The Condor 101:824–831
© The Cooper Ornithological Society 1999

USING RADIO-TRANSMITTERS TO IMPROVE ESTIMATES OF GULL PREDATION ON COMMON EIDER DUCKLINGS[1]

K. MAWHINNEY AND A. W. DIAMOND
Atlantic Cooperative Wildlife Ecology Research Network, University of New Brunswick, P.O. Box 45111, Fredericton, New Brunswick, Canada, E3B 6E1

Abstract. We quantified the efficacy of using pellet numbers to estimate predation rates on Common Eider (*Somateria mollissima*) ducklings by Great Black-backed Gulls (*Larus marinus*) by using eider ducklings fitted with radio transmitters. Ducklings fitted with radio-transmitters were no more vulnerable to gull predation than were other ducklings. The recovery of radio-transmitters attached to eider ducklings and subsequently retrieved from Great Black-backed Gull pellets suggests that traditional methods of estimating the number of eider ducklings eaten by gulls from the remains found in pellets at gull nests and loafing areas underestimates the true number eaten by gulls by a factor of 5–17. Previous low estimates of eider duckling mortality on the Wolves Archipelago, Bay of Fundy cannot be explained by movements of broods to the mainland coast.

Key words: Common Eider, ducklings, Great Black-backed Gull, gull predation, Larus marinus, Somateria mollissima.

INTRODUCTION

Large gulls (*Larus* spp.) are important predators of the eggs and young of other seabirds (Thomas 1972). Studies of the impact of predation by Great Black-backed Gulls (*Larus marinus*) have focused on terns (*Sterna* spp.) (Shealer and Burger 1992), auks (Alcidae) (Harris 1980), and Black-legged Kittiwakes (*Rissa tridactyla*) (Burger and Gochfeld 1994). Harris (1980) found that 30–40 pairs of Great Black-backed Gulls took about 2,700 adult Atlantic Puffins (*Fratercula arctica*) from a colony of 40,000 pairs during a breeding season; yet Beaman (1978) found that only 400 puffins were taken from a colony of 8,000 pairs by a neighboring colony of 1,800 pairs of Great Black-backed Gulls. Clearly, there is no simple relationship between the numbers of gulls and the extent of their predation at nearby colonies of other seabirds.

The range of Great Black-backed Gulls and numbers of Herring Gulls (*L. argentatus*) and Great Black-backed Gulls have expanded considerably along the Atlantic coast of North America since the 1920s (Erskine 1992). Common Eider (*Somateria mollissima*) populations began increasing after they were protected from egging and hunting in 1928 (Gross 1944). Simultaneous increases in the numbers of both Herring Gulls and Common Eiders in the St. Lawrence estuary demonstrate that Herring Gull predation on eider eggs or ducklings need not prevent eider populations from increasing (Munro and Bédard 1977). However, Great Black-backed Gulls are relative newcomers to eastern Canada, their ranges have expanded southward as garbage and fisheries offal became more abundant (Belant et al. 1993), and they are more predatory than Herring Gulls. Great Black-backed Gulls are known to prey on Common Eider eggs and young at the nest site (Ahlén and Åndersson 1970, Bourget 1973) and ducklings on the water (Munro and Bédard 1977, Swennen 1989). The Common Eider now faces a predator that historically was scarce or absent, and whose impact on egg and duckling survival has not been assessed.

Gilliland (1990) suggested that gull depredation in an eider colony accounted for less than 10% of duckling mortality. This estimate was based primarily on the number of duckling remains in pellets (indigestible residue) associated with gull nests and loafing areas. Information gained from studies of regurgitated pellets has been widely used to study the impact of predation by cormorants on fish populations (Derby and Lovvorn 1997), and by Great Skuas (*Catharacta skua*) (Furness 1981) and Great Black-backed Gulls (Furness 1981, Harris 1980) on other seabirds. In addition, pellets have been widely used to study diet and to monitor variation in the use of certain prey items by gulls (Nogales et al. 1995, Oro et al. 1997). However, if gulls move from their normal feeding or roost-

[1] Received 7 April 1998. Accepted 6 July 1999.

ing area, pellets may be unobtainable, and there are marked differences in the ease with which pellets can be found depending on the presence and age of chicks and the vegetation adjacent to the breeding site. In this paper we quantify the efficacy of pellets in estimating predation rates on radio-tagged Common Eider ducklings by Great Black-backed Gulls under a variety of conditions.

METHODS

STUDY AREA

The Wolves Archipelago (44°56′N, 66°44′W) is a group of 5 islands, 12 km offshore from Beaver Harbour, New Brunswick, Canada in the Bay of Fundy. The islands range from 20–2,039 ha in area; most are forested with balsam fir (*Abies balsama*) and spruce (*Picea* spp.), but the smallest, Green Rock, is predominantly grasses (Gramineae spp.) and wild raspberry (*Rubus idaeus*). In addition to Common Eider and Great Black-backed Gulls, other breeding seabirds include Double-crested Cormorants (*Phalacrocorax auritus*), Black Guillemots (*Cepphus grylle*), and Herring Gulls. Recent additions include a colony of Black-legged Kittiwakes (*Rissa tridactyla*) (Kehoe 1994), and two pairs of Razorbills (*Alca torda*) (Mawhinney and Sears 1996).

Petit Manan Island and Green Island (44°30′N, 68°30′W), 25 km east of Bar Harbor, are part of a National Wildlife Refuge in the Gulf of Maine, U.S.A. The islands are connected by a bar at low tide. Both are treeless with thin peaty soil, and vegetation consists mainly of grasses. The removal of gulls in 1984 was followed within 3 weeks by the return of terns (*Sterna* spp.), Atlantic Puffins, Razorbills, eiders, and other seabirds after a 4-year absence. In 1997, 35 Great Black-backed Gulls pairs that had recolonized Green Island were eliminated, but up to 40–65 adult gulls were observed loafing on Green Island throughout the breeding season.

The study was initiated in 1995 on the Wolves Archipelago, New Brunswick (hereafter "the Wolves") where Common Eiders and Great Black-backed Gulls nest in close proximity. In 1996 we carried out limited gull control on the Wolves to assess possible methods to reduce gull predation rates; breeding gulls were killed on two islands and gull clutches were sprayed with oil to prevent hatch on the other two islands. In 1997, work continued on the Wolves and was initiated on an eider colony on Petit Manan and Green Island. Gull control measures had been undertaken on Petit Manan and Green Island in 1984 to facilitate tern restoration (Anderson and Devlin 1998), and Petit Manan Island has since been maintained free of gulls; we studied the eider colony on Green Island.

COMMON EIDERS

Eider colonies in both New Brunswick (1995–1997) and Maine (1997) were searched systematically for eider nests when egg laying started in late April/early May. Nests were marked individually with vinyl flagging and were visited weekly throughout the breeding season. Hatch dates were calculated from direct observations of clutch initiation during visits to nests while laying was in progress and/or the eggs of these clutches were candled (Weller 1956). Incubation periods of 24–25 days and an egg-laying interval of 24 hr (Korschgen 1977) were used to predict hatching dates.

At hatching, ducklings were tagged with standard aluminum web-tags (in 1995 and 1996 only). Each duckling was sexed by cloacal inspection and weighed to the nearest 0.1 g with a spring balance. One duckling from each clutch (41 in 1995, 55 in 1996, and 20 in 1997 from the Wolves; 30 in 1997 from Green Island) was fitted at hatching with an external radio transmitter (Model 384, 150 MHz, Advanced Telemetry Systems, Isanti, Minnesota). The transmitters measured $19 \times 8 \times 11$ mm and weighed 1.9 g (0.03% of duckling body mass). Extending from the rear of the transmitter was a 14 cm long antenna made of 0.54 mm diameter nylon coated stainless steel wire. Protruding 12 mm from the front of the transmitter was an anchor made of 0.61 mm diameter stainless steel wire formed into 2 projecting prongs. A 3–4 mm incision was made in the skin perpendicular to the body axis and the stainless steel anchor was inserted under the skin. Sutures were placed through the skin under the transmitter, and the ends were drawn over the top of the transmitter, tied, and fastened with cyanoacrylate glue (Mauser and Jarvis 1991). Radio-tagged ducklings were monitored by boat at least 3 times each week, and weekly coastal surveys were conducted along the mainland to determine production and/or long distance movements. In 1995 and 1996 aerial brood surveys were conducted in the Bay of

Fundy at 2, 6, and 7 weeks after peak hatch to estimate the number of ducklings produced and to monitor radio-tagged ducklings from the Wolves Archipelago. These surveys covered the New Brunswick coast from Saint John west to St. Andrews and extended to all coastal and offshore islands and the Grand Manan Archipelago. In 1997, a monitoring flight was conducted 6 weeks after peak hatch along the mainland coast of Maine from Schoodic Point to Cape Split, including Green Island, Petit Manan, and all coastal islands in the Gulf of Maine. On all flights, the aircraft was flown at a height of 75 m and speed of 160 km hr^{-1}, approximately 120 m offshore between 1.5 hr before and after high tide. The number of all eiders observed on the 500 m survey path were recorded using a global positioning system (GPS) and marked on 1:50,000 topographic maps. Observations were made with 8 × 30 binoculars

To determine whether our sample of ducklings that were radio-tagged was biased, analysis of variance (ANOVA, SYSTAT, Wilkinson 1988) was used to determine whether the body mass of ducklings hatched (1) on the Wolves Archipelago varied with sex, year, or radio-tagged vs. untagged ducklings, (2) on Green Island varied with sex and/or differed between radio-tagged and untagged ducklings, and (3) varied between the two study areas (the Wolves and Green Island) and/or differed between radio-tagged and untagged ducklings. We used an alpha of 0.05 in all tests and values reported are means ± SD.

GREAT BLACK-BACKED GULLS

All islands in the Wolves Archipelago were searched systematically for Great Black-backed Gull (hereafter, gulls) nests when egg laying started in mid April/early May in 1995–1997. Nests were marked with numbered wooden stakes. Gull debris (indigestible residue and other prey items not eaten) around the nest sites and loafing areas in both study areas was removed prior to the hatching of eider ducklings. Thereafter, gull debris was collected from nest sites and loafing areas regularly throughout the breeding season until the eider ducklings fledged. In the laboratory, gull debris was washed and sorted; the minimum number of ducklings in each sample was determined by dividing the maximum number of duplicate body parts by their frequency of occurrence in a single duckling (e.g., two for tarsometatarsus, one for maxilla). This is the standard method used to estimate the number of prey items eaten by gulls (Nogales et al. 1995, Oro et al. 1997). We were able to test the assumption that remnants of all ducklings depredated are regurgitated around gull nests or loafing areas (Gilliland 1990) using the remains of ducklings marked with transmitters.

The minimum number of ducklings killed was estimated independently using mark-recapture ratios determined from retrieved transmitters. We determined the total number of ducklings that were depredated using the formula, a = x/y, where x is equal to the proportion (%) of transmitters retrieved from gull nests and loafing areas, and y is equal to x divided by the number of transmitters retrieved from depredated ducklings. Simple binomial variance estimates ($\sigma = (p(1 - p)/n)^{1/2}$) were calculated and applied to the count of the number of the ducklings in debris (variance of total estimate = binomial variance x number of ducklings counted in debris); and 95% confidence intervals (CI) (p ± 1.96) were calculated (Sokal and Rohlf 1981). We compared the proportion of gull pellets associated with gull nests and loafing areas between years and study sites using a general Chi-square statistic that addresses an unambiguous null hypotheses of homogeneity among rates (Sauer and Williams 1989). With this statistic, specific hypothesis of homogeneity can be simultaneously tested using contrasts.

RESULTS

DUCKLING CHARACTERISTICS

In 1995 and 1996, 1,271 and 1,068 ducklings, respectively, were web-tagged on the Wolves Archipelago; a total of 353 ducklings were weighed and sexed between 1995 and 1997, and a total of 68 ducklings were weighed and sexed on Green Island in 1997. The weights of ducklings hatched on the Wolves Archipelago did not vary with sex or between radio-tagged and untagged ducklings (sex: $F_{1,1} = 1.3$, $P > 0.3$; marker: $F_{1,1} = 1.1$, $P > 0.3$). Weights did vary between years (sex: $F_2 = 10.8$, $P < 0.001$). Ducklings hatched in 1996 were the heaviest ($\bar{x} = 79.6 \pm 7.2$ g, $n = 157$), followed by those hatched in 1995 ($\bar{x} = 76.4 \pm 5.5$ g, $n = 127$), and 1997 ($\bar{x} = 75.4 \pm 6.3$ g, $n = 69$). The weights of ducklings hatched on Green Island did not vary with sex or between radio-tagged

TABLE 1. Fate of radio-tagged Common Eider ducklings on the Wolves Archipelago, New Brunswick, 1995–1997, and Green Island, Maine, 1997.

	Wolves			Green Island
	1995	1996	1997	1997
No. ducklings tagged	41	55	21	30
No. transmitters lost (%)	8 (19)	11 (20)	5 (24)	4 (13)
No. transmitters not recovered below low tide	1	4	2	0
No. transmitters recovered				
on island tagged	22	34	11	22
on other island	10	8	5	0
in association with gull nests/loafing area (%)	6 (19)	3 (7)	3 (19)	3 (14)
in vegetation (%)	21 (66)	28 (67)	11 (69)	13 (59)
in intertidal (%)	5 (15)	11 (26)	2 (13)	6 (27)
Radio-tagged ducklings fledged	0	0	0	4

and untagged ducklings (sex: $F_{1,1} = 1.1$, $P > 0.3$; marker: $F_{1,1} = 0.2$, $P > 0.7$). The weights of ducklings hatched on Green Island and the Wolves in 1997 did not vary between radio-tagged and untagged ducklings ($F_{1,1} = 2.1$, $P > 0.2$) but did vary between study sites ($F_{1,1} = 17.1$, $P < 0.001$). Ducklings hatched on Green Island were heavier ($\bar{x} = 79.3 \pm 5.1$ g, $n = 68$) than those hatched on the Wolves Archipelago.

RECOVERY OF RADIO-TRANSMITTERS

In all years and at both study sites, 13–24% of radio-transmitters were not recovered (Table 1) and were not detected on live ducklings during monitoring flights throughout the Bay of Fundy (1995–1996) or in the northern Gulf of Maine (1997). With the exception of two ducklings radio-tagged in 1996, all transmitters that were recovered on the Wolves Archipelago between 1995 and 1997 were from radio-tagged ducklings depredated by Great Black-backed Gulls. In 1996, one duckling radio-tagged on Green Rock appeared to have died enroute to the water, and another on Spruce was found dead in the nest. Of the 30 ducklings radio-tagged on Green Island in 1997, 22 were depredated by Great Black-backed Gulls, 2 fledged in the immediate vicinity of Petit Manan Island, and 2 fledged in brood-rearing areas off Bois Bubert Island, 6 km from their hatching island.

In both study areas, all pellets that were retrieved containing ducklings were tightly packed and also contained down and bone fragments. When retrieved, radio-transmitters were buried inside the pellets and the antennas were damaged (broken off or coiled) as a result of ingestion by the gull. Of all the transmitters found in gull pellets on the Wolves Archipelago, only 8 (4 in 1995 and 4 in 1996) contained the corresponding web tag, whereas none of the duckling remains found in the pellets associated with gull nests and loafing areas contained web tags.

The proportion of radio-transmitters recovered from gull pellets at nests and loafing areas on the Wolves Archipelago did not differ between 1995 (18%) and 1997 (17%) ($\chi^2_1 = 2.7$, $P > 0.10$), but in 1996, no gull pellets containing transmitters were found in association with gull nests, and the proportion found at loafing areas (6–7%) was significantly lower than in 1995 and 1997 ($\chi^2_1 = 14.6$, $P < 0.001$). The proportion of radio-transmitters recovered from gull pellets at nests and loafing areas on the Wolves Archipelago in 1995 and 1997 did not differ from that on Green Island in 1997 (14%) ($\chi^2_3 = 2.4$, $P > 0.50$).

A large proportion of transmitters retrieved in gull pellets were located beneath the water (Table 1). Whereas most were retrieved in gull pellets in the intertidal (13–27%), others were in deeper water and were unrecoverable (Table 1). In 1996 on the Wolves Archipelago and in 1997 on Green Island, the proportion of transmitters located beneath the high water levels was similar ($\chi^2_1 = 0.0$, $P > 0.9$), but higher than on the Wolves Archipelago in 1995 and 1997 ($\chi^2_3 = 14.6$, $P < 0.001$) (Table 1). The proportion of transmitters located beneath high water was similar in 1995 and 1997 on the Wolves Archipelago ($\chi^2_1 = 0.6$, $P > 0.30$). The remainder of those transmitters retrieved away from gulls nests or loafing areas, on both the Wolves Archipelago and Green Island (Table 1), were found in gull pellets scattered throughout the

TABLE 2. Estimated number of Common Eider ducklings depredated by Great Black-backed Gulls on the Wolves Archipelago, 1988–1989 (Gilliland 1990), and 1995–1997, and on Green Island 1997. Ducklings depredated in 1988 and 1989 were estimated using mark-recapture ratios from 1995.

	Total ducklings		
	Estimated from pellets	Estimated using ratios from recoverable transmitters (95% CI)	Estimated using ratios from all transmitters relocated
Wolves Archipelago			
1988	189	995 (591–4,725)	1,050
1989	147	775 (459–3,675)	817
1995	184	968 (575–4,600)	1,022
1996	74	1,057 (493–9,250)	1,233
1997	164	863 (421–8,333)	965
Petit Manan/Green Island			
1997	127	907 (454–9,333)	907

vegetation (forest floor, raspberry, tall grass) of the various islands. These pellets would not have been found during a routine survey of nest debris or loafing areas.

The mark-recapture ratios from the transmitters suggest that gull predation on eider ducklings in this population was 5 to 14 times higher than that accounted for by duckling remains found in gull pellets at gull nests and loafing areas (Table 2). If we assume that the radio transmitters that were located but not recoverable below the low tide water were from ducklings depredated by gulls, the ratios of the number of ducklings radio-tagged suggest that gull depredation on eider ducklings was 6 to 17 times higher to those subsequently retrieved (Table 2).

DISCUSSION

DUCKLING CHARACTERISTICS

Our use of mark-recapture ratios of depredated duckling remains in gull pellets rests on our assumption that ducklings marked with radio-transmitters are no more or less vulnerable to gull predation than unmarked ducklings. This assumption is intrinsically difficult to test, but particularly so at the Wolves where virtually all the ducklings produced at this colony were eaten by gulls. As an indirect test we compared weights of radio-tagged and untagged ducklings because a large part of the ducklings' vulnerability to predation has been attributed to poor condition at hatch or low hatch weights (Mendenhall and Milne, 1985, Swennen 1989).

Despite year and site differences in duckling weights, there was nothing in our observations to suggest that there was any *a priori* bias that would make radio-tagged ducklings more vulnerable to predation by gulls. Initial weights of tagged ducklings were similar to those weights of untagged ducklings. Survival rates of broods with ducklings fitted with radio transmitters did not differ from that of broods with unmarked ducklings in all years and in both study areas (unpubl. data). Young broods were most vulnerable and ducklings were depredated within the first 7 days following hatching. In most cases, if a brood was attacked by Great Black-backed Gulls, the entire brood of ducklings was taken. Less than 25 ducklings fledged of the more than 2,000 hatched from the Wolves Archipelago between 1995 and 1997 (unpubl. data). In Maine, where overall duckling survival was considerably higher, only four ducklings fitted with transmitters survived to fledge. In addition, one of the surviving ducklings fitted with a transmitter was one of only two ducklings that survived from an initial brood of four ducklings.

RECOVERY OF TRANSMITTERS

Only a small proportion of gull pellets containing ducklings were located around gull nests and loafing areas. There is no evidence to suggest that the remains of ducklings with radio-transmitters were predisposed to turn up in areas other than gull nests and loafing sites. Additional pellets containing ducklings and other regurgitated food items also were found in the areas away from gull nests and loafing areas. Other studies also have found that total predation of other seabirds cannot be accounted for by gull debris alone. Harris (1980) suggested the impact of a Great Black-backed Gull population on Atlantic Puffins in a Shetland colony must have been even higher than that measured because some corpses and pellets were on unreachable rocks, dropped in the sea, and presumably overlooked. Furness (1980) suggested that only unfledged young which remain on the island, or species which do not feed at sea, are likely to be fully represented in the regurgitated pellets of Great Skuas nesting in Britain.

Mark-recapture ratios of the number of ducklings radio-tagged to those subsequently retrieved suggest that gull depredation on Common Eider ducklings was considerably higher than that accounted for by duckling remains found in gull pellets at gull nests and loafing areas. We have no evidence that gulls regurgitated pellets containing radio transmitters differently from those without transmitters. When located, the transmitters were buried well inside tightly packed pellets and were surrounded by down and bone fragments and often contained the body parts of more than one duckling. Pellets containing ducklings and other prey items were often found in association with pellets located by using radio-telemetry and would not have been found in routine checks of gull nests and loafing areas. The radio-transmitters themselves were less than 2 cm in their largest dimension and represented only a small proportion of the total volume of the pellets, and were in some cases smaller than the larger tarsometarsus bones found in the regurgitations containing older ducklings. Web tags were rarely detected in gull pellets and are likely passed through the gull and excreted in the feces. Web tags were much smaller (< 4 mm) than the smallest tarsometatarsus bones used to identify ducklings in the regurgitations. The use of bird pellets to determine dietary intake is generally acknowledged to under-represent small undigestible body parts such as mandible and invertebrate casings, or soft-bodied and readily digestible food items such as invertebrates and small fish (Annett and Pierotti 1989).

Gilliland (1990) suggested that the lack of ducklings around the Wolves in 1988 and 1989, despite apparently low predation rates by gulls, could be accounted for by hens moving ducklings away from the Wolves to coastal brood-rearing areas. This occurred in Maine, where both marked females with broods and females with radio-tagged ducklings were found in coastal brood rearing areas 6 km from their hatching islands. However, in all 3 years on the Wolves, radio-tagged ducklings (except two that died ashore in 1996) were depredated by gulls, and none were detected on monitoring flights throughout of the Bay of Fundy up to 7 weeks after peak hatch.

The absence of gull chicks and active gull nests on the Wolves Archipelago in 1996 and Green Island in 1997 did not eliminate gull depredation on eider ducklings (unpubl. data). In addition, the retrieval of transmitters from ducklings depredated by gulls was more difficult when the gulls did not remain on a breeding territory. A smaller proportion of the transmitters was found in association with gull loafing areas, and higher proportions were found scattered in the vegetation throughout the islands and in the sea, in 1996 than in 1995 and 1997 when gulls were breeding normally. Fewer ducklings were found in pellets at nest sites and traditional loafing areas on the Wolves in 1996, when gulls were controlled, than in 1995 and 1997 when the gulls breeding on the colony had active nests to maintain.

Hartley (1948) stressed that pellets should not be used in food studies until preliminary trials have established their quantitative and qualitative adequacy. As a result of gull control activities in 1996, the number of active gull nests on the Wolves was slightly lower in 1997 than in 1995. However, the proportion of the transmitters found in pellets associated with gulls' nests and loafing areas in 1997 was similar to that found in 1995. This suggests that these ratios provide a good index for quantifying the number of ducklings taken from the colony by Great Black-backed Gulls with active breeding territories. It is unlikely that any of the pellets containing duckling remains found in this study were from eider ducklings depredated by Herring Gulls, as has been observed in other areas (Ahlén and Åndersson 1970, Bourget 1973). We never observed Herring Gulls attempting to capture Common Eider ducklings in either Maine or New Brunswick, and transmitters and pellets were never found in association with active Herring Gull nests despite the presence of active nests on two islands in the Wolves Archipelago in 1996 and Green Island in 1997. Bourget (1973) also found that Great Black-backed Gulls were the main cause of loss of Common Eider eggs and young in a mixed gull colony.

The mark-recapture ratios cited in this study can give only a minimum estimate of the number of ducklings depredated, because not all transmitters on depredated ducklings were located. For example, of two depredations of tagged ducklings observed in 1996, only one was later retrieved. In all years of this study, a large proportion of transmitters retrieved in gull pellets was found beneath high tide. The signals of these radio-transmitters could be received only at low tide. Some of these transmitters were subsequently retrieved at low tide, but in both 1995 and 1997 a few transmitters were in water so deep that they could not be recovered. The ducklings found in these pellets would not have been found during a routine survey of nest debris littered around the nest sites and/or loafing areas. Therefore, we have no way of knowing how representative the pellets with radio transmitters were of the actual number of ducklings that were depredated by gulls and subsequently regurgitated as pellets into the water. In addition, we feel that the lost transmitters may in fact represent gull depredations regurgitated in unrecoverable areas. However, we cannot eliminate the possibility that these radio-transmitters may have simply failed. Although pellets have been used to monitor variation in the use of certain prey items, our data demonstrate that they cannot be used to accurately assess the impact of gull depredation on Common Eider ducklings.

ACKNOWLEDGMENTS

Financial and logistical support was provided by the Canadian Wildlife Service and Natural Science and Engineering Research Council of Canada through the Atlantic Cooperative Wildlife Ecology Research Network (ACWERN), Delta Waterfowl Foundation, Maine Department of Inland Fisheries and Wildlife, New Brunswick Department of Natural Resources and Energy (Wildlife Branch), and U.S. Fish and Wildlife Service. We thank R. Allen, R. B. Allen, B. Benedict, N. Benjamin, B. DeForrest, K. MacIntosh, G. Raven, C. Robbins, and D. Sears for their assistance in the field, the support of the staff at Petit Manan National Wildlife Refuge, the community of Beaver Harbour, and the pilots of Air Manan for their flying expertise. P. Flint, F. P. Kehoe, G. Robertson, W. D. Koenig, and two anonymous reviewers provided useful comments on earlier drafts of this manuscript. This paper is contribution No. UNB-5 of ACWERN.

LITERATURE CITED

AHLÉN, I., AND A. ÅNDERSSON. 1970. Breeding ecology of an eider population on Spitsbergen. Ornis. Scand. 1:83–106.

ANDERSON, J. G. T., AND C. M. DEVLIN. 1998. Conservation biology and human ecology; umbrellas, flagships, and keystones. Human Ecology Rev. 3: 238–242.

ANNETT, C., AND R. PIEROTTI. 1989. Chick hatching as a trigger for dietary switching in the Western Gull. Colonial Waterbirds 12:4–11.

BEAMAN, M. A. S. 1978. The feeding and population ecology of the Common Eider in northern Scotland. Ibis 120:126–127.

BELANT, J. L., T. W. SEAMANS, S. W. GABREY, AND S. K. ICKES. 1993. Importance of landfills to nesting Herring Gulls. Condor 95:817–830.

BOURGET, A. 1973. Relation of eiders and gulls nesting in mixed colonies in Penobscot Bay, Maine. Auk 90:809–820.

BURGER, J., AND M. GOCHFELD. 1994. Predation and effects of humans on island-nesting seabirds, p. 39–67. *In* D. N. Nettleship, J. Burger, and M. Gochfeld [EDS.], Seabirds on islands: threats, case studies and action plans. Bird Life Conserv. Series No. 1. Bird Life Int., Cambridge.

DERBY, C. E., AND J. R. LOVVORN. 1997. Comparison of pellets versus collected birds for sampling diets of Double-crested Cormorants. Condor 99:549–553.

ERSKINE, A. J. 1992. Atlas of breeding birds of the Maritime Provinces. Nimbus Publications, Halifax, Nova Scotia.

FURNESS, R. W. 1981. The impact of predation by Great Skuas *Catharacta skua* on other seabird populations at a Shetland colony. Ibis 123:534–539.

GILLILAND, S. G. 1990. Predator prey relationships between Great Black-backed Gull and Common Eider populations on the Wolves Archipelago, New Brunswick: a study of foraging ecology. M.Sc. thesis, Univ. Western Ontario, London, Ontario, Canada.

GROSS, A. O. 1944. The present status of the American Eider on the Maine coast. Wilson Bull. 56:15–26.

HARRIS, M. P. 1980. Breeding performance of Puffins *Fratercula arctica* in relation to nest density, laying date and year. Ibis 122:193–209.

HARTLEY, P. H. T. 1948. The assessment of the food of birds. Ibis 90:361–381.

KEHOE, F. P. 1994. A New Brunswick Black-legged Kittiwake, *Rissa tridactyla,* colony. Can. Field-Nat. 108:375–376.

KORSCHGEN, C. E. 1977. Breeding stress of female American Eiders in Maine. J. Wildl. Manage. 41: 360–373.

MAUSER, D. M., AND R. L. JARVIS. 1991. Attaching radio transmitters to 1-day old mallard ducklings. J. Wildl. Manage. 55:488–491.

MAWHINNEY, K., AND D. SEARS. 1996. First nesting of the Razorbill, *Alca torda,* in the Wolves Archipelago, New Brunswick. Can. Field-Nat. 100: 698–700.

MENDENHALL, V. M., AND H. MILNE. 1985. Factors affecting duckling survival of eiders *Somateria mollissima* in northeast Scotland. Ibis 127:148–158.

MUNRO, J., AND J. BÉDARD. 1977. Gull predation and crèching behaviour in the Common Eider. J. Anim. Ecol. 46:124–136.

NOGALES, M., B. ZONFRILLO, AND P. MONAGHAN. 1995. Diets of adult and chicks Herring Gulls *Larus argentatus argentatus* on Ailsa Craig, south-west Scotland. Seabird 17:56–63.

ORO, D., X RUIZ, L. JOVER, V. PEDROCCHI, AND J. GONZÁLES-SOLÍS. 1997. Diet and adult time budgets of Audouin's Gull *Larus audouinii* in response to changes in commercial fishes. Ibis 139:631–637.

SAUER, J. R., AND B. K. WILLIAMS. 1989. Generalized procedures for testing hypotheses about survival and recovery rates. J. Wildl. Manage. 53:137–142.

SHEALER, D. A., AND J. BURGER. 1992. Differential responses of tropical Roseate Terns to aerial intruders throughout the nesting cycle. Condor 94:712–719.

SOKAL, R. R., AND F. J. ROHLF. 1981. Biometry. 2nd ed. W. H. Freeman, San Francisco.

SWENNEN, C. 1989. Gull predation upon eider (*Somateria mollissima*) ducklings: destruction or elimination of the unfit? Ardea 77:21–45.

THOMAS, G. J. 1972. A review of gull damage and management methods at nature reserves. Biol. Conserv. 4:117–127.

WELLER, M. W. 1956. A simple field candler for waterfowl eggs. J. Wildl. Manage. 20:111–113.

WILKINSON, L. 1988. The system for statistics. Version 7.0. 1st ed. SYSTAT, Inc., Chicago.