Trash on the menu: patterns of animal visitation and foraging behaviour at garbage dumps

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Garbage accumulation around terrestrial nature reserves poses a risk to many species. We monitored animal visitation patterns and foraging behaviour at garbage dumps near a forested area in Uttarakhand Himalaya, India, to examine plastic consumption by animals. We recorded 32 species of birds and mammals visiting garbage dumps and classified them as 'peckers', 'handlers' and 'gulpers' based on their foraging behaviour. Gulpers (carnivores and ruminants) were observed feeding more frequently and spent longer durations (3.8 ± 0.2 min) at garbage dumps. Our results highlight the importance of at-source segregation of waste to prevent wild and domestic animals from ingesting hazardous wastes, including plastics at garbage dumps.

Keywords: Animal visitation, foraging behaviour, terrestrial vertebrates, unsegregated garbage.

THE ecological impact of non-biodegradable waste accumulation is an issue of global concern[1–4]. Aggregation of plastics in marine ecosystems is a threat to several endangered species, communities and ecosystems[5,6]. While marine ecosystems have been extensively researched for plastic litter and its impacts, solid waste as a conservation issue has been poorly examined in terrestrial ecosystems[7]. Plastic ingestion can impact animal health and mortality in terrestrial ecosystems too[8–12]. Additionally, toxic compounds leaching from plastic, e.g. bisphenol A (BPA) and phthalates pose serious risks to animal health and reproduction[13–15].

Expanding human settlements in terrestrial ecosystems has resulted in rapid increase in garbage dumps and landfills in and around natural habitats[16]. Such sites attract several vertebrate species as they provide constantly available food at invariant locations[16], leading to diet shifts of wild species towards food waste[17–20]. Regular feeding on garbage can alter animal movement, resource utilization, impact social systems[16,21], may potentially increase human–animal conflicts[22,23] and exacerbate disease transmission risk due to interaction of domestic and wild species at garbage dumps[16,19].

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Accidental ingestion and entanglement in plastic has been reported in over 250 vertebrate species[24]. Plastic ingestion could cause lethal injuries and blockages in the digestive system leading to satiation, starvation, reduced body mass, ulceration or perforation of the digestive tract[11,25]. Entanglement in plastic can cause external abrasions, impaired movement and feeding, reduced fitness, growth problems and premature death[5,26,27]. Further, acute and chronic toxicity induced by chemicals released from plastic can alter development of reproductive and neurological systems, and cause abnormal hormonal functioning[7,28]. These physical and toxicological complications have been reported in several marine and some terrestrial vertebrates[29,30]. Though there are reports of altered food habits due to garbage in terrestrial vertebrate species such as red fox (*Vulpes vulpes*)[19], grizzly bear (*Ursus arctos*)[31], black bear (*Ursus americanus*)[32] and Asian elephant (*Elephas maximus*)[33,34], very few studies have been conducted on plastic ingestion by terrestrial vertebrates[35–37]. Insufficient research on exposure of terrestrial species to garbage requires systematic surveys to understand the occurrence, behaviour and vulnerability of wild species at garbage dumps. In this study, we have characterized the profile of vertebrates that frequented garbage dumps to identify behavioural and life-history traits of species vulnerable to plastic ingestion.

This study was conducted in the Himalayan state of Uttarakhand in North India, which has over 45% forest cover[38]. Uttarakhand receives >20 million tourists annually, many of whom visit nature reserves[39]. Expanding tourism leads to increasing generation and disposal of waste near natural areas[40].

We studied garbage dumps along the edge of a moist temperate mixed forest dominated by oak *Quercus leucotrichophora*, pine *Pinus roxburghii* and rhododendron *Rhododendron arboreum*[41,42] in one village (village name has been kept confidential to avoid targeting one place for this widespread problem) in the Nainital district. The study location is an area of conservation importance, with more than 200 bird species and 75 mammalian species.

We carried out field study during May–June 2015, coinciding with the peak tourist season. We monitored two garbage dumping sites: the main garbage dumping site of the village (henceforth GD; 554 m^2, where residents and business owners disposed unsegregated waste), and a compost pit (henceforth CP; 36 m^2, where only organic food waste was disposed). At GD, food waste was interspersed with non-biodegradable waste, including plastics (packaging, snack wrappers, bottles, tetra-packs), glass bottles, metal cans, light bulbs, cartons, etc. Food waste was the same in GD and CP, which included fruit and vegetable peels, meat and leftover cooked food.

We examined whether vertebrate foraging morphology and behaviour influenced the risk of plastic ingestion by different species. We hypothesized that visitation patterns at garbage dumps would vary across species with different foraging behaviour; and animals with different morphology and foraging behaviour would have different probabilities of ingesting plastic.

We used direct observations and camera-traps to document animal visitation patterns and foraging behaviour at the garbage sites. Two observers using binoculars carried out scan and focal sampling of diurnal visitors for 25 h each at GD and CP. The observations spanned different daylight hours equally (0600–1800 h), and were conducted for a minimum 2 h to maximum 3 h daily on different days, completing 25 h within two months of the study period. Garbage sites were scanned every 10 min to note the number of individuals of different species. Between scans, individuals actively foraging were randomly chosen across species from the individuals foraging at that point of time, for focal observations. During focal observations we recorded duration of feeding activity and the number of times the animal was observed to handle, gulp or peck on food, plastic, metal or glass, till its departure from the dump site. Also, because the individuals were chosen randomly, we could record arrival and departure times only for a few individuals and not for all visitors. Passive infrared camera-traps (Reconyx HC500) were deployed to record nocturnal and crepuscular animals (larger GD = 5 cameras, 100 trap nights; smaller CP = 2 cameras, 28 trap nights). Cameras were placed 60–120 cm above ground and programmed to obtain a sequence of 5 images per trigger, 1 sec apart[43] (Supplementary Appendix 1).

To examine how animals processed unsegregated waste and retrieved food contained in garbage bags, we set up two experiments ('bag' and 'open') which mimicked typical human waste disposal behaviour practiced locally. In 'bag', mixed waste (leftover food, vegetable peels, soiled polythene bags and plastic wrappers) was packed in a polythene bag; in 'open' mixed waste was left exposed as such (Supplementary Figure 1). All waste was procured on site. Experiments were carried at GD, run for 24 h, replicated across ten days, and monitored using camera-traps (Supplementary Appendix 2) to provide an index of relative visitation frequency of different animal species. Frequency of animal visitation was calculated from scan (diurnal) and camera-trap (nocturnal + crepuscular) data separately. To observe the difference between groups in plastic contact rates and stay length (count variables), GLM analysis was performed with Poisson distribution using R software[44].

Based on animal foraging behaviour observations at garbage dumps, visitor species were classified into three categories (Supplementary Figure 2). (a) Peckers – animals with beaks which pulled out food from plastic and other inedible waste. This included all observed birds (19 species) which gleaned through garbage to access food such as annelids, arthropods or edible food waste. (b) Handlers – animals with dexterous hand appendages that were capable of separating food from other waste. This included primates (two species) which removed food from inedible packaging using their hands. (c) Gulpers – animals that lacked dexterous hand or mouthparts, and consequently could not separate food from plastic and other indigestible matter before ingestion. This included all ruminants, carnivores, ungulates and rodent mammals (nine species) which had limited ability to separate food from plastic and frequently swallowed indigestible matter along with edible waste. Plastic was the most commonly observed non-biodegradable waste that was handled or processed by animals at GD. Other materials such as glass and metal were rarely handled by the animals.

Thirty-two vertebrate species (13 mammals, 19 birds) were recorded feeding on garbage. More species were recorded at the larger GD (11 species each of birds and mammals) compared to the smaller CP (7 birds, 5 mammals) (Supplementary Table 1). The proportion of wild animals (84.3%) visiting garbage dumps was observed to be over five times higher than domestic animals (15.6%). Visitation patterns were classified as diurnal (0600–1800 h; $n = 24$ species), crepuscular (0500–0600 h or 1800–1900 h; $n = 8$) and nocturnal (1900–0500 h; $n = 12$). The diurnal species visitation rate at GD was not different from CP (GD: 2.02 ± 0.19/h, CP: 1.02 ± 0.17/h; rank mean: CP = 13.71 and GD = 19.28, $U = 83.5$, $Z = 1.75$, $P > 0.05$, $r = 0.31$). In contrast, visitation rate at GD was higher than that at CP for nocturnal and crepuscular species (GD: 31.29 ± 2.07/h, CP: 26.64 ± 1.45/h; rank mean CP = 16.85 and GD = 18.14, $U = 133.5$, $Z = 0.38$, $P > 0.05$, $r = 0.06$) (Supplementary Figure 3).

On an average, vertebrate visitors spent 2.8 ± 1.3 min at the garbage dump sites. Amongst all visitors, large-billed crow *Corvus macrorhynchos* had the highest contact rate with plastic (214 ± 125.6/h), whereas sambar (*Rusa unicolour*) had the lowest (12.5 ± 5.8/h). The higher rate of contact with plastic could be attributed to the least time spent at the dump sites by large-billed crow (1.6 ± 0.4 min/visit) in comparison with all other species, including the sambar which spent the longest time (5.3 ± 1.6 min/visit) (Supplementary Figure 4).

While foraging for food at GD, handlers and peckers encountered plastic more than twice as frequently as gulpers (GLM, $P < 0.001$) (Table 1 and Figure 1 *a*). However, gulpers were observed feeding more frequently and spent longer duration (3.8 ± 0.2 min) at GD compared to

Table 1. Detailed model for GLM for plastic contact rate

Stay length	Estimate	Standard error	*z* value	Pr(>|z|)
Gulper	2.98145	0.01243	239.78	<2e-16***
Handler	1.71064	0.01669	102.51	<2e-16***
Pecker	0.84921	0.01583	53.64	<2e-16***

Asterisks indicate significant differences: ***$P < 0$. Null deviance: 59,232 on 627 degrees of freedom. Residual deviance: 48,906 on 625 degrees of freedom; AIC: 50532.

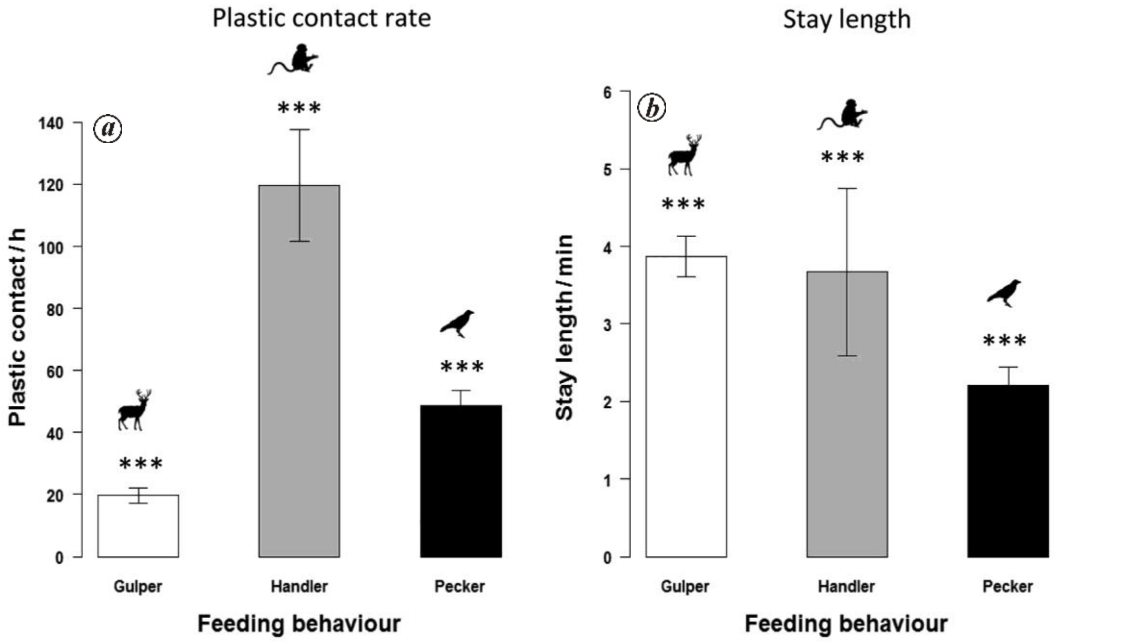

Figure 1. Average plastic contact (***a***) and stay length (***b***) for different feeding groups at the unsegregated garbage dump site (GD). Lines represent standard error and asterisks indicate significant differences: $***P < 0.0001$.

Table 2. Detailed model for GLM for stay length

Stay length	Estimate	Standard error	*z* value	Pr(>|*z*|)
Gulper	1.35297	0.02807	48.197	<2e-16***
Handler	–0.57563	0.08366	–6.881	5.96e-12***
Pecker	–0.56331	0.0528	–10.669	<2e-16***

Asterisks indicate significant differences: $***P < 0.0001$. Null deviance: 2208.9 on 628 degrees of freedom. Residual deviance: 2062.7 on 626 degrees of freedom; AIC: 3684.2.

handlers (3.6 ± 1.0 min) and peckers (2.2 ± 0.2 min). GLM analysis showed significant difference in stay length for all three categories ($P < 0.001$) (Table 2 and Figure 1 *b*). Animals foraging at CP did not encounter any plastic or non-biodegradable waste material as none was present at the site.

In the 'bag' experiment, 51% of bags were torn open by animals attempting to feed on the contained waste; 35% were moved from the original location and could not be traced, while the remaining were found intact after 24 h. The time-delay sequence from camera-traps showed that gulpers were most commonly associated with partially torn status (76%) of polythene bags ($\chi^2 = 51.332$, d$f = 6$, $P < 0.001$) (Figure 2).

Unsegregated garbage aggregating near natural habitats as a result of increased tourism poses a huge conservation threat[10]. We found a diverse range of domestic and wild species groups such as ruminants, carnivores, primates and rodents among mammals; bulbuls, babblers, thrushes, ravens, passerines, doves, woodpeckers and francolins among birds frequenting garbage dumps in a Himalayan landscape.

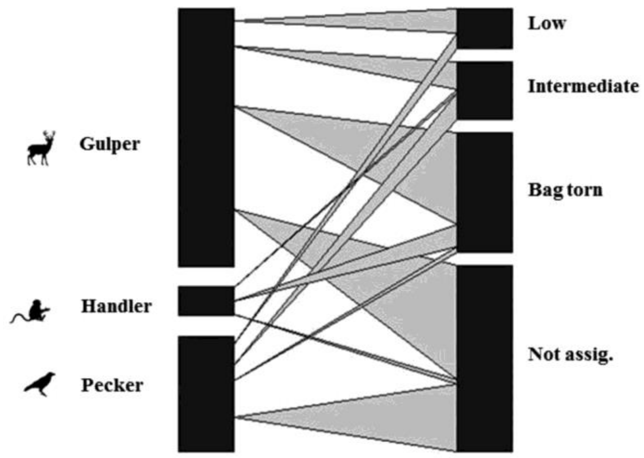

Figure 2. Association of foraging groups with polythene bags containing mixed waste after 24 h. To mimic typical waste disposal behaviour, polythene bags with a measured quantity of food and plastic waste were left in front of camera traps to observe the animal foraging behaviour. 'Low' refers to intact bags and 'intermediate' refers to partially torn bags. When the bag was completely torn it was assigned to 'bag torn'. 'Not assig.' refers to those bags, where the status of the polythene bags could not be assigned or moved from the location and could not be traced.

Although we found that gulpers had lower contact rates with plastic, they spent longer periods foraging at garbage dumps and were more likely to tear open polythene bags. In contrast, although peckers and handlers came into direct contact with plastic more often, they were not seen ingesting plastic unlike gulpers; plastic ingestion among diurnal gulper species was recorded in cow during scan. Whereas in camera-traps, although nocturnal gulper species were seen holding plastic in their mouth (which we categorized as contact with plastic) in the photograph sequences, we could not confirm plastic ingestion from these images captured by camera trap. Macaques (handlers) frequently opened garbage bags with their hands to pick out food material carefully[10]. Insectivorous birds searched trash for grubs and food remains. Gulpers such as deer, civets and martens were unable to extract food efficiently from the bags and thus spent more time foraging at garbage dumps.

Plastic remains have been frequently reported from the stomach contents and faeces of gulpers, including mammals such as red fox and elephant, as well as birds with large beaks such as storks and vultures[19,36,37,45]. Indeed, selective feeders with specialized feeding apparatus (mouth or hand parts) such as primates or insectivorous birds may be less susceptible to plastic ingestion and phthalate accumulation[46] compared to elephants, ruminants or carnivores, which are incapable of selectively retrieving food contained in plastic.

To the best of our knowledge, there are no scientific studies from Asia on the impact of inadequate waste management on terrestrial ecosystems. We conducted this case study to understand animal visitation patterns at human-mediated food resources. Our results underscore an urgency to tackle waste disposal in and around nature reserves which are popular tourist destinations. Reserve managers should be involved in formulating and implementing clear policies for solid waste management in and around the reserves. We emphasize the need of an extensive study covering multiple sites to get a better understanding of the scale of impact of plastic and non-biodegradable waste on terrestrial biota[10]. Creating public awareness on waste segregation and discouraging disposable plastics coupled with preventive measures such as fencing garbage dumps and landfills and shifting garbage dumps away from the forest edge will help reduce exposure of wildlife to plastics and other harmful waste.

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