Diet Changes in Breeding Herring Gulls (*Larus argentatus*) in Witless Bay, Newfoundland and Labrador, Canada, over 40 Years

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Abstract.—The diets of gulls (Laridae) can have consequences for reproductive success, chick growth, and survival, yet there have been no quantitative assessments in eastern Newfoundland since the early 1970s. The diet of Herring Gulls (*Larus argentatus*) was examined through regurgitated prey items and pellets on Gull Island, Witless Bay, Newfoundland and Labrador, Canada, in 2012, and compared with similar data from 1970-1971. There was a significant shift in Herring Gull diet composition from blue mussels (*Mytilus edulis*) and capelin (*Mallotus villosus*) in the 1970s to garbage and Common Murre (*Uria aalge*) eggs in 2012. Delays in capelin spawning and the large increase in breeding Common Murres on Gull Island are likely factors influencing Herring Gull diet. Garbage, which includes human food scraps as well as plastic debris, now constitutes the single largest diet item for Herring Gulls, corresponding with a global increase in plastic pollution. The consistently low contribution of fisheries discards suggests that changes in fishing practices and availability of discards are only one possible factor in the Herring Gull decline in Witless Bay. *Received 16 May 2014, accepted 5 August 2015.*

Key words.—diet, Common Murre, fisheries discards, Herring Gull, *Larus argentatus*, plastic pollution, *Uria aalge*.

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As a group, gulls (Laridae) show great adaptability and flexibility in their diets, exploiting new environments and food sources, or switching among prey types (Harris 1970; McGill 1977; Hobson 1987; Burger 1988). They often make use of anthropogenic food sources (Silva *et al.* 2001; Gilliland *et al.* 2004; Moreno *et al.* 2010; Auman *et al.* 2011), and show varying degrees of individual dietary specialization (Watanuki 1992). This adaptability and diversity of prey items can have consequences for sympatric nesting seabirds (O'Connell and Beck 2003; Oro *et al.* 2005; Donehower *et al.* 2007; Oro and Martínez-Albraín 2007), as well as gull contaminant burden (Mineau *et al.* 1984; Bustnes *et al.* 2000; Hebert *et al.* 2000; Burgess *et al.* 2013) and breeding biology (Panov *et al.* 1980; Pierotti 1982; Pons 1992; Pons and Migot 1995).

The prey with which adult gulls provision their chicks can influence chick growth and reproductive success, and is related to nesting habitat (Pierotti 1982; Pierotti and Annett 1991). In eastern Newfoundland, capelin (*Mallotus villosus*) is an important food source for seabirds, including gulls (Regehr and Rodway 1999; Carscadden *et al.* 2002), but since the mid-1990s, capelin spawning has been significantly delayed, creating a mismatch in timing between gull chick hatching and the availability of their preferred prey (Hipfner 2008; Fisheries and Oceans Canada 2013). This has resulted in large gulls consuming significant numbers of sympatric seabirds, particularly early in the breeding season (Massaro *et al.* 2000; Stenhouse *et al.* 2000; Veitch *et al.* 2016).

The composition of Herring Gull (*Larus argentatus*) diet in eastern Newfoundland was last assessed more than 40 years ago, when it comprised mostly fish (primarily capelin), blue mussels (*Mytilus edulis*) and Leach's Storm-petrels (*Oceanodroma leucorhoa*) (Haycock and Threlfall 1975; Table 1). In the intervening years, there have been significant changes to the ecosystem, including significant reductions in fisheries discards resulting from the closure of groundfish fisheries (Hutchings and Myers 1994), improved waste management in local communities (Veitch *et al.* 2016), delayed capelin spawning (Fisheries and Oceans Canada 2013), climate and oceanic changes (Drinkwater 1996), and significant declines in gull breeding populations (Robertson *et al.* 2001; Bond *et al.* 2016). Elsewhere in Atlantic Canada,

Table 1. The diet of breeding Herring Gulls on Gull Island, Witless Bay, Newfoundland and Labrador, assessed using regurgitations and pellets. Data from 1970-1971 from Haycock and Threlfall (1975).

	Frequency of Occurrence (%)	
Diet Items	1970-1971	2012
Invertebrates		
Crab (*Hyas* sp.)	< 1	4
Woodlice (*Oniscus* sp.)	< 1	0
Insects	1	< 1
Limpet (*Acmaea* sp.)	< 1	0
Blue mussel (*Mytilus edulis*)	22	9
Sea star (*Asterias* sp.)	< 1	0
Urchin (*Strongylocentrotus drobachiensis*)	4	< 1
Vertebrates		
Fish	28	2
Green Frog (*Lithobates clamitans*)	< 1	0
Leach's Storm-petrel (*Oceanodroma leucorhoa*)	18	13
Atlantic Puffin (*Fratercula arctica*) adults	4	2
Atlantic Puffin or Common Murre (*Uria aalge*) chicks	1	3
Atlantic Puffin or Common Murre eggs	1	19
Gull (*Larus* spp.) chicks	< 1	1
Gull (*Larus* spp.) eggs	4	0
Black-legged Kittiwake (*Rissa tridactyla*) chicks	0	< 1
Other diet items		
Fisheries discards	9	4
Garbage	4	42
Total number of diet items	405	292

gull diets have changed significantly over the same period (Ronconi *et al.* 2014).

The objective of this study was to compare the diet of Herring Gulls at Gull Island, Witless Bay, Newfoundland and Labrador, in 2012 with similar data collected in 1970 and 1971 (Haycock and Threlfall 1975) to assess dietary shifts over this period of significant ecosystem change, and to provide a benchmark for future studies of Herring Gull diet and chick provisioning.

Methods

From 9 May to 8 July 2012, I collected Herring Gull boluses and chick regurgitates from nests at the south end of Gull Island ("The Finger"; Robertson *et al.* 2001) during daily visits to ~120 nests over the four main habitat types: meadow, puffin slope, rocky, and forest (Robertson *et al.* 2001; Bond *et al.* 2016). While it is possible that some boluses were from Great Black-backed Gulls (*L. marinus*), there were only two pairs in our study area, one of which failed before the eggs hatched, so the nest was easily avoided during sampling. Prey were identified to taxonomic groups based on previous assessments and compared with data from 1970-1971 (Haycock and Threlfall 1975) using similar methods, but restricted to Haycock and Threlfall's first two sampling periods (mid-May to mid-July). I cawtegorized whole or largely whole fish as prey caught by Herring Gulls, whereas large chunks or sections of larger fish were classified as fisheries discards. No fish or fisheries discards were found in boluses. Boluses and regurgitates can provide different information, as boluses are more biased against soft-bodied organisms, but are easier to collect (Duffy and Jackson 1986).

I calculated the Morisita-Horn's Index (Morisita 1959; Horn 1966; Bond *et al.* 2012) based on the frequency of occurrence of diet items using the package *vegan* (Oksanen *et al.* 2013) in R (R Development Core Team 2014) to determine if there were differences in Herring Gull diet between the two periods. Values range from 0 (complete dissimilarity) to 1 (completely identical), and values > 0.60 generally indicate significant similarities between groups (Catry *et al.* 2009; Bond *et al.* 2012).

Results

I collected 292 prey samples between 9 May and 8 July 2012. The most common prey item was human garbage ($n = 122$, 42% frequency of occurrence), followed by Common Murre (*Uria aalge*) eggs ($n = 56$, 19%), and Leach's Storm-petrels ($n = 37$, 13%). Blue mussels constituted only 9% of prey items ($n = 27$), fisheries discards only 4% ($n = 11$), and fish (capelin) 2% ($n = 7$). All other prey items constituted < 5% of diet items (Table 1). The similarity between Herring Gull diet in 1970-1971 and 2012, measured using the Morisita-Horn's Index, was 0.365, indicating significant differences between the two periods.

Discussion

There were considerable differences in Herring Gull diet between 1970-1971 and 2012, including a decrease in fish and an increase in Common Murre eggs. An individual's diet is strongly related to nesting habitat (Pierotti and Annett 1991), so the differences I observed could be attributable, at least in part, to different proportions of nests sampled from each habitat between the two studies. There are no data relating to the habitat in which prey items were identified in the 1970s, and monitored nests in 2012 were roughly distributed among the four habitat types (forest, meadow, puffin slope, rocky; Bond *et al.* 2016).

One of the most striking changes in Herring Gull diet was the order-of-magnitude increase in the proportion of garbage, from 4% in 1970-1971 to 42% in 2012. The general perception that improved land-based waste management practices have reduced the amount of garbage available to gulls (Weiser and Powell 2011b) does not seem to be applicable here. Garbage includes both edible anthropogenic food subsidies (e.g., meat) and plastic debris, so while human food waste may be less available, there has been a significant increase in the amount of plastic debris in the world's oceans, including in the North Atlantic (Thompson *et al.* 2004; Law *et al.* 2010). Indeed, plastic was generally rare in gull boluses throughout Atlantic Canada in the 1970s (Threlfall 1968; Lock 1973; Provencher *et al.* 2014). Though it was not recorded separately, there was a maximum of nine cases of plastic in Herring Gull diet samples from the 1970s (2%) compared with 100 (34%) in 2012, an 11-fold increase (Table 1). Herring Gulls specializing on garbage tended to have small clutch sizes in some years, and lower hatching success (Pierotti and Annett 1991). However, there has been no concomitant decrease in clutch size in Witless Bay from 1976-2012 (Bond *et al.* 2016). Garbage consumption has been linked to poorer hatching success, so the increase in garbage consumption may have led to decreased hatching success and could help to explain the decline in the Herring Gull breeding population on Gull Island since the 1970s (Bond *et al.* 2016).

There was also a considerable increase in the category "Atlantic Puffin (*Fratercula arctica*) and Common Murre eggs" on Gull Island, from 1% in the 1970s to 19% in 2012. In 2012, these were all Common Murre eggs, and Atlantic Puffin eggs likely contributed little to the total in 1970-1971. Common Murres were relatively uncommon breeders on Gull Island from the 1940s through the 1970s, numbering < 700 breeding pairs (Haycock 1973; Cairns and Verspoor 1980; Robertson *et al.* 2004). More recently, the number of breeding Common Murres increased substantially to ~10,000 breeding pairs in 2012 (Canadian Wildlife Service, unpubl. data), which made Common Murre eggs more available as a prey item for Herring Gulls. Anecdotally, it appeared that Herring Gulls with nesting and feeding territories adjacent to Common Murre nesting cliffs tended to specialize on Common Murre eggs more often than Herring Gulls nesting elsewhere.

In the 1970s, the two most frequent prey items by far were blue mussels and fish (mainly capelin), which contributed 50% of diet items (Haycock and Threlfall 1975), yet declined to a combined 11% in 2012 (Table 1). The decrease in fish can be attributed to the reduction in capelin stocks and the delay in spawning (Massaro *et al.* 2000; Fisheries and Oceans Canada 2013), but the reason for the decrease in blue mussels from 22% in the 1970s to only 9% in 2012 is unknown. Previously, some Herring Gulls had specialized on blue mussels, particularly those nesting in rocky habitat (Pierotti and Annett 1991). These birds tended to have greater hatching and fledging success (Pierotti and Annett 1991), so it is unclear what effects, if any, the reduction in mussel consumption will have on breeding Herring Gulls.

The availability (and recent reduction) in fisheries discards has been suggested as a strong influence on gull population dynamics (Furness *et al.* 1992; Bicknell *et al.* 2013), but it appears that discards have been uncommon in the diet of breeding Herring Gulls in eastern Newfoundland (Haycock and Threlfall 1975; Veitch 2003), comprising < 10% of diet items in the 1970s and only 4% in 2012 (Table 1). There have been significant reductions in fisheries effort resulting from a groundfish moratorium enacted in 1992 (Hutchings and Myers 1994), and an increase in shellfish harvesting. Crabs (*Hyas* sp.) increased from < 1% of Herring Gull diet in the 1970s to 4% in 2012, likely due to the crab processing facility in the town of Witless Bay, Newfoundland (approximately 2 km from the breeding colony). However, given the low occurrence of both finfish and shellfish discards in their diet, populations of breeding Herring Gulls in eastern Newfoundland are not generally influenced by fisheries activity (but see Regular *et al.* 2013; Bond *et al.* 2016; Wilhelm *et al.* 2016). Immature or non-breeding Laridae may exploit these food sources more frequently during the summer months, but observations from Shetland suggest that adult larids outcompete their younger conspecifics (Hudson and Furness 1989). Fisheries discards may be more important as a nutrient subsidy during different times of the breeding cycle for different age classes. Elsewhere in Atlantic Canada, larid populations decreased following large-scale fisheries closures, but were also affected by new anthropogenic food sources and emerging fisheries (Wilhelm *et al.* 2016).

Larids in Witless Bay depredate tens of thousands of Leach's Storm-petrels (*Oceanodroma leucorhoa*) each year, primarily before the arrival of spawning capelin (Stenhouse and Montevecchi 1999; Stenhouse *et al.* 2000). The proportion of Leach's Storm-petrels in Herring Gull diets has remained relatively consistent over time (18% in the 1970s, 13% in 2012; Table 1), but the proportion of breeding storm-petrels to prospecting individuals depredated by Herring Gulls is unknown, and would have considerable implications for the storm-petrels breeding on Gull Island. If prospecting individuals were largely affected, we might not expect a decrease in the local breeding population, as the Leach's Storm-petrel has very high prebreeding dispersal (Huntington *et al.* 1996).

Assessing gull diets using pellets is obviously biased against soft-bodied organisms (Weiser and Powell 2011a), but requires minimal effort compared with other methods and is comparable with previous studies, which was my primary goal. Herring Gulls breeding in eastern Newfoundland appear to have experienced a considerable dietary shift between 1970-1971 and 2012. The reasons for this dietary shift and its consequences are not necessarily apparent, but have the potential to affect reproductive output, and also to be affected by nesting habitat selection (Pierotti 1982; Pierotti and Annett 1991). Future monitoring of Herring Gull diet should consider nesting habitat and sample source (boluses or regurgitates) to maximize comparability among studies. In particular, separating the sample source can partly address the biases of each method (Barrett *et al.* 2007), especially for further refining the contribution of fisheries discards to adults and chicks. Boluses will reflect only prey with hard parts, while some food types may be more prone to regurgitation than others, and regurgitations may not represent entire meals (Barrett *et al.* 2007).

Gulls show incredible dietary flexibility, the consequences of which affect their breeding success, habitat selection, contaminant burden, and survival. Herring Gulls are declining in Witless Bay, but the causes are unknown (Bond *et al.* 2016). Significant changes in Herring Gull diet during the breeding season could be partly responsible for population declines, as demonstrated for Glaucous-winged Gulls (*Larus glaucescens*) (Blight *et al.* 2014), and a better understanding of Herring Gull diet throughout the year is required to assess the importance of foraging behavior in explaining population changes.

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