

**SURVIVAL AND MIGRATION ECOLOGY OF EMPEROR
GEESE ALONG THE ALASKA PENINSULA**

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Abstract - Survival and migratory patterns of emperor geese (*Chen canagica*) were investigated during 1988-90 by marking flightless geese with neck collars and reobserving them on spring and fall staging areas. Forty-five percent of collars applied in 1990 were reobserved in Fall 90, a 41% increase over 1989 and indicative of expanded reobservation efforts. Geese exhibited fidelity to staging areas (79 - 92% seen at the same site as Fall 89) and most (92%) were seen at only 1 site per season. Distribution of failed and/or non-breeders, both within and among lagoons, differed slightly from family groups.

Over-winter survival of juveniles was low and less than over-summer survival. Adult survival was variable with the 1 over-summer estimate between 2 over-winter estimates. A deterministic population model demonstrated that these survival rates may be realistic given other population parameters (e.g., breeding frequency, clutch size, nesting success, gosling survival). Magnitude of adult survivorship had greater effects on population size than did juvenile survivorship.

INTRODUCTION

A recent decline in the emperor goose population (King and Lensink 1971, Petersen and Gill 1982, King and Denlinger 1989) prompted concern about factors affecting their population dynamics. Information on reproductive parameters come from several ecological studies (Eisenhauer and Kirkpatrick 1977, Krechmar and Kondratiev 1982, Petersen MS). Comparatively little is known about survival rates. Butler et al. (MS) have estimated annual survival but these estimates lack age and seasonal specificity. In 1988 the Alaska Fish and Wildlife Research Center (AFWRC) initiated a mark-recapture study of emperor geese designed to estimate age and seasonal specific survival. We here report results from our most recent field season, Fall 1990.

METHODS

Emperor geese, primarily breeding adults and their young, were captured and fitted with coded neck collars while on the Yukon-Kuskokwim Delta during the flightless period in late July and early August, 1988-90. Reobservations of banded geese were obtained at spring and fall migratory staging grounds on the Alaska Peninsula (Fig. 1) with at least two personnel per site and up to 4 sites monitored per season (Table 1).

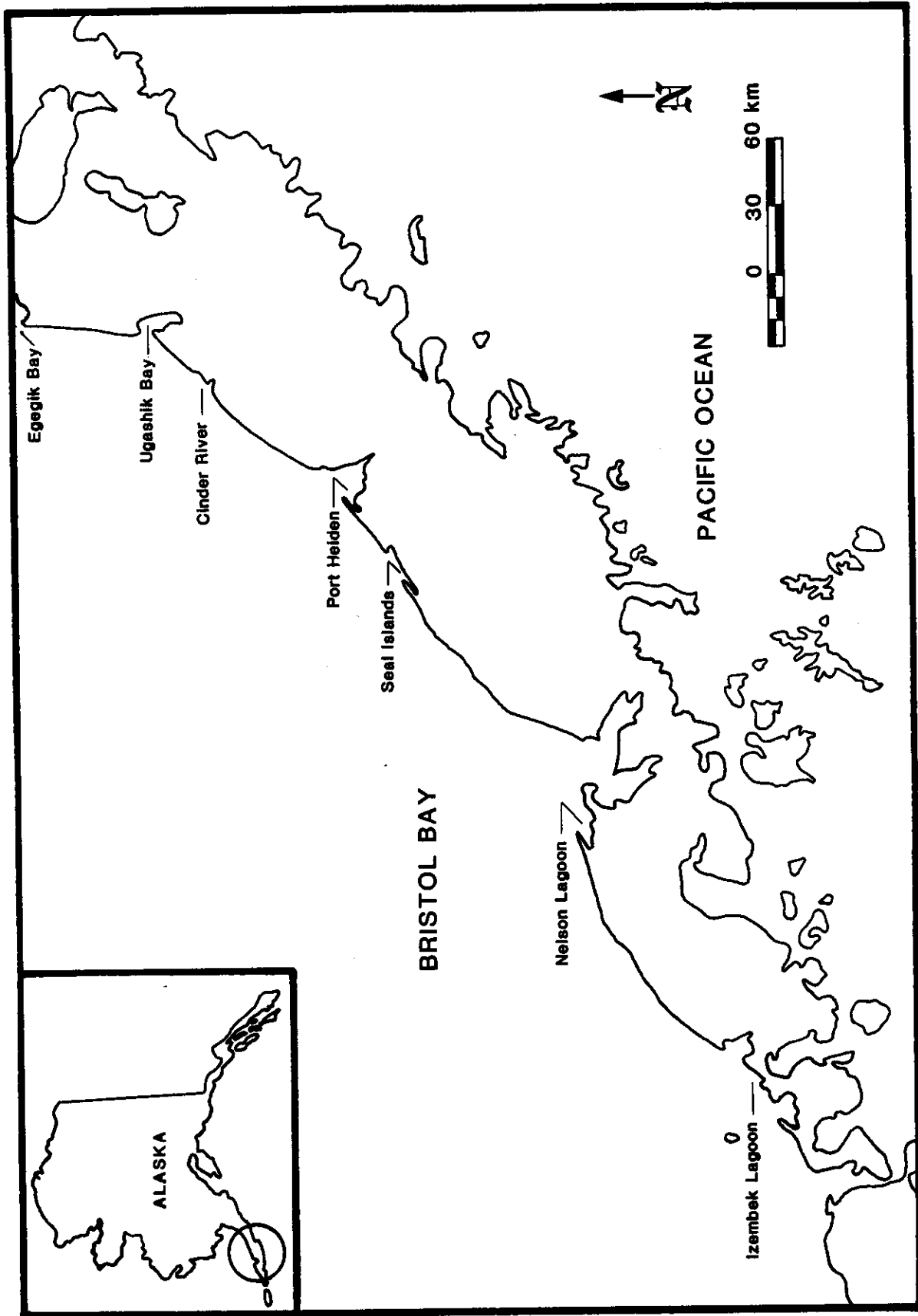


Fig. 1. Major estuaries on the Alaska Peninsula used by emperor geese during spring and fall migrations.

Table 1. Numbers of personnel that collected reobservations of emperor geese at study sites on the Alaska Peninsula, 1988-90.^a

	Cinder Lagoon	Nelson Lagoon	Port Heiden	Seal Islands
Fall 88	2	0	0	0
Spring 89	2	2 ^b	0	0
Fall 89	2	2	0	0
Spring 90	2	2	0	0
Fall 90	2	4	2 ^c	2 ^c

^a Personnel from another AFWRC project collected data at Izembek Lagoon during Fall 89-90 but not on a full-time basis.

^b Geographic coverage of Nelson Lagoon was much less in this season than in subsequent seasons.

^c Personnel were at the site for < 3 weeks.

Most geese were classified during banding into Hatch Year (HY) and After Hatch Year (AHY) age classes. Small numbers of geese (< 5%) were more specifically classified as Second Year (SY) birds based on remnant feathers of the juvenile plumage. We classified geese to sex by cloacal examination. Body mass estimates for juveniles (to the nearest 50 g) were obtained in 1990 using spring scales. During 1990, geese that appeared injured or behaved abnormally upon release were excluded from all analyses.

Observations of collared geese within sites (also called lagoons) were obtained opportunistically to maximize the number of individuals seen. Effects of time, age, breeding location, and lagoon fidelity on use of the various lagoons was investigated by examining the accumulated reobservation histories for each individual, both within and among seasons. We also collected age ratio data (HY versus AHY) from subsamples of flocks. The selection of this subsample was arbitrary but usually constituted the majority if not the entire flock. Ratios were then calculated with Cochran's (1963) weighted ratio estimate with weights designated by the number of geese sampled in each flock.

Survival - We estimated survival by modeling the patterns of reobservation on fall and spring staging grounds using Jolly-Seber mark-recapture models (Jolly 1965, Seber 1965, see review by Pollock et al. 1990) and the computer program SURVIV (White

1983). Geese were classified as alive during a given season if they were located ≥ 1 time at any lagoon anytime during the reobservation period. Survival probabilities pertain to the time period from the midpoint of banding or the observation period to the midpoint of the subsequent observation period. Some of the major assumptions of the Jolly-Seber models are that (1) capture and banding do not affect survival, (2) neckbands are not lost, (3) all individuals within a group (e.g., juveniles) have the same survival and reobservation probabilities, and (4) geese do not permanently emigrate from the study area.

We pooled males and females but conducted separate analyses on HY and AHY geese (SY geese included in AHY). For each analysis, we began with a general model with separate parameters for each season each year. Several reduced-parameter models were also constructed to assume equivalent survival and/or reobservation probability among years and/or seasons. Selection of the most appropriate model was based on goodness-of-fit tests for each model and likelihood ratio tests among models (White 1983).

We examined the effects of collar loss by simulating 10% and 20% constant rates of annual collar loss. After selecting the most appropriate survival model, we then adjusted for these loss rates using the equation given by Hestbeck and Malecki (1989:94) and assuming a variance for loss rate of 0.01.

Probability of survival to fall staging grounds in relation to body mass at banding was examined for juveniles banded in 1990. Assuming that reobservation probabilities were equal among juveniles of different masses, then the number observed in fall 1990 was proportional to survival. A t-test for mass differences between "seen" and "not seen" groups is therefore a test for survival differences.

Population Dynamics - We examined the fit of computed survival estimates to existing population survey data. Every spring and fall since 1981, USFWS personnel conducted aerial surveys (treated as censuses) of the entire Alaska Peninsula to count emperor geese (King and Brackney 1990, King and Dau 1990). Every fall since 1985, age ratios have been calculated from aerial photographs from all major staging areas (Butler et al. MS). A prediction of the spring population, $N_PRED_{s,i}$, in year $i + 1$ can be calculated as

$$(N_{f,i} \times R_i \times S_{j,i}) + (N_{f,i} \times (1 - R_i) \times S_{a,i}) = N_PRED_{s,i+1},$$

where $N_{f,i}$ is the fall population census in year i , R_i is the fall age ratio in year i estimated by aerial photographs, $S_{j,i}$ is our estimate of juvenile over-winter survival from the fall of year i to the spring of year $i + 1$, and $S_{a,i}$ is our estimate of adult over-winter survival from the fall of year i to the spring of

year $i + 1$. We then compared predictions of spring population size to actual spring population surveys.

Irrespective of population surveys, we then constructed a simple, deterministic population model to examine the interaction of survival estimates with other population parameters. We followed Lotka-Leslie methods used by Nichols et al. (1980) and Noon and Biles (1990). We assumed no density dependence nor senescence, a 1:1 sex ratio, and a stable age structure. The demographic life history, defined in terms of females, is shown in Table 2. We assumed a value or range of values for clutch size (c), nesting success (n), breeding frequency (b), age at first reproduction (r), and survival from hatch to fall (s_h) (Table 3). Over-winter juvenile survival and adult annual survival are symbolized by s_v and s_a , respectively. The net reproductive rate, R_0 (also known as net maternity function), is the sum of the $l_x b_x$ column in Table 2 and represents the number of female offspring produced in the lifetime of a female. The net reproductive rate was calculated as

$R_0 = \sum_{x=0}^{\infty} l_x b_x = bcns_h s_v s_a^{r-1} / (1 - s_a)$, where $0 < s_a < 1$. By simulating a range of s_v and s_a and solving for $R_0 = 1$, (i.e., a stable population), we demonstrate what combinations of these survival parameters are necessary to maintain a stable population size.

Table 2. Life history used to model the demographics of emperor geese. In this representation, age at first reproduction is 2 years old.

x^a	l_x^b	b_x^c	$l_x b_x^d$
0	1.0	0	0
1	$s_h s_v$	0	0
2	$s_h s_v s_a$	bcn	$s_h s_v s_a bcn$
3	$s_h s_v s_a^2$	bcn	$s_h s_v s_a^2 bcn$
.	.	.	.
.	.	.	.
x	$s_h s_v s_a^{x-1}$	bcn	$s_h s_v s_a^{x-1} bcn$

^a Age in years.

^b Survival from age 0 to age x .

^c Average number of female goslings produced per female surviving to age x .

^d Net reproductive rate.

Table 3. Population parameters used to model demographics of emperor geese.

Parameter	Simulated value	Observed range	Data Source
Clutch size	5	4.80-5.01 4.95-5.36	Emperors - 1982-86 Petersen MS 1986-90 Stehn et al. (1990)
Nesting success	60%, 90%	38 - 91% 71 - 89%	Emperors - 1982-86 Petersen MS 1988-90 M. Anthony, unpubl. data
Breeding frequency	70%	38 - 52% ≥ 94% ≤ 40%	Emperors - 1982-86 Petersen MS <i>Branta canadensis</i> interior > 4 years old, Moser and Rusch (1989) <i>B. c. interior</i> 2 - 4 years old, Moser and Rusch (1989) No data for emperors
Age 1st reproduction	2, 3		
Survival Hatch to 1 Aug	50%	57%	No data for emperors <i>B. c. moffitti</i> , Eberhardt et al. (1989), calculated from daily survival rates
Survival 1 Aug to Fall	70%	< 75%	Emperors - This study

^a The simulated value for S_h is the product of Survival - Hatch to 1 Aug and Survival - 1 Aug to Fall.

RESULTS

Staging Ecology - During Fall 90, 767 unique neck-collared geese were observed of which 556 were banded in 1990. The proportion seen in their first fall after banding was higher in 1990 (45%) than in either 1989 (32%) or 1988 (19%). This increase was due to the addition of 2 new study sites this fall, Port Heiden and Seal Islands, and expanded efforts at Nelson Lagoon. The number of neck-collared geese seen by lagoon and average lagoon population sizes are given in Table 4.

Table 4. Total number of collared geese observed Fall 90, number of these geese that were subadults, and average fall population by lagoon.

	Total collars	Subadults	Fall Population ^b
Egegik Bay			735
Ugashik Bay			1,661
Cinder Lagoon	238	9	9,607
Hook Lagoon			1,998
Port Heiden	131	7	13,574
Seal Islands	72	4	10,991
Nelson Lagoon/ Port Moller	349	26	26,880
Izembek Lagoon	33	2	3,264
Unimak/False Pass			1,476
South Side of AK Peninsula			4,670
Totals	823 ^c	48	

^a Subadults were geese hatched in 1988 or 1989.

^b Average of 1985-90 fall surveys (King and Brackney 1990).

^c Geese seen at multiple sites were counted for each lagoon therefore resulting in a total greater than the 767 unique collars noted in text.

Most geese (92%) were seen at only 1 site during Fall 90. The best data on length of the staging period were from Cinder Lagoon, the only site where the entire staging population was readily accessible. The majority (55%) of geese at Cinder Lagoon were there for at least 1 month (Fig. 2).

As in previous field seasons (Schmutz et al. 1990), birds seen in Fall 90 were frequently seen in the same lagoons in previous seasons. Of 61 geese seen at only Nelson Lagoon in Fall 1989 and re-sighted in Fall 1990, 92% (56) were re-sighted at Nelson Lagoon. Similarly, of 34 geese seen at only Cinder Lagoon in Fall 1989 and re-sighted in Fall 1990, 79% (27) were re-sighted at Cinder Lagoon. We also obtained data on fidelity from our 2 new study sites. At Port Heiden and Seal Islands, 60% of re-sightings of geese neck-collared before 1990 were never seen prior to Fall 1990 compared to only 21% and 9% at Nelson and Cinder lagoons, respectively.

To ascertain if lagoon use was related to banding area, we assigned geese to 1 of 3 areas of banding - Anerkochik, Kokechik, and Kashunuk. Geese seen at multiple sites and known second-year birds were not included in this analysis to reduce confounding influences from factors other than banding area that might affect migratory patterns. Differing proportions of geese were seen among staging areas depending on which banding area they came from (G-test, $P = 0.003$, Table 5). This significance was due principally to the disproportionate re-sighting rates for geese banded at Kashunuk and seen at Port Heiden and Cinder Lagoon and for geese banded at Kokechik and seen at Seal Islands. Although the test was significant, we suggest care when making inferences from these results because of small sample sizes for geese banded at Kashunuk.

Pooling all Fall 90 observations, the probability of a goose being re-sighted was not dependent on its 1990 banding area (G-test, $P = 0.93$). Although a relationship was evident in 1988 and 1989 (Schmutz et al. 1990), this was likely an artifact of monitoring fewer lagoons.

Differential migration during Fall 90 between breeding and subadult or non-breeding populations was examined by comparing timing and duration of staging of known second-year birds with young of the year. Juveniles and subadults seen at Cinder Lagoon arrived at similar times but juveniles stayed longer (Table 6). At Nelson Lagoon, juveniles arrived earlier and stayed longer than subadults. Comparing arrival times between lagoons is not valid because of different arrival dates of personnel. Equal proportions of subadult geese (2- and 3-year olds) were seen among lagoons (G-test, $P = 0.452$), based on the total number of collared geese seen per lagoon.

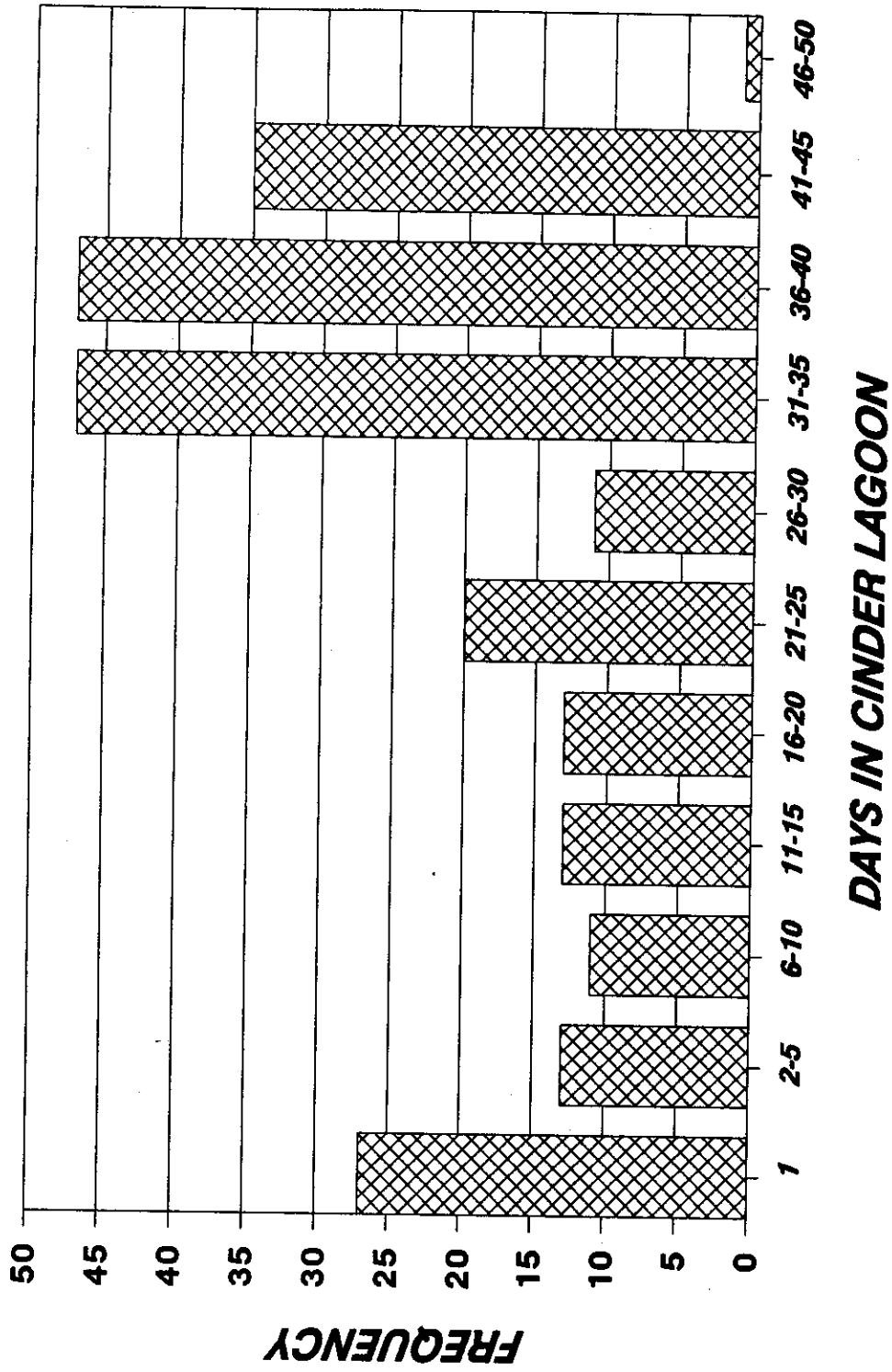


Fig. 2. Length of stay of emperor geese staging at Cinder Lagoon during Fall 90. Length of stay was measured as time between first and last re-sighting of an individual.

Table 5. Proportion (and number) of emperor geese banded at 3 locations in 1990 and reobserved at staging areas on the Alaska Peninsula.

Banding location	Staging Area			
	Cinder Lagoon	Nelson Lagoon	Port Heiden	Seal Islands
Anerkochik	32% (55)	46% (79)	19% (32)	3% (6)
Kokechik	28% (74)	41% (110)	20% (54)	11% (28)
Kashunuk	44% (15)	50% (17)	3% (1)	3% (1)

Table 6. Date of arrival and length of stay by juvenile and subadult emperor geese staging at Cinder and Nelson lagoons during Fall 1990.

	Juveniles	Subadults	P-value ^a
Cinder Lagoon			
Sample size	85	9	
Arrival date	19 Sept ^b (8 ^c)	19 Sept (10)	0.491
Length of Stay	28 (13)	12 (11)	0.029
Nelson Lagoon			
Sample size	97	26	
Arrival date	5 Oct (16)	12 Oct (15)	0.025
Length of Stay	19 (16)	12 (16)	0.010

^a Median test.

^b Mean arrival date.

^c One standard deviation (days).

Age ratios among lagoons, derived from photographs obtained during aerial surveys of entire lagoons (W. Butler unpubl. data), varied; Cinder Lagoon had the highest proportion of young in 1990 (Table 7). Comparison of ground and aerial age ratios revealed that ground-based sampling yielded lower age ratios for Nelson Lagoon, higher for Port Heiden, and virtually the same for Cinder Lagoon. The similarity of estimates for Cinder Lagoon results from the nearly complete sampling of the staging population by personnel at this site. Within Nelson Lagoon, the proportion of young in flocks at vegetated (principally *Carex* and *Puccinellia* spp.) areas was much higher ($38 \pm 15\%$, $n = 12$ flocks) than those in flocks at unvegetated (gravel bar, beach, mudflat, open water) areas ($16 \pm 3\%$, $n = 110$).

Survival - Survival probabilities were computed for 2 first-fall (banding to fall), 2 over-winter (fall to spring), and 1 over-summer (spring to fall) periods (Table 8). In addition to seasonal survival estimates, monthly estimates were calculated to make survival rates among seasons of different duration more comparable. Model selection was no different, however, for seasonal versus monthly survival rates.

Survival from banding to first-fall was not different among years for either juveniles (Log-likelihood ratio, or G-, test, $P = 0.151$) or adults (G-test, $P = 0.227$); therefore a single parameter was estimated for this season within each age class. Because violation of model assumptions was likely most severe during this first period following banding (see Discussion), these rate estimates are not biologically meaningful by themselves. However, since biases due to assumption violation were likely consistent between age classes, the ratio of juvenile to adult survival, 0.75 (SE = 0.10), should be an accurate reflection of relative survivorship between the age classes for this period.

Over-winter survival of juveniles was not statistically different among years. Survival probability for this 6-7 month period was 0.19 (SE = 0.05) (Table 8). In contrast, our one estimate for over-summer survival of juveniles (first spring to second fall) was 0.78 (SE = 0.25). Although this estimate is imprecise, it is still significantly different from the over-winter estimate (G-test, $P = 0.002$). The relative imprecision of the over-summer estimate likely results because it is derived only from the few juveniles still alive in spring.

Table 7. Age ratios ($\bar{x} \pm \text{SE}$) of emperor geese determined from ground and aerial* surveys during Fall 90.

	Staging Area			
	Cinder Lagoon	Nelson Lagoon	Port Heiden	Seal Islands
Ground	0.34 ± 0.03	0.17 ± 0.03	0.33 ± 0.03	0.26 ± 0.06
Aerial	0.34 ± 0.04	0.25 ± 0.03	0.22 ± 0.06	0.23 ± 0.03

* Unpubl. data from W. Butler.

Table 8. Seasonal and monthly survival rate estimates for emperor geese during 1988-1990.

Age	Season	Seasonal survival			Monthly survival		
		$\bar{x}$	SE	95% CI	$\bar{x}$	SE	95% CI
Adults							
	Banding 1988 to Fall 1988 ^a	0.75A ^b	0.04	0.67-0.84	0.89	0.02	0.84-0.93
	Fall 1988 to Spring 1989	0.60	0.10	0.41-0.79	0.93	0.02	0.88-0.97
	Spring 1989 to Fall 1989	0.92	0.15	0.62-1.22	0.98	0.03	0.92-1.04
	Banding 1989 to Fall 1989	0.75A	0.04	0.67-0.84	0.89	0.02	0.84-0.93
	Fall 1989 to Spring 1990	1.0	0.15	0.70-1.30	1.0	0.02	0.95-1.04
Juveniles							
	Banding 1988 to Fall 1988	0.56B	0.09	0.38-0.73	0.77	0.05	0.67-0.88
	Fall 1988 to Spring 1989	0.19C	0.05	0.10-0.28	0.78	0.03	0.72-0.83
	Spring 1989 to Fall 1989	0.78	0.25	0.28-1.28	0.96	0.05	0.85-1.06
	Banding 1989 to Fall 1989	0.56B	0.09	0.38-0.73	0.77	0.05	0.67-0.88
	Fall 1989 to Spring 1990	0.19C	0.05	0.10-0.28	0.78	0.03	0.72-0.83

^a Calendar dates for the seasons extend from the midpoint of one observation/banding period to the midpoint of the next period. Calendar dates are as follows: Banding to Fall = 1 August to 10 October; Fall to Spring = 10 October to 1 May; Spring to Fall = 1 May to 1 August.

^b Survival estimates for different periods but followed by identical letters mean there were no difference among these periods ($P > 0.05$, log-likelihood ratio tests) and therefore a constrained SURVIV model was used to calculate a single estimate.

Over-winter survival of adults was different between 1988-89 and 1989-90 (G-test, $P = 0.028$). The 1 over-summer estimate was between these 2 over-winter estimates but not significantly different from either (G-test, $P > 0.05$).

A simulated annual rate of collar loss of 10% increased over-winter and over-summer survival estimates by 1 - 7% ($\bar{x} = 3.8\%$). Simulating a 20% rate of loss increased these survival estimates by 3 - 14% ($\bar{x} = 8\%$) (Table 9). We have no empirical estimates of collar loss for this study; however, we believe collar loss is low. In 1990 we recaptured 12 previously neck-collared geese of which none had lost their collars. These birds represented 17 years of exposure to potential collar loss.

All banding was completed in 5 days in 1990, which minimized size differences among goslings due to growth during the banding process. There was no relationship between gosling body mass and date of banding ($R^2 < 0.01$, $P > 0.40$ for males and females). Mass of goslings at banding was positively related to survival to fall staging grounds (t-test, $P = 0.047$ for males, $P = 0.033$ for females). However, mean body mass of those observed during Fall 90 was only 2.3% (males) and 2.4% (females) greater than for those not observed.

Population Dynamics - We had 2 winters of survival information to calculate predictions of spring populations. $N_PRED_{s,1989}$ was 39,381 compared to the survey estimate of 45,800. $N_PRED_{s,1990}$ was 57,638 compared to the survey estimate of 67,581. We then computed a series of predicted spring populations that used a range of assumed survival rates instead of our actual estimates (Table 10). For 4 of 5 years, predicted spring populations were within 10% of the observed survey population (Table 11) for some combination of adult and juvenile survival rates. Changes in adult over-winter survivorship had much larger effects on subsequent spring population size than did proportional changes in juvenile over-winter survivorship. The magnitude of this difference is directly correlated to the proportion of adults and juveniles in the fall population.

Annual survival of adults must be about 90% or more to at least maintain a constant population size given the rates of juvenile over-winter survival found in this study (Fig. 3). Variation in nesting success and age of first reproduction has some effect on population growth. However, this variation becomes progressively less important with higher adult and lower juvenile survival. As all slopes of lines in Fig. 3 are less than -1, adult survivorship has a proportionately greater effect on population size than juvenile survivorship.

Table 9. Effect of 10% and 20% constant rates of annual neck-collar loss on survival estimates for emperor geese during 1988-1990.

Age	Season	No collar loss		10% collar loss		20% collar loss	
		$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Adults							
	Banding 1988 to Fall 1988 ^a	0.75A ^b	0.04	0.77	0.08	0.79	0.08
	Fall 1988 to Spring 1989	0.60	0.10	0.64	0.10	0.69	0.10
	Spring 1989 to Fall 1989	0.92	0.15	0.97	0.17	1.02	0.18
	Banding 1989 to Fall 1989	0.75A	0.04	0.77	0.08	0.79	0.08
	Fall 1989 to Spring 1990	1.0	0.15	1.07	0.18	1.14	0.19
Juveniles							
	Banding 1988 to Fall 1988	0.56B	0.09	0.58	0.09	0.59	0.09
	Fall 1988 to Spring 1989	0.19C	0.05	0.20	0.03	0.22	0.03
	Spring 1989 to Fall 1989	0.78	0.25	0.83	0.23	0.87	0.24
	Banding 1989 to Fall 1989	0.56B	0.09	0.58	0.09	0.59	0.09
	Fall 1989 to Spring 1990	0.19C	0.05	0.20	0.03	0.22	0.03

^a Calendar dates for the seasons extend from the midpoint of one observation/banding period to the midpoint of the next period. Calendar dates are as follows: Banding to Fall = 1 August to 10 October; Fall to Spring = 10 October to 1 May; Spring to Fall = 1 May to 1 August.

^b Survival estimates for different periods but followed by identical letters mean there was no difference among these periods ($P > 0.05$, log-likelihood ratio tests) and therefore a constrained SURVIV model was used to calculate a single estimate.

Table 10. Predicted spring_{year i + 1} populations based on fall population surveys (King and Brackney 1990), fall age ratios (Butler et al. MS), and a range of over-winter survival rates.

<u>Overwinter survival rates</u>		<u>Predicted Spring Populations</u>				
Adults	Juveniles	1985-86	1986-87	1987-88	1988-89	1989-90
0.60	0.20	31307	33917	33383	38479	36128
0.70	0.20	36294	38993	38446	<u>44290</u>	41624
0.80	0.20	<u>41280^a</u>	44070	43508	<u>50101</u>	47120
0.90	0.20	<u>46267</u>	<u>49146</u>	<u>48571</u>	55913	52615
0.95	0.20	48760	<u>51685</u>	<u>51102</u>	58818	55363
0.60	0.40	32694	37374	36390	<u>42089</u>	39283
0.70	0.40	37681	42450	41453	<u>47900</u>	44779
0.80	0.40	<u>42668</u>	<u>47527</u>	46516	53712	50274
0.90	0.40	<u>47654</u>	<u>52603</u>	<u>51578</u>	59523	55770
0.95	0.40	50148	<u>55142</u>	<u>54110</u>	62429	58518

^a Underlined values within a column and juvenile survival rate are within 10% of the spring population survey (Table 11) for that year.

Table 11. Fall and spring population surveys of emperor geese along the Alaska Peninsula, 1985-90 (King and Brackney 1990, King and Dau 1990).

Season	<u>Population Surveys</u>				
	1985-86	1986-87	1987-88	1988-89	1989-90
Fall _{year i}	59792	68051	65663	76165	70729
Spring _{year i + 1}	42231	51655	53784	45800	67581

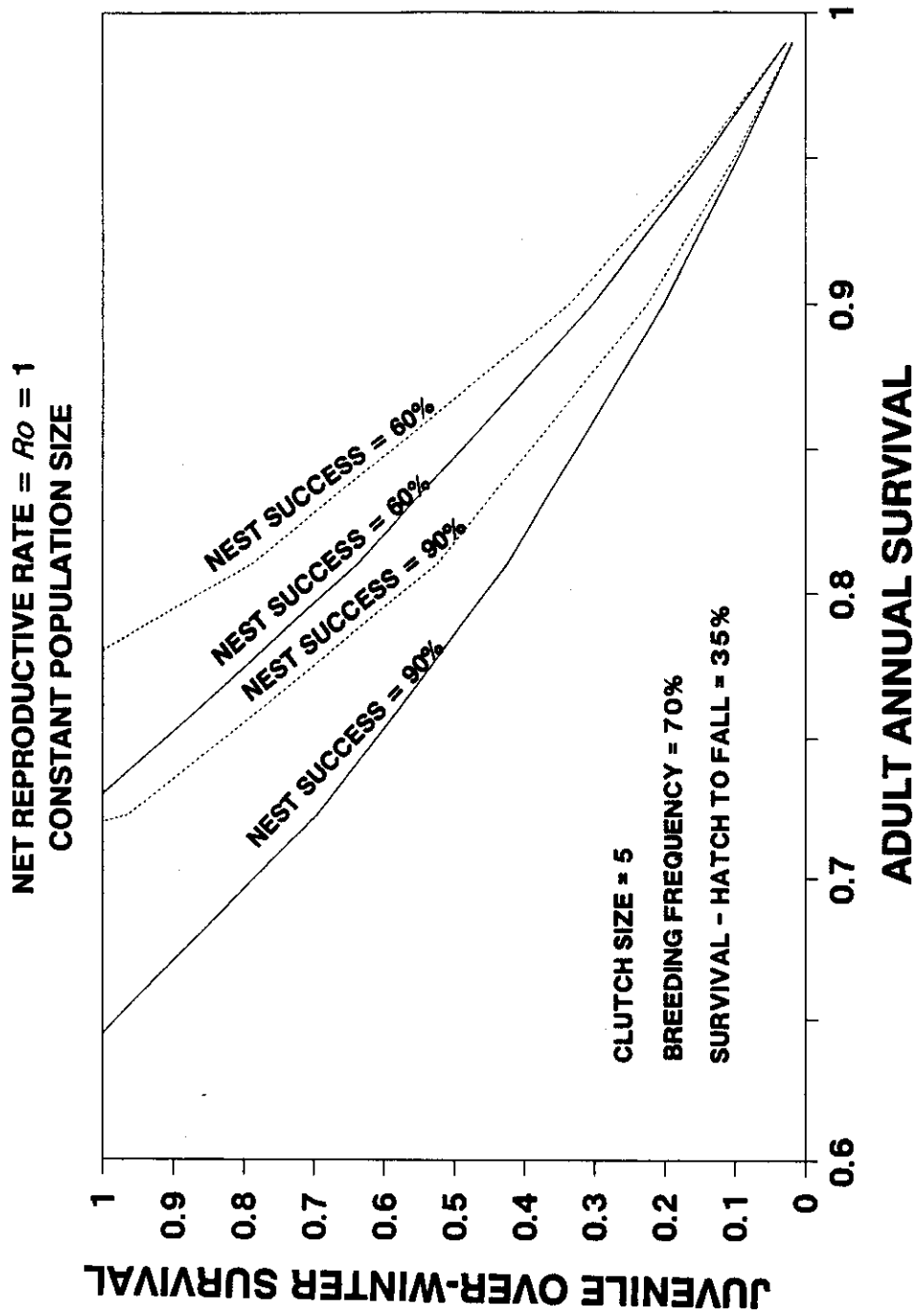


Fig. 3. Values of juvenile over-winter survival and adult annual survival necessary to maintain a stable population given a set of reproductive parameters. Age of first reproduction was 2- (solid line) or 3- (dashed line) years old, and nesting success was 60 or 90%.

DISCUSSION

Staging Ecology - Data from Fall 90 were consistent with previous field seasons in indicating fidelity of collared geese to staging areas. There was interchange among sites, however, as 8 and 21% of geese seen in Fall 89 at Nelson and Cinder lagoons, respectively, were seen during Fall 90 at different sites. Use of multiple sites within seasons was also documented. It seems probable that most emperor geese migrate along the Alaska Peninsula and choose a single site to spend the majority of the staging period. Choice of a site is dependent on previous use, although other factors likely affect lagoon use as well. Either before or after this lengthy stay within a lagoon, geese probably pass through other sites as well. This pattern would partially account for the high number of single sightings of geese within seasons (Fig. 2).

It is still unclear whether failed or non-breeders migrate differently than family groups. Subadult geese were found in equal proportions among lagoons. However, our ground-based age ratios indicated a disproportionate number of failed or non-breeders at Nelson Lagoon. Aerially obtained age ratios (of greater accuracy than ground counts as they sample entire lagoons) also indicated that Nelson Lagoon had a lower proportion of juveniles than Cinder Lagoon, but not different from Port Heiden and Seal Islands. At both Cinder and Nelson lagoons, juveniles stayed longer than known subadults and at Nelson Lagoon they also arrived earlier. However, no such temporal pattern was found in 1989 (Schmutz et al. 1990). If these 2 groups of geese are spatially separated within lagoons, these results could be biased if lagoon populations are not sampled in proportion to their distribution within lagoons. Segregation within lagoons may exist and would account for discrepancies between ground- and aerial-based age ratios. The ground-based estimate for Nelson Lagoon was low compared to the aerial-based one and would suggest that personnel were disproportionately sampling failed and non-breeders. Sampling was highly variable in intensity across Nelson Lagoon due to accessibility. Geese in the barrier islands (Kudobin to Wreck islands) and southeastern portion of the lagoon (First to Third Capes) were sampled most often and in total represented about half the lagoon system's population (R. King pers. comm.). At Cinder Lagoon ground personnel sampled much more uniformly and for 3 falls, 1988-90, ground- and aerial-based age ratios were in agreement (Butler and Schmutz unpubl. data).

Segregation of geese within lagoons may be partially driven by habitat availability. Most feeding activity among all geese occurs during low tide on at least 3 bivalve species. During

high tides, family groups often roosted where *Carex* and *Puccinellia* were accessible and would sporadically feed on these plants during the roosting period. Foraging on crowberries (*Empetrum nigrum*) at high tide has also been noted (pers. obs, D. Ward pers. comm.). In contrast, many flocks with few juveniles would roost on bars, spits, and beaches and not feed until the tide receded to expose intertidal invertebrates.

Assumptions of survival models - Schmutz et al. (1990) indicated that violation of important assumptions would result in biased and imprecise survival estimates of little value. We expanded efforts in 1990 to counter these problems and here address the assumptions.

Collar loss rates vary among goose populations (Zicus and Pace 1986, Hestbeck and Malecki 1989, Samuel et al. 1990). For this study, an empirical estimate of collar loss cannot be readily obtained. However, simulated loss rates had only a minor effect on our results and would not, at this point, change our interpretation.

Some geese undoubtedly do not use lagoons that we monitor. Because geese exhibit some fidelity to lagoons, we would have a low probability of ever reobserving these geese. This situation constitutes permanent emigration from the study area, a factor analytically inseparable from mortality. In Fall 90, we added 2 lagoon systems to our observation program, Port Heiden and Seal Islands, so that in 1990 we monitored all lagoons that had > 5% of the fall and spring staging populations (Table 4). Twenty-nine geese seen at these sites and banded prior to 1990 had never been seen before. Reobservations of such geese increased previous survival estimates and improved precision.

Conducting an analysis with the first reobservation treated as the initial banding period would eliminate permanent emigration that occurred immediately following actual banding. Two such analyses, one for Cinder Lagoon adults and one for Nelson Lagoon adults, resulted in imprecise estimates whose mean values were not different than our original analyses with the entire data set (Schmutz unpubl. data).

Another assumption is that geese do not experience collar-induced mortality. This factor has 2 components: capture effect and the effect of wearing the collar. Capture effect is minimized by careful field procedures and excluding from analysis geese that behave abnormally upon release. Still, capture effect may be a factor but only during the period from banding to first fall. Permanent emigration from the study area is also of greatest concern during this period. We therefore stress that survival rates from banding to first-fall may not be realistic and biological interpretation should be limited to subsequent periods.

Chronic effects from wearing a collar remain unquantified. Ice build-up has been cited as a deleterious effect in other studies (Zicus et al. 1983). A small number of observations of wintering emperor geese on Adak in the Aleutian Islands have yet to demonstrate icing as a problem (Byrd 1989). However, feather wear has been noted on recaptured geese (pers. obs.), and we speculate that feather wear and displacement could have negative thermoregulatory effects.

Survival - Over-winter survival in juvenile emperor geese was very low and less than first year survival seen in most geese (41 - 59% in review by Ogilvie 1978). We have no data on causes of mortality, but the interplay between foraging and energy procurement, thermoregulation, and migration costs may contribute significantly. Juveniles during fall staging are still only about 80% of adult size and likely have proportionately fewer fat reserves (Brackney et al. 1987), thus making them more susceptible to their relatively austere winter environment compared to most geese. During fall staging, emperor geese switch from their herbaceous, summer diet (Laing MS) to a predominately bivalve diet. Juveniles faced with a novel food resource may not feed efficiently. During Fall 90, we observed 2 instances when adults apparently assisted juveniles with procurement of *Macoma* spp. The availability of this bivalve resource changes with tidal magnitudes and weather patterns. Storm systems likely create the most demanding thermoregulatory environment while concomitantly reducing the physical availability of food resources (due to storm tides).

Our limited data show variable survival among adults with the 1 over-summer estimate between the 2 over-winter estimates. Multiplying the first over-winter estimate by the first over-summer estimate, and likewise, the first over-summer estimate by the second over-winter estimate yields 2 related rates of annual survival. These estimates span a range witnessed among adult geese (Ogilvie 1978). Additional seasonal estimates would be desirable for examining this variation in survival.

Population Dynamics - The deterministic, population model indicated the relative importance of the magnitude of adult survival. High adult survivorship (> 90%) is needed for populations to stabilize or grow given our low estimates of over-winter survival among juveniles. Even with survivorship of subadults and adults at > 90%, less than 5% of eggs laid by a nesting emperor goose will result in birds recruited into the breeding population.

We advise caution in interpretation of this model because of its simplicity, assumptions, and the inaccuracy or variability of some parameters. Among geese there is apparently much variability in the proportion of adult geese that breed (Moser

and Rusch 1989, Owen and Black 1989, Petersen MS); we here simulated rates of non-breeding less than empirical estimates for emperors (Petersen MS). We know little about gosling mortality and at what age emperor geese begin breeding. More data for these parameters and models that simultaneously consider variation in population parameters (e.g., Caswell 1978) would improve this demographic analysis.

RECOMMENDATIONS

This report documents 1-1/2 years of survival information. We propose to continue reobservation efforts through Spring 92 which will result in 3 years of survival rates for seasonal and age specific comparisons. We do not plan to band any additional birds as they would not substantively contribute to these first 3 years of data. Our expanded reobservation program was beneficial and must be continued to maintain data quality. At a minimum, we plan to have 2 people at each site - Cinder Lagoon, Nelson Lagoon, Port Heiden, and Seal Islands - during each field season.

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