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ANNEX 4: THE IMPACTS OF LINEAR INFRASTRUCTURE ON BIODIVERSITY AND HABITATS IN ASIA

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ACRONYMS

ASEAN	Association of Southeast Asian Nations
AVC	Animal-Vehicle Collision
BACI	Before-After-Control Impact
BRI	Belt and Road Initiative
GIS	Geographic Information System
IUCN	International Union for the Conservation of Nature
LI	Linear Infrastructure
USAID	United States Agency for International Development
USD	United States Dollar
WFLI	Wildlife-Friendly Linear Infrastructure
WoS	Web of Science

INTRODUCTION

Biodiversity is declining across the globe at an unprecedented rate (McCallum, 2015). With approximately 50 to 70 percent of the Earth's land surface currently modified for human activities (Ceballos et al., 2015), patterns of biodiversity and ecosystem functions worldwide are changing (Mace & Baillie, 2007). The key drivers of biodiversity loss are land use and land cover changes, pollution, climate change, and infrastructure development (Butchart et al., 2010; Sala, 2000).

Linear infrastructure (LI) development, while necessary for the well-being of societies, can be one of the largest contributors to ecological and environmental degradation. Socioeconomic and environmental tradeoffs are especially acute in tropical landscapes (Goosem, 2007; Laurance et al., 2009). In Asia, USAID seeks to identify, evaluate, and improve the capacity of countries to provide adequate biodiversity safeguards during the development of three of Asia's most extensive LI systems: roads, railways, and power lines.

Asia is a reservoir for global biodiversity, harboring a rich variety of living forms (Peh, 2010). The continent is home to seven of the world's top 25 biodiversity hotspots, such as India's Western Ghats, the island of Sri Lanka, southwest China, and the Himalayan foothills of several countries (Myers et al., 2000). Asia is biologically complex, given its variable biogeography and several pronounced divides, which leads to many rich regional patterns of species and natural communities (Hughes, 2017).

The Asian continent comprises 18 global ecological zones that are extremely diverse, ranging from temperate mountain systems to tropical rainforests (IPBES, 2018). The expanding footprint of human activities is not only causing the loss of habitat and biodiversity in many ecological zones, but is also affecting animal movement through fragmented and disturbed habitat (Tucker et al., 2018; Venter et al., 2016). Tropical ecosystems are especially vulnerable to human impacts due to the ecological specialization of species living within the complex, multi-layered architecture of tropical forests; and edge and barrier effects are exceptionally pronounced for tropical species that are more prone to avoid forest edges and clearings (Laurance et al., 2009).

The Asia region also is rich in natural resources such as energy, water, and forests, all vital for underpinning economic wellbeing and for securing countries' long-term, sustainable growth. Yet, these ecosystems and natural resources are threatened by expanding LI systems and unregulated extraction that contribute to rapid and severe environmental degradation and jeopardize the livelihoods of millions who rely on these resources for their survival.

Asia has begun to invest heavily in new infrastructure, often with the support of international development banks (Callaghan & Hubbard, 2016). The Asian Development Bank estimates that USD 1.7 trillion of infrastructure investment is needed per year until 2030 to maintain the Asia region's growth momentum, tackle poverty, and respond to climate change (Asian Development Bank, 2017). Power and transport are the two largest sectors at 56 percent and 32 percent, respectively, of total investment needed. The U.S. Energy Information Administration projects that world energy consumption will grow by nearly 50 percent between 2018 and 2050 (U.S. Energy Information Administration, 2020). Another issue for Asia is China's Belt and Road Initiative (BRI) estimated to cost over USD 5 trillion and connect 65 countries by land and sea (Cai, 2017). There is already concern about the BRI's impending environmental consequences and impacts to biodiversity (Ascensão et al., 2018; Hughes et al., 2020; Lechner et al., 2018).

Besides the effects of direct mortality, LI systems can have many indirect effects on wildlife and their habitat: increased anthropogenic pressures (hunting, development, extraction), habitat loss and fragmentation, and changes in animal occurrence and behaviors near these structures (Biasotto & Kindel, 2018; Fearnside & de Alencastro Graça, 2006; Wilkie et al., 2000). The proliferation of transportation infrastructure, which facilitates human settlement and increases activity in frontier areas, has been identified as one of the primary causes of tropical deforestation (Geist & Lambin, 2002; Laurance et al., 2015). The ambitious LI plans for Asia need to proceed with caution, and a better understanding of the cumulative impacts of LI on wildlife in Asia is needed to inform science-based conservation strategies for planned and future development.

Reviews of the effects of LI on wildlife have largely been from developed nations and temperate areas (Kociolek et al., 2011; Taylor & Goldingay, 2010; Trombulak & Frissel, 2000). Further, the impacts of roads are often qualitatively and quantitatively different in tropical regions than in other ecosystem types (Laurance et al., 2009; Pinto et al., 2020). Therefore, understanding these impacts, or their absence, will help guide LI planning and mitigation measures more suitable for the Asian context. We review existing research on the effects of LI on wildlife communities in Asia describing effects and measures to mitigate impacts. We synthesize our findings for taxa of interest along with key findings that highlight gaps of knowledge and recommendations to improve our knowledge base. The work is timely given the rapid pace of project development throughout the continent. This is the first attempt to compile and synthesize the effects of LI on Asia's rich biodiversity with the aim of advancing science-based solutions to mitigate their impacts.

METHODS

To adhere to the scope of the project, the study area of "Asia" was defined as the following 28 countries: Afghanistan, Bangladesh, Brunei, Bhutan, Cambodia, China, India, Indonesia, Japan, Kazakhstan, Kyrgyzstan, Laos, Malaysia, Mongolia, Myanmar, Nepal, North Korea, Pakistan, Philippines, Singapore, Sri Lanka, South Korea, Tajikistan, Thailand, Timor-Leste, Turkmenistan, Uzbekistan, and Vietnam. A systematic search for relevant peer-reviewed literature was then conducted on Clarivate Analytics' Web of Science™ (WoS), a leading scientific citation search and analytical information platform (Li et al., 2018). We chose this database as it is a widely trusted, multidisciplinary source with the ability to undertake advanced, controlled searches (Mikki, 2009). The database was queried using the following formulaic equation on October 14 and 15, 2020 (Collinson et al., 2019):

"Region" AND "Taxonomy" AND "Impact" AND "Linear infrastructure mode" where "Region" refers to Asia; "Taxonomy" refers to wildlife, biodiversity, and specific taxonomic group; and "Impact" refers to specific effects on wildlife and habitat, as well as suggested mitigation measures (Huijser et al., 2008). This first part of the equation (which remained constant) was then combined with each of three "linear infrastructure modes" (roads, railways, and power lines; Table 1). The search used the field tag "Topic," which looks for the defined search terms in the title, abstract, author, keywords and "keywords plus" (a WoS search feature that finds words or phrases that frequently appear in the titles of references within a given study, but do not appear in the title of the study itself). We searched only for articles in the English language (articles in other languages or with English only abstracts were also included as secondary sources of information; below). We restricted ourselves to papers published between January 1, 2000 and October 15, 2020.

Table 1: Formulaic equations for literature review search

TABLE 1: DETAILS OF FORMULAIC EQUATIONS USED TO SEARCH FOR PEER-REVIEWED SCIENTIFIC PUBLICATIONS WITHIN THE WEB OF SCIENCE DATABASE [A,B]

SEARCH TOPIC	FORMULAIC EQUATION KEYWORDS
Region	Topic=(Asia* OR Uzbekistan OR Kazakhstan OR Tajikistan OR Kyrgyzstan OR Turkmenistan OR China OR Japan OR South Korea OR North Korea OR Mongolia OR Indonesia OR Philippines OR Vietnam OR Thailand OR Myanmar OR Malaysia OR Cambodia OR Laos OR Singapore OR Timor* OR Brunei OR India OR Pakistan OR Bangladesh OR Afghanistan OR Nepal OR Sri Lanka OR Bhutan)
Taxonomy	Topic=(Wildlife OR Vertebrate OR Amphibian OR Reptile OR Bird OR Avi* OR Mammal OR Reptile OR Ungulate OR Carnivore OR Primate OR Bat OR Biodiversity)
Impact	Topic=(Mitigat* OR Electrocut* OR Barrier OR Roadkill OR Road-kill OR Collision OR "Wildlife vehicle collision" OR "WVC" OR Fragmentation OR "Road Effect" OR Mortality OR Strike OR Carcass OR Crash)
Linear infrastructure mode 1: Roads	Topic=("Linear infrastructure" OR Transport* OR Road* OR Highway OR Motorway OR Vehicle OR Traffic)
Linear infrastructure mode 2: Railways	Topic=("Linear infrastructure" OR Rail* OR Train)
Linear infrastructure mode 3: Power lines	Topic=("Linear infrastructure" OR "Power line*" OR Power-line* OR Power lines* OR "Transmission line*" OR "High voltage line*" OR "Transmission system*")

[A] The asterisk (*) is used as a wildcard search technique to maximize search results by looking for all possible endings to a root word.

[B] The quotation marks (" ") are a search technique to ensure search results retrieve the enclosed as an exact phrase.

After conducting each of the above three searches, we utilized the "analyze results" function in WoS (Biasotto & Kindel, 2018) to screen out articles that were unrelated to wildlife, habitat, and LI in Asia. Papers from the following fields of research were removed: Nutrition Dietetics, Education, Educational Research, Geriatrics, Gerontology, Cardiovascular System Cardiology, Oncology, Biochemistry, Molecular Biology, Neurosciences, Neurology, Veterinary Sciences, Health Care Sciences Services, Pathology, Pediatrics, General Internal Medicine, Research Experimental Medicine, Immunology, Pediatrics, and Meteorology Atmospheric Sciences. After downloading the remaining studies, we read the full text of each and pruned the database down using a set of well-defined criteria. Specifically, we excluded studies that were clearly not relevant to LI in the context of wildlife (e.g., technical engineering studies exclusively on the design of roads). We also removed studies that referred to LI only in passing (for example, a few sentences in the discussion in a study focused on some other aspect of conservation). We excluded studies that focused only on modeling landscape structure and metrics unless they were clearly linked to wildlife within that landscape. We also excluded studies for which we were unable to obtain the full text, although we included specific insights from their abstracts in the text of this review if they were clear and relevant. We did not include review and opinion papers for the purposes of classification (below), but we included references provided in such papers if they were relevant.

Following the pruning process, we were left with a set of studies that were relevant to LI in the context of wildlife conservation. We then classified each of these studies into a set of two categories and six sub-categories that summarized its research focus (a given study could be classified into more than one category or sub-category). We first assigned each study into one of two broad categories: effects (studies that focused on describing, developing, implementing, or evaluating the effects of LI on wildlife), and mitigation (studies that focused on describing, developing, implementing, or evaluating mitigation measures for LI). Studies on effects were then further classified into three sub-categories: E1 (direct effects), E2 (indirect effects), and E3 (direct and indirect effects at large scales), in a categorization modified from Bennett (2017). Studies on injury or mortality to wildlife from LI at relatively small scales (e.g., a single railway line or a few specific roads in a given area) were classified under E1. These included anecdotal observations on collisions or electrocutions, as well as detailed studies that quantified mortalities and the variables influencing these mortalities. Studies on the indirect effects of LI at small scales were classified under E2. Such studies included effects such as habitat loss, fragmentation, or degradation relatively close to LI; the role of LI in facilitating human activities such as poaching alongside; changes in local habitat use, including displacement and attraction; and barrier effects of infrastructure on the movement of individuals. E3 studies included both direct and indirect impacts at large spatial scales (relative to the species), studies related to infrastructure impacts at the population or community level, and studies that involved networks of LI. E3 studies included papers on changes in population abundance or large-scale distribution, the study of parameters relevant to demographic impacts of LI, quantification of population-level connectivity, assessment of gene flow, and analysis of variables related to fitness. For example, a study documenting the mortality of tigers (*Panthera tigris*) on a specific highway (Srivastava et al., 2017a) was classified under E1, whereas a range-wide estimation of road impacts on tigers (Carter et al., 2020) was classified under E3. Similarly, a study by Gubbi et al., (2012) on detection rates of large mammals immediately adjacent to a highway was classified under E2, whereas a study by Brodie et al., (2015) on the impact of road networks on the distribution of such mammals across a large region was classified under E3.

Studies on mitigation measures were also classified into three sub-categories following Huijser et al. (2008): M1 (mitigation measures that seek to change animal behavior), M2 (mitigation measures that seek to change human behavior), and M3 (mitigation measures that physically separate wildlife from LI). M1 studies included measures such as animal repellents, physical chasing, measures to reduce attraction, and provision of diversionary alternatives. M2 studies included measures such as speed limits, road closures, and improved visibility. M3 studies involved crossing structures such as overpasses and underpasses. Several studies that were focused on LI effects also provided recommendations for mitigation; however, we included such studies under the mitigation sub-categories only if we judged these recommendations to be substantial, and logically based on insights from that study. For example, Thinley et al., (2020) documented both electrocutions and roadkill of golden langur (*Traphypithecus geei*), and hence their study qualified under E1 for both roads and power lines. However, we did not categorize it under any mitigation sub-category because the recommended management intervention of lowering speed limits was generic rather than being derived from empirical data from the study.

Because the field of wildlife-friendly linear infrastructure (WFLI) is an applied science, we expected that several useful studies would not have been published in the peer-reviewed scientific literature. Therefore, we searched for additional sources of information from the gray literature, including white papers, governmental reports, reports by nongovernmental organizations, and news media. Additionally, our above search in WoS produced papers with English-only abstracts that were written in other languages (mainly Chinese, Japanese, and Korean). We ran such papers through machine translation tools and attempted to understand them in their entirety. For papers that were translated well and whose results were clearly relevant, we included insights in the text of this review. Finally, we extracted relevant information from an existing collection of studies related to roadkill in India, but do not include these in the summary statistics below because no comparable datasets were collected for other countries or LI modes.

SUMMARY OF RESULTS

We found 289 peer-reviewed English language papers related to LI and wildlife in Asia, of which 56 percent were focused on roads, 17 percent on railways, and 27 percent on power lines (Figure 1). An additional 203 documents were also found and used in text when relevant but are excluded from the below statistics; these include 54 papers in other languages, 68 items from the gray literature, and 81 studies obtained from a database specifically of roadkill instances in India. The peer-reviewed papers showed an increasing trend over the period from 2000 to 2020 for all three modes, although the increase in road ecology papers was more rapid (Figure 2). The countries most represented in the road literature were India (33 percent of papers), China (22 percent), and Malaysia (7 percent; Figure 3). India was also the most represented country in the railway literature (39 percent), followed by China (20 percent), and Mongolia (16 percent). The countries with the most papers in the power line literature were India (31 percent), China (18 percent), and Mongolia (15 percent).

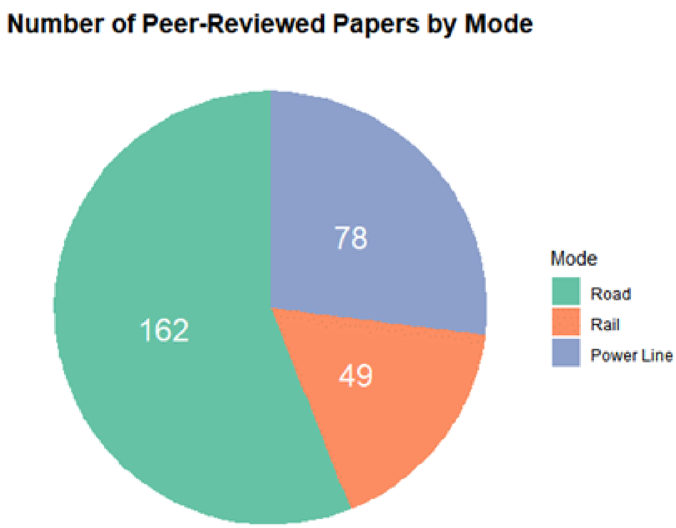

Figure 1. Number of peer-reviewed studies in Asia for roads, railways, and power lines between 2000 and 2020.

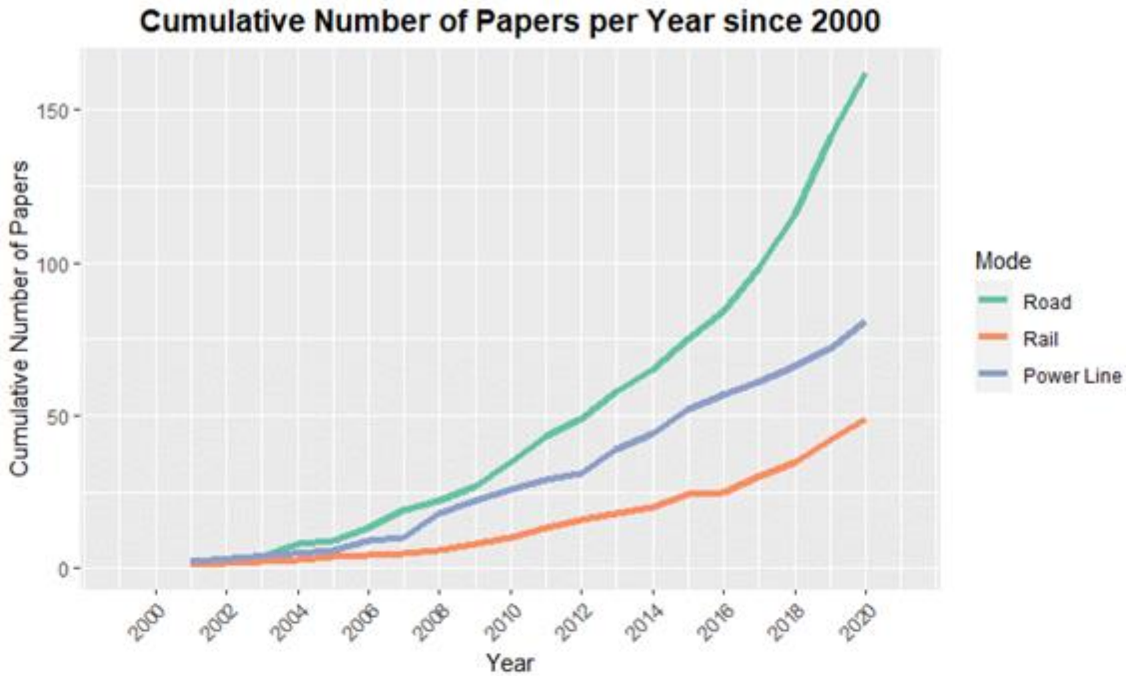

Figure 2. Temporal trends in the number of peer-reviewed scientific publications on roads, railways, and power lines in Asia from 2000 to 2020.

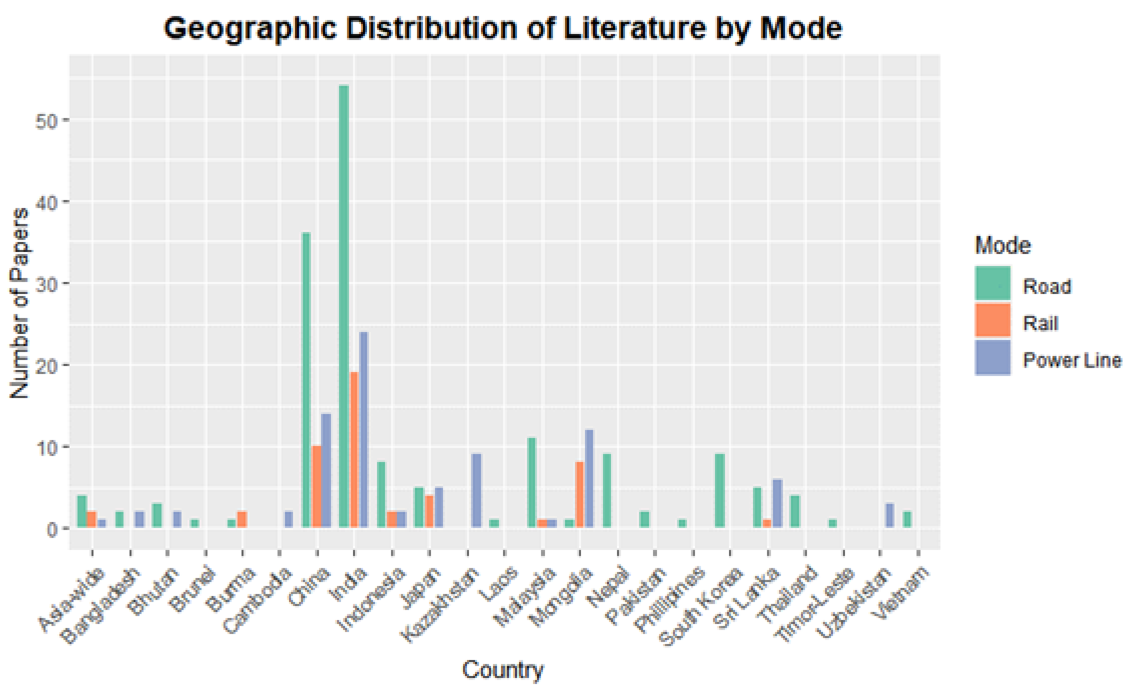

Figure 3. Number of papers in the peer-reviewed scientific literature on (a) roads, (b) railways, and (c) power lines for Asian countries between 2000 and 2020. Seven countries had zero papers across all three modes, and thus are excluded from the figure.

For roads, 142 papers studied the effects of LI (Figure 4a), and 23 studied mitigation of these effects (Figure 4b). Direct road impacts at small scales (E1) were the most studied among the road effects (81 studies, 57 percent), followed by direct and indirect impacts at large scales (E3; 68 studies, 48 percent) and indirect impacts at small scales (E2; 33 studies, 23 percent). Studies on mitigation measures that separate wildlife from roads (M3) were the most prevalent type of mitigation study (17 papers, 74 percent), followed by measures that seek to influence human behavior (M2; 8 papers, 35 percent) and measures that seek to influence animal behavior (M1; 2 papers, 9 percent). In terms of taxonomic representation (Figure 4c), mammals were the most represented in the road literature (111 papers, 69 percent), followed by reptiles (43 papers, 27 percent), birds (33 papers, 20 percent), and amphibians (31 papers, 19 percent). Only three papers on road impacts on invertebrates were found.

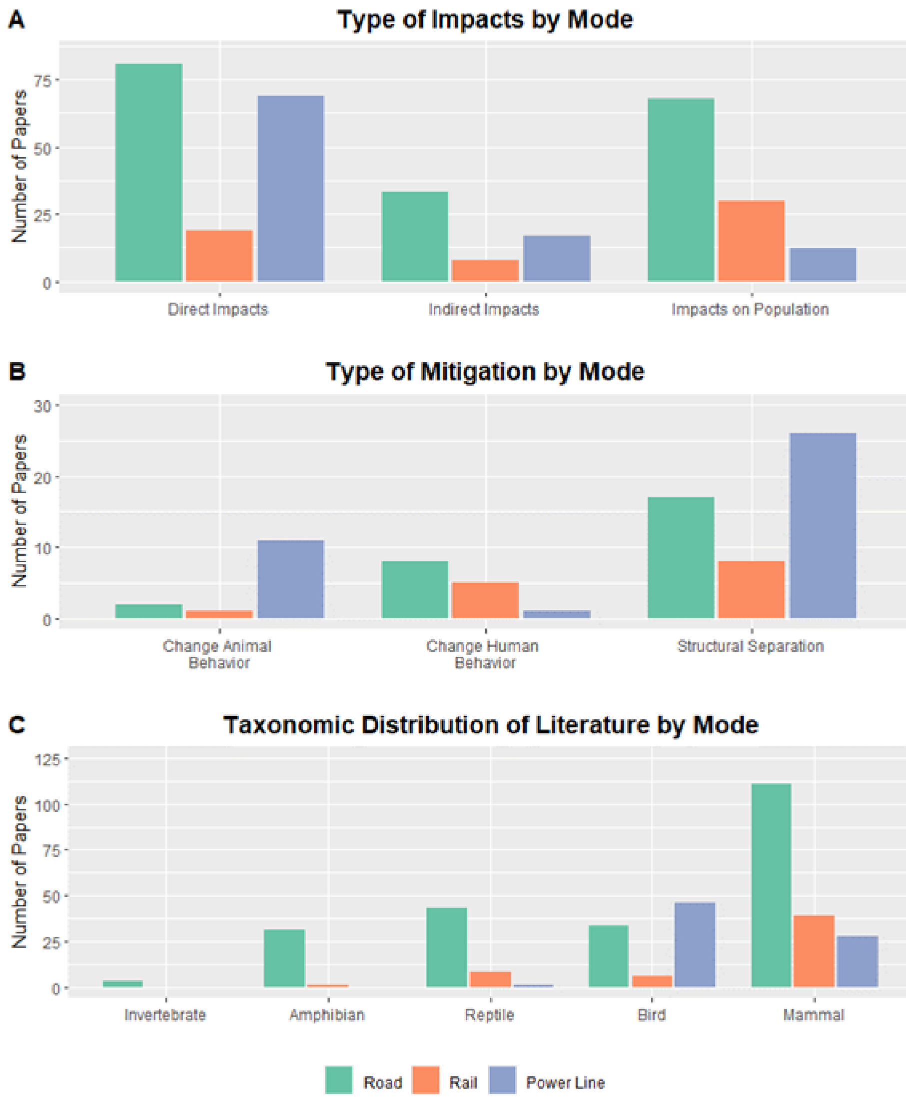

Figure 4. Count of studies related to the three major types of impacts for LI (A), count of studies related to the three major types of mitigation measures for LI (B) and count of studies related to invertebrates, amphibians, reptiles, birds and mammals for LI (C) in Asia between 2000 and 2020.

For railways, 46 papers studied the effects of LI on wildlife (Figure 4a), and 12 studied mitigation of these effects (Figure 4b). Direct and indirect impacts at large scales (E3) were the most studied effects (30 studies, 65 percent), followed by direct railway impacts at small scales (E1; 19 studies, 41 percent) and indirect impacts at small scales (E2; 8 studies, 17 percent). Studies on mitigation measures that separate wildlife from rails (M3) were the most prevalent type of mitigation study (8 papers, 67 percent), followed by measures that seek to influence human behavior (M2; 5 papers, 42 percent) and measures that seek to influence animal behavior (M1; 1 paper, 8 percent). In terms of taxonomic representation (Figure 4c), mammals were the most represented by far (39 papers, 80 percent), followed by reptiles (8 papers, 16 percent), birds (6 papers, 12 percent), and amphibians (1 paper, 2 percent).

For power lines, 71 papers studied the effects of LI on wildlife (Figure 4a), and 14 studied the mitigation of these effects (Figure 4b). Direct power line impacts at small scales (E1) were the most studied among the effects (64 papers, 90 percent), followed by indirect impacts at small scales (E2; 10 papers, 14 percent) and direct and indirect impacts at large scales (E3; 8 papers, 11 percent). Studies on mitigation measures that separate wildlife from power lines (M3) were the most common type of mitigation study (11 papers, 79 percent), followed by measures to change animal behavior (M1; 4 papers, 29 percent). The M2 category (measures to change human behavior) was not represented in the power line literature. In terms of taxonomic representation (Figure 4c), birds were the most represented (41 papers, 53 percent), followed by mammals (31 papers, 40 percent). Reptiles were represented only in one paper.

RESULTS BY MODE: ROADS

EFFECTS OF ROADS ON WILDLIFE

E1: DIRECT EFFECTS OF ROADS

Roads directly affect wildlife in the form of animal-vehicle collisions (AVCs), resulting in injury or mortality; mortality may also result from infrastructure that is directly associated with roads. AVCs have been documented for at least 611 species in Asia (Table 2; Appendix A). Some prominent species directly impacted by AVCs include Asian elephants (*Elephas maximus*; hereafter, "elephant") in Malaysia (Wadey et al., 2018), tigers in India (Srivastava et al., 2017a), Amami woodcocks (*Scolopax mira*) in Japan (Mizuta, 2014) and king cobras (*Ophiophagus Hannah*) in Thailand (Marshall et al., 2018). Infrastructure associated with roads, such as drainage ditches, may also trap small animals such as amphibians and result in their deaths (Z. Zhang et al., 2010). Despite the widespread documentation of roadkill, it is unclear if some taxa are more vulnerable than others. Herpetofauna often contribute the largest proportion in studies across different countries (e.g., India, Baskaran & Boominathan, 2010; Sri Lanka, Karunarathna et al., 2017; China, Wang et al., 2013). However, Silva et al., (2020) found bats to be the most represented vertebrates in a PA of Thailand, and birds were most represented in a PA in India (Menon et al., 2015). Animals that scavenge on roadkill, such as vultures and crows, may themselves become more vulnerable to collisions (Chhangani, 2004b). AVCs are prevalent among invertebrates too; for example, several butterfly and dragonfly species have been documented as roadkill in one study in India (Rao & Girish, 2007). Overall, our literature search highlights the wide prevalence of AVCs across taxonomic groups, with site-level characteristics often determining whether some taxa are more at risk than others.

Table 2: Number of species directly impacted by collisions

TABLE 2: NUMBER OF SPECIES THAT HAVE BEEN DOCUMENTED TO BE DIRECTLY IMPACTED BY COLLISIONS WITH VEHICLES AND ASSOCIATED ROAD INFRASTRUCTURE, SUMMARIZED BY TAXON AND CONSERVATION STATUS PER THE IUCN RED LIST OF THREATENED SPECIES (IUCN, 2020B).

IUCN Red List status	Invertebrate	Amphibian	Reptile	Bird	Mammal	Total
Critically Endangered	-	2	-	2	1	5
Endangered	-	13	1	1	20	35
Vulnerable	-	2	9	3	24	38
Near Threatened	-	7	4	3	8	22
Least Concern	2	41	108	120	95	366
Data deficient	-	1	10	-	-	11
Not evaluated	23	3	108	-	-	134
Total	25	69	240	129	148	611

The risk of AVCs is often specific to the site and the species, but both habitat use and animal behavior play important roles. When roads pass through habitat that is preferred by a given species, roadkill occurrences are higher because local density or habitat use is higher. This pattern is seen in mammals such as leopard cats (*Prionailurus bengalensis*; Kim et al., 2019); amphibians such as Plateau brown frog (*Rana kukunori*; Gu et al., 2011); and reptiles such as Asian water monitor (*Varanus salvator*; Healey et al., 2020). When roads intersect with frequently used movement paths between habitat patches, higher mortalities may result in the intersection zones (Kang et al., 2016). Temporal activity patterns may further increase spatial risks in specific time periods. For example, more amphibians were killed during rainy days (Gu et al., 2011), rainy seasons (Jeganathan, Mudappa, Kumar, et al., 2018), at night (Zhang et al., 2018) and near water (Seo et al., 2015). Migration, dispersal or mating seasons were associated with more occurrence of roadkill of leopard cats(Nakanishi et al., 2010) and Amami woodcocks (Mizuta, 2014), as well as several species of snakes (Lee et al., 2018) and amphibians (Z.-C. Wang et al., 2015). Other life history traits, such as predation behavior, may also influence the likelihood of roadkill: for snakes in South Korea, active hunters were more represented in roadkill than ambush hunters, because they are more likely to encounter roads (Park et al., 2017). Thus, collision risk may be higher in areas and at times where animal activity is higher, with habitat and behavioral characteristics determining such activity patterns.

Physical characteristics of roads may further influence habitat and behavioral risks. Higher traffic volumes are known to increase collision risk for mammals (Piao et al., 2012), birds (Piao et al., 2016), snakes (Pragatheesh & Rajvanshi, 2013), amphibians (Seshadri & Ganesh, 2011) and butterflies (Rao & Girish, 2007). However, roadkill occurrence may not always increase linearly with traffic volume, because animals may not even approach the road when traffic exceeds a certain level (Saeki & Macdonald, 2004). As a result, four-lane highways may have more roadkill than two-lane and six-lane highways (Kim et al., 2019), because they permit more vehicles than the former but repel animals less than the latter. Such threshold-dependent road avoidance may not exist for all taxa; Seshadri & Ganesh (2011) found no such pattern for invertebrates, amphibians, and reptiles. Traffic speed is also linked to higher mortality. For example, Okinawa rails (*Gallirallus okinawae*) died more on straight road stretches where drivers speed up (Kotaka & Sawashi, 2004), and collision risk for small and medium-sized mammals in South Korea was lower on sloped roads where vehicle speed was lower (Kang et al., 2016). Unpaved roads typically have fewer occurrences of roadkill than paved roads because traffic volume and speeds are lower (e.g., Pothwar Plateau of Pakistan; Akrim et al., 2019). Headlights from vehicles at dawn or dusk, or at night are also thought to increase collision risk for several species (Piao et al., 2012; Jeganathan, Mudappa, Kumar, et al., 2018). Thus, the physical characteristics of roads, as well as the attributes of vehicles that run on them, are major influences on AVC risk.

Overall, the literature on direct impacts of roads in Asia is voluminous and documents the prevalence of AVCs across the continent. However, a significant proportion of studies focus only on basic documentation, possibly because such data are not systematically collected by transport or wildlife management agencies in many countries. There is a pressing need to correlate mortalities with habitat, physical, or behavioral characteristics to predict collision risk, and hence develop mitigation measures (Saxena et al., 2019).

E2: INDIRECT EFFECTS OF ROADS

Apart from directly impacting wildlife through collisions, roads may also have several indirect effects at relatively small scales. These include habitat loss and degradation (Bennett, 2017), and catalyzation of human activities, changes in habitat use, and barriers to movement (e.g., Bischof et al., 2017). We found empirical studies involving indirect road effects for 34 species (Table 3; details in Appendix B), all of which were mammals or birds. Indirect effects were studied most in China (16 species from 12 studies) followed by India (10 species from six studies) and Bangladesh (five species from one study).

Table 3: Number of species represented in studies on indirect impacts

TABLE 3: NUMBER OF SPECIES REPRESENTED IN EMPIRICAL STUDIES ON INDIRECT IMPACTS OF ROADS AT SMALL SCALES, CLASSIFIED BY TAXON AND CONSERVATION STATUS ON THE IUCN RED LIST OF THREATENED SPECIES

IUCN Red List status	Bird	Mammal	Total
Endangered	-	6	6
Vulnerable	1	7	8
Near Threatened	1	3	4
Least Concern	7	9	16
Total	9	25	34

Roads lead to the loss as well as degradation of habitat alongside them (known as the road effect zone; Forman et al., 2003). For example, high levels of human activity and land use change along a busy highway in India excluded elephants and gaur (*Bos gaurus*) from the area, despite their wide distribution in the surrounding landscape (Gangadharan et al., 2017). Giant panda (*Ailuropoda melanoleuca*) habitat use was reduced for a distance of 1500m from provincial roads and 5000m from major highways (He et al., 2019). Roads may also facilitate establishment of other types of LI alongside them. In two PAs of Bangladesh, the cumulative impact of new transmission lines aligned along existing roads resulted in loss of canopy contiguity for primates (such as Phayre's leaf monkey (*Trachypithecus phayrei*), capped langur (*Trachypithecus pileatus*), Northern pig-tailed macaques (*Macaca leonine*), and Bengal slow loris *(Nycticebus bengalensis*) and possibly increased both AVCs and electrocutions (Al-Razi et al., 2019). In Southeast Asia, roads have been documented to facilitate access for poachers (e.g., in Malaysia; Hearn et al., 2019). Thus, roads can facilitate degradation and anthropogenic persecution of wildlife at small scales alongside them, and displace animals from the road effect zone.

Despite such displacement, roads and their associated anthropogenic changes may also attract some species. Food is a major attractant; common mynas (*Acriotheres tristis*) were attracted to grain dropped from vehicles in India (Siva & Neelanarayanan, 2020), Siberian chipmunks (*Tamias sibiricus*) to roadside garbage in China (Wang et al., 2013), and Northern Plains gray langur (*Semnopithecus entellus*) to food handouts from passing vehicles in India (Chhangani, 2004a). Asiatic black bears (*Ursus thibetanus*) in Japan selected logging roads due to the abundant secondary growth alongside the roads, despite the higher risk of human encounter (Takahata et al., 2013). Such behavioral changes vary depending on ecological context and nutritional needs; rainforest elephants were attracted to secondary growth along a major Malaysian highway (Yamamoto-Ebina et al., 2016), but elephants in the more open forests of Nepal avoided roads (Sharma et al., 2020). Animals that need to use roads or adjacent areas may modify their behavior to mitigate anthropogenic risks, such as by temporal separation with humans or increased vigilance. Przewalski's gazelles (*Procapra przewalskii)* along a highway in China displaced their peak foraging periods from late afternoon to early morning and late evening to avoid times of high traffic (C. Li et al., 2009). Goral (*Naemorhedus goral)* and tufted deer (*Elaphodus cephalophus)* moved away from a highway during the day but came closer at night (Jia et al., 2015). Tibetan antelope (*Pantholops hodgsoni)* in China spent a large amount of time in vigilance before approaching the Qinghai-Tibet highway (Bao-fa et al., 2007). However, as animals habituate to human disturbance along roads, such vigilance may reduce; Xinjiang ground jays (*Podoces biddulphi)* that occurred near roads allowed closer approach by people (Xu et al., 2013). The ability of animals to take advantage of areas near roads while also mitigating anthropogenic risks may be a key factor in their ability to persist in human-modified areas.

Roads may also impede the free movement of animals; the extent of this impact depends on the interaction between physical attributes of the road, traffic characteristics, life history traits, and human behavior. Elephant movement across a two-lane highway in Malaysia was curtailed by 80 percent due to barriers and ditches alongside the highway (Wadey et al., 2018), and in China by heavy traffic (Huang et al., 2020). Heavy traffic slowed down, but did not prevent crossing by birds like little egrets (*Egretta garzetta)* that were able to simply fly higher while crossing (Stanton & Klick, 2018). Behavioral traits that derive from life history may also influence the willingness of animals to cross roads. In Vietnam, mid-story forest bird species crossed an 8-m-wide paved road more often than understory birds because of higher canopy connectivity at greater heights above the ground (Thinh et al., 2012). In China, Siberian jerboas (*Allactaga sibirica)* that were translocated across highways were more likely to return than great gerbils (*Rhombomys opimus)*; this difference was attributed to the larger size, greater mobility, and better anti-predator responses of the former (Ji et al., 2017). However, there was no such difference between the two species on unpaved country roads (Ji et al., 2017), suggesting that the physical structure of a tarmac road itself may hinder some species. The ability of animals to cross busy roads may also depend on the behavior of people in vehicles; elephants in India abandoned crossing attempts more frequently when people were loud or exited their vehicles to approach them (Vidya & Thuppil, 2010). Although movement across roads may be well within the physical ability of several vertebrate species, it may be curtailed by behavioral constraints on the part of individual animals.

The Asian literature on indirect road effects covers the major impacts of habitat loss and degradation, catalyzing human activities, and behavioral changes including attraction and movement barriers, but it is focused on mammals—particularly large mammals. This is perhaps a reflection of conservation priorities that emphasize umbrella or flagship species, many of which are large mammals. However, the wide variation in these indirect effects suggests that conservation interventions developed for these species may not translate well to other taxa. The one indirect impact where studies on small mammals and birds are concentrated is in movement. This may reflect the relative ease of experimental studies (such as translocation) compared to larger mammals.

E3: POPULATION-LEVEL DIRECT AND INDIRECT EFFECTS OF ROADS

The impact of roads on individual animals—whether direct or indirect—may accumulate at larger scales to influence the viability of populations. Our literature search revealed empirical studies involving population-scale effects for 41 species (

Table 4; details in Appendix C), most of which were mammals. Road impacts at the population scale were studied most in India (11 species from nine studies), Malaysia (10 species from two studies), and China (six species from six studies).

Table 4: Number of species represented in studies on population-scale impacts

TABLE 4: NUMBER OF SPECIES REPRESENTED IN EMPIRICAL STUDIES ON THE IMPACTS OF ROADS AT THE POPULATION SCALE, CLASSIFIED BY TAXON AND CONSERVATION STATUS ON THE IUCN RED LIST OF THREATENED SPECIES

IUCN Red List status	Invertebrate	Amphibian	Reptile	Bird	Mammal	Total
Critically Endangered	-	-	-	-	1	1
Endangered	-	-	-	1	4	5
Vulnerable	-	-	2	-	10	12
Near Threatened	-	-	-	-	1	1
Least Concern	1	1	-	2	15	19
Not evaluated	2	-	-	1	-	3
Total	3	1	2	4	31	41

To understand how the direct impacts of AVCs with individuals scale up at the population level, raw counts need to be converted to population-level estimates of roadkill. One challenge in this exercise (which usually remains unaddressed) arises when carcasses are removed by predators, scavengers, or humans, leaving only a subset available for observation. A rare study of carcass persistence from Indonesia found that carcasses persisted on roads only between 45 and 61 hours for mammals, reptiles, amphibians, and birds (Healey et al., 2020). A similar study from India found rapid disappearance of large mammal carcasses (<12 hours), but relatively longer persistence of large bird and reptile carcasses (>72 hours; Habib, Saxena, Bhanupriya, et al., 2020). Apart from the statistical uncertainties deriving from carcass persistence, it is challenging to extrapolate data from specific locations and times to the entire road network at a large scale (e.g., a state or country). However, when such corrections are made, the resulting numbers are often large. For example, 9,688 annual occurrences of roadkill of vertebrates were estimated in a single PA in Thailand (Silva et al., 2020). At least 60,000 water deer (*Hydropotes inermis*) were estimated to die on the roads of South Korea annually (Choi, 2016), and 110,00–370,00 raccoon dogs (*Nyctereutus procyonoides*) were killed on roads in Japan in one year alone (Saeki & Macdonald, 2004). Yet, the implications of such numbers for population persistence are unclear, because they are rarely placed in the context of total population size for a given species. An alternative indicator of the conservation importance of roadkill can be derived by estimating the proportion of total mortality attributable to AVCs. AVCs comprised 73 percent of all recorded deaths of Okinawa rail between 1998 and 2003 (Kotaka & Sawashi, 2004), making it a serious threat to this species. Other species may be less affected at the population level; 16 percent of mortality in a set of tagged king cobras in Thailand was attributed to roads (Marshall et al., 2018). We found few studies that provided such quantitative information, making it difficult to understand the population-level consequences of direct mortalities on wildlife.

Another key determinant of the impacts of AVCs on population abundance is whether these individuals would have died anyway from other causes (compensatory mortality), or if road mortalities are additional to those causes (additive mortality; e.g., Lebreton, 2005). If roadkill occurrence is selective on categories of individuals that contribute less to future generations, the impact of roadkill on population dynamics may be moderated. Roadkill occurrences are often biased toward males across taxa (e.g., in

Northern Plains gray langur, Chhangani, 2004; wild buffalo *Bubalus arnee*, Heinen & Kandel, 2006; 10 species of snakes, Park et al., 2017; and three species of butterflies, Rao & Girish, 2007). However, Gubbi et al. (2014) found both male and female leopards (*Panthera pardus*) were equally represented, and Vyas & Vasava (2019) found more female than male marsh crocodiles (*Crocodylus palustris*) in a combined dataset of road and rail collisions. Few of these studies correct for the differential availability of males and females in the local population; a rare study that did so found 46 percent higher mortality risk for male rhesus macaques (*Macaca mulatta*; Pragatheesh, 2011). In terms of age class, leopard cat roadkills were dominated by yearlings in Korea (64 percent; Kim et al., 2019) and Japan (70 percent; Nakanishi et al., 2010). Juvenile and sub-adult marsh crocodiles outnumbered adults by a factor of two at a site in India (Vyas & Vasava, 2019). In contrast, adult snakes of 10 species outnumbered juveniles by a factor of 21 in a region in Korea (Park et al., 2017), and adult rhesus macaques were 1.4 times more likely to be represented in roadkill compared to juveniles (Pragatheesh, 2011). The lack of uniformity in these studies, as well as their relatively small number, means that generalizations are difficult to make; however, males may be disproportionately at risk from roadkill occurrences in many species.

The indirect effects of habitat degradation along the road effect zone, as well as heightened human activity, can translate to severe consequence for wildlife populations when aggregated over large areas. In regions such as the Himalayas, the role of roads in opening up "frontier" regions to human use has been flagged as a risk to species such as manul (*Otocolobus manual*; Dhendup et al., 2019) and snow leopard (*Panthera uncia*; Farrington & Tsering, 2020). In Cambodia, the development of a new highway prompted further road development and associated built up areas in a fishbone pattern radiating out from the highway (Clements et al., 2014). Given the challenges of empirically studying distribution over large scales, several studies seek to model and predict the effects of roads on the availability of habitat for animals. For example, Liu et al., (2012) assessed the impact of growing high-speed road networks in a suburban area in China on habitat available for water deer. By identifying patches of suitable habitat that remain unoccupied by a species, the barrier effects of roads that prevent colonization of such patches can also be inferred (e.g., for giant pandas; Zhang et al., 2007). Range-wide risks to habitat from roads can also be modeled (e.g., for tigers; Carter et al., 2020), and species that are most vulnerable to increased road networks can be identified (L. Zhang et al., 2015). The ongoing increase in highway networks across Asia (e.g., the BRI) is likely to greatly increase habitat loss and degradation at large scales across the continent (Hughes, 2019), making such models important for planning.

The displacement or attraction of individual animals with respect to roads can also lead to changes in the distribution of species when aggregated across road networks. In the Bornean rainforest (Malaysia and Indonesia), Sunda clouded leopards (*Neofelis diardi*) were less abundant in areas with high road density (due to avoidance of humans), but sambar (*Rusa unicolor*) abundance increased due to increased forage availability and only limited hunting (Brodie et al., 2015). Tiger distribution was higher further away from major roads in Indonesia (Linkie et al., 2008) and China (T. Wang et al., 2018). In Nepal, Indian and Chinese pangolins (*Manis crassicaudata* and *M. pentadactyla*)—which are subject to high poaching pressure—were distributed at larger distances from highways (Suwal et al., 2020), and amphibian species richness increased with distance from roads (Aryal et al., 2020). Mongolian gazelles (*Procapra gutturosa*) avoided areas with high densities of linear features including roads (Nandintsetseg et al., 2019), and herpetofaunal species richness was lower in areas of high road density in Pakistan (Rais et al., 2015). Changes in the type of habitat alongside roads may change attraction to repulsion. Bonnet macaques (*Macaca radiata)* were abundant along roads when trees were present, but declined by 50 percent between 2003 and 2015 due to urbanization along the verge (Erinjery et al., 2017). Thus, the combined effects of roads and the habitat alongside roads may lead to major changes in the distribution of wildlife populations.

Apart from modeling habitat quality, connectivity at large scales is also modelled within a spatial framework. Connectivity is typically modelled between populations (e.g., tigers in a large region of India, Dutta et al., 2016; giant panda subpopulations in a fragmented region, Qi et al., 2012). More rarely, movement may be modeled at both the small scale (daily movement for foraging) and large scale (dispersal) to yield new insights for management. In one such study, roads impacted long-distance dispersal of black-and-white snub nosed monkeys (*Rhinopithecus bieti)* (~21 percent reduction in modeled movement), but had little impact on daily foraging movement (Clauzel et al., 2015). Although connectivity models are useful for developing hypotheses and predictions, they require better validation with direct observations and telemetry studies. This validation is relatively uncommon in the Asian literature.

The barrier effect of roads on the movement of individual animals may also hinder genetic exchange between populations, leading to lower genetic diversity and consequent impacts on population viability (Balkenhol & Waits, 2009). However, roads are just one among several other natural and anthropogenic impacts that influence gene flow. Population genetics of Chinese wood frogs (*Rana chensinensis)* were influenced mainly by high mountain ridges (Atlas & Fu, 2019), and the genetic structure of nine small mammal species in Malaysia were influenced more by a large river than by roads (Brunke et al., 2019). Anthropogenic land use was the main driver of genetic connectivity for tigers and leopards, although the impact of roads increased with traffic volume (Thatte et al., 2019). Similarly, two panda subpopulations separated by a busy highway had as many as 12 effective migrants per generation in a total population of ~300 (Qiao et al., 2019). However, these apparent low impacts may reflect the relative recency of high-speed and high-volume transportation networks in comparison to North America or Europe. Plateau pikas (*Ochotona curzoniae)* showed indications of genetic divergence a few years after they were separated by a highway (Zhou et al., 2006). After 60 years of separation by a highway, effective migration of Asiatic black bears in a Thailand PA was reduced to one percent, and effective population size was lower than required for long-term viability (Vaeokhaw et al., 2020). The genetic impacts of roads on populations are incipient in many parts of Asia but are likely to grow as roads increase in size and traffic volume.

Indirect road effects may also manifest in indictors of individual fitness, such as body weights and reproductive success. For species that prefer intact forest, such as the Korean field mouse *(Apodemus peninsulae*), individuals that have to live close to roads may have lower body weights than more generalist species such as the striped field mouse (*Apodemus agrarius*), whose body weights were indistinguishable both near and far from roads (Hur et al., 2005). Other species such as white-rumped shamas (*Copsychus malabaricus*) had 21-24 percent higher nesting success near roads, because these areas were avoided by their predators (Angkaew et al., 2019; the effect of lower food availability on the predators is not known). These few studies indicate that roads may have complex effects on fitness, but these effects are rarely investigated in Asia.

Overall, the direct impacts of roads on individual animals are rarely corrected for carcass persistence or extrapolated over space and time, and hence there are few estimates of the total number of animals killed on roads. Further, these counts are not corrected for local population size, making it difficult to understand the implications of roadkill for population viability. The lack of demographic information such as age-sex classes of roadkill, even for large mammals, is a further limitation for inferences. These are key areas that must be addressed for the field to move beyond roadkill documentation to conservation insight. This is a key limitation for prioritization of conservation interventions. The indirect impacts of roads in terms of changes in population distribution and animal movement (particularly for large mammals) are relatively well studied. The impact of movement barriers on population genetics are also increasingly being explored, particularly with the use of non-invasive sampling (e.g., from scat). However, studies on parameters related to fitness, which are critical to understanding population dynamics and undertaking conservation measures, are relatively lacking. Filling in these critical gaps will help prioritize conservation action in the face of burgeoning transportation networks.

MITIGATION OF ROAD EFFECTS ON WILDLIFE

M1: ROAD MITIGATION BY MODIFYING ANIMAL BEHAVIOR

Animal behavior near roads may be influenced in a variety of ways, such as using visual repellents (reviewed by Benten et al., 2018), aversive conditioning (e.g., Kloppers et al., 2005) or habitat management on the verge (e.g., Rea, 2003). We found little documented evidence in the literature for the use of such methods in Asia, although our personal observations indicate that they are quite widespread. The two peer-reviewed studies we found under this subcategory both made suggestions to modify animal behavior based on their study findings. One study suggested a system analogous to diversionary feeding. Because snakes bask on roads due to the warmth of the tarmac in cold weather, Pragatheesh & Rajvanshi (2013) suggested placing artificial surfaces made of thermoregulatory material relatively close to (but not immediately next to) roads as alternative basking locations. Although this suggestion has been echoed in a major policy paper (Wildlife Institute of India, 2016), we have not come across any instance of it being implemented or tested. Gu et al. (2011) suggested removing small patches of wetland around roads that attract amphibians and may therefore serve as ecological traps. Similarly, where wildlife management activities such as creation of waterholes attracts wildlife near roads, such activities can be moved to more interior areas (Rajvanshi & Mathur, 2015). Further exploration of mitigation measures that are based on or informed by animal behavior could throw up new mitigation options in Asia, but this is a field that is poorly documented at the current time.

M2: ROAD MITIGATION BY MODIFYING HUMAN BEHAVIOR

Several methods are used across the world to influence human behavior on roads, and they come under two broad categories: measures to modify traffic characteristics such as traffic volume, and measures to modify the behavior of drivers such as speed limits (e.g., van der Ree et al., 2011). Road closure—either temporary or permanent—is one way to reduce the volume of traffic on roads (and hence, roadkill), and some Asian countries have tried it with varying degrees of success. In Nepal, a highway passing through Bardia National Park originally did not allow night-time traffic; however, when this rule was lifted, the number of roadkill incidents increased sixfold (Rajvanshi & Mathur, 2015). In a tiger reserve in India (where road access as a whole is strictly controlled), relaxation of rules during an annual pilgrimage led to a 14-fold increase in traffic and a 299 percent increase in roadkill occurrences (Seshadri & Ganesh, 2011). One PA in India was able to successfully ban highway traffic at night (apart from emergency vehicles), and fully close down one part of the highway. Gubbi et al. (2012) found 40 percent more animal trails intersected the latter, along with higher encounter rates of chital (*Axis axis*), gaur, and elephant along the verge (although there were no statistically significant differences for sambar, tiger, and leopard). In another PA where night traffic was banned, roadkill rates decreased by a factor of six (Menon et al., 2015). Such examples illustrate the potential benefits of traffic control, but also the challenges in implementing such systems in the face of public pressure. There are few studies outside of South Asia that describe the implementation of such measures or evaluate their efficacy.

Mitigation measures that have been suggested across Asia to change driver behavior include signage, speed limits, better maintenance, and increased driver awareness. Sign boards are commonly used across Asia, but there seems to be little evaluation of their efficacy (e.g., Kong et al., 2013). However, Pragatheesh (2011) noted continued feeding of rhesus macaques from vehicles despite signboards prohibiting this practice. Studies from other parts of the world suggest that temporary signs (particularly for speed reduction) placed at specific locations and times are more likely to be noticed by drivers than permanent signs (Sullivan et al., 2004). Speed limits could reduce roadkill, particularly if they are enforced at specific locations (e.g., based on mortality hotspots; Healey et al., 2020) or times (e.g., during moonlit nights that bring animals to roads; Mizuta, 2014). We have not come across any study that evaluates the impact of posted speed limits on roads. However, one study found lower roadkill when speed breakers (speed humps/speed bumps) were <600m apart than when they were >1 km apart (Menon et al., 2015), possibly because they limited the maximum speeds that drivers could reach. Better maintenance of roads can avoid situations such as snow piling up on sides of roads and blocking large mammals such as red deer (*Cervus elaphus*; Y. Wang et al., 2016). Some studies hint at the potential for awareness messaging to mitigate direct and indirect road impacts. For example, if drivers can be convinced not to feed primates, then primates may be less attracted to roads and may not get killed as often (Chhangani, 2004a). Similarly, if people can be convinced to avoid talking loudly and walking toward elephants that they see on the highway, it is possible that the elephants would be able to cross (Vidya & Thuppil, 2010). Overall, mitigation measures for changing driver behavior are suggested often in the literature, but we found few studies on their implementation or evaluation.

M3: ROAD MITIGATION MEASURES THAT SEPARATE ANIMALS FROM THE ROAD

Physical barriers (such as fences) that are placed along roads can prevent animals from entering, and hence reduce roadkill. The effectiveness of fencing varies depending on how robust it is, the behavior and physical capabilities of target species and how well it is maintained. For example, the ease with which elephants break several types of fences (e.g., Lenin & Sukumar, 2011) means that fences along roads would have to be very robust. Other aspects of fences may also require customization; for example, mesh size may need to be small enough to prevent climbing animals from putting their paws in and climbing (e.g., for raccoon dogs in Japan; Kuramoto et al., 2013). For small animals such as amphibians, the optimal height of fences may also be determined experimentally (Y. Wang et al., 2019). However, physical barriers prevent movement across roads, and therefore they increase the barrier effect of roads. Therefore, fences are often paired with crossing structures that enable animals to safely cross at specific locations. Crossing structures have been built in several countries across Asia, such as Malaysia (Kasmuri et al., 2020), South Korea (Donggul et al., 2018), China (L. Li et al., 2019), Thailand (Silva et al., 2020), and India (Umapathy et al., 2011). Based on our literature search, at least 39 species have been documented to cross roads using these structures (Appendix D).

A key consideration in building crossing structures is to place them at locations that are likely to be used by the target species. On the Kunming-Bangkok Highway in China, crossing structures that were located close to existing movement paths of elephants were used more by them after road construction;

elephants often tried to enter highways at locations where crossing structures had not been built near their existing corridors (Pan et al., 2009). One way to identify optimal locations for crossing structures is through sightings of animals (alive or dead) and their signs along the road. Sign-based surveys for a set of desert ungulates enabled identification of locations for crossing structures (B. Zhang et al., 2019). Similarly, identification of roadkill hotspots resulted in the construction of four crossing structures for mammals, reptiles, and amphibians in South Korea (Seo et al., 2015). A second way is to model movement in a geographic information system (GIS), using habitat use or habitat selection maps; for example, Gangadharan et al., (2017) used such models to identify locations where corridors across a highway could be restored for elephant and gaur. Similar approaches were used to model locations where crossing structures could be placed for Przewalski's gazelle in China (C. Li et al., 2013). A more direct method of identifying crossing locations is through observations of animal movement, which can include both direct sightings and telemetry studies; however, we found few such studies. It is possible that such studies occur at a local scale and not documented in a manner that reaches larger audiences.

Apart from location, the structure and design of crossing structures may also influence the likelihood of their use by the target species. Broadly, crossing structures may consist of those where animals cross above the vehicles (e.g., overpasses, canopy bridges and tunnels for vehicles) or below the vehicles (e.g., underpasses, bridges, flyovers, viaducts, tunnels for animals, and culverts). Different species may have different preferences for the type of structures they cross. Along the Beijing-Xinjiang expressway, for example, five mammal species (Wildcat *Felis sylvetris*, manul, red fox, Tolai hare *Lepus tolai*, and hog badger *Arctonis collaris*) and 14 bird species (including black-billed blue magpie *Pica pica*, and chukar *Alectoris chukar*) crossed under both large bridges and small culverts; however, the bridges were used more frequently by all mammals (L. Li et al., 2019). Artificial canopy bridges can be used to enable arboreal species to cross roads without descending to the ground. Such bridges are used regularly, for example, by lion-tailed macaques (*Macaca silenus*) to move between rainforest fragments (Jeganathan, Mudappa, Raman, et al., 2018). The specific design characteristics of crossing structures are also important, including dimension, shape, substrate, and vegetation in the immediate surroundings. Such designs can be tested experimentally for smaller vertebrates; for example, Chinese brown frogs (*Rana chenisensis*) preferred to use tunnels that were more than 1m in diameter and with soil substrate within (Y. Wang et al., 2019). More rarely, experimental evaluation of infrastructure alongside roads (such as drainage ditches) may also be carried out to improve their designs. Such experiments can determine, for example, the best angles to avoid amphibian entrapment in drainage ditches (45 degrees for Chinese brown frog; Wang et al., 2019), or quantify the importance of vegetation growth within ditches to enable common toads (*Bufo melanostictus*) to escape (Z. Zhang et al., 2010). However, experimental specification of design characteristics for larger species may not be possible, but instead require a combination of natural history knowledge and insights from similar taxa in other parts of the world.

Although it is possible to develop design specifications for different species, implementation of these designs on the ground is a complex task. Out of 415 crossing structures built in South Korea between 1998 and 2014, less than 72 percent of them complied fully with all the mandated design guidelines (Donggul et al., 2018). However, the implications for such design flaws are not necessarily predictable for wildlife. In China, elephants did not use 10 underpasses that were designed for them; yet, they crossed under a bridge that was built purely for engineering purposes (Pan et al., 2009). In Japan, an overpass that was designed for use by humans was also used by four of seven wild mammal species (raccoons *Procyon lotor*, red foxes, raccoon dogs, and sika deer) with the same frequency as the wildlife overpasses—although species such as sable (*Martes zibellina)* and least weasel (*Martes nivalis)* used only the wildlife overpass (Asari et al., 2020). Along the Qinghai-Tibet highway, 11 species of mammals including Eurasian red squirrels (*Sciurus vulgaris)*, yellow throated martens (*Martes flavigula)*, and sables used structures (a tunnel for vehicles, bridges and culverts) that were not specifically built for wildlife use (Y. Wang et al., 2017). In a PA in India, at least eight species including dholes (*Cuon alpinus)* and sloth bears (*Melursus ursinus*) were observed using underpasses that were built for engineering purposes (Menon et al., 2015). The use of such structures by wildlife suggests that it may be possible to repurpose structures that would be built anyway for the purposes of wildlife crossing, at least for generalist species.

CONCLUSION: ROADS

The literature describing studies on the ecological consequences of roads and traffic in Asia is large and varied, incorporating information from 22 countries in the region. The literature is strongly oriented toward direct impacts, including identifying the species that are killed in collisions with vehicles on roads and the variables that correlate with these roadkill occurrences. A significant amount of literature also focuses on the impacts of roads on wildlife movement; these often use models rather than analyze empirical data from telemetry or camera studies. There is also an increasing focus on quantifying the genetic impacts of isolation by roads. Overall, the implications of road infrastructure and associated traffic on population viability is still in its early stages compared to regions such as North America.

Solutions to reduce the impacts of roads on wildlife, or mitigation measures that focus on changing human and animal behavior may be widespread in practice but are not well documented in the literature in terms of their description or efficacy. Studies on mitigation measures that separate animals from the road and vehicles are more prevalent than the above mitigation measures. Most often these are crossing structures that allow animals safe passage over or under the road, while also providing habitat connectivity. Several authors suggest that there may be opportunities to adapt or modify non-specialized structures such as existing bridges and culverts to serve the purpose of wildlife crossing.

RESULTS BY MODE: RAILWAYS

EFFECTS OF RAILWAYS ON WILDLIFE

E1: DIRECT EFFECTS OF RAILWAYS

Trains may collide with wildlife, resulting in injury or mortality; train strikes have been documented for at least 20 species (Table 5; Appendix E), including 13 mammals, one bird, and six reptiles. India was the most-represented country (17 species from 20 studies), followed by one species each from Japan, Sri Lanka, and Mongolia. Train strikes have been documented for terrestrial mammals such as elephants (Dasgupta & Ghosh, 2015), tigers (Warrier, 2018), and Mongolian gazelles (Ito et al., 2008), as well as arboreal mammals such as capped langurs (*Trachypithecus pileatus*; Raman, 2011). Reptiles such as marsh crocodiles (Vyas, 2014), saltwater crocodiles (*Crocodylus porosus*; Amarasinghe et al., 2015), and at least four species of snakes (Raman, 2011; Sivaraj et al., 2018; Kumar & Prasad, 2020) are also known to be killed by trains. Literature from other parts of the world confirm that several species of birds collide with high-speed trains (García de la Morena et al., 2017), but such studies are relatively rare in Asia. However, the Critically Endangered red-headed vulture (*Sarcogyps calvus*) has been documented as a train casualty in India (Khatri et al., 2020). Infrastructure in the immediate vicinity of railway tracks may also cause wildlife mortality; for example, ungulates such as Mongolian gazelles may get entangled in fences along railway tracks and be unable to escape (Ito et al., 2008). Similarly, overhead power lines and poles along railway tracks may also kill birds (Carvalho et al., 2017)—although this is not well studied in Asia.

Table 5: Number of species impacted by collisions with trains

TABLE 5: SPECIES THAT ARE DIRECTLY IMPACTED BY COLLISIONS WITH TRAINS AND ASSOCIATED INFRASTRUCTURE, SUMMARIZED BY CONSERVATION STATUS PER THE IUCN RED LIST OF THREATENED SPECIES (IUCN, 2020B).

IUCN Red List status	Number of species
Critically Endangered	1
Endangered	3
Vulnerable	6
Near Threatened	2
Least Concern	5
Not assessed	3
Total	20

It is likely that collisions with trains impact numerous other species in Asia, although taxonomic bias toward larger charismatic species and lower detectability of smaller species may lead to under-reporting like in other parts of the world (Santos et al., 2017). For example, a study on elephant mortality on railway tracks in one PA in India (Singh et al., 2001) also mentioned—in just a few sentences—instances of leopard, chital, sambar, wild boar (*Sus scrofa*), Himalayan goral (*Nemorhaedus goral*) and Indian rock python (*Python molurus*) being killed by trains at the same site. Notably, these data were collected as a matter of routine by the local wildlife management authority and accessed incidentally by the researchers. Integrating existing field data on less charismatic species into larger databases could support the establishment of baseline information and assist in conservation planning to address direct mortality from railways.

Train strikes may be higher at locations and times where the use of railway tracks by animals is higher, which in turn is determined by habitat characteristics, seasonal changes, and animal behavior. In Japan, mortalities of sika deer were higher along tracks that passed through forest patches, because their densities were higher in these patches (Soga et al., 2015). Daily movements across tracks to access feeding grounds increased collision risk, particularly during winters when sunrise was later (Ando, 2003). Similarly, the risk of elephants being hit by trains was higher when they crossed railway tracks to feed on crops during the harvest season (Roy & Sukumar, 2017). Physical characteristics of the railway tracks may also influence mortality risk. Elephant deaths at one site in India were higher along curved sections of the track, particularly when these areas did not provide for easy escape due to high embankments (Sarma et al., 2008). Elephant deaths at another site in India increased by more than three times after the tracks were converted from standard to broad gauge (which enabled more trains running at faster speeds; Roy et al., 2009). Factors such as track curvature and train speed contribute to train strikes in other countries as well (e.g., Canada; St. Clair et al., 2020). Finally, defensive behavior by animals (maladaptive in anthropogenic landscapes) may increase risk for some species. For example, Joshi & Puri (2019) hypothesized that elephants may attempt to defend their calves from approaching trains, and hence themselves become victims. Overall, the literature on direct impacts is limited in the number of species it covers but offers several important avenues for further investigation.

E2: INDIRECT EFFECTS OF RAILWAYS

Apart from the direct impact of collisions, railways may also indirectly affect individual animals via habitat changes in the surrounding area and impacts on movement. We found empirical studies involving indirect railway effects at small scales for eight species (Table 6; details in Appendix F), of which five were mammals and three were birds. Indirect effects were studied most in China (four species from three studies), followed by Mongolia (two species from two studies), and Japan and India (one species each).

Table 6: Number of species represented in studies on indirect impacts of railways

TABLE 6: NUMBER OF SPECIES REPRESENTED IN EMPIRICAL STUDIES ON INDIRECT IMPACTS OF RAILWAYS AT SMALL SCALES, CLASSIFIED BY STATUS ON THE IUCN RED LIST OF THREATENED SPECIES

IUCN Red List status	Number of species
Endangered	1
Near Threatened	2
Least Concern	5
Total	8

Habitat changes along railways (analogous to the road effect zone) may degrade habitat quality for some species; however, for the rufous-necked snowfinch (*Pyrgilauda ruficollis)*, habitat use was higher near the

Qinghai-Tibet railway and highway zone compared to further away (Z. Li et al., 2010). Such changes in distribution may be the result of attraction to food resources along the railway; for example, elephants may be attracted by feral domesticated plants growing along railway tracks (Roy & Sukumar, 2017). Mongolian gazelles may also be attracted to cross barbed wire fences along railway tracks to access the ungrazed forage available within the right of way (Ito et al., 2013). Carnivores and scavengers may also frequent railway tracks for feeding opportunities arising from the carcasses of train-killed animals (Waller, 2017), although we did not find such documentation in Asia. For some species, frequent use of such anthropogenic areas to access resources may lead to higher habituation (e.g., for three species of snowfinches, *Montifringilla spp*.; Ge et al., 2011), but the consequences of this habituation are unclear. Some species may learn to cross railway tracks at locations that are safer, as suggested for sika deer by Soga et al. (2015). Other species may not habituate easily to traffic, but instead spend significant amounts of time in vigilance when they are near railway tracks (Buho et al., 2011). Railway tracks that are fenced are also known to represent significant movement barriers to Mongolian gazelles (Ito et al., 2013) and Asiatic wild asses (*Equus hemionus*; Kaczensky et al., 2011). Overall, the indirect impacts of railways at small scales appear to be broadly similar to those of roads.

E3: POPULATION-LEVEL DIRECT AND INDIRECT IMPACTS OF RAILWAYS

Direct and indirect railway effects at small scales may aggregate to population-level consequences. Our literature search revealed empirical studies involving population-scale effects for nine species (Table 7; details in Appendix G), including seven mammals and two reptiles. Rail impacts at the population scale were studied most in India (two species from five studies), China (three species from three studies), Mongolia (two species from three studies), and Japan (two species from two studies).

Table 7: Number of species represented in studies on population-scale impacts of railways

TABLE 7: *NUMBER OF SPECIES REPRESENTED IN EMPIRICAL STUDIES ON THE IMPACTS OF RAILWAYS AT THE POPULATION SCALE, CLASSIFIED BY STATUS ON THE IUCN RED LIST OF THREATENED SPECIES*

IUCN Red List status	Number of species
Endangered	2
Vulnerable	1
Near Threatened	2
Least Concern	4
Total	9

Few studies explore the consequences of direct railway impacts on population viability—which in turn is determined by both the number of mortalities in relation to local population size, and the age-sex classes that contribute most to the mortalities. In India, around 310 elephants are known to have been killed by trains over a 32-year period from 1987 to 2019 (Menon & Tiwari, 2019); the total elephant population size in India in 2018 was estimated to be around 30,000 (Williams et al., 2019). However, mortality appears to be concentrated in a few sites, such as North Bengal (89 deaths over a 41-year period (Roy & Sukumar, 2017), with an elephant population size of 674 in 2015). Train strikes comprised 70 percent of all anthropogenic deaths of elephants in one national park in India (Williams et al., 2001), indicating that such strikes could be a major driver of population persistence at least in some areas. In terms of age-sex classes, female marsh crocodiles were slightly more prevalent than males, and juveniles and sub-adults comprised two-thirds of a combined set of road and rail-killed animals (Vyas & Vasava, 2019). Adult female elephants comprise around half of train strikes at two sites in India (Palei et al., 2013; Joshi & Puri, 2019), but such estimates are not corrected for the sex ratio (or age-class distribution) in the larger population. In a rare study that accounted for this factor, adult male elephants were represented 2.5 times more often in train collisions relative to their population size (Roy & Sukumar, 2017). This is worrying since males are also targeted for ivory and retaliatory killing (e.g., Williams et al., 2019); such insights can help prioritize conservation interventions. The general lack of population-level insight in most studies is a drawback in developing targeted conservation plans for mitigating railway impacts in Asia.

In terms of large-scale indirect effects, railways catalyze greater human use and impact the distribution of species. Aung et al. (2004) use historical research to link decades of deforestation, agricultural expansion, and hunting to the construction of the Yangon-Myitkyina railroad in Myanmar in the late 1800s. More recently, the Ulaanbaatar-Beijing railway in Mongolia is thought to have restricted access to 17,000 km^2 of habitat for Asiatic wild asses (Kaczensky et al., 2011), and may prevent recolonization. Mongolian gazelles may also avoid areas with high densities of linear features (including railways), thereby reducing the amount of habitat available for them (Nandintsetseg et al., 2019). The ready availability of spatial data has now prompted a set of modeling studies to predict such large-scale impacts before they occur. The core approach involves intersecting biodiversity-rich areas (e.g., Key Biodiversity Areas; IUCN, 2016) with planned infrastructure routes to identify the amount of habitat that may be degraded, fragmented, or lost at national and regional scales (Alamgir et al., 2019; Hughes, 2019). Large-scale modeling studies are useful in understanding potential impacts of railways on species habitat, but they are usually unable to separate the effects of railways from other LI, such as roads, that run in parallel (e.g., Sulistyawan et al., 2017). Therefore, they could be applied in combination with hypothesis-driven studies at small scales to develop conservation interventions at multiple scales.

The barrier effects of railways to individual animal movement can impact survival as well as population-level connectivity. If railway tracks are impermeable, direct mortality may be low, but a population may be unable to access suitable habitat on the other side. Mongolian gazelles, which must migrate in response to drought, were severely impeded in their movement by fences—which are also used along railways to exclude animals (Olson et al., 2009). This can potentially lead to mass mortalities in regions with severe and variable weather conditions (Ito et al., 2018). Even where railway tracks are permeable, animals may spend large amounts of time in vigilance before they cross (e.g., Tibetan antelopes; Buho et al., 2011; Xu et al., 2019), with unknown consequences for fitness. Modeling studies can help anticipate the impacts of such barriers on connectivity. Such studies may be carried out on individual focal species such as tigers (Rathore et al., 2012; Dutta et al., 2018) and Sunda clouded leopards (Kaszta et al., 2019), or a set of focal large mammals (Jayadevan et al., 2020). Such studies provide broad indices of connectivity at the population level, but not necessarily data on individual animal crossings—with which they must be combined for multi-scale conservation insights.

Restricted connectivity between populations may lead to genetic differentiation and consequent deleterious effects, although this typically takes place over several generations. Further, even a few migrants that cross and breed per generation can ensure adequate gene flow (Mills & Allendorf, 1996). Consequently, studies in Asia on the genetic consequences of isolation by railways are mixed. The severe movement barrier imposed by the fenced Ulaanbaatar-Beijing railway was not reflected in genetic differentiation of Mongolian gazelles on either side (Okada et al., 2012), which may also be due to their large population size (500,000-1.5 million; IUCN SSC Antelope Specialist Group, 2016). However, populations of the Endangered Przewalski's gazelle (*Procapra przewalskii)*, with ~ 5000 individuals in total (IUCN SSC Antelope Specialist Group, 2016), showed distinct genetic structure within just five generations (~10 years) of a section of the Qinghai-Tibet railway being fenced (Yu et al., 2017). Toad-headed lizards (*Phrynocephalus vlangalii)* on either side of the Qinghai-Tibet railway in China formed a continuous population without genetic differentiation, because the railway tracks themselves provided habitat for them (D. Hu et al., 2012). Genetic differentiation may be more pronounced in landscapes with a wide range of anthropogenic barriers that may reinforce each other over long periods of time. For example, wild boars in a multiple-use landscape of Japan showed strong sub-population structure that was consistent with the railways that pass through the site, but was also likely reinforced by the associated development alongside (Tadano et al., 2016). Similarly, even the generalist red fox showed the impacts of lower gene flow among populations separated by railways (Kato et al., 2017). As railway networks continue to expand in Asia, the barrier effects of railways may increasingly manifest themselves in low gene flow among populations.

MITIGATION OF RAILWAY IMPACTS ON WILDLIFE

M1: RAILWAY MITIGATION BY MODIFYING ANIMAL BEHAVIOR

Mitigation measures that modify animal behavior are generally oriented toward modifying habitat to reduce attraction, increase visibility, or create escape routes. Food and water are strong attractants; elephants that had much of their home ranges on one side of the New Delhi-Dehradun railway in India crossed the tracks to access water on the other side (Singh et al., 2001). Following several mitigation measures that included the rejuvenation of waterholes within their home ranges and removal of garbage along the tracks, elephant-train collisions were greatly reduced (WTI, 2016). Because elephants may find it difficult to move off tracks when the embankments are steep, making these slopes more gentle could provide them easier escape (Menon et al., 2015). Further, clearing vegetation along curves can improve visibility and provide extra time for animals to move off tracks (Sarma et al., 2008). However, the efficacy of such mitigation measures is rarely tested in a rigorous manner, making it difficult to assess and replicate elsewhere.

Several technological interventions have been developed and tested recently in other parts of the world to mitigate wildlife-train collisions. These interventions seek to anticipate potential collision incidents at specific locations and times, and avoid them by modifying animal behavior, driver behavior, or both (Figure 5). These technological interventions are typically set up at known or potential collision hotspots (i.e., they are location based), although they may also be attached to trains themselves (vehicle based). Systems that seek to modify animal behavior require a module that reliably detects approaching trains. Trains may be detected by a variety of means, such as sensors that monitor vibrations on the tracks (Backs et al., 2017), or simply feeds from existing automated track management systems (NEEL, 2021). Once the train is detected, on-site responses (e.g., lights and sirens) are set off to either alert the animal to the approaching train or actively repel it from the tracks. These automated responses are then shut off after the train has passed.

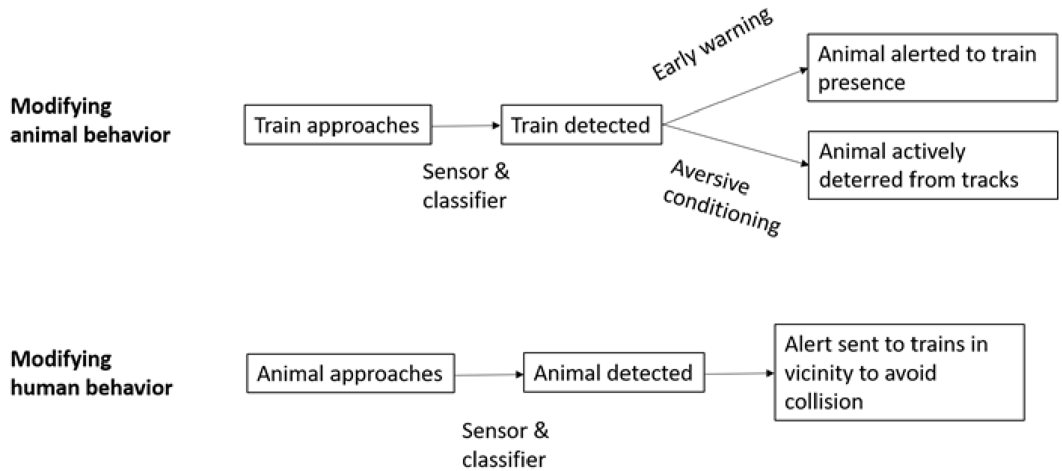

Figure 5. Conceptual mechanism underlying technology-based mitigation of wildlife-train collisions.

M2: RAILWAY MITIGATION BY MODIFYING HUMAN BEHAVIOR

Efforts to influence animal behavior may also be accompanied by efforts to change human behavior via rules, awareness, and early warning. Such changes may be easier to implement for railways than highways, because fewer trains run on a given track than vehicles on a comparable road (Barrientos et al., 2019). These trains are also driven by a limited number of professionals whose behavior can be modified via rules. Further, wildlife-train collisions tend to be concentrated in space and time; for example, elephant collisions may peak during harvest season (Roy & Sukumar, 2017) and along sharp curves (Joshi & Puri, 2019), and most sika deer collisions occur during winters and evenings (Ando, 2003). Therefore, the behavior of train conductors may only need to be modified at these locations and during these specific times. A combined approach of addressing both animal and human behavior change is particularly prevalent in India to mitigate elephant mortality. Measures to change human behavior include reducing speed limits in areas with high risk of collisions, increasing general awareness among conductors, posting lighted signage along known crossing points, and even using regular foot patrols along tracks to detect any elephants nearby and warn train conductors of their presence (Ministry of Environment & Forest, 2015; Panda et al., 2020). Such measures have been credited with reducing elephant-train collisions in some areas (WTI, 2016), but are rarely quantified in a robust manner (similar to the rest of the world; Carvalho et al., 2017).

Sustaining changes in human behavior also requires a high level of effort and commitment. For example, performance pressures may lead to conductors breaking speed limits (Dasgupta & Ghosh, 2015), and daily foot patrols along railway tracks may be time-intensive and dangerous. In such circumstances, automated systems can be used to alert train conductors when animals are detected on tracks (Figure 5). Such systems require a module that can reliably detect animal presence on tracks, which can be done using image-based sensors (i.e., cameras), seismic sensors, and active or passive infrared sensors. The input from these sensors is then processed through software that determines whether an animal is present (for example, a deep learning model that classifies the species in a photograph; IUCN, 2020a). A positive classification can then trigger an alert to conductors of trains in the vicinity to modify their behavior accordingly (e.g., slow down in time). Overall, efforts to modify human behavior may be most effective when they are implemented for charismatic flagship species for which strong conservation support can be leveraged. They may also be most effective in places where mortality or crossing hotspots are relatively constant and well-defined over space.

M3: RAILWAY MITIGATION MEASURES THAT SEPARATE ANIMALS FROM RAILWAY

The direct impacts of train strikes can be mitigated by separating animals from railway tracks through impermeable physical barriers such as fences, but at the cost of increased indirect impacts (e.g., Kaczensky et al., 2011; Nandintsetseg et al., 2019). Further, trade-offs between species or taxa must also be considered. For example, fencing may be erected when railways pass through the habitat of Endangered waterbirds; the fence forces them to fly higher when they cross the tracks, and hence avoid risk of collisions (H. Hu et al., 2020). However, the same fence may severely disrupt the movement of terrestrial mammals in the same area. The indirect impacts of fencing along railways may be mitigated by building crossing structures that allow safe passage of animals at dedicated crossing points. Our search found at least 14 species (all mammals, all in China and India) that have been documented to use such crossing structures to cross railway tracks (Appendix H). A particularly notable example is a metal bridge constructed to allow Western hoolock gibbon (*Hoolock hoolock)* to cross a railway track in India without descending to the ground (Wildlife Institute of India, 2016)—although it is unclear if this was actually used by them (N. Mitra, 2019).

Two key determinants of the effectiveness of crossing structures are location and design. Where such structures are located relatively close to existing wildlife movement routes, such as for Tibetan antelopes on the Qinghai-Tibet railway, they may allow for unhindered and regular passage to numerous individuals (Xia et al., 2007). Where such routes are not known, spatial models can help in identifying potential locations (Zhuge et al., 2015). However, when crossing structures are not located optimally, animals may have to deviate from their preferred routes. For example, Tibetan antelope are thought to have increased their migration distance by 86 km to access a crossing structure; this added expenditure of energy may impact their survival, particularly when they are with young (W. Xu et al., 2019). Further, if the crossing structures are subject to a high level of noise—such as from adjoining highways—they may see less usage by animals (Yin et al., 2006). Such findings emphasize the importance of using fine-scale habitat use or movement data to determine the placement of crossing structures.

However, in some cases, wildlife may use structures such as bridges, culverts, and overpasses that were designed for other purposes (such as for people, livestock, or for engineering reasons). The ability and willingness to do so varies with species, and with habituation. Elephants have been documented to cross under bridges built for trains (Menon et al., 2015). On the Qinghai-Tibet railway, Yin et al., (2006b) found that most culverts and bridges (built to maintain the grade necessary for trains) were not used by large mammals for crossing. Seven years later, however, Wang et al. (2018) documented 13 mammal species using several of these culverts and bridges, with larger ungulates (e.g., wild yak, *Bos mutus*; kiang, *Equus kiang*; Tibetan antelope, and Tibetan gazelle, *Procapra picticaudata*) preferring to cross under bridges and small carnivores (e.g., mountain weasel, *Mustela altaica* and Asian badger, *Mustela leucurus*) through culverts. However, rapid genetic differentiation in Przewalksi's gazelles on either side of the same railway suggest that they may not be using these same structures for crossing (Yu et al., 2017). Similarly, crossing structures built specifically for human and livestock passage were typically avoided by Mongolian gazelles (Ito et al., 2013) and by Asiatic wild asses (Kaczensky et al., 2011) in Mongolia, resulting in these species being unable to safely cross the railway. Customizing the location and design of crossing structures for specific target species is a relatively new field in Asia, and one that will require further collaboration between conservationists and engineers. One such example is currently being implemented in Bangladesh, where the design and location of crossing structures across a new railway are being customized based on field data on elephant movement (Bangladesh Railway, 2018).

CONCLUSION: RAILWAYS

The study of railway impacts on wildlife lags behind the study of road impacts across the world, and Asia is no exception to this pattern. We found less than one-third the number of railway ecology studies compared to roads. However, we were able to identify certain broad themes in this literature. Direct impacts were mainly focused on large, charismatic animals such as elephants; indirect impacts at small spatial scales included ungulates and birds. Similar to the road ecology literature, direct and indirect impacts on wildlife at the population scale were not well studied, making it difficult to make strong conservation statements on the impacts of railways on population persistence. Unlike roads, mitigation measures that involved changes to human and animal behavior were better documented (albeit mainly for elephants), providing some indications of the challenges in deploying these strategies. The use of crossing structures also appears to be increasingly well documented, particularly for mammals.

RESULTS BY MODE: POWER LINES

EFFECTS OF POWER LINES ON WILDLIFE

E1: DIRECT EFFECTS OF POWER LINES

Power lines directly impact wildlife through electrocution and collisions, resulting in mortalities or injuries. Mortalities due to power lines have been recorded for at least 113 species (Table 8), including 92 birds, 20 mammals, and one reptile.

Table 8: Number of species impacted by power lines

TABLE 8: SPECIES THAT ARE DIRECTLY IMPACTED BY ELECTROCUTIONS AND COLLISIONS WITH POWER LINES, SUMMARIZED BY CONSERVATION STATUS PER THE IUCN RED LIST OF THREATENED SPECIES (IUCN, 2020B)

IUCN Red List Status	Bird	Mammal	Reptile	Total
Critically Endangered	2	2	-	4
Endangered	5	9	-	14
Vulnerable	7	4	-	11
Near Threatened	7	-	-	7
Least Concern	71	5	1	76
Total	92	20	1	113

Avian electrocution fatalities have been reported for 92 species in six countries: Bhutan, Kazakhstan, China, India, Sri Lanka, and Mongolia. Raptors are particularly prone to electrocutions and comprise the largest proportion of bird electrocutions, ranging from 44 percent in Kazakhstan (Lasch et al., 2010) to 60 percent in Mongolia (Amartuvshin & Gombobaatar, 2012). Twenty percent (11 species) of raptors are threatened by electrocution in western China (Mei et al., 2008). Electrocution fatalities of species such as the Saker falcon (*Falco cherrug*), greater spotted eagle (*Aquila clanga*), and Steppe eagle (*Aquila nipalensis*) have been reported from multiple countries, indicating that this threat is widespread across much of their known range. Raptor fatalities in Mongolia were exclusively due to electrocutions on poles, and falcons alone accounted for more than half of the raptor mortalities (Lasch et al., 2010).

Electrocution fatalities vary over space and time, showing seasonal differences and are dependent on surrounding habitat (Lasch et al 2010). For example, raptor prey abundance contributed to spatial variation in electrocution rates (Dixon et al., 2017). Moreover, the combination of areas with high small mammal densities and 15kV power lines resulted in Saker falcon electrocution "hotspots" (Dixon, 2016). Power line voltage also played a significant role in explaining electrocution fatalities in Mongolia, with the 15kV power lines accounting for more than 80 percent of all electrocution fatalities (Amartuvshin & Gombobaatar, 2012). However, power pole configuration was the most important determinant of electrocutions in India (Harness et al., 2013).

Nesting, roosting, and perching behavior predispose certain species to electrocution. For example, Saker falcon behavior of nesting on power lines increases risk of electrocution (Ellis, 2010). Upland buzzards (*Buteo hemilasius*) nest on the top of power poles and crossarms, while Saker falcons and lesser kestrels (*Falco naumanni*) roost and perch on the pole and crossarm (Amartuvshin & Gombobaatar, 2012). Dead birds below power lines attract avian scavengers such as crows and ravens, resulting in their mortality (Lasch et al., 2010). Not surprisingly, more than one-third of power line electrocution fatalities are corvid species—37 percent and 34 percent in India and Mongolia respectively (Amartuvshin & Gombobaatar, 2012; Harness et al., 2013).

Bird collisions with power lines also result in fatalities (Burnside et al., 2018; Takase et al., 2020; Tere & Parasharya, 2011) and injuries (Cheng et al., 2019; F. Li et al., 2011). Avian fatalities due to power line collisions have been documented for 35 species in Uzbekistan, Japan, China, India, and Mongolia. Of the 35 species, 29 percent are threatened as per the IUCN Red List of Threatened Species. Waterbirds, waders, Columbids (pigeons, doves, and sandgrouse), and Passerines (hoopoes, woodpeckers, and others) were common collision fatalities (Lasch et al., 2010). The number of fatalities varies seasonally; for example, 80 percent of Asian houbara (*Chlamydotis macqueenii*) collision fatalities occurred in winter (Burnside et al., 2018). Migratory birds routinely perish or are injured due to power lines (Dixon et al., 2013). Seasonal migrants such as the bar-headed geese (*Anser indicus*) have collided with power lines located in the Central Asian flyway (Li et al., 2011). Similarly, power-line-related fatalities and injuries have been reported in China for Endangered red-crowned cranes (*Grus japonensis*) that migrate along the East Asia/Australasia (Cheng et al., 2019; Luo et al., 2014; Su & Zou, 2012).

Power lines that pass through or in the vicinity of areas used intensively by birds, such as breeding habitats (Sundar & Choudhury, 2005), feeding grounds (Tere & Parasharya, 2011), and natural habitat (Kurhade, 2017) pose the highest risk for collision fatalities. Collision fatalities differ significantly based on power line voltage. For example, a long-term study in Mongolia found that ~90 percent of all avian collision fatalities occurred on just two power lines: ~50 percent and ~40 percent on the 110kV and 15kV power lines respectively (Amartuvshin & Gombobaatar, 2012). In contrast, a short-term study in Uzbekistan found that Asian houbaras were equally likely to collide with both high and low voltage lines (Burnside et al., 2018). Even in the same location, closely related species are likely to collide with different kinds of power lines: greater flamingoes (*Phoeniconaias roseus*) were more likely to collide with transmission lines, whereas lesser flamingoes (*Phoeniconaias minor*) were more likely to collide with distribution lines (Tere & Parasharya, 2011). Most collision fatalities in Mongolia were detected mid-span (Amartuvshin & Gombobaatar, 2012), which also indicates the focal area that must be targeted for mitigation measures.

Electrocutions on power lines also cause fatalities and injuries in mammals (Molur et al., 2007), with primates at high risk. For example, electrocution is a major threat to golden langurs in Bhutan and the Northern Plains gray langur in India (Ma et al., 2015; Thinley et al., 2020). Fatalities of 14 threatened primate species have been recorded due to power line electrocutions in Asia, including two Critically Endangered, eight Endangered, and four Vulnerable species. In the case of three species—golden langur, Bengal slow loris, and capped langur—power line fatalities have been reported from multiple countries across their distributional range. Primate electrocutions occur when primates use power lines to cross canopy gaps over roads or climb power line poles for safety—to escape from humans, predators such as dogs, and conspecific aggression (Al-Razi et al., 2019; Dittus, 2020). Primate fatalities vary depending on power line voltage; for example, 71 percent of rhesus macaque electrocution injuries were due to low voltage power lines (Kumar & Kumar, 2015). Power line electrocutions also cause fatalities in many species of bats, such as the Indian flying fox (*Pteropus giganteus*), greater short-nosed fruit bat (*Cynopterus sphinx*), Ratanaworabhan's fruit bat (*Megaerops niphanae*), and the Ryukyu flying fox (*Pteropus dasymallus*) (Vincenot et al., 2015). Indian flying fox electrocutions occur due to the close proximity of power lines to fruiting trees in India (Molur et al., 2007; Rajeshkumar et al., 2013; Senacha, 2009), whereas in Sri Lanka, fatalities were highest on power lines where wires were oriented vertically (Tella et al., 2020). Large, charismatic species such as the Asian elephant are also electrocuted due to low-hanging power lines in Sri Lanka and India (Wijeyamohan et al., 2006; Palei et al., 2014).

E2: INDIRECT EFFECTS OF POWER LINES

Power lines can have significant indirect impacts on taxa from habitat loss, fragmentation, and modification. The clearance of vegetation below power lines for right-of-way requirements results in loss and fragmentation of natural habitat. For example, Indochinese gray langur (*Trachypithecus crepusculus*) habitat in China was lost due to a high-voltage power line (Ma et al., 2015), and prime habitat of the Endangered red panda (*Ailurus fulgens*) was fragmented in Bhutan due to power lines (Dendup et al., 2020). In India, 8,171 hectares of forest land were diverted for power lines over a 32-year period.

E3: POPULATION-LEVEL DIRECT AND INDIRECT IMPACTS OF POWER LINES

Very few studies examined the direct and indirect impacts of power lines on populations. Additionally, raw mortality counts need to be corrected for scavenger and crippling bias, which if not accounted for could potentially lead to an underestimate of mortality. One study in India found that probability of carcass persistence decreased over time and depended on body mass, large bird carcasses were more likely to persist than smaller bird carcasses (Uddin, 2017). A multi-year assessment in India estimated that power line collisions kill nearly one percent of the annual local sarus crane (*Grus antigone*) population (Sundar & Choudhury, 2005). Juvenile, non-breeding, and dispersing sarus cranes were found to be at a higher risk of collision than adult and resident birds, who are perhaps more experienced fliers and familiar with the local habitat (Sundar & Choudhury, 2005). Dixon (2016) estimates annual Saker falcon electrocutions in Mongolia to be 4,116 (90 percent CI = 713–7951) individuals. As expected, there is much variation in intra-annual fatality rates with noticeable peaks pre and post migration (Dixon et al., 2020). While the majority of common kestrel (*Falco tinnunculus*) fatalities were female and immature birds (Lasch et al., 2010), 88 percent of Saker falcon fatalities were juveniles (Dixon et al., 2020). Similarly, juvenile rhesus macaques had the highest electrocution injuries; males were also more likely to be electrocuted than females, and electrocutions were highest in the rainy season (Kumar & Kumar 2015). In the case of Northern Plains gray langur, power line fatalities killed 2.8 percent of the local population at one site (Ma et al., 2015).

MITIGATION OF POWER LINE IMPACTS ON WILDLIFE

M1: POWER LINE MITIGATION BY MODIFYING ANIMAL BEHAVIOR

Wire-marking is the installation of flappers, spirals, and other devices to enhance visibility of power lines to birds, which can reduce avian collisions by 50 percent (Bernardino et al., 2019). The practice of wire-marking in Asia is in its early stages. To prevent power line collisions of the Critically Endangered great

Indian bustard in India, bird diverters have been retrofitted to power lines, but their efficacy is not yet known. Dashnyam et al., (2016) examined the mechanical functionality of bird flight diverters (spiral and flapper types). Nine months after installation, the malfunction rate of spirals was 0 percent, while that of flappers was 21 percent. Malfunction rates were higher in smaller sized flappers when compared to the larger flappers (Dashnyam et al., 2016). In some cases, marking wires alone may not be sufficient and other mitigation measures may need to be employed along with wire-marking. For example, in Japan, a mixed approach of marking wires and partial removal or transfer of wires reduced red-crowned crane collision fatalities from 71 percent of annual mortality in 1970-74 to eight percent of annual mortality in 1985-86 (Masatomi, 1991). Technological advancements such as utilizing unmanned aerial vehicles to fix power line markers could potentially lower costs of installing markers to mitigate avian power line collisions (Lobermeier et al., 2015).

M2: POWER LINE MITIGATION MEASURES THAT SEPARATE ANIMALS FROM POWER LINES

To mitigate the risk of avian electrocutions, several devices and fitments have been tested. Primarily focused on mitigating raptor electrocutions in Mongolia, the devices are mostly retro fitments, and fall into two broad categories: devices that deter birds from perching and devices that prevent contact with energized wires (Dixon et al., 2019). Two methods were assessed to prevent contact with energized wires: 1) placing insulator caps, and 2) and reconfiguring wires. Placing insulation covers on top of the pole mount and crossarms reduced electrocution by 59 percent and 66 percent respectively. Among perch deterrent devices like rotating mirrors, unconnected pin insulators, brush deflectors, and spikes, rotating mirrors installed on the crossarms reduced electrocution by 91 percent but showed the most mechanical failure. Unconnected pin insulators reduced electrocutions by 85 percent (Dixon et al., 2018).

Long-term studies on toque macaques (*Macaca sinica*) in Sri Lanka enabled the design, development, installation, and testing of a unique mitigation measure to prevent primate electrocutions. Fatalities were reduced by 100 percent by installing metal shields on power line poles, which prevented animals from reaching the top of the pole and potentially contacting power lines (Dittus, 2020). Canopy bridges can be an important tool to mitigate the significant impacts of power lines and other LI on primates in forested landscapes by restoring connectivity between patches of natural habitat. While literature on canopy bridges to mitigate power line electrocutions is lacking from Asia, early results from monitoring primate use of canopy bridges is encouraging. For example, in West Java, Javan slow lorises (*Nycticebus javanicus*) started using bridges 3–30 days after installation (Birot et al., 2020). In India, hoolock gibbons used canopy bridges 31 times in a span of two months (Das et al., 2009). Following a period of habituation, Hainan gibbon (*Nomascus hainanus*) use of a canopy bridge increased over time (Chan et al., 2020). To prevent elephant electrocutions with overhead power lines, draft guidelines issued by the Indian government's Ministry of Environment, Forests, and Climate Change recommend that the lowest point of the power lines be 20 feet (six meters) and 30 feet (nine meters) above ground in terrain where the slope is <20 and > 20 degrees, respectively.

CONCLUSION: POWER LINES

The majority of the studies on power lines focused on the direct impacts to wildlife, while only two studies described indirect impacts. While some studies merely recorded observations of power line electrocution and collision fatalities, other studies described direct impacts in more detail and investigated specific factors responsible for fatalities. Similar to roads and rails, rigorous assessments of power line impacts at the population level are lacking. Studies were predominantly focused on birds, followed by mammals (largely primates and bats). The existing mitigation literature has a Central Asian focus, and efforts to mitigate power line impacts elsewhere in Asia are in their infancy. Mitigation measures that separate species from power lines are more common than measures to change animal behavior. Systematic documentation of the efficacy of mitigation measures is lacking and needs to be undertaken.

SPECIES AND TAXA OF INTEREST

ASIAN ELEPHANT

Asian elephants are globally Endangered (Williams et al., 2019) and are the focus of intense conservation efforts across all 13 range countries (reviewed by Sukumar et al., 2003). Consequently, they were a major focus of research in the Asian literature on LI with 29 studies. However, most of these studies were from India (17), followed by China (four). Studies on effects at the population scale (E3) were most represented with 15 studies, followed by direct impacts at small scales (E1; 14 studies) and indirect impacts at small scales (E2; nine studies).

Elephants can be killed in train strikes, collisions with vehicles as well as electrocution from power lines, of which train strikes are the most well studied in the literature. All of the train strikes in the literature are from India (e.g., Roy et al., 2009), possibly because it contains more than half the Asian elephant population (Menon & Tiwari, 2019), and the third longest railway network in the world (World Bank, 2020). However, elephants are increasingly vulnerable to train strikes in other countries where the high speed rail network is growing, such as Sri Lanka (Williams et al., 2019). Collisions with vehicles on roads are more rare but have been documented in countries such as Malaysia (Wadey et al., 2018) and China (Pan et al., 2009). Deaths from accidental electrocution are reported mostly from India, and occur when elephants come into contact with sagging or broken power lines (e.g., Palei et al., 2014). Risk factors associated with elephant-train collisions are thought to include night time (S. Mitra, 2017), anthropogenic garbage attractants along tracks (Singh et al., 2001), sharp curves (Dasgupta & Ghosh, 2015), the number and speed of trains (Roy et al., 2009), steep embankments along tracks that prevent quick escape (Singh et al., 2001), and possibly social bonds among family herds that may cause them to stay in the vicinity of members that are trapped on the rails (Joshi & Puri, 2019). Further, elephants may become vulnerable to collisions with vehicles when they attempt to cross highways at locations of their traditional movement routes (Pan et al., 2009).

To understand the population-level consequences of elephant deaths from LI, estimates of population size (at the appropriate scale) and overall mortality are required. Further, a comparison of the age-sex classes that are killed with the distribution of age-sex classes in the local population would show if particular groups are being disproportionately killed. Such characteristics are not analyzed well in the scientific literature, but additional information from the gray literature suggests that these can have severe impacts at particular sites. For example, train strikes formed 45 percent of all mortalities in a subset of Rajaji National Park in India (Singh et al., 2001). Several studies suggest that more females are killed by trains than males (e.g., Singh et al., 2001; Palei et al., 2013; Joshi & Puri, 2019), but females generally constitute a larger proportion of elephant populations. When corrected for population size, Roy & Sukumar (2017) found that adult males were 2.5 times more likely to be killed by trains than females in North Bengal, India. More males were also found to be electrocuted (both intentionally and accidentally) at a site in India (Palei et al., 2014). Given the vulnerability of adult males to ivory poaching as well as retaliatory killing for conflict (Menon & Tiwari, 2019), additional mortalities from LI could significantly impact male elephant populations. The combined effect of electrocutions (deliberate or accidental) and train strikes comprised 77 percent of the 373 elephant mortalities from anthropogenic causes in India from 2015 to 2018 (Ganesh, 2019). The population-level impacts of collisions with vehicles are less well established; however, the studies from Southeast Asia and China appear to indicate these are relatively uncommon in comparison with train strikes and electrocutions in South Asia.

LI may indirectly impact elephants at both small and large scales through changes in habitat and human activity. Roads in particular facilitate human access, which may be used for poaching elephants (Wadey et al., 2018). Electricity from secondary power lines is often drawn illegally to electrocute elephants, often in retaliation for conflict (Rangarajan et al., 2010). The rapid growth of settlements alongside roads can also prevent elephants from coming close (Gangadharan et al., 2017). Individual animals may therefore avoid these road effect zones, resulting in narrower distribution at larger scales (i.e., less use of habitat that occurs near roads; Sharma et al., 2020) as well as impacts on connectivity between populations. Yet, all three LI modes open up forests to secondary growth, which may attract elephants under some ecological conditions. For example, the construction of a major highway created a large "edge" in a rainforest in Malaysia and attracted elephants to forage in the vicinity (Yamamoto-Ebina et al., 2016). Menon et al. (2015) found more elephant dung under power lines than in the forest, despite the high presence of noxious weeds; they attributed this to elephants using the cleared area under power lines for movement. However, the role of power lines in determining elephant distribution and movement is not well explored.

Movement of individual animals is a key ecological process that is impacted by LI. Highways reduced elephant movement by up to 80 percent, due to heavy traffic (Huang et al., 2020) as well as associated infrastructure such as drainage ditches (Wadey et al., 2018). However, elephants regularly move across lower-speed roads that do not have barriers (e.g., Pan et al., 2009). Apart from traffic volume, traffic speed, and physical barriers, the behavior of people in vehicles may be a key determinant of the ability of elephants to cross roads. For example, elephants often abandoned their attempts at crossing when people stopped, made noise, or when they walked toward the elephants (Vidya & Thuppil, 2010). Elephant movement across railway tracks is common, particularly when they need to access resources on either side (Sarma et al., 2008). The impact of power lines on elephant movement is not known, but they may potentially facilitate movement (Menon et al., 2015). Despite the existence of studies on elephant movement across LI, there is little known about how any reduction in movement impacts demographic rescue or genetic structure. These population-level impacts require much more attention for a comprehensive understanding of how LI impacts elephant populations.

Measures that seek to modify both human and animal behavior are often implemented together to mitigate direct impacts on roads and railway. These include measures to improve detection of elephants in advance, by clearing verge vegetation along curves (Palei et al., 2013), providing signage along known crossing points on roads or railways (Panda et al., 2020), and patrolling along tracks regularly to provide early warning to train conductors (Joshi & Puri, 2019). Speed limits may also be imposed on trains along high-risk stretches (e.g., Ministry of Environment & Forest, 2015). Removal of anthropogenic food along tracks, as well as moving attractants (such as waterholes) away from the tracks are thought to have contributed to greatly reduced mortality at one site in India (WTI, 2016). By providing embankments with gentler slopes, elephants may be better able to escape from oncoming trains (Singh et al., 2001). Mitigation methods for indirect impacts include patrolling and check posts along roads to reduce access by poachers (Clements et al., 2014), and better monitoring of power lines to ensure that electricity is not drawn illegally (Rangarajan et al., 2010). However, many of these methods require high motivation and monitoring to implement; for example, train conductors may exceed speed limits (e.g., Singh et al., 2001), and patrolling along railway tracks during the night may be difficult and risky. Therefore, there is increasing interest in technological interventions for providing early warning (e.g., Roy & Sukumar, 2017). Further, these methods are rarely evaluated in a robust manner (e.g., before-after-control-impact framework), making it difficult to assess their efficacy.

Measures to physically separate elephants from power lines involve maintenance to ensure that these lines do not sag. For roads and railways, elephants may be excluded from the right of way through exclusion fencing. Most types of exclusion fencing are of limited effectiveness against elephants (e.g., Lenin & Sukumar, 2011); however, fences that are themselves made of old rails have proven effective, though they are expensive to implement and maintain (Saklani et al., 2018). To ensure that elephants can cross, crossing structures may be built over or under railway tracks or roadbeds. Elephants may prefer to use crossing structures that are located near their traditional routes, and even try to break through fencing if no structures exist at these locations (Pan et al., 2009). Thus, the placement locations of crossing structures should be identified based on empirical observations of elephant crossings, or modelled routes (e.g., least cost paths between closest elephant presence on either side; Gangadharan et al., 2017). Elephants are also known to sometimes use crossing structures that were built for engineering purposes rather than specifically for wildlife. For example, elephants in China crossed under a long bridge built for engineering purposes (Pan et al., 2009); similarly, elephants in India were observed crossing under a long railway bridge that was not specifically designed for animal use (Menon et al., 2015). Recent studies from Kenya show that African elephants (*Loxodonta africana*) crossed under a high-speed railway using both large bridges as well as smaller underpasses (Okita-Ouma et al., 2021). Thus, crossing structures can be an effective (albeit capital-intensive) method for mitigating collisions with vehicles or trains while also ensuring connectivity for elephants.

FELIDS

We found 46 peer-reviewed studies related to the impacts of LI on *Felidae* in Asia. India contributed 20 of these studies, followed by China, Indonesia, and Malaysia (four each). Studies on direct impacts at small scales (E1) were most represented with 21 papers, followed by direct and indirect effects at the population scale (E3; 20 papers) and indirect impacts at small scales (E2; seven papers).

Most studies related to the direct impacts of LI on felids simply document their presence within larger multi-species studies on road or rail kill. At least 11 species of felids have been documented in such collisions, including Asiatic lions, tigers, leopards, Eurasian lynx (*Lynx lynx*), leopard cats, and rusty-spotted cats (Appendix A). Accidental electrocution of Eurasian lynx from a non-insulated electric cable has been documented from a site in Iran (Kolnegari et al., 2018). Few of these studies examine the specific physical, landscape, or behavioral features associated with mortalities. However, general explanations offered for road or rail kill of felids include increase in road network (Gubbi et al., 2014) and over-speeding by trains (Joshi, 2010). Collision hotspots may also occur at locations that are commonly used by felids to cross roads (Kang et al., 2016). A detailed study of leopard cat mortalities on highways in South Korea suggested that road width, driver behavior, and seasonal patterns in animal movement influenced the number of mortalities (Kim et al., 2019). A greater focus on identifying such variables associated with felid mortality from LI could help mitigate these mortalities.

The indirect impacts of LI at small scales are under-studied for felids in the peer-reviewed literature in Asia. Large felids such as tigers and leopards are known to use roads and trails for movement, particularly if they are unpaved and not frequently used by people. Hence, such roads may not be a barrier to crossing (e.g., Ngoprasert et al., 2007). Further, Gubbi et al., (2012) found no significant difference in encounter rates of tigers and leopards along the verge for a highway segment that was completely closed versus one that was open during the day. Some individual tigers may even be able to live within human-dominated habitats, during which time they regularly cross roads (Athreya et al., 2014). Other species such as leopard cat may avoid the immediate vicinity of roads, but forage at intermediary distances (Mohd-Azlan et al., 2018). Yet, roads also facilitate poaching (e.g., Hearn et al., 2019), and control of human activities on both paved and unpaved roads may be critical to protect species such as tigers (Clements et al., 2014). Individual-level studies focused on fine-scale responses to different types of LI can help further understand the indirect impacts of roads on felids at small scales.

The population-level consequences of mortality from LI may vary widely between species and ecological settings. Leopard cat roadkill occurrences mainly comprised yearlings undertaking natal dispersal in Korea (64 percent; Kim et al., 2019) and Japan (70 percent; Nakanishi et al., 2010)—a process that involves high risk of mortality regardless of the presence of LI). However, adults and females comprised 92 percent and 67 percent of leopard cat roadkills in a site in Malaysia (Laton et al., 2017). For the Critically Endangered Asiatic cheetah (*Acinonyx jubatus venaticus*) in Iran, roadkills (of both male and female adults) were the second highest cause of mortality (Farhadinia et al., 2017),making this a major threat to their persistence. Species such as leopards, which are often found in human-dominated areas, may be particularly susceptible to roadkill (Gubbi et al., 2014), but the consequences of these roadkill occurrences to population viability are not known. For Amur tigers (*Panthera tigris altaica*), persistence may depend on controlling direct mortality from roadkill (second highest cause of death; Goodrich et al., 2008), as well as preventing road access to poachers (Kerley et al., 2002). Studies from other felids (e.g., Florida panther (*Puma concolor coryi*) suggest that the impacts of roads may greatly impact the viability of small populations in regions of high road density (Schwab & Zandbergen, 2011).

LI may catalyze large-scale changes in land use, leading to habitat loss and increased human access that together influence the abundance and distribution of felids. In Myanmar, the construction of the Yangon-Myitkyina railway opened up large areas to human settlement and use, and may have ultimately contributed to the local extirpation of tigers by facilitating poaching (Aung et al., 2004). Such changes in human activity and land use are thought to be emerging threats to felids such as snow leopards and manul in the Himalayan region (Dhendup et al., 2019; Farrington & Tsering, 2020). The abundance of Sunda clouded leopards decreased with road density in Borneo (Brodie et al., 2015), and the distribution of tigers was higher further away from roads in Indonesia (Linkie et al., 2008) and paved roads in China—although detection probability was higher near forest roads due to their use for movement (T. Wang et al., 2018). A range-wide spatial model of tiger distribution has suggested that up to 43 percent of all breeding habitat may fall within the road effect zone, depressing potential tiger abundance by around 20 percent (Carter et al., 2020). Yet, the pace of change in some regions has been such that population sizes of some species are higher than what the recently degraded habitat can support; this "extinction debt" has been documented for Sunda clouded leopard in Malaysia (Kaszta et al., 2019).

Felid abundance and distribution may also be influenced by the extent to which LI hinders movement and connectivity. Connectivity between sub-populations is a key determinant of population viability for felid species that occur at low densities (e.g., tigers; Linkie et al., 2008; Thatte et al., 2018). Consequently, numerous studies use spatial modeling techniques to identify areas that are important for connectivity between core areas. Some of these studies model the current status of connectivity to identify areas for restoration (e.g., Dutta et al., 2018); others model the potential cumulative impacts of planned infrastructure projects such as the BRI (e.g., Kaszta et al., 2020). Similar large-scale models of habitat fragmentation have identified snow leopards as being particularly vulnerable to increasing road networks in China (L. Zhang et al., 2015). However, some studies suggest that the impact of linear features on gene flow may be less than other anthropogenic features, such as land use. For example, gene flow for tigers was not strongly influenced by intervening roads, except for roads with high traffic density (Thatte et al., 2018). The amount of traffic partially explained leopard gene flow, but far less than land use type; and roads had little influence on gene flow in jungle cats (*Felis chaus*; Thatte et al., 2019). Such findings suggest that it is important to supplement connectivity modeling of felids with empirical observations of animal movement, in the form of actual movement across linear barriers or through genetic markers.

Mitigation of LI impacts on felids may involve interventions that change the behavior of animals or humans, but these are not well documented or evaluated. By modeling time taken for felids to cross roads in relation to traffic volume, the probability of roadkill can be estimated to prioritize the most important road stretches for mitigation (Habib et al., 2015). Control of traffic volume by either permanent or temporary (e.g., night-time) road closures can reduce roadkill and barrier effects for several species. However, as noted above, there was no difference in encounter rates of tigers and leopards on road sections that were closed at night compared to those that were permanently closed (Gubbi et al., 2012). Higher night-time encounter rates of ungulate prey on road sections that are open to day-time traffic may suggest that these areas are refugia from predators (Habib, Saxena, Mahima, et al., 2020). This may imply avoidance of roads by large carnivores such as tigers, even when these roads are partially closed. Speed limits may also be imposed on trains in key areas (e.g., location of the last surviving population of Asiatic lions; Rajvanshi et al., 2001). Such measures appear to be rarely evaluated in a robust manner, based on literature available in the public domain.

Given the complexities of modifying human and animal behavior, measures that separate wildlife from LI (mainly roads) but allow passage through over/underpasses are increasingly popular. Such interventions are often driven by the need to conserve large, Endangered species such as tigers, but may be leveraged to develop passage plans for numerous other co-occurring species as well. For example, crossing structures built for tigers at a site in India also served the needs of 17 other species (Habib et al., 2015). Crossing structures for tigers often involve large, elevated roads (often called flyovers or viaducts) of several hundred meters; tigers have been documented to regularly cross such structures, as have leopards, jungle cats, and rusty spotted cats (Habib, Saxena, Jhala, et al., 2020). However, felids may also cross under structures (such as drainage culverts and bridges) that have been built for other purposes. For example, leopards have been documented using drainage culverts to cross (Menon et al., 2015) in India. Wildcat (*Felis sylvestris*) and manul crossed expressways using culverts in China (though they preferred more open bridges; Li et al., 2019), while Eurasian lynx used both culverts and bridges under railway tracks (Y. Wang et al., 2018). The importance of large felids as conservation flagships may be particularly important in developing multi-species passage plans for roads and railways.

PRIMATES

We found 48 peer-reviewed studies related to the impacts of LI on *Primates* in Asia. India contributed 21 of these studies, followed by Indonesia (seven) and Malaysia (four). Studies on direct impacts at small scales (E1) were most represented with 32 papers, followed by direct and indirect effects at the population scale (E3; 14 papers) and indirect impacts at small scales (E2; eight papers).

Primates are susceptible to direct mortality from roads, railways, and power lines. At least 32 species have been documented in these direct impacts (Appendix A), including golden langurs on roads (Thinley et al., 2020), capped langurs on railway tracks (Raman, 2011), and Western hoolock gibbons on power lines (Sati, 2009). Most of these studies document these mortalities, without robust examination of the habitat, behavioral, and physical features associated with them; however, canopy contiguity and anthropogenic food appear to be key risk factors. For roads and railway, lack of canopy contiguity may force primates to cross on the ground and render them vulnerable to collisions with vehicles or trains (Umapathy et al., 2011). Species that are behaviorally reluctant to descend to the ground (e.g., Southern purple faced langur, *Semnopithecus vetulus*; Parker et al., 2008) may even prefer to use power lines instead, and hence risk being electrocuted (Roscoe et al., 2013). For roads and rails, attraction to anthropogenic food (including garbage or deliberate feeding) is a major source of mortality for some species (e.g., Northern Plains grey langur; Chhangani, 2004a). Cumulative impacts of more LI modes may also increase mortality; for example, power lines are often established along existing roads, and may cause both electrocutions and collisions (Al-Razi et al., 2019).

Indirect impacts of LI on primates include changes in local habitat characteristics, modification in behavior, and barriers to movement. LI construction may lead directly to loss of primate habitat (e.g., power lines; Ma et al., 2015). Yet, roadside habitats may provide opportunities for some commensal species to benefit from anthropogenic food (e.g., Srivastava et al., 2017b). However, as the access provided by these roads attracts people and leads to more built-up areas alongside, even these species (such as bonnet macaques) may be displaced (Erinjery et al., 2017). Such habituation is also thought to lead to larger problems of human-primate conflict (such as entering houses in search of food), even for relatively shy rainforest species such as lion-tailed macaques (Jeganathan, Mudappa, Raman, et al., 2018). Finally, humans also often feed dogs, which may then hunt primates along roads (e.g., golden langur; Thinley et al., 2020). Avoidance of such predators may then lead to primates avoiding canopy gaps created by LI such as roads, thereby impeding movement between patches (Y. Zhang et al., 2018).

Direct and indirect impacts of LI at small scales may lead to consequences at the level of populations. Direct mortality of primates from vehicle collisions, train strikes, and electrocutions may impact local population viability. For example, 49 injuries and 33 deaths were recorded from electrocution in a population of approximately 195 Southern purple faced langur in Sri Lanka (Roscoe et al., 2013). Some studies indicate a higher mortality risk for males on roads (e.g., 60 percent of roadkill occurrences for Northern Plains grey langur, Chhangani, 2004a; 46 percent higher mortality risk for rhesus macaques when corrected for availability in local population, Pragatheesh, 2011). Indirect impacts such as deforestation may be caused by large-scale LI expansion to facilitate forestry and agricultural commodity trade (Estrada et al., 2019), or industrial development (Alamgir et al., 2019). However, it is also important to note that LI may not always be the primary threat to primates. For example, Javan slow loris death occurrence was determined primarily by forest characteristics rather than LI (Sodik et al., 2020). There was no relationship between road network density and the local abundance of Southern pig-tailed macaque (*Macaca nemestrina*) across an 88,000 km^2 area of Borneo (Brodie et al., 2015). The scale of study and LI configuration may also mediate barrier effects; for example, highways are thought to restrict dispersal-led connectivity between populations of black-and-white snub nosed monkeys, but not daily movement (Clauzel et al., 2015). Overall, further investigation of population-level impacts of LI on primates is critical to prioritizing mitigation sites and activities.

Mitigation measures for direct and indirect impacts of LI on primates may include measures to modify animal behavior, measures to modify human behavior and measures that separate animals from the infrastructure. Measures to modify human behavior include reduction in speed limits at known mortality hotspots along roads (e.g., Healey et al., 2020). Other measures may include warnings to motorists to avoid feeding primates, although the effectiveness of such strategies is not well known (Pragatheesh, 2011).

Primates may be separated from power lines by placing them at a greater height than the surrounding trees, or by burying them underground (Sati, 2009). Also, crossing structures are often provided to facilitate primate movement across roads, rails, and power lines. For example, such structures may consist of narrow strips of rubberized canvas anchored to trees on either side of the canopy gap for lion-tailed macaques (Jeganathan, Mudappa, Raman, et al., 2018). Numerous other designs for canopy bridges have also been tested for various primate species (e.g., Birot et al., 2020); these bridges may serve the needs of other arboreal species as well (Das et al., 2009). Information obtained from such canopy bridges (although not in a LI context) suggest that there may be differences in the use of such bridges across age-sex classes. For example, female and juvenile Hainan gibbons used canopy bridges more than adult males (which preferred to jump across gaps; Chan et al., 2020). Canopy bridges may even be leveraged in ways that elicit local support for maintenance. For example, aerial water pipes served the purposes of connectivity for Javan slow loris between forest fragments and ensured irrigation for home gardens in a human-dominated landscape in Indonesia (Birot et al., 2020). Apart from canopy bridges, there is at least one large metallic bridge built across railway tracks to enable Western hoolock gibbons to cross (Wildlife Institute of India, 2016)—although anecdotal information suggests that this structure was not used by them (N. Mitra, 2019). More terrestrial species such as bonnet macaques have been documented to cross roads using underpasses that were built for engineering purposes (Menon et al., 2015). The diversity of studies on artificial crossing structures suggest that this is an area of increasing interest for primate conservation in fragmented habitat.

UNGULATES

We found 49 peer-reviewed studies related to the impacts of LI on ungulates in Asia. China and India contributed 12 of these studies each, followed by Mongolia (nine) and Japan (four). Studies on direct impacts at small scales (E1) were most represented with 24 papers, followed by direct and indirect effects at the population scale (E3; 20 papers) and indirect impacts at small scales (E2; 13 papers).

The direct impacts of roads and railways on ungulates are highly prevalent and well documented across Asia and include at least 17 species (Appendix A). They include species ranging from Siberian roe deer (vehicle collisions in China; Wang et al., 2013) to sika deer (train strikes in Japan; Ando, 2003) and goral (train strikes in India; Singh et al., 2001). Mortality may also be caused by infrastructure associated with roads and railways; for example, Mongolian gazelle were frequently caught in fences along railway tracks (Ito et al., 2008). Risk factors associated with ungulate mortality are often studied as part of larger studies on mammals (e.g., Seo et al., 2015), and suggest that collisions are influenced by variables related to local habitat, road/railway characteristics, and animals behavior. Habitat configuration—such as when a railway separates feeding from resting areas—plays an important role in determining the frequency of crossing, and hence the risk of collisions (Ando, 2003). Low visibility (such as during nights and in winter) may interact with animal activity patterns and lead to peak periods in collision risk for sika deer (Soga et al., 2015). For larger ungulates such as gaur, the time taken to cross a highway is thought to increase the probability of being struck by a vehicle compared to smaller ungulates (Habib et al., 2015). Finally, attraction to the road or railway verge (e.g., for foraging) may attract ungulates, sometimes causing them to get trapped if these areas are fenced (Ito et al., 2008).

The consequences of direct impacts at the population level are not well studied for most ungulates in Asia. Up to 60,000 water deer may be killed on roads every year in South Korea (Choi, 2016), which may be significant for a species with an overall declining population trend (Harris & Duckworth, 2014). Mortality from LI may also disproportionately impact specific demographic classes (e.g., male Asiatic water buffalos; Heinen & Kandel, 2006). The contribution of LI to overall mortality may be variable; for example, 15 percent of anthropogenic mortality of nilgai (*Boselaphus tragocamelus*) was caused by collisions with vehicles on roads (Bajwa & Chauhan, 2019). Population-level consequences of mortality from LI is an important area for further investigation in Asia.

Roads and railways also indirectly impact ungulates at small scales by catalyzing human activity, influencing animal use of habitat, and hindering movement. Roads may facilitate hunting of ungulates (Clements et al., 2014). Further, increases in human activity and settlement along roads may displace ungulates such as gaur from the vicinity (Gangadharan et al., 2017). Human access may also increase feral dog populations, which may then hunt ungulates; mortalities may be particularly high when fences also hinder their ability to escape (Bajwa & Chauhan, 2019). Such road effects can lead to lower use of habitats that are near roads (e.g., Asiatic wild ass; Bao-fa et al., 2007). However, if paved roads are avoided by carnivores, some ungulates such as chital may congregate in these predator-free spaces at times when human activity is also low (such as night; Habib, Saxena, Mahima, et al., 2020). Such temporal separation in space use around roads has been observed in Przewalski's gazelle, tufted deer, and goral (all of which were found to be distributed significantly closer to roads at night than in the day), but not in more human-tolerant species such as wild pigs and sika deer (C. Li et al., 2009; Jia et al., 2015). When ungulates do approach roads, they may spend a large proportion of their time in vigilance, which could impact their other activities negatively, such as feeding (Bao-fa et al., 2007). Ungulate movement is also impacted by roads and railways, particularly if they are fenced. For example, fences along railways greatly reduced movement of Mongolian gazelle and Asiatic wild ass (Ito et al., 2013). Where no such fences exist, crossing may be common; it is even hypothesized that sika deer may have learned to cross railway tracks at locations where collisions are less likely (Soga et al., 2015).

The large-scale consequences of indirect impacts are well-studied for some species, and these effects may vary depending on the ecological context. Higher density of LI was associated with lower abundance of Mongolian gazelle on the Steppe (Nandintsetseg et al., 2019), but sambar abundance increased with road density within a rainforest habitat where poaching was controlled (Brodie et al., 2015). The barrier effects of fenced railways are thought to have cut off access to 17,000 km^2 of habitat for Asiatic wild ass (Kaczensky et al., 2011), thereby decreasing their overall area of occupancy. Nomadic species such as Mongolian gazelles may need to move large distances in response to resource availability, but their movement may be prevented by fenced railways and lead to high mortality (Ito et al., 2013; Olson et al., 2009). More generally, the density of LI is thought to reduce connectivity between core populations for species such as gaur and sambar (Jayadevan et al., 2020). Barriers to connectivity caused by LI may be expressed in the form of genetic substructure between previously connected populations. The impacts of a fenced railway in China was evident in genetic drift between Przewalski's gazelle populations on either side in just a few years since construction (Yu et al., 2017). At a site in Japan, wild pig population genetic structure was consistent with the barrier effects of railways (Tadano et al., 2016). However, despite the considerable barriers to movement posed by fenced railways in Mongolia (above), genetic sub-structing was not yet evident in Mongolian gazelle (Okada et al., 2012). This range of results emphasizes the need to better link indirect impacts at small scales with implications for large-scale population characteristics.

We found few examples of mitigation measures that were specifically oriented toward influencing the behavior of ungulates. Mitigation measures that seek to change the behavior of people appear more prevalent, and include interventions such as speed bumps on roads (which may reduce mammal roadkill; Menon et al., 2015). Road closures (during certain times or permanent) may lead to greater use of verge habitat by some species but not others. For example, detection rates of chital and gaur were higher on sections of a highway that were permanently closed compared to sections that were open during the day, but there were no such differences for sambar and wild pig (Gubbi et al., 2012). Mitigation of roads and railways through crossing structures appears to be well documented for ungulates; at least 12 species have been documented to use such structures to cross (Appendices C & D). Ungulates have been documented to cross using structures (such as bridges and pedestrian overpasses) that were not built specifically for their passage. These include Siberian roe deer (Y. Wang et al., 2017), sika deer (Asari et al., 2020), and mouse deer (*Moschiola indica*; Menon et al., 2015). However, the energetic implications of having to cross only at particular locations may not be obvious from such observations. Migrating Tibetan antelope are thought to have to deviate 86 km from their optimal pathways to access crossing structures that would enable them to safely navigate the Qinghai-Tibet railway (W. Xu et al., 2019). Thus, the design and location of crossing structures are important considerations in mitigation of LI or ungulates.

REPTILES

We found 46 peer-reviewed studies related to the impacts of LI on reptiles in Asia. India contributed 23 of these studies, followed by Sri Lanka (four) and China (three). Studies on direct impacts at small scales (E1) were most represented with 41 papers, followed by direct and indirect effects at the population scale (E3; five papers) and indirect impacts at small scales (E2; two papers).

At least 240 reptile species have been documented in direct mortality events from LI (particularly from roads), and they include representatives from snakes, lizards, turtles, and crocodilians. These include two Endangered and nine Vulnerable species (Appendix A). Most of the literature related to reptile mortality from LI simply documents these mortalities, but some studies investigate variables that increase collision risk. Proximity to water bodies as well as monsoon season (when burrows flood and force animals to move) are thought to increase mortality risk of marsh crocodiles on roads and railways at one site in India (Vyas & Vasava, 2019). Proximity to water was also associated with higher roadkill occurrences of Southeast Asian box turtle (*Cuora amboinensis*) and Asian leaf turtle (*Cyclemys dentata)* in the Philippines (Bernardo, 2019). Some families such as *Uropeltidae* may be more active (and therefore more likely to encounter vehicles) after rain (Vijayakumar et al., 2001). More generally, more reptiles may be killed in habitats where they occur more (e.g., forests compared to tea plantations; Jeganathan, Mudappa, Kumar, et al., 2018). Some drivers may deliberately target snakes on roads (Marshall et al., 2018). Reptile behavior may also influence the risk of direct mortality. The attraction of snakes to roads for thermoregulation is thought to be an important reason for them to be run over by vehicles (Pragatheesh & Rajvanshi, 2013). Snakes that actively move in search of prey may be more at risk (because they encounter roads more often) than species that rely on ambush (Park et al., 2017). Further, reptiles may not respond to rapid increases in traffic volume as quickly as mammals do, resulting in more roadkill during periods of high vehicular activity (Seshadri & Ganesh, 2015). However, reptile mortality may not necessarily be correlated with traffic volume (Y. Wang et al., 2016), suggesting that such patterns may be site-specific. Roads also facilitate access by humans, who may then kill snakes that they encounter on the way (Marshall et al., 2018). However, there appears to be little investigation of such indirect impacts of roads on reptiles at small scales.

The population-level impacts of LI on reptiles are also mainly oriented toward direct mortalities. One study found no correlation between the number of individuals of different reptile species that were killed on roads to the number that were found in the adjoining habitat (Bhupathy et al., 2009), suggesting that mortality from roads may be disproportionately higher for some species than others. The contribution of roadkill to overall mortality is not usually studied, but 16 percent of a radio-tracked sample of king cobras were victims of roadkill at a site in Thailand (Marshall et al., 2018). Some demographic groups may also be represented more than others in road or train collisions. In northeast South Korea, 95 percent of snakes of 10 species killed on roads were adults and 70 percent were males (Park et al., 2017). In a site in India, 67 percent of marsh crocodiles killed by vehicles or trains were juveniles or sub-adults (Vyas & Vasava, 2019). As these studies do not correct for the availability of each demographic group in the population, the implications for population viability are not known. One study on the population genetics of toad-headed lizards found that the Qinghai-Tibet railway in China did not form a barrier to gene flow, as the habitat around the railway attracted the lizards and hence facilitated a continuous population (D. Hu et al., 2012). At broader spatial scales, the loss of habitat from large-scale infrastructure projects may also lead to loss or degradation of habitat for reptiles, like for other taxa (Hughes, 2019).

Mitigation of the LI impacts on reptiles may involve measures to change animal behavior, change human behavior, and/or physically separate animals from the infrastructure. One way to reduce reptile attraction to roads could be to set up artificial surfaces made of thermoregulatory material away from the immediate vicinity of roads as alternative basking locations (Pragatheesh & Rajvanshi, 2013). However, we have not come across any implementation of such an intervention. The behavior of drivers in vehicles may be regulated through speed limits (such as by placing speed bumps at close intervals on roads); this may reduce the mortality of several species including reptiles (Menon et al., 2015). Road closures (particularly at night) as well as regulation of traffic volume can help reduce mortality of reptiles (Seshadri & Ganesh, 2011). Mitigation measures related to separation of reptiles from roads involve physical barriers (fences or walls) combined with crossing structures. Such walls are recommended to have "lips" at the top to prevent snakes from climbing over and guide them toward the crossing structures (Pragatheesh & Rajvanshi, 2013). While it is expected that crossing structures built for larger animals (particularly mammals) could also serve reptiles (e.g., if they involve large sections of elevated roads; Habib, Saxena, Jhala, et al., 2020), separate structures for reptiles may be required under some circumstances. Although these may be recommended in road mitigation, the needs of reptiles are not necessarily actually implemented (Donggul et al., 2018).

AMPHIBIANS

We found 32 peer-reviewed studies related to the impacts of LI on amphibians in Asia, of which 31 were from the road literature and one from the rail literature. India contributed 14 of these studies, followed by China (five), and South Korea and Sri Lanka (three each). Studies on direct impacts at small scales (E1) comprised the vast majority (25) of these studies; five studies were conducted on direct and indirect effects at the population scale (E3), and only one on indirect impacts at small scales (E2).

Mortality from AVCs have been documented for at least 69 amphibian species across Asia, including two Endangered and 13 Vulnerable species (Appendix A). Several risk factors are thought to contribute to amphibian collisions with vehicles. When vehicles pass through a favored habitat—which is associated with water bodies for many amphibian species—mortalities may be higher. Such water bodies include rivers (Baskaran & Boominathan, 2010) and wetland patches (Gu et al., 2011). More generally, amphibian mortality rates may be higher in areas where they occur more (e.g., in a forest habitat compared to a tea plantation; Vijayakumar et al., 2001). Temporal patterns in amphibian mortalities are also well documented and may correlate with their activity and breeding patterns. Amphibian roadkill may be higher at night (W. Zhang et al., 2018), during rainy seasons (Jeganathan, Mudappa, Kumar, et al., 2018) and on rainy days (Gu et al., 2011)—but see also Bhupathy et al., (2009). Where amphibians must cross roads to meet their ecological requirements (e.g., to access breeding habitat or natal dispersal), there may be an increased number of collisions (Seo et al., 2015; Seshadri & Ganesh, 2011). High traffic volume may also be correlated with direct mortality of amphibians (Z.C. Wang et al., 2015). Further, the amphibians may not be repelled by increasing traffic volume on roads (in contrast with mammals), and therefore amphibian roadkill may continue to increase with higher traffic volumes (Seshadri & Ganesh, 2011). Apart from direct mortality from collisions with vehicles, amphibians may also sometimes be trapped in infrastructure associated with roads (e.g., drainage ditches) and die in them (Z. Zhang et al., 2010).

The population-level consequences (especially population viability) of amphibian-vehicle collisions are not well known. In multi-species studies on roadkill, amphibians often comprise the largest proportion (e.g., 53 percent at a site in India, Baskaran & Boominathan, 2010; 64 percent at a site in Indonesia, Healey et al., 2020; 86 percent at a site in China, Y. Wang et al., 2013). However, this pattern does not always hold (e.g., Seo et al., 2015; Silva et al., 2020). Such patterns may simply reflect variation in the abundance of amphibians relative to other taxa at these sites. Some studies have found a correlation between the number of roadkill occurrences recorded and the abundance of amphibian species in areas adjoining the road (e.g., Bhupathy et al., 2009). For species that migrate over short periods of time such as Korean clawed salamanders (*Onychodactylus koreanus*), roadkill could be a major threat to survival of the entire population (Shin et al., 2020). Overall, however, a quantitative link between roadkill of amphibians and the consequences for population viability are not well studied.

The indirect impacts of roads (at small scales and population levels) that have been investigated for amphibians mainly comprise changes in habitat use/quality and genetic impacts of isolation. Raised road surfaces may lead to water stagnating on either side and forming pools that are attractive to amphibians (Healey et al., 2020). In the case of poorly designed drainage ditches, such attractive pools could turn out to be ecological traps (Z. Zhang et al., 2010). The attraction of insects to lights along roads may in turn also attract amphibians to prey on them (Bhupathy et al., 2009), but this could also render them vulnerable to roadkill. Over larger landscapes, amphibian species richness has been found to be higher further away from roads (Aryal et al., 2020). Large-scale degradation in habitat caused by LI may also reduce the potential area of occupancy for amphibians, similar to other taxa (Hughes, 2019). Roads may also reduce the number of animals that cross successfully (either through direct mortality in collisions or the road structure making it physically difficult to cross). At least one study has investigated the consequences of such barrier effects for population genetics. It found that mountain ridges had a greater impact on population genetic structure for Chinese wood frogs than roads (Atlas & Fu, 2019). Broadly, the indirect impacts of LI at both small and large scales are not well investigated for amphibians.

Mitigation of direct and indirect impacts by modifying animal behavior is not well established for amphibians, although one study has suggested removal of less-important wetland patches near roads to reduce mortality (Gu et al., 2011). Several mitigation measures have been suggested to change human behavior, including road closure at night (Y. Zhang et al., 2018), improved signposting at collision hotspots (Healey et al., 2020), and speed reductions (Menon et al., 2015). There are few robust evaluations of the efficacy of these methods in the literature. Crossing structures combined with exclusion fencing are increasingly viewed as a means of reducing both roadkill and reducing barrier effects. Overpasses and underpasses are often designed for larger species, and this design often neglects the needs of smaller taxa; for example, 47 percent of sampled underpasses in South Korea did not have features that facilitate amphibian movement (Donggul et al., 2018). A few studies have however been carried out to experimentally determine design features that support amphibian movement. One of these involved experimental testing of the sizes and shapes of tunnels, as well as substrate types within, that are preferred by Chinese brown frogs during migration (Y. Wang et al., 2019). Similarly, experimental tests can help determine optimal shapes of drainage ditches to ensure that amphibians are not trapped within (determined for the common toad; Zhang et al., 2010), and optimal heights of drift fences to ensure they do not enter roads (Y. Wang et al., 2019). The relative ease of translocation studies for amphibians compared to larger taxa could provide opportunities for robust evaluation of the characteristics of crossing structures.

KEY FINDINGS

ROADS

1. India and China were the most represented countries in the 162 peer-reviewed papers and comprised 55 percent of our search results. Japan, South Korea, Nepal, and Malaysia also produced a significant number of studies. The representation of most other countries was relatively low; six of our 28 target countries were not represented in the literature (other than for continent-wide studies).

2. We found a taxonomic bias for mammals, with representation in 69 percent of the papers (Figure 4). Yet, the number of reptile species documented in roadkill occurrences was 62 percent higher than the number of mammal species (Table 2). Although reptiles are roughly twice as speciose as mammals, it is possible that the mammalian emphasis in studies of road impacts to wildlife may limit insights that are applicable for other taxa.

Studies that evaluated the direct and indirect impacts at small scales (e.g., a single railway line or a few specific roads in an area) have been documented for at least 611 species (Table 2) and 34 species (Table 3), respectively. Population-level impacts have been quantified for at least 41 species (

3. Table 4). Taken together, the literature highlights the significant impacts of roads on a wide array of species, representing many taxa throughout Asia. However, the resulting knowledge is heavily skewed toward direct impacts in comparison to indirect impacts and population-level impacts.

4. Direct road impacts were typically studied in a fragmented and site-specific manner at small scales. Direct impact studies were focused far more on documenting road impacts (i.e., producing lists of species that are killed on roads) rather than identifying the drivers of these mortalities and developing evidence-based solutions. As a result, relatively few generalizable or scalable insights for population-scale conservation were produced.

5. In terms of indirect impacts (Appendix B), the barrier effects of roads are relatively well studied, particularly via models that help predict habitat or landscape connectivity. The genetic consequences of these barrier effects are being increasingly addressed, particularly for mammals (Appendix C). Some of these consequences may not yet be apparent, due to the relatively short time that high-speed and high-volume roads have been prevalent in many countries or in biodiverse landscapes in Asia.

6. The impacts of roads (both direct and indirect) on demographic parameters and parameters related to species fitness at the population level (such as reproduction and mortality rates) were rarely studied. This is a major research gap in the literature today.

7. The literature is more oriented toward studying the impacts of roads than in evaluating the effectiveness of mitigation measures to reduce these impacts (495 percent more studies; Figure 4). Mitigation studies were more prevalent in the gray literature than in the peer-reviewed literature.

8. Of the more than 30 mitigation measures evaluated in other parts of the world (Huijser et al., 2008), only 10 were found to have been addressed (even to a small extent) in Asia. Yet, other mitigation measures (particularly those related to modifying human or animal behavior) have been implemented on the ground in several countries (based on the authors' anecdotal observations). The lack of documentation and evaluation of such measures makes it difficult to understand their efficacy in reducing the direct and indirect impacts of roads and developing best practices.

9. Measures that separate wildlife from roads but allow passage through crossing structures (such as overpasses and underpasses) are increasing in numbers across several Asian countries. At least 39 species have been documented using these structures to cross roads (whether they were designed for wildlife use or serve that purpose de facto; Appendix D). While structural separation measures are better documented than the other mitigation measures (Figure 4), there appears to be a mismatch between the hundreds of such structures constructed and the handful of studies that evaluate their effectiveness.

RAILWAYS

1. The 49 peer-reviewed rail studies were mainly concentrated in India, China, and Mongolia (63 percent of the database; Figure 3), and three specific regions within these countries (North Bengal in India, Tibet in China, and the Mongolian desert and steppe). The representation of most other Asian countries in the literature was relatively low; 14 of the 28 countries were not represented at all in this literature.

2. The number of studies that evaluated non-mammalian taxa was particularly low (20; Figure 4), even in comparison to roads. Within mammals, the focus was on large species; specifically, elephants and ungulates constituted 61 percent of rail ecology studies. It is unclear if this lack of representation of other taxa means that railway impacts on non-mammalian taxa (or smaller mammals) are low, or if these impacts are simply not detected or studied. It also makes findings from these studies less amenable for extrapolation to other species.

3. Direct and indirect impacts of individuals at small scales have been documented for at least 20 species (Table 5) and eight species (Table 6), respectively, and population-level impacts have been documented for at least nine species (Table 7). These numbers are much lower than the corresponding figures for the roads review, and when considered along with the low number of rail studies, they suggest the direct and indirect impacts of railways on wildlife in Asia are poorly understood.

4. The direct impacts of train strikes are most well documented for elephants. However, demographic data on the animals killed in train strikes (e.g., age-sex classifications) are surprisingly low even for this flagship species. Further, these data are rarely presented in the context of the local population (we found only one such study). As a result, there is a lack of robust linkages between train strikes on individuals and persistence of the local population of the species.

5. Studies of indirect impacts concentrate on the barrier effects of railways, particularly when the tracks are fenced or associated with human settlement. These barrier effects reduce the ability of wildlife to move in response to changes in resource availability, thereby reducing survival rates; they also reduce the area of occupancy by preventing animals from accessing suitable habitat (Appendix F). The consequences of the barrier effect caused by railways on gene flow are also increasingly being explored (Appendix G).

6. Studies on the impacts of railways are 283 percent more prevalent than studies on their mitigation (Figure 4). However, a diverse range of mitigation measures that aim to modify both human and animal behavior (the latter mainly oriented toward elephants) is being implemented for railways at several locations across Asia. These measures are mostly documented in the gray literature. However, the lack of robust quantification of their efficacy makes it difficult to understand whether they could be replicated in other locales across Asia.

7. There are relatively few studies in Asia on wildlife use of crossing structures built purposefully to provide safe passage across railway tracks. However, at least 14 species (Appendix H) have been documented to use such structures to cross over or under railway tracks. Design and location are key determinants of effectiveness. In particular, structures that are placed at the wrong locations may lead to increased and unnecessary energy expenditure by animals to access and cross them.

8. A handful of studies (mainly from the gray literature) indicate that structures built for engineering reasons (and not specifically for wildlife) may facilitate movement for some species across railway tracks. However, other studies indicate that some species (such as ungulates in Central Asia) may mostly avoid using these structures. The design features that determine whether animals use such structures are not well studied.

POWER LINES

1. The 78 peer-reviewed papers documented the impacts of power lines in 11 Asian countries with 75 percent of the studies from four countries: India, China, Mongolia, and Kazakhstan. Ten of the 28 countries that were the focus of the literature review were not represented in the literature.

2. Birds and mammals dominated the power line literature. Birds alone accounted for 53 percent of the literature and mammals were the focus of 40 percent of the literature.

3. Direct impacts have been documented for at least 113 species (Table 8), which include four Critically Endangered, 14 Endangered, 11 Vulnerable, and seven Near Threatened species in Asia. In contrast, indirect impacts and population-level impacts have been documented only for two and four species respectively.

4. Direct impact studies are mostly observations documenting electrocution and collision fatalities. More studies focused on electrocution impacts than collision impacts. Only a few studies explored direct impacts in detail and investigated factors responsible for observed fatalities.

5. Only two indirect impact observations were documented in the literature: habitat loss and fragmentation. Detailed studies focusing on indirect impacts of power lines and rigorous assessment of power line impacts on populations are completely lacking.

6. Like the road and rail literature, the majority of the studies focused on documenting power line impacts rather than their mitigation.

7. The installation and assessment of mitigation measures are largely focused on power line electrocution fatalities. However, information on the effectiveness of different types of power line mitigation measures that seek to reduce collision fatalities is lacking in the peer-reviewed literature.

RECOMMENDATIONS

RECOMMENDATIONS FOR FUTURE STUDIES ON THE IMPACTS OF LI IN ASIA

1. The three LI modes differ in the extent to which their contribution to direct animal mortality is documented; railways, in particular, require more of these basic data.

   The simple documentation of direct mortalities from LI (animal-vehicle collisions, train strikes, electrocutions and power line or tower collisions) is a crucial first step in the process of understanding the impacts of LI on wildlife populations in Asia. Summary statistics from such studies can offer a rapid and broad understanding of the extent of the problem. The impact of roads on wildlife is now at a stage where 611 species have been documented in AVCs; the problem is well established and demonstrates the need for mitigation. In contrast, Asia still needs to increase scientific inquiry into the direct impacts of rails and transmission lines on its ecosystems and species. Studies of wildlife mortality caused by railways are still in their early stages; it is not yet known whether the low number of species (20) documented is accurate or whether this number simply reflects a study bias on large mammals (such as elephants). Therefore, increased documentation and evaluation of wildlife deaths from trains is required to clarify the extent of train strikes on wildlife.

Knowledge about the impacts of power lines on wildlife is relatively nascent compared to roads, but it is higher than railways. While power line impacts have been documented for 113 species, further documentation would help establish the extent of the problem.

2. Direct mortality of wildlife by LI requires better correlation with explanatory variables to identify (and hence mitigate) risk factors.

   The lack of quality and sophistication in the documentation of direct mortality in most Asian studies hinders the ability to make broader applicability of their findings. To achieve broader applicability, mortality must also be correlated with spatio-temporal variables related to habitat, animal behavior, environment, roadway physical characteristics, and/or infrastructure design. In particular, studies of road impacts lack depth and remain focused on simple counting of roadkill. Studies on direct mortality of wildlife must become more systematic and explanatory in nature to enable robust inferences for conservation within and beyond the study area.

3. The consequences of direct impacts on population viability is currently under-studied across all three modes.

   Even when mortalities are quantified and correlated with explanatory variables, they are not often linked to the viability of the local population, which is usually the key outcome for species conservation. Broadly, this requires comparisons between demographic characteristics of the animals that die (e.g., count, age-sex classes) with the same characteristics of animals in the local population. Across all three modes, there is a clear lack of population-level context that would have been provided by investigating such population characteristics. Data relevant to population viability were surprisingly limited even for species of high conservation concern. For example, only one study on elephants compared sex classes represented in train collisions to sex-class distribution in the local population. Comparison of demographic characteristics of direct mortalities with those of the local population will help accurately assess LI impacts at a population level and prioritize the species/populations most in need of conservation action.

4. The study of animal movement across roads and railways needs to be better linked with demographic rescue, gene flow and access to habitat.

   Animal movement is increasingly being studied across Asia, particularly at large scales where the use of spatial models enables ecological connectivity (or lack thereof) to be modelled over large scales. But in the context of roads and railways, potential barrier effects need to be better linked with their actual impacts on population persistence. Demographic rescue and gene flow can often be accomplished by a low number of effective migrants per generation. By identifying these key thresholds for endangered species, the proper balance between mitigation of direct mortality and barrier effects (which may sometimes be contradictory) can be established. Such studies will also enable better quantification of the economic costs and benefits of restoring movement in comparison with other conservation interventions (e.g., restoring habitat) for ensuring species persistence.

5. Studies that compare standard variables before and after change in LI characteristics are required for evidence-based conservation action.

We found only a handful of studies that evaluated rigorously the impacts of LI or mitigation measures in a before-and-after study design. Before-After-Control-Impact (BACI) study designs can provide a robust framework to understand impacts and evaluate the efficacy of interventions. Although mitigation measures aimed at changing animal or human behavior appear to be commonly deployed across Asia, their effectiveness is poorly evaluated. Without a more rigorous evaluation, it is difficult to identify sound mitigation measures. Greater use of such quasi-experimental designs is crucial for building a robust base of evidence to differentiate effective and non-effective mitigation measures for the wide variety of species impacted by LI in the diverse ecoregions of Asia.

6. Economic benefits of environmental safeguards need greater study.

   Cost-effectiveness studies of the various mitigation measures used for all three modes of LI are needed. This is predicated on the availability of passive-use economic valuations of Asia's wildlife, which has many gaps and shortcomings. However, it is often important that LI decision makers more fully understand and articulate the economic benefits of mitigation measures, not just the costs of their deployment and maintenance. Thus, the current lack of cost-benefit studies of LI mitigation measures is a shortcoming that must be remedied.

7. Cumulative impacts of roads, railways and power lines are rarely addressed, and require greater study.

   Roads, railways, and power lines are often established near each other; consequently, their impacts on wildlife may be cumulative or interactive. Yet, we found few studies that explore these cumulative impacts at the small scale. The studies that do include the impacts of more than one of these modes tend to be large-scale modeling studies (e.g., of habitat loss or connectivity), and typically summarize them as density variables (e.g., road length per unit area). More detailed investigation at smaller scales will help in understanding interactive and non-linear effects that multiple LI modes in close proximity may have on wildlife.

8. Studies driven by flagship species must be leveraged for additional insights on co-occurring species.

   We found that charismatic species (particularly large mammals) are the subject of many more numerous LI studies; inference from these studies are also richer (e.g., in terms of implications for population viability) than those for other taxa (which are often restricted to documenting their deaths). A greater focus on "piggybacking" studies of other taxa along with those on charismatic large mammals can provide broader conservation insights. Similarly, mitigation measures that are implemented for specific focal species (e.g., tigers) also offer opportunities to mitigate impacts for other species—but these are often only restricted to other mammals. By leveraging the popularity and funding for flagship species to also gain knowledge on other co-occurring species, broader conservation benefits can potentially be gained.

RECOMMENDED MEASURES TO REDUCE THE IMPACTS OF LI IN ASIA

1. Carcass counts need to be corrected for persistence.

   The few studies that investigate carcass persistence along LI in Asia suggest that they disappear within hours or a few days for all major taxa, meaning that carcass counts may be under-reported.

While this bias may be mitigated to an extent through study design, it is also important to develop correction factors to improve future estimates.

2. More exploration of technology-based mitigation measures is required.

   Technology-based mitigation measures (e.g., animal detection systems using lidar, radar, or microwaves) have been implemented in some other parts of the world and are increasingly being recommended for investigation in Asia. However, we found almost no testing of these measures in Asia. Evaluation of these interventions under realistic field conditions would greatly help in understanding their costs and benefits under the conditions in Asia.

3. Retrofitting of structures built for other purposes for animal crossing is an important area of investigation.

   At least 30 species have been documented crossing roads and railway tracks using structures that were not specifically designed for wildlife. This suggests that, at least for some species, existing structures may serve the purposes of providing for habitat connectivity and decreasing the barrier effect. By developing clear protocols on retrofitting such structures, and understanding the species that use them, animal movement may be facilitated in a manner that is less expensive and yet effective and can be deployed on existing LI without waiting for a construction project.

4. A study that reviews non-English publications on LI can potentially unlock new ideas and knowledge.

   We came across a significant number of peer-reviewed publications on LI in non-English languages (particularly, Chinese, Japanese, and Korean) but were unable to extract much information from them. Given the large existing and planned infrastructure in these countries, an ancillary study that focuses on reviewing this literature would be a useful addition to the knowledge base of English language journals in Asia.

5. A handbook with guidelines and standards for mitigation of roads, railways, and transmission lines for Asia could offer a customized guide for practitioners.

   Several initial guidelines have recently been developed; for example, one for tiger landscapes and one for roads in Asia. Also, existing standards for practitioners have mostly been developed with a North American context; we found evidence that these guidelines are also used in planning mitigation measures for Asia. Developing a set of guidelines that benefit from the significant store of knowledge that already exists, but also customizes solutions for the species and conditions of Asia, could greatly help in providing robust recommendations to LI practitioners.

6. An online platform that interactively shares and visualizes data from studies on Asian LI could serve as a useful planning tool for practitioners.

   The numerous studies on LI that we found (both peer-reviewed and gray literature) are not collated together in any one location. More importantly, the key statistics from these studies (e.g., collision rates for different species) usually remain in text form within these studies. By extracting and visualizing these statistics in an online visualization platform, and adding to these as new studies come out, practitioners can access a useful spatial planning tool for new infrastructure.

7. Different types of mitigation measures are prevalent in different Asian countries, offering potential opportunities for learning and exchange of ideas.

   By setting up formal or informal opportunities for sharing of experiences and ideas from different countries, best practices and methods of implementation can be identified and possibly replicated. For example, measures to modify animal (mainly elephant) and human behavior are prevalent in India; experimental evaluation of crossing structures for herpetofauna is undertaken in China; South Korea appears to emphasize planning of crossing structures; and the development of a unique solution for primate electrocutions is progressing in Sri Lanka. A peer exchange forum offers the opportunity for practitioners to explore whether these measures would be applicable and feasible in their own countries.

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APPENDICES

APPENDIX A: LIST OF SPECIES DOCUMENTED IN ANIMAL-VEHICLE COLLISIONS IN ASIA

LIST OF SPECIES DOCUMENTED IN ANIMAL-VEHICLE COLLISIONS IN ASIA

TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Amphibian	Plateau brown frog	*Rana kukunoris*	China	Gu et al., 2013	LC
Amphibian	Songpan slow frog	*Nanorana pleskei*	China	Gu et al., 2013	NT
Amphibian	Asiatic Toad	*Bufo gargarizans*	China	Gu et al., 2013	LC
Amphibian	Japanese tree frog	*Dryophytes japonicus*	China	Wang et al., 2013	LC
Amphibian	Asiatic Toad	*Bufo gargarizans*	China	Wang et al., 2013	LC
Amphibian	Oriental Fire-bellied Toad	*Bombina orientalis*	China	Wang et al., 2013	LC
Amphibian	Black-spotted Pond Frog	*Pelophylax nigromaculatus*	China	Wang et al., 2013	NT
Amphibian	Chinese Brown Frog	*Rana chensinensis*	China	Wang et al., 2013	LC
Amphibian	Siberian Salamander	*Salamandrella keyserlingii*	China	Wang et al., 2013	LC
Amphibian	Asiatic Toad	*Bufo gargarizans*	China	Zhang et al., 2018	LC
Amphibian	Chinese Brown Frog	*Rana chensinensis*	China	Zhang et al., 2018	LC
Amphibian	Frogs		India	Anon., 2015	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Baskaran & Boominathan, 2010	LC
Amphibian	Malabar gliding frog	*Rhacophorus malabaricus*	India	Baskaran & Boominathan, 2010	LC
Amphibian	UID Frog		India	Baskaran & Boominathan, 2010	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Bhupathy et al., 2011	LC
Amphibian		*Indosylvirana sp.*	India	Bhupathy et al., 2011	NA
Amphibian	False-hourglass frog	*Polypedates pseudocruciger*	India	Bhupathy et al., 2011	LC
Amphibian	Malabar gliding frog	*Rhacophorus malabaricus*	India	Bhupathy et al., 2011	LC
Amphibian	Indian burrowing frog	*Sphaerotheca breviceps*	India	Bhupathy et al., 2011	LC
Amphibian		*Indirana sp.*	India	Bhupathy et al., 2011	NA
Amphibian			India	Dahanukar & Padhye, 2005	NA
Amphibian	Malabar gliding frog	*Rhacophorus malabaricus*	India	Dahanukar & Padhye, 2005	LC
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Dutta et al., 2016	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Dutta et al., 2016	LC
Amphibian	Skittering frog	*Euphlyctis cyanophlyctis*	India	Dutta et al., 2016	LC
Amphibian	Indian tree frog	*Polypedates maculatus*	India	Dutta et al., 2016	LC
Amphibian	Sri Lankan Bullfrog	*Uperodon taprobanicus*	India	Dutta et al., 2016	LC
Amphibian	Greater balloon frog	*Uperodon globulosus*	India	Dutta et al., 2016	LC
Amphibian	UID Frog		India	Dutta et al., 2016	NA
Amphibian	Amboli toad	*Xanthophryne tigerina*	India	Gaitonde et al., 2016	CR
Amphibian	Sreeni's golden-backed frog	*Indosylvirana sreeni*	India	Ganesh & Arumugam, 2015a	Not assessed
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Ganesh & Arumugam, 2015b	LC
Amphibian	Mangalore bullfrog	*Sphaerotheca dobsonii*	India	Ganesh & Arumugam, 2015b	LC
Amphibian	Sholiga narrow-mouthed frog	*Microhyla cf. sholigari*	India	Ganesh & Arumugam, 2015b	EN
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Ganesh & Arumugam, 2015b	LC
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Ganesh & Arumugam, 2015b	LC

LIST OF SPECIES DOCUMENTED IN ANIMAL-VEHICLE COLLISIONS IN ASIA

TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Amphibian	Sreeni's golden-backed frog	*Indosylvirana sreeni*	India	Ganesh & Arumugam, 2015b	Not assessed
Amphibian	Wayanad bush frog	*Pseudophilautus cf. wynaadensis*	India	Ganesh & Arumugam, 2015b	EN
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Ganesh & Arumugam, 2015b	LC
Amphibian	Wayanad bush frog	*Pseudophilautus cf. wynaadensis*	India	Ganesh & Arumugam, 2015b	EN
Amphibian		*Fejervarya sp.*	India	Ganesh & Arumugam, 2015b	NA
Amphibian		*Fejervarya sp.*	India	Ganesh & Arumugam, 2015b	NA
Amphibian		*Fejervarya sp.*	India	Ganesh & Arumugam, 2015b	NA
Amphibian	Anamalai gliding frog	*Rhacophorus pseudomalabaricus*	India	Harpalani et al., 2015	CR
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Jamdar & Hiware, 2012	LC
Amphibian	Caecilians		India	Jeganathan et al., 2018	NA
Amphibian	Frogs		India	Jeganathan et al., 2018	NA
Amphibian	Frog/Toad		India	Jeganathan et al., 2018	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Joshi & Dixit, 2012	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Joshi & Dixit, 2012	LC
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Joshi & Dixit, 2012	LC
Amphibian	Indian marbled toad	*Duttaphrynus stomaticus*	India	Joshi & Dixit, 2012	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Joshi & Dixit, 2012	LC
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Joshi & Dixit, 2012	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Joshi & Dixit, 2012	LC
Amphibian			India	Pratihar & Deuti, 2011	NA
Amphibian			India	Pratihar & Deuti, 2011	NA
Amphibian	Jerdon's bullfrog	*Hoplobatrachus crassus*	India	Pratihar & Deuti, 2011	LC
Amphibian	Amphibians		India	Rao & Girish, 2007	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Roy & Dey, 2015	LC
Amphibian	Common tree frog	*Polypedates leucomystax*	India	Roy & Dey, 2015	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Roy & Dey, 2015	LC
Amphibian	Nepal wart frog	*Fejervarya nepalensis*	India	Roy & Dey, 2015	LC
Amphibian	Sri Lankan Bullfrog	*Uperodon taprobanicus*	India	Roy & Dey, 2015	LC
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Samson et al., 2016	LC
Amphibian	Unidentified		India	Samson et al., 2016	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Santoshkumar et al., 2017	LC
Amphibian	Nilgiri wart frog	*Fejervarya nilagirica*	India	Santoshkumar et al., 2017	EN
Amphibian	Triangle-spotted Ramanella	*Uperodon triangularis*	India	Santoshkumar et al., 2017	VU
Amphibian	Cross-backed bush frog	*Raorchestes signatus*	India	Santoshkumar et al., 2017	EN
Amphibian	Nilgiri bush frog	*Raorchestes tinniens*	India	Santoshkumar et al., 2017	EN
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Sathish-Narayanan et al., 2016	LC
Amphibian	Southern burrowing frog	*Sphaerotheca rolandae*	India	Sathish-Narayanan et al., 2016	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Amphibian	Bi-coloured frog	*Clinotarsus curtipes*	India	Sathish-Narayanan et al., 2016	NT
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Selvan, 2011	LC
Amphibian	UID Frog		India	Selvan, 2011	NA
Amphibian	UID Caecilian		India	Selvan, 2011	NA
Amphibian	Toad		India	Selvan et al. 2012	NA
Amphibian	Other Amphibians		India	Selvan et al. 2012	NA
Amphibian	Bi-colored frog	*Clinotarsus curtipes*	India	Seshadri & Ganesh, 2011	NT
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Seshadri & Ganesh, 2011	LC
Amphibian	Skittering frog	*Euphlyctis cyanophlyctis*	India	Seshadri & Ganesh, 2011	LC
Amphibian		*Fejervarya sp*	India	Seshadri & Ganesh, 2011	NA
Amphibian	Frog sp		India	Seshadri & Ganesh, 2011	NA
Amphibian	Frog sp 1		India	Seshadri & Ganesh, 2011	NA
Amphibian	Frog sp 2		India	Seshadri & Ganesh, 2011	NA
Amphibian	Frog sp 3		India	Seshadri & Ganesh, 2011	NA
Amphibian	Frog sp 4		India	Seshadri & Ganesh, 2011	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Seshadri et al., 2009	LC
Amphibian	Skittering frog	*Euphlyctis cf. cyanophlyctis*	India	Seshadri et al., 2009	LC
Amphibian	Rufescent burrowing frog	*Fejervarya cf. rufescens*	India	Seshadri et al., 2009	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Seshadri et al., 2009	LC
Amphibian	Ornate narrow-mouthed frog	*Microhyla ornata*	India	Seshadri et al., 2009	LC
Amphibian	Jerdon's narrow-mouthed frog	*Uperodon montanus*	India	Seshadri et al., 2009	NT
Amphibian	Widespread fungoid frog	*Hydrophylax bahuvistara*	India	Seshadri et al., 2009	Not assessed
Amphibian	Western tree frog	*Polypedates cf. occidentalis*	India	Seshadri et al., 2009	DD
Amphibian	Beddome's caecilian	*Ichthyophis beddomei*	India	Seshadri et al., 2009	LC
Amphibian		*Fejervarya sp.*	India	Seshadri et al., 2009	NA
Amphibian		*Nyctibatrachus sp.*	India	Seshadri et al., 2009	NA
Amphibian		*Indirana sp.*	India	Seshadri et al., 2009	NA
Amphibian		*Ichthyophis sp.*	India	Seshadri et al., 2009	NA
Amphibian	Unidentified frogs		India	Seshadri et al., 2009	NA
Amphibian	Amphibians		India	Sharma, 1988	NA
Amphibian			India	Sharma et al., 2011	NA
Amphibian	Amphibians		India	Solanki et al., 2017	NA
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Sundar, 2004	LC
Amphibian	Indian marbled toad	*Duttaphrynus stomaticus*	India	Sundar, 2004	LC
Amphibian	Indian bullfrog	*Hoplobatrachus tigerinus*	India	Sundar, 2004	LC
Amphibian	UID ranids		India	Sundar, 2004	NA
Amphibian	UID frogs		India	Sundar, 2004	NA
Amphibian	Anamalai gliding frog	*Rhacophorus pseudomalabaricus*	India	Vasudevan & Dutta, 2000	CR
Amphibian	Asian common toad	*Duttaphrynus melanostictus*	India	Vijaykumar et al., 2001	LC
Amphibian	Family Ranidae		India	Vijaykumar et al., 2001	NA
Amphibian	Family Rhacophoridae		India	Vijaykumar et al., 2001	NA
Amphibian		*Uraeotphlus sp.*	India	Vijaykumar et al., 2001	NA
Amphibian		*Ichthyophis sp.*	India	Vijaykumar et al., 2001	NA
Amphibian	UID Ranids & Rhacophorids		India	Vijaykumar et al., 2001	NA
Amphibian	Ezo brown frog	*Rana pirica*	Japan	Yanagawa 2003	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Amphibian	Korean clawed salamander	*Onychodactylus koreanus*	South Korea	Shin et al., 2020	Not assessed
Amphibian	Yala toad	*Duttaphrynus atukoralei*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Asiatic Toad	*Duttaphrynus melanostictus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Sri Lankan Bullfrog	*Uperodon taprobanicus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Ornate narrow-mouthed frog	*Microhyla ornata*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Guangdong rice frog	*Microhyla rubra*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Eluru dot frog	*Uperodon variegatus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian		*Uperodon systoma*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Jerdon’s bullfrog	*Hoplobatrachus crassus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Boie's wart frog	*Fejervarya limnocharis*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Skittering frog	*Euphlyctis cyanophlyctis*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Green pond frog	*Euphlyctis hexadactylus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Gravenhorst's frog	*Hydrophylax gracilis*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Indian burrowing frog	*Sphaerotheca breviceps*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Roland's burrowing frog	*Sphaerotheca rolandae*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Ferguson's shrub frog	*Pseudophilautus fergusonianus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Polonnaruwa Shrub Frog	*Pseudophilautus regius*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Sri Lanka whipping frog	*Polypedates cruciger*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Indian tree frog	*Polypedates maculatus*	Sri Lanka	Karunarathna et al., 2013	LC
Amphibian	Ceylon caecilian	*Ichthyophis glutinosus*	Sri Lanka	Karunarathna et al., 2013	VU
Amphibian	Yala toad	*Duttaphrynus atukoralei*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Asiatic Toad	*Duttaphrynus melanostictus*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Montane frog	*Minervarya greenii*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian	Jerdon’s bullfrog	*Hoplobatrachus crassus*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Gravenhorst's frog	*Hydrophylax gracilis*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Gunther's golden backed frog	*Indosylvirana temporalis*	Sri Lanka	Karunarathna et al., 2017	NT
Amphibian	Ornate narrow-mouthed frog	*Microhyla ornata*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Sri Lanka narrow-mouth frog	*Microhyla zeylanica*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian	Indian tree frog	*Polypedates maculatus*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Horton Plains shrub frog	*Pseudophilautus alto*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian	Round-snout pygmy frog	*Pseudophilautus femoralis*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian	Conical wart pygmy tree frog	*Pseudophilautus schmarda*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian	Pug-nosed Shrub Frog	*Pseudophilautus silus*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian	Half-webbed pug-snout frog	*Uperodon palmatus*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian		*Taruga eques*	Sri Lanka	Karunarathna et al., 2017	EN
Amphibian		*Uperodon systoma*	Sri Lanka	Karunarathna et al., 2017	LC
Amphibian	Jerdon’s bullfrog	*Hoplobatrachus crassus*	Sri Lanka	Madawala et al., 2019	LC
Amphibian	Gravenhorst's frog	*Hydrophylax gracilis*	Sri Lanka	Madawala et al., 2019	LC
Amphibian	Asiatic Toad	*Duttaphrynus melanostictus*	Thailand	Silva et al., 2020	LC
Amphibian	Boie's wart frog	*Fejervarya limnocharis*	Thailand	Silva et al., 2020	LC
Amphibian	Chinese edible frog	*Hoplobatrachus rugulosus*	Thailand	Silva et al., 2020	LC
Amphibian		*Occidozyga sp.*	Thailand	Silva et al., 2020	NA
Amphibian	Unknown		Thailand	Silva et al., 2020	NA
Amphibian	Koh Tao Island caecilian	*Ichthyophis kohtaoensis*	Thailand	Silva et al., 2020	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Amphibian	Balloon frog	*Glyphoglossus molossus*	Thailand	Silva et al., 2020	NT
Amphibian	Siam narrowmouth toad	*Kaloula mediolineata*	Thailand	Silva et al., 2020	NT
Amphibian	Banded bull frog	*Kaloula pulchra*	Thailand	Silva et al., 2020	LC
Amphibian		*Kaloula sp.*	Thailand	Silva et al., 2020	NA
Amphibian	Ornate chorus frog	*Microhyla fissipes*	Thailand	Silva et al., 2020	LC
Amphibian		*Microhyla sp.*	Thailand	Silva et al., 2020	NA
Amphibian		*Rana sp.*	Thailand	Silva et al., 2020	NA
Amphibian		*Unknown*	Thailand	Silva et al., 2020	NA
Amphibian	Guangdong frog	*Hylarana macrodactyla*	Thailand	Silva et al., 2020	LC
Amphibian	Black-striped frog	*Sylvirana nigrovittata*	Thailand	Silva et al., 2020	LC
Amphibian		*Unknown*	Thailand	Silva et al., 2020	NA
Amphibian	Common tree frog	*Polypedates leucomystax*	Thailand	Silva et al., 2020	LC
Bird	Eye-browed Thrush	*Turdus obscurus*	China	Wang et al., 2013	LC
Bird	Pale Thrush	*Turdus pallidus*	China	Wang et al., 2013	LC
Bird	White Wagtail	*Motacilla alba*	China	Wang et al., 2013	LC
Bird	Tristram's Bunting	*Emberiza tristrami*	China	Wang et al., 2013	LC
Bird	Pine Bunting	*Emberiza leucocephalos*	China	Wang et al., 2013	LC
Bird	Daurian Redstart	*Phoenicurus auroreus*	China	Wang et al., 2013	LC
Bird	Ural Owl	*Strix uralensis*	China	Wang et al., 2013	LC
Bird	Long-tailed Rosefinch	*Uragus sibiricus*	China	Wang et al., 2013	LC
Bird	Long-tailed Tit	*Aegithalos caudatus*	China	Wang et al., 2013	LC
Bird	Chestnut-eared Bunting	*Emberiza fucata*	China	Wang et al., 2013	LC
Bird	Manchurian Bush-warbler	*Cettia canturians*	China	Wang et al., 2013	LC
Bird	Brown Shrike	*Lanius cristatus*	China	Wang et al., 2013	LC
Bird	Orange-flanked Bush-robin	*Tarsiger cyanurus*	China	Wang et al., 2013	LC
Bird	Hazel Grouse	*Bonasa bonasia*	China	Wang et al., 2013	LC
Bird	Yellow-throated Bunting	*Emberiza elegans*	China	Wang et al., 2013	LC
Bird	Grey-backed Thrush	*Turdus hortulorum*	China	Wang et al., 2013	LC
Bird	Eurasian Bellfinch	*Pyrrhula pyrrhula*	China	Wang et al., 2013	LC
Bird	Gray Wagtail	*Motacilla cinerea*	China	Wang et al., 2013	LC
Bird	Cinereous Bunting	*Emberiza cineracea*	China	Wang et al., 2013	NT
Bird	Barn Swallow	*Hirundo rustica*	China	Wang et al., 2013	LC
Bird	Grey-headed woodpecker	*Picus canus*	China	Wang et al., 2013	LC
Bird	Tree Sparrow	*Passer montanus*	China	Wang et al., 2013	LC
Bird	Coal Tit	*Parus ater*	China	Wang et al., 2013	LC
Bird	Common Buzzard	*Buteo buteo*	China	Wang et al., 2013	LC
Bird	Eurasian Nuthatch	*Sitta europaea*	China	Wang et al., 2013	LC
Bird	Rufous Turtle Dove	*Streptopelia orientalis*	China	Wang et al., 2013	LC
Bird	Olive-backed Pipit	*Anthus hodgsoni*	China	Wang et al., 2013	LC
Bird	Little Grebe	*Tachybaptus ruficollis*	China	Wang et al., 2013	LC
Bird	Marsh Tit	*Parus palustris*	China	Wang et al., 2013	LC
Bird	Ashy Prinia	*Prinia socialis*	India	Anon, 2015	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Anon, 2015	LC
Bird	Large Grey Babbler	*Argya malcolmi*	India	Anon, 2015	LC
Bird	Indian Peafowl	*Pavo cristatus*	India	Anon, 2015	LC
Bird	Nightjar		India	Areendran & Pasha, 2000 in Rajvanshi et al., 2001	NA
Bird	White-rumped Vulture	*Gyps bengalensis*	India	Areendran & Pasha, 2000 in Rajvanshi et al., 2001	CR
Bird	Red Junglefowl	*Gallus gallus*	India	Areendran & Pasha, 2000 in Rajvanshi et al., 2001	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Baskaran & Boominathan, 2010	LC
Bird	Indian Nightjar	*Caprimulgus asiaticus*	India	Baskaran & Boominathan, 2010	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Bird	Common Myna	*Acridotheres tristis*	India	Baskaran & Boominathan, 2010	LC
Bird	Western Spotted Dove	*Spilopelia chinensis*	India	Baskaran & Boominathan, 2010	LC
Bird	Oriental Magpie-robin	*Copsychus saularis*	India	Baskaran & Boominathan, 2010	LC
Bird	Chestnut-shouldered Bush-sparrow	*Gymnoris xanthocollis*	India	Baskaran & Boominathan, 2010	LC
Bird	Common Hoopoe	*Upupa epops*	India	Baskaran & Boominathan, 2010	LC
Bird	UID Bird		India	Baskaran & Boominathan, 2010	NA
Bird	Eurasian Collared-dove	*Streptopelia decaocto*	India	Chhangani 2004a	LC
Bird	Common Babbler	*Argya caudata*	India	Chhangani, 2004a	LC
Bird	House Sparrow	*Passer domesticus*	India	Chhangani, 2004a	LC
Bird	Laughing Dove	*Spilopelia senegalensis*	India	Chhangani, 2004a	LC
Bird	Grey Francolin	*Francolinus pondicerianus*	India	Chhangani, 2004a	LC
Bird	House Crow	*Corvus splendens*	India	Chhangani, 2004a	LC
Bird	Red Turtle-dove	*Streptopelia tranquebarica*	India	Chhangani, 2004a	LC
Bird	White-rumped Vulture	*Gyps bengalensis*	India	Chhangani, 2004a	CR
Bird	Pied Bushchat	*Saxicola caprata*	India	Chhangani, 2004a	LC
Bird	Western Koel	*Eudynamys scolopaceus*	India	Chhangani, 2004a	LC
Bird	Common Quail	*Coturnix coturnix*	India	Chhangani, 2004a	LC
Bird	Grey Junglefowl	*Gallus sonneratii*	India	Chhangani, 2004a	LC
Bird	Jungle Babbler	*Turdoides striata*	India	Chhangani, 2004a	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Chhangani, 2004a	LC
Bird	Indian Peafowl	*Pavo cristatus*	India	Chhangani, 2004a	LC
Bird	Rock Dove	*Columba livia*	India	Chhangani, 2004a	LC
Bird	Indian Vulture	*Gyps indicus*	India	Chhangani, 2004a	CR
Bird	Common Myna	*Acridotheres tristis*	India	Chhangani, 2004a	LC
Bird	Rock Bush-quail	*Perdicula argoondah*	India	Chhangani, 2004a	LC
Bird	Large-billed Crow	*Corvus macrorhynchos*	India	Chhangani, 2004a	LC
Bird	Indian Robin	*Saxicoloides fulicatus*	India	Chhangani, 2004a	LC
Bird	Cattle Egret	*Bubulcus ibis*	India	Chhangani, 2004a	LC
Bird	Black Drongo	*Dicrurus macrocercus*	India	Chhangani, 2004a	LC
Bird	Rufous Treepie	*Dendrocitta vagabunda*	India	Chhangani, 2004a	LC
Bird	Indian Nightjar	*Caprimulgus asiaticus*	India	Chhangani, 2004a	LC
Bird	Common Moorhen	*Gallinula chloropus*	India	Chhangani, 2004a	LC
Bird	Spotted Owlet	*Athene brama*	India	Chhangani, 2004a	LC
Bird	Brahminy Starling	*Sturnus pagodarum*	India	Chhangani, 2004a	LC
Bird	Rosy Starling	*Sturnus roseus*	India	Chhangani, 2004a	LC
Bird	Sirkeer Malkoha	*Taccocua leschenaultii*	India	Chhangani, 2004a	LC
Bird	White-bellied Drongo	*Dicrurus caerulescens*	India	Chhangani, 2004a	LC
Bird	Eurasian Collared-dove	*Streptopelia decaocto*	India	Dhindsa et al., 1988	LC
Bird	House Sparrow	*Passer domesticus*	India	Dhindsa et al., 1988	LC
Bird	Common Myna	*Acridotheres tristis*	India	Dhindsa et al., 1988	LC
Bird	Little Egret	*Egretta garzetta*	India	Dhindsa et al., 1988	LC
Bird	Red-wattled Lapwing	*Vanellus indicus*	India	Dhindsa et al., 1988	LC
Bird	Indian Roller	*Coracias benghalensis*	India	Dhindsa et al., 1988	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Jeganathan et al., 2018	LC
Bird	Red-whiskered Bulbul	*Pycnonotus jocosus*	India	Jeganathan et al., 2018	LC
Bird	Indian Scimitar-babbler	*Pomatorhinus horsfieldii*	India	Jeganathan et al., 2018	LC
Bird	Unidentified birds		India	Jeganathan et al., 2018	NA
Bird	White-breasted Kingfisher	*Halcyon smyrnensis*	India	Jeganathan et al., 2018	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Jeganathan et al., 2018	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Bird	Nightjar sp.		India	Jeganathan et al., 2018	NA
Bird	Western Spotted Dove	*Spilopelia chinensis*	India	Jeganathan et al., 2018	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Joshi & Dixit 2012	LC
Bird	Jungle Owlet	*Glaucidium radiatum*	India	Joshi & Dixit 2012	LC
Bird	Indian Peafowl	*Pavo cristatus*	India	Joshi & Dixit 2012	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Joshi & Dixit 2012	LC
Bird	Blue-tailed Bee-eater	*Merops philippinus*	India	Joshi & Dixit 2012	LC
Bird	Asian Green Bee-eater	*Merops orientalis*	India	Joshi & Dixit 2012	LC
Bird	Wire-tailed Swallow	*Hirundo smithii*	India	Joshi & Dixit 2012	LC
Bird	Pacific Swift	*Apus pacificus*	India	Joshi & Dixit 2012	LC
Bird	Jungle Owlet	*Glaucidium radiatum*	India	Joshi & Dixit 2012	LC
Bird	Alexandrine Parakeet	*Psittacula eupatria*	India	Joshi & Dixit 2012	NT
Bird	Purple Sunbird	*Cinnyris asiaticus*	India	Joshi & Dixit 2012	LC
Bird	Indian Peafowl	*Pavo cristatus*	India	Joshi & Dixit 2012	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Joshi & Dixit 2012	LC
Bird	Blue-tailed Bee-eater	*Merops philippinus*	India	Joshi & Dixit 2012	LC
Bird	Asian Green Bee-eater	*Merops orientalis*	India	Joshi & Dixit 2012	LC
Bird	Wire-tailed Swallow	*Hirundo smithii*	India	Joshi & Dixit 2012	LC
Bird	Pacific Swift	*Apus pacificus*	India	Joshi & Dixit 2012	LC
Bird	Jungle Owlet	*Glaucidium radiatum*	India	Joshi & Dixit 2012	LC
Bird	Purple Sunbird	*Cinnyris asiaticus*	India	Joshi & Dixit 2012	LC
Bird	Slaty-breasted Rail	*Lewinia striata*	India	Kannan et al., 2008	LC
Bird	Savanna Nightjar	*Caprimulgus affinis*	India	Manakadan et al., 2009	LC
Bird	Birds		India	Maurya et al., 2011	NA
Bird	Andaman Coucal	*Centropus andamanensis*	India	Pande et al., 2011	LC
Bird	Grey Francolin	*Francolinus pondicerianus*	India	Prajapati, 2016	LC
Bird	Common Hoopoe	*Upupa epops*	India	Prajapati, 2016	LC
Bird	Indian Roller	*Coracias benghalensis*	India	Prajapati, 2016	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Prajapati, 2016	LC
Bird	Rose-ringed Parakeet	*Psittacula krameri*	India	Prajapati, 2016	LC
Bird	Rock Dove	*Columba livia*	India	Prajapati, 2016	LC
Bird	Eurasian Collared-dove	*Streptopelia decaocto*	India	Prajapati, 2016	LC
Bird	Red-wattled Lapwing	*Vanellus indicus*	India	Prajapati, 2016	LC
Bird	Shikra	*Accipiter badius*	India	Prajapati, 2016	LC
Bird	Cattle Egret	*Bubulcus ibis*	India	Prajapati, 2016	LC
Bird	Black-headed Ibis	*Threskiornis melanocephalus*	India	Prajapati, 2016	NT
Bird	House Crow	*Corvus splendens*	India	Prajapati, 2016	LC
Bird	Large-billed Crow	*Corvus macrorhynchos*	India	Prajapati, 2016	LC
Bird	Common Myna	*Acridotheres tristis*	India	Prajapati, 2016	LC
Bird	Large Grey Babbler	*Argya malcolmi*	India	Prajapati, 2016	LC
Bird	House Sparrow	*Passer domesticus*	India	Prajapati, 2016	LC
Bird			India	Rao & Girish, 2007	NA
Bird	House Crow	*Corvus splendens*	India	Samson et al., 2016	LC
Bird	Common Myna	*Acridotheres tristis*	India	Samson et al., 2016	LC
Bird	Laughing Dove	*Spilopelia senegalensis*	India	Samson et al., 2016	LC
Bird	Eurasian Collared-dove	*Streptopelia decaocto*	India	Samson et al., 2016	LC
Bird	Grey Francolin	*Francolinus pondicerianus*	India	Samson et al., 2016	LC
Bird	Indian Robin	*Saxicoloides fulicatus*	India	Samson et al., 2016	LC
Bird	Jungle Babbler	*Turdoides striata*	India	Samson et al., 2016	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Samson et al., 2016	LC
Bird	House Sparrow	*Passer domesticus*	India	Samson et al., 2016	LC
Bird	Common Tailorbird	*Orthotomus sutorius*	India	Samson et al., 2016	LC
Bird	Western Koel	*Eudynamys scolopaceus*	India	Samson et al., 2016	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Bird	Common Hoopoe	*Upupa epops*	India	Samson et al., 2016	LC
Bird	Western Koel	*Eudynamys scolopaceus*	India	Sathish-Narayanan et al., 2016	LC
Bird	Blue-faced Malkoha	*Phaenicophaeus viridirostris*	India	Sathish-Narayanan et al., 2016	LC
Bird	Common Tailorbird	*Orthotomus sutorius*	India	Sathish-Narayanan et al., 2016	LC
Bird	Jungle Babbler	*Turdoides striata*	India	Sathish-Narayanan et al., 2016	LC
Bird	Jungle Owlet	*Glaucidium radiatum*	India	Selvan, 2011	LC
Bird	Indian Roller	*Coracias benghalensis*	India	Selvan, 2011	LC
Bird	Indian Nightjar	*Caprimulgus asiaticus*	India	Selvan, 2011	LC
Bird	Common Myna	*Acridotheres tristis*	India	Selvan, 2011	LC
Bird	Western Spotted Dove	*Spilopelia chinensis*	India	Selvan, 2011	LC
Bird	Grey-capped Emerlad Dove	*Chalcophaps indica*	India	Selvan, 2011	LC
Bird	UID Bird		India	Selvan, 2011	NA
Bird	UID Cuckoo		India	Selvan, 2011	NA
Bird	Owl		India	Selvan et al., 2012	NA
Bird			India	Selvan et al., 2012	NA
Bird	Cattle Egret	*Bubulcus ibis*	India	Sharma, 1988	LC
Bird	Red-naped Ibis	*Pseudibis papillosa*	India	Sharma, 1988	LC
Bird	Shikra	*Accipiter badius*	India	Sharma, 1988	LC
Bird	White-rumped Vulture	*Gyps bengalensis*	India	Sharma, 1988	CR
Bird	Egyptian Vulture	*Neophron percnopterus*	India	Sharma, 1988	EN
Bird	Grey Francolin	*Francolinus pondicerianus*	India	Sharma, 1988	LC
Bird	Indian Peafowl	*Pavo cristatus*	India	Sharma, 1988	LC
Bird	Sarus Crane	*Grus antigone*	India	Sharma, 1988	VU
Bird	Rock Dove	*Columba livia*	India	Sharma, 1988	LC
Bird	Eurasian Collared-dove	*Streptopelia decaocto*	India	Sharma, 1988	LC
Bird	Rose-ringed Parakeet	*Psittacula krameri*	India	Sharma, 1988	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Sharma, 1988	LC
Bird	Spotted Owlet	*Athene brama*	India	Sharma, 1988	LC
Bird	Asian Green Bee-eater	*Merops orientalis*	India	Sharma, 1988	LC
Bird	Indian Roller	*Coracias benghalensis*	India	Sharma, 1988	LC
Bird	Common Hoopoe	*Upupa epops*	India	Sharma, 1988	LC
Bird	Yellow-crowned Woodpecker	*Leiopicus mahrattensis*	India	Sharma, 1988	LC
Bird	Black Drongo	*Dicrurus macrocercus*	India	Sharma, 1988	LC
Bird	Common Myna	*Acridotheres tristis*	India	Sharma, 1988	LC
Bird	House Crow	*Corvus splendens*	India	Sharma, 1988	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Sharma, 1988	LC
Bird	Jungle Babbler	*Turdoides striata*	India	Sharma, 1988	LC
Bird	Common Tailorbird	*Orthotomus sutorius*	India	Sharma, 1988	LC
Bird	Pied Bushchat	*Saxicola caprata*	India	Sharma, 1988	LC
Bird	Indian Robin	*Saxicoloides fulicatus*	India	Sharma, 1988	LC
Bird	House Sparrow	*Passer domesticus*	India	Sharma, 1988	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Sivakumar & Manakadan, 2010	LC
Bird	Indian Nightjar	*Caprimulgus asiaticus*	India	Sivakumar & Manakadan, 2010	LC
Bird	Common Tailorbird	*Orthotomus sutorius*	India	Sivakumar & Manakadan, 2010	LC
Bird	Spotted Owlet	*Athene brama*	India	Sivakumar & Manakadan, 2010	LC
Bird	Brown Shrike	*Lanius cristatus*	India	Sivakumar & Manakadan, 2010	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Bird	Western Spotted Dove	*Spilopelia chinensis*	India	Sivakumar & Manakadan, 2010	LC
Bird	Oriental Magpie-robin	*Copsychus saularis*	India	Sivakumar & Manakadan, 2010	LC
Bird	Large-billed Crow	*Corvus macrorhynchos*	India	Sivakumar & Manakadan, 2010	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	India	Sivakumar & Manakadan, 2010	LC
Bird	Red-wattled Lapwing	*Vanellus indicus*	India	Sivakumar & Manakadan, 2010	LC
Bird			India	Solanki et al., 2017	NA
Bird	Black-rumped Flameback	*Dinopium benghalense*	India	Sundar, 2004	LC
Bird	Common Hoopoe	*Upupa epops*	India	Sundar, 2004	LC
Bird	Indian Roller	*Coracias benghalensis*	India	Sundar, 2004	LC
Bird	Greater Coucal	*Centropus sinensis*	India	Sundar, 2004	LC
Bird	Rose-ringed Parakeet	*Psittacula krameri*	India	Sundar, 2004	LC
Bird	White-breasted Waterhen	*Amaurornis phoenicurus*	India	Sundar, 2004	LC
Bird	Cattle Egret	*Bubulcus ibis*	India	Sundar, 2004	LC
Bird	Indian Pond-heron	*Ardeola grayii*	India	Sundar, 2004	LC
Bird	House Crow	*Corvus splendens*	India	Sundar, 2004	LC
Bird	Large-billed Crow	*Corvus macrorhynchos*	India	Sundar, 2004	LC
Bird	Brahminy Starling	*Sturnus pagodarum*	India	Sundar, 2004	LC
Bird	Asian Pied Starling	*Gracupica contra*	India	Sundar, 2004	LC
Bird	Common Myna	*Acridotheres tristis*	India	Sundar, 2004	LC
Bird	Bank Myna	*Acridotheres ginginianus*	India	Sundar, 2004	LC
Bird	Plain Prinia	*Prinia inornata*	India	Sundar, 2004	LC
Bird	Large Grey Babbler	*Argya malcolmi*	India	Sundar, 2004	LC
Bird	House Sparrow	*Passer domesticus*	India	Sundar, 2004	LC
Bird	Western Spotted Dove	*Spilopelia chinensis*	India	Vijaykumar et al., 2001	LC
Bird	Red Junglefowl	*Gallus gallus*	Malaysia	Kasmuri et al., 2020	LC
Bird	Family Strigidae		Malaysia	Kasmuri et al., 2020	NA
Bird		*Tyto alba*	Malaysia	Kasmuri et al., 2020	LC
Bird	Buffy fish owl	*Ketupa ketupu*	Malaysia	Kasmuri et al., 2020	LC
Bird	Spotted wood owl	*Strix seloputo*	Malaysia	Kasmuri et al., 2020	LC
Bird	Japanese sparrowhawk	*Accipiter gularis*	Malaysia	Kasmuri et al., 2020	LC
Bird	Eagle		Malaysia	Kasmuri et al., 2020	NA
Bird	White-breasted Waterhen	*Amaurornis phoenicurus*	Malaysia	Kasmuri et al., 2020	LC
Bird	Yellow bittern		Malaysia	Kasmuri et al., 2020	NA
Bird	Common Myna	*Acridotheres tristis*	Malaysia	Kasmuri et al., 2020	LC
Bird	Oriental pied hornbill	*Anthracoceros albirostris*	Malaysia	Kasmuri et al., 2020	LC
Bird	Greater Coucal	*Centropus sinensis*	Malaysia	Kasmuri et al., 2020	LC
Bird	Slaty-breasted rail	*Gallirallus striatus*	Malaysia	Kasmuri et al., 2020	LC
Bird	White-breasted Kingfisher	*Halcyon smyrnensis*	Malaysia	Kasmuri et al., 2020	LC
Bird	Lesser adjutant	*Leptoptilos javanicus*	Malaysia	Kasmuri et al., 2020	VU
Bird	Black-naped oriole	*Oriolus chinensis*	Malaysia	Kasmuri et al., 2020	LC
Bird	Stork-billed kingfisher	*Pelargopsis capensis*	Malaysia	Kasmuri et al., 2020	LC
Bird	Jerdon's nightjar	*Caprimulgus atripennis*	Sri Lanka	Karunarathna et al., 2017	LC
Bird	Chestnut-winged cuckoo	*Clamator coromandus*	Sri Lanka	Karunarathna et al., 2017	LC
Bird	Sri Lanka jungle fowl	*Gallus lafayettii*	Sri Lanka	Karunarathna et al., 2017	LC
Bird	Pied Bushchat	*Saxicola caprata*	Sri Lanka	Karunarathna et al., 2017	LC
Bird	Indian Robin	*Saxicoloides fulicatus*	Sri Lanka	Karunarathna et al., 2017	LC
Bird	Red-vented Bulbul	*Pycnonotus cafer*	Sri Lanka	Karunarathna et al., 2017	LC
Bird		*Turdus merula*	Sri Lanka	Karunarathna et al., 2017	LC
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird	Unknown		Thailand	Silva et al., 2020	NA

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Bird	Prinia sp.		Thailand	Silva et al., 2020	NA
Bird	Western Spotted Dove	*Spilopelia chinensis*	Thailand	Silva et al., 2020	LC
Bird	Large-billed Crow	*Corvus macrorhynchos*	Thailand	Silva et al., 2020	LC
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird	Coral-billed ground cuckoo	*Carpococcyx renauldi*	Thailand	Silva et al., 2020	VU
Bird	Lesser coucal	*Centropus bengalensis*	Thailand	Silva et al., 2020	LC
Bird		*Centropus sp.*	Thailand	Silva et al., 2020	NA
Bird	Western Koel	*Eudynamys scolopaceus*	Thailand	Silva et al., 2020	LC
Bird	Green-billed malkoha	*Phaenicophaeus tristis*	Thailand	Silva et al., 2020	LC
Bird	Greater racket-tailed drongo	*Dicrurus paradiseus*	Thailand	Silva et al., 2020	LC
Bird	Scaly-breasted munia	*Lonchura punctulata*	Thailand	Silva et al., 2020	LC
Bird	White-rumped munia	*Lonchura striata*	Thailand	Silva et al., 2020	LC
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird	Asian fairy-bluebird	*Irena puella*	Thailand	Silva et al., 2020	LC
Bird	Green-eared Barbet	*Megalaima faiostricta*	Thailand	Silva et al., 2020	LC
Bird	Brown-throated sunbird	*Anthreptes malacensis*	Thailand	Silva et al., 2020	LC
Bird	Little spiderhunter	*Arachnothera longirostra*	Thailand	Silva et al., 2020	LC
Bird	Olive-backed sunbird	*Cinnyris jugularis*	Thailand	Silva et al., 2020	LC
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird	House Sparrow	*Passer domesticus*	Thailand	Silva et al., 2020	LC
Bird	Tree Sparrow	*Passer montanus*	Thailand	Silva et al., 2020	LC
Bird	Passer sp.		Thailand	Silva et al., 2020	NA
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird	Domestic chicken	*Gallus gallus domesticus*	Thailand	Silva et al., 2020	NA
Bird	Sooty-headed bulbul	*Pycnonotus aurigaster*	Thailand	Silva et al., 2020	LC
Bird	Ayeyarwady bulbul	*Pycnonotus blanfordi*	Thailand	Silva et al., 2020	LC
Bird	Black-capped bulbul	*Pycnonotus melanicterus*	Thailand	Silva et al., 2020	LC
Bird		*Pycnonotus sp.*	Thailand	Silva et al., 2020	NA
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird	White-breasted Waterhen	*Amaurornis phoenicurus*	Thailand	Silva et al., 2020	LC
Bird	Asian barred owlet	*Glaucidium cuculoides*	Thailand	Silva et al., 2020	LC
Bird	Great myna	*Acridotheres grandis*	Thailand	Silva et al., 2020	LC
Bird		*Acridotheres sp.*	Thailand	Silva et al., 2020	NA
Bird	Common Myna	*Acridotheres tristis*	Thailand	Silva et al., 2020	LC
Bird	Unknown		Thailand	Silva et al., 2020	NA
Bird		*Tyto alba*	Thailand	Silva et al., 2020	LC
Bird	Unknown		Thailand	Silva et al., 2020	NA
Invertebrate	Crimson Rose Butterfly	*Pachliopta hector*	India	Anon, 2015	LC
Invertebrate			India	Choudhury, 2008	NA
Invertebrate	Earthworms		India	Jeganathan et al., 2018	NA
Invertebrate	Scorpions		India	Jeganathan et al., 2018	NA
Invertebrate	Spiders		India	Jeganathan et al., 2018	NA
Invertebrate	Centipedes		India	Jeganathan et al., 2018	NA
Invertebrate	Millipedes		India	Jeganathan et al., 2018	NA
Invertebrate	Pill millipedes		India	Jeganathan et al., 2018	NA
Invertebrate	Crabs		India	Jeganathan et al., 2018	NA
Invertebrate	Beetles		India	Jeganathan et al., 2018	NA
Invertebrate	Butterflies		India	Jeganathan et al., 2018	NA
Invertebrate	Caterpillars		India	Jeganathan et al., 2018	NA
Invertebrate	Cockroaches		India	Jeganathan et al., 2018	NA
Invertebrate	Crickets		India	Jeganathan et al., 2018	NA
Invertebrate	Damselfly		India	Jeganathan et al., 2018	NA
Invertebrate	Glow worms		India	Jeganathan et al., 2018	NA
Invertebrate	Grasshoppers		India	Jeganathan et al., 2018	NA
Invertebrate	Unidentified insects		India	Jeganathan et al., 2018	NA

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Invertebrate	Moths		India	Jeganathan et al., 2018	NA
Invertebrate	Praying mantis		India	Jeganathan et al., 2018	NA
Invertebrate	Stick insects		India	Jeganathan et al., 2018	NA
Invertebrate	Wasp		India	Jeganathan et al., 2018	NA
Invertebrate	Cicada		India	Jeganathan et al., 2018	NA
Invertebrate	Slugs		India	Jeganathan et al., 2018	NA
Invertebrate	Snails		India	Jeganathan et al., 2018	NA
Invertebrate	Double Banded Blue Crow	*Euploea sylvester hopei*	India	Mudai et al., 2015	Not assessed
Invertebrate			India	Rao & Girish, 2007	NA
Invertebrate			India	Roshnath & Cyriac, 2013	NA
Invertebrate	Common Crow	*Euploea core*	India	Sathish-Narayanan et al., 2016	LC
Invertebrate	Northern Lime Swallowtail	*Papilio demoleus*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Indian Jezebel	*Delias eucharis*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Baronet	*Symphaedra nais*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Indian Blue Mormon	*Papilio polymnestor*	India	Satihsh-Narayanan et al., 2016	Not assessed
Invertebrate	Mottled emigrant	*Catopsilia pyranthe*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Odonata (Dragon fly)	*Ortetrum cancellatum*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Grass hoper	*Melanoplus femurrubrum*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Millipedes	*Spinotarsus colosseus*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Pill Bug	*Arthrosphaera magna*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Snail	*Helix aspersa*	India	Sathish-Narayanan et al., 2016	Not assessed
Invertebrate	Scorpion sp 1		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Scorpion sp 2		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Spider sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Centipede sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Millipede sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Pill Millipede sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Ant sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Tawny Coster	*Acraea terpsicore*	India	Seshadri & Ganesh, 2011	Not assessed
Invertebrate	Bee sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Beetle sp 1		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Beetle sp 2		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Bug sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Butterfly sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Caterpillar sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Casemoth caterpillar sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Cricket sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Common Crow	*Euploea core*	India	Seshadri & Ganesh, 2011	LC
Invertebrate	Glow worm sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Grasshopper sp 1		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Grasshopper sp 2		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Hole cricket sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Insect sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate		*Leptogenys processionalis*	India	Seshadri & Ganesh, 2011	Not assessed
Invertebrate	Moth sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Periplanata sp 1		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Periplanata sp 2		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Praying Mantis sp 1		India	Seshadri & Ganesh, 2011	NA

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Invertebrate	Praying Mantis sp 2		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Spider Wasp sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Wasp sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Snail sp		India	Seshadri & Ganesh, 2011	NA
Invertebrate	Common Crow	*Euploea core*	India	Sony & Arun, 2015	LC
Invertebrate	Chocolate Pansy	*Junonia iphita*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Lemon Pansy	*Junonia lemonias*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Common Beak	*Libythea lepita*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Dark Blue Tiger	*Tirumala septentrionis*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Common Jay	*Graphium doson*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Spot Swordtail	*Graphium nomius*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Lime Swallowtail	*Papilio demoleus*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Common Mormon	*Papilio polytes*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Lemon Emigrant	*Catopsilia pomona*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Common Gull	*Cepora nerissa*	India	Sony & Arun, 2015	Not assessed
Invertebrate	Yellow Orange-tip	*Ixias pyrene*	India	Sony & Arun, 2015	Not assessed
Mammal	Golden langur	*Trachypithecus geei*	Bhutan	Thinley et al. 2019	EN
Mammal	Asian elephant	*Elephas maximus*	China	Pan et al., 2009	EN
Mammal	Far Eastern Myotis	*Myotis bombinus*	China	Wang et al., 2013	NT
Mammal	Manchurian Hedgehog	*Erinaceus amurensis*	China	Wang et al., 2013	LC
Mammal	Large Japanese Field Mouse	*Apodemus speciosus*	China	Wang et al., 2013	LC
Mammal	Manchurian Hare	*Lepus mandshuricus*	China	Wang et al., 2013	LC
Mammal	Spotted Giant Flying Squirrel	*Petaurista elegans*	China	Wang et al., 2013	LC
Mammal	Brown Rat	*Rattus norvegicus*	China	Wang et al., 2013	LC
Mammal	Northern Red-backed Vole	*Clethrionomys rutilus*	China	Wang et al., 2013	LC
Mammal	Siberian Chipmunk	*Tamias sibiricus*	China	Wang et al., 2013	LC
Mammal	Eurasian Badger	*Meles meles*	China	Wang et al., 2013	LC
Mammal	Siberian Weasel	*Mustela sibirica*	China	Wang et al., 2013	LC
Mammal	Least weasel	*Mustela nivalis*	China	Wang et al., 2013	LC
Mammal	Siberian Roe Deer	*Capreolus pygargus*	China	Wang et al., 2013	LC
Mammal	Common Shrew	*Sorex araneus*	China	Wang et al., 2013	LC
Mammal	Large Mole	*Mogera robusta*	China	Wang et al., 2013	LC
Mammal	Domestic Cat	*Felis catus*	China	Wang et al., 2013	NA
Mammal	Grey Red-backed Vole	*Clethrionomys rufocanus*	China	Wang et al., 2013	LC
Mammal	Siberian Chipmunk	*Tamias sibiricus*	China	Piao et al., 2012	LC
Mammal	Korean field mouse	*Apodemus peninsulae*	China	Piao et al., 2012	LC
Mammal	Grey Red-backed Vole	*Myodes rufocanus*	China	Piao et al., 2012	LC
Mammal	Siberian Weasel	*Mustela sibirica*	India	Abramov et al., 2016	LC
Mammal	Macaque	*Macaca sp*	India	Adimallaiah et al., 2014	NA
Mammal	Porcupine	*Hystrix sp*	India	Adimallaiah et al., 2014	NA
Mammal	Jungle Cat	*Felis chaus*	India	Anon, 2015	LC
Mammal	Indian Wolf	*Canis lupus pallipes*	India	Anon, 2015	EN
Mammal	Golden Jackal	*Canis aureus*	India	Anon, 2015	LC
Mammal	Black-naped Hare	*Lepus nigricollis*	India	Anon, 2015	LC
Mammal	Wild Boar	*Sus scrofa*	India	Anon, 2015	LC
Mammal	Southern Plains Gray Langur	*Semnopithecus dussumieri*	India	Rajvanshi et al., 2001	LC
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Rajvanshi et al., 2001	LC
Mammal	Tiger	*Panthera tigris*	India	Rajvanshi et al., 2001	EN
Mammal	Ruddy Mongoose	*Herpestes smithii*	India	Rajvanshi et al., 2001	LC
Mammal	Common Palm Civet	*Paradoxurus hermaphroditus*	India	Rajvanshi et al., 2001	LC
Mammal	Rusty-spotted Cat	*Prionailurus rubiginosus*	India	Babu et al., 2013	NT
Mammal	Leopard	*Panthera pardus*	India	Baskaran & Boominathan, 2010	VU

LIST OF SPECIES DOCUMENTED IN ANIMAL-VEHICLE COLLISIONS IN ASIA

TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Wild Boar	*Sus scrofa*	India	Baskaran & Boominathan, 2010	LC
Mammal	Sambar	*Rusa unicolor*	India	Baskaran & Boominathan, 2010	VU
Mammal	Chital	*Axis axis*	India	Baskaran & Boominathan, 2010	LC
Mammal	Indian Mouse Deer	*Moschiola indica*	India	Baskaran & Boominathan, 2010	LC
Mammal	Tufted Gray Langur	*Semnopithecus priam*	India	Baskaran & Boominathan, 2010	NT
Mammal	Bonnet Macaque	*Macaca radiata*	India	Baskaran & Boominathan, 2010	LC
Mammal	Black-naped hare	*Lepus nigricollis*	India	Baskaran & Boominathan, 2010	LC
Mammal	Common Palm Civet	*Paradoxurus hermaphroditus*	India	Baskaran & Boominathan, 2010	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Baskaran & Boominathan, 2010	LC
Mammal	Bandicoot	*Bandicota sp.*	India	Baskaran & Boominathan, 2010	NA
Mammal	Mouse	*Mus sp.*	India	Baskaran & Boominathan, 2010	NA
Mammal	UID Bat		India	Baskaran & Boominathan, 2010	NA
Mammal	Leopard	*Panthera pardus*	India	Behera & Borah, 2010	VU
Mammal	Rusty Spotted Cat	*Prionailurus rubiginosus*	India	Behera & Borah, 2010	NT
Mammal	Jungle Cat	*Felis chaus*	India	Behera & Borah, 2010	LC
Mammal	Bonnet Macaque	*Macaca radiata*	India	Behera & Borah, 2010	LC
Mammal	Tufted Gray Langur	*Semnopithecus priam*	India	Behera & Borah, 2010	NT
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Behera & Borah, 2010	LC
Mammal	Golden Jackal	*Canis aureus*	India	Behera & Borah, 2010	LC
Mammal	Dhole	*Cuon alpinus*	India	Behera & Borah, 2010	EN
Mammal	Chital	*Axis axis*	India	Behera & Borah, 2010	LC
Mammal	Sambar	*Rusa unicolor*	India	Behera & Borah, 2010	VU
Mammal	Small Indian Civet	*Viverricula indica*	India	Behera & Borah, 2010	LC
Mammal	Common Palm Civet	*Paradoxurus hermaphroditus*	India	Behera & Borah, 2010	LC
Mammal	Small Indian Mongoose	*Herpestes auropunctatus*	India	Behera & Borah, 2010	LC
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Behera & Borah, 2010	LC
Mammal	Indian Hare	*Lepus nigricollis*	India	Behera & Borah, 2010	LC
Mammal	Indian Bush-rat	*Golunda ellioti*	India	Behera & Borah, 2010	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Behera & Borah, 2010	LC
Mammal	Wild Boar	*Sus scrofa*	India	Behera & Borah, 2010	LC
Mammal	Madras Treeshrew	*Anathana ellioti*	India	Behera & Borah, 2010	LC
Mammal	Sloth Bear	*Melursus ursinus*	India	Behera & Borah, 2010	VU
Mammal	Leopard	*Panthera pardus*	India	Chhangani, 2004b	VU
Mammal	Striped Hyaena	*Hyaena hyaena*	India	Chhangani, 2004b	NT
Mammal	Golden Jackal	*Canis aureus*	India	Chhangani, 2004b	LC
Mammal	Nilgai	*Boselaphus tragocamelus*	India	Chhangani, 2004b	LC
Mammal	Wild Boar	*Sus scrofa*	India	Chhangani, 2004b	LC
Mammal	Indian Wolf	*Canis lupus pallipes*	India	Chhangani, 2004b	EN
Mammal	Bengal Fox	*Vulpes bengalensis*	India	Chhangani, 2004b	LC
Mammal	Common Palm Civet	*Paradoxurus hermaphroditus*	India	Chhangani, 2004b	LC
Mammal	Jungle Cat	*Felis chaus*	India	Chhangani, 2004b	LC
Mammal	Southern Plains Gray Langur	*Semnopithecus dussumieri*	India	Chhangani, 2004b	LC
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Chhangani, 2004b	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Small Indian Mongoose	*Herpestes auropunctatus*	India	Chhangani, 2004b	LC
Mammal	Five-striped Palm Squirrel	*Funambulus pennantii*	India	Chhangani, 2004b	LC
Mammal	Indian Gerbil	*Tatera indica*	India	Chhangani, 2004b	LC
Mammal	Field Mouse	*Mus platythrix*	India	Chhangani, 2004b	LC
Mammal	Indian Hare	*Lepus nigricollis*	India	Chhangani, 2004b	LC
Mammal	House Mouse	*Mus musculus*	India	Chhangani, 2004b	LC
Mammal	Capped Langur	*Trachypithecus pileatus*	India	Choudhury, 2001	VU
Mammal	Greater Hog Badger	*Arctonyx collaris*	India	Choudhury, 2001	VU
Mammal	Civets		India	Choudhury, 2001	NA
Mammal	Fishing Cat	*Prionailurus viverrinus*	India	Choudhury, 2001	VU
Mammal	Asian Elephant	*Elephas maximus*	India	Choudhury, 2001	EN
Mammal	Wild Boar	*Sus scrofa*	India	Choudhury, 2001	LC
Mammal	Hog Deer	*Axis porcinus*	India	Choudhury, 2001	EN
Mammal	Asian Elephant	*Elephas maximus*	India	Das, 2002	EN
Mammal	Chinkara	*Gazella bennettii*	India	Dookia, 2007	LC
Mammal	Chinkara	*Gazella bennettii*	India	Dookia et al., 2009	LC
Mammal	Chinkara	*Gazella bennettii*	India	Dookia et al., 2009	LC
Mammal	Chinkara	*Gazella bennettii*	India	Dookia et al., 2009	LC
Mammal	Chinkara	*Gazella bennettii*	India	Dookia et al., 2009	LC
Mammal	Chinkara	*Gazella bennettii*	India	Dookia et al., 2009	LC
Mammal	Chinkara	*Gazella bennettii*	India	Dookia et al., 2009	LC
Mammal	Leopard	*Panthera pardus*	India	Fellows et al., 2015	VU
Mammal	Sambar	*Rusa unicolor*	India	Fellows et al., 2015	VU
Mammal	Chital	*Axis axis*	India	Fellows et al., 2015	LC
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Fellows et al., 2015	LC
Mammal	Striped Hyaena	*Hyaena hyaena*	India	Fellows et al., 2015	NT
Mammal	Tiger	*Panthera tigris*	India	Fellows et al., 2015	EN
Mammal	Sambar	*Rusa unicolor*	India	Fellows et al., 2015	VU
Mammal	Chital	*Axis axis*	India	Fellows et al., 2015	LC
Mammal	Chinkara	*Gazella bennettii*	India	Fellows et al., 2015	LC
Mammal	Blackbuck	*Antilope cervicapra*	India	Fellows et al., 2015	LC
Mammal	Barking Deer	*Muntiacus muntjak*	India	Fellows et al., 2015	LC
Mammal			India	Gajera & Dharaiya, 2011	NA
Mammal			India	Gajera & Dharaiya, 2011	NA
Mammal	Asian Wildcat	*Felis silvestris ornata*	India	Gogate, 1997 in Pande et al., 2013	LC
Mammal	Leopard	*Panthera pardus*	India	Gubbi et al., 2014	VU
Mammal	Bat spp.		India	Jeganathan et al., 2018	NA
Mammal	Black-naped Hare	*Lepus nigricollis*	India	Jeganathan et al., 2018	LC
Mammal	Mouse		India	Jeganathan et al., 2018	NA
Mammal	Rat		India	Jeganathan et al., 2018	NA
Mammal	Shrew		India	Jeganathan et al., 2018	NA
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Jeganathan et al., 2018	LC
Mammal	Barking Deer	*Muntiacus muntjak*	India	Jeganathan et al., 2018	LC
Mammal	Sambar	*Rusa unicolor*	India	Jeganathan et al., 2018	VU
Mammal	Indian Mouse Deer	*Moschiola indica*	India	Jeganathan et al., 2018	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Jeganathan et al., 2018	LC
Mammal	Western Ghats Striped Squirrel	*Funambulus tristriatus*	India	Jeganathan et al., 2018	LC
Mammal	Indian Giant Squirrel	*Ratufa indica*	India	Jeganathan et al., 2018	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Jeganathan et al., 2018	LC
Mammal	Common Palm Civet	*Paradoxurus hermaphroditus*	India	Jeganathan et al., 2018	LC
Mammal	Brown Palm Civet	*Paradoxurus jerdoni*	India	Jeganathan et al., 2018	LC
Mammal	Bonnet Macaque	*Macaca radiata*	India	Jeganathan et al., 2018	LC
Mammal	Lion-tailed Macaque	*Macaca silenus*	India	Jeganathan et al., 2018	EN
Mammal	UID		India	Jeganathan et al., 2018	NA
Mammal	Tiger	*Panthera tigris*	India	Johnsingh et al., 1997	EN

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Leopard	*Panthera pardus*	India	Joshi & Dixit, 2012	VU
Mammal	Leopard Cat	*Prionailurus bengalensis*	India	Joshi & Dixit, 2012	LC
Mammal	Sambar	*Rusa unicolor*	India	Joshi & Dixit, 2012	VU
Mammal	Chital	*Axis axis*	India	Joshi & Dixit, 2012	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Joshi & Dixit, 2012	LC
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Joshi & Dixit, 2012	LC
Mammal	Golden Jackal	*Canis aureus*	India	Joshi & Dixit, 2012	LC
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Joshi & Dixit, 2012	LC
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Joshi & Dixit, 2012	LC
Mammal	Indian Pangolin	*Manis crassicaudata*	India	Joshi & Dixit, 2012	EN
Mammal	Five-striped Palm Squirrel	*Funambulus pennantii*	India	Joshi & Dixit, 2012	LC
Mammal	Indian Flying Fox	*Pteropus giganteus*	India	Joshi & Dixit, 2012	LC
Mammal	Leopard	*Panthera pardus*	India	Joshi & Dixit, 2012	VU
Mammal	Sambar	*Rusa unicolor*	India	Joshi & Dixit, 2012	VU
Mammal	Chital	*Axis axis*	India	Joshi & Dixit, 2012	LC
Mammal	Barking Deer	*Muntiacus muntjak*	India	Joshi & Dixit, 2012	LC
Mammal	Indian Hare	*Lepus nigricollis*	India	Joshi & Dixit, 2012	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Joshi & Dixit, 2012	LC
Mammal	Common palm Civet	*Paradoxurus hermaphroditus*	India	Joshi & Dixit, 2012	LC
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Joshi & Dixit, 2012	LC
Mammal	Tarai Gray Langur	*Semnopithecus hector*	India	Joshi & Dixit, 2012	NT
Mammal	Golden Jackal	*Canis aureus*	India	Joshi & Dixit, 2012	LC
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Joshi & Dixit, 2012	LC
Mammal	Nilgai	*Boselaphus tragocamelus*	India	Joshi & Dixit, 2012	LC
Mammal	Five-striped Palm Squirrel	*Funambulus pennantii*	India	Joshi & Dixit, 2012	LC
Mammal	Indian Flying Fox	*Pteropus giganteus*	India	Joshi & Dixit, 2012	LC
Mammal	Leopard Cat	*Prionailurus bengalensis*	India	Joshi & Dixit, 2012	LC
Mammal	Striped Hyaena	*Hyaena hyaena*	India	Joshi & Dixit, 2012	NT
Mammal	Sambar	*Rusa unicolor*	India	Joshi & Dixit, 2012	VU
Mammal	Chital	*Axis axis*	India	Joshi & Dixit, 2012	LC
Mammal	Barking Deer	*Muntiacus muntjak*	India	Joshi & Dixit, 2012	LC
Mammal	Indian Hare	*Lepus nigricollis*	India	Joshi & Dixit, 2012	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Joshi & Dixit, 2012	LC
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Joshi & Dixit, 2012	LC
Mammal	Tarai Gray Langur	*Semnopithecus hector*	India	Joshi & Dixit, 2012	NT
Mammal	Golden Jackal	*Canis aureus*	India	Joshi & Dixit, 2012	LC
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Joshi & Dixit, 2012	LC
Mammal	Five-striped Palm Squirrel	*Funambulus pennantii*	India	Joshi & Dixit, 2012	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Kait & Sahi, 2007	LC
Mammal	Bonnet Macaque	*Macaca radiata*	India	Kumara et al., 2000	LC
Mammal	Lion-tailed Macaque	*Macaca silenus*	India	Kumara et al., 2000	EN
Mammal	Tufted Gray Langur	*Semnopithecus priam*	India	Kumara et al., 2000	NT
Mammal	Nilgiri Langur	*Trachypithecus johnii*	India	Kumara et al., 2000	VU
Mammal	Sambar	*Rusa unicolor*	India	Kumara et al., 2000	VU
Mammal	Barking Deer	*Muntiacus muntjak*	India	Kumara et al., 2000	LC
Mammal	Indian Mouse Deer	*Moschiola indica*	India	Kumara et al., 2000	LC
Mammal	Nilgiri Tahr	*Hemitragus hylocrius*	India	Kumara et al., 2000	EN
Mammal	Wild Boar	*Sus scrofa*	India	Kumara et al., 2000	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Kumara et al., 2000	LC
Mammal	Common Palm Civet	*Paradoxurus hermaphroditus*	India	Kumara et al., 2000	LC
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Kumara et al., 2000	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Mahananda & Jelil, 2017	LC
Mammal	Golden Jackal	*Canis aureus*	India	Maurya et al., 2011	LC
Mammal	Hedgehogs	*Hemiechinus spp.*	India	Maurya et al., 2011	NA

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Maurya et al., 2011	LC
Mammal	Jungle Cat	*Felis chaus*	India	Maurya et al., 2011	LC
Mammal	Rodents	*Gerbillus spp.*	India	Maurya et al., 2011	NA
Mammal	Striped Hyaena	*Hyaena hyaena*	India	Maurya et al., 2011	NT
Mammal	Small Indian Civet	*Viverricula indica*	India	Maurya et al., 2011	LC
Mammal	Indian Hare	*Lepus nigricollis*	India	Maurya et al., 2011	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Maurya et al., 2011	LC
Mammal	Bengal Fox	*Vulpes bengalensis*	India	Maurya et al., 2011	LC
Mammal	Nilgai	*Boselaphus tragocamelus*	India	Maurya et al., 2011	LC
Mammal	Caracal	*Caracal caracal*	India	Maurya et al., 2011	LC
Mammal	Wild Boar	*Sus scrofa*	India	Maurya et al., 2011	LC
Mammal	Asian Wildcat	*Felis silvestris ornata*	India	Maurya et al., 2011	LC
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Maurya et al., 2011	LC
Mammal	Indian Pangolin	*Manis crassicaudata*	India	Murthy & Mishra 2010	EN
Mammal	Rusty-spotted Cat	*Prionailurus rubiginosus*	India	Nayak et al., 2017	NT
Mammal	Golden Jackal	*Canis aureus*	India	Paunikar 2012	LC
Mammal	Golden Jackal	*Canis aureus*	India	Paunikar 2012	LC
Mammal	Rhesus Macaque	*Macaca mulatta*	India	Pragatheesh, 2011	LC
Mammal	Nilgai	*Boselaphus tragocamelus*	India	Prajapati, 2016	LC
Mammal	Golden Jackal	*Canis aureus*	India	Prajapati, 2016	LC
Mammal	Bengal Fox	*Vulpes bengalensis*	India	Prajapati, 2016	LC
Mammal	Asian Wildcat	*Felis silvestris ornata*	India	Prajapati, 2016	LC
Mammal	Jungle Cat	*Felis chaus*	India	Prajapati, 2016	LC
Mammal	Small Indian Mongoose	*Herpestes auropunctatus*	India	Prajapati, 2016	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Prajapati, 2016	LC
Mammal	Indian Hedgehog	*Paraechinus micropus*	India	Prajapati, 2016	LC
Mammal	Indian Hare	*Lepus nigricollis*	India	Prajapati, 2016	LC
Mammal	Bengal Slow Loris	*Nycticebus bengalensis*	India	Radhakrishna et al., 2006	VU
Mammal	Leopard	*Panthera pardus*	India	Rajvanshi et al., 2001	VU
Mammal	Tiger	*Panthera tigris*	India	Rajvanshi et al., 2001	EN
Mammal			India	Rao & Girish, 2007	NA
Mammal	Black-naped Hare	*Lepus nigricollis*	India	Samson et al., 2016	LC
Mammal	House Rat	*Rattus rattus*	India	Samson et al., 2016	LC
Mammal	Bonnet Macaque	*Macaca radiata*	India	Samson et al., 2016	LC
Mammal	Greater Bandicoot Rat	*Bandicota indica*	India	Samson et al., 2016	LC
Mammal	Sambar	*Rusa unicolor*	India	Samson et al., 2016	VU
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Samson et al., 2016	LC
Mammal	Masked Palm Civet	*Paguma larvata*	India	Sathyakumar, 1999	LC
Mammal	Three-striped Palm Squirrel	*Fanambulus palmarum*	India	Sathish-Narayanan et al., 2016	LC
Mammal	House Mouse	*Mus musculus*	India	Sathish-Narayanan et al., 2016	LC
Mammal	Malabar Spiny Tree Mouse	*Platacanthomys lasiurus*	India	Sathish-Narayanan et al., 2016	VU
Mammal	Jungle cat	*Felis chaus*	India	Sathish-Narayanan et al., 2016	LC
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Sathish-Narayanan et al., 2016	LC
Mammal	Leopard	*Panthera pardus*	India	Sayyed & Mahabalh 2015	VU
Mammal	Tufted Gray Langur	*Semnopithecus priam*	India	Selvan, 2011	NT
Mammal	Bonnet Macaque	*Macaca radiata*	India	Selvan, 2011	LC
Mammal	Brown Palm Civet	*Paradoxurus jerdoni*	India	Selvan, 2011	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Selvan, 2011	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Bonnet Macaque	*Macaca radiata*	India	Selvan et al., 2012	LC
Mammal	Other Mammals		India	Selvan et al., 2012	NA
Mammal	Bat sp		India	Seshadri & Ganesh, 2011	NA
Mammal	Field mouse sp		India	Seshadri & Ganesh, 2011	NA
Mammal	Gerbil sp		India	Seshadri & Ganesh, 2011	NA
Mammal	White bellied Wood Rat	*Madromys blanfordi*	India	Seshadri & Ganesh, 2011	LC
Mammal	Tarai Gray Langur	*Semnopithecus hector*	India	Sharma, 2013	NT
Mammal	Jungle Cat	*Felis chaus*	India	Shekhar, 2005	LC
Mammal	Chital	*Axis axis*	India	Rajvanshi et al., 2001	LC
Mammal	Nilgai	*Boselaphus tragocamelus*	India	Rajvanshi et al., 2001	LC
Mammal	Indian Lion	*Panthera leo persica*	India	Rajvanshi et al., 2001	EN
Mammal	Leopard	*Panthera pardus*	India	Rajvanshi et al., 2001	VU
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Rajvanshi et al., 2001	LC
Mammal	Leopard	*Panthera pardus*	India	Singh & Kumara, 2006	VU
Mammal	Gray Slender Loris	*Loris lydekkerianus*	India	Singh et al., 1999	LC
Mammal	Indian Gerbil	*Tatera indica*	India	Sivakumar & Manakadan, 2010	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Sivakumar & Manakadan, 2010	LC
Mammal	Golden Jackal	*Canis aureus*	India	Sivakumar & Manakadan, 2010	LC
Mammal	Gray Slender Loris	*Loris lydekkerianus*	India	Sivakumar & Manakadan, 2010	LC
Mammal	Small Indian Civet	*Viverricula indica*	India	Sivakumar & Manakadan, 2010	LC
Mammal	Black-naped hare	*Lepus nigricollis*	India	Sivakumar & Manakadan, 2010	LC
Mammal	Common Mongoose	*Herpestes edwardsii*	India	Sivakumar & Manakadan, 2010	LC
Mammal			India	Solanki et al., 2017	NA
Mammal	Indian Crested Porcupine	*Hystrix indica*	India	Sridhar et al., 2009	LC
Mammal	Golden Jackal	*Canis aureus*	India	Sundar, 2004	LC
Mammal	Bengal Fox	*Vulpes bengalensis*	India	Sundar, 2004	LC
Mammal	Jungle Cat	*Felis chaus*	India	Sundar, 2004	LC
Mammal	Small Indian Mongoose	*Herpestes auropunctatus*	India	Sundar, 2004	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	India	Sundar, 2004	LC
Mammal	Malabar Spiny Tree Mouse	*Platacanthomys lasiurus*	India	Vijaykumar et al., 2001	VU
Mammal	Leopard	*Panthera pardus*	India	Vyas & Sengupta, 2014	VU
Mammal	Indian Hedgehog	*Paraechinus micropus*	India	Vyas, 2002b	LC
Mammal	Indian Long-eared Hedgehog	*Hemiechinus collaris*	India	Vyas et al., 2009	LC
Mammal	Raccoon dog	*Nyctereutes procyonoides*	Japan	Kawabe & Tanaka, 2003	LC
Mammal	Siberian Weasel	*Mustela sibirica*	Japan	Kawaguchi & Kagaku, 2006	LC
Mammal	Japanese weasel	*Mustela itatsi*	Japan	Kawaguchi & Kagaku, 2006	NT
Mammal	Ryukyus Islands tree-rat	*Diplothrix legata*	Japan	Tamanaha et al., 2017	EN
Mammal	Cat	*Felis catus*	Japan	Tatewaki & Koike, 2018	NA
Mammal	Raccoon dog	*Nyctereutes procyonoides*	Japan	Tatewaki & Koike, 2018	LC
Mammal	Dog	*Canis lupus familiaris*	Japan	Tatewaki & Koike, 2018	NA
Mammal	Masked Palm Civet	*Paguma larvata*	Japan	Tatewaki & Koike, 2018	LC
Mammal	Sika deer	*Cervus nippon*	Japan	Tatewaki & Koike, 2018	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Red fox	*Vulpes vulpes*	Japan	Tatewaki & Koike, 2018	LC
Mammal	Wild Boar	*Sus scrofa*	Japan	Tatewaki & Koike, 2018	LC
Mammal		*Lepus timidus/ Lepus brachyurus*	Japan	Tatewaki & Koike, 2018	NA
Mammal	Northern raccoon	*Procyon lotor*	Japan	Tatewaki & Koike, 2018	LC
Mammal	Japanese macaque	*Macaca fuscata*	Japan	Tatewaki & Koike, 2018	LC
Mammal		*Ursus arctos/ Ursus thibetanus*	Japan	Tatewaki & Koike, 2018	NA
Mammal	Long-clawed shrew	*Sorex unguiculatus*	Japan	Yanagawa et al., 2003	LC
Mammal	Eurasian red squirrel	*Sciurus vulgaris*	Japan	Yanagawa et al., 2003	LC
Mammal	Red fox	*Vulpes vulpes*	Japan	Yanagawa et al., 2003	LC
Mammal	Tiger	*Panthera tigris*	Malaysia	Azhar et al., 2013	EN
Mammal	Panther	*Panthera pardus*	Malaysia	Azhar et al., 2013	VU
Mammal	Sun bear	*Helarctos malayanus*	Malaysia	Azhar et al., 2013	VU
Mammal	Leopard cat	*Prionailurus bengalensis*	Malaysia	Azhar et al., 2013	LC
Mammal	Civet	*Viverra spp*	Malaysia	Azhar et al., 2013	NA
Mammal	Otter	*Lutra sp./ Aonyx sp.*	Malaysia	Azhar et al., 2013	NA
Mammal	Sunda pangolin	*Manis javanica*	Malaysia	Azhar et al., 2013	CR
Mammal	Malayan porcupine	*Hystrix brachyura*	Malaysia	Azhar et al., 2013	LC
Mammal	Pig-tailed macaque	*Macaca nemestrina*	Malaysia	Azhar et al., 2013	VU
Mammal	Monitor lizard	*Varanus sp*	Malaysia	Azhar et al., 2013	NA
Mammal	Malay civet	*Viverra tangalunga*	Malaysia	Colon, 2006	LC
Mammal	Large spotted civet	*Viverra megaspila*	Malaysia	Hamirul et al., 2015	EN
Mammal	Flat headed cat	*Prionailurus planiceps*	Malaysia	Kamil et al., 2011	EN
Mammal	Dhole	*Cuon alpinus*	Malaysia	Kasmuri et al., 2020	EN
Mammal	Sun bear	*Helarctos malayanus*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Pig-tailed macaque	*Macaca nemestrina*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Binturong	*Arctictis binturong*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Wild Boar	*Sus scrofa*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Crab-eating mongoose	*Herpestes urva*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Javan mongoose	*Herpestes javanicus*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Asian elephant	*Elephas maximus*	Malaysia	Kasmuri et al., 2020	EN
Mammal	Tiger	*Panthera tigris*	Malaysia	Kasmuri et al., 2020	EN
Mammal	Leopard	*Panthera pardus*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Leopard cat	*Prionailurus bengalensis*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Sumatran serow	*Capricornis sumatraensis*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Crab-eating macaque	*Macaca fascicularis*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Sunda slow loris	*Nycticebus coucang*	Malaysia	Kasmuri et al., 2020	EN
Mammal	Malayan porcupine	*Hystrix brachyura*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Silvery lutung	*Trachypithecus cristatus*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Black-crested Sumatran langur	*Presbytis sumatranus*	Malaysia	Kasmuri et al., 2020	EN
Mammal		*Presbytis sp.*	Malaysia	Kasmuri et al., 2020	NA
Mammal		*Trachyopithecus cristatus*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Dusky langur	*Trachypithecus obscurus*	Malaysia	Kasmuri et al., 2020	EN
Mammal	Asian small-clawed otter	*Aonyx cinerea*	Malaysia	Kasmuri et al., 2020	VU
Mammal		*Lutra spp*	Malaysia	Kasmuri et al., 2020	NA
Mammal	Hairy-nosed otter	*Lutra sumatrana*	Malaysia	Kasmuri et al., 2020	EN
Mammal	Smooth-coated otter	*Lutrogale perspicillata*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Yellow-throated marten	*Martes flavigula*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Family Viverridea		Malaysia	Kasmuri et al., 2020	NA
Mammal	Common Palm Civet	*Paradoxurus Hermaphroditus*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Malay civet	*Viverra tangalunga*	Malaysia	Kasmuri et al., 2020	LC
Mammal		*Viverra zibetha*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Sambar	*Rusa unicolor*	Malaysia	Kasmuri et al., 2020	VU
Mammal	Malayan tapir	*Tapirus indicus*	Malaysia	Kasmuri et al., 2020	EN

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Sunda pangolin	*Manis javanica*	Malaysia	Kasmuri et al., 2020	CR
Mammal	Moonrat	*Echinosorex gymnura*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Plantain squirrel	*Callosciurus notatus*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Prevost's squirrel	*Callosciurus prevostii*	Malaysia	Kasmuri et al., 2020	LC
Mammal	Cream-coloured giant squirrel	*Ratufa affinis*	Malaysia	Kasmuri et al., 2020	NT
Mammal	Malayan giant squirrel	*Ratufa bicolor*	Malaysia	Kasmuri et al., 2020	NT
Mammal	Sunda clouded leopard	*Neofelis diardi*	Malaysia	Najera et al., 2013	VU
Mammal	Hairy-nosed otter	*Lutra sumatrana*	Malaysia	Tan, 2015	EN
Mammal	Asian elephant	*Elephas maximus*	Malaysia	Wadey et al., 2018	EN
Mammal	Striped hyena	*Hyaena hyaena*	Nepal	Adhikari et al., 2018	NT
Mammal	Rusty-spotted cat	*Prionailurus rubiginosus*	Nepal	Adhikari et al., 2019	NT
Mammal	Tiger	*Panthera tigris*	Nepal	Bhandari et al., 2019	EN
Mammal	Asitic wild buffalo	*Bubalus arnee*	Nepal	Heinen & Kandel, 2006	EN
Mammal	Water deer	*Hydropotes inermis*	South Korea	Choi, 2016	VU
Mammal	Greater short-nosed fruit bat	*Cynopterus sphinx*	Sri Lanka	Edirisinghe et al., 2018	LC
Mammal	Rufous horseshoe bat	*Rhinolophus rouxii*	Sri Lanka	Edirisinghe et al., 2018	LC
Mammal	Jungle cat	*Felis chaus*	Sri Lanka	Karunarathna et al., 2017	LC
Mammal	Three-striped Palm Squirrel	*Funambulus palmarum*	Sri Lanka	Karunarathna et al., 2017	LC
Mammal	Black-naped hare	*Lepus nigricollis*	Sri Lanka	Karunarathna et al., 2017	LC
Mammal	Barking deer	*Muntiacus muntjak*	Sri Lanka	Karunarathna et al., 2017	LC
Mammal	Leopard	*Panthera pardus*	Sri Lanka	Karunarathna et al., 2017	VU
Mammal	Wild Boar	*Sus scrofa*	Sri Lanka	Karunarathna et al., 2017	LC
Mammal	Ohiya rat	*Srilankamys ohiensis*	Sri Lanka	Karunarathna et al., 2017	VU
Mammal	Asian highland shrew	*Suncus montanus*	Sri Lanka	Karunarathna et al., 2017	VU
Mammal	Gaur	*Bos gaurus*	Thailand	Silva et al., 2020	VU
Mammal	Leopard cat	*Prionailurus bengalensis*	Thailand	Silva et al., 2020	LC
Mammal	Javan mongoose	*Herpestes javanicus*	Thailand	Silva et al., 2020	LC
Mammal	Sunda slow loris	*Nycticebus coucang*	Thailand	Silva et al., 2020	EN
Mammal	Finlayson's squirrel	*Callosciurus finlaysonii*	Thailand	Silva et al., 2020	LC
Mammal	Red-cheeked flying squirrel	*Hylopetes spadiceus*	Thailand	Silva et al., 2020	LC
Mammal	Unknown		Thailand	Silva et al., 2020	NA
Mammal	Unknown		Thailand	Silva et al., 2020	NA
Mammal	Long-winged tomb bat	*Taphozous longimanus*	Thailand	Silva et al., 2020	LC
Mammal	Black-bearded tomb bat	*Taphozous melanopogon*	Thailand	Silva et al., 2020	LC
Mammal	Ashy roundleaf bat	*Hipposideros cineraceus*	Thailand	Silva et al., 2020	LC
Mammal	Cantor's roundleaf bat	*Hipposideros galeritus*	Thailand	Silva et al., 2020	LC
Mammal	Intermediate roundleaf bat	*Hipposideros larvatus*	Thailand	Silva et al., 2020	LC
Mammal	Pomona roundleaf bat	*Hipposideros pomona*	Thailand	Silva et al., 2020	EN
Mammal		*Hipposideros sp.*	Thailand	Silva et al., 2020	NA
Mammal	Greater short-nosed fruit bat	*Cynopterus sphinx*	Thailand	Silva et al., 2020	LC
Mammal	Long-tongued fruit bat	*Macroglossus sobrinus*	Thailand	Silva et al., 2020	LC
Mammal	Unknown		Thailand	Silva et al., 2020	NA
Mammal	Croslet horseshoe bat	*Rhinolophus coelophyllus*	Thailand	Silva et al., 2020	LC
Mammal	Woolly horseshoe bat	*Rhinolophus luctus*	Thailand	Silva et al., 2020	LC
Mammal	Least horseshoe bat	*Rhinolophus pusillus*	Thailand	Silva et al., 2020	LC
Mammal	Shamel's horseshoe bat	*Rhinolophus shameli*	Thailand	Silva et al., 2020	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Mammal	Lesser brown horseshoe bat	*Rhinolophus stheno*	Thailand	Silva et al., 2020	LC
Mammal		*Rhinolophus sp.*	Thailand	Silva et al., 2020	NA
Mammal	Tickell's bat	*Hesperoptenus tickelli*	Thailand	Silva et al., 2020	LC
Mammal	Western bent-winged bat	*Miniopterus magnater*	Thailand	Silva et al., 2020	LC
Mammal	Small bent-winged bat	*Miniopterus pusillus*	Thailand	Silva et al., 2020	LC
Mammal	Common bent-wing bat	*Miniopterus schreibersii*	Thailand	Silva et al., 2020	VU
Mammal		*Miniopterus sp.*	Thailand	Silva et al., 2020	NA
Mammal	Round-eared tube-nosed bat	*Murina cyclotis*	Thailand	Silva et al., 2020	LC
Mammal	Wall-roosting mouse-eared bat	*Myotis muricola*	Thailand	Silva et al., 2020	LC
Mammal		*Myotis sp.*	Thailand	Silva et al., 2020	NA
Mammal	Indian pipistrelle	*Pipistrellus coromandra*	Thailand	Silva et al., 2020	LC
Mammal		*Pipistrellus sp.*	Thailand	Silva et al., 2020	NA
Mammal	Lesser Asiatic yellow bat	*Scotophilus kuhlii*	Thailand	Silva et al., 2020	LC
Mammal	Unknown		Thailand	Silva et al., 2020	NA
Reptile	Buff striped keelback	*Amphiesma stolatum*	Bangladesh	Datta et al., 2018	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	Bangladesh	Datta et al., 2018	Not assessed
Reptile	Common smooth water snake	*Enhydris enhydris*	Bangladesh	Datta et al., 2018	LC
Reptile	Common wolf snake	*Lycodon aulicus*	Bangladesh	Datta et al., 2018	Not assessed
Reptile	Mongolia Racerunner	*Eremias argus*	China	Wang et al., 2013	LC
Reptile	Steppes Ratsnakes	*Elaphe dione*	China	Wang et al., 2013	LC
Reptile	Japanese keelback	*Hebius vibakari*	China	Wang et al., 2013	Not assessed
Reptile	Halys pit viper	*Gloydius halys*	China	Wang et al., 2013	Not assessed
Reptile	Red-backed rat snake	*Oocatochus rufodorsatus*	China	Wang et al., 2013	LC
Reptile	Tiger keelback Snake	*Rhabdophis tigrinus*	China	Wang et al., 2013	Not assessed
Reptile	Adder	*Vipera berus*	China	Wang et al., 2013	LC
Reptile	Manchurian Black Water Snake	*Elaphe schrenckii*	China	Wang et al., 2013	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Anon, 2015	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Anon, 2015	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Anon, 2015	Not assessed
Reptile	Common trinket snake	*Coelognathus helena*	India	Anon, 2015	Not assessed
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Anon, 2015	LC
Reptile	Indian monitor	*Varanus bengalensis*	India	Anon, 2015	LC
Reptile	Indian cobra	*Naja naja*	India	Anon, 2015	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Anon, 2015	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Rajvanshi et al., 2001	Not assessed
Reptile	Indian rock python	*Python molurus*	India	Rajvanshi et al., 2001	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	India	Baskaran & Boominathan, 2010	LC
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Baskaran & Boominathan, 2010	LC
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Baskaran & Boominathan, 2010	Not assessed

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Red sand boa	*Eryx johnii*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Beaked worm snake	*Grypotyphlops acutus*	India	Baskaran & Boominathan, 2010	LC
Reptile	Golden tree snake	*Chrysopelea ornata*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Baskaran & Boominathan, 2010	Not assessed
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Baskaran & Boominathan, 2010	LC
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Baskaran & Boominathan, 2010	LC
Reptile	Indian garden lizard	*Calotes versicolor*	India	Bhupathy et al., 2011	Not assessed
Reptile	Common green forest lizard	*Calotes calotes*	India	Bhupathy et al., 2011	Not assessed
Reptile	Blanford's rock agama	*Psammophilus blanfordanus*	India	Bhupathy et al., 2011	LC
Reptile	Asian chameleon	*Chamaeleo zeylanicus*	India	Bhupathy et al., 2011	LC
Reptile	Bronze skink	*Eutropis macularia*	India	Bhupathy et al., 2011	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Bhupathy et al., 2011	LC
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Bhupathy et al., 2011	Not assessed
Reptile	Common sand boa	*Eryx conicus*	India	Bhupathy et al., 2011	LC
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Bhupathy et al., 2011	Not assessed
Reptile	Brown-speckled whipsnake	*Ahaetulla pulverulenta*	India	Bhupathy et al., 2011	LC
Reptile	Beddome's cat snake	*Boiga beddomei*	India	Bhupathy et al., 2011	DD
Reptile	Common trinket snake	*Coelognathus helena*	India	Bhupathy et al., 2011	Not assessed
Reptile	Green keelback	*Rhabdophis plumbicolor*	India	Bhupathy et al., 2011	Not assessed
Reptile	Common kukri snake	*Oligodon arnensis*	India	Bhupathy et al., 2011	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Bhupathy et al., 2011	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Bhupathy et al., 2011	Not assessed
Reptile	Striped coral snake	*Calliophis nigrescens*	India	Bhupathy et al., 2011	LC
Reptile	Russell's viper	*Daboia russelii*	India	Bhupathy et al., 2011	Not assessed
Reptile	Saw-scaled viper	*Echis carinatus*	India	Bhupathy et al., 2011	Not assessed
Reptile	Hump nosed pit viper	*Hypnale hypnale*	India	Bhupathy et al., 2011	Not assessed
Reptile		*Uropeltis sp.*	India	Bhupathy et al., 2011	NA
Reptile	Unidentified gecko		India	Bhupathy et al., 2011	NA
Reptile	Unidentified snake		India	Bhupathy et al., 2011	NA
Reptile	Large-scaled forest lizard	*Calotes grandisquamis*	India	Chandramouli & Ganesh, 2010	LC
Reptile	Captain's wood snake	*Xylophis captaini*	India	Chandramouli & Ganesh, 2010	LC
Reptile	Madurai shieldtail	*Uropeltis madurensis*	India	Chandramouli & Ganesh, 2010	Not assessed
Reptile	Sirumalai Hills earth snake	*Uropeltis cf. dindigalensis*	India	Chandramouli & Ganesh, 2010	DD
Reptile	Sikkim false wolf snake	*Lycodon gammiei*	India	Chettri & Bhupathy, 2009	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Chhangani, 2004b	LC
Reptile	Indian cobra	*Naja naja*	India	Chhangani, 2004b	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Chhangani, 2004b	LC
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Chhangani, 2004b	Not assessed
Reptile		*Varanus sp.*	India	Chhangani, 2004b	NA
Reptile	Indian cobra	*Naja naja*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Common krait	*Bungarus caerulus*	India	Chittaragi & Hosetti, 2014	Not assessed

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Russell's viper	*Daboia russelii*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Bamboo pit-viper	*Trimeresurus gramineus*	India	Chittaragi & Hosetti, 2014	LC
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Common trinket snake	*Coelognathus helena*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Chittaragi & Hosetti, 2014	LC
Reptile	Black-headed snake	*Sibynophis subpunctatus*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Common kukri snake	*Oligodon arnensis*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	India	Chittaragi & Hosetti, 2014	LC
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Elliot's earth snake	*Uropeltis ellioti*	India	Chittaragi & Hosetti, 2014	LC
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Chittaragi & Hosetti, 2014	Not assessed
Reptile	Beaked worm snake	*Grypotyphlops acutus*	India	Chittaragi & Hosetti, 2014	LC
Reptile		*Boiga sp.*	India	Chittaragi & Hosetti, 2014	NA
Reptile	Indian cobra	*Naja naja*	India	Choudhury, 2001	Not assessed
Reptile	Indian rock python	*Python molurus*	India	Choudhury, 2001	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Das, 2008	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Das et al., 2007	Not assessed
Reptile	Many-lined sun skink	*Eutropis multifasciata*	India	Das et al., 2007	LC
Reptile	Tokay gecko	*Gekko gecko*	India	Das et al., 2007	LC
Reptile	Indian rock python	*Python molurus*	India	Das et al., 2007	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Das et al., 2007	Not assessed
Reptile	Arrowback tree snake	*Boiga gokool*	India	Das et al., 2007	Not assessed
Reptile	Assamese Cat Snake	*Boiga quincunciata*	India	Das et al., 2007	Not assessed
Reptile	Common trinket snake	*Coelognathus helena*	India	Das et al., 2007	Not assessed
Reptile	Copper-headed trinket snake	*Coelognathus radiatus*	India	Das et al., 2007	LC
Reptile	Golden tree snake	*Chrysopelea ornata*	India	Das et al., 2007	Not assessed
Reptile	Painted bronzeback	*Dendrelaphis pictus*	India	Das et al., 2007	Not assessed
Reptile	Smooth water snake	*Enhydris enhydris*	India	Das et al., 2007	LC
Reptile	Twin-spotted wolf snake	*Lycodon jara*	India	Das et al., 2007	LC
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Das et al., 2007	Not assessed
Reptile	Chinese ratsnake	*Ptyas korros*	India	Das et al., 2007	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Das et al., 2007	Not assessed
Reptile	Banded krait	*Bungarus fasciatus*	India	Das et al., 2007	LC
Reptile	King cobra	*Ophiophagus hannah*	India	Das et al., 2007	VU
Reptile	White-lipped pit-viper	*Cryptelytrops albolabris*	India	Das et al., 2007	LC
Reptile		*Lygosoma sp.*	India	Das et al., 2007	NA

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile		*Dendralaphis sp.*	India	Das et al., 2007	NA
Reptile	King cobra	*Ophiophagus hannah*	India	Das et al., 2008	VU
Reptile	Common slug snake	*Pareas monticola*	India	Das et al., 2009	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Das et al., 2009	Not assessed
Reptile	Eastern cat snake	*Boiga gokool*	India	Das et al., 2010	Not assessed
Reptile	Eastern cat snake	*Boiga gokool*	India	Das et al., 2010	Not assessed
Reptile	Indian pond terrapin	*Melanochelys trijuga*	India	Deepak & Riddhika, 2009	LC
Reptile	Common green forest lizard	*Calotes calotes*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Olive keelback	*Atretium schistosum*	India	Deepak & Riddhika, 2009	LC
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Indian cobra	*Naja naja*	India	Deepak & Riddhika, 2009	Not assessed
Reptile	Indian smooth snake	*Coronella brachyura*	India	Deshmukh et al., 2015	LC
Reptile	Barred wolf snake	*Lycodon striatus*	India	Deshmukh et al., 2015	Not assessed
Reptile	Yellow-spotted wolf snake	*Lycodon flavomaculatus*	India	Deshmukh et al., 2015	LC
Reptile	Olive keelback	*Atretium schistosum*	India	Deshmukh et al., 2015	LC
Reptile	Stocky sand snake	*Psammophis longifrons*	India	Deshmukh et al., 2015	LC
Reptile	Indian egg-eating snake	*Elachistodon westermanni*	India	Deshmukh et al., 2015	LC
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Deshmukh et al., 2015	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Deshmukh et al., 2015	LC
Reptile	Forstens cat snake	*Boiga forsteni*	India	Deshmukh et al., 2015	LC
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	India	Deshmukh et al., 2016	LC
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Dutta et al., 2016	LC
Reptile	Common wolf snake	*Lycodon aulicus*	India	Dutta et al., 2016	Not assessed
Reptile	Common kukri snake	*Oligodon arnensis*	India	Dutta et al., 2016	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Dutta et al., 2016	Not assessed
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Dutta et al., 2016	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Dutta et al., 2016	Not assessed
Reptile	Indian cobra	*Naja naja*	India	Dutta et al., 2016	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Dutta et al., 2016	Not assessed
Reptile		*Calotes spp.*	India	Dutta et al., 2016	NA
Reptile		*Hemidactylus spp.*	India	Dutta et al., 2016	NA
Reptile		*Typhlops spp.*	India	Dutta et al., 2016	NA
Reptile	UID Lizard		India	Dutta et al., 2016	NA
Reptile	UID Snake		India	Dutta et al., 2016	NA
Reptile	Indian rock python	*Python molurus*	India	Fellows et al., 2015	Not assessed
Reptile	Common green forest lizard	*Calotes calotes*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Blanford's rock agama	*Psammophilus blanfordanus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Peninsular rock agama	*Psammophilus dorsalis*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Forest spotted gecko	*Cyrtodactylus speciosus*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Brook's house gecko	*Hemidactylus cf. brookii*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Bangalore rock gecko	*Hemidactylus graniticolus*	India	Ganesh & Arumugam, 2015b	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Southern ghats slender gecko	*Hemiphyllodactylus aurantiacus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Beddome's Mabuya	*Eutropis beddomei*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Common snake skink	*Lygosoma punctata*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Pruth's supple skink	*Lygosoma cf. pruthi*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Beddome's worm snake	*Gerrhopilus cf. beddomei*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Phipson's shieldtail	*Uropeltis phipsonii*	India	Ganesh & Arumugam, 2015b	VU
Reptile	Elliot's earth snake	*Uropeltis ellioti*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Common trinket snake	*Coelognathus helena*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Travencore wolf snake	*Lycodon travancoricus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Indian flying snake	*Chrysopelea taprobanica*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Forstens cat snake	*Boiga forsteni*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Common green forest lizard	*Calotes calotes*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Peninsular rock agama	*Psammophilus dorsalis*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Forest spotted gecko	*Cyrtodactylus speciosus*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Pruth's supple skink	*Lygosoma cf. pruthi*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Beddome's worm snake	*Gerrhopilus cf. beddomei*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Elliot's earth snake	*Uropeltis ellioti*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Common trinket snake	*Coelognathus helena*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Travencore wolf snake	*Lycodon travancoricus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Forstens cat snake	*Boiga forsteni*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Collared cat snake	*Boiga nuchalis*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Bamboo pit-viper	*Trimeresurus gramineus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Forest spotted gecko	*Cyrtodactylus speciosus*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Bangalore rock gecko	*Hemidactylus graniticolus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Ganesh & Arumugam, 2015b	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Beddome's worm snake	*Gerrhopilus cf. beddomei*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Gower's shieldtail	*Rhinophis goweri*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Ceylon Earth Snake	*Uropeltis ceylanica*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Common trinket snake	*Coelognathus helena*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Travencore wolf snake	*Lycodon travancoricus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Boie's bronzeback	*Dendrelaphis cf. chairecacos*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Forstens cat snake	*Boiga forsteni*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Collared cat snake	*Boiga nuchalis*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Beddome's coral snake	*Calliophis beddomei*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Bamboo pit-viper	*Trimeresurus gramineus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Common green forest lizard	*Calotes calotes*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Blanford's rock agama	*Psammophilus blanfordanus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Kollegal ground gecko	*Cyrtodactylus cf. collegalensis*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile		*Hemidactylus cf. acanthopholis*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Bronze skink	*Eutropis macularia*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Sirumalai Hills earth snake	*Uropeltis dindigalensis*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Travencore wolf snake	*Lycodon travancoricus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Boie's bronzeback	*Dendrelaphis cf. chairecacos*	India	Ganesh & Arumugam, 2015b	DD
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Ganesh & Arumugam, 2015b	Not assessed
Reptile	Forstens cat snake	*Boiga forsteni*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Striped coral snake	*Calliophis nigrescens pentalineatus*	India	Ganesh & Arumugam, 2015b	LC
Reptile	Indian garden lizard	*Calotes versicolor*	India	Ghadage, 2013	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Ghadage, 2013	Not assessed
Reptile	Common trinket snake	*Coelognathus helena*	India	Ghadage, 2013	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Ghadage, 2013	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Ghadage, 2013	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Ghadage, 2013	Not assessed
Reptile	Whitaker's sand boa	*Eryx whitakeri*	India	Ghadage, 2013	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Ghadage, 2013	LC
Reptile	Indian rock python	*Python molurus*	India	Gokula, 1997	Not assessed

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Common kukri snake	*Oligodon arnensis*	India	Gokula, 1997	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Gokula, 1997	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Gokula, 1997	Not assessed
Reptile	Indian cobra	*Naja naja*	India	Gokula, 1997	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Gokula, 1997	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Gokula, 1997	Not assessed
Reptile	Indian rock python	*Python molurus*	India	Jeganathan et al., 2018	Not assessed
Reptile	Toads		India	Jeganathan et al., 2018	NA
Reptile	Agamids		India	Jeganathan et al., 2018	NA
Reptile		*Calotes spp.*	India	Jeganathan et al., 2018	NA
Reptile	Geckos		India	Jeganathan et al., 2018	NA
Reptile	Shieldtails		India	Jeganathan et al., 2018	NA
Reptile	Skinks		India	Jeganathan et al., 2018	NA
Reptile	Snakes		India	Jeganathan et al., 2018	NA
Reptile	Indian cobra	*Naja naja*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Joshi & Dixit, 2012	LC
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Joshi & Dixit, 2012	LC
Reptile	Olive keelback	*Atretium schistosum*	India	Joshi & Dixit, 2012	LC
Reptile	Indian rock python	*Python molurus*	India	Joshi & Dixit, 2012	Not assessed
Reptile	King cobra	*Ophiophagus hannah*	India	Joshi & Dixit, 2012	VU
Reptile	Indian cobra	*Naja naja*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Joshi & Dixit, 2012	LC
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Joshi & Dixit, 2012	LC
Reptile	Olive keelback	*Atretium schistosum*	India	Joshi & Dixit, 2012	LC
Reptile	Indian cobra	*Naja naja*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Joshi & Dixit, 2012	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Joshi & Dixit, 2012	LC
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Joshi & Dixit, 2012	LC
Reptile	Olive keelback	*Atretium schistosum*	India	Joshi & Dixit, 2012	LC
Reptile	Reptiles		India	Jothivel, 2014	NA
Reptile	Nikhil's kukri snake	*Oligodon nikhili*	India	Kanagavel, 2013	DD
Reptile	Indian flap-shelled turtle	*Lissemys punctata*	India	Kannan, 2007	LC
Reptile	Common green forest lizard	*Calotes calotes*	India	Kannan, 2007	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Kannan, 2007	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Kannan, 2007	LC
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Kannan, 2007	Not assessed
Reptile	Common kukri snake	*Oligodon arnensis*	India	Kannan, 2007	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Kannan, 2007	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Kannan, 2007	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Kannan, 2007	Not assessed
Reptile	Kashmir rock agama	*Laudakia tuberculata*	India	Kumar & Srinivasulu, 2015	Not assessed
Reptile	Large-scaled pit-viper	*Peltopelor macrolepis*	India	Kumara et al., 2000	NT
Reptile	Malabar pit-viper	*Trimeresurus malabaricus*	India	Kumara et al., 2000	LC
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Kumara et al., 2000	Not assessed
Reptile	Beddome's keelback	*Hebius beddomei*	India	Kumara et al., 2000	LC
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Kumara et al., 2000	Not assessed
Reptile	Indian coral snake	*Calliophis melanurus*	India	Kumara et al., 2000	Not assessed
Reptile	Striped coral snake	*Calliophis nigrescens*	India	Kumara et al., 2000	LC
Reptile	Two-lined black earth snake	*Melanophidium bilineatum*	India	Kumara et al., 2000	VU
Reptile	Palni mountain burrowing snake	*Brachyophidium rhodogaster*	India	Kumara et al., 2000	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Phipson's shieldtail	*Uropeltis phipsonii*	India	Kumara et al., 2000	VU
Reptile	Red-spotted shieldtail	*Uropeltis rubromaculatus*	India	Kumara et al., 2000	LC
Reptile	Elliot's earth snake	*Uropeltis ellioti*	India	Kumara et al., 2000	LC
Reptile	Ocellated earth snake	*Uropeltis ocellata*	India	Kumara et al., 2000	LC
Reptile	Ceylon earth snake	*Uropeltis ceylanica*	India	Kumara et al., 2000	LC
Reptile		*Lycodon sp.*	India	Kumara et al., 2000	NA
Reptile		*Boiga sp.*	India	Kumara et al., 2000	NA
Reptile		*Keelback sp.*	India	Kumara et al., 2000	NA
Reptile		*Uropeltis sps.*	India	Kumara et al., 2000	NA
Reptile	Common krait	*Bungarus caeruleus*	India	Kundu et al., 2016	Not assessed
Reptile	Reptiles		India	Maurya et al., 2011	NA
Reptile	Giri's Geckoella	*Cyrtodactylus varadgirii*	India	Mirza et al., 2010	Not assessed
Reptile	Reptiles		India	Nagar et al., 2013	NA
Reptile	Stocky sand snake	*Psammophis longifrons*	India	Nande & Deshmukh, 2007	LC
Reptile	Indian smooth snake	*Coronella brachyura*	India	Nande & Deshmukh, 2007	LC
Reptile	Beaked worm snake	*Grypotyphlops acutus*	India	Nande & Deshmukh, 2007	LC
Reptile	Calamaria reed snake	*Liopeltis calamaria*	India	Narayanan, 2016	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Pandirkar et al., 2015	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Parasharya & Tere, 2007	LC
Reptile	Red sand boa	*Eryx johnii*	India	Patel et al., 2014	Not assessed
Reptile	Diadem snake	*Spalerosophis diadema*	India	Patel et al., 2014	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Patel et al., 2014	Not assessed
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Patel et al., 2014	LC
Reptile	Indian monitor	*Varanus bengalensis*	India	Patel et al., 2014	LC
Reptile	Reptiles		India	Paunikar, 2014	NA
Reptile	Bamboo pit-viper	*Trimeresurus gramineus*	India	Pragatheesh & Rajvanshi, 2013	LC
Reptile	Barred wolf snake	*Lycodon striatus*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Beaked worm snake	*Grypotyphlops acutus*	India	Pragatheesh & Rajvanshi, 2013	LC
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Pragatheesh & Rajvanshi, 2013	LC
Reptile	Common krait	*Bungarus caeruleus*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Common kukri snake	*Oligodon arnesis*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Common sand boa	*Eryx conicus*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Common trinket snake	*Coelognathus helena helena*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Forstens cat snake	*Boiga forsteni*	India	Pragatheesh & Rajvanshi, 2013	LC
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Indian rock python	*Python molurus*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Russell's kukri snake	*Oligodon taeniolatus*	India	Pragatheesh & Rajvanshi, 2013	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Russell's viper	*Daboia russelii*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Saw scaled viper	*Echis carinatus*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Indian cobra	*Naja naja*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Pragatheesh & Rajvanshi, 2013	Not assessed
Reptile	UID		India	Pragatheesh & Rajvanshi, 2013	NA
Reptile	Star tortoise	*Geochelone elegans*	India	Prajapati, 2016	VU
Reptile	Indian flap-shelled turtle	*Lissemys punctata*	India	Prajapati, 2016	LC
Reptile	Indian garden lizard	*Calotes versicolor*	India	Prajapati, 2016	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Prajapati, 2016	LC
Reptile	Common krait	*Bungarus caeruleus*	India	Prajapati, 2016	Not assessed
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Prajapati, 2016	Not assessed
Reptile	Saw-scaled viper	*Echis carinatus*	India	Prajapati, 2016	Not assessed
Reptile		*Hemidactylus sp.*	India	Prajapati, 2016	NA
Reptile	Reptiles		India	Rao & Girish, 2007	NA
Reptile	Common wolf snake	*Lycodon aulicus*	India	Roy & Dey, 2015	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Roy & Dey, 2015	Not assessed
Reptile	Twin-spotted wolf snake	*Lycodon jara*	India	Roy & Dey, 2015	LC
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Roy & Dey, 2015	Not assessed
Reptile	Diard's blindsnake	*Argyrophis diardii*	India	Roy & Dey, 2015	LC
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	India	Samson et al., 2016	Not assessed
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Samson et al., 2016	LC
Reptile	Indian garden lizard	*Calotes versicolor*	India	Samson et al., 2016	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Samson et al., 2016	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Samson et al., 2016	LC
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Samson et al., 2016	Not assessed
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Samson et al., 2016	LC
Reptile	Russell's viper	*Daboia russelii*	India	Samson et al., 2016	Not assessed
Reptile	Perrotet's shieldtail	*Plectrurus perrotetii*	India	Santoshkumar et al., 2016	LC
Reptile	Two-lined ground skink	*Kaestlea bilineata*	India	Santoshkumar et al., 2017	LC
Reptile	Horsfield's spiny lizard	*Salea horsfieldii*	India	Santoshkumar et al., 2017	LC
Reptile	Perrotet's shieldtail	*Plectrurus perrotetii*	India	Santoshkumar et al., 2017	LC
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Santoshkumar et al., 2017	Not assessed
Reptile	Jerdon's kukri snake	*Oligodon venustus*	India	Santoshkumar et al., 2017	LC
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Santoshkumar et al., 2017	Not assessed
Reptile	Perrotet's mountain snake	*Xylophis perroteti*	India	Santoshkumar et al., 2017	LC
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Hump nose moccasin	*Hypnale hypnale*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Elliot's earth snake	*Uropeltis ellioti*	India	Sathish-Narayanan et al., 2016	LC
Reptile	Russell's viper	*Daboia russelii*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Red sand boa	*Eryx johnii*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Sathish-Narayanan et al., 2016	LC

LIST OF SPECIES DOCUMENTED IN ANIMAL-VEHICLE COLLISIONS IN ASIA

TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Sathish-Narayanan et al., 2016	LC
Reptile	Common green forest lizard	*Calotes calotes*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Sathish-Narayanan et al., 2016	Not assessed
Reptile	Indian pond terrapin	*Melanochelys trijuga*	India	Sathish-Narayanan et al., 2016	LC
Reptile	Russell's viper	*Daboia russelii*	India	Selvan, 2011	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Selvan, 2011	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Selvan, 2011	Not assessed
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	India	Selvan, 2011	LC
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Selvan, 2011	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Selvan, 2011	LC
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Selvan, 2011	LC
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Selvan, 2011	Not assessed
Reptile	Red sand boa	*Eryx johnii*	India	Selvan, 2011	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Selvan, 2011	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Selvan, 2011	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	India	Selvan, 2011	LC
Reptile	UID Viper		India	Selvan, 2011	NA
Reptile	Snake		India	Selvan et al., 2012	NA
Reptile	Other Reptiles		India	Selvan et al., 2012	NA
Reptile	Calotes sp		India	Seshadri & Ganesh, 2011	NA
Reptile	Indian garden lizard	*Calotes versicolor*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Sand Boa sp	*Eryx sp*	India	Seshadri & Ganesh, 2011	NA
Reptile		*Gecko sp*	India	Seshadri & Ganesh, 2011	NA
Reptile	Bark Gecko	*Hemidactylus leschenaultii*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Termite Hill Gecko	*Hemidactylus triedrus*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Common kukri snake	*Oligodon arnensis*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	India	Seshadri & Ganesh, 2011	Not assessed
Reptile	Snake sp		India	Seshadri & Ganesh, 2011	NA
Reptile	Viper sp	*Trimeresurus spp.*	India	Seshadri & Ganesh, 2011	NA
Reptile	Reptiles		India	Sharma, 1988	NA
Reptile	Banded racer	*Argyrogena fasciolata*	India	Sharma, 2004	Not assessed
Reptile	Indian egg-eating snake	*Elachistodon westermanni*	India	Sharma, 2014	LC
Reptile	Saw-scaled viper	*Echis carinatus*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	India	Sivakumar & Manakadan, 2010	LC
Reptile	Russell's viper	*Daboia russelii*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Common cat snake	*Boiga trigonata*	India	Sivakumar & Manakadan, 2010	LC
Reptile	Indian cobra	*Naja naja*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Olive keelback	*Atretium schistosum*	India	Sivakumar & Manakadan, 2010	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Red sand boa	*Eryx johnii*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Sivakumar & Manakadan, 2010	Not assessed
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Sivakumar & Manakadan, 2010	LC
Reptile	Indian pond terrapin	*Melanochelys trijuga*	India	Sivakumar & Manakadan, 2010	LC
Reptile	Indian monitor	*Varanus bengalensis*	India	Sivakumar & Manakadan, 2010	LC
Reptile	Pakistani ribbon snake	*Psammophis leithii*	India	Solanki et al., 2015	Not assessed
Reptile	Desert monitor	*Varanus griseus*	India	Solanki et al., 2015	Not assessed
Reptile	Indian spiny-tailed lizard	*Saara hardwickii*	India	Solanki et al., 2015	LC
Reptile	Reptiles		India	Solanki et al. ,2017	NA
Reptile	Banded krait	*Bungarus fasciatus*	India	Srinivasulu et al., 2009	LC
Reptile	Red sand boa	*Eryx johnii*	India	Sundar, 2004	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Sundar, 2004	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Sundar, 2004	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	India	Sundar, 2004	Not assessed
Reptile	Indian flap-shelled turtle	*Lissemys punctata*	India	Sundar, 2004	LC
Reptile		*Oligodon sp.*	India	Sundar, 2004	NA
Reptile	UID reptiles		India	Sundar, 2004	NA
Reptile	Indian spiny-tailed lizard	*Saara hardwickii*	India	Sunderraj & Andavan, 2010	LC
Reptile	Montane trinket Snake	*Coelognathus helena monticollaris*	India	Thakur, 2011	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Thakur, 2011	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Thakur, 2011	Not assessed
Reptile	Elliot's forest lizard	*Calotes ellioti*	India	Vijaykumar et al., 2001	LC
Reptile	Nilgiri forest lizard	*Calotes nemoricola*	India	Vijaykumar et al., 2001	LC
Reptile	Many-keeled grass skink	*Eutropis carinata*	India	Vijaykumar et al., 2001	LC
Reptile	Anamally earth snake	*Uropeltis macrorhyncha*	India	Vijaykumar et al., 2001	LC
Reptile	Ceylon earth snake	*Uropeltis ceylanica*	India	Vijaykumar et al., 2001	LC
Reptile	Two-lined black earth snake	*Melanophidium bilineatum*	India	Vijaykumar et al., 2001	VU
Reptile	Phipson's shieldtail	*Uropeltis phipsonii*	India	Vijaykumar et al., 2001	VU
Reptile	Beddome's keelback	*Hebius beddomei*	India	Vijaykumar et al., 2001	LC
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Vijaykumar et al., 2001	Not assessed
Reptile	Sri Lanka cat snake	*Boiga ceylonensis*	India	Vijaykumar et al., 2001	Not assessed
Reptile	Pirmad cat snake	*Boiga dightoni*	India	Vijaykumar et al., 2001	DD
Reptile	Olive keelback	*Atretium schistosum*	India	Vijaykumar et al., 2001	LC
Reptile	Short-tailed kukri snake	*Oligodon brevicauda*	India	Vijaykumar et al., 2001	VU
Reptile	Indian coral snake	*Calliophis melanurus*	India	Vijaykumar et al., 2001	Not assessed
Reptile	Large-scaled pit-viper	*Peltopelor macrolepis*	India	Vijaykumar et al., 2001	NT
Reptile		*Calotes sp.*	India	Vijaykumar et al., 2001	NA
Reptile		*Mabuya sp.*	India	Vijaykumar et al., 2001	NA
Reptile		*Cnemaspis sp.*	India	Vijaykumar et al., 2001	NA
Reptile		*Uropeltis sp.*	India	Vijaykumar et al., 2001	NA
Reptile	Unidentified		India	Vijaykumar et al., 2001	NA
Reptile		*Lycodon spp 1*	India	Vijaykumar et al., 2001	NA
Reptile		*Lycodon spp 2*	India	Vijaykumar et al., 2001	NA
Reptile		*Boiga sp.*	India	Vijaykumar et al., 2001	NA

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Unidentified sp. 1.		India	Vijaykumar et al., 2001	NA
Reptile	Unidentified sp. 2.		India	Vijaykumar et al., 2001	NA
Reptile	Unidentified (others)		India	Vijaykumar et al., 2001	NA
Reptile	Unidentified reptiles		India	Vijaykumar et al., 2001	NA
Reptile	Indian garden lizard	*Calotes versicolor*	India	Vyas, 2002a	Not assessed
Reptile	Hardwicke's bloodsucker	*Calotes minor*	India	Vyas, 2002a	DD
Reptile	Spiny-headed fan-throated lizard	*Sitana spinaecephalus*	India	Vyas, 2002a	Not assessed
Reptile	Indian chameleon	*Chamaeleo zeylanicus*	India	Vyas, 2002a	LC
Reptile	Indian monitor	*Varanus bengalensis*	India	Vyas, 2002a	LC
Reptile	Red sand boa	*Eryx johnii*	India	Vyas, 2002a	Not assessed
Reptile	Oriental ratsnake	*Ptyas mucosa*	India	Vyas, 2002a	Not assessed
Reptile	Saw-scaled viper	*Echis carinatus*	India	Vyas, 2002a	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	India	Vyas, 2007	Not assessed
Reptile	Banded racer	*Argyrogena fasciolata*	India	Vyas, 2007	Not assessed
Reptile	Cantor's black-headed snake	*Sibynophis sagittarius*	India	Vyas, 2007	Not assessed
Reptile	Russell's viper	*Daboia russelii*	India	Vyas, 2007	Not assessed
Reptile	Bamboo pit-viper	*Trimeresurus gramineus*	India	Vyas, 2007	LC
Reptile	Checkered keelback	*Xenochrophis piscator*	India	Vyas, 2007	Not assessed
Reptile	Indian egg-eating snake	*Elachistodon westermanni*	India	Vyas, 2010	LC
Reptile	Common sand boa	*Eryx conicus*	India	Vyas, 2011	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	India	Vyas, 2011	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	India	Vyas, 2011	Not assessed
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	India	Vyas, 2011	LC
Reptile	Beaked worm snake	*Grypotyphlops acutus*	India	Vyas et al., 2001	LC
Reptile	Elliot's earth snake	*Uropeltis ellioti*	India	Wadatkar & Chikhale, 2010	LC
Reptile	Yellow-spotted wolf snake	*Lycodon flavomaculatus*	India	Walmiki et al., 2011	LC
Reptile	Indochinese rat snake	*Ptyas korros*	Indonesia	Auliya, 2002	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Water monitor	*Varanus salvator*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Amboina box turtle	*Cuora amboinensis*	Malaysia	Kasmuri et al., 2020	EN
Reptile	Malayan pit viper	*Calloselasma rhodostoma*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Viperidae		Malaysia	Kasmuri et al., 2020	NA
Reptile	Reticulated python	*Malayopython reticulatus*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Sumatran short-tailed python	*Python curtus*	Malaysia	Kasmuri et al., 2020	LC
Reptile	King cobra	*Ophiophagus Hannah*	Malaysia	Kasmuri et al., 2020	VU
Reptile	Monocled cobra	*Naja kaouthia*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Equatorial spitting cobra	*Naja sumatrana*	Malaysia	Kasmuri et al., 2020	LC
Reptile		*Ptyas spp.*	Malaysia	Kasmuri et al., 2020	NA
Reptile	Indo-Chinese rat snake	*Ptyas korros*	Malaysia	Kasmuri et al., 2020	Not assessed
Reptile	Dog-toothed cat snake	*Boiga cynodon*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Mangrove snake	*Boiga dendrophila*	Malaysia	Kasmuri et al., 2020	Not assessed
Reptile	Malayan krait	*Bungarus candidus*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Black copper rat snake	*Coelognathus flavolineatus*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Copper-headed tricket snake	*Coelognathus radiatus*	Malaysia	Kasmuri et al., 2020	LC
Reptile	Cave racer	*Elaphe taeniura*	Malaysia	Kasmuri et al., 2020	Not assessed
Reptile	Cave racer	*Elaphe taeniura*	Malaysia	Kasmuri et al., 2020	Not assessed
Reptile	Asiatic Toad	*Duttaphrynus melanostictus*	Nepal	Rawat, 2020	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Indian monitor	*Varanus bengalensis*	Nepal	Rawat, 2020	LC
Reptile	Red sand boa	*Eryx johnii*	Nepal	Rawat, 2020	Not assessed
Reptile	Common trinket snake	*Coelognathus helena*	Nepal	Rawat, 2020	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	Nepal	Rawat, 2020	Not assessed
Reptile	Tiger keelback snake	*Rhabdophis tigrinus*	South Korea	Lee, 2018	Not assessed
Reptile	Steppes Ratsnakes	*Elaphe dione*	South Korea	Lee et al., 2018	LC
Reptile	Ussuri pit viper	*Gloydius ussuriensis*	South Korea	Lee et al., 2018	Not assessed
Reptile	Asian king snake	*Lycodon rufozonatus*	South Korea	Lee et al., 2018	LC
Reptile	Short-tailed pit viper	*Gloydius brevicaudus*	South Korea	Lee et al., 2018	Not assessed
Reptile	Amur rat snake	*Elaphe shrenckii*	South Korea	Lee et al., 2018	Not assessed
Reptile	Central Asian pit viper	*Gloydius intermedius*	South Korea	Lee et al., 2018	Not assessed
Reptile	Japanese keelback	*Hebius vibakari*	South Korea	Lee et al., 2018	Not assessed
Reptile	Red-backed rat snake	*Oocatochus rufodorsatus*	South Korea	Lee et al., 2018	LC
Reptile	Slender racer	*Orientocoluber spinalis*	South Korea	Lee et al., 2018	Not assessed
Reptile	Steppes Ratsnakes	*Elaphe dione*	South Korea	Park et al., 2017	LC
Reptile	Ussuri pit viper	*Gloydius ussuriensis*	South Korea	Park et al., 2017	Not assessed
Reptile	Short-tailed pit viper	*Gloydius brevicaudus*	South Korea	Park et al., 2017	Not assessed
Reptile	Amur rat snake	*Elaphe shrenckii*	South Korea	Park et al., 2017	Not assessed
Reptile	Red-backed rat snake	*Oocatochus rufodorsatus*	South Korea	Park et al., 2017	LC
Reptile	Asian king snake	*Lycodon rufozonatus*	South Korea	Park et al., 2017	LC
Reptile	Tiger keelback Snake	*Rhabdophis tigrinus*	South Korea	Park et al., 2017	Not assessed
Reptile	Japanese keelback	*Hebius vibakari*	South Korea	Park et al., 2017	Not assessed
Reptile	Rock mamushi	*Gloydius saxatilis*	South Korea	Park et al., 2017	LC
Reptile	Slender racer	*Orientcoluber spinalis*	South Korea	Park et al., 2017	Not assessed
Reptile	Indian rock python	*Python molurus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Green vine snake	*Ahaetulla nasuta*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Brown vine snake	*Ahaetulla pulverulenta*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Buff striped keelback	*Amphiesma stolatum*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Boie's rough-sided snake	*Aspidura brachyorrhos*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Olive keelback	*Atretium schistosum*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Sri Lanka cat snake	*Boiga ceylonensis*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Forstens cat snake	*Boiga forsteni*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Common trinket snake	*Coelognathus helena*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Boulenger's bronzeback	*Dendrelaphis bifrenalis*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Vellore bridle snake	*Lycodon nympha*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Common wolf snake	*Lycodon aulicus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Colombo wolf snake	*Lycodon osmanhilli*	Sri Lanka	Karunarathna et al., 2013	LC

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Barred wolf snake	*Lycodon striatus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Green keelback	*Macropisthodon plumbicolor*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Common kukri snake	*Oligodon arnensis*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Dumeril's kukri snake	*Oligodon sublineatus*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Oriental rat snake	*Ptyas mucosa*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Dumeril's black headed snake	*Sibynophis subpunctatus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Sri Lankan keelback	*Fowlea asperrimus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Checkered keelback	*Xenochrophis piscator*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Common krait	*Bungarus caeruleus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Sri Lanka krait	*Bungarus ceylonicus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Indian coral snake	*Calliophis melanurus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Indian cobra	*Naja naja*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Brahminy blindsnake	*Indotyphlops braminus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Ceylonese cylinder snake	*Cylindrophis maculatus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Russell's viper	*Daboia russelii*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Hump nose moccasin	*Hypnale hypnale*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Sri Lanka hump-nosed viper	*Hypnale cf. nepa*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile		*Trimeresurus trigonocephalus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Marsh crocodile	*Crocodylus palustris*	Sri Lanka	Karunarathna et al., 2013	VU
Reptile	Indian pond terrapin	*Melanochelys trijuga*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Star tortoise	*Geochelone elegans*	Sri Lanka	Karunarathna et al., 2013	VU
Reptile	Common green forest lizard	*Calotes calotes*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Ceylon bloodsucke	*Calotes ceylonensis*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Black-spotted kangaroo lizard	*Otocryptis nigristigma*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Spotted bow-finger gecko	*Cyrtodactylus triedrus*	Sri Lanka	Karunarathna et al., 2013	NT
Reptile	Common four-clawed gecko	*Gehyra mutilata*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Spotted house gecko	*Hemidactylus parvimaculatus*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Sri Lanka leaf-toed gecko	*Hemidactylus depressus*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Common house gecko	*Hemidactylus frenatus*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Bark Gecko	*Hemidactylus leschenaultii*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Sri Lanka Leaf-toed Gecko	*Hemidactylus lankae*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Common supple skink	*Lankascincus fallax*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Common snake skink	*Lygosoma punctata*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Many-keeled grass skink	*Eutropis carinata*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Bronze skink	*Eutropis macularia*	Sri Lanka	Karunarathna et al., 2013	Not assessed
Reptile	Indian monitor	*Varanus bengalensis*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Water monitor	*Varanus salvator*	Sri Lanka	Karunarathna et al., 2013	LC
Reptile	Buff striped keelback	*Amphiesma stolatum*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Common rough-sided snake	*Aspidura trachyprocta*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Indian garden lizard	*Calotes versicolor*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Black-cheek lizard	*Calotes nigrilabris*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Rhino-horned lizard	*Ceratophora stoddartii*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Ceylon deaf agama	*Cophotis ceylanica*	Sri Lanka	Karunarathna et al., 2017	Not assessed

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TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Common bronzeback tree snake	*Dendrelaphis tristis*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Many-keeled grass skink	*Eutropis carinata*	Sri Lanka	Karunarathna et al., 2017	LC
Reptile	Star tortoise	*Geochelone elegans*	Sri Lanka	Karunarathna et al., 2017	VU
Reptile	Rough-scaled sand boa	*Gongylophis conicus*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Bark Gecko	*Hemidactylus leschenaultii*	Sri Lanka	Karunarathna et al., 2017	Not assessed
Reptile	Ceylon tree skink	*Lankascincus taprobanensis*	Sri Lanka	Karunarathna et al., 2017	NT
Reptile	Indian pond terrapin	*Melanochelys trijuga*	Sri Lanka	Karunarathna et al., 2017	LC
Reptile	Streaked kukri snake	*Oligodon taeniolatus*	Sri Lanka	Karunarathna et al., 2017	LC
Reptile	Dumeril's kukri snake	*Oligodon sublineatus*	Sri Lanka	Karunarathna et al., 2017	LC
Reptile	Indian monitor	*Varanus bengalensis*	Sri Lanka	Karunarathna et al., 2017	LC
Reptile	Sri Lanka cat snake	*Boiga ceylonensis*	Sri Lanka	Madawala et al., 2019	Not assessed
Reptile	Buff striped keelback	*Amphiesma stolatum*	Taiwan	Lin et al., 2019	Not assessed
Reptile	Kelung cat snake	*Boiga kraepelini*	Taiwan	Lin et al., 2019	LC
Reptile	Greater green snake	*Ptyas major*	Taiwan	Lin et al., 2019	LC
Reptile	King ratsnake	*Elaphe carinata*	Taiwan	Lin et al., 2019	Not assessed
Reptile	Long-tailed sun skink	*Eutropis longicaudata*	Taiwan	Lin et al., 2019	LC
Reptile	Taiwan japalure	*Diploderma swinhonis*	Taiwan	Lin et al., 2019	LC
Reptile	Asian king snake	*Lycodon rufozonatus*	Taiwan	Lin et al., 2019	LC
Reptile	Ruhstrat's wolf snake	*Lycodon ruhstrati*	Taiwan	Lin et al., 2019	LC
Reptile	Formosa kukri snake	*Oligodon formosanus*	Taiwan	Lin et al., 2019	LC
Reptile	Black-banded trinket snake	*Oreocryptophis porphyraceus*	Taiwan	Lin et al., 2019	Not assessed
Reptile	Oriental rat snake	*Ptyas mucosa*	Taiwan	Lin et al., 2019	Not assessed
Reptile		*Trimeresurus stejnegeri*	Taiwan	Lin et al., 2019	LC
Reptile	Water monitor	*Varanus salvator*	Thailand	Duengkae et al., 2009	LC
Reptile		*Liopeltis stoliczkae*	Thailand	Hauser, 2018	LC
Reptile	Many-banded green snake	*Ptyas multicinctus*	Thailand	Hauser, 2019	LC
Reptile	King cobra	*Ophiophagus Hannah*	Thailand	Marshall et al., 2019	VU
Reptile	Masked spiny lizard	*Acanthosaura crucigera*	Thailand	Silva et al., 2020	LC
Reptile	Forest garden lizard	*Calotes emma*	Thailand	Silva et al., 2020	Not assessed
Reptile	Indo-Chinese forest lizard	*Calotes mystaceus*	Thailand	Silva et al., 2020	Not assessed
Reptile		*Calotes sp.*	Thailand	Silva et al., 2020	NA
Reptile	Indian garden lizard	*Calotes versicolor*	Thailand	Silva et al., 2020	Not assessed
Reptile		*Draco sp.*	Thailand	Silva et al., 2020	NA
Reptile	Unknown		Thailand	Silva et al., 2020	NA
Reptile		*Dendrelaphis sp.*	Thailand	Silva et al., 2020	NA
Reptile	Tokay gecko	*Gekko gecko*	Thailand	Silva et al., 2020	LC
Reptile	Southeat Asian box turtle	*Cuora amboinensis*	Thailand	Silva et al., 2020	EN
Reptile	Unknown		Thailand	Silva et al., 2020	NA
Reptile	Bronze skink	*Eutropis macularia*	Thailand	Silva et al., 2020	Not assessed
Reptile	Many-lined sun skink	*Eutropis multifasciata*	Thailand	Silva et al., 2020	LC
Reptile		*Eutropis sp.*	Thailand	Silva et al., 2020	NA
Reptile	Unknown		Thailand	Silva et al., 2020	NA
Reptile	Indian monitor	*Varanus bengalensis*	Thailand	Silva et al., 2020	LC
Reptile	Water monitor	*Varanus salvator*	Thailand	Silva et al., 2020	LC
Reptile	Green cat snake	*Boiga cyanea*	Thailand	Silva et al., 2020	Not assessed
Reptile	Many-spotted cat snake	*Boiga multomaculata*	Thailand	Silva et al., 2020	Not assessed
Reptile	Siamese cat snake	*Boiga siamensis*	Thailand	Silva et al., 2020	Not assessed
Reptile	Golden tree snake	*Chrysopelea ornata*	Thailand	Silva et al., 2020	Not assessed
Reptile	Black copper rat snake	*Coelognathus flavolineatus*	Thailand	Silva et al., 2020	LC
Reptile	Copper-headed tricket snake	*Coelognathus radiatus*	Thailand	Silva et al., 2020	LC

LIST OF SPECIES DOCUMENTED IN ANIMAL-VEHICLE COLLISIONS IN ASIA

TAXON	COMMON NAME	SCIENTIFIC NAME	COUNTRY	REFERENCE	IUCN REDLIST STATUS
Reptile	Painted bronzeback	*Dendrelaphis pictus*	Thailand	Silva et al., 2020	Not assessed
Reptile		*Dendrelaphis sp.*	Thailand	Silva et al., 2020	NA
Reptile	Mountain Bronzeback	*Dendrelaphis subocularis*	Thailand	Silva et al., 2020	LC
Reptile	Arboreal ratsnake	*Gonyosoma oxycephalum*	Thailand	Silva et al., 2020	LC
Reptile	Oriental wolf snake	*Lycodon capucinus*	Thailand	Silva et al., 2020	LC
Reptile	Laotian wolf snake	*Lycodon laoensis*	Thailand	Silva et al., 2020	LC
Reptile		*Lycodon sp.*	Thailand	Silva et al., 2020	NA
Reptile	Malayan banded wolf snake	*Lycodon subcinctus*	Thailand	Silva et al., 2020	LC
Reptile	Ashy kukri snake	*Oligodon cinereus*	Thailand	Silva et al., 2020	LC
Reptile	Small-banded kukri snake	*Oligodon fasciolatus*	Thailand	Silva et al., 2020	LC
Reptile	False striped kukri snake	*Oligodon pseudotaeniatus*	Thailand	Silva et al., 2020	LC
Reptile		*Oligodon sp.*	Thailand	Silva et al., 2020	NA
Reptile	Striped Kukri Snake	*Oligodon taeniatus*	Thailand	Silva et al., 2020	LC
Reptile	Common mock viper	*Psammodynastes pulverulentus*	Thailand	Silva et al., 2020	Not assessed
Reptile	Indochinese rat snake	*Ptyas korros*	Thailand	Silva et al., 2020	Not assessed
Reptile	Oriental rat snake	*Ptyas mucosa*	Thailand	Silva et al., 2020	Not assessed
Reptile		*Ptyas sp.*	Thailand	Silva et al., 2020	NA
Reptile	Red-necked keelback	*Rhabdophis subminiatus*	Thailand	Silva et al., 2020	LC
Reptile	Triangle many-tooth snake	*Sibynophis triangularis*	Thailand	Silva et al., 2020	NT
Reptile	Unknown		Thailand	Silva et al., 2020	NA
Reptile		*Xenochrophis flavipunctatus*	Thailand	Silva et al., 2020	LC
Reptile	Checkered keelback	*Xenochrophis piscator*	Thailand	Silva et al., 2020	Not assessed
Reptile		*Xenochrophis sp.*	Thailand	Silva et al., 2020	NA
Reptile	Common pipe snake	*Cylindrophis ruffus*	Thailand	Silva et al., 2020	LC
Reptile	Malayan krait	*Bungarus candidus*	Thailand	Silva et al., 2020	LC
Reptile	Speckled coral snake	*Calliophis maculiceps*	Thailand	Silva et al., 2020	LC
Reptile	Monocled cobra	*Naja kaouthia*	Thailand	Silva et al., 2020	LC
Reptile	Indochinese spitting cobra	*Naja siamensis*	Thailand	Silva et al., 2020	VU
Reptile		*Naja sp.*	Thailand	Silva et al., 2020	NA
Reptile	King cobra	*Ophiophagus hannah*	Thailand	Silva et al., 2020	VU
Reptile	MacClelland's coral snake	*Sinomicrurus macclellandi*	Thailand	Silva et al., 2020	Not assessed
Reptile	Common smooth water snake	*Enhydris enhydris*	Thailand	Silva et al., 2020	LC
Reptile	Boie's mud snake	*Hypsiscopus plumbea*	Thailand	Silva et al., 2020	LC
Reptile		*Enhydris sp.*	Thailand	Silva et al., 2020	NA
Reptile	Puff-faced water snake	*Homalopsis buccata*	Thailand	Silva et al., 2020	LC
Reptile	Asian vine snake	*Ahaetulla prasina*	Thailand	Silva et al., 2020	LC
Reptile	Keeled slug-eating snake	*Pareas carinatus*	Thailand	Silva et al., 2020	LC
Reptile	Mountain slug snake	*Pareas margaritophorus*	Thailand	Silva et al., 2020	LC
Reptile	Burmese python	*Python bivittatus*	Thailand	Silva et al., 2020	VU
Reptile	Reticulated python	*Malayopython reticulatus*	Thailand	Silva et al., 2020	LC
Reptile		*Python sp.*	Thailand	Silva et al., 2020	NA
Reptile	Malayan pit viper	*Calloselasma rhodostoma*	Thailand	Silva et al., 2020	LC
Reptile		*Trimeresurus albolabris*	Thailand	Silva et al., 2020	LC
Reptile		*Trimeresurus macrops*	Thailand	Silva et al., 2020	LC
Reptile		*Trimeresurus sp.*	Thailand	Silva et al., 2020	NA
Reptile		*Xenopeltis unicolor*	Thailand	Silva et al., 2020	LC

APPENDIX B: SUMMARY OF STUDIES ON INDIRECT IMPACTS OF ROADS ON WILDLIFE AT RELATIVELY SMALL SCALES IN ASIA

SUMMARY OF STUDIES ON INDIRECT IMPACTS OF ROADS ON WILDLIFE AT RELATIVELY SMALL SCALES IN ASIA						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF INDIRECT IMPACT	REFERENCE
Changes in Habitat and Human Persecution						
Giant panda	*Ailuropoda melanoleuca*	VU	Mammal	China	Habitat degradation	He et al., 2019
Asian elephant	*Elephas maximus*	EN	Mammal	India	Habitat loss	Gangadharan et al., 2017
Gaur	*Bos gaurus*	VU	Mammal	India	Habitat loss	Gangadharan et al., 2017
Asian elephant	*Elephas maximus*	EN	Mammal	Malaysia	Poaching from roads	Wadey et al., 2018
Phayre's leaf monkey	*Trachypithecus phayrei*	EN	Mammal	Bangladesh	Additive impact of transmission lines along roads	AlRazi et al., 2019
Capped langur	*Trachypithecus pileatus*	VU	Mammal	Bangladesh	Additive impact of transmission lines along roads	AlRazi et al., 2019
Northern pig-tailed macaques	*Macaca leonina*	VU	Mammal	Bangladesh	Additive impact of transmission lines along roads	AlRazi et al., 2019
Bengal slow loris	*Nycticebus bengalensis*	EN	Mammal	Bangladesh	Additive impact of transmission lines along roads	AlRazi et al., 2019
Rhesus macaque	*Macaca mulatta*	LC	Mammal	Bangladesh	Additive impact of transmission lines along roads	AlRazi et al., 2019
Asiatic wild ass	*Equus kiang*	LC	Mammal	China	Lower habitat use near highway	Bao-fa et al., 2007
Chital	*Axis axis*	LC	Mammal	India	Lower habitat use near highway sections that were open compared to those that were closed	Gubbi et al., 2012
Gaur	*Bos gaurus*	VU	Mammal	India	Lower habitat use near highway sections that were open compared to those that were closed	Gubbi et al., 2012
Asian elephant	*Elephas maximus*	EN	Mammal	India	Lower habitat use near highway sections that were open compared to those that were closed	Gubbi et al., 2012
Sambar	*Rusa unicolor*	VU	Mammal	India	No difference in habitat use between highway sections that were open compared to those that were closed	Gubbi et al., 2012
Wild pig	*Sus scrofa*	LC	Mammal	India	No difference in habitat use between highway sections that were open compared to those that were closed	Gubbi et al., 2012

SUMMARY OF STUDIES ON INDIRECT IMPACTS OF ROADS ON WILDLIFE AT RELATIVELY SMALL SCALES IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF INDIRECT IMPACT	REFERENCE
Leopard	*Panthera pardus*	VU	Mammal	India	No difference in habitat use between highway sections that were open compared to those that were closed	Gubbi et al., 2012
Tiger	*Panthera tigris*	EN	Mammal	India	No difference in habitat use between highway sections that were open compared to those that were closed	Gubbi et al., 2012
Rufous-necked snowfinch	*Montifringilla ruficollis*	LC	Bird	China	Higher habitat use near highway and railway than further away	Li et al., 2010
Behavioral changes						
Asian elephant	*Elephas maximus*	EN	Mammal	Malaysia	Attraction at large scales	Wadey et al., 2018
Asiatic black bear	*Ursus thibetanus*	VU	Mammal	Japan	Attraction at small scales	Takahata et al., 2013
Tibetan antelope	*Pantholops hodgsoni*	NT	Mammal	China	Increased vigilance before approaching highway	Bao-fa et al., 2007
Przewalski's gazelle	*Procapra przewalskii*	EN	Mammal	China	Temporal displacement of activity	Li et al., 2009
Tufted deer	*Elaphodus cephalophus*	NT	Mammal	China	Temporal displacement of activity	Jia et al., 2015
Goral	*Naemorhedus goral*	NT	Mammal	China	Temporal displacement of activity	Jia et al., 2015
Wild pig	*Sus scrofa*	LC	Mammal	China	No temporal displacement of activity	Jia et al., 2015
Sika deer	*Cervus nippon*	LC	Mammal	China	No temporal displacement of activity	Jia et al., 2015
Cabot's tragopan	*Tragopan caboti*	VU	Bird	China	Variable habitat use depending on traffic	Sun et al., 2009
Asian elephant	*Elephas maximus*	EN	Mammal	India	Context dependent response to human behavior	Vidya & Thuppil, 2010
Asian elephant	*Elephas maximus*	EN	Mammal	India	Size based response to vehicles	Vidya & Thuppil, 2010
Common myna	*Acriotheres tristis*	LC	Bird	India	Attraction to grain dropped on roads	Siva & Neelanarayanan, 2020
Rhesus macaque	*Macaca mulata*	LC	Mammal	India	Deliberate feeding by people along road	Srivastava et al., 2017
Rhesus macaque	*Macaca mulata*	LC	Mammal	India	Deliberate feeding by people along road	Pragatheesh, 2011

SUMMARY OF STUDIES ON INDIRECT IMPACTS OF ROADS ON WILDLIFE AT RELATIVELY SMALL SCALES IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF INDIRECT IMPACT	REFERENCE
Siberian chipmunk	*Tamias sibiricus*	LC	Mammal	China	Attraction to garbage along road	Wang et al., 2013
Lion-tailed macaque	*Macaca silenus*	EN	Mammal	India	Attraction to garbage along road	Jeganthan et al., 2018
Xinjiang ground jay	*Podoces biddulphi*	NT	Bird	China	Attraction to garbage along road	Londei, 2011
Xinjiang ground jay	*Podoces biddulphi*	NT	Bird	China	Smaller alert distance and flight initiation distance at locations with more human disturbance	Xu et al., 2013
			Movement impacts			
Asian elephant	*Elephas maximus*	EN	Mammal	China	Movement barrier	Huang et al., 2020
Siberian jerboa	*Allactaga sibirica*	LC	Mammal	China	Movement barrier	Ji et al., 2017
Great gerbil	*Rhombomys opimus*	LC	Mammal	China	No movement barrier	Ji et al., 2017
Asian elephant	*Elephas maximus*	EN	Mammal	Malaysia	Movement barrier	Wadey et al., 2018
Little egret	*Egretta garzetta*	LC	Bird	China	No movement barrier	Stanton & Klick, 2018
Pin-striped tit-babbler	*Mixornis gularis*	LC	Bird	Vietnam	Movement barrier	Thinh et al., 2020
Indochinese fulvetta	*Fulvetta danisi*	LC	Bird	Vietnam	Movement barrier	Thinh et al., 2020
Puff-throated babbler	*Pellorneum ruficeps*	LC	Bird	Vietnam	No movement barrier	Thinh et al., 2020
Buff-breasted babbler	*Trichastoma tickelli*	LC	Bird	Vietnam	No movement barrier	Thinh et al., 2020

APPENDIX C: SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF ROADS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF ROADS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
Density, abundance, distribution, and habitat use						
Korean field mouse	*Apodemus peninsulae*	LC	Mammal	South Korea	Lower abundance near road	Hur et al., 2005
Striped field mouse	*Apodemus agrarius*	LC	Mammal	South Korea	Higher abundance near road	Hur et al., 2005
Asian elephant	*Elephas maximus*	EN	Mammal	Nepal	Lower occurrence near highway	Sharma et al., 2020
Indian pangolin	*Manis crassicaudata*	EN	Mammal	Nepal	Lower occurrence near highway	Suwal et al., 2020
Chinese pangolin	*Manis pentadactyla*	CR	Mammal	Nepal	Lower occurrence near highway	Suwal et al., 2020
Bonnet macaque	*Macaca radiata*	VU	Mammal	India	Lower abundance when immediate road verge became more urbanized	Erinjery et al., 2017
Sunda clouded leopard	*Neofelis diardi*	VU	Mammal	Malaysia/ Indonesia	Lower local abundance in areas with higher road density	Brodie et al., 2015
Tiger	*Panthera tigris*	EN	Mammal	Indonesia	Lower occurrence close to roads	Linkie et al., 2008
Tiger	*Panthera tigris*	EN	Mammal	China	Lower occurrence close to roads	Wang et al., 2018
Sambar	*Rusa unicolor*	VU	Mammal	Malaysia/ Indonesia	Higher local abundance in areas with higher road density	Brodie et al., 2015
Banded palm civet	*Hemigalus derbyanus*	NT	Mammal	Malaysia/ Indonesia	No influence of road density on local abundance	Brodie et al., 2015
Sun bear	*Helarctos malayanus*	VU	Mammal	Malaysia/ Indonesia	No influence of road density on local abundance	Brodie et al., 2015
Southern pig-tailed macaque	*Macaca nemestrina*	VU	Mammal	Malaysia/ Indonesia	No influence of road density on local abundance	Brodie et al., 2015
Mongolian gazelle	*Procapra guturosa*	LC	Mammal	Mongolia	Lower abundance in areas of high linear infrastructure density	Nandintsetseg et al., 2019
Siberian jerboa	*Allactaga sibirica*	LC	Mammal	China	No significant difference in abundance along countryside roads compared to highways	Ji et al., 2017
Great gerbil	*Rhombomys opimus*	LC	Mammal	China	Higher abundance along countryside roads compared to highways	Ji et al., 2017
Mortality, reproduction, and proxies for fitness						
Korean field mouse	*Apodemus peninsulae*	LC	Mammal	South Korea	Lower body weight for	Hur et al., 2005

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF ROADS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
					individuals near road	
Striped field mouse	*Apodemus agrarius*	LC	Mammal	South Korea	No difference in body weight near or far from roads	Hur et al. ,2005
White-rumped shama	*Copsychus malabaricus*	Not assessed	Bird	Thailand	Higher nesting success	Angkaew et al., 2019
King cobra	*Ophiophagus hannah*	VU	Reptile	Thailand	16% of mortality of tracked animals were roadkill	Marshall et al., 2019
Okinawa rail	*Hypotaenidia okinawae*	EN	Bird	Japan	73% of all recorded mortality was from roadkill	Kotaka & Sawashi, 2004
Nilgai	*Boselaphus tragocamelus*	LC	Mammal	India	15% of anthropogenic mortality was from roadkill	Bajwa & Chauhan, 2019
Oriental reed warbler	*Acrocephalus orientalis*	LC	Bird	South Korea	0.8% of mortality of migratory birds on a stopover were om roads	Chang et al., 2012
Mountain white eye	*Zosterops japonicus*	LC	Bird	South Korea	0.8% of mortality of migratory birds on a stopover were on roads	Chang et al., 2012
Marsh crocodile	*Crocodylus palustris*	VU	Reptile	India	67% of road & rail killed animals were juveniles or sub-adults	Vyas & Vasava, 2019
Marsh crocodile	*Crocodylus palustris*	VU	Reptile	India	33% of road & rail killed animals were females	Vyas & Vasava, 2019
Leopard cat	*Prionailurus bengalensis*	LC	Mammal	South Korea	64% of roadkilled animals were less than one year old	Kim et al., 2019
Leopard cat	*Prionailurus bengalensis*	LC	Mammal	Malaysia	92% of leopard cat roadkills were adults	Laton et al., 2017
Tsuishima leopard cat	*Prionailurus bengalensis*	LC	Mammal	Japan	70% of roadkilled animals were less than one year old	Nakanishi et al., 2010
Rhesus macaque	*Macaca mulatta*	LC	Mammal	India	138% higher mortality risk for adults (corrected for local availability) than juveniles	Pragatheesh, 2011
	Combined sample of Elaphe dione, Gloydius ussuriensis, Gloydius brevicaudus, Elaphe shrenckii, Oocatochus rufodorsatus, Dinodon rufozonatus, Rhabdophis tigrinus, Amphiesma vibakari, Gloydius saxatilis, Coluber spinalis			South Korea	95% of roadkilled snakes were adults	Park et al., 2017
	Combined sample of Elaphe dione, Gloydius ussuriensis, Gloydius brevicaudus, Elaphe			South Korea	70% of roadkilled snakes were males	Park et al., 2017

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF ROADS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
	shrenckii, *Oocatochus rufodorsatus*, *Dinodon rufozonatus*, *Rhabdophis tigrinus*, *Amphiesma vibakari*, *Gloydius saxatilis*, *Coluber spinalis*					
Leopard	*Panthera pardus*	VU	Mammal	India	Equal number of road killed males and females	Gubbi 2014
Common Mormon	*Papilio polytes*	Not evaluated	Invertebrate	India	Higher number of males killed on roads	Rao & Girish, 2007
Danaid Eggfly	*Hypolimnas misippus*	LC	Invertebrate	India	Higher number of males killed on roads	Rao & Girish, 2007
Plain Tiger	*Danaus chrysippus*	Not evaluated	Invertebrate	India	Higher number of males killed on roads	Rao & Girish, 2007
Asiatic wild buffalo	*Bubalus arnee*	EN	Mammal	Nepal	All three animals killed on highway were male	Heinen & Kandel, 2006
Northern Plains gray langur	*Semnopithecus entellus*	LC	Mammal	India	60% of road collisions were with males	Chhangani et al., 2004
Rhesus macaque	*Macaca mulatta*	LC	Mammal	India	46% higher mortality risk for males (corrected for local availability) than females	Pragatheesh, 2011
Leopard cat	*Prionailurus bengalensis*	LC	Mammal	Malaysia	67% of leopard cat roadkills were females	Laton et al., 2017
			Genetic Structures			
Tiger	*Panthera tigris*	EN	Mammal	India	Land use has greater influence on genetic structure, roads play a role at high traffic densities	Thatte et al., 2019
Jungle cat	*Felis chaus*	LC	Mammal	India	Roads per se had little influence, but density of linear features influenced genetic structure	Thatte et al., 2019
Leopard	*Panthera pardus*	VU	Mammal	India	Road traffic had a linear influence on genetic structure patterns	Thatte et al., 2019
Sloth bear	*Melursus ursinus*	VU	Mammal	India	Roads and linear features explained little of genetic structure; land use did	Thatte et al., 2019
Tiger	*Panthera tigris*	EN	Mammal	India	Tiger dispersal effective across roads unless traffic is very high	Thatte et al., 2018
Chinese wood frog	*Rana chensinensis*	LC	Amphibian	China	Mountain ridges structured	Atlas & Fu, 2019

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF ROADS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
					genetics more than roads	
Giant panda	*Ailuropoda melanoleuca*	VU	Mammal	China	Gene flow indicates effective panda dispersal across a busy highway	Qiao et al., 2019
Whitehead's Sundaic maxomys	*Maxomys whiteheadi*	VU	Mammal	Malaysia	No genetic differentiation in populations separated by a paved road	Brunke et al., 2019
Sundaic arboreal niviventer	*Niviventer cremoriventer*	LC	Mammal	Malaysia	No genetic differentiation in populations separated by a paved road	Brunke et al., 2019
Muller's sundamys	*Sundamys muelleri*	LC	Mammal	Malaysia	No genetic differentiation in populations separated by a paved road	Brunke et al., 2019
Plantain squirrel	*Callosciurus notatus*	LC	Mammal	Malaysia	No genetic differentiation in populations separated by a paved road	Brunke et al., 2019
Northern long-footed tree shrew	*Tupaia longipes*	LC	Mammal	Malaysia	No genetic differentiation in populations separated by a paved road	Brunke et al., 2019
Asiatic black bear	*Ursus thibetanus*	VU	Mammal	Thailand	Low effective migration between two populations separated for 60 years by highway	Vaeokhaw et al., 2020
Plateau pika	*Ochotona curzoniae*	LC	Mammal	China	Beginning of genetic structuring in populations recently separated by highway	Zhou et al., 2006
Community Metrics						
			Amphibian	Nepal	Amphibian species richness higher far from roads	Aryal et al., 2020
			Mammal	Malaysia	Mammal species richness higher at intermediate distances from road	Mohd-Azlan et al., 2019
			Amphibian	Pakistan	Road density and traffic level negatively correlated with herpetofaunal species richness	Rais et al., 2015
			Reptile	Pakistan	Road density and traffic level negatively	Rais et al., 2015

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF ROADS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
					correlated with herpetofaunal species richness	
			Bird	China	Higher richness of birds near highway and railway compared to further away	Li et al., 2010

APPENDIX D: LIST OF SPECIES DOCUMENTED TO CROSS ROADS USING WILDLIFE OVERPASSES, WILDLIFE UNDERPASSES, OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING

LIST OF SPECIES DOCUMENTED TO CROSS ROADS USING OVERPASSES, UNDERPASSES OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	NOTES ON USE OF CROSSING STRUCTURE	REFERENCE
Asian elephant	*Elephas maximus*	EN	Mammal	China	Use of overpass to cross road	Pan et al., 2009
Asian elephant	*Elephas maximus*	EN	Mammal	China	Crossing under a bridge built for engineering purposes	Pan et al., 2009
Wildcat	*Felis silvestris*	LC	Mammal	China	Use of both culverts and bridges to cross; bridges preferred	Li et al. 2019
Manul	*Otocolobus manul*	LC	Mammal	China	Use of both culverts and bridges to cross; bridges preferred	Li et al., 2019
Red fox	*Vulpes vulpes*	LC	Mammal	China	Use of both culverts and bridges to cross; bridges preferred	Li et al., 2019
Tolai hare	*Lepus tolai*	LC	Mammal	China	Use of both culverts and bridges to cross; bridges preferred	Li et al., 2019
Northern hog badger	*Arctonis albogularis*	LC	Mammal	China	Use of both culverts and bridges to cross; bridges preferred	Li et al., 2019
Common pheasant	*Phasianus colchicus*	LC	Bird	China	Crossed under culvert and bridge	Wang et al., 2017
Hazel grouse	*Bonasa bonasia*	LC	Bird	China	Crossed over tunnel and under bridge	Wang et al., 2017
Manchurian hare	*Lepus mandshuricus*	LC	Mammal	China	Crossed over tunnel, under culvert and under bridge	Wang et al., 2017
Asian badger	*Meles leucurus*	LC	Mammal	China	Crossed over tunnel	Wang et al., 2017
Siberian weasel	*Mustela sibirica*	LC	Mammal	China	Crossed over tunnel, under culvert and under bridge	Wang et al., 2017
Least weasel	*Mustela nivalis*	LC	Mammal	China	Crossed over tunnel, under culvert and under bridge	Wang et al., 2017
Siberian roe deer	*Capreolus pygargus*	LC	Mammal	China	Crossed over tunnel and under bridge	Wang et al., 2017
Yellow-throated marten	*Martes flavigula*	LC	Mammal	China	Crossed over tunnel, under culvert and under bridge	Wang et al., 2017
Eurasian red squirrel	*Sciurus vulgaris*	LC	Mammal	China	Crossed over tunnel, under culvert and under bridge	Wang et al., 2017
Sable	*Martes zibellina*	LC	Mammal	China	Crossed over tunnel and under culvert	Wang et al., 2017
Silver fox	*Vulpes vulpes*	LC	Mammal	China	Crossed under culvert	Wang et al., 2017

LIST OF SPECIES DOCUMENTED TO CROSS ROADS USING OVERPASSES, UNDERPASSES OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	NOTES ON USE OF CROSSING STRUCTURE	REFERENCE
Northern raccoon	*Procyon lotor*	LC	Mammal	Japan	Used both overpasses built for wildlife and for humans	Asari et al., 2020
Red fox	*Vulpes vulpes*	LC	Mammal	Japan	Used both overpasses built for wildlife and for humans	Asari et al., 2020
Sika deer	*Cervus nippon*	LC	Mammal	Japan	Used both overpasses built for wildlife and for humans	Asari et al., 2020
Raccoon dog	*Nyctereutes procyonoides*	LC	Mammal	Japan	Used both overpasses built for wildlife and for humans	Asari et al., 2020
Least weasel	*Mustela nivalis*	LC	Mammal	Japan	Used only wildlife overpass not human overpass	Asari et al., 2020
Sable	*Martes zibellina*	LC	Mammal	Japan	Used only wildlife overpass not human overpass	Asari et al., 2020
Eurasian red squirrel	*Sciurus vulgaris*	LC	Mammal	Japan	Used only wildlife overpass not human overpass	Asari et al., 2020
Lion-tailed macaque	*Macaca silenus*	EN	Mammal	India	Used canopy bridges to cross roads	Umapathy et al., 2011
Lion-tailed macaque	*Macaca silenus*	EN	Mammal	India	Used canopy bridges to cross roads	Jeganathan et al., 2018
Chital	*Axis axis*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Gaur	*Bos gaurus*	VU	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Black naped hare	*Lepus nigricollis*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Golden jackal	*Canis aureus*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Jungle cat	*Felis chaus*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Leopard	*Panthera pardus*	VU	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Monitor	*Varanus bengalensis*	LC	Reptile	India	Used underpasses built for wildlife	Habib et al., 2020
Nilgai	*Boselaphus tragocamelus*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Common palm ciet	*Paradoxurus hermaphroditus*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Indian peafowl	*Pavo cristatus*	LC	Bird	India	Used underpasses built for wildlife	Habib et al., 2020
Indian porcupine	*Hystrix indica*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Rusty spotted cat	*Prionailurus rubiginosus*	NT	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Sambar	*Rusa unicolor*	VU	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Sloth bear	*Melursus ursinus*	VU	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Small Indian civet	*Viverricula indica*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Tiger	*Panthera tigris*	EN	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Dhole	*Cuon alpinus*	EN	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020

LIST OF SPECIES DOCUMENTED TO CROSS ROADS USING OVERPASSES, UNDERPASSES OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	NOTES ON USE OF CROSSING STRUCTURE	REFERENCE
Wild pig	*Sus scrofa*	LC	Mammal	India	Used underpasses built for wildlife	Habib et al., 2020
Bonnet macaque	*Macaca radiata*	LC	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015
Dhole	*Cuon alpinus*	EN	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015
Leopard	*Panthera pardus*	VU	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015
Mouse deer	*Moschiola indica*	LC	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015
Wild pig	*Sus scrofa*	LC	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015
Sambar	*Rusa unicolor*	VU	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015
Chital	*Axis axis*	LC	Mammal	India	Used underpasses built for engineering purposes	Menon et al., 2015

APPENDIX E: LIST OF SPECIES DOCUMENTED IN TRAIN STRIKES IN ASIA.

LIST OF SPECIES DOCUMENTED IN TRAIN STRIKES IN ASIA

TAXON	COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	COUNTRY	REFERENCE
Mammal	Elephant	*Elephas maximus*	EN	India	Chamling & Bera, 2020
Mammal	Elephant	*Elephas maximus*	EN	India	Dasgupta & Ghosh, 2015
Mammal	Elephant	*Elephas maximus*	EN	India	Joshi & Puri, 2019
Mammal	Elephant	*Elephas maximus*	EN	India	Mitra, 2017
Mammal	Elephant	*Elephas maximus*	EN	India	Palei et al., 2013
Mammal	Elephant	*Elephas maximus*	EN	India	Roy & Sukumar,2017
Mammal	Elephant	*Elephas maximus*	EN	India	Roy et al., 2009
Mammal	Elephant	*Elephas maximus*	EN	India	Williams et al., 2001
Mammal	Gaur	*Bos gaurus*	VU	India	Gowda, 2015
Mammal	Tiger	*Panthera tigris*	EN	India	Warrier, 2018
Mammal	Asiatic lion	*Panthera leo*	EN	India	Ghangar, 2018
Mammal	Leopard	*Panthera pardus*	NT	India	Joshi, 2010
Mammal	Leopard	*Panthera pardus*	NT	India	Singh et al., 2001
Mammal	Sloth bear	*Melursus ursinus*	VU	India	Pinjarkar, 2020
Mammal	Mongolian gazelle	*Procapra gutturosa*	LC	Mongolia	Ito et al., 2008
Mammal	Sika deer	*Cervus nippon*	LC	Japan	Ando, 2003
Mammal	Sika deer	*Cervus nippon*	LC	Japan	Soga et al., 2015
Mammal	Chital	*Axis axis*	LC	India	Singh et al., 2001
Mammal	Sambar	*Rusa unicolor*	VU	India	Singh et al., 2001
Mammal	Capped langur	*Trachypithecus pileatus*	VU	India	Raman, 2011
Mammal	Wild boar	*Sus scrofa*	LC	India	Singh et al. 2001
Mammal	Goral	*Nemorhaedus goral*	NT	India	Singh et al. 2001
Bird	Red headed vulture	*Sarcogyps calvus*	CR	India	Khatri et al., 2020
Reptile	Indian rock python	*Python molurus*	Not evaluated	India	Singh et al. 2001
Reptile	Indian rock python	*Python molurus*	Not evaluated	India	Raman, 2011
Reptile	Common krait	*Bungarus caeruleus*	Not evaluated	India	Kumar & Prasad, 2020
Reptile	Indian rat snake	*Ptyas mucosa*	Not evaluated	India	Kumar & Prasad, 2020
Reptile	King cobra	*Ophiophagus hannah*	VU	India	Sivaraj et al., 2018
Reptile	Saltwater crocodile	*Crocodylus porosus*	LC	Sri Lanka	Amarasinghe et al., 2015
Reptile	Marsh crocodile	*Crocodylus palustris*	VU	India	Vyas & Vasava, 2019
Reptile	Marsh crocodile	*Crocodiyus palustris*	VU	India	Vyas, 2014

APPENDIX F: SUMMARY OF STUDIES ON INDIRECT IMPACTS OF RAILWAYS ON WILDLIFE AT RELATIVELY SMALL SCALES IN ASIA

SUMMARY OF STUDIES ON INDIRECT IMPACTS OF RAILWAYS ON WILDLIFE AT RELATIVELY SMALL SCALES IN ASIA						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF INDIRECT IMPACT	REFERENCE
Changes in Habitat and Human Persecution						
Rufous-necked snowfinch	*Montifringilla ruficollis*	LC	Bird	China	Higher habitat use near highway and railway than further away	Li et al., 2010
Mongolian gazelle	*Procapra gutturosa*	LC	Mammal	Mongolia	Forage within fenced railway verge could be an attractant	Ito et al., 2008
Behavioral changes						
Tibetan antelope	*Pantholops hodgsoni*	NT	Mammal	China	Several days of vigilance near railway before crossing	Buho et al., 2011
White-rumped snowfinch	*Montifringilla taczanowskii*	LC	Bird	China	Lower alert distance and flight initiation distance close to railway and highway	Ge et al., 2011
Plain-backed snowfinch	*Montifringilla blanfordi*	LC	Bird	China	Lower alert distance and flight initiation distance close to railway and highway	Ge et al., 2011
Rufous-necked snowfinch	*Montifringilla ruficollis*	LC	Bird	China	Lower alert distance and flight initiation distance close to railway and highway	Ge et al., 2011
Elephant	*Elephas maximus*	EN	Mammal	India	Attraction to feral food plants growing on railway verge	Roy & Sukumar, 2017
Movement impacts						
Mongolian gazelle	*Procapra gutturosa*	LC	Mammal	Mongolia	Fenced railway is a severe barrier to movement	Ito et al., 2013
Sika deer	*Cervus nippon*	LC	Mammal	Japan	Crossing occurs at locations where there are fewer collisions, indicating potential learning	Soga et al., 2013
Asiatic wild ass	*Equus hemionus*	NT	Mammal	Mongolia	Fenced railway is a severe barrier to movement	Kaczensky et al., 2011

APPENDIX G: SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF RAILWAYS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF RAILWAYS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA						
COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
Density, Abundance, Distribution and Habitat Use						
Asiatic wild ass	*Equus hemionus*	NT	Mammal	Mongolia	Fenced railway restricted access to 17,000 km2 of potential habitat	Kaczensky et al., 2011
Mortality, Reproduction, and Proxies for Fitness						
Mongolian gazelle	*Procapra gutturosa*	LC	Mammal	Mongolia	Fenced railroads prevent migration to access resources in winter and cause mortality	Ito et al., 2008
Elephant	*Elephas maximus*	EN	Mammal	India	48% of mortalities from train strikes were adult females	Joshi & Puri, 2019
Elephant	*Elephas maximus*	EN	Mammal	India	48% of mortalities from train strikes were females	Palei et al., 2013
Elephant	*Elephas maximus*	EN	Mammal	India	Adult males 2.5 times more represented in train strikes compared to their proportion in population	Roy & Sukumar, 2017
Marsh crocodile	*Crocodylus palustris*	VU	Reptile	India	67% of road & rail killed animals were juveniles or sub-adults	Vyas & Vasava, 2019
Marsh crocodile	*Crocodylus palustris*	VU	Reptile	India	33% of road & rail killed animals were females	Vyas & Vasava, 2019
Elephant	*Elephas maximus*	EN	Mammal	India	70% of anthropogenic mortality was due to train strikes	Williams et al., 2001
Tibetan antelope	*Pantholops hodgsoni*	NT	Mammal	China	Migration distance increased by 86 km to access railway underpass	Xu et al., 2019
Genetic Structure						
Toad-headed lizard	*Phrynocephalus vlangalii*	LC	Reptile	China	No genetic differences between populations on either side of railway	Hu et al., 2012
Red fox	*Vulpes vulpes*	LC	Mammal	Japan	Railway delineates two populations with low gene flow	Kato et al., 2017

SUMMARY OF STUDIES ON DIRECT AND INDIRECT IMPACTS OF RAILWAYS ON WILDLIFE AT LARGE SCALES RELEVANT TO POPULATIONS IN ASIA

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	TYPE OF POPULATION IMPACT	REFERENCE
Mongolian gazelle	*Procapra gutturosa*	LC	Mammal	Mongolia	Railway not a barrier to gene flow	Okada et al., 2012
Wild pig	*Sus scrofa*	LC	Mammal	Japan	Genetic structure of populations is determined by rivers and railways	Tadano et al., 2016
Przewalski's gazelle	*Procapra przewalskii*	EN	Mammal	China	Strong genetic structure caused by fenced railway	Yu et al., 2017

APPENDIX H: LIST OF SPECIES DOCUMENTED TO CROSS RAILWAY TRACKS USING WILDLIFE OVERPASSES, WILDLIFE UNDERPASSES OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING

LIST OF SPECIES DOCUMENTED TO CROSS RAILWAY TRACKS USING OVERPASSES, UNDERPASSES OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	NOTES ON USE OF CROSSING STRUCTURE	REFERENCE
Tibetan antelope	*Pantholops hodgsoni*	NT	Mammal	China	Crossed railway via crossing structure built for the purpose	Buho et al., 2011
Tibetan antelope	*Pantholops hodgsonii*	NT	Mammal	China	Crossed railway under small bridge, preferred this to culvert	Wang et al., 2018
Tibetan antelope	*Pantholops hodgsonii*	NT	Mammal	China	They appear to prefer underpasses (bridges); avoid those with human activity	Xia et al., 2007
ibetan antelope	*Pantholops hodgsonii*	NT	Mammal	China	Crossed railway via crossing structure built for the purpose	Xu et al., 2019
Kiang	*Equus kiang*	LC	Mammal	China	Crossed railway under small bridge, preferred this to culvert; longer structures avoided	Wang et al., 2018
Wild yak	*Bos mutus*	VU	Mammal	China	Crossed railway under small bridge, preferred this to culvert; taller structures preferred	Wang et al., 2018
Tibetan gazelle	*Procapra picticaudata*	NT	Mammal	China	Crossed railway under small bridge, preferred this to culvert; wider crossing structures preferred	Wang et al., 2018
Eurasian lynx	*Lynx lynx*	LC	Mammal	China	Both culvert and bridges used to cross railway	Wang et al., 2018
Corsac fox	*Vulpes corsac*	LC	Mammal	China	Crossed using both culverts and bridges	Wang et al., 2018
Beech marten	*Martes foina*	LC	Mammal	China	Crossed using both culverts and bridges	Wang et al., 2018
Mountain weasel	*Mustela altaica*	NT	Mammal	China	Crossed using culverts in preference to under bridges	Wang et al., 2018
Asian badger	*Meles leucurus*	LC	Mammal	China	Crossed using culverts in preference to under bridges	Wang et al., 2018
Common wolf	*Canis lupus*	LC	Mammal	China	Crossed using both culverts and bridges	Wang et al., 2018
Tibetan fox	*Vulpes ferrilata*	LC	Mammal	China	Crossed using both culverts and bridges	Wang et al., 2018
Woolly hare	*Lepus oiostolus*	LC	Mammal	China	Wider crossing structures preferred	Wang et al., 2018

LIST OF SPECIES DOCUMENTED TO CROSS RAILWAY TRACKS USING OVERPASSES, UNDERPASSES OR STRUCTURES THAT WERE NOT SPECIFICALLY BUILT FOR WILDLIFE CROSSING

COMMON NAME	SCIENTIFIC NAME	IUCN REDLIST STATUS	TAXON	COUNTRY	NOTES ON USE OF CROSSING STRUCTURE	REFERENCE
Himalayan marmot	*Marmota himalayana*	LC	Mammal	China	Crossed using both culverts and bridges	Wang et al., 2018
Elephant	*Elephas maximus*	EN	Mammal	India	Crossed under bridge built for engineering purposes	Menon et al., 2015

APPENDIX I: BIBLIOGRAPHY OF ROAD LITERATURE

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APPENDIX K: BIBLIOGRAPHY OF POWER LINE LITERATURE

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