RESEARCH ARTICLE

Garbage consumption by Arctic terrestrial predators in one of the most pristine land areas on Earth

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Abstract

Garbage may cause substantial environmental perturbations, in part because of its consumption by wildlife. Such consumption may have direct health implications for animals and may also influence trophic relationships. Even in pristine Arctic ecosystems, wildlife feeding in marine environments consume garbage in the form of plastic debris transported by ocean currents. We show that Arctic wildlife in pristine terrestrial environments may also ingest garbage or food items derived from abandoned camp sites. We found the remains of a chocolate wrapper and a milk powder bag in two Arctic fox (*Vulpes lagopus*) scats and a piece of cloth in an Arctic wolf (*Canis lupus arctos*) scat collected near Nares Strait, northern Greenland, one of the most pristine terrestrial wilderness regions on Earth. Found on Washington Land and associated with long-abandoned camp sites, these three scats were among 657 Arctic fox scats and 92 wolf scats collected as part of a larger study. Our study demonstrates that these two highly opportunistic predators managed to consume garbage despite the almost complete lack of human activity in this High-Arctic region. Our results highlight that abandoned anthropogenic material in the High Arctic may function as a source of garbage for local terrestrial wildlife over extended time periods, and that garbage consumption may become a potential issue if human activity in remote Arctic regions increases.

Keywords

Litter; terrestrial; Arctic fox, Arctic wolf; Greenland; Canada

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Introduction

Garbage may lead to significant environmental disturbances, as it accumulates at an ever-increasing rate (Barnes et al. 2009; Hoellein et al. 2014; Tekman et al. 2022). For instance, the annual influx of plastic litter into the ocean is estimated at about 500 kilotonnes per year, with an estimated annual increase of 4% (Kaandorp et al. 2023). The impacts of garbage on the environment are diverse (Barnes et al. 2009; MacLeod et al. 2021) and include its consumption by wildlife (Oro et al. 2013; Vegter et al. 2014). Garbage consumption has been observed in a wide range of species, ranging from large terrestrial mammals such as elephants (*Elephas maximus indicus*; Katlam et al. 2022) to small fish (Savoca et al. 2021), and garbage can also influence invertebrates (Pirillo & Baranzini 2022). Garbage can either be consumed as litter, that is, debris left in the environment, or as anthropogenic food remains. Both types of garbage consumption can have significant adverse effects on animals, including intoxication, gut obstructions, choking and altered food habits (Browne et al. 2015; Tekman et al. 2022). Garbage consumption can also indirectly affect ecosystems through altered trophic interactions or competition (Plaza & Lambertucci 2017; Newsome et al. 2019).

Arctic ecosystems experience rapid environmental perturbations, partly caused by an accelerated climate change in the region (Rantanen et al. 2022). Although some Arctic areas, particularly in the Eurasian Arctic, harbour significantly industrialized sites, the Arctic still has some of the most pristine terrestrial ecosystems on

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Earth (Ellis & Ramankutty 2008). While garbage consumption is well documented in marine environments throughout the Arctic (Collard & Ask 2021), much of this garbage is in the form of litter transported passively over long distances (Cózar et al. 2017). Consumption of this litter can be substantial. For instance, close to 90 % of northern fulmars (*Fulmarus glacialis*) examined in Svalbard had plastic in their stomachs (Trevail et al. 2015). Even terrestrial predators consume marine litter during periods of low food availability (Hallanger et al. 2022). Garbage consumption by animals in terrestrial Arctic environments is less well documented but has been associated with garbage dumps, industrial sites and major air bases (e.g., Garrott et al. 1983; Kapel 1999; Smith et al. 2022).

In terrestrial environments, mammalian carnivores (order Carnivora) represent a diverse group of animals, some of which feed opportunistically and are therefore particularly prone to consuming garbage (Newsome et al. 2015; Collard & Ask 2021; Ayala et al. 2023). Garbage consumption by terrestrial carnivores has been observed worldwide and may influence behaviour (Beckmann & Berger 2003), diet (Newsome et al. 2019) and disease transmission (Mackenstedt et al. 2015). Although the consumption of anthropogenic food remains may provide nutritional benefits (Oro et al. 2013), such consumption may also be fatal (Lunn & Stirling 1985). Carnivores may consume garbage—as litter, as anthropogenic food remains, or a combination—either deliberately or accidentally (Thompson et al. 2009; Plaza & Lambertucci 2017; Belton et al. 2018a) and may do it within protected areas (Belton et al. 2018b; Hatch et al. 2022). Consequently, garbage consumption by terrestrial carnivores has been identified as one of the key issues related to human–wildlife co-existence (Treves & Karanth 2003). However, most studies have focused on the consumption of anthropogenic food remains and not on other types of garbage (Thompson et al. 2009; Plaza & Lambertucci 2017; Belton et al. 2018a, b; Hatch et al. 2022).

Here, we report observations of garbage consumption by two terrestrial Arctic carnivores, the Arctic fox (*Vulpes lagopus*, hereafter referred to as "fox"/"foxes") and the Arctic wolf (*Canis lupus arctos*, hereafter referred to as "wolf"/"wolves") in terrestrial environments in the region surrounding Nares Strait, including land areas in northern Greenland and on Ellesmere Island, Canada. This region experiences extremely limited human activity and is one of the most remote land areas on Earth (McColl 2005). We highlight that the widespread litter and garbage pollution, which has been raised as a serious concern for Arctic marine environments (Brigham 2011), may also be of concern to Arctic wildlife across terrestrial environments.

Methods

Study area

The Nares Strait region contains several peninsulas and smaller islands and is characterized by dramatic coastlines interspersed with deep fjords on both the Canadian and Greenland sides (Fig. 1a). The area is notable for its limited human infrastructure, which is restricted to a small number of gravel landing strips, some small cabins, and a few abandoned camp sites. The often-heavy ice flows through Nares Strait makes the region largely inaccessible from the sea. Many of the landing strips in the area are in poor condition and can only accommodate specific aircraft capable of landing on rough runways. Most of the other infrastructures found in this area are abandoned. Furthermore, both Ellesmere Island and the North Greenland National Park have strict access requirements. Consequently, the Nares Strait region is likely one of the least visited land areas in the Arctic (McColl 2005).

The closest human settlement—about 200 km away from our study area—is the military base of Alert on northern Ellesmere Island, Canada. Comprised of a small airport and several buildings, Alert has no permanent residents but has been continuously inhabited since 1950. The current population ranges from approximately 65 persons during the winter to over 150 during the summer. The nearest communities with permanent residents are Qaanaaq, in Greenland, which is home to about 630 inhabitants (StatBank Greenland 2023), and the nearby Pituffik Space Base (previously Thule Air Base), which holds significant infrastructure and a large airfield. These locations are situated approximately 375 km to the south of the study area.

Sample collection and diet identification

Scat samples from foxes and wolves were collected during two icebreaker-based expeditions, one in August 2015 (the Petermann 2015 expedition) and one in 2019 (the Ryder 2019 expedition). Both expeditions used the Swedish icebreaker *Oden* as a research platform. Land was accessed using helicopters from the vessel, and scats were identified opportunistically while walking (Dalerum et al. 2018; Abrham 2023). We collected fox and wolf scats on several peninsulas surrounding Nares Strait, including Judge Daly Promontory, Ellesmere Island, Hall Land and Washington Land on Greenland during the 2015 expedition, and on several peninsulas in Greenland during the 2019 expedition: Hall Land, Nyeboe Land, Warming Land, Henrik's Ø and Wulff Land (Abrham 2023). All collected scats were frozen on the vessel. Thawed scats were subsequently washed in water over a 0.5 mm mesh and

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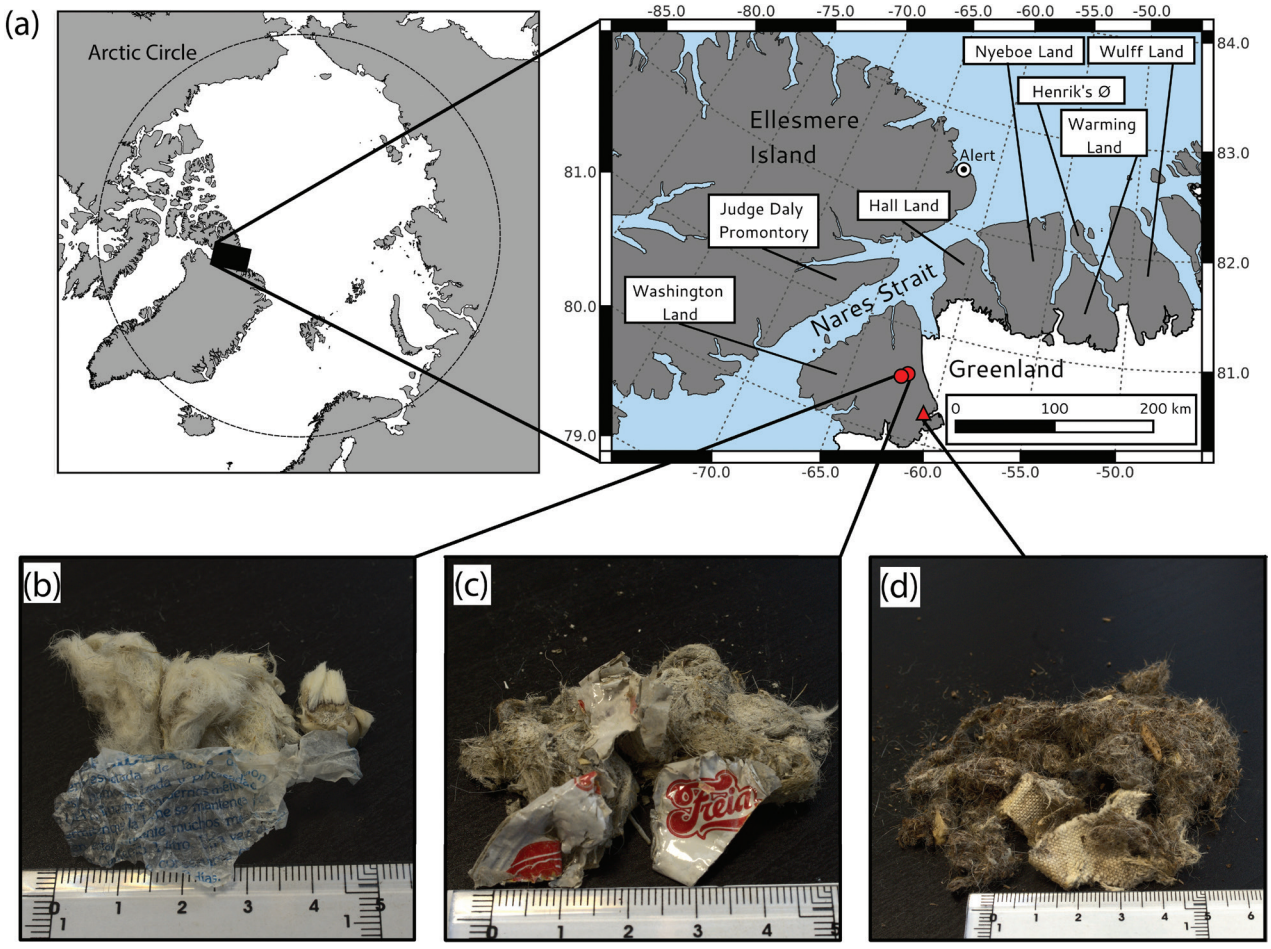

Fig. 1 (a) Location of the study area, the names of the peninsulas where scat samples were collected, and the collection locations of the three scat samples that contained human garbage, as well as the content of the scat samples of (b, c) Arctic fox and (d) Arctic wolf. Centimetre ruler provided for scale.

dried overnight at a temperature of 80°C. Food items present in scats were identified on the basis of macroscopic and microscopic characteristics (Dalerum et al. 2018; Abrham 2023).

Results

We analysed 657 individual scats from Arctic foxes and 92 from wolves. We found garbage in two scats from Arctic foxes (0.30 %) and in one from a wolf (1.08 %; Table 1). All three scats were collected on Washington Land, one of the southernmost of the Greenland peninsulas in the Nares Strait region (Fig. 1a). We collected 130 fox and 26 wolf scats on this peninsula (Table 1). Both of the fox scats that contained garbage were collected in 2019, whereas the wolf scat containing garbage was collected in 2015. The exact locations of the collection sites of the fox scats were 80.62°N, 61.77°E and 80.59°N, 62.00°E, and for the wolf scat 80.27°N, 60.63°E. One fox scat contained the remains of a powdered milk package (Fig. 1b) and the other the remains of the wrapper from a Freia chocolate bar (Fig. 1c). The wolf scat contained remains of canvas fabric (Fig. 1d), most likely from a tarpaulin. Neither of

Table 1 Number of analysed scat samples from Arctic foxes (*Vulpes lagopus*) and wolves (*Canis lupus arctos*) collected during two icebreaker-based expeditions in the High-Arctic region surrounding Nares Strait.

	Arctic fox		Wolf	
	total	with garbage	total	with garbage
Judge Daly Promontory	100	0	16	0
Washington Land	130	2	26	1
Hall Land	176	0	25	0
Nyeboe Land	84	0	5	0
Henrik's Ø	22	0	1	0
Warming Land	53	0	12	0
Wulff Land	92	0	7	0

these materials came from our field activities. These three scats also contained remains of Arctic hare (*Lepus arcticus*) and Greenland lemming (*Dictrosonyx groenlandicus*), which are the normal prey for these predators in the area (Dalerum et al. 2018; Abrham 2023).

The fox scats were collected at 5.5 km and 100 m from an abandoned mining prospecting site. The site was set up by Avannaa Resources Ltd (London) in 2012 and 2013, with approximately 20 people working there (Rehnström & Vaughan 2014). In 2019, the site included a tarp-covered storage tent of approximately 4 × 10 m, and some scattered debris (mostly wood). The storage tent still contained several boxes of intact food material, such as dry food and tins. It is therefore possible that the garbage discovered in the two fox scats was the remains of plastic wrappings that, when the foxes ingested them, still contained food (chocolate and milk powder). Alternatively, the garbage was consumed as empty plastic wrappings, perhaps with traces of food that left an odour that attracted the animals.

The wolf scat was collected 2 km from an abandoned camp site presumably associated with the latest, in 1995 (Perry 1995), recovery mission of Kee Bird, a B-29 aircraft that was forced to make an emergency landing on a frozen lake in 1947 (Wack 1992). During our visit in 2015, we observed no standing structures, but several barrels and debris that included wood and canvas cloth. There were also some scattered tins, but we observed no remaining stash of food items. Hence, we assume that the garbage identified in the wolf scat represented ingested litter rather than actual food remains.

Discussion

Both foxes and wolves have previously been recognized as opportunistic species that may consume garbage (Garrott et al. 1983; Prestrud 1992; Kapel 1999; Hallanger et al. 2022). It is nonetheless remarkable that they managed to do so in this very remote High Arctic region. Our observations exemplify the exceptional opportunism by which Arctic carnivores utilize all resources available to them, including resources left behind by people. Although the High Arctic so far largely has seen limited human development, this opportunism underscores the potential for expanded human presence to lead to an increased garbage consumption by Arctic wildlife. Therefore, an escalation in human activities in High Arctic areas may lead to significant disturbances to resident wildlife. Such an escalation in human presence is ongoing (Runge et al. 2020), although it may not necessarily be accompanied by an increased garbage consumption in all areas (e.g., Technau et al. 2022).

Previous garbage consumption is well documented in the Arctic for organisms feeding in marine ecosystems (Collard & Ask 2021) and in human-modified terrestrial areas (Prestrud 1992; Hallanger et al. 2022). Although our findings of garbage consumption in this study are few—we found garbage in just 0.3 % of the analysed fox scats and 1.1 % of the wolf scats—we show here that it can take place in very remote and pristine terrestrial Arctic environments without the influx of ocean transported litter or high levels of human activity.

The samples containing garbage were found close to (i.e., 100 m to 5 km) long abandoned campsites. The longest distance to any of these sites is well within the recorded daily movements for these species, for example, up to 75 km for each of the species (Mech & Cluff 2011; Poulin et al. 2021). Since we did not observe any other signs of human activity, we regard these sites as the likely sources of the ingested materials. Hence, our study demonstrates that not only passively transported marine litter can be used by Arctic wildlife in remote locations, but also material that has been actively transported into Arctic environments and later abandoned, and that such material persists over extended time periods.

Conclusion

Our study shows that not only organisms feeding in marine ecosystems, but also those in terrestrial ones, may be influenced by garbage left by human activities in the Arctic. Our results highlight that there are likely very few areas where terrestrial organisms exist completely without human influence. Furthermore, if human presence should increase, we expect that garbage consumption may become a potential problem in Arctic environments, since many terrestrial Arctic predators are highly opportunistic in their feeding habits.

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Disclosure statement

The authors declare no conflict of interest.

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