SEASONAL ASPECTS OF THE DIET OF BONAPARTE'S GULLS (*LARUS PHILADELPHIA*) IN THE QUODDY REGION, NEW BRUNSWICK, CANADA

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ABSTRACT.—During July–December 1978–1984, Bonaparte's Gulls (*Larus philadelphia*) on annual migration through the Quoddy region off New Brunswick, Canada, fed on fish, euphausiids, insects, and other marine invertebrates (mainly polychaetes and amphipods) in varying proportions as the summer and autumn progressed. The seasonal variation in the diet was related directly to food availability, which, in turn, was dictated by natural cycles of prey in the region. The frequency with which plastic particles were found in the stomachs also had a statistically significant seasonal trend. Fish provided the largest energy contribution (75–91%) to the diet at all times in the region. There was no significant difference between diets of juvenile and adult birds. *Received 23 April 1986, accepted 15 August 1986.*

BONAPARTE'S Gull (*Larus philadelphia*) is a widely distributed North American species. The Quoddy region of New Brunswick in the Bay of Fundy, Canada, is a major autumn staging ground for migrating Bonaparte's Gulls, resulting in the largest known concentration of this species in eastern Canada (Canadian Wildl. Serv. 1979). The anomalous tidal regime of the Quoddy region results from interaction of large-amplitude, semidiurnal tides with the complex physiography of the area; these conditions affect the local concentration and distribution of zooplankton, thereby creating important feeding sites for fish, seabirds, and marine mammals (Smith et al. 1984). This localized concentration of food, in combination with ease of access to the area, creates a favorable situation for intensive study of Bonaparte's Gull (Braune and Gaskin 1982a).

The diet of the Bonaparte's Gulls in the Quoddy region during September 1978 and August 1979 was summarized by Braune and Gaskin (1982a). The objective of the present study was to evaluate seasonal aspects of the diet of Bonaparte's Gulls during autumn migration during 1978–1984, and to compare prey types with those taken by the birds in other areas of North America.

METHODS

Collection of birds.—As part of a study on heavy metal accumulation in the marine ecosystem, 222 Bonaparte's Gulls were collected by shotgun (under Scientific Kill Permits issued by Canadian Wildlife Service) from 22 July through 28 December 1978–1984 in the Quoddy region off southeastern New Brunswick, Canada (Fig. 1). The birds were pooled into 4 periods of approximately 6 weeks each (Table 1). Birds were collected at various times of day on flood and ebb tides. An adult gull also was obtained from the breeding grounds near Churchill, Manitoba, on 8 August 1982. The proventriculus and gizzard of each bird were removed as a unit and the contents preserved in 10% formalin in 1978 and 70% alcohol in 1979–1984. Seven stomachs were empty. The birds were then aged as juvenile or adult by plumage (Grant 1982) and sexed by examination of gonads.

Diet analysis.—Food items from collected stomach contents were categorized into four major groups: insects, euphausiids, other marine invertebrates, and small fish. Insects were identified to order (Borror and White 1970), and euphausiids and most other marine invertebrates were identified to species (Gosner 1971). Fish were assigned to species based on morphological characteristics (Leim and Scott 1966) and otoliths (Smith and Gaskin 1974). Numbers of partially digested fish were calculated based on counts of vertebrae and otoliths.

To minimize bias resulting from birds feeding opportunistically on one food type to the exclusion of most others at the time of sampling, stomach-content data were pooled over the years to gain average representative dietary trends as well as a temporal sequence (July–December) of dietary information. Data are presented as percentage frequency of occurrence of major food types among stomach-content samples. Food items unidentifiable to order or species were included only in the respective major prey category.

The *G*-test of independence using Williams's correction (Sokal and Rohlf 1969) was used to test for

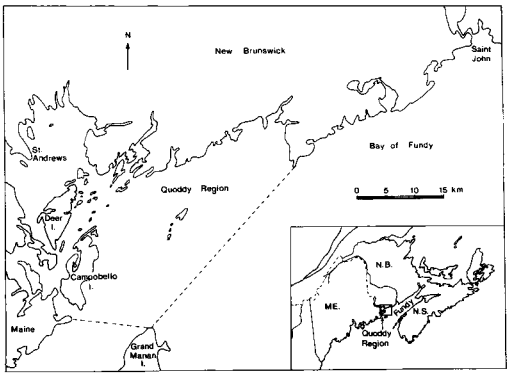

Fig. 1. The Quoddy region in the southwestern Bay of Fundy off New Brunswick, Canada.

differences in diet between juvenile and adult Bonaparte's Gulls collected from the same feeding flock. For each of six disparate samples containing both juveniles and adults, *G*-tests were performed separately for each of the four major food types (insects, euphausiids, fish, other invertebrates) based on raw frequency of occurrence data. Chi-square tests were used to test for seasonal changes in the frequency of occurrence of the food types in the stomach-content samples collected over the four time periods. For all statistical analyses, the level of significance was set at $P \leq 0.05$.

RESULTS

With the exception of two isolated cases, there was no significant difference between diets of juvenile and adult Bonaparte's Gulls in the Quoddy region (Table 2), so data from both age groups were pooled. Euphausiids were taken more frequently than fish during July to early October, but fish were taken with significantly greater frequency during October-November than earlier in the season (Table 3). Other invertebrates were taken significantly more frequently as the autumn progressed (Table 3). The occurrence of insects decreased significantly until none were taken during December.

The insects most commonly found in the stomachs of Bonaparte's Gulls were from the orders Coleoptera, Hymenoptera, and Diptera. Other than insects and euphausiids, polychaetes (*Nereis virens*) and amphipods (*Gammarus oceanicus*) were found frequently. The stomach of the adult bird collected from the breeding grounds (Churchill, Manitoba) contained insects (Ephemeroptera, Trichoptera) exclusively.

The frequency with which stones were found in the gizzards paralleled the frequency trend of the other invertebrates, and the presence of plastic particles (fragments and pellets: 1–4 mm diameter) increased significantly over the season (Table 3).

DISCUSSION

Quoddy region.—Euphausiid surface swarms provide a highly concentrated and readily accessible food source in the Quoddy region (Smith et al. 1984). Such surface swarms are particularly important for seabirds because most species, including Bonaparte's Gull, feed only at the surface (Brown et al. 1979). Surface swarming of euphausiids occurs most frequently in August and September, with another peak during November-December (Fish and Johnson 1937). The occurrence of euphausiids in the diet of Bonaparte's Gulls closely followed swarming trends (Table 3).

Young herring (*Clupea harengus*) tend to concentrate in inshore shoal areas, particularly in summer and autumn (Ridgway 1975), to feed in the upper water layers (Legare and Maclellan 1960), where they are readily available to feeding gulls. Species of fish found in the stomachs of gulls varied over the years; harbor pollock (*Pollachius virens*) replaced herring as

TABLE 1. Numbers of Bonaparte's Gulls (J = juveniles, A = adults) collected from the Quoddy region during July–December 1978–1984.

	Year							Total	
Period	1978	1979	1980	1981	1982	1983	1984	J	A
22 July–30 Aug		7	17	30	23	10		14	73
31 Aug–9 Oct	18			25	22	21		31	55
10 Oct–18 Nov					20	5	12	2	35
19 Nov–28 Dec					11	1			12
Total	18	7	17	55	76	37	12	47	175

TABLE 2. Corrected *G*-values for comparisons of frequency of occurrence of major prey types in stomach contents between juvenile (j) and adult (a) Bonaparte's Gulls collected from the same flock in the Quoddy region on six occasions.[a]

Prey type	Aug 1981 $n_j = 9$ $n_a = 10$	Sept 1978 $n_j = 3$ $n_a = 8$	Sept 1981 $n_j = 6$ $n_a = 8$	Sept 1982 $n_j = 11$ $n_a = 11$	Oct 1983 $n_j = 11$ $n_a = 10$	Nov 1984 $n_j = 2$ $n_a = 10$
Insects	4.37*	0.01	0.78	1.12	0.94	0.53
Euphausiids	0.39	2.44	0.78	1.60	0.00	0.05
Fish	0.00	0.21	0.00	3.96*	0.25	0.05
Other invertebrates	1.04	0.01	0.00	0.96	3.17	0.05

[a] * = $0.025 < P < 0.05$.

the major fish prey species during 1980 and 1982. Harbor pollock were taken only during late July to early September (Table 3). The pollock is a larger, heavier fish than the herring (Kohler et al. 1970), and after September most harbor pollock are too large for gulls to capture and swallow easily.

The highest concentrations of insects occurred mainly during mass emergences such as those of winged ants (Hymenoptera) during August–September. During the emergences, the birds fed on the insects mainly by "hawking" for them. At other times, insects were taken from the water surface layer or from floating weed fragments (Braune and Gaskin 1982a). As insect availability declined during the autumn, other invertebrate species, primarily polychaetes and amphipods that occur in large concentrations locally inshore, were ingested more frequently (Table 3). The parallel trend in frequency of occurrence of stones probably can be attributed to their ingestion with polychaetes and amphipods along the shoreline.

The number of prey individuals equal to the energy content of one herring (4 g) varied dramatically among the different prey types (Table 4). Insects, euphausiids, and other invertebrates may be exploited most effectively only when they occur in large, dense concentrations. When high prey densities occur, the gulls may settle on the water and seize surface prey (Braune and Gaskin 1982b).

Fish contributed the most energy to the diet (Table 5). Euphausiids contributed more energy to the diet during July to early October than from October to December. Insects were taken more frequently than their dietary energy input would suggest (cf. Tables 3 and 5), but overall, insects and other invertebrates contributed little energy to the diet.

Prolonged retention of fish otoliths and polychaete jaws presented a potential bias to

TABLE 3. Percentage frequency of occurrence of prey types and nonfood items collected from the stomachs of Bonaparte's Gulls, July–December 1978–1984. Chi-square values are given for seasonal changes in frequency of occurrence of prey types and nonfood items found in stomach contents.[a]

Stomach contents	22 July–30 Aug ($n = 85$)	31 Aug–9 Oct ($n = 85$)	10 Oct–18 Nov ($n = 35$)	19 Nov–28 Dec ($n = 10$)	χ^2
Insects[b]	49	41	37	0	9.58**
Euphausiids	65	68	43	70	7.40
Meganyctiphanes norvegica	(51)	(64)	(31)	(50)	10.53**
Thysanoessa inermis	(34)	(44)	(20)	(30)	6.33
Fish	58	32	71	60	20.13***
Clupea harengus	(27)	(16)	(34)	(30)	5.26
Pollachius virens	(22)	(1)	(0)	(0)	28.47***
Other invertebrates[c]	8	15	43	20	21.35***
Stones	4	16	23	10	11.34**
Plastic particles	0	2	9	20	16.45***

[a] ** = $0.01 < P < 0.025$, *** = $P < 0.001$.

[b] Ephemeroptera, Orthoptera, Hemiptera, Homoptera, Coleoptera, Trichoptera (larvae), Lepidoptera (eggs), Diptera, Hymenoptera, and unidentified pupae.

[c] Polychaeta, Amphipoda, Mysidacea, Gastropoda, and Bivalvia.

TABLE 4. Mean wet mass (g/individual), energy content (kJ/g wet mass), and number equivalents based on energy values of major prey types found in the stomachs of Bonaparte's Gulls collected from the Quoddy region.

Prey	Mean wet mass	Energy content	Prey number equivalents
Fish			
Clupeidae	4.0[a]	10.925[e]	1
Gadidae	6.0[a]	5.651[f]	1.3
Other invertebrates			
Polychaeta	2.24[b]	2.675[g]	7
Amphipoda	0.138[b]	3.910[g]	81
Euphausiids			
Meganyctiphanes norvegica	0.127[c]	4.098[c]	84
Thysanoessa inermis	0.032[c]	4.098[c]	334
Insects	0.032[d]	3.177[g]	430

[a] Kohler et al. (1970); based on fish of 8 cm total length such as those found intact in the digestive tracts of gulls.
[b] Based on individuals collected from areas with feeding gulls (Polychaeta: $n = 10$, Amphipoda: $n = 10$).
[c] Kulka and Corey (1982).
[d] Based on intact individuals found in proventriculi ($n = 50$).
[e] Keiver (1982).
[f] Wiens and Scott (1975).
[g] Cummins and Wuycheck (1971).

the dietary information because counts of individual prey often were based on numbers of these structures present. In a variety of seabirds, fish otoliths are retained for no more than 24 h (Furness et al. 1984). However, Bar-tailed Godwits (*Limosa lapponica*) retained polychaete jaws for 6–7 months (Smith 1975), and a Shy Albatross (*Diomedea cauta*) retained squid beaks (similar in composition to polychaete jaws) for 1–2 months (Furness et al. 1984). Retention time of such structures is likely to be species specific, depending on grinding efficiency of the gizzard and the presence of grit. Small stones and grit were found regularly in the muscular gizzards of Bonaparte's Gulls, suggesting a shorter retention time for the jaws in gulls than in shorebirds (see Table 3). The dietary energy contribution of polychaetes probably was overestimated because of the inclusion of retained jaws in counts of polychaete numbers (Table 5: Other invertebrates).

The frequency with which plastic particles occurred in the stomach contents of Bonaparte's Gulls in the Quoddy region increased significantly throughout the summer and autumn (Table 3). As the availability of insects decreased and surface swarms of euphausiids and shoals of small fish became less frequent than in summer and early autumn, the birds began to exploit other food resources. This was apparent in the increased consumption of other invertebrates, and probably also accounts for the increased occurrence of plastic particles in the diet. With the increased patchiness and decreased availability of fish and euphausiids in the area, it is likely that the birds more frequently picked up items that appeared edible.

Other areas.—Other studies on the diet of Bonaparte's Gulls indicate that insects, shrimplike crustaceans, and small fish are common prey across North America (Table 6). In inland areas, such as nesting grounds near bogs and muskegs, the birds are mainly insectivorous, as suggested by Bent (1921) and Plough (1951) and by the stomach contents of the gull collected at Churchill, Manitoba. Bonaparte's Gull is less of a scavenger than other gulls, and although it shows little interest in chum (Rowlett 1980), bits of refuse and food scraps floating on the surface are sometimes ingested (Sprunt 1954, Burleigh 1958). Little, if any, plant material is taken (Bent 1921).

A description of diet cannot be based solely

TABLE 5. Average percentage energy contribution to the diet of prey types collected from the stomachs of Bonaparte's Gulls, July–December 1978–1984.

Prey types[a]	22 July–30 Aug ($n = 85$)	31 Aug–9 Oct ($n = 85$)	10 Oct–18 Nov ($n = 35$)	19 Nov–28 Dec ($n = 10$)
Insects	1	1	<1	0
Euphausiids	15	18	5	8
Fish	82	75	85	91
Other invertebrates	3	7	10	1

[a] See Table 3 for detailed description of prey types. For calculations of energy content, prey unidentifiable to order or species were pooled with the order or species containing the highest number of identified individuals in each of the 4 major prey categories found in a given stomach or over a specific sampling period.

TABLE 6. Diet of Bonaparte's Gull across North America.

Location	Food	Source
Nelson Lagoon, Alaska	Large shrimp	Gill and Hall (1983)
Frederick Sound, Alaska	Insects, euphausiids, sand launce	L. H. MacIvor (unpubl. data)
Washington state	Insects	Bowles (1906)
Monterey Bay, California	Insects, euphausiids, marine worms, fish	Baltz and Morejohn (1977)
Florida	Insects, crustaceans, snails, fish	Sprunt (1954)
Appalachicola R. mouth, Florida	Small fairy shrimp	L. Atherton (pers. comm.)
Georgia	Insects, fish, other marine life	Burleigh (1958)
South Carolina	Insects, crustaceans, snails, fish	Sprunt and Chamberlain (1949)
Manomet, Massachusetts	Amphipods	L. H. MacIvor (pers. comm.)
Nantucket Is., Massachusetts	Sand launce	Heil (1984)
New England	Insects	Nuttall (1974)
Quoddy region, New Brunswick	Insects, euphausiids, fish, other invertebrates	This study
Pennsylvania	Fish	Todd (1940)
Upper Niagara River, Ontario–New York	Emerald shiners	Axtell (1959)
Coast	Fish, shrimp, other crustaceans, marine worms	Bent (1921)
Inland	Insects	Bent (1921), Plough (1951)

on one or two sampling sessions, even from a localized area such as the Quoddy region. Food types may remain relatively consistent between years, but prey species may vary from year to year, as illustrated by the consumption of herring and harbor pollock. The diet is subject to seasonal variation in prey availability, which, in turn, is related to annual cycles of prey behavior, migration, and growth.

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