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Anthropogenic waste ingestion of Southern Beaufort Sea polar bears, Alaska (2010–2020)

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Abstract: We report on anthropogenic waste ingestion and associated foreign-body gastric pathology in polar bears (*Ursus maritimus*) within the North Slope Borough, Alaska, from stomach content analysis of 42 bears during 2010 to 2020. User plastics and rubbish other than plastics were observed in 28.6% (12/42) and 11.9% (5/42), respectively. Acute gastritis was present in 33.3% (14/42) of polar bear stomachs. Fifty percent of the acute gastritis cases ($n = 7$) were observed in animals with user plastics in their stomach content. The findings of our multiyear polar bear stomach-content analysis emphasize that anthropogenic waste ingestion is common in polar bears of the Southern Beaufort Sea subpopulation. For the future, controlling access to anthropogenic foods (e.g., garbage dumps, stored wildlife resources) will be an important component of proactive human polar bear management on the North Slope, Alaska, and for the entire Arctic.

Key words: Alaska, anthropogenic waste, food conditioning, health, human–wildlife conflict, plastics, polar bear, *Ursus maritimus*

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Plastic pollution is an emerging problem in the Arctic with both local sources and outside sources via long-range atmospheric and ocean current transport (Bergmann et al. 2022, Walther and Bergmann 2022) contributing to increasing levels of plastic litter and microplastics within arctic ecosystems. Marine and terrestrial surveillance monitoring studies of plastic pollution (litter, microplastics) and their effects on Arctic wildlife have been gaining momentum and are an important tool to further our understanding about sources, transport, pathways, fate, and effects of plastic litter in the Arctic (Lusher et al. 2022, Provencher et al. 2022). Polar bears (*Ursus maritimus*, Phipps, 1774) are iconic Arctic predators and, in Alaska, the legal harvest of polar bears continues to be central to Inupiaq and Siberian Yupik peoples (Voorhees et al. 2014, Kochnev and Zdor 2016, Braund et al. 2018, Rode et al. 2021). Under the U.S. Marine Mammal Protection Act (MMPA), the subsistence needs of coastal-dwelling Alaska Natives are recognized and authorize the harvest of marine mammals, including polar bears (MMPA 16 USC 31 1972). The U.S. Fish and Wildlife Service (USFWS) is the federal agency responsible for conservation and management of polar bears under terms of the MMPA. The North Slope Borough Department of Wildlife Management (NSB DWM) maintains community-based harvest and health monitoring programs for marine mammal species. These programs include monitoring of polar bears to better understand cumulative stressor effects on their health and well-being in a rapidly changing Arctic. We report on anthropogenic waste ingestion and foreign-body-associated digestive pathology from stomach content analysis of polar bears of the Southern Beaufort Sea subpopulation over a 10-year period (2010–2020). Circumpolar-wide the use of anthropogenic food by polar bears is an emerging threat (Smith et al. 2022). Findings from our study provide empirical support for the latter, establish baseline data on plastic ingestion for Southern Beaufort Sea polar bears, highlight that anthropogenic waste ingestion by polar bears has management and individual animal health consequences, and emphasize the importance of waste management in polar bear country.

Study area

The study area is the North Slope Borough, Alaska (246,049 km^2), the farthest north municipal government of the United States. Two polar bear subpopulations, the Chukchi Sea (CS) and Southern Beaufort Sea (SB), which occupy adjacent geographic ranges, occur largely within the municipal region. Polar bears are harvested for subsistence purposes within the SB subpopulation area by the coastal communities: Wainwright, Utqiaġvik, Nuiqsut (Cross Island), and Kaktovik (Amstrup et al. 2005, Amirkhanov 2018; Fig. 1).

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Fig. 1. Locations of the coastal North Slope Borough communities within the Southern Beaufort Sea (SB) polar bear (*Ursus maritimus*) subpopulation area (Wainwright, Barrow/Utqiaġvik, Nuiqsut/Cross Island, and Kaktovik) in Alaska, USA, in which we studied anthropogenic waste ingestion from 2010 to 2020. Polar bears hunted near these communities are assigned to the SB subpopulation (Amstrup et al. 2005).

Materials and methods

Frozen and fresh polar bear carcasses (skinned; head removed; meat salvaged for food) taken for subsistence purposes or defense of life, as well as those found dead (entire carcass) during 2010 to 2020 were submitted to the NSB DWM, in Utqiaġvik (formerly Barrow), Alaska, for postmortem examination. Polar bear hunters provided harvest information on age (cub, juvenile, subadult, adult) and sex (male, female) of bear, and the type of kill (subsistence hunt, defense of life; USFWS Marking, Tagging and Reporting Program https://www.fws.gov/alaska/pages/marine-mammal-management/marking-tagging-reporting). Additional information regarding bear incidents (Hopkins et al. 2010) that preceded kills (e.g., bears wandered into town or whaling camp; bears attacked dogs; bears that could not be deterred) was documented. Polar bear research and tissue collection are authorized under USFWS permits #MA134907-1 and MA80164B-0, issued to the NSB DWM.

Stomach content analysis

We analyzed stomachs both in the field and laboratory. For stomachs examined in the field, we opened stomachs and visually inspected the contents and broadly categorized them into natural food remains (FOO), natural nonfood remains (NFO), and various debris categories (e.g., plastics, rubbish, etc.). We did not measure, weigh, or count debris items.

If the polar bear carcass was examined in the laboratory, we removed stomachs during routine veterinary postmortem examination and examined them for gross lesions (e.g., ulcers, erosions, tumors). We rinsed the entire contents in a metal sieve with 7-mm mesh. Categorization of debris followed established methodological guidelines for marine debris studies in seabirds (Van Franeker and Kühn 2020). Main categories applied in our study were plastics (PLA), rubbish other than plastics (RUB), pollutants (POL), FOO, and NFO. We further differentiated PLA and RUB into subcategories as described by Van Franeker and Kühn (2020). We counted and categorized sheet-like plastic (SHE) items as described by Provencher et al. (2017) by size (e.g., meso 5–20 mm, macro >20–100 mm, and mega >100 mm). Our study was not designed to detect microplastics (<5 mm).

Natural food remains and nonfood remains

We visually examined natural food remains and categorized them based on species-specific morphological criteria identified to the lowest taxa possible. For the skin (with the blubber layer), we used the color to determine whether remains were from bowhead (*Balaena mysticetus*; black) or beluga (*Delphinapterus leucas*; white; gray) whales. For pinnipeds such as ringed seal (*Phoca* (*pusa*) *hispida*), bearded seal (*Erignathus barbatus*), spotted seal (*Phoca largha*), and Pacific walrus (*Odobenus rosmarus*) we used pelt coloration and diagnostic morphology of claws, teeth, and vibrissae to determine species consumed. Food items that could not be assigned to a species we classified as unknown. We identified avian remains by the presence of feathers but did not further specify. Other natural nonfood remains documented included vegetation, wood, gravel, and sand. We did not further determine vegetation to species level. We calculated the percent frequency of occurrence (% FO) for main debris categories (PLA, RUB, POL) and the respective subcategories, FOO and NFO. We calculated the % FO as the number of stomachs containing that item divided by the total number of stomachs examined.

Table 1. Sex and age classes of polar bears (*Ursus maritimus*) harvested (n = 38) and found dead (n = 4) from which stomachs were collected for content analysis during 2010–2020, North Slope Borough region of Alaska.

	Adult	Subadult	Juvenile	Cub	Totals
Female	2	5	1	0	8
Male	14	16	2	2	34
Totals	16	21	3	2	42

Results

Stomachs of 42 polar bears collected from January to December during 2010–2020 were included in this study (Table 1). Bear incidents played a role in the harvest of 12 bears. Harvest of bears occurred near communities (<15 km radius) and, based on harvest records, 33 stomachs were from Utqiaġvik, 6 from Kaktovik, 2 from Wainwright, and 1 from Cross Island (Fig. 1). Cross Island, a small offshore island in the Beaufort Sea, is used by Nuiqsut whaling crews as a staging area for their autumn bowhead whale hunt. Yearly and monthly distribution of samples collected was 2010 (1), 2012 (3), 2013 (6), 2014 (4), 2015 (6), 2016 (3), 2017 (3), 2018 (6), 2019 (4), 2020 (6); and January (5), February (4), March (4), April (4), May (3), June (1), July (1), August (2), September (5), October (2), November (3), December (6), respectively. Two animals could not be assigned to a specific date, including one harvested between the months of December to January and the other during January to March.

Of the 42 examined stomachs 7% (3/42) were processed in the field and 93% (39/42) were processed at the NSB DWM laboratory in Utqiaġvik, Alaska. Four of the 42 polar bears had empty stomachs. Natural nonfood remains occurred in 33% (14/42) of examined stomachs, user plastics in 28.6% (12/42), rubbish other than plastic in 11.9% (5/42), and pollutant in 2.4% (1/42) of examined stomachs (Fig. 2). Percent frequency of occurrence (% FO) for all categories found in the stomachs are detailed and summarized in Table 2. Of the 12 stomachs with user plastics (PLA), 7 contained only PLA, 4 contained PLA and rubbish other than plastics (RUB), and 1 stomach contained all three items (PLA, RUB, and pollutant [POL]). Total number of sheet-like plastics (SHE) items recovered from 11 stomach contents was 126 with the following size distribution: 5.6% (7/126) for meso, 46.8%

Table 2. Percent frequency of occurrence (% FO) of items in stomach contents from polar bears (*Ursus maritimus; n* = 42), Alaska, 2010–2020. The percent frequency of occurrence (% FO) is provided for main debris categories and respective subcategories. % FO was calculated as the number of stomachs containing that item divided by the total number of stomachs examined. Categorization of debris in stomach contents follows established methodological guidelines for marine debris studies in seabirds (Van Franeker and Kühn 2020).

Stomach contents[a]	No. of stomachs	% FO	Description of observed items
PLA	12	28.6	User plastics
SHE	11	26.2	Plastic beige shopping bag; black and gray heavy-duty garbage bag; cellophane; disposable gloves either clear, blue, or black in color
thr	3	7.14	Rope; string; thread; towel
foam	4	9.5	Foam insulation; foam drinking cup
frag	1	2.4	Bottle caps; electric fuses
poth	2	4.8	Cigarette filters
RUB	5	11.9	Food wrapper; food and sanitizing towelette packaging; cardboard; wax paper; paper towel
kit	2	4.8	Fruit peels; carrot; water chestnut
rubvar	1	2.4	Ice cream wooden stick
POL	1	2.4	Lump of mechanical grease
FOO	32	76.1	Natural food remains
Cetaceans	25	59.6	Bowhead whale (20); beluga whale (5)
Pinnipeds	12	28.6	Ringed seal (3); bearded seal (3); spotted seal (2); unknown seal (4); pacific walrus (1)
Caribou	1	2.4	Caribou fur
Birds	2	4.8	Feathers
Unknown	1	2.4	Unidentified meat sludge
NFO	14	33	Vegetation; natural wood; gravel and sand

[a]PLA = user plastics; SHE = sheet-like user plastics; thr = thread-like user plastics; foam = foamed user plastics; frag = fragments; poth = other; RUB = rubbish other than plastics; kit = kitchen food; rubvar = various rubbish; POL = pollutants; FOO = natural food remains; NFO = natural nonfood remains.

(59/126) for macro, and 47.6% (60/126) for mega. Maximum length of sheet-like plastic observed was 45 cm. Prevalence of stomach contents containing plastics between 2010 and 2020 varied from 33.3 to 66.6%: 2013 (2/6; 33.3%), 2016 (1/3; 33.3%), 2018 (3/6; 50%), 2019 (2/4; 50%), 2020 (4/6; 66.7%). Polar bears with user plastics in their stomach were all male and included 1 juvenile, 8 subadults, and 3 adults. Of these, 8 bears were killed for human consumption, 3 were killed in the context of human–polar bear conflict (2 on land and 1 on sea ice during spring whaling), and 1 bear was found dead as a result of blunt thoracic trauma (R. Stimmelmayr and D.S. Rotstein, unpublished data). Grossly visible signs of acute gastritis were present in 33.3% (14/42) of the stomachs and included hyperemic gastric mucosa, mucosal erosions, and hemorrhage. Seven of the acute gastritis cases (50%) were observed in polar bears with user plastics in their stomachs.

Discussion

Multiyear evidence from polar bears from Churchill, Manitoba, Canada, confirms that polar bears can rapidly adapt to other food sources, including food waste found at landfills and around human settlements (Stirling et al. 1977, Lunn and Stirling 1985). Though anthropogenic waste ingestion by polar bears throughout the North Slope Borough, Alaska, is not new, with isolated cases reported as early as 1996 in Utqiaġvik (T. O'Hara and B. Adams, North Slope Borough Department of Wildlife Management, unpublished data) and in 2009 in Kaktovik (Sheffield 2009), the findings of our systematic polar bear stomach content analysis over a 10-year period (2010 to 2020) emphasize that anthropogenic waste ingestion is common in SB polar bears near coastal communities (Table 2). For comparison, foraging dietary studies based on scat analysis for Hudson Bay (Gormezano and Rockwell 2013), and Svalbard (Iversen et al. 2013) report prevalence rates between 2.5% and 6.7%. Though present across different age classes, subadult males made up the largest group (66.7%) in our study, followed by male adults (25%) and one juvenile male. Observed case materials are likely reflective of individual hunter bias (preference for smaller sized bears), the current male-biased SB harvest regime under the native to native Inuvialuit–Inupiat Polar Bear

Fig. 2. Example of user plastics and rubbish other than plastics from the stomach of an adult polar bear (*Ursus maritimus*) harvested for subsistence purposes, near Utqiaġvik, Alaska. Scale is 1 cm.

Management Agreement in the Southern Beaufort Sea (https://polarbearagreement.org/polar-bear-management/bilateral-cooperation/inuvialuit-inupiat-agreement), as well as sex and age class differences in spatial ecology and behavior (Clark et al. 2012, Johnson and Derocher 2020).

Natural food remains identified by this stomach content analysis of SB polar bears, to our knowledge the first reported, are consistent with what is known about their diet from traditional ecological knowledge, field observations, and fatty acid and stable isotope analysis (Lowry et al. 1987, Herreman and Peacock 2013, McKinney et al. 2017, Boucher et al. 2019, Rode et al. 2021). Though consumption of vegetation and natural nonfood remains (e.g., wood, sand, gravel) has not been previously documented for SB polar bears, it has been reported by other polar bear diet studies (Lønø 1970, Russell 1975, Gormezano and Rockwell 2013, Iversen et al. 2013).

The evident food conditioning of SB polar bears throughout the North Slope Borough, Alaska, to anthropogenic food sources from garbage dumps and stored wildlife resources within communities has implications across the range of polar bears. From a wildlife health perspective, anthropogenic waste ingestion causes various negative physical (e.g., blockage and physical damage of the digestive tract, impaired foraging efficiency due to debris-associated gut fullness and satiety, mortality) and physiological (e.g., contaminant exposure from debris) health consequences (National Oceanic and Atmospheric Administration Marine Debris Program 2014). In this study we documented acute gastritis in 58% (7/12) of polar bear stomachs with user plastics. To our knowledge acute gastritis associated with foreign body ingestion has not been reported previously in free-ranging polar bears. Though evidence for blockage and bezoar formation (buildup of nondigestible debris with semidigested food items over time to an indigestible mass) was absent, polar bears are likely candidates for digestive blockage from indigestible anthropogenic debris given their stomach anatomy and foraging habits. Polar bears have large single-chambered stomachs with a narrow pyloric outlet (2-cm diameter), and can ingest up to 20% of their body mass in food per foraging bout. We did not test for plastic additives (e.g., phthalates) in polar bear adipose tissue, but phthalate metabolites have been detected in Svalbard polar bears, though at low levels (Routti et al. 2021). From a polar bear management perspective, habituation to people and food conditioning are considered important factors leading to increased human–polar bear conflicts (Clark et al. 2012, Wilder et al. 2017, Smith and Herrero 2018, Smith et al. 2022). Southern Beaufort Sea polar bears are increasingly spending more time on land in recent years (Atwood et al. 2016), thereby placing them in greater proximity to people and anthropogenic food sources (e.g., garbage dumps, stored harvested wildlife; Clark et al. 2012). On land, bear incidents were reported for 16.7% (2/12) of the harvested bears with anthropogenic waste in their stomach content. Though not included in this study, the most recent human–bear conflict occurred February 2022 in Kaktovik and involved a subadult male with user plastic (clear plastic, fabric and waterproof outerwear), rubbish other than plastics (cardboard; paper towel), as well as bowhead whale in its stomach (C. SimsKayotuk and R. Stimmelmayr, unpublished data). For the future, controlling access to local sources of anthropogenic waste across the range of polar bears is critical to reduce human–polar bear conflicts as well as to protect polar bear health.

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