Gulls as habitat and ecosystem bio-indicators on Sable Island

Final Report

04 March 2012

Prepared for

Nova Scotia Habitat Conservation Fund
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Funding and support

This work was funded by Encana Corporation through Encana's Research and Development Fund, with extensive additional in-kind support, and matching funds from NSERC's Collaborative Research and Development program (CRD), Canadian Wildlife Federation, Nova Scotia Habitat Conservation Fund (contributions from hunters and trappers), and Environment Canada. Additional in-kind support and supplementary purchase of telemetry tags was provided by Environment Canada, Parks Canada, and ExxonMobil Corporation.

Acknowledgements

We thank Marielle Thillet for her partnership in the project, development of the project scope, assistance in the field and continued support through Encana Corporation. We thank Karel Allard, Carina Gjerdrum, Andrew Boyne, Karen Potter, Jen Rock, Julie McKnight, and Greg Robertson (Environment Canada), Deb Austin and Chris McCarthy (Parks Canada), Megan Tuttle (ExxonMobil), Marty Leonard, Andy Horn, Ian McLaren, Phil McLoughlin all helped with various aspects of planning and implementing the project. Individuals at Main Station, Sable Island assisted with logistics there, and personnel from Department of Fisheries and Oceans, Canada and Dalhousie University assisted with working on Sable Island (Damian Lidgard, Don Bowen, Jim McMillan). Field crews and support personnel on Country Island (Environment Canada) and Bon Portage Island (Acadia University; Lee Adams, Janice Chard and ABO volunteers Mike O'Brien). Crew from platform supply vessels kept watchful eyes for wing-tagged birds. A number of landowners also graciously allowed us to place antennas and receivers on their properties.

Permits

Wildlife capture and handling procedures were approved by Acadia Animal Care Committee (certificate numbers: 15-11, 15-11R#1, 15-11R#1A#1, 06-09) and permit for scientific sampling was issued by Environment Canada (permits SC2761, SC2718, SC2741). Bird banding, tagging, and colour marking was authorized under by the Bird Banding Office (permits 10480-S, 10851, 10273-AH**,** 10695, 10273). Parks Canada Research and Collection Permit (SI-2012-0001) to work on Sable Island and deploy a VHF receiver station in Kejimkujik NP Seaside Adjunct. Permit to work in Sable Island Migratory Bird Sanctuary (MBS/SI-2011-1, MBS/SI-2012-1).

1. Summary

Seabirds are widely regarded as indicators of habitat health in marine and coastal ecosystems. This study investigated gull habitat use and diets as indicators of ecosystem changes and important habitat areas around Sable Island, NS. Satellite tags were deployed on Herring Gulls to track their movements, and diets of both Herring and Great Black-backed Gulls were studied from analysis of regurgitated pellets around nest sites and stable isotope analysis of blood samples collected from live caught birds. The results provide insight into individual variability in foraging strategies, interactions with offshore oil and gas platforms, changes in gull diets since the 1970's, potential pathways of contaminants in gull eggs, and the impact of gulls on local tern populations.

***Movement patterns* –** Six Herring Gulls were fitted with satellite tags to track their movements during breeding and post-breeding periods around Sable Island. Gulls showed high individual variability in foraging strategies with some foraging in offshore areas north of Sable, some making frequent trips to offshore platforms southwest of Sable, and others remaining on the island until migration departure. Likewise, timing of migration departure from the Sable Island area was highly variable ranging from 26 June to 28 October. Birds migrated to mainland Nova Scotia, through Cape Cod, MA, terminating within 125 km of each other in coastal in inland New Jersey.

***Gull-platform interactions* -** Satellite tags revealed gull-platform interactions for 2 of 6 Herring Gulls tracked. These individuals spent 6 and 12% of their time within 200 m of offshore platforms prior to departing the Sable Island area. Most interactions occurred between mid July and mid August with less frequent interactions during September and October. Most interactions were short (<2 h) though one was as long as 40 h.

***Gull diets* –** Examination of more than 1300 prey items from regurgitated pellets in 2011/2012 revealed changes in gull diets since 1969/1970. Contemporary gull diets show higher proportions of seal and clams, lower proportions of fish, and near absence of terns and tern eggs. Stable isotope analysis of blood samples from nearly 100 individuals revealed strong differences in diet between Herring and Great Black-backed Gulls. Isotopic mixing models estimated crabs and seal carcasses to be the primary prey of Great Black-backed Gulls, whereas, crab, sand lance, and to lesser extent amphipods, were the primary prey of Herring Gulls.

***Conservation implications* –** Gull diets have shifted considerably since the 1970's notably with an increase in seal remains in their diet, associated with the exponential increase in Sable Island's breeding population of grey seals over the past 4 decades. Although Great Black-backed Gulls were once thought to be heavy predators of Sable tern colonies, potentially contributing to historical population declines, this no longer appears to be the case as terns make up a very small proportion of gull diets in 2011/2012. High contaminant loads have been documented in the eggs of Herring Gulls breeding on Sable Island, though the sources of these contaminants remain unknown. This study of gull diets and foraging movements may provide insight into sources of contaminants for this population.

2. Background

Seabirds, including gulls, are widely regarded as indicators of marine and coastal ecosystem health. Tracking of gull movements with satellite tags can identify important breeding, foraging, and migratory habitats in marine, coastal and inland areas. Moreover, sampling of gull eggs and diets can be used to monitor trends in pollutants (Gauthier et al. 2009; Gebbink et al. 2011) as well as changes in aquatic and marine food supplies (Farmer and Leonard 2011; Hebert et al. 2009). In combination, studying the movements, diets and contaminants in gulls can provide a robust assessment of coastal ecosystem health (Mallory et al. 2010).

In Nova Scotia, gulls are among the most abundant, conspicuous, and widespread avian predators (Boyne and Beukens 2004), making them ideal indicator species of ecosystems health for coastal habitats, particularly in remote areas. Located more than 160 km offshore, Sable Island is one of Nova Scotia’s most remote and unique wilderness areas, which provides important breeding and foraging habitat for resident and migratory birds (Huettmann and Diamond 2000; McLaren 1981). Nesting species on Sable include Herring Gull (*Larus argentatus*), Great Black-backed Gull (*L. marinus*), terns (3 species, *Sterna sp.*), and the endemic Ipswich Sparrow (*Passerculus sandwichensis princeps*).

Conservation and management issues regarding Sable Island gulls include a) high levels of contaminants in Herring gull eggs (Gebbink et al. 2011), b) potential predation on terns and sparrows, including the endangered Roseate Tern (COSEWIC 2009; Lock 1973), and c) attraction to offshore oil and gas platforms and supply vessels for foraging/roosting (Baird 1990; Tasker et al. 1986). Gebbink et al. (2011) identified high contaminant loads in the eggs of Sable Island Herring Gulls, but lack of information on diets and foraging areas mean that contaminant sources are unknown. Diet studies have not been conducted on Sable since 1970 when predation rate on terns was high (Lock 1973), but this pressure has potentially lessened since seal populations have increased dramatically providing year-round foraging opportunities for gulls scavenging on seal carcasses (Ronconi pers. obs.). Although foraging and roosting opportunities from platforms may be beneficial to gulls, this may also increase gull survival and populations, resulting in undesirable, indirect effects on terns. For this suite of reasons, there is an important need to study the habitat use and diets of Sable gulls in order to manage local populations and identify potential pathways of contaminants in the ecosystem.

3. Goals and objectives

1) Identify patterns of habitat use by Sable Island gulls during breeding and post-breeding periods:
    a. Map foraging hotspots in coastal and offshore locations
    b. Quantify the timing, duration, and frequency of gull interactions with offshore platforms and vessels
    c. Identify winter and pre-breeding habitats where gulls may be exposed to contaminants prior to egg laying
2) Quantify gull diets through pellet and stable isotope analysis in order to:
    a. Identify changes in diet since the 1970's
    b. Quantify contemporary gull diets to identify potential sources of contaminant exposure
    c. Provide base-line data for monitoring dietary changes and ecosystem health in the future.

4. Methods

Between May and August, 2012, field studies were conducted on Sable Island with the aim of tracking the movements of gulls at breeding colonies, in the vicinity of offshore platforms and along migration routes. Dietary studies were also undertaken by sampling pellets around gull nests and collecting blood samples from birds of various age classes and during different seasons.

4.1 Study sites and species

Sable Island is a unique gull colony because of its proximity to the continental shelf edge, lack of coast influence and isolation from anthropogenic influences such as urban areas and garbage dumps, where gulls commonly feed. The island is 42 km long and 1.2 km across its widest point, composed of vegetated sand dues, sand flats, and some freshwater ponds on the south side of the island (Figure 1). An estimated 1950 to 2020 pairs of Herring Gulls, and over 630 pairs of Great Black-backed Gulls were breeding on the island in 1970 (Lock 1973), though no recent population census has been completed. Gulls breed all over the island in mixed colonies, but are more concentrated on the north side of the island near the dune edges.

Gulls are opportunistic foragers, feeding on a wide range of prey including fish, marine and terrestrial invertebrates, carcasses of beached marine mammals, small birds, fisheries discards, and refuse from garbage dumps (Steenweg et al. 2011, Good 1998, Pierotti and Good 1994). On Sable Island, historical data from Herring Gull pellets sampled in 1970 (Lock 1973) showed high occurrence of fish, crabs and terrestrial insects (combined 70% of prey items) in their diets. However, these data were collected prior to contaminant sampling programs (Burgess et al. 2013, Chen et al. 2012, Gebbink et al. 2011) and therefore provide little insight into dietary sources of contaminants. Moreover, since this time, Sable Island and the surrounding area has undergone significant ecological and anthropogenic change since 1970, with the exponential increase of breeding grey seals (*Halichoerus grypus*), now the largest colony in the world (Bowen et al. 2003) and the development of six natural gas drilling platforms within 40 km of Sable Island (Figure 1). These changes have the potential to influence gull diets since gulls feed around the lights of offshore platform supply vessels and scavenge extensively on seal carcasses on the island (Ronconi pers obs).

Gulls are commonly attracted to platforms and supply vessels for foraging/roosting (Baird 1990; Tasker et al. 1986) and also pose the greatest threat to helicopter operations at unmanned SOEP platforms (M. Tuttle, ExxonMobil, pers. comm.). Gulls are also predators of terns nesting on Sable Island and elsewhere (Lock 1973; Whittam and Leonard 1999). For satellite tag deployments and collection of blood samples for dietary analysis, during May and June, gulls were captured on Sable Island using a combination of a hand-pulled leg noose set around the rim of nests, remotely activated bow nets (Modern Falconry, 4ft Fast Action Bownet) set around nests, or leg-loop noose carpets set around seal carcasses on the beach. Most Herring Gulls were captured with the first two methods and most Great Black-backed Gulls were captured with the later. Great Black-backed Gull chicks were captured near nest sites prior to fledging.

Figure 1 – Location of offshore natural gas platforms surrounding Sable Island (43.93°N, 59.90°W, approximate centre). Sable Island is approximately 40 km in length, and 1.2 km wide at the centre.

4.2 Tag deployments

GPS-satellite tags (Solar Argos/GPS PTT-100, 22 g, Microwave Telemetry Inc., Columbia, MD, U.S.A.) were deployed on Herring Gulls (n = 6) in May, 2012. Tags were attached with leg-loop harness (Mallory and Gilbert 2008) made of Teflon tape (Bally Ribbon #8476, Natural Brown, 6.35 mm width: Bally Ribbon Mills, Bally, PA, U.S.A.) with a total tag and harness weight of less than 2.5% of the bird's body mass. Tags were programmed with two seasonal duty cycles to optimize use of solar power: 1) spring/summer/fall: 21-Feb to 21 Oct, 15 GPS positions daily at hours 00, 1, 2, 4, 6, 8, 9, 10, 12, 14, 16, 17, 18, 20, 22, and transmit cycle = 4 d; 2) winter: 21-Oct to 21-Feb, n = 8 positions at 00, 3, 6, 9, 12, 15, 18, 21, and transmit cycle = 5 d. Satellite tags provide bird locations from anywhere on the planet and do not rely on our network of receiver stations.

4.3 Dietary analysis

Pellet sampling **-** Regurgitated pellets were collected and enumerated for Herring and Great Black-backed Gulls during June in 2011, and May and June in 2012. Pellets and other undigested hard parts of prey items (e.g. crab carapace and claws) were sampled opportunistically around nest sites for both species of gulls and itemized following methods by Lock (1973). For Great Black-backed Gulls, pellets were counted within ~ 2 m of individual nests. For Herring Gulls, all pellets and nests were counted throughout small sub-colonies (typically 5 to 30 nests each) around nests and adjacent loafing sites (e.g. dune ridges) between nests but within colonies. Prey items from pellet samples were identified in the field to the lowest taxonomic level possible, and were removed from nesting areas (or destroyed) during counting. This ensured no double counting of items and cleared sites for recounting at later dates. Most (approximately > 80%) of the nests were sampled in the western half of Sable Island, Great Black-backed Gull nests were counted only once, and a few sub-colonies of Herring Gulls were counted twice. Great Black-backed Gull nests were sampled during late incubation and early chick-rearing. Herring Gull nests were sampled during incubation and approximately one week post hatching.

We calculated frequencies of occurrence (FO%) as the number of pellets with a given prey type, expressed as a percentage of the total number of prey items counted (as per Lock 1973). Most pellets contained only a single prey type, but those containing two or more prey types were counted as separate prey items in the FO% statistics. When possible, the total prey count included the maximum number of items that could be uniquely identified (e.g. maximum number of crab carapaces or right claws, or multiple species of fish within individual pellets, Steenweg et al. 2011). Most often, however, multiple prey items of the same prey type were counted as single records because, for example, it was not possible to count individual prey items when they were ground up within a pellet (e.g. beetle carapaces, fish bones, crab shells, and vegetation). This method assumes that one pellet represents a single meal, thus underestimating the actual count (numerical frequency) of individual items within a meal. Nonetheless, the results present indices of diets from 2011 and 2012 that are comparable to those collected on Sable Island in 1969 and 1970 (Lock 1973). In order to determine the changes in diet since 1969-70, pellet samples from Lock (1973) were compared to those from this study. Proportion of change in diet was calculated by subtracting mean proportion contemporary (2011 and 2012) from mean proportion historical (1969 and 1970).

***Bird sampling for stable isotopes* -** For stable isotope analysis, blood samples were collected from gulls during two breeding periods (07-14 June 2011 and 19 May to 17 June 2012), one post-breeding period (24-26 August 2012), and two winter periods (06-15 January 2012 and 2013). Samples were collected from adult Herring Gulls (n = 47), and adult (n = 27), immature (n = 15), and chick Great Black-backed Gulls. We sampled only one chick from each nest. A small (< 1 ml) blood sample was collected by venipuncture of the tarsus or wing for stable isotope analysis. After collection in the field blood samples were frozen until further processing.

For stable isotope mixing models to estimate diet of gulls, representative prey samples were also collected for stable isotope analysis, based on known diet items identified from pellet analysis in this study and other studies (Lock 1973, Steenweg et al 2011). Prey samples of northern short-fin squid (*Illex illecebrosus*, n = 5), sand lance (*Ammodytes sp.*, n = 9), haddock (*Melanogrammus aeglefinus*, n = 5), capelin (*Mallotus villosus*, n = 5), longhorn sculpin (*Myoxocephalus octodecemspinosus*, n = 4), mackerel (*Scomber scombrus*, n = 3), atlantic herring (*Clupea harengus*, n = 5), rock crab (*Cancer borealis*, n = 6) and shrimp (*Pandalus borealis*, n = 4) were collected during research trawl surveys within 50 km of Sable Island conducted by the Department of Fisheries and Ocean from survey vessel CCGS Alfred Needler (08 July – 04 August 2012). Other prey samples were gathered on Sable Island: rock crab (n = 3) and Atlantic surf clam (*Spisula solida*, n = 3) were found on beaches and around nests, nine spine stickleback (*Pungitius pungitius*, n = 5) were collected by dip net from freshwater ponds, sand lance (n = 5) collected by hand from the east tip of the island, and invertebrates (grubs n = 4; june bugs, *Phyllophaga sp.* n = 3; amphipods, *Gammarus lawrencianus* n = 5) were collected by hand from dunes, beaches and vegetation. Sub-samples of grey seal muscle, liver, and intestine tissues were collected opportunistically from adults in the summer (n = 5) and pups in the winter (n = 4) from carcasses washed ashore. These three tissues were selected as sub-samples from seals since we frequency observed gulls scavenging these body parts. All prey samples were stored frozen until processing for stable isotope analysis.

Sample preparation - Blood samples were dried in epindorf tubes in an oven set at 40°C for 24 hours. Prey samples were thawed, homogenized with a food processor or mortar and pestle and sub-samples were dried in the oven. Whole prey items were homogenized except for crab (meat was removed from the carapace, legs and claw), long-horned sculpin (thick jaw, horns and vertebrae removed prior to grinding), clam (muscle removed from shells and multiple individuals combined) and seal (sub-sample of tissues collected in field). After drying, samples were soaked in a 2:1 choloroform-methanol solution for 24 hours to remove lipids from the samples and rinsed with fresh solution (as per Cherel et al. 2005), air-dried or re-dried in the oven for larger samples and then ground into a fine powder. Sub-samples of 0.250mg ±0.05 were weighed with a microbalance and folded in a tin capsule. Stable isotope analysis for $\delta^{13}C$ and $\delta\, ^{15}N$ of blood and prey samples was conducted at The Environmental Isotope Lab, University of Waterloo. See Steenweg et al. (2011) for additional details on sample processing.

Mixing models – We used a Bayesian isotope mixing (IsotopeR; Hopkins & Ferguson 2012) to estimate the proportion of prey items in gull diets. These models compare the stable isotope signatures of predators to those signatures of their potential prey items (see details of representative prey samples above). Given the generalist diets of gulls, mixing models may suffer from too many potential prey sources (Phillips and Greg 2003), especially when isotope signatures overlap between similar prey items. Therefore, we excluded some prey items which are not known to occur in gull diets (e.g. shrimp and squid) and grouped prey items with similar isotopic signatures (e.g. medium sized offshore fish). See results below for list of species and groupings for mixing models. Mixing models used fractionation values from Steenweg et al. (2011) which were selected for whole blood samples from fish eating birds and lipid-extracted prey samples.

5. Results

5.1 Bird movements

The primary objectives of this study relating to bird tracking with satellite tags was to investigate: a) foraging hotspots in coastal and offshore locations, b) quantify the timing, duration, and frequency of gull interactions with offshore platforms and vessels, and c) identify winter and pre-breeding habitats where gulls may be exposed to contaminants prior to egg laying. This section examines preliminary analysis of all bird movement data from 6 satellite tags deployed on Herring Gulls in May 2012.

Satellite tags deployed on 6 Herring Gulls resulted in a total of 516 bird-tracking days and 5,343 GPS locations in the Sable Island area, prior to migration departure (Table 1). Preliminary data analysis was conducted on unfiltered data of GPS positions which have a typical accuracy of < 15 m (as specified by the tag manufacturer). There was a high degree of individual variability in movement behaviour demonstrating that some individuals forage almost exclusively on Sable Island, while others make long foraging trips at sea, sometimes great than 100 km away, to areas north of Sable where no platform activity exists (Fig. 2). Together this demonstrates the wide range of individual variability in foraging habitats and contrasting foraging strategies.

*Table 1 – Summary of tracking data and GPS locations obtained from 6 satellite tags deployed on Herring Gulls on Sable Island. Tags were deployed on 26-28 May, 2012. * Departure date not given for bird 115927 because tag fell off bird 22 June 2012.*

				Locations within 200m of platform							
Tag ID	**Departure from Sable***	**Days tracked in Sable area**	**# GPS locations**	**Deep Panuke**	**Thebaud**	**North Triumph**	**Alma**	**Venture**	**South Venture**	**All platforms**	**% of total GPS locations**
115925	23-Aug-12	89	1259	0	0	0	0	0	0	0	0.0
115926	19-Oct-12	145	1171	74	42	1	22	0	0	139	11.9
115927	n/a	26	266	0	0	0	0	0	0	0	0.0
115928	9-Aug-12	74	1017	0	0	0	0	0	0	0	0.0
115929	26-Jun-12	29	414	0	0	0	0	0	0	0	0.0
115930	28-Oct-12	153	1216	5	66	0	1	0	0	72	5.9
TOTAL		516	5343	79	108	1	23	0	0	211	3.9

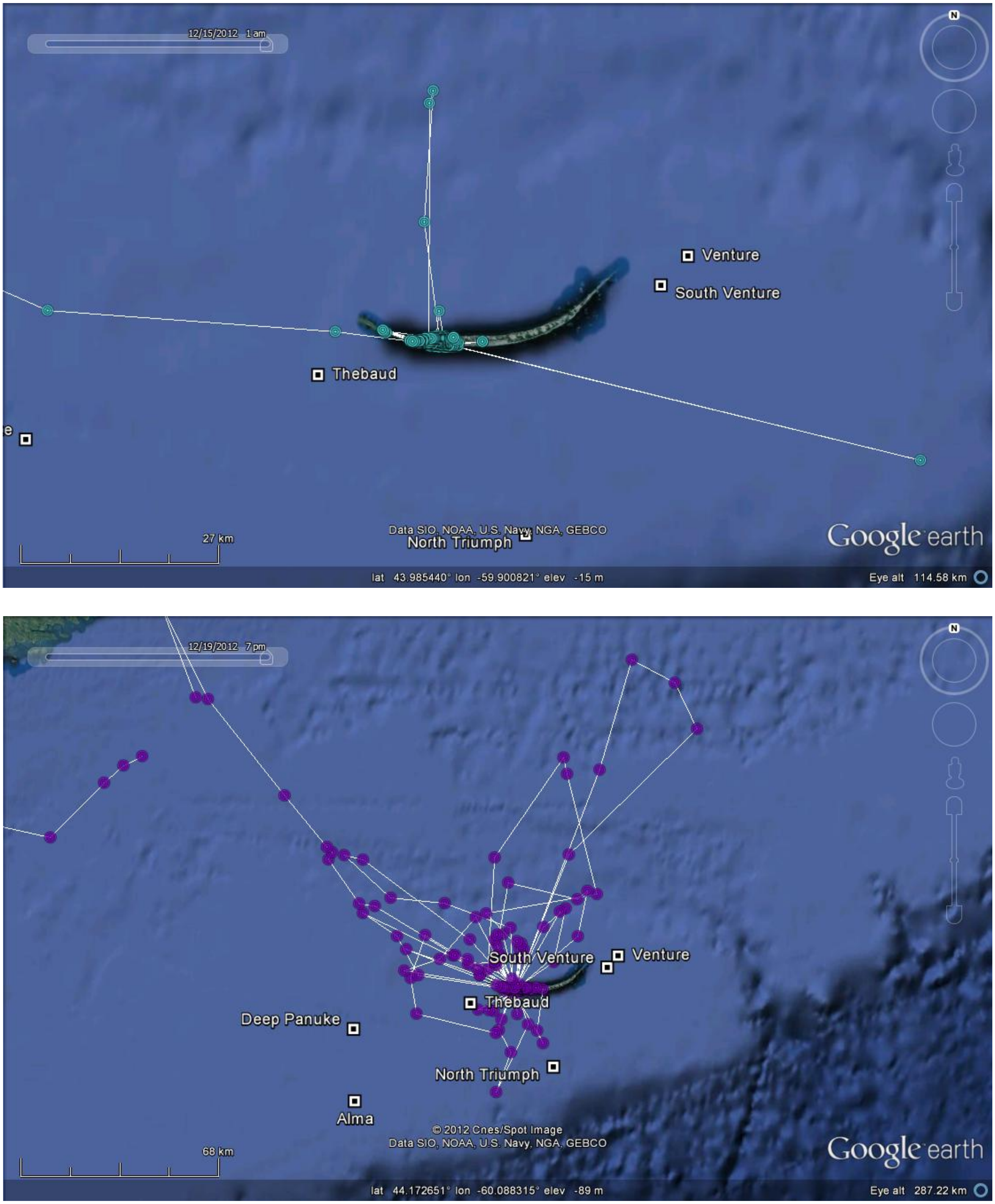

Figure 2 – Satellite tracking data from two Herring Gulls (ID# 115925 and 115928, upper and lower panels respectively) which show contrasting foraging strategies between individuals that remain on Sable Island (upper) and individuals making long-distance, offshore foraging trips offshore (lower).

Two of six birds interacted with the platforms whereby 12 and 6 % of all GPS locations occurred within 200 m of any platform during 298 days of tracking (Table 1, Figure 3). Interactions with platforms were categorize into bird-platform interaction events, defined as a series of consecutive GPS positions occurring with 200 m of a platform, and event duration was calculated from the time between first and last detections in a series. Interaction events are summarized in Table 2. Fifty two events were recorded at four of six platforms: Thebaud (73% of events), Deep Panuke (19%), Alma (6%), and North Triumph (2 %, representing a single event). Thirty-seven percent of the events (19/52) included only a single detection within 200 m of a platform suggesting short interactions (likely < 1 or 2 hrs) or birds passing by. The overall mean event duration was 5.2 h (including events of single locations recorded as 0 hrs): 33% of events were between 1-5 h, 17% between 6-10 h, and 13% were > 10 h. The longest sustained interaction was a 40 h event recorded at the Deep Panuke platform beginning on 28-July. Most interactions occurred from mid July and late August with only two events in September/October (Figure 4).

From satellite telemetry data we can also determine departure dates from the Sable Island area which can help identify seasonal periods when Sable Island gulls will no longer interact with offshore platforms. From five satellite tracked individuals (Table 2, above), departure dates were highly variable including late June (1 individual), August (2), and late October (2). Departures were followed by direct migration to mainland Nova Scotia and eventual migrations to southern Nova Scotia and New Jersey (Figure 5).

Table 2 – Summary 52 gull-platform interaction events recorded by satellite tags from 2 Herring Gulls. An event was defined as a series of consecutive GPS locations occurring within 200 m of a platform. Duration of event was calculated from the first and last time stamp in a series of consecutive detections. When only one detection occurred, the duration was recorded as zero hours.

			Duration of event (h)		**Date of event**		
Platform	**# of events**	**# events with 1 detection**	**Mean**	**Max**	**First**	**Last**	**Mean**
Alma	3	1	10.7	16	9-Jul	11-Aug	29-Jul
Deep Panuke	10	4	11.7	40	19-Jul	9-Aug	29-Jul
Thebaud	38	13	3.2	11	4-Jul	7-Oct	10-Aug
North Triumph	1	1	n/a	0	7-Aug	7-Aug	7-Aug
TOTAL	**52**	19	5.2		4-Jul	7-Oct	7-Aug

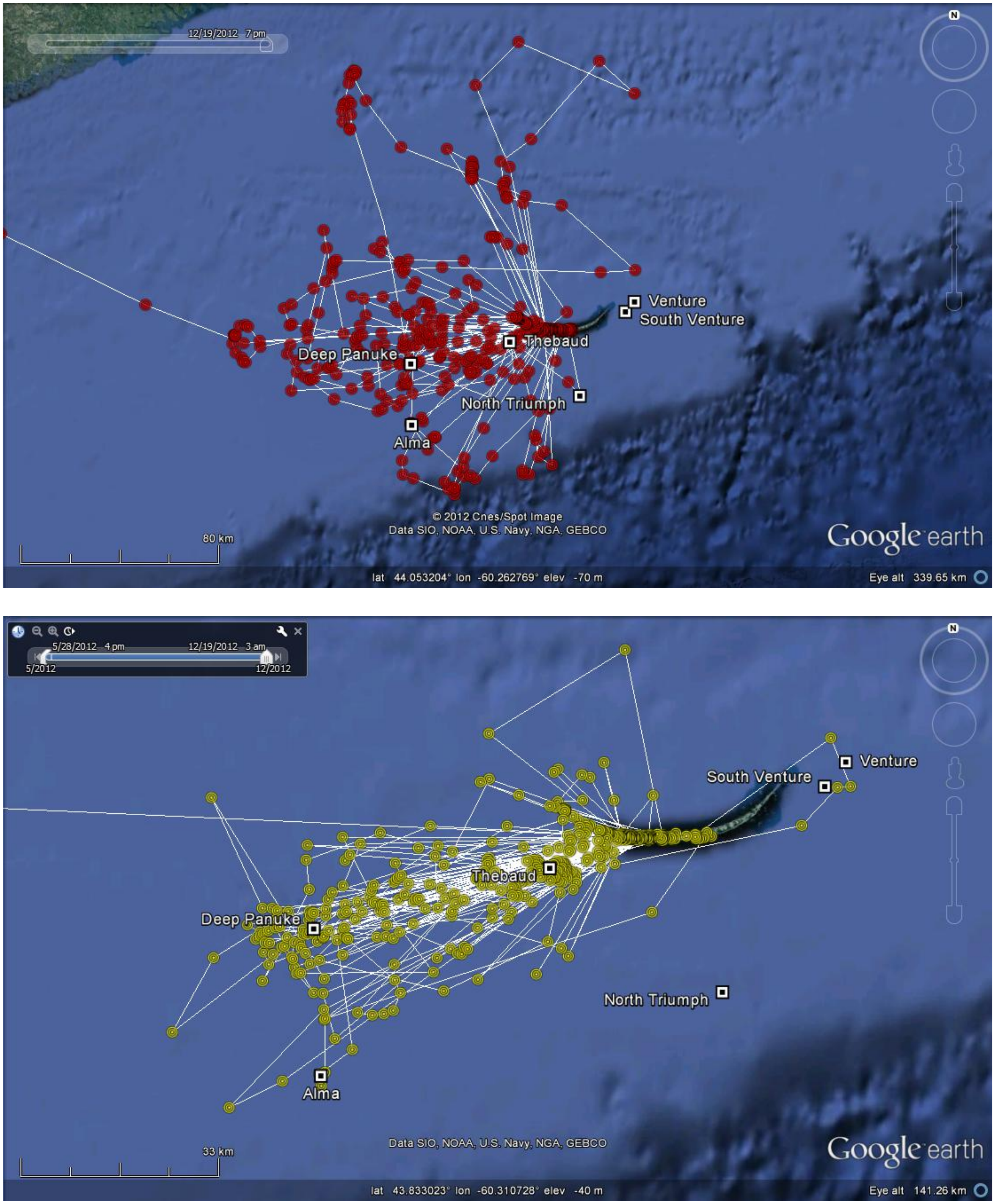

Figure 3 – Tracking data from Herring Gull ID# 115926 (upper panel) and 115930 (lower panel) that showed frequent interactions with offshore platforms around Sable Island.

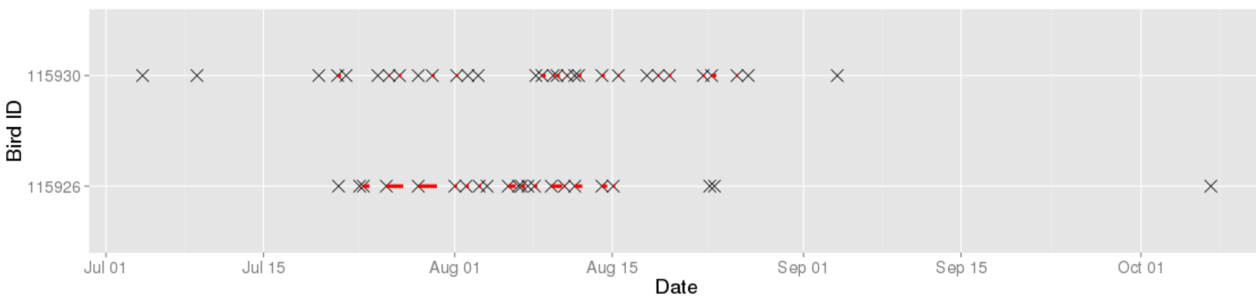

Figure 4 – Timing and duration of gull-platform interaction events recorded by satellite tags deployed on Herring Gulls in 2012. Bird ID refers to satellite tag number (see Table 2 above). An event was defined as a series of consecutive GPS locations occurring within 200 m of a platform. Duration of event was calculated from the first and last time stamp in a series of consecutive detections. "X" indicates start time of events and the red line indicates the duration of the even. An "X" that is not followed by a red line represents a single detection within 200 m of a platform, therefore event < 2h.

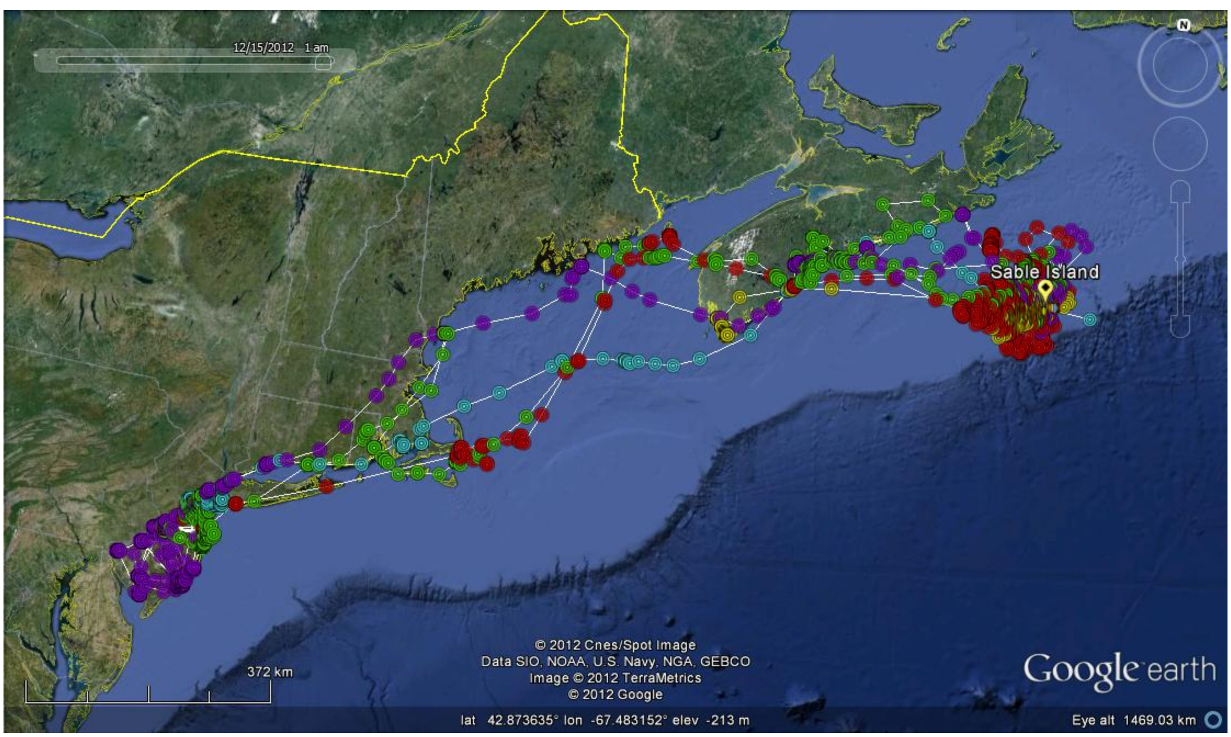

Figure 5 – Satellite tracking data from five Herring Gulls tagged on Sable Island (26-28 May 2012) until 20 December 2012. Migration routes are shown between Sable Island and New Jersey (4 birds) and southern Nova Scotia (1 bird in yellow).

5.2 Gull diets

The primary objectives of this study relating to dietary analysis were to investigate: a) changes in diet since the 1970's; b) quantify contemporary gull diets to identify potential sources of contaminant exposure; and c) provide base-line data for monitoring dietary changes and ecosystem health in the future. This section examines preliminary results of dietary analysis conducted from pellet collection and blood sampling from 2011 and 2012.

Pellet analysis - More than 1300 prey items were identified in Herring and Great Black-backed Gull pellets examined in 2011 and 2012, which were compared to 1500 prey items identified from pellets in 1969 and 1970. Proportions of prey items are presented in Tables 3 and 4 showing changes between the two sampling periods. Largest changes in Herring Gull diet between 1970 and 2011 & 2012 (averaged) was observed in fish, which decreased by 16%, molluscs (+51%), and crab (-15%). Notably seal remains made up 1% of Herring Gull diet in 1970, but increased to 9% and 12% in 2011 and 2012 respectively (Table 3). Largest shifts in Great Black-backed Gull diet from 1969 & 1970 (averaged) to 2011 & 2012 (averaged) included a near absence of tern eggs and chicks, a decline in fish (-19%), and increases in molluscs (20%), crab (15%) and seal remains (29%; Table 4).

*Table 3 - Proportion of food types found in pellets collected from Herring Gull nests during the summers of 1970, 2011 and 2012. Pellets were sampled from 72 and 147 nests in 2011 and 2012 respectively; number of nests sampled in 1970 is unknown. *change in percentage points: ((2011+2012)/2) – 1970*

Year (nests)	**1970**	**2011 (72)**	**2012 (147)**	
Number of pellets	**690**	**539**	**462**	
Food Type	**Proportion**	**Proportion**	**Proportion**	**Change***
Fish	0.21	0.03	0.08	-0.16
Molluscs	0.07	0.80	0.36	0.51
Insects	0.22	0.02	0.17	-0.13
Cancer irroratus	0.27	0.04	0.20	-0.15
Sea cucumber	<0.01	0	0	0
Other crustacea	<0.01	<0.01	0	0
Crandberries & crowberries	0.09	0.01	0.05	-0.07
Leaves	0.01	0	<0.01	0
Pelagic birds	0.04	<0.01	0.01	-0.03
Passerine birds	0.02	0.01	0.01	-0.01
Unidentified birds	0.01	0	<0.01	-0.01
Terns	0.02	0	0	-0.02
Tern eggs	0.01	0	0	-0.01
Gull chicks	0	0	0	0
Gull eggs	0.02	0	0	-0.02
Seal remains	0.01	0.09	0.12	0.10
Garbage	0.01	0	0	-0.01
Seaweed	-	<0.01	<0.01	NA
Horse	-	0	0	NA
Total	1	1	1	

*Table 4 - Proportion of food types in pellets collected from Great Black-backed Gull nests during the summers of 1969, 1970, 2011 and 2012. * change in percentage points: ((2011+2012)/2) - ((1969+1970)/2)*

Year (nests)	**1969**	**1970**	**2011 (20)**	**2012 (36)**	
Number of pellets	**186**	**627**	**143**	**173**	
Food Type	**Proportion**	**Proportion**	**Proportion**	**Proportion**	**Change***
Fish	0.20	0.27	0.06	0.02	-0.19
Molluscs	0.01	0.03	0.29	0.14	0.20
Insects	0	<0.01	0.06	0.03	0.04
Cancer irroratus	0.04	0.14	0.19	0.29	0.15
Sea cucumber	0	0	0	0	0
Other crustacea	0	<0.01	0	0	0
Crandberries & crowberries	0	0.01	0	0	-0.01
Leaves	0	0	0.01	0	0.01
Pelagic birds	0.04	0.15	0.03	0.02	-0.07
Passerine birds	0.01	0.03	0.01	0	-0.02
Unidentified birds	0	0	0	0	0
Terns	0.08	0.12	0.01	0.01	-0.09
Tern eggs	0.53	0.07	0	0	-0.3
Gull chicks	0.01	0.01	0	0	-0.01
Gull eggs	0.01	0.04	0	0	-0.02
Seal remains	0.06	0.12	0.29	0.49	0.29
Garbage	0.02	0.01	0.03	0	0.01
Seaweed	-	-	0	0	NA
Horse	-	-	0.02	0	NA
Total	1	1	**1**	1	

Stable isotope analysis - Overall, general linear models showed significant differences in between gull species in both $\delta^{13}C$ and $\delta^{15}N$ (Table 5). $\delta^{13}C$ signatures were significantly higher for Great Black-backed Gulls than Herring Gulls ($P<0.001$) indicating preferences for different prey types, while the significantly higher $\delta^{15}N$ for Great Black-backed Gulls ($P<0.001$) indicate that Great Black-backed Gulls feed at a higher trophic level. Among Great Black-backed Gull age groups, $\delta^{13}C$ signatures for adults were significantly higher than for chicks ($t=-3.55$, DF= 48, $P<0.001$) indicating that adults are consuming different prey types than they are feeding their chicks. $\delta^{15}N$ signatures for adults were also significantly higher than for chicks ($t=-2.06$, DF= 48, $P<0.05$) indicating adults feed at a higher trophic level than they feed their chicks.

Adult (after third year) and immature (first winter to third year birds) Great Black-backed Gulls did not exhibit significantly different $\delta^{13}C$ and $\delta^{15}N$ signatures ($P=0.65$ and 0.99, respectively, Table 5). $\delta^{15}N$ signatures for adult and immature Great Black-backed Gulls are higher during the breeding season than during the winter (P=0.03) indicating that there is seasonal variation in diet and Great Black-backed Gulls feed at a higher trophic level during the breeding season. In addition, an age by season effect is present for $\delta^{13}C$, adults exhibited a little to no change in $\delta^{13}C$ values from the breeding period to the winter period, however, $\delta^{13}C$ signatures for immature gulls decreased from -18.22 to -18.66, indicating that a seasonal change in their feeding preference from the summer to the winter.

Stable isotope values for potential prey are listed in Table 6. Most species had distinct isotopic signatures which, therefore, could be included in mixing models. However, most of the offshore fish species showed considerable overlap and therefore were grouped together as fish of similar size into the categories 'small fish' and 'medium fish'. Sand lance were not grouped because their $\delta^{15}N$ was distinct from all other fish species. Shrimp and squid were excluded from isotope mixing models because their signatures overlapped with those of other prey but these species are not known to be consumed by gulls.

Stable isotope mixing model Isotope R was used to estimate the contribution of prey items to gull diets. In both years, primary prey items for Herring Gulls were crab (46-60%), sand lance (31-33%) and amphipods (5-11%; *Gammarus*). All other prey items made up < 1% of estimated diets except for clams (2% in 2011 and 6% in 2012). For all age classes and both seasons, primary prey items for Great Black-backed Gulls included crab (27-66%), seal (16-38%), and medium sized offshore fish (1-33%). However, chicks and post-fledging juveniles (samples in August) show much more variability in their diet estimates and tended to include more fish and less crab.

Table 5 - Stable isotope values for adult, chick, juvenile and immature age classes of Herring and Great Black-backed Gulls during winter and breeding seasons

Species	**Season**	**Age**	**n**	**$\delta^{13}C$ (SD)**	**$\delta^{15}N$ (SD)**
Herring Gull	Breeding	Adult	47	-19.27 (0.62)	14.31 (0.86)
Great Black-backed Gull	Breeding	Chick	10	-18.72 (0.38)	16.01 (0.53)
		Juvenile	6	-18.56 (0.22)	16.97 (0.57)
		Immature	5	-18.22 (0.61)	16.38 (1.28)
		Adult	20	-18.11 (0.32)	16.93 (0.62)
	Winter	Immature	4	-18.66 (1.15)	16.16 (2.95)
		Adult	7	-18.15 (0.12)	16.34 (0.63)
Great Black-backed Gull	All	All	51	-18.31 (0.40)	16.63 (0.75)

Table 6 - Stable isotope values of prey samples (SD). Grouping for mixing models indicates the prey types that were grouped together for mixing models; a = small offshore fish, b = medium offshore fish, c = all ages of seals combined. Sshrimp and squid were excluded from the mixing model.

Species	**n**	**mass (g)**	**length (mm)**	**δ^{13}C (SD)**	**δ^{15}N (SD)**	**C/N ratio**	**Grouping for mixing models**
Grub	4	0.84 (0.2)	NA	-25.17 (0.2)	12.12 (0.8)	3.4	
Junebug	3	0.70 (0.1)	NA	-24.17 (0.6)	4.41 (2.5)	3.26	
Ninespine stickleback	4	0.59 (0.2)	45 (3.7)	-23.31 (0.2)	15.86 (0.42)	3.33	
Gammerus	5	0.07 (0.05)	NA	-22.98 (1.0)	9.22 (1.15)	4.01	
Clams	3	NA	NA	-19.60 (0.2)	9.66 (0.4)	3.74	
Rock crab	6	110.53 (30.3)	94 (10.7)	-17.95 (0.3)	12.24 (0.6)	3.34	
Shrimp	4	9.99 (2.2)	NA	-18.2 (0.3)	12.41 (0.2)	3.13	excl
Squid	5	81.39 (17.8)	158 (11.6)	-19.38 (0.3)	11.92 (0.2)	3.19	excl
Sand lance	14	7.76 (7.5)	126 (53.5)	-19.78 (0.5)	11.11 (0.3)	3.09	
Capelin - small	2	3.52 (0.8)	86	-20.47 (0.2)	12.15 (0.3)	3.12	a
Capelin - large	3	14.01 (1.3)	137	-19.57 (0.1)	12.80 (0.1)	3.15	b
Haddock - small	3	38.53 (3.6)	133 (11.3)	-20.35 (0.2)	13.01 (0.2)	3.17	a
Haddock - medium	2	86.11 (20.8)	210 (19.8)	-18.99 (0.2)	13.39 (0.3)	3.19	b
Herring	4	159.67 (53.8)	240 (23.5)	-19.39 (0.2)	12.51 (0.2)	3.39	b
Mackerel	4	140.04 (14.3)	243 (4.5)	-19.5 (0.2)	6.67 (0.2)	3.11	b
Longhorned sculpin	4	233.07 (188.7)	254 (70.4)	-18.39 (0.4)	14.32 (0.7)	3.3	b
Grey seal - pups	4	NA	NA	-18.35 (1.0)	16.93 (0.2)	3.3	c
Grey seal - adults	5	NA	NA	-17.99 (0.7)	16.68 (0.6)	3.13	c

Table 7 - Model estimates of the contribution of prey items in the diets of Herring Gull diets during two breeding periods on Sable Island. Proportion of diet composition estimated using a Bayesian mixing model. IsotopeR outputs of the mean (standard deviation) and minimum (2.5th) and maximum (97.5th) percentiles are shown. Top 3 prey items are highlighted.

	Summer 2011			**Summer 2012**		
	Mean (SD)	**Min**	**Max**	**Mean (SD)**	**Min**	**Max**
Clam	0.02 (0.03)	0	0.1	0.06 (0.09)	0	0.27
Crab	0.60 (0.17)	0.28	0.82	0.46 (0.31)	0	0.76
Gammarus	0.05 (0.08)	0	0.19	0.11 (0.09)	0	0.28
Grub	0	0	0	0	0	0.03
Junebug	0.01 (0.01)	0	0.04	0.01 (0.01)	0	0.04
Medium fish	0.01 (0.02)	0	0.06	0	0	0
Ninespine Stickleback	0	0	0	0.01 (0.01)	0	0.04
Sandlance	0.31 (0.25)	0	0.72	0.33 (0.45)	0	1
Seal	0.01 (0.01)	0	0.05	0.01 (0.01)	0	0.03
Small fish	0	0	0.01	0.01 (0.02)	0	0.04

Table 8 - Model estimates of the contribution of prey items in the diets of Great Black-backed Gulls for different age classes and seasons on Sable Island. Proportion of diet composition estimated using a Bayesian mixing model. IsotopeR outputs of the mean (standard deviation) and minimum (2.5th) and maximum (97.5th) percentiles are shown. Top 3 prey items are highlighted.

	Adult/Immature Summer				**Adult/Immature Winter**				**Juvenile post-fledging**				**Chick summer**			
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**
Clam	0.01	0.01	0	0.04	0	0.01	0	0.03	0	0.01	0	0.02	0.01	0.01	0	0.03
Crab	0.61	0.05	0.52	0.71	0.66	0.09	0.49	0.83	0.27	0.21	0	0.56	0.36	0.28	0	0.74
Gammarus	0	0	0	0	0	0.01	0	0.02	0	0	0	0.01	0.01	0.02	0	0.08
Grub	0.01	0.01	0	0.02	-	-	-	-	0	0	0	0	0.02	0.03	0	0.09
Junebug	0	0	0	0.01	-	-	-	-	0	0	0	0.01	0	0	0	0
Medium fish	0.01	0.01	0	0.03	0.06	0.05	0.01	0.17	0.29	0.28	0	0.72	0.33	0.48	0	1
Ninespine Stickleback	0	0	0	0.01	-	-	-	-	0.01	0.03	0	0.07	0	0	0	0.01
Sandlance	0.01	0.01	0	0.03	0	0.01	0	0.01	0	0	0	0	0.08	0.09	0	0.29
Seal	0.35	0.06	0.22	0.45	0.27	0.07	0.13	0.38	0.38	0.08	0.24	0.52	0.16	0.13	0	0.35
Small fish	0	0	0	0	0	0	0	0.01	0.04	0.07	0	0.2	0.02	0.03	0	0.1

6. Discussion and Recommendations

6.1 Foraging and platform interactions

Movement patterns identified from a small set of satellite tagged Herring Gulls (n = 6) showed high individual variability in foraging strategies. Two individuals foraged exclusively on Sable Island, suggesting that ample food supply exists from terrestrial sources or scavenging on beach litter. Another two individuals conducted multiple foraging trips to the north of Sable Island where they foraged on some of the offshore banks, including Middle Bank and Misaine Bank, which are foraging areas used by Grey Seals from Sable Island (Breed et al. 2009). The remaining two birds foraged frequently south-west of Sable Island in areas surrounding offshore natural gas platforms.

Analysis of the two tagged gulls which showed interactions with platforms revealed the timing, frequency and duration of gull-platform interactions. Most interactions occurred in July/August and less frequent interactions through September and October. These patterns are in general agreement with other tracking methods (VHF tags and reports of coloured wing-bands) used by our group in 2011 and 2012. From the time of tag deployments to their departures from the Sable area in late October, these individuals spent 6 and 12% of their time within 200 m of offshore platforms. These time budgets include time on Sable Island when gulls could be incubating eggs, feeding young, and/or roosting, therefore these percentages under represent the total proportion of at-sea foraging that was associated with platforms.

Satellite tracked Herring Gulls also provide additional detailed information on the characteristics of bird-platform interactions. First, based on the time-stamps from obtained GPS locations, we observed that most gull-platform interactions were brief (37% of 52 platform interaction events included only a single location within 200 m of a platform), but some events are long (13% > 10 h) and the longest series of detections near a platform was 40 h. Next step will be to investigate the time of day and environmental conditions surrounding these platform events to better understand the factors the promote gull-platform interactions. Second, because GPS tags track birds anywhere, we can quantify the spatial-temporal patterns of gull interactions with all platforms in the area. Data reveal that most of the 52 interaction events occurred at one platform (Thebaud – 73%), which is the closest platform to Sable Island, followed by the Deep Panuke (19% of events). These are the only two manned platforms in the region, suggesting that human presence (both platforms) and proximity to the breeding colony (Thebaud) influence gull-platform interactions. However, these patterns also differ between individual birds, suggesting individual preferences for habitat use (Table 1). Gull 115926 had 139 locations within 200 m of platforms, which included 53, 30, 21, and <1% near Deep Panuke, Thebaud, Alma and North Triumph, respectively. In contrast, gull 115930 had 72 locations within 200 m of platforms, which included 7, 92, and 1% near Deep Panuke, Thebaud, and Alma. Thus, the behaviour of individual birds must be taken into account when understanding and managing gull-platform interactions, rather than population level management.

Together, wing-tag resightings, colony based-VHF monitoring (Ronconi and Taylor 2012), and satellite tracking (this report) reveal a wide range in timing of colony departure for both species of gulls. Satellite tags showed Herring Gull departures from the Sable area ranging from 26 Jun to 28 Oct. Likewise with Great Black-backed Gulls, the first report of wing-tagged gull away from the colony was on 25 June when it was seen from a US oceanographic vessel in the Gulf of Maine, which suggests a long-distance dispersal away from Sable immediately after breeding. VHF monitoring at the colony suggests most gulls depart in the second half of July and mainland sightings of both HERG and GBBG increased in Aug and early September. By November wing-tagged GBBG were seen in Maine and wing-tagged HERG in Massachusetts. Together these resighting reports and tracking data, along with data from 2011 (Ronconi and Taylor 2012), suggest a) colony departures in mid July correspond with periods of platform attendance by gulls, b) both HERG and GBBG typically arrive on the mainland sometime in August/September, though some much later, and c) HERG move further south for the winter than do GBBG.

Satellite tracking of Herring Gulls also revealed migration routes through Nova Scotia and Cape Cod, MA, to wintering locations along coastal and inland areas of New Jersey. All 5 individuals tracked to their wintering grounds are foraging and roosting in areas with 125 km of each other, suggesting a very limited wintering range for this population, despite dramatically different foraging strategies in the summer and differential timing in colony departure.

One of the conservation and management concerns for the Sable Island Herring Gull population is the high levels of contaminants found in their eggs (Burgess et al. 2013, Chen et al. 2012, Gebbink et al. 2011). Through satellite telemetry we can identify foraging areas during the breeding season and over wintering areas where they might accumulate such contaminants. Because of the individual variability in breeding season foraging areas but similarity over-winter sites, examination of the variability in contaminants among eggs of individuals may shed insight into sources of contaminants. If egg contaminants are highly variable among individuals, then this provides evidence for contaminant sources being derived from variability in breeding season foraging areas. Conversely, if egg contaminants are similar among individuals, this provides evidence of common wintering ground origins for contaminant sources. The most direct link, however, between contaminant exposure and birds movements is likely to be inferred from foraging areas identified in the month prior to egg laying, a period for which we do not yet have tracking data.

6.2 Dietary shifts in gull diets

Pellet sampling is a non-invasive method to determine prey sources by enumerating undigested parts of prey that have been regurgitated by gulls, however, it is generally biased towards hard tissues, such as bone and shells, only the most recent meals, and only those items eaten around nesting and loafing sites (Weiser and Powell 2011). Nevertheless, these biases will remain consistent and therefore pellet sampling may be a simple way to assess dietary changes over time. Comparison of contemporary pellet analysis with historical surveys in 1969/1970, revealed some noticeable changes in the prey composition for both Herring Gulls (HERG) and Great Black-backed Gulls (GBBG). The proportion of molluscs was the most noticeable increase of prey items for both HERG and GBBG. Lock (1973) referred to this category of prey as “lamellibranch molluscs” which are bivalves including clams and mussels. Though Lock did not indicate which type of molluscs were encountered, roughly >95% of the molluscs counted in 2011/2012 were fragments of clam shells that were regurgitated in mall piles; we counted only piles of regurgitated shells, therefore underestimating the numerical frequency of this prey item. Proportion of fish in diets declined for both gull species while proportion of crabs increased for GBBG but decreased for HERG. On Sable, clam shells and dead crabs frequently wash up in the surf after storm, and increased reliance on these prey sources, coupled with a decline in fish in their diets, suggests that coastal scavenging, rather than offshore foraging may be a dominant source of prey for Sable Island gulls. Tracking data support this.

Another large shift in proportion of pellet items was an increase in seal remains for both Herring Gulls (10% increase from 1% historical) and Great Black-backed Gulls (29% increase from 6 to 12 % historical). This is not surprising given the exponential increase of the Sable Island grey seal population since the 1970's. Lock (1973) attributed the seal consumption of the 1969-1970 period to scavenging on the carcasses and placenta of harbour seals (*Phoca vitulina*) born on Sable in May and June. The harbour seal population of Sable Island has nearly disappeared since then and has been replaced with the largest grey seal colony in the world. Although grey seals give birth in December and January, providing ample scavenging opportunities for wintering Great Black-backed Gulls, these animals return to Sable in May and June when they moult annually. During this time gulls, and Great Black-backed Gulls in particular, are frequently observed scavenging on carcasses of seals washed up on the beach, presumably injured by sharks. Therefore, even outside of the pupping season, seals seem to provide an important food source for Sable Island gulls. Rich in proteins and fats, seal carcasses may be a preferred food source which the larger Great Black-backed Gulls out compete the smaller Herring Gulls for access to. While using noose carpets to catch gulls at carcasses, we captured only 1 Herring Gull during nearly 30 captures of Great Black-backed Gulls.

One additional shift in diet that was small but noteworthy is the decline in proportion of terns and tern eggs in the pellets of both gull species. Although Herring Gulls rarely consumed terns or their eggs, Lock (1973) suggested that Sable Island tern colonies were "heavily preyed upon" by Great Black-backed Gulls and that this may have been a factor in declining populations over the previous fifty years. In 2011 and 2012, we found no tern remains in Herring Gull pellets and only 4 pellets containing terns from 2 Great Black-backed Gull nests (1 nest in each study year). In 1969, Lock (1973) recorded tern eggs as 53% of all pellet items for Great Black-backed Gulls, but also notes that 2/3 of the tern eggs were from a single nest, suggesting tern predation by a specialist rather than colony wide predation. We found no tern eggshells in pellets. Tern populations have since increased on the island and low occurrence of terns as prey items for gulls suggests that gull predation is not a likely factor influencing terns. Increased availability of seal carcasses on the island may have reduced Great Black-back Gull reliance on terns as a food source.

Without historical blood samples from Sable Island gulls, it is not possible to determine dietary shifts from stable isotope signatures. Throughout Atlantic Canada, Farmer and Leonard (2011) observed a significant decline in feather stable isotope signatures of Great Black-backed Gulls over 110 years, which began at a mean $\delta^{15}N$ of 17.80 in 1896 and ended at a mean of 15.54 in 2006. This decline was correlated with long-term declines in ground fish landings in Atlantic Canada, suggesting that gulls, as generalist predators, are acting as ecological indicators of changing food availability in this region. In our study, mean stable isotope signatures of breeding Great Black-backed Gulls on Sable was 16.93, suggesting a relatively high trophic level position for this population when compared with the rest of Atlantic Canada. This may again be a result of increased reliance on seal carcasses for Sable Island gulls.

Stable isotope analysis of blood samples, which represent assimilated diet from the previous 2 weeks, support some but not all of the results of pellet analysis. First of all, the higher $\delta^{15}N$ signatures of GBBG compared to HERG, suggest foraging at a higher trophic level, in this case likely related to the higher proportion of seal in GBBG diets compare to HERG diets (pellets and isotopic mixing models). Neither species showed high proportions of medium sized offshore fish in adult gull diets, also in agreement with low rates of fish remains identified in pellets. Mixing models results for Herring Gulls, however, identified sand lance as the second most important prey source (~32% of diet). We observed Herring Gulls foraging at the tips of the island where we also collected sand lance by hand in the shallow surf. Sand lance are small and easily digestible prey, compared to other fish species, and therefore hard parts may not be regurgitated in pellets.

For many of the invertebrate prey items, mixing models estimates of prey consumption differed from proportions in pellet analyses. Mixing models estimated very low contribution of clams to Herring Gull (<6%) and Great Black-backed Gull (<1%) diets compared to pellets (14-29% for GBBG and 36-80% for HERG). This is likely a typical example of bias associated with indigestible hard parts occurring more frequently in pellet analyses than are actually assimilated by predators. Conversely, crabs, whose hard parts are also indigestible, were at higher occurrence in mixing model estimates than in pellets, possibly because internal organs of crabs were consumed away from nest sites, thus limiting the number of crab carapaces and claws found around nesting areas. Mixing models also identified amphipods (i.e. *Gammarus sp.*) as a relatively common prey item for Herring Gulls (5-11% of diet). We observed Herring Gulls feeding on amphipods along shorelines and dunes; the digestibility of these invertebrates would make them undetectable in pellets. Junebugs, however, are the primary terrestrial insect frequently documented in gull pellets on Sable, which are easily identified by carapace fragments. Mixing models estimate < 1% occurrence of junebugs in Herring Gull diets, possibly due to the timing of sampling since blood (isotope) samples were collected throughout May and June, reflecting diet from the previous weeks, whereas junebugs were only emerging during the last 5-10 days of the field studies. Together, these discrepancies identify some important biases in dietary sampling of invertebrates from regurgitated pellets.

Together, the results of pellet analysis and isotopic mixing models present a picture of changing dietary regimes for Sable Island gull populations since 1970. Pellet enumeration showed an increased occurrence of molluscs and seals, and decline in fish, in diets of both gull species. Mixing models suggest different diets between gull species with both reliant heavily on rock crabs but Great Black-backed Gulls consuming more seal remains and Herring Gulls eating more sand lance. This identified prey types which may be contributing to contaminant loads observed in Herring Gull eggs, though contaminants have not yet been examined in Great Black-backed Gull eggs. Both pellet and isotopic analysis of gull blood samples may provide tools for long-term monitoring of gull diets, complimentary analysis to contaminant sampling, and broad scale indices of marine ecosystem changes around Sable Island

7. Summary of expenditures

Summary of project expenditures and expenses paid from Habitat Conservation (HC) Fund grant.

Item	HC Funds	Other Cash	In Kind	Vouchers
Human Resources	0	27,900	0	Rob Ronconi's pay from account 41-0-205305-6352120
Travel & Field				
food/accom.***	0	0	0	***requested permission to remove from budget - granted
travel sable	0	$12,000	0	Maritime Air B0001824 **- v0504641, v0505811, v0506394, v0507972**
Material & Supplies				
satellite tags	7500	22500	0	Microwave telemetry: **v0506979**, Livingston, **v0507151** + **v0504061**,
tracking fees***	0	2400	0	***request reduction in budget - granted: CLS America B0001779 see voucher #s below
isotope analysis	2325	0	0	U of Waterloo: **v0513585, v0513584**
misc. supplies	175			ZoeCrysler first aid supplies for sable **v0506917**
Administration				
Acadia Mgmt Fee	0	0	2000	
	10000	64800	2000	Project total = $76,800

CLS America Voucher Numbers: **v0504792, v0506131, v0506895, v0507828, v0509236, v0510550, v0512763**

8. Literature Cited

Baird, P.H., 1990. Concentrations of seabirds at oil-drilling rigs. Condor 92, 768-771.

Bowen, W.D., McMillan, J.I., and Mohn, R. 2003. Sustained exponential population growth of the grey seal on Sable Island. ICES Journal of Marine Science 60: 1265-1374.

Boyne, A.W., Beukens, J.T., 2004. Census of gulls and other seabirds along the coast of mainland Nova Scotia—2002. Canadian Wildlife Service, Atlantic Region. Technical Report Series 409.

Breed, G.A., I.D. Jonsen, R.A. Myers, W.D. Bowen, M.L. Leonard (2009) Sex-specific, seasonal foraging tactics of adult grey seals (*Halichoerus grypus*) revealed by state-space analysis. Ecology 90: 3209-3221.

Burgess, N.M., Bond A.L., Hebert C.E., Neugebauer E., Champoux L. 2013. Mercury trends in herring gull (*Larus argentatus*) eggs from Atlantic Canada, 1972-2008: temporal change or dietary shift? Environmental Pollution 172: 216-222.

Chen, D. R.J. Letcher, N.M. Burgess, L. Champoux, J.E. Elliott, C.E. Hebert, P. Martin, M. Wayland, D.V.C. Weseloh, L. Wilson, 2012. Flame retardants in eggs of four gull species (Laridae) from breeding sites spanning Atlantic to Pacific Canada. Environmental Pollution 168: 1-9.

COSEWIC, 2009. COSEWIC assessment and update status report on the Roseate Tern *Sterna dougallii* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 48 pp. (www.sararegistry.gc.ca/status/status_e.cfm).

Farmer, R.G., Leonard, M.L., 2011. Long-term feeding ecology of Great Black-backed Gulls (*Larus marinus*) in the northwest Atlantic: 110 years of feather isotope data. Canadian Journal of Zoology-Revue Canadienne De Zoologie 89, 123-133.

Gauthier, L.T., Potter, D., Hebert, C.E., Letcher, R.J., 2009. Temporal trends and spatial distribution of Non-polybrominated Diphenyl Ether flame retardants in the eggs of colonial populations of Great Lakes Herring Gulls. Environmental Science & Technology 43, 312-317.

Gebbink, W.A., Letcher, R.J., Burgess, N.M., Champoux, L., Elliott, J.E., Hebert, C.E., Martin, P., Wayland, M., Weseloh, D.V.C., Wilson, L., 2011. Perfluoroalkyl carboxylates and sulfonates and precursors in relation to dietary source tracers in the eggs of four species of gulls (Larids) from breeding sites spanning Atlantic to Pacific Canada. Environment International 37, 1175-1182.

Hebert, C.E., Weseloh, D.V.C., Idrissi, A., Arts, M.T., Roseman, E., 2009. Diets of aquatic birds reflect changes in the Lake Huron ecosystem. Aquatic Ecosystem Health & Management 12, 37-44.

Huettmann, F., Diamond, A.W., 2000. Seabird migration in the Canadian northwest Atlantic Ocean: moulting locations and movement patterns of immature birds. Canadian Journal of Zoology-Revue Canadienne De Zoologie 78, 624-647.

Lock, A.R., 1973. The breeding biology of two species of gulls on Sable Island, Nova Scotia. PhD Thesis. Dalhousie University, Halifax, NS, Canada.

Mallory, M.L., Gilbert, C.D., 2008. Leg-loop harness design for attaching external transmitters to seabirds. Marine Ornithology 36, 183–188.

Mallory, M.L., Robinson, S.A., Hebert, C.E., Forbes, M.R., 2010. Seabirds as indicators of aquatic ecosystem conditions: A case for gathering multiple proxies of seabird health. Marine Pollution Bulletin 60, 7-12.

McLaren, I.A., 1981. The birds of Sable Island, Nova Scotia. Proceedings of the Nova Scotia Institute of Science 31, 1-84.

Phillips, D.L., Gregg, J.W., 2003. Source partitioning using stable isotopes: coping with too many sources. Oecologia 136, 261-269.

Steenweg, R.J., Ronconi, R.A., Leonard, M.L., 2011. Seasonal and age-dependent dietary partitioning between the Great Black-backed and Herring Gulls. Condor 113, 795-805.

Tasker, M.L., Jones, P.H., Blake, B.F., Dixon, T.J., Wallis, A.W., 1986. Seabird associations with oil production platforms in the North Sea. Ringing & Migration 7, 7-14.