DIET OF HERRING GULL *LARUS ARGENTATUS* CHICKS IN THE GULF AND ESTUARY OF THE ST. LAWRENCE RIVER, QUÉBEC, CANADA

HET VOEDSEL VAN KUIKENS VAN ZILVERMEEUWEN IN DE GOLF EN HET ESTUARIUM VAN ST LAWRENCE RIVER, QUÉBEC, CANADA

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Food availability is often an important regulating factor of seabird populations. In the Estuary and Gulf of the St. Lawrence River, most colonies of Herring Gulls are actually decreasing while diet information is lacking. Collection of 635 regurgitations in three areas (Estuary, Corossol Island and Carleton colonies) revealed that the overall diet of Herring Gull chicks was extremely varied and variable over time and space, which is typical of an opportunist species. Nevertheless, capelin, a key species in the food chain in the St. Lawrence Estuary and Gulf, constituted the bulk of gulls' diet. At Carleton, located in the southern Gulf, capelin was less abundant, and more human waste completed the chicks' diet, in comparison with the other sites. This study provides baseline data for future investigation of the relationship between trends in Herring Gull populations and food availability in the Estuary and Gulf of the St. Lawrence River.

Rail J-F. & G. Chapdelaine 2000. Diet of Herring Gull *Larus argentatus* chicks in the Gulf and Estuary of the St Lawrence River, Quebec, Canada. Atlantic Seabirds 2(1): 19-34.

INTRODUCTION

Biologists recognised that the tremendous increase of gull populations during the present century was closely related to their opportunistic ability to obtain extra food supplied indirectly by man through the intensification of commercial fishery, resulting in more discarded fish and offal (Furness *et al.* 1992; Oro *et al.* 1995, 1996), and utilisation of refuse dumps and other sources of human waste (Spaans 1971; Hunt 1972; Nisbet 1978; Cavanagh 1992; Brousseau *et al.* 1996). The Herring Gull *Larus argentatus* is an important component of the larids group in the Estuary and Gulf of St Lawrence as the total breeding population had been estimated at 35 000 pairs (Brousseau 1996). Populations on the North Shore (Chapdelaine & Rail 1997) and Gaspé Peninsula (Chapdelaine & Brousseau 1992) indicate a general downward trend during the last 15 years while some specific colonies continued to increase or stabilised. Similar declines are also reported in the Estuary (Brousseau 1996; J. Bédard pers. comm.).

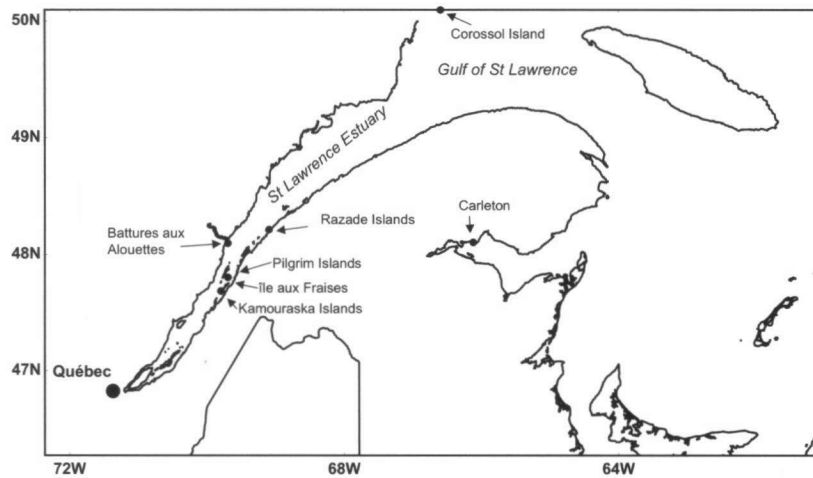

Figure 1. Study area, St Lawrence estuary and Gulf of St Lawrence in eastern Canada.
Figuur 1. Onderzoeksgebied, monding van de St Lawrence rivier en de Golf van St Lawrence in oostelijk Canada.

Chapdelaine & Rail (1997) attributed the decline of some colonies on the North Shore to the decrease in commercial fishing activities in the region but had no data on the diet of Herring Gull to demonstrate conclusively the relative importance of fish offal before and after the fishery collapse. Surprisingly, diet of Herring Gull during the breeding season is not very well known in marine waters of eastern Canada (Threlfall 1968; Haycock & Threlfall 1975; Pierotti 1983) and very few quantitative data exist for birds nesting in the Estuary and Gulf of St Lawrence (Guillemette 1997).

Gulls, unlike many other seabird species, are characterised by their lack of specialisation to the marine environment, and a high diversity of food items is expected in their diet. They would also exploit resources which are abundant both spatially and temporally to keep up breeding success. Within the context of using the Herring Gull as a marine bio-indicator (Rail *et al.* 1996), there was a strong need to have a current and closer look at the diet of this species. The present study aims to provide new data on the Herring Gull's diet in the Estuary and Gulf.

METHODS

Herring Gull regurgitations (n = 635) were collected between 1994-97 in five colonies in the St. Lawrence Estuary, and in two colonies in the Gulf of St. Lawrence (Fig. 1, Table 1). All sampling was done between 8 June and 1

Table 1. Number of regurgitations (n=) of Herring Gull chicks and number of visits (v) to each of the colonies in the St Lawrence Estuary and Gulf, summers of 1994-97.

Tabel 1. Aantal braaksels (n=) van Zilvermeeuwenkuikens and het aantal koloniebezoeken (v) in het St Lawrence estuarium en de Golf van St Lawrence, 1994-97.

	1994		1995		1996		1997		Total 1994-97	
	n =	(v)	*n* =	(v)	*n* =	(v)	*n* =	(v)	*n* =	(v)
-Ile aux Fraises	18	(3)							18	(3)
-Battures aux Alouettes	19	(1)							19	(1)
-Kamouraska Islands	17	(1)	24	(1)					41	(2)
-Pilgrim Islands	11	(2)	238	(14)					249	(16)
-Razade Islands	21	(1)							21	(1)
Total Estuary	86	(8)	262	(15)					348	(23)
Corossol Island					53	(5)	142	(28)	195	(33)
Carleton	92	(22)							92	(22)
Total	178	(30)	262	(15)	53	(5)	142	(28)	635	(78)

August, during the chick rearing period of each colony. All material comes from young gulls that regurgitated their stomach content when the colony was disturbed or when they were manipulated.

Regurgitations were either preserved individually (in 70% alcohol, 70% formaldehyde, or kept frozen) or analysed in the field. Each prey item was identified to the lowest taxon possible after Scott & Scott (1988) and a reference collection of specimen that we gradually developed. Plants, non-edible waste (e.g. plastic, paper), and parasite worms (Nematoda) were excluded from the results, since the presence of such material in the regurgitations is believed to be incidental, and moreover its nutritional value appears negligible.

The relative importance of each prey category is expressed by frequency of occurrence (the proportion of regurgitations containing a prey category), and percent mass or volume (the total volumetric or weight percentage of a prey category within a sample). Samples from the five Estuary colonies were regrouped. For samples from the Estuary and Carleton, volumes were measured by water displacement in a graduated cylinder at the nearest 0.1 ml. At Corossol Island, samples were weighed in the field at the nearest 0.5 g. Items too small to be measured were attributed 0.1 ml or 0.5 g, respectively.

Statistical analyses Data from regurgitations were regrouped by area and year. For each prey category, logistic regression was used to test the null hypotheses of no difference in frequency of occurrence between areas. Two-by-two comparisons of prey frequency of occurrence were also made between the five data subgroups (area-year). The distribution of the response variable was

Table 2. Composition of 635 Herring Gull chick regurgitations collected in colonies in the Estuary and Gulf of the St Lawrence River, 8 June-1 August in 1994-97.
Tabel 2. Samenstelling van 635 braaksels van Zilvermeeuwenkuikens in het St Lawrence estuarium en de Golf van St Lawrence, 8 juni-1 augustus, 1994-97.

Taxon	frequency (%)		volume or mass (%)	
Capelin *Mallotus villosus*	392	(61.7)	7189.6	(62.5)
gunnels *Pholis* spp.	7	(1.1)	58.3	(0.5)
Rainbow Smelt *Osmerus mordax*	7	(1.1)	103.1	(0.9)
clupeids *Clupea* spp.	7	(1.1)	166.0	(1.4)
sandeel *Ammodytes* spp.	24	(3.8)	502.5	(4.4)
other fish	5	(0.8)	80.0	(0.7)
unidentified fish	132	(20.8)	1705.2	(14.8)
crustaceans	41	(6.5)	565.6	(4.9)
annelids	20	(3.1)	181.4	(1.6)
human waste	20	(3.1)	564.0	(4.9)
other food	53	(8.3)	387.9	(3.4)
Total			11503.6	(100.0)

approximated by the binomial distribution in the model. In cases of overdispersion of the model, we fitted the generalised linear model by using the quasi-likelihood method to approximate the response distribution, and by estimating the scale parameter of the response distribution using the mean Pearson chi-square (instead of the maximum-likelihood estimate).

RESULTS

Diet composition The diet of Herring Gull chicks in the Estuary and Gulf was extremely varied. However, fish were most important as they represented 85.2% (in mass/volume) of the 635 regurgitations collected (Table 2). Capelin *Mallotus villosus* was by far the dominant prey, in frequency of occurrence (61.7%) as well as in mass/volume (62.5%). With the exception of the 'unidentified fish' category (14.8% in mass/volume), every other prey category amounted for less than 5% of the volume of regurgitations (Table 2). Moreover, capelin too degraded for identification may have represented a large fraction of the volume of 'unidentified fish'.

Regional variations Tables 3 and 4 compare the composition of Herring Gull regurgitations by area (Estuary, Corossol Island and Carleton) and by area-year, respectively. Fish was the main food of young Herring Gulls at all locations, representing between 59% (at Carleton in 1994) and 96% (Corossol Island in 1997) of the total volume of regurgitations. Also depending on locality and year,

Table 3. Composition of 635 Herring Gull regurgitations collected in the Estuary and Gulf of the St Lawrence River, by area (frq = frequency of occurrence; vol = percent volume).

Tabel 3. Samenstelling van 635 braaksels van Zilvermeeuwenkuikens in het St Lawrence estuarium en de Golf van St Lawrence, per deelgebied. (frq = frequentie; vol = volumepercentage).

Taxon	Estuary 1994-95 (n = 348)		Corossol 1996-97 (n = 195)		Carleton 1994 (n = 92)	
	frq (%)	vol (%)	frq (%)	vol (%)	frq (%)	vol (%)
Capelin *Mallotus villosus*	75.6	68.5	55.9	69.6	21.7	20.0
gunnels *Pholis* spp.	2.0	1.2	0.0	0.0	0.0	0.0
Rainbow Smelt *Osm. mordax*	1.7	1.9	0.0	0.0	1.1	0.6
clupeids *Clupea* spp.	1.4	1.9	0.5	0.7	1.1	2.5
sandeel *Ammodytes* spp.	0.0	0.0	12.3	10.0	0.0	0.0
other fish	0.3	0.1	0.5	0.7	3.3	2.5
unidentified fish	7.5	9.7	27.2	14.2	57.6	33.6
crustaceans	7.8	7.4	3.1	2.1	8.7	6.2
annelids	5.2	3.6	0.0	0.0	2.2	0.2
human waste	1.1	1.8	3.1	2.2	10.9	23.6
other food	7.8	4.0	3.1	0.5	21.7	10.9
Total		100.0		100.0		100.0

80% to 97% of the volume of fishes that were identified to species was capelin. Noteworthy is the lower proportions (in frequency of occurrence as well as in percent mass/volume) of capelin in regurgitations from Carleton (Table 3 and 4). However, a large proportion of fishes were unidentified, and capelin could account for most of it. But even then, capelin would represent a smaller volumetric proportion of gulls' regurgitations at Carleton.

Apparently compensating for the low abundance of capelin is a large proportion of food other than fish in chicks' diet at Carleton. The collection of 10 regurgitations containing large volumes of human refuse (such as sausages, ham, animal fat, chicken wings, etc.) resulted in human waste being the most important food category in volume (23.6%) at the Carleton colony in 1994. The prey category 'other food' was also better represented in regurgitations from Carleton (in 21.7% of regurgitations; 10.9% of total volume), in comparison with the other sampling sites (Estuary and Corossol Island, Table 3-4). At Carleton, this food category was composed of bird eggs (presumably of *Sterna* sp.), molluscs, and insects (4.7%, 3.4% and 2.8% of total volume, respectively). The 'unidentified fish' and 'other food' categories were the only ones present in regurgitations from all three areas for which the 'area' variable had a statistical significant effect on their frequency of occurrence (Table 4). Unidentified fishes

Table 4. Logistic regressions analyses on the frequency of occurrence (frq, %) of each prey category; different letters express significant differences (P < 0.05) of two-by-two comparisons between data subgroups (area-year). For prey categories present at more than one site, we also tested for an area effect.

Tabel 4. Resultaten van logistieke regressieanalyse van de frequentie van voorkomen (frq, %) van de verschillende prooisoorten; verschillende letters drukken significante verschillen uit (P < 0.05) van paarsgewijze vergelijkingen tussen de verschillende datasets (gebied-jaar). Voor alle prooisoorten die op meer dan één kolonie werden gevonden werd een test voor de gebieden uitgevoerd.

	Carleton 1994		Corossol Island 1996		1997		Estuary Islands 1994		1995		test for an area effect	
Prey category	frq (%)		frq (%)		frq (%)		frq (%)		frq (%)		*F*	*P* =
Capelin *Mallotus villosus*	21.7	d*	64.2	b	52.8	bc	40.7	c	87.0	a	2.03	0.36
gunnels *Pholis* spp.	-	-	-	-	-	-	5.8	a	0.8	b	-	-
Rainb. Smelt *Osm. mordax*	1.1	a	-	-	-	-	1.2	a	1.9	a	0.19	0.67
clupeids *Clupea* spp.	1.1	a	-	-	0.7	a	-	-	1.9	a	0.89	0.64
sandeel *Ammodytes* spp.	-	-	3.8	b	15.5	a	-	-	-	-	-	-
other fish	3.3	a	1.9	a	-	-	1.2	a	-	-	1.99	0.37
unidentified fish	57.6	a	28.3	b	26.8	b	11.6	c	6.1	c	64.24	<0.01
crustaceans	8.7	b	-	-	4.2	b	29.1	a	0.8	c	0.13	0.93
annelids	2.2	b	-	-	-	-	18.6	a	0.8	b	0.03	0.85
human waste	10.9	a	5.7	ab	2.1	b	4.7	ab	-	-	2.39	0.30
other food	21.7	a	7.5	b	1.4	c	8.1	b	7.6	b	9.88	<0.01

occurred more often at Carleton than at Corossol Island, and less frequently in the Estuary than in the two other areas; however, rather than being of any biological significance, this likely reflects the differences in experience and laboratory facilities of the person(s) that performed the identification of samples. The 'other food' category also occurred significantly more frequently at the Carleton colony than anywhere else.

Among other regional variations in the composition of gulls' regurgitations, blennies or gunnels *Pholis* sp. were present only in the Estuary, and sandeel *Ammodytes* sp. only at Corossol Island. Also, smelt *Osmerus mordax* and annelid worms were absent at Corossol Island.

Inter-annual variation Tables 5-7 show the annual composition of Herring Gull regurgitations from the Estuary, Corossol Island and Carleton respectively. At Estuary colonies, the proportion of capelin in 1995 was more than twice that of 1994 (Table 4-5). Surprisingly large quantities of annelids and crustaceans completed the gulls' diet in 1994 (together representing 34.6% of total volume in 1994, versus 0.1% in 1995). However, careful examination of the data revealed

Table 5. Composition of regurgitations of Herring Gull chicks collected between 9 June and 11 July in 1994 (n = 86) and 1995 (n = 262) at five St Lawrence Estuary colonies.

Tabel 5. Samenstelling van braaksels van Zilvermeeuwenkuikens verzameld tussen 9 juni en 11 juli in 1994 (n = 86) en 1995 (n = 262) op vijf kolonies in het St Lawrence estuarium.

	1994				1995			
Taxon	frequency (%)		volume (%)		frequency (%)		volume (%)	
Capelin	35	(40.7)	564.7	(36.1)	228	(87.0)	2832.5	(83.4)
gunnels	5	(5.8)	33.3	(2.1)	2	(0.8)	25.0	(0.7)
Rainbow Smelt	1	(1.2)	0.1	(<0.1)	5	(1.9)	94.0	(2.8)
clupeids	0	(0.0)	0	(0.0)	5	(1.9)	93.0	(2.7)
Winter Flounder*	1	(1.2)	7.0	(0.4)	0	(0.0)	0	(0.0)
unidentified fish	10	(11.6)	318.0	(20.3)	16	(6.1)	161.0	(4.7)
crustaceans	25	(29.1)	366.0	(23.4)	2	(0.8)	0.6	(<0.1)
annelids	16	(18.6)	175.3	(11.2)	2	(0.8)	3.0	(0.1)
insects	6	(7.0)	9.0	(0.6)	13	(5.0)	5.4	(0.2)
human waste	4	(4.7)	90.0	(5.8)	0	(0.0)	0.0	(0.0)
other food**	1	(1.2)	0.1	(<0.1)	7	(2.7)	183.0	(5.4)
Total			1563.5	(100.0)			3397.5	(100.0)

**Pseudopleuronectes americanus* ***Meadow vole *Microtus pennsylvanicus*, green sea urchin *Strongylocentrotus droebachiensis*, gull egg, unidentified animal flesh

that for the Estuary in 1994, 85.7% of the volume of crustaceans came from a single visit to Battures aux Alouettes, on 11 July, which in fact was the only time (over two years) that this colony was sampled. All (n = 19) regurgitations collected then were composed exclusively of euphausids (*Thysanoessa raschii* and *Meganyctiphanes norvegica*). Also on 11 July, 11 out of 17 regurgitations gathered at the Kamouraska Islands colony were entirely composed of earthworms, representing 93.0% of the volume of annelids for the Estuary in 1994. With the exception of the significantly lower occurrence of gunnels in 1995, other annual variations in prey occurrence for the Estuary relate to the absence of uncommon prey types in one year or the other.

At Corossol Island (Table 6), sandeel, which was rather uncommon in 1996's regurgitations (1.4% of total mass), occurred significantly more often and was among the main prey fed to young Herring Gulls in 1997 (13.1% in mass). Insects (under the category 'other food' in Table 4) were also present significantly more often in 1996 than in 1997. A larger quantity of human wastes was found in 1996 (6.1% of total mass, versus 0.8% in 1997), but its occurrence did not differ between years (it was observed in three regurgitations in each year). Finally, shrimps Malacostraca (few) and herring *Clupea harengus*

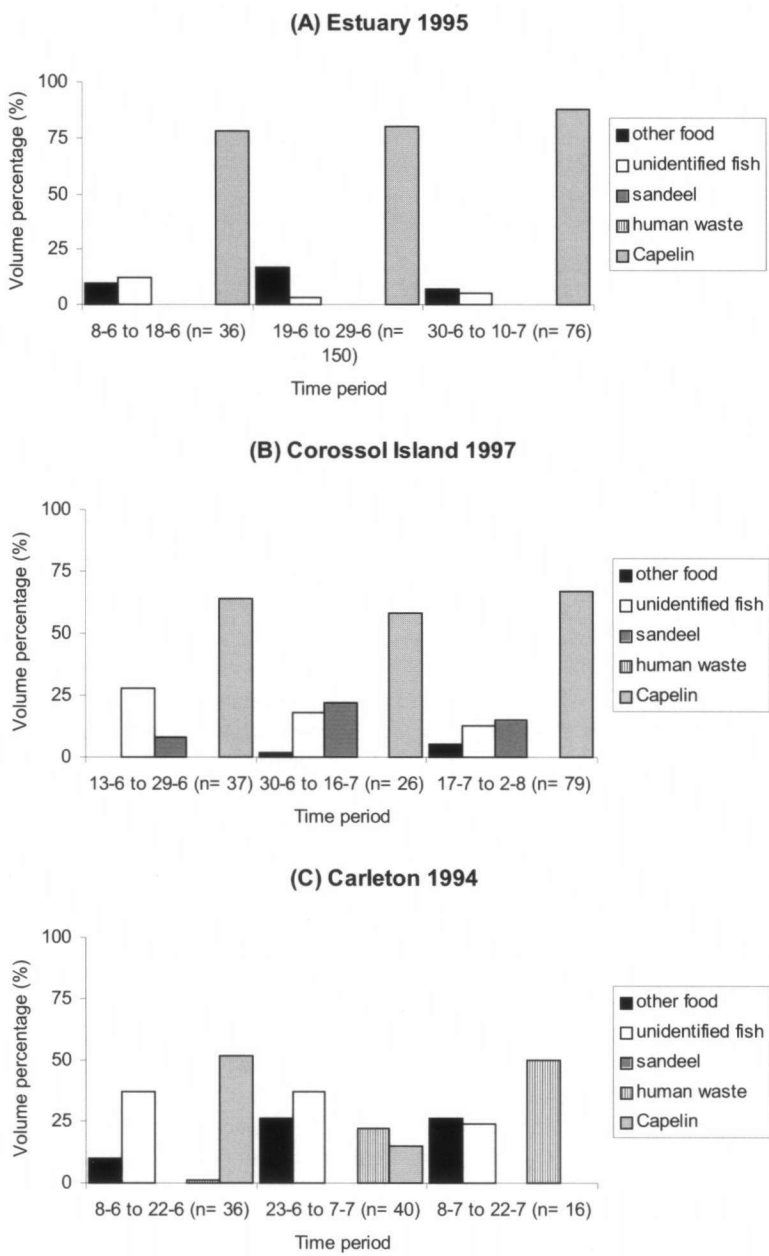
(A) Estuary 1995
Volume percentage (%)
100
75
50
25
0
8-6 to 18-6 (n= 36)
19-6 to 29-6 (n= 150)
30-6 to 10-7 (n= 76)
Time period
other food
unidentified fish
sandeel
human waste
Capelin
(B) Corossol Island 1997
Volume percentage (%)
100
75
50
25
0
13-6 to 29-6 (n= 37)
30-6 to 16-7 (n= 26)
17-7 to 2-8 (n= 79)
Time period
other food
unidentified fish
sandeel
human waste
Capelin
(C) Carleton 1994
Volume percentage (%)
100
75
50
25
0
8-6 to 22-6 (n= 36)
23-6 to 7-7 (n= 40)
8-7 to 22-7 (n= 16)
Time period
other food
unidentified fish
sandeel
human waste
Capelin

Figure 2. Seasonal trends in the volume of prey categories entering the diet of Herring Gull chicks from three areas of the St Lawrence Estuary and Gulf. Data come from regurgitations collected (A) in the Estuary in 1995, (B) at Corossol Island in 1997 and (C) at Carleton in 1994. For each area, sampling was divided in three time periods of equal duration (11, 17, and 15 days respectively).

Figuur 2. Seizoenpatronen in het volume prooisoorten dat deel uitmaakte van het voedsel van Zilvermeeuwenkuikens in het St Lawrence riviergebied (Estuarium en Golf). De gegevens werden verzameld (A) op kolonies in het Estuarium in 1995, (B) op Corossol Eiland in 1997 en (C) bij Carleton in 1994. Voor elk gebied werd de bemonstering in drie perioden van gelijke duur onderverdeeld (respectievelijk 11, 17 en 15 dagen).

(one fish) were recorded only in the larger sample of 1997. In general, regurgitations' composition was quite stable in 1996-1997 at Corossol Island, being largely dominated by capelin.

Seasonal trends Diet sampling that seemed adequate to visually detect real seasonal trends, *i.e.* sampling regular enough and covering most of the nesting season, was run in the Estuary in 1995, at Corossol Island in 1997, and at Carleton in 1994. For each of these data sets, Figure 2 shows the seasonal variation in the volumetric percentage of major prey items over three time-periods of equal length. It was preferable to regroup data by period instead of looking at daily variation because samples were sometimes very small.

In the Estuary in 1995 (Fig. 2a), diet composition was stable with capelin dominating the diet in each 11-day period (between 78% and 88% of total volume). Other prey categories were of minor importance. The picture was quite similar at the Corossol Island colony (Fig. 2b), as capelin was the main food in all three periods (between 58% and 71% of total mass). On the other hand, sandeel abundance in the regurgitations varied noticeably, from a total absence in the first period, to an important part of the diet (23% in mass) in the second period, and finally to an intermediate proportion (13%) in the last period. Actually, sandeel occurred fairly regularly during a short period, late in the season. It was first recorded on July 12 (*i.e.* on the 29th day of a sampling period that extended over 49 days), and last detected on July 26: during 15 days, it was present in about one third of regurgitations, and in 6 out of 8 samples (visits). Other prey types were poorly represented.

In contrast, major seasonal trends in the diet are visible in the graphic for Carleton's regurgitations in 1994 (Fig. 2c). Capelin abundance declined sharply from a little more than half of the volume of regurgitation in the first period (51.7%), to 15.8% and a complete absence in the second and third period, respectively. Actually, capelin was not detected after June 29. Interestingly,

Table 6. Composition of regurgitations of Herring Gull chicks collected between 14 June and 1 August in 1996 (n = 53) and 1997 (n = 142) at the Corossol Island colony.
Tabel 6. Samenstelling van braaksels van Zilvermeeuwenkuikens verzameld tussen 14 juni en 1 augustus in 1996 (n = 53) en 1997 (n = 142) op Corossol Eiland.

Taxon	1996				1997			
	frequency (%)		mass (%)		frequency (%)		mass (%)	
Capelin	34	(64.2)	970.0	(73.7)	75	(52.8)	2515.0	(68.2)
Mackerel*	1	(1.9)	34.0	(2.6)	0	(0.0)	0.0	(0.0)
clupeids	0	(0.0)	0.0	(0.0)	1	(0.7)	35.0	(0.9)
sandeel	2	(3.8)	18.5	(1.4)	22	(15.5)	484.0	(13.1)
unidentified fish	15	(28.3)	202.0	(15.4)	38	(26.8)	508.0	(13.8)
shrimps	0	(0.0)	0.0	(0.0)	6	(4.2)	104.0	(2.8)
human waste	3	(5.7)	80.0	(6.1)	3	(2.1)	31.0	(0.8)
insects	4	(7.5)	11.0	(0.8)	2	(1.4)	12.0	(0.3)
Total			1315.5	(100.0)			3689.0	(100.0)

* *Scomber scombrus*

food of anthropogenic origin underwent an almost exact opposite trend, passing from 2.8% to 19% and reaching 50.2% in volume in the last period. The volume of 'other food' (*i.e.* other fish species, crustaceans, birds, molluscs, insects and annelids) also increased between the first and second period (from 11.8% to 26.2%), and remained high at 26.9% in the third period.

DISCUSSION

Fish was the main food of young Herring Gulls at all locations. Also, 80% to 97% of the volume of fishes that were identified to species was capelin (depending on locality and year). In brief, capelin constituted the bulk of young Herring gulls' diet in the Estuary and Gulf of the St. Lawrence River. The menu would be opportunistically completed by many other species of fish (e.g. sandeel, herring, smelt), crustaceans (mostly shrimps and euphausids), annelids (earthworms and polychaetes), molluscs, urchins, insects, bird eggs, small mammals, and by human wastes. Overall, other kinds of food appeared to be of minor importance compared to capelin. However the diet was quite variable temporally, and regional differences were also observed. Also interesting to note is the total absence of fish offal or discards from the diet.

Regional variations of diet The most obvious regional difference is the low abundance of capelin in gulls' diet at Carleton, counterbalanced by a large volume of human waste and a high occurrence of the 'other food' category. Data on food availability would be necessary to confirm whether Carleton's gulls eat

Table 7. Composition of regurgitations of Herring Gull chicks collected between 8 June and 22 July in 1994 (n = 92) at the Carleton colony.
Tabel 7. Samenstelling van braaksels van Zilvermeeuwenkuikens verzameld tussen 8 juni en 22 juli in 1994 (n = 92) op Carleton.

Taxon	frequency (%)		volume (%)	
Capelin	20	(21.7)	307.4	(20.0)
Rainbow smelt	1	(1.1)	9.0	(0.6)
Clupeids	1	(1.1)	38.0	(2.5)
Other fish*	3	(3.3)	39.0	(2.5)
Unidentified fish	53	(57.6)	516.2	(33.6)
Crustaceans	8	(8.7)	95.0	(6.2)
Annelids	2	(2.2)	3.1	(0.2)
Birds**	4	(4.3)	72.0	(4.7)
Molluscs	5	(5.4)	52.1	(3.4)
Insects	11	(12.0)	43.4	(2.8)
Human waste	10	(10.9)	363.0	(23.6)
Total			1538.1	(100.0)

*Atlantic Tomcod *Microgadus tomcod*, Threespine Stickleback *Gasterosteus aculeatus* and Witch Flounder *Glyptocephalus cynoglossus* **Chicks and eggs of terns *Sterna sp.*

less capelin because other food sources are easily available, or rely on alternative food sources because capelin is less abundant than anywhere else. However, the latter hypothesis seems more likely, since capelin is a cold water species whose abundance is highest in the northern part of the Gulf and in the Estuary (Scott & Scott 1988; Grégoire *et al.* 1997). Thus, in conditions where capelin was presumably less available than around Corossol Island and in the Estuary, gulls at Carleton provided their young with a more varied diet. The fact that a large proportion of food in Carleton gulls' diet originates from terrestrial and tidal habitats also suggests an adaptation of the gulls in terms of changing foraging habits.

Another regional particularity in the diet of young Herring Gulls was the notable presence of sandeel at Corossol Island only. The absence of sandeel in the Estuary fits the distribution of the species (Scott & Scott 1988). Based on the same reference it is almost surprising that no sandeel were found in Carleton, but a large proportion of fishes remained unidentified.

Inter-annual variations A major part of the large quantities of crustaceans and annelids that characterised gulls' diet in the Estuary in 1994 came from two colonies sampled on 11 July. Daytime surface swarming of the euphausid *M. norvegica* has been observed to attract many predators, including the Herring Gull (Brown *et al.* 1979). The fact that on 11 July, all regurgitations collected at Battures aux Alouettes (Estuary) were composed exclusively of euphausids

suggests that such a phenomenon (euphausids daytime surface swarming) occurred near the colony on that day. As for the unusual abundance of earthworms in samples from Kamouraska Island on 11 July, it could be explained by the ploughing of a nearby agricultural land. Indeed, large numbers of Herring Gulls are often observed during field ploughing, as they follow the machinery and pick up exposed earthworms.

Therefore we must conclude that most of the apparent annual variation in gulls' diet in the Estuary is a consequence of irregular and uneven sampling. In fact, if we exclude the visits at Battures aux Alouettes and Kamouraska Islands on 11 July, and take into account that most unidentified fish in 1994 must have been capelin, the diet of young Herring Gulls in the Estuary appears nearly stable in 1994-1995. Because of the opportunistic ability of Herring Gulls to detect and take advantage of a sudden food source availability, biases in diet assessment on a given breeding season are easily introduced, unless sampling is exhaustive and well distributed over time.

The other notable annual variation of gulls' diet was the higher abundance of sandeel at Corossol Island in 1997, compared to 1996. However, while sandeel was regularly represented during 15 days in 1997, sampling of gulls' diet in 1996 did not cover most of the chick rearing period, so that a momentary abundance of sandeel in waters surrounding Corossol Island could easily have gone undetected through gulls' diet in 1996.

Seasonal trends It is apparent that the sometimes important daily variations in young Herring Gulls' diet were mainly due to small samples (e.g. $n < 10$). In a few cases where larger samples were collected on consecutive days, the diet actually appeared more stable. It seems however that momentary specialisation of the diet will occur in association with punctual phenomena such as fish/crustacean surface swarming, or any other extra availability of food. In fact, sampling in this study was not designed to assess daily variations in the diet. Nevertheless, we were able to detect an obvious seasonal trend in gulls' diet at the Carleton colony in 1994. As capelin, that constituted half of the volume of regurgitations in the first third of the season, gradually vanished to a complete absence from the diet, the proportions of human wastes and other kinds of food (crustaceans and molluscs in particular) increased accordingly.

Comparisons with other studies A comparison of results from several studies of Herring Gull's diet around the world underscores the adaptability of the species (e.g. Burger 1988). Undoubtedly as reflected by the regional availability of food sources, the diet may either be dominated by a particular species of fish (Spaans 1971; Haycock & Threlfall 1975; Fox *et al.* 1990; Belant *et al.* 1993), bivalves (Pierotti 1983; Bukaciñska *et al.* 1996), fishery discards (Furness 1984) or dump waste (Harris 1965; Sibly & McCleery 1983). Our study demonstrates

once again that capelin is a key species in the food webs of seabirds in the St. Lawrence Estuary and Gulf's ecosystems (e.g. Rail *et al.* 1996), as it is elsewhere in the NW Atlantic (Brown & Nettleship 1984; Carscadden 1984).

Beyond these observations, the comparison of results between studies is difficult because the use of different methods of sampling, (e.g. pellets, food remains, regurgitations, observation) analysis and data presentation (frequency of occurrence, numerical frequency, volume, etc.) obviously influence diet assessment (Duffy & Jackson1986; Buckley 1990). Also, the fact that the diet of adults and young chicks may differ (Spaans 1971; Mudge & Ferns 1982; Cavanagh 1992) is rarely taken into account and samples from all age categories are often lumped together. For example, adult gulls may prefer to feed young chicks with fish instead of nutritionally inferior landfill waste (Cavanagh 1992). Thus the results presented in our study may not be representative of adult diet.

Herring Gull as bioindicator of marine resources The extraordinary adaptability of the Herring Gull enables the species to rely on a variety of food sources, and to quickly adjust its diet and foraging habits according to local variations in food availability. This suggests that the species would be an effective bioindicator for local trends in the relative abundance of its prey, especially capelin. However, assessing the availability of prey irregularly present in gulls' diet would require a more intensive, careful sampling.

Also, annual diet sampling of a network of gull colonies, distributed in the Estuary and Gulf, could be used to monitor large scale variations in abundance and distribution of prey species. For example, capelin distribution expanded in the southern part of the Gulf of St. Lawrence since the early 1990's, apparently as a result of abnormally cold water temperatures (Grégoire *et al.* 1997). We assume that the occurrence of capelin in young Herring Gulls' diet at Carleton in 1994 is an indicator of this phenomenon; since in 'normal' conditions (*i.e.* warm water temperature in the vicinity of Carleton) capelin would have been even less abundant in gulls' diet.

Conclusion and recommendations This study provides baseline data that could be useful for future investigation of the relationship between trends in Herring Gull populations and food availability in the Estuary and Gulf of the St. Lawrence River. Our assessment of Herring Gull chicks' diet demonstrated the generalist and opportunist character of the species. The diet was varied and variable, spatially and temporally. Nevertheless, capelin, a forage fish that is most important in term of biomass in the food chain in the St. Lawrence Estuary and Gulf, constituted the bulk of gulls' diet. At the colony of Carleton, located in the southern Gulf, capelin was less abundant, and more human waste completed the chicks' diet, in comparison with Corossol Island and Estuary colonies.

Our difficulty to analyse the diet spatially and temporally despite an overall considerable sampling effort demonstrates the usefulness to plan for a regular, well-balanced sampling. A minimum of ten regurgitations per visit would have been necessary to account for daily variations. To minimise sampling biases, several visits to a colony should be evenly spaced throughout the season, sample size on each visit should be kept nearly constant, and ultimately, results from each visit should be weighed equally.

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SAMENVATTING

De geweldige toename van veel soorten meeuwen in het Noord-Atlantische gebied in de afgelopen eeuw wordt vaak geweten aan verbeterde omstandigheden, zoals een toegenomen aanbod van voedsel op open vuilstortplaatsen en bij vissersschepen (visafval). De Zilvermeeuw Larus argentatus *is een soort waarvan veel populaties de afgelopen tientallen jaren echter onder druk staan, zo ook in oostelijk Canada, in het mondinggebied van de St Lawrence Rivier, waar het onderzoek waarover in dit artikel wordt gerapporteerd werd uitgevoerd. Als voedsel een oorzaak van de toename zou zijn geweest, ligt het voor de hand om te veronderstellen dat een verandering in voedselaanbod aanleiding heeft gegeven voor de afname die wordt waargenomen. Zoals zo vaak werden eerst conclusies getrokken (de afname zou samenhangen met een afname in het aanbod van visafval bij trawlers), waarna geconstateerd moest worden dat de noodzakelijke gegevens om tot zo'n uitspraak te kunnen komen feitelijk ontbraken. De onderzoekers constateerden dat er nauwelijks adequate gegevens voorhanden waren over de voedselkeuze van Zilvermeeuwen in het gebied. Zilvermeeuwen zijn opportunistische meeuwen die een grote verscheidenheid van prooien op het menu hebben staan. In dit artikel wordt het voedsel van kuikens (aan de hand van uitgebraakt voedsel) beschreven en vergeleken over de jaren 1994-97 in vijf kolonies in het St Lawrence estuarium en twee kolonies in de Golf van St Lawrence (steeds verzameld tussen 8 juni en 1 augustus).*

Het voedsel van de meeuwenkuikens bleek bijzonder gevarieerd te zijn, maar liefst 85.2% van het opgebraakte voedsel (massa/volume) van de in totaal 635 braaksels bestond uit vis. Lodde Mallotus villosus, *een kleine spieringachtige vis, was veruit de belangrijkste prooi (61.7% in frequentie, 62.5% als massapercentage). Uiteraard was het monsterprogramma niet uitputtend (635 monsters verdeeld over zeven kolonies in vier onderzoeksjaren over een periode van ruim 50 dagen per seizoen), en de onderzoekers hadden daardoor nogal wat last van 'verrassingen'. Zo werd het voedsel tijdens een bezoek op 11 juli 1994 in het estuarium plotseling gedomineerd door krillachtige garnaaltjes, vermoedelijk als gevolg van een plotseling en bovendien nogal zeldzaam aanbod van overdag naar de oppervlakte zwermende diertjes. Het weglaten van dergelijke 'uitbijters' in de resultaten laat een veel minder gevarieerd dieet zien en het maakte dat de verschillen van jaar tot jaar en van plaats tot plaats toch vrij beperkt waren.*

Geconstateerd wordt, vooral na een vergelijking met vergelijkbaar voedselonderzoek elders in de wereld, dat de voedselkeuze van de Zilvermeeuw een belangrijk inzicht kan geven in veranderingen in het voedselaanbod in de onmiddellijke omgeving van de kolonies. Om ten volle als

'bio-indicator' geschikt te zijn, is het echter noodzakelijk om plotselinge en bovendien kleinschalige fluctuaties in het aanbod te kunnen onderscheiden van het grote patroon. Daarvoor is een uitgebreid monsterprogramma noodzakelijk, met precieze aanpassingen in de onderzoeksopzet zodat de onderliggende vraag (bijvoorbeeld variaties in de loop van een seizoen, in de ruimte, of tussen jaren) ook inderdaad beantwoord kan worden. De hier gepresenteerde resultaten zullen vooral van betekenis zijn als basismateriaal voor toekomstig onderzoek aan het voedsel van Zilvermeeuwen in oostelijk Canada. Bijzonder inzicht in de achtergronden van de afnemende populatie heeft dit onderzoek nog niet gegeven, behalve dat 'discards' (snijafval en ondermaatse vis in de commerciële visserij), tegen de verwachting in, in het geheel niet op het menu van Zilvermeeuwenkuikens bleek te staan.

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Appendix 1. List of prey items identified to lowest taxonomic rank in 534 regurgitations of Herring Gull chicks, collected in the St. Lawrence Estuary and Gulf in 1994-1997 (**Prey type** [Class/order/family] Lowest taxon): **Fish** [Ammodytidae] *Ammodytes* sp., [Clupeidae] *Clupea harengus*, unidentified clupeidae, [Gadidae] *Microgadus tomcod,* [Gasterosteidae] *Gasterosteus aculeatus*, [Osmeridae] *Mallotus villosus, Osmerus mordax*, unidentified osmeridae, [Pholidae] *Pholis fasciata, Pholis* sp., [Pleuronectidae] *Pseudopleuronectes americanus, Glyptocephalus cynoglossus*, [Scombridae] *Scomber scombrus*, and unidentified fish; **Crustaceans** [Amphipoda] *Gammarus* sp., [Mysidacea] unidentified Mysidae, [Decapoda] *Eualus pusiolus*, *Crangon septemspinosa,* unidentified shrimp, *Hyas araneus*, *Cancer irroratus*, [Euphausiacea] *Meganyctiphanes norvegica, Thysanoessa raschi,* unidentified euphausiacea, and unidentified crustaceans; **Molluscs** [Gastropoda] *Littorina saxatilis,* unidentified gasteropod, [Bivalvia] *Mytilus edulis,* and unidentified molluscs; **Echinoderms** [Echinoidea] *Strongylocentrotus droebachiensis*; **Annelids** [Polychaeta] *Nereis virens*, [Oligochaeta] *Lumbricus* sp.; **Insects** [Diptera] unidentified muscidae, tipulidae, diptera, [Hymenoptera] unidentified formicidae, vespidae, and hymenoptera, [Coleoptera] unidentified carabidae and coleoptera, [Lepidoptera] unidentified butterfly, and unidentified insect; **Birds** [Laridae] *Sterna* sp. (eggs and chicks), unidentified larid egg; **Mammals** [Cricetidea] *Microtus pennsylvanicus*; **Human waste** miscellaneous food remains