Chapter

The Predicament of Macaque Conservation in Malaysia

Siew Shean Choong, Mimi Armiladiana Mohamad, Li Peng Tan and Ruhil Hayati Hamdan

Abstract

Macaques are commonly found in Malaysia, with the current existing three species placed between endangered to least concern status under the IUCN Red List, namely the stump-tailed macaque (*Macaca arctoides*), pig-tailed macaque (*Macaca nemestrina*), and the notorious long-tailed macaque (*Macaca fascicularis*). The species classified under the endangered and vulnerable group are facing threats mainly from the loss of habitat. Conversely, species that are categorized as least concerned are often cited at the top of human-wildlife conflicts reports in various countries, although they too are facing pressure from habitat loss. There are different methods employed to control the fast-growing population of these species, calling for different levels of investment in terms of resources. It is of great interest to understand the disparities between these species, as they are able to adapt to environmental changes and some find ways to survive in alternative localities, including urban areas. The proximity of macaques to human dwellings raises a public health concern through the transmission of zoonotic diseases. More scientific studies are imperative in order to further understand the needs of these animals for continued survival and co-existence with humans and other animals in the ecosystem. Urgent efforts must be taken to preserve the macaque's natural habitats while creating the public awareness on the predicament of these species. The focus should be on human-wildlife conflicts todispute the existing false impression that all macaques are on equal ground and abundance in numbers.

Keywords: macaque conservation, non-human primate conservation, public health, zoonoses

1. Introduction

Malaysia is located in the equatorial region where most parts of the natural landscape are covered by the tropical rainforests. The country is well known for its rich flora and fauna biodiversity. Non-human primate species found natively in Malaysia include the great ape: Bornean orangutan (*Pongo pygmaeus*); lesser ape: Agile gibbon (*Hylobates agilis*), White-handed gibbon (*Hylobates lar*), Bornean gibbon (*Hylobates muelleri*), Siamang (*Symphalangussyndactylus*); old world monkeys: Banded leaf monkey (*Presbytis femoralis*), White-fronted langur (*Presbytis frontata*), Gray leaf monkey (*Presbytis hosei*), Red leaf monkey (*Presbytis rubicunda*), Silver leaf monkey (*Trachypithecuscristatus*), Dusky leaf monkey (*Hylobates funereus obscurus*), Long-tailed macaque (*Macaca fascicularis*), pig-tailed macaque (*Macaca nemestrina*), stump-tailed macaque(*Macaca arctoides*); the lorisids: Sunda slow loris (*Nycticebuscoucang*), Kayan slow loris (*Nycticebuskayan*); lastly the Western tarsier (*Tarsiusbancanus*).

The focus of this chapter is management aspects of macaques as the conservation of these species is generally neglected in the country. They were at the extreme end of the conservation status as indicated by the IUCN Red List of Threatened Species, where long-tailed macaques are categorized as least concerned, while the pig-tailed macaques are endangered. Furthermore, reports, conservation efforts, and research centers on macaques are almost unheard of, except human-macaque conflicts that mainly involved the long-tailed macaques. It may be fortunate that young macaques do not appear cute and cuddly compared to that of orangutans and leaf monkeys, they are less often reported to be illegally traded or poached. However, this may also be one of the reasons they are not seen as "attractive" subjects of for research and conservation. Therefore, this chapter aspires to highlight the plight of macaques.

2. The macaques population in Malaysia

Although the long-tailed macaques are considered as pests in Malaysia, the species is listed as vulnerable under the IUCN Red List [1]. This is particularly true as their natural habitats are diminishing. According a report by Wicke et al. [2], Malaysia has lost 20 percent of forest land within a 30-year span due to anthropogenic activities. The downward trend of primary forest cover continues. The 91.9% of the cover remained in 2011 was further reduced to 83% in 2020 [3]. Although deforestation was significantly controlled over the past decade, the conversion of forest land is expected to continue creating more fragmented forest areas and forest edges [4], which are suitable habitats for long-tailed macaques. Subsequently, this would further escalate the frequencies of human-wildlife conflicts. Continuous mass removal of the long-tailed macaque which has been adopted to minimize human-wildlife conflicts subject the species to a risk of losing genetic diversity [5]. In fact, hybridization of populations and potential inbreeding depression of the populations could potentially occur if translocation operations intensified [6]. Additionally, long-tailed macaques in Peninsular Malaysia are morphologically assigned to two subspecies, namely *M. f. fascicularis* and *M. f. argentimembris* [7].

On the other hand, pig-tailed macaques and long-tailed macaques are generally regarded as crop raiders and, therefore, have more direct negative interactions with people. However, pig-tailed macaques have proved to be beneficial to mankind. They have traditionally been kept and trained to harvest fruits, especially coconuts, and forest products for over a century in Malaysia and other countries in Southeast Asia as the species is bigger and has more physical strength than long-tailed macaques. A recent research has indicated that the presence of pig-tailed macaques benefits the oil palm plantations by acting as a biological control for rodents that cause the industry monetary losses of US$930mil (RM3.9bil) every year [8]. In comparison, the damage caused by the pig-tailed macaques on the oil palm crops is relatively minimal.

Pig-tailed macaques are listed as endangered in Malaysia since 2009, although it is still categorized as vulnerable when the entire population worldwide is considered [9]. It is of interest to note that both long-tailed macaques and pig-tailed macaques shared similar natural habitats and are omnivorous. However, the latter is more sociable towards humans, less aggressive, and more habituated. Currently, efforts to conserve the species in the wild are not viewed as critical. The breeding of pig-tailed macaques is generally undertaken as the animals are needed for fruit plucking purposes. Yet, this effort is not nationwide, but concentrated only in the East Coast of Peninsular Malaysia and mostly unable to sustain the population if the animals go extinct in the wild.

Stump-tailed macaques are found only in the North-western region in Peninsular Malaysia, specifically at the Wan Kelian forest areas in Perlis State Park. In fact, the global geographical range published by IUCN indicated that this is the most southern region where stump-tailed macaques can be detected. Their presence could be found further north in Thailand, Myanmar, Laos, Cambodia, Vietnam, Bangladesh, and China. Distributions of the stump-tailed macaques are similarly in habitat pockets as in Malaysia, not widespread throughout the countries listed, and the populations are mostly declining [10]. Unfortunately, wildlife censuses have been excluding macaques as the species of interest in research, thus making more recent data unavailable. Despite its vulnerable status under the IUCN Red List [11], these macaques received the least attention from the government, public, and even researchers compared to the other two macaque species in Malaysia [7, 12]. Small population size, movement between country borders (Malaysia and Thailand) which that is prone to heavy poaching, and their tendencies to avoid humans [12] further complicate research of this species. It is interesting to note that all three macaque species: stump-tailed macaques, pig-tailed macaques and long-tailed macaques are found sympatrically within the Perlis State Park Forest Areas [12, 13]. However, interspecies associations were not recorded between the three species [12, 14].

3. Macaques involvement in human-wildlife conflicts

Among the non-human primate species found in the country, the long-tailed macaques and pig-tailed macaques can be found in areas that often overlap with high anthropogenic activity areas such as plantations, the secondary forest surrounding human settlements, besides their natural habitats in the wild [1, 9]. Between the two species, the long-tailed macaques are most sighted and involved in human-wildlife conflicts in both rural and urban areas, accounting for between 35 and over 65 percent of conflict reports received by the wildlife department [15, 16]. This species has successfully adapted to the human settlements and continues to multiply at alarming rates, which further contributes to human-wildlife conflicts. The damages caused by macaque related conflicts include injuries such as scratches and bites sustained by people during the encounter with macaques, destruction of properties and materials within when macaques enter and ransack the properties, disturbance to residents and tourists due to the animals' aggressive behavior [17] to snatch and steal when needed.

In general, the main reason for human-wildlife conflicts caused by long-tailed macaques is food motivation. Conversely, by and large, these past behaviors were triggered by human actions: feeding of animals by "good samaritans", an improper garbage disposal that allow animals to forage for scraps, destruction of natural habitats due to deforestation and agricultural activities, and encroachment of human settlement into the forested areas [18]. The authorities manage the macaque human-wildlife conflict through several approaches including culling, public education, and awareness creation program (particularly with the help of non-government organizations), and translocation of the animals (Pers. Observation).

A study on the dietary composition of wild stump-tailed macaques indicated that they mainly consume plant materials from the forest [19]. Unlike its cousins, the long-tailed macaques and pig-tailed macaques are more often spotted at human concentrated areas, and at times orchards, plantations, and even garbage collection sites. Essentially, absence of human-wildlife conflict reports on stump-tailed macaques explains why public knowledge on the species is minimal.

4. Zoonotic diseases in macaques

The genetic relatedness of non-human-primates to humans generally gives the perception that interaction with non-human-primates poses higher zoonotic risks compared to other animal species. The natural habitats of non-human-primates are located at the equatorial zone worldwide, expanding across tropical rainforest in Southeast Asia, West and Central Africa, and South and Central America, also smaller patches in areas adjacent to these. Additionally, non-human-primates can be found in captivity such as in zoological gardens, rescue centers, and animal research facilities. Therefore, it is logical to acknowledge that a large portion of the human population has direct or indirect contact with non-human primates, thus making zoonotic disease spillover a major public health concern. Additionally, interactions of non-human primates with livestock have been reported to initiate multidirectional pathogen transmission between these species, and ultimately lead to spillover to the human population [20]. This is further evident from host-pathogen databases analysis among primates showed that sympatric host species have high probabilities to share parasite species [21].

Interestingly, consumption of bushmeat from non-human primates is not widely practiced or acceptable by the local communities, mainly due to religious practices among the majority of the population. This might have significantly reduced the probability of zoonotic diseases transmission and potential mutagenic changes in the pathogens, particularly viruses. Most popular bushmeat in Malaysia is reportedly from wild pigs (*Sus scrofa*), bearded pigs (*Sus barbatus*), deer (including Sambar deer (*Cervus unicolor*), barking deer (*Muntiacus muntjac*) and mousedeer (*Tragulus kanchil* and *Tragulus napu*), Malayan porcupine (*Hystrix brachyura*), bats, and others [22–25]. On the other hand, sun bears (*Helarctos malayanus*)were hunted for their bile to cater for traditional medicines [26]. Some examples of zoonotic or potential zoonotic diseases reported in macaques are discussed hereunder. However, a comprehensive description of zoonotic disease risks from macaques is still lacking. The degree of impact of macaques on possible future epidemics needs to be elucidated with further studies utilizing the one health approach integrating data on human, animal, and environmental health. Epidemiology of diseases often stimulates research in wildlife species, especially in the recent years with emerging zoonotic diseases suspected to have originated from wildlife as evidenced from a large number of scientific articles published [27–30]. Conversely, conservation of these species could result in the preservation of ecosystem integrity and creating a buffer zone against novel disease outbreaks [31]. The outcomes from studies of these species may help the conservation authorities to strategize the long-term plans and inform the national policies on effective management and conservation of macaques species in Malaysia.

5. Bacterial diseases

Fecal samples from wild long-tailed macaques and pig-tailed macaques involved in human-wildlife conflicts areas in the Lopburi district of Thailand were found to carry *Esherichai coli*, *Staphylococcus spp*, and *Salmonella* spp. [32]. In another study carried out in the Wulongkou Scenic Area, Henan Province of China discovered that about a quarter of over 400 fecal samples contained *Shigella spp*., *Escherichia coli*, *Klebsiella pneumoniae*, and *Leptospira spp*. Other bacteria detected in lesser prevalence included *Campylobacter jejuni*, *Salmonella spp*., *Staphylococcus aureus*, *Streptococcus pneumonia*, *Yersinia spp*., and *Hafnia paralvei*. Among these bacteria, *Salmonella*, *Shigella*, *E. coli*, *C. jejuni*, and *Yersinia* are zoonotic i.e. shared with humans and other animals.

In a preliminary study of zoonotic pathogens in captive pig-tailed macaques detected *Neisseria spp.* in all four swab samples, namely nasal, buccal, throat, and anal, from 30 individuals. Other bacteria isolated were *Pasturella spp.* and *Moraxella spp.* from the nasal swabs, and *Stenotrophomonas* sp. or *Acinetobacter* sp. from the buccal swabs. Whereas for the anal swabs, *Pasturella spp*., and *Streptobacillus spp*. were detected, besides *Neisseria spp.* [33]. The different species isolated in the previous studies with the current research may be due to the fact that the former was from wild animals, and fresh droppings were collected, while the latter was from captive macaques and collected directly from multiple orifices of the animals.

6. Viral diseases

RNA viruses are considered a major threat among emerging infectious diseases at the human-non-human primate interface [34], and studies conducted in Malaysia are very much concentrated on this group of viruses. As discussed before, long-tailed macaques are involved in most of the human-macaque conflicts and often these issues were dealt with through capture and relocation to deep forest areas [35, 36]. Therefore, researchers took the opportunity to investigate the viruses carried by these animals to determine if these animals could serve as a reservoir host for these pathogens and pose significant disease threats to human and other animal species in the habitat.

In a study by Ain-Najwa et al. [37] using archived long-tailed macaque samples, where sera were used to detect West Nile virus (WNV) antibody through competitive enzyme-linked immunosorbent assay (c-ELISA), and WNV RNA from oropharyngeal swabs via RT-PCR. Results showed that the macaques were all negative for WNV RNA, yet high WNV antibody prevalence was observed. These results may indicate that the macaques are exposed to WNV from other animals in their habitat, yet infectivity was low, and they may not serve as a reservoir to WNV in the wild.

In Malaysia, Zika virus (ZIKV) was detected in 0.2% of patients with clinical signs corresponding to Zika virus infection during the Malaysia ZIKV surveillance between June 2015 and December 2017 after the declaration of the Public Health Emergency of International Concern (PHEIC) by World Health Organization. The source of infection was undetermined and possible zoonotic transmission from wildlife species, such as macaques, was suspected [38]. A total of 234 long-tailed macaques trapped from multiple sites throughout Peninsular Malaysia in the Wildlife Disease Surveillance Program were evaluated for ZIKV prevalence. The researchers were unable to detect ZIKV RNA from any of the macaques sampled, and only 1.3% showed seropositive for neutralizing antibodies. Thus, the study concluded that long-tailed macaques are not likely to be reservoirs for the Zika virus in Malaysia [39].

On the other hand, Malaysia has experienced massive outbreaks of Chikungunya virus (CHIKV) infection in humans in Malaysia between 1998 and 1999 [40] and cases have been reported since with sporadic surges of infections recorded [41]. Researches were conducted to elucidate the potential of macaques in maintaining the Chikungunya virus during inter-epidemic periods, to explain the sporadic disease occurrences, as the virus has been isolated from monkeys in Africa [42]. A study carried out by Sam et al. (2015) found that viraemia among the wild long-tailed macaques tested was not only lacking but also the seroprevalence rate was low. Therefore, it was concluded that long-tailed macaques living at the human-wildlife conflict areas would have played a minor role in CHIKV transmission, if any, during CHIKV outbreak episodes [36]. In fact, later work by Suhana et al. [43] suggested that CHIKV detected in long-tailed macaques may be a spillover of the virus from humans, based on molecular characterization and phylogenetic analysis of the isolates.

Macacine herpesvirus 1 (MaHV1), commonly known as B virus, has been detected among wild macaques in Asia [44]. However, there is minimal information regarding MaHV1 in macaques of Malaysia. To date, there was only one report indicating that 39% of wild long-tailed macaques sampled from six different states in the country during wildlife management program under the Department of Wildlife and National Parks, Peninsular Malaysia was shedding MaHV1 DNA [45]. While animals from different age groups were detected to shed the virus, through PCR of urogenital and oropharyngeal swabs, seroprevalence through ELISA was highest among the adults [45]. The seroprevalence result corresponded with a previous study from Bali, Indonesia, where most adults were expected to have been infected or exposed to MaHV1 [46]. MaHV1 is designated as Biosafety Level 4 (BSL-4) pathogen because humans with untreated MaHV1 infection have over 70% mortality rate [47]. With the high human-macaque conflict reported in Malaysia, wildlife officers and rangers carried out many translocation operations as a mitigation approach; also reports of bites and scratches from macaques are rather common among people that reside in or visited areas with macaques. In fact, some persons bitten and scratched by macaques may have experienced MAHV1 infection yet did not experience clinical signs of infections [48]. However, peculiar reports of human MaHV1 infections were confined to personnel working with macaques or macaque tissues in a husbandry or research environment in the US and Europe. This could be explained by the fact that wild macaques are not shedding the virus in such high concentrations compared to laboratory animals, as the latter may be constantly confined in captivity and exposed to high-stress conditions, where they are handled and manipulated. While their wild cousins are generally free in their natural habitat, and people only have random and occasional encounters with these animals [49]. Even so, workers in contact with wild macaques are recommended to put on appropriate personal protective equipment, as capture and translocation efforts may induce stress on these animals and increased viral shedding or reactivation of infection that could potentially infect the workers [45].

In a preliminary study [33] of captive pig-tailed macaques showed the prevalence of several RNA viruses, such as retrovirus, influenza virus, and lyssavirus, through RT-PCR of the buffy coat. Retrovirus was detected in all individuals sampled, followed by influenza virus (56.6%), then lyssavirus at 13.3%. Further investigation using cell culture and nested PCR to detect Simian Foamy virus (SFV) from these samples as SFV has been reported to infect nearly all captive and free-ranging macaques in Asia [50, 51]. HeLa cell culture demonstrated cytopathogenic effects (CPEs) such as being refractile, detached from the culture surface, floating, clumping, increased in cell distance after just the first passage, and foamy appearance was observed in the cells under high magnification by the third passage [33]. However, detection of SFV using nested PCR targeting the Pol genes and LTR genes from extracted trypsinized tissue culture samples did not turn up positive results. Therefore, further work is required to determine if CPE resulted from SFV or other viruses.

Overall, evidence that wild and captive macaques in Malaysia serve as a reservoir for zoonotic viruses is still lacking. Zoonotic infections from macaque to human is very much understudied, and often prevalence research on pathogens in macaques are not incorporated with sampling from the keepers, owners, and other personnel in contact, such as the wildlife rangers. Additionally, pig-tailed macaque owners surveyed did not report illness related to animals kept, as these animals often share the living quarters, food, and drinks with their owners. However, it is safe to say that personnel in contact with macaques should take the necessary precautions to minimize infection transmission from these animals.

7. Parasitic diseases

The most prominent zoonotic parasite reported in macaques is *Plasmodium knowlesi*, recognized as the fifth cause of human malaria, which is transmitted from animals to humans through Anopheles mosquito vector. Knowlesi malaria has now topped the number of human malaria cases reported across most states in Malaysia, especially in Sabah and Sarawak [52, 53]. This situation may be as a result of increased encroachment of human settlement into the forested areas [54], and advancement of malaria diagnosis to molecular method instead of the conventional microscopy detection of the stained blood smear [55].

On another note, gastrointestinal (GI) parasites from macaques are often neglected although these organisms may cause detrimental consequences in humans. A report from Baluran National Park at East Java, Indonesia indicated 89% of fecal samples collected from wild long-tailed macaque were positive of GI parasite, and protozoal infection was slightly higher (89%) compared to helminth (83%). The study found that the most prevalent GI parasite in the macaques is *Trichostrongylus*sp (66%), the next highest parasite is *Entamoeba* sp. (53%), and followed by *Strongyloides* sp. (32%), *Blastocystis* sp. (32%), *Trichuris* sp. (17%), *Giardia* sp. (10%) and *Enterobius* sp. (3%) [56]. Conversely, the prevalence of GI parasites infection was lower at the Kosumpee Forest Park, MahaSarakham, Thailand, where only 35.11% of the fecal samples were positive, including *Strongyloides* spp. (15.27%), *Trichuris* spp. (22.9%), hookworm (4.58%) and *Ascaris* spp. (1.53%) [57].

A comprehensive project was undertaken to investigate GI parasites in Malaysia's non-human primates from the wild, and animals living in urban habitats, and the ones in captivity. This study examined a total of 12 local non-human primate species and illustrated at least 44 species of GI parasites were detected, including seven species of protozoans, 26 species of nematodes, five species of cestodes, five species of trematodes, and one species of pentastomida. The GI parasite distributions were not significantly different between the three groups, and the most prevalent GI parasite was Ascaris spp. (49.7%), followed by *Oesophagostomum* spp. (26.9%) [58]. A study specifically looking into captive pig-tailed macaques showed that an overall GI parasite prevalence rate of 52%. Among the species, five species belonged to Nematoda viz. *Anatrichosoma* sp., Capillaridae, *Strongyloides* sp., *Trichostrongylus* sp., and *Trichuris* sp. Only one Trematoda species was detected, which is *Paramphistomum* sp. The most common GI parasites are *Trichuris* sp. (38%), followed by *Trichostrongylus* sp. (24%), *Paramphistomum* sp. (14%), *Anatrichosoma* sp. and *Strongyloides* sp. (10%) each, and lastly Capillaridae (5%). It should be noted that about one-third of animals tested had double GI parasite infection (33%), 14% of the infection was single, and 5% had a triple infection. Most of the macaque owners did not administer anthelmintics to their animals as preventive medicine. The authors also examined thick blood smears from these captive pig-tailed macaques and found one sample positive for filaria nematode [59].

On the whole, the GI parasites and haemoparasite identified in these studies are of known public health importance and zoonotic concern that needs to be seriously addressed, specifically raising awareness of people in close contact with macaques.

8. Population control

Due to the success of the long-tailed macaques in adapting to human settlements, particularly in the urban areas, they are the culprit in most reported human-wildlife conflict cases in Malaysia, up to 65% of total annual case reports, compared to any other wildlife species [15–17]. It is most often created serious public nuisance and concerns on the animals causing property damage and bodily harm to people encountered during the conflict episodes. The short-term solution most often resorted to is population control, in the hope to reduce the occurrence of conflicts.

Currently, an effective contraceptive method, besides capturing and physical handling of the animals for surgical and non-surgical neutering methods, is lacking. Zona pellucida vaccination, oral contraceptives are temporary and require reapplication, which is troublesome, labor intensive, and recurring cost. Neutering needs animals to be captured, especially for the females as surgical methods involve laparotomy. The effort starts with procuring and setting up suitable traps, then to restrain, anesthetize, and application of chemical or surgical methods for permanent sterilization.

The most frequently used method for sterilization of the male macaques is castration that involves the removal of the testicles, and this procedure does not require an invasive procedure into the abdominal cavity. Compared with the procedures in the females, often healing time is much quicker and may not require an extended holding period. In a report by Karuppannan et al. [60], non-surgical castration through intraepididymal injections of ethanol-formalin mixture to induce tubular blockage resulted in over 90 percent (32/35) success among the animals tested. This method is labor intensive, requires the animals to be caught first, training of staff and precision during the injection process. Furthermore, this method is most suitable for adult males as epididymis in juveniles and subadults are small and difficult to locate to ensure accurate injection of the ethanol-formalin mixture. This chemical castration method is compared to surgical castration that requires surgical skills and can only be performed by veterinarians, yet the age of animals is usually not an issue for successful removal of testis. However, the chemical approach can be done within a shorter period and the males are expected to sustain their sexual behavior as the testicular tissues remained intact [60].

The impact of castration on male macaques is still debatable. Castration does not appear to impact the social interactions between male Japanese macaques (*Macaca fuscata*) in the group. Instead of linear hierarchy as in the intact males, castrated males are less aggressive and have a more lateral relationship with one another [61]. Thus, Takeshita et al. [61] recommend that castration can be adopted as an effective population control measure. On the other hand, studies indicated possible dental health issues where castrated rhesus macaques (*Macaca mulatta*) that lived till old age have greatly receded alveolar bone with signs of periodontitis more severe than in intact old males, as well as severe temporomandibular joint osteoarthritis in the former [62]. The Department of Wildlife and National Parks would adopt the chemical castration described above as this method would not affect male hormone levels in the animals [60].

On the other hand, sterilization in females will definitely necessitate penetration of the abdominal cavity for removal of the ovaries, and/or the uterus. The length of incision and operation period depends on the method chosen, through laparotomy or laparoscopic approach. Surgical methods have been reported in other countries, the caveat of laparotomy for ovariohysterectomy in the female would require the animals to be kept for at least three to 4 days before release to ensure the suture site has healed. This will require facilities to temporarily house the animals. The use of laparoscopy may alleviate this problem, where tubectomy, removal of the Fallopian tube, ovariectomy (removal of ovaries) in females; and vasectomy in males can be conducted. If done correctly, only two to three small and bloodless (or minimal bleeding) incisions are required to access the reproductive organs [63]. The use of a laparoscope has minimized the length of the abdominal incision, especially in females [64]. Nevertheless, the downside of laparoscopic procedures is costly equipment, the requirement of trained staff, and electricity supply.

9. Conservation of macaques in Malaysia

Malaysia is inhabited by ≥25 non-human primate species from five families, one of the most diverse primate faunas on earth. Unfortunately, most of these primates are threatened with extinction due to habitat loss, degradation and fragmentation, hunting, and the synergies among these processes. Despite the charisma and cultural importance of primates, the significance of primates in ecological processes such as seed dispersal, and the robust development of biodiversity-related sciences in Malaysia, there is relatively little research specifically focusing on wild primates since the 1980s. Forest clearing for plantation agriculture has been a primary driver of forest loss and fragmentation in Malaysia. Selective logging has also negatively impacted the primates. However, these impacts vary across primate taxa. Previously-logged forests were 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 subjected to retaliatory or pre-emptive killing as pests, trapped for translocation to minimize human-wildlife conflicts, and captured for illegal trade as pets. Additionally, translocation operations should consider conservation of the unique evolutionary lineages of the macaque species, particularly the long-tailed macaques found to be of two distinctive subspecies [5]. Further research on the distribution, abundance, ecology, and behavioral biology of Malaysian primates is needed to inform effective management interventions. Outreach and education are also essential to reduce primate-human conflicts and illegal trade targeting primates as pets. Ultimately, researchers, civil organizations, government authorities, and local and indigenous communities in Malaysia must work together to develop, promote and implement effective strategies to protect Malaysian primates and their habitats.

Of the three macaque species, long-tailed macaques seemed to be able to adapt well within human settlements, despite a high number of human-wildlife conflicts reported [15]. The major conservation challenge facing macaque is habitat loss, degradation, and fragmentation resulting from forest clearing for plantation agriculture, selective logging, and a dense network of roads connecting many cities and townships in the country [65]. Macaques may not be popular as bushmeat, but are also trapped or hunted for illegal trade as pets [65]. Further research on habitat needs for all macaque species is imperative in order to understand the disparity of population density between the species, despite the similarities of natural habitats, diet, and behavior. A good example is a study conducted by Holzner et al. [66] citing the significant changes in sociality behavior of pig-tailed macaques that visit oil palm plantations in Malaysia, which may debilitate individual fitness and infant survival. This proves that despite the ability of pig-tailed macaques to temporarily adapt to human-altered habitats, the proximity of forest is vital for the survival of the species. Research done in recent years indicated an urgent need for macaque conservation strategies to preserve the remaining and segregated pig-tailed macaque and stump-tailed macaque populations involving the authorities, local communities, and general public [12, 67]. The authorities and non-government organizations are urged to increase public awareness on macaque species, particularly their roles in the ecosystem, as little is known about the species.

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References

[1] Eudey, A., Kumar, A., Singh, M. &Boonratana, R. (2020) *Macaca fascicularis*. The IUCN Red List of Threatened Species 2020: e.T12551A 17949449. [Internet]. Available from: https://dx.doi.org/10.2305/IUCN.UK.2020-2.RLTS.T12551A17949449.en [Accessed: 2020-12-16]

[2] Wicke B, Sikkema R, Dornburg V, Faaij A. Exploring land use changes and the role of palm oil production in Indonesia and Malaysia. Land Use Policy. 2011;**28**(1):193-206

[3] Global Forest Watch (2021) Primary forest loss in Malaysia. https://gfw.global/3gtXC2v

[4] Omran A, Schwarz-Herion O. Deforestation in Malaysia: The Current Practice and the Way Forward. In: Omran A, Schwarz-Herion O, editors. Sustaining our Environment for Better Future. Singapore: Springer; 2020. DOI: 10.1007/978-981-13-7158-5_11

[5] Abdul-Latiff MAB, Ruslin F, Faiq H, Hairul MS, Rovie-Ryan JJ, Abdul-Patah P, et al. Continental monophyly and molecular divergence of peninsular Malaysia's. Macaca Fascicularis fascicularis. 2014;**2014**:897682

[6] DeSalle R, Amato G. The expansion of conservation genetics. Nature Reviews. Genetics. 2004;**5**(9):702-712. DOI: 10.1038/nrg1425 PMID: 15372093

[7] Abdul-Latiff MAB, Abdul-Patah P, Yaakop S, Md-Zain BM. Aiding pest control management of long-tailed macaques (*Macaca fascicularis fascicularis*) in Malaysia by using molecular markers of mitochondrial DNA. AIP Conference Proceedings. 2017;**1891**:020003. DOI: 10.1063/1.5005336

[8] Holzner A, Ruppert N, Swat F, Schmidt M, Weiß BM, Villa G, et al. Macaques can contribute to greener practices in oil palm plantations when used as biological pest control. Current Biology. 2019;**29**(20):R1066-R1067

[9] Ang, A., Boonratana, R., Choudhury, A. &Supriatna, J. (2020) Macaca nemestrina. The IUCN Red List of Threatened Species 2020: e.T12555A 181324867. [Internet]. Available from: https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T12555A181324867.en. [Accessed: 2020-12-16]

[10] Molur S, Brandon-Jones D, Dittus W, Eudey A, Kumar A, Singh M, et al. The Status of South Asian Primates: Conservation Assessment and Management Plan (CAMP) Workshop Report. Coimbatore, India: Zoo Outreach Organisation/CBSG-South Asia; 2003

[11] Chetry, D., Boonratana, R., Das, J., Long, Y., Htun, S. & Timmins, R.J. 2020. Macaca arctoides. The IUCN Red List of Threatened Species. Gland, Switerland: IUCN; 2020: e.T12548A185202632. https://dx.doi.org/10.2305/IUCN.UK.2020-3.RLTS.T12548A185202632.en. Downloaded on 28 June 2021

[12] Syamil AR, Mohd-Ridwan AR, Amsah MA, Abdul-Latiff MAB, Md-Zain BM. Population census and age category character of Stump tailed macaque, *Macaca arctoides*, in Northern Peninsular Malaysia. Biodiversitas. 2019;**20**(9):2446-2452

[13] Jayaraj VK, Daud SHM, Azhar M-I, Sah SAM, Mokhtar SI, Abdullah MT. Diversity and conservation status of mammals in Wang Kelian State Park, Perlis. Malaysia. Check List. 2013;**9**(6):1439-1448

[14] Malaivijitnond S, Hamada Y. A new record of stump-tailed macaques in Thailand and the sympatry with long-tailed macaques. The Natural

History Journal Chulalongkorn University. 2005;**5**(2):93-96

[15] Saaban S, Yazid AZ, Mustapa AR, Keliang C. (2016) In MPOC / SWD Human – Wildlife Conflict Workshop held on 22-23 November 2016 at FourPoints by Sheraton, Sandakan, Sabah. Available at http://mpoc.org.my/human-wildlife-conflict-in-peninsular-malaysia-current-status-and-overview-2/upload/Paper%202%20-%20PERHILITAN%20-%20Human-Wildlife%20Conflict%20in%20Peninsular%20Malaysia%20-%20Current%20Status%20and%20Overview.pdf

[16] Sabah Wildlife Department (2016) In MPOC / SWD Human – Wildlife Conflict Workshop held on 22-23 November 2016 at FourPoints by Sheraton, Sandakan, Sabah. Available at: http://www.mpoc.org.my/upload/Paper%201%20-%20Sabah%20Wildlife%20Department%20-%20Human-Wildlife%20Conflict%20in%20Sabah%20-%20Current%20Status%20&%20Overview.pdf

[17] Sadili A. Human-macaque conflict between tourists and long- tailed macaques in Kanching recreational forest [Masters thesis]. Rawang, Selangor, Malaysia: Universiti Putra Malaysia; 2016

[18] Hambali K, Ismail A, Zulkifli SZ, Md-Zain BM, Amir A. Human-macaque conflict and pest behaviors of long-tailed macaques (*Macacafascicularis*) in Kuala Selangor Nature Park. Tropical Natural History. 2012;**12**(2):189-205

[19] Osman NA, Abdul-Latiff MAB, Mohd-Ridwan AR, Yaakop S, Nor SM, Md-Zain BM. Diet composition of the wild stump-tailed macaque (Macaca arctoides) in Perlis State Park, Peninsular Malaysia, using a chloroplast tRNL DNA metabarcoding approach: A preliminary study. Animals (Basel). 2020;**10**(12):2215. DOI: 10.3390/ani10122215

[20] Morse SS, Mazet JA, Woolhouse M, Parrish CR, Carroll D, Karesh WB, et al. Prediction and prevention of the next pandemic zoonosis. Lancet. 2012; **380**(9857):1956-1965. DOI: 10.1016/S0140-6736(12)61684-5 PMID: 23200504; PMCID: PMC3712877

[21] Davies TJ, Pedersen AB. Phylogeny and geography predict pathogen community similarity in wild primates and humans. Proc Roy Soc B. 2008;**275**:1695-1701

[22] Anon. Bush meat widely sold in Sabah. In: The Star. Petaling Jaya, WP: Star Media Group Berhad; 2015 https://www.thestar.com.my/news/nation/2015/11/23/bush-meat-widely-sold-in-sabah/

[23] Lee TM, Sigouin A, Pinedo-Vasquez M, Nasi R. The harvest of wildlife for bushmeat and traditional medicine in East, South and Southeast Asia: Current knowledge base, challenges, opportunities and areas for future research. In: Occasional Paper 115. Bogor, Indonesia: CIFOR; 2014

[24] Then S. Trade in bushmeat and body parts depleting wildlife population in Sarawak. In: The Star. 2020 https://www.thestar.com.my/metro/metro-news/2020/12/01/trade-in-bushmeat-and-body-parts-depleting-wildlife-population-in-sarawak

[25] Yii MCK, Mohd-Azlan J. Wildlife Hunting and Utilization in Ulu Baleh, Sarawak, Malaysian Borneo. Ethnobiology Letters. 2020;**11**(1):76-84. DOI: 10.14237/ebl.11.1.2020.1647

[26] Shepherd C, Shepherd L. The poaching and trade of Malayan sun bears in Peninsular Malaysia. TRAFFIC Bulletin. 2010;**23**:49-52

[27] Ahmad T, Khan M, Mussa TH, Nasir S, Hui J, Bonilla-Aldana DK, et al. COVID-19: Zoonotic aspects. In: Travel Medicine and Infectious Disease. Advance online publication;

2020;**36**:101607. DOI: 10.1016/j.tmaid.2020.101607

[28] Corlett RT, Primack RB, Devictor V, Maas B, Goswami VR, Bates AE, et al. Impacts of the coronavirus pandemic on biodiversity conservation. Biological Conservation. 2020;**246**:108571

[29] Daly, N. (2020). Seven More Big Cats Test Positive for Coronavirus at Bronx Zoo. https://www.nationalgeographic.com/animals/2020/04/tiger-coronavirus-covid19-positive-testbronx-zoo/

[30] Kideghesho JR, Kimaro HS, Mayengo G, Kisingo AW. Can the Tanzania wildlife sector survive the COVID-19 pandemic? Tropical Conservation Science. 2021;**14**:1-18. DOI: 10.1177/19400829211012682

[31] Terraube J, Fernández-Llamazares Á. Strengthening protected areas to halt biodiversity loss and mitigate pandemic risks. Current Opinion in Environmental Sustainability. 2020;**46**:35-38. DOI: 10.1016/j.cosust.2020.08.014

[32] Thongyuan S, Sanyathitiseri P, Viriyarumpa S, Duangrasamee S, Boonkusol D, Tulayakul P. A study of bacterial contamination in feces of macaques in Lopburi Province, Thailand. International Journal of Infectious Diseases. 2016;**53**(Supplement):63. DOI: 10.1016/j.ijid.2016.11.159

[33] Mohamad MA. Identification of zoonotic pathogens in working pig-tailed macaques (*Macaca nemestrina*) In Kota Bharu &Bachok, Kelantan (Unpublished master's thesis). Malaysia: Universiti Malaysia Kelantan; 2021

[34] Burgos-Rodriguez AG. Zoonotic diseases of primates. Veterinary Clinics of Exotic Animals. 2011;**14**:557-575

[35] Ahmad T, Khan M, Haroon MTH, Nasir S, Hui J, Bonilla-Aldana DK, et al. COVID-19: Zoonotic aspects. Travel Med Infect Dis. 2020;**36**:101607. DOI: 10.1016/j.tmaid.2020.101607

[36] Sam IC, Chua CL, Rovie-Ryan JJ, Fu JY, Tong C, Sitam FT, et al. Chikungunya Virus in Macaques, Malaysia. Emerging Infectious Diseases. 2015;**21**(9):1683-1685. DOI: 10.3201/eid2109.150439

[37] Ain-Najwa MY, Yasmin AR, Arshad SS, Omar AR, Abu J, Kumar K, et al. Exposure to Zoonotic West Nile Virus in Long-Tailed Macaques and Bats in Peninsular Malaysia. Animals (Basel). 2020;**10**(12):2367. DOI: 10.3390/ani10122367 PMID: 33321964; PMCID: PMC7764493

[38] Woon Y, Lim M, Rashid TA, Thayan R, Chidambaram SK, Syed Abdul Rahin SS, et al. Zika virus infection in Malaysia: An epidemiological, clinical and virological analysis. BMC Infectious Diseases. 2019;**19**(152). DOI: 10.1186/s12879-019-3786-9

[39] Chua C, Chan Y, Andu E, Rovie-Ryan JJ, Sitam F, Verasahib K, et al. Little Evidence of Zika Virus Infection in Wild Long-tailed Macaques. Peninsular Malaysia. Emerging Infectious Diseases. 2019;**25**(2):374-376. DOI: 10.3201/eid2502.180258

[40] Lam SK, Chua KB, Hooi PS, Rahimah MA, Kumari S, Tharmaratnam M, et al. Chikungunya infection--an emerging disease in Malaysia. The Southeast Asian Journal of Tropical Medicine and Public Health. 2001;**32**(3):447-451 PMID: 11944696

[41] AbuBakar S, Sam IC, Wong PF, MatRahim N, Hooi PS, Roslan N. Reemergence of endemic Chikungunya, Malaysia. Emerging Infectious Diseases. 2007;**13**(1):147-149. DOI: 10.3201/eid1301.060617. PMID: 17370532; PMCID: PMC2725805

[42] Diallo M, Thonnon J, Traore-Lamizana M, Fontenille D. Vectors of chikungunya virus in Senegal: current data and transmission cycles.

The American Journal of Tropical Medicine and Hygiene. 1990;**60**:281-286

[43] Suhana O, Nazni WA, Apandi Y, Farah H, Lee HL, Sofian-Azirun M. Insight into the origin of chikungunya virus in Malaysian non-human primates via sequence analysis. Heliyon. 2019;**5**(12):e02682. DOI: 10.1016/j.heliyon.2019.e02682

[44] Cohen JI. Chapter 144 - Herpes B Virus. In: Bennett JE, Dolin R, Blaser MJ, editors. Mandell, Douglas, and Bennett's Principles and Practice of Infectious Diseases (Eighth Edition). New York: W.B. Saunders; 2015. pp. 1783-1786, ISBN 9781455748013. DOI: 10.1016/B978-1-4557-4801-3.00144-2

[45] Lee M, Rostal MK, Hughes T, Sitam F, Lee C, Japning J, et al. Macacine herpesvirus 1 in long-tailed Macaques, Malaysia, 2009-2011. Emerging Infectious Diseases. 2015;**21**(7):1107-1113. DOI: 10.3201/eid2107.140162

[46] Engel GA, Jones-Engel L, Schillaci MA, Suaryana KG, Putra A, Fuentes A, et al. Human exposure to herpesvirus B-seropositive macaques, Bali, Indonesia. Emerging Infectious Diseases. 2002 Aug;**8**(8):789-795. DOI: 10.3201/eid0808.010467 PMID: 12141963; PMCID: PMC3266706

[47] Elmore D, Eberle R. Monkey B virus (Cercopithecine herpesvirus 1). Comparative Medicine. 2008;**58**(1):11-21

[48] Bryan BL, Espana CD, Emmons RW, Vijayan N, Hoeprich PD. Recovery from encephalomyelitis caused by herpesvirus simiae: Report of a case. JAMA Internal Medicine. 1975;**135**(6):868-870

[49] Eberle R, Jones-Engel L. Questioning the extreme neurovirulence of monkey B virus (Macacinealphaherpesvirus 1). Advances in Virology. 2018;**2018**: 5248420, 17 pages. DOI: 10.1155/2018/5248420

[50] Jones-Engel L, May CC, Engel GA, Steinkraus KA, Schillaci MA, Fuentes, A....Linial, M. L. Diverse contexts of zoonotic transmission of simian foamy viruses in Asia. Emerging Infectious Diseases. 2008;**14**(8):1200-1208. DOI: 10.3201/eid1408.071430

[51] Jones-Engel L, Steinkraus KA, Murray SM, Engel GA, Grant R, Aggimarangsee N, et al. Sensitive assays for simian foamy viruses reveal a high prevalence of infection in commensal, free-ranging Asian monkeys. Journal of Virology. 2007;**81**(14):7330-7337. DOI: 10.1128/JVI.00343-07

[52] Hussin N, Lim YAL, Goh PP, et al. Updates on malaria incidence and profile in Malaysia from 2013 to 2017. Malaria Journal. 2020;**19**:55. DOI: 10.1186/s12936-020-3135-x

[53] Yusof R, Lau YL, Mahmud R, Fong MY, Jelip J, Ngian HU, et al. High proportion of knowlesi malaria in recent malaria cases in Malaysia. Malaria Journal. 2014 May;**3**(13):168. DOI: 10.1186/1475-2875-13-168 PMID: 24886266; PMCID: PMC4016780

[54] Singh B, Daneshvar C. Plasmodium knowlesi malaria in Malaysia. The Medical Journal of Malaysia. 2010;**65**(3):166-172 PMID: 21939162

[55] Rahim MAFA, Munajat MB, Idris ZM. Malaria distribution and performance of malaria diagnostic methods in Malaysia (1980-2019): A systematic review. Malaria Journal. 2020;**19**:395. DOI: 10.1186/s12936-020-03470-8

[56] Kurniawati DA, Suwanti LT, Lastuti NDR, Kusdarto S, Suprihati E, Mufasirin M, et al. Zoonotic potential of gastrointestinal parasite in long-tailed Macaque Macaca fascicularis at Baluran National Park, Situbondo, East Java. Indonesia. Aceh Journal of Animal Science. 2020;**5**(1):47-56. DOI: 10.13170/ajas.5.1.15397

[57] Damrongsukij P, Doemlim P, Kusolsongkhrokul R, Tanee T, Petcharat P, Siriporn B, et al. One health approach of melioidosis and gastrointestinal parasitic infections from *Macaca fascicularis* to human at Kosumpee Forest Park, MahaSarakham, Thailand. Infect Drug Resist. 2021; **15**(14):2213-2223. DOI: 10.2147/IDR. S299797 PMID: 34163186; PMCID: PMC8214530

[58] Adrus M, Zainudin R, Ahamad M, Jayasilan MA, Abdullah MT. Gastrointestinal parasites of zoonotic importance observed in the wild, urban, and captive populations of non-human primates in Malaysia. Journal of Medical Primatology. 2019;**48**(1):22-31. DOI: 10.1111/jmp.12389 Epub 2018 Oct 29. PMID: 30370934

[59] Choong SS, Mimi Armiladiana M, Ruhil HH, Peng TL. Prevalence of parasites in working pig-tailed Macaques (*Macaca nemestrina*) in Kelantan, Malaysia. J Med Primatol. 2019;**48**(4):207-210. DOI: 10.1111/ jmp.12416

[60] Karuppannan KV, Saaban S, Firdaus Ariff AR, Mustapa AR. Non-surgical castration in controling long tailed macaque (Macaca fascicularis) population by Deparatment of Wildlife and National Parks (DWNP) Peninsular Malaysia. Malaysian Journal of Veterinary Research. 2013;**4**(1):33-36

[61] Takeshita RSC, Huffman MA, Kinoshita K, Bercovitch FB. Effect of castration on social behavior and hormones in male Japanese macaques (*Macaca fuscata*). Physiology & Behavior. 2017;**181**:43-50

[62] Wang Q, Kessler MJ, Kensler TB, Dechow PC. The mandibles of castrated male rhesus macaques (*Macaca mulatta*): The effects of orchidectomy on bone and teeth. American Journal of Physical Anthropology. 2016;**159**(1):31-51. DOI: 10.1002/ajpa.22833

[63] Kumar V, Kumar V. Clinical evaluation of laparoscopic sterilization techniques in female Rhesus Macaques (*Macaca mulatta*). Archives of Veterinary Science. 2012;**17**(3):20-26

[64] Yu PH, Weng CC, Kuo HC, Chi CH. Evaluation of endoscopic salpingectomy for sterilization of female Formosan macaques (Macaca cyclopis). American Journal of Primatology. 2014;**77**(4):359-367. DOI: 10.1002/ajp.22354

[65] Lappan S, Ruppert N. Primate research and conservation in Malaysia. CAB Reviews. 2018;**14**(4):1-10

[66] Holzner A, Balasubramaniam KN, Weiß BM, et al. Oil palm cultivation critically affects sociality in a threatened Malaysian primate. Scientific Reports. 2021;**11**:10353. DOI: 10.1038/s41598-021-89783-3

[67] Dzulhelmi MN, Suriyanti S, Manickam S. Population, behaviour and conservation status of long-tailed macaque, *Macaca fascicularis* and southern pig-tailed macaque, *Macaca nemestrina* in Paya Bakau Park, Perak, Malaysia. The Journal of Animal & Plant Sciences. 2019;**29**(2):611-618