

Reduction of Garbage in the Diet of Nonbreeding Glaucous Gulls Corresponding to a Change in Waste Management

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ABSTRACT. Glaucous gulls (*Larus hyperboreus*) are major predators in the Arctic and may benefit from human development. We studied use of garbage by glaucous gulls in Barrow, Alaska, in 2007, when municipal waste was disposed of in a landfill, and in 2008, when it was incinerated. In both years, diet samples from breeding adult gulls contained less garbage than those from loafing nonbreeding gulls (mostly subadults of less than four years), possibly because the breeding colony was more distant than many loafing sites from the landfills. Although breeding gull samples showed no change, garbage in regurgitated pellets and food remains of nonbreeding gulls was significantly less prevalent in 2008 than in 2007 (28% vs. 43% occurrence in diet samples), and this reduction could be explained by the switch from landfill to waste incineration. Yet garbage remained a substantial part of nonbreeding gull diet after the management change. Other aspects of waste management, such as storage prior to disposal, may also be important in limiting scavengers' access to garbage and thus reducing the indirect impact of human development on prey species of conservation concern.

Key words: development, diet, glaucous gull, human refuse, human-subsidized predators, *Larus hyperboreus*, management

RÉSUMÉ. Dans l'Arctique, le goéland bourgmestre (*Larus hyperboreus*) est un important prédateur, et celui-ci pourrait bénéficier du développement humain. Nous nous sommes penchés sur l'utilisation qu'a fait le goéland bourgmestre des déchets à Barrow, en Alaska, en 2007 lorsque les déchets municipaux aboutissaient dans un site d'enfouissement puis en 2008, lorsque les déchets municipaux étaient incinérés. Au cours de ces deux années, les échantillons alimentaires prélevés chez les goélands adultes reproducteurs renfermaient moins de déchets que les échantillons prélevés auprès des goélands non-reproducteurs qui flânaient (des goélands immatures de moins de quatre ans dans la plupart des cas), probablement parce que la colonie de reproduction était plus loin des sites d'enfouissement que des nombreux lieux de flânerie. Bien que les échantillons prélevés chez les goélands reproducteurs ne laissent entrevoir aucun changement, les déchets se trouvant dans les pelotes de régurgitation et les restes d'aliments des goélands non-reproducteurs étaient beaucoup moins considérables en 2008 qu'en 2007 (soit une occurrence de 28 % par rapport à 43 % dans les échantillons alimentaires), réduction qui pourrait être attribuable au fait que les déchets étaient incinérés et non plus enfouis. Pourtant, les déchets constituaient toujours une partie importante du régime alimentaire des goélands non-reproducteurs après que la méthode d'élimination des déchets a subi des changements. D'autres aspects de la gestion des déchets, tels que le stockage des déchets avant leur élimination, pourraient également jouer un rôle important quand vient le temps de restreindre l'accès de ces charognards aux déchets, ce qui aurait pour effet de réduire les incidences indirectes du développement humain sur les espèces de proies suscitant des inquiétudes en matière de conservation.

Mots clés : développement, régime, goéland bourgmestre, déchets humains, prédateurs assistés par les humains, *Larus hyperboreus*, gestion

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INTRODUCTION

Human-subsidized predators benefit from associating with development, often through use of food waste or artificial breeding sites (Gompper and Vanak, 2008). In some cases, this benefit can allow predator population numbers or densities to increase (Steenhof et al., 1993; National Research Council, 2003; Contesse et al., 2004). If these predators also feed on natural prey, their anthropogenically enhanced

populations could have negative consequences for prey species, including reduced reproductive output, diminished populations, or even extinction (Holt, 1984; Garrott et al., 1993). Effects of human activity on predators are therefore of great interest to conservation efforts in developed or developing areas.

One group of human-subsidized predators is *Larus* gulls, which experienced worldwide population growth during the 20th century (Kadlec and Drury, 1968; Fordham and

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Cormack, 1970; Harris, 1970; Conover, 1983; Yorio et al., 1998). A likely cause of this trend was a general increase in the availability of anthropogenic foods, including household garbage and discards from fisheries, which may have improved gull survival or reproductive success, or both (Fordham and Cormack, 1970; Conover, 1983; Chapdelaine and Rail, 1997; Duhem et al., 2008). Future development may similarly cause gull population growth unless gull access to anthropogenic subsidies is limited.

The Arctic Coastal Plain (ACP) of Alaska, USA, is particularly susceptible to the impacts of future development. Widespread oil exploration began on the ACP in the 1950s; development for production began in the 1970s and continues today (National Research Council, 2003). Further development is expected as additional areas of the National Petroleum Reserve–Alaska are leased and explored for production. The potential effects of development on ACP wildlife are of great concern because this region supports many tundra-nesting birds. Of the 40 species of waterfowl and shorebirds that breed in the area (Poole, 2007), 28 have declined or are listed as species of moderate to high conservation concern, and two are listed as threatened under the U.S. Endangered Species Act (Table 1). Alaska Natives in the region hunt some of these birds for subsistence, so factors influencing population trends in these species could have implications for human residents as well as for conservation efforts.

The most abundant predator that may benefit from municipal waste on the ACP is the glaucous gull (*Larus hyperboreus*; Liebezeit et al., 2009), with a local population of about 11 000–14 000 individuals (Larned et al., 2010). Among other prey, these gulls feed on eggs, young, or adults of at least 19 species of waterfowl and shorebirds (Weiser, 2010). Reproductive success of glaucous gulls in this area is positively associated with the amount of garbage in the gulls' diets (Weiser and Powell, 2010), so development with an associated increase in garbage availability may cause gull population growth. Unfortunately, historical data on glaucous gull numbers on the ACP are scarce, so it is not clear whether populations have increased in response to past development (Noel et al., 2006). However, there is anecdotal evidence that glaucous gull densities may have increased in developed areas of western and northern Alaska in recent decades (Springer, 1987; USFWS, 2003). Moreover, recent aerial surveys have revealed higher concentrations of glaucous gulls near villages and oilfields than in surrounding undeveloped areas (Noel et al., 2006). The cause of this pattern is not clear, but one possibility is that anthropogenic foods support or attract higher densities of gulls than undeveloped areas.

If anthropogenically enhanced numbers of glaucous gulls could be detrimental to populations of prey species, it will be important to prevent this effect from becoming more widespread with future development. Waste management strategies can limit the benefit predators and scavengers receive from human subsidies (Curtis et al., 1995; Kurosawa et al., 2003), but their effects are not often

quantified. If effective, such strategies may be of interest to future developers on the ACP.

We used regurgitated pellets and food remains to quantify the use of human food waste and natural food items by glaucous gulls in one region of the ACP. During our study, waste management in the area switched from dumping putrescible waste in a traditional landfill to incinerating it. We tested for a reduction of garbage in gull diet corresponding to the change in waste management. We also compared the diets of loafing (nonbreeding; Spear, 1988) and breeding adult gulls to determine whether the benefit derived from garbage changed with age or breeding status or both, and we tested for a potential effect of distance to landfill on the amount of garbage in gull diet at each site. The effect of waste incineration on gull diet will be relevant to developers and managers in areas where current or future gull population growth would be detrimental to local wildlife or human residents.

METHODS

Study Area

This study was conducted in Barrow, Alaska, USA (71°18' N, 156°45' W), a city with about 4000 residents located on the ACP (Fig. 1). A variety of shorebirds and waterfowl, loons, ptarmigan, and sparrows nest on the ACP; lemmings, voles, and freshwater and marine fish are also available as potential prey. Subsistence-hunted whale, seal, caribou, and waterfowl carcasses are often available to be scavenged near residential areas.

Barrow is not accessible by road, and the nearest major city (Fairbanks, Alaska) is 500 miles (ca. 800 km) to the south. Barrow's remote nature makes it highly impractical to ship waste to major processing or recycling facilities, so garbage and other waste are dealt with locally. Until mid July 2007, a landfill northeast of town was used for disposal of household waste; since then, waste has been incinerated and the ashes deposited in a new landfill southeast of town (Fig. 1). Fresh waste continued to be available in open dumpsters at the old landfill throughout the summer of 2007 as the city switched over to the new system. When describing gull diet under different management regimes, we therefore considered 2007 to represent the traditional landfill, and 2008 to represent the new waste incineration strategy. In both years, household waste was available in open dumpsters around the city before being deposited in the landfill or incinerated.

Diet Analysis

We characterized glaucous gull diet at eight to nine loafing sites around Barrow, Alaska in each year (Fig. 1). Since most gulls that use loafing sites are subadults (which do not breed) or nonbreeding adults (Spear, 1988), we used these sites to characterize nonbreeding gull diet. In an effort to

TABLE 1. Waterfowl and shorebird species of conservation concern that breed on the Arctic Coastal Plain of Alaska (Poole, 2007) and the conservation status of each.

Common name	Latin name	Status
Black-bellied plover	<i>Pluvialis squatarola</i>	Moderate concern ¹
American golden-plover	<i>Pluvialis dominica</i>	High concern; declining ¹
Whimbrel	<i>Numenius phaeopus</i>	High concern ¹
Bar-tailed godwit	<i>Limosa lapponica baueri</i>	High concern; declining ¹
Ruddy turnstone	<i>Arenaria interpres interpres</i>	Moderate concern ¹
Red knot	<i>Calidris canutus roselaari</i>	High concern; declining ¹
Sanderling	<i>Calidris alba</i>	High concern; declining ¹
Semipalmated sandpiper	<i>Calidris pusilla</i>	Moderate concern; declining ¹
Western sandpiper	<i>Calidris mauri</i>	High concern; declining ¹
Least sandpiper	<i>Calidris minutilla</i>	Moderate concern; declining ¹
White-rumped sandpiper	<i>Calidris fuscicollis</i>	Moderate concern; declining ¹
Dunlin	<i>Calidris alpina arctica</i>	High concern; declining ¹
Stilt sandpiper	<i>Calidris himantopus</i>	Moderate concern ¹
Buff-breasted sandpiper	<i>Tryngites subruficollis</i>	High concern; declining ¹
Long-billed dowitcher	<i>Limnodromus scolopaceus</i>	Moderate concern ¹
Wilson's snipe	<i>Gallinago delicata</i>	Moderate concern; declining ¹
Red-necked phalarope	<i>Phalaropus lobatus</i>	Moderate concern; declining ¹
Red phalarope	<i>Phalaropus fulicarius</i>	Moderate concern; declining ¹
Black brant	<i>Branta bernicla nigricans</i>	Declining ²
Cackling goose	<i>Branta hutchinsii</i>	Declining ²
Mallard	<i>Anas platyrhynchos</i>	Declining ²
Northern pintail	<i>Anas acuta</i>	Declining ²
Greater scaup	<i>Aythya marila</i>	Declining ²
Steller's eider	<i>Polysticta stelleri</i>	Threatened ³
Spectacled eider	<i>Somateria fischeri</i>	Threatened ³
King eider	<i>Somateria spectabilis</i>	Past declines ⁴
Common eider	<i>Somateria mollissima</i>	Declining ⁵
Surf scoter	<i>Melanitta perspicillata</i>	Declining ⁶
Long-tailed duck	<i>Clangula hyemalis</i>	Declining ⁵
Red-breasted merganser	<i>Mergus serrator</i>	Declining ⁵

¹ Alaska Shorebird Group, 2008.

² USFWS, 2005.

³ Listed under the U.S. Endangered Species Act of 1973.

⁴ Suydam et al., 2000.

⁵ Dickson and Gilchrist, 2001.

⁶ Goudie et al., 1994.

sample the entire population of nonbreeding gulls around Barrow, we collected samples at all sites where gulls were observed loafing in each year, even when sites differed between years. All sites were within 20 km of both landfills and the city, well within the typical daily foraging range (up to 70 km) of glaucous gulls in northern Alaska (Declan Troy, Troy Ecological Research Associates, unpubl. data).

Once a week in summer (June–August) 2007 and 2008, we counted the gulls present at each loafing site. On the basis of plumage, we assigned each gull to one of two age classes that were easily discernable in the field (Gilchrist, 2001): subadult (less than four years old) and adult (at least four years old). We also collected regurgitated pellets and food remains during each site visit. These diet samples consist of indigestible parts of prey and are abundant in gull loafing and breeding areas (González-Solís et al., 1997). To ensure the samples were produced in the current year, we did not collect items that showed evidence of weathering, such as sun-bleaching, epiphyte growth, or tannin stains. Diet data from these samples are biased against highly digestible prey (Duffy and Jackson, 1986), but the samples are appropriate for monitoring variation in consumption

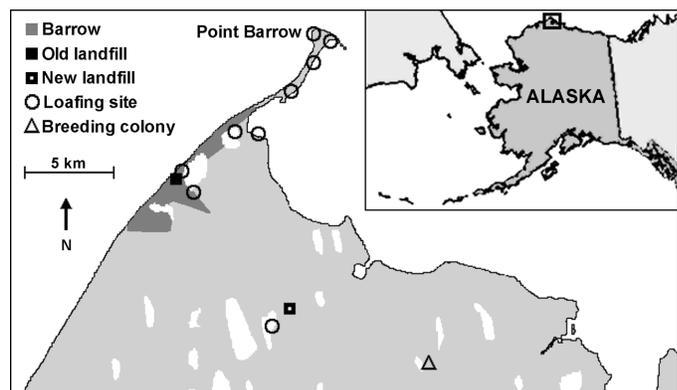


FIG. 1. Collection sites for glaucous gull diet samples in 2007 and 2008. Inset shows location of enlarged map in Alaska.

of food items with indigestible parts, including garbage (González-Solís et al., 1997; Weiser, 2010).

In each year, we also collected diet samples from the breeding colony closest to Barrow, once in late June and once in early August (Fig. 1). Again, we did not collect weathered items to ensure samples were produced during the year of

collection. Adult glaucous gulls regurgitate prey to feed their chicks and exclude foreign adults and subadults from the colony (Gilchrist, 2001), so all of our diet samples collected at colonies represented prey captured by breeding adults. In each year, we recorded the number of breeding pairs (based on the number of current-year nests) and counted the chicks present at the colony just prior to fledging.

Data Analysis

We calculated the percent of gulls at each loafing site that were subadults, and calculated the mean and standard deviation of percent subadults across sites within each year. We also calculated the mean and standard deviation for group size within each year. We used linear regression to test for a temporal trend in loafing group size or age composition over the course of the summer in each year and Mann-Whitney U tests to test for differences between years in loafing group size or percentage of subadults. A critical significance level of 0.05 was used for these tests.

We dissected the pellets and visually examined food remains to identify the foods present in each sample. We identified prey to the lowest possible taxonomic level, but since many prey items could not be consistently identified below class, we grouped prey at class level for diet analysis and considered garbage an additional food class. For each group of gulls (breeding or nonbreeding) in each year, we recorded the number of diet samples (pellets and food remains) in which each food class occurred. We used pairwise chi-square independence tests to test for interannual differences in frequency of occurrence of each prey class in diet samples for each group of gulls, as well as for differences between nonbreeding and breeding gulls within each year. We did not conduct these tests where expected values were less than five for at least one cell. We used a significance level of 0.01 because we were making multiple comparisons (i.e., for several food types) between groups.

Finally, we used linear regression to test for a relationship between distance to active landfill (old landfill in 2007, new landfill in 2008) and percent occurrence of garbage in diet samples from each loafing site, assuming that sites were independent between years. We included only sites with five or more diet samples for each year and tested this relationship at the 0.05 significance level. We then visually assessed the breeding site data in relation to this regression to evaluate whether breeding adults may have shown a different relationship between distance to landfill and diet than nonbreeding gulls. We could not perform a regression on breeding sites because we had only two samples from the same colony, and these were likely not independent between years because individual glaucous gulls tend to return to the same breeding colony year after year (Gaston et al., 2009). To determine whether a relationship between distance to landfill and garbage in diet could explain any apparent diet differences between years, we used a Mann-Whitney U test to detect any differences between years in average distance from loafing sites to active landfill.

All analyses were conducted in program R, version 2.9.2 (R Development Core Team, 2009).

RESULTS

Average loafing group size was 25 (\pm 29) in 2007 and 23 (\pm 24) in 2008, and most of the gulls at each loafing site were subadults (87% \pm 16% in 2007, 72% \pm 35% in 2008). Neither loafing group size nor age composition differed significantly between years ($U < 192$, $p > 0.1$), and neither was linearly related to date of observation in either year ($p > 0.15$).

We collected 193 diet samples from nonbreeding gulls at the loafing sites in 2007 and 248 samples in 2008 (Table 2). In nonbreeding gull diet samples from 2007, the most prevalent food detected was garbage, followed by birds (mostly waterfowl and shorebirds), crustaceans (unidentified crab species, the marine isopod *Saduria entomon*, and euphausiids), and mammals (mostly brown lemmings, *Lemmus trimucronatus*). In the 2008 samples, crustaceans were most prevalent, followed by garbage, birds, and mammals (Table 2). Fish, bivalves, gastropods, insects, and unidentified prey were present in a small proportion of nonbreeding diet samples. Garbage was significantly less prevalent when the city incinerated its waste (28% occurrence) than when the traditional landfill was used (43%; $\chi^2_1 = 10.5$, $p = 0.001$). Occurrence of other prey classes did not differ significantly between years ($p > 0.01$).

The breeding colony contained 10 breeding pairs of gulls that fledged 11 chicks in 2007 and 13 pairs with 18 chicks in 2008. We collected 46 diet samples at the breeding colony in 2007 and 403 samples in 2008 (Table 2). We did not collect all samples available in 2007 because we initially planned that year to be a pilot season for a study of breeding gull diet. However, although the 2007 diet samples represented a smaller portion of the colony than the 2008 samples, the collection was not biased by diet sample type or content.

In 2007, the most common food in breeding gull diet samples was birds (mostly shorebirds with some waterfowl), followed by mammals (mostly brown lemmings with a few scavenged caribou and arctic fox), and garbage. In 2008, mammals were most common, followed by birds and garbage. Fish, crustaceans, bivalves, and unidentified prey were minor components of breeding gull diet in both years (Table 2). Garbage was present in only 7% of the diet samples from the breeding colony in 2007 and 13% in 2008, with no significant difference between years ($p > 0.1$). Mammals occurred more frequently in breeding diet samples in 2008 than in 2007 ($\chi^2_1 = 14.7$, $p < 0.001$). There were no other significant differences between years in occurrence of food types ($p > 0.01$).

In both years, garbage was more prevalent in diet samples from nonbreeding gulls than in those from breeding gulls (Table 2). Breeding gull diet samples contained proportionally more birds, more mammals, and fewer crustaceans than those from nonbreeding gulls in both years. We identified seven shorebird species in gull diet (Table 3),

TABLE 2. Percent occurrence of each food class in diet samples (pellets and food remains) from nonbreeding and breeding glaucous gulls around Barrow, Alaska, when garbage was disposed of in a landfill (2007) and incinerated (2008). Occurrences do not sum to 100% because each diet sample can contain more than one food type.

	2007 (Landfill)			2008 (Incineration)		
	Nonbreeding	Breeding	Chi-square ¹	Nonbreeding	Breeding	Chi-square
Garbage	43	13	14.3*	28	7	54.4*
Mammals	16	43	16.6*	22	71	150.5*
Birds	33	59	10.3*	27	48	29.0*
Fish	3	4	-	5	6	0.7
Crustaceans	29	0	17.0*	38	1	156.6*
<i>n</i> ²	193	46		248	403	

¹ Chi-square tests were used to detect differences between nonbreeding and breeding gulls in frequency of occurrence of each prey class ($df = 1$ and $\alpha = 0.01$ for each test). Asterisks (*) indicate significant differences. Bivalves, gastropods, insects (Pterygota), and unidentified items, which were present in 5% or less of samples from each group in each year, were not tested for differences between groups.

² Number of pellets and food remains analyzed for each gull group in each year.

six of which are experiencing population declines (Alaska Shorebird Group, 2008).

For nonbreeding gulls, we found a significant relationship between distance to active landfill and percent occurrence of garbage in diet samples for loafing sites with at least five diet samples (seven sites in each year; Fig. 2). Data from breeding adults qualitatively matched this pattern. Average distance from loafing sites to active landfill (5.3 ± 3.9 km in 2007, 9.7 ± 4.4 km in 2008) did not vary significantly between years ($U = 16.5$, $p > 0.067$).

DISCUSSION

The change in waste management apparently did not affect the group size or age composition of nonbreeding glaucous gulls using loafing areas around Barrow. For nonbreeding gulls, garbage was a common diet component in both years, but was significantly less prevalent after waste incineration was implemented. For breeding adults, garbage was less prevalent in the diet than for nonbreeding gulls, and its occurrence in breeding diet samples did not change with the shift in waste management.

The reduced amount of garbage in nonbreeding gull diet in 2008 compared to 2007 corresponded with a slight increase in the average distance of loafing areas from landfills. This increase in distance was not significant, but with only eight to nine sites in each year, we may not have had sufficient power to detect such a trend. However, because we sampled all areas used by gulls in each year, the differences in sites sampled reflected changes in gull use of loafing sites between years. It may be that nonbreeding gulls changed their patterns of loafing site use when less waste was available, shifting to sites that were farther from the landfills.

The relationship between distance to landfill and percent occurrence of garbage in diet samples could be explained in two ways. Gulls that spend time closer to landfills may use more waste, or gulls may choose loafing areas near the site of their last meal to digest and produce pellets. One study

TABLE 3. Percent occurrence of each shorebird species or bird taxon in diet samples (pellets and food remains) from nonbreeding and breeding glaucous gulls around Barrow, Alaska, when garbage was disposed in a landfill (2007) and incinerated (2008). Some species are easier to identify than others (e.g., phalaropes have distinctive lobed feet), so the number of occurrences identified may not be proportionally representative of the number of times the species was eaten by gulls. All species listed are declining except pectoral sandpiper, *Calidris melanotos* (Alaska Shorebird Group, 2008).

Species	Nonbreeding		Breeding	
	2007	2008	2007	2008
American golden-plover	0	< 1	0	0
Long-billed dowitcher	0	0	2	1
Dunlin	1	0	4	< 1
Pectoral sandpiper	0	0	2	1
Semipalmated sandpiper	0	0	0	< 1
Red phalarope	1	< 1	17	11
Red-necked phalarope	0	< 1	0	< 1
Total identified shorebirds	2	1	26	13
Unidentified shorebird	3	1	13	8
Other bird	23	15	11	9
Unidentified bird	6	10	9	19

found that about 38% of great skua (*Catharacta skua*) pellets were produced within six hours of a meal (Votier et al., 2001), suggesting that gulls could produce pellets or food remains at the first loafing site used after feeding. Nonbreeding gulls may show fidelity to both foraging and loafing sites (Spear, 1988), which could explain the observed differences in diet among loafing sites.

The apparent dietary differences between breeding and nonbreeding gulls could be due to differences in gulls' access to waste. The breeding colony we studied was more distant than some loafing sites from the landfills. If breeding sites have a relationship between garbage in diet and distance to active landfill similar to the one we found for loafing sites, this factor could explain why garbage is less prevalent in breeding gull diet than in nonbreeding gull diet.

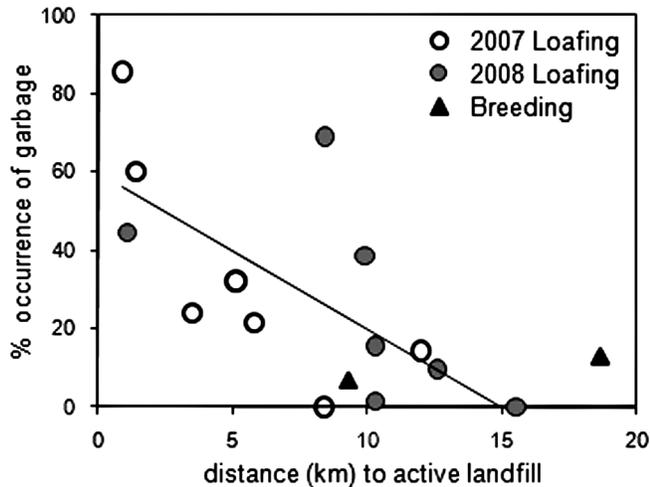


FIG. 2. Relationship between distance to landfill and percent occurrence of garbage in diet samples for glaucous gull loafing sites near Barrow, Alaska ($r^2 = 0.47$, $p = 0.007$). The two points that represent breeding sites, though not included in the regression, fall roughly within the same space occupied by points from loafing gulls. Although two data points do not suffice to draw a conclusion, they show that the breeding data could potentially follow the pattern of the loafing data.

Glaucous gulls and other birds that experience deferred sexual maturity use their time as nonbreeding subadults to develop foraging skills (Ashmole, 1963). Subadult gulls forage less efficiently than adults on both natural foods and municipal waste (Searcy, 1978; Skórka and Wójcik, 2008), improving progressively with age (MacLean, 1986). Subadult glaucous gulls may therefore benefit from waste as a food source because it is predictably available at certain times and places and easier to obtain than natural prey, such as lemmings and shorebirds. Unlike breeding adult gulls, subadults and nonbreeding adults around Barrow did not increase their consumption of mammals (mostly brown lemmings) in 2008 despite the very high local lemming abundance in that year (Rick Lanctot, USFWS, unpubl. data). In both years, breeding adults also consumed higher proportions of birds, especially shorebirds, than nonbreeding gulls did. Subadults may not yet have the skills to hunt live prey such as lemmings and shorebirds consistently, even when such prey is unusually abundant. These gulls may derive a substantial benefit from easily obtained anthropogenic foods. Garbage in diet can increase body condition of gulls (Auman et al., 2008), and proximity to anthropogenic food sources can improve survival of American crows (*Corvus brachyrhynchos*; Marzluff and Neatherlin, 2006); it is likely that garbage could improve survival to adulthood for immature gulls. The subadult gulls using the Barrow landfills move widely throughout the ACP, western Arctic Canada, and coastal Russia during the summer (Declan Troy, Troy Ecological Research Associates, pers. comm.), staying only briefly (up to a week) in any given area, and they may eventually breed anywhere in the region. Anthropogenic subsidies in any one location could therefore affect breeding gull population sizes throughout the western Arctic.

Although incineration was apparently effective in reducing the amount of garbage in nonbreeding gull diet, garbage remained an important component of that diet even after the change in disposal method. Storage methods may be as important as disposal in regulating waste availability; open dumpsters offer ready access to garbage for avian scavengers. Effective waste control at all stages of disposal will be a necessary step in limiting the negative indirect effects of future development on wildlife.

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