

Foraging Ecology of Great Black-backed and Herring Gulls on Kent Island in the Bay of Fundy

By

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TABLE OF CONTENTS

ABSTRACT	3
1. INTRODUCTION	4
2. LITERATURE REVIEW	7
2.1 General biology and reproduction	7
2.2 Composition of adult and chick gull diets - changes over the breeding season	8
2.3 General similarities and differences between gull species	9
2.4 Predation on Common Eider Ducklings	10
2.5 Techniques	10
3. MATERIALS AND METHODS	13
3.1 Study site and species	13
3.2 Lab Methods	16
3.3 Data Analysis	17
4. RESULTS	18
4.1 Pellet and regurgitate samples	19
4.2 Stable isotope analysis	21
4.3 Estimates of diet	25
5. DISCUSSION	26
5.1 Main components of diet	26
5.2 Differences between species and age classes	28
5.3 Variability between breeding stages	30
5.4 Seasonal trends in diet	32
5.5 Discrepancy between plasma and red blood cell stable isotope signatures	32
6. CONCLUSION, LIMITATIONS AND RECOMMENDATIONS	33
ACKNOWLEDGMENTS	35
REFERENCES	36

ABSTRACT

I studied the foraging ecology of the generalist predators Great Black-backed (*Larusmarinus*) and Herring (*Larusargentatus*) Gulls on Kent Island, in the Bay of Fundy. To study diet, I collected pellets casted in and around nests supplemented with tissue samples (red blood cells, plasma, head feathers and primary feathers) obtained from chicks and adults for stable isotope analysis. I collected 51 pellets from Herring Gulls and 31 from Great Black-backed Gulls. 12 adult and 12 chick Great Black-backed and 38 adult and 12 chick Herring Gulls were captured and sampled. Pellets indicated that Herring Gulls predominantly feed on fish and crab and Great Black-backed Gulls on crab and fish. There were consistent differences in isotopic signatures between species, age and tissue types. All of the adult Great Black-backed Gull $\delta^{15}\text{N}$ levels were higher than for adult Herring Gulls. Adults of both species also had higher $\delta^{15}\text{N}$ levels than the chicks and Great Black-backed Gull chicks were higher than Herring Gull chicks. Thus Great Black-backed Gulls feed at a higher trophic level than Herring Gulls and adults at a higher trophic level than the chicks. Adult Great Black-backed Gulls had higher $\delta^{13}\text{C}$ levels than Herring Gulls for compact red blood cells and primary feathers. Herring Gull $\delta^{13}\text{C}$ levels decreased over the May and June, but no significant change was seen in $\delta^{15}\text{N}$ levels. Adults of both species were estimated to feed their chicks more krill and mackerel than they feed on themselves. Given their broad diet and reliance of fisheries offal, gulls were determined to be more suited towards monitoring for pollutants in the marine environment.

1. INTRODUCTION

The Bay of Fundy is one of the most important marine ecosystems in the Maritimes. It supports many breeding seabird colonies (Ronconi and Wong 2003), non-breeding populations of migratory seabirds (Brown et al. 1981), internationally significant stop over for shorebird-migrations (Hamilton et al. 2003) and important foraging sites for marine mammals (Read and Westgate 1997). Moreover, the Bay of Fundy supports several important commercial fisheries including traditional lobster and herring fisheries and more recently numerous salmon farms around Grand Manan. The Bay of Fundy Atlantic herring (*Clupeaharengus*) fishery is the largest in the western Atlantic (Stephenson et al. 1992). Due to its important wildlife habitat and significant socio-economic value it is important to develop tools to monitor the health of the Bay of Fundy ecosystem (Wells 2003).

Seabird diets can be used as bio indicators to monitor the health of marine environments (Furness et al. 1997, Piatt et al. 2007) including fluctuations in fish stocks (Cairns 1987). Gulls (family *Laridae*) are among the top avian predators in many marine and aquatic ecosystems, and long-term studies of gulls have been successfully used to monitor environmental pollutants (Fox et al. 1998, Gauthier et al. 2008) as well as changes in prey fish abundance (Hebert et al. 2009). Thus information on seasonal and annual changes in gull diets may be valuable tools for to ecosystem monitoring. Monitoring changes in diet over time can indicate changes in the health of the ecosystem. Changes in the availability of prey can reflect changes in the ecosystem due to over fishing, pollutants or other physical changes (Diamond and Devlin 2003).

Gulls are the most abundant and conspicuous breeding seabirds in the Bay of Fundy and elsewhere in the Maritimes (Diamond and Devlin 2003, Gilliland et al. 2004) thus, they may be used to monitor the health of the Bay of Fundy ecosystem. Herring Gull populations have decreased since 1979, likely due to changes in reliance on fishery discards and closing of open

landfills (Robertson et al. 2001, Kakela et al. 2005). In 2001 there were an estimated 11 809 Herring Gull (*Larus argentatus*) and 602 Great Black-backed Gull (*Larus marinus*) breeding pairs in the Grand Manan Archipelago in the Bay of Fundy (Ronconi and Wong 2003). Successful use of gulls as bio indicators requires baseline information on gull diets, factors that influence variability, and differences in diet among species.

Great Black-backed and Herring Gulls are generalist predators. Both species predominantly feed on fish, fishery offal, marine invertebrates, other birds and refuse (Pierotti and Annett 1987, Rome and Ellis, 2004, Gilliland et al. 2004, Ewins et al. 1994). Great Black-backed Gulls prey on more fish and terrestrial prey while Herring Gulls prey on more crab and other marine invertebrates (Rome and Ellis 2004). In addition, one of the many sources of food for gulls in the Bay of Fundy are Common Eider ducklings (*Somateria mollissima*) (Gilliland et al. 2004, Mawhinney and Diamond 1999). It is widely thought that Great Black-backed Gulls depredate eiders more frequently than Herring Gulls since Great Black-backed Gulls are typically the dominant bird in nesting colonies (Good 1998).

As generalist predators, gulls exhibit a great deal of flexibility in dietary choices, which may change on a seasonal or annual basis, and differ among species (McLellan and Shutland 2009). There are several possible patterns that may explain changes in feeding preferences throughout different breeding stages. There may be a difference between what the gulls are feeding their chicks and what they are keeping for themselves. Gulls may reserve the items with the greater amount of energy to feed to their broods or selectively forage for items after their chicks have hatched (Annett and Pierotti 1989, Garthe et al. 1999). Another possibility is that gulls may forage for higher energy food sources during the pre-breeding season to develop energy stores to serve them through incubation (Lindsay and Meathrel 2008, Hario et al. 1991).

There may be a difference between male and female diets during this stage, as females must have more energy in order to produce the eggs for laying (Houston et al. 1983).

In this study I assessed the interspecific differences in diet among Herring Gulls and Great Black-backed Gulls, changes in diet within the breeding season, and comparison of breeding vs. non-breeding diets. Two methods were used to assess gull diets. First, pellet analysis, is a technique where regurgitated pellets of hard indigestible tissues from prey were gathered from nests both weekly and opportunistically. While pellet analysis is valuable as it is a non-invasive method to assess diet, it has an associated bias towards indigestible, identifiable parts. This method also does not account for prey eaten away from the nest. The second, stable isotope analysis of tissues, is a technique where isotopes from body tissues, including head feathers, newly grown primary feathers, plasma and red blood cells are used to identify the trophic level at which a species is feeding and the species consumed. Stable isotope analysis of $\delta^{15}\text{N}$ can indicate trophic level while $\delta^{13}\text{C}$ can indicate inshore or offshore breeding habits as well as marine vs. terrestrial preferences (Hobson, 1994, Hobson and Wassenaar, 1999, Knoff et al. 2002). With these two measures it is possible to model the contribution of different prey items in animal diets (Phillips and Gregg, 2003).

The goal of this study is to describe the diets of nesting Great Black-backed and Herring Gulls on Kent Island in the Bay of Fundy. Specifically, I used stable isotope analyses and analyses of regurgitated food pellets to address three main questions: 1) describe the main components of Herring Gull and Great Black-backed Gull diets; 2) examine differences in diet among species and age classes (adults vs. chicks); and 3) investigate the variability within and among different breeding stages (non-breeding, incubating and hatching). In addition, this study will be using both pellets and isotopes to assess diet so it will be possible to look at biases

associated with these approaches. As a result, recommendations can be made for dietary sampling in the future if gulls will be used as indicator species.

2. LITERATURE REVIEW

2.1 General biology and reproduction

The Herring Gull's breeding range extends from Alaska to Newfoundland and southwards until South Carolina as well as around the Great Lakes. They also breed in Europe and Central Asia. They overwinter throughout their breeding range and along the east and west coasts of North America extending to south Panama (Pierotti and Good 1994). Herring Gulls are monogamous and often mate for life (Tinbergen 1960). Both sexes build the nest, incubate eggs and feed offspring. Eggs are laid mid to end of May, are incubated for 30 days and chicks fledge at 6-7 weeks (Pierotti and Good, 1994, Drent 1970).

The Great Black-backed Gull breeds along the east coast of North America from Newfoundland and Baffin Island until as far south as North Carolina, around the Great Lakes and in Northern Europe. They overwinter in their breeding range and as far south as South Carolina (Good 1998). Great Black-backed Gulls are also monogamous and mate for multiple seasons (Good 1998, Cramp and Simmons 1983). Like Herring Gulls, both sexes are involved in nest building, incubate eggs and feed offspring. However, eggs are laid earlier than Herring Gulls in late April and Early May. Eggs are incubated for 30 days and chicks fledge at 6-7 weeks (Good 1998).

One major difference between species is their size; Great Black-backed Gulls weigh 1300 – 2000g (Good 1998) and Herring Gulls weigh 900 - 1250g (Pierotti and Good 1994). Great Black-backed Gull populations are increasing and are displacing Herring Gulls, whose

populations are subsequently decreasing (Boyne and McKnight 2004, Robertson et al. 2001, Rome and Ellis 2004). Because Great Black-backed Gulls establish their territory and lay eggs before other Gulls and will kill smaller species (Good 1998), they displace Herring Gulls.

2.2 Composition of adult and chick gull diets and changes over the breeding season

Due to their large populations, vast diet and influence on their environment, gulls have been species of interest for many dietary studies. Some of these studies assess the diet of Great Black-backed Gulls in the Bay of Fundy. Gilliland et al. (2004) looked at diet during brood rearing. They estimated that Great Black-backed Gulls ate 251 Common Eider ducklings in 1989 on the Five Islands group, The Wolves, in the Bay of Fundy. Other common prey items were Atlantic Herring, Krill, lump fish, other fish, fishing boat offal, Herring and Great Black-backed Gull chicks, and Common Eider Ducklings. The proportions that each item contributed to diet varied over the chick-rearing period. Herring and krill were the largest contributors, likely due to their wide availability in this area.

Changes in diet during chick rearing may occur because of food availability or energy requirements. Reproductive success is highly determined by diet quality during chick rearing (Rome and Ellis 2004) as well as food availability (Gilliland et al. 2004). Food availability and quality can change during the season depending on which prey items are present or more easily available. In the Great Lakes, Herring Gulls were found to have different diets depending on the season, year and location; when food sources were abundant Herring Gulls exploited them opportunistically (Ewins et al. 1994). The presence of ducklings in gull diet, which have similar energy content to Atlantic Herring (Gilliland et al. 2004), is likely due to their availability. While

ducklings are available gull consumption of Herring may decrease while consumption of ducklings may increase.

Not only does food availability change but energy requirements can also vary for gulls during different breeding stages. During pre-breeding while defending territory and building nests, both males and females will require more energy. In addition, egg formation for females and vigilance for males require more energy (Lindsay and Meathrel 2008, Hario et al. 1991) during this time. Other species of Gulls were found to switch diet immediately after their eggs hatched likely to supplement growing chicks with adequate energy (Pierotti and Annett 1987, Garthe et al. 1999). Thus, during different breeding stages gulls require a different amount of energy which they acquire through changes in diet.

2.3 General similarities and differences between gull species

Great Black-backed Gulls are moving farther south, outcompeting and displacing Herring Gull populations (Good 1998, Rome and Ellis 2004). Great Black-backed Gull populations increased 2.5 times between 1978 and 1998 and Herring Gulls numbers decreased by half (Mawhinney et al. 1999). However, both Great Black-backed and Herring Gull numbers increased in the Grand Manan Archipelago in the Bay of Fundy between 1998 and 2001 (Ronconi and Wong 2003). Both species are generalist predators, forage in a variety of habitats and colonize the same areas (Rome and Ellis 2004, Good 1998, Pierotti and Good 1994).

Most of the studies focus primarily on Great Black-backed Gulls diet rather than on Herring Gull diet or a comparison between the two. Rome and Ellis (2004) was the only study found to compare the foraging ecology and interactions between the two species. They found that both species have similar diets and prey preferences. Great Black-backed Gulls, however,

were consistently dominant in all foraging habitats and were more aggressive than the Herring Gulls. In all interactions the Great Black-backed Gulls inhibited Herring Gulls' foraging abilities and would consume the larger prey. We can predict then that Great Black-backed Gulls will consume more high energy and larger prey than the Herring Gulls in the same colony.

2.4 Predation on Common Eider Ducklings

Due to the high energy content of Common Eider ducklings compared to other common prey species (Gilliland et al. 2004), Great Black-backed Gulls may outcompete Herring Gulls for this food source. In 1996 and 1997 Mawhinney and Diamond (1999) found that gulls depredated all tagged Common Eider ducklings on The Wolves. Mawhinney and Diamond (1999) attribute the predation of Common Eider ducklings predominantly to Great Black-backed Gulls.

Ducklings were only present in diet for the first 3 weeks in June. Gilliland et al. (2004) did not discuss why ducklings were only present in the diet for 3 weeks. Ducklings are most vulnerable 1-10 days after hatching (Mahwinney et al. 1999, Blinn et al. 2008). The presence of ducklings in gull diet may correspond with their availability. We can predict that ducklings will be present in gull diet for the 3 weeks surrounding peak hatch date while they are the most vulnerable.

2.5 Techniques

Different methods have been used in most gull studies to determine diet;stomach content analysis, pellet analysis, regurgitation analysis, and stable isotope analysis. Stomach content analysis involves euthanizing the organism and identifying the prey consumed in their stomach. While stomach content analysis can provide a complete picture of gull diet prior to collection, it

does not provide any long-term diet trends (Seefelt and Gillingham 2006). In contrast, regurgitate analysis involves collecting anything the gull vomited when captured. Given that gulls do not reliably regurgitate upon capturing, this method of diet determination is unreliable and entirely opportunistic. It is also possible to collect regurgitate by extracting food items from a chick's proventriculus (Gilliland et al 2004). Removing prey items from a chick's proventriculus is invasive and the investigator must wait until the chick is fed by its parents before extracting any food. Both regurgitate methods only provide data from the period immediately before sampling and soft tissues are usually still intact so prey is easily identifiable. Pellet analysis involves collecting any pellets casted by gulls around their nesting area (Lindsay and Meathrel 2008, Rome and Ellis 2004, Wilkens and Exo 1998). This form of diet analysis is advantageous because it is non-invasive and it is possible to follow longer-term diet trends during the breeding season, however, it is biased towards hard tissues and easily identifiable prey.

In a study of Pacific Gull (*Larus pacificus*) diet Lindsay and Meathrel (2008) used only pellet analysis to determine diet. The authors cautioned against using only simple techniques such as this one. They predicted that their pellet analysis failed to find 90% of the mass of food consumed. Their study, however, examined the diet of Pacific Gulls in Australia, which may consume more soft bodied prey resulting in a smaller presence of hard animal parts in pellets than Herring or Great Black-backed Gulls may. Rome and Ellis (2004) also used pellet analysis to determine diet. They indicated that previous studies had found that pellet analysis, when compared to stomach contents, closely reflected actual diet. Gilliland et al. (2004) used pellet and chick regurgitation analysis to determine diet. In addition to surveying nest sites for pellets as Lindsay and Meathrel (2008) did, Gilliland et al. (2004) also removed regurgitations from

chicks' proventriculus immediately following parental feeding. This ensured that they acquired both the hard and soft tissues from the prey items. While Gilliland et al.'s (2004) method is more invasive it may be more accurate.

Due to the debate between whether or not pellet analysis is an accurate method for diet composition my study used isotope analysis in addition to pellet analysis. Hobson et al. (1994) and Forero et al. (2004) used stable isotope analysis of $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ to examine the trophic levels of seabirds and food web interactions. Hobson et al. (2004) indicates that using isotope analysis to complement pellet analysis can provide integrated dietary information over different time periods. Stable isotope analysis also eliminates the bias associated with pellet and regurgitates analysis as discussed earlier. The ability to trap gulls, obtain various tissue samples and acquire dietary information from different time periods reduces the need to disturb the gulls. Using different tissue samples, with different metabolic rates, provides information about diet during time periods when gulls are not nesting in their colony so pellets would not be available. Tissues containing keratin such as feathers, nails and hair, reflect the diet of the organism when that tissue was grown (Cherel et al. 2005). Thus, the primary feathers, grown during pre-breeding reflect spring diet and head feathers, moulted in the winter, reflect winter diet.

Stable isotope analysis provides the ratio ($\delta^{15}\text{N}$ or $\delta^{13}\text{C}$) between the heavier ^{15}N or ^{13}C and lighter ^{14}N or ^{12}C isotopes compared to standards (Forero and Hobson 2002). Consumers, in this case the Gulls, excrete the lighter isotopes and become enriched in the heavier isotopes, so the higher the trophic level of the organism the higher its $\delta^{15}\text{N}$ ratio. $\delta^{13}\text{C}$ provides inshore or offshore feeding preferences because inshore plants have heavier ^{13}C than offshore phytoplankton (Forero and Hobson 2002). Both the $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ ratios can provide information indicating trophic level and inshore versus offshore feeding preferences. The possible

proportions of prey contributing to diet can be estimated using $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values of both the prey and consumer and entering them into an IsoSource mixing model (Phillips and Gregg 2003). Given that IsoSource provides the possible proportions of various prey items in diet, it is important to ensure that all possible items of prey are incorporated in the model. Unfortunately the model also becomes less accurate as $\delta^{15}\text{N}$ increases (Phillips and Gregg 2003). For this reason it is important to supplement stable isotope analysis with other diet sampling methods such as pellet analysis.

3.METHODS

3.1 Study site and species

The study was conducted on Kent Island in the Bay of Fundy (44.58°N 66.75°W) from 25 May until 7 July 2009. Kent Island has a mixed colony of Great Black-backed Gulls, Herring Gulls and Common Eiders (Ronconi & Wong 2003). Gulls were trapped on all parts of the island except for the North End where there were few nests. Because few Great Black-backed Gulls were nesting on Kent in 2009, some adults (n=7) were captured on the neighbouring Sheep Island, only 200m to the west and connected to Kent through shallow intertidal terrain.

Adults were captured with traps set over gull nests where the eggs were temporarily replaced with wooden dummies to prevent breaking during captures (Figure 1A and B). When adults returned to their nest to incubate the “dummy” eggs, the trap would fall over the nest and the gull. The gulls were promptly removed from the nest, placed in a cloth bag and moved away from the nest and other gulls to prevent further disturbance to the colony.

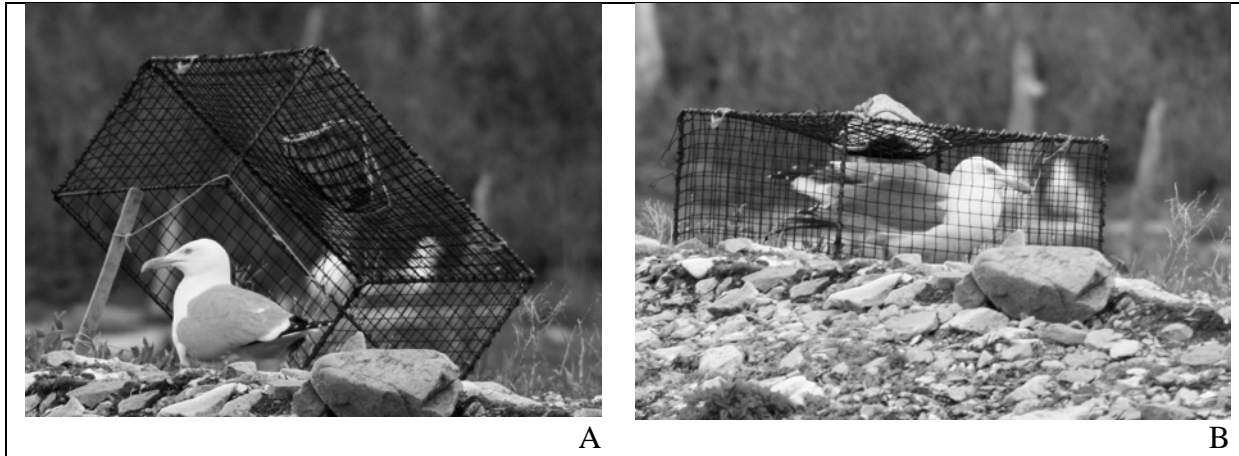


Figure 1: Adult gull trap set (A) and fallen with adult gull (B). (photo S. Wong)

When gulls were startled they sometimes vomit so any regurgitates were opportunistically collected from the nests and stored frozen. Once away from the nests birds were banded and standard measurements taken including; mass, tarsus length, culmen, bill depth at gonys, total head bill length and wingchord. Moulting of primary feathers was scored for each feather on a scale 0-5 to approximate the growth stage of the feather samples taken (as per Ginn and Melville 1983). An approximately 2cm in length tip of the newest grown primary (P1 to P4) was collected. Five head feathers were collected from the back of the head. Primary and head feathers are grown during winter and breeding (Ginn and Melville 1983) and the isotope values represent diet during growth so the head feathers represent winter diet and primaries represent breeding diet. A blood sample of no more than 5ml was taken from the brachial vein in the wing. The blood was kept on an ice pack in a cooler while in the field for no more than 4 hours. Blood samples were spun in a centrifuge for 10 minutes, separating blood into plasma and compact red blood cells. Plasma and compact red blood cells were transferred to ependorf tubes and placed in the freezer until they could be transferred off the island to a lab. One ml of the plasma was taken to provide samples for a fatty acid analysis in another study

Ten chicks of each species were caught between 5 and 7 July 2009. When chicks were at least 2 weeks old, researchers removed a single chick from nests. The chick was taken away from the nesting area so that the other chicks in the brood could return to the nest under the cover of their parent. The protocol for processing the chicks was identical to the adults with the following exceptions; only 1 ml of blood was sampled and feather samples were taken only from primary feathers since head feathers were grown simultaneously and provided no “winter” signature of diets as for the adults.

Estimating peak Common Eider hatch date

To determine the peak hatch date for Common Eiders, I located 32 nests, counted the eggs, candled them to determine age and predict hatching dates (Weller 1956) and took a GPS coordinate of each. I then checked the nests every two days beginning two days before the predicted hatch date. For each nest I recorded the hatch date and the number of egg shells/membranes remaining in the nest to determine if any eggs had been predated prior to hatching. To reduce the risk of predation to nests following checks I placed the down layer back over the eggs, after each nest check. If there were ducklings in the nest was ensured that they under the down before the nest was left to reduce the impact researchers may have had on the ducklings and to ensure that gulls would not find the hatched ducklings.

Collection of pellet and regurgitated food samples

Beginning 1 June and continuing each week until 3 July 2009 pellet samples were removed when available from each of 36 Herring Gull and nine Great Black-backed Gull nests. To ensure re-sampling of the same nests in subsequent weeks, each nest was flagged with a marker placed four steps to the south. Re-sampling of a subset of nests allowed for investigation of within-season changes in diet. Pellet samples were aggregated for each check of nests, and

stored frozen until further identification in the lab. Pellets were identified to the lowest taxonomic level possible. For each sample the number of different items found in the pellet were recorded under the categories listed in Table 1. Two items of the same prey species were recorded as one.

Collecting prey items

Samples of prey items were collected to provide a reference for stable isotope analysis. Jonah (*Cancer borealis*, n=1) and Rock (*Cancer irroratus*, n=1) crabs, mussels (*Mytiloida sp.*, n=7), sea urchins (*Echinoidea sp.*, n=6), and Northern krill (*Meganyctiphanes norvegica*, n=13) were gathered from the Bay of Fundy. Isotope values from Atlantic mackerel (*Scomberscombrus*, n=7) that was collected a previous year in the Bay of Fundy was also used and Atlantic herring (n = 115) from summers 2006 to 2009. Each sample was pulled apart and food items identified as precisely as possible. Prey items were identified to species when possible however for most fish, mussels and urchins, this was not possible and these were classified as unknown.

3.2 Lab Methods

Half of each RBC, plasma and whole blood samples were transferred onto a separate piece of glass microfiber and placed on a metal tray. Samples were dried in a drying oven at 38°C for 24 hours. Samples were removed and placed in labelled plastic vials.

The edible parts of each prey item was ground into a paste and placed in the incubator at 38°C until dry. Prey items and feather samples were soaked in a 2:1 methyl-chloroform solution in a glass vile for 24 hours to remove lipids (as per Cherel et al, 2005). Tissues were removed from the vials, rinsed with methyl-chloroform solution, dried and placed in new plastic vials. If

some items were not adequately dried and cleaned they were placed in the incubator, soaked and rinsed again. Each prey item was ground into a powder using a mortar and pestle to prepare a homogenous mixture for stable isotope analysis. Feathers were placed in their original paper envelopes.

Subsamples of ~0.250 mg (+/- 0.005) were weighed on a microbalance (Sartorius) and folded in a tin capsule. The Environmental Isotope Lab, University of Waterloo, analyzed the samples for stable isotopes $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$. Stable isotope analysis determines the abundance of ^{13}C and ^{15}N in a sample compared to a standard, denoted as $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$:

$$\delta^n\text{X}(\text{‰}) = ((R_{\text{sample}} - R_{\text{standard}})/R_{\text{standard}}) * 1000$$

(Knoff et al. 2002, Kurlle 2002). Given that ^{13}C and ^{15}N change in predictable way when consumers eat their prey, isotope-fractionation values were used (Kurlle 2002, McLellan and Shutland 2009). Average fractionation values were calculated between prey and blood to be $\delta^{15}\text{N} + 2.75$ and $\delta^{13}\text{C} - 0.06$ (Cherel et al. 2005) and were used for mixing models.

3.3 Data Analysis

Statistical analyses

Gulls moult their head feathers in the winter and their primary wing feathers in the spring these samples provided information about gull diet in winter and in spring. For the chicks, their fullest grown primary wing feather would have grown since hatching and provided information about what the gull was fed by its parents. Blood samples were taken in the summer (from both adults and chicks), which provided information about what the gulls had eaten in the past month (Cherel et al. 2005).

General Linear Model ANOVAs were used to determine differences in stable isotope signatures $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$, from different tissues (plasma, red blood cells, primary feathers and head feathers) between species, age and breeding stage. To determine how Herring Gull plasma and red blood cell $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ levels changed over time, the relationship was graphed and a regression performed.

Stable isotope analysis

Stable isotope signatures were analyzed with the Visual Basic program IsoSource (version 1.3). This program provided all possible combinations of prey items in the gulls' diet (Phillips and Gregg, 2003). Stable isotope values from adult red blood cells and plasma and chick whole blood was compared between species and between adults and chicks to determine if any significant differences were evident in diet. Early Herring gull plasma samples corresponding to 26 May – 13 June and late samples from 17 – 30 June were also compared.

4. RESULTS

Adult Great Black-backed Gulls ($n = 12$) were trapped from 25 May to 30 May during the last week of incubation, while adult Herring Gulls ($n = 38$) were trapped from 25 May to 30 June. On the 5 and 6 July, chicks of both species were sampled ($n = 12$ Herring Gulls and $n = 12$ Great Black-backed Gull). From 30 May until 30 June Herring Gull ($n = 51$, 36 nests) and Great Black Backed Gull ($n = 31$, 9 nests) pellet samples were collected from nests.

Herring Gull adult mean mass was $1044 \pm 129\text{g}$ ($\pm\text{SD}$) and for chicks was $708 \pm 1212\text{g}$ ($\pm\text{SD}$). Great Black-backed Gull adults had a mean mass of $1694 \pm 260\text{g}$ ($\pm\text{SD}$) and chicks $1140 \pm 344\text{g}$ ($\pm\text{SD}$). Mean moult scores for newly grown primary feathers taken for isotope analysis for Herring Gull adults were 2.0, 1.7 and 0.2 for first, second and third primary feathers,

respectively. Great Black-backed Gull adult primary feathers had a mean moult score of 2, 1.6 and 0.1. These moult scores indicate that the feathers were indeed moulting at the time of sampling and, thus, are representative of diet during the breeding stage.

Eider crèches were initially seen 6 June 2009. Common Eider hatch date ($n = 28$) ranged from 4 June until 29 June and peak hatch date was estimated to have occurred 15 June 2009 \pm 6 days (\pm SD). Four nests were depredated after initial nest checking where all the eggs were eliminated. For the remaining 28 nests, all eggs hatched with an average clutch size of 4 ± 1 (\pm SD).

4.1 Pellet and regurgitate samples

From 36 Herring Gull nests and 11 regurgitate samples 18 prey items were identified. From nine Great Black-backed Gull nests and four regurgitates 17 prey items were identified. Herring Gull diet consisted predominantly of fish, crab, marine invertebrates, birds, mussels, mammals and urchins. Great Black-backed gull diet consisted of mostly of crab, fish, mussels, urchins, birds, mammals and terrestrial invertebrates. The dominant prey types found in pellets in Herring Gull nests was fish (45%), crab (14%) and marine invertebrate (12%) and in their regurgitates the dominant prey type was herring. In pellets gathered from Great Black-backed Gull nests the dominant prey types were crab (42%), fish (28%) and birds (16%). In their regurgitates there was an equal amount of herring, mackerel lumpfish and an unidentified fish (Table 1).

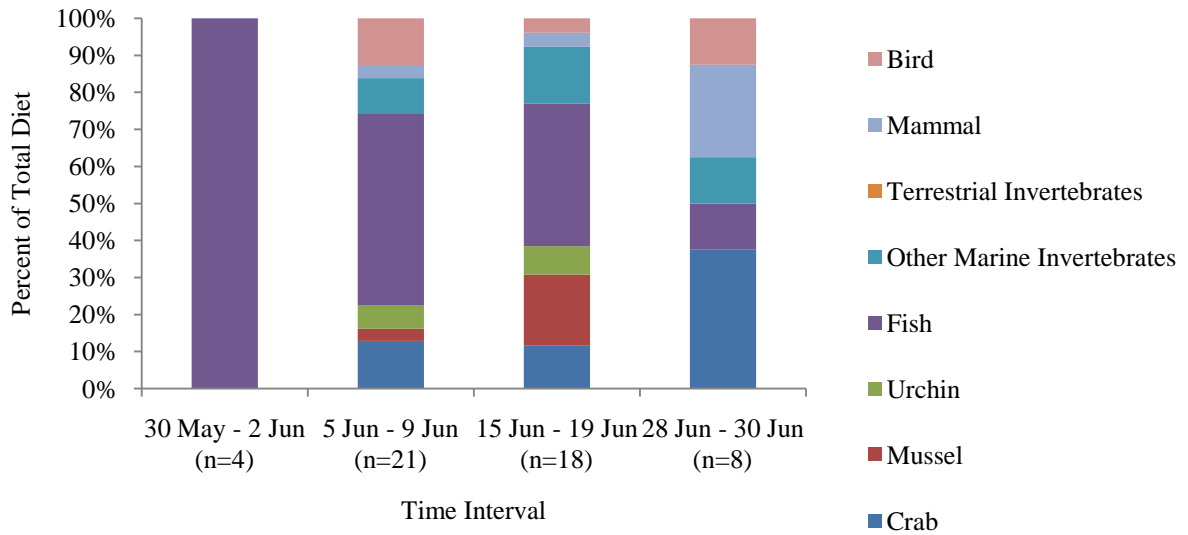
Seasonal variation in prey items found in pellets was evident for both Herring Gulls and Great Black-backed Gulls. Fish comprised 100% of Herring Gull diet during the first week of sampling and then decreased each week thereafter to a low of 12% during the last week of

sampling; evidence of crab and mammals in diet increased (Figure 2a). Fish and crab was present in Great Black Backed Gull diet throughout the sampling period. Fish varied between 20 and 40% while crab varied between 27 and 55%; overall fish and crab composed the greatest proportion of Great Black-backed Gull diet across all weeks. Presence of birds in diet peaked 22 June at 22% but was consistently at least 10% present each week (Figure 2b). The birds found in diet were young eiders, gull chicks and chicken scraps.

Table 1: Prey type found in pellets gathered from nests and regurgitates collected during capturing.

Prey Items	Herring Gull		Great Black-backed Gull	
	Pellets	Regurgitates	Pellets	Regurgitates
Herring	3	4		
Mackerel				1
Sculpin			4	1
Lump Fish				1
Unidentified fish	28	2	15	1
Muskrat	3		1	
Unidentified mammal	1		4	
Songbird	2			
Chicken scraps	1		2	
Gull Chick	1		2	
Eider			1	
Young Eider			2	
Petrel	1			
Unidentified bird	1	1	4	
Jonah Crab	10	1	29	
Mussel	6		1	
Urchin	4		3	
Shrimp		1		
Krill		1		
Sandworm	4			
Periwinkle	3			
Unidentified marine invertebrate	1			
Sand flies		1		
June bugs			1	
Vegetation	1			
Total	70	11	69	4

a) Herring Gull



b) Great Black-backed Gull

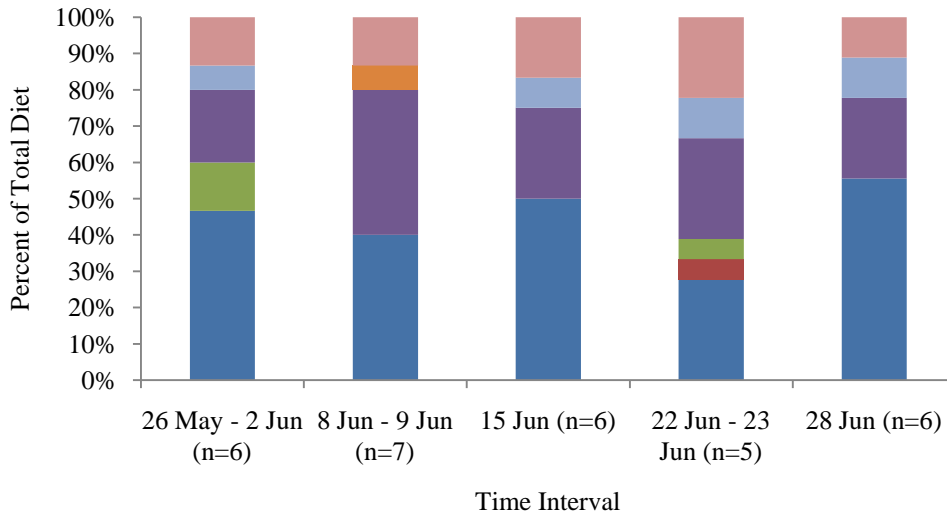


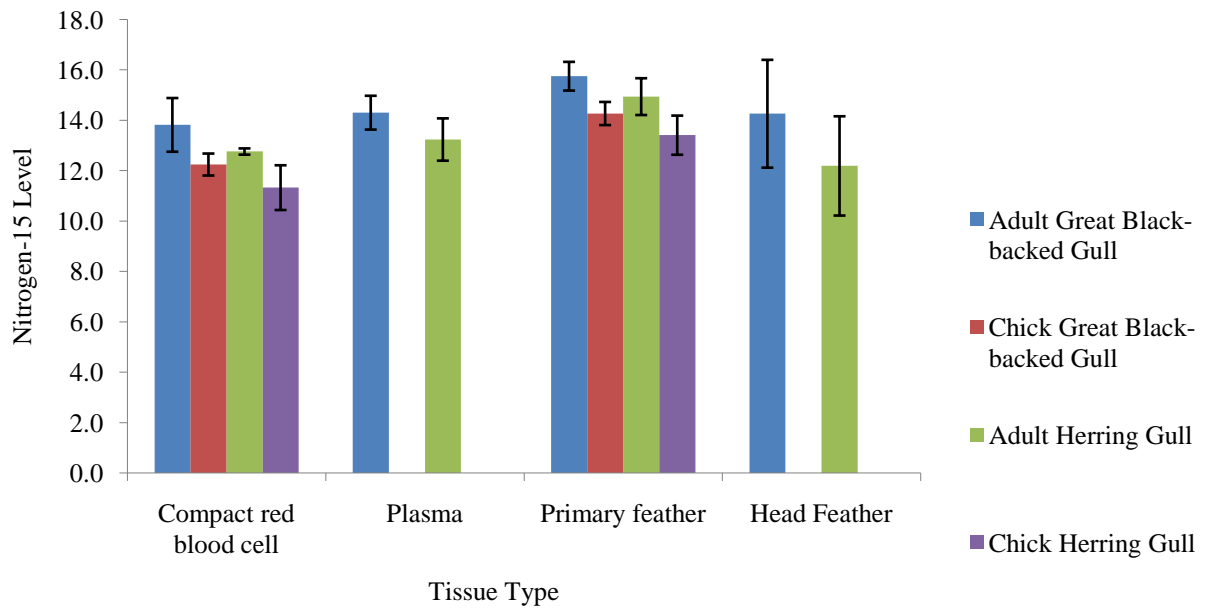
Figure 2: Seasonal variation in prey remains found in pellets for (a) Herring Gulls and (b) Great Black-backed Gulls.

4.2 Stable isotope analysis

There were consistent differences in isotopic signatures between species, age and tissue types. All of the adult Great Black-backed Gull $\delta^{15}\text{N}$ levels were higher than for adult Herring Gulls. Adults of both species also had higher $\delta^{15}\text{N}$ levels than the chicks and Great Black-backed

Gull chicks were higher than Herring Gull chicks (figure 3a). Adult Great Black-backed gulls had higher $\delta^{13}\text{C}$ levels than Herring Gulls for compact red blood cells and primary feathers (figure 3b).

a) $\delta^{15}\text{N}$ levels



b) $\delta^{13}\text{C}$ levels

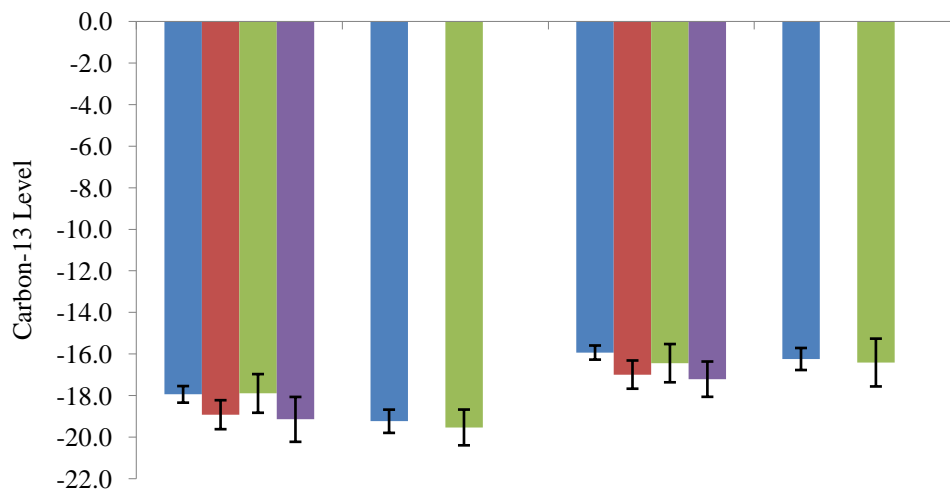


Figure 3: Isotope signatures from various tissues from Adult and Chick Great Black-backed and Herring Gulls.

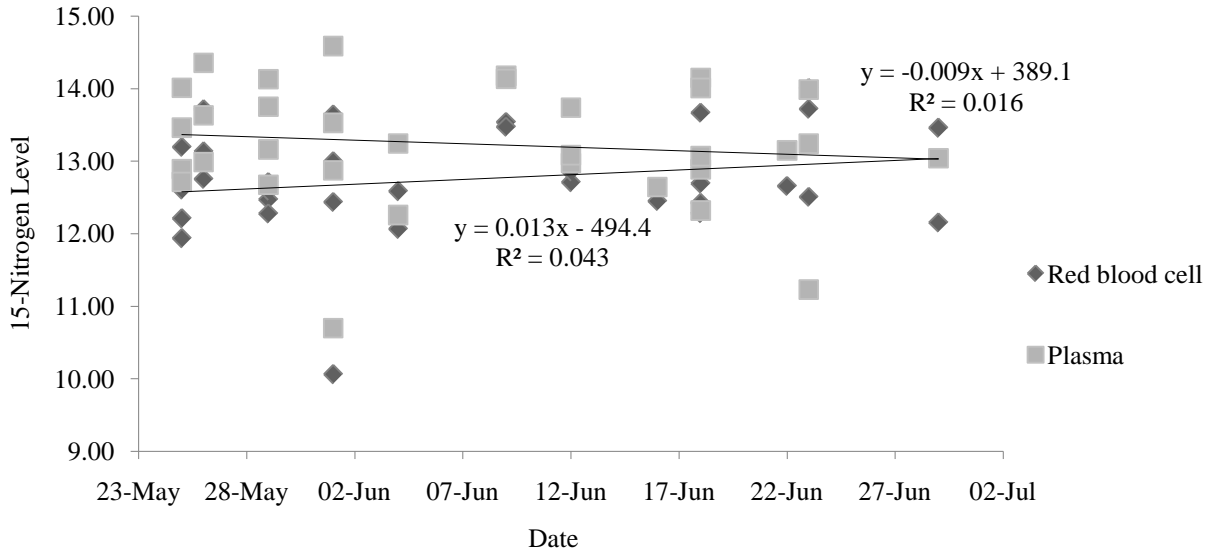
Stable isotope signatures of red blood cells showed differences in diet between species and age (ANOVA statistics). Age was associated with differences in both $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ levels (p

< 0.001 for both), but species effects were restricted to $\delta^{15}\text{N}$ ($p < 0.001$, $\delta^{13}\text{C}$: $p = 0.617$). Stable isotope signatures of plasma also showed differences in diet between species. Species was associated with differences in $\delta^{15}\text{N}$ ($p < 0.001$) but not $\delta^{13}\text{C}$ ($p = 0.273$). Stable isotope signatures of head feathers, again, showed differences in diet between species. Species was associated with differences in $\delta^{15}\text{N}$ ($p = 0.002$) but not $\delta^{13}\text{C}$ ($p = 0.604$).

Stable isotope signatures of head feathers and newly grown primary feathers showed that diet varied between breeding and non-breeding stages. Species and breeding status was associated with differences in $\delta^{15}\text{N}$ ($p < 0.001$ for both). However species and breeding status was not associated with differences in $\delta^{13}\text{C}$ ($p = 0.795$ and $p = 0.212$ respectively).

Neither Herring Gull plasma nor compact red blood cell $\delta^{15}\text{N}$ levels changed significantly over the season. Plasma and red blood cells did not show significant differences over the season ($p = 0.484$ and $p = 0.239$ respectively, figure 4a). Herring Gull plasma and red blood cell $\delta^{13}\text{C}$ levels decreased over the summer ($p = 0.002$ and $p = 0.001$, respectively, Figure 4b).

a) Herring Gull plasma and red blood cell $\delta^{15}\text{N}$ levels.



b) Herring Gull plasma and compact red blood cell $\delta^{13}\text{C}$ levels

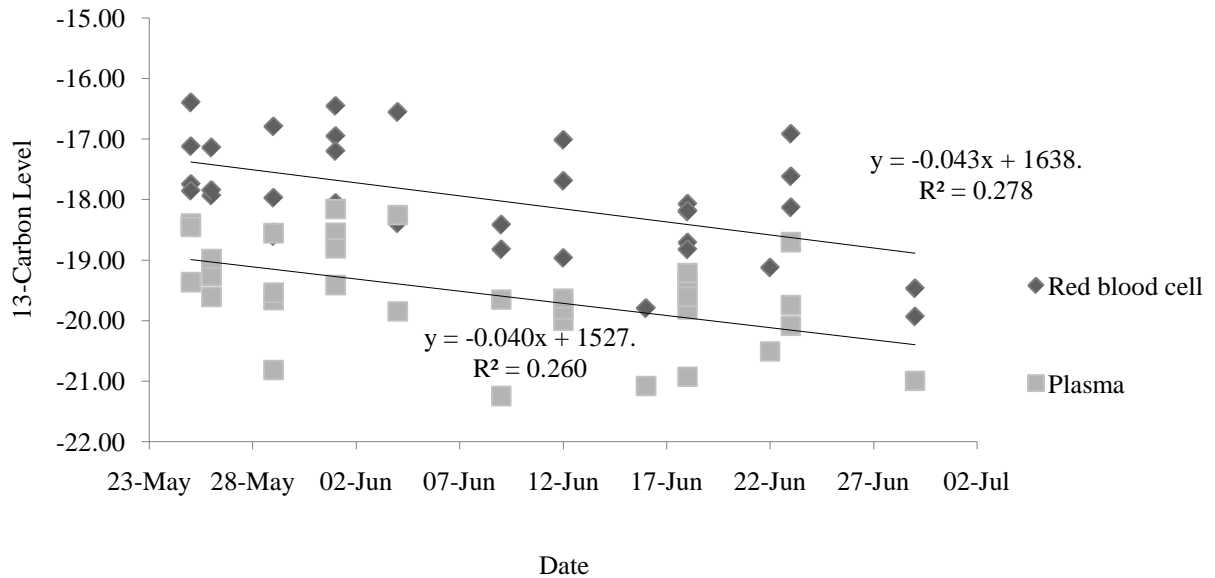


Figure 4: The relationship between time and Herring Gull(a) $\delta^{15}\text{N}$ levels in plasma ($p=0.484$) and compact red blood cells($P=0.239$) and (b) $\delta^{13}\text{C}$ levels in plasma ($p= 0.002$) compact red blood cells ($P= 0.001$).

4.3 Estimates of diet

Isotope signatures of prey items used in mixing models are presented in table 2. A post-hoc comparison of signatures of prey items indicates that they are significantly different ($p < 0.001$).

Table 2: Prey items and associated $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ levels.

Prey Item	$\delta^{13}\text{C}(\pm\text{SD})$	$\delta^{15}\text{N}(\pm\text{SD})$
Urchin (n = 6)	-15.9± 0.3	4.9± 0.2
Mussel (n = 6)	-17.9± 0.2	6.0± 0.2
Krill (n = 13)	-18.6± 0.6	7.9± 0.6
Crab (n = 2)	-17.1± 0.4	9.1± 0.2
Herring (n = 115)	-18.5± 0.8	11.7± 0.8
Mackerel (n = 7)	-19.3± 0.5	12.7± 0.3

Isotope analysis of red blood cells indicates herring and mackerel were present in the highest proportions in Herring Gull diet, but plasma indicates that krill and mackerel were most abundant. Isotope analysis of whole blood indicates that krill and mackerel were present in the highest proportions in Herring Gull chick diet (Table 3). For Great Black-backed Gulls isotope analysis of red blood cells indicates that crab and herring were most abundant and plasma indicates that krill and mackerel were most abundant in adult diet. Isotope analysis of whole blood indicated Great Black-backed gull chick diet composed of krill and mackerel.

Table 3: Mean proportion of prey type in diet estimated for Herring Gull and Great Black-backed Gull adults and chicks.

Species	Herring Gull			Great Black-backed Gull		
	Adult		Chick	Adult		Chick
Tissue	Compact Red Blood Cells	Plasma	Whole Blood	Compact Red Blood Cells	Plasma	Whole Blood
Mussel	0.04 ± 0.03	0.02 ± 0.03	0.09 ± 0.08	0 ± 0	0.03 ± 0.03	0.03±0.03
Urchin	0.10 ± 0.07	0	0	0.02 ± 0.03	0	0
Crab	0.10 ± 0.14	0	0	0.30 ± 0.09	0	0
Herring	0.31 ± 0.18	0.02 ± 0.03	0.04 ± 0.04	0.54 ± 0.17	0.02 ± 0.02	0.02±0.02
Krill	0.05 ± 0.04	0.35 ± 0.05	0.67 ± 0.13	0.01 ± 0.01	0.18 ± 0.04	0.61±0.04
Mackerel	0.18 ± 0.12	0.62 ± 0.03	0.20 ± 0.06	0.12 ± 0.11	0.77 ± 0.02	0.34 ±0.02

Mixing models of stable isotope analysis of plasma indicate that Herring Gull diet is different in early summer compared to late summer. Herring Gulls diet was composed of more mussel and herring and less mackerel and krill in the early summer than in the late summer (Figure 5).

a) Early summer (26 May - 13 June)

b) Late summer (17 - 30 June)

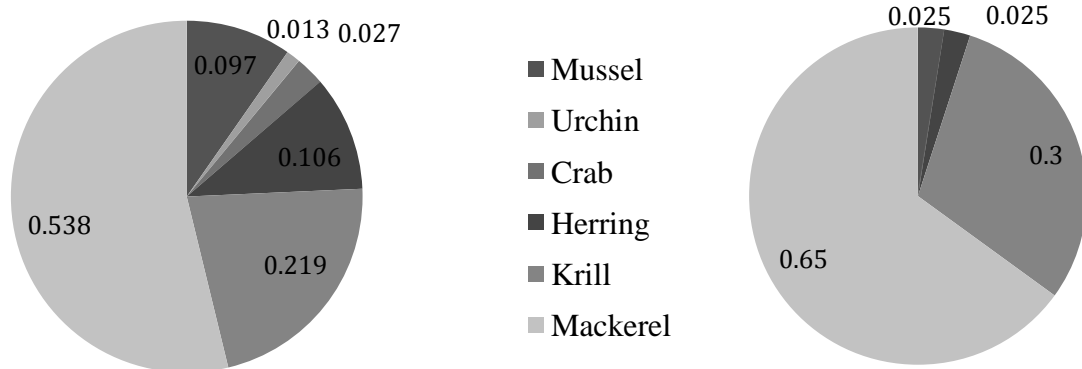


Figure 5: Mean proportions of prey type in diet in Herring gull estimated from plasma for a) early summer and b) late summer.

5. DISCUSSION

5.1 Main components of diet

In general, pellet analysis indicated that Herring Gull and Great Black-backed Gulls diets were similar, however there was a difference between the changes in proportions of the most common prey types over the season.

During the first week of collection, Herring Gull pellets consisted of 100% fish. This large proportion of fish, not only pertains to the first week of gathering pellets, but also to the time since the nest was built. The first week of pellet collection is biased towards items that would have lasted in the nest for a long time, such as fish bones. The estimated proportion of fish in diet may be larger in the first week due to this collection bias. The proportion of fish in pellets

steadily decreased over the season to a low of 12% during the last week, however it remained relatively constant for Great Black-backed Gulls. The proportion of crab, however, increased and mammals increased from 0 to 25% during the last week. The only mammals on Kent Island are muskrats (*Ondatra zibethicus*) and their fur was found in Herring Gull nests (n=3) most frequently during the last week of collection. Herring Gulls had likely scavenged on dead muskrats in the area. Marine invertebrates found in nests were most often sand worms (*Atilavirens*, n=3). Pellet analysis suggests that Herring Gulls have a diverse diet that predominantly consists of fish and crab.

For Great Black-backed Gulls the two dominant prey types were also fish and crab. The presence of birds in pellets peaked 22-23 June at 22%. The birds in these pellets were mostly chicken scraps and one gull chick. Common Eider ducklings were only found in pellets the week of July 5, so they had only been there since the last nest check on 28 June. Therefore, the presence of birds in pellets was not associated with the peak common eider hatch date.

Overall more fish was found in Herring Gull pellets and more crab was found in Great-Black-backed Gull pellets. Both species were found to consume little mussel and urchin, supporting research on Great Black-backed Gulls' foraging ecology in the Bay of Fundy (Gilliland et al. 2004, Rome and Ellis 2004). However, Rome and Ellis' (2004) found more crab remains in Herring Gull nests and more fish in Great Black-backed Gull nests. They also found that the abundance of fish in diet decreased in Herring Gulls and Great Black-backed Gulls. Most of these results agree with ours, however we found that abundance of fish in Great Black-backed Gull diet remained somewhat constant. Overall, more long-term studies need to be conducted to gain more information about seasonal shifts in diet.

Pellet analysis supported the results obtained from $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ isotope analysis of prey items and tissue types. Isotope values obtained from compact red blood cells and whole blood describe diet from within a month before capture and plasma isotope levels indicate diet from within the week before capture (Cherel et al. 2005). With the use of mixing models of isotope levels from red blood cells it was found that the prey types that were most likely to make up the largest proportion of adult Herring Gull diet were herring and mackerel while plasma isotope levels indicated that krill and mackerel make up the largest proportion of diet. Isotope levels from Great Black-backed Gull compact red blood cells indicated that herring, crab and mackerel were most likely to make up the largest proportions of their diet while plasma isotope levels indicated that they feed predominantly on krill and mackerel. During fieldwork mackerel was found in Great Black-backed Gull regurgitates, while not in Herring Gulls. Thus adult Great Black-backed Gulls may feed on more mackerel and crabs than Herring Gulls do.

Isotope analysis of chick whole blood indicated that both Herring and Great Black-backed Gull chicks were primarily fed krill and mackerel. In addition, Great Black-backed Gull chicks were found to feed on herring.

5.2 Differences between species and age classes

$\delta^{15}\text{N}$ levels differed significantly between these species for plasma, compact red blood cell, head feather and new primary feathers, but $\delta^{13}\text{C}$ levels did not. Stable isotope $\delta^{15}\text{N}$ levels increases with trophic level feeding preference while $\delta^{13}\text{C}$ indicates an inshore versus offshore preference (Hobson et al 1994, Cherel et al 2005). The lack of difference in $\delta^{13}\text{C}$ values suggests that adult Herring and Great Black-backed Gulls have similar inshore/offshore feeding preferences. In contrast, $\delta^{15}\text{N}$ values show clearly that Great Black-backed Gulls are consistently

feeding at higher trophic levels than Herring Gulls (Table 2) during the summer breeding season (blood and primary feathers) and during winter non-breeding periods (head feathers). Great Black-backed Gull chicks were also fed from a higher trophic level than Herring Gull chicks. In addition, herring and mackerel have higher $\delta^{15}\text{N}$ levels and were found to make up a greater proportion of Great Black-backed Gull diet than Herring Gull diet (Table 3). This is consistent with behavioural studies that show that Great Black-backed Gulls are the dominant species on gull colonies (Rome and Ellis, 2004), outcompeting Herring Gulls and forcing them to feed at a lower trophic level.

Age was found to be associated with differences in both compact red blood cell and primary feather $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ levels. The tissues of both chick species had lower $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ levels than in adults thus Herring Gull adults feed their chicks prey items from a lower trophic level than they feed on themselves. In contrast, Arctic birds (Hobson, 1993) and Glaucous Gulls (*Larus hyperboreus*) were found to feed their chicks prey from higher trophic levels (Schmutz and Hobson, 1998) but Puffins were found to feed their chicks from a slightly lower trophic level (Williams 2008). It appears that species vary in the trophic levels from which they feed their chicks. Using a mixing model with isotopes it was estimated that a high proportion of Herring Gull chick diet consisted of krill (0.67) and mackerel (0.20). It was estimated that chicks consumed more krill than adults. Herring Gulls in Newfoundland (Pierotti and Annett 1987) and Lesser Black-backed Gulls in the German North Sea (Garthe et al. 1999) were found to shift their diet towards higher energy and higher protein sources after chicks hatched, the switch did not coincide with a change in prey availability. In addition, Western Gulls on Alcatraz were found to shift their diet from garbage to fattier, higher protein and higher energy sources like fish after eggs hatched (Annett and Pierotti 1989). Gulls shift their diet after eggs hatch because

chicks require higher calcium and higher energy foods for growth and because chicks are unable to consume large food items (Pierotti and Annett 1987). Thus, Herring Gull adults may feed their chicks more krill and mackerel because they are both more manageable and high in energy (Gilliland et al. 2004).

A large proportion of Great Black-backed Gull diet was also estimated to consist of herring (0.54), crab (0.30) and mackerel (0.12). It was estimated that chicks consumed more krill (0.61) and less mackerel (0.34) and herring (0.02) than adults. Gilliland et al (2004) also found that Great Black-backed gulls fed their chicks predominantly herring, krill and other fish (mackerel is included in this category), but found that herring, rather than krill, made up the largest proportion of their diet. Great Black-backed Gulls, like Herring Gulls, may also feed their chicks more krill not only because it is high in energy but also more manageable for the chicks to eat.

Both species of gulls are frequently seen following lobster and other types of fishing boats to feed on fishing discards such as herring (Kakela et al. 2005, Garthe and Scherp 2003). Given that Great Black-backed Gulls were shown to consume more herring than Herring Gulls, Great Black-backed Gulls likely out compete Herring Gulls for this resource. In addition, there is an increased lobster fishing effort in the Grand Manan area beginning in May until late June (Murison, pers. comm.), resulting in more herring discards and an increase in herring consumption being reflected in the primary feathers $\delta^{15}\text{N}$ signatures.

5.3 Variability between breeding stages

Stable isotope analysis from head and primary feathers was used to compare differences in diet between different breeding stages (non-breeding and breeding). Gulls moult head feathers

after the winter (non-breeding) and their primary feathers during breeding (Good, 1998). These primary feather moult scores from Herring and Great Black-backed Gulls indicated that the gulls were moulting their primary feathers at time of collection and thus indicate diet during the breeding stage. $\delta^{15}\text{N}$ levels increased from non-breeding to breeding indicating that gulls seasonally change their diet.

Gull diet may change over different breeding stages depending on energy requirements or because of changes in food availability. Gulls may feed on prey with lower $\delta^{15}\text{N}$ levels during non-breeding, in the winter, because these items may be more readily available during this time. During winter, intertidal species are more common (Annett and Pierotti 1989) and also have a lower $\delta^{15}\text{N}$ level (Table 2) meaning that gulls likely feed on more intertidal species during their overwintering times. Hobson (1993) indicated that breeding seabirds feed on prey from higher trophic levels than non-breeding birds. Herring gulls migrate away from their offshore colonies during the fall and winter towards more coastal areas (Pierotti and Good 1994). However, if it were the case that gulls migrate to inshore areas during the winter, then one would expect that there would be a significant difference between non-breeding and breeding $\delta^{13}\text{C}$ levels, which indicates an inshore versus offshore feeding preference. Our results indicate that there was no significant difference in the $\delta^{13}\text{C}$ values. Thus gulls are not overwintering more inshore. Herring Gulls from Kent Island remained within 20km of the colony during incubation and chick rearing, but migrated to Chesapeake Bay in the winter (Ronconi, unpublished data). Chesapeake Bay is widely known for their oysters. Herring Gulls may be feeding on oysters during the winter, which would result in a decrease in $\delta^{15}\text{N}$ values, but not $\delta^{13}\text{C}$. In addition, as Great Black-backed Gulls are known to remain offshore in the Gulf of Maine, during the winter, $\delta^{13}\text{C}$ would not

decrease. Further more the lobster season goes year round in Maine (Murison, pers. comm.), so the gulls could be following the lobster boats, obtaining herring discards during the winter.

5.4 Seasonal trends in diet

Herring Gull $\delta^{13}\text{C}$ levels decreased over the season but $\delta^{15}\text{N}$ levels did not (Figure 3). Diet shifting from mostly fish to crab, as was evident in pellet analysis, would cause both an increase in $\delta^{13}\text{C}$ and a decrease in $\delta^{15}\text{N}$. Isotope analysis of both plasma and compact red blood cells indicate that $\delta^{13}\text{C}$ levels decreased. This suggests that Herring Gulls fed offshore more frequently during this time. Herring Gulls may shift their diet to limit their time away from the offshore colony, resulting in a more offshore diet. In addition, during this time gulls may follow offshore fishing boats, feeding on fishery offal such as bait. Both of these factors would shift gull diet towards a lower $\delta^{13}\text{C}$ level. Further research is required to determine why Herring Gulls would shift their diet over the summer.

5.5 Discrepancy between plasma and red blood cell stable isotope signatures

Stable isotope analysis of plasma and red blood cells yielded significantly $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ levels. As a result, estimations of diet composition were different for red blood cells and plasma. Different tissues vary in their isotopic signatures because they have different biochemical composition and metabolic rates (Bearhop, 2000). While lipid content in blood is low, the lipids are contained in the plasma (Bearhop, 2000), thus, the plasma has not only a different time signature than the red blood cells, but has a higher lipid content that may alter the stable isotope signature. Lipids decrease $\delta^{13}\text{C}$ levels, so lipids should be extracted from tissues before isotope analysis (Kojadinovic, 2008). $\delta^{13}\text{C}$ values for plasma -19.24 and -19.53 are significantly lower

than red blood cell values, -17.94 and -17.89 for adult Great Black-backed and Herring Gulls, respectively. The plasma $\delta^{13}\text{C}$ values are likely lower because of its lipid content. In addition, mackerel and krill were estimated to have the lowest $\delta^{13}\text{C}$ levels and were estimated to contribute the most to gull diet using plasma values. Thus, stable isotope analysis of plasma is unreliable for use with mixing models. The whole blood samples taken from chicks also contained lipids and indicated that a large component of both species chick diet was mackerel and krill. While whole blood may not have as high of a percentage of lipids as plasma, and given that overall lipid content in blood is low, overall $\delta^{13}\text{C}$ levels may have decreased slightly but not to the extent that plasma had. As a result further studies should use only red blood cells to compare the diets of chicks and adults or should remove lipids from whole blood and plasma before isotope analysis.

6. LIMITATIONS, RECOMMENDATIONS AND CONCLUSION

This study combined two different methods to assess gull diet; pellet analysis and stable isotope analysis of tissues. As pellet analysis has an associated bias towards large, easily identifiable items, isotope analysis was also used to ensure than not only large items were identified in diet. However, the more prey items that are used in mixing models to assess likely proportions of prey, the less accurate the mixing model becomes (Phillips and Gregg 202). In addition it is impossible to include all prey items into the mixing models. One goal of the study was to assess, using isotope analysis, if gulls were predated Common Eider ducklings. However, we did not have a duckling sample to determine its isotope signature, so this could not be determined. In addition muskrat could be added to the mixing model as muskrats are present on Kent Island and fur was frequently found in gull pellets.

Further studies should begin collecting pellets from more Herring Gull nests. The Herring Gull sample was limited as pellets were found in their nests less frequently than Great Black-backed Gulls. Repeat sampling of nests was limited. In addition, Great Black-backed Gulls should be captured earlier in the season. We obtained only one week of Great Black-backed Gull tissue samples because the majority of the eggs had hatched by the second week. As a result, we were unable to obtain a relationship of changes in diet over time.

Further studies should also investigate the energy levels associated with the prey items such as Gilliland et al. (2002) did for Great Black-backed Gulls. Gulls may switch their diet not only because of availability, but also depending on the energy content of prey. For example, it was determined that gulls feed their chicks more krill than they eat themselves, krill may have a higher energy content and thus gulls would select these items to help their chicks grow. In addition, comparisons could be made between the energy contents of Great Black-backed and Herring Gull diets. The larger species may obtain foods that are not only larger but may also have higher energy content.

Further studies also need to investigate the effect of lipids on stable isotope analysis of gull plasma. While Bearhop et al. (2000) indicates lipids in plasma should not significantly affect stable isotope analysis; in this study $\delta^{13}\text{C}$ signatures from plasma were significantly lower than those for red blood cells. Subsequent studies should compare the stable isotope signatures obtained from whole blood, compact red blood cells and plasma

Overall it was found that gull diet consisted of primarily crab, herring and mackerel. Great Black-backed Gulls fed on more mackerel than Herring Gulls. Both species of chicks were fed more krill than adults. Great Black-backed Gulls fed at a higher trophic level than Herring Gulls, but they had a similar inshore versus offshore feeding preference. Gulls change their diet

depending on breeding stage; they feed at higher trophic levels during breeding than in the winter during non-breeding. Herring Gulls consumed prey with decreasing $\delta^{13}\text{C}$ levels during the summer.

Given that Gulls are generalist feeders they could be used as indicators for the marine environment. Great Black-backed Gulls are perhaps more suited for this role as they are known to remain in the Bay of Fundy over the winter, and thus, could provide a longer-term picture of the Bay of Fundy, where as Herring Gulls tend to over-winter southwards. However, given that a large proportion of gulls diet is composed of fishery offal and there is no way to differentiate between wild herring and mackerel and fisheries discards, Gulls may be better suited towards monitoring for pollutants rather than direct ecosystem monitoring.

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