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Review Article

Research priorities for the conservation of Nepal's lesser terrestrial vertebrates

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ABSTRACT

Located along the boundary of two zoogeographic provinces, and with the highest peaks and deepest valleys on Earth, Nepal is a center of adaptive radiation for many taxa. Early zoological research was mostly focused on high-profile large mammals due to availability of funding and policy priorities, but knowledge gaps remain for most other vertebrate taxa. Technologies ranging from genetic mapping to GPS, GIS, digital cameras and micro-transmitters have advanced with time and greatly expanded research capacities. Here, we present our suggestions of research needs for the lesser terrestrial vertebrate fauna of Nepal and the broader Himalayan region, pointing out knowledge gaps and suggesting where to go from here. The growing numbers of Nepali researchers focusing on small mammalian and avian research is encouraging, but the status of many taxa remains unknown and much of the country remains under-surveyed for breeding and migratory populations. Major knowledge gaps persist for reptiles and amphibians and for the role of local wildlife markets in exploitation. We conclude with suggestions on priorities for research on, and conservation of, Nepal's lesser terrestrial vertebrates.

Key words: Amphibians, birds, conservation, mammals, Nepal, research, reptiles

INTRODUCTION

The concept of adaptive radiation, inherent to Darwinian natural selection, was formalized in the early 20th Century (Osborn, 1902). There are known centers of adaptive radiation worldwide depending on geology, geographical isolation and the adaptations of ancestral groups (Glor, 2010). Mountainous regions in or near the tropics are predicted to have the highest terrestrial biodiversity on Earth because of the tropical and subtropical origins of many lineages and the great climatic variation from lowlands to alpine zones (Dimitrov, Nogués-Bravo & Scharff, 2012). Valleys cutting through central massifs provide further isolation and speciation potential. For these reasons, and because they form the border between two zoogeographic provinces as the Subcontinent encroaches upon the Eurasian Plate (Sinha, 1989) the Himalayas have very high species diversity and some areas are even more diverse than others depending on local conditions (Basnet *et al*., 2016).

Further compounding the elevational gradient is the east-west rainfall gradient from northeastern India, with up to five meters of rain annually in the eastern edge of the gradient Nandargi & Dhar, 2011). For these reasons, the eastern Himalayas, including Nepal, are a major biodiversity hotspot (Fjeldsa, 2013; Paudel & Sipos, 2014) and Nepal alone boasts many distinct ecoregions (Pearch, 2011; Dinerstein *et al*., 2017). New range records are made regularly in the country (Heinen, 1990; Thapa *et al.,* 2016; Chetri *et al.,* 2014; Subba *et al.,* 2014; Lama *et al*., 2016; Lamichhane *et al*. 2016), as are descriptions of new species (Khatiwada *et al.,* 2017; Pradhan *et al*., 2019). The concern over global warming is pronounced for mountainous regions (Hughes, 2000; Beever *et al*., 2010; Telwala *et al*., 2013) which present opportunities to study how species respond (Inouye *et al.,* 2000) and whether assisted colonization is effective in conserving sensitive taxa (Hunter, 2007).

Since 1973, Nepal has made great strides in developing its park system and other protected areas (PAs) managed by the Department of National Parks and Wildlife Conservation (DNPWC), which now cover over 20% of its land area (Heinen *et al*., 2019). Tourism is a main source of foreign exchange (Nepal, 2002) and several Nepalese PAs have been tourist destinations for decades (Heinen & Thapa, 1988), bringing in millions (USD) annually to the national and local economies (Baral *et al*., 2017). The DNPWC supports wildlife research and seminal studies on many large mammals were done in Nepal. These include major works on tigers (Smith, 1993) and their prey (Aryal *et al*. 2016), rhinoceros (Dinerstein, 2003), sloth bear (Joshi, Garshelis & Smith, 1995), wild buffalo (Heinen & Paudel, 2015a) and snow leopard (Oli, 1994). There has also been attention focused on birds in part because of interest spawned by the Nepalese affiliate of Bird Conservation International (Baral *et al*. 2012). The Government of Nepal (GoN) has been very effective in moving conservation policy forward with the passage of the National Biodiversity Strategy, (the) Control of International Trade of Endangered Wild Fauna and Flora Act (2017), and the National Wetland Policy (Heinen *et al*., 2019). Despite implementation problems (Heinen and Sah, 2006; Dongol & Heinen, 2012), progress has been made in reducing poaching and many target species are

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recovering (Ale, Yonzon & Thapa, 2007).

Despite successes with some high-profile species, many others are under high degrees of threat as recognized by IUCN (Yonzon & Hunter, 1991; Jnawali *et al*., 2011; Paudel & Heinen, 2015a) and faunal collapse has been documented in many protected areas (Heinen, 1995; Thorn, 2019). The research focus on large mammals informed the planning of the PA system but came at the cost of comparatively little research on other taxa. Given that large mammals are among the most extinction-prone fauna (Terborgh, 1974) and can act as umbrellas for entire ecosystems (Roberge & Angelstam, 2004), this made sense initially. Now that the PA system is large and tree cover has increased in many places largely because of the success of the community forestry program, (Pokharel & Suvedi, 2007), the time has come for more comprehensive research on the biodiversity of Nepal. While large mammals inspire awe and funding, and we encourage more research on them as their populations expand, we contend that major scientific and conservation breakthroughs now lie with lesser taxa.

Here we focus on terrestrial vertebrates other than large mammals. We begin with smaller mammals, followed by birds, reptiles and amphibians, and we end with our thoughts on research priorities. We avoid the use of scientific names in favor of accepted English alternatives for clarity and space considerations. We encourage study of all taxa - and from the genetic to ecosystem levels of biology - in the spirit of the 1992 Convention on Biological Diversity, of which Nepal is Party. We also hope that the First National Conference on Zoology, 2020, for which the draft of this manuscript was initially prepared, inspires more work by young Nepali researchers.

Mammals

Mammals are arguably the most important group discussed here for several reasons. The largest species inspire awe and play major ecological roles. Both large mammalian herbivores (Heinen & Castillo, 2019) and carnivores (Smith, Peterson & Houston, 2003) can act as keystone species via their trophic inactions and many mammals are seed dispersers (Corlett, 1998). Many are exploited and some are vectors for viruses such as Hantavirus (Kang *et al.*, 2011) and rabies, the latter of which alone takes an estimated 50,000 lives annually in South Asia (Pant *et al*., 2011). Even bubonic plague, considered a Middle Ages relic by many, occasionally erupts in Nepal when rodents are unusually abundant (Hull, Montes & Mann, 1986).

Since the Small Mammals Conservation and Research Foundation (SMCRF) was established in Kathmandu in 2009, research into the ecology of many taxa has greatly increased. Among the first district-level field surveys on bats is available (Adhikari, 2011) as is a guide for that taxon (Acharya *et al*., 2012). General guides are also available (Baral & Shah, 2008), as are comprehensive references on species status (Amin *et al*., 2018) and surveys exploring the diversity of small mammals. This began with Hodgson's (1845) work in and around Kathmandu Valley and continues to the present. The Foundation has also placed efforts on red panda and pangolin conservation. Apart from that, various foundation members prepared the Kathmandu Valley Bat Action Plan (SMCRF, 2019), separated the species of red panda found in Nepal from that in China (Hu *et al*., 2020), and completed a national survey and monitoring guidelines for pangolins in the country (DNPWC, 2019; Suwal *et al*., 2020).

Many small mammal surveys have been done in central Nepal, and more exploratory work is needed throughout the country (Agrawal & Chakraborty, 1971; Ingles *et al*., 1980). While labor-intensive, we encourage the use of non-lethal trapping grids maintained consistently over time to learn more about species presence, densities and population cycles. Sites within PAs are obvious places to work given their protected status, but we also encourage small mammal surveys in locations such as sacred forests and community forests under long-term protection (Timilsina & Heinen, 2008). The collection of hair and fecal samples useful for genetic studies (Chetri *et al*., 2019) should be a priority given that there are likely cryptic species complexes of some rodent and shrew taxa (Motokawa *et al*., 2008).

Compared to the smaller mammals, more is known about general distributions of larger rodents such as tree squirrels and marmots (Thapa *et al*., 2016; Thapamagar *et al*., 2021) and lagomorphs such as the endangered hispid hare (Khadka *et al*., 2017a), but information is still lacking from many parts of Nepal. Poudel *et al*. (2015) showed that marmots change their foraging behavior due to seasonal livestock grazing, and trekkers within PAs could have similar effects on them as well as pikas (Koju, Chalise & Kyes, 2013). Extensive genetic studies on pikas in particular would be interesting given the number of known species throughout the mountains of South and Central Asia and the potential for cryptic species complexes within this group (Thapa *et al*., 2018; Bhattacharyya & Ishtiaq, 2019). These taxa are generally more visible than the smallest mammals or smaller carnivores (below) and they can be drawn to mineral licks from which hair samples could be collected with Velcro traps (Moe, 1993; Harris & Nicol, 2010).

Perhaps the most interesting recent findings on mammals in Nepal have been on small carnivores. The diversity of felids, herpestids, viverrids and mustelids is high across Asia (Mudappa, 2013; Thapa, 2014) and many new species records have been made in Nepal (below), some of which used to be found as fur coats for sale in Kathmandu's tourist areas (Heinen & Leisure, 1993). The rusty-spotted cat, previously known from peninsular India, was documented in Sukla Phanta and Bardia National Parks (Lamichhane *et al*., 2016) and the Pallas's cat, previously known from the Tibetan Plateau and Central Asia, was documented in the Annapurna region (Regmi *et al*., 2020). Other recent findings include the first ruddy mongoose and steppe polecat (Chetri *et al.*, 2014)) records for Nepal, as well as range extensions for crab-eating mongoose (Rayamajhi *et al*., 2019) and yellow-bellied weasel (Baral *et al*., 2019). They are likely all more widespread in the country, but many places have not been systematically searched. Dedicated studies on linsang, civets and binturong are also a high priority as little is known about them throughout their ranges (Jennings and Veron, 2015).

Most small carnivores are nocturnal and camera trapping has greatly increased our knowledge about them (Appel *et al.*, 2013) but more work remains. Many can be attracted to camera traps using scent posts (Conner, Labisky & Progulske, 1983) and Velcro hair traps can be used in combination to collect samples for genetic analyses. This may prove especially valuable for weasels. There is evidence that the wide-ranging Siberian weasel is a species complex based on recent anatomical

studies (Abramov, Puzachenko & Masuda, 2018) but genetic samples from across its range would be needed to confirm this. Otters are another priority. Three species may occur in the country, but their status is poorly known and there is large-scale exploitation of these animals for their pelts in Nepal (Savage & Shrestha, 2018) and throughout Asia (Gomez & Bouhuys, 2018) . Unlike many other carnivores, otters apparently do not readily come to scent stations (Robson & Humphrey, 1985), but they tend to be diurnal, making visual observations by boat or canoe feasible.

The use of telemetry was successful in some studies of large mammals cited above, but the technology has rarely been used on smaller carnivores in Nepal, with a few exceptions (Joshi, Smith & Cuthbert, 1995). While it is more costly and riskier for both animal subjects and human researchers, we encourage more feasibility studies into its use, especially given the recent advances in small transmitter technology. This could prove especially valuable within PAs where human interference is minimized. In other places (buffer zones and national, sacred or community forests) scent stations with Velcro hair traps may be optimal with or without camera traps depending on the likelihood of human interference. In any case, much more information on the abundance, distribution and genetics of smaller mammals is needed throughout Nepal.

Birds

Due to interest among Nepalis and international visitors, more is perhaps known about birds than other vertebrate taxa (Inskipp *et al*., 2017). Bird Conservation Nepal has been active since the early 1980s and foreign birders visit regularly and provide a good deal of data for certain regions; however, except for some areas in and around Kathmandu and Pokhara Valleys and the more-visited PAs, coverage is inconsistent or lacking (Baral *et al*, 2012**;** Inskipp *et al*., 2017). Of studies focusing on particular groups, published accounts are available for pheasants and cranes because of their cultural importance (Kaul & Shakya, 2001; Singh *et al.*, 2011; Katuwal, 2016), *Gyps* vultures because of their precipitous decline and partial recovery (Galligan *et al*., 2020) and rarities such as floricans because some are endangered (Baral, Tamang & Timilsina, 2003). Strides have been made in general knowledge of Nepal's avifauna, but much more needs to be done to estimate population trends. Several entire groups - birds dependent on old growth forests, wetlands and grasslands - are thought to be in decline nation-wide (Inskipp & Baral, 2010; Adhikari, Bhattarai & Thapa, 2018) but long-term data are largely lacking. Most existing information consists of lists indicating presence, migratory or overwintering ranges (Heinen, 1990; Khadka, Acharya & Rajbhandari, 2017b) but little else.

While general lists provide necessary information, they are not useful for estimating population trends important in conservation. Bock and Root (1981) discussed shortcomings of Christmas Bird Counts in the United States, but the fact that they have been done consistently for over a century makes them useful for long-term studies such as how winter ranges change with global warming, and they provide some density information to study population trends. Breeding bird surveys (Link & Sauer, 1998) are better for estimating population trends but they're more costly and, in both cases, reliance on volunteers assumes people are equally adept at species recognition. While field identification is easier for large birds and those in breeding condition, Nepal's avifauna (nearly 900 species) is more diverse than any area of similar size in North America or Europe, requiring people to have more training to be proficient. We encourage efforts along these lines, and especially in areas where well-practiced Nepali birders reside such as Kathmandu and Pokhara Valleys and in or around PAs with tourist lodges. Such efforts could be extended if, for example, Bird Conservation Nepal expanded partnerships with the DNPWC and, potentially, the tourism sector, to encourage trained volunteers to visit PAs for set periods annually to survey birds along fixed routes, with one or both institutions archiving data for researchers.

Reptiles and Amphibians

Other than Maskey's (1989) pioneering work on gharial, there has been little specific research on Nepal's herpetofauna. This is quite fortunately changing with the recent foundation of the Companions for Amphibian and Reptiles of Nepal (CARON; www.caron.org.np), a non-governmental organization dedicated to the research and conservation of Nepal's herpetofauna. To date, even the status of high-profile taxa of conservation concern such as yellow monitors and Indian pythons, is little-known (Khatiwada & Ghimire, 2009; Ghimire, Phuyal & Shah, 2014). Good identification references exist (Schleich & Kastle, 2002), but most publications contain species lists even more scattered spatially and temporally than those available for the birds of Nepal (Zug & Mitchell, 1995; Nepali & Singh, 2020).

Of highest priority, given their global diversity and many threats, are surveys that explore amphibian species presence and distribution. They would be especially useful in eastern Nepal with its high rainfall (Khatiwada *et al*., 2017) and in wetland areas throughout the country (Bhattari *et al*., 2017). To date, one species each of salamander and caecilian is known from the country and there are likely more. While 42 species of frogs and toads have been recorded, a species new to science was recently described (Khatiwada *et al*., 2019) and there are likely more of them, as well as more known species yet to be documented within Nepal. Skin swabs for studying the Chytrid fungus affecting frog populations worldwide (Scheele & Hollanders, 2021) would also be useful in assessing threats. Another high priority are studies on the status and distribution of turtles and tortoises in decline globally (Rhodin *et al*. 2018) and widely exploited for food, medicine and the pet trade (Aryal *et al*., 2010; Altherr and Lameter, 2020). Other than work by Kharel and Chhetry (2012), and inclusion on general species lists, we found very little information for this entire group from Nepal. CARON (above) considers this a high priority and has several ongoing efforts in turtle research and conservation.

Snakes are generally better-known than other herpetofauna perhaps because Nepal harbors several species of venomous vipers, cobras and kraits. Yet distribution and abundance data are lacking in many places and sporadic where available (Kharel & Chhetry, 2012). This is true even for some viper and krait species found at higher elevations. The World Health Organization estimates 50,000+ people per year are killed by snakebites in India, and the penchant for some species, such as cobras and kraits, to occur in or near villages is a major reason. While numbers are much lower, people die regularly from snakebites in Nepal, which are likely under-reported (Sharma *et al*., 2004). Pandey *et al*. (2018) discovered that Russell's viper, one of the "big four" deadliest snakes in India, also occurs in Nepal.

But the perception within Nepal that all snakes be killed on sight needs attention (Pandey *et al*., 2016). A photographic field guide is now available (Sharma *et al*., 2013) but education programs are lacking (Rashnath & Divakar, 2019), as are people who respond to calls to remove dangerous snakes from villages. It's encouraging to note that several such groups are now active in parts of India and Nepal (see Youtube: Snake Rescue: King Cobra Rescue and Release: Pokhara: Nepal: Rohit Giri).

Heyer *et al*. (2014) and McDiarmid *et al*. (2012) are excellent references for describing techniques to study reptiles and amphibians in the wild. While we are encouraged to see growing interest, knowledge of Nepal's herpetofauna is inadequate. And, as with some mammals (above), genetic studies are crucial to understanding their diversity given that some species prove to be cryptic multi-species complexes, such as Nepalese fan-throated lizards now classified into three separate species (Deepak and Karanth, 2018).

DISCUSSION

We have made many recommendations highlighting research priorities for many taxa (above), but there are more-general issues to consider. To expand knowledge on the ecology and conservation status of various vertebrates, we argue that broader use of habitat and genetic studies, market surveys, and local outreach and education are needed nation-wide.

China is a major sink for both wild animal and plant products from Nepal and elsewhere (Heinen & Chapagain, 2002; Liu *et al*., 2014; Chen, Liu & Heinen, 2019), while India has been a major source of animal products such as furs (Heinen & Leisure, 1993) and it remains a major sink for medicinal plants (Kuniyal *et al*., 2019). Due to these factors, a great deal of effort has been placed on reducing transboundary trade of animal products by DNPWC and several non-governmental organizations (Dongol & Heinen, 2012; Paudel *et al.,* 2020) and in regulating the medicinal plant trade by the Department of Forests and Department of Plant Resources (Heinen & Shrestha-Acharya, 2011). Yet there is little attention paid to the effects of local markets on the depletion of wild products in Nepal. Furs can be found for sale in some local markets (Savage & Shrestha, 2018) and songbirds and turtles can regularly be seen for sale as food or pets (Aryal *et al*., 2010).

Local demand for wildlife is growing worldwide (Altherr & Lameter, 2020) but the number of species affected by local exploitation is little-understood and likely greater than that affected by transboundary trade. Systematic surveys of local markets would be relatively easy to accomplish and whole specimens and some parts (such as furs and pangolin scales) can be readily identified to species. In other cases, small samples could be collected for genetic analyses. Given that local markets typically take place on fixed schedules, one or a few researchers could potentially cover important sites throughout entire districts rotationally, which would result in large data sets for at-risk taxa and could be used to inform law enforcement where to focus attention.

General and specific habitat studies throughout Nepal are also needed. Great strides have been made in modeling habitats to predict where species are found (Yonzon, Jones & Fox, 1991; Smith, Ahearn & Mcdougal, 1998; Kafley, 2008) or to locate potential areas for reintroduction (Aryal, Brunton & Raubenheimer, 2013; O'Neil & Bump, 2014; Paudel, Hais & Kindlmann, 2015b). Assessing general habitat suitability can be done quickly with remote sensing techniques (Heinen & Mead, 1984; Kanagaraj *et al*., 2011; Reddy *et al.,* 2017). The PA system is now large and well-protected, but units are not distributed proportionally throughout the ecosystems of the country (Paudel & Heinen, 2015c). High and low elevations are well-represented, but intermediate elevations and habitats are not (Hunter & Yonzon, 1993). To assess the habitat value of non-protected areas, remote sensing analyses in combination with field verification are needed (Basnet *et al*., 2016) as are studies that explore local human uses that deplete forest biomass (Shrivastava & Heinen, 2007; Timilsina & Heinen, 2008; Dahal, McAlpine & Maron, 2014). Exploited forests can have some habitat potential (Thapa & Chapman, 2010) but they are generally lower in native diversity compared to PAs.

Finally, there are social components to conservation that can be used and expanded upon. While most field biologists are amenable to talking with local residents, they are generally not trained in techniques used in the social sciences. Local ecological knowledge (LEK), widely considered in anthropology, can be valuable in assessing presence and population trends for wild species that local people exploit or compete with (Shrestha-Acharya & Heinen, 2006; Rehage *et al*., 2019). Given that many people use alternative local names, photographic guides are helpful in querying residents about species of interest (Edwards, Heinen & Rehage, 2016). Beginning in Costa Rica (Janzen & Hallwachs, 2011) , and now used in other parts of the developing world (Schmiedel *et al*., 2016), local residents trained as parataxonomists can be very helpful in collecting reference specimens of many taxa. While pressing plants and pinning insects are rather easy skills to learn, well-trained amateurs could also collect and document, for example, small vertebrate specimens for wet preservation and eggshells, nests, fecal, fur, scale and feather samples for genetic analyses. Local outreach, LEK and parataxonomist programs could be structured into small scale economic and social incentives to promote conservation, as has been described elsewhere for various purposes (Low & Heinen 1993; Heinen, 1994; Dinerstein *et al*., 2013; McGinnis & Ostrom 2019). District-level offices to store specimens, and a national repository, would also be necessary, which could be met by the district forest offices located throughout Nepal and the Natural History Museum and Herbarium in Kathmandu. Funding would also be needed to train and pay local collectors.

We also contend that efforts are needed nationwide to make recommendations and implement interventions to mitigate conflicts. There are dozens of published accounts on wildlife conflicts throughout Nepal and the Himalaya, especially concerning livestock and crop depredation and human deaths by large mammals. There is also a need to explore conflicts with many other species. For example, small mammalian carnivores, monitor lizards and raptors prey on domestic fowl and eggs; piscivorous birds and snakes prey on farmed fish; and poisonous snakes present a direct threat, especially in the lowland terai along the Indo-Nepalese border.

Wildlife extension professionals could address these conflicts on a national scale. Ideas for reducing crop damage and livestock loss by large mammals have emerged from the literature (Sapkota *et al*., 2014).

Other simple recommendations - such as locking poultry into coops at night and plugging holes in walls and storing grains in closed bins - would reduce domestic bird depredation and the propensity for rodents, and hence snakes, to enter village households. In any case, extension personnel with conflict resolution skills could prove most helpful to address these issues throughout Nepal and South Asia.

CONCLUSIONS

The main conclusions from our review are that many great strides have been made over the past half century in studying and protecting Nepal's wildlife, but further efforts are needed. It's likely that a six or low seven-figure (US$) project funded by a major bi-or multilateral donor, headquartered in Kathmandu with operations nation-wide, would be needed to fund the entire agenda outlined here all at once. However, some of the above activities have already begun in Nepal as this review shows and, even without a large, external funding source, progress in most areas continues. NGOs such as Bird Conservation Nepal, Small Mammals Conservation and Research Foundation, CARON, Resources Himalaya and Wildlife Conservation Nepal have been active and successful in garnering funding to further their research and conservation agendas. International non-government organizations such as WWF-Nepal, IUCN-Nepal, The Mountain Institute and ICIMOD have been active for decades and successful at garnering major funding.

Most encouraging is that the foundations for expanding this research agenda are underway.

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