Global Ecology and Conservation 46 (2023) e02549

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Plastic ingestion by greater one-horned rhinos in Nepal: An emerging conservation threat

Balram Awasthi [a,b,c,*,1], Babu Ram Lamichhane [d,2], Kim R. McConkey [e,3]

[a] CAS Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla,Yunnan 666303, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] Department of Zoology, Siddhanath Science Campus, Tribhuvan University, Mahendranagar, Nepal
[d] NTNC Biodiversity Conservation Center, Ratnanagar-6, Sauraha, Chitwan, Nepal
[e] School of Environmental and Geographical Sciences, University of Nottingham Malaysia, Kajang, Selangor, Malaysia

ARTICLE INFO

Keywords:
Rhinoceros unicornis
Garbage
Plastic pollution
Terai-Arc Landscape
Dung

ABSTRACT

Plastic pollution is potentially a major threat to the health of terrestrial organisms, including megafauna, but its effects are relatively understudied compared to marine ecosystems. Here we document the presence of plastic macro-particles in the dung of the greater one-horned rhino (*Rhinoceros unicornis*) in the Terai landscape of Nepal. Field data were collected deep within Chitwan National Park and its fringe zone during the monsoon and post-monsoon season of 2020, 2021 and 2022. Over three years, we recorded plastic in ~10% of 258 rhino dungs piles. This is an underestimate since we did not record micro-particles or search entire dungs. More dungs located deep within the national park (core zone) contained plastic compared to the fringe zone and we recorded no difference in plastic incidence between riverine forest and floodplain grasslands. Rhinos do not appear to target garbage dumps as food sources but are exposed to plastic when foraging. The plastic is carried down river during monsoonal floods and deposited in rhino habitat as the flood waters recede. The relatively higher rate of plastic detection in rhino dungs from the core zone is probably due to details of rhino ranging, and is a potential threat to other wildlife in the river floodplains. We recommend more detailed studies on the patterns and effects of plastic ingestion by rhinos and other wildlife. A comprehensive waste management system within the landscape is required to reduce such threats.

1. Introduction

Plastic pollution is recognized as a pivotal driver of animal mortality in marine environments (Beaumont et al., 2019), including megafauna such as whales (de Stephanis et al., 2013; Guerrini et al., 2019). Plastic ingestion is comparatively poorly reported in terrestrial fauna (Katlam et al., 2022, 2018). Yet, because plastic degrades slowly in the environment (Chamas et al., 2020), it has

* Corresponding author at: CAS Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, Mengla,Yunnan 666303, China.
E-mail address: awbalramsnsctu@gmail.com (B. Awasthi).
[1] orcid.org/0000–0002-8288–2603
[2] orcid.org/0000–0003-0580–7682
[3] orcid.org/0000–0002-3793–7732

https://doi.org/10.1016/j.gecco.2023.e02549
Received 1 March 2023; Received in revised form 16 June 2023; Accepted 17 June 2023
Available online 19 June 2023

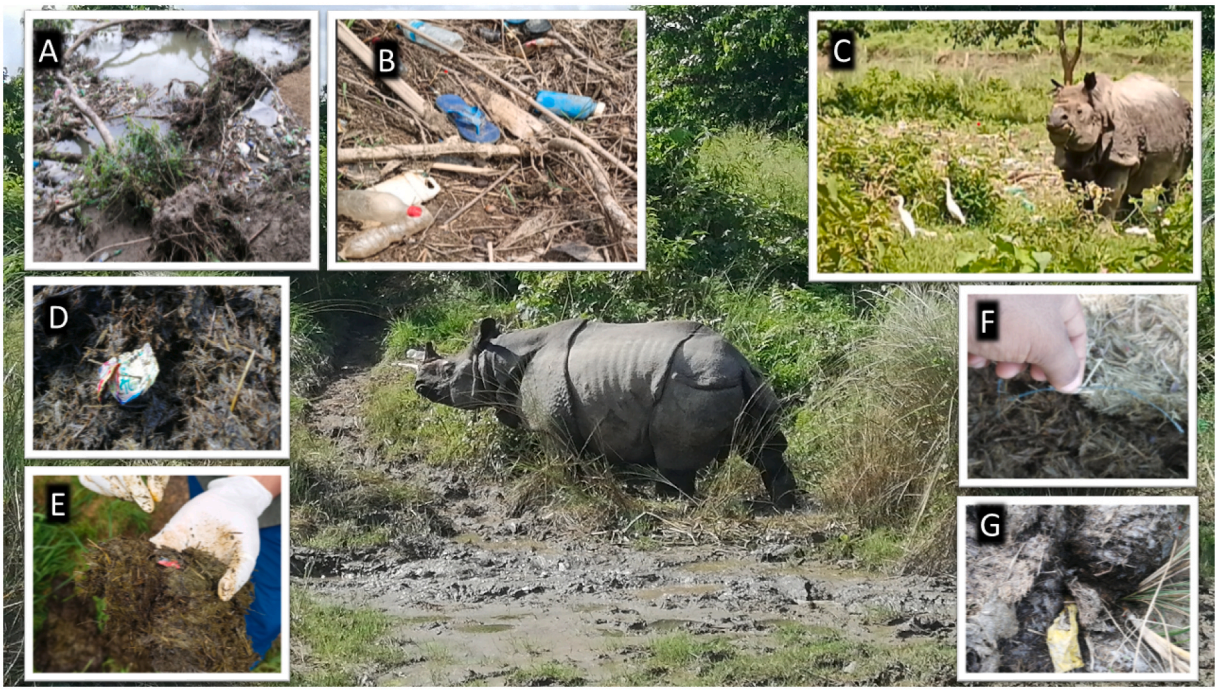

Fig. 1. (A) Plastic debris is carried along swollen monsoonal rivers and (B) deposited within rhino habitat when the flood waters recede. (C) Plastic particles are probably eaten accidentally by grazing rhinos (note plastic among the grasses in the photo) and is later deposited within the dung (D-G). Pictures taken by B. Awasthi.

become ubiquitous in all terrestrial ecosystems, and likely causes major problems for terrestrial fauna as well (de de de Souza Machado et al., 2018; Malizia and Monmany-Garzia, 2019). The few available studies confirm that plastic pollution is a major form of anthropogenic disturbance for some terrestrial organisms including large herbivores and megafauna (Breton, 2019; Katlam et al., 2022, 2018; Liyanage et al., 2021).

Over the past few hundred years, rapid human population growth, habitat loss, and hunting have caused the extinction or population reduction of the world's largest herbivores, such as rhinoceros and elephants (Sandom et al., 2014). These megafaunal species often persist only in protected areas, but can remain in close contact with humans and are at threat from conflict, poaching, and other forms of anthropogenic disturbance (Bhandari et al., 2022, de la Shaffer et al., 2019, de la Torre et al., 2021). Due to their uniquely large size, the impact of population declines on the ecological functions of megafauna can have potentially cascading impacts on other species (Doughty et al., 2013; Galetti et al., 2018).

The vulnerable greater one-horned rhinoceros (*Rhinoceros unicornis*) are now distributed in India and Nepal with a fragmented population of around 4000 individuals (Subedi et al., 2013, 2017). Historically, the species was found across Bangladesh, Bhutan and possibly Pakistan, but human encroachment, habitat loss and poaching have resulted in its extirpation from these countries and fragmented its remaining population (Jhala et al., 2021, Laurie et al., 1982). As megaherbivores, greater one-horned rhinoceros (hereafter rhinos) rely on grass and browse, preferring to forage within mosaics of grassland and riverine forests in the floodplains of the rivers (Dinerstein, 1992; Dinerstein and Wemmer, 1988; Jnawali, 1995; Laurie, 1982). Part of the restricted distribution of rhinos is shared with human populations, mostly within the buffer zone and fringe areas of national parks (Baral, 2013; Gross et al., 2018). The main long-term threats to the rhinoceros are insufficient habitat quality and quantity, climate change and associated flooding risk, poaching, tiger attacks and fighting among rhinos (possibly due to lack of space) (Bhandari et al., 2022; DNPWC, 2017; Pant et al., 2020; Sarma et al., 2009; Subedi, 2012).

Rhinos defecate in common latrines (large dung piles), possibly connected to scent marking (Bhattacharya and Chakraborty, 2016). While conducting a study on seed dispersal by rhinos in Chitwan National Park, we noticed the presence of visible plastic debris within the dungs. We subsequently characterized and quantified plastic from the dung samples of rhinos from floodplain grasslands and riverine forests in the core zone (deep within the park) and fringe zone (edge of the park). Our aim was to identify patterns in plastic presence within rhino dungs that could be used as a reference for detailed future studies and inform authorities to initiate conservation action. We compared the proportion of dungs containing plastic across (i) years of study, (ii) habitats and (iii) within the core zone vs. fringe zone of the national park. We expected to find less plastic in dung during 2020 when covid lockdowns prevented tourist access to the park. We expected to find more plastic in dung within the fringe zone where anthropogenic activities are higher compared to the core zone. We had no prior prediction for plastic presence in dung from different habitats.

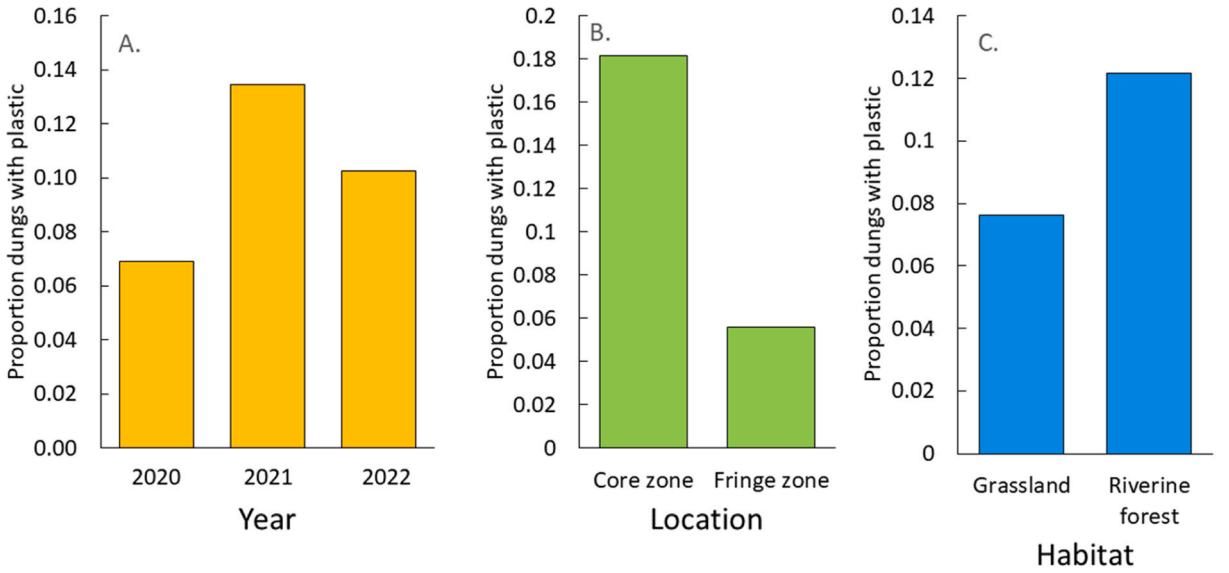

Fig. 2. Deposition patterns of plastic in the dung of rhinos in Nepal. Bars indicate the proportion of dungs containing plastics. (A) Over the past three years the proportion of dungs containing plastic has remained approximately the same, despite the covid lockdowns in 2020. (B) Significantly more plastic-containing dung was found in the core zone of Chitwan National Park, compared to the fringe zone. (C) More dung containing plastic was deposited in riverine forest compared to grasslands, but the difference was not statistically significant.

Table A1
Sampling of rhino dungs in Chitwan National Park.

Date	No. dung checked (Riverine forest/grassland)	
	Core Zone	Fringe Zone
August 2020	13 (2/11)	29 (11/18)
September	5 (5/0)	39 (28/11)
October	13 (0/13)	17 (6/11)
August 2021	18 (11/7)	24 (8/16)
September	15 (12/3)	13 (8/5)
October	13 (0/13)	21 (11/10)
August 2022	NA	11 (5/6)
September	NA	10 (5/5)
October	NA	18 (8/10)

2. Material and methods

The study was conducted in the eastern sector of Chitwan National Park, Nepal (CNP; 27°17'−27°42' north, 83°50'−84°46' east): within the fringe zone or at the edge of the national park (Icherney), and the core area, deep within the park (Jayamangala). CNP covers an area of 953 km^2 with an altitudinal range of 150–800 m and a buffer zone of 729 km^2. The climate is subtropical monsoon (mean annual rainfall is 2000 m), with three seasons: rainy season (July to October), dry and cold (November to February) and dry and hot (March to June). CNP is part of the Terai-Arc Landscape, which is an important landscape for the conservation of several threatened species, in addition to rhinos, such as tigers *Panthera tigris*, leopards *Panthera pardus*, and elephants *Elephas maximus*. CNP is Nepal's flagship national park with at least 68 species of mammals, 544 species of birds, 56 species of herpetofauna and 126 species of fish (CNP, 2019). CNP has the world's second largest population of rhinos (about 700 rhinos in 2021; CNP, 2021).

CNP's three major rivers (Rapti, Narayani, Ren) and the tributaries that flow through rhino habitat carry plastic waste during the rainy season (Fig. 1). In the winter months, as water levels decrease, large quantities of plastic remain on the river bed and the adjacent floodplains and riverine forests, where the rhinos preferentially graze (B. Awasthi personal observation). Tourists also discard plastic waste in the park, such as tobacco or biscuit packets, plastic bottles and facial masks (B. Awasthi personal observation).

From August to October in 2020, 2021 and 2022, rhino dungs were checked inside the core zone of the national park (Jayamangala) and the fringe zone (Icherney) (Appendix 1). The checks were done as part of a seed dispersal study conducted in 2020 and 2021, but plastic particles were also recorded when observed (116 dung samples in 2020, 104 in 2021). Sampling in 2022 was initiated as a further check specifically for plastic and was only done in the fringe zone since the main study had ended (38 dungs sampled in 2022). Sampling was conducted across two habitats (floodplain grassland and riverine forests). Rhinos repeatedly defecate in the same location (latrines), but only fresh dung on the latrines were checked. Rhino dung weighs 18 kg on average (Subedi, 2012); we removed

a ¼ sample of each dung for a thorough check for plastic. If any plastic material was visible, then we investigated the remaining ¾ of dung as well. All dung sampling and data recording were done in the field. We identified all plastic particles visible to the naked eye (approximately >5 mm) and recorded the presence, number and identity.

3. Results

Of 258 dungs assessed across the years in all habitats 10.1% contained visible plastic parts (Appendix 2). The incidence of plastic within dungs differed over the three years (Fig. 2A), but the difference was not significant (Chi-square test, $\chi^2 = 2.36$, $P > 0.05$). More plastic was found in 2021 (13% of sampled dungs) compared to 2020 (7%) and 2022 (10%). More dungs sampled in the core zone of the National Park contained plastic (18%), compared to the fringe zone (6%) ($\chi^2 = 7.93$, $P < 0.01$) (Fig. 2B). There was no significant difference in plastic incidence between the floodplain grasslands (8%) and riverine forests (12%) ($\chi^2 = 1.15$, $P > 0.05$).

At least eight different types of plastic were visible in the dungs (two items could not be identified) (Fig. 1). These included two hard items (plastic balls in two dungs) and a Coca Cola bottle top in another. The remaining six identifiable plastic types were soft items: chewing tobacco sachets (nine dungs), plastic bags (six dungs), biscuit packets (five dungs) and rubber bands, chocolate packet and a shampoo packet (one dung each). In most dungs ($n = 21$, 80.7%) we found a single (visible) plastic particle, with three particles found in one dung (plastic bags, rubber bands) and two particles found in another (ball, shampoo packet).

4. Discussion

We documented large plastic particles in at least 10% of the dungs of the greater one-horned rhino that were investigated in Nepal during 2020–2022. The plastic is probably swallowed accidentally as the rhino grazes, since rhinos have not been recorded consuming foods from garbage dumps. This differs to elephants and other herbivores that target garbage dumps to forage and incidentally consume plastic, often to access the food it contains (Katlam et al., 2022, 2018; Liyanage et al., 2021). There are two potential sources of plastic within the rhino's habitat. The first and primary source is trash from upstream deposited by the river during flooding, on floodplains and in riverine forest where the rhinos preferentially graze (Fig. 1A-C). The second and minor source is trash (face masks, food packets, drink bottles) discarded directly by visitors to the national park or locals within the community forest (B. Awasthi personal observation). Rhinos can be seen foraging in habitats strewn with this discarded plastic (Fig. 2C).

The ingestion and defecation of plastic by this globally threatened rhino species could represent a significant threat to its health and conservation. Plastic consumption has been linked to health problems and deaths in animals, when it causes gut blockages or poisoning (Bucci et al., 2020). Plastic was recorded in 32% of elephant dungs in north India (Katlam et al., 2022), and plastic is a cause of elephant mortality in Sri Lanka (Liyanage et al., 2021). Like elephants, rhinos are simple stomach folivores (Clemens and Maloiy, 1982), but they have more complex digestive systems with a compartmentalized colon (Stevens and Hume, 2004). This might make them more vulnerable to negative health implications from plastic ingestion than elephants. Poaching of rhinos has reduced in recent years but rhino mortality from natural causes such as tiger attacks on calves, fighting and old age has increased in recent years (Bhandari et al., 2022). This change has resulted from improved protection from poachers and increases in rhino and tiger densities (Bhandari et al., 2022; Subedi et al., 2017). While no deaths due to plastic consumption have been reported, around 10% of mortality is unexplained. It is imperative that plastic pollution is managed so that it does not cause health issues, increasing the chances of rhino mortality in the future.

The incidence of plastic particles in rhino dung is underestimated in this study since we only documented visible particles and did not usually search entire dungs. We noticed the presence of plastic within the dungs early in a study on seed dispersal by rhinos, but did not appreciate its prevalence until after months of observing rhino dungs. Detailed investigations of macro- and microplastics within rhino dungs is required, as well as quantitative documentation of the sources of plastic contamination within the rhino habitat.

More dungs containing plastic were found in the core zone of Chitwan National Park than within the fringe zone, which is surprising considering the higher incidence of trash within the fringe zone (B. Awasathi personal observation). This pattern probably reflects the foraging patterns of rhinos that can pass between the two areas within a single day (Subedi, 2012). If they are transporting plastic from the fringe to the core zone of the national park – as was observed in elephants in India (Katlam et al., 2022) – then this creates additional problems in the landscape for other animals. Although we documented more plastic within dungs located in riverine forest compared to grasslands the difference was not significant. Habitat differences are important to follow-up with further studies to determine whether certain habitats might be more vulnerable to plastic deposition by rhinos.

5. Conclusions

We documented plastic ingestion by greater one-horned rhinos, a previously unrecognized threat to this vulnerable megafauna species, by visually identifying macro-plastics present in dung samples. Rhinos appear to consume plastic incidentally while grazing rather than by making targeted visits to garbage dumps. Hence, prevention requires a comprehensive waste management strategy within all rhino habitat as well as in the catchments of the rivers that flow through these habitats. Immediate action should include cleanup campaigns to be carried out after monsoonal floods to remove any plastic deposited in the rhino habitat. In addition, plastic pollution should be considered as a threat to rhinos, and for other animals sharing the landscape. Such a strategy can reduce the threat of plastic-related health issues for rhinos and potentially also benefit other animals that share the same habitats.

CRediT authorship contribution statement

Balram Awasthi: Conceptualization (equal); data curation; formal analysis (equal); methodology; project administration; writing–original draft (equal); writing–review and editing (equal). **Kim McConkey**: Conceptualization (equal); formal analysis (equal); supervision; writing–review and editing (equal). **Babu Ram Lamichhane**: writing–review and editing (equal).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgments

This research was funded by the Xishunagbanna Tropical Botanical Garden (XTBG), Chinese Academy of Sciences. We would like to thank the Department of National Parks and Wildlife Conservation (DNPWC), and Chitwan National Park Nepal for granting us permission to conduct field research. Professor Dr. Chen Jin, supervised, reviewed and provided crucial feedback on an earlier version of the manuscript. We thank National Trust for Nature Conservation (NTNC), for support during the field work. We acknowledge the help of field assistants, Ms. Anil Mahato, Mr. Suresh Kumal, Mr. Surendra Chaudhary and Mr. Ganesh Lama. We thank to the support of the Director General of DNPWC and chief conservation officers of Chitwan National Park during this study.

Appendix 1

.

For the broader study of seed dispersal by rhinos we searched for dung over an area of approximately 5 km^2 in the core and fringe zone of Chitwan National Park, from August to October in 2020, 2021 and 2022 (Table A1). We selected fresh dung piles that had been deposited on rhino latrines, aiming to sample at least 10 fresh dung piles each month. The exception to this was in September 2020, when we could only locate five dung piles. The same area was searched each month and, in some cases, the same latrines were investigated; however, because only fresh dung were searched we did not recheck the same dungs each month. Fresh dung was distinguished by its color (greenish black to deep greenish brown) or by direct observations of the defecating rhino or presence of dung beetles. Older dung is a straw color. Dungs were investigated in both riverine forest and grassland according to how often they were encountered. In 2022, the main study had ended and checks were done specifically for plastic only and the searches were limited to the fringe zone of the park.

Appendix 2

Summary of dungs of the greater one-horned rhino checked from 2020 to 2022. Checks were done across two sites from 2020 to 2021 (Icherney, fringe zone and Jayamangala, within the core zone of Chitwan National park). Checks in 2022 were only done in the fringe zone as the main study had ended. Proportion of all dungs is the proportion of all checked dungs which were in that year, site and habitat (for 2020 and 2021 only), to indicate sampling evenness.

Site	Vegetation	Number of dungs	Year	Number of dungs with plastic	Proportion of dungs with plastic
Fringe zone	Grassland	40	2020	5	0.13
Fringe zone	Riverine forest	45	2020	0	0.00
Core zone	Grassland	11	2020	0	0.00
Core zone	Riverine forest	20	2020	3	0.15
Fringe zone	Grassland	31	2021	3	0.10
Fringe zone	Riverine forest	27	2021	0	0.00
Core zone	Grassland	23	2021	0	0.00
Core zone	Riverine forest	23	2021	11	0.48
Fringe zone	-	39	2022	4	0.10
Totals		259		26	

References

Baral, A., 2013. Impacts of wildlife tourism on poaching of Greater One-horned Rhinoceros (*Rhinoceros unicornis*) in Chitwan National Park, Nepal (MSc. Thesis). Lincoln University.

Beaumont, N.J., Aanesen, M., Austen, M.C., Börger, T., Clark, J.R., Cole, M., Hooper, T., Lindeque, P.K., Pascoe, C., Wyles, K.J., 2019. Global ecological, social and economic impacts of marine plastic. Mar. Pollut. Bull. 142, 189–195. https://doi.org/10.1016/j.marpolbul.2019.03.022.

Bhandari, S., Adhikari, B., Baral, K., Subedi, S.C., 2022. Greater one-horned rhino (*Rhinoceros unicornis*) mortality patterns in Nepal. Glob. Ecol. Conserv. 38, e02189 https://doi.org/10.1016/j.gecco.2022.e02189.

Bhattacharya, A., Chakraborty, K., 2016. Defecation behaviour of great Indian one horned rhinoceros (*Rhinoceros unicornis*, Linn.). Int. J. Sci. Res. 5, 923–928.

Breton, J.L., 2019. Visitation patterns of African elephants (*Loxodonta africana*) to a rubbish dumpsite in Victoria Falls. Zimb. Pachyderm 60, 45–54.

Bucci, K., Tulio, M., Rochman, C.M., 2020. What is known and unknown about the effects of plastic pollution: a meta-analysis and systematic review. Ecol. Appl. 30, e02044 https://doi.org/10.1002/eap.2044.

Chamas, A., Moon, H., Zheng, J., Qiu, Y., Tabassum, T., Jang, J.H., Abu-Omar, M., Scott, S.L., Suh, S., 2020. Degradation rates of plastics in the environment. ACS Sustain. Chem. Eng. 8, 3494–3511. https://doi.org/10.1021/acssuschemeng.9b06635.

Clemens, E.T., Maloiy, G.M.O., 1982. The digestive physiology of three East African herbivores: the elephant, rhinoceros and hippopotamus. J. Zool. 198, 141–156. https://doi.org/10.1111/j.1469-7998.1982.tb02066.x.

CNP. 2019. Annual report of Chitwan National Park, Kasara, Nepal. https://ntnc.org.np/sites/default/files/doc_publication /2020–09/NTNC_Annual_Report_2019.

Dinerstein, E., 1992. Effects of *Rhinoceros unicornis* on Riverine Forest Structure in Lowland Nepal. Ecology 73, 701–704. https://doi.org/10.2307/1940778.

Dinerstein, E., Wemmer, C.M., 1988. Fruits rhinoceros eat: dispersal of *Trewia nudiflora* (Euphorbiceae) in lowland Nepal. Ecology 69, 1768–1774.

DNPWC. 2017. The Greater One-horned Rhinoceros Conservation Action Plan for Nepal (2017–2021) Department of National Parks and Wildlife Conservation, Kathmandu, Nepal (unpublished report).

Doughty, C.E., Wolf, A., Malhi, Y., 2013. The legacy of the Pleistocene megafauna extinctions on nutrient availability in Amazonia. Nat. Geosci. 6, 761–764. https://doi.org/10.1038/ngeo1895.

Galetti, M., Moleón, M., Jordano, P., Pires, M.M., Guimarães, P.R., Pape, T., Nichols, E., Hansen, D., Olesen, J.M., Munk, M., Mattos, J.S., de, Schweiger, A.H., Owen-Smith, N., Johnson, C.N., Marquis, R.J., Svenning, J.-C., 2018. Ecological and evolutionary legacy of megafauna extinctions. Biol. Rev. 93, 845–862. https://doi.org/10.1111/brv.12374.

Gross, E.M., Lahkar, B.P., Subedi, N., Nyirenda, V.R., Lichtenfeld, L.L., Jakoby, O., 2018. Seasonality crop type and crop phenology influence crop damage by wildlife herbivores in Africa and Asia. Biodivers. Conserv. 27, 2029–2050. https://doi.org/10.1007/s10531-018-1523-0.

Guerrini, F., Mari, L., Casagrandi, R., 2019. Modeling Plastics Exposure for the Marine Biota: Risk Maps for Fin Whales in the Pelagos Sanctuary (North-Western Mediterranean). Frontiers in Marine Science 6.

Jhala, H.Y., Qureshi, Q., Jhala, Y.V., Black, S.A., 2021. Feasibility of reintroducing grassland megaherbivores, the greater one-horned rhinoceros, and swamp buffalo within their historic global range. Sci. Rep. 11, 4469. https://doi.org/10.1038/s41598-021-83174-4.

Jnawali S. 1995. Population ecology of greater one-horned rhinoceros (*Rhinoceros unicornis*) with particular emphasis on habitat preference, food ecology and ranging behavior of a reintroduced population in Royal Bardia National Park in lowland Nepal. PhD Thesis, Agricultural University of Norway.

Katlam, G., Prasad, S., Aggarwal, M., Kumar, R., 2018. Trash on the menu: patterns of animal visitation and foraging behaviour at garbage dumps. Curr. Sci. 115, 2322–2326.

Katlam, G., Prasad, S., Pande, A., Ramchiary, N., 2022. Plastic ingestion in Asian elephants in the forested landscapes of Uttarakhand, India. J. Nat. Conserv. 68, 126196 https://doi.org/10.1016/j.jnc.2022.126196.

Laurie, W.A., 1982. Behavioural ecology of the Greater one-horned rhinoceros (*Rhinoceros unicornis*). J. Zool. 196 (3), 307–341. https://doi.org/10.1111/j.1469-7998.1982.tb03506.x.

Liyanage, D.J., Fernando, P., Dayawansa, P.N., Janaka, H.K., Pastorini, J., 2021. The elephant at the dump: how does garbage consumption impact Asian elephants. Mamm. Biol. 101, 1089–1097. https://doi.org/10.1007/s42991-021-00114-5.

Malizia, A., Monmany-Garzia, A.C., 2019. Terrestrial ecologists should stop ignoring plastic pollution in the Anthropocene time. Sci. Total Environ. 668, 1025–1029. https://doi.org/10.1016/j.scitotenv.2019.03.044.

Pant, G., Maraseni, T., Apan, A., Allen, B.L., 2020. Climate change vulnerability of Asia's most iconic megaherbivore: greater one-horned rhinoceros (*Rhinoceros unicornis*). Glob. Ecol. Conserv. 23, e01180 https://doi.org/10.1016/j.gecco.2020.e01180.

Sandom, C., Faurby, S., Sandel, B., Svenning, J.-C., 2014. Global late Quaternary megafauna extinctions linked to humans, not climate change. Proc. R. Soc. B Biol. Sci. 281, 20133254. https://doi.org/10.1098/rspb.2013.3254.

Sarma, P.K., Talukdar, B.K., Sarma, K., Barua, M., 2009. Assessment of habitat change and threats to the greater one-horned rhino (*Rhinoceros unicornis*) in Pabitora Wildlife Sanctuary, Assam, using multi-temporal satellite data. Pachyderm 46, 18–24.

Shaffer, L.J., Khadka, K.K., Van Den Hoek, J., Naithani, K.J., 2019. Human-Elephant conflict: a review of current management strategies and future directions. Front. Ecol. Evol. 6.

de Souza Machado, A.A., Kloas, W., Zarfl, C., Hempel, S., Rillig, M.C., 2018. Microplastics as an emerging threat to terrestrial ecosystems. Glob. Change Biol. 24, 1405–1416. https://doi.org/10.1111/gcb.14020.

de Stephanis, R., Giménez, J., Carpinelli, E., Gutierrez-Exposito, C., Cañadas, A., 2013. As main meal for sperm whales: plastics debris. Mar. Pollut. Bull. 69, 206–214. https://doi.org/10.1016/j.marpolbul.2013.01.033.

Stevens, C.E., Hume, I.D., 2004. Comparative Physiology of the Vertebrate Digestive System. Cambridge University Press.

Subedi N. 2012. Effect of *Mikania micrantha* on the demography, habitat use, and nutrition of greater one-horned rhinoceros in Chitwan National Park, Nepal. PhD Thesis, Forest Research Institute University, Dehradun.

Subedi, N., Jnawali, S.R., Dhakal, M., Pradhan, N.M.B., Lamichhane, B.R., Malla, S., Amin, R., Jhala, Y.V., 2013. Population status, structure and distribution of the greater one-horned rhinoceros *Rhinoceros unicornis* in Nepal. Oryx 47, 352–360. https://doi.org/10.1017/S0030605313000562.

Subedi, N., Lamichhane, B.R., Amin, R., Jnawali, S.R., Jhala, Y.V., 2017. Demography and viability of the largest population of greater one-horned rhinoceros in Nepal. Glob. Ecol. Conserv. 12, 241–252. https://doi.org/10.1016/j.gecco.2017.11.008.

de la Torre, J.A., Wong, E.P., Lechner, A.M., Zulaikha, N., Zawawi, A., Abdul-Patah, P., Saaban, S., Goossens, B., Campos-Arceiz, A., 2021. There will be conflict – agricultural landscapes are prime, rather than marginal, habitats for Asian elephants. Anim. Conserv. 24, 720–732. https://doi.org/10.1111/acv.12668.