

Ranging Behavior of Genus *Macaca* in Disturbance Habitat: A Review

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Numerous studies examined the effects of human disturbance on the home ranges of mammals, reptiles, and birds. Primates adjusted home range size according to habitat characteristics. However, there is a lack of reports that synthesize the ranging behavior across primate species under anthropogenic pressure. To facilitate our understanding, this study reviewed the literature on the ranging behavior of the genus *Macaca* in areas affected by various human disturbances. We found 41 reports, published between 1989 and 2025, that covered locations across regional areas from Asia, Africa, and Europe. The home ranges of the genus *Macaca*, which involved 15 macaque species, were documented as being impacted by human settlement, followed by agriculture and habitat degradation. The macaque species whose home range included human settlements and agricultural areas adopted smaller home ranges in response to provisioning food and crops, respectively. Meanwhile, the macaques tended to avoid areas exhibiting high levels of habitat degradation, expanding their home range in response to intensive logging. Our review provided important information to consider the anthropogenic impact in developing conservation management.

Key words: home range, genus *Macaca*, macaques, human disturbance

INTRODUCTION

Human population growth in several regions, such as Asia, Africa, and the Americas, is projected to decline in the remaining closed forests (Wright & Muller-Landau 2006). Such human landscape modification has been estimated to reduce primate populations (Chapman & Lambert 2000), as evidenced by later findings in primate communities (de Almeida-Rocha *et al.* 2017). Human disturbance affected primates in multiple ways, i.e., increasing physiological stress (Kaisin *et al.* 2021), facilitating pathogen transmission (Dunay *et al.* 2018), and altering behavioral ecology (Hasan *et al.* 2023, 2025), all of which had implications for primate populations. Numerous aspects of ecology and primate behavior are affected by habitat change (Schwitzer *et al.* 2011). Habitat alteration, for example, led the primate to adjust to different spatial patterns based on the degree of human disturbance (Riley 2008) and to employ distinct spatial shapes over several years (Riley *et al.* 2021). Spatial patterns related to energy cost are considered based on the benefits obtained, i.e., food (Albert *et al.* 2013a), which may be attributed to altered resource availability (Gerber *et al.* 2012).

Home range has long been defined as the area an

animal travels, typically to search for food, mate, and care for its young (Burt 1943). The area is part of an animal's cognitive map of its surroundings, which is chosen and updated (Powell & Mitchell 2012). In mammals, although home range was principally determined by body mass and group size, diet also influenced home range (Tucker *et al.* 2014; Campos *et al.* 2014). Previous studies demonstrated that primates adjusted home range size in response to habitat characteristics, particularly weather, the availability of natural food (Reinegger *et al.* 2023), human food (Hasan *et al.* 2023, 2025), and habitat fragmentation (Ramsay *et al.* 2023). Several study sites exhibited different habitat characteristics; primates inhabiting protected forests tended to have larger home ranges (Montilla *et al.* 2021). Primates under less anthropogenic influence had larger home ranges than those under higher anthropogenic pressure (Hansen *et al.* 2020; Jayapali *et al.* 2023). In a fragmented forest, conversely, arboreal primates utilized a smaller home range, possibly due to a lack of canopy links between trees (Ahsan 2000), precluding travel and expansion of their home range (Huang *et al.* 2017). Thus, examining home range provides information on spatial behavior that can reflect ongoing habitat conditions.

Numerous studies have examined the effect of human disturbance levels on home range between habitat sites. For example, Šálek *et al.* (2015) found

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that the home range size of carnivore mammals decreased along a gradient from natural to urban habitats. Similarly, alongside reptiles and birds, O'Donnell & delBarco-Trillo (2020) also investigated the impact of urban disturbance on mammals across various taxa. However, those studies did not encompass primates. Indeed, although studies on primate behavior in anthropogenic habitats have increased markedly since the 2000s (McLennan *et al.* 2017), there is a lack of reports that synthesize ranging behavior under anthropogenic pressure. By examining this study, the home ranges that primates have long adapted to under varying levels of human disturbance can be discussed.

Genus *Macaca* was recognized as comprising 19 species distributed from North Africa to Southeast Asia (Fooden 1976). Members of this genus exhibited adaptability by adjusting their range behavior in response to anthropogenic impacts, such as *Macaca fascicularis* (Hasan *et al.* 2023, 2025), *M. leonina* (Albert *et al.* 2013a), *M. sinica* (Jayapali *et al.* 2023), *M. tonkeana* (Riley 2008), *M. maura* (Albani *et al.* 2020; Riley *et al.* 2021), *M. sylvanus* (Neves *et al.* 2023), and *M. silenus* (Dhawale & Sinha 2022). When natural food availability decreased while agricultural resources were abundant, for example, *M. fuscata* frequently inhabited forest edges (Ebihara & Takatsuki 2021). Thus, varying degrees of human-modified environmental conditions altered the extent of the macaque's home range (Klegarth *et al.* 2017). In the present study, we reviewed the literature on the ranging behavior of the genus *Macaca* in areas subject to various human disturbances.

MATERIALS AND METHODS

Literature Compilation. From August 2024 to December 2025, we collected literature from the Scopus and Google Scholar databases by supplementing several terms in the search box. Our review focused on published journal articles, book chapters, and theses/dissertations examining several human disturbances on the ranging behavior of macaques across biogeographic regions. We used the keywords: 'primate', '*Macaca*', 'home range', 'daily travel', 'daily path', 'urban', 'anthropogenic', 'provision*', and 'disturbance', and connected them using operators such as AND or OR. Human disturbance was determined by several terms, such as 'fragmentation', 'urbanization', 'agriculture' or 'cultivation', 'logging', 'provisioning', and 'human contact'.

Screening and Standardization. Our study focused on free-ranging macaque populations. For each selected article, we categorized the types of

human disturbance based on the locations covered home range of macaques. We distinguished human disturbance based on the following categories: 1) agriculture, defined as areas utilized for crop production and cultivation intended for harvesting; 2) habitat degradation, defined as habitat alteration that undergo degraded due to fragmentation, exploitation, logging, or livestock grazing; 3) human settlement, defined as locations covering residential zones across rural, urban, or specific university landscapes, where provisioning food also commonly occurs, including tourist sites, temples, and roadside. We did not consider the tools used by authors in the literature for collecting coordinate points, whether handled or collar GPS; all of them were used. Additionally, since we obtained a relatively limited number of articles, all studies, whether the authors stated the number of coordinates obtained (range: 26–4485) or did not clearly explain it, were used. In this case, we identified 41 studies published between 1989 and 2025 that covered 47 locations across Asia, Africa, and Europe (Figure 1).

To summarize home range size, we considered the method used by the authors. The scope of the literature we included encompassed home range methods: kernel density estimation (KDE) with its variants (adaptive, fixed, and autocorrelated kernels) and minimum convex polygon (MCP). We also used the term "other" for methods reported in a few studies, such as grid, characteristic hull polygon, and biased random bridge. Studies that did not clearly state a specified method within the literature were omitted. Of the 41 studies, 35 articles were eligible for inclusion. Then, we extracted home range values of the study groups from the selected articles. If home range size were reported as a range or interval (e.g., 31.2 to 42.9 ha), we took the midpoint of the range. We standardized the home range values to hectares (ha) for all data obtained.

RESULTS

The home range from a total of 96 macaque groups was documented as being affected by human disturbances, with varying area sizes across species (Table 1). Of the 15 macaque species in the dataset, 47% were currently classified as Endangered, 20% were Vulnerable, 13% were Least Concern, 13% were Near Threatened, and 7% were Critically Endangered (Figure 2). Home range of the genus *Macaca* was affected by several human disturbance factors, with human settlement being most commonly reported (54%), followed by agriculture (29%) and habitat degradation (17%) (Figure 3). The home ranges of three macaque species — *M. sylvanus*, *M. silenus*, and

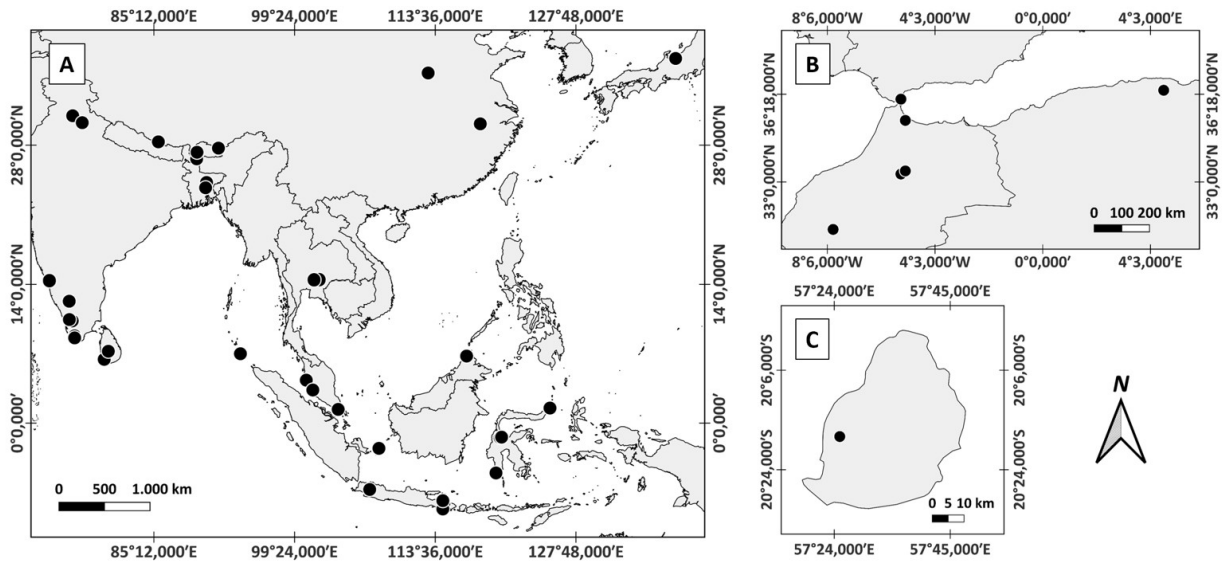


Figure 1. Map of study location (black dots) where data on the home range of the genus *Macaca* in human disturbance were collected from literature sources. The regions include several countries in (A) Asia: Indonesia, India, China, Malaysia, Singapore, Thailand, Japan, Nepal, Bhutan, Sri Lanka, and Bangladesh, (B) Europe: Gibraltar (upper map site) and Africa: Morocco and Algeria (lower map site); and C) Mauritius, another country in the Africa region

Table 1. Mean±SD of home range size (ha) of the genus *Macaca* in human disturbance as reported in literature studies

Species	IUCN red list	N	Group sizes	KDE (ha)	MCP (ha)	Other (ha)	References
<i>Macaca assamensis</i>	NT	2	12–30	55*	670*	NA	1, 2
<i>Macaca fascicularis</i>	EN	18	14–89	29.5±14.5	13.6±5.8	49.9±22.8	3, 4, 5, 6, 7, 8, 9, 10, 11, 12
<i>Macaca fuscata</i>	LC	22	18–131	372.9±199.4	NA	NA	13
<i>Macaca leonina</i>	VU	3	35–141	301±305.5	NA	56.3*	14, 15, 16
<i>Macaca maura</i>	EN	1	35	36*	NA	NA	17
<i>Macaca mulatta</i>	LC	5	40–64	313±282.9	NA	NA	1, 18, 19
<i>Macaca munzala</i>	EN	2	13–22	NA	22±8.5	NA	20
<i>Macaca nemestrina</i>	EN	1	53	181*	NA	NA	21
<i>Macaca nigra</i>	CR	5	34–97	NA	219.6±124.8	NA	22, 23
<i>Macaca radiata</i>	VU	4	32–41	NA	NA	7.3±1.7	24
<i>Macaca silenus</i>	EN	9	25–96	82.1±95.6	NA	318*	25, 26, 27
<i>Macaca sinica</i>	EN	3	17–32	NA	25.1±33.7	NA	28, 29
<i>Macaca sylvanus</i>	EN	17	12–38	134.5±140.5	NA	550±368.2	30, 9, 31, 32, 33
<i>Macaca thibetana</i>	NT	3	35–52	253±52.1	NA	NA	34
<i>Macaca tonkeana</i>	VU	1	25	NA	NA	44.5*	35

IUCN (International Union for Conservation of Nature) Red List was assessed for the period 2020–2025 (NT = Near Threatened, EN = Endangered, LC = Least Concern, VU = Vulnerable, CR = Critically Endangered); N is the number of macaque groups; Asterisks (*) refer to total home range; NA is not available; Sources: 1. Khatiwada *et al.* 2020, 2. Oi *et al.* 2016, 3. Brotcorne *et al.* 2014, 4. Hambali *et al.* 2014, 5. Hasan *et al.* 2023, 6. Hasan *et al.* 2025, 7. Sha & Hanya 2013, 8. Hansen *et al.* 2020, 9. Klegarth *et al.* 2017, 10. Velankar *et al.* 2024, 11. Hartati *et al.* 2023, 12. Stark *et al.* 2019, 13. Izumiyama *et al.* 2003, 14. Albert *et al.* 2013a, 15. Gazagne *et al.* 2020b, 16. José-Domínguez *et al.* 2015, 17. Riley *et al.* 2021, 18. Anand *et al.* 2021, 19. Bindhani *et al.* 2025, 20. Kumar *et al.* 2007, 21. Ruppert *et al.* 2018, 22. O’Brien & Kinnaird 1997, 23. Joly *et al.* 2023, 24. Gajbe 2018, 25. Dhawale & Sinha 2022, 26. Erinjery *et al.* 2015, 27. Santhosh *et al.* 2015, 28. Jayapali *et al.* 2023, 29. Weerasekara & Ranawana 2017, 30. Neves *et al.* 2023, 31. Namous & Znari 2018, 32. Mehlman 1989, 33. Waterman 2016, 34. Li *et al.* 2022, 35. Pombo *et al.* 2004

M. fascicularis — were affected by the overall human disturbance (Figure 4).

DISCUSSION

Mammals adopted a spatial pattern that varied with the degree of human disturbance (Salek *et al.* 2014). They decreased home range with higher-level impact and did not change movement patterns with minimal impact (O’Donnell & delBarco-Trillo 2020).

However, a more detailed explanation was needed to identify the primary disturbances that influenced ranging behavior of macaques. For example, when human food was given, *M. fascicularis* and *M. mulatta* decreased their daily travel distance (Sengupta *et al.* 2015; Hasan *et al.* 2023, 2025). *M. maura* expanded the larger home range to use more productive but riskier habitat, due to its history of provisioning (Albani *et al.* 2020). A similar pattern was observed in *M. sylvanus*, which showed smaller home ranges and

shorter daily path length in an agricultural area (Naves *et al.* 2023). Primates inhabiting highly fragmented forests adopted a smaller home range (Yanuar & Chiver 2010). They used an energy-minimizing strategy by traveling at a slower rate in response to lower overall food availability (Mekonnen *et al.* 2017).

Human Settlement. Provisioning food occurred at several sites, where it usually occurred as a consequence of the human-macaque interface. Provisioning was a common behavior among humans engaged in urban (Jaman & Huffman 2013), ecotourism sites (Hasan *et al.* 2023, 2025), human-cultural contexts, i.e., temple (Howells *et al.* 2022), and road (Riley *et al.* 2021). People visited the ecotourism site primarily to see the macaques (Sengupta *et al.* 2021), and they were motivated to provision by the desire to observe them

closely, concern over decreasing their food resources, and religious affinities (Sengupta & Radhakrishna 2020). Human food was frequently given at concentrated distribution, which consequently affected ranging behavior. For example, direct provisioning or the human trash that clumped in refuse sites has been widely reported to decrease travel activity of several macaque species, i.e., *M. leonina*, *M. fascicularis*, and *M. sylvanus* (Albert *et al.* 2013a; Klegarth *et al.* 2017; Hasan *et al.* 2023, 2025). This could be attributed to

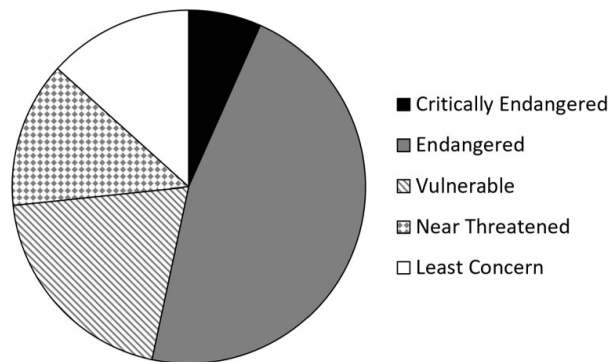


Figure 2. Conservation status of 15 species of the genus *Macaca* in publications about home range in human disturbance. IUCN Red List Categories were assessed for the period 2020–2025

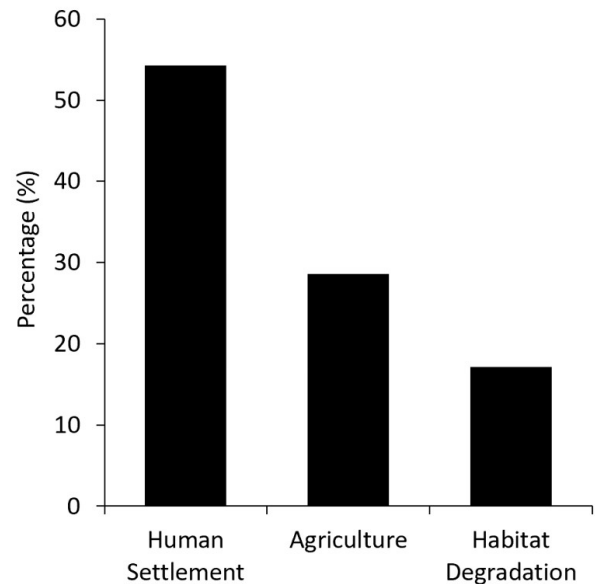


Figure 3. Percentage of publications reporting human disturbance impact categories on the ranging behavior of the genus *Macaca*

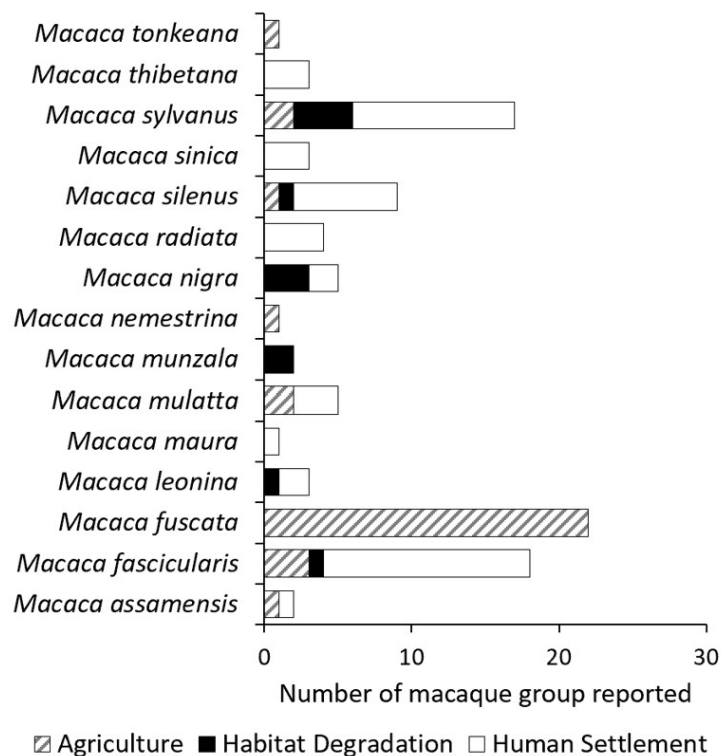


Figure 4. Distribution of macaque species across several human disturbances based on literature studies reported

the food readily available in the same area, leading the macaques not to travel as far as non-provisioned macaques (Hansen *et al.* 2020).

The role of provisioning in altering ranging behavior carries implications for seed dispersal effectiveness and safety risks of macaques. When we compared wild/non-provisioning and provisioning groups, in the non-provisioning group, especially during foraging, the macaques continuously expanded their home ranges to obtain sufficient food (Hansen *et al.* 2020; Reinegger *et al.* 2023). Therefore, this potentially increased the number of seeds dispersed far from the parent tree (Albert *et al.* 2013b). However, when the daily range size was reduced due to provisioning food, the ability of seeds to disperse declined (Sengupta *et al.* 2015). This condition, however, differed when provisioning occurred along roadsides (Waterman *et al.* 2020), leading the macaques to extend their range size to access the irregularly available food sources from traffic (Sha & Hanya 2013; Riley *et al.* 2021). Evidence from several studies indicated that roadside provisioning increased the risk of injury and mortality among macaque populations, including *M. maura* (Riley *et al.* 2021), *M. mulatta* (Pragatheesh 2011), *M. radiata*, and *M. silenus* (Jeganathan *et al.* 2018).

Habitat Degradation. Habitat degradation driven by plantation forestry, selective logging, large-scale clear-cutting, and grazing pressure has been shown to alter ranging behavior strategies across macaque species. In plantation forests, characterized by lower canopies and smaller diameter at breast height, *M. leonina* showed a smaller home range (Gazagne *et al.* 2020b) compared to another wild-feeding group inhabiting primary forests (José-Domínguez *et al.* 2015). When fruit availability in natural forests decreased, the macaques increased their range by showing lower daily site fidelity to exploit plantations (Gazagne *et al.* 2020a). With low availability and scattered distribution of fruit resources, the macaques also need to exhibit a sparse and largely non-random pattern of sleeping tree use across their home range (Gazagne *et al.* 2020b). In *M. fuscata*, a reduction of food availability due to forest plantations led macaques to frequently inhabit forest edges, coinciding with the time of increased food resources from agricultural areas (Ebihara & Takatsuki 2021).

Selective logging that altered local plant species composition also affected the ranging behavior of *M. silenus* (Santosh *et al.* 2015). Logging activities reduced forest cover and increased cleared areas, prompting the macaques to expand their range during deforestation temporarily (Stark *et al.* 2019). Logging also reduced the number of feeding trees, leaving them unevenly distributed. Therefore, the macaques shortened their daily travel distance to forage in a

specific area where food was concentrated (Singh *et al.* 2002). In areas undergoing clear-cutting, *M. nemestrina* showed lower occupancy, which might be affected by high-sensitivity disturbances within its home range (Holzner *et al.* 2021). *M. maura* was also reported to be infrequently detected in clear-cut areas and in locations with non-species-specific hunting traps, compared to forested habitats (Beltrán Francés *et al.* 2022). This behavior indicated a tendency to avoid areas with high levels of degradation and threat.

With respect to grazing pressure, this factor was proposed to lead to a significant decrease in herbaceous production and species richness as feeding plant of *M. sylvanus* (Ciani *et al.* 2005; Ménard *et al.* 2014). Thus, probably affected the ranging behavior of macaques. A previous study emphasized that the macaques used a strategy of uneven range use due to herding goats and domestic dogs, further reducing access to food resources (Mehlman 1989). The strategy of ranging behavior in response to grazing pressure needs further investigation.

Agriculture. Previous studies reported that the home ranges of several macaque species spanned agricultural landscapes, enabling them to raid and consume a wide range of crops (Pombo *et al.* 2004; Ruppert *et al.* 2018; Neves *et al.* 2023). The macaques concentrated their activities within or adjacent to the crop area (Namous & Znari 2018; Anand *et al.* 2021), despite remaining relatively fearful toward local farmers (Namous & Znari 2018). Agriculture provided concentrated food resources that are often available year-round (Riley *et al.* 2013), supplementing the macaque diet (Ruppert *et al.* 2018). When the habitat provided abundant crops, the macaques typically foraged in a smaller area (Wenyuan *et al.* 1993). This behavioral adaptation was reflected in *M. sylvanus*, which adopted a strategy of minimum energy expenditure by maintaining smaller home ranges and shorter daily path lengths to increase its foraging efficiency (Neves *et al.* 2023). Similarly, *M. fascicularis umbrosus* also reduced home range size due to a diet primarily composed of cultivated plants (Velankar *et al.* 2024). However, home range size often varies seasonally based on resource availability. Fluctuations in crop yields could trigger changes in ranging patterns; macaques expanded their home range when food became scarce and reduced their ranging when food was abundant (Erinjery *et al.* 2015).

The home range of macaques that encompasses agricultural landscapes is frequently associated with crop-raiding behavior. Farmers considered macaques the primary cause of crop loss (Mishra *et al.* 2020). Conflict due to crop raiding remained a persistent problem, because primate habitats were increasingly converted into agricultural land to meet market demands

(Estrada *et al.* 2017). In *M. ochreata brunnescens*, the macaques tend to be commonly observed to raid close (<10 m) to crop perimeters (Priston *et al.* 2012), and within 20 m of the forest edge experienced greater crop damage by *M. mulatta* (Koirala *et al.* 2021). Several main crops targeted during raiding included maize, potatoes, and cereal (Priston *et al.* 2012; Regmi *et al.* 2013; Koirala *et al.* 2021). Interestingly, in Northern India, crop raiding by *M. mulatta* was not primarily driven by reliance on agricultural food sources, since crop consumption accounted for only a small portion of their overall diet (Anand *et al.* 2021). Instead, the raiding behavior was mediated by the proximity of agricultural fields to forest edges that provided safe refuges, such as tall trees, which allowed them to navigate the area securely (Anand *et al.* 2021). A similar pattern was observed in *M. fuscata*. The macaques occupied edge habitats located between forests and agricultural areas by adopting a slow travel behavior to feed on peripheral vegetation and to rest (Yamada & Muroyama 2010). This behavior indicated that the macaque species considered risk avoidance to maximize their foraging efficiency.

In summary, many studies emphasized the home ranges of the genus *Macaca*, which are affected by several human disturbances. Most species mentioned in the literature were listed as Endangered by the IUCN. Endangered macaques—*M. fascicularis*, *M. sylvanus*, and *M. silenus*—often change their range patterns in landscapes dominated by human disturbance. Several macaque species with other statuses, however, also showed similar adaptations. The macaques whose home ranges included human settlements adopted smaller home ranges in response to the availability of human food. Similarly, ranging behavior was highlighted when crop raiding occurred in agricultural areas. The macaques also showed a tendency to expand their home range due to high levels of degradation, i.e., intensive logging or tree clear-cutting. Our review provided important information to consider the anthropogenic impact in developing conservation management. Several studies examining the ranging behavior of the genus *Macaca* did not clearly report total home range size. Thus, our data might not fully cover the ranging behavior of macaque species based on the research trends in the existing literature. Future studies need to consider the basic data of home range size to explore detailed spatial behavior.

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