

AN ABSTRACT OF THE THESIS OF

Susan E. Sheaffer for the degree of Doctor of Philosophy in
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Title: Population Ecology of the Dusky Canada Goose (*Branta*
canadensis occidentalis Baird)

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Robert L. Jarvis

Adult dusky Canada geese (*Branta canadensis occidentalis* Baird) were banded with plastic neck bands and observed on the winter range during 1985-92. Annual survival rates of adult geese estimated from observation data ranged from 76% to 85%. A model of Canada goose population dynamics was developed to illustrate relationships between survival rates, harvest regulations, and recruitment parameters and to predict trends in population size. Model simulations using recent estimates of survival and recruitment indicated that without significant increases in recruitment, survival rates must remain at or above present levels for the dusky Canada goose population to maintain itself.

Observations of geese banded with tarsal and neck bands were used to estimate within-year survival rates and rates of neck band loss during 1990-92. Average monthly survival was 97% and was not significantly different among harvest and nonharvest periods (X^2 , $P = 0.3882$). Neck band

retention rates were 100% and 98% the first and second year after banding, respectively, for male and female geese. Resighting probabilities for neck and tarsal bands were significantly lower for female than for male geese (χ^2 , $P < 0.020$).

Midwinter population size was estimated using neck band observations and a capture-resighting model. Dusky Canada goose population estimates ranged from 12,400 to 19,800 during 1990-92. Population estimates generally agreed with the U.S. Fish and Wildlife Service midwinter inventory during this period.

Subflocks of wintering dusky Canada geese were identified using a clustering algorithm and the number of weeks neck banded geese were observed in regions of the winter range. Over 65% of geese in subflocks affiliated with the northern and southern regions of the winter range were never observed outside their region of affiliation. Geese affiliated with the middle regions of the winter range exhibited greater movement, as most were seen at least once outside their region of affiliation. Although large groups could be identified based on regional use patterns, associations between group members could only be demonstrated for small groups of ≤ 10 geese and adult pairs.

POPULATION ECOLOGY OF THE DUSKY CANADA GOOSE
(*Branta canadensis occidentalis* Baird)

by

Susan E. Sheaffer

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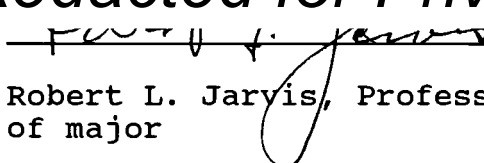
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POPULATION ECOLOGY OF THE DUSKY CANADA GOOSE
(*Branta canadensis occidentalis* Baird)

INTRODUCTION

Dusky Canada geese (*Branta canadensis occidentalis* Baird) comprise a well defined population with a restricted breeding and wintering range. This dark breasted subspecies nests primarily on the Copper River Delta, Alaska (Hansen 1962). Considered uncommon in Oregon before the 1940's (see review in Cornely et al. 1985), information from band recoveries identified the primary wintering grounds as the Willamette Valley of northwestern Oregon (Hansen 1968). Recent population surveys indicate that significant numbers also winter in the lower Columbia River Basin in southwestern Washington/northwestern Oregon.

Annual postseason counts of dusky Canada geese have been conducted on the winter range since 1952. During 1952-59, estimates of postseason population size varied between 10,000 and 17,000 (Hansen 1968). The need for refuges to provide sanctuary for the population during the harvest season was recognized in the late 1950's. The U.S. Fish and Wildlife Service subsequently purchased land for a 3 refuge complex in the lower Willamette Valley during 1963-65 (Timm et al. 1979). With the establishment of refuge lands, the dusky Canada goose population increased to over 20,000 by 1969.

The increase in dusky Canada goose numbers during the 1960's occurred despite a 3 bird daily bag limit and extended harvest seasons. Hunter harvest on wintering areas was considered the major source of mortality for this population (Hansen 1962, Chapman et al. 1969). Chapman et al. (1969) concluded that the breeding grounds could support a much higher population and that harvest was the primary factor limiting population growth.

The substantial harvest pressure on the dusky Canada goose population prompted formation of the Dusky Canada Goose Subcommittee of the Pacific Flyway Technical Committee in 1972. A management plan for the dusky Canada goose was developed and published in 1973 with the objective of maintaining a postseason population of 20,000 to 25,000 geese. By 1979, the dusky Canada goose population had reached 25,500 geese. However, the status of this population would significantly change in the following years.

During the 1980's there was a dramatic decrease in dusky Canada goose numbers. The population declined from 25,500 geese in 1979 to 12,200 geese in 1986. Concern about their status prompted modification of the flyway management plan recommending limited harvest when the population reaches 13,000, and closure of the harvest season when the wintering population is below 10,000 (Pacific Flyway Council 1985). The dusky Canada goose population presently remains

below the 20,000 bird objective despite restricted harvest since 1983.

The reasons for the decrease in population size are not well documented. High mortality on the wintering grounds and low recruitment rates are considered the primary factors that contributed to the decline (Campbell 1987). Dusky Canada geese undergo high mortality on the winter range, primarily due to hunting (Chapman et al. 1969, Simpson and Jarvis 1979, Jarvis and Cornely 1988). Although dusky Canada goose numbers have declined, Taverner's Canada geese (*B. c. taverneri*) wintering in the Willamette Valley have increased from a few thousand in the mid 1970's to over 50,000 in the mid 1980's (Jarvis and Cornely 1988). Harvest rates of dusky Canada geese during 1976-78 were twice those calculated for Taverner's Canada geese (Simpson and Jarvis 1979). Havel and Jarvis (1988) concluded that dusky Canada geese were more vulnerable to harvest than Taverner's Canada geese due to differences in flocking behavior and distribution on the winter range.

Declining reproductive success has been attributed to detrimental changes in breeding habitat resulting from the "Great Alaska Earthquake" (Cornely et al. 1985). On March 27, 1964 the Copper River Delta was uplifted approximately 1.9 m (Crow 1972). As a result, the channel bank vegetation and interchannel areas that were prime dusky Canada goose nesting habitat were no longer reached by the high tides

(Crow 1972). Resultant drying of these areas permitted invasion of upland plants and subsequent degradation of the nesting habitat. Shepherd (1965), Crow (1968, 1972), Potyondy et al. (1975) and Bromley (1976) all predicted that plant succession on the Delta would produce a shrub-forest community over much of the area. Bromley (1976) also suggested that a stable habitat with reduced nesting densities would develop within 20 to 30 years.

Deterioration of nesting habitat and subsequent increased predation rates on the breeding range have undoubtedly reduced reproductive success in recent years. Nest success averaged over 80% prior to 1975, but averaged only 37% between 1979-87 (Campbell 1984). Overall recruitment rates declined from an average of 26.8% in the 1970's to 11.5% during 1983-87 (Campbell 1990). Failure of dusky Canada goose numbers to increase despite restricted harvest seasons indicates that harvest mortality is no longer the primary factor limiting the population. However, the roles of harvest mortality and reproductive success in the dynamics of this population are not clearly understood.

The restricted range of this population presents a unique opportunity to study the dynamics of a Canada goose population. In 1984 marking of dusky Canada geese with plastic, individually coded neck bands was initiated with the objectives of estimating annual and within-year survival rates. Neck banded geese were observed on the wintering

grounds during 1985-92. The observation effort was restructured during 1988-92 to additionally estimate midwinter population size and to examine winter distributions and movements. The following papers are the result of an intensive observation study of marked dusky Canada geese.

The first paper documents past trends in dusky Canada goose population dynamics by examining band recovery data, neck band observation data, and trends in recruitment and harvest parameters. Estimates of survival and recruitment are incorporated in a model of Canada goose population dynamics to further assess the present status of the population and to provide guidelines for future management strategies.

The second paper presents a model to simultaneously estimate within-year survival and neck band retention rates based on observations of double marked dusky Canada geese. The model also identifies periods within the annual cycle critical to adult dusky Canada goose survival.

The third paper presents estimates of midwinter population size (1989-92) based on capture-resighting estimators and observations of neck banded geese. Differences between capture-recapture and capture-resighting models are identified, and the statistics needed to estimate population size from resightings of previously marked individuals are defined.

The fourth paper examines the existence and cohesiveness of wintering subflocks using observations of neck banded dusky Canada geese.

CHAPTER I

STATUS AND POPULATION DYNAMICS OF DUSKY CANADA GEESE

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INTRODUCTION

Dusky Canada geese (*Branta canadensis occidentalis* Baird) comprise one of the smallest populations of Canada geese that presently sustains an annual sport harvest. This subspecies breeds primarily on the Copper River Delta, Alaska and winters in the valleys of the Willamette River of northwestern Oregon and the Lower Columbia River along the Oregon/Washington border. During the period 1979-89 the dusky Canada goose population declined dramatically from an estimated 25,500 to 12,000 geese. Although the reasons for the decline in numbers are not well documented, high mortality on the winter range and depressed recruitment are thought primarily responsible (Campbell 1978, Simpson and Jarvis 1979, Cornely et al. 1985, Havel and Jarvis 1988, Jarvis and Cornely 1988).

Production studies on the Copper River Delta have provided substantial information on recruitment for this

population. Decreased recruitment since the 1970's has been linked to habitat changes on the Copper River Delta resulting from the 1964 earthquake and subsequent increases in predation rates of nests and goslings (Bromley 1976, Campbell 1984, 1987). Concern about the status of this population prompted restrictions in harvest regulations since 1983. Dusky Canada geese are estimated 2 to 3 times more vulnerable to harvest than Taverner's Canada geese (*B. c. taverneri*) that share their winter range (Simpson and Jarvis 1979). However, harvest restrictions have limited the data from band returns and information on survival is lacking.

The restricted range of this subspecies presents a unique opportunity to study the dynamics of a Canada goose population. Detailed studies on both the breeding grounds and the winter range, along with annual pre-season banding, have occurred since the 1950's (Trainer 1959, Hansen 1962, 1968, Chapman et al. 1969, Bromley 1976, Simpson and Jarvis 1979, Havel and Jarvis 1988). In 1984 banding of dusky Canada geese with engraved plastic neck bands was initiated with the objectives of reliably estimating annual and within-year survival rates. The objectives of this paper include documenting past trends in dusky Canada goose population dynamics using recently developed statistical techniques, and identifying recent trends in annual survival rates. Estimates of survival and recruitment are

incorporated in a model of population dynamics to further assess their present status and to provide guidelines for future management strategies of this population.

METHODS

Survival Rates Estimated from Band Recoveries.

Recovery records of dusky Canada geese banded on the Copper River Delta, Alaska 1952-92 were obtained from the U.S. Fish and Wildlife Service Office of Migratory Bird Management (USFWS-OMBM). Survival and recovery rates were estimated for periods with sufficient band recoveries using methods and computer programs developed by Brownie et al. (1985). We used only recoveries of normal, adult and immature geese banded with a USFWS leg band, and recovered as shot or found dead between 1 September - 31 March.

Survival Rates Estimated from Observation Data.

Dusky Canada geese were captured on the Copper River Delta, Alaska during July, 1984-91. A total of 5,040 adult geese was banded with uniquely coded plastic neck bands. Low production during this period resulted in the capture of few immature geese; therefore our analysis was restricted to adult geese.

Observations of marked geese were conducted by state and federal personnel during 1 November through 31 March,

1985-92. The winter range was divided into 3 sections and 1 of 3 observers was assigned per section to routinely sample flocks of geese. Observers visited all locations in their assigned section every 1-2 weeks. Codes on neck bands were read using a high power spotting scope mounted on a vehicle or tripod.

Annual survival rates for 1986-91 were estimated for adult geese using observations of neck bands and capture-resighting estimators derived from the models of Jolly (1965) and Seber (1965) as described in Pollock et al. (1990). We defined 1-28 February as our annual sample period, and survival was estimated for each banded cohort from July banding to 1 February, and thereafter from 1 February - 31 January. Sheaffer and Jarvis (in review) estimated that during 1989-92 neck band retention rates for dusky Canada geese exceeded 95% for the first 2 years after banding. We therefore estimated survival rates for each banded cohort separately over a 3-4 year period, using the 1st annual survival rate estimate as representative of survival rates for the population that calendar year. For example, the survival rate from 1 February 1986 - 31 January 1987 was estimated from the cohort banded in July 1985.

Jolly-Seber basic statistics, calculated from resightings during sample periods, were defined as n_i , the number of individuals sighted in the i th sample; m_i , the number of marked individuals sighted in the i th sample; R_i ,

the number of marked individuals released from the i th sample; r_i , the number of marked individuals released from the i th sample which are subsequently resighted; and z_i , the number of marked individuals, not observed in the i th sample, but subsequently resighted. Resightings during 1 November - 31 January and 1-31 March were additionally used to compute r_i and z_i to increase the precision of the estimates. Survival rates were estimated using program JOLLY (Pollock et al. 1990). We used a X^2 test and program CONTRAST (Hines and Sauer 1989) to test for significant differences in survival rates between time periods and cohorts.

Model of Population Dynamics.

Estimates of survival, recruitment, and changes in harvest regulations were used to develop a model of Canada goose population dynamics. The purpose of the model is to illustrate relationships between survival rates, harvest regulations, and recruitment parameters by predicting trends in population size based on user specified conditions. The model is constructed in FORTRAN 77 and designed for interactive use allowing survival rates and recruitment parameters to be varied during any given year. Annual mortality can be partitioned within years to reflect changes in harvest regulations.

The model assumes an equal sex ratio but discriminates

between age classes. One set of age-specific survival and recruitment parameters apply throughout the population since we assumed no spatial differences in the population. The initial population size and the proportion of individuals in each age class are specified by the user. Output from the program includes annual population size, age structure of the population, monthly and total kill during the harvest season, annual harvest rate, and immature/adult ratios in the harvest (Figure I.1).

We defined annual recruitment as the number of young per breeding adult alive at the end of July (late gosling stage). Annual recruitment was calculated as $1/2$ the product of clutch size, hatching success, nest success, fledgling survival, and the percentage of each age class nesting. Breeding age classes were defined as either 2 year old geese, or geese ≥ 3 years of age. The model allows changes in any of the above parameters for both breeding age classes. The effects of stochastic environmental events on recruitment are simulated by random variations in annual nest success rates within ± 2 standard errors (SE). The user provides average estimates of nest success rate and standard errors. Constant recruitment rates can be modeled using a nest success rate SE = 0.

The user also provides average annual survival rate estimates and standard errors for young (<1 year old) and adult birds (≥ 1 year of age). The anniversary of annual

Figure I.1. Flow chart for the model of Canada goose population dynamics.

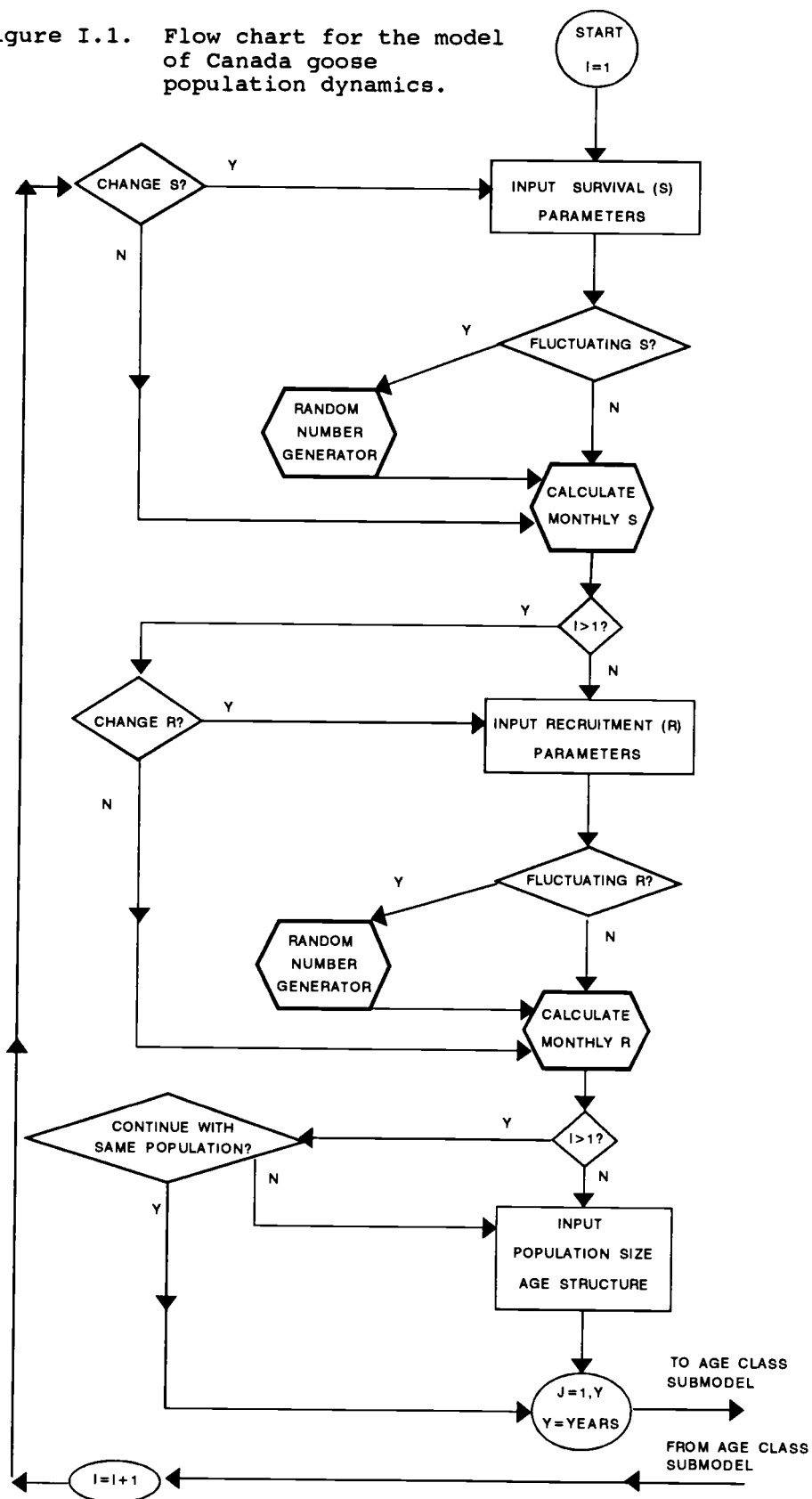
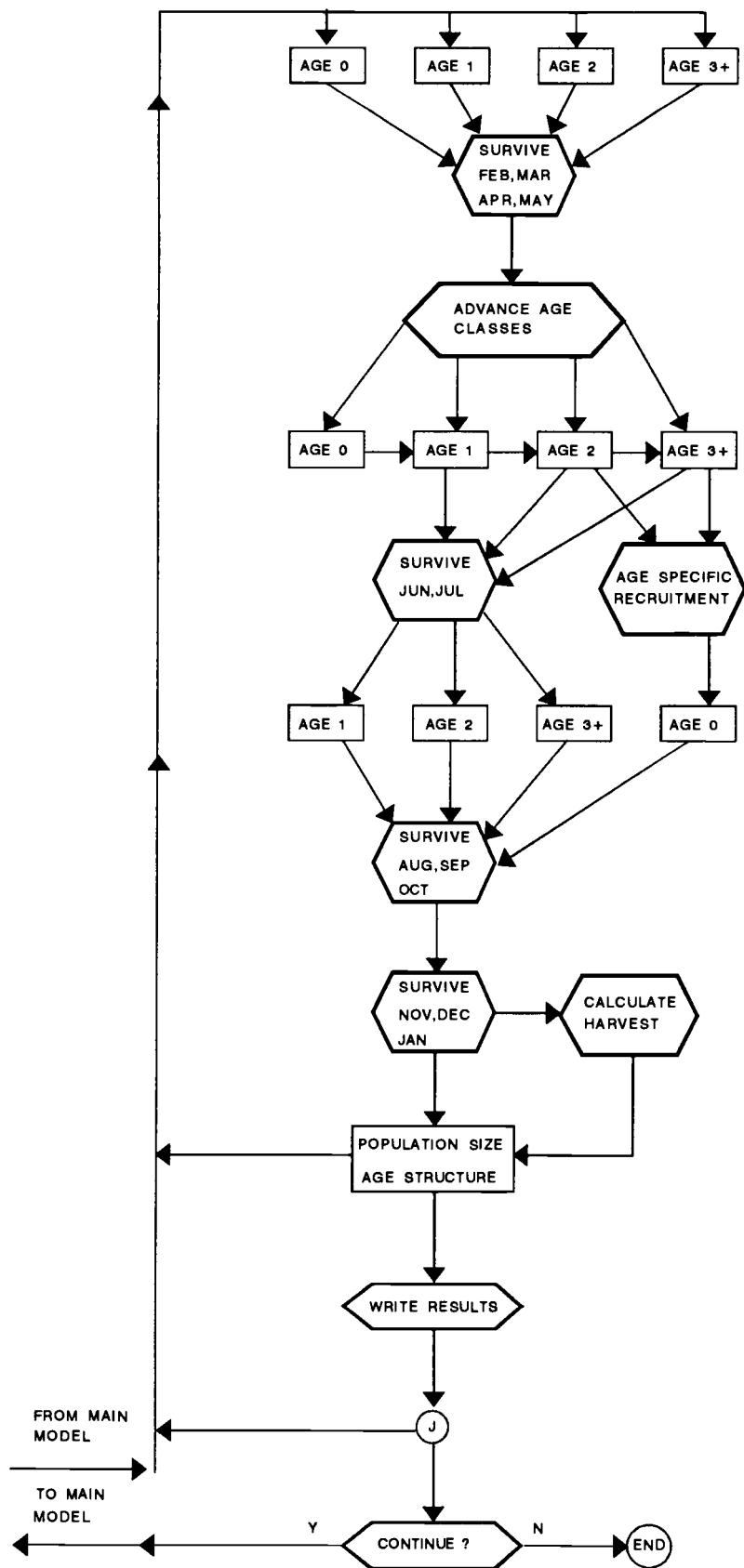


Figure I.1. (continued).



survival rates is 1 August to correspond with preseason banding efforts. Stochastic events affecting annual survival are modeled by randomly fluctuating annual survival rates within ± 2 SE. Constant annual survival rates can be modeled using a survival rate SE = 0. The model also partitions mortality into a 3 month harvest and 9 month nonharvest period, thereby allowing variable mortality rates between periods. The user provides the proportion of annual mortality that occurs during the harvest season.

Model Validation.

To validate our model, we attempted to predict past trends in USFWS-OMBM midwinter inventory estimates during 1956-90. We started with an initial population size of 11,370 that corresponded to the midwinter estimate in 1956. Chapman et al. (1969) estimated the 1952-59 fall flights contained 22-24% first year birds and 20% yearlings. Beginning age structure for this simulation was 25% immatures (<1 year old), 20% 1 year old geese, 10% 2 year old geese, and 45% ≥ 3 years of age. Trends in recruitment rates during periods of different harvest regulations were identified from the literature and recruitment parameters used to simulate midwinter population size are presented in Table I.1.

We identified 3 major categories of harvest regulations for the Willamette Valley and Lower Columbia River Basin;

Table I.1. Recruitment parameters used to simulate midwinter population size for dusky Canada geese during 1956-90.

	1956-75 High Recruitment	1976-82 Moderate recruitment	1983-90 Low recruitment
<hr/>			
Age class: ≥3 years			
<hr/>			
Clutch size	5.20 ^a	5.20 ^b	5.20 ^c
Nest success	0.90 ^d	0.60 ^e	0.35 ^c
Hatching success	0.95 ^{e,a}	0.95 ^b	0.95 ^f
Fledgling survival	0.90 ^d	0.80 ^g	0.70 ^g
% age class nesting	0.90 ^d	0.90 ^f	0.90 ^f
Recruitment per individual	1.80	1.07	0.54
 Age class: 2 years			
<hr/>			
Clutch size	5.20 ^a	5.20 ^b	5.20 ^c
Nest success	0.80 ^h	0.50 ^h	0.25 ^h
Hatching success	0.95 ^{e,a}	0.95 ^b	0.95 ^f
Fledgling survival	0.80 ^h	0.70 ^h	0.60 ^h
% age class nesting	0.60 ^d	0.70 ⁱ	0.80 ⁱ
Recruitment per individual	0.95	0.61	0.30

^aHansen 1961

^bBromley 1975

^cCampbell 1990

^dChapman et al. 1969

^eTrainer 1959

^fNo estimate during time period, assumed equal to previous period.

^gNo estimate during time period, assumed ≤ previous period value due to increasing predator densities.

^hAssumed 10% less than rate for geese ≥3 years of age.

ⁱNo estimate during time period, assumed ≥ previous periods due to decreasing nest densities.

liberal harvest during 1955-69 (3 bird bag, 90 day season), moderate harvest during 1970-82 (2 bird bag, 60-90 day season), and a restricted harvest during 1983-92 involving a quota system limiting harvest to less than 500 dusky Canada geese annually.

Average annual survival rates estimated from band recoveries were used to simulate midwinter population size. We assumed a constant rate of 0.66 adult and 0.39 immature survival during 1956-75, 0.70 adult and 0.31 immature survival during 1976-82, and 0.78 adult survival during 1983-90. Although we have no estimate of immature survival during 1983-90, we assumed an immature survival rate of 0.50.

Henny (1967) concluded over 90% of annual mortality for dusky Canada geese was due to hunter harvest. We therefore assumed 90% of annual mortality occurred in the harvest season during liberal harvest simulation (1956-69) and 70% during moderate harvest simulation (1970-82). Sheaffer and Jarvis (in review) found no significant difference in monthly survival rates of adult dusky Canada geese between harvest and nonharvest periods during 1990-92. Mortality was therefore distributed evenly throughout the year for simulation during 1983-90.

Model Simulations of Dusky Canada Goose Population Dynamics.

The sensitivity of our model to changes in survival and

recruitment parameters was examined by individually varying either adult survival, immature survival, or recruitment rates and measuring the change in population size over a 5 year period. Initial input parameters were restricted to biologically realistic values for the dusky Canada goose population. All simulations began with an initial population size of 12,000 geese and a beginning age structure of 25% immatures, 15% 1 year old geese, 10% 2 year old geese, and 50% ≥ 3 years of age. The beginning age structure corresponded to the age structure predicted by our model during simulation of midwinter estimates for the period 1983-90.

Simulations with changes in survival were run for 3 levels of recruitment (low, moderate, and high as presented in Table I.1). Standard survival was 70% for adults and 40% for immature geese, and changes in survival rates ranged from 10% to 40%. Simulations with changes in recruitment were run for 3 levels of survival. The survival rates used were low (adult = 60%, immature = 30%), moderate (adult = 70%, immature = 40%), and high (adult = 80%, immature = 50%). Standard recruitment rates were moderate and changes in recruitment ranged from 10% to 40%.

Survival and recruitment rates during the 1980's were used to examine the probability for population increase over a 10 year period given fluctuations in survival and recruitment rates. Although fluctuations in survival and

recruitment in ecological systems are often correlated and not random (Begon et al. 1990), we used random fluctuations in a large number of simulations to examine the stability of the system. Simulations were run using combinations of 2 sets of survival estimates and 3 sets of recruitment parameters. Simulations for each set were run 100 times with a beginning population size of 12,000 geese and beginning age structure of 25% immatures, 15% 1 year olds, 10% 2 year olds, and 50% ≥ 3 years of age.

One set of survival rates represented present survival (78% adult, 50% immature) and harvest regulations with mortality partitioned evenly throughout the year. The second set represented a 5% decrease in annual survival (73% adult, 45% immature) caused by additional harvest (all additional mortality was partitioned to occur during the harvest period). Survival rates were allowed to randomly vary within $\pm 10\%$ to coincide with estimated variation in survival rates from band-recovery and mark-resight data.

Two of the recruitment rates used were low and moderate recruitment as presented in Table I.1. A third recruitment rate (sub-moderate) was intermediate between low and moderate and was intended to represent conditions during 1991 and 1992. Sub-moderate recruitment had the same parameter estimates as moderate recruitment with the following exception: nest success was 40% for geese ≥ 3 years of age and 30% for geese 2 years old, and the

proportion of 2 year old geese attempting to nest was 80%. Although the average estimated nest success rate for 1983-90 was 31.5% (Campbell 1990), annual estimates ranged from 4.3% to 75.8%. Nest success rates were therefore allowed to vary within $\pm 25\%$ and $\pm 50\%$. Variations in nest success caused proportional variations in overall recruitment.

RESULTS

Survival Rates Estimated from Band Recoveries.

The band-recovery data were not sufficient to obtain reliable annual estimates of survival, but they were sufficient to estimate average annual survival for several periods. Adult and immature survival rates were estimated for 1953-60, 1965-68 and 1974-78 (Table I.2). Likelihood ratio tests indicated Model H02 (Brownie et al. 1985) best fit the data (Model H02 vs Model H1, $P \geq 0.05$) for all 3 periods. The assumptions of Model H02 are that recovery rates are year-specific and survival rates are constant over time. Bandings during 1983-90 were insufficient to estimate immature survival rates, however they were adequate to estimate adult survival (Table I.2). Likelihood ratio tests indicated Model M2 (Brownie et al. 1985) best fit the data for 1983-90 (Model M2 vs M1, $P = 0.2287$). The assumptions of Model M2 are that recovery rates are year-specific and survival rates are constant over time.

Table I.2. Average annual survival (*S*) and recovery (*R*) rate estimates for dusky Canada geese based on recoveries from leg banded geese, and significance levels (*P* values) of model goodness-of-fit. Estimates were calculated using program BROWNIE or ESTIMATE (Brownie et al. 1985). Standard errors are in parentheses.

Period	Adult		Immature		Adult		Immature		<i>P</i>
	<i>S</i>	SE(<i>S</i>)	<i>S</i>	SE(<i>S</i>)	<i>R</i>	SE(<i>R</i>)	<i>R</i>	SE(<i>R</i>)	
1953-60 ¹	0.658	(0.017)	0.386	(0.029)	0.133	(0.009)	0.175	(0.007)	0.055
1965-68 ¹	0.693	(0.045)	0.425	(0.060)	0.080	(0.008)	0.162	(0.015)	0.635
1974-78 ¹	0.695	(0.030)	0.307	(0.038)	0.068	(0.005)	0.124	(0.009)	0.525
1983-90 ²	0.772	(0.044)	---	---	0.014	(0.001)	---	---	0.129

¹ Estimates from Model H02 (Brownie et al. 1985)

² Estimates from Model M2 (Brownie et al. 1985).

Immature geese had significantly lower average survival rates ($P < 0.0001$) and significantly higher average recovery rates ($P < 0.0001$) for all periods (Table I.2). Average adult survival rates increased as we went from liberal to restricted harvest periods, however there was no significant difference between consecutive periods ($P = 0.0947$). We could detect no significant difference in immature survival rates between periods ($P = 0.1466$).

Survival Rates Estimated from Observation Data.

The neck band observation data did not fit any of the models when males and females were pooled ($P \leq 0.0010$). Inspection revealed heterogeneity in resighting probabilities among male and female geese, and we therefore estimated survival rates for males and females separately. Likelihood ratio tests indicated the data best fit Model A ($P \geq 0.0500$) suggesting that survival and resighting probabilities were time-specific (Pollock et al. 1990). The data fit the model for each cohort with the exception of the male and female cohorts banded in 1985 (Table I.3). Survival rates were not significantly different between males and females ($P = 0.3919$), and they were not significantly different among years ($P = 0.9457$).

Annual survival rates from neck band observations ranged from 73-85%, yielding an average survival rate of 78.8% (SE = 6.4%). This rate was not significantly

Table I.3. Annual survival (S) rate estimates for adult dusky Canada geese based on observations of neck banded geese, and significance levels (P values) of model goodness-of-fit. Estimates were calculated using program JOLLY, Model A (Pollock et al. 1990). Standard errors are in parentheses.

Period	Cohort	Male		Female		P	
		S	SE(S)	S	SE(S)	Male	Female
FEB 86-JAN 87	Banded 85	0.809	(0.125) ¹	0.731	(0.110) ¹	<0.001	<0.001
FEB 87-JAN 88	Banded 86	0.760	(0.088)	0.798	(0.072)	0.085	0.013
FEB 88-JAN 89	Banded 87	0.774	(0.053)	0.767	(0.079)	0.130	0.080
FEB 89-JAN 90	Banded 88	0.849	(0.047)	0.779	(0.065)	0.279	0.255
FEB 90-JAN 91	Banded 89	0.854	(0.050)	0.759	(0.056)	0.012	0.096
\bar{S}		0.809	(0.067)	0.767	(0.060)		

¹ Standard errors adjusted to account for lack-of-fit of the data to the model using a variance inflation factor method as described in Burnham et al (1987).

different from the average survival rate estimated from leg band recoveries during 1983-90 ($P = 0.8368$). Campbell and Becker (1991) estimated first year neck band loss rates to be 12.5% for adult female and to range from 15.4-24.5% for adult male dusky Canada geese. We did not correct our survival estimates for these rates of band loss because they resulted in unrealistic survival estimates ($>100\%$).

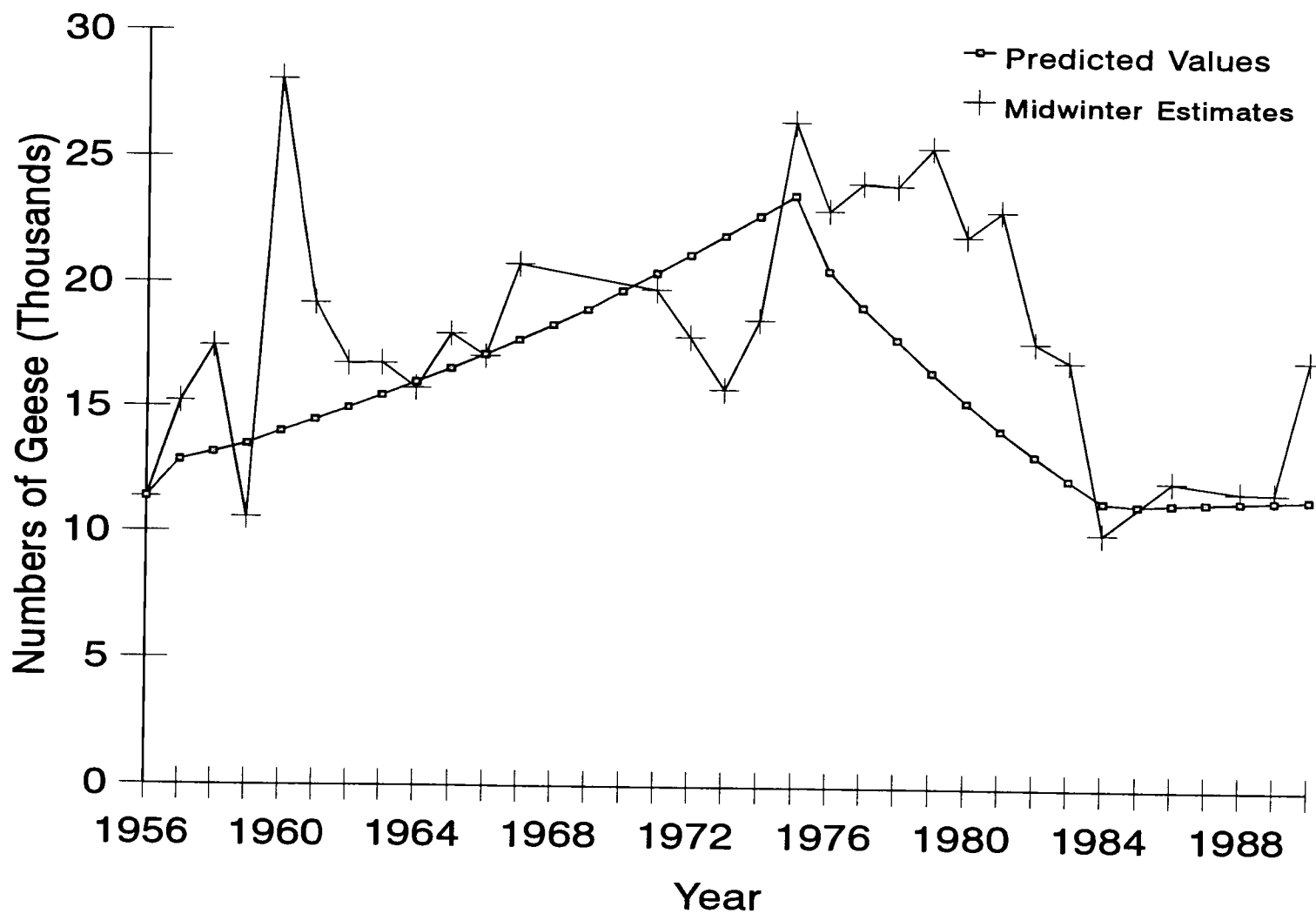
Similarity of the mark-resight and the band-recovery estimates supports our assumption that marker loss during the first year after banding was relatively small, and that survival rates from first year banded geese were representative of annual survival for the marked population.

Model Validation.

The model performed well predicting trends in midwinter estimates. Starting with an initial population size of 11,370, the model predicted that within 10 years the population would reach 17,160 geese, and after 19 years the population would reach 23,591 geese (Figure I.2). Actual midwinter estimates were 17,100 in 1966, and 26,500 in 1975. Simulated harvest rates for this period were 45% for 1956-69 and 42% for 1970-75. The simulated proportion of young in the fall flight was 49%.

During the next period (1976-82) recruitment and immature survival rates declined, while adult survival rates increased. Simulated harvest rate was 39% and the

Figure I.2. Simulated midwinter estimates of dusky Canada geese using a model of Canada goose population dynamics. Actual U.S. Fish and Wildlife midwinter estimates are shown for comparison.



proportion of young in the fall flight was 42%. The model predicted a decline from 24,697 to 11,372 geese (actual midwinter estimate 1984 = 10,100), corresponding to the trend in midwinter estimates during 1976-82.

Recruitment rates during 1983-90 were very low, while survival rates increased. Simulated harvest rate and proportion of young in the fall flight were 8% and 28%, respectively, for this period. The model predicted that over the next 8 years the population would remain relatively stable at about 11,000 geese. This corresponded to trends observed during 1984-89 when midwinter estimates fluctuated between 10,000 and 12,000 geese. Estimated final age structure was 24% immature geese, 15% 1 year olds, 12% 2 year olds, and 49% ≥ 3 years of age.

Model Simulations of Dusky Canada Goose Population Dynamics.

Model simulations were most sensitive to changes in adult survival rates (Tables I.4 and I.5). A 10% change in adult survival had approximately the same effect as a 40% change in recruitment. Changes in adult survival also had a larger effect on simulated population size than changes in survival rates of immatures. At low recruitment rates, a 10% change in adult survival had approximately the same effect as a 50% change in immature survival rates. However, the relative effect of adult and immature survival was not constant because at high recruitment rates a 10% change in

Table 1.4. Percent change in simulated population size relative to percent change in survival rates. Population size was simulated for 10 year periods and 3 levels of constant recruitment rates. Initial population size for each simulation was 12,000 individuals.

Adult Survival Rate			Immature Survival Rate			Percent change in population size		
Initial value	Altered value	% Change	Initial value	Altered value	% Change	Low ¹ recruitment	Moderate ² recruitment	High ³ recruitment
0.70	----	None	0.40	----	None	----	----	----
0.70	0.42	-40	0.40	----	None	-98	-98	-97
	0.49	-30				-95	-93	-92
	0.56	-20				-84	-82	-80
	0.63	-10				-58	-55	-53
	0.77	+10				+121	+108	+100
	0.84	+20				+361	+312	+280
	0.91	+30				+809	+674	+589
	0.98	+40				+1612	+1295	+1102
0.70	----	None	0.40	0.24	-40	-50	-63	-70
				0.28	-30	-40	-51	-58
				0.32	-20	-28	-37	-42
				0.36	-10	-15	-20	-23
				0.44	+10	+16	+23	+28
				0.48	+20	+35	+50	+61
				0.52	+30	+55	+80	+99
				0.56	+40	+77	+114	+144

¹ Low recruitment rates = 0.30 young/2 year old individual, and 0.54 young/individuals ≥ 3 years of age.

² Moderate recruitment rates = 0.61 young/2 year old individual, and 1.07 young/individuals ≥ 3 years of age.

³ High recruitment rates = 0.95 young/2 year old individual, and 1.80 young/individuals ≥ 3 years of age.

Table I.5. Percent change in simulated population size relative to percent change in recruitment rates. Population size was simulated for 10 year periods and 3 levels of constant survival rates. Initial population size for each simulation was 12,000 individuals.

Recruitment rate Geese >3 years old			Recruitment rate 2 year old geese			Percent change in population size		
Initial value	Altered value	% Change	Initial value	Altered value	% Change	Low ¹ survival	Moderate ² survival	High ³ survival
1.07	----	None	0.61	----	None	----	----	----
1.07	0.64	-40	0.61	0.37	-40	-61	-63	-64
	0.75	-30		0.43	-30	-49	-51	-52
	0.86	-20		0.49	-20	-35	-37	-38
	0.96	-10		0.55	-10	-20	-20	-21
	1.18	+10		0.67	+10	+22	+23	+24
	1.28	+20		0.73	+20	+48	+50	+52
	1.39	+30		0.79	+30	+77	+82	+85
	1.50	+40		0.85	+40	+117	+125	+131

¹ Low survival rates = 0.60 for adult and 0.30 for immature geese.

² Moderate survival rates = 0.70 for adult and 0.40 for immature geese.

³ High survival rates = 0.80 for adult and 0.50 for immature geese.

adult survival had the same effect as a 30% change in immature survival rates. Population size was relatively more sensitive to changes in adult survival as recruitment rates declined.

Results of simulations with fluctuations in survival and recruitment are presented in Table I.6. Mean estimated harvest rate was 11% when adult survival was 78% and immature survival was 50%. With high survival, the projected population increased in 100% of simulations with moderate recruitment and 73-93% of simulations with sub-moderate recruitment. However, when recruitment was low the population increased in only 15-25% of the simulations. Populations with low recruitment had higher chances of increasing with greater variation in recruitment rates. Variation allowed the possibility of concurrent years of above average recruitment. Simulations with low recruitment that yielded more than 12,000 geese resulted from more than 6 years of "above average recruitment", which effectively raised average recruitment above the value specified for the simulation.

Reducing survival rates by 5% corresponded to an average increase in harvest rates of 11-17%. Low recruitment rates resulted in 10 year population projections of less than 12,000 geese in all simulations. Reduced survival dramatically lowered the number of simulations with sub-moderate recruitment resulting in more than 12,000 geese

Table I.6. Simulated dusky Canada goose population sizes after a 10 year period. Recruitment rates for geese ≥ 3 years of age were low (0.54 young/individual), sub-moderate (0.71 young/individual), and moderate (1.06 young/individual). Recruitment rates for geese 2 years old were reduced by 30%. Simulations are based on an initial population size of 12,000 geese with beginning age structure of 25% immature geese, 15% 2 year old geese, and 60% ≥ 3 years of age.

<u>Survival Rate</u>			<u>Recruitment</u>		Mean % Young in Fall Flight	Number of simulations with final population size:		Final population size extremes		
AD	IM	Range	Rate	Range		$\geq 12,000$	$\geq 20,000$	Low	High	Average
.78	.50	$\pm 10\%$	Low	$\pm 25\%$	.28	15	0	4,941	15,584	9,656
				$\pm 50\%$	.28	25	0	5,492	18,143	10,099
			Sub-moderate	$\pm 25\%$	.33	93	33	10,043	30,175	17,628
				$\pm 50\%$	.32	73	18	6,067	32,547	15,706
			Moderate	$\pm 25\%$	.39	100	97	17,556	63,320	38,205
				$\pm 50\%$	.38	100	97	16,052	88,917	39,418
.73	.45	$\pm 10\%$	Low	$\pm 25\%$	.29	0	0	2,468	9,548	4,861
				$\pm 50\%$	.28	0	0	2,052	10,162	4,620
			Sub-moderate	$\pm 25\%$	.33	8	0	3,875	14,063	8,099
				$\pm 50\%$	.33	13	0	3,901	15,573	8,345
			Moderate	$\pm 25\%$	.40	92	36	8,585	41,370	19,149
				$\pm 50\%$	.39	82	41	6,685	59,307	18,509

(only 8-13% increased) and reduced the number of simulations with moderate recruitment that increased by 8-18%.

DISCUSSION

Historically the dusky Canada goose population has had low survival and high recruitment rates. If we compare trends in harvest regulations with our estimates of survival rates, a pattern emerges of increasing adult survival rates with increasing restrictions in harvest. We do not have information on immature survival during the 1980's. Based on estimates of recruitment, adult survival, and midwinter population size, our model indicates that immature survival rates have also increased. However, survival rates were not high enough to offset low recruitment rates during the late 1970's and early 1980's.

Midwinter estimates since 1989 have not indicated further declines, and recent increases in nest success and overall recruitment rates (Campbell 1992) are encouraging. Model simulations indicate that the chance for population increase is favorable if recruitment and survival rates remain at or above present levels. We should not, however, expect to see dramatic increases in the dusky Canada goose population even though adult survival rates are very high. We suggest that even with complete elimination of harvest, we will not see the dramatic increases in population size that characterized the 1960's and 1970's if recruitment

rates remain low.

Our model indicates that changes in survival rates have a larger effect on population size than relative changes in recruitment. This is comparable to other avian species with similar life history trends such as delayed sexual maturity, extended parental care, long reproductive spans, and high survival rates. Sensitivity to changes in survival rates has also been demonstrated for Atlantic Flyway Canada geese (Trost et al. 1986), bald eagles (*Haliaeetus leucocephalus*) (Grier 1980), and California condors (*Gymnogyps californianus*) (Snyder and Snyder 1989).

Our model also demonstrates that Canada goose populations are less sensitive to changes in adult survival when recruitment rates are high. Simulations with sustained low recruitment resulted in populations composed of 75% adult individuals, while sustained high recruitment produced populations containing up to 48% immature geese. Small changes in adult survival will have a greater effect on population size when the ratio of immature to adult geese in the population declines.

The dusky Canada goose population will be sensitive to small reductions in adult survival rates as long as recruitment rates are low. Survival rates of adult geese have increased during recent periods with restrictions in harvest. However, present recruitment rates suggest that any decrease in survival rates will promote further declines

in population size. Without significant increases in recruitment, survival rates must remain at or above present levels for the population to maintain itself.

The model we developed provides opportunity to examine the dynamics of Canada goose populations. Based on estimates of survival and recruitment, the model can be used to examine relative changes in population size, population age structures, harvest rates, and immature to adult harvest ratios. Differential partitioning of annual mortality allows asking "what if" questions about changes in within year survival rates and possible effects of changes in harvest regulations. Stochastic components of the model allow for assessment of probable outcomes given various ranges of parameters.

CHAPTER II

SIMULTANEOUS ESTIMATES OF SURVIVAL AND MARKER RETENTION
RATES USING OBSERVATIONS OF DOUBLE MARKED DUSKY CANADA GEESE

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INTRODUCTION

The use of plastic neck bands to identify individual Canada geese was initially developed as a method to study their behavior (MacInnes and Lief 1968) and movements (Koerner et al. 1974, Raveling 1978, Trost et al. 1980, Craven and Rusch 1983). Development of capture-recapture-resighting models for open populations allowed the use of reobservations of neck banded geese to estimate survival (Pollock et al. 1980, Hestbeck and Malecki 1989a). One advantage of using observation data to estimate survival is that neck bands allow multiple observations of individual geese as opposed to a single recovery of a leg band. However, one problem with neck bands is an increased rate of marker loss (Zicus and Pace 1986, Samuel et al. 1990).

Arnason and Mills (1981) demonstrated that marker loss results in a loss of precision and underestimation of

survival rates. Previous neck band studies have estimated neck band retention rates from recapture data at annual banding occasions and from hunter recoveries of previously neck banded geese (Fjetland 1973, Craven 1979, Zicus and Pace 1986, Hestbeck and Malecki 1989a). Neck band retention was estimated as a simple proportion at specific time intervals. Problems with these methods have included small sample sizes that limited information on causes of variation in retention rates, and large time intervals between samples that can produce biased estimates (Samuel et al. 1990).

An additional problem with recapture data is the timing of recapture periods. Recaptures of Canada geese usually occur during summer banding periods, while reobservations often occur during winter. Annual estimates of band retention therefore do not correspond to the time periods of survival rate estimates. Observation data allows partitioning of survival rates within years. The models of Nichols et al. (1992) allow use of recapture and resighting data that do not correspond to identical time periods. However, annual estimates of band retention cannot be adjusted to within-year survival rate estimates unless a constant rate of neck band loss within a year is assumed.

Double marking of geese with plastic neck and tarsal bands is one method to simultaneously census geese for survival and neck band retention. Just as neck bands allow multiple observations of individuals for estimation of

survival, double banding of geese allows multiple census occasions of individuals for band retention. Unbiased estimates of neck band retention can be calculated over variable time intervals that coincide with survival rate estimates, thereby reducing assumptions of constant rates of neck band loss within a year.

Within-year survival rates are an important management concern for the dusky Canada goose (*Branta canadensis occidentalis* Baird) population. The population dramatically declined from an estimated 25,500 birds in 1979 to 12,200 birds in 1986. The reasons for this decline are not clear, although high susceptibility to harvest (Simpson and Jarvis 1979) and depressed recruitment rates (Campbell 1978) are thought to be primarily responsible. Estimates of within-year survival rates are needed to identify periods within the annual cycle critical to dusky Canada goose survival. Our objectives are to estimate neck band retention rates from observations of double marked geese, and to develop a model to simultaneously estimate band retention rates and within-year survival rates from observations of neck banded dusky Canada geese.

METHODS

Observations of Double Marked Geese

Adult dusky Canada geese were banded on the breeding grounds in Alaska during July, 1990 and 1991. Low

production restricted the opportunity to mark immature geese, and we therefore limited our analysis to adults. Adult geese were banded with a red plastic neck band engraved with a white, 3 digit alpha numeric code. Each goose was also banded with a white plastic tarsal band engraved with a black, 3 digit code that matched the code on the neck band. Tarsal bands were made of the same material as the neck bands and were placed on the right leg. A standard U.S. Fish and Wildlife Service aluminum leg band was placed on the left.

Observations of marked geese were conducted 5 days a week in Oregon and Washington during 1-31 November and 1-31 March 1990-91 and 1991-92. We defined neck bands as the primary band used to estimate survival rates, and tarsal bands as the secondary band used to estimate retention rates of the primary band. Codes on both tarsal and neck bands were read using high power spotting scopes. All censusing was done by observation, and censusing for band retention rates was conducted independently of censusing for survival rates. Three observers routinely sampled flocks of geese by examining necks for neck bands. Neck band observers identified geese by their neck band codes and recorded presence or absence of a tarsal band. An additional observer sampled flocks of geese by examining legs for tarsal bands. The tarsal band observer identified geese by reading tarsal band codes and recorded presence or absence of a neck

band.

Estimation of Band Retention Rates

Neck band retention rates were estimated using a single estimation model that included both neck band retention and tarsal resighting probabilities. We defined the tarsal band resighting probability as the probability that a goose was identified by a tarsal band during a specified sampling period. Time-specific resighting probabilities and neck band retention rates were modeled using program SURVIV (White 1983).

Previous studies of neck band retention on waterfowl suggest that band loss is a function of time since banding and not of calendar time (Hestbeck and Malecki 1989, Samuel et al. 1990, Nichols et al. 1992). Therefore, the probability of retaining a neck band was modeled as a function of time after banding. The probability of censusing a bird for band loss was modeled as a function of calendar time. Reobservation data of double banded geese were modeled as in the standard capture-recapture-resighting model of Pollock (1981). This was analagous to modeling a survival rate for neck bands conditional on survival of the individual.

The expected number of individuals retaining a neck band at time j (M_{ij}) was modeled as

$$E(M_{ij}) = N_{ij} \prod_{k=1}^{j-i} R_k$$

where N_{ij} denotes the number of individuals in a particular cohort banded at time i and alive at time j , M_{ij} denotes the number of N_{ij} individuals retaining a neck band at time j . The statistic R_k denotes the probability of an individual retaining a neck band during the k th time period after banding, given that the individual retained a neck band $k-1$ time periods after banding. If C_j is the probability that a tarsal banded individual is censused (observed) for neck band retention at calendar time j , then the expected number of double banded individuals alive at time j that have retained a neck band and are observed during j ($(M_{ij})_{obs}$) is

$$E(M_{ij})_{obs} = N_{ij} \left(\prod_{k=1}^{j-i} R_k \right) C_j .$$

A standard capture history matrix is represented by a series of 0's and 1's where 1 denotes captured or sighted and 0 denotes not captured or sighted. Representation of data for tarsal banded individuals censused for neck band retention incorporated 3 symbols where 1 denoted captured (observed) with retention of a neck band, 2 denoted captured (observed) with loss of a neck band, and 0 denoted not captured (observed). Cohorts were defined by the time of banding and were conditional on the last time period of reobservation (Table II.1). For example, individuals banded

Table II.1. Expected number of resightings of geese double marked with tarsal and neck bands under a general model.

Number of geese with specified sighting history ^a	Expected number of sightings ^b
X_{111}	$N_{ij} R_1 C_{i+1} R_2$
X_{112}	$N_{ij} R_1 C_{i+1} (1-R_2)$
X_{122}	$N_{ij} (1-R_1) (1-C_{i+1})$
X_{101}	$N_{ij} R_1 C_{i+1} R_2$
X_{102}	$N_{ij} (1-R_1 R_2) C_{i+1}$
X_{011}	$N_{i+1,j} R_1 C_{i+2}$
X_{012}	$N_{i+1,j} (1-R_1) C_{i+2}$

^aProbability statements are conditional on N_i and N_{i+1} number of geese surviving until time j where $j = i+2$.
 $X_{i,i+1,i+2}$ = the number of tarsal banded geese with observation history specified by the subscripts where 1 denotes sighting and retaining a neck band, 2 denotes sighting with a loss of neck band, and 0 denotes not seen.

^b N_{ij} = the number of geese banded and released during time i , known to be alive (last reobserved) in time j .
 R_k = the probability of a goose with a neck band at the beginning of the k th time period after banding, retaining its neck band during the k th time period after banding.
 C_i = the probability of sighting a tarsal banded goose during time i , given that it is alive at time i .

in time period 1 and last observed in time period 3 had the following probable capture histories: 111, 112, 122, 101, and 102. Information from this cohort can be used to estimate the probability of retaining a band 1 and 2 time periods after banding, and the probability of being censused during time period 2. By definition, the probability of being censused during the last observation period for a given cohort is 1.

Estimation of Survival Rates

Our model was expanded to include probability statements for independent observations of neck bands to estimate survival rates corrected for neck band loss. The probability of survival during a specific time period was modeled as a function of calendar time, unlike the probability of neck band retention which was dependent on time since banding. Reobservation data of neck bands were modeled as in the standard capture-recapture-resighting model of Pollock(1981) except we included not only parameters for survival and resighting probability, but also for probability of neck band retention (Table II.2). The probability of resighting a neck band was modeled as a separate parameter from the probability of resighting a tarsal band. The probability that an individual banded during calendar year i would be seen in the observation period $i+1$ and $i+2$ was modeled as $S_i R_1 P_{i+1} S_{i+1} R_2 P_{i+2}$, where S_i is

Table II.2. Expected number of resightings of neck bands under a general model that includes neck band retention parameters.

Number of geese with specified sighting history _a	Expected number of sightings _b
X_{111}	$N_i S_i R_1 P_{i+1} S_{i+1} R_2 P_{i+2}$
X_{110}	$N_i S_i R_1 P_{i+1} (1 - S_{i+1} R_2 + S_{i+1} R_2 (1 - P_{i+2}))$
X_{101}	$N_i S_i R_1 (1 - P_{i+1}) S_{i+1} R_2 P_{i+2}$
X_{100}	$N_i (1 - S_i R_1 + S_i R_1 (1 - P_{i+1}) (1 - S_{i+1} R_2 + S_{i+1} R_2 (1 - P_{i+2})))$
X_{011}	$N_{i+1} S_{i+1} R_1 P_{i+2}$
X_{010}	$N_{i+1} (1 - S_{i+1} R_1 + S_{i+1} R_1 (1 - P_{i+2}))$

^a $X_{i,j+1,j+1}$ = the number of neck banded geese with observation history specified by the subscripts where 1 denotes sighting and 0 denotes not seen.

^b N_i = the number banded and released during time i .

S_i = the probability of surviving from time i to $i+1$.

R_k = the probability of a goose with a neck band at the beginning of the k th time period after banding, retaining its neck band during the k th time period after banding.

P_i = the probability of sighting a neck banded goose during time i , given that it is alive at time i .

the probability of an individual surviving from time i to $i+1$, and P_i is the probability of observing an individual during time i . Note that the subscripts of survival and observation probability correspond to calendar year and the neck band retention subscripts denote the number of time periods since banding.

Observations of tarsal and neck bands were independent, but the probability statements for both data sets included neck band retention parameters. We were therefore able to separate band retention and survival parameters by modeling 2 multinomial distributions using program SURVIV. Data from the tarsal band observer were used to model neck band retention rates, and data from neck band observers were used to model survival rates.

Survival rates and band retention rates were modeled over 3 time periods: 22 July to 14 November (post-banding), 15 November to 14 February (harvest period), 15 February to 14 November (nonharvest period). Monthly survival rates were calculated for comparison between intervals as $S_{month} = S_i^{(1/t)}$ where t =the number of months per interval, with variance estimate $\text{var}(S_{month}) = \text{var}(S_i) / ((t)^2 (S_i))$. We used program CONTRAST (Hines and Sauer 1989) to test for significant differences in survival rates and resighting probabilities between time periods and cohorts.

The full model to estimate survival rates from neck band observations had 4 parameter classes; neck band

retention rates (R_n), tarsal band resighting probabilities (C_i), survival rates (S), and neck band resighting probabilities (P_n) (Tables II.1 and II.2). The general model had separate C_i , S and P_n for each time period and sex, and separate R_n for each time period. We then examined a number of reduced parameter models to test hypotheses about sex- and time-specific variation in all parameters. Our reduced parameter models were not all nested within each other, and we therefore used Akaike's Information Criteria (AIC) as described by Burnham and Anderson (1993) along with χ^2 goodness-of-fit tests to select the most parsimonious model.

Neck band observers also recorded presence or absence of tarsal bands, and we were able to switch the data sets and use neck band observations to model tarsal band retention rates, and tarsal band observations to model survival rates. The full model included tarsal band retention rates (R_i), neck band resighting probabilities (C_n), survival rates (S), and tarsal band resighting probabilities (P_i). When using neck band observations to estimate tarsal band retention rates, the probability of resighting a neck band was conditional on being able to examine the legs for presence or absence of a tarsal band. We again examined a variety of reduced parameter models.

RESULTS

Dusky Canada geese banded with tarsal and neck bands totaled 271 males and 214 females in 1990, and 295 males and 210 females in 1991. No tarsal banded geese were observed without a neck band during the first year after banding. Recapture data during the second banding period supported the observation data since no tarsal banded geese were recaptured without a neck band. Only 2 males and 1 female lost a neck band during the second year after banding; all were initially observed without a neck band during November or December of 1991.

The full model was too general for our data and all parameters were not identifiable. When we used neck band observations to estimate survival and tarsal band observations to estimate neck band retention, the data did not fit any of the reduced parameter models for males or females. Neck band retention was virtually 1.0 for 3 of the 4 periods, and estimating parameters at the upper boundry of 1.0 affected the fit of the data to the model. If neck band retention parameters were constrained to equal 1.0 for period 1, 2, and 4, the data fit a number of the reduced parameter models (χ^2 , $P \geq 0.05$). AIC indicated the most parsimonious model that corrected for band loss was the model with time-specific survival rates, tarsal band resighting probabilities, and neck band retention rates, and sex- and time-specific neck band resighting probabilities

Table II.3. Within year survival rates for dusky Canada geese estimated from observations of neck bands. Neck band retention rates were estimated using observations of geese double banded with tarsal and neck bands. Standard errors are in parentheses. The data did not fit the model (X^2 , $P = 0.0092$).

<u>Interval</u>	<u>Neck Band Retention</u>		
BAND-NOV	1.0000 (0.0327)		
NOV 90-FEB 91	1.0000 (0.0296)		
FEB 91-NOV 91	0.9783 (0.0188)		
NOV 91-FEB 92	1.0000 (0.0248)		
	<u>Tarsal Band Resighting Probability</u>		
NOV 1990	0.4192 (0.0327)		
FEB 1991	0.5507 (0.0427)		
NOV 1991	0.2648 (0.0299)		
	<u>Interval Survival Rate</u>	<u>Monthly Survival Rate</u>	
JUL 90-NOV 90	0.8002 (0.0342)	0.9458 (0.0096)	
JUL 91-NOV 91	0.8667 (0.0392)	0.9649 (0.0105)	
NOV 90-FEB 91	0.9297 (0.0398)	0.9760 (0.0138)	
FEB 91-NOV 91	0.8128 (0.0422)	0.9772 (0.0052)	
NOV 91-FEB 92	0.9009 (0.0524)	0.9658 (0.0184)	
	<u>Neck Band Resighting Probability</u>		
	<u>Adult Female</u>	<u>Adult Male</u>	
NOV 1990	0.6251 (0.0396)	0.6921 (0.0335)	
FEB 1991	0.6793 (0.0347)	0.7550 (0.0324)	
NOV 1991	0.5095 (0.0329)	0.5622 (0.0285)	
FEB 1992	0.6793 (0.0347)	0.7550 (0.0324)	

(Appendix II). Estimates from this model with unconstrained retention parameters are presented in Table II.3.

Our results indicated almost no neck band loss, and the most parsimonious model for our data was a reduced one that estimated survival rates from neck band observations without correction for band loss. The data fit a number of the reduced parameter models (X^2 , $P \geq 0.01$), and AIC again indicated the most parsimonious model was one with time-specific survival rates and band retention rates, and sex- and time-specific neck band resighting probabilities (Appendix II). Estimates from the model without correction for band loss rates are presented in Table II.4 for comparison. Monthly survival rates were not significantly different during harvest and nonharvest periods (X^2 , $P = 0.3882$). Neck band resighting probabilities were significantly lower for females than for males (X^2 , $P = 0.0116$). Neck band resighting probabilities were also significantly lower during the November observation period than during February for both males (X^2 , $P = 0.0010$) and females (X^2 , $P = 0.0072$).

The full model was also too general when using tarsal band observations to estimate survival rates and neck band observations to estimate tarsal band retention rates. The data did fit a number of the reduced parameter models (X^2 , $P \geq 0.05$). AIC indicated the most parsimonious model was one with time-specific survival rates, tarsal band retention

Table II.4. Survival rate estimates and neck band resighting probabilities estimated from observation data under a model without correction for neck band retention rates. Standard errors are in parentheses. The data fit the model (X^2 , $P = 0.0500$).

<u>Interval</u>	<u>Interval Survival Rate</u>	<u>Monthly Survival Rate</u>
JUL 90-NOV 90	0.8002 (0.0221)	0.9458 (0.0062)
JUL 91-NOV 91	0.8667 (0.0287)	0.9649 (0.0077)
NOV 90-FEB 91	0.9297 (0.0287)	0.9760 (0.0098)
FEB 91-NOV 91	0.7951 (0.0378)	0.9748 (0.0047)
NOV 91-FEB 92	0.9009 (0.0486)	0.9658 (0.0171)
<u>Neck Band Resighting Probability</u>		
	<u>Adult Female</u>	<u>Adult Male</u>
NOV 1990	0.6251 (0.0396)	0.6921 (0.0335)
FEB 1991	0.6793 (0.0346)	0.7550 (0.0324)
NOV 1991	0.5095 (0.0329)	0.5622 (0.0285)
FEB 1992	0.6793 (0.0346)	0.7550 (0.0324)

rates, tarsal band resighting probabilities within November and within February, and sex- and time-specific tarsal band resighting probabilities. The data fit the model (X^2 , $P = 0.1147$), and estimates from this model are presented in Table II.5. Tarsal band resighting probabilities were significantly lower for female than for male geese (X^2 , $P = 0.0110$) and were significantly lower during November than during February for both males (X^2 , $P = 0.0001$) and females (X^2 , $P = 0.0002$). Tarsal band resighting probabilities (Table II.5) were significantly lower than neck band resighting probabilities (Table II.4) for both males and females (X^2 , $P < 0.0001$). Differences in survival rates estimated from tarsal bands and from neck bands were not significant (X^2 , $P = 0.1698$).

DISCUSSION

The single estimation model that included band loss and survival rates was overparameterized for our neck band data. Double banded geese experienced virtually no neck band loss during the 2 years of the study, and estimation of band retention rates was therefore inefficient. The model fit the data only when we constrained neck band retention rates to equal 1.0. Rates of tarsal band loss were higher than rates of neck band loss, and the model fit the data when we estimated tarsal band retention using neck band observations. Use of a single estimation model that

Table II.5. Within year survival rates for dusky Canada geese estimated from observations of tarsal bands. Tarsal band retention rates were estimated using observations of geese double banded with tarsal and neck bands. Standard errors are in parentheses. The data fit the model (χ^2 , $P = 0.1147$).

<u>Interval</u>	<u>Tarsal Band Retention</u>	
	<u>Interval</u>	<u>Monthly</u>
BAND - NOV	0.9963 (0.0037)	0.9991 (0.0009)
NOV 90-FEB 91	0.9858 (0.0074)	0.9952 (0.0025)
FEB 91-NOV 91	0.9399 (0.0246)	0.9931 (0.0028)
NOV 91-FEB 92	0.9528 (0.0346)	0.9840 (0.0118)
<u>Neck Band Resighting Probability*</u>		
NOV 1990	0.4244 (0.0320)	
FEB 1991	0.5405 (0.0497)	
NOV 1991	0.2588 (0.0290)	
	<u>Survival Rate</u>	
	<u>Interval</u>	<u>Monthly</u>
JUL 90-NOV 90	0.7126 (0.0401)	0.9188 (0.0119)
JUL 91-NOV 91	0.8322 (0.0589)	0.9551 (0.0161)
NOV 90-FEB 91	0.9060 (0.0695)	0.9676 (0.0243)
FEB 91-NOV 91	0.8714 (0.0890)	0.9848 (0.0106)
NOV 91-FEB 92	0.8156 (0.0702)	0.9343 (0.0259)
	<u>Tarsal Band Resighting Probability</u>	
	<u>Adult Female</u>	<u>Adult Male</u>
NOV 1990	0.2990 (0.0273)	0.3703 (0.0273)
FEB 1991	0.4991 (0.0479)	0.5818 (0.0403)
NOV 1991	0.2990 (0.0273)	0.3703 (0.0273)
FEB 1992	0.4991 (0.0479)	0.5818 (0.0403)

*Defined as the probability that a neck band was resighted and the legs were visible for examination for presence or absence of tarsal bands.

includes parameters for marker loss and survival rates is efficient only if there is marker loss. We believe that resightings of double marked geese successfully monitored neck band loss for the dusky Canada goose. Observations indicated there was no neck band loss during the first year after banding for both years of the study, and recapture data during 1991 supported these results for the first year.

Resighting probabilities for tarsal bands were significantly lower than for neck bands. Although there was less observation effort for tarsal bands, the lower resighting probability of tarsal bands was partially due to the increased difficulty of reading the smaller tarsal bands, and difficulty observing legs as opposed to necks. Habitat was also a factor as tarsal bands were visible only in areas with short ground cover. The relatively large size of the dusky Canada goose, along with the short grass cover on much of the winter range, provided sufficient opportunities to read tarsal bands. Resighting probabilities would probably decrease in areas with tall ground cover or for smaller birds.

Both neck and tarsal band resighting probabilities were lower for female geese. Model selection procedures and goodness-of-fit tests strongly selected models with sex-specific resighting probabilities and same-sex survival rates, as opposed to sex-specific survival rates and same-sex resighting probabilities. Heterogeneous resighting

probabilities could be due to the smaller size of female geese. Tarsal bands were harder to read in taller ground cover, hence they were also harder to read on smaller geese. Difficulties reading neck bands in relation to size were not as obvious. Behavioral differences between males and females could also affect resighting probabilities. We suggest that male geese are more aggressive and spend more time alert and moving about, increasing the chance that an observer would identify their band.

One assumption of our model is that the probability of sighting a tarsal band is independent of the presence of a neck band. If tarsal bands are more frequently seen when the goose has a neck band, then estimated neck band retention rates will be biased high. The lower resighting probability for tarsal bands means that fewer geese will be identified by tarsal bands than by neck bands. The tarsal band observer was instructed to examine legs of geese and ignore neck bands to reduce this bias. Although it was difficult to ignore presence of a neck band, we believe this can be done with a minimum bias. Observers censusing for neck band retention must identify a goose by the code on the tarsal band, not by the neck band. If geese are identified by the neck band code, then geese without neck bands will be identified less often than those with neck bands and retention estimates will be biased.

Another assumption is that tarsal band loss is

independent of neck band loss. Estimates of neck band loss will be biased if tarsal band loss is correlated with neck band loss. Recapture data could be used to test for differences in neck band retention rates for birds banded with and without tarsal bands. We had no way to test this since all geese banded with a neck band during 1990 and 1991 were also given a tarsal band. However, we have no indication that this was not a valid assumption. We did not recapture any double banded geese that lost both a tarsal and neck band.

Ideally there should be no tarsal band loss. High rates of tarsal band loss will reduce the number of double banded individuals and decrease the precision of estimates of neck band loss. Rees et al (1990) estimated that annual loss rates of plastic tarsal bands on Barnacle Geese averaged only 0.35% during 1973-86, but ranged from 5.8% to 27.6% for different groups of swans. Differential rates of tarsal band loss were related to the diameter of the band and the size and strength of the bird. Our study was relatively short and rates of tarsal band loss on dusky Canada geese were minimal. Tarsal band loss rates could be significant for long term studies or for larger birds.

Previous studies concluded that hunting mortality was the primary limiting factor for the dusky Canada goose population (Hansen 1962, Chapman et al. 1969, Bromley 1976). Hunter harvest was not the primary source of mortality of

dusky Canada geese during 1990-92. Fewer geese survived nonharvest periods because of the longer time interval. However, there was no significant difference in monthly survival rates during harvest and nonharvest periods.

Survival rate estimates using tarsal band observations, although not significantly different from estimates using neck bands, were low with large standard errors. This was not unexpected as the sampling effort was designed to collect more observations of neck bands than of tarsal bands. Low resighting probabilities produced poor survival rate estimates from tarsal bands. The lower resighting probabilities of tarsal bands must be considered when allocating sampling effort in future observation studies. However, if tarsal band resighting probabilities are higher than recapture probabilities, more precise estimates of marker retention can be obtained from resighting data than from recapture data. Observations can be partitioned so that the major effort is reading primary bands, and a reduced effort can be used to estimate primary band retention rates from observations of secondary bands.

Nichols et al. (1992) suggested that information from a double marking study is essential for estimation of survival rates when there are marker losses. Recapture data is the only feasible method to estimate marker loss for many species. A single estimation model that includes recapture and resighting data, such as those of Kremers (1987) and

Nichols et al. (1992), can be efficiently used if there are sufficient numbers of recaptures. Our model can also be used with recapture data by defining the resighting probability as the probability of recapture.

We believe that for Canada geese, resighting data of double marked individuals can provide a more efficient method to monitor tag loss rates. Multiple observations of double marked individuals will provide increased information that can be used to identify causes of variation in marker retention rates. Simultaneous observations to estimate rates of survival and marker loss will estimate tag loss rates over periods that coincide with survival rate estimates. This will allow unbiased estimation of survival rates adjusted for marker loss rates over variable time periods.

CHAPTER III

ESTIMATES OF DUSKY CANADA GOOSE POPULATION SIZE FROM
OBSERVATIONS OF MARKED INDIVIDUALS

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INTRODUCTION

The Jolly-Seber model (Jolly 1965, Seber 1965, 1982) is commonly used to estimate survival rates and total numbers of animals from capture-recapture data. Although the basic open population model was originally defined for capture-recapture data, the same statistics can be used to estimate survival rates from capture-resighting data where individuals are marked and later resighted but not recaptured. Capture-resighting and capture-recapture studies differ because only marked individuals can be "captured" during a resighting period, while both marked and unmarked individuals can be captured during a recapture period. Estimation of population size from capture-resighting data therefore requires additional statistics.

Estimation of population size (N) from capture-resighting data requires 2 components: estimation of the total number of marked individuals (M), and estimation of the proportion of marked individuals in the population.

Program JOLLY (Pollock et al. 1990) is one of the comprehensive computer programs that can be used to estimate M . If capture-resighting data is designed with 1 initial marking period and subsequent periods where only individuals marked in the initial sample period are resighted, then \hat{M}_i estimated using JOLLY is an unbiased estimate of M at time i . This was the approach Hestbeck and Malecki (1989b) used to estimate population size of Atlantic Flyway Canada geese (*Branta canadensis*) from resightings of neck banded birds that were banded or sighted during an initial sample period.

The data used by Hestbeck and Malecki (1989b) differed from many neck band studies of Canada geese because bandings and observations occurred simultaneously. Many neck band projects do not have concurrent banding and observation periods. Recaptures of neck banded geese are usually few, and estimated probabilities of capture during a banding period are significantly different for unmarked and marked geese. If multiple observation and banding periods are interspersed in a capture-resighting design, extreme heterogeneity of capture probabilities among banded cohorts usually results in lack-of-fit of the data to the model. It is often advantageous to disregard banding data and use only observations of previously marked individuals in the analysis.

When using only observation data, the first sighting of a marked individual is interpreted in a capture history as

the initial time of marking. Estimation of N becomes confounded because capture history data include information on initial and recurrent sightings of marked individuals, but no information on unmarked individuals. Program JOLLY can be used to estimate M ; however the statistics must be redefined for resighting data.

Our objectives are to identify the statistics needed to estimate population size using only resightings of previously marked individuals, and to estimate the midwinter population size of dusky Canada geese (*B. c. occidentalis* Baird) during 1989-92 from observations of neck banded geese.

METHODS

Estimation of the Number of Marked Individuals.

The basic Jolly-Seber model as described by Pollock et al. (1990) estimates population size using information from individual capture histories. Capture history information is usually represented by series of zero's and one's that represent not captured or captured, respectively, in a particular sample. The first one in an individual capture history represents the period an unmarked individual was initially captured and marked. Sample statistics calculated include m_i , u_i , and n_i , defined as the number of marked, unmarked, and total number of individuals captured in the i th sample period, respectively. The estimator of M_i , the

number of marked individuals in the population at the time of the i th sample, is given by:

$$\hat{M}_i = m_i + \frac{(R_i + 1) z_i}{r_i + 1},$$

where R_i is the number of n_i released after the i th sample, r_i is the number of R_i that are captured again, and z_i is the number of individuals capture before i , not in i , and capture again later. The estimator for N_i , the total number of individuals in the population at time i , is given by:

$$\hat{N}_i = \frac{(n_i + 1) \hat{M}_i}{(m_i + 1)}$$

Resighting information can also be represented by series of zero's and one's that represent not sighted and sighted, respectively. We ignored banding periods and calculated resighting histories for each marked individual sighted. The first one in a resighting history represented the initial sighting of a previously marked individual. The initial sighting of a marked individual was therefore analogous to the initial capture of an unmarked individual.

We defined n'_i as the total number of marked individuals sighted in the i th sample, u'_i as the number of marked individuals sighted for the first time, and m'_i as the number of marked individuals in the i th sample that had been sighted in a previous sample. Because there are no losses on resighting, n'_i was equal to the number "released"

(number sighted) from the i th sample. The statistic \hat{M}'_i is given by:

$$\hat{M}'_i = m'_i + \frac{(n'_i + 1) z'_i}{r'_i + 1} ,$$

where r'_i is the number of n'_i individuals sighted after time i , and z'_i is the number of individuals sighted previous to i , not seen in i , but sighted again later. The statistic \hat{M}'_i estimates the number of marked individuals, that were sighted in at least 1 sample previous to i , alive in the population at time i .

The total number of marked individuals in the population, M_i , was estimated by \hat{N}'_i . The statistic \hat{N}'_i was given by:

$$\hat{N}'_i = \frac{(n'_i + 1) \hat{M}'_i}{(m'_i + 1)} .$$

Asymptotic variances of \hat{M}'_i and \hat{N}'_i were estimated as in Pollock et al. (1990) by substituting n'_i for n_i and R_i , and substituting m'_i , r'_i , \hat{M}'_i , and \hat{N}'_i for m_i , r_i , \hat{M}_i , and \hat{N}_i , respectively. The estimators \hat{M}'_i and \hat{N}'_i and their respective variances were calculated from resighting histories using program JOLLY and were represented in the output as M_i and N_i , respectively.

Estimation of Total Population Size Using \hat{N}'_i .

Estimation of the total population size required calculation of an additional statistic we defined as \hat{A}_i , the estimated ratio of the total number of individuals sighted (marked and unmarked) to the number of marked individuals sighted in the i th sample. We calculated \hat{A}_i (Snedecor and Cochran 1980:455) as:

$$\hat{A}_i = \sum_{j=1}^{f_i} \frac{g_{ij}}{n'_{ij}}$$

where g_{ij} is the number of individuals examined in the j th group in the i th sample, n'_{ij} is the number of marked individuals sighted in the j th group during the i th sample, and f_i is the number of groups observed during the i th sample. The number n'_{ij} included all marked individuals sighted in a given flock regardless of their previous sighting history. The estimated variance of \hat{A}_i was calculated (Snedecor and Cochran 1980:455) as:

$$V(\hat{A}_i) = \sum_{j=1}^{f_i} \frac{(g_{ij} - A_i n'_{ij})^2}{f_i (f_i - 1)} \left(1 - \frac{f_i}{F_i} \right)$$

where F_i is the total number of groups present during the i th sample period. We could not determine F_i so we assumed F_i was large compared to f_i and $(1-f_i/F_i)=1$.

The total population size, N_i , was estimated by the statistic \hat{P}_i , given by:

$$\hat{P}_i = (\hat{N}'_i) (\hat{A}_i) \quad .$$

The estimated variance of \hat{P}_i was calculated as (Goodman 1960):

$$V[\hat{P}_i] = (\hat{A}_i)^2 V[\hat{N}_i] + (\hat{N}_i)^2 V[\hat{A}_i] + V[\hat{N}_i] V[\hat{A}_i] \quad .$$

Estimation of Total Population Size Using \hat{M}'_i .

Total population size was also estimated using \hat{M}'_i instead of \hat{N}'_i by defining \hat{A}^*_i as the estimated ratio of the number of individuals sighted (marked and unmarked) to the number of marked geese sighted in the i th sample that were sighted in at least 1 sample previous to i . The ratio \hat{A}^*_i was calculated as:

$$\hat{A}^*_i = \sum_{j=1}^{f_i} \frac{g_{ij}}{m'_{ij}}$$

where m'_{ij} , g_{ij} and f_i were defined as before. The number m'_{ij} included only marked geese sighted in i , that had also been sighted in a previous sample period. Variance estimates for \hat{A}^*_i were calculated as for \hat{A}_i by substituting values of m'_{ij} for n'_{ij} . Total population size \hat{N}_i was estimated as $\hat{P}_i = \hat{M}'_i \hat{A}^*_i$ with variance estimates for \hat{P}_i calculated by substituting \hat{M}'_i for \hat{N}'_i .

Estimation of Dusky Canada Goose Midwinter Population Size.

Adult dusky Canada geese were banded on the Copper River Delta, Alaska during July, 1985-92. Geese were banded with red plastic neck bands engraved with white, 3 digit alpha-numeric codes, and standard U.S. Fish and Wildlife Service (USFWS) aluminum leg bands. Codes on neck bands were visible using a high powered spotting scope. Three observers routinely located wintering flocks in the Willamette Valley and Lower Columbia River Basin of Oregon and Washington during 16 November - 15 April, 1988-92. Observers recorded codes of neck bands sighted, and the number of marked and unmarked geese in each flock examined.

The number of marked individuals in the population was estimated using resightings of previously marked geese and program JOLLY (Pollock et al. 1990). The values \hat{M}'_i , \hat{N}'_i and corresponding variances were calculated from a 5 sample model and program JOLLY. The 5 sample periods were defined as 16-30 November, 16-31 December, 16-31 January, 15-28 February, and 16-31 March. Midwinter population size was estimated during the 16-31 January sample period.

Observations during sample periods were used to calculate n'_i , m'_i , u'_i , r'_i , and z'_i . Sightings between sample periods during 1-15 December, 1-15 January, 1-14 February, 1-15 March, and 1-15 April were additionally used to calculate r'_i and z'_i . Observations between sample periods increased the number of individuals known alive but

not sighted during previous sample periods, and therefore increased the precision of \hat{M}'_i and \hat{N}'_i .

Estimates of \hat{M}'_i and \hat{N}'_i were calculated using Model A, the Jolly-Seber model with both death and immigration (Pollock et al. 1990). When χ^2 goodness-of-fit tests indicated lack of fit of the data to the model, standard errors of \hat{M}'_i and \hat{N}'_i were adjusted using the variance inflation factor method as described by Burnham et al. (1987:245). Coefficients of variation were calculated to examine relative variation of the estimates. Coefficients of variation (CV) were calculated as

$$CV = S.E. (\theta) / \theta$$

where $S.E.(\theta)$ is the standard error of the estimate, and θ is the value of the estimate.

RESULTS

Estimates of midwinter population size for dusky Canada geese ranged from 12,400 to 19,800 (Tables III.1 and III.2). Population estimates using \hat{M}'_i or \hat{N}'_i were not significantly differently within years ($P > 0.1000$). Coefficients of variation (Table III.3) indicated that estimates of \hat{M}'_i were more precise than \hat{N}'_i , and estimates of \hat{A}_i were more precise than \hat{A}^*_i . Population estimates were relatively more precise using \hat{P}^*_i .

Table III.1. Estimated number of marked individuals (\hat{N}'), ratio of flock size/marked individuals (\hat{A}), and midwinter population size (\hat{P}) of dusky Canada geese during 16-31 January, 1990, 1991 and 1992. Estimates of \hat{N}' were derived using observations of neck banded geese during 16 November - 15 April and a 5 sample capture-resighting model. U.S. Fish and Wildlife Service Midwinter Inventory Estimates (MWE) are presented for comparison.

Year	\hat{N}'	SE(\hat{N}')	SE(\hat{N}')adj ¹	\hat{A}	SE(\hat{A})	\hat{P}	SE(\hat{P})	MWE
1990	1,049.72	29.26	94.51	13.08	0.71	13,730	1,445	11,704
1991	1,027.48	30.88	94.18	18.44	1.41	18,947	2,259	---- ²
1992	1,139.08	42.28	80.14	16.86	1.13	19,205	1,865	19,080

¹ Standard errors of estimated number of marked individuals (\hat{N}') adjusted for model lack-of-fit.

² No estimate this year.

Table III.2. Estimated number of marked individuals previously sighted (\hat{M}'), ratio of flock size/previously sighted marked individuals (\hat{A}^*), and midwinter population size (\hat{P}^*) of dusky Canada geese during 16-31 January, 1990, 1991 and 1992. Estimates of \hat{M}' were derived using observations of neck banded geese during 16 November - 15 April and a 5 sample capture-resighting model. U.S. Fish and Wildlife Service Midwinter Inventory Estimates (MWE) are presented for comparison.

Year	\hat{M}'	SE(\hat{M}')	SE(\hat{M}')adj ¹	\hat{A}^*	SE(\hat{A}^*)	\hat{P}^*	SE(\hat{P}^*)	MWE
1990	628.82	9.36	30.23	19.78	1.27	12,438	997	11,704
1991	638.92	10.05	30.65	30.97	2.76	19,768	2,001	----- ²
1992	568.40	13.85	22.99	31.66	2.47	17,996	1,580	19,080

¹ Standard errors of estimated number of marked individuals previously sighted (\hat{M}') adjusted for model lack-of-fit.

² No estimate this year.

Table III.3. Coefficients of variation for parameter estimates \hat{M}' , \hat{N}' , \hat{A} , \hat{A}^* , \hat{P} , and \hat{P}^* .

Year	\hat{M}'	\hat{A}^*	\hat{P}^*	\hat{N}'	\hat{A}	\hat{P}
1990	0.05	0.06	0.08	0.09	0.05	0.11
1991	0.05	0.09	0.10	0.09	0.08	0.12
1992	0.04	0.08	0.09	0.07	0.07	0.10

Mark-resight estimates agreed with the USFWS midwinter inventory in 1990 and 1992. Inventory estimates in both years were within the 95% confidence interval of the mark-resight estimate. No USFWS midwinter inventory estimate was available for 1991.

DISCUSSION

Bandings can be incorporated into a resighting model if a banding period occurs during the initial sample period, and subsequent sample periods contain only resightings of individuals banded or initially sighted during the first sample. With this design, there are no sightings of marked individuals that were not "marked" in the initial sample. Interpretation of statistics generated by JOLLY are simplified as $m'_{ij} = n'_{ij}$, and therefore $\hat{M}'_i = \hat{N}'_i$. Total population size is calculated using the estimated ratio of all marked individuals in the population \hat{A}_i , and the estimated value of \hat{M}_i .

Multiple banding periods can also be incorporated if banding periods occur during observation periods. With this design, \hat{M}_i is defined as the number of marked individuals alive at time i that were banded or initially sighted in a previous sample. Total population size is estimated using \hat{N}'_i or \hat{M}'_i and the appropriate ratio \hat{A}_i or \hat{A}^*_i . We caution, however, that use of multiple banding and observation

periods could produce heterogeneity of capture probabilities among marked and unmarked individuals and cause lack-of-fit of the data to the model. The degree of heterogeneity will depend on the magnitude of difference between the banding and observation effort.

If banding and observation periods are not concurrent and observations are from multiple banded cohorts, then only resighting data should be used. Population point estimates calculated from \hat{N}'_i or \hat{M}'_i should not differ significantly if the appropriate ratio estimate is used. This was demonstrated for the dusky Canada goose data. However, differences in the relative variation of \hat{P}_i and \hat{P}^*_i could be significant.

The precision of the population estimate will depend on the precision of \hat{M}'_i or \hat{N}'_i and the appropriate ratio \hat{A}^*_i or \hat{A}_i . Estimated values of \hat{N}'_i will have proportionately larger variance than \hat{M}'_i due to the added variance when estimating \hat{N}'_i from \hat{M}'_i . However, the estimated variance of \hat{A}_i will be proportionately smaller than \hat{A}^*_i because \hat{A}_i is estimated using a greater number of marked individuals in the population.

In general, \hat{P}^*_i will be more precise unless a large proportion of individuals are initially sighted during time i . For the dusky Canada goose data, 35-40% of the sightings

during the January period were initial sightings. The relative precision of \hat{A}_i and \hat{A}_i^* differed by only 1%, while \hat{N}'_i was 3-4% more precise than \hat{M}'_i . Population estimates using \hat{P}_i^* were therefore more precise. However, if >50% of the sightings during the period of population estimation are initial sightings, loss of precision when estimating \hat{A}_i^* could be larger than gains in precision when using \hat{M}'_i , and \hat{P}_i will be more precise than \hat{P}_i^* .

Whether to use \hat{P}_i or \hat{P}_i^* will involve a tradeoff in gains in precision between the estimated number of marked individuals and the estimated ratio of marked individuals in the population. The precision of both estimates will be influenced by the observation effort. This has important implications to the design of a capture-resighting study. Estimates of population size from resighting data will be most precise when a relatively large number of marked individuals are initially sighted in a sample period before time i , and a large number of flocks are sampled during time i . Observation effort should be designed to maximize the number of individuals seen previous to time i , and the number of flocks counted during time i .

CHAPTER IV

IDENTIFICATION OF WINTERING SUBFLOCKS OF DUSKY CANADA GEESE
FROM OBSERVATIONS OF MARKED INDIVIDUALS

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INTRODUCTION

Canada geese (*Branta canadensis*) show a strong tendency to home to specific breeding and wintering areas (Hanson and Smith 1950, Bellrose 1980). Raveling (1969) concluded that large wintering flocks were composed of smaller subflocks with discrete roosting areas and recognizable flight patterns to feeding sites. Composed primarily of family units, these subflocks had common breeding origins and shared associations throughout the year (Raveling 1979). Cohesive groups helped to maintain family bonds, minimized aggression between individuals, and promoted efficient use of available food resources and roost areas (Raveling 1969, 1970). From a management perspective, the existence of subflocks can have relevance with regard to local and regional harvest strategies.

Several studies have supported the existence of subflocks (Raveling 1979, Koerner et al. 1974, Zicus 1981). However, other investigators have demonstrated a lack of

cohesion among geese using specific winter roost sites (Anderson and Joyner 1986, Harvey et al. 1983). While the concept of cohesive subflocks has intuitive appeal, identification of such cohorts for management purposes is often tenuous.

The well defined winter distribution of the dusky Canada goose (*B.c. occidentalis* Baird) population provides an ideal setting to examine the existence of subflocks. The dusky Canada goose winters primarily in the valleys of the Willamette River in northwestern Oregon and the lower Columbia River basin along the border of Oregon and Washington. During 1988-1992, an extensive database was generated from observations of neck banded individuals. Our objective is to document the existence and cohesiveness of subflocks of dusky Canada geese on wintering grounds using observations of neck banded individuals.

METHODS

Dusky Canada geese were banded on the Copper River Delta, Alaska during July, 1985-92. A total of 5,040 adult geese were banded with red plastic neck bands engraved with white, 3 digit alpha-numeric codes, and standard U.S. Fish and Wildlife Service aluminum leg bands. Three observers recorded codes on neck bands sighted using a high powered spotting scope mounted on a vehicle or tripod. Each observer monitored wintering flocks on 1/3 of the winter

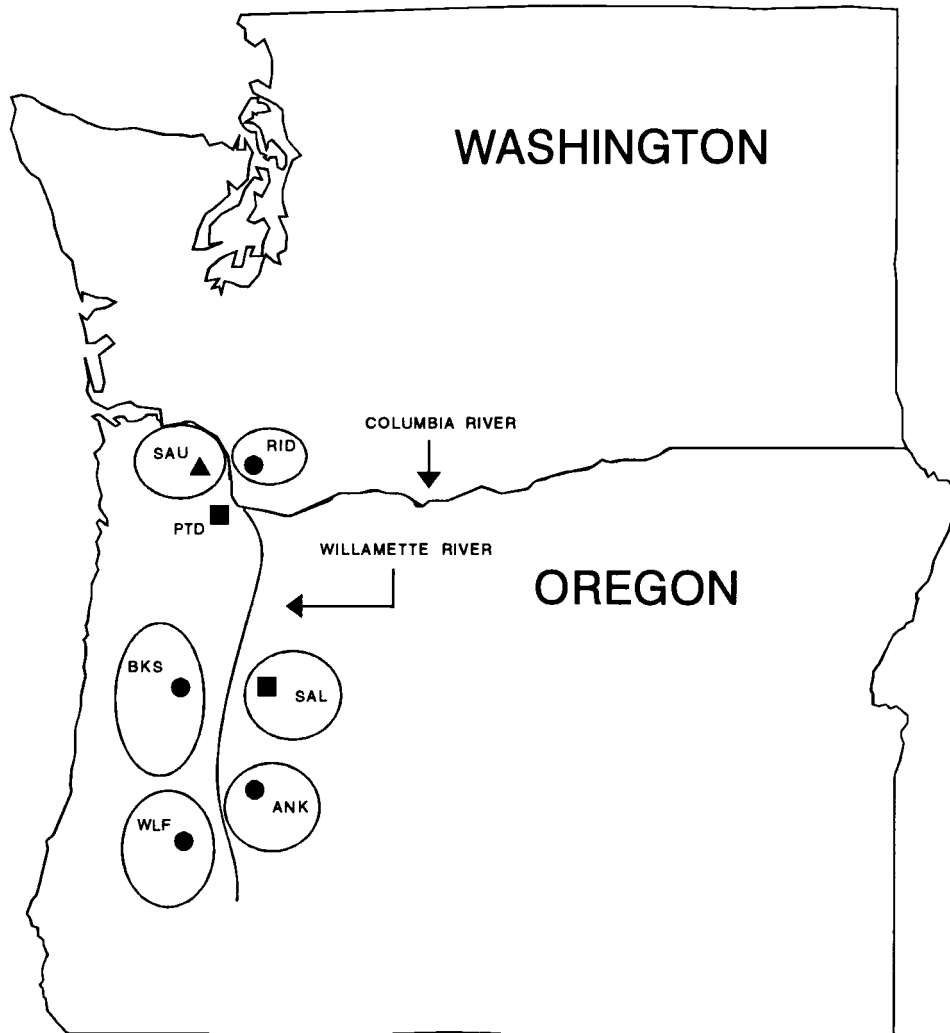
range. Observers visited all locations containing flocks of geese every 1-2 weeks during 16 November - 15 April, 1989-92.

A subflock was defined as a group of geese with similar spatial distributions on the winter range during the harvest (1 November - 20 January) and nonharvest (21 January - 31 March) season. Within each year we used only observations of individuals known to have survived the harvest season. Geese were identified as having survived the harvest season if they were observed during February or March of that year, or in a subsequent observation year.

Winter distributions were identified by dividing the winter range into 6 regions (Figure IV.1). Regions centered around the Sauvie Island Management Area (SAU), Ridgefield National Wildlife Refuge (RID), Baskett Slough National Wildlife Refuge (BKS), Ankeny National Wildlife Refuge (ANK), the Salem area east of the Willamette River (SAL), and the William L. Finley National Wildlife Refuge (WLF). The number of weeks an individual was seen in each region was calculated during the harvest and nonharvest season.

Subflocks were identified using a clustering algorithm and program CLUSB (Smith 1987). Originally developed for use in community ecology, CLUSB is a divisive clustering algorithm designed to partition n sample units with p attributes in k clusters. We defined a neck banded goose as a sample unit, and the number of times the goose was

Figure IV.1. Primary regions of the dusky Canada goose winter range.



LEGEND

- City
 - SAL - Salem
 - PTD - Portland
- National Wildlife Refuge
 - RID - Ridgefield
 - BKS - Baskett Slough
 - ANK - Ankeny
 - WLF - William L. Finley
- ▲ STATE WILDLIFE MANAGEMENT AREA
 - SAU - Sauvie Island

observed in a specific region during a harvest or nonharvest period as an attribute. Subflocks were therefore defined using 12 attributes (6 regions during 2 periods). Cluster means were calculated for each attribute and represented the average number of weeks marked geese were seen in each region during harvest and nonharvest periods. The primary affiliation for geese in a specific cluster was defined as the region with the largest mean value.

Associations between geese within a subflock were quantified by calculating a Jaccard similarity coefficient (Sokal and Sneath 1963) as modified by Kingsford (1990). A similarity value was calculated for all possible pairs of individuals observed. The similarity value (C_{ij}) between individuals i and j was calculated as

$$\hat{C}_{ij} = \frac{T_{ij}}{I_j + J_i + T_{ij}}$$

where T_{ij} is the total number of observations of individual i and j in the same flock, I_j is the number of observations of individual i in a flock without j , and J_i is the number of observations of individual j in a flock without i .

Similarity values ranged from 0 to 1, where 0 represented 2 individuals never seen together, and 1 represented 2 individuals always observed in the same flock. Associated geese were identified as groups of individuals whose similarity values were ≥ 0.5 .

RESULTS

Cluster analysis was done on 1,107, 1,059, and 947 individuals during 1989-90, 1990-91 and 1991-92, respectively. Program CLUSB identified 9 clusters in 1989-90 and 1990-91, and 10 in 1991-92 that had a distinct region of primary affiliation (Tables IV.1-3). Individuals not assigned to these clusters made up an additional cluster each year with no clear affiliation. Clusters without a clear affiliation were composed primarily of geese that were seen ≤ 3 times within a year.

All of the subflocks identified had the same primary affiliation during the harvest and nonharvest season. The percentage of individuals within a subflock observed at least once outside their area of affiliation ranged from 20-35% for geese affiliated with SAU or WLF, and 31-78% for individuals affiliated with RID, BKS, SAL, and ANK (Table IV.4).

Geese with similarity values ≥ 0.5 comprised 206, 205, and 191 groups during 1989-90, 1990-91, and 1991-92, respectively (Table IV.5). Group size ranged from 2-10 during 1989-90, and 2-9 during 1990-91 and 1991-92. Mean group size identified by associations was 2.8 (S.E. = 1.4) for all 3 years. Over 95% of all groups contained at least 1 adult male and 1 adult female.

Table IV.1. Results of cluster analysis on observation data 1989-90. The number of geese, primary affiliation (Affil), and mean number of observations in regions of the winter range during harvest and nonharvest periods are presented for each cluster.

Cluster	Number of geese	Affil	Mean number of observations/goose											
			1 November - 20 January						21 January - 31 March					
			SAU	RID	BKS	SAL	ANK	WLF	SAU	RID	BKS	SAL	ANK	WLF
1	204	SAU	1.9	0.1	0.1	Tr ¹	Tr	Tr	1.4	0.1	0.1	Tr	Tr	0.1
2	48	SAU	1.7	0.2	0.1	Tr	0.0	0.2	5.0	0.0	Tr	0.0	Tr	0.0
3	26	SAU	5.2	0.2	0.0	0.0	Tr	0.0	4.0	Tr	0.1	0.0	0.0	0.0
4	57	RID	0.7	3.3	Tr	Tr	0.0	0.0	1.1	0.4	0.2	0.1	Tr	0.0
5	36	RID	0.1	3.0	0.0	0.0	0.0	0.0	0.5	2.8	Tr	0.0	0.0	0.0
6	61	BKS	Tr	Tr	3.9	0.2	Tr	0.1	Tr	0.0	2.2	0.3	Tr	0.2
7	46	BKS	0.2	0.0	2.4	0.3	0.2	Tr	0.2	0.0	4.4	0.4	0.0	Tr
8	40	SAL	0.1	0.0	0.1	4.9	0.0	0.3	Tr	0.0	0.6	2.0	Tr	0.2
9	69	ANK	0.0	0.0	0.1	0.1	2.3	0.2	Tr	0.0	0.2	Tr	1.9	0.1
10	172	WLF	0.1	Tr	0.1	0.1	0.1	4.1	Tr	0.0	Tr	Tr	0.0	4.0
11	348	None	0.1	0.1	0.4	0.2	Tr	0.1	0.3	Tr	0.6	0.5	Tr	0.0

¹ Tr = trace (<0.1).

Table IV.2. Results of cluster analysis on observation data 1990-91. The number of geese, primary affiliation (Affil), and mean number of observations in regions of the winter range during harvest and nonharvest periods are presented for each cluster.

Cluster	Number of geese	Affil	Mean number of observations/goose											
			1 November - 20 January						21 January - 31 March					
			SAU	RID	BKS	SAL	ANK	WLF	SAU	RID	BKS	SAL	ANK	WLF
1	135	SAU	4.2	Tr ¹	0.1	0.0	Tr	Tr	1.2	Tr	0.2	0.0	0.1	0.2
2	97	SAU	3.0	Tr	Tr	0.0	Tr	Tr	4.0	0.0	Tr	0.0	0.0	0.0
3	42	RID	0.3	1.7	0.1	0.0	0.0	Tr	0.2	3.2	0.0	0.0	0.0	0.0
4	28	RID	0.1	5.4	Tr	0.0	0.0	0.0	0.1	2.9	0.2	Tr	0.1	Tr
5	58	BKS	0.2	Tr	5.3	0.0	0.1	Tr	0.1	0.0	5.6	0.0	0.1	Tr
6	50	BKS	0.1	Tr	4.8	0.0	0.1	0.1	0.1	0.0	1.6	0.0	0.1	0.5
7	41	SAL	0.2	0.0	0.2	1.4	Tr	Tr	0.1	0.0	0.1	2.0	Tr	0.1
8	81	ANK	0.2	0.0	0.4	0.1	2.9	0.3	0.1	0.0	0.1	0.0	3.2	0.1
9	150	WLF	0.1	Tr	0.1	0.0	0.1	2.3	Tr	Tr	0.1	0.0	Tr	3.0
10	47	WLF	0.1	0.0	0.2	Tr	Tr	5.6	0.0	0.0	Tr	0.0	0.0	5.7
11	330	None	0.4	0.1	0.2	0.0	Tr	0.1	0.4	0.1	0.7	0.0	0.5	0.2

¹ Tr = trace (<0.1).

Table IV.3. Results of cluster analysis on observation data 1991-92. The number of geese, primary affiliation (Affil), and mean number of observations in regions of the winter range during harvest and nonharvest periods are presented for each cluster.

Cluster	Number of geese	Affil	Mean number of observations/goose											
			1 November - 20 January						21 January - 31 March					
			SAU	RID	BKS	SAL	ANK	WLF	SAU	RID	BKS	SAL	ANK	WLF
1	100	SAU	1.0	0.1	Tr ¹	0.0	Tr	0.1	3.8	0.1	Tr	0.0	Tr	Tr
2	68	SAU	2.5	Tr	0.1	0.0	0.0	Tr	1.0	0.0	0.2	0.0	0.1	0.4
3	28	SAU	4.1	0.1	0.0	0.0	0.0	Tr	4.0	0.0	0.0	0.0	0.0	0.2
4	35	RID	0.1	2.9	0.1	0.0	0.0	0.0	0.4	1.8	Tr	0.0	0.0	0.1
5	25	RID	Tr	1.5	Tr	0.0	0.0	0.0	0.6	3.5	0.0	0.0	Tr	Tr
6	111	BKS	0.2	0.1	1.2	Tr	Tr	0.1	0.1	0.0	1.9	0.0	0.0	Tr
7	46	BKS	0.0	Tr	4.3	0.0	0.1	Tr	Tr	0.0	2.3	0.0	Tr	Tr
8	13	SAL	0.0	0.0	0.2	2.5	0.2	0.0	0.0	0.0	0.0	1.3	0.1	0.3
9	68	ANK	0.2	Tr	0.3	Tr	1.2	1.0	0.1	Tr	Tr	0.0	1.9	0.2
10	10	ANK	0.1	0.0	0.0	0.0	5.4	0.0	0.0	0.0	0.0	0.0	4.1	0.0
11	137	WLF	0.1	Tr	0.1	Tr	Tr	3.6	Tr	0.0	Tr	0.0	0.0	3.2
12	306	None	0.2	0.1	0.1	Tr	Tr	0.2	0.8	0.1	0.1	0.0	0.1	0.5

¹Tr = trace (<0.1).

Table IV.4. Number of geese observed outside their region of primary affiliation at least once.

<u>Cluster</u>	<u>Primary Affiliation</u>	<u>Number of geese</u>	<u>Number of geese observed outside region of primary affiliation (%)</u>
1989			
1	SAU	204	53 (26%)
2	SAU	48	12 (25%)
3	SAU	26	5 (20%)
4	RID	57	32 (56%)
5	RID	36	28 (78%)
6	BKS	61	33 (54%)
7	BKS	46	32 (70%)
8	SAL	40	26 (65%)
9	ANK	69	31 (45%)
10	WLF	172	44 (25%)
1990			
1	SAU	135	47 (35%)
2	SAU	97	15 (15%)
3	RID	42	17 (40%)
4	RID	28	9 (32%)
5	BKS	58	23 (40%)
6	BKS	50	23 (46%)
7	SAL	41	16 (39%)
8	ANK	81	42 (52%)
9	WLF	150	52 (35%)
10	WLF	47	14 (30%)
1991			
1	SAU	100	26 (26%)
2	SAU	68	23 (10%)
3	SAU	28	8 (29%)
4	RID	35	13 (37%)
5	RID	25	11 (44%)
6	BKS	111	41 (37%)
7	BKS	46	16 (35%)
8	SAL	13	4 (31%)
9	ANK	68	37 (54%)
10	ANK	10	4 (40%)
11	WLF	137	39 (28%)

Table IV.5. The number and mean group size of groups composed of marked individuals with similarity values between group members ≥ 0.5 .

	1989-90	1990-91	1991-92
Number of observations	7,901	8,602	5,869
Number of geese seen	1,274	1,228	1,228
Number of geese with association values ≥ 0.5	586	582	544
Number of groups	206	205	191
Group size			
Range	2-10	2-9	2-9
Mean (SE)	2.8 (1.4)	2.8 (1.3)	2.8 (1.4)

DISCUSSION

The clustering algorithm identified subflocks of geese based on the number of weeks they were observed in regions of the winter range. Although subflocks could be identified by regional use patterns, associations between subflock members could only be demonstrated for small groups of ≤ 10 geese and adult pairs. The small groups identified from similarity values were probably family groups composed of adult pairs with second or third year young. However, because no first year geese were marked, the ability to make inferences about family groups was limited.

The data indicated that most of the geese had a region of primary use; however a large number were seen at least once outside their region of affiliation. Geese that were affiliated with the extreme northern region (SAU) and the southern region (WLF) of the winter range showed the most site fidelity; $\geq 65\%$ of these individuals were never observed outside their region of affiliation. Geese affiliated with the middle regions of the Willamette Valley showed greater movement. Most of these geese were seen at least once outside their region of affiliation.

The ability to use observations of neck banded geese to identify discrete subflocks was limited. Affiliations could not be determined for over 35% of the marked individuals

observed because they were not sighted enough times within a year. For groups of geese that could be affiliated with a specific region, strong association between individuals could not be adequately examined. We could not determine whether similarity values of <0.5 were due to lack of strong cohesive groups or insufficient data. The ability to assess group cohesiveness was restricted because the probability of identifying all marked individuals in a flock was <1 . The inability to see all marked individuals in a flock renders inferences about subflock composition and cohesiveness from neck band observation data inconclusive.

CONCLUSION

Prior to 1975 the dusky Canada goose population was characterized by low survival and high recruitment rates. If we compare trends in harvest regulations with survival estimates during 1960-90, survival rates gradually increased with increasing restrictions in harvest. Although annual adult survival rates approached 80% during the late 1970's and early 1980's, they were not high enough to offset decreasing recruitment rates, and the population declined.

Recent population estimates suggest that the population is no longer declining and could be increasing. A model of Canada goose population dynamics indicated that the chance for population increase is favorable if recruitment and survival rates remain at or above present levels. However, simulations also demonstrated that without significant increases in recruitment, adult survival rates must remain at or above present levels for the population to maintain itself. The population will be sensitive to small

reductions in adult survival rates as long as recruitment remains depressed.

Previous studies concluded that harvest mortality was the primary factor limiting the dusky Canada goose population. Harvest was not the major source of mortality during 1990-92. Estimates of monthly survival were not significantly different during harvest and nonharvest periods. Fewer geese survived nonharvest periods because of the longer time interval.

Neck band retention rates were 100% and 98% the first and second year after banding, respectively, for male and female geese. Resightings of geese double banded with tarsal and neck bands effectively monitored neck band loss rates for dusky Canada geese. The advantage of resighting data is that double banding geese allows multiple census occasions of individuals for band retention, and provides unbiased estimates of band retention over time intervals that coincide with survival estimates. This technique could be effective for other goose populations, however one consideration is that resighting probabilities for tarsal bands were significantly lower than for neck bands. Although there was less observation effort for tarsal bands, the small size of the band and the habitat contributed to low resighting probabilities. These factors should be appraised in future studies when designing sampling effort.

Midwinter population estimates from observation data

generally agreed with the U.S. Fish and Wildlife service midwinter inventory. The similarity of the capture-resighting estimate and the inventory suggests that the inventory is a reliable index to population size. The precision of population estimates from capture-resighting data depended on the precision of the estimated number marked and the estimated ratio of marked individuals in the population. These estimates can be influenced by observation effort, which has important implications to the design of sampling effort. If only resightings of previously marked individuals are used, estimates of population size will be most precise when a large proportion of marked individuals are initially sighted before the time period of interest. Observation effort should be designed to maximize the number of individuals seen before, and the number of flocks counted during, the period when population size is to be estimated.

Observations of neck banded geese were used with a cluster analysis to identify subflocks of geese affiliated with specific regions of the winter range. Over 65% of geese in subflocks affiliated with the northern and southern regions of the winter range were never observed outside their region of affiliation. Geese affiliated with the middle regions of the winter range exhibited greater movement as most were seen at least once outside their region of affiliation. The ability to assess group

cohesiveness within subflocks was limited because there were no immature geese marked, and the probability of identifying all marked individuals in a flock was <1 . Large groups could be identified based on regional use patterns; however associations could be demonstrated only for small groups of ≤ 10 geese and adult pairs.

BIBLIOGRAPHY

- Anderson, D.R., and D.E. Joyner. 1985. Subflocking and winter movements of Canada geese in southern Illinois. *J. Wildl. Manage.* 49:422-428.
- Arnason, A.N. and K.H. Mills. 1981. Bias and loss of precision due to tag loss in Jolly-Seber estimates for mark-recapture experiments. *Can. J. Fish. Aquatic Sci.* 38:1077-1095.
- Begon, M., J.L. Harper, and C.R. Townsend. 1990. *Ecology: individuals, populations and communities.* Blackwell Sci. Publ., Oxford, London. 945pp.
- Bellrose, F.C. 1980. Ducks, geese and swans of North America. *Wildl. Manage. Inst.*, Washington, D.C. 544pp.
- Bromley, R.G. 1976. Nesting habitat studies of the dusky Canada goose (*Branta canadensis occidentalis* Baird) on the Cooper River Delta, Alaska. M.S. Thesis. Univ. of Alaska, Fairbanks. 81pp.
- Brownie, C., D.R. Anderson, K.P. Burnham, and D.S. Robson. 1985. Statistical inferences from band recovery data: A handbook. 2nd ed. U.S. Fish and Wildl. Serv., Resour. Publ. 156. 305pp.
- Burnham, K.P., and D.R. Anderson. 1993. Data-based selection of an appropriate biological model: the key to modern data analysis. Pages 16-30 in McCullough, D.R., and Barrett, R.H., eds. *Wildlife 2001: populations.* Elsevier Scientific Publ. Co., Amsterdam.
- _____, _____, G.C. White, C. Brownie, and K.H. Pollock. 1987. Design and analysis methods for fish survival experiments based on release-recapture. *American Fisheries Soc. Monogr.* 5:1-437.
- Campbell, B.H. 1984. Status of the dusky Canada goose on the Copper River Delta. Pages 33-37 in *Proceedings of the Tenth Copper River Delta Conference.* U.S. Forest Service, Cordova, Alaska.
- _____. 1987. A review of factors affecting the population size of the dusky Canada goose. Unpubl. report, Alaska Dept. of Fish and Game, Anchorage.
- _____. 1990. Annual waterfowl program progress report. Unpub. Rep., Alaska Dep. Fish and Game. Anchorage. 41pp.

- _____. , and E.F. Becker. 1991. Neck collar retention in dusky Canada geese. *J. Field Ornith.* 62:521-527.
- Chapman, J.A. 1967 Population characteristics, hunter kill and productivity of dusky Canada geese. M.S. Thesis. Oregon State Univ., Corvallis. 82pp.
- _____, C.J. Henny and H.M. Wight. 1969. The status, population dynamics and harvest of the dusky Canada goose. *Wldl. Monogr.* 18:1-48.
- Cornely, J.C., B.H. Campbell, and R.L. Jarvis. 1985. Productivity, mortality and population status of dusky Canada geese. *Trans. N. Am. Wildl. Res. Conf.* 50:540-548.
- Craven, S.R. 1979. Some problems with Canada goose neckbands. *Wildl. Soc. Bull.* 7:268-273.
- _____, and D.H. Rusch. 1983. Winter distribution and affinities of Canada geese marked on Hudson and James bays. *J. Wildl. Manage.* 47:307-319.
- Crow, J.H. 1968. Plant ecology of the Copper River Delta, Alaska. Ph.D. Thesis. Washington State Univ., Pullman. 120pp.
- _____. 1972. Earthquake-initiated changes in the nesting habitat of the dusky Canada goose. Pages 130-136 in *The great Alaska earthquake of 1964: biology*. Publ. 1609 Natl. Acad. Sci., Washington, D.C.
- Fjetland, C.A. 1973. Long-term retention of plastic collars in Canada geese. *J. Wildl. Manage.* 37:176-178.
- Goodman, L.A. 1960. On the exact variance of products. *Am. Stat. Assoc. J.* 55:708-713.
- Grier, J.W. 1980. Modeling approaches to bald eagle population dynamics. *Wildl. Soc. Bull.* 8:316-322.
- Hansen, H.A. 1962. Canada geese of coastal Alaska. *Trans. N. Amer. Wildl. Conf.* 27:301-329.
- _____. 1968. Pacific Flyway Canada goose management - Federal and state cooperation. Pages 43-49 in R.L. Hine and C. Schoenfeld, eds. *Canada goose management*. Dembar Educ. Res. Ser., Madison, Wisconsin. 195pp.
- Hanson, H.C., and R.H. Smith. 1950. Canada geese of the Mississippi flyway, with special reference to an Illinois flock. *Bull. Ill. Nat. Hist. Surv.* 25:59-210.

- Harvey, W.F., R.A. Malecki, and E.C. Soutiere. 1983. Roost site use and foraging flights by Canada geese wintering in Maryland. Proc. Int. Canada Goose Symp. In Press. Milwaukee, WI.
- Havel, L.H. and R.L. Jarvis. 1988. Formation of feeding flocks during winter by dusky and Taverner's Canada geese in Oregon. Pages 91-102 in M.W. Weller, ed. Waterfowl in winter. Univ. Minn. Press, Minneapolis.
- Henny, C.J. 1967. Population characteristics of the dusky Canada goose as determined from banding data. M.S. Thesis. Oregon State Univ., Corvallis. 98pp.
- Hestbeck, J.B., and R.A. Malecki. 1989a. Estimated survival rates of Canada geese within the Atlantic flyway. J. Wildl. Manage. 53:91-96.
- _____, and _____. 1989b. Mark-resight estimate of Canada goose midwinter number. J. Wildl. Manage. 53(3):749-752.
- Hines, J.E., and J.R. Sauer. 1989. Program CONTRAST - A general program for the analysis of several survival or recovery rate estimates. U.S. Fish Wildl. Serv., Fish Wildl. Tech. Rep. 24. 7pp.
- Jarvis, R.L. and J.E. Cornely. 1988. Recent changes in wintering populations of Canada geese in western Oregon and southwestern Washington. Pages 517-528 in M.W. Weller, ed. Waterfowl in winter. Univ. Minn. Press, Minneapolis.
- Jolly, G.M. 1965. Explicit estimates from capture-recapture data with both death and immigration - stochastic model. Biometrika 52(1/2):225-247.
- Kingsford, R.T. 1990. Flock structure and pair bonds of the Australian Wood Duck *Chenonetta jubata*. Wildfowl 41:75-82.
- Koerner, J.W., T.A. Bookhout, and K.E. Bednarik. 1974. Movements of Canada geese color-marked near southwestern Lake Erie. J. Wildl. Manage. 38:275-298.
- Kremers, W.K. 1987. Estimation of survival rates in the presence of tag loss: the binomial and hypergeometric model. Universitat Dortmund Fachbereich Statistik, Forschungsbericht Nr.87/6. 20pp.

- MacInnes, C.D., and B.C. Lieff. 1968. Individual behavior and composition of a local population of Canada geese. Pages 93-101 in R.L. Hine and C. Schoenfeld, eds. Canada goose management. Dembar Educ. Res. Serv., Madison, Wisconsin.
- Nichols, J.D., Bart, J., Limpert, R.J., Sladen, W.J.L., and Hines, J.E. 1992. Annual survival rates of adult and immature eastern population tundra swans. J. Wildl. Manage. 56(3):485-494.
- Olson, S.T. 1954. Migratory waterfowl studies: Copper River Delta banding and production studies. U.S. Fish Wildl. Serv. Fed. Aid Wildl. Rest. Quart. Rept. Proj. W-3-R-9, Work Plan C. Append. B., Juneau, Alaska. 9 pp.
- Pacific Flyway Council. 1985. Pacific Flyway management plan for the dusky Canada geese. Pac. Flyway Counc. Rep. 23pp.
- Pollock, K.H. 1981. Capture-recapture models allowing for age-dependent survival and capture rates. Biometrics 37:521-529.
- _____, J.D. Nichols, C. Brownie, and J.E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildl. Monogr. 107. 97pp.
- Potyondy, J.P., M.P. Meyer, and A.C. Mace, Jr. 1975. An analysis of 1964 earthquake effects upon the vegetation and hydrology of the Copper River Delta, Alaska. Inst. Agric., Forest. Home Econ., Remote Sens. Lab. Rep. 75-6. 84pp.
- Raveling, D.C. 1969. Roost sites and flight patterns of Canada geese in winter. J. Wildl. Manage. 33:319-330.
- _____. 1978. Dynamics of distribution of Canada geese in winter. Trans. N. Am. Wildl. Nat. Resour. Conf. 43:206-225.
- _____. 1979. Traditional use of migration and wintering roost sites by Canada geese. J. Wildl. Manage. 43:229-235.
- Rees, E.C., M. Owen, H. Gitay, and S. Warren. 1990. The fate of plastic leg rings used on geese and swans. Wildl. fowl 41:43-52.

- Samuel, M.D., N.T Wiess, D.H. Rusch, S.R. Craven, R.E. Trost, and F.D. Caswell. 1990. Neck-band retention for Canada geese in the Mississippi Flyway. J. Wildl. Manage. 54(4):612-621.
- Seber, G.A.F. 1965. A note on the multiple recapture censuses. Biometrika 52(1/2):249-259.
- _____. 1982. The estimation of animal abundance and related parameters. Second ed. MacMillan, New York, N.Y. 654pp.
- Shepherd, P.E.K. 1965. A preliminary evaluation of earthquake damage to waterfowl habitat in southcentral Alaska. Ann. Conf. West. ASSoc. State Game and Fish Comm. 9pp.
- Simpson, S.G. and R.L. Jarvis. 1979. Comparative ecology of several subspecies of Canada geese during winter in western Oregon. Pages 223-240 in R.L. Jarvis and J.C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis.
- Smith, B.G. 1987. CLUSB Version 3: Recoding for microcomputer and manual revision. Oregon State University. Corvallis. 18pp.
- Snyder, N. and H. Snyder. 1989. Biology and conservation of the California condor. Current Ornithology 6:175-268.
- Sokal, R.R., and P.H.A. Sneath. 1963. Principles in numerical taxonomy. W.H.Freeman and Co., San Francisco.
- Timm, D.E., R.G. Bromley, D.E. McKnight, and R.S. Rodgers. 1979. Management evolution of dusky Canada geese. Pages 322-330 in R.L. Jarvis and J.C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State University Book Stores, Corvallis.
- Trainer, C.E. 1959. The 1959 western Canada goose (*Branta canadensis occidentalis*) study on the Copper River Delta, Alaska. in Ann. Waterfowl Rep., Alaska. U.S. Bur. Sport Fish. Wildl. Mimeo. 9pp.
- Trost, R.E., R.A. Malecki, L.J. Hindman, and D.C. Luszc. 1986. Survival and recovery of Canada geese from Maryland and North Carolina 1963-1974. Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies. 40:454-464.

- _____, D.H. Rusch, and D.H. Orr. 1980. Population affiliation of Canada geese from six southern refuges. Proc. Southeast. Assoc. Fish Wildl. Agencies. 35:598-606.
- White, G.C. 1983. Numerical estimation of survival rates from band-recovery and biotelemetry data. J. Wildl. Manage. 47:716-728.
- Zicus, M.C. 1981. Flock behavior and vulnerability to hunting of Canada geese nesting at Crex Meadows, Wisconsin. J. Wildl. Manage. 45:830-841.
- _____, and R.M. Pace III. 1986. Neckband retention in Canada geese. Wildl. Soc. Bull. 14:388-391.

APPENDICES

APPENDIX I. DEFINITION OF VARIABLES AND PROGRAM LISTING FOR
MODEL OF DUSKY CANADA GOOSE POPULATION DYNAMICS

DEFINITION OF VARIABLES

ACS=Average clutch size for geese ≥ 3 years old.
 AFR(20)=Matrix of annual recruitment rates for geese ≥ 3 years old.
 AFS=Survival rates of young fledged from geese ≥ 3 years old; survival from 1 June to 1 August.
 AHS=Hatching success (fertility) of eggs in clutches of geese ≥ 3 years old.
 AN=Percentage of geese ≥ 3 years old attempting to nest.
 ANS=Average annual nest success rates of geese ≥ 3 years old; input by user
 ANSR(20)=Matrix of up to 20 annual nest success rates of geese ≥ 3 years old adjusted for random variation.
 AOM=Mortality rate of geese ≥ 1 years old during non-harvest season.
 AR=Annual recruitment rate for geese ≥ 3 years old.
 AS(20,12)=Matrix of 12 monthly survival rates for up to 20 years for geese ≥ 1 years old.
 DIE(12,11)=Matrix of the number of individuals dying each month in 11 age classes.
 FALL=Population size of the fall flight (population size at 1 September).
 HMSA=Monthly survival rate during harvest season of geese ≥ 1 years old.
 HMSI=Monthly survival rate during harvest season of geese < 1 years old.
 HSA=Survival rate of geese ≥ 1 years old during harvest season.
 HSI=Survival rate of geese < 1 years old during harvest season.
 HR=Annual harvest rate.
 HRAD=Annual harvest rate for geese ≥ 1 years old.
 HRIM=Annual harvest rate for geese < 1 years old.
 IMAD=Ration of immature (< 1 years old)/adult geese in the annual harvest.
 IOM=Mortality rate of geese < 1 years old during non-harvest season.
 IS(20,12)=Matrix of 12 monthly survival rates for up to 20 years for geese < 1 years old.
 KILL=Number of geese that die per month during the harvest season.
 KILLAD=Number of geese ≥ 1 years old that die per month during the harvest season.
 KILLIM=Number of geese < 1 years old that die per month during the harvest season.
 N=Initial population size; input by user.
 N2=Number of iterations (years) for one simulation run.
 NA1=Initial number of geese in the 0 age class (< 1 years old age); input by user.
 NA2=Initial number of geese in the 1 year old age class; input by user.
 NA3=Initial number of geese in the 2 year old age class; input by user.
 NA4=Initial number of geese ≥ 3 years old; input by user.
 NAGE(11)=Matrix of the number of geese in 11 age classes.
 OMSA=Monthly survival rate of geese ≥ 1 years old during the non-harvest season.
 OMSI=Monthly survival rate of geese < 1 years old during the non-harvest season.
 OSA=Survival rate of geese ≥ 1 years old during the harvest season.
 OSI=Survival rate of geese < 1 years old during the harvest season.
 PA=Proportion of the annual mortality rate for geese ≥ 1 years old that occurs during the harvest season.
 PAO=Proportion of the annual mortality rate for geese ≥ 1 years old that occurs during the non-harvest season.
 PER(1)=Percentage of geese < 1 years old in the fall flight.
 PI=Proportion of the annual mortality rate for geese < 1 years old that occurs during the harvest season.
 PIO=Proportion of the annual mortality rate for geese < 1 years old that occurs during the non-harvest season.
 PRE=Annual pre-harvest population size (1 November).

PREAD=Number of geese ≥ 1 years old in pre-harvest population (1 November). 96
PREHAD=Number of geese ≥ 1 years old at the beginning of each month during the harvest season.
PREHAR=Total number of geese alive at the beginning of each month during the harvest season.
PREHIM=Number of geese < 1 years old at the beginning of each month during the harvest season.
PREIM=Number of geese < 1 years old in pre-harvest population (1 November).
SA=Average annual survival rate for geese ≥ 1 years old; input by user.
SAR=Annual survival rate for geese ≥ 1 years old adjusted for random variation.
SASE=Standard error of SA; input by user.
SEED1=Seed for random number generator.
SEED2=Seed for random number generator.
SI=Average annual survival rate for geese < 1 years old; input by user.
SIR=Annual survival rate for geese < 1 years old adjusted for random variation.
SISE=Standard error for SI; input by user.
TOT=Total population size.
TOTAD=Total number of geese ≥ 1 years old.
TOTIM=Total number of geese < 1 years old.
TOTKIL=Total number of geese killed per harvest season.
Y2FR(20)=Matrix of annual recruitment rates for geese 2 years old.
YCS=Average clutch size for geese 2 years old.
YFS=Survival rates of young fledged from geese 2 years old; survival from 1 June to 1 August.
YHS=Hatching success (fertility) of young from geese 2 years old.
YN=Proportion of 2 year old geese attempting to nest.
YNS=Average annual nest success rate for 2 year old geese; input by user.
YNSR(20)=Matrix of up to 20 annual nest success rates of 2 year old geese adjusted for random variation.
YR=Annual recruitment rate for 2 year old geese.
YS(20,12)=Matrix of 12 monthly survival rates for geese < 1 years old for up to 20 years.

C DECLARE VARIABLES

\$LARGE

```

      INTEGER I,J,K,N,N1,N2,L,M,P
      REAL NAGE(11),TOT,PER(11),IMAD,TOTAD,TOTIM,PRE,TOTKIL,HR
      REAL AFR(20),Y2FR(20),SA,SI,SEED1,SEED2,ADULT
      REAL ANS,AHS,AFS,AN,YNS,YHS,YFS,YN,ACS,YCS,AR,YR,PREHAR
      REAL NA1,NA2,NA3,NA4,PER1,FALL,SASE,SISE,PA,PI
      REAL HSA,OSA,HMSA,OMSA,HSI,OSI,HMSI,OMSI,S1,S2,SIR,SAR,IOM,AOM
      REAL AS(20,12),YS(20,12),IS(20,12),ANSR(20),YNSR(20),DIE(12,11)
      REAL PREHAD,PREHIM,PREAD,PREIM,HRAD,HRIM,PAO,PIO
      REAL KILLIM,KILLAD,KILL
      CHARACTER*1 S,R,A1,A2,SP,CH
      CHARACTER*3 FLAG
      CHARACTER*4 MARK
      CHARACTER*30 PARAM

```

```

      DO 19 I=1,20
      ANSR(I)=0.0
      YNSR(I)=0.0
19  CONTINUE

      FLAG='1ST'

      IF (FLAG.EQ.'1ST') GOTO 450

457 WRITE(*,451)
451 FORMAT(1X,'DO YOU WANT TO CHANGE SURVIVAL PARAMETERS? (Y OR N)')
      READ(*,452) CH
452 FORMAT(A1)
      IF (CH.EQ.'N') GOTO 403

```

C PROMPT USER FOR INPUT OF SURVIVAL RATES

```

450 WRITE (*,500)
500 FORMAT (1X,'ENTER ADULT SURVIVAL')
      READ (*,501) SA
501 FORMAT (F6.4)
      WRITE(*,506)
506 FORMAT (1X,'ENTER ADULT SURVIVAL RATE STANDARD ERROR')
      READ(*,501) SASE
      WRITE (*,502)
502 FORMAT (1X,'ENTER IMMATURE SURVIVAL')
      READ (*,501) SI
      WRITE (*,507)
507 FORMAT (1X,'ENTER IMMATURE SURVIVAL RATE STANDARD ERROR')
      READ(*,501) SISE

```

C PROMPT USER FOR INPUT OF SEED NUMBERS FOR RANDOM NUMBER GENERATOR
C (FIRST SIMULATION RUN ONLY)

```

      IF (FLAG.EQ.'1ST') THEN
      WRITE(*,301)
301 FORMAT(1X,'ENTER SEED1 FOR RANDOM NUMBER GENERATOR (I5)')
      READ(*,302) SEED1
302 FORMAT(F5.0)
      WRITE(*,303)
303 FORMAT(1X,'ENTER SEED2 FOR RANDOM NUMBER GENERATOR (I5)')

```

```
READ(*,302) SEED2
ENDIF
```

98

C PROMPT USER FOR CONSTANT OR PARTITIONED SURVIVAL RATES WITHIN YEARS

```
WRITE(*,400)
400 FORMAT (1X,'ENTER C FOR CONSTANT MONTHLY OR T FOR PARTITIONED MONT
+HLY SURVIVAL')
READ(*,401) S
401 FORMAT(A1)

IF (S.EQ.'T') THEN
WRITE(*,503)
503 FORMAT (1X,'ENTER PERCENTAGE OF ADULT MORTALITY DURING HARVEST SEA
+SON')
READ(*,501) PA
WRITE(*,505)
505 FORMAT (1X,'ENTER PERCENTAGE OF IMMATURE MORTALITY DURING HARVEST
+SEASON')
READ(*,501) PI
ENDIF
```

C PROMPT USER FOR NUMBER OF YEARS

```
403 WRITE(*,553)
553 FORMAT (1X,'NUMBER OF ITERATIONS ? (2-20)')
READ(*,*) N2
```

C INITIALIZE MATRICES FOR SURVIVAL RATES

```
DO 592 K=1,20
DO 593 L=1,12
AS(K,L)=0.0
IS(K,L)=0.0
593 CONTINUE
592 CONTINUE
```

C COMPUTE ANNUAL SURVIVAL RATES

```
DO 591 J=1,N2
```

C COMPUTE ANNUAL SURVIVAL RATES USING RANDOM NUMBER GENERATOR

```
CALL RAND(SEED1,S1)
IF (S1.LE.0.50) THEN
MARK='LESS'
ELSEIF (S1.GT.0.50) THEN
MARK='MORE'
ENDIF

CALL RAND(SEED2,S2)
IF (MARK.EQ.'LESS') THEN
SAR=SA-((2*SASE)*S2)
SIR=SI-((2*SISE)*S2)
WRITE(*,700) J,SAR,SIR
ELSEIF (MARK.EQ.'MORE') THEN
SAR=SA+((2*SASE)*S2)
SIR=SI+((2*SISE)*S2)
WRITE(*,700) J,SAR,SIR
700 FORMAT (1X,'SURVIVAL YEAR ',I2,': ',3X,'AD= ',F6.4,3X,'IM= ',F6.4)
ENDIF
```

C COMPUTE MONTHLY SURVIVAL RATES


```

      IF (S.EQ.'C') THEN
C COMPUTE CONSTANT MONTHLY SURVIVAL RATE

      DO 31 I=1,12
      AS(J,I)=EXP(LOG(SAR)/12.0)
      IS(J,I)=EXP(LOG(SIR)/12.0)
31 CONTINUE

      ELSEIF (S .EQ. 'T') THEN
C COMPUTE PARTITIONED MONTHLY SURVIVAL RATE

      PAO=1-PA
      AOM=PAO*(1-SAR)
      OSA=1-AOM
      HSA=SAR/OSA
      HMSA=EXP(LOG(HSA)/3.0)
      OMSA=EXP(LOG(OSA)/9.0)
      PIO=1-PI
      IOM=PIO*(1-SIR)
      OSI=1-IOM
      HSI=SIR/OSI
      HMSI=EXP(LOG(HSI)/3.0)
      OMSI=EXP(LOG(OSI)/9.0)
      DO 590 I=1,12
      IF (I.LE.9) THEN
      AS(J,I)=OMSA
      IS(J,I)=OMSI
      ELSEIF (I.GT.9) THEN
      AS(J,I)=HMSA
      IS(J,I)=HMSI
      ENDIF
590 CONTINUE

      ENDIF

591 CONTINUE

      IF (FLAG.EQ.'1ST') GOTO 600

C PROMPT USER FOR CHANGES IN POPULATION INFORMATION AFTER A
C SIMULATION RUN

      WRITE(*,550)
550 FORMAT (1X,'SAME POPULATION?')
      READ(*,551) SP
551 FORMAT(A1)
      IF (SP.EQ.'Y') GOTO 552

C PROMPT USER FOR POPULATION SIZE AND AGE STRUCTURE

600 WRITE (*,601)
601 FORMAT (1X,'ENTER THE INITIAL POPULATION SIZE IN I6 FORMAT')
      READ (*,621) N
621 FORMAT (I6)
      WRITE (*,622)
622 FORMAT(1X,'ENTER THE PERCENTAGE OF AGE1, AGE2, AGE3, AGE4')
      READ(*,*) NA1,NA2,NA3,NA4
623 FORMAT(4(F4.2,1X))

C COMPUTE NUMBER OF INDIVIDUALS IN EACH AGE CLASS

```

```

NAGE(1)=N*NA1
NAGE(2)=N*NA2
NAGE(3)=N*NA3
NAGE(4)=N*NA4

```

```

NAGE(4)=0.20*NA4*N
NAGE(5)=0.20*NA4*N
NAGE(6)=0.20*NA4*N
NAGE(7)=0.15*NA4*N
NAGE(8)=0.15*NA4*N
NAGE(9)=0.05*NA4*N
NAGE(10)=0.05*NA4*N
NAGE(11)=0.0*NA4*N

```

552 CONTINUE

C INITIALIZE DEFAULT VALUES FOR RECRUITMENT PARAMETERS
C (FIRST SIMULATION RUN ONLY)

```

IF (FLAG.EQ.'1ST') THEN
  ACS=5.2
  AHS=0.95
  AFS=0.90
  YCS=5.2
  YHS=0.95
  YFS=0.80
  ANS=0.0
  YNS=0.0
  AN=0.90
  YN=0.60
ENDIF

```

C PROMPT USER TO ENTER INITIAL NEST SUCCESS VALUES

```

IF (FLAG.EQ.'1ST') THEN
  WRITE(*,402)
402 FORMAT (1X,'ENTER C FOR CONSTANT OR T FOR TIME-SPECIFIC RECRUITMEN
+T')
  READ (*,401) R
  WRITE (*,*) 'ENTER ADULT NEST SUCCESS'
  READ (*,107) ANS
  WRITE(*,*) 'ENTER ADULT NS STANDARD ERROR'
  READ(*,107) ANSE
  WRITE(*,*) 'ENTER 2YR OLD NEST SUCCESS'
  READ(*,107) YNS
  WRITE(*,*) 'ENTER 2YR OLD NS STANDARD ERROR'
  READ(*,107) YNSE
ENDIF

```

C COMPUTE RECRUITMENT RATES

```

AR=ACS*ANS*AHS*AFS*AN*(0.50)
YR=YCS*YNS*YHS*YFS*YN*(0.50)

```

C PROMPT USER FOR CHANGES IN RECRUITMENT PARAMETERS

```

WRITE (*,101)
101 FORMAT (1X,'DO YOU WANT TO CHANGE RECRUITMENT?')
READ (*,102) A1
102 FORMAT (A1)
IF (A1 .EQ. 'N') GOTO 42
IF (FLAG.EQ.'1ST') GOTO 40

```

```

WRITE(*,402)
READ(*,401) R
40 WRITE(*,103) ACS,ANS,AHS,AFS,AN,YCS,YNS,YHS,YFS,YN,AR,YR
103 FORMAT(1X,'CURRENT PARAMETER VALUES ARE:',/,/,1X,'1: ADULT CLUTC
+H SIZE = ',F5.3,/,1X,'2: ADULT NEST SUCCESS = ',F6.4,/,1X,'3: AD
+ULT HATCHING SUCCESS = ',F5.3,/,1X,'4: ADULT FLEDGLING SURVIVAL
+= ',F5.3,/,1X,'5: % ADULTS NESTING = ',F5.3,/,/,1X,'6: 2YR OLD C
+LUTCH SIZE = ',F5.3,/,1X,'7: 2YR OLD NEST SUCCESS = ',F6.4,/,1X,'8
+: 2YR OLD HATCHING SUCCESS = ',F5.3,/,1X,'9: 2YR OLD FLEDGLING SU
+RVIVAL = ',F5.3,/,1X,'10: % 2YR OLD NESTING = ',F5.3,/,/,1X,'ADULT
+ RECRUITMENT = ',F6.4,/,1X,'2YR OLD RECRUITMENT = ',F6.4,/)

WRITE(*,104)
104 FORMAT(1X,'ENTER THE PARAMETER YOU WANT TO CHANGE OR <NONE>')
READ(*,105) PARAM
105 FORMAT(A30)
IF(PARAM.EQ. 'NONE') GOTO 41
WRITE(*,106)
106 FORMAT(1X,'ENTER NEW VALUE')
IF(PARAM.EQ. '1') THEN
READ(*,107) ACS
ENDIF
IF(PARAM.EQ. '2') THEN
WRITE(*,*) 'ENTER ADULT NEST SUCCESS'
READ(*,107) ANS
WRITE(*,*) 'ENTER ADULT NS STANDARD ERROR'
READ(*,107) ANSE
ENDIF
IF(PARAM.EQ. '3') THEN
READ(*,107) AHS
ENDIF
IF(PARAM.EQ. '4') THEN
READ(*,107) AFS
ENDIF
IF(PARAM.EQ. '5') THEN
READ(*,107) AN
ENDIF
IF(PARAM.EQ. '6') THEN
READ(*,107) YCS
ENDIF
IF(PARAM.EQ. '7') THEN
WRITE(*,*) 'ENTER 2YR OLD NEST SUCCESS'
READ(*,107) YNS
WRITE(*,*) 'ENTER 2YR OLD NS STANDARD ERROR'
READ(*,107) YNSE
ENDIF
IF(PARAM.EQ. '8') THEN
READ(*,107) YHS
ENDIF
IF(PARAM.EQ. '9') THEN
READ(*,107) YFS
ENDIF
IF(PARAM.EQ. '10') THEN
READ(*,107) YN
ENDIF
107 FORMAT(F6.4)
AR=ACS*ANS*AHS*AFS*AN*(0.50)
YR=YCS*YNS*YHS*YFS*YN*(0.50)
GOTO 40
41 CONTINUE
42 AR=ACS*ANS*AHS*AFS*AN*(0.50)
YR=YCS*YNS*YHS*YFS*YN*(0.50)

```

```

        WRITE (*,900) AR,YR
900 FORMAT (1X,'ADULT RECRUITMENT = ',F6.4,/,1X,'2YR OLD RECRUITMENT
+ = ',F6.4,/)

```

102

C INITIALIZE MATRIX OF ANNUAL RECRUITMENT RATES

```

        DO 48 I=1,20
        AFR(I)=0.0
        Y2FR(I)=0.0
48 CONTINUE

```

C COMPUTE CONSTANT ANNUAL RECRUITMENT RATES

```

        IF (R .EQ. 'C') THEN
        DO 22 I=1,N2
        AFR(I)=AR
        Y2FR(I)=YR
22 CONTINUE
        ENDIF

```

C COMPUTE VARIABLE NEST SUCCESS RATES USING RANDOM
C NUMBER GENERATOR

```

        IF (R .EQ. 'T') THEN
        DO 23 I=1,N2

        CALL RAND(SEED1,S3)
        IF (S3.LE.0.50) THEN
            MARK='LESS'
        ELSEIF (S3.GT.0.50) THEN
            MARK='MORE'
        ENDIF

```

```

        CALL RAND(SEED2,S4)
        IF (MARK.EQ.'LESS') THEN
            ANSR(I)=ANS-((2*ANSE)*S4)
            YNSR(I)=YNS-((2*YNSE)*S4)
        ELSEIF (MARK.EQ.'MORE') THEN
            ANSR(I)=ANS+((2*ANSE)*S4)
            YNSR(I)=YNS+((2*YNSE)*S4)
        ENDIF

```

C WRITE VARIABLE ANNUAL NEST SUCCESS RATES TO SCREEN

```

        WRITE (*,409) I,ANSR(I),YNSR(I)
409 FORMAT (1X,'NEST SUCCESS YEAR ',I2,': ',3X,'AD= ',F6.4,3X,'2YR= ',F
+6.4)

        23 CONTINUE
        ENDIF

```

C COMPUTE ANNUAL CHANGES IN POPULATION FOR N2 NUMBER OF YEARS

```

        N1=1

        DO 10 K=1,N1

        WRITE (*,6)
6 FORMAT (1X,/, ' THE RESULTS FOLLOW:')

        DO 20 I=1,N2

```

C CALCULATE ANNUAL RECRUITMENT RATES IF USING RANDOM VARIATION
C IN NEST SUCCESS RATES

103

```
IF (R.EQ.'C') GOTO 29
AFR(I)=ACS*ANSR(I)*AHS*AFS*AN*(0.50)
Y2FR(I)=YCS*YNSR(I)*YHS*YFS*YN*(0.50)
```

C INITIALIZE MATRIX OF MORTALITY FIGURES

```
29 DO 83 M=1,12
   DO 84 P=1,11
     DIE(M,P)=0.0
84 CONTINUE
83 CONTINUE
```

C UPDATE POPULATION FOR 4 MONTH PERIODS (FEB-MAY)

```
DO 24 J=1,4
```

C COMPUTE THE NUMBER OF INDIVIDUALS IN EACH AGE CLASS THAT
C DIE EACH MONTH

```
DIE(J,1)=(1-IS(I,J))*NAGE(1)
DIE(J,2)=(1-AS(I,J))*NAGE(2)
DIE(J,3)=(1-AS(I,J))*NAGE(3)
DIE(J,4)=(1-AS(I,J))*NAGE(4)
DIE(J,5)=(1-AS(I,J))*NAGE(5)
DIE(J,6)=(1-AS(I,J))*NAGE(6)
DIE(J,7)=(1-AS(I,J))*NAGE(7)
DIE(J,8)=(1-AS(I,J))*NAGE(8)
DIE(J,9)=(1-AS(I,J))*NAGE(9)
DIE(J,10)=(1-AS(I,J))*NAGE(10)
DIE(J,11)=(1-AS(I,J))*NAGE(11)
```

C COMPUTE THE NUMBER OF INDIVIDUALS IN EACH AGE
C CLASS THAT SURVIVE EACH MONTH

```
NAGE(4)=AS(I,J)*(NAGE(4))
NAGE(3)=AS(I,J)*(NAGE(3))
NAGE(2)=AS(I,J)*(NAGE(2))
NAGE(1)=IS(I,J)*(NAGE(1))

NAGE(5)=AS(I,J)*(NAGE(5))
NAGE(6)=AS(I,J)*(NAGE(6))
NAGE(7)=AS(I,J)*(NAGE(7))
NAGE(8)=AS(I,J)*(NAGE(8))
NAGE(9)=AS(I,J)*(NAGE(9))
NAGE(10)=AS(I,J)*(NAGE(10))
NAGE(11)=AS(I,J)*(NAGE(11))
```

```
24 CONTINUE
```

C ADVANCE ALL INDIVIDUALS INTO NEXT AGE CLASS (JUNE 1)

```
NAGE(11)=NAGE(10)+NAGE(11)
NAGE(10)=NAGE(9)
NAGE(9)=NAGE(8)
NAGE(8)=NAGE(7)
NAGE(7)=NAGE(6)
NAGE(6)=NAGE(5)
NAGE(5)=NAGE(4)
NAGE(4)=NAGE(3)
NAGE(3)=NAGE(2)
NAGE(2)=NAGE(1)
```

```

      ADULT=0.0
      DO 59 I=4,11
      ADULT=ADULT+NAGE(I)
59  CONTINUE

C  COMPUTE ANNUAL RECRUITMENT (NUMBER OF YOUNG AT AUG 1)

      NAGE(1)=(ADULT*AFR(I))+(NAGE(3)*Y2FR(I))

C  UPDATE POPULATION FOR 8 MONTH PERIODS (JUN-JAN)
      DO 25 J=5,12

      IF (J.GE.7) GOTO 27

C  COMPUTE THE NUMBER OF INDIVIDUALS IN EACH AGE CLASS THAT
C  DIE EACH MONTH (JUN-JUL)

      DIE(J,2)=(1-IS(I,J))*NAGE(2)
      DIE(J,3)=(1-AS(I,J))*NAGE(3)
      DIE(J,4)=(1-AS(I,J))*NAGE(4)
      DIE(J,5)=(1-AS(I,J))*NAGE(5)
      DIE(J,6)=(1-AS(I,J))*NAGE(6)
      DIE(J,7)=(1-AS(I,J))*NAGE(7)
      DIE(J,8)=(1-AS(I,J))*NAGE(8)
      DIE(J,9)=(1-AS(I,J))*NAGE(9)
      DIE(J,10)=(1-AS(I,J))*NAGE(10)
      DIE(J,11)=(1-AS(I,J))*NAGE(11)

C  COMPUTE THE NUMBER OF INDIVIDUALS IN EACH AGE
C  CLASS THAT SURVIVE EACH MONTH (JUN-JUL)

      NAGE(4)=AS(I,J)*(NAGE(4))
      NAGE(3)=AS(I,J)*(NAGE(3))
      NAGE(2)=IS(I,J)*(NAGE(2))
      NAGE(5)=AS(I,J)*(NAGE(5))
      NAGE(6)=AS(I,J)*(NAGE(6))
      NAGE(7)=AS(I,J)*(NAGE(7))
      NAGE(8)=AS(I,J)*(NAGE(8))
      NAGE(9)=AS(I,J)*(NAGE(9))
      NAGE(10)=AS(I,J)*(NAGE(10))
      NAGE(11)=AS(I,J)*(NAGE(11))

      GOTO 28

C  COMPUTE THE NUMBER OF INDIVIDUALS IN EACH AGE CLASS THAT
C  DIE EACH MONTH (AUG-JAN)

27  DIE(J,2)=(1-AS(I,J))*NAGE(2)
      DIE(J,3)=(1-AS(I,J))*NAGE(3)
      DIE(J,4)=(1-AS(I,J))*NAGE(4)
      DIE(J,5)=(1-AS(I,J))*NAGE(5)
      DIE(J,6)=(1-AS(I,J))*NAGE(6)
      DIE(J,7)=(1-AS(I,J))*NAGE(7)
      DIE(J,8)=(1-AS(I,J))*NAGE(8)
      DIE(J,9)=(1-AS(I,J))*NAGE(9)
      DIE(J,10)=(1-AS(I,J))*NAGE(10)
      DIE(J,11)=(1-AS(I,J))*NAGE(11)

      IF (J.GE.7) DIE(J,1)=(1-IS(I,J))*NAGE(1)

C  COMPUTE HARVEST STATISTICS (NOV-JAN)

      IF (J.GE.10) THEN

```

```
KILL=0.0
KILLAD=0.0
KILLIM=0.0
PREHAD=0.0
PREHIM=0.0
PREHAR=0.0
```

C INITIALIZE ANNUAL VARIABLES

```
IF (J.EQ.10) THEN
TOTKIL=0.0
TOTAD=0.0
TOTIM=0.0
ENDIF
```

C COMPUTE HARVEST

```
KILLIM=DIE(J,1)
DO 80 L=2,11
KILLAD=KILLAD+DIE(J,L)
80 CONTINUE
KILL=KILLAD+KILLIM
TOTAD=TOTAD+KILLAD
TOTIM=TOTIM+KILLIM
TOTKIL=TOTKIL+KILL
PREHIM=NAGE(1)
DO 81 L=2,11
PREHAD=PREHAD+NAGE(L)
81 CONTINUE
PREHAR=PREHAD+PREHIM
IF (J.EQ.10) PRE=PREHAR
IF (J.EQ.10) PREAD=PREHAD
IF (J.EQ.10) PREIM=PREHIM
```

C WRITE MONTHLY KILL TO SCREEN

```
WRITE(*,82) KILL,PREHAR
82 FORMAT(1X, 'MONTHLY KILL=', F9.2, ' OUT OF ', F9.2, ' GEESE.')
IF (J.EQ.12) THEN
```

C COMPUTE HARVEST RATE

```
HR=TOTKIL/PRE
HRAD=TOTAD/PREAD
HRIM=TOTIM/PREIM
```

C WRITE TOTAL NUMBER KILLED AND HARVEST RATE TO SCREEN

```
WRITE(*,85) TOTKIL,TOTAD,TOTIM
85 FORMAT(1X, 'TOTAL KILLED= ', F9.2, 3X, 'AD= ', F9.2, 3X, 'IM= ', F9.2)
WRITE(*,89) HR,HRAD,HRIM
89 FORMAT(1X, 'HARVEST RATE= ', F6.4, 3X, 'AD= ', F6.4, 3X, 'IM= ', F6.4)
IMAD=TOTIM/TOTAD
```

C WRITE IMMATURE TO ADULT RATIO IN HARVEST TO SCREEN

```
WRITE(*,86) IMAD
86 FORMAT(1X, 'IMMATURE/ADULT RATIO IN HARVEST=', F8.4)
ENDIF
ENDIF
```

C COMPUTE THE NUMBER OF INDIVIDUALS IN EACH AGE

```

C CLASS THAT SURVIVE EACH MONTH (AUG-JAN)
  IF (J.GE.7)  NAGE(1)=IS(I,J)*(NAGE(1))

```

106

```

  NAGE(4)=AS(I,J)*(NAGE(4))
  NAGE(3)=AS(I,J)*(NAGE(3))
  NAGE(2)=AS(I,J)*(NAGE(2))
  NAGE(5)=AS(I,J)*(NAGE(5))
  NAGE(6)=AS(I,J)*(NAGE(6))
  NAGE(7)=AS(I,J)*(NAGE(7))
  NAGE(8)=AS(I,J)*(NAGE(8))
  NAGE(9)=AS(I,J)*(NAGE(9))
  NAGE(10)=AS(I,J)*(NAGE(10))
  NAGE(11)=AS(I,J)*(NAGE(11))

```

```

C COMPUTE FALL FLIGHT POPULATION SIZE (1 SEPTEMBER)

```

```

  28  IF (J.EQ.7) THEN
      FALL=0.0
      DO 39 L=1,11
        FALL=FALL+NAGE(L)
      39 CONTINUE

```

```

C COMPUTE PERCENTAGE OF YOUNG IN THE FALL FLIGHT AND WRITE
C TO SCREEN

```

```

      PER1=NAGE(1)/FALL
      IF (I.EQ.1)  WRITE(*,410) AN,YN
      WRITE(*,36) PER1
  36  FORMAT(1X,'FALL FLIGHT PERCENTAGE OF YOUNG = ',F8.2)
      ENDIF

```

```

  25 CONTINUE

```

```

C COMPUTE TOTAL POPULATION SIZE (MIDWINTER; 1 FEBRUARY)

```

```

      TOT=0.0
      DO 69 L=1,11
        TOT=TOT+NAGE(L)
      69 CONTINUE

```

```

C COMPUTE PERCENTAGE OF POPULATION IN EACH AGE CLASS

```

```

      PER(1) = (NAGE(1)/TOT)*100.0
      PER(2) = (NAGE(2)/TOT)*100.0
      PER(3) = (NAGE(3)/TOT)*100.0
      PER(4) = (NAGE(4)/TOT)*100.0
      PER(5) = (NAGE(5)/TOT)*100.0
      PER(6) = (NAGE(6)/TOT)*100.0
      PER(7) = (NAGE(7)/TOT)*100.0
      PER(8) = (NAGE(8)/TOT)*100.0
      PER(9) = (NAGE(9)/TOT)*100.0
      PER(10) = (NAGE(10)/TOT)*100.0
      PER(11) = (NAGE(11)/TOT)*100.0

```

```

C WRITE TO SCREEN ANNUAL MIDWINTER POPULATION SIZE

```

```

      WRITE (*,3) I,I,TOT
  3  FORMAT (1X,I3,' THE TOTAL NUMBER OF GEESE WHICH SURVIVED YEAR ',
    +I3,' IS ',2X,F9.2)

```

```

      N=TOT

```


C WRITE AGE STRUCTURE OF MIDWINTER POPULATION TO SCREEN

```

      WRITE (*,1)
1  FORMAT (//,' THE MIDWINTER AGE STRUCTURE OF THE POPULATION IS:',/
+)

      DO 30, J=1,11
      WRITE (*,2) J,NAGE(J),PER(J)
2  FORMAT (1X,' NUMBER OF AGE',I2,' = ',F12.2,2X,
+'PERCENT OF TOTAL = ',2X,F5.2)
30 CONTINUE

10 CONTINUE

```

C PROMPT USER TO CONTINUE OR END SESSION

```

      FLAG='2ND'
      WRITE (*,800)
800  FORMAT(1X,'DO YOU WANT TO CONTINUE?')
      READ (*,401) A2
      IF (A2 .EQ. 'Y') GOTO 457

```

```

      STOP
      END

```

C

C The SUBROUTINE RAND is based on the method outlined by
C D.E. Knuth, The Art of Computer Programming, Vol.2 pp 155-156,
C and on a routine for the IBM 370 by I. Francis (Cornell 1973).

C

```

SUBROUTINE RAND(IY,RY)
  INTEGER*4 IY
  INTEGER*2 K
  REAL RY
  INTEGER*4 IA,IB,IC,ID,IE,AD,BC,BD,IZ,IV
  INTEGER*2 IS(6),IF(3),B,C
  EQUIVALENCE (IF(2),B),(IF(3),C),
*              (IF(2),IC),(IF(1),IZ)
  EQUIVALENCE (AD,IS(1)),(BC,IS(3)),(BD,IS(5))
  DATA IV/453806245/
  DATA IB,IA/12453,4793/
  IZ = IY
  C = 0
  ID = IC
  B = 0
  IE = IZ
  IC = 32768 * IE
  BD = IB * IE
  BD = BD + IC
  AD = IA * IE
  IC = 32768 * ID
  BC = IB * ID
  BC = BC + IC
  IF(IS(6) .lt. 0) IS(6) = IS(6) + 32767 + 1
  IS(2) = IS(1)
  IS(1) = 0
  IF(IS(2) .lt. 0) IS(2) = IS(2) + 32767 + 1
  IS(4) = IS(3)
  IS(3) = 0

```

```
IF(IS(4) .lt. 0) IS(4) = IS(4) + 32767 + 1
BD = BD + BC
IF(IS(6) .lt. 0) IS(6) = IS(6) + 32767 + 1
BD = BD + AD
IF(IS(6) .lt. 0) IS(6) = IS(6) + 32767 + 1
BD = BD + IV
IF(IS(6) .lt. 0) IS(6) = IS(6) + 32767 + 1
IY = BD
RY = IY
RY = RY * 0.4656613E-9
RETURN
END
```

APPENDIX II. SUMMARY OF THE MODELS USED TO ESTIMATE WITHIN
YEAR SURVIVAL RATES AND MARKER RETENTION RATES
FROM OBSERVATIONS OF DOUBLE MARKED DUSKY CANADA
GEESE

Table AII.1. Sex and time specific parameters under the full model used to estimate within year survival rates from neck band observations and neck band retention rates using observations of double banded dusky Canada geese.

Parameter	Time Period					
	Banded 1990				Banded 1991	
	Nov 1990	Feb 1991	Nov 1991	Feb 1992	Nov 1991	Feb 1992
<u>Neck Band Retention</u>						
Males	$R_{m,1,1}^1$	$R_{m,1,2}$	$R_{m,1,3}$	$R_{m,1,4}$	$R_{m,2,1}$	$R_{m,2,2}$
Females	$R_{f,1,1}$	$R_{f,1,2}$	$R_{f,1,3}$	$R_{f,1,4}$	$R_{f,2,1}$	$R_{f,2,2}$
<u>Tarsal Band Resighting Probability</u>						
Males	$C_{m,1,2}^2$	$C_{m,1,3}$	$C_{m,1,4}$	$C_{m,1,5}$	$C_{m,2,4}$	$C_{m,2,5}$
Females	$C_{f,1,2}$	$C_{f,1,3}$	$C_{f,1,4}$	$C_{f,1,5}$	$C_{f,2,4}$	$C_{f,2,5}$
<u>Survival Rate</u>						
Males	$S_{m,1,1}^3$	$S_{m,1,2}$	$S_{m,1,3}$	$S_{m,1,4}$	$S_{m,2,3}$	$S_{m,2,4}$
Females	$S_{f,1,1}$	$S_{f,1,2}$	$S_{f,1,3}$	$S_{f,1,4}$	$S_{f,2,3}$	$S_{f,2,4}$
<u>Neck Band Resighting Probability</u>						
Males	$P_{m,1,2}^4$	$P_{m,1,3}$	$P_{m,1,4}$	$P_{m,1,5}$	$P_{m,2,4}$	$P_{m,2,5}$
Females	$P_{f,1,2}$	$P_{f,1,3}$	$P_{f,1,4}$	$P_{f,1,5}$	$P_{f,2,4}$	$P_{f,2,5}$

¹ $R_{s,i,j}$ denotes the probability of retaining a neck band j time periods after banding for a bird of sex s (m =male, f =female) banded at time i .

² $C_{s,i,j}$ denotes the probability of reading a tarsal band during time j on a bird of sex s (m =male, f =female) banded at time i .

³ $S_{s,i,j}$ denotes the probability of surviving from time j to time $j+1$ for a bird of sex s (m =male, f =female) banded at time i .

⁴ $P_{s,i,j}$ denotes the probability of reading a neck band during time j on a bird of sex s (m =male, f =female) banded at time i .

Table AII.2. Constraints on the parameters of model 0 (Table AII.1) that define the more restrictive models to estimate within year survival rates from neck band observations and band retention rates using observations of double banded dusky Canada geese.

Model	Constraints
0	No constraints.
1	$R_{m,1,1}=R_{m,1,2}=R_{m,1,4}=R_{f,1,1}=R_{f,1,2}=R_{f,1,4}=R_{m,2,1}=R_{m,2,2}=R_{f,2,1}=R_{f,2,2}=1.0$
2	$R_{m,1,1}=R_{f,1,1}=R_{m,2,1}=R_{f,2,1}$, $R_{m,1,2}=R_{f,1,2}=R_{m,2,2}=R_{f,2,2}$, $R_{m,1,3}=R_{f,1,3}$, $R_{m,1,4}=R_{f,1,4}$,
3	Model 2 constraints; $P_{m,1,3}=P_{m,1,5}=P_{m,2,5}$, $P_{f,1,3}=P_{f,1,5}=P_{f,2,5}$
4	Model 2 & 3 constraints; $P_{m,1,2}=P_{m,1,4}=P_{m,2,4}$, $P_{f,1,2}=P_{f,1,4}=P_{f,2,4}$
5	Model 2 constraints; $P_{m,1,2}=P_{m,1,3}=P_{m,1,4}=P_{m,1,5}=P_{m,2,4}=P_{m,2,5}$, $P_{f,1,2}=P_{f,1,3}=P_{f,1,4}=P_{f,1,5}=P_{f,2,4}=P_{f,2,5}$
6	Model 2 constraints; $P_{m,1,2}=P_{m,1,3}=P_{m,1,4}=P_{m,1,5}=P_{m,2,4}=P_{m,2,5}=P_{f,1,2}=P_{f,1,3}=P_{f,1,4}=P_{f,1,5}=P_{f,2,4}=P_{f,2,5}$
7	Model 2 & 3 constraints; $C_{m,1,2}=C_{m,2,4}=C_{m,1,4}$, $C_{f,1,2}=C_{f,2,4}=C_{f,1,4}$
8	Model 2 & 3 constraints; $C_{m,1,2}=C_{m,2,4}=C_{m,1,4}=C_{m,1,3}$, $C_{f,1,2}=C_{f,2,4}=C_{f,1,4}=C_{f,1,3}$
9	Model 2 & 3 constraints; $C_{m,1,2}=C_{m,2,4}=C_{m,1,4}=C_{m,1,3}=C_{f,1,2}=C_{f,2,4}=C_{f,1,4}=C_{f,1,3}$
10	Model 2 & 3 constraints; $C_{m,1,2}=C_{f,1,2}$, $C_{m,1,3}=C_{f,1,3}$, $C_{m,1,4}=C_{m,2,4}=C_{f,1,4}=C_{f,2,4}$, $C_{m,1,5}=C_{m,2,5}=C_{f,1,5}=C_{f,2,5}$
11	Model 10 constraints; $S_{m,1,4}=S_{m,2,4}$, $S_{f,1,4}=S_{f,2,4}$
12	Model 10 constraints; $S_{m,1,4}=S_{m,2,4}=S_{m,1,2}$, $S_{f,1,4}=S_{f,2,4}=S_{f,1,2}$
13	Model 2 constraints; $S_{m,1,1}=S_{f,1,1}$, $S_{m,1,2}=S_{f,1,2}$, $S_{m,1,3}=S_{f,1,3}$, $S_{m,2,3}=S_{f,2,3}$, $S_{m,1,4}=S_{f,1,4}=S_{m,2,4}=S_{f,2,4}$
14	Model 10 & 12 constraints

Table AII.3. Descriptive summary of the models (Table AII.2) to estimate within year survival rates from neck band observations and neck band retention rates using observations of double banded dusky Canada geese.

Model	Neck band retention rate	Tarsal band resighting probability	Survival rate	Neck Band resighting probability
0	No constraints.	No constraints.	No constraints.	No constraints.
1	Retention rates equal 1.0 for 1,2, and 4 periods after banding.	No constraints.	No constraints.	No constraints.
2	Male and female rates equal.	No constraints.	No constraints.	No constraints.
3	Model 2 constraints.	No constraints.	No constraints.	Resighting probabilities within Feb constant over time within sex.
4	Model 2 constraints.	No constraints.	No constraints.	Model 3 constraints; Resighting probabilities within Nov constant over time within sex.
5	Model 2 constraints.	No constraints.	No constraints.	Resighting probabilities constant over time within sex.
6	Model 2 constraints.	No constraints.	No constraints.	Resighting probabilities constant over time.
7	Model 2 constraints.	Resighting probabilities within Nov equal over time.	No constraints.	Model 3 constraints.
8	Model 2 constraints.	Resighting probabilities constant over time within sex.	No constraints.	Model 3 constraints.

Table AII.3. Continued.

<u>Model</u>	<u>Neck band retention rate</u>	<u>Tarsal band resighting probability</u>	<u>Survival rate</u>	<u>Neck Band resighting probability</u>
9	Model 2 constraints.	Resighting probabilities constant over time.	No constraints.	Model 3 constraints.
10	Model 2 constraints.	Male and female resighting probabilities equal.	No constraints.	Model 3 constraints.
11	Model 2 constraints.	Model 10 constraints.	Survival during Nov-Feb equal among banded cohorts 1991-92.	Model 3 constraints.
12	Model 2 constraints.	Model 10 constraints.	Survival during Nov-Feb equal over time within sex.	Model 3 constraints.
13	Model 2 constraints.	No constraints.	Male and female survival equal.	No constraints.
14	Model 2 constraints.	Model 10 constraints.	Model 11 constraints.	Model 3 constraints.

Table AII.4. Akaike's Information Criterion (AIC) values for capture-resighting models (Table AII.2) to estimate within year survival rates from neck band observations and neck band retention rates using observations of double banded dusky Canada geese. 114

Model	Log-likelihood	Number of parameters	AIC
0	-151.031	34	370.062
1	-151.048	30	362.096
2	-151.048	30	362.096
3	-151.048	28	358.096
4	-157.410	26	366.820
5	-171.580	23	389.154
6	-157.009	26	366.018
7	-166.958	24	381.916
8	-168.067	23	382.134
9	-152.059	26	356.118
10	-152.802	25	355.604
11	-156.727	24	353.626
12	-153.459	23	338.962
13	-153.538	21	352.918
14	-155.292	18	346.589

Table AII.5. Sex and time specific parameters under the full model used to estimate within year survival rates from observations of neck banded dusky Canada geese.

Parameter	Time Period					
	Banded 1990				Banded 1991	
	Nov 1990	Feb 1991	Nov 1991	Feb 1992	Nov 1991	Feb 1992
<u>Survival Rate</u>						
Males	$S_{m,1,1}^1$	$S_{m,1,2}$	$S_{m,1,3}$	$S_{m,1,4}$	$S_{m,2,3}$	$S_{m,2,4}$
Females	$S_{f,1,1}$	$S_{f,1,2}$	$S_{f,1,3}$	$S_{f,1,4}$	$S_{f,2,3}$	$S_{f,2,4}$
<u>Neck Band Resighting Probability</u>						
Males	$P_{m,1,2}^2$	$P_{m,1,3}$	$P_{m,1,4}$	$P_{m,1,5}$	$P_{m,2,4}$	$P_{m,2,5}$
Females	$P_{f,1,2}$	$P_{f,1,3}$	$P_{f,1,4}$	$P_{f,1,5}$	$P_{f,2,4}$	$P_{f,2,5}$

¹ $S_{s,i,j}$ denotes the probability of surviving from time j to time $j+1$ for a bird of sex s (m =male, f =female) banded at time i .

² $P_{s,i,j}$ denotes the probability of reading a neck band during time j on a bird of sex s (m =male, f =female) banded at time i .

Table AII.6. Constraints on the parameters of model 0 (Table AII.5) that define the more restrictive models to estimate within year survival rates from observations of neck banded dusky Canada geese.

Model	Constraints
0	No constraints.
1	$P_{m,1,3}=P_{m,1,5}=P_{m,2,5}, P_{f,1,3}=P_{f,1,5}=P_{f,2,5}$
2	Model 1 constraints; $P_{m,1,2}=P_{m,1,4}=P_{m,2,4}, P_{f,1,2}=P_{f,1,4}=P_{f,2,4}$
3	$P_{m,1,2}=P_{m,1,3}=P_{m,1,4}=P_{m,1,5}=P_{m,2,4}=P_{m,2,5}, P_{f,1,2}=P_{f,1,3}=P_{f,1,4}=P_{f,1,5}=P_{f,2,4}=P_{f,2,5}$
4	$P_{m,1,2}=P_{m,1,3}=P_{m,1,4}=P_{m,1,5}=P_{m,2,4}=P_{m,2,5}=P_{f,1,2}=P_{f,1,3}=P_{f,1,4}=P_{f,1,5}=P_{f,2,4}=P_{f,2,5}$
5	$S_{m,1,4}=S_{m,2,4}=S_{m,1,2}, S_{f,1,4}=S_{f,2,4}=S_{f,1,2}$
6	Model 1 constraints; Model 5 constraints
7	$S_{m,1,1}=S_{f,1,1}, S_{m,1,2}=S_{f,1,2}, S_{m,1,3}=S_{f,1,3}, S_{m,2,3}=S_{f,2,3}, S_{m,1,4}=S_{f,1,4}=S_{m,2,4}=S_{f,2,4}$
8	Model 1 constraints; Model 7 constraints

Table AII.7. Descriptive summary of the models (Table AII.6) to estimate within year survival rates from observations of neck banded dusky Canada geese.

Model	Survival rate	Neck Band resighting probability
0	No constraints.	No constraints.
1	No constraints.	Resighting probabilities within Feb constant over time within sex.
2	No constraints.	Model 1 constraints; Resighting probabilities within Nov constant over time within sex.
3	No constraints.	Resighting probabilities constant over time within sex.
4	No constraints.	Resighting probabilities constant over time.
5	Survival during Nov-Feb constant over time within sex.	No constraints.
6	Model 5 constraints.	Model 1 constraints.
7	Male and female survival equal.	No constraints.
8	Model 7 constraints.	Model 1 constraints.

Table AII.8. Akaike's Information Criterion (AIC) values for 118
capture-resighting models (Table AII.6) to estimate
within year survival rates from neck band observations.

Model	Log-likelihood	Number of parameters	AIC
0	- 92.635	20	225.270
1	- 96.635	18	221.270
2	- 98.997	16	229.994
3	-110.647	14	249.294
4	-113.164	13	252.328
5	- 93.646	16	219.292
6	- 93.855	14	215.710
7	- 94.743	14	217.486
8	- 95.125	11	212.250

Table AII.9. Sex and time specific parameters under the full model used to estimate within year survival rates from tarsal band observations and tarsal band retention rates using observations of double banded dusky Canada geese.

Parameter	Time Period					
	Banded 1990				Banded 1991	
	Nov 1990	Feb 1991	Nov 1991	Feb 1992	Nov 1991	Feb 1992
<u>Tarsal Band Retention</u>						
Males	$R_{m,1,1}^1$	$R_{m,1,2}$	$R_{m,1,3}$	$R_{m,1,4}$	$R_{m,2,1}$	$R_{m,2,2}$
Females	$R_{f,1,1}$	$R_{f,1,2}$	$R_{f,1,3}$	$R_{f,1,4}$	$R_{f,2,1}$	$R_{f,2,2}$
<u>Neck Band Resighting Probability</u>						
Males	$C_{m,1,2}^2$	$C_{m,1,3}$	$C_{m,1,4}$	$C_{m,1,5}$	$C_{m,2,4}$	$C_{m,2,5}$
Females	$C_{f,1,2}$	$C_{f,1,3}$	$C_{f,1,4}$	$C_{f,1,5}$	$C_{f,2,4}$	$C_{f,2,5}$
<u>Survival Rate</u>						
Males	$S_{m,1,1}^3$	$S_{m,1,2}$	$S_{m,1,3}$	$S_{m,1,4}$	$S_{m,2,3}$	$S_{m,2,4}$
Females	$S_{f,1,1}$	$S_{f,1,2}$	$S_{f,1,3}$	$S_{f,1,4}$	$S_{f,2,3}$	$S_{f,2,4}$
<u>Tarsal Band Resighting Probability</u>						
Males	$P_{m,1,2}^4$	$P_{m,1,3}$	$P_{m,1,4}$	$P_{m,1,5}$	$P_{m,2,4}$	$P_{m,2,5}$
Females	$P_{f,1,2}$	$P_{f,1,3}$	$P_{f,1,4}$	$P_{f,1,5}$	$P_{f,2,4}$	$P_{f,2,5}$

¹ $R_{s,i,j}$ denotes the probability of retaining a tarsal band j time periods after banding for a bird of sex s (m =male, f =female) banded at time i .

² $C_{s,i,j}$ denotes the probability of reading a neck band during time j on a bird of sex s (m =male, f =female) banded at time i , given that the legs were visible for examination to determine presence or absence of a tarsal band.

³ $S_{s,i,j}$ denotes the probability of surviving from time j to time $j+1$ for a bird of sex s (m =male, f =female) banded at time i .

⁴ $P_{s,i,j}$ denotes the probability of reading a tarsal band during time j on a bird of sex s (m =male, f =female) banded at time i .

Table AII.10. Constraints on the parameters of model 0 (Table AII.9) that define the more restrictive models to estimate within year survival rates from tarsal band observations and tarsal band retention rates using observations of double banded dusky Canada geese.

Model	Constraints
0	No constraints.
1	$R_{m,1,1}=R_{f,1,1}=R_{m,2,1}=R_{f,2,1}$, $R_{m,1,2}=R_{f,1,2}=R_{m,2,2}=R_{f,2,2}$, $R_{m,1,3}=R_{f,1,3}$, $R_{m,1,4}=R_{f,1,4}$,
2	Model 1 constraints; $P_{m,1,3}=P_{m,1,5}=P_{m,2,5}$, $P_{f,1,3}=P_{f,1,5}=P_{f,2,5}$
3	Model 1 & 2 constraints; $P_{m,1,2}=P_{m,1,4}=P_{m,2,4}$, $P_{f,1,2}=P_{f,1,4}=P_{f,2,4}$
4	Model 1 constraints; $P_{m,1,2}=P_{m,1,3}=P_{m,1,4}=P_{m,1,5}=P_{m,2,4}=P_{m,2,5}$, $P_{f,1,2}=P_{f,1,3}=P_{f,1,4}=P_{f,1,5}=P_{f,2,4}=P_{f,2,5}$
5	Model 1 constraints; $P_{m,1,2}=P_{m,1,3}=P_{m,1,4}=P_{m,1,5}=P_{m,2,4}=P_{m,2,5}=P_{f,1,2}=P_{f,1,3}=P_{f,1,4}=P_{f,1,5}=P_{f,2,4}=P_{f,2,5}$
6	Model 1 & 2 constraints; $C_{m,1,2}=C_{m,2,4}=C_{m,1,4}$, $C_{f,1,2}=C_{f,2,4}=C_{f,1,4}$
7	Model 1 & 2 constraints; $C_{m,1,2}=C_{m,2,4}=C_{m,1,4}=C_{m,1,3}$, $C_{f,1,2}=C_{f,2,4}=C_{f,1,4}=C_{f,1,3}$
8	Model 1 & 2 constraints; $C_{m,1,2}=C_{m,2,4}=C_{m,1,4}=C_{m,1,3}=C_{f,1,2}=C_{f,2,4}=C_{f,1,4}=C_{f,1,3}$
9	Model 1 & 3 constraints; $C_{m,1,2}=C_{f,1,2}$, $C_{m,1,3}=C_{f,1,3}$, $C_{m,1,4}=C_{m,2,4}=C_{f,1,4}=C_{f,2,4}$, $C_{m,1,5}=C_{m,2,5}=C_{f,1,5}=C_{f,2,5}$
10	Model 9 constraints; $S_{m,1,4}=S_{m,2,4}$, $S_{f,1,4}=S_{f,2,4}$
11	Model 9 constraints; $S_{m,1,4}=S_{m,2,4}=S_{m,1,2}$, $S_{f,1,4}=S_{f,2,4}=S_{f,1,2}$
12	Model 1 constraints; $S_{m,1,1}=S_{f,1,1}$, $S_{m,1,2}=S_{f,1,2}$, $S_{m,1,3}=S_{f,1,3}$, $S_{m,2,3}=S_{f,2,3}$, $S_{m,1,4}=S_{f,1,4}=S_{m,2,4}=S_{f,2,4}$
13	Model 9 & 12 constraints

Table AII.11. Descriptive summary of the models (Table AII.10) to estimate within year survival rates from tarsal band observations and tarsal band retention rates using observations of double banded dusky Canada geese.

Model	Tarsal band retention rate	Neck band resighting probability	Survival rate	Tarsus Band resighting probability
0	No constraints.	No constraints.	No constraints.	No constraints.
1	Male and female rates equal.	No constraints.	No constraints.	No constraints.
2	Model 1 constraints.	No constraints.	No constraints.	Resighting probabilities within Feb constant over time within sex.
3	Model 1 constraints.	No constraints.	No constraints.	Model 2 constraints; Resighting probabilities within Nov constant over time within sex.
4	Model 1 constraints.	No constraints.	No constraints.	Resighting probabilities constant over time within sex.
5	Model 1 constraints.	No constraints.	No constraints.	Resighting probabilities constant over time.
6	Model 1 constraints.	Resighting probabilities within Nov equal over time.	No constraints.	Model 3 constraints.
7	Model 1 constraints.	Resighting probabilities constant over time within sex.	No constraints.	Model 3 constraints.
8	Model 1 constraints.	Resighting probabilities constant over time.	No constraints.	Model 3 constraints.

Table AII.11. Continued.

<u>Model</u>	<u>Tarsal band retention rate</u>	<u>Neck band resighting probability</u>	<u>Survival rate</u>	<u>Tarsal Band resighting probability</u>
9	Model 1 constraints.	Male and female resighting probabilities equal.	No constraints.	Model 3 constraints.
10	Model 1 constraints.	Model 9 constraints.	Survival during Nov-Feb equal among banded cohorts 1991-92.	Model 3 constraints.
11	Model 1 constraints.	Model 9 constraints.	Survival during Nov-Feb equal over time within sex.	Model 3 constraints.
12	Model 1 constraints.	No constraints.	Male and female survival equal.	No constraints.
13	Model 1 constraints.	Model 9 constraints.	Model 12 constraints.	Model 3 constraints.

Table AII.12. Akaike's Information Criterion (AIC) values for 123
capture-resighting models (Table AII.10) to estimate
within year survival rates from tarsal band observations
and tarsal band retention rates using observations of
double banded dusky Canada geese.

Model	Log-likelihood	Number of parameters	AIC
0	-171.027	34	410.054
1	-172.841	30	405.682
2	-172.841	28	401.682
3	-177.234	28	410.468
4	-190.331	24	428.662
5	-191.200	23	428.400
6	-187.855	24	423.710
7	-199.905	22	443.810
8	-201.347	21	444.694
9	-179.677	23	405.354
10	-183.685	21	409.370
11	-190.170	19	418.340
12	-179.506	23	405.012
13	-184.762	16	401.524

APPENDIX III. SUMMARY OF BANDING AND OBSERVATION DATA FOR
ADULT DUSKY CANADA GEESE MARKED WITH A NECK
BAND DURING 1984-92.

Table AIII.1. Number of adult dusky Canada geese marked with a neck band during 1984-91 on the Copper River Delta, Alaska.

Year	Number banded			Total
	Male	Female	Unknown	
1984	215	181	6	402
1985	1,026	904	10	1,940
1986	255	200	0	455
1987	259	184	0	443
1988	233	176	4	413
1989	248	177	0	425
1990	272	214	0	486
1991	295	201	0	496
Total	2,803	2,237	20	5,060

Table AIII.2. Number of observations and number of individual dusky
Canada geese sighted during 1 November - 31 March,
1985-92. Observations are of adult geese banded with a
neck band.

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Period	Number of observations			Number of individuals		
	Adult Male	Adult Female	Total	Adult Male	Adult Female	Total
1985-86	5,909	5,110	11,019	819	714	1,533
1986-87	4,582	3,949	8,531	815	666	1,481
1987-88	4,241	3,766	8,007	732	628	1,360
1988-89	2,487	2,269	4,756	640	582	1,222
1989-90	5,951	5,744	11,695	737	686	1,423
1990-91	5,769	5,073	10,842	705	633	1,338
1991-92	4,216	3,973	8,198	696	625	1,321

Table AIII.3. Frequency distribution of the number (#) and percentage (%) of dusky Canada geese observed during 1 November - 31 March, 1985-92. Observations are of adult geese banded with a neck band.

Number of sightings	1985-86		1986-87		1987-88		1988-89		1989-90		1990-91		1991-92	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%
1	238	15.4	280	18.9	317	23.2	335	27.3	228	16.0	213	15.9	218	16.5
2	210	13.6	227	15.3	212	15.5	182	14.8	93	6.5	99	7.4	146	11.0
3	173	11.2	192	12.9	167	12.2	163	13.3	97	6.8	96	7.2	145	11.0
4	152	9.9	159	10.7	136	10.0	155	12.6	95	6.6	81	6.0	123	9.3
5	99	6.4	123	8.3	98	7.2	101	8.2	88	6.2	89	6.6	112	8.5
6	113	7.3	97	6.5	69	5.1	78	6.4	111	7.8	78	5.8	97	7.3
7	87	5.7	70	3.2	57	4.2	65	5.3	95	6.7	83	6.2	84	6.3
8	83	5.4	48	2.2	52	3.8	36	2.9	78	5.5	82	6.1	67	5.1
9	64	4.2	32	2.4	30	2.2	29	2.4	71	5.0	77	5.7	74	6.0
10	49	3.2	35	2.2	26	1.9	25	2.0	73	5.1	83	6.2	49	3.8
≥11	179	17.7	167	17.4	133	14.7	58	4.8	313	27.8	275	26.9	168	15.2