UNUSUALLY LOW SUCCESS OF HERRING GULLS *LARUS ARGENTATUS* BREEDING ON THE NORTH SHORE OF THE GULF OF ST. LAWRENCE, QUEBEC, CANADA

ANDREW W. BOYNE[1,2], MAGELLA GUILLEMETTE[1,3], RODGER D. TITMAN[1] & NATHALIE BAYS[1,4]

Boyne A.W., Guillemette M., Titman R.D. & Bays N. 2001. Unusually low success of Herring Gulls *Larus argentatus* breeding on the North Shore of the Gulf of St. Lawrence, Quebec, Canada. Atlantic Seabirds 3(3): 125-136. *Herring Gulls* Larus argentatus *are the most numerous species of seabird in the Mingan Archipelago National Park Reserve (MANPR), however little is known about their nesting ecology or reproductive success. The number of active nests, nest density, clutch size, fate of eggs, number of successful nests, hatching success, and mean and median nest hatching dates were recorded in two study polygons on Île Nue, an island in the MANPR, 1994-1996. Clutch size was lower and mean hatching date was later on Île Nue than for typical Herring Gull colonies in all three years of the study. Hatching success was extremely low in 1995. In response, polygons with varying degrees of disturbance were set up to determine the effects of researcher disturbance and a clutch removal experiment was set up to determine whether there were sufficient food sources to allow gulls to produce replacement clutches. Low clutch size and hatching success could not be explained by researcher disturbance, predation, or competition for nest sites, leaving food-stress as the most likely explanation for the low reproductive success.*

[1]Department of Natural Resource Sciences, Macdonald Campus, McGill University, 21,111 Lakeshore, Ste.-Anne-de-Bellevue, Quebec, H9X 3V9, Canada; [2]Canadian Wildlife Service, Environment Canada, 17 Waterfowl Lane, P. O. Box 6227, Sackville, New Brunswick, E4L 1G6, Canada, E-mail: andrew.boyne@ec.gc.ca; [3]Département de biologie et sciences de la santé, Université du Québec à Rimouski, 300 Allée des Ursulines, Rimouski, Québec, G5l 3A1, Canada; [4]Oak Hammock Marsh Interpretive Centre, P. O. Box 1160, Oak Hammock Marsh, Manitoba, R0C 2Z0, Canada

INTRODUCTION

In northern environments, Herring Gulls *Larus argentatus* form an important part of the coastal ecosystem. The Mingan Archipelago National Park Reserve, on the North Shore of the Gulf of St. Lawrence, Canada is an important seabird breeding area and, numerically, Herring Gulls *Larus argentatus smithsonianus* are the most important seabird species breeding in the Park. The number of Herring Gulls nesting in the Archipelago increased from 3772 breeding pairs in 1978 (Chapdelaine & Bourget 1981) to 9598 breeding pairs in 1990 (Grenier & Kavanagh 1993). The majority of the increase occurred on Île Nue, where the

Herring Gull colony increased from 1753 pairs in 1978 (Chapdelaine & Bourget 1981) to 6718 pairs in 1990 (Grenier & Kavanagh 1993), making it the largest colony in the Park. Factors that may have contributed to the increase in Herring Gulls on Île Nue include the increased protection that the colony received following the establishment of the National Park in 1984 (Grenier & Kavanagh 1993); increases in the availability of artificial food sources, such as fisheries' discards; increases in natural prey, such as capelin *Mallotus villosus*; and immigration from other colonies (Guillemette 1997).

Despite their abundance, little is known about the breeding biology of Herring Gulls in the Park. Parks Canada was concerned that the increase in the gull population may impact negatively upon the vegetation on Île Nue and other seabirds nesting in the Park (Grenier & Kavanagh 1993). In 1994 we initiated a three year study of the breeding biology of Herring Gulls nesting on Île Nue, and in 1996 we investigated whether food limitation or researcher

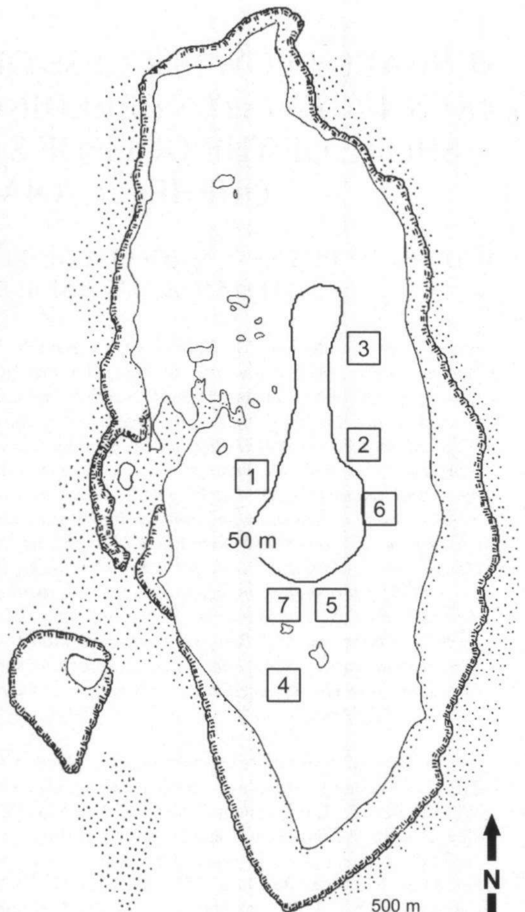

Figure 1. Île Nue showing seven study polygons; 1, 2 nesting polygons, 3 low disturbance, 4 moderate disturbance, 5 high disturbance and 6, 7 clutch removal polygons.

Figuur 1. Île Nue en de zeven studieplots met verstoringsexperimenten.

disturbance could explain the low clutch sizes observed in 1994 and 1995, and the low hatching success observed in 1995. In 1995, the majority of eggs disappeared during a short time period and no replacement clutches were observed. Polygons with varying degrees of disturbance were set up to determine the effects of researcher activities and a clutch removal experiment was set up as an indirect method of determining food abundance. We postulated that if human disturbance was the cause of low clutch size and hatching success, polygons with the most disturbance would have the lowest mean clutch size and hatching success, and if food availability was affecting the colony, the gulls would be unable to lay replacement clutches and clutch size would remain low regardless of disturbance rates.

This paper describes the nesting ecology of Herring Gulls on Île Nue and offers suggestions for what factors may be affecting their reproductive success in the pre-laying and incubation periods.

METHODS

Ile Nue is located 4 km off shore in the easternmost section of the Mingan Archipelago National Park Reserve on the middle North Shore of the Gulf of St. Lawrence, Quebec, Canada (50°13'N, 64°08'W). Île Nue is 7 km in circumference and is dominated by shrub heath barren, lichen heath barren, and bog habitat. The most abundant plant species are fireweed *Epilobium angustifolium*, Labrador tea *Ledum groenlandicum*, and crowberry *Empetrum nigrum*. The largest colony of Herring Gulls in the Park nests on Île Nue, as well as smaller colonies of Arctic Terns *Sterna paradisaea*, Common Terns *S. hirundo*, Great Black-backed Gulls *L. marinus*, Black-legged Kittiwakes *Rissa tridactyla*, and Common Eiders *Somateria mollissima*.

Nesting ecology, 1994-1996 Nesting ecology of the Herring Gull colony on Île Nue was followed 1994-1996 in two study polygons (referred to collectively as nesting polygons; Figure 1). The eastern polygon was 65 m x 65 m (area: 0.423 ha) and the western polygon was 120 m x 82.5 m x 81 m x 95.9 m (area: 0.909 ha). The western polygon was marked off during thick fog which explains the irregularities of its dimensions.

The polygons were visited approximately every three days from the time that eggs were first observed until the last egg hatched. During each visit new nests were marked with numbered stakes, and the number of eggs and chicks was recorded. Some eggs may have been laid and disappeared during the period between visits so the number of nests and eggs may be underestimated. From this we calculated the number of active nests (nests with at least one egg), nest density, mean clutch size, fate of eggs (hatched, dead/addled, or missing), number of successful nests (nests that hatched at least one egg), hatching success (number of eggs hatched divided by the number of eggs laid), number of eggs hatched per nest, and mean and median nest hatching dates. We estimated date of hatching by assuming that it takes an egg three days to hatch once starring begins (small cracks but no hole) and one day after pipping begins (hole in shell). To minimise disturbance, visits to each polygon rarely exceeded 15 minutes.

Researcher disturbance In 1996, three additional polygons were set up to determine the effect of researcher disturbance; low, moderate, and high disturbance polygons (Figure 1). The high and low disturbance polygons were 75 m x 75 m (area: 0.562 ha). The boundaries of the moderate disturbance polygon were irregular and were not measured.

The low disturbance polygon was visited once during the incubation period and every three days after the median date of hatching to determine hatching success. This allowed us to collect nesting information with a minimum number of visits. The moderate disturbance polygon was visited approximately every three days starting when the first eggs were laid, which was similar to the number of visits to the nesting polygons, and the high disturbance polygon was visited approximately every two days from the time the first eggs were laid (Table 1). The same nesting parameters were measured in the three disturbance polygons as were measured in the nesting polygons.

Clutch removal Also in 1996, two study polygons (75 m x 75 m, area: 0.562 ha) were set up to explore the ability of Herring Gulls on Île Nue to replace lost clutches (Figure 1). On 8 June, approximately four weeks before the mean hatching date, 15 Herring Gull nests with 3-egg clutches were selected within the study polygons. This date coincided with the period in 1995 when most of the eggs disappeared, i.e. 6-14 June. A mixture of Malachite Green (18.75 g), petroleum jelly (250 g), and isopropyl alcohol (25 g) was applied to the top of the eggs in each clutch to mark the breasts of the incubating adults (Belant & Seamans 1993). This mixture was sufficient for the dye to last until the gulls renested, i.e. approximately 13 days. After at least one adult from each nest was marked by the dye, the eggs were removed from the nest. The length and width of each egg were measured to the nearest 0.1 mm with Vernier callipers, and volume was calculated using the formula, volume = length x width^2 x 0.476 (Harris 1964).

We visited each polygon approximately every three days to look for replacement clutches. Herring Gulls often line their nests with breast feathers and we were able to identify replacement nests by locating green feathers. Herring Gulls tend to lay replacement clutches on their original territories

Table 1. Parameters describing nesting of Herring Gulls on Île Nue in the nesting polygons, 1994-96. Percentages are given in brackets. Parameters with similar letters are not significantly different (notation is only shown if there were significant differences; $P < 0.05$).
Tabel 1. Broedresultaten van Zilvermeeuwen op Île Nue in de studieplots, 1994-96. Tussen haakjes zijn percentages weergegeven. Met een (overeenkomstige) letter aangeduide uitkomsten zijn niet significant verschillend.

Parameters	Year			Overall
	1994[1]	1995	1996	
Active nests (n)	100	73	83	256
Successful nests (n)	82 (86.3)	12 (16.4)	69 (83.1)	163 (63.7)
Nest density (nests ha^{-1})	75	55	62	64
Eggs laid (n)	204	135	178	517
Fate of eggs				
Hatched	157 (81.3)	19 (14.1)	140 (78.5)	316 (62.5)
Missing	33 (17.1)	115 (85.2)	32 (18.0)	180 (35.5)
Dead	3 (1.6)	1 (0.7)	6 (3.4)	10 (2.0)
Eggs hatched $nest^{-1}$	1.65	0.26	1.69	1.26
Average clutch size	2.04	1.85	2.14	2.02
Date first nest hatched	20 June	21 June	20 June	-
Median hatching date	29 June	28 June	4 July	-
Mean hatching date	30 June [a]	28 June [a]	6 July [b]	-

[1]Unable to relocate 5 nests (total 11 eggs)

(Parsons 1976). We were confident determining which pair laid each replacement clutch because none of the pairs that we followed had territories bordering each other. When a new nest with green feathers was found, we measured distance to the original nest with a 25 m tape measure, and calculated the volume of each egg. We continued to follow replacement nests every three days to determine hatching date, which allowed us to estimate laying date (calculated by subtracting 30 days - the length of the incubation period - from the day the first egg hatched), length of refractory period (time between the removal of the original clutch and the initiation of the replacement clutch), mean clutch size and hatching success.

Wilcoxon signed ranks test was used to compare clutch size and paired *t*-tests were used to compare total clutch volume, egg volume, volume of the largest egg, and volume of the smallest egg for original and replacement clutches. Likelihood ratio chi squares (G^2), comparing observed and expected frequencies were used to compare clutch size and hatching success in the nesting and disturbance polygons. The two nesting polygons were pooled before analysis as spatial differences were very small and our intention was mostly to look at temporal variation of breeding parameters. ANOVAs were used to compare hatch dates (Zar 1984). Data were tested for normality and the level of significance was set at $P < 0.05$ for all tests. Means are given ± 1 SD. SYSTAT was used for all statistical analyses (SYSTAT Inc. 1992).

RESULTS

Nesting ecology, 1994-1996 The overall mean clutch size in the two nesting polygons, 1994-1996, was 2.02 (Table 1). There was no significant difference in the frequency of 1-, 2-, and 3-egg clutches between years ($G_4^2 = 7.378$, P = 0.117). The mean hatching date for all nests, 1994-1996, was 2 July. Mean hatching date was significantly later in 1996 than either 1995 or 1994 ($F_2 = 13.19$, P < 0.0001; Table 1).

The number of successful nests differed between years ($G_2^2 = 100.66$, $P < 0.0001$). In 1994 and 1996 over 80% of nests were successful, whereas in 1995 less than 20% of nests were successful. Hatching success of eggs was also low in 1995. Most eggs in 1995 went missing; only one dead/addled egg was found (Table 1).

Researcher disturbance In 1996, mean clutch size in the nesting, and low, moderate, and high disturbance polygons was 2.20 eggs per nest. The frequency of 1-, 2-, and 3-egg clutches did not differ significantly between polygons ($G_8^2 = 6.54$, $P = 0.365$). The number of successful nests was high in all polygons, and hatching success was highest in the high disturbance polygon (Table 2). Mean hatching date in the nesting polygons was later than in the low, moderate, and high disturbance polygons ($F_3 = 8.97$, $P < 0.0001$; Table 2).

Clutch removal Fourteen pairs out of 15 laid replacement clutches, each on its original territory. In all cases it was possible to identify replacement nests by identifying green feathers in the nest bowls. It is possible but unlikely that a fifteenth pair laid a replacement clutch somewhere other than on its original territory and was thus not detected. Average clutch size for the 14 pairs was 2.71 ± 0.47 (Table 3).

Replacement clutches had significantly fewer eggs than original clutches ($Z = -2.12$, $P = 0.034$). However, total volume of the 10 replacement clutches with three eggs and the volume of their original clutches did not differ significantly ($t_9 = -1.7$, $P = 0.12$). There were no significant differences in mean egg volume between original and replacement clutches ($t_{13} = 1.155$, $P = 0.269$), although the largest egg in each of the 14 replacement clutches was significantly smaller than the largest egg in their original clutches ($t_{13} = -3.5$, $P = 0.0038$). There was no significant difference between the smallest eggs ($t_{13} = 0.24$, $P = 0.81$) (Table 3).

Table 2. Parameters describing nesting of Herring Gulls in the nesting, low disturbance, moderate disturbance, and high disturbance polygons on Île Nue in 1996. Percentages are given in brackets. Parameters with similar letters are not significantly different (notation is only shown if there were significant differences; p < 0.05).

Tabel 2. Broedresultaten van Zilvermeeuwen in studieplots met geringe, matige en zware verstoringen door onderzoekers op Île Nue in de studieplots, 1996. Percentages zijn tussen haakjes weergegeven. Met een (overeenkomstige) letter aangeduide uitkomsten verschillen niet significant.

Parameters	Polygon			
	Nesting[1]	Low disturbance	Moderate disturbance	High disturbance
Visits (n)	12,13	6	13	16
Visits before mean hatching	4,6	1	7	8
Date of first visit	6,7 June	14 June	7 June	11 June
Active nests (n)	83	43	54	44
Successful nests (n)	73 (88.0)	43 (100.0)	49 (90.1)	43 (97.7)
Nest density (nests ha^{-1})	62	76	-	78
Number of eggs laid	178	101	125	99
Fate of eggs				
Hatched	140 (78.5)	92 (91.1)	107 (85.6)	92 (92.9)
Missing	32 (18.0)	2 (2.0)	8 (6.4)	0 (0.0)
Dead	6 (3.4)	7 (6.9)	10 (8.0)	7 (7.1)
Eggs hatched per nest	1.92	2.14	1.98	2.09
Average clutch size	2.14	2.35	2.31	2.20
Date first nest hatched	20 June	26 June	17 June	14 June
Median hatching date	4 July	27 June	1 July	3 July
Mean hatching date	6 July [a]	29 June [b]	30 June [b]	2 July [b]

[1] Two polygons were pooled together and collectively called the nesting polygons. In cases where there are two numbers in the same cell, the first number is from the eastern polygon and the second is from the western polygon (see Methods).

The mean distance between the location of the original nests and replacement nests was 4.48 ± 2.58 m (n = 13) and the mean refractory period was 13.15 ± 2.48 days (n = 13). One replacement nest disappeared before the distance between it and the original nest was measured.

Hatching success of replacement clutches was 74% which was similar to hatching success in the two nesting polygons (Table 1); all of the eggs hatched in 10 nests; the eggs in two 3-egg clutches did not hatch; a single egg did not hatch in another 3-egg clutch; and one 3-egg clutch disappeared.

Table 3. Mean egg volume, clutch size, hatching date, and hatching success of original clutches and replacement clutches of 15 pairs of Herring Gulls included in a clutch removal experiment on Île Nue in 1996.
Tabel 3. Gemiddeld eivolume, legselgrootte, uitkomstdatum en uitkomstpercentage van eerste legsels en vervangende legsels bij 15 paren Zilvermeeuwen in het verwijderingsexperiment op Île Nue in 1996.

Parameter	Clutch removal polygons	
	Original nests	Replacement nests
Volume of all eggs (ml)	78.39	76.12
Volume of largest eggs (ml)*	83.32	78.56
Volume of smallest eggs (ml)	73.24	73.87
Clutch size†	3	2.71
Hatching success (%)	Eggs removed	73.68
Hatching date	Eggs removed	21 July

* The volume of the largest egg in original nests was significantly larger than the largest egg in replacement nests (paired t-test: $t_{13} = -3.5$, $P = 0.0038$).
† Clutch size of original nests was significantly larger than clutch size of replacement nests (paired t-test: $t_{14} = 2.2$, $P = 0.048$).

DISCUSSION

Mean hatch date was later and mean clutch size was lower on Ile Nue, 1994-1996, than in other Herring Gull colonies in the Gulf of St. Lawrence. Mean hatching dates for Herring Gulls on Île Nue ranged from 28 June - 6 July, which is 2-3 weeks later than other colonies in the Gulf of St. Lawrence. The peak of hatching was 11-12 June in western Newfoundland (Howes & Montevecchi 1993), and the mean hatching date on the Gaspé Peninsula, Quebec, was 10 June (Guillemette 1994). In North America, *Larus* gulls tend to breed later at higher latitudes (see Ryder 1993, Pierotti & Annett 1995, Winkler 1996), and Île Nue is further north than other colonies studied in the Gulf of St. Lawrence. Furthermore, Herring Gulls on Île Nue rely on capelin during the breeding season (Boyne 1999), and capelin typically migrate inshore to spawn later along the North Shore of the Gulf of St. Lawrence than along the Gaspé Peninsula (Grégoire 1996) and Newfoundland (Carscadden 1982), possibly resulting in later clutch initiation on Île Nue. To maximise breeding success, seabirds synchronise the timing of nesting so that the hatching of young coincides with the period of greatest food availability (Lack 1968).

The average clutch size on Île Nue was never greater than 2.35 eggs per nest in any of the study polygons, and over the three breeding seasons the average clutch size in the two nesting polygons was only 2.02 eggs per nest. Mean clutch size at other colonies in the Gulf of St. Lawrence has been more than 20% higher: 2.55 - 2.76 in Kouchibouguac National Park, New Brunswick

(Martin & LaPierre 1986, Martin 1987); and 2.6 on the Gaspé Peninsula, Quebec (Guillemette 1994). Clutch sizes also tend to be higher in other colonies in eastern Canada and western Europe: 2.8 ± 0.4, in the Dutch Frisian Islands, the Netherlands (Bukacinska *et al.* 1996); 2.79 - 2.90 in Brittany, France (Pons & Migot 1995); 2.71 in Wales (Hiom *et al.* 1991); 2.94 ± 0.23 in Georgian Bay, Ontario (Chudzik *et al.* 1994); and 2.52 - 2.77 on Boot Island, Nova Scotia (Macfarlane 1996). However, the mean clutch size at a Herring Gull colony thought to be food-stressed on Great Island, Newfoundland, was only 1.82 - 2.14 (Rodway & Regehr 1999), which is very similar to the mean clutch size observed on Île Nue. Food stress during the pre-laying period is known to cause low clutch sizes in Herring Gulls (Hiom *et al.* 1991).

The most striking difference among the three years of the study, was the low hatching success in 1995. In 1995 we were off the island during the period when the majority of eggs disappeared. We only found one unhatched egg so the fate of the majority of eggs was unknown. Robert & Ralph (1975) found that human disturbance affected hatching success in large gulls, however, the methodology in our study was similar in all three years and thus can not explain the low hatching success in 1995. In addition, hatching success in 1996 was highest in the high disturbance polygon, supporting the speculation that factors other than researcher disturbance affected hatching success. Researcher disturbance could not explain low clutch size either as there were no differences in mean clutch sizes among the five disturbance polygons.

As an indirect method of evaluating food availability we examined the ability of Herring Gulls to lay replacement clutches. In 1995, the majority of eggs laid in the nesting polygons disappeared during a short time period and no replacement clutches were observed. We hypothesised that the gulls could not lay replacement clutches in 1995 because food was limiting. This was not the case in 1996, as 14 of 15 pairs in the removal experiment laid replacement clutches after a refractory period of about 13 days. This time interval was similar to another study of Herring Gulls (Parsons 1976). Replacement clutches usually contain fewer and/or smaller eggs than first clutches (Paludan 1951; Parsons 1976), although in 1996, the clutch volume of 3-egg replacement clutches did not differ significantly from the volume of original clutches, and the mean clutch size of replacement clutches was higher than the mean clutch size in the nesting polygons. This result is puzzling and we underline two factors that probably led to favourable conditions for renesting: (1) we removed clutches from early layers, which tend to be older, more experienced birds (e.g. Reid 1988, Pyle *et al.* 1991), and we only removed 3-egg clutches which is an indication of parental quality (e.g. Pyle *et al.* 1991); and (2) food availability likely increased for at least the last few days of the refractory period; the period when females would have been acquiring the necessary body reserves to produce a second clutch. Herring Gulls switched to feed mainly on capelin, an important food source for gulls in the Gulf of St. Lawrence (Boyne 1999; Cairns *et al.* 1991), around 18 June, likely in response to the pre-spawning migration of capelin to inshore waters (Boyne 1999). The arrival of capelin inshore would have increased food availability and quality because they migrate in large shoals and are of high nutritional value (Pierotti & Annett 1987).

Other potential factors affecting reproductive success on Île Nue include egging, predation, and conspecific competition. Historically, egging was a common practice on the North Shore of the Gulf of St. Lawrence (Blanchard 1994), but this practice has all but disappeared since the creation of the National Park Reserve. Moreover, it is difficult to believe that eggs were taken from both polygons since they were ca. 0.5 km apart and separated by a plateau. Mammalian predators can not explain the egg loss as only muskrats and small rodents are present on the island, however it is not possible to rule out avian predators although few, if any, avian predators are capable of removing such a large number of eggs from a gull colony. Mean nest density on Île Nue was low (ca. 64 nests/ ha), so competition for nesting territories or other density-dependant factors also can not explain low reproductive success.

Researcher disturbance, competition for nest sites, and egging, cannot explain the low hatching success in 1995 or the low clutch sizes observed throughout the study. Although it is not possible to demonstrate that food is limiting the reproductive success of Herring Gulls on Île Nue, food-stress is known to cause low clutch sizes (Hiom *et al.* 1991), and increase predation on eggs of conspecifics (Parsons 1971; Robert & Ralph 1975). Although food-stress during the laying period did not prevent replacement clutches in 1996, the majority of chicks that were followed that year as part of another study, died of starvation (Boyne 1999). Years of poor capelin abundance along the North Shore, causing high Herring Gull chick mortality, have been noted in the past (Lewis 1934). The timing of capelin spawning in a given year may dictate at which stage of the breeding season food is limiting. Recently, cold surface water temperatures in the early 1990s delayed and even deterred capelin from spawning in eastern Newfoundland, causing breeding failure in Black-legged Kittiwakes and low reproductive success in Herring Gulls (Rodway & Regher 1999; Regehr & Montevecchi 1997).

ACKNOWLEDGEMENTS

D.M. Bird, G. Chapdelaine, and J.W. Chardine reviewed earlier drafts of the manuscript. We wish to thank S. Burelle and C. Murphy for their help with field work, and S. Yamasaki and P. Dutilleul for their assistance with statistical analysis. The wardens and staff of the MANPR provided logistical support in the field. The project was funded through Parks Canada, with additional funding from the Province of Quebec Society for the Protection of Birds.

ONGEWOON GERING BROEDSUCCES ONDER ZILVERMEEUWEN NESTELEND AAN DE NOORDKUST VAN DE GOLF VAN ST LAWRENCE, QUEBEC, CANADA

Zilvermeeuwen Larus argentatus *behoren tot de talrijkste zeevogelsoorten in het Mingan Archipelago National Park Reserve (MANPR). Het aantal 'actieve' nesten, de nestdichtheid, legselgrootte, uitkomst- en uitvliegsucces en de gemiddelde en mediane uitkomstdata werden onderzocht in twee studiegebieden op Île Nue, een eiland in MANPR, 1994-1996. In ieder jaar was de legselgrootte kleiner en de gemiddelde uitkomstdatum later dan karakteristiek voor de Zilvermeeuw. Het uitkomstsucces was extreem laag in 1995. Om uit te vinden wat er aan de hand was werden enkele experimenten opgezet, waarbij studieplots met verschillende gradaties van verstoring werden geconfronteerd terwijl elders een aantal legsels werd verwijderd om te bezien of de meeuwen gezien de beschikbare hoeveelheden voedsel in het gebied fysiek in staat waren om nieuwe legsels te produceren. Kleine legsels en een gering uitkomstsucces konden niet worden verklaard door de verstoring van onderzoekers. Predatie of competitie om nestgelegenheid waren vermoedelijk de factoren verantwoordelijk voor het geringe broedsucces.*

REFERENCES

Belant J.L. & Seamans T.W. 1993. Evaluation of dyes and techniques to color-mark incubating Herring Gulls. J. Field Ornithol. 64: 440-451.

Blanchard K.A. 1994. Culture and seabird conservation: the north shore of the Gulf of St. Lawrence, Canada *In:* Nettleship D.N., Burger J. & Gochfeld M. (eds) Seabirds on islands: threats, case studies and action plans: 294-310. BirdLife Conservation Series No. 1., BirdLife International, Cambridge.

Boyne A.W. 1999. Diet and reproductive success of herring gulls nesting on the middle north shore of the Gulf of St. Lawrence. MS-thesis, McGill University, Montreal.

Bukacinska M., Bukacinski D. & Spaans A.L. 1996. Attendance and diet in relation to breeding success in Herring Gulls (*Larus argentatus*). Auk 113:300-309.

Cairns D.K., Chapdelaine G. & Montevecchi W.A. 1991. Prey exploitation by seabirds in the Gulf of St. Lawrence. *In:* Therriault J-C. (ed.) The Gulf of St. Lawrence: small ocean or big estuary?. Can. Spec. Publ. Fish. Aqu. Sc. 113: 277-291.

Carscadden J. E. 1983. Capelin (*Mallotus villosus*) in the Northwest Atlantic. *In:* Nettleship D.N., Sanger G. A. & Springer P.F. (eds). Marine Birds: Feeding Ecology and Commercial fisheries: 170-183. Proc. Pacific Seabird Group Symp. Can. Wildl. Serv. Special Publ., Ottawa.

Chapdelaine G. & Bourget A. 1981. Distribution, abondance et fluctuations des populations d'oiseaux marins de l'Archipel de Mingan (Golfe du Saint-Laurent, Québec). Nat. Canadien 108: 219-227.

Chudzik J.M., Graham K.D. & Morris R.D. 1994. Comparative breeding success and diet of Ring-billed and Herring Gulls on South Limestone Island, Georgian Bay. Col. Waterb. 17: 18-27.

Grégoire F. 1996. Capelin in the Gulf of St. Lawrence. DFO, Atlantic Fisheries, Stock Report 96/25. Maurice Lamontagne Institute, Mont Joli, Québec.

Grenier A. & Kavanagh C. 1993. État des populations de goélands (*Larus argentatus, L. delawarensis* et *L. marinus*) de La Réserve de Parc National de L'Archipel-de-Mingan - 1991. Unpubl. report, Service des parcs, Service de la conservation des ressources naturelles, District de Mingan.

Guillemette M. 1994. Élimination des goélands prédateurs et impact de cette intervention sur la productivité de la Sterne pierregarin (*Sterna hirundo*) nichant sur le banc de Carelton. Unpubl. report, Service de la Faune, Région du Québec.

Guillemette M. 1997. Influence de l'activité humaine sur l'interaction goéland-végétation et sur le maintien des populations aviennes de la RPNAM. Unpubl. report, Service de conservation des ressources naturelles, Parcs Canada, Région du Québec.

Harris M.P. 1964. Aspects of the breeding biology of the gulls *Larus argentatus*, *L. fuscus*, and *L. marinus*. Ibis 106: 432-456.

Hiom L., Bolton M., Monaghan P. & Worrall D. 1991. Experimental evidence for food limitation of egg production in gulls. Orn. Scand. 22: 94-97.

Howes L-A. & Montevecchi W.A. 1993. Population trends and interactions among terns and gulls in Gros Morne National Park, Newfoundland. Can. J. Zool. 71: 1516-1520.

Lack D. 1968. Ecological adaptations for breeding in birds. Meuthen & Co, London.

Lewis H.F. 1934. Notes on birds of the Labrador Peninsula in 1931, 1932 and 1933. Can. Fld-Nat. 48: 98-102.

Macfarlane A. 1996. Boot Island National Wildlife Area Nova Scotia; Bird colony census - May 13 1996. Unpubl. report, Can. Wildl. Serv., Habitat Program, Sackville, Canada.

Martin G. 1987. Comptage des nids et bagage de jeunes de la colonie de goélands de la dune Richibucto Nord - 1987. Unpubl. report Parc national Kouchibouguac, Canada.

Martin G. & LaPierre L. 1986. Observations ecologiques sur la colonie de goélands (*Larus*, spp.) de la dune Richibucto Nord du Parc National Kouchibouguac - 1986. Unpubl. report, Département de biologie, Université de Moncton, Canada,.

Paludan K. 1951. Contributions to the breeding biology of *Larus argentatus* and *L. fuscus*. Vidensk. Medd. fra Dansk naturh. Foren. 114: 1-128.

Parsons J. 1971. Cannibalism in Herring Gulls. British Birds 64: 528-537.

Parsons J. 1976. Factors determining the number and size of eggs laid by the Herring Gull. Condor 78: 481-492.

Pierotti R. & Annett C. 1987. Reproductive consequences of dietary specialization and switching in an ecological generalist. *In:* A.C. Kamil, J. Krebs & R. Pulliam (eds) Foraging Behaviour: 417-442. Plenum Publ., New York.

Pierotti R. & Annett C. 1995. Western Gull. *In:* Poole A., P. Stettenheim & F. Gill (eds) The Birds of North America. No. 174. The Academy of Natural Sciences, Philadelphia and The American Ornithologists' Union, Washington, DC.

Pons J-M. & Migot P. 1995. Life-history strategy of the Herring Gull: changes in survival and fecundity in a population subjected to various feeding conditions. J. Anim. Ecol. 64: 592-599.

Pyle P., Spear L.B., Sydeman W.J. & Ainley D.G. 1991. The effects of experience and age on the breeding performance of Western Gulls. Auk 108: 25-33.

Reid W.V. 1988. Age-specific patterns of reproduction in the Glaucous-winged Gull: increased effort with age? Ecology 69: 1454-1465.

Regehr H.M. & Montevecchi W.A. 1997. Interactive effects of food shortage and predation on breeding failure of Black-legged Kittiwakes: indirect effects of fisheries activities and implications for indicator species. Mar. Ecol. Progr. Ser. 155: 249-260.

Robert H.C. & Ralph C.J. 1975. Effects of human disturbance on the breeding success of gulls. Condor 77: 495-499.

Rodway M.S. & Regehr H.M. 1999. Habitat selection and reproductive performance of food-stressed Herring Gulls. Condor 101: 566-576

Ryder J.P. 1993. Ring-billed Gull. *In:* Poole A., Stettenheim P. & Gill F. (eds) The Birds of North America. No. 33. The Academy of Natural Sciences, Philadelphia and The American Ornithologists' Union, Washington, DC.

SYSTAT Inc. 1992. SYSTAT for windows: Statistics, version 5 edition. Evanston, Illinois.

Winkler D.W. 1996. California Gull. *In:* Poole A., Stettenheim P. & Gill F. (eds) The Birds of North America. No. 259. The Academy of Natural Sciences, Philadelphia and The American Ornithologists' Union, Washington, DC.

Zar J.H. 1984. Biostatistical Analysis, 2nd edition. Prentice-Hall, Englewood Cliffs, New Jersey.