as a monkey trainer when he was 14 years old. He would train other monkeys at his house, but would also take his own monkeys out to collect coconuts, at a price of 25 satang per coconut.

He later moved to Phuket to continue his training business. Fourteen years ago, he decided to start a show in Chiang Mai to earn greater income, which is now more than 100,000 baht per month.

On a busy day, Mr Prasit conducts more than 10 shows for up to 200 visitors, with each show lasting about half an hour. Visitors come from many countries, including China, France, Dubai, Bahrain and Israel. The constant flow of tourists means Mr Prasit has learned to speak Chinese and Hebrew.

“Due to my lack of education, I like this type of challenge,” he said while waiting for the next group of tourists to arrive. “I studied until the fourth grade and the only knowledge I have is of monkeys.” He admitted some foreigners express anger about the way the monkeys are used, but he denies that it is cruel. “Some of them would have died if they stayed in the jungle,” he said.

TAKEN AWAY

That most of the monkeys used to collect coconuts are captured from the wild as opposed to being bred in captivity highlights loopholes in the way the animals are regulated.

Overlooked: Edwin Wiek says monkey welfare is often ignored.

While Mr Noi acknowledged he purchases his pig-tailed macaques from poachers in Chumphon province, he denied that the mothers are killed in order to take away the babies. Instead, a bait is used to lure the monkeys into a cage. The monkeys are then separated by age (those used for training are about one year old) and sex. Females are never used, said Mr Noi, because they cause a commotion among the male monkeys, and also because they menstruate, which can be a burden during transportation.

Pig-tailed macaques are protected animals under the 1992 Wild Animal Reservation and Protection Act and cannot be obtained from the wild.

Thiradej Palasuwan, head of the wildlife protection division at the Department of National Parks, Wildlife and Plant Conservation (DNP), said pig-tailed macaques are one of the 61 animal species allowed for breeding.

They can only be purchased from farms registered by the DNP.

Once the breeder issues documents indicating that a monkey is from the farm, the buyer can take the documents to the DNP, which checks the area the monkey will be raised in and issues a permit for the new owner. Since the law was enacted in 1992, the government held two rounds of registration for people to obtain legal permits for their monkeys — one in 1992 and another in 2003 — regardless of the animal's origin.

Authorities then performed checks at the owner’s residence to assess their capability of raising the animals.

But monkey owners often evade the law regarding ownership by using one licence for different monkeys, wildlife experts say.

“So they can have 15 monkeys on paper, but they also have 15 or 20 on other copies of the same paper,” said Edwin Wiek, founder and director of the Wildlife Friends Foundation Thailand. “If the authorities enforce the

the babies stay with their mother until two and a half to three years old. They drink their mother's milk for 18 months.

Based in Phetchaburi province, the foundation has 40 pig-tailed macaques whose owners gave them away after their "retirement age".

"In terms of animal cruelty," Mr Thiradej said, "even though you don't have a permit [to own monkeys], you need to make sure that the animals are taken care of and are not abused."

'IT'S NOT REALLY CULTURE'

Using animals for labour and entertainment is not illegal under the Cruelty Prevention and Welfare of Animal Act, which came into effect in December.

The law, however, prohibits cruelty against animals, which is defined broadly as an act which causes an animal to suffer physically or mentally. This includes overwork or forcing the animal to perform when it is ill, too old or too young. The maximum penalty for an act of animal cruelty is two years' jail, a fine not exceeding 40,000 baht, or both.

The Department of Livestock Development is in the process of drafting a separate law, expected to be enacted within the next year, containing specific guidelines concerning the welfare of each type of animal. The list includes regulations on monkeys used to harvest coconuts, such as age guidelines and training restrictions, said Roger Lohanan, who is among the drafters of the legislation.

Chaichan Laohasiripanya, secretary-general of the Thai Society for the Prevention of Cruelty to Animals, said the use of animals for labour is acceptable as long as they are treated humanely.

"It will be a problem, though, if a person is able to prove to the court, for instance, that the animal is working for eight to nine hours a day without stopping," he said. "Monkeys are living creatures that cannot speak, so they should not be overworked."

Those using monkeys to collect coconuts argue it is part of a culture that has been around for hundreds of years.

But Mr Weik estimates there are at least 20 "illegal mini-zoos" operating under the guise of training schools in Koh Samui, Phuket, Chiang Mai and Pattaya.

"When you look at the monkey training, many of the schools claim that it's the culture. But since most of them are using [the monkeys] as a tourist to a new market of Russians, Chinese and Indians who have different views on animal welfare or sometimes don't have a view on it at all."

Ashley Fruno, a senior campaigner at Peta Asia, condemned both practices as unethical acts that will "drive tourists away in droves".

"The public is outraged to know that monkeys are taken from their families, kept chained constantly, and put into a life of labour in order to collect coconuts," Ms Ashley said.

Trainers use the constant threat of physical punishment to force the monkeys to perform in shows consisting of uncomfortable tricks, she said.

"Monkeys do not voluntarily ride bicycles or walk on tightropes. They don't perform these and other difficult tricks because they want to; they perform them because they're afraid of what will happen if they don't," Ms Ashley said.

On a recent Sunday afternoon, Mr Noi prepared to use his day off to watch a local boxing match. Sometimes, a tour guide brings along some tourists to visit Mr Noi at his house to observe how he trains the monkeys.

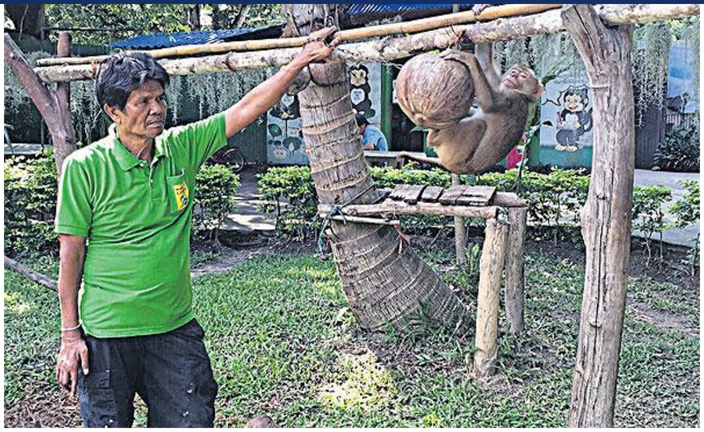
"You can't do this job unless you love it. It's like people who raise fighting cocks and fish," he said. "These monkeys — they are the smartest animals on Earth. I think in the future, they will definitely become [evolve into] human beings."

Helping handlers: The owners of coconut plantations, like this one in Bang Saphan district of Prachuap Khiri Khan, usually employ monkey handlers to come in and help harvest their crop.

Good harvest: One of Mr Noi's clients in Bang Saphan prepares her coconuts for sale.

On a tight leash: Macaques are often kept on short chains due to their aggressiveness.

Crowd pleaser: Above and below, monkeys perform at a 'school' in Chiang Mai province.



Making a show of it: Prasit Cheundang earns more than 100,000 baht a month from his school.

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TRENDING

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End of the NLD

The party that Aung San Suu Kyi led to two decisive victories in Myanmar's brief democratic interlude is no more, dissolved by the junta-backed election commission.

28 Mar 2023

WORLD

At least 39 migrants die in Mexico fire

CIUDAD JUAREZ, Mexico: A fire started by migrants protesting against their expected deportation killed at least 39 people at a Mexican immigration detention centre near the US border, authorities said on Tuesday.

28 Mar 2023

THAILAND

City Hall revives Songkran events

The Bangkok Metropolitan Administration (BMA) will organise a major event to celebrate Songkran next month after a three-year pause due to the Covid-19 pandemic, Bangkok governor Chadchart Sittipunt said on Tuesday.

28 Mar 2023

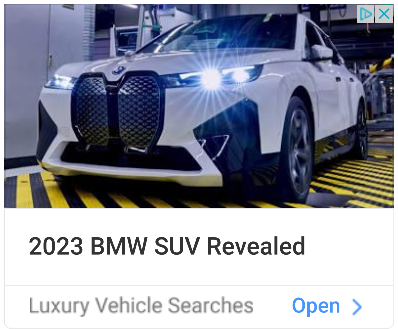

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Exhibit 28

Animal Diversity Web

University of Michigan Museum of Zoology

Macaca nemestrina
pigtail macaque

Facebook Twitter

By Kayla Ayers and Candace Vanderpoel

Geographic Range

Pigtail macaques are widely distributed throughout Southeast Asia in the oriental biogeographic region. They are found in many countries including India (northeast), China (south), Indonesia (Borneo, Kalimantan, Sumatra), Bangladesh (east), Burma, Thailand, Laos, Cambodia, Vietnam, Malaysia (Malay Peninsula) (Cawthon Lang, 2009). Also found in Assam, Yunnan, Indochina, Bangka, and neighboring islands (Nowak, 1999). (Cawthon Lang, 2009; Nowak, 1999)

Macaque species are often capable of being introduced into other areas of the world with success. Pigtail macaques have been introduced in Singapore and the Natuna Islands (Nowak, 1999). (Nowak, 1999)

Biogeographic Regions: oriental (introduced , native)

Classification

Kingdom
Animalia
animals

Phylum
Chordata
chordates

Subphylum
Vertebrata
vertebrates

Class
Mammalia
mammal

Order
Primate
primate

Habitat

Pigtail macaques live in elevations starting at sea level and ranging to above 2000 m. They live in forests, mostly rainforests, and swamps. They prefer dense, humid rainforest with temperatures ranging from 18 to 30 degrees Celsius (64 to 86 Fahrenheit). Temperatures change seasonally and vary regionally. Rainforests they inhabit also get more than 2500 mm (8.20 ft) of rain each year. (Cawthon Lang, 2009)

Habitat Regions: tropical ; terrestrial

Terrestrial Biomes: rainforest

Wetlands: swamp

Range elevation
0 to 2000 m
0.00 to ft

Physical Description

Pigtail macaques get their name from a unique feature of their morphology. Their short tails, which they carry half-erect, resemble the tails of pigs, thus giving them their name "pigtail" macaque. Their tails also have very little hair or no hair at all (Cawthon Lang, 2009). Tail length for females varies from 130 mm to 253 mm and for males the tail length varies from 160 mm to 245 mm (Rowe, 1996). (Cawthon Lang, 2009; Rowe, 1996)

Pigtail macaques have light brown hair covering their bodies and white underbellies. The hair on the top of their heads is either dark brown or black and grows so that it looks like they have an indentation on the tops of their heads (Cawthon Lang, 2009). Males have mane like hair around their faces (Wildscreen, 2003). Pigtail macaques also have long legs and hairless snouts (Wildscreen, 2003). Infant pigtail macaques are born black and develop adult coloration as they age (Cawthon Lang, 2009). (Cawthon Lang, 2009; "ARKive: Images of Life on Earth", 2003)

Pigtail macaques are sexually dimorphic, with males being larger (Cawthon Lang, 2009). Females are roughly half the size of males (Wildscreen, 2003). The average length of males varies from 495 mm to 564 mm. The average weight of males varies from 6.2 kg to 14.5 kg. The average length of females varies

Family
Cercopithecidae
Old World monkeys

Genus
Macaca
macaques

Species
Macaca nemestrina
pigtail macaque

from 467 mm to 564 mm. The average weight of females varies from 4.7 kg to 10.9 kg (Cawthon Lang, 2009; Rowe, 1996). Males also have large canine teeth that average 12 mm in length. These teeth are often used in agonistic encounters (Cawthon Lang, 2009). The average length of female canine teeth is 7.3 mm (Rowe, 1996). (Cawthon Lang, 2009; Rowe, 1996; "ARKive: Images of Life on Earth", 2003)

The average weight of the brain of an adult pigtail macaque is 106 g (Rowe, 1996). Pigtail macaques move around on the ground and throughout the trees on all fours (quadrupedally) (Cawthon Lang, 2009). (Cawthon Lang, 2009; Rowe, 1996)

> **Other Physical Features:** endothermic ; homoiothermic ; bilateral symmetry
>
> **Sexual Dimorphism:** male larger ; sexes shaped differently

Range mass	**Range length**
4.7 to 14.5 kg	467 to 564 mm
10 35 to 31 94 lb	18 39 to 22 20 in

Reproduction

Pigtail macaques are not monogamous and females will mate with multiple males during a lifetime. They do not discriminate between adolescents and adult males. When there are only a few females that are in estrus, the highest ranking males will be able to monopolize them. They can keep younger and lower-ranking males from attempting to mate and will often act aggressively toward the male and the female if the lower-ranking male attempts to copulate. However, if there are more than a few females in estrus, the top ranking males cannot effectively control females and lower-ranking males gain opportunities to copulate. When a female reaches sexual maturity at 3 years of age, she can present herself to males with her anogenital swelling during estrus for reproduction. When this time comes, the female will show her backside, including her anogenital swelling, and look over her shoulder at the male. The male will then draw back his ears and push his lips outward. (Cawthon Lang, 2009)

Although higher-ranking males are generally able to copulate more frequently with more females, this does not mean that they produce more offspring than do lower-ranking males. According to a study done with captive pigtail macaques, female rank is more important to reproductive success. It also helps to determine the sex of offspring. Higher-ranking female pigtail macaques will produce female offspring. This is because female infants are more energetically expensive. They require a lot more attention from their mothers because they stay with the group and nurse more often. Higher-ranking females can benefit from this because they gain allies in their daughters. Lower-ranking females will give birth to male offspring because they nurse less often and do not require as much attention. Once they are old enough they leave the group to join another group, hopefully gaining a higher position in that group through competition. (Cawthon Lang, 2009)

> **Mating System:** polygynandrous (promiscuous)

Pigtail macaques are year-round breeders. However, there is a slight increase during the months of January and May. Females have reproductive cycle of about 30 to 35 days and during this time display a large, purple-pink anogenital swelling. They give birth to single infants after a gestation period between 162 and 186 days. Young pigtail macaques are then nursed for 8 to 12 months. After one year pigtail macaques are considered adolescents until they reach reproductive maturity at the age of 3 years old for females and 4.5 years old for males. (Cawthon Lang, 2009; Nowak, 1999)

> **Key Reproductive Features:** iteroparous ; year-round breeding ; gonochoric/gonochoristic/dioecious (sexes separate) ; sexual ; viviparous

Breeding interval
The breeding interval is between 1 year and 2 years.

Breeding season
Pigtail macaques breed throughout the year.

Range number of offspring
1 to 2

Average number of offspring
1

Range gestation period
162 to 186 days

Average gestation period
171 days

Average weaning age
12 months

Range time to independence
8 to 12 months

Range age at sexual or reproductive maturity (female)

3 to 3.5 years

Range age at sexual or reproductive maturity (male)
4 to 4 5 years

Females provide the majority of care for the young. Mothers nurse young, carry them, and protect them throughout their first year of life. After that they still provide some care, especially to female offspring, generally through grooming and social support. This can last throughout their whole lives or until they leave the natal group. (Cawthon Lang, 2009)

During the first month of their lives, offspring and mothers are hardly ever separated. After the fifth week though, the infant will separate from its mother and begin to explore its surroundings. This can cause problems because the infant is then in danger of being kidnapped by other adult females. This is particularly the case when higher-ranking females seize lower-ranking female’s offspring. However, if the infant is separated from its mother for too long, it will more than likely die from starvation or dehydration. (Cawthon Lang, 2009)

When pigtail macaques are born they have a black coat, but by the third month of life, this starts to change to an olive brown, which is typical of adults. At one year old pigtail macaques are no longer considered infants. After one year pigtail macaques are considered adolescents until they reach reproductive maturity at the age of 3 for females and 4.5 for males. (Cawthon Lang, 2009)

> **Parental Investment:** altricial ; pre-fertilization (provisioning , protecting female) ; pre hatching/birth (provisioning female , protecting : female) ; pre-weaning/fledging (provisioning : female , protecting female) ; pre independence (provisioning female , protecting : female) ; post-independence association with parents ; extended period of juvenile learning ; maternal position in the dominance hierarchy affects status of young

Lifespan/Longevity

Pigtail macaques have an expected lifespan of about 26 years in the wild if they survive to sexual maturity. Captive individuals have lived up to almost 35 years. (Carey and Judge, 2002)

Range lifespan
Status: wild
30 (high) years

Average lifespan
Status: wild
26 years

Range lifespan
Status: captivity
34.3 (high) years

Average lifespan
Status: captivity
27 1 years

Behavior

Pigtail macaques live in multi-male, multi-female groups. The females stay with the natal group, making it a female bonded society. The largest group seen is 81 monkeys. The average group size is between 15 and 40 individuals. When a male is between the ages of 5 and 6, they leave the natal group and roam independently or try to join another group. If they happen to join another group, they go in as the lowest-ranking male and have to work their way up through competition with the other males. Females also have their own dominance hierarchy, with the highest ranking females generally being sisters who share this role and are tolerant of one another. They display this by grooming, kissing, and feeding together. (Cawthon Lang, 2009; Rowe, 1996)

Males are socially dominant over females. However, groups of females will band together against a male and attack him. Sometimes females will attack lower-ranking males with the help of their relatives because of competition for food. There is also aggression between higher-ranking males and lower-ranking males. Aggression levels are especially high when solitary males are trying to join a new group. (Cawthon Lang, 2009; "ARKive: Images of Life on Earth", 2003)

After agonistic encounters, there are different forms of reconciliation, depending on gender and rank. Females may mount each other after an aggressive encounter. The dominant one will mount the subordinate one. In males it is the opposite. The dominant male will be mounted by the subordinate one, showing the dominant's tolerance of those lower than himself. Dominant females also have a way of showing their tolerance. This is generally done through the dominant female kissing the subordinate one. (Rowe, 1996)

The dominant male in a captive environment sometimes takes part in infanticide within the group. This has only been seen in captive pigtail macaques. (Cawthon Lang, 2009)

Pigtail macaques are diurnal. The spend most of their time in the trees, with only 8.4% of their time on the ground. Their arboreal time is also divided between different canopy levels, with most time spent in the middle canopy (47.4%), then the lower canopy (33.8%), and finally the upper canopy (10.4%) (Rowe, 1996)

> **Key Behaviors:** arboreal ; terricolous ; diurnal ; motile ; sedentary ; territorial ; social ; dominance hierarchies

Home Range

Pigtail macaques cover long distances while foraging, indicating that they have large home ranges. Their home ranges vary in size from about 0.6 to 8.28 km^2 (0.232 and 3.20 mi^2). In a day of foraging they will travel linear distances between 825 and 2964 m. Home ranges usually overlap with other groups and there has been little evidence to suggest that they defend these areas. However, when in a specific area at a specific time, they may drive off other groups of monkeys. Larger groups might also overthrow smaller ones. (Rowe, 1996)

Communication and Perception

Some researchers describe pigtail macaques as silent monkeys because they seem to be very quiet. When seen running away after an episode of crop raiding, pigtail macaques are almost completely silent. This silent tactic is not limited to simply crop raiding and shows up in most encounters where pigtail macaques are fleeing a certain area. However, they do make a lot of vocalizations. The most often used vocalization when moving through the middle and upper canopies of the rainforest is the “coo.” It is generally used while pigtail macaques are foraging and can be either a short call or a long call, depending on the information being exchanged. Some other vocalizations are made when pigtail macaques are being threatened or endangered, especially during agonistic encounters with other pigtail macaques. These other sounds include “squeals,” “screams,” “growls,” “barks,” and “screeches.” (Cawthon Lang, 2009)

Pigtail macaques use other forms of communication like visual cues and body postures. Both males and females use a form of puckering to communicate. Males use their lips to attract females who are in estrous for mating, which generally occurs right after the communication exchange. But males also direct this facial expression to other males. In this case, it usually makes the lower-ranking male withdraw from the encounter. Another way to threaten other males is to shake branches. This is also used to attract females for copulation. Pigtail macaques use another very common facial expression that includes bared teeth and silence. However, unlike the puckering lips, lower-ranking males direct this signal to more dominant males. Females have their own form of visual cues. When in estrous they get large anogenital swellings that turn a purple-pink color. This allows males to know that they are ready for copulation. Like other primates, touch and chemical cues also are likely to play a role in social communication. (Cawthon Lang, 2009)

> **Communication Channels:** visual ; tactile ; acoustic ; chemical
>
> **Perception Channels:** visual ; tactile ; acoustic ; chemical

Food Habits

Pigtail macaques are primarily frugivorous. The vast majority of the foods that they eat are fruits, but they also eat insects, seeds, leaves, dirt, and fungus (Cawthon Lang, 2009). Other foods in the diet of pigtail macaques include nestling birds, termite eggs and larvae, and river crabs (Rowe, 1996). Pigtail macaques are ground foragers. They divide into small groups while foraging (about 2 to 6) but keep in contact with the other groups through vocalizations. They range widely when searching for food. Pigtail macaques are known for raiding the fruit crops of farmers. They will set up a guard to look for humans and shout a warning signal to those in the fields (Cawthon Lang, 2009). (Cawthon Lang, 2009; Rowe, 1996)

Research in captivity has looked at which types of fruits and vegetables are preferred by pigtail macaques. The foods chosen at the highest frequency by the pigtail macaques studied were mango and pineapple. The food chosen least was carrots (Laska, 2001). (Laska, 2001)

> **Primary Diet:** herbivore (frugivore)
>
> **Animal Foods:** birds ; insects ; aquatic crustaceans
>
> **Plant Foods:** leaves ; seeds, grains, and nuts
>
> **Other Foods:** fungus

Predation

Perhaps one of the biggest predators of pigtail macaques is humans. Pigtail macaques are hunted and killed by humans for food, medicinal purposes, and for research (Cawthon Lang, 2009). Native predators are not reported, but are likely to include large felids or snakes. (Cawthon Lang, 2009)

Pigtail macaques often come in contact with white-handed gibbons (*Hylobates lar*). White-handed gibbons compete with the pigtail macaques for resources and are often an annoyance to pigtail macaques (Rowe, 1996). (Rowe, 1996)

Known Predators

- humans (*Homo sapiens*)

Ecosystem Roles

Pigtail macaques affect their ecosystems with their foraging habits. By eating the fruits, leaves, and other vegetation they participate in spreading seeds around the forest. Their diets include many fruits, plants, fungus and other living things such as insects, nestling birds, and river crabs. (Cawthon Lang, 2009)

Pigtail macaques are also known to participate in exploitative and interference competition with white-handed gibbons (*Hylobates lar*). This in turn affects the amount of resources available to white-handed gibbons (Whitington, 1992). (Whitington, 1992)

One study of a colony of pigtail macaques in captivity showed them to be intermediate hosts of the parasite *Echinococcus granulosus*. Pigtail macaques can become infected with this by eating *E. granulosus* eggs in the feces of canids. Canids are the definitive host of this parasite. (Plesker, et al., 2001)

About 90% of macaques and old-world monkeys are infected with respiratory mites. These mites affect the lungs of the monkeys. (Kim and Kim, 2003)

A study was conducted on parasites in an outdoor breeding colony in Louisiana. The study included baboons, rhesus macaques, and pigtail macaques and the data reflect the parasites for all three species combined. The study did a fecal and blood survey of over 4000 of the animals. Endemic pathogenic intestinal parasites included *Trichuris trichiura* found in 35%, *Strongyloides fülleborni* found in 34%, *Balantium coli* found in 21%, and *Giardia lamblia* found in 0.3%. Only one endemic pathogenic blood parasite was found, which was *Trypansoma cruzi* in 0.8%.

> **Ecosystem Impact:** disperses seeds

Commensal/Parasitic Species

- *Echinococcus granulosus*
- respiratory mites
- *Trichuris trichiura*
- *Strongyloides fülleborni*
- *Balantium coli*
- *Giardia lamblia*
- *Trypansoma cruzi*

Economic Importance for Humans: Positive

Pigtail macaques have been domesticated and trained in some areas of the Malay peninsula by farmers to retrieve coconuts and other fruit from trees. (Cawthon Lang, 2009; Nowak, 1999)

Pigtail macaques are sought for use in medical research, such as research on HIV. Local populations of humans hunt them for food. (Nowak, 1999)

> **Positive Impacts:** food ; source of medicine or drug ; research and education

Economic Importance for Humans: Negative

Pigtail macaques are pests to farmers because they often raid crops. They steal corn and coconuts from local crops and use lookouts to warn the group of the approach of humans (Cawthon Lang, 2009). (Cawthon Lang, 2009)

> **Negative Impacts:** crop pest

Conservation Status

Pigtail macaques are classified as vulnerable on the IUCN redlist. Their vulnerability comes from many sources. The first source that poses a threat for the pigtail macaques is destruction of their natural habitat. From large scale timber companies cutting down trees to small families taking wood for fire or building, each time forests are cut, pigtail macaque habitat is destroyed. Effective protection of forested habitat and education of local people is necessary to help protect this species. (Cawthon Lang, 2009)

Pigtail macaques are often killed by locals for food. They are being shot and killed at higher rates in some places, such as Borneo, where they are becoming rare (Nowak, 1999). Pigtail macaques are also targeted in order to become the subjects of biomedical research especially for research on HIV/AIDS (Cawthon Lang, 2009). (Cawthon Lang, 2009; Nowak, 1999)

Another threat to pigtail macaques, especially in India, is the effects of the nearby coal mines. Pollution from the coal mines is harmful to the pigtail macaques that live nearby. This problem could be solved by the Indian government taking steps to regulate the coal mining system. (Cawthon Lang, 2009)

One promising conservation effort was reported in a study by Steinmetz, Chutipong, and Seuaturien (2006). They led wildlife workshops in local villages in Southeast Asia in order to teach villagers about the status of endangered animals (including pigtail macaques) and what to do to help these animals thrive. The workshops involved assessing the level of danger to the animals, determining what activities were leading to the endangerment of the species, and coming up with a plan of action to protect the species. The study also involved inter-village cooperation. Villages were brought together to understand and help these endangered animals. This study had promising results that led to less killing of pigtail macaques in the villages that participated. It is possible that implementing more educational workshops and cooperative programs could lead to helping change the vulnerable status of pigtail macaques and other species. (Steinmetz, et al., 2006)

IUCN Red List
Vulnerable
More information

IUCN Red List
Vulnerable
More information

US Federal List
No special status

CITES
No special status

State of Michigan List
No special status

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The ADW Team gratefully acknowledges their support.

Exhibit 29

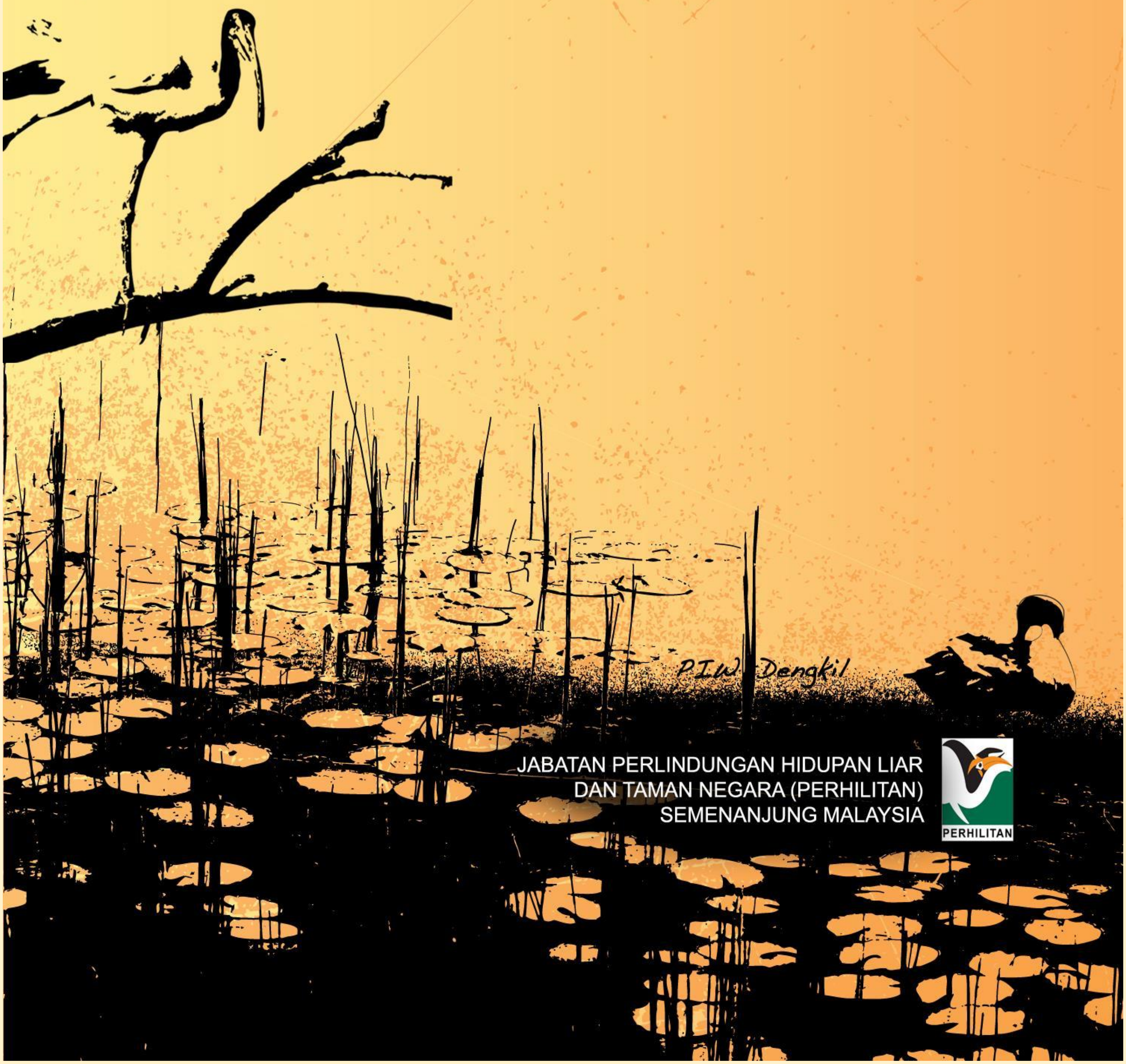
Lampiran B: Aduan Gangguan Hidupan Liar Tahun 2015
Appendix B: Wildlife Disturbances In 2015

Spesies/*Species*	SLGR	JHR	PRK	PHG	N.SBLN	TRGN	KDH	W.P	MLK	P.PNG	KLTN	PRLS	Jumlah Aduan *Total Report*	%
Kera *Long-tailed Macaque*	1,094	714	381	320	348	167	272	203	175	147	47	47	3,915	62.58
Babi Hutan *Wild Boar*	79	81	123	91	59	126	63	11	55	64	25	1	778	12.44
Gajah *Elephant*	0	70	43	83	0	70	22	0	0	0	59	0	347	5.55
Beruk *Pig-tailed Macaque*	44	36	40	34	35	36	22	21	5	3	31	13	320	5.12
Musang Pulut *Common palm Civet*	91	22	23	6	16	5	28	70	17	29	12	6	325	5.20
Lotong Chenekah *Mitred Leaf Monkey*	2	21	4	4	18	10	2	4	15	2	0	9	91	1.45
Lotong Cengkong *Dusky Leaf Monkey*	20	2	2	15	1	0	9	0	0	8	0	0	57	0.91
Biawak Air *Water Monitor Lizard*	9	5	5	4	1	1	2	10	4	14	2	0	57	0.91
Beruang *Malayan Sun Bear*	8	0	2	15	1	18	1	0	0	0	6	0	51	0.82
Lain-lain Ular *Other Snakes*	18	8	2	2	3	1	1	9	0	3	1	0	48	0.77
Ular Sawa *Python*	15	8	5	1	1	1	4	7	1	0	1	0	44	0.70
Tapir *Tapir*	2	2	2	8	10	3	0	0	1	0	2	0	30	0.48

Exhibit 30

LAPORAN TAHUNAN 2016

1437 H



JABATAN PERLINDUNGAN HIDUPAN LIAR
DAN TAMAN NEGARA (PERHILITAN)
SEMENANJUNG MALAYSIA

D: Rekod Aduan Konflik Manusia - Hidupan Liar Tahun 2016.
Human Wildife Conflict Reports In Year 2016.

Spesies	**SLGR**	**JHR**	**PRK**	**PHG**	**N.SBLN**	**P.PNG**	**TRGN**	**KDH**	**W.P**	**MLK**	**KLTN**	**PRLS**	**Jumlah aduan / *Total report***	**%**
Kera *Long-tailed Macaque*	1,002	836	455	427	335	256	186	278	137	192	79	54	4,237	62.59
Babi Hutan *Wild Boar*	100	108	113	123	70	94	128	61	7	56	50	1	911	13.46
Beruk *Pig-Tailed Macaque*	27	40	43	47	40	8	21	16	38	10	34	6	330	4.88
Gajah *Elephant*	0	70	58	64	4	0	55	10	0	0	67	0	328	4.85
Musang Pandan *Common Palm Civet*	56	20	24	5	14	46	8	44	59	15	11	6	308	4.55
Lotong *Leaf Monkey*	19	25	6	17	19	22	12	17	9	16	1	7	170	2.51
Lain-lain ular *Other Snakes*	14	10	22	0	6	7	2	2	17	3	0	1	84	1.24
Biawak *Monitor Lizard*	13	4	6	3	2	15	0	2	11	1	0	0	57	0.84
Beruang *Sun Bear*	6	1	0	9	2	0	19	1	0	0	8	0	46	0.68
Ular Sawa *Python*	4	10	4	0	2	2	1	2	9	2	3	0	39	0.58
Ular Tedung *Cobras*	12	3	10	1	2	2	0	2	2	0	0	0	34	0.50

Exhibit 31

Lampiran E: Rekod Aduan Konflik Manusia - Hidupan Liar Tahun 2017.
Appendix E: Human Wildife Conflict Reports In Year 2017.

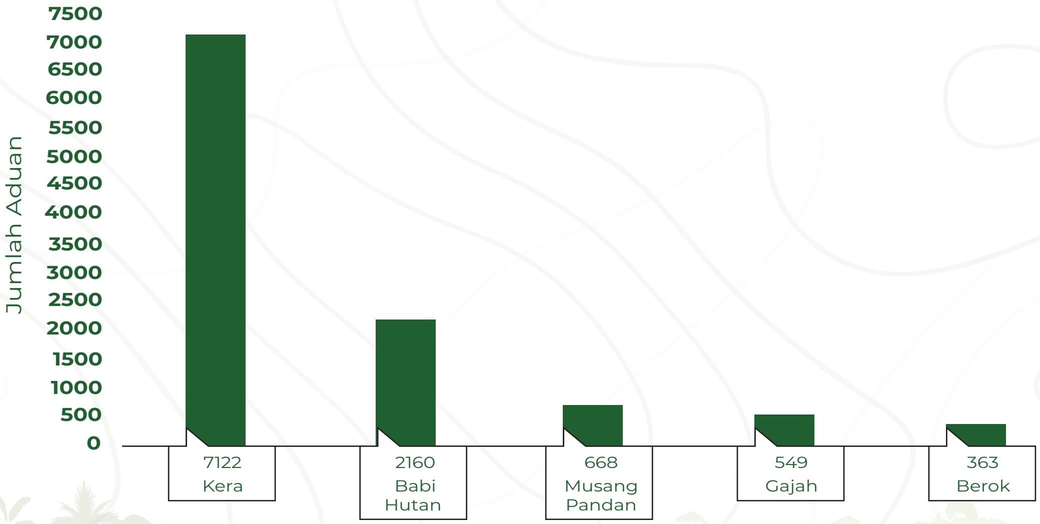
Bil.	Spesies	SLGR	JHR	PRK	PHG	P.PNG	KDH	TRGN	N.SBLN	MLK	KLTN	W.P	PRLS	Jumlah aduan / *total report*	%
1	Kera / Long-tailed macaque	1,404	718	514	476	304	355	211	293	278	98	190	86	4,927	66.13
2	Babi Hutan / Wild boar	80	82	124	99	116	88	169	65	22	51	2	4	902	12.11
3	Gajah / Elephant	0	91	50	46	0	10	45	6	0	94	0	0	342	4.59
4	Musang Pandan / Common palm civet	98	25	16	3	52	37	15	15	12	5	39	10	327	4.39
5	Beruk / Pig-tailed macaque	49	34	36	40	8	17	27	38	9	43	12	7	320	4.29
	Lotong Cengkong/ Leaf Monkey	17	14	8	12	34	15	8	10	5	2	6	13	144	1.93
7	Biawak Air / Monitor Lizard	9	8	4	0	18	6	1	2	6	1	13	0	68	0.91
9	Beruang / Sun Bear	3	3	2	7	0	1	22	1	0	13	0	0	52	0.70
10	Lain-lain Ular / Other Snakes	18	5	3	1	3	2	0	2	1	1	15	0	51	0.68
11	Tapir / Tapir	7	8	2	8	0	0	5	9	0	4	0	0	43	0.58
12	Ular Sawa / Python	17	4	3	1	3	1	3	0	0	0	8	2	42	0.56
13	Harimau Belang / Tiger	1	2	5	6	0	0	10	0	0	11	0	0	35	0.47
14	Burung Hantu / Owl	9	6	1	3	2	4	1	4	0	0	0	0	30	0.40
15	Ular Tedung / Cobras	10	3	4	1	2	2	2	1	1	1	0	1	28	0.38
16	Buaya / Crocodile	4	3	5	4	2	1	2	1	1	1	1	0	25	0.34
17	Lain-lain Spesies / Other	5	0	4	0	0	2	0	1	0	1	7	2	22	0.30
18	Kelawar / Bat	6	3	3	1	1	0	2	1	0	0	4	0	21	0.28
19	Lain-lain Burung / Other Birds	2	3	3	2	2	2	2	1	0	0	4	2	23	0.31
20	Harimau Kumbang / Black Panther	0	0	4	3	0	3	1	6	0	1	0	1	19	0.25
21	Burung Helang / Eagle	4	3	0	3	1	0	1	3	0	0	1	0	16	0.21
22	Memerang / Otter	1	0	0	0	2	0	1	0	0	0	1	0	5	0.07
23	Harimau Dahan / Clouded Leopard	1	0	0	0	0	1	0	1	0	1	0	0	4	0.05
25	Musang Tenggalung / Malayan Civet	0	0	1	0	0	0	1	0	0	1	0	0	3	0.04
26	Kucing Batu / Leopard Cat	0	1	0	0	0	0	0	0	0	1	0	0	2	0.03
Jumlah Aduan		**1,745**	**1,016**	**792**	**716**	**550**	**547**	**529**	**460**	**335**	**330**	**303**	**128**	**7,451**	**100.00**

Exhibit 32

Pengurusan Konflik Manusia – Hidupan Liar
Human-Wildlife Conflict Management

Sebanyak 11,811 aduan gangguan hidupan liar yang melibatkan pelbagai spesies telah diterima dari seluruh Semenanjung Malaysia. Lima aduan tertinggi yang diterima adalah adalah seperti di Rajah 32.

A total of 11,811 wildlife disturbance complaints involving various species were received throughout Peninsular Malaysia. The top 5 species are as shown in Figure32.



Rajah 32 : Aduan gangguan hidupan liar mengikut lima spesies tertinggi bagi tahun 2020

Figure 32 : Number of wildlife disturbance compaints, by top five species in year 2020

Exhibit 33

Search
English
Dark mode

Home > Macaca nemestrina

Macaca nemestrina

Kingdom
Fauna

Phylum
Chordata

Class
Mammalia

Order
Primates

Family
Cercopithecidae

Rank
Species

Listing
II

Genus
Macaca

For general enquiries
info@cites.org

For media enquiries
cites-media@un.org

Convention on International Trade in
Endangered Species of Wild Fauna and Flora

Exhibit 34

Home > Appendices

Appendices

Introduction Appendices in pdf format

Appendices I, II and III

valid from 23 February 2023

Interpretation

1. Species included in these Appendices are referred to:

   a) by the name of the species; or

   b) as being all of the species included in a higher taxon or designated part thereof.

2. The abbreviation “spp.” is used to denote all species of a higher taxon.

3. Other references to taxa higher than species are for the purposes of information or classification only. The common names included after the scientific names of families are for reference only. They are intended to indicate the species within the family concerned that are included in the Appendices. In most cases this is not all of the species within the family.

4. The following abbreviations are used for plant taxa below the level of species:

   a) “ssp.” is used to denote subspecies; and

   b) “var(s).” is used to denote variety (varieties).

5. As none of the species or higher taxa of FLORA included in Appendix I is annotated to the effect that its hybrids shall be treated in accordance with the provisions of Article III of the Convention, this means that artificially propagated hybrids produced from one or more of these species or taxa may be traded with a certificate of artificial propagation, and that seeds and pollen (including pollinia), cut flowers, seedling or tissue cultures obtained *in vitro*, transported in sterile containers of these hybrids are not subject to the provisions of the Convention.

6. The names of the countries in parentheses placed against the names of species in Appendix III are those of the Parties submitting these species for inclusion in this Appendix.

7. When a species is included in Appendix I, II or III, the whole, live or dead, animal or plant is always included. In addition, all parts and derivatives thereof are also included in the same Appendix unless, for animal species listed in Appendix III and plant species listed in Appendix II or III, the species is annotated with the symbol # followed by a number to indicate that only specific parts and derivatives are included. The symbol # followed by a number placed against the name of a species or higher taxon included in Appendix II or III refers to a footnote that indicates the parts or derivatives of animals or plants that are designated as 'specimens' subject to the provisions of the Convention in accordance with Article I, paragraph (b), subparagraph (ii) or (iii).

8. The terms and expressions below, used in annotations in these Appendices, are defined as follows:

Extract

Any substance obtained directly from plant material by physical or chemical means regardless of the manufacturing process. An extract may be solid (e.g. crystals, resin, fine or coarse particles), semi-solid (e.g. gums, waxes) or liquid (e.g. solutions, tinctures, oil and essential oils).

Finished musical instruments

A musical instrument (as referenced by the Harmonized System of the World Customs Organization, Chapter 92; musical instruments, parts and accessories of such articles) that is ready to play or needs only the installation of parts to make it playable. This term includes antique instruments (as defined by the Harmonized System codes 97.05 and 97.06; Works of art, collectors' pieces and antiques).

Finished musical instrument accessories

A musical instrument accessory (as referenced by the Harmonized System of the World Customs Organization, Chapter 92; musical instruments, parts and accessories of such articles) that is separate from the musical instrument, and is specifically designed or shaped to be used explicitly in association with an instrument, and that requires no further modification to be used.

Finished musical instrument parts

A part (as referenced by the Harmonized System of the World Customs Organization, Chapter 92; musical instruments, parts and accessories of such articles) of a musical instrument that is ready to install and is specifically designed and shaped to be used explicitly in association with the instrument to make it playable.

Finished products packaged and ready for retail trade

Products, shipped singly or in bulk, requiring no further processing, packaged, labelled for final use or the retail trade in a state fit for being sold to or used by the general public.

Powder

A dry, solid substance in the form of fine or coarse particles.

Shipment

Cargo transported under the terms of a single bill of lading or air waybill, irrespective of the quantity or number of containers, packages, or pieces worn, carried or included in personal baggage.

Ten (10) kg per shipment

For the term "10 kg per shipment", the 10 kg limit should be interpreted as referring to the weight of wood of each individual annotated species of genus Dalbergia *or* Guibourtia *present in the items in the shipment. The 10 kg limit is to be assessed only against the individual weights of the portions of wood of each individual annotated species contained in each item of the shipment, and not against the total weight of the shipment. The total weights present of each individual annotated species are considered individually to determine whether a CITES permit or certificate is required for each individual annotated species, and weights of different individual annotated species are not added together for this purpose.*

Transformed wood

Defined by Harmonized System code 44.09: Wood (including strips, friezes for parquet flooring, not assembled), continuously shaped (tongued, grooved, rebated, chamfered, V-jointed, beaded, moulded, rounded or the like) along any of its edges, ends or faces, whether or not planed, sanded or end-jointed.

Woodchips

Wood that has been reduced to small pieces.

✉ **For general enquiries**
info@cites.org

✉ **For media enquiries**
cites-media@un.org

Exhibit 35

How CITES works

CITES works by subjecting international trade in specimens of selected species to certain controls. All import, export, re-export and introduction from the sea of species covered by the Convention has to be authorized through a licensing system. Each Party to the Convention must designate one or more Management Authorities in charge of administering that licensing system and one or more Scientific Authorities to advise them on the effects of trade on the status of the species.

The species covered by CITES are listed in three Appendices, according to the degree of protection they need. (For additional information on the number and type of species covered by the Convention click here.)

Appendices I and II

Appendix I includes species threatened with extinction. Trade in specimens of these species is permitted only in exceptional circumstances.

Appendix II includes species not necessarily threatened with extinction, but in which trade must be controlled in order to avoid utilization incompatible with their survival.

The Conference of the Parties (CoP), which is the supreme decision-making body of the Convention and comprises all its Parties, has agreed in Resolution Conf. 9.24 (Rev. CoP17) on a set of biological and trade criteria to help determine whether a species should be included in Appendices I or II. At each regular meeting of the CoP, Parties submit proposals based on those criteria to amend these two Appendices. Those amendment proposals are discussed and then submitted to a vote. The Convention also allows for amendments by a postal procedure between meetings of the CoP (see Article XV, paragraph 2, of the Convention), but this procedure is rarely used.

Appendix III

This Appendix contains species that are protected in at least one country, which has asked other CITES Parties for assistance in controlling the trade. Changes to Appendix III follow a distinct procedure from changes to Appendices I and II, as each Party's is entitled to make unilateral amendments to it.

A specimen of a CITES-listed species may be imported into or exported (or re-exported) from a State party to the Convention only if the appropriate document has been obtained and presented for clearance at the port of entry or exit. There is some variation of the requirements from one country to another and it is always necessary to check on the national laws that may be stricter, but the basic conditions that apply for Appendices I and II are described below.

Appendix-I specimens

1. An import permit issued by the Management Authority of the State of import is required. This may be issued only if the specimen is not to be used for primarily commercial purposes and if the import will be for purposes that are not detrimental to the survival of the species. In the case of a live animal or plant, the Scientific Authority must be satisfied that the proposed recipient is suitably equipped to house and care for it.

2. An export permit or re-export certificate issued by the Management Authority of the State of export or re-export is also required.
   An export permit may be issued only if the specimen was legally obtained; the trade will not be detrimental to the survival of the species; and an import permit has already been issued.

   A re-export certificate may be issued only if the specimen was imported in accordance with the provisions of the Convention and, in the case of a live animal or plant, if an import permit has been issued.

In the case of a live animal or plant, it must be prepared and shipped to minimize any risk of injury, damage to health or cruel treatment.

Appendix-II specimens

1. An export permit or re-export certificate issued by the Management Authority of the State of export or re-export is required.

   An export permit may be issued only if the specimen was legally obtained and if the export will not be detrimental to the survival of the species.

   A re-export certificate may be issued only if the specimen was imported in accordance with the Convention.

2. In the case of a live animal or plant, it must be prepared and shipped to minimize any risk of injury, damage to health or cruel treatment.

3. No import permit is needed unless required by national law.

In the case of specimens introduced from the sea, a certificate has to be issued by the Management Authority of the State into which the specimens are being brought, for species listed in Appendix I or II. For further information, see the text of the Convention, Article III, paragraph 5 and Article IV, paragraph 6.

Appendix-III specimens

1. In the case of trade from a State that included the species in Appendix III, an export permit issued by the Management Authority of that State is required. This may be issued only if the specimen was legally obtained and, in the case of a live animal or plant, if it will be prepared and shipped to minimize any risk of injury, damage to health or cruel treatment.

2. In the case of export from any other State, a certificate of origin issued by its Management Authority is required.

3. In the case of re-export, a re-export certificate issued by the State of re-export is required

Exemptions and special procedures (see separate page for more details and links)

In its Article VII, the Convention allows or requires Parties to make certain exceptions to the general principles described above, notably in the following cases:

- for specimens in transit or being transhipped [see Resolution Conf. 9.7 (Rev. CoP15)];
- for specimens that were acquired before CITES provisions applied to them (known as pre-Convention specimens, see Resolution Conf. 13.6 (Rev. CoP18);
- for specimens that are personal or household effects [see Resolution Conf. 13.7 (Rev. CoP17)];
- for animals that were ‘bred in captivity’ [see also Resolution Conf. 10.16 (Rev. CoP19)];
- for plants that were ‘artificially propagated’ [see also Resolution Conf. 11.11 (Rev. CoP18)];
- for specimens that are destined for scientific research [see also Resolution Conf. 11.15 (Rev. CoP18)];
- for animals or plants forming part of a travelling collection or exhibition, such as a circus [see also Resolution Conf. 12.3 (Rev. CoP19)].

There are special rules in these cases and a permit or certificate will generally still be required. Anyone planning to import or export/re-export specimens of a CITES species should contact the national CITES Management Authorities of the countries of import and export/re-export for information on the rules that apply.

When a specimen of a CITES-listed species is transferred between a country that is a Party to CITES and a country that is not, the country that is a Party may accept documentation equivalent to the permits and certificates described above.

Exhibit 36

MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN
REPUBLIK INDONESIA

PERATURAN MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN
REPUBLIK INDONESIA
NOMOR P.20/MENLHK/SETJEN/KUM.1/6/2018
TENTANG
JENIS TUMBUHAN DAN SATWA YANG DILINDUNGI

DENGAN RAHMAT TUHAN YANG MAHA ESA

MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN REPUBLIK INDONESIA,

Menimbang :

a. bahwa berdasarkan ketentuan Pasal 4 Peraturan Pemerintah Nomor 7 Tahun 1999 tentang Pengawetan Jenis Tumbuhan dan Satwa, telah ditetapkan jenis tumbuhan dan satwa yang dilindungi;

b. bahwa jenis tumbuhan dan satwa yang dilindungi berdasarkan Peraturan Pemerintah sebagaimana dimaksud dalam huruf a, statusnya dapat berubah (dinamis), sehingga Lampiran dalam Peraturan Pemerintah dimaksud dilakukan perubahan status dari jenis tumbuhan dan satwa yang dilindungi menjadi tidak dilindungi dan sebaliknya setelah mendapat pertimbangan Otoritas Keilmuan (*Scientific Authority*);

c. bahwa dalam hal Menteri memiliki data dan informasi ilmiah yang cukup mengenai suatu jenis tumbuhan atau satwa telah memenuhi kriteria untuk dilindungi, atau Menteri menerima usulan dari instansi Pemerintah lain atau Lembaga Swadaya Masyarakat untuk melindungi suatu jenis tumbuhan atau satwa dengan informasi ilmiah yang cukup, Menteri dapat menetapkan jenis tersebut untuk dilindungi, sedangkan dalam hal usulan melindungi jenis tumbuhan dan satwa berasal dari LIPI maka Menteri langsung menetapkan jenis tumbuhan atau satwa menjadi dilindungi;

d. bahwa Kepala Pusat Penelitian Biologi LIPI sesuai dengan surat Nomor B.2230/IPH.1/KS.02.04/V/2018 tanggal 4 Mei 2018 perihal Rekomendasi Revisi Lampiran Peraturan Pemerintah Nomor 7 Tahun 1999 tentang Pengawetan Jenis Tumbuhan dan Satwa, memberikan pertimbangan untuk jenis tumbuhan dan satwa yang ditetapkan sebagai jenis yang dilindungi;

e. bahwa berdasarkan pertimbangan sebagaimana dimaksud dalam huruf a sampai dengan huruf d, perlu menetapkan Peraturan Menteri Lingkungan Hidup dan Kehutanan tentang Jenis Tumbuhan dan Satwa yang Dilindungi;

Mengingat : 1. Undang-Undang Nomor 5 Tahun 1990 tentang Konservasi Sumberdaya Alam Hayati dan Ekosistemnya (Lembaran Negara Republik Indonesia Tahun 1990 Nomor 49, Tambahan Lembaran Negara Republik Indonesia Nomor 3419);

2. Undang-Undang Nomor 5 Tahun 1994 tentang Pengesahan *United Nations Convention on Biological Diversity* (Konvensi Perserikatan Bangsa-Bangsa Mengenai Keanekaragaman Hayati) (Lembaran Negara Republik Indonesia Tahun 1994 Nomor 41, Tambahan Lembaran Negara Republik Indonesia Nomor 3556);

3. Undang-Undang Nomor 41 Tahun 1999 tentang Kehutanan (Lembaran Negara Republik Indonesia Tahun 1999 Nomor 167, Tambahan Lembaran Negara Republik Indonesia Nomor 3888), sebagaimana telah diubah dengan Undang-Undang Nomor 19 Tahun 2004 tentang Penetapan Peraturan Pemerintah Pengganti Undang-Undang Nomor 1 Tahun 2004 tentang Perubahan atas Undang-Undang Nomor 41 Tahun 1999 tentang Kehutanan menjadi

Undang-Undang (Lembaran Negara Republik Indonesia Tahun 2004 Nomor 86, Tambahan Lembaran Negara Republik Indonesia Nomor 4412);

4. Undang-Undang Nomor 31 Tahun 2004 tentang Perikanan (Lembaran Negara Republik Indonesia Tahun 2004 Nomor 118, Tambahan Lembaran Negara Republik Indonesia Nomor 4433), sebagaimana telah diubah dengan Undang-Undang Nomor 45 Tahun 2009 tentang Perubahan atas Undang-Undang Nomor 31 Tahun 2004 tentang Perikanan (Lembaran Negara Republik Indonesia 2009 Nomor 154, Tambahan Lembaran Negara Republik Indonesia Nomor 5073);
5. Undang-Undang Nomor 32 Tahun 2009 tentang Perlindungan dan Pengelolaan Lingkungan Hidup (Lembaran Negara Republik Indonesia Tahun 2009 Nomor 140, Tambahan Lembaran Negara Republik Indonesia Nomor 5059);
6. Undang-Undang Nomor 18 Tahun 2013 tentang Pencegahan dan Pemberantasan Perusakan Hutan (Lembaran Negara Republik Indonesia Tahun 2013 Nomor 130, Tambahan Lembaran Negara Republik Indonesia Nomor 5432);
7. Undang-Undang Nomor 23 Tahun 2014 tentang Pemerintahan Daerah (Lembaran Negara Republik Indonesia Tahun 2014 Nomor 244, Tambahan Lembaran Negara Republik Indonesia Nomor 5887), sebagaimana telah diubah beberapa kali terakhir dengan Undang-Undang Nomor 9 Tahun 2015 tentang Perubahan Kedua atas Undang-Undang Nomor 23 Tahun 2014 tentang Pemerintahan Daerah (Lembaran Negara Republik Indonesia Tahun 2015 Nomor 58, Tambahan Lembaran Negara Republik Indonesia Nomor 5679);
8. Peraturan Pemerintah Nomor 7 Tahun 1999 tentang Pengawetan Jenis Tumbuhan dan Satwa (Lembaran Negara Republik Indonesia Tahun 1999 Nomor 14, Tambahan Lembaran Negara Republik Indonesia Nomor 3803);

9. Peraturan Pemerintah Nomor 8 Tahun 1999 tentang Pemanfaatan Jenis Tumbuhan dan Satwa Liar (Lembaran Negara Republik Indonesia Tahun 1999 Nomor 15, Tambahan Lembaran Negara Republik Indonesia Nomor 3802);
10. Peraturan Pemerintah Nomor 45 Tahun 2004 tentang Perlindungan Hutan (Lembaran Negara Republik Indonesia Tahun 2004 Nomor 147, Tambahan Lembaran Negara Republik Indonesia Nomor 4453), sebagaimana telah diubah dengan Peraturan Pemerintah Nomor 60 Tahun 2009 tentang Perubahan atas Peraturan Pemerintah Nomor 45 Tahun 2004 tentang Perlindungan Hutan (Lembaran Negara Republik Indonesia Tahun 2009 Nomor 137, Tambahan Lembaran Negara Republik Indonesia Nomor 5956);
11. Peraturan Presiden Nomor 16 Tahun 2015 tentang Kementerian Lingkungan Hidup dan Kehutanan (Lembaran Negara Republik Indonesia Tahun 2015 Nomor 17);
12. Peraturan Menteri Lingkungan Hidup dan Kehutanan Nomor P.18/MenLHK-II/2015 tentang Organisasi dan Tata Kerja Kementerian Kehutanan (Berita Negara Republik Indonesia Tahun 2015 Nomor 713);

MEMUTUSKAN:

Menetapkan : PERATURAN MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN TENTANG JENIS TUMBUHAN DAN SATWA YANG DILINDUNGI.

Pasal 1

Menetapkan jenis tumbuhan dan satwa yang dilindungi sebagaimana dimaksud dalam Lampiran yang merupakan bagian tidak terpisahkan dari Peraturan Menteri ini.

Pasal 2

Pada saat Peraturan Menteri ini mulai berlaku, Lampiran Peraturan Pemerintah Nomor 7 Tahun 1999 tentang Pengawetan Jenis Tumbuhan dan Satwa (Lembaran Negara Republik Indonesia Tahun 1999 Nomor 14, Tambahan Lembaran Negara Republik Indonesia Nomor 3803), dicabut dan dinyatakan tidak berlaku.

Pasal 3

Peraturan Menteri ini mulai berlaku pada tanggal diundangkan.

Agar setiap orang mengetahuinya, memerintahkan pengundangan Peraturan Menteri ini dengan penempatannya dalam Berita Negara Republik Indonesia.

Ditetapkan di Jakarta
pada tanggal 29 Juni 2018

MENTERI LINGKUNGAN HIDUP DAN
KEHUTANAN REPUBLIK INDONESIA,

ttd

SITI NURBAYA

Diundangkan di Jakarta
pada tanggal 11 Juli 2018

DIREKTUR JENDERAL
PERATURAN PERUNDANG-UNDANGAN
KEMENTERIAN HUKUM DAN HAK ASASI MANUSIA
REPUBLIK INDONESIA,

ttd

WIDODO EKATJAHJANA

BERITA NEGARA REPUBLIK INDONESIA TAHUN 2018 NOMOR 880
Salinan sesuai dengan aslinya
KEPALA BIRO HUKUM,

ttd

KRISNA RYA

LAMPIRAN PERATURAN MENTERI LINGKUNGAN HIDUP DAN KEHUTANAN REPUBLIK INDONESIA

NOMOR P.20/MENLHK/SETJEN/KUM.1/6/2018
TENTANG PENETAPAN JENIS TUMBUHAN DAN SATWA YANG DILINDUNGI

No	Nama Ilmiah	Nama Indonesia
	SATWA	
1. MAMALIA		
	Balaenopteridae	
1	*Balaenoptera acutorostrata*	paus tombak
2	*Balaenoptera bonaerensis*	paus minke antartika
3	*Balaenoptera borealis*	paus sei
4	*Balaenoptera edeni*	paus edeni
5	*Balaenoptera musculus*	paus biru
6	*Balaenoptera omurai*	paus omura
7	*Megaptera novaeangliae*	paus bongkok
	Bovidae	
8	*Bos javanicus*	banteng
9	*Bubalus depressicornis*	anoa dataran rendah
10	*Bubalus quarlesi*	anoa gunung
11	*Capricornis sumatraensis*	kambing hutan sumatera
	Canidae	
12	*Cuon alpinus*	anjing ajag
	Cercopithecidae	
13	*Macaca maura*	monyet darre
14	*Macaca nigra*	monyet yaki
15	*Macaca ochreata*	monyet digo
16	*Macaca pagensis*	beruk mentawai
17	*Macaca tonkeana*	monyet boti
18	*Nasalis larvatus*	bekantan
19	*Presbytis comata*	lutung surili
20	*Presbytis frontata*	lutung jirangan
21	*Presbytis melalophos*	lutung simpai
22	*Presbytis natunae*	kekah
23	*Presbytis potenziani*	lutung joja
24	*Presbytis rubicunda*	lutung merah
25	*Presbytis thomasi*	lutung kedih
26	*Simias concolor*	lutung simakobu
27	*Trachypithecus auratus*	lutung budeng
28	*Trachypithecus cristatus*	lutung kelabu
	Cervidae	
29	*Axis kuhlii*	rusa bawean
30	*Muntiacus muntjak*	kijang muncak
31	*Muntiacus atherodes*	kijang kuning
32	*Rusa timorensis*	rusa timor
33	*Rusa unicolor*	rusa sambar
	Delphinidae	
34	*Delphinus capensis*	lumba lumba moncong panjang
35	*Feresa attenuata*	paus pemangsa kerdil
36	*Globicephala macrorhynchus*	paus pilot bersirip pendek
37	*Grampus griseus*	lumba-lumba risso
38	*Lagenodelphis hosei*	lumba-lumba fraser
39	*Orcaella brevirostris*	pesut mahakam
40	*Orcinus orca*	paus pembunuh, paus seguni
41	*Peponocephala electra*	paus kepala melon
42	*Pseudorca crassidens*	paus pemangsa palsu
43	*Sousa chinensis*	lumba-lumba bongkok

44	*Stenella attenuata*	lumba-lumba totol
45	*Stenella coeruleoalba*	lumba-lumba garis
46	*Stenella longirostris*	lumba-lumba moncong panjang
47	*Steno bredanensis*	lumba-lumba gigi kasar
48	*Tursiops aduncus*	lumba-lumba hidung botol indopasifik
49	*Tursiops truncatus*	lumba-lumba hidung botol
	Dugongidae	
50	*Dugong dugon*	duyung
	Elephantidae	
51	*Elephas maximus*	gajah asia
	Felidae	
52	*Catopuma badia*	kucing merah
53	*Catopuma temminckii*	kucing emas
54	*Neofelis nebulosa diardi*	macan dahan
55	*Panthera pardus melas*	harimau tutul/ macan tutul
56	*Panthera tigris sumatrae*	harimau sumatera
57	*Pardofelis marmorata*	kucing batu
58	*Prionailurus bengalensis*	kucing kuwuk
59	*Prionailurus planiceps*	kucing tandang
60	*Prionailurus viverrinus*	kucing bakau
	Hominidae	
61	*Pongo abelii*	mawas sumatera/ orangutan sumatera
62	*Pongo pygmaeus*	mawas kalimantan/ orangutan kalimantan
63	*Pongo tapanuliensis*	mawas tapanuli/ orangutan tapanuli
	Hylobatidae	
64	*Hylobates agilis*	owa ungko
65	*Hylobates albibarbis*	owa jenggot putih
66	*Hylobates klossi*	owa bilau
67	*Hylobates lar*	owa serudung
68	*Hylobates moloch*	owa jawa
69	*Hylobates muelleri*	owa kalawat
70	*Symphalangus syndactylus*	owa siamang
	Hystricidae	
71	*Hystrix javanica*	landak jawa
	Leporidae	
72	*Nesolagus netscheri*	kelinci sumatera
	Lorisidae	
73	*Nycticebus coucang*	kukang
74	*Nycticebus javanicus*	kukang jawa
75	*Nycticebus menagensis*	kukang kalimantan
	Macropopidae	
76	*Dendrolagus dorianus*	kangguru pohon ndomea
77	*Dendrolagus goodfellowi*	kangguru pohon hias
78	*Dendrolagus inustus*	kangguru pohon wakera
79	*Dendrolagus mbaiso*	kangguru pohon mbaiso
80	*Dendrolagus ursinus*	kangguru pohon nemena
81	*Thylogale browni*	pelandu nugini
82	*Thylogale brunii*	pelandu aru
83	*Thylogale stigmatica*	pelandu merah
	Manidae	
84	*Manis javanica*	trenggiling
	Mustelidae	
85	*Arctonyx collaris*	sigung sumatera
86	*Lutra lutra*	berang-berang pantai
87	*Lutra sumatrana*	berang-berang gunung
88	*Lutrogale perspicillata* (I. Geoffroy Saint-Hilaire,	berang-berang wregul
	Phalangeridae	
89	*Ailurops melanotis*	kuskus talaud
90	*Phalanger alexandrae*	kuskus gebe
91	*Phalanger carmelitae* Thomas, 1898	kuskus gunung

92	*Phalanger gymnotis*	kuskus guannal
93	*Phalanger intercastellanus*	kuskus selatan
94	*Phalanger matabiru*	kuskus matabiru
95	*Phalanger rothschildi*	kuskus obi
96	*Phalanger sericeus*	kuskus yaben
97	*Phalanger vestitus*	kuskus siku putih
98	*Spilocuscus maculatus*	kuskus pontai
99	*Spilocuscus papuensis*	kuskus scham-scham
100	*Spilocuscus rufoniger*	kuskus bohai
101	*Strigocuscus celebensis*	kuskus tembung
102	*Strigocuscus pelengensis*	kuskus peleng
	Phocoenidae	
103	*Neophocaena phocaenoides* (Cuvier, 1829)	lumba-lumba hitam tak bersirip
	Physeteridae	
104	*Kogia breviceps*	paus lodan kecil jauba
105	*Kogia sima*	paus lodan kecil
106	*Physeter macrocephalus*	paus sperma
	Prionodontidae	
107	*Prionodon linsang*	musang lingsang
	Pteropodidae	
108	*Acerodon humilis*	codot talaud
109	*Neopteryx frosti*	codot gigi kecil
110	*Pteropus pumilus*	kalong talaud
	Rhinocerotidae	
111	*Dicerorhinus sumatrensis*	badak sumatera
112	*Rhinoceros sondaicus*	badak jawa
	Sciuridae	
113	*Iomys horsfieldi*	cukbo ekor merah
114	*Lariscus hosei*	bokol borneo
	Suidae	
115	*Babyrousa babyrussa*	babirusa tualangio
	Tachyglossidae	
116	*Tachyglossus aculeatus*	nokdiak moncong pendek
117	*Zaglossus bruijni*	nokdiak moncong panjang
	Tapiridae	
118	*Tapirus indicus*	tapir tenuk
	Tarsiidae	
119	*Tarsius bancanus*	krabuku ingkat
120	*Tarsius dentatus*	krabuku diana
121	*Tarsius lariang*	tarsius lariang
122	*Tarsius pelengensis*	krabuku peleng
123	*Tarsius pumilus*	krabuku kecil
124	*Tarsius sangirensis*	krabuku sangihe
125	*Tarsius tarsier*	krabuku tangkasi
126	*Tarsius tumpara*	tarsius siau
	Tragulidae	
127	*Tragulus javanicus*	pelanduk kancil
128	*Tragulus kanchil*	kancil kecil
129	*Tragulus napu*	pelanduk napu
	Ursidae	
130	*Helarctos malayanus*	beruang madu
	Viverridae	
131	*Arctictis binturong*	binturong
132	*Cynogale bennettii*	musang air
133	*Macrogalidia musschenbroekii*	musang sulawesi
	Ziphiidae	
134	*Indopacetus pacificus*	paus hidung botol
135	*Mesoplodon densirostris*	paus paruh blainville
136	*Mesoplodon ginkgodens*	paus paruh bergigi ginkgo
137	*Ziphius cavirostris*	paus paruh angsa

II. BURUNG		
	Accipitridae	
138	*Accipiter badius*	elang alap shikra
139	*Accipiter cirrhocephalus*	elang alap kalung
140	*Accipiter erythrauchen*	elang alap maluku
141	*Accipiter fasciatus*	elang alap coklat
142	*Accipiter griseiceps*	elang alap kepala-kelabu
143	*Accipiter gularis*	elang alap nipon
144	*Accipiter henicogrammus*	elang alap halmahera
145	*Accipiter hiogaster*	elang alap kelabu
146	*Accipiter melanochlamys*	elang alap mantel-hitam
147	*Accipiter meyerianus*	elang alap meyer
148	*Accipiter nanus*	elang alap kecil
149	*Accipiter nisus*	elang alap eurasia
150	*Accipiter poliocephalus*	elang alap pucat-sosonokan
151	*Accipiter rhodogaster*	elang alap dada-merah
152	*Accipiter soloensis*	elang alap cina
153	*Accipiter sylvestris*	elang alap tenggara
154	*Accipiter trinotatus*	elang alap ekor-totol
155	*Accipiter trivirgatus*	elang alap jambul
156	*Accipiter virgatus*	elang alap besra
157	*Aquila audax*	rajawali ekor-baji
158	*Aquila fasciata*	elang bonelli
159	*Aquila gurneyi*	rajawali kuskus
160	*Aviceda jerdoni*	baza jerdon
161	*Aviceda leuphotes*	baza hitam
162	*Aviceda subcristata*	baza pasifik
163	*Butastur indicus*	elang kelabu
164	*Butastur liventer*	elang sayap-coklat
165	*Butastur teesa*	elang mata putih
166	*Buteo japonicus*	elang buteo
167	*Circaetus gallicus*	elang ular jari-pendek
168	*Circus aeruginosus*	elang rawa katak
169	*Circus approximans*	elang rawa coklat
170	*Circus assimilis*	elang rawa tutul
171	*Circus melanoleucos*	elang rawa tangling
172	*Circus spilonotus*	elang rawa timur
173	*Circus spilothorax*	elang rawa papua
174	*Clanga clanga*	rajawali totol
175	*Elanus caeruleus*	elang tikus
176	*Erythrotriorchis buergersi*	elang alap bahu coklat
177	*Gyps himalayensis*	nasar himalaya
178	*Haliaeetus leucogaster*	elang laut perut-putih
179	*Haliastur indus*	elang bondol
180	*Haliastur sphenurus*	elang siul
181	*Harpyopsis novaeguineae*	rajawali papua
182	*Henicopernis longicauda*	elang ekor-panjang
183	*Hieraaetus pennatus*	elang setiwel
184	*Hieraaetus weiskei*	elang kecil
185	*Ichthyophaga humilis*	elang ikan kecil
186	*Ichthyophaga ichthyaetus*	elang ikan kepala-kelabu
187	*Ictinaetus malaiensis*	elang hitam
188	*Lophotriorchis kienerii*	elang perut-karat
189	*Macheiramphus alcinus*	elang kelelawar
190	*Megatriorchis doriae*	elang alap doria
191	*Milvus migrans*	elang paria
192	*Nisaetus alboniger*	elang gunung
193	*Nisaetus bartelsi*	elang jawa
194	*Nisaetus cirrhatus*	elang brontok
195	*Nisaetus floris*	elang flores

196	*Nisaetus lanceolatus*	elang sulawesi
197	*Nisaetus nanus*	elang wallace
198	*Pandion haliaetus*	elang tiram
199	*Pernis celebensis*	sikep madu sulawesi
200	*Pernis ptilorhynchus*	sikep madu asia
201	*Spilornis cheela*	elang ular bido
202	*Spilornis kinabaluensis*	elang ular kinabalu
203	*Spilornis rufipectus*	elang ular sulawesi
	Aegithalidae	
204	*Psaltria exilis*	cerecet jawa
	Alcedinidae	
205	*Actenoides capucinus*	cekakak hutan kepala-hitam
206	*Actenoides concretus*	cekakak hutan melayu
207	*Actenoides monachus*	cekakak hutan tunggir-hijau
208	*Actenoides princeps*	cekakak hutan dada-sisik
209	*Alcedo euryzona*	raja udang kalung-biru jawa
210	*Alcedo peninsulae*	raja udang kalung-biru sumatera
211	*Caridonax fulgidus*	cekakak tunggir-putih
212	*Ceyx sangirensis*	raja udang sangihe
213	*Dacelo tyro*	kukabura aru
214	*Tanysiptera carolinae*	cekakak pita numfor
215	*Tanysiptera ellioti*	cekakak pita kofiau
216	*Tanysiptera riedelii*	cekakak pita biak
217	*Todirhamphus australasia*	cekakak kalung-coklat
218	*Todirhamphus enigma*	cekakak talaud
219	*Todirhamphus funebris*	cekakak murung
220	*Todirhamphus lazuli*	cekakak lazuli
221	*Todirhamphus saurophagus*	cekakak pantai
	Anatidae	
222	*Anseranas semipalmata*	boha wasur
223	*Cairina scutulata*	mentok rimba
224	*Nettapus coromandelianus*	trutu hijau
225	*Salvadorina waigiuensis*	itik gunung
	Apodidae	
226	*Aerodramus vulcanorum*	walet gunung
227	*Hydrochous gigas*	walet raksasa
	Ardeidae	
228	*Ardea alba*	cangak besar
229	*Ardea sumatrana*	cangak laut
230	*Ardeola bacchus*	blekok cina
231	*Egretta eulophotes*	kuntul cina
232	*Egretta novaehollandiae*	kuntul australia
233	*Egretta picata*	kuntul belang
234	*Gorsachius goisagi*	kowak jepang
235	*Gorsachius melanolophus*	kowak melayu
236	*Ixobrychus eurhythmus*	bambangan coklat
237	*Ixobrychus flavicollis*	bambangan hitam
238	*Nycticorax caledonicus*	kowakmalam merah
239	*Zonerodius heliosylus*	bambangan rimba
	Bucerotidae	
240	*Anorrhinus galeritus*	enggang klihingan
241	*Anthracoceros albirostris*	kangkareng perut-putih
242	*Anthracoceros malayanus*	kangkareng hitam
243	*Berenicornis comatus*	enggang jambul
244	*Buceros bicornis*	enggang papan
245	*Buceros rhinoceros*	enggang cula
246	*Rhabdotorrhinus corrugatus*	julang jambul-hitam
247	*Rhabdotorrhinus exarhatus*	kangkareng sulawesi
248	*Rhinoplax vigil*	rangkong gading
249	*Rhyticeros cassidix*	julang sulawesi

250	*Rhyticeros everetti*	julang sumba
251	*Rhyticeros plicatus*	julang irian
252	*Rhyticeros undulatus*	julang emas
	Burhinidae	
253	*Burhinus grallarius*	wili-wili semak
254	*Esacus magnirostris*	wili-wili besar
	Cacatuidae	
255	*Cacatua alba*	kakatua putih
256	*Cacatua galerita*	kakatua koki
257	*Cacatua goffiniana*	kakatua tanimbar
258	*Cacatua moluccensis*	kakatua maluku
259	*Cacatua sanguiena*	kakatua rawa
260	*Cacatua sulphurea*	kakatua jambul-kuning
261	*Probosciger aterrimus*	kakatua raja
	Capitonidae	
262	*Calorhamphus fuliginosus*	takur ampis-kalimantan
263	*Caloramphus hayii*	takur ampis-sumatera
264	*Psilopogon armillaris*	takur tohtor
265	*Psilopogon chrysopogon*	takur gedang
266	*Psilopogon corvinus*	takur bututut
267	*Psilopogon eximius*	takur leher-hitam
268	*Psilopogon henricii*	takur topi-merah
269	*Psilopogon javensis*	takur tulung-tumpuk
270	*Psilopogon lineatus*	takur bultok
271	*Psilopogon monticola*	takur gunung
272	*Psilopogon mystacophanos*	takur warna-warni
273	*Psilopogon oorti*	takur bukit
274	*Psilopogon pulcherrimus*	takur tengkuk-emas
275	*Psilopogon pyrolophus*	takur api
276	*Psilopogon rafflesii*	takur tutut
	Caprimulgidae	
277	*Caprimulgus concretus*	cabak kolong
278	*Eurostopodus diabolicus*	taktarau iblis
	Casuariidae	
279	*Casuarius bennetti*	kasuari kerdil
280	*Casuarius casuarius*	kasuari gelambir-ganda
281	*Casuarius unappendiculatus*	kasuari gelambir-tunggal
	Charadriidae	
282	*Charadrius alexandrinus*	cerek tilil
283	*Charadrius javanicus*	cerek jawa
284	*Charadrius placidus*	cerek paruh-panjang
285	*Charadrius ruficapillus*	cerek topi-merah
286	*Charadrius veredus*	cerek asia
287	*Erythrogonys cinctus*	cerek lutut-merah
288	*Vanellus indicus*	trulek gelambir-merah
289	*Vanellus cinereus*	trulek kelabu
290	*Vanellus macropterus*	trulek jawa
291	*Vanellus miles*	trulek topeng
	Chloropseidae	
292	*Chloropsis media*	cica daun dahi-emas
293	*Chloropsis cochinchinensis*	cica daun sayap-biru
294	*Chloropsis kinabaluensis*	cica daun sayap-biru kalimantan
295	*Chloropsis moluccensis*	cica daun sayap-biru sumatera
296	*Chloropsis cyanopogon*	cica daun kecil
297	*Chloropsis sonnerati*	cica daun besar
298	*Chloropsis venusta*	cica daun sumatera
	Ciconiidae	
299	*Ciconia episcopus*	bangau sandang-lawe
300	*Ciconia stormi*	bangau storm
301	*Ephippiorhynchus asiaticus*	bangau leher-hitam

302	*Leptoptilos javanicus*	bangau tongtong
303	*Mycteria cinerea*	bangau bluwok
	Cnemophilidae	
304	*Cnemophilus loriae*	cenderawasih loria
305	*Cnemophilus sanguineus*	cenderawasih jambul
306	*Loboparadisea sericea*	cenderawasih sutera
	Columbidae	
307	*Caloenas nicobarica*	junai emas
308	*Columba argentina*	merpati hutan perak
309	*Gallicolumba hoedtii*	delimukan wetar
310	*Goura cristata*	mambruk ubiaat
311	*Goura sclaterii*	mambruk selatan
312	*Goura victoria*	mambruk victoria
313	*Ptilinopus dohertyi*	walik rawa-manu
314	*Ptilinopus granulifrons*	walik benjol
315	*Treron psittaceus*	punai timor
316	*Treron teysmannii*	punai sumba
	Corvidae	
317	*Cissa chinensis*	ekek layongan
318	*Cissa thalassina*	ekek geling
319	*Corvus florensis*	gagak flores
320	*Corvus fuscicapillus*	gagak kepala-coklat
321	*Corvus orru*	gagak orru
322	*Corvus splendens*	gagak rumah
323	*Corvus tristis*	gagak kelabu
324	*Corvus typicus*	gagak sulawesi
325	*Corvus unicolor*	gagak banggai
326	*Corvus validus*	gagak halmahera
327	*Crypsirina temia*	tangkar centrong
328	*Dendrocitta cinerascens*	tangkar uli kalimantan
329	*Dendrocitta occipitalis*	tangkar uli sumatera
330	*Platylophus galericulatus*	tangkar ongklet
331	*Platysmurus leucopterus*	tangkar kambing
	Cuculidae	
332	*Carpococcyx viridis*	tokhtor sumatra
333	*Centropus nigrorufus*	bubut jawa
334	*Centropus rectunguis*	bubut teragop
335	*Clamator coromandus*	bubut pacar jambul
336	*Cuculus crassirostris*	kangkok sulawesi
	Estrildidae	
337	*Lonchura vana*	bondol arfak
338	*Lonchura oryzivora*	gelatik jawa
	Falconidae	
339	*Falco berigora*	alap-alap coklat
340	*Falco cenchroides*	alap-alap layang
341	*Falco longipennis*	alap-alap australia
342	*Falco moluccensis*	alap-alap sapi
343	*Falco peregrinus*	alap-alap kawah
344	*Falco severus*	alap-alap macan
345	*Falco subbuteo*	alap-alap walet
346	*Falco tinnunculus*	alap-alap erasia
347	*Microhierax fringillarius*	alap-alap capung
348	*Microhierax latifrons*	alap-alap dahi putih
	Fregatidae	
349	*Fregata andrewsi*	cikalang christmas
350	*Fregata minor*	cikalang besar
	Fringillidae	
351	*Chrysocorythus estherae*	kenari melayu
	Glareolidae	
352	*Glareola maldivarum*	terik asia

353	*Stiltia isabella*	terik australia
	Gruidae	
354	*Antigone rubicunda*	jenjang brolga
	Haematopidae	
355	*Haematopus fuliginosus*	kedidir kelam
356	*Haematopus longirostris*	kedidir belang
	Heliornithidae	
357	*Heliopais personatus*	pedendang topeng
	Hydrobatidae	
356	*Hydrobates matsudairae*	petrel badai matsudairae
357	*Hydrobates monorhis*	petrel badai swinhoe
	Indicatoridae	
358	*Indicator archipelagicus*	pemandulebah asia
	Laridae	
359	*Anous minutus*	camar angguk hitam
360	*Anous stolidus*	camar angguk coklat
361	*Chlidonias hybrida*	dara laut kumis
362	*Chlidonias leucopterus*	dara laut sayap-putih
363	*Gelochelidon nilotica*	dara laut tiram
364	*Gygis alba*	dara laut putih
365	*Hydroprogne caspia*	dara laut caspia
366	*Larus brunnicephalus*	camar kepala-coklat
367	*Larus fuscus*	camar baltik
368	*Larus novaehollandiae*	camar perak
369	*Larus ridibundus*	camar kepala-hitam
370	*Larus schistisagus*	camar punggung-abu
371	*Onychoprion aleuticus*	dara laut aleutian
372	*Onychoprion anaethetus*	dara laut batu
373	*Onychoprion fuscatus*	dara laut sayap-hitam
374	*Onychoprion lunatus*	dara laut fiji
375	*Sterna dougallii*	dara laut jambon
376	*Sterna hirundo*	dara laut biasa
377	*Sterna paradisea*	dara laut arktik
378	*Sterna sumatrana*	dara laut tengkuk-hitam
379	*Sterluna albifrons*	dara laut kecil
380	*Thalasseus bengalensis*	dara laut benggala
381	*Thalasseus bergii*	dara laut jambul
382	*Thalasseus bernsteini*	dara laut cina
383	*Xema sabini*	camar sabine
	Leitotrichidae	
384	*Garrulax bicolor*	poksai sumatra
385	*Garrulax leucolophus*	poksai jambul
386	*Garrulax rufifrons*	poksai kuda
387	*Laniellus albonotatus*	cica matahari
388	*Leiothrix laurinae*	mesia telinga-perak
	Megapodiidae	
389	*Aepypodius arfakianus*	maleo gunung
390	*Aepypodius bruijnii*	maleo waigeo
391	*Eulipoa wallacei*	gosong maluku
392	*Macrocephalon maleo*	maleo senkawor
393	*Megapodius bernsteinii*	gosong sula
394	*Megapodius cumingii*	gosong pilipina
395	*Megapodius decollatus*	gosong papua
396	*Megapodius forstenii*	gosong forsten
397	*Megapodius freycinet*	gosong kelam
398	*Megapodius geelvinkianus*	gosong biak
399	*Megapodius reinwardt*	gosong kaki-merah
400	*Megapodius tenimberensis*	gosong tanimbar
401	*Talegalla cuvieri*	maleo kamur
402	*Talegalla fuscirostris*	maleo paruh-hitam

403	*Talegalla jobiensis*	maleo kerah-coklat
	Meliphagidae	
404	*Macgregoria pulchra*	cendrawasih elok
405	*Melipotes carolae*	melipotes foja
406	*Melipotes fumigatus*	melipotes pipi-kuning
407	*Melipotes gymnops*	melipotes arfak
	Meropidae	
	Meropogon forsteni	cirikcirik Sulawesi
	Monarchidae	
408	*Eutrichomyias rowleyi*	seriwang sangihe
409	*Symposiachrus boanensis*	kehicap boano
410	*Symposiachrus brehmii*	kehicap biak
411	*Symposiachrus everetti*	kehicap tanah-jampea
412	*Symposiachrus julianae*	kehicap kofiau
413	*Symposiachrus sacerdotum*	kehicap flores
	Muscicapidae	
414	*Cyornis concretus*	sikatan besar
415	*Cyornis ruckii*	sikatan aceh
416	*Cyornis sanfordi*	sikatan matinan
417	*Cynornis brunneatus*	sikatan rimba coklat
418	*Muscicapa sodhii*	sikatan rimba sulawesi
	Nectariniidae	
419	*Aethopyga duyvenbodei*	burung madu sangihe
420	*Aethopyga mystacalis*	burung madu jawa
421	*Aethopyga siparaja*	burung madu sepah-raja
422	*Anthreptes rhodolaemus*	burung madu leher-merah
423	*Cinnyris buettikoferi*	burung madu sumba
	Oceanitidae	
424	*Oceanites oceanicus*	petrel-badai coklat
425	*Pelagodroma marina*	petrel-badai muka-putih
	Otididae	
426	*Ardeotis australis*	kalkun padang australia
	Pachycephalidae	
427	*Colluricincla megarhyncha*	anis bentet kecil
428	*Colluricincla sanghirensis*	anis bentet sangihe
	Paradisaeidae	
429	*Astrapia nigra*	astrapia arfak
430	*Astrapia splendidissima*	astrapia cemerlang
431	*Cicinnurus magnificus*	cendrawasih belah-rotan
432	*Cicinnurus regius*	cendrawasih raja
433	*Cicinnurus respublica*	cendrawasih botak
434	*Drepanornis albertisi*	paruh sabit ekor-kuning
435	*Drepanornis bruijnii*	paruh sabit paruh-putih
436	*Epimachus fastosus*	paruh sabit kuri-kuri
437	*Epimachus meyeri*	paruh sabit coklat
438	*Lophorina magnifica*	toowa cemerlang
439	*Lophorina superba*	cendrawasih kerah
440	*Lycocorax obiensis*	cenderawasih gagak-obi
441	*Lycocorax pyrrhopterus*	cendrawasih gagak
442	*Manucodia ater*	manukodia kilap
443	*Manucodia chalybatus*	manukodia leher-keriting
444	*Manucodia jobiensis*	manukodia jobi
445	*Paradigalla brevicauda*	paradigalla ibinimi
446	*Paradigalla carunculata*	paradigalla ekor-panjang
447	*Paradisaea apoda*	cendrawasih besar
448	*Paradisaea minor*	cendrawasih kecil
449	*Paradisaea rubra*	cendrawasih merah
450	*Parotia berlepschi*	parotia foja
451	*Parotia carolae*	parotia carola
452	*Parotia sefilata*	parotia arfak

453	*Phonygammus keraudrenii*	manukodia terompet
454	*Pteridophora alberti*	cendrawasih panji
455	*Seleucidis melanoleucus*	cendrawasih mati-kawat
456	*Semioptera wallacii*	bidadari halmahera
	Pelecanidae	
457	*Pelecanus conspicillatus*	undan kacamata
458	*Pelecanus onocrotalus*	undan putih
459	*Pelecanus philippensis*	undan paruh-totol
	Pellorneidae	
460	*Ptilocichla leucogrammica*	berencet kalimantan
461	*Turdinus macrodactylus*	berencet besar
	Petroicidae	
462	*Petroica archboldi*	robin salju
463	*Petroica bivittata*	robin gunung
	Phaethontidae	
464	*Phaethon lepturus*	buntut sate putih
465	*Phaethon rubricauda*	buntut sate merah
	Phalacrocoracidae	
466	*Anhinga melanogaster*	pecukular asia
	Phalaropodidae	
467	*Phalaropus lobatus*	lakirumbai kecil
	Phasianidae	
468	*Argusianus argus*	kuau raja
469	*Lophura bulweri*	sempidan kalimantan
470	*Pavo muticus*	merak hijau
471	*Polyplectron chalcurum*	kuau kerdil sumatera
472	*Polyplectron schleiermacheri*	kuau kerdil kalimantan
	Picidae	
478	*Mulleripicus fulvus*	pelatuk kelabu-sulawesi
479	*Mulleripicus pulverulentus*	pelatuk kelabu-besar
	Pittidae	
480	*Erythropitta arquata*	paok kalung-biru
481	*Erythropitta dohertyi*	paok dohertyi
482	*Erythropitta granatina*	paok delima
483	*Erythropitta venusta*	paok topi-hitam
484	*Erythropitta caeruleitorques*	paok mopo-sangihe
485	*Erythropitta celebensis*	paok mopo-sulawesi
486	*Erythropitta inspeculata*	paok mopo-talaud
487	*Erythropitta macklotii*	paok mopo-papua
488	*Erythropitta palliceps*	paok mopo-siau
489	*Erythropitta rubrinucha*	paok mopo-amboyna
490	*Erythropitta rufiventris*	paok mopo-sultan
491	*Hydrornis baudii*	paok kepala-biru
492	*Hydrornis caeruleus*	paok sintau
493	*Hydrornis schneideri*	paok schneider
494	*Hydrornis guajanus*	paok pancawarna-jawa
495	*Hydrornis irena*	paok pancawarna-sumatera
496	*Hydrornis schwaneri*	paok pancawarna-kalimantan
497	*Pitta elegans*	paok laus
498	*Pitta maxima*	paok halmahera
499	*Pitta megarhyncha*	paok bakau
500	*Pitta moluccensis*	paok hujan
501	*Pitta morotaiensis*	paok morotai
502	*Pitta nympha*	paok bidadari
503	*Pitta rosenbergii*	paok hijau-biak
504	*Pitta sordida*	paok hijau
505	*Pitta versicolor*	paok lantang
	Podargidae	
506	*Batrachostomus harterti*	paruh-kodok dulit
	Podicipedidae	

507	*Podiceps cristatus*	titihan jambul
508	*Tachybaptus novaehollandiae*	titihan australia
509	*Tachybaptus ruficollis*	titihan jelaga
	Procelariidae	
510	*Ardenna carneipes*	pengguntinglaut kaki-merah
511	*Ardenna pacifica*	pengguntinglaut pasifik
512	*Bulweria bulwerii*	petrel bulwer
513	*Bulweria fallax*	petrel hindia
514	*Calonectris leucomelas*	pengguntinglaut belang
515	*Daption capense*	petrel tanjung
516	*Pachyptila desolata*	petrel antartika
517	*Pseudobulweria rostrata*	petrel tahiti
518	*Pterodorma baraui*	petrel barau
519	*Pterodorma sandwichensis*	petrel galapagos
520	*Puffinus heinrothi*	pengguntinglaut heinroth
	Psittacidae	
521	*Alisterus amboinensis*	nuriraja ambon
522	*Alisterus chloropterus*	nuriraja sayap-kuning
523	*Aprosmictus erythropterus*	nuriraja papua
524	*Aprosmictus jonquillaceus*	nuriraja kembang
525	*Chalcopsitta atra*	nuri hitam
526	*Chalcopsitta duivenbodei*	nuri coklat
527	*Chalcopsitta scintillata*	nuri aru
528	*Charmosyna josefinae*	perkici josephina
529	*Charmosyna multistriata*	perkici garis
530	*Charmosyna papou*	perkici papua
531	*Charmosyna placentis*	perkici dagu-merah
532	*Charmosyna pulchella*	perkici punggung-hitam
533	*Charmosyna rubronotata*	perkici kepala-merah
534	*Charmosyna stellae*	perkici stella
535	*Charmosyna toxopei*	perkici buru
536	*Charmosyna wilhelminae*	perkici kerdil
537	*Cyclopsitta diophthalma*	nuriara mata-ganda
538	*Cyclopsitta gulielmitertii*	nuriara dada-jingga
539	*Cyclopsitta melanogenia*	nuriara pipi-hitam
540	*Cyclopsitta nigrifrons*	nuriara dahi-hitam
541	*Eclectus roratus*	nuri bayan
542	*Eos bornea*	nuri Maluku
543	*Eos cyanogenia*	nuri sayap-hitam
544	*Eos histrio*	nuri talaud
545	*Eos reticulata*	nuri tanimbar
546	*Eos semilarvata*	nuri telinga-biru
547	*Eos squamata*	nuri kalung-ungu
548	*Geoffroyus geoffroyi*	nuri pipi-merah
549	*Geoffroyus simplex*	nuri kalung-biru
550	*Loriculus amabilis*	serindit maluku
551	*Loriculus aurantiifrons*	serindit papua
552	*Loriculus catamene*	serindit sangihe
553	*Loriculus exilis*	serindit paruhmerah
554	*Loriculus flosculus*	serindit flores
555	*Loriculus galgulus*	serindit melayu
556	*Loriculus pusillus*	serindit jawa
557	*Loriculus sclateri*	serindit sula
558	*Loriculus stigmatus*	serindit sulawesi
559	*Lorius domicella*	kasturi tengkuk-ungu
560	*Lorius garrulus*	kasturi ternate
561	*Lorius lory*	kasturi kepala-hitam
562	*Micropsitta bruijnii*	nuri-kate dada-merah
563	*Micropsitta geelvinkiana*	nuri-kate geelvink
564	*Micropsitta keiensis*	nuri-kate topi-kuning

565	*Micropsitta pusio*	nuri-kate pusio
566	*Neopsittacus musschenbroeki*	perkici paruh-kuning
567	*Neopsittacus pullicauda*	perkici paruh-jingga
568	*Oreopsittacus arfaki*	perkici arfak
569	*Prioniturus flavicans*	kringkring dada-kuning
570	*Prioniturus mada*	kringkring buru
571	*Prioniturus platurus*	kringkring bukit
572	*Pseudeos fuscata*	nuri kelam
573	*Psittacella brehmii*	nuri-macan brehm
574	*Psittacella lorentzi*	nuri-macan lorentz
575	*Psittacella madaraszi*	nuri-macan madarasz
576	*Psittacella modesta*	nuri-macan sederhana
577	*Psittacella picta*	nuri-macan berbiru
578	*Psittacula alexandri*	betet biasa
579	*Psittacula longicauda*	betet ekor-panjang
580	*Psittaculirostris cervicalis*	nuri-ara muka-merah
581	*Psittaculirostris desmarestii*	nuri-ara besar
582	*Psittaculirostris edwardsii*	nuri-ara edward
583	*Psittaculirostris godmani*	nuri-ara kuduk-kuning
584	*Psittaculirostris salvadorii*	nuri-ara pipi-kuning
585	*Psitteuteles goldiei*	perkici lembayung
586	*Psitteuteles iris*	perkici iris
587	*Psittinus cyanurus*	nuri tanau
588	*Psittrichas fulgidus*	nuri kabare
589	*Tanygnathus gramineus*	betet-kelapa buru
590	*Tanygnathus lucionensis*	betet-kelapa filipina
591	*Tanygnathus megalorynchos*	betet-kelapa paruh-besar
592	*Tanygnathus sumatranus*	betet-kelapa punggung-biru
593	*Trichoglossus capistratus*	perkici oranye
594	*Trichoglossus euteles*	perkici timor
595	*Trichoglossus flavoviridis*	perkici kuning-hijau
596	*Trichoglossus forsteni*	perkici dada-merah
597	*Trichoglossus haematodus*	perkici pelangi
598	*Trichoglossus meyeri*	perkici kuning-gelap
599	*Trichoglossus ornatus*	perkici dora
600	*Trichoglossus rosenbergii*	perkici biak
601	*Trichoglossus weberi*	perkici flores
	Ptilonorhynchidae	
602	*Ailuroedus buccoides*	burung kucing kuping-putih
603	*Ailuroedus melanotis*	burung kucing tutul
604	*Amblyornis flavifrons*	namdur dahi-emas
605	*Amblyornis inornata*	namdur polos
606	*Amblyornis macgregoriae*	namdur jambul-emas
607	*Archboldia papuensis*	namdur archbold
608	*Chlamydera cerviniventris*	namdur coklat
609	*Chlamydera lauterbachi*	namdur dada-kuning
610	*Sericulus ardens*	namdur api
611	*Sericulus aureus*	namdur topeng
	Pycnonotidae	
612	*Pycnonotus zeylanicus*	cucak rawa
613	*Setornis criniger*	empuloh paruh-kait
	Rallidae	
614	*Amaurornis magnirostris*	kareo talaud
615	*Aramidopsis plateni*	mandar dengkur
616	*Eulabeornis castaneoventris*	mandar bakau
617	*Gymnocrex rosenbergii*	mandar mukabiru
618	*Gymnocrex talaudensis*	mandar talaud
619	*Habroptila wallacii*	mandar gendang
620	*Megacrex inepta*	mandar kasuari
621	*Rallicula forbesi*	mandar gunung koma

622	*Rallicula leucospila*	mandar gunung garis-putih
623	*Rallicula mayri*	mandar gunung mayr
624	*Porzana paykullii*	tikusan siberia
625	*Porzana tabuensis*	tikusan polos
	Recurvirostridae	
626	*Himantopus himantopus*	gagang bayang belang
	Rhipiduridae	
627	*Rhipidura euryura*	kipasan bukit
628	*Rhipidura javanica*	kipasan belang
629	*Rhipidura phoenicura*	kipasan ekor-merah
	Rostratulidae	
630	*Rostratula benghalensis*	berkikkembang besar
	Scolopacidae	
631	*Limnodromus scolopaceus*	trinil-lumpur paruh-panjang
632	*Limnodromus semipalmatus*	trinil-lumpur asia
633	*Numenius arquata*	gajahan erasia
634	*Numenius madagascariensis*	gajahan timur
635	*Numenius minutus*	gajahan kecil
636	*Numenius phaeopus*	gajahan penggala
637	*Scolopax celebensis*	berkikgunung sulawesi
638	*Scolopax rochussenii*	berkikgunung maluku
639	*Scolopax rosenbergii*	berkikgunung papua
640	*Scolopax saturata*	berkikgunung merah
641	*Tringa erythropus*	trinil tutul
642	*Tringa flavipes*	trinil kaki-kuning
643	*Tringa guttifer*	trinil nordmann
644	*Tringa incana*	trinil penjelajah
645	*Tringa ochropus*	trinil hijau
	Stercorariidae	
646	*Catharacta maccormicki*	skua kutub
647	*Stercorarius longicaudus*	camar kejar kecil
648	*Stercorarius parasiticus*	camar kejar arktika
649	*Stercorarius pomarinus*	camar kejar pomarin
	Stirgidae	
650	*Ninox burhani*	pungguk togian
651	*Ninox ios*	pungguk merah-tua
652	*Otus alfredi*	celepuk flores
653	*Otus angelinae*	celepuk jawa
654	*Otus beccarii*	celepuk biak
655	*Otus brookii*	celepuk raja
656	*Otus collari*	celepuk sangihe
657	*Otus enganensis*	celepuk enggano
658	*Otus jolandae*	celepuk rinjani
659	*Otus manadensis*	celepuk sulawesi
660	*Otus mendeni*	celepuk banggai
661	*Otus mentawi*	celepuk mentawai
662	*Otus siaoensis*	celepuk siau
663	*Otus umbra*	celepuk simalur
	Sturnidae	
664	*Achridotheres melanopterus*	jalak putih-sayap hitam
665	*Achridotheres tricolor*	jalak putih - punggung abu
666	*Acridotheres tertius*	jalak putih - tunggir abu
667	*Gracula religiosa*	tiong emas
668	*Gracula robusta*	tiong nias
669	*Gracula venerata*	tiong nusa-tenggara
670	*Gracupica jalla*	jalak suren
671	*Leucopsar rothschildi*	curik bali
	Sulidae	
672	*Papasula abbotti*	angsa-batu christmas
673	*Sula dactylatra*	angsa-batu topeng

674	*Sula leucogaster*	angsa-batu coklat
675	*Sula sula*	angsa-batu kakimerah
	Threskiornithidae	
676	*Platalea regia*	ibis sendok raja
677	*Plegadis falcinellus*	ibis rokoroko
678	*Pseudibis davisoni*	ibis karau
679	*Threskiornis melanocephalus*	ibis cucukbesi
680	*Threskiornis moluccus*	ibis australia
681	*Threskiornis spinicollis*	ibis papua
	Timaliidae	
682	*Stachyris grammiceps*	tepus dada-putih
	Trogonidae	
683	*Apalharpactes reinwardtii*	luntur jawa
684	*Apalharpactes mackloti*	luntur sumatera
685	*Harpactes oreskios*	luntur diard
686	*Harpactes orrhophaeus*	luntur putri
687	*Harpactes duvaucelli*	luntur kepala-merah
688	*Harpactes diardii*	luntur kasumba
689	*Harpactes erythrocephalus*	luntur harimau
690	*Harpactes whiteheadi*	luntur tunggir-coklat
691	*Harpactes kasumba*	luntur kalimantan
	Turdidae	
692	*Cochoa azurea*	ciung-mungkal jawa
693	*Kittacincla malabarica*	kucica Hutan
694	*Cochoa beccarii*	ciung-mungkal sumatera
	Turnicidae	
695	*Turnix everetti*	gemak sumba
	Tytonidae	
696	*Tyto inexspectata*	serak minahasa
697	*Tyto nigrobrunnea*	serak taliabu
	Zosteropidae	
698	*Heleia javanica*	opior jawa
699	*Zosterops flavus*	kacamata jawa
700	*Zosterops nehrkorni*	kacamata sangihe
701	*Heleia wallacei*	kacamata wallacea
III. AMPHIBI		
	Bufonidae	
702	*Leptophryne cruuentata*	kodok merah
IV. REPTIL		
	Agamidae	
703	*Chlamydosaurus kingii*	soa payung
	Carettochelyidae	
704	*Carettochelys insculpta*	labi-labi moncong babi
	Chelidae	
705	*Chelodina mccordii*	kura-kura rote
706	*Chelodina novaeguineae*	kura-kura papua leher panjang
	Cheloniidae	
707	*Caretta caretta*	penyu bromo
708	*Chelonia mydas*	penyu hijau
709	*Eretmochelys imbricata*	penyu sisik
710	*Lepidochelys olivacea*	penyu lekang
711	*Natator depressus*	penyu pipih
	Crocodilidae	
712	*Crocodylus novaeguineae*	buaya irian
713	*Crocodylus porosus*	buaya muara
714	*Crocodylus siamensis*	buaya siam
715	*Tomistoma schlegelii*	buaya sinyulong
	Dermochelyidae	
716	*Dermochelys coriacea*	penyu belimbing
	Geoemydidae	

717	*Batagur affinis*	biuku
718	*Batagur borneoensis*	beluku
719	*Orlitia borneensis*	bajuku
	Lanthanotidae	
720	*Lanthanotus borneensis*	biawak kalimantan
	Pythonidae	
721	*Malayophython timoriensis*	sanca timor
722	*Morelia viridis*	sanca hijau
723	*Python bivittatus*	sanca bodo
724	*Simalia boeleni*	sanca bulan
	Testudinidae	
725	*Manouria emys*	baning coklat
	Trionychidae	
726	*Chitra chitra*	labi-labi bintang
	Varanidae	
727	*Varanus auffenbergi*	biawak rote
728	*Varanus beccari*	biawak aru
729	*Varanus boehmei*	biawak waigeo
730	*Varanus indicus*	biawak maluku
731	*Varanus komodoensis*	biawak komodo
732	*Varanus melinus*	biawak banggai
733	*Varanus nebulosus*	biawak abu-abu
734	*Varanus panoptes*	biawak coklat
735	*Varanus prasinus*	biawak hijau
736	*Varanus reisingeri*	biawak misool
737	*Varanus similis*	biawak kerdil
738	*Varanus timorensis*	biawak timor
739	*Varanus togianus*	biawak togian
V. IKAN		
	Balitoridae	
740	*Homaloptera gymnogaster*	selusur maninjau
	Cyprinidae	
741	*Balantiocheilos melanopterus*	ikan balashark
742	*Barbodes microps*	wader goa
743	*Neolissochilus thienemanni*	ikan batak
744	*Schismatorhynchus heterorhynchus*	pasa
	Dasyatidae	
745	*Himantura oxyrhyncha*	pari sungai tutul
746	*Himantura polylepis*	pari sungai raksasa
747	*Himantura signifer*	pari sungai pinggir putih
748	*Urolophus kaianus*	pari kai
	Latimeridae	
749	*Latimeria menadoensis*	ikan raja laut
	Notopteridae	
750	*Chilata borneensis*	belida borneo
751	*Chilata hypselonotus*	belida sumatra
752	*Chilata lopis*	belida lopis
753	*Notopterus notopterus*	belida jawa
	Ostoglossidae	
754	*Scleropages formosus*	siluk kalimantan
755	*Scleropages jardinii*	siluk irian
	Pristidae	
756	*Anoxypristis cuspidata*	pari gergaji lancip
757	*Pristis clavata*	pari gergaji kerdil
758	*Pristis pristis*	pari gergaji gigi besar
759	*Pristis zijsron*	pari gergaji hijau
VI. SERANGGA		
	Nymphalidae	
760	*Cethosia myrina*	kupu-kupu bidadari
	Papilonidae	

761	*Ornithoptera aesacus*	kupu-kupu sayap burung obi
762	*Ornithoptera chimaera*	kupu-kupu sayap burung chimaera
763	*Ornithoptera croesus*	kupu-kupu sayap burung wallace
764	*Ornithoptera goliath*	kupu-kupu sayap burung goliath
765	*Ornithoptera meridionalis*	kupu-kupu sayap burung meridionalis
766	*Ornithoptera paradisea*	kupu-kupu sayap burung surga
767	*Ornithoptera priamus*	kupu-kupu sayap burung priamus
768	*Ornithoptera rothschildi*	kupu-kupu sayap burung rothschildi
769	*Ornithoptera tithonus*	kupu-kupu sayap burung tithonus
770	*Trogonoptera brookiana*	kupu-kupu raja brooke
771	*Troides amphrysus*	kupu-kupu raja malaya
772	*Troides andromache*	kupu-kupu raja borneo
773	*Troides criton*	kupu raja criton
774	*Troides cuneifera*	kupu-kupu raja cuneifera
775	*Troides dohertyi*	kupu-kupu raja talaud
776	*Troides haliphron*	kupu-kupu raja haliphron
777	*Troides helena*	kupu-kupu raja helena
778	*Troides hypolitus*	kupu-kupu raja hypolitus
779	*Troides miranda*	kupu-kupu raja miranda
780	*Troides oblongomaculatus*	kupu-kupu raja oblongomaculatus
781	*Troides plato*	kupu-kupu raja Timor
782	*Troides prattorum*	kupu-kupu raja prattorum
783	*Troides riedeli*	kupu-kupu raja tanimbar
784	*Troides vandepolli*	kupu-kupu raja vandepolli
785	*Troides meoris*	
VII. KRUSTASEA		
	Coenobitidae	
786	*Birgus latro*	ketam kenari
VIII. MOLUSKA		
	Cassidae	
787	*Cassis cornuta*	kepala kambing
	Nautilidae	
788	*Nautilus pompilius* **Linne, 1758**	nautilus berongga
	Ranellidae	
789	*Charonia tritonis*	triton terompet
	Tridacnidae	
790	*Hippopus hippopus*	kima tapak kuda
791	*Hippopus porcellanus*	kima cina
IX. XIPHOSURA (KETAM TAPAL KUDA)		
	Limulidae	
792	*Tachipleus gigas*	belangkas besar
793	*Tachipleus tridentatus*	belangkas tigaduri
794	*Carcinoscorpius rotundicauda*	belangkas padi
X. TUMBUHAN		
	ARACEAE	
795	*Amorphophallus decus-silvae*	acung jangkung
796	*Amorphophallus titanum*	bunga bangkai raksasa
	ARAUCARIACEAE	
797	*Agathis borneensis*	damar pilau
798	*Agathis labillardieri*	damar putih
	ARECACEAE	
799	*Borassodendron borneense*	bindang
800	*Caryota no*	palem ekor ikan
801	*Ceratolobus glaucescens*	palem jawa
802	*Johannesteijsmannia altifrons*	daun sang gajah
803	*Pigafetta filaris*	wanga
804	*Pinanga javana*	pinang jawa
	ASTERACEAE	

805	*Anaphalis javanica*	edelweis
	DIPTEROCARPACEAE	
806	*Dipterocarpus cinereus*	palahlar mursala
807	*Dipterocarpus littolaris*	palahlar nusakambangan
808	*Upuna borneensis*	upan
809	*Vatica bantamensis*	kokoleceran
810	*Vatica javanica*	resak jawa
	FAGACEAE	
811	*Castanopsis argentea*	saninten
	LAURACEAE	
812	*Beilschmiedia madang*	medang lahu
813	*Eusideroxylon zwageri*	ulin
	LEGUMINOSAE	
814	*Intsia palembanica*	kayu besi maluku
815	*Koompassia excelsa*	kempas kayu raja
816	*Koompassia malaccensis*	kempas malaka
	MALVACEAE	
817	*Camptostemon philippinense*	kayu baluno filipina
818	*Heritiera globosa*	dungun besar
	NEPENTHACEAE	
819	*Nepenthes adnata*	kantong semar menggala
820	*Nepenthes adrianii*	kantong semar slamet
821	*Nepenthes albomarginata*	kantong semar bibir putih
822	*Nepenthes aristolochioides*	kantong semar guci
823	*Nepenthes bicalcarata*	kantong semar taji dua
824	*Nepenthes bongso*	kantong semar putri bungsu
825	*Nepenthes boschiana*	kantong semar daun sompitan
826	*Nepenthes campanulata*	kantong semar lonceng
827	*Nepenthes clipeata*	kantong semar kelam
828	*Nepenthes danseri*	kantong semar danser
829	*Nepenthes densiflora*	kantong semar bibir seksi
830	*Nepenthes diatas*	kantong semar bandahara
831	*Nepenthes dubia*	kantong semar tutup lidah
832	*Nepenthes ephippiata*	kantong semar pelana
833	*Nepenthes epiphytica*	kantong semar epifit
834	*Nepenthes eustachya*	kantong semar rumah siput
835	*Nepenthes eymae*	kantong semar cawan
836	*Nepenthes fusca*	kantong semar tutup kunci
837	*Nepenthes glabrata*	kantong semar gundul
838	*Nepenthes gymnamphora*	kantong semar pinggang seksi
839	*Nepenthes hamata*	kantong semar tutup bersungut
840	*Nepenthes hirsuta*	kantong semar daun berbulu
841	*Nepenthes hispida*	kantong semar bulu sikat
842	*Nepenthes inermis*	kantong semar trombon
843	*Nepenthes insignis*	kantong semar bibir lebar
844	*Nepenthes izumiae*	kantong semar Izumi
845	*Nepenthes jacquelineae*	kantong semar Jaklin
846	*Nepenthes jamban*	kantong semar jamban
847	*Nepenthes klossii*	kantong semar antariksa
848	*Nepenthes lamii*	kantong semar Lam
849	*Nepenthes lavicola*	kantong semar lahar
850	*Nepenthes lingulata*	kantong semar lidah panjang
851	*Nepenthes lowii*	kantong semar kukusan
852	*Nepenthes mapuluensis*	kantong semar mapulu
853	*Nepenthes maxima*	kantong semar maksimum
854	*Nepenthes mikei*	kantong semar pangulubao
855	*Nepenthes mollis*	kantong semar kemal
856	*Nepenthes naga*	kantong semar naga
857	*Nepenthes neoguineensis*	kantong semar sayap rumbai

858	*Nepenthes nigra*	kantong semar hitam
859	*Nepenthes ovata*	kantong semar bibir merekah
860	*Nepenthes paniculata*	kantong semar malai
861	*Nepenthes papuana*	kantong semar papua
862	*Nepenthes pectinata*	kantong semar bersisir
863	*Nepenthes pilosa*	kantong semar meroma
864	*Nepenthes pitopangii*	kantong semar gading
865	*Nepenthes rhombicaulis*	kantong semar belah ketupat
866	*Nepenthes rigidifolia*	kantong semar daun kaku
867	*Nepenthes singalana*	kantong semar singgalang
868	*Nepenthes spathulata*	kantong semar spatula
869	*Nepenthes spectabilis*	kantong semar bibir bergaris
870	*Nepenthes stenophylla*	kantong semar daun sempit
871	*Nepenthes sumatrana*	kantong semar sayap alur
872	*Nepenthes tentaculata*	kantong semar bersungut
873	*Nepenthes tobaica*	kantong semar toba
874	*Nepenthes tomoriana*	kantong semar tomori
875	*Nepenthes treubiana*	kantong semar Treub
876	*Nepenthes undulatifolia*	kantong semar daun gelombang
877	*Nepenthes veitchii*	kantong semar kerah lebar
	ORCHIDACEAE	
878	*Cymbidium hartinahianum*	anggrek ibu Tien
879	*Paphiopedilum gigantifolium*	anggrek kasut raksasa
880	*Paphiopedilum glanduliferum*	anggrek kasut berkelenjar
881	*Paphiopedilum glaucophyllum*	anggrek kasut berbulu
882	*Paphiopedilum kolopakingii*	anggrek kasut Kolopaking
883	*Paphiopedilum liemianum*	anggrek kasut Liem
884	*Paphiopedilum mastersianum*	anggrek kasut master
885	*Paphiopedilum nataschae*	anggrek kasut Natascha
886	*Paphiopedilum primulinum*	anggrek kasut kuning
887	*Paphiopedilum robinsonianum*	anggrek kasut Robinson
888	*Paphiopedilum sangii*	anggrek kasut Sang
889	*Paphiopedilum supardii*	anggrek kasut Supardi
890	*Paphiopedilum victoria-mariae*	anggrek kasut maria
891	*Paphiopedilum victoria-regina*	anggrek kasut regina
892	*Paphiopedilum violacens*	anggrek kasut ungu
893	*Paphiopedilum wilhelminae*	anggrek kasut Wilhelmina
894	*Paraphalaenopsis denevei*	anggrek ekor tikus deNevi
895	*Paraphalaenopsis labukensis*	anggrek tikus labuk
896	*Paraphalaenopsis laycockii*	anggrek ekor tikus Laycock
897	*Paraphalaenopsis serpentilingua*	anggrek ekor tikus lidah ular
898	*Phalaenopsis bellina*	anggrek kelip
899	*Phalaenopsis celebensis*	anggrek bulan sulawesi
900	*Phalaenopsis floresensis*	anggrek bulan flores
901	*Phalaenopsis gigantea*	anggrek bulan raksasa
902	*Phalaenopsis javanica*	anggrek bulan jawa
903	*Phalaenopsis sumatrana*	anggrek bulan sumatera
904	*Vanda celebica*	anggrek vanda mungil minahasa
905	*Vanda sumatrana*	anggrek vanda sumatera
	RAFFLESIACEAE	
906	*Rafflesia arnoldii*	rafflesia raksasa
907	*Rafflesia bengkuluensis*	rafflesia bengkulu
908	*Rafflesia gadutensis*	rafflesia gadut
909	*Rafflesia hasseltii*	tindawan biring
910	*Rafflesia lawangensis*	rafflesia lawang
911	*Rafflesia meijeri*	rafflesia Meyer
912	*Rafflesia micropylora*	rafflesia mulut kecil
913	*Rafflesia pricei*	rafflesia Prise
914	*Rafflesia rochussenii*	perud kibarera

915	*Rafflesia tuan-mudae*	bunga pakma
916	*Rafflesia zollingeriana*	patma, kembang banyu
917	*Rafflesia patma*	patmo sari
918	*Rafflesia kemumu*	rafflesia kemumu
	SIMAROUBACEAE	
919	*Eurycoma apiculata*	pasak bumi daun runcing
	TAXACEAE	
920	*Taxus sumatrana*	taksus
	THYMELAEACEAE	
921	*Aetoxylon sympetalum*	gaharu buaya

Salinan sesuai dengan aslinya
KEPALA BIRO HUKUM,

ttd

KRISNA RYA

MENTERI LINGKUNGAN HIDUP DAN
KEHUTANAN REPUBLIK INDONESIA,

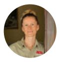
ttd

SITI NURBAYA

Exhibit 37

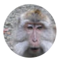
Conservation of Long-tailed Macaques: Implications of the Updated IUCN Status and the CoVID-19 Pandemic

Article *in* Primate Conservation February 2021



Malene Friis Hansen
Princeton University

Susan Cheyne
Oxford Brookes University



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Conservation of Long-tailed Macaques: Implications of the Updated IUCN Status and the CoVID-19 Pandemic

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Abstract: The often synanthropic long-tailed macaque (*Macaca fascicularis*) is listed in Appendix II of CITES and was recently updated to Vulnerable on the IUCN Red List. The update was highly anticipated, as it can have wide-reaching implications for long-tailed macaque conservation and trade. Long-tailed macaques have suffered from intensive capture for biomedical research since the 1960s. From 2008–2019, at least 450,000 live long-tailed macaques, and over 700,000 "specimens" from an unknown number of individuals were part of this trade, with over 50,000 termed as wild-caught. These official trade numbers exclude laundering of wild-caught individuals as captive bred, harvesting for breeding center upkeep, their capture for the pet trade, hunting for consumption, and culling due to human-macaque conflicts. With Fooden's population estimate of 3 million long-tailed macaques in Southeast Asia in 2006, this is likely not sustainable. In some areas, they have already been extirpated because of this trade, as detected by a survey of 200 km of suitable habitat in Cambodia in 2008. Long-tailed macaques are one of the most geographically widely dispersed and adaptable primate species. However, their flexibility and preference for the forest edge draws them to anthropogenic habitats, where their visibility results in assumptions of over-abundance, as was demonstrated on Java in 2009 and 2017. Long-tailed macaques face many threats, and there is an urgent need for systematic demographic and range surveys across Southeast Asia, as well as investigation into local, regional and national perceptions of long-tailed macaques. Current conservation foci should include dynamic widespread synanthropic species, such as long-tailed macaques, which are often targets of intensive trade and other threats. Insights from such studies may be critical for effective conservation and management in the 21st century.

Keywords: Primates**,** CoVID-19, population decline, synanthrope, trade, conservation status

Introduction

In 2008, Ardith Eudey, co-founder of the International Primate Protection League and long-time chair of the Asia section of the IUCN Primate Specialist Group, raised concerns at the International Primatological Society's presentation of the "World's 25 Most Endangered Primates" regarding the declining populations and increasing threats to long-tailed macaques *Macaca fascicularis* (Raffles, 1821). This was consolidated and expanded upon in a paper "The crab-eating macaque (*Macaca fascicularis*): widespread and rapidly declining" published by Eudey in *Primate Conservation* in 2008. In 2015, she again raised the alarm bells at another meeting of the International Primatological Society, and it is now recognized that, as a species, long-tailed macaques meet the criteria for them to be listed as Vulnerable on the IUCN Red List (Eudey *et al*. 2020). In January 2021, three of the nine *M. fascicularis* subspecies were also listed as Vulnerable on the IUCN Red List—the nominate subspecies *Macaca f. fascicularis*, the Con Son long-tailed macaque *M. f. condorensis*, and the Nicobar Islands long-tailed macaque *M. f. umbrosa*. The remaining six, all island forms, were listed as Data Deficient (Table 1). The new update for this species has the potential to increase attention to the burgeoning plight of the species and, with that, the funding needed for urgent research initiatives and conservation measures.

A comprehensive compilation of long-tailed macaque behavior, ecology, management, and interactions with humans was published a decade ago (Gumert *et al*. 2011a). Subsequent research and anecdotal evidence suggests that long-tailed macaque populations are decreasing in various parts of their range (Kyes *et al*. 2011; Lee 2011; Hansen *et al*. 2019). For instance, in 2008 in Cambodia, a survey of suitable habitats and meat markets found no long-tailed macaques (Lee 2011), and a survey on the Indonesian island of Java found apparently suitable forests to be devoid of long-tailed macaques (Kyes *et al*. 2011). Overall, however, the species is still perceived as abundant (Eudey *et al*. 2020), but researchers have speculated that the presence of long-tailed macaques in anthropogenic areas may lead to overestimation of their population size (for example, Kyes *et al*. 2011). A recent survey in East Java did find that extrapolating road densities to non-anthropogenic areas leads to overestimation of population size. Estimated density, when extrapolated from road and trail observations only was 1,449 individual/km², whereas the estimated density from a survey covering all habitats (non-anthropogenic and anthropogenic) was only 41 individuals/km² (Hansen *et al*. 2019). In anthropogenic landscapes, densities of provisioned long-tailed macaques range from 67 individuals/km² in Vietnam (Son 2004) to ~600 individuals/km² in Bali, Indonesia (Brotcorne 2014) and ~800 individuals/km² in East Java, Indonesia (Hansen *et al*. 2020a) with a mean of 100 individuals/km² across Southeast Asia (Fooden 1995). Densities of non-provisioned populations in non-anthropogenic landscapes range from 25 individuals/km² in East Java, Indonesia (Hansen *et al*. 2020a) and 70 individuals/km² in Bali (Brotcorne 2014) to 10–143 individuals/km² in Sumatra (Fooden 1995; Yanuar *et al.* 2009) with a mean across Southeast Asia of 55 individuals/km² (Fooden 1995). Semi-provisioned populations in Singapore were found to range from 1–34 individuals/km² (Sha *et al*. 2009; Riley *et al*. 2015). Comparing the above densities underlines the disparity between habitats with varying degrees of anthropogenic influence. Extrapolating densities between non-anthropogenic habitats

Table 1. Conservation status and distribution of the nine subspecies of long-tailed macaques (Fooden, 1995; Eudey *et al*. 2020). CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern; DD = Data Deficient.

Popular name	Scientific name	2008 RL status	2015 PSG Asia recommendation*	2020 RL status**	Geographic location	Population size	Population trend
Long-tailed macaque	*Macaca fascicularis*	LC	VU	VU	-	Unknown	Declining
Common long-tailed macaque	*M. fascicularis fascicularis*	LC	VU	VU	Indonesia, Malaysia, Philippines, Thailand, Cambodia, Singapore, Vietnam	Unknown	Declining
Dark-crowned long-tailed macaque	*M. fascicularis atriceps*	DD	VU	DD	Khram Yai Island, Thailand	Unknown	Unknown
Burmese long-tailed macaque	*M. fascicularis aurea*	DD	DD	DD	Myanmar, Bangladesh, Laos, western and southern Thailand near the Myanmar border	Unknown	Unknown
Con Son long-tailed macaque	*M. fascisularis condorensis*	VU	EN	VU	Con Son Island, Hon Ba Island, Vietnam	<1000 individuals on Con Son. Suspected to be the same on Hon Ba	Declining
Simeulue long-tailed macaque	*M. fascicularis fusca*	DD	LC	DD	Simeulue Island, Indonesia	Unknown	Unknown
Lasia long-tailed macaque	*M. fascicularis lasiae*	DD	DD	DD	Lasia Island, Indonesia	Unknown	Unknown
Karimunjawa long-tailed macaque	*M. fascicularis karimondjawae*	DD	CR	DD	Karimunjawa Islands, Indonesia	<500 individuals***	Declining
Maratua long-tailed macaque	*M. fascicularis tua*	DD	DD	DD	Maratua Island, Indonesia	Unknown	Unknown
Nicobar long-tailed macaque	*M. fascicularis umbrosa*	VU	EN	VU	Nicobar Islands, India	958 individuals in two of the three islands****	Declining

*IUCN SSC PSG (2015), **IUCN Red List 31 December 2020, ***Afendi *et al*. (2011), ****Saren *et al*. (2019)

may also be problematic as habitat preference and selection varies (for example, Hansen *et al*. 2019, 2020a) and density patterns are not continuous (for example, with most long-tailed macaques found within 1 km of river edges in Tanjung Putting National Park, Kalimantan, Indonesia: Gumert *et al.* 2012).

Incorrect extrapolations and overestimation of long-tailed macaque population sizes may be occurring across their range, and systematic surveys are needed to assess their true population size to ensure that policy makers are correctly informed when creating management plans for the species. In Thailand, researchers have called for urgent research into the status of the long-tailed macaque and for the creation of conservation measures after they found long-tailed macaque habitat preference to have changed from forests to temples and recreation areas (Malaivijitnond and Hamada 2008). In Penang National Park in Malaysia, long-tailed macaques were found to only inhabit beaches and not forests, which researchers recommended be considered in management strategies (Qiao and Ruppert 2017).

In the following, we outline the main threats faced by long-tailed macaques, and we end with an outline of what we wish to achieve in the future, and what we recommend for other long-tailed macaque researchers to focus on—all to ensure future conservation and management initiatives that are based on scientific evidence, so as to avoid that the long-tailed macaque comes to face the same fate as other abundant species, such as the Siamese crocodile (*Crocodylus siamensis*), the Black-winged Myna (*Acridotheres melanopterus*) and the Passenger pigeon (*Ectopistes migratorius*). The Siamese crocodile and the Black-winged Myna are Critically Endangered in the wild having experienced dramatic declines because of trade (Bezuijen *et al*. 2012; BirdLife International 2018) and both have captive populations in breeding facilities that outnumber the wild populations (Thorbjarnarnson 1992; Nijman *et al*. 2018). The once ubiquitous passenger pigeon began to disappear with little fanfare, or notice, until it was clearly on the path towards extinction (Schorger 1955).

Distribution

The long-tailed macaque is distributed across Southeast Asia (Fooden 1995; Eudey *et al*. 2020) (Table 1). Formerly with 10 subspecies, the Philippine long-tailed macaque, *M. f. philippinensis* (I. Geoffroy Saint-Hilaire, 1843), listed by Groves (2001) was found to be insufficiently genetically differentiated (Smith *et al.* 2014; Liedigk *et al.* 2015) and is now considered to be a junior synonym of *M. f. fascicularis*. Information on population size and distribution and genetic and cultural diversity is insufficient or lacking for the nine remaining subspecies, yet highly needed to ensure effective conservation measures (Gumert *et al.* 2011b). Due to their synanthropic nature, long-tailed macaques are distributed in both anthropogenic and non-anthropogenic areas, and therefore often not reliant on protected areas. In Vietnam, however, they might only be found in protected areas because of severe hunting (Son *et al*. 2009). Although we refer to the long-tailed macaque as a species in this paper, from a practical and management perspective, conservation initiatives will also have to be targeted at the smaller geographical scales including the seven insular subspecies and otherwise geographically restricted regions.

For the species' global distribution, we still largely rely on the maps published by Fooden (1995), which were based on field surveys in the 1970s and 1980s and, for many areas, on museum collections. The range map used by the IUCN Red List (Ong and Richardson 2008; Eudey *et al*. 2020) is an updated version of the Fooden map. A more recent distribution map is not available, however the Species Survival Network (2012) indicated that several populations across the range of long-tailed macaques, especially island populations may well be decimated.

Flexibility and Ecological Roles

Long-tailed macaques are able to inhabit diverse habitats, including deciduous forests, evergreen forests, savannah, mangroves and beaches, from sea level to at least 1900 m asl (Fooden 1995; Thierry 2007; Yanuar *et al*. 2009; Gumert *et al*. 2011a). Tool use has been observed in several long-tailed macaque communities (Gumert and Malaivijitnond 2012; Gumert *et al*. 2013), and substantial behavioral and "cultural" diversity within the species reflects the significant ecological and behavioral flexibility and adaptability of long-tailed macaques (Gumert *et al*. 2011a).

This flexibility and adaptability allows them to occupy several ecological roles across diverse ecosystems, as, for example, seed dispersers as well as predators and prey (Seidensticker and Suyono, 1980; Corlett and Lucas, 1990; Gumert and Malaivijitnond, 2012), and to engage in polyspecific associations (Hansen *et al*. 2020b). It also enables them to recover from natural disasters, such as tsunamis (Velankar *et al*. 2016). They consume a wide variety of food, and can also thrive on human foods (Sha and Hanya 2013). Long-tailed macaques aid in seed dispersal and, thereby, habitat regeneration (Corlett and Lucas 1990; Lucas and Corlett 1998).

Overlap with Humans

Long-tailed macaques are faced with numerous threats. Many are the same as those of non-synanthropic species, yet many are a direct effect of their presence in human-influenced areas. Threats vary depending on subspecies and subpopulation, and include, but not exclusively, habitat loss and degradation, logging, mining, aquaculture and agriculture, large-scale plantations and hydropower development, illegal and legal domestic and international trade, human expansion and urbanization, including dependence on human foods and conflicts with humans, hunting and poaching, genetic pollution and diseases from introduced macaques, use in traditional medicine, persecution as pests, and tourism activities (Eudey 2008; Eudey *et al*. 2020).

Long-tailed macaques are able to exploit anthropogenic areas across much of their range. They include cities, villages, roads, tourist sites, agriculture, and temple sites (Fooden 1995; Muroyama and Eudey 2004; Gumert *et al*. 2011a). In anthropogenic areas, long-tailed macaques are often provisioned, which increases population sizes locally. In these circumstances they face human-macaque interactions, and risks of bi-directional pathogen transfer and other health issues, creating a platform for a range of conflict possibilities (Engel *et al*. 2002; Chapman *et al*. 2005; Lane *et al*. 2010; Hambali *et al*. 2012; Ilham *et al*. 2017). In urban and recreational areas, long-tailed macaques are often provisioned on roads and therefore risk collision with vehicles. In Malaysia, a study found that long-tailed macaques endured the second highest number of animal-vehicle collisions of all species surveyed (Kasmuri *et al*. 2020).

Governments in countries with human-macaque conflicts are tasked with mitigating them, often with negative consequences for the macaques. In the last ten years, both Malaysia and Singapore initiated substantive culling actions against the macaques, with Singapore culling approximately one-third of their population in 2013 and 2015 according to Agri-Food and Veterinary Authority reports (for example, Riley *et al*. 2015). In 2017, the Indonesian Ministry of Forestry and Environment created a macaque-conflict mitigation task force and called for data on conflicts across Indonesia (R. M. Wiwied Widodo pers. comm. 2018). While these data have yet to be released, the government issued a statement in 2018 allowing the culling of long-tailed macaques in conflict zones (Hardiyanto 2018). Even though population sizes of long-tailed macaques are widely unknown, culling is a reoccurring practice across their range, and the number of individuals culled is often not revealed (Riley *et al*. 2015). The long-term implications of removing individuals from groups through culling and other forms of population control, harmful human activities such as trapping, and human-macaque interactions have yet to be fully investigated and understood. Whether it be selecting individuals randomly or targeting certain personalities, it may affect the population, possibly changing group dynamics, affecting individual health, changing selection pressure and survival rates, and reducing cultural variability (Gumert *et al*. 2011b). While understanding the behaviors of individuals is believed to increase the effectiveness of certain wildlife management strategies that are destined to reduce human-wildlife conflict (Balasubramaniam *et al*. 2020), this would involve studying populations in greater detail than is common for long-tailed macaque populations in conflict situations.

Human-macaque conflict task forces have been created in Thailand and in Singapore involving governments, NGOs and researchers collaborating to resolve human-macaque conflicts and sharing knowledge on macaque behavior (Tan 2017; JGI 2020; New York Times 2020). In Sumatra, researchers have called for more research into the effects of provisioning and management on urban macaque populations to avoid conflicts from escalating (Ilham *et al*. 2017).

Long-tailed macaques captured from the wild are also used in aspects of popular entertainment. As an example, the "*Topeng Monyet*" or "Masked Monkey," which consists of the use of macaques for street performances. *Topeng monyet* is a folkloric tradition in Java, and until recently hundreds of macaques were used by its practitioners, but it is now an illegal practice in Jakarta (2013) and in East Java Province (2015) (Jakarta Animal Aid Network – JAAN 2019; Rahman 2019). What effect this specific practice has had on wild macaques is unknown, but it is likely that it either added to their capture in the wild or added to the demand for them in local animal markets, or both.

Perception as Pests

The interface with humans has led to long-tailed macaques being classified as pests and as a 'weed species' (Richard *et al*. 1989; Muroyama and Eudey 2004). Richard *et al*. (1989) divided the different species of macaques into weed or non-weed species according to their ability to exploit human-influenced areas. They were aware that this could cause negative connotations yet may not have known that the classification would last. Terminology applied by researchers regarding macaques may have important psychological and practical impacts on the field, discouraging students and others from focusing on this species, and restricting access to funding for their study (in behavioral, ecological and conservation contexts). Terminology such as weeds and pests might also affect local communities and tourists, convincing them that this species is not in need of conservation efforts or attention.

Studies on the ecology of non-provisioned long-tailed macaques are few and of older origin (for example, Van Schaik *et al*. 1983; Corlett and Lucas 1990; Fooden 1995; Engelhardt *et al.* 2005). Long-tailed macaques are perceived as common, and this may reduce conservation and research efforts (Radhakrishna and Sinha 2011). Primate conservation funding tends to prioritize primates classified as threatened with extinction, and the classification as 'Least Concern' on the IUCN Red List until now (Ong and Richardson 2008) has undoubtedly contributed to a lack of funding for research on this species (Gumert 2011).

The use of negative terminology regarding long-tailed macaques in media, may be another important trigger of negative perceptions and connotations amongst the public. For instance, from 166 news items about long-tailed macaques collected from Indonesian media sources between 2017 and the present, only 30 were considered to invoke positive connotations (Karmele L. Sanchez pers. obs.). With the use of words in headlines such as "attack," "bite," and "destroy" in the interface context, media might

Figure 1. Female common long-tailed macaque (*Macaca fascicularis fascicularis*) grooming an infant. Baluran National Park, East Java, Indonesia. Photograph by Ventie Angelia Nawangsari.

be perpetuating a perception of macaques as dangerous pests. We are currently looking into media presentation of long-tailed macaques in Hong Kong, and so far, results are similar to those from Indonesia (Chris Pawson pers. comm. 2019).

The Legal Trade

The international primate trade peaked in many countries across Southeast Asia in the decades up to and including the 1970s with, for instance, India alone exporting ~50,000 live wild-caught primates per year throughout the 1960s (Nijman *et al*. 2011). While the international trade in all primate species has been regulated since the ratification of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the legal and illegal trade in primates remains a significant threat to primate species throughout Southeast Asia (Nijman and Healy 2016; Estrada *et al*. 2017). In a survey conducted by Shepherd (2010) on primate trade in Indonesian wildlife markets between 1997 and 2008, long-tailed macaques were found to be the most heavily traded primate species. Similarly, Nijman *et al*. (2017) reported that this species was the most traded in Indonesian wildlife markets between 2012 and 2014. The long-tailed macaque is the predominant species in the international trade in live primates for research. From 2008–2019, at least 450,000 live long-tailed macaques (captive and wild-caught), and over 700,000 specimens (a broad-ranging term that can include tissue or blood samples, body parts or hair) from an unknown number of long-tailed macaques were part of this trade, with over 50,000 identified as wild-caught (specimens and live) (CITES Trade Database 2021). Indonesia started the export of macaques for biomedical research in the early 1970s, peaking in the late 1980s, which motivated the establishment of farms and breeding facilities across Indonesia to supply the growing industry (Shepherd 2010). In 2009, trapping of wild-caught individuals for breeding center upkeep and national research increased, with permits to trap 15,100 individuals (5,100 in 2008) (SSN 2012). Local communities, however, said that often more individuals were caught than allowed (BUAV 2009; SSN 2012). Since 2016, the quota for wild-caught macaques in Indonesia has been zero (KLHK 2020) but, in 2019, the Ministry of Forestry and Environment in Indonesia revealed a desire to conduct the capture of wild long-tailed macaques from conflict areas to be exported abroad (Karmele L. Sanchez pers. obs.). The Philippines also intends to reinitiate the harvesting of wild long-tailed macaques for breeding centers (BM 2020). This may not be sustainable, and research into the population status and attempts to mitigate these conflicts should commence as soon as possible.

The trade uses biomedical purposes as the main reason for the exploitation of macaques, although trade demand in Indonesia is mostly local rather than international and most macaques may, therefore, be destined for the pet trade (Shepherd 2010). Within the domestic pet trade long-tailed macaques are usually sold as infants or juveniles after having been trapped using nets (Nijman *et al*. 2017), sometimes in locations where macaques are considered a nuisance. Together with the pig-tailed macaque (*Macaca nemestrina*), they are the only primate species in Indonesia that are not yet included in the list of protected species (MLHKR Indonesia 2018) even though trade is one of the main causes of their exploitation.

Following a CITES review of significant trade in species, in 2014, Laos, Vietnam and Cambodia were subjected to a review of trade in long-tailed macaques (CITES 2014). In 2016, a CITES notification to all the parties recommended a suspension of trade with Laos in long-tailed macaques following unresolved concerns about its legality (CITES 2016). Vietnam has been identified as a center for the illegal laundering of wild-caught long-tailed macaques into breeding centers. It is suggested that stocks of long-tailed macaques are supplemented by a network of wholesalers that harvest wild macaques from Laos, Cambodia and Myanmar (Hoang 2008; Hamada *et al.* 2010).

The global demand for live macaques for biomedical testing and related uses inevitably provides incentives to supply this market, likely with substantive consequences for local populations of macaques. In Cambodia, the high price that dealers will pay for wild-caught macaques, which are then laundered to new commercial farms (Eudey 2008; SSN 2012) or illegally smuggled into Vietnam and China (SSN 2015a; SSN 2015b), has possibly led to the unrecorded extirpation of long-tailed macaques in much of the country (Lee 2011; SSN 2015b). The temptation to supplement low rural income with a side-line in trapped long-tailed macaques may be increasing despite the widespread global availability of captive-bred macaques. In 2004–2006, Cambodian farmers were paid about US$50 for each live animal they sold to dealers, which at that time was more than twice the average monthly rural wage (Rawson 2010; Lee 2011). The export price the was ~US$ 460 according to industry insiders. By 2016, the international export price had increased to ~US$2800. According to an industry insider, one potential market for these illegally traded macaques from Cambodia is the booming biomedical start up sector in China where wild-caught macaques are used for proof of concept-testing as prices undercut captive-bred specimens from Chinese farms (Mike Gill pers. obs.). Given that the same European broker reported a 25% growth in units per year in 2018, price pressure as an incentive for illegal trade in wild-caught macaques is unlikely to be alleviated anytime soon.

We urge journal editors and funding agencies to demand proof of origin for long-tailed macaques used in research to ensure their conservation and welfare and to ensure high quality results.

The European Union importers are not required to monitor nor inspect the breeding farms from which they acquire the macaques (EU Directive 2010/63), and therefore even wild-caught and illegally traded long-tailed macaques may be imported into the EU on false papers. Additionally, discrepancies in the CITES data system, as described by the United Nations Environment World Conservation Monitoring Centre (UNEP-WCMC) CITES Trade Database Guide (UNEP-WCMC 2013), may be detrimental to this species, allowing the perpetuation of a system that legalizes potentially exploitative trade. Furthermore, animal welfare may be compromised at these breeding facilities since they lack systems to ensure they fulfil minimum welfare standards. As the need for long-tailed macaques in research does not seem to decrease, we urge practitioners to follow the three Rs (Replace, Reduce and Refine: see Understanding Animal Research. 2020), especially Reduce, and to source only from monitored and inspected high quality facilities.

CoVID-19

Long-tailed macaques are heavily traded for biomedical research as discussed above, and with the CoVID-19 pandemic and a need for vaccines and treatment, the trade is not likely to diminish. Currently, China has ceased exportation of long-tailed macaques, and the USA is voicing concerns over problems importing long-tailed macaques through China (The Atlantic 2020; The Times 2020). However, illegal trade may have increased, as recent confiscations indicate (ABS-CBN 2021; PAREPOS 2021), possibly due to the increased demand and the lack of focus and enforcement during the pandemic. Long-tailed macaques are susceptible to SARS-CoV strains (Rockx *et al*. 2011), and are used for research into the spread of SARS-CoV2 and treatment of CoVID-19 (Rockx *et al*. 2020). Their susceptibility endangers them in terms of increased demand for laboratory research and due to their proximity to humans in many human-macaque interfaces. If infected in the wild they can infect other group members as well as become a reservoir for the virus, thus potentially infecting other humans (Liu 2020). When infected they show only mild symptoms (Rockx *et al*. 2011). Researchers now advocate to expand protection efforts of wild populations of non-human primates to include macaques (Liu 2020). An unexpected outcome of the current pandemic on long-tailed macaques has been the effects of lockdown on provisioned groups. Lockdown has decreased tourism tremendously and may be leaving many provisioned groups hungry and starving. Thailand has reported problems with aggression in formerly provisioned macaques as they search for food in and around their habitats, which for many includes villages, towns and temples (The Guardian 2020).

Conclusion and Perspectives

In the Anthropocene, we need new lenses to understand synanthropic species such as the long-tailed macaque. We also need to reassess our way of evaluating conservation status and ecological importance. We currently focus on the smallest populations of the least adaptable species, which may not be sustainable. We are in need of species-specific and perhaps even area-specific approaches to conserve primate species (Estrada *et al*. 2017; Bezanson and McNamara 2019). In our efforts to conserve the smallest populations of the least adaptable species, we unintendedly portray adaptable species as unimportant, as least concern, which affects human perceptions of these species.

Long-tailed macaques easily adapt to human settings. However, this is not enough to ensure their longevity in the wild as a species, especially at a time where they are being culled and harvested at high rates and experiencing diverse threats. Because of the intense use of long-tailed macaques for biomedical research and its economic impact, the demand for them will continue into the foreseeable future. Many areas inhabited by long-tailed macaques are not protected, as protected areas mostly contain habitats without human influence (Joppa and Pfaff 2009). A recent study on the bias in research sites and species, revealed that much primate research does not take the ecological complexity of species into consideration (Bezanson and McNamara 2019), and thereby reduces the foundation on which important decisions are made. Long-tailed macaques inhabit many different areas across Southeast Asia, and exhibit diverse 'cultures' across their range, such as for example tool use (Luncz *et al*. 2019) and ecological functions such as seed dispersal (Lucas and Corlett 1998), leading to a need for different management approaches across sites. Yet we still know very little about free-ranging long-tailed macaque behavior and population ecology, and more research is needed, especially in the form of systematic surveys on population size, and ethnographic surveys on the perception of local human communities regarding long-tailed macaques. Before effective management plans can be implemented, we need more information and we need to include all stakeholders, especially local communities (Larrosa *et al.* 2016).

It is important to change our discourse and terminology when assessing and understanding human-other animals' relations in the Anthropocene, most especially in the case of such intensively synanthropic species as the long-tailed macaques. Words such as "natural" and "unnatural", "endangered" and "non-endangered" may not offer sufficient nuance and scope to be relevant in this context. We encourage all researchers working in the range of long-tailed macaques to contact us if they wish to share information regarding the population ecology of long-tailed macaques at their field site, be it presence points, camera-trap footage or other useful information. Our objectives and recommendations for future research and action:

- Conduct population censuses across all habitat types including synanthropic and non-synanthropic groups of long-tailed macaques.
- Investigate the perception of long-tailed macaques with policy makers and in literature, media, and in human-macaque interfaces. This will enable the pinpointing of areas in need of macaque management, knowledge sharing and collaboration with involved agencies, institutions and local communities.
- Compare the culture and behavior of synanthropic and non-synanthropic groups.
- Research the effects of synanthropic long-tailed macaque groups on ecosystems and sympatric species. Here we also urge more research into zoonotic pathogen transfer between wild long-tailed macaques and people and wild long-tailed macaques and sympatric species, especially and urgently to SARS-CoV2.
- Develop new criteria for assessing threatened status of wildlife species, especially synanthropes. Here we propose to include human-influenced areas as well as areas without human-influence. We also propose to include both protected and non-protected areas. In all areas, we propose area-specific population censuses, ensuring that densities from human-influenced areas are not extrapolated to areas without human influence and vice versa.
- Develop a clearer and simpler way of reporting trade numbers through CITES, where actual numbers are reported and import certificates created at the same time as export certificates, also within trade regions such as the European Union. When assessing legal international trade amounts, national trade amounts should also be assessed and incorporated to ensure international trade numbers do not exceed long-tailed macaque population capacity. Urgently, we need to assess the amounts traded for biomedical research into CoVID-19 vaccines.
- Disseminate knowledge of the new conservation status of Vulnerable and divulge the results of future census surveys to policy makers in long-tailed macaque habitat countries to enable the creation of new more sustainable management initiatives and trade policies.

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Exhibit 38

CAB Reviews 2019 **14**, No. 004

Primate research and conservation in Malaysia

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Abstract

Malaysia is inhabited by ≥25 nonhuman primate species from five families, one of the most diverse primate faunas on earth. Unfortunately, most Malaysian primates are threatened with extinction due to habitat loss, degradation, and fragmentation, hunting and the synergies among these processes. Here, we review research on primates and issues related to their conservation in Malaysia. Despite the charisma and cultural importance of primates, the importance of primates in ecological processes such as seed dispersal, and the robust development of biodiversity-related sciences in Malaysia, relatively little research specifically focused on wild primates has been conducted in Malaysia since the 1980s. Forest clearing for plantation agriculture has been a primary driver of forest loss and fragmentation in Malaysia. Selective logging also has primarily negative impacts on primates, but these impacts vary across primate taxa, and previously-logged forests are important habitats for many Malaysian primates. Malaysia is crossed by a dense road network, which fragments primate habitats, facilitates further human encroachment into forested areas and causes substantial mortality due to road kills. Primates in Malaysia are hunted for food or as pests, trapped for translocation due to wildlife-human conflict and hunted and trapped for illegal trade as pets. Further research on the distribution, abundance, ecology and behavioural biology of Malaysian primates is needed to inform effective management plans. Outreach and education are also essential to reduce primate-human conflict and demand for primates as pets. Ultimately, researchers, civil organizations, governmental authorities and local and indigenous communities in Malaysia must work together to develop, promote and implement effective strategies for protecting Malaysian primates and their habitats.

Keywords: Great apes, Small apes, Monkeys, Lorises, Tarsiers, Ecosystems,

Review Methodology: We searched for data on Google Scholar, PubMed, Mendeley and Science Direct using as search terms the Latin and English names for each primate species in Appendix 1 with "Malaysia" (for all species) and "Borneo" (for species in Sabah and Sarawak). We also searched using names applying to multiple species, such as "macaque", "slow loris", or "langur". For example, for *Hylobates lar*, we searched using the terms: ["white-handed gibbon" + "Malaysia"] and ["Hylobates lar" + "Malaysia"] and ["gibbon" + "Malaysia"]. Our use of Latin names in the text follows a recent review of Asian primate taxonomy [1], but also searched using older names. To find information about threats to Malaysian primates, we used threats identified in the IUCN Red List [2] threat assessments as search terms. For example, to seek information about hunting we used the search terms ["illegal hunting" + "primate" + "Malaysia"] and ["hunting" + "primate" + "Malaysia"] and ["poaching" + "primate" + "Malaysia"] and ["poaching" + "primate" + "Borneo"].

We included studies in wild and captive settings in Malaysia and included some information about Bornean species from studies conducted in nearby Indonesia. Relevant works located but not specifically cited in this review are listed in Appendix 2.

Introduction

From the second half of the twentieth century to the present, Malaysia has experienced rapid economic development, resulting in dramatic changes in land use practices and human livelihoods, many of which put pressure on wildlife. At the time of writing, nine (41%) of 22 Malaysian primate taxa for which adequate data are available have been Red Listed by the IUCN as Endangered or Critically Endangered, seven (32%) as Vulnerable, and four as Near Threatened (18%; Appendix 1). Two species were not evaluated, and only one Malaysian species, *Presbytis* *rubicunda*, has been categorized as being of Least Concern. In this review, we briefly describe the biogeography and primate fauna of Malaysia, outline threats to the long-term persistence of Malaysian primates, describe current primate conservation policy and practices in Malaysia, and make recommendations for the conservation of Malaysia's unique and charismatic primates.

Primate Diversity in Malaysia

Malaysia includes two geographically distinct parts: East Malaysia, which includes Sabah in the northeastern part of the island of Borneo and Sarawak in northwestern Borneo, and West Malaysia, or Peninsular Malaysia, which is contiguous with mainland Asia. These two land masses are now separated by a wide water barrier but during glacial periods, Malaysia formed part of a land bridge that connected mainland Asia and the Sunda Shelf islands of Borneo, Sumatra, Java and Bali [3]. Alternating cycles of connection and separation from the continental shelf created ideal conditions for colonization, followed by speciation, resulting in the evolution of many regional endemics in the Sundaland biodiversity hotspot [4], as well as permitting rapid colonization by widespread and cosmopolitan species. Therefore, despite its relatively small size (ca. 300 000 km^2), Malaysia is recognized as one of 17 'megadiverse' countries [5] and is estimated to be home to more than 15 000 species of flowering plants and more than 175 000 animal species [6].

Among primate habitat countries, Malaysia is one of only 22 identified by the IUCN in 2008 as having more than 20 species [2]. Malaysia's primate fauna is particularly diverse taxonomically and ecologically, and Malaysia is one of only two countries in Asia (with Indonesia), and five countries globally (with Brazil, Madagascar, Indonesia and the Democratic Republic of the Congo), that are home to members of five primate families [7]. Malaysian primates include at least 25 primate species and nine genera from the families Lorisidae (*Nycticebus coucang, Nycticebus menagensis, Nycticebus kayan,* and *Nycticebus bengalensis*), Tarsiidae (*Cephalopachus bancanus),* Cercopithecidae (including macaques [subfamily Cercopithecinae: *Macaca nemestrina, Macaca arctoides, Macaca fascicularis*] and colobine monkeys [subfamily Colobinae: *Presbytis femoralis, Presbytis siamensis, Presbytis chrysomelas, Presbytis rubicunda, Presbytis hosei, Presbytis sabana, Presbytis frontata*, *Trachypithecus cristatus, Trachypithecus selangorensis, Trachypithecus obscurus,* and *Nasalis larvatus*]), Hylobatidae *(Hylobates lar, Hylobates agilis, Hylobates abbotti, Hylobates funereus*, *Symphalangus syndactylus*) and Hominidae (*Pongo pygmaeus*). Of these, 12 species in six genera are found in Peninsular Malaysia, and 15 species in eight genera occur in Malaysian Borneo [1] (Appendix 1).

Malaysian primates span almost the entire range of primate body sizes, from the tiny Horsfield's tarsier (ca. 120 g [8]) to the enormous Bornean orangutan (ca. 78 kg [8]), include nocturnal (*Nycticebus* spp. and *Cephalopachus bancanus*) and diurnal species, and animals with a broad variety of dietary preferences (predominantly frugivorous: Hylobatidae [9–16], Hominidiae [17–19]; folivorous: Colobinae [20–24]; omnivorous: Cercopithecinae [25, 26]; gumnivorous: Lorisidae [27, 28]; insectivorous: Tarsiidae [29, 30]), and social systems (solitary: Hominidae, Lorisidae [31]; unimale-multifemale groups: Colobinae [32]; multimale-multifemale groups: Cercopithecinae; pairs: Hylobatidae [15], Tarsiidae).

Malaysian Primate Research

Primates are charismatic, play important roles in Hindu and Buddhist mythology and Malay and indigenous folktales, are economically important for tourism, and provide important ecosystem services [7]. Nonetheless, despite the high primate diversity in Malaysia, relatively little research, and especially field research, has been conducted on Malaysian primates (Appendix 2). Studies from the 1970s and 80s still comprise the most-cited literature about Malaysian primates, especially those in Peninsular Malaysia. This stands in contrast to the robust development of other zoological fields in Malaysia in the past 50 years.

Threats to Malaysian Primates

The principle threats to primates in Malaysia include habitat loss, degradation and fragmentation, hunting and trapping, and accidental mortality associated with human infrastructure (primarily road kills). These threats mirror the pattern of threats in Southeast Asia more broadly [33]. While primate species differ in their sensitivity to each of these threats, populations of all Malaysian primates are declining [2] and synergies between processes such as road-building, habitat degradation and fragmentation, hunting and trapping for food and live capture for the pet trade exacerbate the impacts of human activities on wildlife, including primates [34, 35].

Forest loss

Almost all (99.5%) [36] of Malaysia's land was originally covered by forest, including lowland dipterocarp forest, tropical montane forest, semi-evergreen forest, heath forest, forest in limestone areas, mangrove forest, peat swamp forest, fresh-water swamp forest and seasonal swamp forest [37]. By 2016, however, only 43.8% of Peninsular Malaysia [38] and 56% of Sabah and Sarawak [39] remained forested and much of the remaining forest has been degraded [39]. Between 1973 and 2009, Malaysia lost more than 14% of its forest cover, the largest percentage loss in Southeast Asia [40] and the rate of forest loss had not slowed in 2018 [41]. Lowland forest has been particularly heavily impacted by agricultural activity, industry and urbanization [36]. A diverse set of crops are grown in Malaysia, including fruit, spices, rubber and farmed trees (usually *Acacia mangium*) for the pulp and paper industry, but over the last few decades, large-scale oil palm plantations have increasingly dominated the landscape, making Malaysia the second-largest producer of palm oil globally [42]. Much of the land currently planted with oil palm was forested in 1990 [42], suggesting that oil palm production is a major driver of deforestation in Malaysia.

Some Malaysian primates can forage or travel in human-dominated landscapes such as urban green spaces and agricultural plantations (e.g. *Macaca fascicularis* [43–45], *M. nemestrina* [26, 43], *Nasalis larvatus* [46], *Trachypithecus obscurus* [47] *Trachypithecus cristatus* [43, 48] and *P. pygmaeus* [49, 50]). However, other primates have not been recorded sleeping or foraging in large-scale plantations (e.g. *Hylobatidae* [49]), and most primates that forage in plantations have altered behaviour when foraging in plantations (e.g. *P. pygmaeus* [49], *M. nemestrina* [26]) and appear to require access to adjacent fragments of natural forest to persist in agricultural landscapes [26, 43, 49, 50]. While *Nasalis larvatus* have been observed feeding in coconut plantations [46], most *N. larvatus* populations rarely or never enter oil palm or other agricultural plantations [24, 51, 52], indicating that plantations probably do not comprise important habitat for this species. Therefore, conversion of forest for agricultural use represents a loss of primary habitat or reduction of its carrying capacity for most Malaysian primates. For example, in the Maliau Basin in Sabah, densities of all primates studied (*P. pygmaeus*, *M. nemestrina*, *M. fascicularis* and *C. bancanus*) were substantially lower in habitats dominated by oil palm than those dominated by unlogged or previously-logged forest [53]. Agricultural production in Malaysia is projected to continue to expand through the twenty-first century [7].

Forest degradation

Most remaining forested areas in Malaysia are managed by State Forestry Departments (in Peninsular Malaysia [38], Sabah and Sarawak, respectively) as Permanently Reserved Forests. National regulations, especially the National Forestry Act of 1984, the National Forestry Policy of 1978 and subsequent amendments to these two policies, provide an overarching legal framework, but each state has substantial latitude in making management decisions. In 2010, approximately 70% of the remaining forest in Malaysia was gazetted as ‘production forest’ (one category of Permanent Forest Reserve) [54], to be managed for timber production through selective logging, generally on a 30-year cycle, while the remaining 30% was designated as ‘protection forest’ (i.e. national and state parks, wildlife reserves, other categories of forest reserves) [54]. Similarly, in 2001, more than 70% of forest in Sabah was designated for commercial exploitation to provide revenue to the state [55]. Selective logging inevitably involves additional damage to the forest, and almost invariably requires the construction of logging roads, which can lead to further forest degradation [56, 57]. Moderate habitat disturbances, such as selective logging, can lead to alterations in survival probability and activity budgets of wild Malaysian primates. For example, *Hylobates lar* and *Presbytis melalophos* spent more time resting and less time feeding and travelling in the 12 months after selective logging than they had in the 14 months prior to logging, probably due to the reduced availability of preferred foods [58, 59]. The survival of primates in moderately disturbed forests is determined by a complex of different variables [60] whereby the degree of frugivory showed a significant negative correlation with survival probability, and body size and percentage of frugivory combined could explain 44% of the variation in survival in Malaysian primates resulting from moderate habitat disturbances.

Habitat disturbance, fragmentation and conversion have mainly negative effects on primate communities. Primate species richness is negatively correlated with the level of habitat disturbance in Sabah [61]. Surveys in Peninsular Malaysia have also shown reduced densities of mammals, including primates, in disturbed forests [62, 63], although disturbed areas contiguous to areas of unlogged forest may be less affected [64]. Nonetheless, degraded forests, including those that have been repeatedly logged, remain valuable for primate conservation as demonstrated by numerous other studies in other geographical regions [53, 65]. Indeed, some taxa, such as *M. fascicularis* and *P. melalophos*, may occur at higher densities in lightly disturbed forests than forests without a recent history of disturbance [66]. For ten of 11 primate taxa assessed in a recent study of the conservation impacts of selective logging and hunting in Malaysian Borneo, hunting pressure is a more important predictor of primate occurrence than history of logging for forests logged >10 years previously [34], indicating the importance of measures to protect primates in previously-logged forests. In contrast, conversion of forest to oil palm plantations had mainly negative effects on the primate community richness [61], decreasing species richness and abundance.

Habitat fragmentation

Conversion of forested habitat to plantation agriculture, and especially monocultures such as oil palm and rubber, has led to increased forest fragmentation in Malaysia [67, 68]. Fragmentation may have an effect on extinction probabilities beyond the effect caused simply by loss of total forest cover [69]. Primates may persist in small, isolated forest fragments for decades after the surrounding area was deforested [70–72], but this does not necessarily indicate the potential for long-term persistence. Little research has been conducted in Malaysia on the effects of habitat fragmentation (as distinguished from forest loss) on primates [64]. However, the predicted general pattern of loss of mammalian species, including primates, in small, isolated fragments has also been documented in Malaysia [64, 73]. Fragmentation may increase the risks of predation and human hunting [57], and habitat degradation due to edge effects, increasing the risk of local extinction in the long term. Recent studies show a relationship between fragment size and the occurrence of specific mammalian taxa in Malaysia. For example, *Symphalangus symphalangus* was present in two of six large fragments and absent from all small and medium-sized forest fragments in a survey of 14 forest fragments including Virgin Jungle Reserves and adjacent disturbed forests in Peninsular Malaysia [64]. Similarly, both *P. pygmaeus* and *M. fascicularis* were absent from small isolated fragments of formerly High Conservation Value Forest in an oil palm landscape in Sabah [73]. These observations suggest that fragmentation may increase local extinction risk even when habitat quality within the fragment remains high. The ongoing Stability of Altered Forest Ecosystems (SAFE) project, a large-scale field experiment initiated in Sabah that is currently examining the ecological impacts of fragmentation of tropical forests should shed further light on the effect of the landscape- and fragment-level processes on animals, including primates, in fragments [74].

The development of road infrastructure also poses a direct threat to primates in Malaysia, which is covered by a dense network of paved and unpaved roads [35], including roads that bisect otherwise remote frontier areas, such as the East-West Highway in Peninsular Malaysia [57] and the Samling Road in Sarawak [56]. Roads not only contribute to forest loss, habitat degradation, fragmentation and hunting pressure [56, 57], they also are increasingly causing direct mortality of primates due to road kills [33]. The wildlife authorities of Peninsular Malaysia reported 2 444 road kills of wild animals between 2012 and 2017, including 439 primates [75], but this figure probably severely underestimates the toll on smaller animals such as primates, as accidents involving primates especially less charismatic macaques are less likely to be reported to wildlife authorities. Road mortality has been identified as a major threat to *Trachypithecus obscurus* [47, 76, 77], *M. fascicularis* [78] and *Nycticebus bengalensis* [79] and many other Malaysian primates are probably also affected.

Hunting and illegal trade

Primates are legally protected from hunting, trapping, trade, possession, import and export throughout Malaysia Appendix 1. Many Malaysians do not consume meat from nonhuman primates due to religious or cultural taboos. However, hunting of primates for food is a traditional practice among indigenous hunter-gatherers in Malaysia [34, 80, 81], and Schedule 6 of the Wildlife Conservation Act of 2010 provides for an exception for subsistence hunting of *M. fascicularis*, *M. nemestrina*, *T. cristatus* and *T. obscurus* by indigenous Malaysians [82] in Peninsular Malaysia. Reports suggest that indigenous hunter-gatherers also hunt other primate species [83], but the impact of indigenous hunting on primate populations in Malaysia is not well understood. Almost 5% of animal biomass killed by indigenous communities in six longhouses in Sarawak from 1993 to 1995 and 2.4% of animal biomass killed by three hunting-farming communities in Sabah [84] consisted of primates, and primate densities were substantially lower in areas with higher hunting pressure [85]. While humans have been hunting Malaysian primates for tens of thousands of years, changes in hunting technology (shotguns), human population density and changes in mobility patterns are likely to make hunting a greater threat now than in the past [85]. Archaeological and historical data, as well as data from other geographic regions, also suggest that some Malaysian primates, and particular gibbons and orangutans, are very vulnerable to population declines when subjected to hunting pressure [86]. For example, >100 000 Bornean orangutans are estimated to have disappeared from 1999 to 2015 [84]. The highest rates of population decline for orangutans were in landscapes most affected by forest conversion [84]. However, total losses of animals in primary and selectively-logged forests were actually higher, as more orangutans are found in these landscapes, indicating that hunting was a primary driver in this dramatic population decline. In Malaysia, primates are also hunted for use in traditional medicines [87], or kept as pets [88], working monkeys for harvesting coconuts [89] or in the entertainment industry [90]. Prior to the 1980s, *M. fascicularis* were also captured in large numbers for legal export as laboratory animals [44].

The high demand for primates as pets in Malaysia may be stimulated in part by images in social media depicting prominent celebrities, and in some cases even researchers, cuddling infant primates. Illegal primate pet traders in Malaysia use social media and deploy increasingly sophisticated methods to evade law enforcement [91], although occasional captures do occur [88, 92]. Hunting for the pet trade is a major threat for Sunda slow lorises (*Nycticebus coucang*) [93], which are the most common CITES Appendix-I species offered for sale on Facebook in Malaysia [88]. Many other primate species, especially langur infants, are also trafficked and sold as pets in Malaysia [88, 94], although the impact on wild populations of most species has not yet been quantified. It is unclear whether all of the animals traded in Malaysia were also hunted in Malaysia, as transborder trafficking is common [95].

Human-macaque conflict

Macaques (especially *M. fascicularis*) often cause disturbance in human-impacted areas and are the species for which people filed the most complaints to the Department of Wildlife and National Parks (DWNP) Peninsular Malaysia (>70% of total complaints from 2006 to 2015 involved primates, with 66% for *M. fascicularis* alone) [96]. In 2012, a large-scale campaign by DWNP that allegedly culled almost 100 000 individuals (of an estimated 740 000 in Peninsular Malaysia) (http://www.wildlife.gov.my/index.php/en/penerbitan/108-laporan-tahunan) has sparked widespread concern among animal welfare groups [97, 98]. The long- and short-term effects on the populations of this species have not been studied but since the cull, *M. fascicularis* has continued to receive the most complaints. Rare attacks by macaques in Malaysia further paint a negative image about primates in general in the public [96].

Conservation Opportunities and Recommendations

Protection of primate habitats

In 2017, approximately 30% of the forested area in Peninsular Malaysia was gazetted in National and State Parks, Wildlife Reserves, Virgin Jungle Reserves, or other categories conferring legal protection from potentially destructive forms of resource extraction [54], while the remaining 70% remains in Forest Reserves that are more vulnerable. Malaysia's National Physical Plan (2005) and the subsequent Central Forest Spine Master Plan (CFSMP) identifies protection of four major forest complexes and enhancement of the degraded ecological linkages between these fragmented forests a conservation priority for Peninsular Malaysia [99]. The Heart of Borneo agreement, signed by Malaysia, the Sultanate of Brunei, and Indonesia in 2007, also mandates the protection of 240 000 km^2 of forest on Borneo, including large areas in Sabah and Sarawak, for biodiversity and ecosystem services as well as sustainable development to improve human welfare [100]. Protecting these forests and other crucial primate habitats will be an important step toward protecting primate populations across much of Malaysia.

Several recent government actions occurring at the time of writing should result in enhanced protection for primate habitats in Malaysia. In Sabah, 19 069 km^{2}of forest were designated as totally protected areas in 2018, more than doubling the area so designated [101]. In Peninsular Malaysia, several new areas were also slated or proposed for permanent protection in 2018, including a 100-km^2 area in Terengganu protected as the Lawit-Cenana State Park in August 2018, and the proposed Segari Melintang State Park, which at the time of writing had been submitted for approval to the Perak State government [102]. Also in 2018, in response to growing public demand, the Kedah State Forestry Department declared an end to logging in the Ulu Muda Forest Reserve, one of the largest unprotected areas of intact forest in Malaysia, and a watershed of critical importance for northwestern Malaysia [103]. It is important to note, however, that such declarations can be reversed. Further identification, protection and where necessary, restoration of high-priority habitats is crucial to ensure the persistence of vulnerable primate species in Malaysia.

Education

Illegal trade in primates as pets can be combated through education to reduce demand. Ironically, most domestic trade in primates appears to result from misplaced affection for Malaysia's charismatic primates. Accordingly, local (e.g. Malaysian Primatological Society: https://www.facebook.com/malaysianprimatologicalsociety; Gibbon Protection Society Malaysia: https://www.facebook.com/gibbonprotectionsociety) and international (e.g. TRAFFIC, WWF-Malaysia, WCS-Malaysia) organizations are working in Malaysia to monitor and expose illegal trade in wildlife or to educate the public about the harm done by the pet trade, an effort that has also received some support from local celebrities. These efforts are given a very public face by governmental and nongovernmental organizations (NGOs), such as Sepilok Orangutan Rehabilitation Centre, Semenggoh Wildlife Centre, and Gibbon Protection Society Malaysia, working to rehabilitate rescued primates for eventual reintroduction into the wild. Primate rescue and rehabilitation can serve multiple purposes, including protecting animal welfare, promoting law enforcement, supporting education programs to reduce demand and potentially contributing to the reestablishment of wild populations in forest fragments from which they have been extirpated.

Research

To design effective conservation plans for Malaysia's primates, managers require adequate information about the distribution, abundance, behaviour and habitat preferences of each taxon. For most Malaysian species, this information is lacking. Accordingly, the IUCN recommends further research on the primates themselves, their habitats, threats to their populations and on the effects of different types of conservation interventions, as well as monitoring of population trends for primates in Malaysia (citations in Appendix 2). Most recent information about the distribution, abundance, and behaviour of Malaysian primates is derived from biodiversity surveys focused on broad sets of mammalian data. For primate species that are nocturnal, arboreal and rare, standard survey methods such as line transect surveys may be inadequate to establish a species' presence or to estimate its density [104], and most previous camera trap surveys in Malaysia have placed their cameras near the ground and focused on terrestrial species. Therefore, there is an urgent need for more research on primate distribution and abundance using appropriate methods for each primate taxon.

Research on the effects of conservation interventions is also urgently required. Government strategies to reduce the effect of roads on wildlife, such as building underpasses and viaducts to allow wildlife to travel under or over roads, are ineffective for arboreal mammals, including most primates. Therefore, experimentation with alternative interventions, such as canopy bridges, to reduce the impacts of existing roads on primates, is essential to develop new methods for reducing the impacts of infrastructure on primates. Similarly, there is substantial empirical support for the establishment of habitat corridors between habitat fragments to reduce the effects of fragmentation on wildlife [105], but little is known about the optimal size or composition of habitat corridors to facilitate dispersal of Malaysian primates between fragments. Finally, while it is clear that changing human attitudes toward primates is essential toward facilitating coexistence between human and nonhuman primates, little research to date has been done on the effectiveness of different types of conservation education and public awareness programs in changing human attitudes and behaviour in Malaysia. While foreign researchers, such as the authors of this review, can play an important role in initiating and supporting research efforts in Malaysia, the importance of training and supporting Malaysian primatologists as they take the lead in these efforts cannot be overstated.

Management by local and indigenous communities

Research in other regions has shown that forest management by indigenous and local communities can reduce deforestation and forest degradation [106]. In Malaysia, confiscation and deforestation of lands traditionally used by indigenous people are common, despite legislation ostensibly protecting the rights of Malaysia's indigenous peoples to inhabit and use protected forests [83]. While indigenous communities in Malaysia face complex economic and social pressures that can lead to unsustainable use of forest resources, communities that rely on forest resources often have strong incentives to manage forests and wildlife sustainably when their rights to manage and access forest resources are secure [83]. Indigenous communities in Malaysia have used legal processes [107] and nonviolent direct action [108] to defend forests from destructive land use practices. Given that primates are among the animals most commonly hunted by at least some of Malaysia's indigenous people [83], the development of legal frameworks that protect indigenous land and use rights and facilitate meaningful partnerships between wildlife and forestry officials and indigenous and other rural people to sustainably manage of endangered primate populations should be a high priority for primate conservationists.

Conclusions

Malaysian primates are threatened by habitat loss, degradation and fragmentation, hunting and trapping, and mortality due to human infrastructure, such as roads. The same factors threaten a broad variety of Malaysian wildlife, and some of the solutions, including protecting Malaysia's remaining forests from degradation, are evident.

While the existing legal framework to protect primates and their habitats in Malaysia is generally solid, with a few loopholes in the laws about primate trade that are currently being revised by the government, often enforcement is weak due to the lack of manpower and funding to patrol large landscapes to counteract poaching activities or to infiltrate online syndicates that operate on countless social media platforms.

Primate education and research programs in Malaysia have gained strong momentum in recent years with the formation of primate-centered NGOs such as Malaysian Primatological Society (founded 2015) and Gibbon Protection Society of Malaysia (founded 2016) that engage communities in primate conservation through outreach, education, awareness and capacity building and research on wild and captive primates. Strong and enduring collaborations between governmental and NGOs and community involvement to protect primates and their habitats are the ingredients for sustainable conservation efforts in Malaysia and elsewhere. Although the foundation has been set to create and conduct these programs, much still needs to be done.

Supplementary material

The supplementary material for this article can be found at the end of the article.

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Appendix 1. Protected status of Malaysian primates in Peninsular Malaysia under the Wildlife Conservation Act of 2010 (Act 716), in Sabah under the Wildlife Conservation Enactment of 1997 (Act 6 of 1997), and in Sarawak under the Wildlife Protection Ordinance of 1998. “Protected” indicates that no hunting, keeping, or trade is permitted without a license from the relevant wildlife authority in each jurisdiction. Totally Protected Status has different meanings in different jurisdictions. Throughout Malaysia, penalties for illegal hunting, trapping, sale, or keeping of Totally Protected species are greater than those for Protected species. In Sabah, Totally Protected species cannot be hunted under any circumstances, whereas in Sarawak, there is a limited provision for hunting or trapping of Totally Protected species with permission of the Commissioner for scientific or educational purposes or for the protection or conservation of the animal itself, and in Peninsular Malaysia, hunting of Totally Protected wildlife requires a special permit.

Species	**Peninsular Malaysia**	**Sabah**	**Sarawak**
Cephalopachusbancanus	Protected	Protected	Totally Protected
Hylobates spp.	Totally Protected	Protected	Totally Protected
Macacaarctoides	Totally Protected	n/a	n/a
Macacafascicularis	Protected	Protected	Protected
Macacanemestrina	Protected	Protected	Protected
Nasalis larvatus	Totally Protected	Totally Protected	Totally Protected
*Nycticebus*spp.	Totally Protected	Protected	Totally Protected
Pongo pygmaeus	Totally Protected	Totally Protected	Totally Protected
Presbytis spp.	Protected	Protected	Totally Protected
Symphalangussyndactylus	Totally Protected	n/a	n/a
Trachypithecus spp.	Protected	Not protected	Protected

Appendix 2. Published studies of Malaysian primates (not cited in the main text).

Primate family	General ecology and behavior	Phylogeny, distribution and abundance	Feeding ecology	Habitat use, travel distances and sleeping sites	Health, diseases and parasites
Hominidae	Andau et al. 1994, Ancrenaz et al. 2004a,b; Davies 1986, Davies et al. 2017; Kuze et al. 2005; Hayashi et al. 2018; MacKinnon 1971, 1974.	Ancrenaz et al. 2004a; Goosens et al. 2005, 2009; Kanamori et al. 2017; Voigt et al. 2018.	Kanamori et al. 2010.	Ancrenaz et al. 2004b, 2005.	Kilbourn et al. 2003; Wolfe et al. 2001, 2002.
Hylobatidae	Chivers et al. 1975, Chivers 2000; Ellefson 1967; Gittins 1980; Kawabe 1970; Clink et al. 2017, 2018a, 2018b.	Khan 1970.	Gittins 1982, 1983; Raemaekers 1978.	Caldecott 1980; Inoue et al. 2016; Gittins 1980,1982,1983; Raemaekers 1980.	
Cercopithecidae	Bennett & Sebastian 1988, Bennett & Gombek 1993; Bernstein 1967; Boonratana 1993, 2002; Caldecott 1986a,b; Dura et al. 2018; Kawabe & Mano 1972; Matsuda et al. 2012; Karim & Anuar 2010, 2011a; Kavanagh & Lauresen 1984; Kombi & Abdullah 2013; Md-Zain et al. 2010a,b; Puteri & Ruppert 2017; Qiao & Ruppert 2017; Rajanathan & Bennett	Abdul-Latiff et al. 2018; Abegg & Thierry 2002; Ampeng & Md-Zain 2012; Bernard 1995; Bernard & Zulhazman 2006; Bennett 1988; Duckworth et al. 2011; Eudey 2008; Harding 2011; Jalil 2006; Karim & Anuar 2011b, 2012, Karim et al. 2014; Karuppannan 2014; Lee & Gan 2017; Md-Zain et al. 2008; Meyer 2011; Munshi-	Davies et al. 1988; Hanya & Bernard 2013; Lambert 1990; Matsuda 2008, Matsuda et al. 2009, Matsuda et al. 2013, 2014; Salter et al. 1985	Bernard et al. 2011; Boonratana 2000; Hambali et al. 2016; Matsuda 2008; Matsuda et al. 2008; 2010; Ruppert et al. 2018; Salter et al. 1985; Stark et al. 2018.	Apandi et al. 2009; Bernard et al. 2011; Eberle & Jones-Engel 2018; Hasegawa et al. 2003; Klaus et al. 2017, 2018; Lee et al. 2011; Sam et al. 2015; Vythilingam 2008.

	1990;Röper et al. 2014; Ruppert et al. 2014, 2018; Wolf & Fleagle 1977.	South & Bernard 2011; Salter & Mackenzie 1985; Sha et al. 2008; Schultz & Beck 1999; Stark et al. 2012			
Lorisidae	Elliot & Elliot 1967; Nekaris 2014; Nekaris & Starr 2015; Wiens & Zitzmann 1999, 2003; Wiens 2002.	Munds et al. 2013; Nijman & Nekaris 2010.	Wiens et al. 2006.	Munds et al. 2014.	Colley & Mullin 2011; Frias et al. 2018.
Tarsiidae	Crompton & Randau 1987;Shekelle & Nietsch 2008.	Sahimi et al. 2017; Munds et al. 2014; Nijman & Nekaris 2010.	Jablonski & Crompton 1994.		
Primate communities	Chivers 1980; Johns 1986.	Bernard et al. 2016; Harrison et al. 2006; Jalil 2006; Johns 1987; Johns & Johns 1995; Marsh & Wilson 1981; Matsuda et al. 2016 ; Southwick & Cadingan 1972.		Goosens et al. 2002; Rajanathan 1991.	

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Exhibit 39

Taxon: Macaca nemestrina (Animalia)

Taxon: Macaca nemestrina (Animalia)

Id_WCMC: 7094
Class: Mammalia **Order**: Primates
Family: Cercopithecidae
Genus: Macaca

FR Name: Pig-tailed
Macaque **Name EN:** Pig-tailed Macaque; Pigtail Macaque
Name ES: Macaca cola de cerdo

Synonyms : None

Identification Guide: None

Range:

Brunei Darussalam , Indonesia , Malaysia , Singapore , Thailand

European and international reference system (with history):

The link below allows you to consult the "Species+" sheet concerning this Taxon. This fact sheet in English includes the following official sections:

1. CITES LISTING - This field specifies in which CITES Appendice(s) the taxon is found. It also mentions reservations decided by certain countries (R = date of entry into force of the reservation, W = date of withdrawal of the reservation). A reservation is a national decision by which a country unilaterally decides not to apply the CITES listing.

2. QUOTAS - This field lists all export quotas in force for the taxon. The quotas for this taxon can also be consulted directly in French in this sheet by clicking on the link in the section below entitled "Quotas".

3. SUSPENSIONS - This field lists possible international trade suspensions against certain countries, with a link to CITES Notifications introducing these measures. This information can be found in French in the section below "CITES Instructions" of this sheet.

4. EU LISTING - This field specifies which annex(s) to Regulation (EC) No 338/97 the taxon is located, with a link to the relevant EU regulation.

5. EU DECISION - This field lists the import suspensions decided by the European Union for the taxon in question concerning certain third countries of origin, with a link to the reports of the Scientific Review Group (SRG) that introduced these measures or a link to the European regulations that formalized this suspension. This information can be found in French in the section below "EU Decision" of this sheet.

For each of these 5 sections, the history can be viewed by clicking on the "Show history" tab. This information then appears on a sky blue background.
Species+
taxon sheet

Regulation

Click here to view the history

ORIGIN	ANNEX	DATE	NOTE
CITES	II	04/02/1977	
EU	B	01/06/1997	

As well

Click here to consult any commercial farms / nurseries registered in the CITES Secretariat registers for this taxon (NB: these registrations only concern species listed in Appendix I of CITES).

Instructions CITES

Click here to view the history

	TITLE	DATE	NOTES	COUNTRY

	Notification: **CITES**	27/03/2023	**Alert!** **MEXICO - Suspension of trade** CITES Secretariat Notification No. 2023/037 recommends that CITES Parties suspend all trade in specimens of CITES species with Mexico until further notice. This follows the transmission by Mexico to the Secretariat of an action plan in the context of the fight against illegal trade in totoaba, within the framework of the decisions taken by SC75. The Secretariat considered this plan inadequate. See the Notification.	All countries
	Notification: **CITES**	03/06/2022	**Alert!** **Chad: Lifting of trade suspension for all specimens** The recommendation to suspend trade in CITES-listed species is lifted for Chad. Notification 2022/044 replaces Notification 2022/032 of 13 May which recommended suspending all trade in specimens of CITES-listed species with Chad.	All countries
	Notification: **CITES**	30/05/2022	**Security** Stamp Notification No. 2020/037 of 23 April 2020 replaces Notification to Parties No. 2011/052 of 30 November 2011. Latest notifications: Since 1 December 2020 Uganda has been using security stamps. January 18, 2021: Uruguay will no longer use security stamps until further notice. January 27, 2021: The UAE will no longer use security stamps. 25 May 2022: New Zealand will no longer use security stamps List of countries using security stamps following notification 2020/037: Argentina, Bahamas, Benin, Bermuda, Brazil, Burkina Faso, Cambodia, Cameroon, Cayman Islands, Chile, Colombia, Congo, Costa Rica, Côte d'Ivoire, Croatia, Denmark, Ecuador, Denmark (Greenland), Russian Federation (for caviar permit only), Finland, Gabon, Ghana, Guatemala, Guinea, Guinea-Bissau, Guyana, Honduras, Iceland, India, Indonesia, Iran (Islamic Republic of), Jersey, Japan, Kenya, Kuwait, Kyrgyzstan, Libya, Luxembourg, Madagascar, Malaysia, Mali, Mongolia, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Norway, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Czech Republic, Dominican Republic, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, United Republic of Tanzania, Uzbekistan, Romania, Serbia, Slovakia, Slovenia, Sri Lanka, Sudan, Suriname, Sweden, Togo, Viet Nam, Zambia and Zimbabwe Former countries present in the 2011 notification: Botswana, Cuba, Chad, Eritrea, Jamaica, Kazakhstan, Liberia, Malawi, Malta, Switzerland, Trinidad and Tobago, Vanuatu, Venezuela.	All countries
	Notification: **CITES**	17/05/2022	**Alert!** **SAO TOME AND PRINCIPE: Suspension of trade for all specimens** The Standing Committee (SC74) concluded that Sao Tome and Principe had not provided an annual report for three consecutive years without sufficient justification, and had not provided information on national legislation.	All countries

			It is therefore recommended that Parties no longer allow, until further notice, trade in specimens of CITES-listed species with Sao Tome and Principe. Notification 2022/034 of 13/05/2022 and Notification 2022/038 of 17/05/2022	
	Notification: **CITES**	13/05/2022	**Alert!** **LIBYA - suspension of trade for all specimens** The Standing Committee (SC74) concluded that Libya had failed to provide an annual report for three consecutive years without sufficient justification. It is therefore recommended that Parties no longer allow, until further notice, trade with Libya in specimens belonging to CITES-listed species. Notification 2022/033	All countries
	Notification: **CITES**	04/07/2019	**Alert!** **Somalia: Trade suspension recommendation maintained** In recent years, Somalia has been working on draft legislation to implement the Convention. To date, however, this project has not been finalized or submitted for approval. Therefore, the recommendation to suspend trade with Somalia is maintained. This notification replaces Notification to the Parties No. 2004/055 dated 30 July 2004.	All countries
	Notification: **CITES**	04/07/2019	**Alert!** **Mauritania: Lifting of** recommendation to suspend trade The recommendation to suspend trade in CITES-listed species is lifted for Mauritania. Notification 2019/034 replaces Notification No. 2004/055 of 30 July 2004 which recommended suspending all trade in specimens of CITES species with Mauritania. The trade suspension recommendation is still maintained for Somalia.	All countries
	Notification: **CITES**	07/02/2017	**Alert!** **Explanatory Notes to Export Quotas** By notification No. 2017/015 of 7 February 2017, the Secretariat sent a notification to the Parties containing elements and explanations on the different types of export quotas (see notification in P.J.	All countries
	Notification: **CITES**	26/01/2017	**Alert!** Reservations on Annexes I and II By notification No. 3017/010 of 26 January 2017, the Secretariat informed the Parties that reservations had been made to the amendments to **Annexes I and II** at COP 17 (see notification in P.J.).	All countries
	Notification: **CITES**	16/03/2016	**Alert!** **GRENADA - Suspension** of trade The Standing Committee requested all Parties to suspend, until further notice, trade with Grenada in specimens belonging to CITES-listed species (Notification No. 2016/022 of 16 March 2016).	All countries
	Notification: **CITES**	17/05/2013	**AFGHANISTAN: Trade suspended for non-submission** of annual reports By Notification No. 2013/018 of 17 May 2013, the CITES Secretariat, in accordance with Resolution Conf.11.17 (Rev.CoP 14), issued a recommendation to suspend trade with Afghanistan for failure to provide its	All countries

			annual reports.	
	Notification: **CITES**	19/01/2011	**DJIBOUTI: general suspension of** trade By Notification No. 2011/010, the CITES Secretariat reissued a recommendation to suspend trade imports and (re)exports with Djibouti, due to the country's failure to communicate its national legislation implementing CITES.	All countries
	Notification: **CITES**	30/07/2004	**MAURITANIA and SOMALIA -Suspension of trade** Suspension of trade with Mauritania and Somalia (notification No. 055/2004 of 30/07/2004).	All countries

Instructions EN

Click here to view the history

	TITLE	DATE	NOTES	COUNTRY
	Notification: **EN**	31/12/2007	**Failure to implement** the personal property waiver Japan, Thailand, Indonesia and China (with the exception of Hong Kong and Macao) have objected to the implementation of the personal property waivers (general and crocodilian), which means that these countries require CITES documents to import Appendix II personal belongings, under their national measures stricter than CITES. In addition, for crocodilian skin leather goods, Switzerland has limited the derogation to 2 specimens per person (instead of 4).	China , Indonesia , Japan , Switzerland , Thailand

EU Decision

Click here to view the history

National Science Advisory

Quotas

Click on this link to view any export quotas in force for this taxon, as well as their history.

Exhibit 40

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Tourist Behavior Predicts Reactions of Macaques (*Macaca fascicularis* and *M. nemestrina*) at Sepilok Orang-utan Rehabilitation Centre, Sabah, Malaysia

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Abstract

Conservationists continue to grapple with the practical risks that accompany ecotourism initiatives, where access to threatened ecosystems is exchanged for financial support for both protected areas and local communities. One of the most practical ways to mitigate the potentially harmful effects of an increasing number of visitors is to identify problematic human behaviors and attempt to limit them through education or staff intervention. We observed the behavior of both visitors and macaques in a hybrid group (*Macaca fascicularis* × *M. nemestrina*) at Sepilok Orang-utan Rehabilitation Center in Sabah, Malaysia over a period of 10 months to better understand patterns in tourist-directed aggression. We witnessed 307 encounters between macaques and tourists but intense aggression was absent. Overall rates of minor visitor-directed aggression were low, with only 0.71 bouts observed per hour. Eye contact between tourists and macaques was associated with significantly higher odds of experiencing minor human-directed aggression, such as an open mouth threat. Taking a picture, however, was associated with reduced odds of experiencing aggression from the macaques. Tourists were not able to provision the animals, which may help explain the lower rates of intense aggression compared to those at other tourist sites. Although improved education signs and staff supervision could further reduce visitor-directed aggression at Sepilok, these results are promising because they highlight the role that relatively simple policies (such as those that forbid provisioning by tourists) can play in reducing unwanted behavior by both humans and nonhuman primates at ecotourism locations.

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Keywords Human–primate contact · *Macaca* · Rehabilitation · Tourism · Tourist management

Introduction

The travel and tourism industries are among the largest sources of employment globally, and they generated an estimated 8.9 trillion USD in 2019 (WTTC 2020). The extent to which tourism will help or hinder local communities and ecosystems depends largely on the type of experience being offered. Ecotourism has been heralded as a form of sustainable tourism development and represents an ever-expanding portion of tourism revenue in many tropical countries (Brandt and Buckley 2018). This is particularly relevant for the well-being of nonhuman primate species (hereafter primates), who are the frequent focus of such tourism initiatives. As ecotourism has become more established throughout primate habitat countries, researchers have justifiably questioned the potential harmful effects of the regular exposure of primates to humans (Jones-Engel *et al.* 2005; Muehlenbein *et al.* 2010; Muehlenbein and Wallis 2014; Russon and Wallis 2014; Wallis and Lee 1999; Williamson and Feistner 2003).

Primates typically need to be at least semihabituated to humans for tourists to be able to spend time in the same vicinity (Woodford *et al.* 2002). This consistent exposure over time may alter social and ecological behavior and may result in an increased risk of injury to both humans and primates. For example, primates have been shown to alter their foraging patterns when repeatedly exposed to tourists (McKinney 2011) and they also experience increased rates of intragroup and human-directed aggression (Fuentes and Gamerl 2005; Maréchal *et al.* 2016). Primates may also range closer to human settlements as they become habituated, which puts them at an increased risk of injury from people who wish to protect themselves or their crops (Lee and Priston 2005; Schillaci *et al.* 2010).

Researchers who have investigated wildlife tourism, particularly primate-based tourism, have often focused on the risks associated with the transmission of zoonoses (diseases passed from primate to human) and anthropozoonoses (diseases passed from human to primate). The risk of such transmission between species is considered to be higher in these scenarios compared to other taxa because of the close evolutionary relationship between humans and other primates (Muehlenbein and Wallis 2014; Wolfe *et al.* 1998; Woodford *et al.* 2002). Tourism can facilitate this disease transmission by encouraging frequent contact between primates and both foreign and local tourists (Wallis and Lee 1999). However, the amount of contact between species may vary depending on the degree to which staff or government officials intervene to limit unsafe behavior from people (Goldsmith 2014; Riley *et al.* 2016).

When staff intervention is high, tourist behavior is restricted by rules that have been established to protect the health and safety of both humans and primates. Generally speaking, these sites subscribe to best practice guidelines (Macfie and Williamson 2010), which means that tourists are not allowed to provision the animals and staff do not attempt to limit the ranging behavior of the primates. Close contact between primates and tourists is avoided as much as possible (Goldsmith 2014; Hanes *et al.* 2018). At the opposite end of the spectrum are sites with low staff intervention, where primates often interact with tourists in environments where provisioning is encouraged, direct contact inevitable, and primate aggression toward humans frequent (Brotcorne *et al.* 2017; Wheatley 1999). Sites of this nature may also actively restrict the home range of primates so that tourists can see them more easily (Berman *et al.* 2007).

Macaques (*Macaca* sp.) have been the subject of numerous studies on human–wildlife interactions due to their ubiquity throughout Asia and North Africa. They are an important taxon to study in tourism contexts because their bold and generalist nature means that they frequently interact with visitors to obtain food (Eudey 2008). Many sites that are popular with visitors do not have effective measures in place to reduce unwanted contact between humans and macaques. The long-tailed macaques (*M. fascicularis*) of Bali are notorious for engaging in close contact with visitors in an environment with low rates of staff intervention. In Padangtegal, for example, macaques are provisioned throughout the temple complex several times per day by the local staff (Brotcorne *et al.* 2020; Fuentes 2006; Lane *et al.* 2010). Tourists are also not only permitted but also encouraged to feed the monkeys. In the event that a macaque steals any personal belongings from a tourist, staff use small bags of peanuts to coax the monkey to return the item (Brotcorne *et al.* 2020; Peterson and Fuentes 2018). Primate aggression toward humans by the macaques is frequent, especially when food is present, and minor bites and scratches that break tourists' skin are not uncommon. These results also illustrate how significant demographic factors can predict aggression, as adult male macaques were more likely to participate in tourist-directed aggression compared to other age and sex classes (Fuentes and Gamerl 2005).

The mere presence of humans has been associated with changes in grooming and self-scratching behavior in wild long-tailed macaques in Kuala Lumpur (Marty *et al.* 2019). Moreover, specific tourist behaviors have been linked to changes in macaque aggression in other settings where there is little supervision of tourists (McCarthy *et al.* 2009). In periurban environments such as Singapore, for example, 65% of the interactions between humans and long-tailed macaques involved food or food cues (Sha *et al.* 2009) and 100% of the noncontact threats from long-tailed macaques occurred while they were being fed by humans (Fuentes *et al.* 2008). Others have observed a positive correlation between tourist decibel levels and threat frequency from provisioned Tibetan macaques (*Macaca thibetana*) at Mt. Huangshan, China (Ruesto *et al.* 2010). Tourist density likewise appeared to be a significant contributing factor to rates of aggression in Barbary macaques (*M. sylvanus*) in Gibraltar, although the results of Ruesto *et al.* (2010) beg the question of whether it is density, decibels, or a combination of both that might inflate rates of aggression (Fa 1992).

A better understanding of the behavioral patterns associated with increased rates of aggression from macaques may help staff at tourism sites reduce contact between primates and visitors (McCarthy *et al.* 2009). This has important health implications because open wounds inflicted by primates significantly increase the risk of disease transmission between primates and humans (Jones-Engel *et al.* 2005; Wallis and Lee 1999). Aggression between tourists and monkeys may also increase the likelihood of other injuries; humans may be injured while fleeing aggressive monkeys or by the monkeys themselves (Fuentes 2010; Wheatley 1999; Zhao and Deng 1992), and the monkeys might be injured by tourists in retaliation. Staff may use projectiles (e.g., rocks) to deter unwanted behavior or to corral the primates closer to the tourists (Berman *et al.* 2007; Berman *et al.* 2014; Jones-Engel *et al.* 2001; Riley *et al.* 2016; Schillaci *et al.* 2010).

This study explores the nature of encounters between humans and a hybrid group of wild macaques (*Macaca fascicularis* × *M. nemestrina*) at Sepilok Orang-utan Rehabilitation Centre (SORC) and adjacent Bornean Sun Bear Conservation Centre (hereafter referred to collectively as Sepilok) in Sabah, Malaysia. Both of these centers have some tourist management strategies in place, albeit ones that were designed with the health and safety of the rehabilitating animals in mind. Human–macaque encounters at Sepilok represent a kind of *incidental* encounter, where the visitors are interested primarily in seeing animals other than the study species (Grossberg *et al.* 2003). This work builds on research from sites with high rates of human-directed aggression by examining the behavior of macaques at a site where there are strict, effective rules in place to prevent tourists from hand-feeding wild animals. Previous research at the SORC found that 15% of visitors were experiencing a symptom of infection. Many were also unaware of their vaccination status for common diseases such as hepatitis A and measles, which highlights the need to continually monitor and reduce direct contact between people and primates (Muehlenbein *et al.* 2008, 2010). The ultimate aim of this research is to make concrete suggestions for tourist management strategies to reduce the potentially negative effects of tourism on wild primates.

We used an exploratory approach with mixed models to assess the effects of human-specific behaviors on the probability of receiving aggression from macaques while controlling for interindividual variations. Given that the presence of food as well as demographic variables such as age and sex have been associated with higher rates of aggression in previous studies, we created separate models with only these predictor variables in the exploratory model comparisons. We also included species category in its own model.

Methods

Study Site

The SORC and BSBCC seek to rehabilitate and release orphaned orang-utans (*Pongo pygmaeus*) and sun bears (*Helarctos malayanus*), respectively, while educating visitors about local conservation issues. Located in eastern Sabah, both centers are located in the 55 km^2 Kabili–Sepilok Forest Reserve (5.51841°N, 117.57003°E), which features primarily lowland dipterocarp forests that are partially logged, as well as heath and mangrove forests along the coast. Elevation ranges between 0 and 170 m above sea level and the mean annual temperature is 27°C (Liu *et al.* 2018). With a mean annual rainfall of 3136 mm (±921 SD), the reserve borders the Sulu Sea to the east and is surrounded by secondary forest, oil palm plantations, and cash crops (Margrove *et al.* 2015; Maycock *et al.* 2005).

While the orang-utan population at Sepilok is largely the result of the rehabilitation efforts by SORC, there are six naturally occurring primate species present in the reserve: red langur (*Presbytis rubicunda*), Philippine slow loris (*Nycticebus menagensis*), Horsfield's tarsier (*Tarsius bancanus*), northern gray gibbon (*Hylobates funereus*), long-tailed macaque (*Macaca fascicularis*), and the pig-tailed macaque (*M. nemestrina*). Of these six species, only the macaques take advantage of the provisioned food at the orang-utan and sun bear centers. Proboscis monkeys (*Nasalis* *larvatus*) are also present on the border of the reserve near the mangrove forests, *ca.* 7 km away from the rehabilitation centers.

Visitors to SORC may encounter macaques in several contexts. Most notably, the twice-daily feedings for free-ranging orang-utans draw the greatest number of visitors. At 10:00 h and 15:00 h guests wait on the designated viewing platform and may observe one or more orang-utans visiting the adjacent feeding platform to feed on seasonal fruit and vegetables. The study group fed frequently on this available food, while another group of pig-tailed macaques visited sporadically. We did not observe any long-tailed macaque groups at Sepilok during this study. Visitors may also encounter the wild macaques around the center on the viewing platforms and boardwalks.

The BSBCC is immediately adjacent to the SORC (Fig. 1). The centers share a parking lot and canteen, but they operate independently of each other. The BSBCC is open between 09:00 and 16:00 h, with peak visitation periods following the orang-utan feedings (W. Siew Te *pers. comm.*, September 25, 2016). The macaques routinely visit this part of the forest reserve to feed on both naturally occurring vegetation and the food provided to the bears by BSBCC staff. In doing so, they often come into close contact with tourists. Both the orang-utans and the sun bears are fed the same amount of food daily regardless of tourist attendance. Strict rules at Sepilok limit the ability of tourists to interfere with the animals. Visitors to SORC must leave their belongings in a locker near the reception counter and staff patrol the visitor area so that they can monitor any orang-utan that approaches the viewing platform or boardwalks. The sun bears are housed in large enclosures reminiscent of a traditional zoo. Visitors may keep their

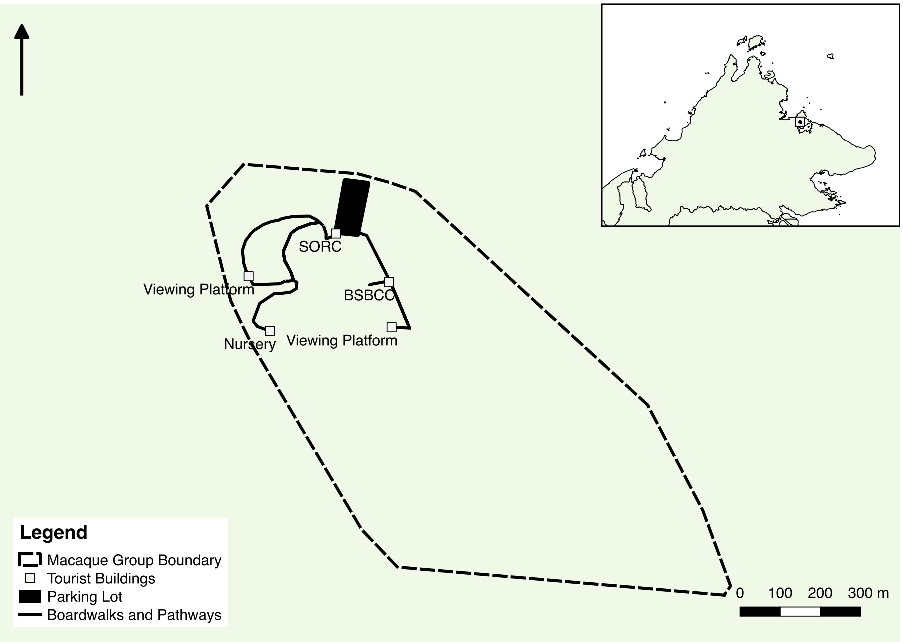

Fig. 1 Map of Sepilok Orang utan Rehabilitation Centre and the Bornean Sun Bear Conservation Centre in the Malaysian state of Sabah (inset). The areas visited by tourists are depicted along with a minimum convex polygon of the study group's home range from November 2016 to August 2017 (L. J. Gilhooly unpubl. data).

belongings with them at BSBCC, but they are forbidden from having open food containers and they cannot reach the bears. There is enough staff supervision at both facilities that these rules are generally enforced without issue.

Interactions between tourists and macaques are slightly different from the interactions that tourists have with orang-utans and sun bears. Since the macaques are not a part of a rehabilitation program, there are no dedicated staff members to guide visitor behavior or to intervene in the event of close contact or aggression. Both SORC and BSBCC staff typically advise tourists to back away from the macaques, but staff do not monitor the macaques the same way they monitor the orang-utans, which means they are not always present to defuse close encounters between tourists and macaques.

Study Group

The study group consisted of long-tailed macaques, pig-tailed macaques, and their hybrid offspring who traveled, foraged, and socialized together daily. We assessed hybridity based on physical characteristics such as body size, facial morphology, and pelage patterns as well as staff testimony (Fig. 2). We chose this study group because it was the only group of macaques that visited the center regularly. We divided the macaques featured in this report into two age classes: adult and juvenile. We considered individuals to be juveniles if they were fully weaned from their mother and lacked signs of sexual development, such as anogenital swelling in females and descended testes in males (Blakley *et al.* 1981; Fooden 1995; Steiner and Bremner 1981). Infants (i.e., those still breast feeding) were not included the analysis of human–macaque encounters.

Data Collection

We collected data on the study group for 10 consecutive months from November 2016 to August 2017. The group contained 21 individuals at the beginning of the study period and 23 by the end due to one death, one emigration, and four births (Table I). We used observational methods adapted from research on human–primate interactions

Fig. 2 A suspected first generation hybrid long tailed × pig tailed macaque (middle) and a true long tailed macaque (right) at Sepilok Orang utan Rehabilitation Centre in November 2016. (Photo by L. J. Gilhooly).

Table I Composition of the study group of macaques at Sepilok Orang utan Rehabilitation Centre as of August 2017

Species	Adult females	Adult males	Juvenile females	Juvenile males	Infant females	Infant males	Total
Long tailed macaque	1	1	0	1	0	1	4
Pig tailed macaque	3	3	4	2	1	1	14
Hybrid macaque	2	0	1	1	0	1	5
Total	6	4	5	4	1	3	23

at multiple tourist sites (e.g., Fuentes and Gamerl 2005; McKinney 2014; Ruesto *et al.* 2010). As part of a larger study, we conducted full-day follows of the macaque group to collect data on feeding and ranging patterns and on encounters with tourists. We use data on the proportion of time the macaques spent near visitors, which we recorded every minute during 10-min focal follow sessions of adults and juveniles in the study group. We noted whether a focal animal was <3 m from visitors, <10 m from visitors, >10 m from visitors, or if no visitors were present. We allowed for one missing data point in each 10-min session. If we missed more than one data point, we discarded that session and began again with a new focal animal (McKinney 2014).

Although multiple assistants collected data during focal follows, the first author was responsible for all data collection on human–macaque encounters. Since we could not predict the timing and location of encounters with tourists, we relied on *ad libitum* all-occurrences sampling techniques during focal follows to record data on the nature and outcome of tourist–macaque encounters (Altmann 1974). We collected approximately 1100 hours' worth of focal follow data on 15 individuals, including 12 adults and 3 juveniles. Here, we report data on all of the individuals in the study group that we observed having an encounter with a visitor ($N = 16$). Our observations of such encounters may have been biased toward more central individuals and obvious signs of aggression (e.g., chasing), though focal follow sessions of peripheral animals should have helped to reduce this bias.

Human–Macaque Encounters

We defined an encounter as beginning when 1) a macaque directed behavior toward a human, or vice versa or 2) when a macaque approached a human on the boardwalk or viewing platforms, or vice versa. Encounters could involve one or more behaviors, as the categories were not mutually exclusive (Table II). We coded five of the possible behavioral categories as present or absent, and we coded *approach* as human, macaque, or absent in the event that both individuals were stationary. We also included the name, sex, species, and age class of the macaque in the encounter. We scored encounters as either aggressive or nonaggressive in a binary dependent outcome based on the presence of one or more aggressive behaviors (Table II).

In cases where in which were multiple macaques grouped together, we included only the behavior of the individual nearest to the tourist to ensure that we did not miss

Table II Ethogram of macaque and human behavior during encounters at Sepilok Orang utan Rehabilitation Centre from November 2016 to August 2017

Behavior	Type	Description
Approach	Macaque	Macaque walks, runs, or climbs toward or past a human.
	Human	Human walks or runs towards or past a macaque.
Gesture	Point	Human extends their hand toward the macaque.
	Wave	Human waves to try to get the macaque's attention.
	Bend down	Human bends down to talk to macaque or take picture.
Vocalization	Mouth noise	Human clicks tongue or lips to try to get the macaque's attention.
	Hooting	Human makes an "ape" noise or otherwise imitates the macaque's call.
	Talking	Human talks to macaque in normal voice.
	Whistle	Human whistles to macaque.
Take picture		Human takes picture with either smartphone or camera.
Food	Food	Macaque handles human food.
	Food cue	Human food waste, e.g., empty wrapper.
	Drink bottle	Macaque handles plastic bottle.
	Wild food	Human offers plant material to macaque, e.g., palm kernel.
Eye contact		Human and macaque meet each other's gaze.
Macaque aggression	Eyebrow flash	Macaque raises eyebrows while looking at human.
	Open mouth threat	Macaque opens its mouth while looking at human.
	Lunge	Macaque moves either upper body or entire body toward human.
	Chase	Macaque pursues fleeing human.
	Grab	Macaque takes hold of human or their belongings, e.g., clothes.

subtle facial cues such as eye contact or eyebrow flashes. We used the same approach when collecting data on small groups of visitors, where only the person closest to the macaque was included in the analysis. To ensure independence of observations, we did not record successive encounters when there were multiple people or macaques. We removed encounter events involving infant macaques, as there were only two events recorded for infants, each from a separate individual.

Statistical Analysis

We observed tourist–macaque encounters during focal follow sessions that characterized more general macaque behavior, and we did not spend the same amount of time following each individual. We used Spearman's rank tests to look for biases in encounter detection due to sampling effort by testing the total number of observation hours for each animal against the number of encounters with tourists and the number of aggressive encounters. We also used pairwise chi-square tests to check collinearity assumptions due to the possibility of scoring more than one behavior as present within a single encounter. The chi-square tests showed some evidence of significant collinearity between *gesture* and *food* (χ^2 (1) = 8.776, $P = 0.003$), *gesture* and *vocalization*

(χ^2 (1) = 4.033, $P = 0.045$), and between *take picture* and *vocalization* (χ^2 (1) = 5.7459, $P = 0.017$), suggesting these behavioral cues were more likely to co-occur within a single encounter than expected due to chance. We therefore did not include these explanatory terms together in generalized linear mixed models (GLMMs).

We used binomial GLMMs with logit links to determine whether specific human behaviors and macaque demographic variables were associated with changes in rates of visitor-directed aggression. This approach allowed us to include *macaque ID* as a random effect to account for individual differences in rates of aggression. We used the package lme4 to carry out our GLMMs using maximum likelihood and the Laplace approximation (Bates *et al.* 2015). Each row of data that we used to fit our models represented one encounter between one tourist and one macaque. To avoid overfitting, and due to collinearity between some behavioral variables, we created several separate models to test our hypotheses. We used this approach because a single global model with all nine explanatory variables contained category combinations that were not observed and therefore would not converge.

The nested structure between *age class*, *sex*, *species*, and *macaque ID* was problematic in such a small data set. We checked for significance using likelihood ratio tests to compare models with and without the fixed term of interest. This involved separate models for 1) *age class* and *sex*, 2) *species*, and 3) all six human behaviors. We used all of the significant terms from these preliminary submodels in a single combined model. We assessed only *take picture* and *eye contact* as interaction variables due to all other combinations co-occurring in <5% of encounters. We assessed all hypothesized models with the bbmle package (Bolker and R Development Core Team 2020) using the Akaike information criterion corrected for small sample sizes (ΔAICc) <2, as well as Akaike weight (AICcWt). We used the function r.squaredGLMM in the MuMin package (Bartoń 2018) to compute both marginal and conditional R^2 values (theoretical model variance explained with and without random effects, respectively) for each model (Nakagawa *et al.* 2017). The best performing model was used for subsequent analyses.

We evaluated classification of this final model using the package DHARMa (Hartig 2020). 250 simulations with random noise added were used to compare with fitted residuals from the model. This was then used to assess over-/underdispersion, frequency of outliers, heteroscedasticity, and a Kolgorov–Smirnoff test for goodness-of-fit. We also used the package emmeans (Lenth 2020) for *post hoc* comparisons of marginal means between the predictor categories from the best performing model. We converted output units from log-odds into probability and used Z-tests with Tukey corrections for contrasts of predictor levels. We plotted the marginal means using the package ggeffects (Lüdecke 2018). We carried out all analyses in R version 4.0.2 (R Core Team 2020).

Ethical Note

This research complied with the University of Western Ontario's nonmedical review ethics board (NM-REB) as well as the joint best practices for field primatology laid out by the American Society of Primatologists and the International Primatological Society (Riley *et al.* 2014). Permission to conduct research was obtained from the Sabah

Wildlife Department and the Sabah Biodiversity Council. Research protocols adhered to both state and federal legal requirements.

Data Availability The data analyzed in this article are available from the corresponding author upon reasonable request.

Results

Aggression Frequency

We observed a total of 307 tourist–macaque interactions between 16 different monkeys over *ca.* 45 observation hours where the macaques were seen in the same vicinity as the tourists. Spearman's rank tests revealed no significant correlation between the time spent following a particular macaque and the number of overall encounters ($\rho = 0.416$, $N = 15$, $P = 0.123$) or bouts of human-directed aggression observed ($\rho = 0.214$, $N = 15$, $P = 0.443$). Therefore, variation in the amount of time spent following each individual should cause minimal bias in the number of aggressive encounters that we observed.

The macaques engaged in visitor-directed aggression at a rate of 0.71 bouts per hour ($N = 32$) and exhibited five types of minor aggression (Fig. 3). The remaining interactions ($N = 275$) did not involve aggressive responses from the macaques. Tourists did not attempt to frighten, displace, or hurt a macaque either before or after aggressive encounters. None of the monkeys bit or scratched a tourist, which means that no open wounds occurred as the result of primate aggression toward humans. Macaques grabbed at shirts, backpacks, and hair at a rate of 0.16 incidents per hour, but no skin-to-skin contact occurred during aggressive encounters. No tourist tried to pet the macaques or lure them onto their shoulder to get a picture.

Nearly two-thirds (63%, $N = 10$) of the monkeys that had encounters with tourists were observed to be aggressive at least once. However, primate aggression toward humans was not distributed evenly between macaques (Table III). A single adult male long-tailed macaque engaged in 0.38 aggressive bouts per hour, while an adult pig-tailed macaque was observed being aggressive toward tourists 0.20 times per hour. Together, these two individuals accounted for 81% ($N = 26$) of all of the aggressive

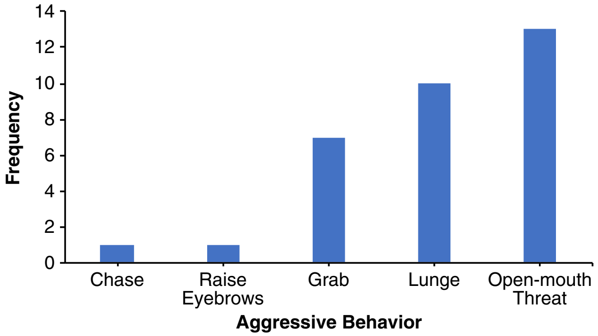

Fig. 3 Frequency of aggression (N 32) during encounters between a hybrid macaque group and tourists (N 307) at Sepilok Orang utan Rehabilitation Centre from November 2016 to August 2017.

Table III Summary of individual macaque participation in aggressive encounters with tourists at Sepilok Orang utan Rehabilitation Centre (November 2016 August 2017)

Name	Species	Age category	Sex	Bouts of aggression	Aggressive grabs
Bruno	Long tailed	Adult	Male	13	4
Bunga	Hybrid	Adult	Female	2	1
Campur	Hybrid	Adult	Female	1	0
Charlie	Pig tailed	Adult	Male	1	0
Hitam	Pig tailed	Adult	Female	1	1
Jagindas	Pig tailed	Adult	Male	8	1
Juvi	Pig tailed	Juvenile	Male	1	0
Manis	Long tailed	Adult	Female	1	0
Pirate	Long tailed	Adult	Male	1	0
Tabu	Hybrid	Juvenile	Male	3	0
Total:				32	7

incidents that we recorded. Those two macaques were also responsible for the majority of the aggressive grabs that we witnessed (0.11 grabs per hour; $N = 5$).

Human Behavior and Macaque Aggression

Of the six human behavioral categories considered, only two were significantly associated with changes in the probability of an aggressive outcome from a macaque (Table IV). Both *take picture* (likelihood ratio: χ^2 (1) = 6.509, $P = 0.011$) and *eye contact* (likelihood ratio: χ^2 (1) = 41.03, $P < 0.0001$) were significant predictors of human-directed aggression, and models that included them as an interaction term outperformed those that did not. The inclusion of *age class* and *sex* also improved the top model's performance (Table IV). Likelihood ratio tests suggested that neither *gesture*, *approach*, nor *vocalization* were significant predictors of aggression (gesture: χ^2 (1) = 1.719, $P = 0.190$; approach: χ^2 (2) = 2.664, $P = 0.264$); vocalization: χ^2 (1) = 0.237, $P = 0.626$).

The results of the *post hoc* comparison between the marginal means of the four variables included in the best performing model indicate that interactions between *eye contact* and *take picture* affected the outcome of encounters (Table V). When *eye contact* was present, *take picture* reduced the probability of experiencing an aggressive outcome (Fig. 4). The large standard error observed in the estimation of the probability of aggression reflects considerable variation in rates of aggression between individual macaques.

Food

Encounters that involved food were extremely rare, and tourists never offered their own food or garbage to the monkeys. The two attempts by tourists to feed a macaque involved palm kernels that had been dropped by another monkey. The macaque either gingerly accepted the food before discarding it ($N = 1$) or ignored the offer ($N = 1$). We

Table V Comparisons of all binomial GLMMs used to predict human-directed aggression from a hybrid macaque group at Sepilok Orang-utan Rehabilitation Centre from November 2016 to August 2017

Fixed terms of model	Akaike information criterion corrected for sample size (AICc)	Difference in AICc between current and top model (ΔAICc)	Log likelihood: overall model fit (LL)	Difference in LL between current and null model (ΔLL)	Number of parameters (*k*)	Model weight (AICcWt)	Marginal R^2	Conditional R^2
Take picture + Eye contact + Sex + Age class + Take picture: Eye contact	132 84	0 00	–59 23	32 99	7	0 781	0 557	0 659
Take picture + Eye contact + Sex + Take picture: Eye contact	135 83	2 99	–61 78	30 44	6	0 174	0 464	0 629
Take picture + Eye contact + Take picture: Eye contact	138 70	5 86	–64 25	27 97	6	0 041	0 281	0 617
Take picture + Eye contact	144 40	11 56	–68 13	24 09	5	0 002	0 328	0 592
Eye contact	149 49	16 65	–71 70	20 51	3	<0 001	0 250	0 570
Age class + Sex	179 87	47 04	–85 87	6 35	4	<0 001	0 363	0 453
Take picture	184 01	51 17	–88 97	3 25	3	<0 001	0 075	0 441
Null model	188 48	55 64	–92 22	0 00	2	<0 001	0 000	0 409
Gesture	188 80	55 96	–91 36	0 86	3	<0 001	0 009	0 421
Who approached	189 91	57 07	–90 89	1 33	4	<0 001	0 023	0 422
Food	190 03	57 19	–91 97	0 25	3	<0 001	0 004	0 417
Vocalization	190 28	57 45	–92 10	0 12	3	<0 001	0 002	0 406
Species	192 19	59 35	–92 03	0 19	4	<0 001	0 021	0 421

Macaque ID is included as a random intercept for all models

Table V Probability estimates for the fixed terms included in a binomial generalized linear mixed model exploring human directed aggression from macaques at Sepilok Orang utan Rehabilitation Centre (November 2016 August 2017)

Category level 1[a]	Category level 2[a]	Marginal mean estimate as a percentage probability (SE)		*Z* ratio	*P* value
		Category level 1	Category level 2		
Female	Male	0.5 (72.9)	8.2 (66.0)	−2.899	0.003
Adult	Juvenile	6.7 (63.7)	0.7 (75.5)	2.087	0.037
Photo 0 (eye 0)	Photo 1 (eye 0)	0.5 (72.0)	1.4 (71.4)	−0.903	0.367
Photo 0 (eye 1)	Photo 1 (eye 1)	21.2 (63.8)	1.1 (79.0)	2.581	0.010
Eye 0 (photo 0)	Eye 1 (photo 0)	0.5 (72.0)	21.2 (63.8)	−4.845	<0.0001
Eye 0 (photo 1)	Eye 1 (photo 1)	1.4 (71.4)	1.1 (79.0)	0.160	0.873

The associated *Z* ratio values provide a test of the significance of the contrast between category level 1 and category level 2

[a] 0 absent; 1 present

did not observe aggression toward humans during these feeding attempts, nor did we see any staff present. A binomial GLMM with *food* as the only fixed term was not significantly different from the null model (likelihood ratio test: χ^2 (1) = 0.492, P = 0.483).

On one occasion an adult man was seen holding out his water bottle to a juvenile male macaque, but the man then fled when the macaque lunged at him from 2 m away. On one other occasion, an adult female macaque tried to take a water bottle that had been left on a bench by a preoccupied tourist. These instances occurred at or near BSBCC where visitors are allowed to have their belongings with them.

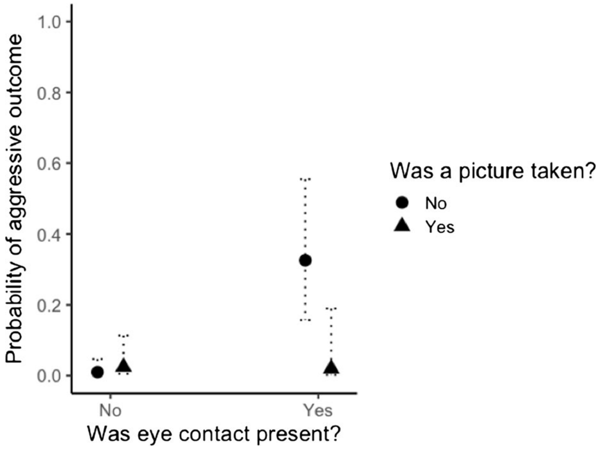

Fig. 4 Estimated effects from the binomial GLMM for the combined outcomes of the presence or absence of *eye contact* and *take picture* on the probability of aggression during an encounter with a hybrid macaque group at Sepilok Orang utan Rehabilitation Centre from November 2016 to August 2017. Standard errors reflect the interindividual variability observed within the group.

Age and Sex

In an initial model examining only *age class* and *sex* as fixed effects, we found that *sex* was significant (likelihood ratio test: χ^2 (1) = 12.315, $P < 0.001$), while *age class* was close to significant (likelihood ratio test: χ^2 (1) = 3.311, $P = 0.069$). Our top model suggests that encounters between visitors and male macaques had a significantly higher probability of an aggressive outcome compared to those with females (Table V). We assessed models both with and without *age class* as a predictor variable, given that it approached significance only in the initial model. The combined model that included *age class* had a better fit (>2AICc) compared to the model that did not (Table IV). The difference between adults and juveniles was significant in this combined model, suggesting that adults had a higher probability of being aggressive toward tourists (Table V).

Species

Macaque species was not a significant predictor of visitor-directed aggression (likelihood ratio test: χ^2 (2) = 0.383, $P = 0.826$).

Discussion

The severity and frequency of primate aggression toward humans observed at Sepilok were drastically lower than in similar studies on long-tailed macaques throughout Asia. Upward of 78% of the observed primate aggression toward humans at Padangtegal, Bali was classified as "intense," which included all physical contact, such as bites (Fuentes and Gamerl 2005). Simple threats, however, accounted for only 12% of the observed primate aggression toward humans at Padangtegal. This is in stark contrast to Sepilok, where we considered 41% (N = 14) of the macaque aggression that we observed as a simple threat, including open-mouth threats and raised eyebrows. Only 23% (N = 7) of the aggression involved direct contact and we did not observe any biting or scratching. All of the direct skin-to-skin contact was the result of one monkey; on 25 occasions, a juvenile female pig-tailed macaque touched tourists' arms or legs gently as they walked by. These encounters were always peaceful and never resulted in threatening or fleeing behavior, and therefore were not included in our analyses.

Age/sex class had a significant effect on the probability of visitor-directed aggression at Sepilok, which is similar to findings of previous research on macaques at tourist sites and may help explain why the total number of aggressive encounters was not correlated with the total time spent following each macaque (Fuentes and Gamerl 2005). We found that males and adults were more likely to be aggressive, but we did not control for the age/sex class of the humans involved in the encounter. It is possible that different patterns would emerge when controlling for the age/sex class of the observers, as well as the overall number of people present (Beisner *et al.* 2015; Fa 1992).

Although there was no significant difference in the rates of aggression between species categories at Sepilok, there is evidence that long-tailed and pig-tailed macaques have markedly different reactions to humans (Sussman *et al.* 2013). However, the small size of the study group (23 individuals including infants) may have precluded an accurate analysis of differences in rates of aggression according to species. At only 0.71 bouts of aggression per hour, we would require an unrealistically long period of data collection to achieve a sample size large enough for a reliable generalization of visitor-directed aggression from statistical analysis. A larger group with a more even number of long-tailed, pig-tailed, and hybrid males would make comparisons between species categories easier.

The significant results for *take picture* and *eye contact* are consistent with previous findings in which specific human behaviors predicted macaque aggression (Ruesto *et al.* 2010). Understanding which human behaviors may elicit aggression from specific macaque age/sex classes in particular contexts is a crucial component of reducing tourist-directed aggression. Taking pictures might be associated with lower odds of experiencing aggression at Sepilok because the tourists are looking at their phone or through their camera, rather than making prolonged eye contact, which was associated with significantly increased odds of experiencing aggression. Eye contact or staring between conspecifics has been associated with aggression in a number of macaque species, including long-tailed macaques (Cannon *et al.* 2016; Chance *et al.* 1977), pig-tailed macaques (Oettinger *et al.* 2007), and rhesus macaques (*Macaca Mulatta*: Pomerantz and Baker 2017; Symons 1974). Research that demonstrated that macaques are aware of and sensitive to human gaze dates back to the 1960s (e.g., Wada 1961), and previous work on macaques and tourism listed eye contact as a potential cause of human-directed aggression (Beisner *et al.* 2015; Fuentes and Gamerl 2005). Our data on eye contact suggest that the macaques at Sepilok exhibit the same tendency to view as threatening those human behaviors that closely resemble aggressive cues in macaques (Beisner *et al.* 2015; Berman *et al.* 2014; Fuentes and Gamerl 2005; Ruesto *et al.* 2010). Although we did not quantify tour guide behavior at Sepilok, a minority of guides advised their guests to maintain a safe distance from the monkeys and to avoid direct eye contact, but visitors frequently ignored this advice. Other visitors did not receive this advice at all, either because their guide did not mention it or because they were traveling without one.

The presence of human food appears to be a strong and frequent contributing factor in visitor-directed aggression at other tourist sites throughout Asia (Fuentes and Gamerl 2005; Sengupta and Radhakrishna 2018, 2020; Sha *et al.* 2009). Unlike those locations, interactions that involved food at Sepilok constituted only 2% of the total observed number of human–macaque encounters (0.16 bouts per hour). Similar results have been reported from Silver Spring State Park in Florida, where wild rhesus macaques experienced low rates of provisioning and human-directed aggression (Riley and Wade 2016). The provisioning of rhesus macaques in India was not associated with increased rates of aggression. However, taunting (offering food and then pulling it away) was strongly associated with macaque aggression toward humans (Beisner *et al.* 2015). Likewise, tourists offering food to macaques or having it stolen resulted in higher rates of aggression toward humans at Padangtegal, Bali and in Singapore, although the authors did not specify whether taunting was included in those results (Fuentes *et al.* 2008; Fuentes and Gamerl 2005; Sha *et al.* 2009). Therefore, the fact that tourists are unable to provision the macaques at Sepilok may contribute to the low frequency and intensity of visitor-directed aggression from the macaques. These findings lend support to the hypothesis that eliminating provisioning by tourists should reduce aggressive encounters

(Mallapur 2013; Sha *et al.* 2009). Site policies that consistently restrict visitors' access to food may have tangible effects on reducing the risk of aggression and, by extension, injury from macaques. This may also decrease the risk of disease transmission at the human–macaque interface.

The results of this study suggest that eye contact between tourists and wild pig-tailed and long-tailed macaques is associated with increased odds of experiencing aggression. We recommend that tourist sites that are home to macaques post multilingual educational material that advises visitors to avoid eye contact with the monkeys. Visitors should also have backpacks and purses locked away to reduce the likelihood of engaging in direct contact with macaques or experiencing visitor-directed aggression.

Long-tailed and pig-tailed macaques were previously listed as Threatened and Vulnerable, respectively, according to the IUCN Red List of Threatened Species. Their recent upgrade to Vulnerable and Endangered (Cheyne and Eudey 2020; Eudey *et al.* 2020) reflects the threats that both species face and highlights the importance of protecting primate health at tourist sites, regardless of the incidental nature of how tourists and primates interact (Grossberg *et al.* 2003). The ability to anticipate which human behaviors may cause macaque aggression will allow us to better mitigate undesirable tourist behavior, which will benefit primates living near ecotourism sites while also teaching tourists appropriate behavior for future encounters with wildlife. It is essential that we measure the effects of specific tourist intervention strategies to tailor recommendations for relevant primate species, tourism styles, and cultural and environmental contexts (Riley and Wade 2016). The measures of success will differ for each site depending, for example, on whether rehabilitation is a part of the site's mandate, the geographic layout of a location, the behavior and past experiences of the resident primates, and the expectations of the tourists (Sengupta and Radhakrishna 2020). Understanding these conflicting conditions along with the biological reality of disease transmission and the financial costs of expanding educational programs is essential to make effective, practical changes to tourist sites. Any changes to education programs or tourist guidelines will need to be made through collaboration with local site personnel given that they are typically the ones best situated to understand the potential impacts of changes to site policies (Muehlenbein and Wallis 2014). Ideally, effective tourist management strategies that are based on specific behavioral patterns will have positive effects beyond reducing the frequency of one or two unwanted behaviors.

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Author Contributions LJG, SS, and ICC designed the study. LJG conducted fieldwork. LJG and RB performed the data analysis. LJG and RB wrote the manuscript with editorial advice from SS and ICC.

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ORIGINAL ARTICLE

Boundary zone between northern and southern pig-tailed macaques and their morphological differences

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Abstract Based on previous conflicting reports that the two forms of pig-tailed macaque (northern and southern) exist as separate species, subspecies, or forms, and that their boundary zone lies in Thailand, a survey of the distribution range and morphology of pig-tailed macaques in Thailand was conducted during 2003 2010. We first conducted a questionnaire survey. Questionnaires were sent to 7,410 subdistricts throughout Thailand. We then traveled to 72 of the 123 subdistricts reporting the presence of pig-tailed macaques. However, due to a lack of reports of the presence of free-ranging pig-tailed macaques living south of the Isthmus of Kra, a survey of pet pig-tailed macaques was also conducted during 16 24 September 2011. Furthermore, 35 wild northern pig-tailed macaques inhabiting northern Thailand (13°13′N, 101°03′E) were temporarily caught and their morphological characters were measured and then compared to those of the southern form captured from Sumatra, Indonesia. Although largely allopatric, the ranges of the northern and southern pig-tailed macaques in Thailand were found to have a partially sympatric boundary at the Surat Thani Krabi depression (8 9°30′N). Morphologically, these two forms were very distinctive, with different morphological characters such as the crown patch, the white color of the triangle above the eyes, the red streak at the external rim of the eyes, pelage color, ischial callosity, tail length and carriage, facial height, and limb length in both sexes, and patterns of sex skin swelling and reddening in females. These differences in morphological characters between the northern and southern forms should help settle the problems of their taxonomy.

Keywords Ischial callosity · Isthmus of Kra · Pig-tailed macaque · Sex skin · Surat Thani Krabi depression · Tail carriage

Introduction

Thailand is an important biodiversity location since it is located at the connection of the peninsular and insular regions of Southeast Asia, and is also the boundary between the Indochinese and Sundaic subregions, a phytogeographical or zoogeographical transition zone (Woodruff 2003; Woodruff and Turner 2009). One of the primate species, which is currently under controversial taxonomical reclassification, is the pig-tailed macaque, where it remains equivocal if the northern and southern forms are two distinct species, subspecies, or just forms of the same species. Indeed, two related controversies still abound. The first relates to their taxonomic status; that is, it is unclear if they should be separated into two subspecies, *Macaca*

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nemestrina leonina and *M. n. nemestrina* (Fooden 1975; Albrecht 1980; Rosenblum et al. 1997; Abegg and Thierry 2002; Evans et al. 2003), into two distinct species, *M. leonina* and *M. nemestrina* (Groves 2001; Brandon-Jones et al. 2004; Roos et al. 2007; Yanuar et al. 2009), or even into just two forms of the single species, *M. nemestrina* (Choudhury 2003). The second controversy is whether the ranges of these two forms are separated from each other at the Isthmus of Kra (10°30′N) (Groves 2001; Brandon-Jones et al. 2004; Nadler et al. 2007) or south of the Isthmus of Kra, at the Surat Thani Krabi depression (8 9°N) (Fooden 1975).

In the past, the characters used to aid classification between these two forms of pig-tailed macaques were morphological, such as pelage color, tail length and carriage, and crown patch (Fooden 1975), and more recently genetic characters, such as mtDNA analysis (Rosenblum et al. 1997; Groves 2001; Roos et al. 2007). In addition to these characters, northern and southern pig-tailed macaques have also been categorized at the subspecies level based descriptively on their behavior. Specifically, southern pig-tailed macaques were reported to be terrestrial whilst northern pig-tailed macaques were reported to be arboreal (Fooden 1975, 1982). However, some of the potentially distinctive morphological characters, such as the red streak at the external rim of the eyes, the hair pattern on the face, and the shape of the ischial callosity, have not been well evaluated for their expression in the two forms across their ranges (Fooden 1975; Gippoliti 2001; Juliandi et al. 2009). Moreover, no survey to find out the exact boundary between the forms and their sympatric areas (if any) has been conducted.

Therefore, we surveyed pig-tailed macaques throughout Thailand, especially in the lower southern part (6.30 13°N), locating both forms of pig-tailed macaque with distinctive morphological characters. In particular, the cyclic females of each of the two forms showed different patterns of sex skin swelling and reddening. We also temporarily caught northern pig-tailed macaques that originated in northern Thailand and southern pig-tailed macaques that originated at Sumatra, Indonesia, and measured their morphological characters for direct comparison. The comparison of the morphological characters, pelage color, and sex skin swelling and reddening between northern and southern pig-tailed macaques performed in this study should help to resolve whether the taxonomic status between these two groups of monkeys should be at the subspecies or species level, and also to resolve how useful such easily visible morphological characters would be for reliably discriminating between the two proposed subspecies/species in the field.

Methods

Questionnaire survey

A questionnaire covering about 13 species of nonhuman primates in Thailand (Lekagul and Mc Neely 1977) was sent with a brochure and stamped envelope to the leader of each of the 7,410 subdistricts throughout Thailand (Malaivijitnond et al. 2011). When the completed questionnaires were returned, we classified locations that had reported the presence of primates, and especially those that had reported pig-tailed macaques in the area, and traveled to survey those locations that had reported their presence.

Field survey

We visited the subdistricts where pig-tailed macaques were reported between August 2003 and December 2010. The presence of the macaques was ascertained and species identification was performed by direct sighting. During these surveys, we recorded the location names, geographical coordinates, macaque species present, the number of macaques observed, evidence for the release of heterospecific or conspecific macaques to the troop, history of the troop, impact on and conflict with humans, habitat types (i.e., natural forest or anthropogenic), morphological characters, and behavior.

Due to a lack of reports on the presence of free-ranging pig-tailed macaques living south of the Isthmus of Kra from the questionnaire survey, which would be expected to be the southern form, a survey for pet pig-tailed macaques was also conducted between September 16th 24th 2011 throughout the south of Thailand, except at the four southernmost provinces (Satun, Yala, Pattani, and Narathiwat), which are essentially inaccessible at present because of the political situation. All of the pet pig-tailed macaques from our survey were kept for coconut picking, and the surveys were targeted accordingly by asking people who lived in houses where buying and selling of coconuts occurred as well as those domiciled in coconut plantation areas. At each location, we interviewed the owners, senior local people or neighbors, and collected fecal and/or hair samples for genetic analysis in the future.

During the surveys, the morphological characters of the macaques (e.g., the patterns of crest, crown, direction of cheek hair, pelage color, red streaks extending laterally from the external rim of the eyes, body size, tail length and carriage of both sexes, and the degree and pattern of the swelling and reddening of the sex skin in female monkeys) were observed. Photographs were also taken for further analysis and archival reference.

Temporary capture of free-ranging northern pig-tailed macaques in northern Thailand

A wild population of northern pig-tailed macaques that range freely without provisioned food inside and outside of the Khao Khieow Open Zoo, Chonburi Province, eastern Thailand (13°13′11.48″N, 101°03′24.71″E), formed the subjects for this study. The zoo was established in 1967, but the macaque population was seen in that area before the establishment of the zoo (information from VA). Thirty-five macaques (27 females and 8 males) were temporarily caught with a net trap ($W \times L \times H = 6 \times 6 \times 2$ m) in December 2010. Monkeys were anesthetized by intramuscular injection with 5 15 mg/kg BW of ketamine hydrochloride (Biomedic-VTC Company) and 1 2 mg/kg BW of xylazine (Ilium Xylazil-100). While the monkeys were immobilized, their body mass, sitting height, trunk length, tail length, head length, upper facial height, nasal height, upper arm length, forearm length, thigh length, leg length, foot length, and pelage color were recorded, blood samples were collected, and their overall health was examined. The macaques were released back to the troop when they had completely recovered from anesthesia.

To scrutinize the classification of northern and southern pig-tailed forms, at the subspecies or species levels, the morphometric data for both sexes of the abovementioned northern pig-tailed macaques were compared to those of their southern counterparts. Although it would be more appropriate to compare the data between the two forms of pig-tailed macaques which live in Thailand, there are currently no such records for wild southern pig-tailed macaques in Thailand (Malaivijitnond et al. 2005). Therefore, the data from 32 wild southern pig-tailed macaques that originated from southern Sumatra, Indonesia, and were transferred to the compound of a monkey trader in Cengkareng, Jakarta, where they were measured by YH in August 1984, were used instead.

The age of each macaque was estimated from their dentition, according to Smith et al. (1994), and the attritional status of their teeth, covering a range of 1 20 years old. Macaques were then categorized into three age classes: juvenile (1 3 years old), subadult (>3 6 years old), or adult (>6 years old), as shown in Table 1.

Table 1 Age and sex classes of the wild northern and southern pig tailed macaques used in this study

Age class	Northern pig tailed macaques (*n* 35)		Southern pig tailed macaques (*n* 32)	
	Female	Male	Female	Male
Juvenile	11	6	4	6
Subadult	5	0	4	9
Adult	11	2	2	7
Total	27	8	10	22

Determination of pelage color

Pelage color was quantitatively determined on the CIE $L^*a^*b^*$ scale using a color reflectometer (model CR-200 color analyzer$^{\text{TM}}$, Minolta Co., Ltd., Japan) following the method described by Hamada et al. (2006). Color is expressed by the three parameters of: (1) lightness (L^*), ranging from dark (0) to light (100); (2) the hue of green (a^*), ranging from -60 to red ($+60$); and (3) the hue of blue (b^*), ranging from -60 to yellow ($+60$). We measured the color at the vertex of the head, the back (interscapular), the lateral aspect of the upper arm and forearm, the dorsum of the hand, the waist (suprailiac), the lateral aspect of the thigh and the leg, and the dorsum of the foot. Note, however, that the CIE $L^*a^*b^*$ system was not measured on the southern pig-tailed macaque population from Sumatra.

Statistical analysis

The data are expressed as the mean ± one standard deviation (SD). Differences in morphological characters between northern and southern pig-tailed macaques of the same sex were analyzed by the Student unpaired t test. Differences in those values between age classes of the same monkey form were analyzed by one-way analysis of variance (ANOVA) with an LSD post hoc test using the SPSS software package (version PC11.0). In all cases, significance was accepted at $p < 0.05$.

Results

Information from the questionnaire and the field surveys

Of the 7,410 questionnaires sent, a total of 1,417 questionnaires (19.1 %) were returned, among which 705 questionnaires contained positive reports of the presence of primates, and 123 of those reported the presence of pig-tailed macaques in the area. Seventy-two (58.53 %) of these 123 potential locations were surveyed. However, pig-tailed macaques were only located at seven of the sites; the other 65 positive reports were based on misidentifications of long-tailed, rhesus, and stump-tailed macaques at 59, 5, and 1 location (81.94, 6.94, and 1.39 %), respectively. Moreover, five of the seven positive reports were from the same location (no. 1). Thus, only three different locations of wild pig-tailed macaques were observed (nos. 1, 4, and 8 in Table 2).

Table 2 Names and geographical coordinates obtained using the global positioning system (GPS) for pig tailed macaques found in Thailand

	Name of location and province	GPS (N, E)	No. counted	Date of observation
1	Wat Tham Kham, Sakon Nakhon	17°13′, 103°54′	86	10 Oct 2004
2	Phu Khieow Wildlife Sanctuary, Chaiyaphum	16°27′, 101°39′	N/A	23 Aug 2007
3	Erawan Monastery, Lop Buri	14°47′, 100°52′	N/A	28 Mar 2008
4	Khao Yai National Park, Nakhon Ratchasima	14°24′, 101°30′	10 20	11 Aug 2003
5	Khao Khieow Open Zoo, Chonburi	13°13′, 101°03′	65	6 Dec 2010
6	Khao Chi on Non hunting area, Chonburi	12°46′, 100°58′	50 100	18 Mar 2005
7	Piew Waterfall National Park, Chanthaburi	12°31′, 102°10′	N/A	22 Sep 2008
8	Wat Tham Prutakhian, Chumphon	10°50′, 99°15′	26	17 Jul 2005

Wat and Khao mean “temple” and “mountain” or “hill,” respectively, in Thai

Whilst surveying other areas for different macaque species in Thailand (i.e., long-tailed, rhesus, Assamese, and stump-tailed macaques), we also searched for and recorded the locations of pig-tailed macaques, which resulted in us finding five more locations for wild northern pig-tailed macaques (Table 2). However, this means that all eight locations from the field survey were solely the northern form. The northernmost group was at Wat Tham Kham, Sakon Nakhon Province (17°13′N, 103°54′E).

From the pet survey, we visited 50 locations and received information about 74 pig-tailed macaques, including where and when the macaques had been captured. Of these 74 specimens, 57 were the northern form (14 females and 43 males) and 17 the southern form (6 females and 11 males). No natural hybrid forms were observed. However, we found one human-made hybrid macaque which was mothered by a northern-pigtailed macaque and fathered by a southern pig-tailed macaque. Most of the pet monkeys were caught from the forest when they were less than two years old with known origins. The locals informed us that if the monkeys were more than two years old it was too difficult to train them to harvest coconuts. The locals also preferred to keep male monkeys more than females, because the males are stronger and more robust for coconut picking, resulting in an average harvesting ability of 500 1,200 coconuts/day/male monkey compared to only 300 500 coconuts/day/female monkey. They also said that the northern form was more skillful at coconut picking than the southern form, which would agree with the proposed arboreal lifestyle of northern pig-tailed macaques compared to the terrestrial lifestyle for the southern form (Fooden 1975, 1982). On average, each owner kept 2.08 ± 1.20 pet monkeys (mean ± SD), with the range being 1 5 monkeys.

The distribution map of the northern and southern pig-tailed macaques derived from our field surveys revealed that the two forms reached their range limits near Surat Thani Krabi Provinces at 8°30′N, and that the potential sympatric area was located within 8 9°30′N (Fig. 1).

Morphological characteristics of northern and southern pig-tailed macaques, as derived from the field surveys in Thailand

Northern pig-tailed macaques had a dark brown crown patch of hair that radiated from the center (Fig. 2a), and all specimens examined had a triangle-shaped patch of white below the crown patch and above the eyes, whilst the external rim of the eyes had a red streak point up to the direction of the ears. The hairs on the cheek radiated out and had an approximately round shape. The muzzle was shorter than that of the southern forms. The pelage showed a black streak in the middle of the back and some (especially adult) males had a bipartite pattern of a reddish color on the upper part while the lower part was a bit darker (Fig. 2c f). The ischial callosity was mostly an oval shape (Fig. 2b). The tails of northern pig-tailed macaques were blackish, the same as in the southern form, but were shorter and slenderer, with thin fur. Four patterns of tail carriage were noted in northern pig-tailed macaques: (1) point up at 90° to the back (Fig. 2c); (2) directed forward at 45° to the back (Fig. 2d); (3) directed forward and then parallel with the back (Fig. 2e); and (4) arched forward over its back (Fig. 2f). However, some monkeys did not always keep the tails in those positions; their tails were sometimes directed downwards.

Southern pig-tailed macaques had a dark brown crown patch similar to the northern form, except that it was darker (Fig. 3a). Neither the triangle shape of white color below the crown patch nor the red streak from the eyes was observed. The hairs on the cheek did not radiate out; they formed an approximate balloon shape. The muzzle was longer than in the northern forms. Their pelage was black on the mid-dorsal region up to the crown patch. The dark area was larger on the lower part, and no bipartite pattern was observed. Their ischial callosities were very different from those of the northern pig-tailed macaques, being butterfly shaped (Fig. 3b). Tails of the southern form were longer and hairier, and typically arched rearwards, with the

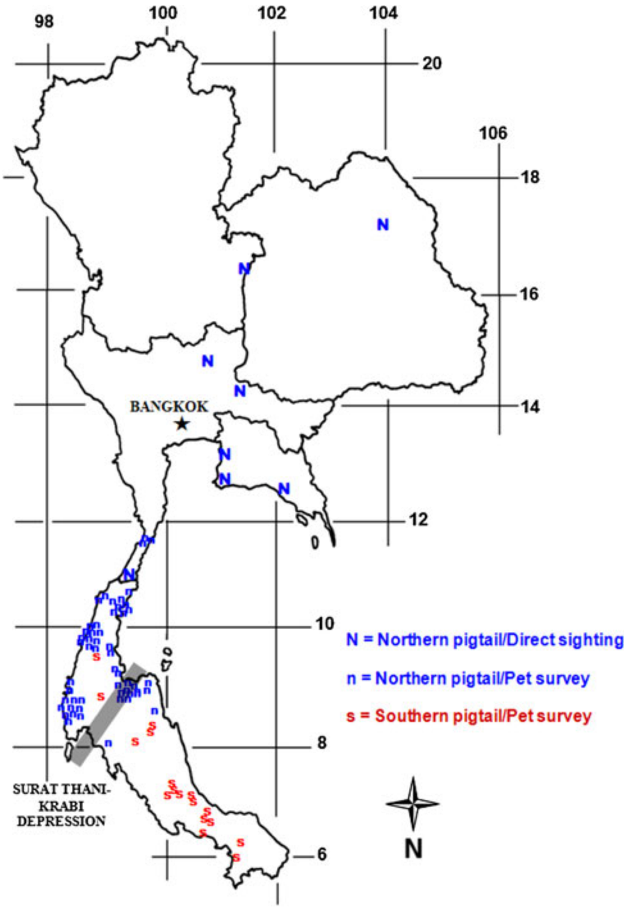

Fig. 1 Distribution of northern and southern pig tailed macaques in Thailand and the sympatric areas at the Surat Thani Krabi depression. *N* indicates troops of wild northern pig tailed macaques, whilst *n* and *s* indicate the northern and southern pig tailed macaque localities derived from surveys of pet macaques. The Surat Thani Krabi depression is shown as a *gray hatched area*

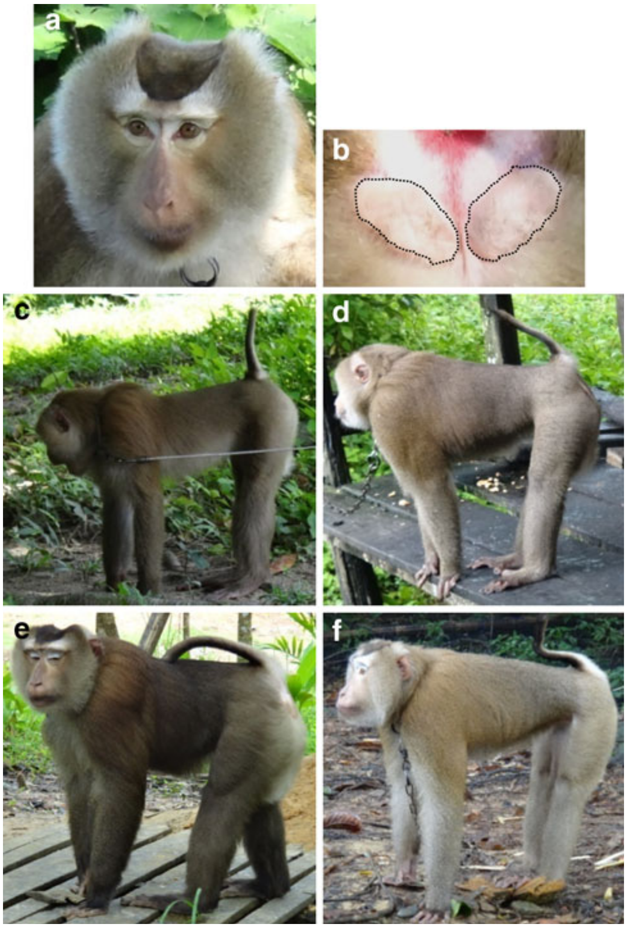

Fig. 2 Morphological characteristics of the northern form, showing the **a** face, **b** shape of ischial callosity, and **c f** tail length and carriage

tip of the tail often directed downwards, but not always (Fig. 3c, d). Indeed, two of the 17 pet monkeys showed a similar tail carriage (arched forward over its back) to those of the northern pig-tailed macaques (Fig. 3e, f).

The male hybrid infant (age 11 months) had a similar hair pattern on its face, shape of ischial callosity, and tail length to his southern father, and had a red streak at the eye and pelage color that were similar to his northern mother, while he kept his tail carriage similar to both his father's and mother's styles (Fig. 4).

Somatometric measurements and pelage color of the northern form in comparison to those of the southern form of pig-tailed macaque

As only two adult male northern pig-tailed macaques and two adult female southern pig-tailed macaques were inspected, the changes in the morphological values in relation with age were only considered in female northern and male southern pig-tailed macaques. Body mass, trunk length, foot length, and the percentage of relative facial length (Fig. 5a c) all increased with age (Pearson's correlation test: r^2 from 0.856 to 0.931 for ♀; r^2 from 0.679 to 0.788 for ♂, all $p < 0.05$), but reached a plateau at an age of around 15 years, and then, perhaps, tended to decrease beyond this (Fig. 5a c). The relative tail length, in contrast, decreased with increasing age (Pearson's correlation test: $r^2 = 0.477$ for ♀, $p < 0.05$).

In comparison to the southern form, no significant differences in the body mass, anterior trunk length, and crown-rump length were observed (Table 3). Their upper facial height, nasal height, and head length tended to be numerically lower in the northern form in both sexes compared to that for the southern form, although these differences were not statistically significant. However, their relative (1) upper facial height (against head length), (2) upper limb length, and (3) lower limb length (against trunk length) were all significantly shorter in the northern form than those of the southern form in both sexes

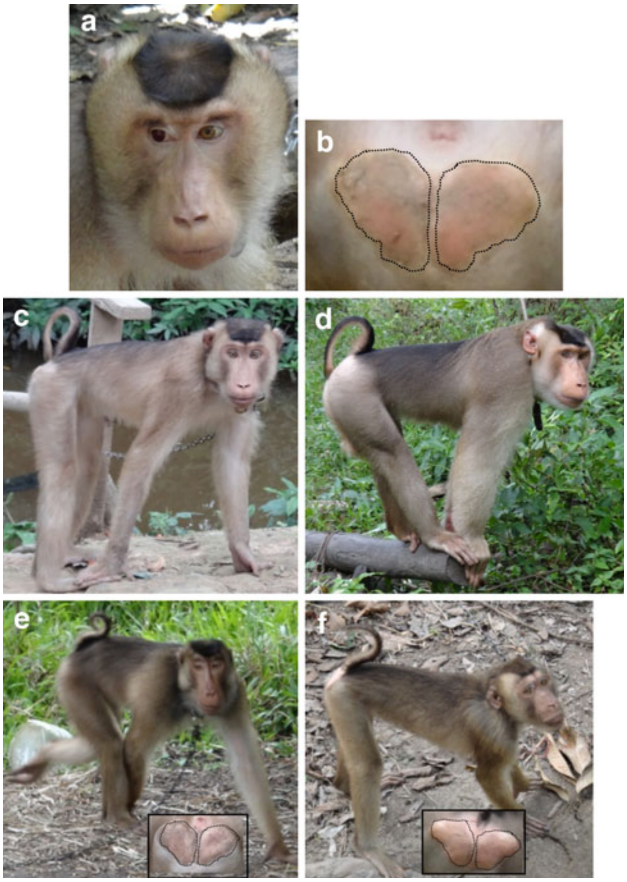

Fig. 3 Morphological characteristics of the southern form, showing the face (**a**), shape of ischial callosity (**b**, and *insets* of **e** and **f**), and tail length and carriage (**c**, **d**)

Fig. 4 Human made male hybrid macaque (age 11 months) which was mothered by a northern pig tailed macaque and fathered by a southern pig tailed macaque

(independent *t* test: ♀: $df = 11$, ♂: $df = 7$, $p < 0.05$). In contrast, the relative tail length (%) and intermembral index were not significantly different between the northern and southern forms of pig-tailed macaques within the same sex. In general, the degree of sexual dimorphism in which the values of each character for adult males were higher than that for adult females was comparable between the northern and southern forms.

According to the CIE $L^*a^*b^*$ color scale values, there were no significant differences between the age classes and sex classes in the northern form, except that the adult males had a darker (L^*) (ANOVA: $df = 4$, $p < 0.05$) and relatively more contrasting (a^* and b^*) hue to their pelages (Fig. 6). The high contrast in a^* and b^* values between the upper and lower parts of the body in adult males caused a bipartite pattern in appearance (Fig. 2). Unfortunately, in 1984, we did not measure the L^*, a^*, and b^* values in the southern pig-tailed macaques. However, from our observations, the pelage color pattern of adult males of the southern form, which originated from southern Sumatra, Indonesia, was similar to that of their northern counterpart from Khao Khieow Open Zoo, Thailand, except that it was less vivid in general and the mid-dorsal region of the trunk and the crown patch were darker in the larger areas.

Sex skin swelling in northern and southern pig-tailed macaques

Six of the 14 northern-form females and all six southern-form females among the pet macaques that we surveyed and observed in Thailand were in the estrous stage. Only one of the 11 adult female pig-tailed macaques inhabiting Khao Khieow Open Zoo, Thailand, which we inspected, showed a prominent sex skin swelling, and none of the ten females originating from Sumatra, Indonesia had a sex skin swelling. We therefore took photos of sex skin swelling and reddening of female southern pig-tailed macaques reared at Ragunan Zoo, Indonesia, for comparison.

There were two types of sex skin swelling observed in the northern form. First, the sex skin swelling in pubertal females (age 3.5 6 years old) can be subdivided into three separate swollen areas; one subcaudal, and a pair para-anal and lateroventral to the vulva (Fig. 7a, a′, b, b′). Generally, the circumanal swelling was more reddish than the

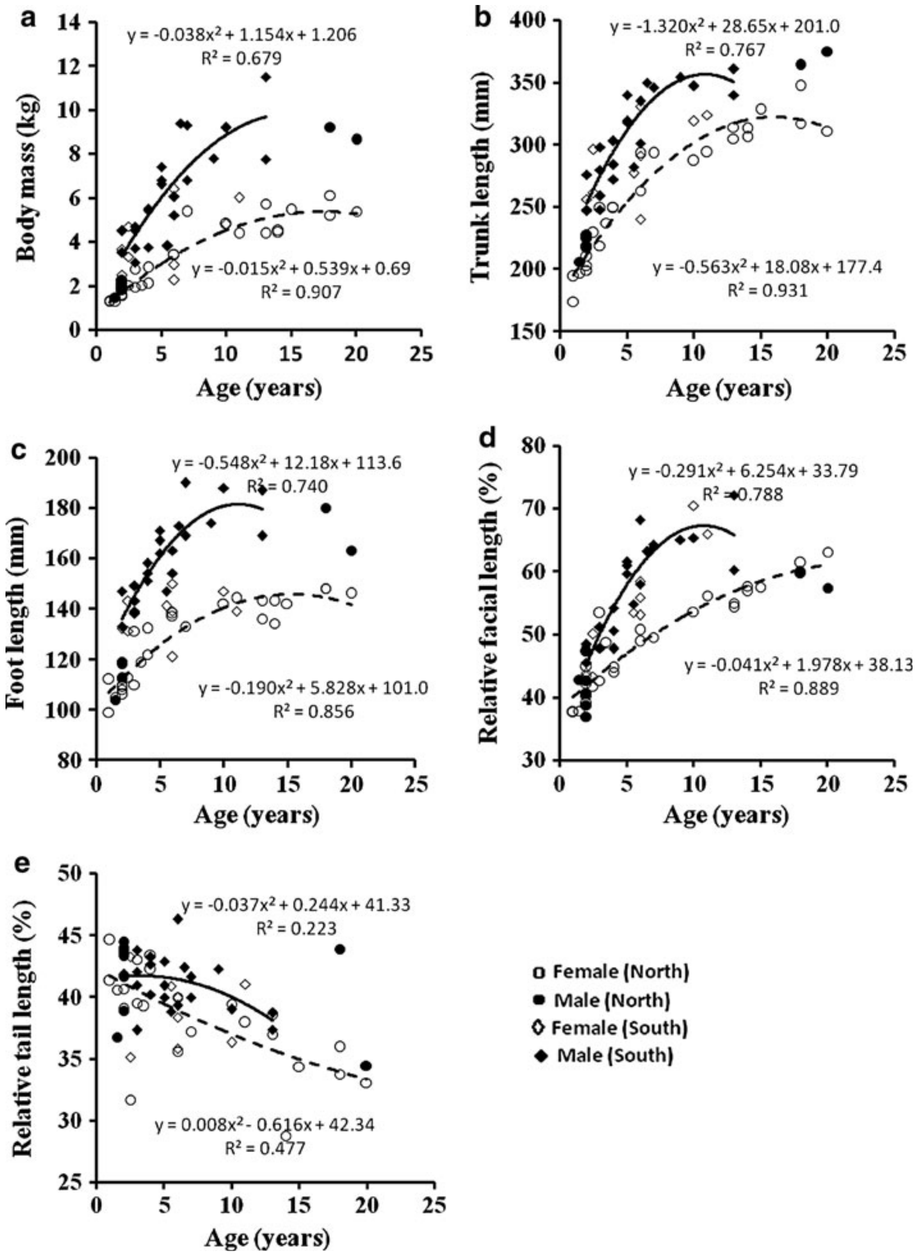

Fig. 5 The **a** body mass, **b** trunk length, **c** foot length, **d** % relative facial length, and **e** % relative tail length in relation to the age of the macaque for wild northern pig tailed macaques inhabiting Khao Khieow Open Zoo, Chonburi Province, eastern Thailand and southern pig tailed macaques from Sumatra, Indonesia

swelling at the vulva area. No swelling was observed around the ischial callosities, and the swellings were approximately oval in shape. Secondly, in fully mature or aged females (age >6 years old), the swelling mostly occurred at the subcaudal area, but sometimes at the para-anal area (Fig. 7c, c′).

Sex skin swellings in the southern forms inhabiting southern Thailand and Indonesia were slightly different. Generally, the pattern was similar to that reported by Fooden (1975), and was subdivided into five areas for those originating in southern Thailand; one subcaudal swelling and a pair each of para-anal and ventral vulval swellings (Fig. 8a, a′). With respect to the southern form from Indonesia, it was subdivided into seven parts that could be demarcated: one subcaudal swelling and pairs of para-anal, ventral vulva, and inguinal swellings (Fig. 8b, b′). In addition, the swelling at the para-anal and ventral vulval areas had a dark blue color mixed with the reddish color. The swellings in southern pig-tailed macaques extended laterally and largely around the ischial callosities, and appeared as a triangle shape.

Discussion

Although all the literature indicates that the boundary between the northern and southern forms of pig-tailed macaques is in southern Thailand, the exact location is still

Table 3 Comparison of morphological characters in adult males and females between northern and southern pig tailed macaques

Morphological values	Northern pig tailed macaques		Southern pig tailed macaques	
	Female	Male	Female	Male
Animal number	11	2	2	7
Body mass (kg)	5.1 ± 0.6	8.9 ± 0.4	5.4 ± 0.9	8.8 ± 1.5
Anterior trunk length (mm)	306 ± 20.6	370 ± 7.8	297 ± 34.8	348 ± 19.4
Crown rump length (mm)	456 ± 27.6	552 ± 3.5	453 ± 41.6	526 ± 36.9
Upper facial height (mm)	47.9 ± 4.7	56.5 ± 2.1	53.7 ± 8.9	62.6 ± 5.8
Nasal height (mm)	41.5 ± 4.4	55.0 ± 2.8	46.8 ± 6.9	56.8 ± 6.2
Head length (mm)	86.0 ± 3.4	96.5 ± 0.7	89.8 ± 5.1	99.6 ± 8.7
Relative upper facial height (%)[a]	55.7 ± 4.3*	58.5 ± 1.8*	59.5 ± 7.2	63.0 ± 5.2
Relative upper limb length (%)[b]	95.4 ± 3.3*	93.7 ± 8.1*	103 ± 6.7	104 ± 5.1
Relative lower limb length (%)[c]	102 ± 5.2*	98.6 ± 5.9*	108 ± 6.4	112 ± 5.3
Relative tail length (%)[d]	36.6 ± 2.3	39.1 ± 6.7	38.7 ± 3.4	40.6 ± 2.5
Intermembral index[e]	93.8 ± 3.0	95.0 ± 2.5	95.3 ± 93.8	93.5 ± 3.2

* $p < 0.05$ compared to southern pig tailed macaques

[a] Relative upper facial height upper facial height/head length × 100

[b] Relative upper limb length upper limb length/trunk length × 100

[c] Relative lower limb length lower limb length/trunk length × 100

[d] Relative tail length tail length/crown rump length × 100

[e] Intermembral index upper limb length/lower limb length × 100

controversial (Fooden 1975; Rosenblum et al. 1997; Groves 2001; Brandon-Jones et al. 2004; Nadler et al. 2007). From our survey, it was quite clear that the boundary between the northern and southern pig-tailed macaques was at Surat Thani Province southwestwards to Krabi Province (8 9°N), the so-called Surat Thani Krabi depression (Fooden 1975) or Khlong Marui fault (KMF) (Woodruff 2003; Woodruff and Turner 2009). This is located south of the Isthmus of Kra (10°30′N), where many biogeographers believed that the Indochinese and Sundaic subregions meet (Hughes et al. 2003; Woodruff and Turner 2009). The transition of northern and southern pig-tailed macaques is in agreement with those of rodents (Chaimanee and Jaeger 2000a, b; Tougard and Montuire 2006). The consensus in the scientific literature is that the seaway of the KMF breached the Thai Malay peninsula and reached into the northern (9 13°30′N) and central (6 9°N) peninsulas during the rising sea levels in the Miocene and Pliocene periods (Woodruff 2003; Woodruff and Turner 2009). The $\geq$100 m higher sea level stands in both the Miocene and the Pliocene ages may have had unsuspected effects on the paleogeography of the northern and central peninsulas, with the seaways breaching the central peninsula on two occasions of $>$1 Myr duration. Such straits may have served as obstacles to the dispersal of pig-tailed macaques, and may be causally related to the present-day concordant species range boundaries and the provincial transition (Woodruff 2003).

Although many details remain controversial, the diversification of the northern and southern forms of pig-tailed macaques is widely accepted by two hypotheses, based on mitochondrial DNA analysis. Previously, it was suggested that an ancestor of all *silenus* group macaques, including pig-tailed, Mentawai and Sulawesi macaques, originated in the Sunda region, with one lineage in Sumatra and Peninsular Malay and the other lineage in Borneo. During periods of low sea levels associated with glaciations, an ephemeral land bridge connected the Sunda Region (Borneo, Sumatra, Java, and Peninsular Malaysia), and the lineage on Sumatra and Peninsular Malay expanded northeastwards into mainland Asia (as *M. n. leonina* and *M. silenus*) and westwards to the Mentawai Islands (as *M. n. pagensis*), whilst the Bornean lineage dispersed to Sulawesi, probably by rafting (Evans et al. 2003; Meijaard 2003). Recently, it was argued that Mentawai macaques (*M. pagensis*) from Mentawai Island are the ancestor of their mainland relatives (*M. siberu*, *M. nemestrina*, *M. leonina* and *M. silenus*). The Mentawai macaques first colonized the Mentawai Islands using a land bridge from Sumatra, which emerged during a major global cooling event about 2.4 2.6 Mya (million years ago) during the late Pliocene. Subsequently, this progenitor became extinct over most of its range in Southeast Asia during a particularly cold and dry glacial period in the late Pliocene, but was able to survive in a number of equatorial islands (including the Mentawai). After having colonized the

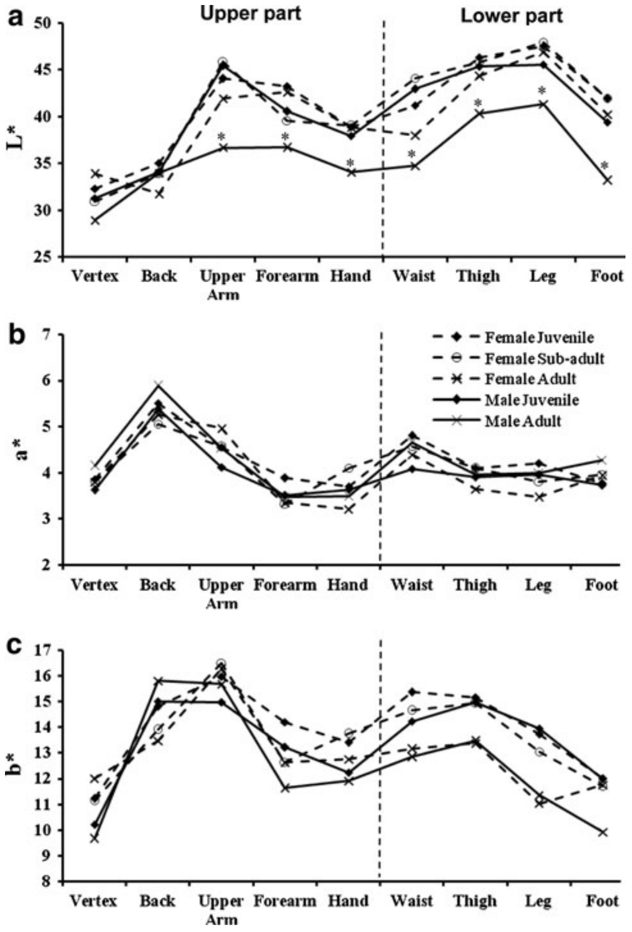

Fig. 6 Pelage color in wild northern pig tailed macaques inhabiting Khao Khieow Open Zoo, Chonburi Province, northern Thailand, showing the **a** *L** (lightness), **b** *a** (*green red*) and **c** *b** (*blue yellow*) color scales. $^*p < 0.05$ for comparisons between adult males and juvenile males or all female age classes (color figure online)

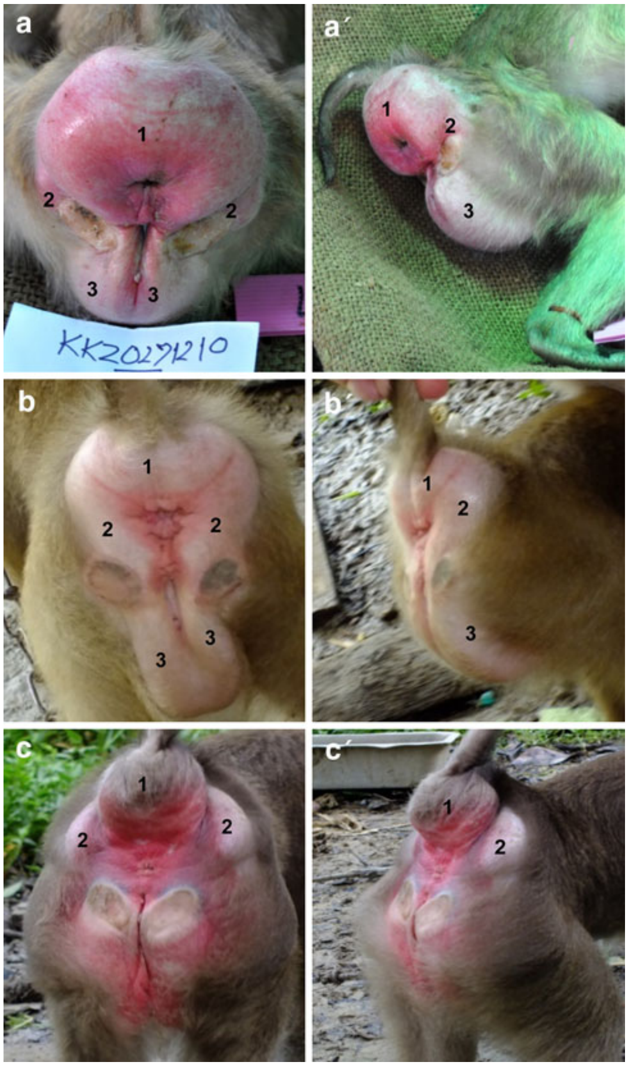

Fig. 7 Sex skin swelling and reddening in female northern pig tailed macaques in the front views (**a**, **b**, **c**) and lateral views (**a**′, **b**′, **c**′). Pubertal female monkeys inhabiting Khao Khieow Open Zoo, Chonburi Province, eastern Thailand (13°13′N, 101°03′E) (**a**, **a**′), pubertal female monkeys (**b**, **b**′), and fully matured female monkeys (**c**, **c**′) living close to the boundary zone at Ranong Province, Thailand (9°22′N, 98°24′E)

Mentawai archipelago, these macaques became isolated from Sumatra with the advent of a warmer climate and raised sea levels, and differentiated and evolved independently, while some macaques from Siberut (*M. siberu*) were able to recolonize Sumatra during a low sea level period about 1.5 1.7 Mya. Once established again in mainland Sumatra, this Siberut lineage diversified into *M. nemestrina*, *M. leonina*, and *M. silenus* during the Pleistocene period about 1.1 1.7 Mya (Ziegler et al. 2007).

Seemingly, the fossil evidence does not agree with the mtDNA analysis. Whilst the distribution of pig-tailed macaques, in terms of mtDNA analysis, was from the Sunda land to the Indochinese, the fossil records suggest a reverse direction. Inferring from the fossil evidence, it appears that Asian macaques split from African macaques (*M. sylvanus*) and colonized Asia about 5.5 Mya (Delson 1980) in the late Miocene/early Pliocene period. Asian macaques subsequently diversified to the *silenus* group lineage and the proto-*fascicularis* lineage (Morales and Melnick 1998). When the sea levels were 100 m above the present-day level, during the early Pliocene period (5.5 4.5 Mya), the ancestor of the *silenus* group was refuged in appropriate habitats and evolved independently (Woodruff 2003). They might have evolved into pig-tailed macaques in the Indochina subregion before expanding into the Sunda land when the sea levels lowered. This diversification is supported by the fossil record of pig-tailed macaques (*M. nemestrina*; Tougard 2001) of the late middle Pleistocene period, which was unearthed at Thum Wiman Nakin, northeastern Thailand, and the late Pleistocene fossils that were discovered at Lida Ajer, Sumatra, and Niah, Borneo. Interestingly, a pig-tailed macaque fossil

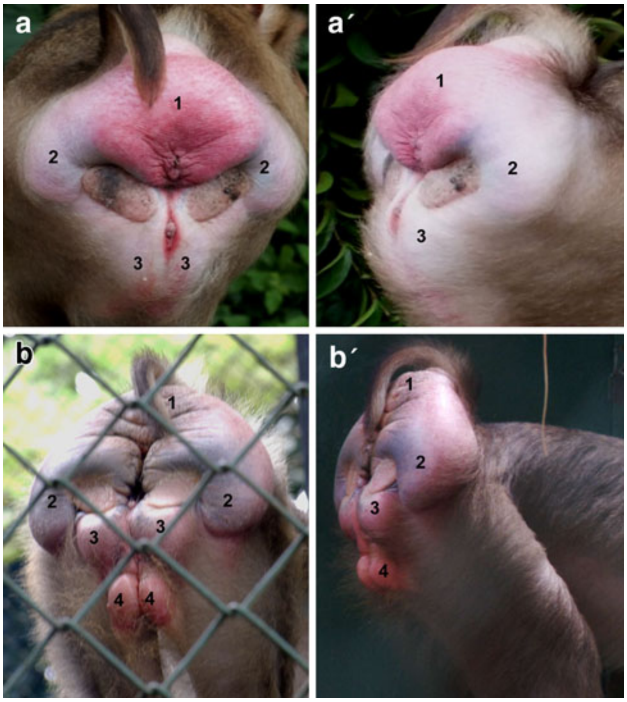

Fig. 8 Sex skin swelling and reddening in female southern pig tailed macaques, showing the front (**a**, **b**) and lateral (**a′**, **b′**) views. Adult females living close to the boundary zone at Songkhla Province, Thailand (6°57′N, 100°33′E) (**a**, **a′**) and kept at Ragunan Zoo, Jakarta, Indonesia (**b**, **b′**)

from the late Pleistocene period was also discovered from Punung, Java, where the extant species is no longer present (Tougard 2001).

Although our study does not help to clarify which of these hypotheses is correct, it supports that the KMF separated the two forms. Besides the KMF, the central peninsula (6 9°N), where the southern forms were observed, was also transected from the southern peninsula (1 6°N) by the Kangar Pattani line (6°30′N) during the high stand of sea level. This implies that the habitat of southern forms in the central peninsula shrank and remained only at the Nakhon Si Thammarat mountain range, a mountain range on the central peninsula of southern Thailand (Woodruff and Turner 2009). We suppose that the ancestor of southern pig-tailed macaques in the central peninsula would have been separated from the southern peninsula. Thus, the genetic diversity of southern pig-tailed macaques should be compared between southern Thailand, Malay, and Sumatra. Here, we found that the swelling patterns of the southern pig-tailed macaques that originated in Thailand are potentially different from those from Sumatra, Indonesia, although more populations will need to be examined across these ranges for confirmation. In accordance, Rosenblum et al. (1997) indicated that the separation and subsequent morphological divergence of southern and northern pig-tailed macaques (*M. n. nemestrina* and *M. n. leonina* in their study) may have been caused by a marine transgression that bisected the Thai Malay peninsula at the KMF. However, they did not include samples of southern pig-tailed macaques from Thailand in their study.

The average body weights of adult female and male northern pig tailed macaques (5.06 ± 0.61 and 8.93 ± 0.40 kg, respectively) were similar to those for the Indonesian (southern form) macaques (5.40 ± 0.85 and 8.82 ± 1.54 kg, respectively, in this study) or that reported for the wild-born southern form (4.4 and 8.6 ± 1.6 kg, respectively) (Rahlmann et al. 1967). In contrast, the average body weight of male northern and southern pig-tailed macaques in our study was significantly lower than that of the captive pig-tailed macaques (*M. nemestrina*) reared at the University of Washington Regional Primate Research Center (mean body weight = 11.6 kg) (Lipkin et al. 2001). However, this may simply reflect differences in nutritional conditions and physical activity.

Based on their visual appearances, these two groups of pig-tailed macaques appeared to have very different morphological characters and pelage colors, although a quantitative measurement of the pelage color (via the CIE $L^*a^*b^*$ scale) of the southern form was not performed. The measurements of the upper facial height, nasal height, and relative upper facial height reported here are in agreement with those reported by Kloss (1919) and Fooden (1975), who stated that the southern form had a longer muzzle than the northern form. Consistent with the notion that quadrupeds have comparable lengths of forelimbs and hindlimbs (Fleagle 1988) is the fact that both the northern and southern pig-tailed macaques included in this study had an intermembral index of 93 95. Additionally, the forelimbs and hindlimbs of arboreal quadrupeds are usually short, so as to bring the center of gravity closer to the substrate, whilst terrestrial quadrupeds have relatively long limbs to allow for long strides and speed (Fleagle 1988). This being the case, is consistent with the speculation that the northern pig-tailed macaque is arboreal and its southern counterpart is terrestrial (Fooden 1975, 1982), the relative upper and lower limb lengths of the southern form were longer than the respective lengths of the northern counterpart. Generally, the use of the tail carriage to discriminate between the northern and southern pig-tailed macaques has been viewed as a reliable indicator (Fooden 1975). However, not all of the adult northern pig-tailed macaques observed in our study carried their tails arched forward over their backs, in agreement with that reported by Choudhury (2002). Likewise, some of the southern pig-tailed macaques in our study were found to carry their tails arched forward over their backs, as did their northern counterparts. Apart from these general differences in tail carriage, we also found that tail length was slightly longer in the southern form. That aside, considering all of these differences in their respective morphologies, it seems likely that our data supported the classification of the northern and southern forms of pig-tailed macaques into the different species *M. leonina* and *M. nemestrina*, respectively, which was recently derived from mitochondrial DNA fragment sequence analysis (Roos et al. 2007; Ziegler et al. 2007).

This is the first report on sex skin swelling and reddening in the wild northern pig-tailed macaque, and also the first comparison of the sex skin swelling and reddening between the southern and northern forms. Based on the swelling patterns, the sex skin swelling and reddening in the northern form are markedly different from those in the southern form (Fooden 1975; this study), and are more similar to those seen in chimpanzees (Mori et al. 2007). Changes in the coloration and swelling of the adult female's sex skin reflect changes in the serum estrogen levels during the menstrual cycle, which is the highest during the late follicular phase (Dixson 1998). Although copulation is reported to occur in pig-tailed macaques throughout the menstrual cycle, the majority of males ejaculate during the follicular or periovulatory phase, when the tumescence and coloring of the sex skin are prominent (Eaton and Resko 1974). Other than in pig-tailed macaques, sex skin swelling is usually observed in other Old World Monkeys that live in a multi-male multi-female mating system, such as long-tailed macaques (Engelhardt et al. 2005; Malaivijitnond et al. 2007a). Based upon the sex skin evolution patterns proposed by Dixson (1998), the sex skin swellings found in the southern pig-tailed macaque in this study are the most complex, because they include swellings at the paracallosal region and ventral tail root, whereas the northern form had a less complex swelling akin to that found in *Mandrillus*, *Papio*, and *Pan*. The more complex sex skin swelling found in the southern pig-tailed macaques could be coherent with their terrestrial habitat, which involves a greater reliance upon visual cues rather than semiochemical ones (Fooden 1975). Thus, this characteristic also supports the distinctiveness of the two forms, and could serve as a reproductive isolation mechanism, and has been found to be the case in closely related species which tend to have similar morphological characters and are geographically intergrade (Fooden 1964).

Although it was reported that the two forms of pig-tailed macaques intergrade at 8 9°N (Fooden 1975), and from our survey there were potential sympatric areas at 8 9.5°N, we did not see any wild (natural) monkeys with hybrid forms, based on their morphological characters. However, we observed one human-made hybrid, and his morphological characters were fairly mixed between the two parental forms. One possible explanation for the absence of the natural hybridization is that these two forms of pig-tailed macaques have different lifestyles, with the northern form being arboreal and the southern form being terrestrial (Fooden 1975). Fooden (1975) hypothesized that the present zoogeographic relationship between the two forms is one of secondary contact and limited intergradations after a previous period of isolation allowed some degree of genetic, behavioral, and morphological differentiation. Noticeably, the different sex skin swelling and reddening patterns between the two forms that were observed in this study might indicate their reproductive isolation, although this remains to be confirmed. If so, the pattern of sex skin swelling might help to identify and classify pig-tailed macaques to the species level. Likewise, long-tailed (*M. fascicularis*) and rhesus macaques (*M. mulatta*) distributed in Thailand had similar morphological characters, but showed different patterns of sex skin swelling (Fooden 2000; Engelhardt et al. 2005; Malaivijitnond et al. 2007a; Hamada et al. 2006, 2008). On the other hand, macaques at different subspecies levels i.e., common long-tailed macaques (*M. fascicularis fascicularis*) and Burmese long-tailed macaques (*M. fascicularis aurea*) have the same pattern of sex skin swelling at the base of the tail (Malaivijitnond et al. 2007a; San and Hamada 2009). In particular, the subcaudal swelling is highly developed in northern pig-tailed macaques, closely resembling that of *M. silenus* (Gippoliti 2001), and in agreement with the results of mtDNA analysis (Evans et al. 2003; Roos et al. 2003; Ziegler et al. 2007).

Not much attention has been paid to use the different shapes of ischial callosities for species identification. Previously, the two forms of pig-tailed macaques were distinguished on the basis of pelage, tail length and carriage, bacula proportions, blood protein phenotypes, ecology, behavior, and the body and skull size (Fooden 1975). However, changes in some morphological characters are influenced by ecogeographical clinal effects, including the body and skull sizes, so they are not appropriate characters for identifying pig-tailed macaques and hybrids (Albrecht 1980). Thus, the ischial callosity could be of use to help identify controversial taxonomical specimens of northern and southern pig-tailed macaques. Also, the distinctive shape of the ischial callosity should support the classification of the northern and southern pig-tailed macaques into separate species, as recently used for species identification of the Sulawesi macaques (Juliandi et al. 2009).

Taken together, our study suggests that the northern and southern forms of pig-tailed macaques are separated at the Surat Thani Krabi depression, about 150 200 km south of the Isthmus of Kra. The separation might have been caused by a marine transgression during the Pleistocene period, and facilitated the evolutionary divergence of the different forms of pig-tailed macaques. The different morphological characters, such as the pelage color, facial development, limb length, tail length and carriage, the shape of the ischial callosity, and differences in the sex skin swelling, all support the recent classification (based on mtDNA analysis) of the northern and southern forms of pig-tailed macaques into two different species, *M. leonina* and *M. nemestrina*, respectively (Groves 2001; Brandon-Jones et al. 2004; Roos et al. 2007; Ziegler et al. 2007). Indeed, the differences in these parameters between the two groups of pig-tailed macaques are much greater than the differences found between the two species of the *fascicularis* species group that meet in northern Thailand (15–20°N) rhesus (*M. mulatta*) and long-tailed (*M. fascicularis*) macaques (Hamada et al. 2006, 2008; Malaivijitnond et al. 2007b, 2008). However, it is still unclear whether natural hybrids of these two forms occur at the sympatric areas (8–9.5°N); DNA analysis, which we will conduct in the near future, is awaited.

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