Adult Survival of Herring Gulls Breeding in the Canadian Arctic

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Abstract.—Apparent survival of adult Herring Gulls (*Larus argentatus*) occupying two distinct breeding habitats within the East Bay Migratory Bird Sanctuary, on Southampton Island, Nunavut was estimated. The first group occurred on a small island where 30 pairs bred at relatively high densities sympatrically with Common Eider (*Somateria mollissima*), on whose eggs they feed. The larger group occurred at lower densities on a wet coastal plain on the surrounding Southampton Island mainland, where nesting birds were sparsely distributed. Program Mark was used to analyze capture-mark-resight (CMR) data obtained over six years from 62 adults captured between 1998 and 2002; 47 and 15 nesting on the island and mainland respectively. Factors in models included group and time effects on survival and reduced time effects on encounter probabilities; additional factors and interactions were not tested due to sparse data. High model selection uncertainty and wide 95% confidence intervals around model effect sizes precluded ability to draw inferences concerning the importance of group and time factors in survival. Given these results, focus was placed mainly on an estimate of annual survival (0.87±0.03 SE) from the time- and group-independent model. This is the only known survival estimate produced for Herring Gull adults at the northern limit of their North American breeding range and falls within the wide range of values reported elsewhere. *Received 12 July 2005, accepted 10 January 2006.*

Key words.—apparent survival, capture-mark-resight (CMR), range limit, breeding strategy, adult, Herring Gull, *Larus argentatus*.

Adult survival is a key parameter in determining population trends, especially in long-lived species (Lebreton and Clobert 1991). Changing environmental conditions can lead to modification of the energetic balance of individuals in terms of thermoregulation (Carrascal *et al.* 2001) and/or intake rates of prey (Finney *et al.* 1999), ultimately affecting reproductive output and survival (Benton and Grant 1996; Saether *et al.* 1996; Oro *et al.* 1999). This may be of greatest importance for populations that are both at the periphery of their range, and at high latitudes where climatic extremes, long migration distances and short breeding seasons may stress breeding adults.

Adult survival is well studied in larids generally, and in Herring Gulls (*Larus argentatus*) in certain parts of Europe (Chabrzyk and Coulson 1976; Coulson and Butterfield 1986; Migot 1992; Lebreton *et al.* 1995; Pons and Migot 1995). Estimates of survival of North American Herring Gulls in particular are limited and out of date (Marshall 1947; Paynter 1947, 1966; Kadlec 1976) although some of these data (Paludan 1951) have been revisited and newer methods of analysis applied (Freeman and Morgan 1992). In addition, previous North American estimates originate from the southern and eastern extent of the species' breeding range. In Canada, the northernmost breeding range limit currently extends across the northern Yukon, Northwest Territories and Nunavut mainland to Southampton Island, Foxe Basin and the southern Baffin Island region (Sutton 1932; Harrison 1983; Pierotti and Good 1994).

Herring Gulls are known to depredate eggs and young of several seabird species (Pierotti and Good 1994), including Common Eider (*Somateria mollissima*) (Cooch 1965; Munro and Bédard 1977; Götmark and Åhlund 1988; Swennen 1989). Herring Gulls show a wide variety of nesting habits; some nest with other seabirds in colonies (Pierotti 1982), others more solitarily in other habitats (Pierotti and Good 1994). Such differences might be indicative of different life history strategies (Stearns 1992; Nager *et al.* 2001; Oro and Furness 2002).

In this paper, capture-mark-recapture models (Lebreton *et al.* 1992) were used to

investigate apparent survival of the breeding Herring Gull in the Arctic at the East Bay Migratory Bird Sanctuary, Southampton Island, as a function of year and nesting habit. This value was related to values reported for the Herring Gull elsewhere in North America and Europe.

METHODS

In all years but 1998, capture at the nest was by self-releasing box trap or noose. To minimize abandonment of nests, eggs were removed from nests and placed in an insulated carrying case, and replaced with wooden replicas. In 1998, twelve gulls were captured of which five adults were caught with leg nooses at the nest, and an additional seven (four adult plumage, three non-breeding subadults) with a remotely activated net trap using seal carcass as bait. Individuals received a unique combination of stainless steel engraved and plastic colored engraved and non-engraved bands.

From 1999 to 2004, banded Herring Gulls were resighted using spotting scopes and naked eye twice daily from May to August at the island colony. Resighting was done from blinds distributed throughout the colony, and totalled no less than two hours daily. Additional resightings on the island were acquired opportunistically. Marked birds in the mainland group were resighted by intensive three to six hour searches. In 2003 and 2004, resighting effort was largely reduced, although this was rectified at the island colony in 2004 by dedicating an individual to match previous years' efforts.

CMR Analysis

CMR data were analyzed using the program MARK (White and Burnham 1999). This approach was taken because: 1) some encounter probabilities were expected to be less than one and MARK provides estimates of this parameter, 2) MARK provides an easy and robust method of model selection allowing comparisons between groups of birds, and 3) MARK provides confidence intervals around its survival and encounter probability estimates. Model factors were selected prior to analysis, based on herring gull biology, limitations of the small dataset, and knowledge of anomalies in the dataset. As not all individuals in the sample could be sexed with confidence, a sex effect was not examined. The starting or global model, the most parameterized or complex model in the set, included group and annual effects on survival and three specific time effects on encounter probabilities, a unique effect for the mainland site in 2003 and 2004 and a unique effect for the island site in 2003. With the exception of the three encounter probabilities affected by these effects, all other encounter probabilities in our models were fixed to one, based on knowledge that all survivors were seen in these years. Due to sparse data, not all possible reduced forms of our global model could be examined. Instead, a small set of reduced models was built to assess support for factors fitted to encounter probabilities in the global model while maintaining group and time effects on survival (Lebreton *et al.* 1992). The most supported encounter model from this set was maintained in subsequent survival models. All possible combinations of group and time effects on survival were then tested.

Goodness-of-fit of the global model was assessed initially by calculating an adjusted $\hat{c}$ value using the bootstrap option in program MARK (White and Burnham 1999): deviance of the global model divided by the mean deviance of 1000 bootstraps. The $\hat{c}$ value provides an all-inclusive measure of poor fit from structural deficiencies in the global model and overdispersion; data can become overdispersed in the presence of heterogeneity, lack of independence, and other sources (Anderson *et al.* 1994). Unadjusted $\hat{c} > 1$ and ≤ 4 is evidence that the structure of the model is adequate, but the data are overdispersed (Burnham and Anderson 2002); structural deficiencies may be present when estimates of are above four. When overdispersion alone is detected in the data, is applied as an adjustment to AICc and sampling variances. Sparse data precluded goodness-of-fit testing with programs Release (White and Burnham 1999) or UCARE (Choquet *et al.* 2003).

Support, for models and effects in the set, was determined using information-theoretic criteria and 95% confidence intervals around model effects. Focus was placed mostly on differences between the model with the lowest AICc score and competing models ($\cong \Delta$AICc) where AICc is Akaike's Information Criterion with a small-sample adjustment term. 95% CIs were used as a measure of uncertainty for effects in models that attained some ΔAICc support. Guidelines for interpreting ΔAICc values were adopted from Burnham and Anderson (2002): models within 3 AICc units from the top model have substantial support, those within four to seven AICc units are moderately supported, and those above ten have no support. To account for model selection uncertainty, all models in the set were incorporated to produce weighted estimates (i.e., using AICc weights) of apparent survival and encounter probabilities (Burnham and Anderson 2004).

STUDY AREA

Adult breeding Herring Gulls were observed at two locations within the East Bay Migratory Bird Sanctuary (64°01N 81°47W), which covers 1,166 km^2 on Southampton Island, Nunavut, Canada, annually from late May to early August. The first location is a small (36ha) treeless island (64°04N 81°40W) with relatively high densities of nesting gulls within an eider colony. This island supports up to 4,500 Common Eider, 50 King Eider (*Somateria spectabilis*), and 30 Herring Gull pairs, as well as several other breeding bird species (Allard and Gilchrist 2002). The second location hosts larger numbers of nesting gulls but at lower densities on the surrounding mainland coastal plain. The coastal plain also supports a large colony of the Lesser Snow Goose (*Anser caerulescens*), Arctic Terns (*Sterna paradisaea*), and Sabine's Gulls (*Xema sabini*) (Abraham and Ankney 1986). Arctic Foxes (*Alopex lagopus*) and Polar Bears (*Ursus maritimus*) visited both locations and consumed Herring Gull eggs, but not adults.

RESULTS

Capture-Mark-Resight Dataset

A total of 62 (47 island, 15 mainland) adult Herring Gulls were captured and

marked from 1998 to 2002. To avoid introducing bias into the models through inclusion of the seven birds captured away from nests in 1998, which included sub-adults and possibly adults in transit, individuals entered the analysis (i.e., were "released") only after having bred within the study area. The encounter histories for birds in the analysis are summarized in Table 1.

Goodness-of-fit

The estimate of $\hat{c}$ from 1,000 bootstraps, 27.989/27.794 = 1.007, suggests the data fitted the global model well. Since the value was close to unity, an estimate of $\hat{c}$ was not applied as an adjustment to AICc and sampling variances (Burnham and Anderson 2002).

CMR Analysis

ΔAICc marginally favoured the p (03-04 m, 03i) design over the no effects p (.) and global designs (Table 2) where 03-04 m is a unique effect on encounter in 2003 and 2004 for the mainland group and 03i is a unique effect on encounter in 2003 for the island group. The 03m effect, a unique effect on encounter in 2003 for the mainland group, in the global model bounded zero substantially (-1.44, 3.60 95% CI), precluding confident inference. The single 03-04 m effect in model p (03-04 m, 03i) did not bound zero and was negative; encounter probabilities, as suspected, were apparently anomalously low in these years. Based on all the evidence, p (03-04 m, 03i) was retained in all subsequent survival models.

The overall best survival model was the no effects ϕ (.) model (Table 2). Although model ϕ (g) and ϕ (t) acquired substantial (ΔAICc = 2.02) and moderate (ΔAICc = 6.27) support respectively, time (e.g., year 2001, -1.01, 3.08 95% CI) and group effects (-1.13, 1.49) in these models bounded zero widely. Given the uncertainty as to which model was best, model-averaged estimates of survival and encounter probabilities were calculated initially using the full model set. However, weak time and group effects resulted in annual estimates that were essentially the same. In response, survival estimates are provided from the two top models, ϕ (g) and ϕ (.) (Table 3), and encounter estimates from the top AICc ranked model (Table 3), rather than the model-averaged estimates. Given the uncertainty about the magnitude of the group effect in model ϕ (g), inference in the discussion was reserved to only the ϕ (.) survival estimate, 0.87 ± 0.03 (SE).

Supplementary Data

The migration habits and wintering range of Herring Gulls from the region are not well known. A male, banded in 1999, and photo-

Table 1. Summary of encounter histories for breeding Herring Gulls captured and then re-encountered in subsequent breeding seasons at two locations within the East Bay Migratory Bird Sanctuary, 1998 to 2004. Only breeding birds are included in the dataset.

Release year	Group[1]	No. released	No. re-encountered in each year					
			1999	2000	2001	2002	2003	2004
1998	I	5	3	3	3	2	1	1
	M	0	0	0	0	0	0	0
1999	I	8		7	5	5	3	3
	M	2		2	2	2	1	0
2000	I	12			10	9	5	8
	M	2			1	1	0	0
2001	I	20				18	14	14
	M	11				9	2	1
2002	I	2					2	2
	M	0					0	0

[1]I = Island, M = Mainland.

Table 2. Models and selection criteria including △ AICc used to determine support for competing models; global model is shown in bold text.

Model	AICc	△ AICc	Akaike Weight	Model Likelihood	K	Model Deviance
ϕ (.) p (03-04m, 03i)	189.07	0.00	0.698	1.000	3	33.44
ϕ (g) p (03-04m, 03i)	191.10	2.02	0.254	0.363	4	33.36
ϕ (t) p (03-04m, 03i)	195.34	6.27	0.030	0.044	8	28.96
ϕ (g+ t) p (03-04m, 03i)	197.36	8.29	0.011	0.016	9	28.75
ϕ (g + t) p (03m, 04m, 03i)	198.85	9.78	0.005	0.008	10	27.99
ϕ (g + t) p (.)	202.45	13.37	0.001	0.001	8	36.07

K = number of estimable parameters in the model, ϕ = survival parameter, p = resighting parameter, (.) no effects, (g) group effect, (t) time effect, (m) mainland, (i) island, 03-04m = unique effect on encounter in 2003 and 2004 for the mainland group, 03i = unique effect on encounter in 2003 for the island group, 03m = unique effect on encounter in 2003 for the mainland group, 04m = unique effect on encounter in 2004 for the mainland group.

graphed on 3 April 2000 in Texas near the Gulf of Mexico, returned to breed at the East Bay colony at the end of May of the same year. A second male, banded in 2000, and observed in November 2000 at Niagara Falls, New York, also returned to the colony to breed.

DISCUSSION

Loss of incoloy bands placed on adult larids can occur, but is unlikely within the time span of this study (Coulson 1976; Hatch and Nisbet 1983). Loss of plastic bands did occur but use of unique combinations of bands ensured ability to identify individuals.

Different life-history strategies can result in differences in survival (Nager et al. 2001). A group effect was introduced because of observed differences in nest attendance, foraging habits and reproductive output between the island and mainland groups (K. A., unpublished data). Failure to detect a biologically important group effect likely resulted from either lack of an effect or sparse data. Further, studies of herring gulls at other locations with larger samples have failed to detect a sex effect on survival (Pons and Migot 1995; Wanless et al. 1996). Little or no evidence of intermittent breeding (Calladine and Harris 1997) was detected at East Bay; once an individual was "missed" during a given season, the individual was not seen again in subsequent years, except in years 2003 and 2004, where individuals likely were missed due to lower resighting effort at one or both study locations.

The Herring Gull has generally increased over the last century in North Amer-

Table 3. Estimates of apparent survival probabilities from models ϕ (.) and ϕ (g) and encounter probabilities from the top ranked AICc model ϕ (.) p (03-04m, 03i) (Table 1).

Survival Estimate from Model ϕ (.):					
Group	Interval	Estimate	SE	LCI	LCI
Both	All	0.866	0.027	0.805	0.910
Survival Estimates from Model ϕ (g):					
Island	All	0.869	0.028	0.803	0.915
Mainland	All	0.846	0.081	0.619	0.949
Encounter Estimates[b]					
Group	Occasion	Estimate	SE	LCI	UCI
Island	2003	0.765	0.076	0.586	0.882
Mainland	2003, 04	0.206	0.096	0.076	0.450

ϕ = survival parameter, (.) no effects, (g) group effect.
[a]First release for the mainland group was in 1999.
[b]Encounter probabilities not shown were fixed to 1.0.

Table 4. Estimates of apparent adult survival from North American and European Herring Gulls. Studies either assume constant survival during the period or average yearly survival among cohorts. Earliest studies were excluded, unless data were re-analyzed with modern methods.

Continent	Location	First release to last resight/ recovery	Estimate (SE)	Source
N. America	Canada, Arctic	1998 to 2004	0.87 (0.03)	
N. America	U.S.A., Mass.	1967 to 1974	0.80-0.85	Kadlec 1976
N. America	Canada, Kent Isl.	1934 to 1939	0.824 (0.069)	Freeman and Morgan 1992 (data from Paynter 1966)[*]
Europe	France, Brittany	1983 to 1990	0.88 (0.01)	Pons and Migot 1995
Europe	France, Brittany	1983 to 1987	0.923 (0.012)	Lebreton et al. 1995[**]
Europe	U.K., Isle of May	1989 to 1994	0.88 (0.13)	Wanless et al. 1996
Europe	France, Brittany	1983 to 1986	0.89 (0.02)	Migot 1992
Europe	U.K., N.E. England	1979 to 1985	0.917 (0.018)	Coulson and Butterfield 1986
Europe	U.K., Isle of May	1966 to 1974	0.935 (0.100)	Chabrzyk and Coulson 1976[*]

[*]Capture-Mark-Recovery data.
[**]Comparison between Capture-Mark-Resight and Capture-Mark-Recovery data.

ica and Europe (Graham 1975; Furness *et al.* 1992) but may now be declining (Hebert 1989; Howes and Montevecchi 1993; Pierotti and Good 1994; Gilchrist and Robertson 1999). The estimate of adult survival for all Herring Gulls presented in this study falls within the broad range of survival estimates derived for the species at other locations in both North America and Europe (Table 4). Though large standard errors around survival estimates preclude confident inference, North American survival estimates presented in Table 4 are consistently lower than European estimates. Band loss has been proposed as a possible cause for the disparity (Pierotti and Good 1994), but loss of bands did not affect this study. Clearly, this pattern warrants further attention.

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