Challenges and possible conservation implications of recolonizing dholes *Cuon alpinus* in Nepal

Yadav Ghimirey*[1,2], Raju Acharya[1], Kaushal Yadav[3], Jeevan Rai[3], Rishi Baral[4], Utsav Neupane[5], Binod Basnet[6], Martin Gilbert[7], Shashank Poudel[8] and Berndt J. van Rensburg[9,10,11]

Abstract The Endangered dhole *Cuon alpinus* is a medium-sized canid that was historically distributed widely across East, Central, South and Southeast Asia. In Nepal, following heavy persecution during the 1970s and 1980s, the species was locally extirpated across large parts of the country. After decades of near absence, the dhole is reportedly showing signs of recovery in various areas of Nepal. We carried out three surveys using camera traps (resulting in a total of 6,550 camera-trap days), reviewed literature and interviewed herders and conservation practitioners (40 interviews) to determine the historical and current distribution of dholes in the country, and the species' current status. Our camera traps recorded five images of dholes, and the literature review and interview survey provided further insights into the historical and current presence of dholes in Nepal. The combined findings suggest dholes have recolonized many areas where they had been locally extirpated, such as the Annapurna Conservation Area in central Nepal and the Tinjure–Milke–Jaljale forests in the eastern part of the country. Although these returns are encouraging, challenges remain for dhole recolonization, including conflict with livestock herders, human hunting of wild ungulates affecting the species' prey base, increasing infrastructure development in forested areas, and diseases.

Keywords Asiatic wild dog, habitat loss, human–wildilfe conflict, livestock depredation, persecution, protected areas, recolonization

*Corresponding author, yadavghimirey@ufl.edu
[1]Friends of Nature (FON Nepal), Kathmandu, Nepal
[2]Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, Florida, USA
[3]Nature Conservation and Study Centre, Kathmandu, Nepal
[4]Department of Environmental Veterinary Science, Laboratory of Wildlife Biology and Medicine, Hokkaido University, Japan
[5]Birat Environmental Consultancy, Biratnagar, Nepal
[6]National Trust for Nature Conservation, Khumaltar, Nepal
[7]Cornell Wildlife Health Center, College of Veterinary Medicine, Cornell University, Ithaca, New York, USA
[8]Department of Natural Resources and Environment, Cornell University, Ithaca, New York, USA
[9]School of Environment, University of Queensland, St Lucia, Queensland, Australia
[10]Department of Zoology, University of Johannesburg, Johannesburg, South Africa
[11]Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa

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Introduction

The Asiatic wild dog or dhole *Cuon alpinus* is an apex predator found in the forests of South and Southeast Asia and is categorized as Endangered on the IUCN Red List, with a global population estimated to be 949–2,215 mature individuals in the wild (Kamler et al., 2015). Dholes have been persecuted by people across large parts of their range because of the perceived threat they pose to livestock (Durbin et al., 2004). The species was hunted almost to extinction in many parts of India during the colonial era, when they were labelled as vermin, before receiving legal protection in 1972 (Cohen, 1978; Kamler et al., 2015). This persecution, together with large-scale habitat loss, has caused the overall dhole distribution to contract to less than 25% of the species' former global range in the 20th century (Wolf & Ripple, 2017). Formerly distributed widely across East, Central, South and Southeast Asia, dhole populations have contracted considerably and are now mostly limited to the protected areas of 11 countries in South and Southeast Asia (Kamler et al., 2015; Srivathsa et al., 2019; Kao et al., 2020).

In Nepal, dholes have been categorized as Endangered on the national Red List, with an assumed population of fewer than 500 individuals. Dholes have been reported to occur in Bardia, Chitwan, Rara, Parsa and Shuklaphanta National Parks (Jnawali et al., 2011). Recent records suggest the species also occurs in locations where it had not been previously recorded, and that it has reappeared in areas where it had been extirpated. These sites include Kanchenjunga Conservation Area (Khatiwada et al., 2011), Dhorpatan Hunting Reserve (Aryal et al., 2015) and Barandabhar Corridor Forests (Lamichhane et al., 2018).

We reviewed the available literature, interviewed relevant stakeholders and conducted a camera-trap survey to assess the historical presence and distribution of dholes in Nepal and the reasons for their decline. We also gathered recent records to augment our understanding of the current status of dholes in the country, and we discuss potential challenges to their recolonization.

Methods

Camera trapping

We conducted camera-trap surveys at two study sites: Annapurna Conservation Area during January–March 2017 and April–November 2018, and the Tinjure–Milke–Jaljale forests during December 2017 (Fig. 1). Annapurna Conservation Area is a gazetted protected area, whereas the Tinjure–Milke–Jaljale forests are not. The survey in the Annapurna Conservation Area was primarily conducted to estimate the occupancy of the clouded leopard *Neofelis nebulosa*, and that in the Tinjure–Milke–Jaljale forests to detect the presence of the binturong *Arctictis binturong* (Ghimirey et al., 2018; Rai, 2018a). However, camera traps placed along well-established trails are also suitable for detecting other wildlife, livestock and people (Linkie et al., 2013; Williams et al., 2021). Camera-trap stations consisted of single camera traps (Reconyx Hyperfire, Reconyx, Holmen, USA; HCO Scoutguard, HCO Outdoor Products, Dulluth, USA; Bushnell cameras, Bushnell Outdoor Products, Overland Park, USA) set up 45–60 cm above ground level. We set cameras to operate continuously, with a delay of 10 s between successive captures. Camera traps were active for a minimum of 9 days (in the Tinjure–Milke–Jaljale forests) to a maximum of 107 days (in Annapurna Conservation Area), depending on the survey site and the individual camera-trap location.

Literature review

We reviewed both peer-reviewed and grey literature published during 1950–2022 using the platforms Google Scholar (Google, 2022), Scopus (Elsevier, Amsterdam, The Netherlands) and Web of Science (Clarivate, Philadelphia, USA). The search terms included ['Asiatic wild dog' OR 'dhole' OR '*Cuon alpinus*'] AND ['occurrence' OR 'decline'] AND 'Nepal'. We also searched for studies focused on other wildlife species in which dholes may also have been recorded. Keywords used included ['wildlife survey' OR 'wildlife research' OR 'mammal survey'] AND 'Nepal'. We screened titles and abstracts of the resulting literature to identify potentially relevant reports that could provide information on dhole presence and distribution in present and historical contexts. We reviewed relevant articles and information on dhole occurrences, declines and other parameters recorded.

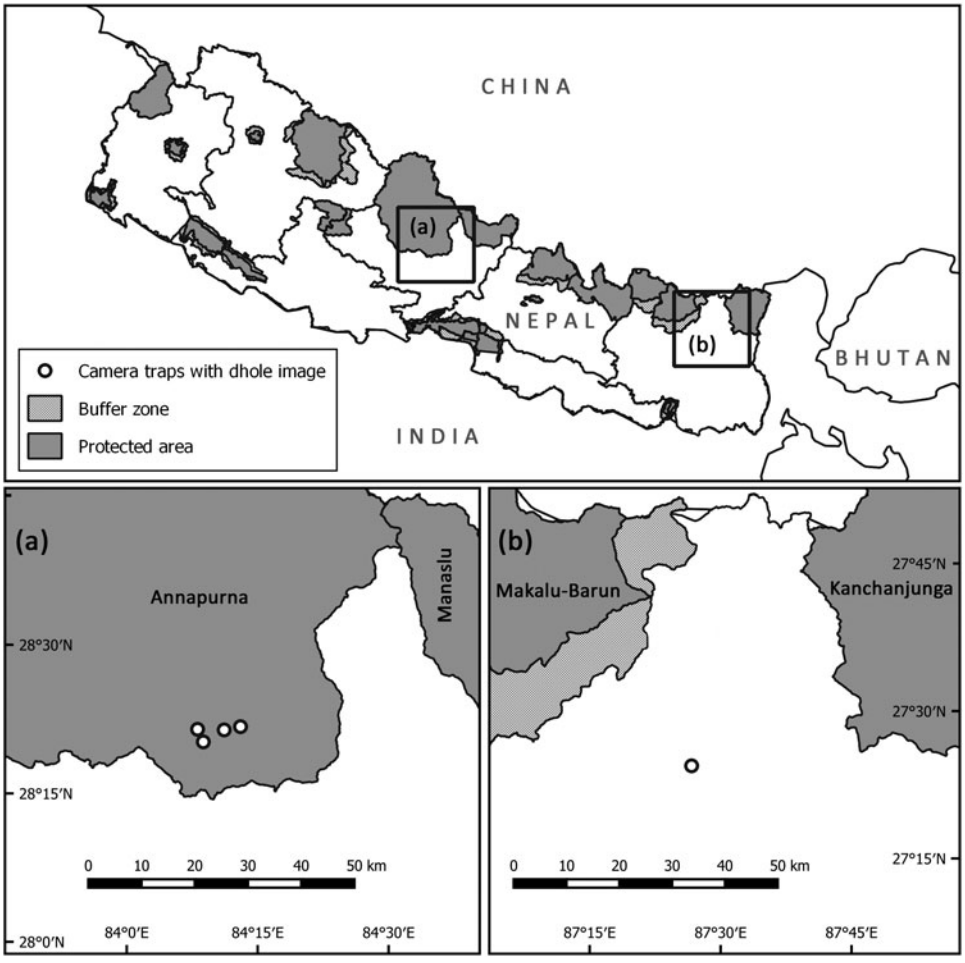

FIG. 1 Areas in Nepal where we carried out camera-trap surveys. White dots indicate locations where dholes *Cuon alpinus* were recorded.

TABLE 1 Summary of the results from three camera-trapping surveys in Nepal (Fig. 1) indicating the reappearance of the dhole *Cuon alpinus* in Annapurna Conservation Area and the Tinjure–Milke–Jaljale forests. The abundance index for the dhole is the number of independent detections per 100 camera-trap days. Numbers given for potential prey and competitor species, livestock and people represent independent detections.

	Annapurna Conservation Area		Tinjure–Milke–Jaljale forests
	2017	2018	2017
Camera-trap survey details			
Camera-trap stations	48	31	30
Camera-trap days	4,345	1,799	406
Dhole *Cuon alpinus*			
Independent detections	2	2	1
Abundance index	0.05	0.11	0.25
Potential prey			
Northern red muntjac *Muntiacus vaginalis*	631	222	8
Mainland serow *Capricornis thar*	53	13	0
Himalayan goral *Naemorhedus goral*	7	5	0
Assamese macaque *Macaca assamensis*	46	20	1
Nepal gray langur *Semnopithecus schistaceus*	5	3	1
Wild boar *Sus scrofa*	0	0	1
Potential competitors			
Leopard *Panthera pardus*	84	17	5
Clouded leopard *Neofelis nebulosa*	8	0	0
Livestock	81	1,225	78
People	324	504	155

Stakeholder interviews

We further explored dhole recolonization through interviews with 40 respondents, comprising conservation professionals and local people (herders, current/past hunters), to collect additional anecdotal evidence of dhole presence and apparent absence in various areas in Nepal. We interviewed herders and hunters in person, and conservation professionals using digital platforms such as email and social media (primarily Facebook; Meta Platforms, 2022). The aim of these interviews was solely to assess whether the interviewees were aware of any historical or current records of dholes in their local area (i.e. not for testing any specific hypothesis); we thus asked a range of questions on the historical presence and current status of dholes across Nepal. We asked for evidence of any reported presence of the species (e.g. photographs or pelts) to verify such reports if possible. If declines of dhole populations were reported, we asked interviewees for the possible causes of such declines. To ensure that interviewees were clear about the species under discussion, we asked questions on morphological features and behavioural attributes of dholes. As far as possible, we avoided leading questions, to ensure that interviewees responded based on what they knew and not on what we wanted to hear (Fox, 2006; Cairns-Lee et al., 2022).

Results

A total of 6,550 camera-trap days resulted in 10,114 independent images, with 3,723 images (37%) showing wildlife, including 26 species of mammals. Dholes were photographed five times in total, with only a single individual evident in each image. Potential dhole prey species detected by camera traps were the northern red muntjac *Muntiacus vaginalis*, mainland serow *Capricornis thar*, Himalayan goral *Naemorhedus goral*, Assamese macaque *Macaca assamensis* and Nepal gray langur *Semnopithecus schistaceus*. Detections of people and livestock (buffalos, goats, sheep, domesticated yaks) varied greatly across the two areas. Potential dhole competitors detected were the leopard *Panthera pardus*, the apex predator of the area in both Annapurna Conservation Area and the Tinjure–Milke–Jaljale forests, and the clouded leopard, which was recorded only in Annapurna Conservation Area in 2017. Details regarding the camera-trapping surveys are provided in Table 1.

Our literature review identified a total of 27 publications (Supplementary Material 1) containing relevant information on the historical or current distribution of dholes in Nepal.

Based on all the data that we obtained (from camera-trap surveys, literature review and stakeholder interviews), we documented historical records of dholes (although few) and their current distribution in 10 districts and 18 protected areas (Table 2).

Historical presence and decline

Dholes were historically documented in Lamtang National Park, Sagarmatha National Park, Bardia-Karnali Wildlife

TABLE 2 Summary of dhole historical records and current distribution (Fig. 2) in Nepal based on data obtained from camera traps, literature review and stakeholder interviews.

Site	Historical record	Source	Current distribution	Source
Annapurna Conservation Area	Found but extirpated	This study	Confirmed presence	This study
Api-Nampa Conservation Area	Possibly found but extirpated	N/A	Possibly absent	A. Bashyal (pers. comm., 2022)
Banke National Park	Possibly found but extirpated	Dinerstein (1980)	Confirmed presence	Anon. (pers. comm., 2021)
Bardia National Park	Found but extirpated	Dinerstein (1980)	Confirmed presence	Yadav et al. (2019)
Bhojpur district	Found but extirpated	Rai (2018b)	Possibly absent	Rai (2018b)
Chitwan National Park	Found but extirpated	Jnawali et al. (2011)	Confirmed presence	Thapa et al. (2013)
Dadeldhura district	Found but extirpated	K. Shah (in litt., 2022)	Possibly absent	Thapa et al. (2022)
Dang district	Possibly found but extirpated	N/A	Confirmed presence	Anon. (pers. comm., 2023)
Dhorpatan Hunting Reserve	Found with no clear evidence of local extirpation	Wilson (1981)	Possibly absent	Regmi et al. (2023)
Gaurishankar Conservation Area	Possibly found	S. Thami (in litt., 2022)	Possibly absent	S. Thami (in litt., 2022)
Humla district	Found with no clear evidence of local extirpation	K. Lama (pers. comm., 2013)	Possibly absent	R. Lama (in litt., 2023)
Ilam district	Found but extirpated	M.B. Gurung (pers. comm., 2007)	Possibly absent	Lama (2018)
Jajarkot district	Found with no clear evidence of local extirpation	G. Singh (in litt., 2023)	Confirmed presence	G. Singh (in litt., 2023)
Kanchenjunga Conservation Area	Found	Khatiwada et al. (2011)	Confirmed presence	Khatiwada et al. (2011)
Khaptad National Park	Possibly found but extirpated	N/A	Possibly absent	Khaptad National Park (2019)
Lamtang National Park	Found but extirpated	Kharel (1997)	Confirmed presence	N. Sherpa (pers. comm., 2019)
Makalu-Barun National Park	Found but extirpated	This study	Confirmed presence	Byers et al. (2014)
Manang district	Found but extirpated	S. Ale (in litt., 2022)	Possibly absent	T.R. Ghale (in litt., 2022)
Manaslu Conservation Area	Possibly found	N/A	Possibly absent	M. Gurung (in litt., 2022)
Mustang district	Possibly found	N/A	Possibly absent	This study
Panchthar district	Possibly found but extirpated	N/A	Possibly absent	Lama (2018)
Parsa National Park	Found but extirpated	N/A	Confirmed presence	Thing et al. (2022)
Rara National Park	Found but extirpated	B.V. Dahal (pers. comm., 2021)	Possibly absent	S. Khadka (pers. comm., 2020)
Sagarmatha National Park	Found but extirpated	Lovari et al. (2009)	Possibly absent	Sagarmatha National Park (2019)
Shey-Phoksundo National Park	Found but extirpated	G. Khanal (in litt., 2022)	Confirmed presence	G. Khanal (in litt., 2022)
Shivapuri-Nagarjun National Park	Uncertain	N/A	Possibly absent	L. Paudyal (pers. comm., 2022)
Tinjure–Milke–Jaljale forests	Found but extirpated	This study	Confirmed presence	This study
Udayapur district	Found but extirpated	Shah et al. (2018)	Possibly absent	Shah et al. (2018)

Reserve (present-day Bardia National Park and possibly Banke National Park), Chitwan National Park (Jnawali et al., 2011), Dhorpatan Hunting Reserve, Kanchenjunga Conservation Area and the Salpa Pokhari area in eastern Nepal (Dinerstein, 1980; Green, 1981; Lovari et al., 2009; Sherchan & Bhandari, 2017; Rai, 2018b). Interviews indicated the historical presence of dholes in Makalu-Barun National Park, Humla district, Mustang district, Manang

district (S. Ale, in litt., July 2022), Ilam district (M.B. Gurung, pers. comm., 2007) and Jajarkot district (G. Singh, in litt., July 2022). Dholes reportedly predated heavily on livestock, leading to retaliatory persecution through poisoning of bait carcasses, which killed large numbers of dholes (Lovari et al., 2009; Khatiwada et al., 2011; G. Singh, in litt., July 2022). There was also evidence of the disappearance of dholes from Chitwan National Park and Bardia National Park during the early 1990s (Jnawali et al., 2011; Yadav et al., 2019).

Current dhole presence

Camera traps confirmed the presence of dholes in Annapurna Conservation Area and the Tinjure–Milke–Jaljale forests (Ghimirey, 2017; NTNC/ACAP, 2018; Rai, 2018a). A total of five images of dholes were captured, all of which showed single individuals (Plate 1). We assumed these captures to be of five different individuals, based on conversations with herders. The literature review provided evidence of dholes from Makalu-Barun National Park (Byers et al., 2014) and the Topke Gola area outside Kanchenjunga Conservation Area (Shrestha et al., 2016). Interviews indicated dhole presence in Lamtang National Park, Shey-Phoksundo National Park and Jajarkot district. A total of five potential packs were recorded in Chitwan National Park (Thapa et al., 2013), four or five packs are believed to live in the Yamphudin region in Kanchenjunga Conservation Area and two packs in the lower area of Shey-Phoksundo National Park (Sherchan & Bhandari, 2017; G. Khanal, in litt., July 2022). From the information we obtained through literature review, interviews and camera-trap surveys, the presence of dholes was confirmed in 12 different sites in Nepal (Fig. 2). The literature review and interviews indicated the potential absence of dholes from Gaurishankar Conservation Area (B. Pandey & S. Thami, in litt., July 2022), Ilam-Panchthar district (Lama, 2018), Dadeldhura district (Thapa et al., 2022), Manaslu Conservation Area (M.B. Gurung, in litt., July 2022), Rara National Park (S. Khadka, in litt., 2020) and Udayapur district (Shah et al., 2018).

PLATE 1 Camera-trap photo of a dhole *Cuon alpinus* in Annapurna Conservation Area, Nepal. Photo: Friends of Nature.

Discussion

The historical presence of dholes in Nepal has been documented by various explorers (Blower, 1973; Dinerstein, 1980; Green, 1981; Johnsingh, 1985; Yonzon, 1989; Heinen, 1995; Mehta & Kellert, 1998; Lovari et al., 2009). As most of these explorations were carried out at a local scale, little information is available regarding the historical presence of dholes for large parts of the country (but see Blower (1973), who refers to their wide distribution in the country up to altitudes of c. 3,700 m). Our interviews with herders and conservation practitioners corroborated the previous observation that dholes were historically present in various areas in Nepal, from lowlands to areas above 3,500 m (Blower, 1973).

The exact reason for the decline of dholes in Nepal is unknown, although reduction in its forest habitat during 1947–1980, when forest cover in the country was reduced from 57% to 23%, is believed to be an important factor (Chaudhary et al., 2016). Poaching was also a problem during this period, which supposedly led to faunal collapse in the lowlands of Nepal (Heinen, 1995). However, forest loss in the mid-hills and high mountains was less severe during this period, which suggests that retaliatory killing and/or prey loss could have played a role, as these are commonly implicated in the extirpation of dholes from many areas of their historical range (Kamler et al., 2015). Research has shown the negative impacts of carcass poisoning in Kanchenjunga Conservation Area and Annapurna Conservation Area in Nepal (Khatiwada et al., 2011; Acharya et al., 2013), as well as in Bhutan (Kamler et al., 2015) and India (Burton, 1940). Dholes prey on medium to large wild ungulates such as sambar *Rusa unicolor* (Cohen, 1978; Durbin et al., 2004), which have possibly been hunted to extinction from large areas in the mountains of Nepal (Shah et al., 2018). Thus, reduced prey availability could have contributed to the dhole population decline either directly through reduction in food availability or indirectly through retaliatory persecution, as dholes are forced to rely on livestock to fulfil their nutritional needs. This decline and/or local extirpation of dhole populations has also been inferred from the results of wildlife surveys in various areas of the mid-hills in Nepal conducted in the early 2000s and 2010s, where dholes remained undetected (Ghimirey, 2010; Ghimirey & Acharya, 2012; Pandey, 2012; Acharya et al., 2013; Khanal, 2016; Can et al., 2020; GPFD, 2021).

Currently, dholes are known to occur in 12 sites across Nepal. The evidence of dhole presence in some areas requires critical analysis and cross-validation. For example, the presence of dholes in Api-Nampa Conservation Area has

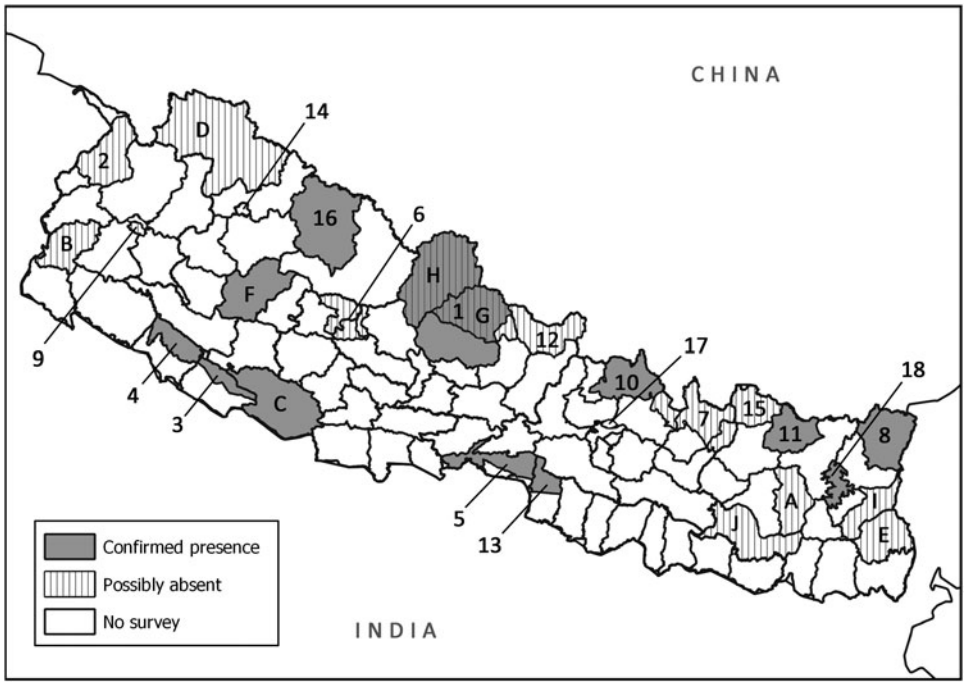

FIG. 2 Current knowledge on the distribution of dholes in the districts and protected areas of Nepal (Table 2). Districts: A, Bhojpur; B, Dadeldhura; C, Dang; D, Humla; E, Ilam; F, Jajarkot; G, Manang; H, Mustang; I, Panchthar; J, Udayapur. Protected areas (CA, Conservation Area; NP, National Park): 1, Annapurna CA; 2, Api-Nampa CA; 3, Banke NP; 4, Bardia NP; 5, Chitwan NP; 6, Dhorpatan Hunting Reserve; 7, Gaurishankar CA; 8, Kanchenjunga CA; 9, Khaptad NP; 10, Lamtang NP; 11, Makalu-Barun NP; 12, Manaslu CA; 13, Parsa NP; 14, Rara NP; 15, Sagarmatha NP; 16, Shey-Phoksundo NP; 17, Shivapuri-Nagarjun NP; 18, Tinjure-Milke-Jaljale forests. Note: Annapurna CA extends across several districts, with dholes present in the southern area but possibly absent from the northern part (in Manang and Mustang districts), hence the overlap of confirmed presence and possible absence.

been determined previously based on scat (Neupane, 2017); however, interviews with one respondent indicated that this could be a case of misidentification. Park personnel in Khaptad National Park confirmed the presence of dholes based on a camera-trap image of a red fox (KNP, 2019). The presence of dholes in the Badhimalika region in western Nepal has been reported previously, but without evidence to support this claim (Karki et al., 2002). Similarly, there have also been areas where an intensive survey in 2015 failed to detect the species (Can et al., 2020), but interviews with herders in 2019 indicated recent sightings. In a recent camera-trap survey in Dhorpatan Hunting Reserve, where dholes are believed to be present, no dholes were detected (Regmi et al., 2023).

Challenges to dhole recolonization

Recent evidence of the reappearance of dholes in many of its formerly occupied areas (e.g. Annapurna Conservation Area and the Tinjure–Milke–Jaljale forests, as shown by our camera-trap data) suggests that the species could be recovering in some parts of Nepal, but this brings its own set of challenges. Recolonization efforts, like reintroductions, will only be successful if the threats that drove a species to extinction are either completely absent or their magnitude/intensity is significantly reduced (IUCN SSC, 2013). Therefore, it is important to assess these threats before conducting such efforts. Annapurna Conservation Area is frequently used by people for the collection of non-timber forest products and for livestock herding, which are important sources of revenue for local communities; this may lead to human–dhole conflict in future.

If dhole numbers were to increase in these areas, we expect they would form social packs to facilitate efficient hunting of their prey (Durbin et al., 2004). Our camera-trap records indicate that the relative abundance of prey species on which dholes typically rely, such as the northern red muntjac and mainland serow, varies significantly, with encounter rates of 20.3–24.2 and 1.7–2.6 photos per 100 trap-days, respectively (Ghimirey, 2017). In addition, the encounter rate for human disturbance (defined as any photographs showing people; 16 photos per 100 trap-days) provides evidence of high human activity, including hunting, as indicated by multiple camera-trap pictures of hunters carrying guns (Ghimirey, 2017). Such presence will probably increase livestock depredation, and there is already evidence of livestock depredation by dholes in the area (Supplementary Plate 1). Repeated livestock depredation may lead to retaliatory actions, threatening the recovery of dhole populations. There are also reports of an increasing number of human–dhole conflict incidents in

Kanchenjunga Conservation Area (Sherchan & Bhandari, 2017) and Shey-Phoksundo National Park (G. Khanal, in litt., July 2022). Although depredation incidents were also reported in Dhorpatan Hunting Reserve (P. Thapa, in litt., July 2022), these need further validation, as recent camera-trapping efforts did not record the species in the area (Regmi et al., 2023). Nevertheless, this potential for negative human–wildlife interactions represents a significant challenge for dhole recolonization in many mid-hill regions in Nepal, including Makalu-Barun National Park, Lamtang National Park and the Tinjure–Milke–Jaljale forests, where dhole populations appear to be recovering.

Furthermore, the mid-hills in Nepal, despite increasing forest cover because of community forestry (Oldekop et al., 2018), are subject to habitat destruction and fragmentation because of hydropower projects and road construction (Plate 2). At least 220 hydropower projects (> 1 megawatt) are in the construction phase across Nepal (Investopaper, 2022), and evidence suggests that hydropower projects in Nepal do not always comply with environmental regulations (Ghimirey, 2020; Ghimire et al., 2021). Forests in the lowland region have a high density of prey, making them ideal for recolonizing dholes, but there has been a rapid decline in forest cover over the last 50 years in these areas, with the highest deforestation rate in Nepal (DFRS, 2015; Chaudhary et al., 2016). The lowland region supports nearly 50% of the total human population of the country, putting pressure on lowland forests and thus on dholes and their habitats.

Our camera traps recorded multiple images of domestic dogs, highlighting a risk of disease transmission between dogs and dholes, a threat that has not yet been evaluated. Dholes are known to be susceptible to infectious diseases, particularly rabies and canine distemper viruses (Durbin et al., 2004), which have proven to be serious concerns to the conservation of other threatened canid populations, including Ethiopian wolves *Canis simensis* (Haydon et al., 2002; Gordon et al., 2015) and African wild dogs *Lycaon pictus* (Gascoyne et al., 1993). As yet, the impact of these viruses on the recovery of dholes in Nepal remains unknown, but both viruses are widespread and common in the country (Devleesschauwer et al., 2016; Ng et al., 2019) and have a disproportionate impact on the viability of small populations (Gilbert et al., 2014; Marino et al., 2017).

We expect positive impacts in areas where dholes are recolonizing, most importantly the regulation of large ungulate populations (Kamler et al., 2020), which can have a detrimental impact on vegetation (Ripple et al., 2015). However, because the landscape that dholes are recolonizing is also being used by people, dhole population growth could affect livestock herding negatively. As livestock herding is one of the most important livelihood activities in the mid-hills of Nepal (Ghimire & Parajuli, 2001; Bhattarai & Kindlmann, 2012), a rise in dhole populations could lead to livestock depredation and consequently retaliatory killings of dholes. It is therefore necessary to prepare for such potential negative dhole–human interactions by working with relevant stakeholders to introduce predator avoidance measures, support depredation compensation from the government (DNPWC, 2013) and possibly explore insurance schemes to try to prevent retaliation if livestock depredation occurs. Furthermore, the impacts of infrastructure development in potential dhole habitats need to be carefully assessed as such information has been lacking previously (Ghimirey, 2020) and the mitigation of prospective threats is urgent. Dholes recolonizing the forests in Nepal is an inspiring conservation story; however, effective in situ conservation efforts are necessary for the long-term conservation of this species in Nepal.

Plate 2 Dhole habitat destruction caused by hydropower infrastructure construction near Tangting village, Madi Rural Municipality, Nepal (March 2019). Photo: Yadav Ghimirey.

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Author contributions Fieldwork and data collection: YG, RA, KY, JR, UN; writing, revision: all authors. YG, JR and MG contributed equally.

Conflicts of interest None.

Ethical standards This research involved a non-invasive survey and otherwise abided by the *Oryx* guidelines on ethical standards. The survey was conducted in a socially responsible manner and images showing people were used and stored in a way that protects privacy and does not cause harm to people.

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