



## Primate Research And Conservation In Malaysia

By: **Susan Lappan** and Nadine Ruppert

### Abstract

Malaysia is inhabited by  $\geq 25$  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.

**Lappan, S.** & Ruppert, N. (2019). Primate research and conservation in Malaysia. *CAB Reviews* 14: 1-10. doi: 10.1079/PAVSNR201914004. Publisher version of record available at: <http://www.cabi.org/cabreviews>

# Primate research and conservation in Malaysia

Susan Lappan<sup>1,2</sup> and Nadine Ruppert<sup>1\*</sup>

**Address:** <sup>1</sup> Primate Research and Conservation Lab, School of Biological Sciences, Universiti Sains Malaysia, 11800 USM, Pulau Pinang, Malaysia. <sup>2</sup> Department of Anthropology, Appalachian State University, Boone, NC 28608, USA.

\***Correspondence:** Nadine Ruppert. Email: n.ruppert@usm.my

doi: 10.1079/PAVSNNR201914004

The electronic version of this article is the definitive one. It is located here: <http://www.cabi.org/cabreviews>

© CAB International 2019 (Online ISSN 1749-8848)

## Abstract

Malaysia is inhabited by  $\geq 25$  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<sup>2</sup>), 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], Hominidae [17–19]; folivorous: Colobinae [20–24]; omnivorous: Cercopithecinae [25, 26]; gummivorous: 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<sup>2</sup> 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<sup>2</sup> 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<sup>2</sup> 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.

### **Acknowledgments**

We thank the Universiti Sains Malaysia, Appalachian State University and the USA Fulbright Program that provided financial and technical support during the writing of this review. We thank the Malaysian Department of Wildlife and National Parks (DWNP) and the Forestry Department Peninsular Malaysia for granting us permission to conduct research on Endangered species in Peninsular Malaysia. We are grateful for the logistical and technical support from the Malaysian Primatological Society and the members of the Primate Research and Conservation Lab, School of Biological Sciences, USM. Two anonymous reviewers provided insightful comments and suggestions that substantially improved this manuscript.

### **References**

1. Roos C, Boonratana R, Supriatna J, Fellowes JR, Groves CP, Nash SD, *et al.* An updated taxonomy and conservation status review of Asian primates. *Asian Primates Journal* 2014;4:2–38.
2. IUCN. *The IUCN Red List of Threatened Species. Version 2018*; 2018.

3. Harrison T, Krigbaum J, Manser J. In Lehman S, Fleagle J, editors. Primate Biogeography: Progress and Prospects. Springer; 2006. p. 331–72.
4. Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. *Nature* 2000;403:853, doi: 10.1038/35002501, Available from: URL: <https://www.nature.com/articles/35002501#supplementary-information>.
5. Mittermeier RA, Robles-Gil P, Mittermeier CG. Megadiversity. Earth's Biologically Wealthiest Nations (CEMEX/Agropacion Sierra Madre, Mexico City, 1997).
6. NRE. Malaysia's 5th report to the convention on biological diversity. (Ministry of Natural Resources and Environment Malaysia (NRE), Putrajaya, 2014).
7. Estrada A, Garber PA, Mittermeier RA, Wich S, Gouveia S, Dobrovolski R, *et al.* Primates in peril: The significance of Brazil, Madagascar, Indonesia, and the Democratic Republic of the Congo for global primate conservation. *Peer* 2018;J6: e4869, doi: <https://doi.org/10.7717/peerj.4869>.
8. Smith RJ, Jungers WL. Body mass in comparative primatology. *Journal of Human Evolution* 1997;3:523–59.
9. Bartlett TQ. In Campbell C, Fuentes A, MacKinnon K, Bearder S, Stumpf R editors. Primates in Perspective. 2nd ed. Oxford University Press; 2011. p. 300–12.
10. Chivers DJ, Raemaekers JJ. In Chivers DJ, editor. Malayan Forest Primates. Springer; 1980. p. 209–60.
11. Ellefson JO. A natural history of white-handed gibbons in the Malayan peninsula [PhD thesis]. University of California, Berkeley; 1967.
12. Chivers DJ. Malayan Forest Primates: Ten Years' Study in Tropical Rain Forest. Springer, New York; 1980.
13. Gittins SP. Feeding and ranging in the agile gibbon. *Folia Primatologica* 1982;38:39–71.
14. Chivers DJ. Long-term observations of siamang behaviour. *Folia Primatologica* 1975;23:1–49.
15. Chivers DJ. The swinging singing apes: fighting for food and family in Far-East forests. In *The Apes: Challenges for the 21st Century*. Chicago Zoological Society, Chicago. p. 1–28.
16. Raemaekers JJ. Changes through the day in the food choice of wild gibbons. *Folia Primatologica* 1978;30:194–205.
17. MacKinnon J. The behaviour and ecology of the orang-utan (*Pongo pygmaeus*). *Animal Behaviour* 1974;22:3–74.
18. Kanamori T, Kuze N, Bernard H, Malim TP, Kohshima S. Fluctuations of population density in Bornean orangutans (*Pongo pygmaeus morio*) related to fruit availability in the Danum Valley, Sabah, Malaysia: a 10-year record including two mast fruitings and three other peak fruitings. *Primates* 2017;58:225–35.
19. Kanamori T, Kuze N, Bernard H, Malim TP, Kohshima S. Feeding ecology of Bornean orangutans (*Pongo pygmaeus morio*) in Danum Valley, Sabah, Malaysia: A 3-year record including two mast fruitings. *American Journal of Primatology* 2010;72:820–40.
20. Davies AG, Bennett EL, Waterman PG. Food selection by two South-east Asian colobine monkeys (*Presbytis rubicunda* and *Presbytis melalophos*) in relation to plant chemistry. *Biological Journal of the Linnean Society* 1988;34:33–56.
21. Hanya G, Bernard H. Functional response to fruiting seasonality by a primate seed predator, red leaf monkey (*Presbytis rubicunda*). *Tropical Ecology* 2013;54:383–95.
22. Matsuda I, Tuuga A, Higashi S. The feeding ecology and activity budget of proboscis monkeys. *American Journal of Primatology* 2009;71:478–92.
23. Matsuda I. Feeding and Ranging Behaviors of Proboscis Monkey *Nasalis larvatus* in Sabah, Malaysia. PhD thesis, Hokkaido University, Sapporo, Japan; 2008.
24. Salter RE, Mackenzie NA, Aken KM, Chai PK. Habitat use, ranging behaviour, food habits of the proboscis monkey, *Nasalis larvatus* (van Wurmb), in Sarawak. *Primates* 1985;26:436–51.
25. Lambert F. Some notes on fig-eating by arboreal mammals in Malaysia. *Primates* 1990;31:453–58.
26. Ruppert N, Holzner A, See KW, Gisbrecht A, Beck A. Activity budgets and habitat use of wild southern pig-tailed macaques (*Macaca nemestrina*) in oil palm plantation and forest. *International Journal of Primatology* 2018;39:237–51.
27. Wiens F, Zitzmann A, Hussein NA. Fast food for slow lorises: is low metabolism related to secondary compounds in high-energy plant diet? *Journal of Mammalogy* 2006;87:790–8.
28. Nekaris KAI. Extreme primates: ecology and evolution of Asian lorises. *Evolutionary Anthropology* 2014;23:177–87.
29. Jablonski NG, Crompton RH. Feeding behavior, mastication, and tooth wear in the Western Tarsier (*Tarsius bancanus*). *International Journal of Primatology* 1994;15:29–59.
30. Crompton RH, Andau PM. Ranging, activity rhythms, and sociality in free-ranging *Tarsius bancanus*: a preliminary report. *International Journal of Primatology* 1987;8:43–71.
31. Wiens F, Zitzmann A. Social structure of the solitary slow loris *Nycticebus coucang* (Lorisidae). *Journal of Zoology* 2003;261:35–46.
32. Wolf KE, Fleagle J. Adult male replacement in a group of silvered leaf-monkeys (*Presbytis cristata*) at Kuala Selangor, Malaysia. *Primates* 1977;18:949–55.
33. Boonratana R. In Latiff A, Masshor M, editors. Primate conservation in Southeast Asia: Threats, issues, and constraints. In: *Ex Situ Conservation of Orang Utan*. BMOUIF, Semanggol, Malaysia; 2013. p. 14–40.
34. Brodie JF, Giordano AJ, Zipkin EF, Bernard H, Mohd-Azlan J, Ambu L. Correlation and persistence of hunting and logging impacts on tropical rainforest mammals. *Conservation Biology* 2015;29:110–21.
35. Ibsch PL, Hoffmann MT, Kreft S, Pe'er G, Kati V, Biber-Freudenberger L, *et al.* A global map of roadless areas and their conservation status. *Science* 2016;354:1423–7.
36. Sodhi NS, Koh LP, Brook BW, Ng PK. Southeast Asian biodiversity: An impending disaster. *Trends in Ecology and Evolution* 2004;19:654–60.
37. Whitmore TC. A vegetation map of Malesia at scale 1:5 million. *Journal of Biogeography* 1984;11:461–71.
38. Malaysian Department of Forestry. (2016). *Forestry Statistics*. Available from: URL: <https://www.forestry.gov.my/index.php/en/2016-06-07-02-53-46/2016-06-07-03-12-29>.
39. Bryan JE, Shearman PL, Asner GP, Knapp DE, Aoro G, Lokes B. Extreme differences in forest degradation in Borneo: Comparing practices in Sarawak, Sabah, and Brunei. *PLoS*



- ONE 2013;8:e69679, doi: <https://doi.org/10.1371/journal.pone.0069679>.
40. Hughes AC. Understanding the drivers of Southeast Asian biodiversity loss. *Ecosphere* (Washington, D.C) 2017;8: e01624, doi: 10.1002/ecs2.1624.
  41. Global Forest Watch. (2018). Available from: URL: <https://www.globalforestwatch.org/dashboards/country/MYS>.
  42. Vijay V, Pimm SL, Jenkins CN, Smith SJ. The impacts of oil palm on recent deforestation and biodiversity loss. *PLoS ONE* 2016;11:e0159668, doi: 10.1371/journal.pone.0159668.
  43. Azhar B, Lindenmayer DB, Wood J, Fischer J, Zakaria M. Ecological impacts of oil palm agriculture on forest mammals in plantation estates and smallholdings. *Biodiversity and Conservation* 2014;23:1174–91.
  44. Eudey AA. The crab-eating macaque (*Macaca fascicularis*): widespread and rapidly declining. *Primate Conservation* 2008;23:129–32.
  45. Md-Zain BM, Sha'ari NA, Mohd-Zaki M, Ruslin F, Idris NI, Kadderi MD, *et al.* A comprehensive population survey and daily activity budget on long-tailed macaques of Universiti Kebangsaan Malaysia. *Journal of Biological Sciences* 2010;10:608–15.
  46. Sha JCM, Bernard H, Nathan S. Status and conservation of proboscis monkeys (*Nasalis larvatus*) in Sabah, East Malaysia. *Primate Conservation* 2008;23:107–20.
  47. Yap JL, Ruppert N, Fadzly NR. Activity Budgets, Habitat use and Feeding Ecology of Dusky Leaf Monkeys (*Trachypitecus obscurus*). School of Biological Sciences, Universiti Sains Malaysia, Penang; 2018.
  48. Md-Zain BM, Mohd Daut N, Shukor MN. Characterizing silvered leaf monkey-visitor interactions at Bukit Melawati, Kuala Selangor, Malaysia. *The Journal of Wildlife and National Parks* 2010;26:83–94.
  49. Arcus Foundation. State of the Apes. Industrial Agriculture and Ape Conservation. (Cambridge University Press, Cambridge, 2015).
  50. Meijaard E, Albar G, Nardiyono, Rayadin Y, Ancrenaz M, Spehar S. Unexpected ecological resilience in Bornean orangutans and implications for pulp and paper plantation management. *PLoS ONE* 2010;5:e12813, doi: 10.1371/journal.pone.0012813.
  51. Boonratana R. In Marsh LK, Chapman CA, editors. Fragmentation and its significance on the conservation of proboscis monkey (*Nasalis larvatus*) in the lower Kinabatangan, Sabah (North Borneo). In: *Primates in Fragments: Complexity and Resilience*. Springer, New York; 2013. p. 459–74.
  52. Boonratana R. Ranging behavior of proboscis monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, Northern Borneo. *International Journal of Primatology* 2000;21:497–518.
  53. Wearn OR, Rowcliffe JM, Carbone C, Pfeifer M, Bernard H, Ewers RM. Mammalian species abundance across a gradient of tropical land-use intensity: a hierarchical multi-species modeling approach. *Biological Conservation* 2017;212:162–71.
  54. FAO. Global Forest Resources Assessment. Country Report: Malaysia. Available from: URL: <http://www.fao.org/3/a-az266e.pdf> (Report of the Food and Agriculture Organization of the United Nations, 2015).
  55. McMorrow J, Talip MA. Decline of forest area in Sabah, Malaysia: relationship to state policies, land code, and land capability. *Global Environmental Change* 2001;11:217–30.
  56. Laurance WF, Goosem M, Laurance SGW. Impacts of roads and linear clearings on tropical forests. *Trends in Ecology and Evolution* 2009;24:659–69.
  57. Clements GR, Lynam AJ, Gaveau D, Yap WL, Lhota S, Goosem M, *et al.* Where and how are roads endangering mammals in Southeast Asia's forests. *PLoS ONE* 2014;9: e115376, doi: <https://doi.org/10.1371/journal.pone.0115376>.
  58. Johns AD. Effects of selective logging on the behavioral ecology of West Malaysian primates. *Ecology* 1986;67:684–94.
  59. Davies AB, Ancrenaz M, Oram F, Asner GP. Canopy structure drives orangutan habitat selection in disturbed Bornean forests. *Proceedings of the National Academy of Sciences, USA* 2017;114:8307–12.
  60. Johns AD, Skorupa JP. Responses of rain forest primates to habitat disturbance: A review. *International Journal of Primatology* 1987;8:157–91.
  61. Bernard H, Bili R, Matsuda I, Hanya G, Wearn OR, Wong A, *et al.* Species richness and distribution of primates in disturbed and converted forest landscapes in Northern Borneo. *Tropical Conservation Science* 2016;9:1–11, doi: <https://doi.org/10.1177/1940082916680104>.
  62. Marsh CW, Wilson WL. A survey of primates in peninsular Malaysian forests. Final report for the Malaysian Primates Research Programme July 1981 (Universiti Kebangsaan Malaysia and University of Cambridge, UK, 1981).
  63. Magintan D, Md. Nor S, Ean TP, Lechner AM, Azhar B. The conservation value of unlogged and logged forests for native mammals on the east coast of Peninsular Malaysia. *Journal for Nature Conservation* 2017;40:113–9.
  64. Laidlaw RK. Effects of habitat disturbance and protected areas on mammals of Peninsular Malaysia. *Conservation Biology* 2000;14:1639–48.
  65. Johns AD. Species conservation in managed tropical forests. In: Whitmore TC, Sayer JA, editors. *Tropical Deforestation and Species Extinction*. Chapman and Hall, London; 1992. p. 15–53.
  66. Southwick CH, Cadingan FC. Population studies of Malaysian primates. *Primates* 1972;13:1–18.
  67. Abdullah SA, Nakagoshi N. Forest fragmentation and its correlation to human land use change in Selangor, Peninsular Malaysia. *Forest Ecology and Management* 2007;241:39–48.
  68. Brühl CA, Eitz T, Linsenmair KE. Size does matter: effects of tropical rainforest fragmentation on the leaf litter ant community in Sabah, Malaysia. *Biodiversity and Conservation* 2003;12:1371–89.
  69. Arroyo-Rodriguez V, Cuesta-del Moral E, Mandujano S, Chapman CA, Reyna-Hurtado RA, Fahrig L. Assessing habitat fragmentation effects on primates: the importance of evaluating questions at the correct scale. In: Marsh L, Chapman C, editors. *Primates in Fragments*. Springer, New York; 2013. p. 13–28.
  70. Bennett EL, Caldecott JO. Unexpected abundance: The trees and wildlife of the Lima Belas Estate Forest Reserve near Slim River, Perak. *The Planter* 1981;57:516–9.

71. Turner IM, Corlett RT. The conservation value of small, isolated fragments of lowland tropical forest. *Trends in Ecology and Evolution* 1996;11:330–3.
72. Marsh LK, Chapman C. *Primates in Fragments: Complexity and Resilience*. (Springer, 2013).
73. Bernard H, Baking EL, Giordano AJ, Wearn OR, Ahmad AH. Terrestrial mammal species richness and composition in three small forest patches within an oil palm landscape in Sabah, Malaysian Borneo. *Mammal Study* 2014;39:141–54.
74. Ewers RM, Didham DK, Fahrig L, Gonçalo Ferraz G, Hector A, Holt RD, *et al.* A large-scale forest fragmentation experiment: The Stability of Altered Forest Ecosystems Project. *Philosophical Transactions of the Royal Society B: Biological Sciences* 2011;336:3292–02.
75. The Star. (2018). Available from: URL: <https://www.thestar.com.my/news/nation/2018/06/10/latest-tapir-killed-by-van-pushes-roadkill-of-iconic-species-to-over-70/>.
76. Boonratana R. Of road kills and dead langurs. *Malayan Naturalist* 2003;57:34–9.
77. Boonratana R, Traeholt C, Brockelman WY, Htun S. *Trachypithecus obscurus*. *The IUCN Red List of Threatened Species 2008e*.T22039A9349397, 2008. Available from: URL: <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T22039A9349397.en>.
78. Ruppert N. (personal observation).
79. Streicher U, Singh M, Timmins RJ, Brockelman WY. *Nycticebus bengalensis*. *The IUCN Red List of Threatened Species 2008e*.T39758A10263081. 2008. Available from: URL: <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T39758A10263081.en>.
80. Kuchikura Y. Efficiency and focus of blowpipe hunting among Semaq Beri hunter-gatherers of Peninsular Malaysia. *Human Ecology* 1988;16:271–305.
81. Venkataraman VV, Kraft TS, Dominy NJ. Hunter-gatherer residential mobility and the marginal value of rainforest patches. *Proceedings of the National Academy of Sciences, USA* 2017;14:3097–102.
82. Malaysia LO. *Wildlife Conservation Act 2010*. (Government of Malaysia, 2010).
83. Aziz SA, Clements GR, Rayan DM, Sankar P. Why conservationists should be concerned about natural resource legislation affecting indigenous peoples' rights: lessons from Peninsular Malaysia. *Biodiversity and Conservation* 2013;22:639–56.
84. Voigt M, Wich SA, Ancrenaz M, Meijaard E, Abram N, Banes GL, *et al.* Global demand for natural resources eliminated more than 100 000 Bornean orangutans. *Current Biology* 2018;28:761–9.
85. Bennett EL, Nyaoi AJ, Sompud J. In *Hunting for Sustainability in Tropical Forests*. Columbia University Press; 2000. p. 305–24.
86. Corlett RT. The impact of hunting on the mammalian fauna of tropical Asian forests. *Biotropica* 2007;39:292–303.
87. Nijman V, Healy A. Present-day international primate trade in historical context. In: Wich SA, Marshall AJ, editors. *An Introduction to Primate Conservation*. Oxford University Press; 2016. p. 129–142.
88. Krishnasamy K, Stoner S. Trading faces: A rapid assessment of the use of Facebook to trade wildlife in Peninsular Malaysia. (TRAFFIC, Petaling Jaya, Selangor, Malaysia, 2016).
89. Lee PC, Priston NEC. In *Commensalism and Conflict, the Human-Primate Interface*. American Society of Primatologists; 2005. p. 1–23.
90. Agooramorthy G, Hsu MJ. Use of nonhuman primates in entertainment in Southeast Asia. *Journal of Applied Animal Welfare Science* 2010;8:141–9.
91. Alberts CA. Woman devotes her life to saving gibbons from the pet trade. *The Dodo*; 2017. Available from: URL: <https://www.thedodo.com/in-the-wild/woman-rescues-gibbons-pet-trade-malaysia>.
92. Times NS. Uproar over exotic pets, 23 March, 2018. 2018. Available from: URL: <https://www.nst.com.my/actionline/2018/03/348283/uproar-over-exotic-pets>.
93. Nekaris KAI, Streicher U. *Nycticebus coucang*. *The IUCN Red List of Threatened Species 2008e*.T39759A10263403. 2008. Available from: URL: <http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T39759A10263403.en>.
94. Zainol MZ, Fadzly NR, Ruppert N. in *XXVII Congress of the International Primatological Society* Vol. 2018. Available from: URL: [https://www.researchgate.net/publication/327933004\\_Assessment\\_of\\_illegal\\_online\\_primate\\_trade\\_in\\_Malaysia\\_\(Nairobi,Kenya\)](https://www.researchgate.net/publication/327933004_Assessment_of_illegal_online_primate_trade_in_Malaysia_(Nairobi,Kenya)).
95. Nijman V. An overview of international wildlife trade from Southeast Asia. *Biodiversity and Conservation* 2010;19:1101–14.
96. Saaban S, Yazid AZ, Mustapa AR, Keliang C. in *Biodiversity Forum 2016* Vol. 2016. Available from: URL: [http://www.mpoc.org.my/upload/13144901\\_HUMAN\\_WILDLIFE\\_CONFLICT\\_IN\\_PENINSULAR\\_MALAYSIA\\_CURREN\\_STATUS\\_AND\\_OVERVIEW.pdf](http://www.mpoc.org.my/upload/13144901_HUMAN_WILDLIFE_CONFLICT_IN_PENINSULAR_MALAYSIA_CURREN_STATUS_AND_OVERVIEW.pdf) (Awana Resort, Genting Highlands, Malaysia).
97. Al-Jazeera. Massive Malaysian monkey cull spurs concerns. 2013. Available from: URL: <https://www.aljazeera.com/indepth/features/2013/04/2013422143220434441.html>.
98. IPPL. in *International Primate Protection League* Vol. 2018; 2013. Available from: URL: <https://www.ippl.org/gibbon/blog/malaysias-monkey-war-take-action/>.
99. UNDP-GEF. United Nations Development Programme Global Environmental Facility. Improving Connectivity in the Central Forest Spine (CFS) Landscape. 2014. Available from: URL: <http://www.my.undp.org/content/dam/malaysia/docs/Central%20Forest%20Spine%20Final%20Pro%20Doc.pdf>.
100. Stone R. Last-gasp effort to save Borneo's tropical rainforests. *Science* 2007;317:192.
101. Sabah Forestry Department. Sustainable forest management. 2018. Available from: URL: <http://www.forest.sabah.gov.my/>.
102. Malay Mail. Perak to open fifth state park at Segari Melintang. *Malay Mail* 9 July 2018, 2018. Available from: URL: <https://www.msn.com/en-my/news/national/perak-to-open-fifth-state-park-at-segari-melintang/ar-AAzMFxU>.
103. Chow MD. Forest lovers hail move to ban logging at Ulu Muda. *Free Malaysia Today* 7 September 2018, 2018. Available from: URL: <https://www.freemalaysiatoday.com/category/highlight/2018/2009/2007/forest-lovers-hail-move-to-ban-logging-at-ulu-muda/>.
104. Ross C, Reeve N. Survey and census methods: Population distribution and density. In: Setchell JM, Curtis DJ, editors.

Field and Laboratory Methods in Primatology: A Practical Guide. Cambridge University Press, Cambridge; 2011. p. 90–109.

105. Haddad NM, Bowne DR, Cunningham A, Danielson BJ, Levey DJ, Sargent S, *et al.* Corridor use by diverse taxa. *Ecology* 2003;84:609–15.
106. Schwartzman S, Moreira A, Nepstad D. Rethinking tropical forest conservation: peril in parks. *Conservation Biology* 2009;14:1351–7.
107. Lim TW. Critical review of the forest regulatory framework and its implementation in Malaysia. In: Scheyvens H, editor. *Critical Review of Selected Forest-Related Regulatory Initiatives: Applying A Rights Perspective*. Institute for Global Environmental Strategies, Kanagawa, Japan; 2011. p. 51–66.
108. Kaur M. Orang Asli form blockades to stop Gua Musang logging. *Free Malaysia Today* 17 February 2018; 2018. Available from: URL: <https://www.freemalaysiatoday.com/category/nation/2018/02/17/orang-asli-form-blockades-to-stop-gua-musang-logging/>.

**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.

| <b>Species</b>                  | <b>Peninsular Malaysia</b> | <b>Sabah</b>      | <b>Sarawak</b>    |
|---------------------------------|----------------------------|-------------------|-------------------|
| <i>Cephalopachus bancanus</i>   | Protected                  | Protected         | Totally Protected |
| <i>Hylobates</i> spp.           | Totally Protected          | Protected         | Totally Protected |
| <i>Macaca arctoides</i>         | Totally Protected          | n/a               | n/a               |
| <i>Macaca fascicularis</i>      | Protected                  | Protected         | Protected         |
| <i>Macaca nemestrina</i>        | Protected                  | Protected         | Protected         |
| <i>Nasalis larvatus</i>         | Totally Protected          | Totally Protected | Totally Protected |
| <i>Nycticebus</i> spp.          | Totally Protected          | Protected         | Totally Protected |
| <i>Pongo pygmaeus</i>           | Totally Protected          | Totally Protected | Totally Protected |
| <i>Presbytis</i> spp.           | Protected                  | Protected         | Totally Protected |
| <i>Symphalangus syndactylus</i> | Totally Protected          | n/a               | n/a               |
| <i>Trachypithecus</i> spp.      | Protected                  | Not protected     | Protected         |



**Appendix 2.** Published studies of Malaysian primates (not cited in the main text).

| <b>Primate family</b> | <b>General ecology and behavior</b>  | <b>Phylogeny, distribution and abundance</b>   | <b>Feeding ecology</b>   | <b>Habitat use, travel distances and sleeping sites</b>   | <b>Health, diseases and parasites</b>  |
|-----------------------|--|--|--|---|--|
| 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. |  |

## References of Appendix

Abdul-Latiff, M.A.B., Baharuddin, H., Abdul-Patah, P., Md-Zain, B.M. (2018). Is Malaysia's banded langur, *Presbytis femoralis*, actually *Presbytis neglectus neglectus*? Taxonomic revision with new insights on the radiation history of the *Presbytis* species group in Southeast Asia. *Primates*, DOI:10.1007/s10329-018-0699-y.

Abegg, C. & Thierry, B. (2002). Macaque evolution and dispersal in insular south-east Asia. *Biological Journal of the Linnean Society*, 75(4), 555–576.

- Ampeng, A. & Md-Zain, B.M. (2012). Ranging patterns of Critically Endangered Colobine, *Presbytis chrysomelas chrysomelas*. *The Scientific World Journal*, DOI:10.1100/2012/594382.
- Andau, P.M., Hiong, L.K., Sale, J.B. (1994). Translocation of pocketed orang-utans in Sabah. *Oryx*, 28, 263-268.
- Ancrenaz, M., Goossens, B., Gimenez, O., Sawang, A., Lackman-Ancrenaz, I. (2004a). Determination of ape distribution and population size using ground and aerial surveys: a case study with orang-utans in lower Kinabatangan, Sabah, Malaysia. *Animal Conservation*, 7(4), 375-385.
- Ancrenaz, M., Calaque, R., Lackman-Ancrenaz, I. (2004b). Orangutan nesting behavior in disturbed forest of Sabah, Malaysia: implications for nest census. *International Journal of Primatology*, 25, 983-1000
- Ancrenaz, M., Gimenez, O., Ambu, L., Ancrenaz, K., Andau, P., Goossens, B., Payne, J., Sawang, A., Tuuga, A., Lackman-Ancrenaz, I. (2005). Aerial surveys give new estimates for orangutans in Sabah, Malaysia. *PLOS Biology*, 3(1), DOI:10.1371/journal.pbio.0030003.
- Ancrenaz, M., Sollmann, R., Meijaard, E., Hearn, A. J., Ross, J., Samejima, H., [...] Wilting, A. (2014). Coming down from the trees: Is terrestrial activity in Bornean orangutans natural or disturbance driven? *Scientific Reports*, 4, 3-7.
- Apandi, Y., Nazni, W.A., Azleen, Z.A.N., Vythilingam, I., Noorazian, M.Y., Azahari, A.H., Zainah, S., Lee, H.L. (2009). The first isolation of chikungunya virus from non- human primates in Malaysia. *Journal of Medical Entomology*, 1(3), 35-39.
- Bennett, E.L. (1988). Proboscis monkeys and their swamp forests in Sarawak. *Oryx*, 22(2), 69-74.
- Bennett, E.L. & Sebastian, A.C. (1988). Social organisation and ecology of proboscis monkey (*Nasalis larvatus*) in mixed coastal forest in Sarawak. *International Journal of Primatology*, 9, 233-255.
- Bennett, E.L. & Gombek, F. (1993). *Proboscis Monkeys of Borneo*. Natural History Publications (Borneo) Snd. Bhd, Kota Kinabalu.
- Bernard, H. (1995). A study on the distribution and abundance of proboscis monkey (*Nasalis larvatus*) in the Klias Peninsula, Sabah, North Borneo. *Journal of Wildlife Management and Research Sabah*, 1, 1-72.
- Bernard, H. & Zulhazman, H. (2006). Population size and distribution of the proboscis monkey (*Nasalis larvatus*) in the Klias Peninsula, Sabah, Malaysia. *Malayan Nature Journal*, 59(2), 153-163.

- Bernard, H., Matsuda, I., Hanya, G., Ahmad, A.H. (2011). Characteristics of night sleeping trees of proboscis monkeys (*Nasalis larvatus*) in Sabah, Malaysia. *International Journal of Primatology*, 32(1), 259-267.
- Bernard, H., Bili, R., Matsuda, I., Hanya, G., Wearn, O. R., Wong, A., & Ahmad, A. H. (2016). Species richness and distribution of primates in disturbed and converted forest landscapes in Northern Borneo. *Tropical Conservation Science*, 9(4), 194008291668010. <https://doi.org/10.1177/1940082916680104>
- Bernstein, I.S. (1967). A field study of the pigtail monkey (*Macaca nemestrina*). *Primates*, 8(3), 217–228.
- Boonratana, R. (1993). *The Ecology and Behaviour of the Proboscis Monkey (Nasalis larvatus) in the Lower Kinabatangan, Sabah*. PhD dissertation. Faculty of Graduate Studies, Mahidol University, Thailand.
- Boonratana, R. (2000). Ranging behaviour of proboscis monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, Northern Borneo. *International Journal of Primatology*, 21, 497–518.
- Boonratana, R. (2002). Social organisation of proboscis monkeys (*Nasalis larvatus*) in the Lower Kinabatangan, Sabah, Malaysia. *Malayan Nature Journal*, 56(1), 57–75.
- Caldecott, J.O. (1980). Habitat quality and populations of two sympatric gibbons (Hylobatidae) on a mountain in Malaya. *Folia Primatologica*, 33, 291–309.
- Caldecott, J. O. (1986a). Mating patterns, societies and the ecogeography of macaques. *Animal Behaviour*, 34, 208–220.
- Caldecott J.O. (1986b). An ecological and behavioural study of the pig-tailed macaque. In: Szalay FS, (ed.) *Contributions to Primatology*, Vol. 21. Basel (Switzerland): Karger.
- Chivers, D. J., Raemeakers, J., Aldrich-Blake, F.P.G. (1975). Long-term observations of Siamang behaviour. *Folia Primatologica*, 23, 1–49.
- Chivers, D.J. (1980). *Malayan Forest Primates: Ten Years' Study in Tropical Rain Forest*. Springer, New York.
- Chivers, D. J. (2000). The swinging singing apes: Fighting for food and family in far-east forests. In *The Apes: Challenges for the 21st Century Conference Proceedings*, May 10-13, 2000.(Keynote Papers, pp. 1–28). Brookfield Zoo: Chicago Zoological Society.



- Clink, D.J., Bernard, H., Crofoot, M.C., Marshall, A.J. (2017). Investigating individual vocal signatures and small-scale patterns of geographic variations in female Bornean gibbon (*Hylobates muelleri*) great calls. *International Journal of Primatology*, 38, 656-671.
- Clink, D.J., Charif, R.A., Crofoot, M.C., Marshall, A.J. (2018a). Evidence for vocal performance constraints in a female nonhuman primate. *Animal Behaviour*, 141, 85-94.
- Clink, D.J., Grote, M.N., Crofoot, M.C., Marshall, A.J. (2018b). Understanding sources of variance and correlation among features of Bornean gibbon (*Hylobates muelleri*) female calls. *Journal of the Acoustical Society of America*, 144, 698-708.
- Colley, F.C. & Mullin, S.W. (2011). *Eimeria pachylepyron* sp. (Protozoa: Eimeriidae) from the slow loris in Malaysia. *The Journal of Parasitology*, 58(1), 110–111.
- Crompton, R.H. & Andau, P.M. (1987). Ranging, activity rhythms, and sociality in free-ranging *Tarsius bancanus*: A preliminary report. *International Journal of Primatology*, 8(1), 43–71.
- Davies, A.G., Bennett, E.L., Waterman, P.G. (1988). Food selection by two South-east Asian colobine monkeys (*Presbytis rubicunda* and *Presbytis melalophos*) in relation to plant chemistry. *Biological Journal of the Linnean Society*, 34, 33–56.
- Davies, G. (1986). The orangutan in Sabah. *Oryx*, 20(1), 40-45.
- Davies, A.B., Ancrenaz, M., Oram, F., & Asner, G.P. (2017). Canopy structure drives orangutan habitat selection in disturbed Bornean forests. *Proceedings of the National Academy of Sciences*, 114(31), 201706780.
- Duckworth, J.W., Sebastian, A.C., Kelsh, R.N., Jones, D.B. (2011). On the apparent occurrence of Hose's Surili *Presbytis hosei* in Similajau National Park, Sarawak, Malaysia. *Asian Primates Journal*, 2(1), 1–44.
- Dura, E.M., Sheeran, L.K., Ruppert, N., Arango, C.P., Blue, S.K. (2018). Mother-infant interactions in a wild group of Southern pig-tailed macaques, *Macaca nemestrina* (Linnaeus). *Asian Primates Journal*, accepted November 2018.
- Eberle, R. & Jones-Engel, L. (2018). Questioning the extreme neurovirulence of Monkey B Virus (*Macacine alphaherpesvirus 1*), *Advances in Virology*: DOI: 10.1155/2018/5248420.
- Ellefson, J.O. (1967). *A Natural History of White-handed Gibbons in the Malayan Peninsula*. PhD dissertation. University of California, Berkeley.

- Elliot, O. & Elliot, M. (1967). Field notes of the Slow loris in Malaya. *Journal of Mammalogy*, (December), 497–498.
- Eudey, A.A. (2008). The crab-eating macaque (*Macaca fascicularis*): widespread and rapidly declining. *Primate Conservation*, 23(1), 129–132.
- Frias, L., Stark, D., Lynn, M.S., Nathan, S.K.S.S., Goossens, B., Okamoto, M., MacIntosh, A.J.J. (2018). Lurking in the dark: cryptic *Strongyloides* in a Bornean slow loris. *International Journal for Parasitology: Parasites and Wildlife*, 7(2), 141–146.
- Gittins, S.P. (1980). Territorial behaviour in the agile gibbon. *International Journal of Primatology*, 1(4), 381–399.
- Gittins, S.P. (1982). Feeding and ranging in the agile gibbon. *Folia Primatologica*, 38(1–2), 39–71.
- Gittins, S.P. (1983) Use of forest canopy by the agile gibbon. *Folia Primatologica*, 40, 134–144.
- Goossens, B., Setchell, J.M., Abulani, D.M A, Jalil, F., James, S.S., Aris, S.H., Lakim, M.H., Seventri, A.D., Sariningsih, S.S., Ancrenaz, M. (2002). A boat survey of primates in the Lower Kinabatangan Wildlife Sanctuary. In: *Lower Kinabatangan Scientific Expedition*, Maryati, M., Takano, A.B., Goossens, B., Indran, R. (eds.), pp.37–45. Universiti Malaysia Sabah.
- Goossens, B., Chikhi, L., Jalil, M.F., Ancrenaz, M., Lackman-Ancrenaz, I., Mohamed, M., Andau, P., Bruford, M.W. (2005). Patterns of genetic diversity and migration in increasingly fragmented and declining orang-utan (*Pongo pygmaeus*) populations from Sabah, Malaysia. *Molecular Ecology*, 14(2), 441–456.
- Goossens, B., Chikhi, L., Jalil, M.F., James, S., Ancrenaz, M., Lackman-Ancrenaz, I., Bruford M.W. (2009). Taxonomy, geographic variation and population genetics of Bornean and Sumatran orangutans. In: Wich, S.A., Utami Atmoko, S.S., Setia, T.M., van Schaik, C.P. (eds.) *Orangutans: Geographic Variation in Behavioral Ecology and Conservation*. Oxford University Press, Oxford, pp 215–224.
- Hanya, G. & Bernard, H. (2013). Functional response to fruiting seasonality by a primate seed predator, red leaf monkey (*Presbytis rubicunda*). *Tropical Ecology*, 54(3), 383–395.
- Hambali, K., Md-Zain, B. M., Amir, A. (2016). Daily movement, sleeping sites and canopy level use of habituated silvered-leaf monkeys (*Trachypithecus cristatus*) in Bukit Malawati, Kuala Selangor, Malaysia. *Journal of Sustainability Science and Management*, 11(2), 21–30.

- Harding, L. E. (2011). Red morph of silvered lutung (*Trachypithecus cristatus*) rediscovered in Borneo, Malaysia. *TAPROBANICA*, 3(1), 47–48.
- Harrison, T., Krigbaum, J., Manser, J. (2006). Primate biogeography and ecology on the Sunda Shelf Islands: A paleontological and zooarchaeological perspective. In: Lehman, S., Fleagle, J. (eds). *Primate Biogeography: Progress and Prospects*. Springer, New York, pp. 331-372.
- Hasegawa, H., Matsuo, K., Onuma, M. (2003). *Enterobius (Colobenterobius) serratus sp. nov.* (Nematoda: Oxyuridae) from the Proboscis monkey, *Nasalis larvatus* (Wurmb, 1787) (Primates: Cercopithecidae: Colobinae), in Sarawak, Borneo, Malaysia. *Comparative Parasitology*, 70(2), 128–131.
- Hayashi, M., Kawakami, F., Roslan, R., Hapiszudin, N. M., Dharmalingam, S. (2018). Behavioral studies and veterinary management of orangutans at Bukit Merah Orang Utan Island, Perak, Malaysia. *Primates*, 59(2), 135–144.
- Inoue, Y., Sinun, W., & Okanoya, K. (2016). Activity budget, travel distance, sleeping time, height of activity and travel order of wild East Bornean Grey gibbons (*Hylobates funereus*) in Danum Valley Conservation Area. *Raffles Bulletin of Zoology*, 64, 127–138.
- Jablonski, N. G. & Crompton, R. H. (1994). Feeding behavior, mastication, and tooth wear in the western tarsier (*Tarsius bancanus*). *International Journal of Primatology*, 15(1), 29-59.
- Jalil, M.F. (2006). *Comparative Phylogeography of Three Primate Species in the Lower Kinabatangan Wildlife Sanctuary, Sabah, Malaysia*. Thesis. Cardiff University. Retrieved from <http://orca.cf.ac.uk/55451>.
- Johns, A. D. (1986). Effects of selective logging on the behavioral ecology of West Malaysian primates. *Ecology*, 67(3), 684–694.
- Johns, A. D., & Skorupa, J. P. (1987). Responses of rain forest primates to habitat disturbance: A review. *International Journal of Primatology*, 8(2), 157–191.
- Johns, A. G., & Johns, B. G. (1995). Tropical forest primates and logging: long-term coexistence? *Oryx*, 29(3), 205–211.
- Kanamori, T., Kuze, N., Bernard, H., Malim, T. P., Kohshima, S. (2010). Feeding ecology of Bornean orangutans (*Pongo pygmaeus morio*) in Danum Valley, Sabah, Malaysia: A 3-year record including two mast fruitings. *American Journal of Primatology*, 72(9), 820–840.

- Kanamori, T., Kuze, N., Bernard, H., Malim, T. P., & Kohshima, S. (2017). Fluctuations of population density in Bornean orangutans (*Pongo pygmaeus morio*) related to fruit availability in the Danum Valley, Sabah, Malaysia: a 10-year record including two mast fruitings and three other peak fruitings. *Primates*, 58(1), 225–235.
- Karim, K. & Anuar, S. (2010). Activity budget of *Macaca fascicularis* in Botanical Garden Penang, Malaysia. *Technics Technologies Education Management*, 5(4), 719-729.
- Karim, K. & Anuar, S. (2011a) Social organization and mating system of *Macaca fascicularis*(Long-tailed macaques). *International Journal of Biology*,3(2), 23-29.
- Karim, K. & Anuar, S. (2011b). Condition and population size of *Macaca fascicularis* (long-tailed macaque). *Journal of Cell and Animal Biology*, 5(3), 41-46.
- Karim K. & Anuar, S. (2012) The dominant species of monkeys (*Macaca fascicularis*) in northern region of Peninsular Malaysia. *Pakistan Journal of Zoology*, 44(6), 1567-1574.
- Karim K., Anuar, S., Dauda, M.S., Nidaullah, H (2014). Population structure analysis of monkeys in selected protected and non-protected areas of Peninsular Malaysia. *Journal of Animal & Plant Sciences*, 24(6), 1772-1779.
- Karuppannan, K., Saaban, S., Mustapa, A.R., Zainal Abidin, F.A., Azimat, N.A., Keliang, C. (2014). Population status of long-tailed macaque (*Macaca fascicularis*) in Peninsular Malaysia. *Journal of Primatology*, DOI: 10.4172/2167-6801.1000118.
- Kavanagh, M. & Laursen, E. (1984). Breeding seasonality among long-tailed macaques, *Macaca fascicularis*, in Peninsular Malaysia. *International Journal of Primatology*, 5(1), 17–29.
- Kawabe, M. (1970). A preliminary study of the wild siamang gibbon (*Hylobates syndactylus*) at Fraser’s Hill, Malaysia. *Primates*, 11(3), 285–291.
- Kawabe, M. & Mano, T. (1972). Ecology and behavior of the wild proboscis monkey, *Nasalis larvatus* (Wurmb), in Sabah, Malaysia. *Primates*, 13(2), 213–227.
- Khan, M.K.M. (1970). Distribution and population of siamang and gibbons in the state of Perak. *Malayan Nature Journal*, 24, 3–8.



- Kilbourn, A.M., Karesh, W.B., Wolfe, N.D., Bosi, E.J., Cook, R.A., Andau, M. (2003). Health evaluation of free-ranging and semi-captive orangutans (*Pongo pygmaeus pygmaeus*) in Sabah, Malaysia. *Journal of Wildlife Diseases*, 39(1), 73–83.
- Klaus, A., Zimmermann, E., Röper, K.M., Radespiel, U., Nathan, S., Goossens, B., Strube, C. (2017). Co-infection patterns of intestinal parasites in arboreal primates (proboscis monkeys, *Nasalis larvatus*) in Borneo. *International Journal for Parasitology: Parasites and Wildlife*, 6(3), 320-329.
- Klaus, A., Strube, C., Röper, K.M., Radespiel, U., Schaarschmidt, F., Nathan, S., Goossens, B., Zimmermann, E. (2018). Fecal parasite risk in the endangered proboscis monkey is higher in an anthropogenically managed forest environment compared to a riparian rain forest in Sabah, Borneo. *PLOS ONE*, 13:4, e0195584.
- Kombi, M.B., & Abdullah, M.T. (2013). Ethogram of free ranging *Nasalis larvatus* in Bako National Park, Sarawak. *Malayan Nature Journal*, 65(2&3), 1–21.
- Kuze, N., Malim, T. P., Kohshima, S. (2005). Developmental changes in the facial morphology of the Borneo orangutan (*Pongo pygmaeus*): possible signals in visual communication. *American Journal of Primatology*, 65(4), 353-376.
- Lambert, F. (1990). Some notes on fig-eating by arboreal mammals in Malaysia. *Primates*, 31(3), 453–458.
- Lee, B.P.Y.-H. & Gan, J. (2017). Pale-thighed langur *Presbytis siamensis* at Karak, Pahang, Peninsular Malaysia. *Southeast Asian Vertebrate Records*, August, 50–51.
- Lee, K.S., Divis, P.C.S., Zakaria, S.K., Matusop, A., Julin, R.A., Conway, D.J., Cox-Singh, J., Singh, B. (2011). *Plasmodium knowlesi*: Reservoir hosts and tracking the emergence in humans and macaques. *PLOS Pathogens*, 7(4), e1002015.
- MacKinnon, J. (1971). The orang-utan in Sabah today: A study of a wild population in the Ulu Segama Reserve. *Oryx*, 11, 141–191
- MacKinnon, J. (1974). The behaviour and ecology of wild orang-utans (*Pongo pygmaeus*). *Animal Behavior*, 22, 3–74.
- Marsh, C.W., & Wilson, W.L. (1981). *A Survey of Primates in Peninsular Malaysian Forests*. Final report for the Malaysian Primates Research Programme July 1981. Universiti Kebangsaan Malaysia and University of Cambridge, UK.
- Matsuda, I. (2008). *Feeding and Ranging Behaviors of Proboscis Monkey Nasalis larvatus in Sabah*, Malaysia. PhD dissertation. Graduate School of Environmental Earth Science, Hokkaido University, Japan.

- Matsuda, I., Tuuga, A., Akiyama, Y., Higashi, S. (2008). Selection of river crossing location and sleeping site by proboscis monkeys (*Nasalis larvatus*) in Sabah, Malaysia. *American Journal of Primatology*, 70(11), 1097–1101.
- Matsuda, I., Tuuga, A., Higashi, S. (2009). The feeding ecology and activity budget of proboscis monkeys. *American Journal of Primatology*, 71(6), 478-492.
- Matsuda, I., Kubo, T., Tuuga, A., Higashi, S. (2010). A Bayesian analysis of the temporal change of local density of proboscis monkeys: implications for environmental effects on a multilevel society. *American Journal of Physical Anthropology*, 5, NA-NA.
- Matsuda, I., Tuuga, A., Bernard, H., Furuichi, T. (2012). Inter-individual relationships in proboscis monkeys: a preliminary comparison with other non-human primates. *Primates*, 53(1), 13-23.
- Matsuda, I., Tuuga, A., Bernard, H., Sugau, J., Hanya, G. (2013). Leaf selection by two Bornean colobine monkeys in relation to plant chemistry and abundance. *Scientific Reports*, 3, 1873–1879.
- Matsuda, I., Akiyama, Y., Tuuga, A., Bernard, H., Clauss, M. (2014). Daily feeding rhythm in proboscis monkeys: a preliminary comparison with other non-human primates. *Primates*, 55(2), 313-326.
- Matsuda, I., Otani, Y., Bernard, H., Wong, A., Tuuga, T. (2016). Primate survey in a Bornean flooded forest: evaluation of best approach and best timing. *Mammal Study*, 41(2), 101-106.
- Md-Zain, B.M., Morales, J.C., Hasan, M.N., Abdul, J., Lakim, M., Supriatna, J., Melnick, D.J. (2008). Is *Presbytis* a distinct monophyletic genus: inferences from mitochondrial DNA sequences. *Asian Primates Journal*, 1(1), 26–35.
- Md-Zain, B.M., Sha`ari, N.A., Mohd-Zaki, M., Ruslin, F., Idris, N.I., Kadderi, M.D., Idris, W.M.R. (2010a). A comprehensive population survey and daily activity budget on long-tailed macaques of Universiti Kebangsaan Malaysia. *Journal of Biological Sciences*.
- Md-Zain, B.M., Mohd Daut, N., Shukor, M.N. (2010b). Characterizing silvered leaf monkey–visitor interactions at Bukit Melawati, Kuala Selangor, Malaysia. *The Journal of Wildlife and Parks*, 26: 83–94.
- Meyer, D. (2011). *Taxonomy and Phylogeny of Leaf Monkeys (Colobinae) with Focus on the Genus Presbytis (Eschscholtz, 1821)*. PhD dissertation. Georg-August-Universitaet zu Goettingen.

- Munds, R.A., Nekaris, K.A.I., Ford, S.M. (2013). Taxonomy of the Bornean slow loris, with new species *Nycticebus kayan* (Primates, Lorisidae). *American Journal of Primatology*, 75(1), 46–56.
- Munds, R.A., Ali, R., Nijman, V., Nekaris, K.A.I., Goossens, B. (2014). Living together in the night: abundance and habitat use of sympatric and allopatric populations of slow lorises and tarsiers. *Endangered Species Research*, 22(3), 269–277.
- Munshi-South, J. & Bernard, H. (2011). Genetic diversity and distinctiveness of the proboscis monkeys (*Nasalis larvatus*) of the Klias Peninsula, Sabah, Malaysia. *Journal of Heredity*, 102(3), 342–346.
- Nekaris, K.A.I. (2014). Extreme primates: ecology and evolution of Asian lorises. *Evolutionary Anthropology: Issues, News and Reviews*, 23, 177–187.
- Nekaris, A. & Starr, C.R. (2015). Conservation and ecology of the neglected slow loris: priorities and prospects. *Endangered Species Research*, 28(1), 87–95.
- Nijman, V. & Nekaris, K.A.I. (2010). Checkerboard patterns, interspecific competition, and extinction: lessons from distribution patterns of tarsiers (*Tarsius*) and slow lorises (*Nycticebus*) in insular Southeast Asia. *International Journal of Primatology*, 31(6), 1147–1160.
- Puteri, S.M.A.S. & Ruppert, N. (2017). Effects of environmental enrichment on activities of captive orangutans at Taiping Zoo, Malaysia. *Malayan Nature Journal*, 69(4), 327–335.
- Qiao, C.W. & Ruppert, N. (2017). Preliminary assessment of distribution and behaviours of primates at Penang National Park, Malaysia. *Malayan Nature Journal*, 69(4), 345–351.
- Raemaekers, J. (1978). Changes through the and day in the food choice of wild gibbons. *Folia Primatologica*, 30, 194–205.
- Raemaekers, J. (1980). Causes of variation between months in the distance traveled daily of gibbons. *Folia Primatologica*, 34(1-2), 46-60.
- Rajanathan, R. & Bennett, E.L. (1990). Notes on the social behaviour of wild proboscis monkey (*Nasalis larvatus*). *Malayan Nature Journal*, 44, 35–44.

- Rajanathan, R. (1991). *Differential Habitat Use by Primates in Samunsam Wildlife Sanctuary, Sarawak, and its Application to Conservation Management*. M.Sc. thesis, University of Florida, Gainesville.
- Röper, K.M., Scheumann, M., Wiechert, A.B., Nathan, S., Goossens, B., Owren, M.J., Zimmermann, E. (2014). Vocal acoustics in the endangered proboscis monkey (*Nasalis larvatus*). *American Journal of Primatology*, 76(2), 192-201.
- Ruppert, N., Asyraf, M., Sharul Anuar, M.S. (2014). A key role of the Southern Pig-tailed Macaque *Macaca nemestrina* (Linnaeus) in seed dispersal of non-climbing rattans in peninsular Malaysia. *Asian Primates Journal*, 4(2), 42–51.
- Ruppert, N., Holzner, A., See, K.W., Gisbrecht, A., Beck, A. (2018). Activity budgets and habitat use of wild southern pig-tailed macaques (*Macaca nemestrina*) in oil palm plantation and forest. *International Journal of Primatology*, 39(2), 237–251.
- Sahimi, H.N.M., Chubo, J.K., Top, M.M., Saripuddin, B., Rahim, S.S.A. (2017). The distribution and population density of Bornean Tarsier, *Tarsius bancanus borneanus* (Elliot) in secondary and rehabilitated forests of Universiti Putra Malaysia, Bintulu Sarawak Campus, Sarawak Malaysia. *Tropical Life Science Research*, 29(1), 139–154.
- Salter, R.E. & Mackenzie, N.A. (1985). Conservation status of the proboscis monkey in Sarawak. *Biological Conservation*, 33, 119–132.
- Salter, R.E., Mackenzie, N.A., Aken, K.M, Chai, P.K. (1985). Habitat use, ranging behaviour, food habits of the proboscis monkey, *Nasalis larvatus* (van Wurm), in Sarawak. *Primates*, 26(4), 436–451.
- Sam, I.-C., Chua, C.L., Rovie-Ryan, J.J., Fu, J.Y.L., Tong, C., Sitam, F.T., Chan, Y.F. (2015). Chikungunya virus in macaques, Malaysia. *Emerging Infectious Diseases*, 21(9), 1683–1685.
- Schultz, C. H. & Beck, J. (1999). A record of Proboscis monkey (*Nasalis larvatus*) (Mammalia: Primates: Cercopithecidae) from Kinabalu Park, Sabah, Malaysia. *Sabah Parks Nature Journal*, 2, 23–26.
- Sha, J.C.M., Bernard, H., Nathan, S. (2008). Status and conservation of proboscis monkeys (*Nasalis larvatus*) in Sabah, East Malaysia. *Primate Conservation* 23, 107-120.
- Shekelle, M. & Nietsch, A. (2008). Tarsier longevity: data from a recapture in the wild and from captive animals. *Primates of the Oriental Night*, 85–89.



Southwick, C. H., & Cadingan, F. C. (1972). Population studies of Malaysian primates. *Primates*, 13(1), 1-18.

Stark, D.J., Nijman, V., Lhota, S., Robins, J.G., Goossens, B. (2012). Modeling population viability of local proboscis monkey *Nasalis larvatus* populations: conservation implications. *Endangered Species Research*, 16(1), 31-43.

Stark, D.J., Vaughan, I.P., Evans, L.J., Kler, H., Goossens, B. (2018). Combining drones and satellite tracking as an effective tool for informing policy change in riparian habitats: a proboscis monkey case study. *Remote Sensing in Ecology and Conservation*, 4(1), 44-52.

Voigt, M., Wich, S. A., Ancrenaz, M., Meijaard, E., Abram, N., Banes, G. L., [...], Kühl, H. S. (2018). Global demand for natural resources eliminated more than 100,000 Bornean orangutans. *Current Biology*, 28(5), 761–769.

Vythilingam, I., Noorazian, Y.M., Huat, T.C., Jiram, A.I., Yusri, Y.M., Azahari, A.H., Norparina, I., Noorain, A., Lokmanhakim, S. (2008). *Plasmodium knowlesi* in humans, macaques and mosquitoes in peninsular Malaysia. *Parasites and Vectors*, 1(1), 1–10.

Wiens, F. (2002). *Behavior and Ecology of Wild Slow Lorises (Nycticebus coucang): Social Organization, Infant Care System, and Diet*. PhD Dissertation. Bayreuth University.

Wiens, F. & Zitzmann, A. (1999). Predation on a wild slow loris (*Nycticebus coucang*) by a reticulated python (*Python reticulatus*). *Folia Primatologica*, 70(6), 362–364.

Wiens, F., & Zitzmann, A. (2003). Social structure of the solitary slow loris *Nycticebus coucang* (Lorisidae). *Journal of Zoology*, 261(1), 35–46.

Wiens, F., Zitzmann, A., Hussein, N.A. (2006). Fast food for slow lorises: is low metabolism related to secondary compounds in high-energy plant diet? *Journal of Mammalogy*, 87(4), 790–798.

Wolf, K.E. & Fleagle, J.G. (1977). Adult male replacement in a group of silvered leaf-monkeys (*Presbytis cristata*) at Kuala Selangor, Malaysia. *Primates*, 18(4), 949–955.

Wolfe, N. D., Kilbourn, A. M., Karesh, W. B., Rahman, H. A., Bosi, E. J., Cropp, B. C., Andau, M., Spielman, A., & Gubler, D. J. (2001). Sylvatic transmission of arboviruses among Bornean orangutans. *The American Journal of Tropical Medicine and Hygiene*, 64(5), 310-316.

Wolfe, N. D., Karesh, W. B., Kilbourn, A. M., Cox-Singh, J., Bosi, E. J., Rahman, H. A., Prosser, A. T., Singh, B., Andau, M., & Spielman, A. (2002). The impact of ecological conditions on the prevalence of malaria among orangutans. *Vector-Borne and Zoonotic Diseases*, 2(20), 97-103.