

Conservation Assessment for the Dusky Canada Goose (*Branta canadensis occidentalis* Baird)

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This report was prepared as a synthesis of biological information to assist agencies responsible for the management of dusky Canada geese and their habitats. Under a 1998 Memorandum of Understanding, the U.S. Fish and Wildlife Service, Alaska Department of Fish and Game, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, and U.S. Department of Agriculture, Forest Service and Animal and Plant Health Inspection Service have agreed to cooperate to provide for the protection, management, and maintenance of the dusky Canada goose population.

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Abstract

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Dusky Canada geese compose one of the smallest populations of geese in North America and have exhibited a marked decline in the past 30 years. A comprehensive synthesis of past and current biological information on the subspecies has been compiled to provide insights into the ecology and demography of the population, as well as explore management efforts to promote long-term conservation. Dusks occupy a discrete range, which has allowed the development of focused, long-standing management programs. The 1964 Alaska earthquake set in motion significant ecological changes in wetlands, plant communities, and the suite of predators on the dusky goose breeding grounds. A subsequent decline in goose productivity has become the primary challenge to this population. Concurrently, habitats on the western Washington and Oregon wintering grounds became more favorable for geese, but over 250,000 Canada geese of five other subspecies now occupy the region where formerly dusks were the majority. In the 1960s, the harvest of dusky geese was recognized as a primary management concern and regulation was effectively implemented. At present, protection of diminished dusks amid 10 times as many other Canada geese has created great complications for both management of hunting and attention to increasing complaints of crop depredation by wintering flocks. Important information needs are suggested to improve population monitoring, evaluate specific causes of lost productivity, and assess the direction and effects of succession of breeding ground habitats and conversion of winter habitats.

Keywords: Dusky Canada goose, *Branta canadensis occidentalis*, Alaska, Copper River Delta, nest predation, Willamette Valley.

Preface

Canada geese (*Branta canadensis*) are among the most genetically diverse waterfowl species in North America, with 11 distinct subspecies (Delacour 1954), including the dusky. Historical data and recent studies of genetics suggest that the Canada geese of the north Pacific coast have expanded and segregated into several breeding populations only since the last glacial retreat, and that genetic composition among Canada geese is quite dynamic in some areas. These characteristics challenge wildlife agencies not only to answer the essential question of “What is a dusky Canada goose?” but also to develop a regime of goose management that is both practical and conservative of biodiversity.

The dusky Canada goose population nests primarily on the Cooper River Delta of Alaska’s south-central coast. The 1964 earthquake that occurred in this region triggered significant, long-term changes to habitats used by geese and a suite of avian and mammalian predators. Over the past 20 years, high predation rates on eggs, goslings, and adult geese have resulted in significantly lower goose production. Agencies responsible for the management of dusky Canada geese and their habitats recognize the diminished capacity for production in this population, as well as the special challenges involved in addressing their long-term conservation needs. They share the goals of ensuring that the dusky Canada goose population remains secure and that its public values are perpetuated. This conservation assessment is intended to provide a thorough summary of historical and recent biological information about dusky geese as a resource for evaluating the current status of the population and planning future management and research programs.

Waterfowl in the United States are managed cooperatively within four administrative flyways. The dusky Canada goose is restricted in its distribution to the Pacific Flyway, and its management is coordinated through the Pacific Flyway Council (11 Western States) and cooperators. Key agencies include the U.S. Department of the Interior Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Washington Department of Fish and Wildlife, Alaska Department of Fish and Game, and U.S. Department of Agriculture Forest Service. Long-term conservation goals, current issues, and recommended management activities are embodied in the Pacific Flyway Management Plan for the Dusky Canada Goose (Pacific Flyway Council 1997). Successful management of dusky Canada geese relies on extensive cooperation among state and federal wildlife agencies, agencies that manage public lands, and private landowners that support goose conservation.

The status of the dusky Canada goose and priority actions for its conservation are key elements in efforts to integrate management of aggregate wintering Canada goose stocks, public hunting, and goose depredation on agricultural crops in the Pacific Northwest. Guidelines for addressing these more complex issues are found in the Northwest Oregon/Southwest Washington Canada Goose Agricultural Depredation Control Plan (Pacific Flyway Council 1998).

Summary

The dusky Canada goose (*Branta Canadensis occidentalis* Baird) is a medium-sized, dark-plumaged subspecies that nests in the Copper River Delta (CRD) region of south-central Alaska, migrates along the Pacific coast, and winters in southwestern Washington and western Oregon. Originally thought to include geese breeding in coastal regions of southeast Alaska and northern British Columbia, it is now recognized as being unique to a small part of the Gulf of Alaska. Subpopulations include those that nest on the CRD, and those that nest on islands within Prince William Sound and on Middleton Island in the Gulf of Alaska. This assessment focuses on the birds of the CRD; this subpopulation is the one experiencing decline and uncertainty, whereas island geese have been stable or increasing in number.

Over the past two decades, numbers of geese on the CRD have varied, but generally declined from 20,000 to 25,000 in the 1970s to between 12,000 and 15,000 in the 1990s. In response to the changing status of this population, the Pacific Flyway Council and Study Committee, and agencies participating in the management of duskys, cooperated in the development of this conservation assessment. The purposes are to (1) provide a comprehensive synthesis of current biological information on dusky Canada geese complementary to the recently revised Pacific Flyway Management Plan for the Dusky Canada Goose (Pacific Flyway Council 1997), (2) present an updated assessment of factors affecting the size and stability of the population, and (3) serve as an aid to conservation planning and identification of information needs.

Dusky Canada geese winter in nutrient-rich, agricultural cropland where they store large fat reserves important in meeting the energy needs of migration and reproduction. In early to mid April, they migrate to the nesting grounds where they again feed vigorously to supplement fat reserves prior to and during egg laying. Clutch size is four to six, and eggs are incubated for about 27 days. By early to late June, most eggs hatch, and young gain flight by early to mid August, about the time breeding adults complete their molt. Fall departure begins in September and is complete by late October. Little is known about migration ecology, but geese arrive on the wintering grounds in October and November.

The CRD, the summer habitat of the geese, is a highly dynamic region continually influenced by tectonic, glacial, riverine, and tidal forces. Duskys were highly productive during the 1950s through 1970s, and the population was thought limited by hunting mortality, primarily on wintering grounds. There was minor loss of eggs to inundation by high spring tides, and similarly low rates of loss of adults, eggs, and young to predators. Indeed, numbers of geese responded quickly and positively to restrictive hunting regulations, and to the establishment of refuges on their wintering grounds during the mid-1960s. In 1964, however, an earthquake caused an uplift of the nesting grounds on the CRD, accelerating natural succession of marsh habitat toward forested habitat. Although breeding success remained high during the first 12 to 15 years postearthquake, substantial changes in nesting and brood-rearing habitat began to occur. As soil salts were leached away by high rainfall and lack of regular tidal inundation, the salt-tolerant plant community gave way to expansion of willows, alders, and sweet gale. More recently, spruce and cottonwoods have become well established in the old marsh habitat still used by nesting geese.

Associated with changes in the plant ecology on the delta were concomitant faunal changes. In particular, brown bears and coyotes occurred on nesting and brood-rearing areas in greater abundance than previously and were much more active predators on the geese and their eggs. Nest success rates wavered, then plummeted to low levels (4 to 44 percent) where they have remained over the past decade. As succession progressed, predator species, numbers, and effect on duskys varied. Current research on predators of eggs, adults, and goslings indicates that bald eagles may be the most important predator on the delta. Duskys responded to high rates of nest depredation by renesting, a phenomenon not documented previously. First nests often have relatively low success compared to nests initiated later in the season, probably because alternative prey become abundant as the season progresses. Nevertheless, average nest success of individual pairs remains low and is made worse by low gosling survival.

Beginning in the late 1930s and through the late 1940s, managers recognized that dusky geese wintered primarily in the Willamette Valley, Oregon, and in the lower Columbia River of Oregon and Washington. Analysis of leg bands returned in the mid-1950s established that these geese were from the CRD, and by the 1960s, most of the geese on the wintering grounds were enumerated as dusky geese. As conditions changed in summer habitats, other events caused changing conditions on wintering grounds. Perhaps because of protection provided to dusky geese, as well as favorable agricultural food resources, other subspecies of geese increased in both diversity and abundance on the wintering grounds of dusky geese. Starting in the early 1970s, a noticeable increase in Taverner's (*B.c. taverni* Delacour) and lesser Canada geese (*B.c. parvipes* Cassin) was recorded. Since then, numbers of western Canada geese (*B.c. moffitti* Aldrich) also have increased, and, in the 1990s, the majority of cackling Canada geese (*B.c. minima* Ridgway) shifted their winter range from California to western Oregon. Small numbers of Vancouver Canada geese (*B.c. fulva* Delacour) have always wintered there, but trends in their wintering number remain unknown. Thus, where 25,000 geese, primarily dusky geese, once wintered, there are now over 250,000 birds of which only a small proportion are dusky geese.

In response to low productivity and high vulnerability to hunting mortality relative to other sympatric wintering geese, managers began to limit the harvest of dusky geese in the 1980s. Currently, Canada goose hunting is permitted in wintering areas only as long as the harvest includes less than an annual quota of 250 dusky geese. Consequently, survival rates of adult birds have increased dramatically. The population, however, is now limited by factors associated with accelerated ecological succession on the breeding grounds, primarily depredation of eggs, young, and adults. Thus, since the late 1970s, the population has declined to about half its former peak abundance. Significant management efforts on the breeding grounds have included experimentation with, and operational establishment and maintenance of, artificial nesting islands on the CRD. Dusky geese consistently have much higher nest success (averaging 59 percent) on the structures than at natural sites (averaging 22 percent).

The size of the dusky population has been monitored on wintering grounds since 1947 and on breeding grounds since 1978, but survey difficulties persist for both areas. On the wintering grounds, traditional midwinter aerial surveys sufficed until other races of geese began wintering sympatrically with and in greater numbers than dusky geese. Subsequently, aerial surveys were complemented with ground surveys in the mid-1970s, and aerial photography was implemented in the 1980s to determine the proportions of large dark geese in the midwinter population. Since 1995, a mark-resight procedure has been used to yield an indirect population estimate. Ratios of dusky geese marked with colored neckbands to unmarked dusky geese are determined from samples of geese observed during two resighting periods. A population estimate is developed by expanding the total number of recorded marked individuals by a factor for the unmarked proportion of the population. This method, however, assumes that all marked geese are equally likely to be observed during resighting survey periods. Results of recent surveys suggest that the detectability of marked geese and accuracy of the indirect estimates may vary by year; major weather events in some years have thoroughly mixed dusky geese to produce unusually effective sampling. Monitoring of the CRD subpopulation during winter has been even more challenging because these geese winter with island geese from Prince William Sound and Middleton Island. The problem of observers not being able to distinguish the groups is exacerbated to an unknown degree by other large dark birds such as Vancouver Canada geese and immature urban geese from Anchorage mixing with dusky geese in Oregon and Washington.

On the CRD, aerial surveys seem to have provided reliable trends in numbers of geese on nesting areas. Experimental work has yielded widely differing and unpredictable air-to-ground correction factors, thus preventing the derivation of total estimates from aerial survey indices. Rapidly increasing canopy closure from accelerated shrub succession on the delta has further thwarted development of visibility correction factors. Despite these complexities, there is general agreement that the CRD population increased in number until the late 1970s, then rapidly declined in the 1980s, and has remained low but relatively stable through the 1990s. Efforts to increase the reliability of population estimates remain a priority for managers.

In the short term, accelerated succession is expected to continue on the CRD, and productivity of geese will likely remain low because of high levels of predator activity. New marsh habitat will slowly develop on accreting upper tidal areas, but it will not likely affect productivity of the dusky goose population in the near term. Artificial nest islands will continue to enhance gosling production, but the degree to which this program improves gosling and adult survival and recruitment is a critical unknown. Therefore, adult mortality remains a critical parameter warranting close monitoring of the population and cautious management of harvest.

Although there are no known examples of dispersal between CRD geese and island geese, it is likely that some exchange between subpopulations occurs. In the context of a metapopulation, dispersal between subpopulations likely will gain significance over time. The CRD is currently a sink for geese, but it is possible that geese from Middleton Island and Prince William Sound will become a source for dusky. Contributions of breeding birds dispersing from these areas to the CRD will either help the CRD population persist over time until favorable habitat conditions are restored or will help to reestablish dusky after salt-marsh conditions return. The enhancement of this possibility is seen as a management opportunity.

In the long term, studies have indicated that the delta is characterized by cycles of uplift followed by gradual subsidence that occur over intervals of 600 to 900 years. Thus, over the next hundreds of years, gradual development of new marsh, coupled with subsidence of the old marsh, will eventually cause reversion of much of the CRD to salt marsh once again. To benefit in the future, dusky must survive as a viable population over the long term. Based on the examples of several other small populations of geese that have persisted in coastal Alaska, and with the degree of management attention being directed to dusky, there are reasons to be optimistic. Vigilant monitoring and innovative management will likely be key as habitat evolves, predators change, and the influence of man is manifested in unpredictable ways.

Important topics for research include taxonomic review of regional populations of breeding geese; improvement of population estimates; detection and enhancement of dispersal between subpopulations; evaluation of the potential effect of an aging population on their productivity; regular updating of information on important predators and their changing roles in the face of habitat change, with an eye toward management opportunities; assessment of how habitat changes will influence nutritional aspects of reproduction; and investigation of establishment of new coastal marsh, including development of methods to predict rates of expansion.

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Introduction

The dusky Canada goose (*Branta canadensis occidentalis* Baird) is a distinctive race of medium-size geese (about 3 kg) with dark brown plumage that primarily nests on the Copper River Delta (CRD), Alaska, migrates through south-eastern coastal Alaska and coastal British Columbia, and winters primarily in southwestern Washington and western Oregon. The population has been intensively managed since the 1950s (Pacific Flyway Council 1973, 1985, 1992). Despite management, the size of the population has gone through considerable fluctuations over the past three decades, with an overall decline since the late 1970s. Events on both the breeding and wintering grounds have affected the status of dusks. In 1964, an earthquake caused the nesting grounds of the geese to be uplifted an average of 2 m, initiating decades of dramatically accelerated plant and animal succession and physiographic change that is ongoing today. This succession has resulted in significant habitat changes, with associated effects on activities and populations of goose predators and subsequent detrimental effects on productivity and numbers of geese.

Beginning in the early 1970s and increasing to the present, tens of thousands of Canada geese of several other races began wintering sympatrically with dusks. Only 25,000 Canada geese, the vast majority being dusks, wintered in the Willamette Valley of Oregon in 1973. Over 250,000 Canada geese, less than 10 percent dusks, winter there today. Harvest management and population estimation of dusks became more complex and challenging in the face of this massive buildup of geese, particularly given the dusks' declining productivity and relatively high vulnerability to hunting.

In response to the changing status of this population, the Pacific Flyway Council and Study Committee and agencies participating in the management of dusks cooperated in the development of this conservation assessment. The purposes are to (1) provide a comprehensive synthesis of current biological information on dusky Canada geese complementary to the recently revised Pacific Flyway Management Plan for the Dusky Canada

Goose (Pacific Flyway Council 1997), (2) present an updated assessment of factors affecting the size and stability of the population, and (3) serve as an aid to conservation planning and identification of information needs.

Taxonomic Status

Original Description

The type specimen for dusky Canada geese (*Branta canadensis occidentalis* Baird), originally *Bernicla occidentalis*, was collected near Port Townsend, Washington, in 1857 and described by Baird (1858). The bird had upperparts of dark wood brown, and the underparts were very dark brown. He reported a total body length of about 890 mm and a tarsus of 87.4 mm. Baird (1858) reported the habitat (range) as the west coast of North America.

Recognition as Valid, Well-Defined Subspecies

All large, dark Canada geese (white-cheeked geese) breeding on the Pacific Coast from Prince William Sound (PWS) to northern California or at least to Vancouver Island, British Columbia, were originally placed in *occidentalis* (Aldrich 1946, AOU 1910), until Delacour (1951, 1954) split *Branta canadensis fulva* off as a separate subspecies. The Vancouver Canada goose (*B. c. fulva*) is slightly larger and lighter-plumed than the dusky (Johnson et al. 1979). Vernacular names (dusky and Vancouver) follow Hansen and Nelson (1964). The dusky is generally now recognized as a valid subspecies (Aldrich 1946; Bellrose 1986; Delacour 1951, 1954); however, Dickinson (1953), Ogilvie (1978), and Palmer (1976) suggest combining *B. c. fulva* with *occidentalis*, and Sibley and Monroe (1990) did not recognize dusky geese in their review of world bird taxonomy.

Richard C. Banks, chief taxonomist with the U.S. Fish and Wildlife Service (USFWS), in a 1992 memo to Chief, Office of Migratory Bird Management (Banks 1992), reported that the National Museum of Natural History follows the American Ornithologists' Union checklist, 5th edition (AOU

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1957), for subspecies classifications of Canada geese. Banks recognizes the 10 subspecies listed there, including *B. c. occidentalis* and *fulva*, plus an 11th, Taverner's (*B. c. taverneri* Delacour). Although the dusky Canada goose was not included in the 6th edition of the checklist (AOU 1983), it is currently recognized and managed as a distinct subspecies (Pacific Flyway Council 1997).

Morphology

Copper River Delta geese—The dusky Canada goose is a medium-sized race with a body mass of 2.7 to 3.9 kg during winter (Bromley 1981, Chapman 1970). The subspecies is characterized by dark plumage overall, with dark ventral feathers varying from rich brown (chestnut to near chocolate) to medium charcoal gray (Bellrose 1986, Chapman 1970). Morphological measurements of CRD birds are summarized in table 1. General consistency is apparent between studies, although measurements were not combined for analyses because of insufficient overlap in the set of measurements taken in each study, and to avoid the problems of potential biases between measurers.

Island-nesting geese—Canada geese breeding throughout PWS west of the CRD, and on Middleton Island in the Gulf of Alaska (hereafter referred to as island geese) are not well studied. An unknown number of Canada geese breed in PWS, nesting on islands and the forested mainland shore (Isleib and Kessel 1973), with known concentrations on Green Island, Constantine Harbor of Hinchinbrook Island, and Middleton Island (Isleib 1977, Kurhajec 1977, Nysewander and Knudtson 1977). Thirteen island geese collected in PWS by J. Reynolds of Alaska Department of Fish and Game in 1970 and 1974 apparently were intermediate in morphological characteristics between duskys and Vancouvers (Isleib 1977), although the four birds (one nesting pair, one nesting female, and a nonbreeding female) col-

lected in 1970 were identified by J. Aldrich on the basis of morphological measurements as three dusky females and one Vancouver male (Timm 1972b). Isleib (1977) also presented weight, culmen, and tail-length measurements of four island geese collected by Ansel Johnson of the USFWS. Presented by age class but not sex, culmen measurements were typical of the upper range of duskys, weights were 300 to 1000 g greater than averages for duskys, and tail feathers were typical of Vancouvers (Chapman 1970, Ratti and Robards 1977). Four adult female geese measured by Crowley et al. (1998) on Green Island were slightly larger than CRD birds (table 2).

Middleton Island is situated in the Gulf of Alaska, 150 km south-southwest of Cordova, Alaska. Canada geese only recently became established on the island (reviewed in Campbell 1987), as observers did not detect resident, breeding geese there prior to 1981 (Gould and Zablouil 1981). Soon after they became established, Middleton Island geese gradually increased in the 1980s (Campbell 1987, Campbell and Rothe 1990) and grew rapidly in the 1990s (Campbell 1990a, Petrula et al. 2002). These geese are indistinguishable in appearance from CRD geese, and geese from both Middleton and Green Islands have similar morphology to CRD geese (table 2)(Crowley et al. 1998).

Egg measurements for island geese are also available for comparison (table 3). Although insufficient data are presented to allow statistical comparisons, eggs from geese on Hawkins Island (n = 23) were smaller than both duskys (Timm 1972b) and Vancouvers (J.G. King in Timm 1972b; also, see Lebeda 1980 for additional Vancouver egg measurements that agree well with King's). Another sample (n = 26 eggs) from Hinchinbrook Island (Kurhajec 1977), however, appeared longer than Vancouver eggs but narrower than those of duskys. Eggs from Green and Gravina Islands (Crowley and Petrula 1998) were very similar to those of CRD geese.

Table 1—Morphological measurements of dusky Canada geese from the Copper River Delta, Alaska

Measurement	Adults						Juveniles									
	Males			Females			Males			Females						
	1970	1979 ^a	1970	1970	1979 ^a	1970	1970	1970	1970	1970	1970					
n	\bar{x}	sd	n	\bar{x}	sd	n	\bar{x}	sd	n	\bar{x}	sd					
	-----Millimeters-----						-----Millimeters-----									
Culmen	214	46.5	2.7	46.3	2.4	199	44.4	2.1	43.5	2.4	368	46.9	2.2	350.0	44.6	2.2
Bill width at nares				21.3	.8				20.0	.9						
Bill nail length				14.8	1.0				13.8	.9						
Diagonal tarsus	80	92.3	6.1	88.6	3.5	61	85.9	4.1	81.3	3.0	47	91.2	4.2	47.0	91.2	4.2
Total tarsus				106.2	3.9				97.3	3.4						
Midtoe + nail	79	88.0	3.8	80.8	7.4	61	83.1	3.4	74.6	6.5	48	86.2	4.0	52.0	81.4	3.2
Midtoe																
Flattened wing	79	479.0	12.6			61	450.0	15.1			48	462.0	13.8	52.0	440.0	12.9
Tail length	79	143.5	6.5			60	137.4	6.8			48	129.7	7.5	47.0	124.4	6.6

^aJohnson et al. (1979) measured a total of 261 adult dusky Canada geese, but did not report the sample size for each sex. Source: Chapman 1970 and Johnson et al. 1979.

Table 2—Morphological measurements of Canada geese from Green and Middleton Islands, Alaska

Measurement	Green Island		Middleton Island			
	Adult Females (n=4)		Adult Females (n=12)		Adult Males (n=18)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
	<i>Millimeters</i>					
Culmen	45.0	1.24	43.2	1.85	46.0	1.86
Front nares	22.8	.66	24.3	.56	24.9	1.07
Bill nail length	14.3	.45	14.7	.91	15.5	.82
Bill nail width	11.9	.64	11.7	1.02	12.9	1.05
Bill width at base	23.7	.82	23.7	1.62	25.3	.96
Bill width at nares	21.1	.66	20.9	.77	22.1	1.12
Bill width at nail	17.8	.64	18.1	.53	18.9	.41
Total tarsus	98.6	1.30	98.2	3.69	104.3	4.12
Diagonal tarsus	84.9	1.56	85.1	5.03	89.5	4.05
Middle toe with nail	66.4	3.09	70.9	5.30	76.1	5.16
Wing chord	433.0	6.16	NA	NA	NA	NA

Source: Crowley et al. 1998.

Table 3—Egg measurements of dusky Canada geese and closely related populations

Population	Location	n	Length			Width		
			Mean	Min.	Max.	Mean	Min.	Max.
			<i>Millimeters</i>					
Dusky ^a	Copper River Delta	296	81.7	75.5	90.0	55.8	51.1	60.8
Island ^b	Hinchinbrook Island	23	79.7	77.7	83.8	55.1	53.7	56.5
Island ^c	Hinchinbrook Island	26	84.6	80.0	91.1	53.2	52.0	58.2
Island ^d	Gravina and Green Islands	25	82.3	76.3	88.2	54.0	49.9	57.7
Vancouver ^e	Admiralty Island	36	86.1	81.5	94.0	56.4	51.5	61.8
Vancouver ^f	Juneau	14	82.7	78.3	87.6	59.5	58.3	61.6

^a Timm 1972b

^b Reynolds in Timm 1972b

^c Kurhajec 1977

^d Crowley et al. 1998

^e Lebeda 1980

^f J.G. King in Timm 1972b

Comparisons with closely related subspecies—

Morphological profiles of six Alaska subspecies of Canada geese, including duskys, are fairly distinct (Johnson et al. 1979); however, separations between duskys, lesser Canada geese (*B. c. parvipes* Cassin), and Vancouver Canada geese were not considered adequate. By using discriminant function analyses of culmen, tarsus, total tarsus, and middle-toe measurements to examine species pairs and *B. c. fulva*, they found close to 80 percent of geese were correctly assigned to their subspecies; however 8 to 9 percent of geese in the first pair comparisons were incorrectly classified, and 12 percent in the second pair comparisons were incorrectly classified (table 4).

Pearce and Bollinger (1997) examined measurements of 51 lessers from the Anchorage population, and 52 duskys from the CRD to assess their ability to morphologically discriminate between the races. In comparing lesser males with dusky females, they found 86 to 90 percent accuracy in separation by using bill width at base. When they used both bill width at base and bill width at nares, only 9.8 percent of geese were misclassified. This work is preliminary, and further analyses are in progress (Pearce 1999).

Genetic Analyses

In the mid-1970s, Timm (1975) submitted Canada goose blood samples from Cook Inlet (n = 13), PWS (n = 4), and the CRD (n = 19) to a laboratory at the University of Maryland. Morgan et al. (1977) confirmed through electrophoresis of blood serum that all three groups of birds were distinguishable. The Cook Inlet birds were subsequently identified as lesser Canada geese.

Shields and Wilson (1987b) studied mitochondrial DNA (mtDNA) by using restriction fragment length polymorphisms from five subspecies of Canada geese: Aleutian (*B. c. leucopareia* Brandt), Taverner's, cackling (*B. c. minima* Ridgway), western (*B. c. moffitti* Aldrich), and giant (*B. c. maxima* Delacour). They were able to clearly differentiate between subspecies and found a separation between large- and small-bodied Canada geese. By using a calibration method developed earlier (Shields and Wilson 1987a), they were able to estimate that small and large forms separated just over 500,000 years ago. Subspeciation into currently recognized races began about 150,000 years ago and continued into recent times (Ploeger 1968), a much shorter period than is typical of subspeciation in mammals.

Table 4—Error in classification of dusky Canada geese and closely related subspecies based on 2-step discriminant function analyses of morphological measurements

Subspecies pairs comparisons	Morphological measurements	Sample sizes		Error rate <i>Percent</i>
		Males	Females	
Lesser - dusky <i>parvipes-occidentalis</i>	Exposed culmen Diagonal tarsus Total tarsus	141	149	9.0
Lesser - dusky <i>parvipes-occidentalis</i>	As above, plus middle toe	134	144	7.9
Dusky - Vancouver <i>occidentalis-fulva</i>	Exposed culmen Diagonal tarsus	326	300	12.6

Source: Johnson et al. 1979: 70.

Scribner et al. (1997, in press) and Pearce et al. (1998) conducted an extensive study of Pacific Flyway Canada goose stocks by using nuclear microsatellite DNA markers and mtDNA sequence data. With the exception of island geese, combined mtDNA and microsatellite data showed concordance with taxonomic designations (table 5). They found a fixed mtDNA difference between small- and large-bodied birds, as no mtDNA haplotypes are shared by these two groups (table 6). Within the large-bodied birds, mtDNA haplotypes and microsatellite alleles are shared between populations; however, there is a statistically significant difference between all populations based on both mtDNA and microsatellite data. The one exception to shared mtDNA haplotypes is the unique “H” haplotype found in island geese only. Ely and Scribner (1994) have noted that unique haplotypes are useful for the identification of Canada goose subspecies; however, the “H” haplotype of island geese differs by only one base pair, derived from females only. Work on genetic material of male geese is needed to study gene flow between populations, particularly to elucidate relationships between CRD geese and island geese.

Pearce et al. (1998) extended and refined the original work (Scribner et al. 1997) by examining samples of other Canada goose populations within the Pacific Flyway, increasing the number of nuclear microsatellite markers examined (from Buchholz et al. 1998), and increasing mtDNA sequences to 20 per population (summarized in Scribner et al., in press). Based solely upon allele frequency data from nuclear microsatellite markers, they confirmed that dusky Canada geese from the CRD clearly fit within the large-bodied group and are distinct from other populations, including island geese (though the difference here is small). Replicate sampling through the 100-percent simulations of mtDNA sequencing data yielded confirmation that, similar to results of nuclear DNA analyses, there was a detectable separation between CRD geese and island (Green and Middleton Islands) geese. Accuracy and precision estimates for assigning breeding geese to their population of origin indicated that 96 percent (90

percent confidence interval = ± 4 percent) of CRD geese could correctly be classified to their point of origin, with about 3 percent of the birds having unknown affiliations. Accuracy of classifications were 86 percent (± 8 percent) for Green Island and 91 percent (± 6 percent) for Middleton Island, with 6 percent and 4 percent, respectively, assigned to unknown populations. If combined, however, island geese would be classified with about 95 percent accuracy.

In southwest Washington and western Oregon, Canada goose seasons are closed if a quota of dusky is exceeded. Pearce et al. (2000) tested the use of current morphological and plumage characteristics to correctly classify CRD dusky Canada geese by criteria used for regulatory purposes at hunter check stations (USDI Fish and Wildlife Service 1996). They analyzed genetics of 106 hunter-shot female Canada geese (*Branta canadensis* subsp.) from the wintering grounds in Washington and Oregon. Of the 50 birds that met the regulatory criteria for bill length (culmen 40 to 50 mm) and breast color (Munsell 10 YR color value < 5), 51 percent (90 percent CI = 38 to 64 percent, maximum likelihood estimate) were estimated to be CRD geese. The remainder of qualifying birds included 14 percent (CI = 6 to 25 percent) from Middleton Island, 2 percent (CI = 0 to 6 percent) from Green Island, 11 percent (CI = 3 to 24 percent) from Admiralty Island (Vancouver Canada geese), and 15 percent of unknown origin. Of the geese not meeting all of the morphological and plumage criteria, few were thought to be CRD or island birds, although there was a substantial proportion of birds with unknown origins.

Pearce et al. (2000) point out that study results must be interpreted with caution because (1) only a one-time sample of hunter-shot geese was examined, and it may not be representative of Canada goose composition on the wintering grounds or in the harvest (e.g., varying geographic distribution throughout the season and differential vulnerability of subspecies); and (2) male dispersal makes it more difficult to understand the proportional contribution of breeding populations to an admixed winter group. These

Table 5—Microsatellite DNA allele frequencies (locus 4AC) observed in breeding populations of Pacific Flyway Canada geese. Note how the diversity and frequency of alleles change across breeding populations, an indicator of the spatial dispersion of genetic variation that results in high probabilities of population classification

Allele	Small-bodied form				Large-bodied form						
	North Slope (n=22)	Yukon Delta (n=41)	Aleutian Island (n=20)	Fairbanks (n=18)	Anchorage (n=42)	Copper R. Delta (n=51)	Green Island (n=30)	Middleton Island (n=35)	Admiralty Island (n=45)	Washington (n=17)	
180					0.01	0.05					0.18
182			0.15				0.02	0.01			.12
184			.05								.09
186	0.75	1.00	.28	0.58	.68	.50	.35	.34	0.92		.09
188			.03	.22	.04		.02	.06			.03
190			.03								
196	.07		.20	.06	.21	.17	.15	.24			.09
198			.03		.02	.03	.03		.08		
200	.07		.20	.14	.01	.15	.23	.26			.06
202							.02				.12
204	.09		.03		.02	.08	.18	.07			.15
206											.06
208	.02		.03			.03		.01			.03

Source: Pearce et al. 1998.

Table 6—Geographic distributions of mitochondrial haplotypes for Canada goose subpopulations sampled across the Pacific Flyway

Sampling location	Putative subspecies	Sample size	mtDNA sequence type (haplotype)																									
			A	B	C	D	G	H	I	J	R	F	K	L	M	N	O	P	Q	S	U	W	X	Y	Z			
Large-bodied forms																												
Fairbanks	<i>B.c. parvipes</i>	19	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Anchorage	<i>B.c. parvipes?</i>	19	9	1	*	*	*	*	7	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Copper R. Delta	<i>B.c. occidentalis</i>	20	*	9	7	*	*	*	4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Green Island	<i>B.c. ?</i>	23	*	*	*	*	*	23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Middleton Island	<i>B.c. ?</i>	26	*	*	*	*	*	26	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Admiralty Island	<i>B.c. fulva</i>	17	4	*	13	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Washington	<i>B.c. moffitti</i>	15	13	*	*	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Small-bodied forms																												
North Slope	<i>B.c. taverneri</i>	8	*	*	*	*	*	*	*	*	*	6	2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Yukon Delta	<i>B.c. minima</i>	17	*	*	*	*	*	*	*	*	2	*	10	*	*	*	*	*	*	*	2	2	*	*	*	*	1	*
Aleutian Islands	<i>B.c. leucopareia</i>	22	*	*	*	*	*	*	*	*	*	*	13	2	4	1	1	1	1	*	*	*	*	*	*	*	*	*
Hunter-shot sample		93	36	9	13	*	2	10	5	2	*	*	4	*	*	*	*	*	*	1	4	1	1	1	1	2	3	

Note: Analyses are based on sequence analysis of 144 base pairs of a hypervariable portion of the control region.
Source: Pearce et al. 1998.

factors are currently being assessed (Pearce 1999). It seems clear, however, that because the check-station classification criteria for dusky geese encompass a proportion of non-CRD and non-dusky geese (at least among females), estimates of dusky harvest are likely to be somewhat inflated. As a result, the quota system operates conservatively, erring on the side of conservation.

Perspectives on Taxonomy for This Report

Differentiation of Canada geese along the north Pacific coast has apparently been a recent phenomenon in geologic time. Given the geologically young age and very active status of the Pacific coast, and the retreat of glaciers from the region only 10,000 years ago (Pewe 1975), it is not surprising that coastal populations of geese are also “young” and thus closely related (Ploeger 1968). The term “geologically young” certainly describes the CRD, where a cycle of uplift and subsidence has characterized the region for thousands of years (Plafker 1990). With this process, coastal marsh habitat has varied dramatically in both quantity and quality. Canada geese occupying the area must certainly have struggled to keep pace with the changes and adapted, or not, as conditions permitted. Faced with these circumstances, managers have necessarily adopted practical guidelines for managing groups of breeding geese while more detailed studies of subpopulations are being conducted and taxonomic decisions are pending.

Although managers recognize that island-nesting geese of PWS and Middleton Island exhibit minor but unique genetic characteristics (see “Genetic Analyses” above), island geese and CRD geese are currently considered to be subpopulations of dusky Canada geese based on several considerations: (1) the degree of difference between CRD geese and island geese is small compared to differences with more distant groups in Cook Inlet or southeast Alaska, (2) the two groups are indistinguishable to observers in the

wild, and (3) they winter sympatrically. This assessment focuses on dusky Canada geese of the CRD because this is the main body of the subspecies population. It is also the subpopulation experiencing decline and uncertainty, whereas island geese have been stable or increasing in number. Nevertheless, potential interactions between subpopulations may prove to be important in the long-term conservation of dusky geese, so they are briefly discussed.

On the wintering grounds, CRD dusky geese and other large dark geese are managed in the aggregate based on evidence that the wintering flock of large dark geese is composed of a mixture of subspecies and subpopulations (Hansen 1962, Pacific Flyway Council 1997, Ratti and Timm 1979). Recent evidence confirms this finding (see “Genetic Analyses” above, and Pearce et al. 2000). In addition, telemetry and neck collar observations demonstrated that geese from Green and Middleton Islands indeed winter sympatrically with CRD geese in the Willamette Valley (ADFG 1999, Crowley et al. 1998). Johnson et al. (1979) pointed out that information from banding is usually more valuable than simply knowing the subspecies classification of birds, because management usually requires more precise data, and a subspecies often is composed of several populations. Thus, although the wildlife agencies manage island geese collectively with CRD birds as the dusky goose population, they are committed to conservation of specific breeding populations regardless of taxonomic designations.

Population Delineation and Distribution

Breeding Range

Historical notes—Early investigators considered all large dark Canada geese breeding along the Pacific coast, i.e., from PWS south to the Queen Charlotte Islands (QCI), British Columbia, to be *occidentalis*. Baird et al. (1884) reported that *occidentalis* occurred along the northwest coast from Sitka to California. However, Grinnell (1910 in Delacour 1951) noted that,

The Prince William Sound birds are still darker, even, than the Sitkan district birds... It will be noted from the accompanying table of measurements that the PWS birds are decidedly smaller than the Sitkan district examples....Taking both coloration and size into account, the systematic status of these birds is decidedly unsatisfactory. I am using the name *occidentalis* for them only as a makeshift.

Swarth (1911) concurred with this view. Initial observations were few, and any records were of interest. Dixon (1908) found a nest in thick underbrush near a large tree on Hawkins Island in PWS. Bailey (1927) concluded that Canada geese, identified as *occidentalis* (which included birds classified today as *fulva*), were resident year-round in southeast Alaska, although he suspected that most were migratory. He found breeding Canada geese to be common in Glacier Bay in mid-June.

Moffitt (1937) concluded a review of distributional records of *occidentalis* by noting that the largest forms of the race apparently breed in the southern part of their range, from Vancouver Island to Glacier Bay, as found earlier by Grinnell (1910) and Swarth (1911). Upon his death, Moffitt's extensive notes were combined with the indepth work of Jean Delacour, and the subspecies *occidentalis* was split to recognize the new subspecies *fulva* distinct from *occidentalis* (Delacour 1951). Delacour considered *fulva* resident on the islands and along the coast of British Columbia and southern Alaska, from north of Vancouver Island to Glacier Bay. *Occidentalis* bred around PWS, Alaska, and perhaps farther south and north, intergrading with *taverneri* inland and with *leucopareia* to the northwest. Early banding by Fred Robards and Urban Nelson provided the first definitive evidence that dusky from the CRD migrated south for the winter (Nelson 1953). Gabrielson and Lincoln (1959) considered the breeding range of dusky to include the regions of PWS, Cook Inlet, and inland through the Copper River drainage. They also noted that numerous flocks occurred in Yakutat Bay during spring.

Using extensive aerial survey experience, Hansen (1962: 303) delineated the breeding range of dusky, which extended "along the coast from the vicinity of the Bering Glacier on the southeast to Cook Inlet on the west, a distance of about 275 miles" (440 km). He noted that only small numbers of geese occurred in PWS and the lower Susitna River, Cook Inlet, and even fewer near the confluence of the Bremner River with the Copper River. Hansen clearly defined two zones essentially devoid of breeding Canada geese, because of habitat differences, that helped to define and isolate the range of dusky from those of Taverner's (250 km to the northwest) and Vancouver's (500 km to the south).

Contemporary understanding—Geese breeding on Cook Inlet, Alaska, were identified as lesser Canada geese in the mid-1970s (Timm 1975, 1976). Thus, the breeding range of dusky is no longer considered to extend that far to the northwest. The primary nesting range of *occidentalis* remains the CRD, Alaska (fig. 1). This distribution extends eastward through Martin Lake to include the lake at the foot of the Bering Glacier (Frair and Liska 1998).

Island geese nest on Middleton Island and in narrow coastal strips of both the islands and the mainland of PWS, Alaska. Island geese in PWS are most prevalent in the southern and eastern regions of the sound (Isleib 1977, Isleib and Kessel 1973, Nysewander and Knudtson 1977), with highest numbers occurring on Montague, Hinchinbrook (especially Constantine Harbor) (Kurahajec 1977, Nysewander and Knudtson 1977), and Hawkins Islands, and along the shores of Orca Inlet and Orca Bay. Small numbers occur in northern PWS near the Columbia Glacier and on Green and Gravina Islands (Crowley et al. 1998, Isleib 1977). Middleton Island has hosted about 1,400 breeding adult geese in recent years (Petrula et al. 2002), but the number of island geese in PWS is unknown.

Transplant to Willapa Bay, Washington—In accord with a previous USFWS policy to establish breeding Canada goose flocks, 41 dusky goslings were transplanted from the CRD to the Willapa National Wildlife Refuge in July 1958,

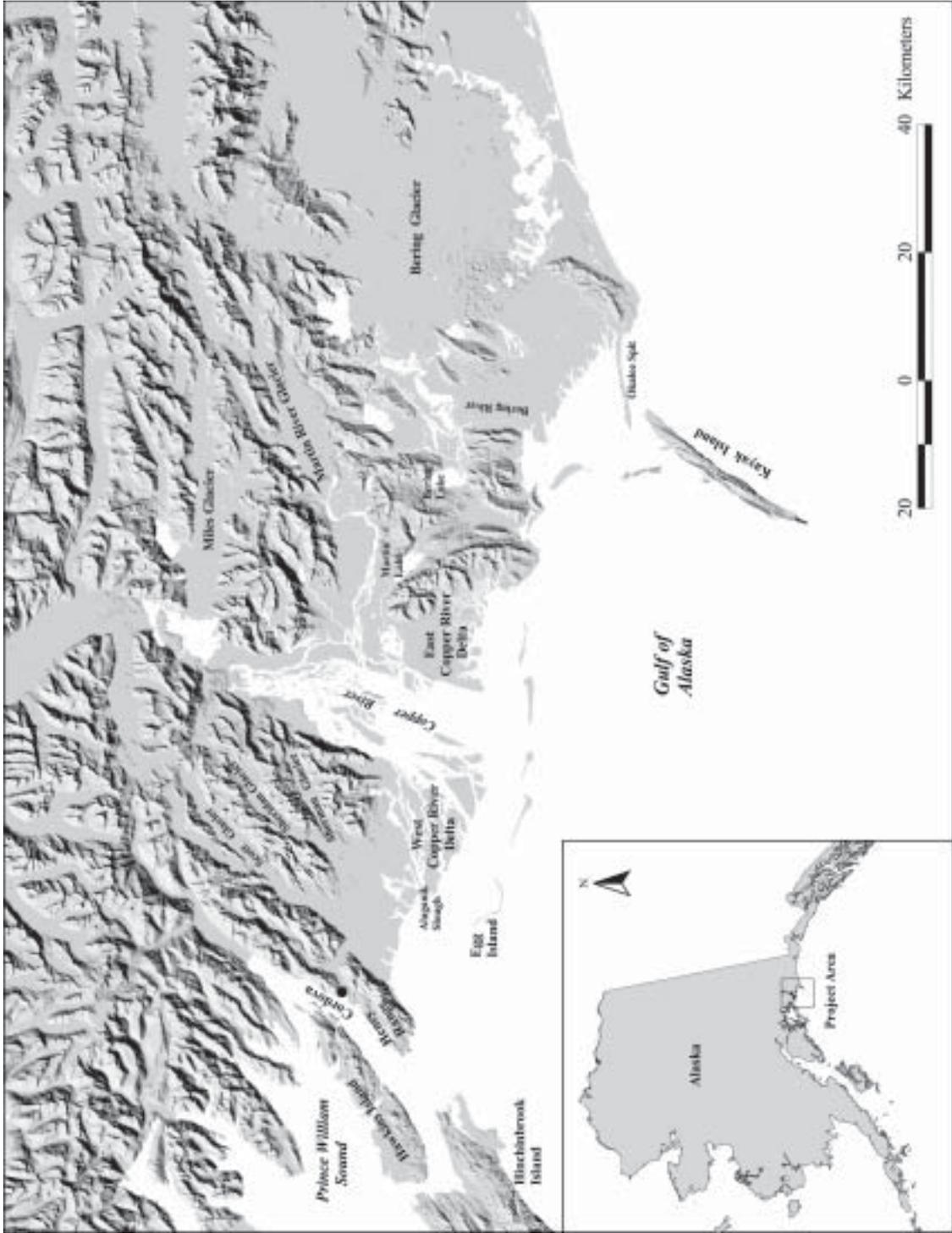


Figure 1—The primary nesting range of *Branta canadensis occidentalis* is the Copper River Delta, Alaska, extending eastward to the coastal front of the Bering Glacier.

of which 38 survived to 1961 when successful nesting began. This flock grew to become free-flying by 1967. In 1971, 95 pinioned birds were transported to William L. Finley National Wildlife Refuge in Oregon; their fate was unmonitored and is unknown. The Willapa flock continued to grow and was 407 birds in 1977 (Welch 1978). Refuge personnel now distinguish between migrant dusks, resident dusks, and dusky hybrids (Atkinson 1987). About 120 to 175 resident birds are still associated with the refuge; however, the total regional number of resident dusks and dusky hybrids is unknown.

Transplant to Middleton Island, Alaska—

Middleton Island hosted no breeding Canada geese prior to 1978 (Hatch in Campbell 1987, Rausch 1958). By 1981, however, a small number of geese had become established there as breeders. These geese were tentatively identified as dusks (Campbell 1987, Gould and Zablouil 1981, Isleib 1986). In an effort to enhance the dusky goose population as a whole, dusks from the CRD (49 male, 47 female goslings; 1 male and 9 female adults) were transplanted to Middleton Island in July 1987 (Campbell et al. 1988). The island was considered a good prospect for enhancement because it was free of mammalian predators and it had a small established breeding population of geese. A subsequent transplant of 35 male and 48 female goslings and 3 adult females was done in July 1988 (Campbell and Rothe 1989). A third transplant, scheduled for 1989, was cancelled because of poor return rates of previously transplanted birds, unexpected high levels of predation by eagles, and poor gosling production on the CRD. Ultimately, the transplant program was discontinued because the naturally established Middleton geese seemed to be increasing (Campbell and Rothe 1990).

Annual monitoring from 1987 to 1992, and again in 1996, 1997, 2000, and 2002 revealed a rapid and natural increase in the Middleton geese, from about 100 birds in the first year to over 2,200 geese by 1996 and 2,500 in 2000 (Campbell 1991c; Campbell and Rothe 1989, 1990; Campbell et al. 1988, 1992; Crowley et al. 1997; Petrula 2000; Petrula et al. 2002;

Rosenberg et al. 1996). Investigators concluded that the transplants from CRD had contributed very little to this irruption (Campbell et al. 1992), and subsequent genetic analyses confirmed that Middleton geese were essentially the same as island-nesting geese (Pearce et al. 1998). Of six collared geese observed on Middleton Island from 1988 to 1997, three were birds transplanted there as female goslings, and three were banded on the CRD as after-hatching-year birds (two males banded in 1991, one female banded in 1988).

Wintering Range

Historical notes—Baird et al. (1884) reported that *occidentalis* occurred as far south as California. Dawson (1909) noted that *occidentalis* migrated through the Washington coast area but was not a common resident in Puget Sound. Brooks (1917, 1923) reported large dark geese in interior British Columbia and near Porcher Island on the coast. In his later report, he mentioned that the geese resident near Porcher Island likely belonged to the large dark race occurring on QCI and generally identified as *occidentalis*, but he may have been referring to the large-bodied form, later classified as *fulva*.

Specimens of *occidentalis* were reported from several places in Oregon, including the coastal areas of Gold Beach and Netarts Bay, and for the first time including specimens from the Salem and Eugene areas in the Willamette Valley (Jewett 1932). Moffitt (1937) reviewed the taxonomy and distribution of *occidentalis* and confirmed the presence of the race in northern California, specifically near Ferndale, Humboldt County (about 200 geese in 1932), near Eel River (about 225 in 1933), and at Crescent City (about 150). He reported observations of about 300 birds between Eureka and Capetown in 1937.

In the late 1930s, *occidentalis* apparently still wintered largely along the Oregon coast, with only occasional stragglers inland (Gabrielson and Jewett 1940). However, during the late 1930s and through the mid-1940s, large dark geese, presumably *occidentalis*, were observed to be common

spring and fall migrants and winter visitors in the southern Willamette Valley, outnumbering the light geese in a ratio of 2:1 (Gullion 1951). Delacour (1951), in his review of Canada goose subspecies and splitting off of *fulva* from *occidentalis*, noted that *occidentalis* wintered at least as far south as Oregon.

Jewett (1953) reported observations and harvest of duskys from throughout the Willamette Valley (Corvallis, McMinnville, Rickreal) and Sauvie Island, Oregon, from 1931 through 1952. He noted that “this coastal species [is] fairly common along the ocean beaches the entire length of Oregon, but is becoming either better known to hunters, or is actually increasing during the fall and winter months in the Willamette Valley and Lower Columbia River Valleys.” In *Birds of Washington State*, Jewett et al. (1953) reported few records, with observations restricted to the coastal fringe, but concluded that the race was probably much more common than present information indicated.

Finally, Hansen (1962) compiled an extensive data set based on 1,129 recoveries of 3,943 duskys banded on the CRD, and on 164 recoveries of 3,593 Vancouvers banded in the vicinity of Glacier Bay, to demonstrate that to a great extent their ranges were discrete, and that duskys wintered primarily in the Willamette Valley. Based on band recoveries, duskys largely bypassed coastal Alaska in fall migration, stopping en route south in the QCI and on Vancouver Island, where a few overwintered. Most continued on to Willapa Bay (where small numbers wintered), then up the Columbia River to winter primarily in the Willamette Valley. An aberrant few wintered on the northwest coast of California. Hansen (1962: 307) estimated that about 1,000 to 1,500 duskys wintered in PWS; Isleib and Kessel (1973) observed a few to hundreds of Canada geese wintering there. In contrast, Vancouvers were largely sedentary in southeast Alaska and British Columbia, with relatively few birds migrating to winter on the coast of

Washington and in the Willamette Valley. Interestingly, although the type specimen for Vancouvers was collected on the QCI, only dusky bands were recovered there (Hansen 1962: 319).

By the mid-1960s, just prior to the effective establishment of refuges, concentrations of duskys wintering in the Willamette Valley had shifted from the southern end of the valley to the middle valley, particularly to the Oak Knoll complex near Corvallis and Albany (Chapman et al. 1969).

Contemporary understanding—Dusky Canada geese primarily winter in the Willamette Valley of Oregon and in the lower Columbia River Valley of Washington and Oregon (fig. 2). Cornely et al. (1998) identified 11 core areas used by wintering duskys in the mid-1980s in Washington (from Willapa National Wildlife Refuge through the Columbia River valley islands) and in Oregon (Sauvie Island and several locations throughout the Willamette Valley from southwest of McMinnville to the Fern Ridge Reservoir near Eugene). They also found that a small number of birds collared on the CRD wintered in PWS near Whittier; near Craig on Prince of Wales Island, southeast Alaska; on the QCI, British Columbia; and on Vancouver Island, British Columbia. Sightings of duskys were made through all winter months at the Delkatla Wildlife Refuge, QCI, indicating that some birds wintered there. Between the winters of 1982-83 and 1995-96, peak midwinter counts of 300 to 850 geese were considered to be primarily duskys (Hearne 1999). Similarly, Macgregor (1993) and VanderPol (1997) confirmed the presence of dusky geese (neck-collared on CRD) wintering on the Saanich Peninsula of Vancouver Island in flocks of 50 and 60 geese, respectively, throughout the 1990s.

In recent years, small numbers of duskys have consistently used Willapa Bay (fig. 2), particularly the Willapa National Wildlife Refuge and the Nelson Ranch. Numbers overwintering there have been estimated at 600 to 750 in Willapa Bay during the mid-1980s (Anonymous 1986,

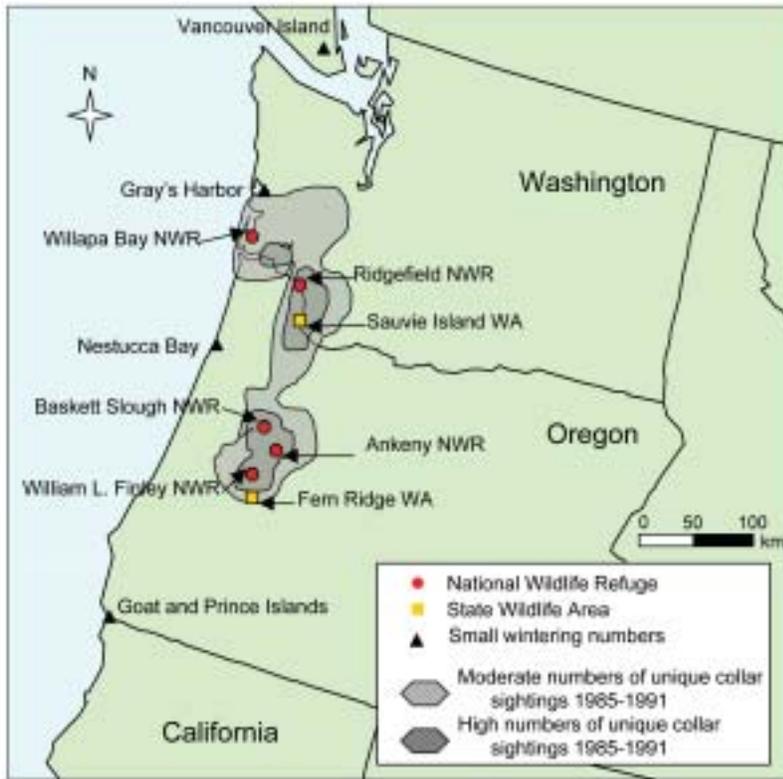


Figure 2—Winter distribution of dusky Canada geese based on observations of unique neck collars of Copper River Delta birds, 1985-1991 (Naughton 1992).

Atkinson 1987); numbers on the refuge, typically around 200 to 300, have ranged from 130 to 800 birds during winters from 1986-87 to 1992-93 (Atkinson 1987, 1988, 1989, 1990, 1991, 1992; Murphie 1993). Other areas consistently used include Chehalis Bay, south Gray's Harbor, and Wallace, with small numbers at Silver Lake and La Center, and possibly Port Susan Bay (Kraege 1995).

Small numbers of dusky geese still winter along the Oregon coast (fig. 2): about 500 to 700 in Nestucca Bay, Tillamook County, and about 100 at Goat and Prince Islands using pastures along the Smith River just inside California (Lowe 1987).

There is strong evidence that island geese winter sympatrically with CRD dusky geese. In summer 1998, 4 geese on Green Island and 20 geese on Middleton Island were marked with VHF radios on neck collars; 12 additional geese on Middleton were marked only with collars. During November 1998 through April 1999, all 4 (100 percent) of

the Green Island birds, and 24 (75 percent) of the Middleton geese were detected in Oregon and Washington on the traditional wintering area of dusky geese (ADFG 1999).

Migration

Fall—Little is known about the specific routes and timing of movements of dusky geese during migration. Hansen (1962) suggested that they migrate offshore, seldom stopping during the fall migration to wintering areas. Hawkings (1982) and Mickelson et al. (1980) reported that dusky geese began arriving on the eastern CRD from the western CRD in early August as nonbreeders regained flight after the molt. The movement continued with geese staging on the eastern CRD throughout September, prior to departure in early to mid October (although a few dusky geese had not yet departed when observers left in mid-October). Grand (1997) found that two radio-marked birds moved from core nesting areas on the western CRD to the Bering Glacier and Martin Lake area,

just off the CRD to the northeast (fig. 1), about the time of molt. Crowley (1999a) reported 110 geese on Hinchinbrook Island, PWS, in September 1996, 5 of which were dusky collared on the CRD, indicating the possibility of similar dispersal and staging to the west prior to migration. Crouse (1994a) conducted aerial surveys of the Copper and Bering River deltas in fall 1992 and observed that large numbers present on 2 October were greatly reduced by 14 October.

Geese are known to use the Yakutat Forelands for fall staging (Petersen et al. 1981), but there are few other known sites within Alaska. Some areas used by geese during fall migration, as determined from leg-band returns, include the southwest coast of Prince of Wales Island, Alaska; Graham Island, British Columbia; the northern tip and west-central coast of Vancouver Island, British Columbia; and the southern interior of British Columbia (Hansen 1960). Dusky also use the QCI, British Columbia. Hearne (1999) has provided observations of dusky that use the Delkatla Wildlife Sanctuary at Masset, Maast Island, and the Port Clements area, including Kumdis Bay and Slough, the Yakoun Estuary, and Stewart Bay in the QCI. Geese departing Vancouver Island, along with birds passing that point, fly to Gray's Harbor and Willapa Bay, Washington (Chapman et al. 1969). Dawson (1909) reported that *occidentalis* migrate through, but are not a common winter resident in Puget Sound, Washington. From the southwest Washington coast, the majority of the population moves up the Columbia River to the mouth of the Willamette River where most turn south until settling in the central Willamette Valley (Chapman et al. 1969).

Leg-band recoveries give a gross level of distribution for geese during the migration period (table 7), reflecting concentration sites for geese that are accessible to hunters. The distribution of band recoveries generally reflects the observations discussed above.

Spring—Information is even more scant for the distribution of dusky during spring migration. Dusky briefly build on Sauvie Island, Oregon, in the lower Columbia River (LCR) valley as the

migration begins, and a subsequent surge in numbers is observed at Willapa Bay, Washington. A brief increase in geese is noted also at the QCI, British Columbia. Large flocks have been observed in Yakutat Bay, southeastern Alaska, in spring (Gabrielson and Lincoln 1959, Petersen et al. 1981). Mickelson et al. (1980) observed dusky on the eastern CRD descending from altitudes greater than 150 m during mid-April 1979. Hawkings (1982) concluded that most of the spring migration of dusky through the eastern CRD had already occurred when observations began on 23 April 1978. In 1979, Hawkings (1982) observed dusky moving through the area when observations began on 16 April, with the last major movement observed on 21 April. Mickelson et al. (1980) and Hawkings (1982) found that most dusky migrated through the area without stopping during spring. Crouse (1994a) surveyed the Copper and Bering River deltas weekly from 1 April through 1 May. Few geese were observed on 1 April, and numbers peaked on 23 April. Important use areas included Okalee Spit on 1 and 8 April, and coastal areas between the Edward and Bering Rivers during the 16 April surveys. Geese were present on the CRD during surveys on 8 and 16 April, and a large movement onto the area was noticed on the 23 April survey (Crouse 1994a).

Significant Events in Recent History of Dusky Canada Geese

Alaska Earthquake 1964

On 27 March 1964, an earthquake lasting 4 to 5 minutes, and of Richter magnitude 8.4 to 8.6 occurred in Alaska, with the main epicenter 130 km west of the CRD. This event has had major effects on the CRD because of the 1.8 to 3.4 m uplift of the land surface relative to sea level (Hansen and Eckel 1971, Reimnitz and Marshall 1971). Important ecological changes were predicted (Shepherd 1966) and have largely come to pass (fig. 3). As a result of the uplift and the associated cessation of tidal flooding, the rate of plant community succession on the CRD has been

Table 7—Percentage distribution of leg-band returns from dusky Canada geese in the Pacific Flyway, 1951-1994

Hunting season	n	Alaska	British Columbia	Washington	Oregon	Other
----- <i>Percent</i> -----						
1951	3	0.0	0.0	0.0	100.0	—
1952	35	17.7	2.9	5.7	74.3	—
1953	105	8.6	24.8	8.6	58.1	—
1954	201	10.0	7.0	18.4	64.2	0.5 ^a
1955	92	5.4	4.3	9.8	80.4	—
1956	86	4.7	26.7	9.3	59.3	—
1957	172	4.1	22.1	8.1	64.5	1.2 ^a
1958	135	4.4	14.1	11.1	70.4	—
1959	140	7.1	22.1	4.3	66.4	—
1960	156	5.1	19.9	17.3	57.7	—
1961	48	12.5	18.8	12.5	56.3	—
1962	105	13.3	11.4	11.4	63.8	—
1963	123	5.7	15.4	6.5	69.9	2.4 ^a
1964	64	4.7	7.8	18.8	68.8	—
1965	112	7.1	14.3	14.3	63.4	.9 ^a
1966	95	9.5	7.4	3.2	80.0	—
1967	73	8.2	6.8	16.4	68.5	—
1968	96	9.4	17.7	10.4	62.5	—
1969	97	10.3	10.3	11.3	68.0	—
1970	159	10.7	8.2	8.8	72.3	—
1971	67	11.9	6.0	9.0	73.1	—
1972	103	9.7	0	8.7	80.6	11 ^a
1973	66	18.2	4.5	10.6	66.7	—
1974	191	13.6	5.2	13.6	67.5	—
1975	194	13.9	5.2	13.9	67.0	—
1976	235	10.2	10.6	14.0	64.7	.4 ^b
1977	243	16.5	4.9	9.1	69.1	.4 ^a
1978	236	24.2	2.1	13.6	57.6	2.5 ^{a c}
1979	98	16.3	2.0	12.2	69.4	—
1980	104	2.9	2.9	8.7	84.6	1 ^a
1981	69	4.3	0	10.1	85.5	—
1982	33	24.2	0	9.1	63.6	3 ^d
1983	76	6.6	0	5.3	88.2	—
1984	62	21.0	8.1	8.1	63.0	—
Mean		10.4	9.2	10.4	69.7	0.4

Table 7—Percentage distribution of leg-band returns from dusky Canada geese in the Pacific Flyway, 1951-1994 (continued)

Hunting season	n	Alaska	British Columbia	Washington	Oregon	Other
----- <i>Percent</i> -----						
1985	37	10.8	18.9	37.8	32.4	—
1986	17	17.6	17.6	11.8	52.9	—
1987	29	27.6	17.2	10.3	44.8	—
1988	25	40.0	16.0	24.0	20.0	—
1989	44	54.5	4.5	11.4	29.5	—
1990	40	44.4	6.7	26.7	22.2	—
1991	19	52.6	0	15.8	31.6	—
1992	26	30.8	3.8	19.2	38.5	7.7 ^e
1993	9	11.1	0	33.3	55.6	—
1994	13	38.5	0	15.4	46.2	—
Mean^f		32.8	8.5	20.6	37.4	0.8

^a California.

^b Minnesota.

^c Utah.

^d Idaho.

^e North Dakota and Wyoming.

^f Period of significant restrictive harvest regulations after 1984.



Pete Dahl Cutoff Cabin 1975



Pete Dahl Cutoff Cabin 1998



Tiedeman Cabin 1975



Tiedeman Cabin 1998



Ancient buried forest exposed by 1964 earthquake.



New marsh establishing on tidal flats between Alaganik and Pete Dahl Sloughs.

Figure 3—Photos of the Copper River Delta, Alaska, illustrating habitat changes caused by the 1964 earthquake.

greatly enhanced (Potyondy et al. 1975, Shepherd et al. 1967, Thilenius 1995), leading to detrimental effects on productivity and survival of dusks. As succession proceeds, open habitat supporting salt-tolerant species has become increasingly closed habitat as the growth of shrubs and trees has been promoted. Predators of geese and their eggs have become more prominent and effective as habitats have become more favorable to them (Campbell 1990a, Shepherd 1966). Concurrently, a “new marsh” zone is developing slowly along the outer CRD as graminoid species occupy former intertidal flats that were uplifted (Reimnitz and Marshall 1971; Thilenius 1990a, 1995). Accelerated woody plant succession (Thilenius 1990b), accompanying changes in fauna, and the development of new marsh are continuing on the CRD today; thus, both direct and indirect changes to the habitats of geese, many of which are not predictable, will continue.

Establishment of Refuges on Wintering Grounds

In the late 1950s, managers recognized the need for additional management of harvest and habitats within core wintering areas of dusks (USDI Fish and Wildlife Service 1980). Hansen (1962: 317) confirmed “A shortage of wintering habitat is probably the greatest limiting factor at present.” He noted that a majority of the population wintered within 32 km of Corvallis, Oregon, and that a concentration of nearly one-third of this winter population occurred in one small area 13 km south of that community. Thus, in the mid-1960s, several federal refuges were established to provide wintering habitat for geese in Washington and Oregon. These refuges have played an important role in the wintering biology and management of dusky Canada geese.

Wintering Ground Complex of Canada Goose Subspecies

During the 1800s, early naturalists visiting the Willamette Valley noted only a few small Canada geese that they referred to as Hutchin’s geese (*B. c. hutchinsii*) (see Aldrich 1946), and some large Canadas referred to as *B. c. canadensis*

(Anthony 1886, Johnson 1880, Townsend 1839, Woodcock 1902). Jarvis and Bromley (1998) assumed these authors were seeing *B. c. taverneri*, *B. c. parvipes*, or both for the small race, and *moffitti* for the large race. By the 1950s, however, most geese in the valley were large, dark Canada geese, presumably dusks, while one-third were light-colored Canada geese (Gullion 1951). There was an apparently brief but substantial “intrusion” of other geese during the winter of 1959-60 (Hansen 1962) that inflated the midwinter inventory of dusks, but by the time refuges were established in the mid-1960s, other races were rarely mentioned in discussions of geese in the valley. Chapman et al. (1969) found 96 percent of geese checked in the possession of hunters during the 1965-66 season, and 99 percent during the 1967-68 season, were dusks. Smith (1971) estimated 90 to 94 percent of the wintering geese were dusks. Thus, harvest estimates, harvest regulations, and population surveys on the wintering grounds of the dusks were straightforward.

By 1973, however, an increase in other races was becoming apparent (Pacific Flyway Council 1973). The subsequent buildup of Taverner’s and lessers to 85 percent of the wintering Canada geese by winter 1977-78 (Simpson and Jarvis 1979), the occurrence of Vancouver and Aleutian Canada geese (Jarvis and Cornely 1988), and the more recent increase of cackling and western Canada geese (Jarvis and Bromley 1998) on the wintering grounds is well documented. Much of this response, given the abundant nutritious food provided by agriculture, likely was due to management practices that were designed to benefit dusks, but yielded even greater benefits to other races within the wintering area (Simpson and Jarvis 1979, Timm et al. 1979). The midwinter index of Canada geese in the Willamette Valley during 1997-98 was 133,000 (Pacific Flyway Council 1998), up from about 25,000 in the early 1970s, while the proportion that is dusky dwindled to an estimated 6 to 16 percent in recent years (Pacific Flyway Council 1997). In fact, the situation may be even more extreme. The actual population of Canada geese wintering in the Willamette Valley may be two to three times

larger than the index (Pacific Flyway Council 1998: 7), making the dusky a much smaller segment of the wintering population.

Management challenges have arisen because dusky are much more susceptible to hunting mortality than are sympatric races of Canada geese, and because estimation of harvest and population size has become much more difficult given the presence of look-alike populations (Timm et al. 1979). Vulnerability of dusky to hunting, relative to Taverner's geese, is 2.7 to 3.0 times higher (Jarvis and Cornely 1988, Simpson and Jarvis 1979), so hunting regulations must be finely crafted to effectively protect dusky. Coincidentally, regulations that favor dusky have greatly benefited other races, leading to a soaring Canada goose population wintering within the range of dusky. Thus, managers had to develop unique methodology to both distinguish dusky from other races in the harvest (Johnson et al. 1979, USDI Fish and Wildlife Service 1996) and to estimate midwinter population size of dusky (e.g., Drut et al. 1997, Jarvis 1992, Sheaffer and Jarvis 1995). Finally, burgeoning numbers of wintering Canada geese and high vulnerability of dusky to hunting mortality led to the development of unique hunting regulations permitting the take of other races while largely protecting dusky from harvest, and of a crop depredation control plan to minimize crop damages resulting from high wintering populations of geese (Pacific Flyway Council 1998).

Biology

Reproduction

Chronology—The first dusky Canada geese arriving in spring on the CRD are frequently observed in March (Campbell and Rothe 1985, Crouse et al. 1997, Isleib 1986). Major influxes occur some time later (table 8), apparently depending on weather conditions and the state of spring snowmelt. In 1964, inclement spring weather delayed the arrival of geese by 3 weeks compared to normal (Shepherd 1965). Records of major arrival dates (table 8) range from 9 April (Campbell and Rothe 1986, Crouse et al. 1997) to 18-25 April (Bromley and Jarvis 1993).

Peak nest initiation (laying) dates (table 8) have varied annually from 29 April-5 May 1992 (Campbell 1992a) to early June 1972 (Timm 1972b, and Timm and Havens 1973). On the eastern CRD, initiation dates in 1978 and 1979 ranged from 6 to 31 May, with a peak from 6 to 11 May (Mickelson et al. 1980). Renesting occurs, especially in years of high loss of early nests, causing the period of nest initiation to be much longer than for first nests, and in some years resulting in a bimodal distribution (fig. 4) of initiation dates (e.g., Campbell et al. 1987, Grand et al. 1998). Duration of the initiation period was 30 days in 1974 and 39 days in 1975 (Bromley 1976), and averaged 38 days, with a maximum of 50 days, from 1993 to 1995 (Crouse et al. 1997). Shepherd et al. (1967) found that a severe storm in mid-May 1966 interrupted nest initiation and caused nest abandonment and delayed initiation such that there were three distinct ages of goslings observed later in the summer.

Using brood ages, Olson (1953, 1954b) estimated peak hatch dates of 20-25 June 1953 and 22-27 June 1954. Other peak hatch dates were about 1 July 1971 (Timm and Havens 1973) and 12-18 June 1974 and 17-23 June 1975 (Bromley 1976). Crouse et al. (1997), for the years 1993-95, noted earliest hatch dates of 4 June in 1994 and 1995, and 13 June 1993, with median hatch dates of 27 June 1993 and 17 June 1995.

By 5 August 1953, about one-third to one-half of young observed could fly, whereas one-quarter of the young were capable of flight on 5 August 1954 (Olson 1954b). An estimated one-half to three-quarters could fly by 12 August that year (Olson 1954a). Trainer (1959) estimated that 5 percent of goslings were still flightless on 19 August 1959, and Bromley (1976) noted a few flightless young as late as the second week of September.

Energetics of reproduction—Bromley and Jarvis (1993) studied the energetics of migration and reproduction of dusky during three reproductive seasons, 1977-79. They found that during spring hyperphagia on the wintering grounds in

Table 8—Peak arrival and nest initiation dates, duration of the prelaying period, and mean clutch size of dusky Canada geese on the Copper River Delta, Alaska, 1959-1998

Year	Major arrival	Peak nest initiation	Approx. duration of prelay period	Mean size	clutch (n)	Source
1959	—	first nest 6 May	—	5.6	(194)	Trainer 1959
1964	—	delayed 3 weeks	—	4.3	(114)	Shepherd 1967
1965	—	—	—	5.8	(140)	McKnight 1971
1966	—	—	—	4.8	(100)	Shepherd et al. 1967
1968	—	—	—	5.1	(75)	Timm and Havens 1973
1970	—	—	—	5.4	(146)	McKnight 1971
1971	—	3 weeks late	—	3.6	(113)	Timm 1972b
1972	—	very late	—	4.4	(57)	Timm and Havens 1973
1973	—	—	—	4.9	(48)	Timm 1974
1974	25 Apr	9-14 May	13 days	5.6	(81)	Bromley 1976
1975	22 Apr	16-21 May	24 days	4.8	(215)	Bromley 1976
1976	—	—	—	4.8	(168)	Timm 1977
1977	17-22 Apr	2-7 May	16 days	5.4	(181)	Bromley and Jarvis 1993
1978	14-20 Apr	1-9 May	17 days	—	—	Bromley and Jarvis 1993
1979	18-25 Apr	3-7 May	15 days	5.7	(338)	Bromley and Jarvis 1993
1980	—	—	—	5.4	(152)	Timm 1982
1981	—	—	—	4.9	(28)	Timm 1982
1982	—	—	—	4.8	(135)	Campbell and Timm 1983
1983	—	6-10 May	—	5.5	(87)	Campbell 1984
1984	9-15 Apr	3-8 May	12-19 days	5.6	(123)	Campbell and Rothe 1985
1985	15-21 Apr	27 May-1 June	43 days	4.4	(64)	Campbell and Rothe 1986
1986	—	5-12 May	—	4.9	(78)	Campbell et al. 1987
1987	early Apr	5-12 May	30 days	5.5	(121)	Campbell et al. 1988
1988	—	8-14 May	—	5.5	(52)	Campbell and Rothe 1989
1989	20 Apr	11-17 May	22 days	5.3	(25)	Campbell and Rothe 1990
1990	26-31 Mar	8-17 May	38 days	5.3	(50)	Campbell 1990a
1991	31 Mar-6 Apr	10-16 May	35 days	5.4	(51)	Campbell 1991c
1992	mid-Apr	29 April-5 May	27-35 days	5.1	(93)	Campbell et al. 1992
1993	9-13 Apr	—	21+ days	5.1	(24)	Crouse et al. 1997
1994	8-12 Apr	about 22 May	20-30 days	5.1	(58)	Crouse et al. 1997
1995	31 Mar-3 Apr	about 2 May	—	5.6	(65)	Crouse et al. 1997
1998	early Apr	28 Apr- ?	20 days	—	—	Youkey 1998

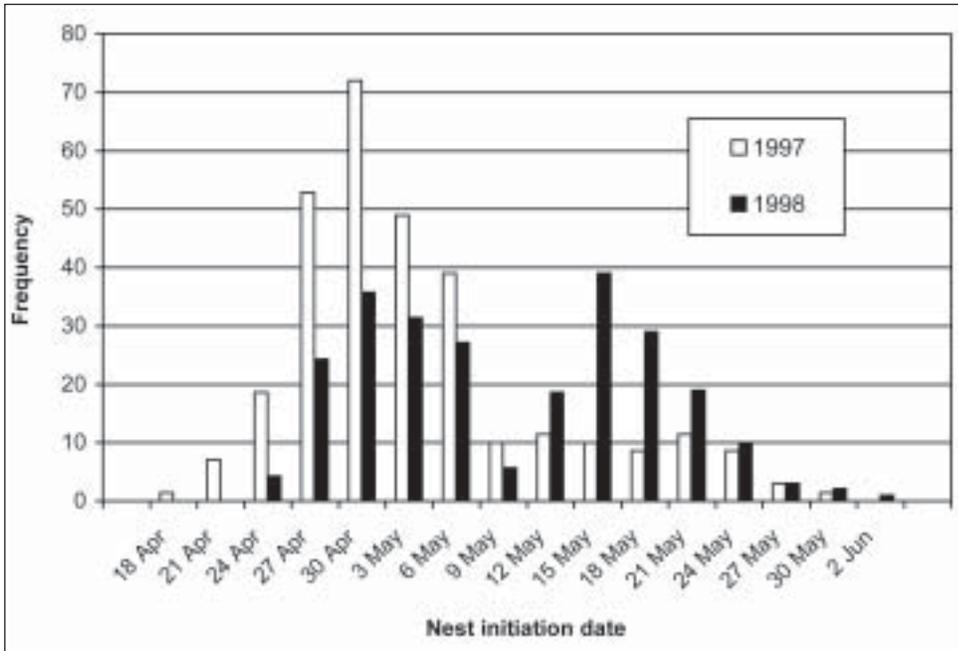


Figure 4—Bimodal distribution of dusky Canada goose nest initiation dates on the Copper River Delta, Alaska, typical of years when there is a considerable degree of renesting after high rates of early nest depredation. Nest initiation dates from Alaganik Slough study area (from Grand et al. 1998).

the Willamette Valley, geese accumulated large lipid reserves (30 percent of body mass) that were subsequently depleted by over 50 percent during the spring migration of 2600 km to the CRD. During the prenesting period on the CRD, however, geese restored some of their lipid reserves, increased their protein reserves, and met the costs of egg formation through intensive feeding on new, high-quality spring growth of vegetation. The energy and nutrient costs of egg laying were high, and were met largely through feeding and to a lesser extent by drawing upon reserves, particularly protein reserves. Catabolism of lipid and protein reserves accounted for about 75 percent of the estimated costs of incubation, with food consumed during incubation recesses meeting the remaining requirements. The energetics of subsequent stages in the life history of duskys has not been investigated.

Prenesting—Raveling (1978) hypothesized that some geese time their arrival on nesting grounds to permit the period of rapid development of ovarian follicles to occur there so that nest initiation (laying of the first egg) would be uniquely syn-

chronized with annual snowmelt conditions, and that this period would be a minimum of about 12 days for Canada geese. Duskys, for which the minimum prelaying period (peak arrival to peak nest initiation) is about 13 days (Bromley and Jarvis 1993), appear to fit this pattern (table 8). For duskys arriving on the CRD, ovarian follicles were increasing in diameter at a slow rate of <0.1 mm per day. However, when geese subsequently entered the stage of rapid development of ovarian follicles some time after arrival, growth rates increased more than twentyfold, to >2 mm per day (Bromley and Jarvis 1993).

Incubation—Trainer (1959) determined a mean incubation period (i.e., “the number of days between the laying of the last egg and the hatching of the last egg”) of 30.2 days (n = 36, range = 28 to 33 days). However, Bromley (1976), defining incubation as the period from the day after the last egg was laid to hatch of the first egg, found a mean of 27.4 days (n = 21, range = 25 to 31 days). Possibly the chilling effect of tidal flooding (Hansen 1961, Trainer 1959) slowed embryo development (e.g., Bromley 1984, Drent 1973)

and led to a longer incubation period during preearthquake times.

Constancy of incubation for successful dusky females was 89.5 percent, with twice the amount of recess time during the last third compared to the first two-thirds of incubation (Bromley 1984). This pattern reflected changes in body weight, where steep declines were observed for the first two-thirds of incubation, and no change thereafter. Females switched emphasis from dependence on endogenous reserves to a much greater reliance on environmental food resources during the last phase of incubation. Constancy of incubation and recess frequency steadily declined during the first 13 days of incubation for unsuccessful nesting geese, whereas no change was detected during this period for successful nesters (Bromley 1984).

Reproductive parameters—Eggs of dusky Canada geese on the CRD average about 56 mm wide by 82 mm long (table 3), with a fresh egg mass of about 140 to 144 g (Bromley and Jarvis 1993, Crouse et al. 1997). They are laid at the rate of one per day (Bromley 1976).

Clutch size—Mean annual clutch size has ranged from a low of 3.6 in 1971 to a high of 5.8 in 1965 (table 8), with individual clutches ranging from 2 to 8 eggs. Typically, low mean clutch size is observed in phenologically late springs (e.g., 1964, 1971, and 1972), and high mean clutch size occurs in early springs (e.g., 1959, 1979).

Egg success—Bromley (1976) compared the fate of eggs in Trainer's (1959) study ($n = 1,162$ eggs) to results from 1974 ($n = 283$) and 1975 ($n = 1,036$). Hatching success of eggs was 0.80 in 1959, 0.67 in 1974, and 0.28 in 1975. Seven percent, 17.2 percent, and 62.3 percent of the eggs were destroyed by predators in the 3 years, respectively. Of the remaining eggs in 1959 (206) and in 1975 (100), 10.2 percent and 30 percent were deserted, 30.1 percent and 0 percent were flooded, 40.8 percent and 16 percent were dead embryos, 3.4 percent and 10 percent were dead in pipped eggs, 4.4 percent and 7 percent were infertile, and 11.2 percent and 37 percent were of unknown fate. An insufficient sample was obtained

in 1974. Hansen (1961) demonstrated that most of the egg failure in the 1959 study was caused by flooding during the high spring tides, a phenomenon not observed in the mid-1970s after the 1964 earthquake (Bromley 1976). Beginning in 1982, investigators began to classify the cause of nest destruction based on published characteristics of depredation and locally acquired experience (Campbell 1990a, 1990b). Whereas nest destruction during early studies was largely due to avian predators (Bromley 1976, Trainer 1959), much of the depredation during the 1980s was attributed to large mammalian predators, primarily brown bears (*Ursus arctos*) and coyotes (*Canis latrans*). Subsequently, colonization of the nesting area by beaver (*Castor canadensis*) in the late 1980s combined with record levels of precipitation resulted in much of the area being flooded, causing wetter habitat in general (Campbell 1992b; Campbell et al. 1988, 1992) and increased egg loss due to flooding (Campbell and Rothe 1989, Campbell et al. 1988), a phenomenon not experienced since the earthquake.

Renesting—Investigators have long suspected that renesting occurred in dusky geese, based on different ages of broods observed late in the season (Olson 1953, 1954a) and distribution of nest initiation dates (Bromley 1976; Campbell and Rothe 1989; Campbell et al. 1987, 1988; Grand et al. 1998). Evidence of renesting became stronger with records of several second nests in the same bowls as earlier nests that had been destroyed (Campbell and Rothe 1989), and finally with the collection of five females in 1997 from relatively late-initiated nests, for which examination of ovarian condition provided certainty that at least four of the five were renesting (Grand and Anthony 1997). Grand et al. (1998) have attempted to model the extent of renesting based on nesting data during 1997 and 1998 (fig. 4).

Nest success—Many investigators have determined annual nest success from 1954 to the present (table 9), ranging from a high of 97 percent in 1966 to a low of 4 percent in 1993. Although Mayfield-type nest success (Mayfield 1975) was not calculated until 1997 (Grand et al. 1998), destroyed nests were easily detected, at

Table 9—Fate of dusky Canada goose nests on the Copper River Delta, 1959-1998

Year	n	Fate				Type of destruction			
		Successful	Destroyed	Abandoned	Unknown	Mammal	Avian	Flooded	Unknown
		-----Percent-----				-----Percent-----			
1959 ^a	1,162	79.6	6.0	1.8	2.0	0.0	11.4	88.6	0.0
1964 ^b	102	82.4	9.8	7.8	—	—	—	—	—
1965 ^b	221	62.9	30.3	6.8	—	—	—	—	—
1966 ^b	100	97.0	0	3.0	—	—	—	—	—
1968 ^b	38	86.8	13.2	0	—	—	—	—	—
1970 ^b	186	88.2	8.6	3.2	—	—	—	—	—
1971 ^b	100	76.0	24.0	0	—	—	—	—	—
1972 ^b	116	81.0	19.0	0	—	—	—	—	—
1974 ^c	81	82.7	14.8	2.5	—	—	—	—	—
1975 ^c	215	31.6	64.6	3.7	—	—	—	—	—
1977 ^d	229	79.0	—	—	—	—	—	—	—
1978 ^d	390	56.2	—	—	—	—	—	—	—
1979 ^d	409	18.2	—	—	—	—	—	—	—
1982 ^e	158	49.2	49.0	1.8	—	45.0	33.8	0	21.8
1983 ^e	162	51.9	36.5	6.0	8.0	64.8	5.6	0	29.6
1984 ^e	161	75.8	14.9	3.1	6.2	62.4	37.6	0	4.0
1985 ^e	258	7.0	81.0	1.9	10.0	78.8	18.4	0	2.8
1986 ^e	201	11.4	67.2	9.0	12.5 ^j	83.7	5.2	0	11.1
1987 ^e	213	23.9	61.0	14.1	1.0	45.6	47.3	7.0	.2
1988 ^e	110	17.3	61.8	3.6	17.3 ^j	53.3	40.0	6.7	.1
1989 ^e	94	4.3	76.6	3.2	15.9 ^j	54.1	45.8	0	.1
1990 ^e	88	44.3	34.1	5.7	15.9 ^j	15.0	85.0	0	0
1991 ^f	91	31.9	35.2	6.6	26.4 ^j	7.2	92.9	0	0
1992 ^g	96	40.6	28.1	7.3	24.0 ^j	33.3	51.9	0	14.8
1993 ^h	100	4.0	68.0	3.0	25.0 ^j	2.9	7.4	0	89.7
1994 ^h	205	4.9	79.0	0	16.1 ^j	—	—	—	—
1995 ^h	106	12.3	84.9	2.8	0	56.7	8.9	0	34.4
1998 ⁱ	81	14.8	71.6	8.6	4.9 ^j	—	—	—	—

^a Trainer 1959; egg success rather than nests.

^b Timm and Havens 1973.

^c Bromley 1976.

^d Bromley unpubl. data.

^e Campbell and Rothe 1990.

^f Campbell 1991c.

^g Campbell et al. 1992.

^h Crouse et al. 1997.

ⁱ Youkey 1998.

^j Nests still active at last visit: 1986—9%; 1988—17.3%; 1989 and 1990—unknown; 1991—23.1%; 1992— 22%; 1993—12%; 1994—8%; 1998—4.9%.

least until recent times, and were included in the apparent nest success estimates, alleviating much of the inherent bias estimating true nest success rates. Clearly, nest success was much higher during the 1950s through the early 1970s than it has been since, and thus an overall declining trend is reflected (fig. 5). Note that in several years, nest success estimates are minimums, because late-initiated nests that typically are more successful than early-initiated nests were not followed to completion. Nevertheless, because nest success has been so low, net productivity of adults has declined over time.

The high degree of renesting in the 1980s and 1990s (Campbell and Rothe 1989; Campbell et al. 1987, 1988; Crouse 1995; Grand and Anthony 1997; Grand et al. 1998) may have mitigated, to some degree, the lower success of individual females, particularly because nest success was higher in late-initiated nests compared to earlier ones in some years. Bromley (1976) and Bromley et al. (1995) found that most depredations on Canada goose nests occur during the early stages of nesting. Although relatively low in absolute numbers, re-nests and late-initiated nests have higher success than do early nests.

Before the 1964 earthquake, nest loss was caused primarily by tidal flooding during spring and depredation by avian predators (Hansen 1961, Shepherd 1967, Trainer 1959), but the rate of nest loss was low. Dusky nests were apparently quite robust to flooding, and eggs could survive some degree of immersion in water (Hansen 1961). Immediately after the earthquake, mammalian predators appeared to be more abundant on the CRD than they had been earlier, and rates of nest loss to predators increased (Shepherd 1966). Nest success has been highly variable thereafter, with a long-term declining trend to the present (fig. 5).

Bromley (1976) observed a close relation between annual production of young and annual spring conditions—reflected by the amount of snow on the ground on 1 May—and monthly deviations from long-term, normal temperature and precipitation. He estimated that spring conditions accounted for 80 percent of the variation in percentage of young in the population from 1971

through 1975. Campbell (1990b) conducted a similar investigation for 1982-86 and found that weather continued to play a significant role in affecting annual production. He concluded that the relation operated via habitat availability; during late springs, preferred nesting habitats are unavailable because of persistent snow, thereby resulting in greater use of open drainage levees that are frequented by nest predators.

Brood survival to fledge—Beginning in 1971 (table 10), the proportion of young in the population was estimated annually by an aerial survey conducted when the young were about two-thirds grown (Timm 1972b). Thus, to some extent, a comparison of nest success with the proportion of young in the population observed later in the season yielded a rough index to gosling survival. This estimate is necessarily crude because it does not account for variables such as the proportion of adult birds that are breeders versus nonbreeders each year. During most years, when nest success was high, the proportion of young seen on the production survey was high and vice versa, although there were exceptions. In 1988 and 1991, there were more young than could be expected from the very low nest success observed, thereby indicating that brood survival, or perhaps undetected renesting, was higher than usual despite low nest success recorded on surveys. In 1972, 1975, 1983, and 1984, there were far fewer young than expected given high nest success (tables 9 and 10), thereby indicating the likelihood of very poor brood/gosling survival in those years (Campbell and Rothe 1985, Cornely et al. 1985).

Studies of brood survival by using radio-marked goslings were initiated in 1997 (Grand and Anthony 1997). Preliminary results from their first 2 years of study indicate relatively low gosling survival caused by high rates of depredation (Grand et al. 1998).

Production—Production estimates for dusky on the nesting grounds, in the form of percentage of young in the population [(no. young/(no. adults + no. young)) x 100], have been conducted annually since 1971 by the Alaska Department of Fish

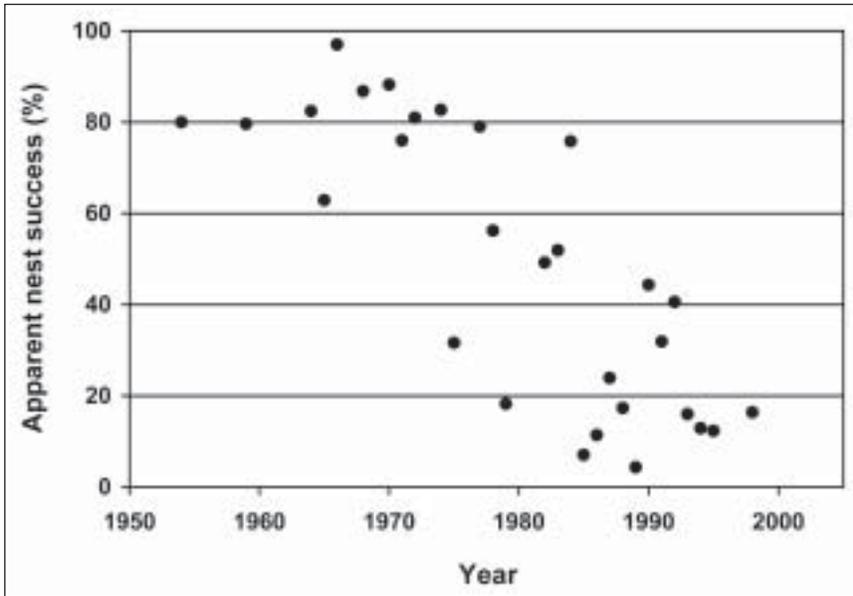


Figure 5—Nest success rates of dusky Canada geese on the Copper River Delta, Alaska, 1954-2000.

Table 10—Percentage of young observed among dusky Canada geese on the Copper River Delta, Alaska, from July aerial surveys, 1971-2002

Year	Young	Year	Young
	<i>Percent</i>		<i>Percent</i>
1971	16.2	1987	9.8
1972	10.6	1988	22.8
1973	36.0	1989	8.6
1974	51.4	1990	23.5
1975	17.9	1991	21.5
1976	24.2	1992	23.1
1977	44.3	1993	5.0
1978	24.8	1994	5.7
1979	16.0	1995	3.9
1980	23.7	1996	21.7
1981	17.9	1997	10.5
1982	23.7	1998	11.7
1983	15.0	1999	14.7
1984	18.3	2000	24.1
1985	3.7	2001	25.4
1986	10.7	2002	30.5

and Game (Timm 1972b). Initial observers noticed that during surveys on which Beaver aircraft were used in low and slow flight, identification of pure adult flocks and mixed flocks of both adults and young could be discriminated. They recommended that for mixed flocks one observer count young and another count adults. Furthermore, to account for their inability to detect all young in brood flocks, they arbitrarily assumed a visibility rate of 50 percent, and thus doubled the number of young to derive a final estimate of the percentage of young in the population. This method was used through 1984 and yielded estimates that were supported by independent estimates from age ratios in the harvest, adjusted for differential vulnerability to hunting (Timm et al. 1979). Also, for 1975 through 1984, trends (decreasing or increasing) between years for age ratios in the harvest on refuges in Oregon (Jarvis and Cornely 1988) were entirely consistent with estimates of percentage of young in the population on the breeding ground (Campbell 1984, Campbell and Rothe 1985, Campbell and Timm 1983, Timm 1982, Timm and Sellers 1979, Timm et al. 1979).

From 1985 through 1991, a Cessna 185 was used with a pilot and two observers: one observer in the front assisted with spotting and navigation, then counted adults and took aerial oblique photographs of flocks (1986-88), and the observer in the rear counted young and recorded data (Campbell and Rothe 1986). Logistical problems prevented visibility-corrected estimates in 1985 and 1989-91 (Campbell and Rothe 1986, 1990), but weighted regressions were used to estimate both numbers of adults and young in 1986-88 (Campbell and Rothe 1989; Campbell et al. 1987, 1988) (table 10). From 1992 to the present (Petrula 2001, 2002; Rothe 1993, 1994, 1995, 1996, 1997, 1998, 1999; Rothe and Petrula 2000), a Robinson 22 helicopter was used, wherein the pilot and one observer flew 4.8 to 6.0 hours of survey each year. Total numbers of adults and young observed, and percentage of young were reported. Recorded numbers of young were doubled in all cases, as with original counts (Timm 1972b). During the period 1971 through 1984, production ranged from 10.6 to 51.4 percent young and averaged 24 percent young (table

10). Since 1985, the annual proportions of young have been variable (3.7 to 30.5) averaging only 15 percent young, and production has been below 10 percent in 6 of the past 18 years.

Nest densities and nearest neighbors—Using 100 random plots of 2.6 ha, Courtright (in Olson 1954c) determined a nest density of 0.03 to 0.04 nests per ha on a 225-km² study area between Copper (Alaganik) Slough and Kokanhenic Channel in 1954. In a high-density area of about 4.1 km², Trainer (1959) found 0.42 nests per ha. These studies reflect a relatively low density of nests before the 1964 earthquake.

Shepherd et al. (1967) established 15 random 2-ha plots, in which they located 13 nests in 1966 (0.4 per ha). Seven of these plots hosted 27 nests (1.9 per ha) in 1970 (McKnight 1971) and 20 nests (1.4 per ha) in 1972 (Timm and Havens 1973). Bromley (1976) found, in 20 random plots of 2 ha, a mean density of 0.6 nests per ha in 1974, and in larger nonrandom plots spanning low-, medium-, and high-density strata, densities of 0.3 to 1.3 nests per ha in 1975. One of these large plots, overlapping with part of Trainer's (1959) study area, had a density of 0.8 nests per ha in 1975. Studies in the late 1960s through the 1970s reflected continually increasing densities of nests on the CRD.

Alaska Department of Fish and Game biologists continued searching the eight sample plots established by Bromley (1976) through 1992 (table 11), adding a 9th plot in 1981 and a 10th in 1983; the size of the plots ranged from 0.23 to 0.88 km² and totaled 4.3 km². Nest densities remained stable at about 0.7 nests per ha through 1980, dropped to about 0.5 nests per ha throughout the 1980s, then declined further to 0.4 nests per ha by the early 1990s (table 11). Whereas consistent plot surveys were intended to illustrate changes in nest density between 1975 and 1992, habitat succession on the plots may have caused redistribution of geese, thereby obscuring actual trends in nest densities. The high nest densities characteristic of the coastal stratum plummeted between the mid-1970s and the early 1990s (fig. 6a), whereas densities in the middle and inland strata

Table 11—Dusky Canada goose nest densities on standardized study plots, Copper River Delta, Alaska, 1975-1991

	Plot								All plots	
	1	2	3	4	5	6	7	8		
	----- Area (km ²) -----								km ²	
	0.23	0.36	0.23	0.61	0.87	0.28	0.20	0.49	3.27	
Year	----- Nests/km ² -----								km ²	Nests/km ²
1975	1.13	1.12	0.70	0.64	0.68		0.50	0.16	298.9	0.70
1976	1.04		.70	.66	.53		.55	.10	263.1	.60
1977	1.26	.78	.70	.52	.64	0.50	.60	.31	326.9	.66
1978	1.52	1.03	.57	.48	.63	.50			257.9	.79
1979	.48	.53	.70	.44	.54	.79			257.9	.58
1980	.87	.61		.54	.53				206.9	.64
1981	.35	.8	.17	.33	.16	.21	.20		277.9	.22
1982	.56	.33	.48	.48	.55	.79	.25	.22	326.9	.46
1983	.74	.42	.39	.31	.43	.68	.45	.33	326.9	.47
1984	.43	.20	.52	.41	.43	.93	.30	.29	326.9	.44
1985	.91	.28	.61	.30	.41	.75	.40	.29	326.9	.49
1986	.82	.39	.43	.38	.50	1.11	.25	.41	326.9	.54
1987	.52	.47	.35	.34	.50	.86	.30		277.9	.48
1988	.61	.42	.35			1.04	.50		129.9	.58
1989	.48	.39	.30			.79	.70		129.9	.53
1990	.39	.22	.39			.57	.55		129.9	.43
1991	.13	.25	.30			.71	.65		129.9	.41

Data sources: Original data from Bromley 1976, Bromley unpubl. data, and Alaska Department of Fish and Game annual reports: Campbell 1984, 1991c; Campbell and Rothe 1985, 1986, 1989, 1990; Campbell and Timm 1983; Campbell et al. 1987, 1988.

remained fairly stable overall (fig. 6d) but actually increased in some plots (e.g., plot 7, fig. 6c and plot 6, fig. 6b). In 1992, the Pacific Flyway Subcommittee on the Dusky Canada Goose recommended discontinuing these searches because the data were not being used in management decisions. Instead, the subcommittee recommended a program of nest searches of random plots throughout the CRD, to be conducted every 3 years, to provide nest-density data that might be useful in population estimation, similar to the method used in western Alaska (Stehn 1991). The new nest survey regime, implemented by the USDA Forest Service, Cordova Ranger District, was also intended to provide occasional measures of nest success in relation to types of nest predators and trends in habitat use by dusky geese across the CRD.

Thus, random plots were established within a 212-km² extensive study area; average nest densities were 22.0 ± 4.3 per km² (0.2 per ha) from 1993 through 1995 (Crouse 1994b, 1995; Crouse et al. 1995). In 1998, Youkey (1998) repeated the survey and found 17.7 nests per km² (0.18 nests per ha—uncorrected for detection rates and late-initiated nests) during the early search (i.e., probably did not include later renests). They also examined nest detection rates by next-day repeat searches of plots with independent field crews, and derived a detection rate of 83.2 percent ± 0.4 percent (95 percent CI) for nests on plots. Thus, a corrected mean density would be about 0.21 nests per ha. In an area overlapping with Trainer (1959) and Bromley (1976), Grand and Anthony (1997) found 412 nests in 13.5 km² (0.31 per ha) within

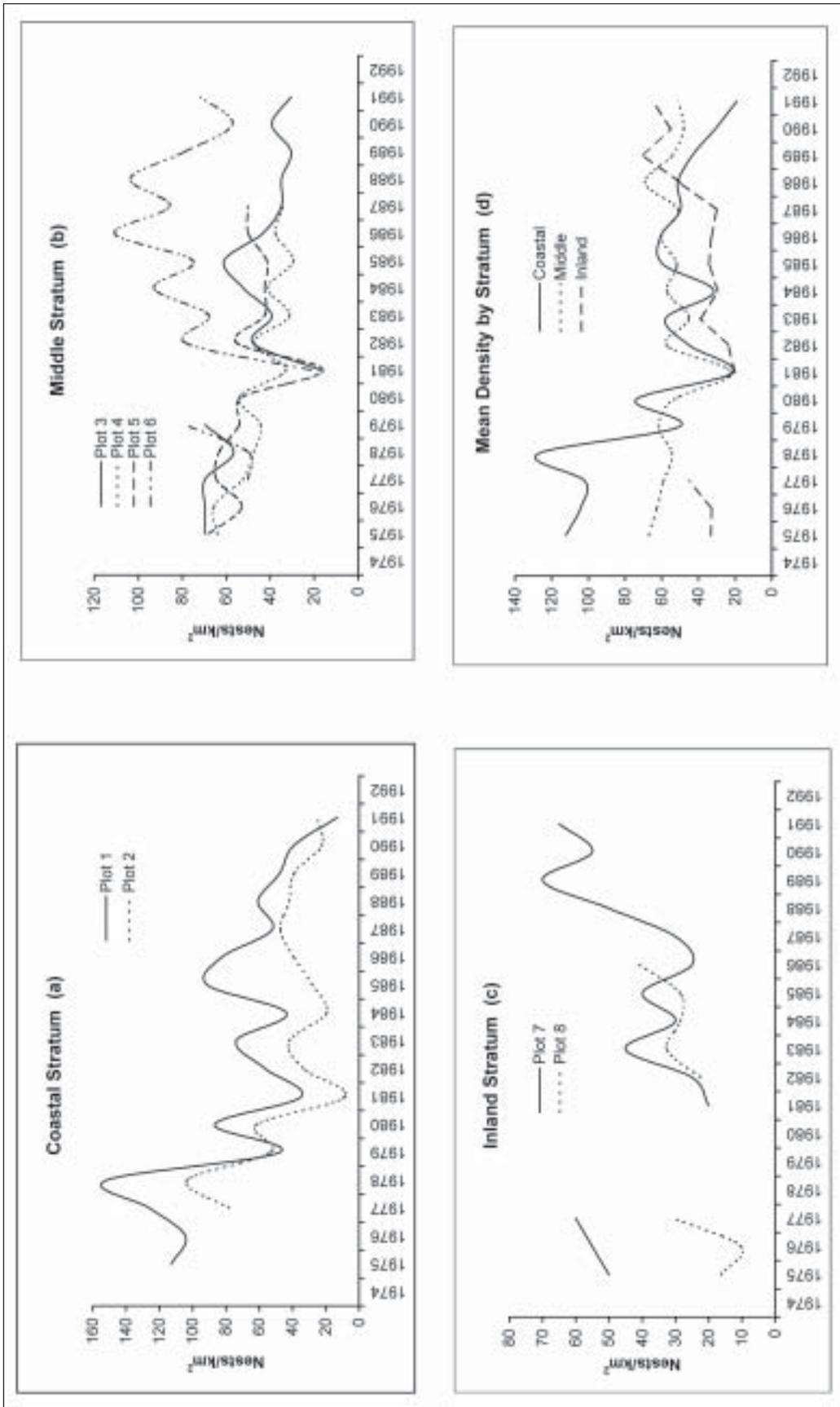


Figure 6—Nest densities of dusky Canada geese on sample plots on the Copper River Delta, Alaska, 1975 through 1991.

the high-density stratum in 1997. Based on these studies, nest densities apparently peaked in 1978 and declined thereafter to levels similar to those measured during the 1950s.

Little work has been conducted on the eastern CRD; however, Mickelson et al. (1980) sampled 1.56 km² of belt transects on a 91.5-km² study area there and estimated a mean density of 1.9 nests per km² (0.02 per ha) in 1978 and 1979.

Trainer (1959) found that nearest nesting neighbors were at least 91 m apart, and most were at least 183 m. In one of Bromley's (1976) plots in 1975, nearest neighbors averaged 51 m (n = 40 nests, sd = 15, range = 31 to 88 m), which was consistent with nest densities that were higher in the 1970s than in the 1950s.

In summary, major efforts using large samples of random plots to determine nest densities were conducted in 1954, 1993 through 1995, and in 1998, and consistent surveys were conducted on nonrandom plots from 1975 through 1992. Although not all estimates are comparable, it appears that nest densities increased from a low in the 1950s to a peak in the mid-1970s, then declined to a level similar to that of the 1950s. Random sample plots yield the best estimates of representative nest densities throughout the CRD. These surveys will be continued every 3 years (Pacific Flyway Council 1997). However, the tendency for dusky to reneest at higher rates in years with late springs, associated with high rates of nest loss early in the season, makes it problematic to interpret nest densities over time as an index to the density of breeding pairs (e.g., Crouse et al. 1997, Grand et al. 1998).

Molt and dispersal—Olson (1953, 1954a) observed the first flightless dusky of the year on 4 July in 1953 and 5-10 July in 1954. He concluded that most adult geese were flightless by 20-27 July 1953 and by 19 July 1954, and that one-third could fly by 4-5 August each year. One-half to three-quarters could fly by 10 August 1953, and three-quarters were flight capable by 12 August 1954. Trainer (1959) reported the first flightless geese of 1959 on 6 July, with most geese molting by 15 July. Bromley (1976) reported flightless

birds by the second week of July 1974 and 1975, and estimated that 95 percent of adult geese were capable of flight by mid-August. Although Mickelson et al. (1980) saw few geese during the breeding season on the eastern CRD, geese were observed using the area for molting in August, with at least 120 of 500 to 700 birds still flightless on 9 August. Grand (1997) observed premolt movements of two nest-trapped and radio-marked females out of high-density nesting areas near Alaganik Slough. These two birds lost or abandoned broods and moved south and east up to 105 km to areas near the Martin and Bering Rivers, and Bering Glacier.

Beginning in mid-August, and by the end of August, redistribution occurs in which geese disperse into areas not used since early spring, such as onto the upper CRD and the eastern CRD. Crowley (1999a) observed 110 Canada geese, including five neck-collared dusky, on Hinchinbrook Island in PWS in September 1996. Mickelson et al. (1980) interpreted a movement of large numbers of dusky onto the eastern CRD throughout August as a postmolt dispersal onto fall staging habitat.

Migration

Dusky begin an eastward shift in mid-August through early September, after which the majority of the population has departed from the western CRD; remaining geese, an estimated 2,000 to 3,000 in both 1978 and 1979 on the eastern CRD (Hawkings 1982), stage from early to at least mid-October before the final exodus (Crouse 1994a, Hawkings 1982, Mickelson et al. 1980). Some birds move southeast to stage on the Yakutat Forelands. Petersen et al. (1981) reported two peaks of dusky staging there, one during 15-25 August and another during 4-10 October 1980. Hawkings (1982) examined weather conditions associated with visible bird migration through the eastern CRD during late fall and concluded that migration was associated with the most favorable upper air winds at Anchorage and surface winds at Cordova, southwest winds in the upper air and at the surface, and rapidly increasing atmospheric pressure.

Based on leg band returns, Hansen (1960, 1962) concluded that dusks had left the CRD by 15 October, and he suggested that the birds migrate offshore stopping at relatively few accessible places en route south. Petersen et al. (1981) reported that far fewer dusks were observed during fall migration at the Yakutat Forelands, Alaska, than during spring. Hansen (1960) found the first band returns from Vancouver Island about 20 October. Observations in the QCI indicate that for the years 1982, 1986, 1988, and 1990, when consistent records were kept, goose numbers tended to increase during early to mid October each year (Hearne 1999). Kebbe (1958), examining the date of band returns in the Willamette Valley for the period 1951-57, concluded that although occasional flocks arrived as early as mid-October, average peak arrival was mid-November. Looking at band returns during consecutive 10-day periods, Chapman et al. (1969) described the chronology of fall migration from Alaska to Oregon. Peak arrival dates in the Willamette Valley were early to mid November. Zeillemaker (1973) noted that dusks began arriving at Baskett Slough National Wildlife Refuge (NWR) in Oregon on 25 September 1971-73, with the first dusks at William L. Finley NWR on 1 October 1973. Numbers built rapidly through 2 November of that year. Naughton (1993) reported the first dusks at William L. Finley NWR on 12 October in both 1985 and 1986.

Rodgers (in Timm 1972b) noted that dusks departed William L. Finley NWR on 14 April 1972. On 23 April of the same year, Timm (1972a) with B. Wood of Alaska Department of Fish and Game, saw many flocks of what appeared to be dusks at Ketchikan, Alaska, heading north. Zeillemaker (1974) observed dusks departing from Willamette Valley refuges 14-19 April 1973 and 19-21 April 1974, noting of the latter that it was late compared to the average departure date of 14 April. Spring departures of dusks from wintering sites also were observed on 18-19 April 1975 (Rodgers 1975) and 15-21 April 1976 (Annear 1976), and Naughton (1993) reported the last departures from William L. Finley NWR by 15 April each year during the mid-1980s. Dusks

migrated by the Yakutat Forelands during 9-19 April 1980 (Petersen et al. 1981). On the eastern CRD, dusks migrated through in small flocks during mid to late April, with numbers declining rapidly after 17 April 1979; spring migration was much briefer and more concentrated than fall migration (Hawkings 1982). Visible bird migration through the eastern CRD area coincided with high pressure systems over the CRD bringing southwest surface winds and northwest upper air winds, high pressure, clear skies, and large diurnal range in temperature (Hawkings 1982).

Bromley (1984) recorded one family group of five dusks, including three uniquely neck-colored individuals that migrated from William L. Finley NWR, Oregon, to the CRD in a maximum of 4 days; however, he noted the average time for spring migration was about 11 days.

Wintering

Before the establishment of federal refuges, hunt clubs strongly influenced the distribution and harvest of wintering dusks in Oregon (Chapman et al. 1969, Hansen 1962). Chapman et al. (1969) reported that in the absence of a public refuge program, the harvest could have been much greater had the hunt clubs not provided refuge and regulation of the take. By the late 1960s, however, refuges had assumed the role of providing food and haven for geese (Chapman et al. 1969, Hansen 1968).

Dusks arrive in the LCR and Willamette Valley before the arrival of the most abundant races, cackling and Taverner's Canada geese (Jarvis and Bromley 1998, Simpson and Jarvis 1979). The relative abundance of dusks is consistently highest at William L. Finley NWR, particularly after the hunting season is over (Simpson and Jarvis op. cit.). Sheaffer (1993) studied subflock behavior based on 947 individually marked dusks and concluded that those wintering at the southern and northern extremes of their wintering range, near William L. Finley NWR and Sauvie Island Wildlife Area, respectively, had the highest wintering site fidelity. Over 65 percent of these geese were not observed outside of their respective wintering areas. The marked geese formed 9 to

10 indistinct clusters of 191 to 206 groups averaging 2.8 marked birds per group each for the 3 years of study, and groups had the same affiliations during both harvest and nonharvest periods (Sheaffer 1993).

Duskys typically select smaller fields for feeding than do other sympatric races of wintering Canada geese (Havel and Jarvis 1988, Simpson and Jarvis 1979). Based on research at Sauvie Island, Oregon, where duskys commonly winter in mixed aggregations with other subspecies, Havel and Jarvis (1988) concluded that duskys are segregated during commuting flights but mixed during feeding, and that they select fields with fewer geese to feed in and approach lower and circle less before landing than do other subspecies. These characteristics result in higher vulnerability of duskys to harvest (Havel and Jarvis 1988, Jarvis and Cornely 1988, Simpson and Jarvis 1979).

Food Habits

Reproduction—Food habits during nesting, brood rearing, and molt are poorly known. Dusky geese feed on tidal mudflats in early spring and during brood rearing and molt. They use spring melt pools in horsetail (*Equisetum* spp.) and sedge (*Carex* spp.) stands during the early spring melt, and they have been observed feeding on early sedge and horsetail shoots, and unfurled leaves of prostrate willow (*Salix arctica* Pall.) late in the melt (Bromley pers. obs.). During late incubation, the esophageal and proventricular contents of 12 adult female geese on the CRD contained sedge leaves and seeds, horsetail, prostrate willow leaves, and vetch (*Lathyrus* spp.) stems and leaves (Bromley 1984).

Migration—Duskys consumed at least 26 species of 13 families of plants on the eastern CRD during September and October (Hawkings 1982). In particular, 15 species of Cyperaceae, Gramineae, Juncaginaceae, and Juncaceae, together with horsetail (*Equisetum arvense* L.), accounted for 87 percent of the total volume of the diet (Hawkings 1982). Leaves were the most important component by volume overall; however, seeds and roots increased in importance as

fall advanced. In freshwater habitat on the eastern CRD, geese selected horsetail, Lyngbye's sedge (*C. lyngbyei* Hornem.), Nootka alkali grass (*Puccinellia nutkaensis* (Presl) Fern. & Weath.), and plantain (*Plantago maritima* L.). In salt marsh, they selected arrow grass (*Triglochin palustris* L.), horsetail, bent grass (*Agrostis* spp.), and rush (*Juncus alpinus* Vill.) (Hawkings 1982).

Wintering—Although there have been no studies on diet of duskys during winter, it is commonly understood that they rely largely on agricultural crops (e.g., Clark and Jarvis 1978, Pacific Flyway Council 1998). Federal and state refuge management directed toward providing food crops is likely a good reflection of the favored winter foods of duskys. On William L. Finley NWR during the mid-1980s, crops provided included about 1,000 acres of perennial ryegrass (*Lolium perenne* L.), 500 to 700 acres of annual ryegrass (*L. multiflorum* Lam.), 320 acres of pasture (grasses and forbs), 200 acres of tall fescue (*Festuca arundinacea* Schreb.), and 35 acres of winter wheat; there were 185 acres of corn during one winter (Naughton 1993). During this period, Canada geese, of which about half were duskys, tended to use annual and perennial ryegrass most extensively, particularly during early and late winter; tall fescue and pasture were predominantly used during midwinter, with pasture being used significantly less than any other forage type (Naughton 1993). Crop plants on the refuge decreased in height and cover from November through January, then increased from February until the geese departed; numbers of geese on the refuge followed a similar pattern (Naughton 1993). Naughton (1993) observed a relation between goose use of fields and food quality during spring 1986, but not during the following spring. She noted, however, that the average quality and quantity of these forage crops are high. Thus, other factors such as weather and security may influence patterns of field selection for foraging.

Crops most commonly provided on federal and state lands in total, in descending order of acreage, include pasture grasses, moist soil vegetation (Fredrickson and Taylor 1982), annual ryegrass, perennial ryegrass, fescue, Sudan grass/millet

(*Sorghum bicolor* (L.) Moench ssp. *drummondii* (Nees ex steud.) deWet and Harlan), clover, and corn (Pacific Flyway Council 1998). On the Saanich Peninsula of Vancouver Island, British Columbia, Macgregor (1993) observed dusks feeding on waste carrots and pasture.

Habitat

Breeding—Almost the entire population of dusky Canada geese nests on the CRD in south-central Alaska. The Copper River, originating at the Copper Glacier on the border between Alaska and Yukon, flows 179 km to the Gulf of Alaska (Kruger and Tyler 1995). There, the river, in concert with much smaller rivers from several adjacent glaciers (Scott, Sheridan, and Sherman on the west, and Bering on the east), deposits huge silt loads in the relatively still waters of the Gulf of Alaska. The combined effect of the glaciers and rivers yields a characteristic pattern from inland to the sea, of "...kettle-kame topography, moraines, outwash plains or flood plains, deltaic deposits and dune-dominated landscapes fronting the ocean" (Boggs 2000), with the upper landscapes consisting of glacial outwash gravel deposits. Although this general pattern persists, the finer terrestrial and aquatic features of the delta are constantly experiencing dynamic change, as they are carved and molded by glacial, riverine, tidal, and tectonic forces.

The Chugach Mountains shielding the delta from the cold interior air masses to the north, and the marine environment to the south combine to develop a maritime climate with mild, wet summers and cool, wet winters. Precipitation is high, averaging 218 cm midway across the piedmont, and an average of 262 days per year are cloudy (Searby 1969). Boggs (2000) reports that "mean monthly temperatures at sea-level range from -4 °C in January to 14 °C in July."

Upon arrival in early spring and when extensive snow cover remains, dusks concentrate for staging and foraging in snow- and ice-free intertidal zones in Orca Inlet, such as in Hartney Bay, and early snow-free habitats along the Copper River Highway through the upper delta. These habitats were not greatly affected by the earthquake, and

this pattern persists today. As snowmelt progresses on the outer delta, geese gradually move out to set up territories in their nesting habitats (Bromley pers. obs.).

In the late 1950s and early 1960s, nesting geese on the delta concentrated in an outer 4- to 6-km-wide zone dominated by extensive sedge flats with slough levees vegetated by forbs, grass, and a low shrub, sweet gale (*Myrica gale* L.) (Nelson 1953; Olson 1954c; Trainer 1959, 1967; Trainer and Shepherd in Hansen 1961). Restricted in their use of different habitats by frequent, high, inundating tides, dusks nested largely within the grass-forb habitat along the raised levees bordering the tidal channels (97 percent of nests in 1959 (Trainer 1959)). The grass-forb habitat occasionally experienced tidal inundation during the nesting season (Hansen 1961). As this zone integrated with inland habitat dominated by alder (*Alnus* spp.) and willow (*Salix* spp.), nest densities of geese decreased (Shepherd 1961; Trainer 1959, 1967). Nests were highly successful because there was little loss to depredation (Courtright in Olson 1954a, Trainer 1959).

Dramatically accelerated successional changes have occurred because of the uplift by the 1964 earthquake. Essentially all preearthquake intertidal habitats are no longer flooded by tides (Potyondy et al. 1975; Shepherd 1966; Thilenius 1990a, 1990b). Freedom from tidal influence led to desalinization of soils, a process enhanced and accelerated by high annual rainfall (Crow 1971, Shepherd et al. 1968), and an increased rate of community succession, including colonization of all habitats by the shrubs sweet gale, willow, and alder (Shepherd et al. 1967, Thilenius 1995). Salt-tolerant plants have been replaced with other species often of less nutritional value to geese (Crow 1971). Shrubs became established quickly in previously intertidal basins and levees, but less quickly on the higher levees, possibly because of interspecific plant competition in those habitats (Crow 1971). Today, the sharp delineation of ecotones typical during preearthquake times (Crow 1968) is no longer obvious, and habitats have considerably more closed canopies than previously (Thilenius 1995). The new salt marsh

zone, developing about 15 km seaward, is relatively small and expanding slowly with the interaction of colonizing sedges and silt trapping. Remaining habitats are no longer saline, and although they still often host extensive swards of Lyngbye's sedge, they have become colonized and are visually dominated by shrubs (sweet gale, willow, and alder) (Thilenius 1995).

Despite the great changes, geese have continued to occupy the same zone on the outer delta as previously described by Campbell (1988), Trainer (1959), Shepherd (1961), and Hansen (1961). Within 3 years of the earthquake, however, geese began increasing their use of the sedge meadow habitat for nesting (Shepherd et al. 1968). Geese were no longer restricted to the levees for nesting because tides no longer flooded meadow habitat. The increase in use of sedge meadow for nesting continued through 1975 when 20 percent of their nests were in this habitat (Bromley 1976), and during 1982-86 when an average of 40 percent were in sedge meadow (Campbell 1990b). The greater extent of shrubs in all communities, but particularly in sedge basins, did not deter geese from nesting there. By 1975, 23 percent of nests were in low shrub habitat (Bromley 1976), and during 1982-86 an average of 46 percent of nests were in low and tall shrub habitat (Campbell 1990b). Geese did not stop using sedge meadow and grass-forb nesting habitat even with the prolific colonization of those habitats by low and tall shrubs.

During the late 1980s, beavers colonized the nesting area in great abundance, damming up old tidal channels and causing substantial flooding in habitats that were relatively dry in the 1970s (Campbell 1992b, Campbell and Rothe 1989, Campbell et al. 1988). Although this caused some nests to be flooded during the early years of this phenomenon when spring precipitation was much above normal, the extensive new impoundments may have resulted in a decrease in nest predation by large mammalian predators (Campbell 1992b, Campbell et al. 1988). In recent years, no nests have been lost to flooding (Crouse et al. 1995).

Three studies of nest habitat availability and use have been conducted on the CRD. During the mid-1970s, nesting geese preferred low shrub and grass-forb or levee habitats, while tending to avoid the sedge habitat (Bromley 1976). A decade later, nesting geese still preferred low shrub habitat, and also the new tall shrub habitat, while selecting against the levee habitat; they used sedge meadow habitat in proportion to its availability (Campbell 1990b). Both investigators concluded that nesting cover was an important factor for nesting geese, and Campbell (1990b) found that annual variation in nesting habitat selection was accounted for by spring habitat conditions and phenology. During late springs, snowmelt in shrub habitats is retarded relative to that in open habitats, and thus shrub habitats are relatively less available to nesting geese. During 1993-95, Crouse et al. (1997) reported findings similar to Bromley (1976), with geese using willow and sweet gale community types in a greater proportion than their availability, and avoiding sedge community types for nesting. Further, they demonstrated that geese used peninsulas and new marsh sites in greater proportions than their availability, and avoided levees and interlevee basins.

Both Crouse et al. (1997) and Bromley (1976) concluded that geese preferred low shrub cover at nest sites. Bromley (1976) suggested that the geese might be selecting for good visibility from nests, and ease of sudden escape if attacked by predators. Campbell (1990b) and Crouse et al. (1997) found that during 1982-86 and 1993-95, nests in all community types were equally susceptible to depredation.

New tidal marsh habitat has been slow to develop on previously subtidal land exposed by the earthquake (Kempka et al. 1995). Slopes of the submarine and tidal portions of the delta increased from an estimated 3 to 4.5° preearthquake to 6° post-earthquake (Reimnitz 1972) so that the effective area exposed for development of beneficial nesting habitat for geese in the short term is small. Shepherd (1966) predicted that the area would not likely be over 50 km². Boggs (2000), however, reviewed the processes involved and noted that conditions for the development of new tidal

marsh are currently excellent. Pioneer species such as dwarf alkali grass (*Puccinellia pumila* (Vasey) Hitchc.) and Lyngbye's sedge are now becoming established on the tideflats and will result in accretion and stabilization, causing the marsh front to advance seaward. In addition, the delta apparently has experienced a cycle of sudden uplift and gradual subsidence at least four times in the past. Because of the uplift, two buried forest horizons were revealed (Reimnitz 1972); subsequently two others were located, and carbon-14 aging of the material has indicated an interval of 600 to 950 years between earthquake events that resulted in sudden uplifts with gradual subsidence of 2 to 7 mm per year (Plafker 1990). During the 800 years before the 1964 earthquake, the rate of interseismic subsidence averaged 3 to 5 mm per year, and the longer term (3,000 years) net vertical change on the CRD has been one of submergence (i.e., including tectonic subsidence, eustatic and isostatic sea level rise totaling 4.5 to 6.5 mm per year), rather than uplift (Plafker et al. 1992). Based on these studies, Boggs (2000), using a long-term perspective, expects that CRD tidal marshes likely will continue to exist and even expand over a period of hundreds to thousands of years.

Migration—Little is known of migration habitat for dusks. Hansen (1962) suggested that geese migrate offshore, stopping occasionally at the few accessible places en route. During early September to mid-October staging on the eastern CRD, geese use first salt marsh habitat, then freshwater meadow habitat (Crouse 1994a, Hawkings 1982). Crouse (1994a) surveyed the Copper and Bering River deltas and concluded that the most important concentration areas during fall were Dan Bay off Hinchinbrook Island, Egg Island, intertidal habitat off the central western CRD, and Okalee Spit near Controller Bay. Petersen et al. (1981) concluded that the Yakutat Forelands, Alaska, were potentially important staging habitat for dusks, in particular the Blacksand and Ahrnklin Rivers during early fall, and the Dangerous, Italio, and Akwe Rivers during late fall. Riverine habitats were more important than estuarine habitats.

Bromley and Jarvis (1993) concluded that about one-half of the energy for geese spring migration was derived from lipid reserves, with the remainder met through acquisition of food en route. Thus, staging areas that are regularly used by migrating dusks must be important, but they remain poorly known at this time. Petersen et al. (1981) suggested geese usually stop for about 1 day on the Yakutat Forelands during spring migration.

Wintering—The LCR and the Willamette Valley, characterized by mild, wet climate during winter and by extensive agriculture, provide ideal habitat for wintering Canada geese (Chapman et al. 1969, Cornely et al. 1985). Common agricultural practices, including dairy farming and production of ryegrass seed (Kimerling and Jackson 1985), yield high-quality forage with high protein content (Riewe and Mondart 1985, and reviewed in Jarvis and Bromley 1998). A network of federal and state waterfowl refuges established in the mid-1960s provides an additional attraction and security for wintering geese. On 19 February 1963, the Migratory Bird Conservation Commission authorized the establishment of three national wildlife refuges to be located at traditional goose concentration areas in the Willamette Valley (USDI Fish and Wildlife Service 1980). In 1964, land acquisition for William L. Finley NWR (2155 ha) was completed; Baskett Slough NWR (1009 ha) was established during 1965-67, and Ankeny NWR (1132 ha) was established during 1965-71. In addition, Ridgefield NWR (2060 ha) on the LCR in southwest Washington was acquired in 1965 to provide wintering habitat for dusks (Pacific Flyway Council 1998). The mandate of these valley refuges, under the authority of the Migratory Bird Conservation Act and the Migratory Bird Hunting Stamp Act, is to provide wintering habitat for dusky Canada geese. Dusks also use the coastal Oregon Islands NWR, established for seabird habitat in the mid-1960s, near Nestucca, in Tillamook County (Lowe 1987).

The state of Oregon's Sauvie Island Wildlife Area, for which acquisition began in 1947 to preserve and develop habitat for wintering waterfowl

and to provide for public hunting, is now over 4800 ha (Oregon Department of Fish and Wildlife, n.d.). The Shillapoo and Vancouver Lake State Wildlife Areas in southwest Washington along the Columbia River flood plain encompass 627 ha. Since the establishment of Shillapoo in 1952, the Washington Department of Fish and Wildlife has been expanding these areas through acquisitions.

Duskys tend to concentrate in and near federal and state wildlife refuges in the Willamette Valley and the LCR in Washington and Oregon, with about 700 wintering near Nestucca on the Oregon coast (Havel and Jarvis 1988; Lowe 1987, 1999; Simpson and Jarvis 1979). In particular, the largest proportion of wintering Canada goose flocks that are duskys consistently occur on and in association with William L. Finley NWR, the southernmost of the valley refuges; the smallest proportion of duskys occur on Ankeny NWR (Simpson and Jarvis 1979). Although there are seasonal differences related to the timing of spring and fall migration, the proportions of duskys are consecutively smaller at Sauvie Island Wildlife Area, Ridgefield NWR, and Willapa Bay NWR (Atkinson 1992, Havel and Jarvis 1988).

Wintering habitat of geese in British Columbia remains poorly known. Macgregor (1993) consistently observed wintering duskys using carrot fields and pasture in the Blenkeinsop Valley of the Saanich Peninsula on Vancouver Island, and Hearne (1999) observed duskys using the coastal marshes of Delkatla Wildlife Sanctuary in the QCI throughout the winter season.

There is increasing concern about crop depredation by feeding geese in association with rapidly increasing numbers of Canada geese wintering in the Willamette Valley and southwest Washington (Pacific Flyway Council 1998). Clark and Jarvis (1978) demonstrated that, at grazing intensities characteristic of the mid-1970s, geese had little to no detrimental effect on ryegrass crops (8 of 10 fields); in some cases (2 of 10 fields), yields were greater in grazed fields. Wintering Canada geese, however, now number about 10 times that of the 1970s, and crop depredation complaints are com-

mon. In response, the Pacific Flyway Study Committee and the Canada Goose Agricultural Depredation Working Group is currently implementing an agricultural depredation control plan to address these concerns (Pacific Flyway Council 1998). This effort is sensitive to the concerns for conservation of dusky geese.

Population Dynamics

Population Status

The dusky population has been estimated annually in western Oregon since 1947 (Kebbe 1958), and in Washington and Oregon since 1953 (Hansen 1962); it has fluctuated from lows during the mid-1950s (~5,000) to highs during the late 1970s (~20,000 to 25,000) and back to lows during the 1990s (~12,000 to 14,000) (fig. 7) (Drut and Trost 2003, Pacific Flyway Council 1997). Different methods used to estimate population size are briefly described below.

Wintering grounds—Kebbe (1958) reported winter inventories of duskys in western Oregon for 1947-58 (fig. 7), without giving methods of counting, but presumably, they were aerial counts as reported by Hansen (1962). Based on calculations of numbers of geese produced and harvested from studies by Olson (1953, 1954c) and Trainer (1959) and compared with wintering ground studies (Kebbe in Hansen 1962), Hansen (1962, 1968) concluded that the best estimates of dusky numbers were the midwinter aerial survey counts conducted in Oregon. He noted, however, that counts did not include Washington and British Columbia, so he recommended adding 2,000 birds to annual estimates to account for this gap. Thus, total population estimates from 1953 to 1960 ranged from 7,080 to 16,450 birds. Hansen (1968: 48) noted that there was no evidence that this subspecies had ever been abundant.

Photo estimates—Aerial surveys were soon standardized to include the same counties and locales each year in Oregon and Washington but still excluded British Columbia; these surveys were continued through 1975 (fig. 7) with little change in methods (Jarvis and Rodgers 1976; Rodgers 1973, 1974) (unadjusted for birds wintering in

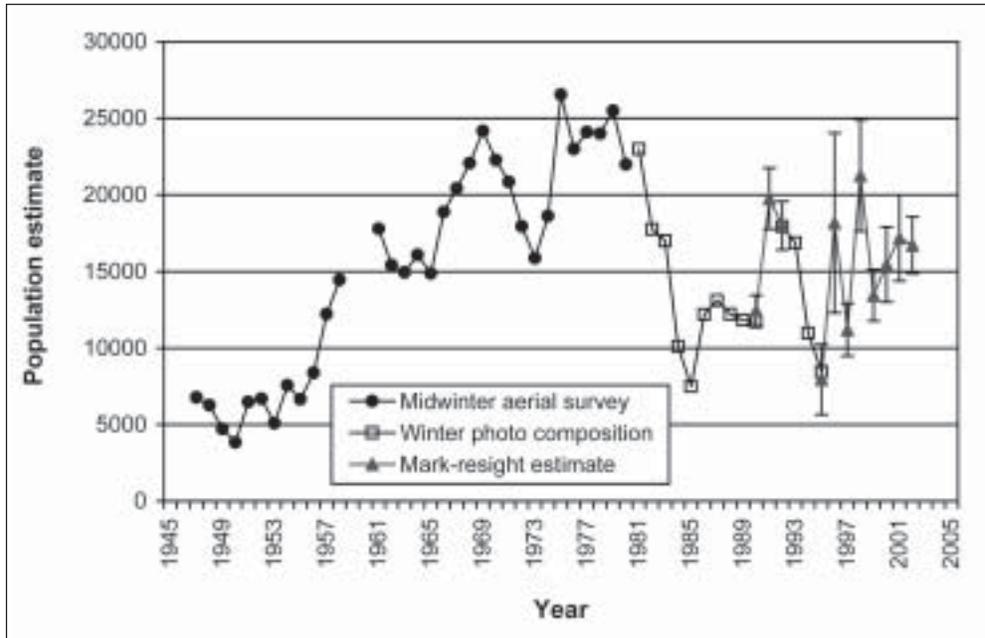


Figure 7—Winter population estimates of dusky Canada geese in Oregon and Washington, 1947-2002, from the three primary methods used to index the population for management purposes.

British Columbia). Because of increasing numbers of other races of Canada geese within the census area, however, methods differed thereafter (fig. 7). In 1976, because of the influx of other Canada geese, the midwinter survey of dusky yielded unrealistically high numbers. Therefore, an estimate of dusky was made by averaging the dusky harvest for the past 3 years and subtracting it from the fall flight estimate provided by the Alaska Department of Fish and Game (Jarvis and Rodgers 1976). In winter 1976-77, ground-based surveys were conducted in the Willamette Valley and LCR to estimate the proportion of Canada geese that were dusky, and this estimate (82.9 percent dusky) was applied to the midwinter index of total Canada geese. The 1977-78 midwinter counts of all Canada geese from late November to early December (48,000) were much higher than counts in January and February (31,000), so the practice of using the maximum winter count was adopted; thus, the estimate was based on a maximum winter count of 48,000 geese with a composition of 42.5 percent dusky (Jarvis 1978). This method was continued in 1979 and 1980.

A method to estimate the proportion of dusky based on aerial photographs was developed in 1979, with the first official implementation in 1981 (Jarvis 1980, Jarvis and Sekora 1981). The reason for this was threefold: (1) the numbers of nondusky Canada geese were continuing to grow in all parts of the dusky's winter range but in varying proportions, (2) the overall wintering Canada goose flock was growing rapidly, and (3) geese were no longer reliably concentrated in and near the refuges during censuses in January. The aerial survey and photography method was used and refined through 1992 (Cornely and Jarvis 1984, 1985; Cornely et al. 1986; Jarvis 1982, 1989, 1990, 1992; Jarvis and Cornely 1983). By 1992, the technique involved vertical, large-format color photography of flocked geese from 90 to 130 m above ground, yielding photographs that permitted subspecies identification for large numbers of geese based on color and size, and enumeration of neck collars by color (Jarvis 1992). This method was continued through 1997 (fig. 7) (Jarvis 1993, 1994, 1995, 1997). However, because the method was plagued by aircraft scheduling and weather problems, and because it had

unknown sampling and statistical properties, the Pacific Flyway Study Committee discontinued this method in March 1997 for a more statistically sound estimation technique (Jarvis 1997).

Mark-resight estimates—Beginning in 1990 (fig. 7) (Pacific Flyway Council 1997), mark-resight methods were investigated as a means of obtaining indirect estimates of the dusky goose population on the wintering grounds (Sheaffer 1993). The method employs Chapman's (1951) modification to the traditional Petersen estimate (Le Cren 1965) as described in Seber (1973: 60) to estimate the total number of marked geese present. Ratios of duskys marked with colored neckbands to unmarked duskys are determined from samples of geese observed during two resighting periods. A population estimate is developed by expanding the estimated total number of marked individuals by a factor for the unmarked proportion of the population. Subsequently, a "least-biased" estimator was developed and applied to the population via observations of geese marked with uniquely coded neck collars, and annual population estimates with standard errors were developed for 1990 through 1993 (Sheaffer and Jarvis 1995). This method was tested by the USFWS in 1995 for comparison with results of the traditional midwinter inventory that used aerial photography method to estimate subspecies composition (Trost et al. 1995). The indices were found comparable, and the technique was adopted by the Pacific Flyway Study Committee as the operational method for annual post-hunting season estimates in 1997 and thereafter (Drut and Trost 2003, Drut et al. 1997, Pacific Flyway Council 1997).

Recent discussions on annual indexing methods have focused on several sources of error apparent in the mark-resight method. The method assumes that all marked geese are equally likely to be observed during resighting survey periods. Campbell and Becker (1991) reviewed collar retention rates for dusky geese; collar loss, which varies among goose populations, can affect estimates of population size and survival. Results of recent surveys suggest that the detection rates of marked geese vary considerably from year to

year. Severe storms in some years have thoroughly mixed duskys to produce exceptionally effective sampling of all marked geese. Because the midwinter dusky estimate is derived from a large geographic area, investigators have concluded that, unless a major weather event occurs, there are segments of the population that are not sampled during the resight periods (Drut and Trost 1999, Drut et al. 1998). Thus, annual population estimates that have fluctuated widely reflect varying degrees of population mixing.

The second issue affecting the indirect winter indices is the accuracy of the critical marked: unmarked ratio used to expand the estimates. From the early 1960s on, it was known from banding data that, although most birds counted as duskys were from the CRD, the counts included similar-looking geese such as Vancouver Canada geese, and possibly others (Chapman et al. 1969, Hansen 1962). Recent studies on genetic composition of geese that are classified as duskys for regulatory purposes (Pearce et al. 1998) support the presence of "look-alikes" that confound enumeration of unmarked duskys. Over the past 10 years, numbers of urban geese from Anchorage increased (Crowley 1998), and island geese have increased (Petrula et al. 2002); both winter sympatrically with CRD duskys (ADFG 1999, Crowley et al. 1998). Because CRD dusky numbers declined (Eldridge et al. 1998), the proportion of non-CRD geese in the midwinter population estimates of duskys has increased. Waterfowl managers have not been concerned about the occurrence of Middleton Island geese in the dusky winter index because the population by definition includes island geese. Without good estimates of the numbers of other geese wintering sympatrically with and counted as duskys (e.g., Vancouvers, large juvenile lessers, stocks of unknown origin), however, it is not feasible to develop an accurate expansion factor to estimate the number of CRD duskys. Given these problems with the indirect wintering population estimates, development of accurate estimates from the breeding grounds has become increasingly important in monitoring CRD duskys (Drut and Trost 1999, Pacific Flyway Council 1997).

Breeding grounds—Similar to the adaptation of methods on the wintering grounds, estimation of the population of dusky geese on the CRD has changed in response to dramatic succession of habitats and to demand for more accurate results. Surveys on the breeding grounds have had to address important biological and environmental factors including (1) variable spring conditions affecting the phenology of nest initiation and optimal survey timing, (2) spring weather also affecting residual snow cover and leaf-out of shrubs that influence visibility of geese, (3) significant expansion of shrub communities since the late 1970s compounding visibility problems, (4) variable rates of nest predation early in the season that affect the proportion of geese actively nesting and observable as pairs, and (5) variable rates of nest loss and reneating that complicate attempts to relate annual estimates of breeding pairs from aerial surveys to nest densities and production estimated from ground surveys.

Elkins (1952) provided the first estimate of the dusky breeding population on the CRD in 1952 at 4,000 nesting geese and 2,000 nonbreeding geese. Development of a formal breeding ground aerial survey by the Alaska Department of Fish and Game began in 1974, when 9.3 percent of the CRD (788 km²) was surveyed in mid-May. Geese were counted in 0.2-km strips on either side of 182 km of linear transects. A population estimate was derived by expanding strip counts to the area of the entire study area and by applying a visibility correction factor of 1.25 under the assumption that 80 percent of geese were visible on transects (fig. 8) (Timm 1974). Subsequent population surveys in 1975, 1976, 1978, 1979, and 1980 followed the same procedures but were designed to also investigate problems of bias associated with varying densities of geese. Results were compared among flights with different transect widths (100 versus 200 m) and ocular versus photographic counts (Timm 1975, 1976, 1978, 1980; Timm and Sellers 1979).

In 1983, the USFWS assumed responsibility for the surveys, following the methods of Timm (1978) but without adjustment for bias in visibil-

ity of geese, and covering a smaller study area of 343 km² (Conant and Hodges 1986). Both total geese and breeding pairs were estimated. These surveys were continued through 1990 (fig. 8) (Conant and Dau 1989, 1990). Beginning in 1986, the USFWS initiated a second, newly designed survey, using ratio-estimate procedures and without correction for visibility bias, to provide statistical rigor and comparisons between counts (Butler 1986) (fig. 8). After 5 years of overlap with the previous survey method (Butler 1987, 1988, 1989, 1990, 1991), a review was conducted (Butler and Eldridge 1991) and the new procedure was adopted as the operational survey method. This method, including the precise plotting of all goose observations by using global positioning system locations and a geographic information system, is still in use today (fig. 8) (Butler 1992, 1993, 1994; Eldridge and Dau 2002; Eldridge and Platte 1995, 1996; Eldridge et al. 1997, 1998; Pacific Flyway Council 1997).

In 1987-89, in association with the new USFWS survey, helicopter-based counts were conducted on a sample of transects in an attempt to develop a reliable visibility rate correction factor for the annual fixed-wing aerial surveys (Butler 1987, 1988, 1989). Because of the high costs of helicopter surveys and high variability in the derived correction factors, the effort to develop a visibility correction factor was terminated (Butler and Eldridge 1991).

From 1993 through 1995 (Crouse et al. 1997) and in 1998 (Youkey 1998), the USDA Forest Service conducted nest censuses of randomly selected 9-ha plots within a 212-km² study area. This procedure has become an operational program, to be conducted once every 3 years (Pacific Flyway Council 1997). Although confounded by the annually varying extent of reneating, these data, in concert with reneating studies (Grand and Anthony 1997, Grand et al. 1998), may at some point be sufficient to correct and refine aerial survey indices for dusky geese (Butler et al. 1995, Stehn 1999).

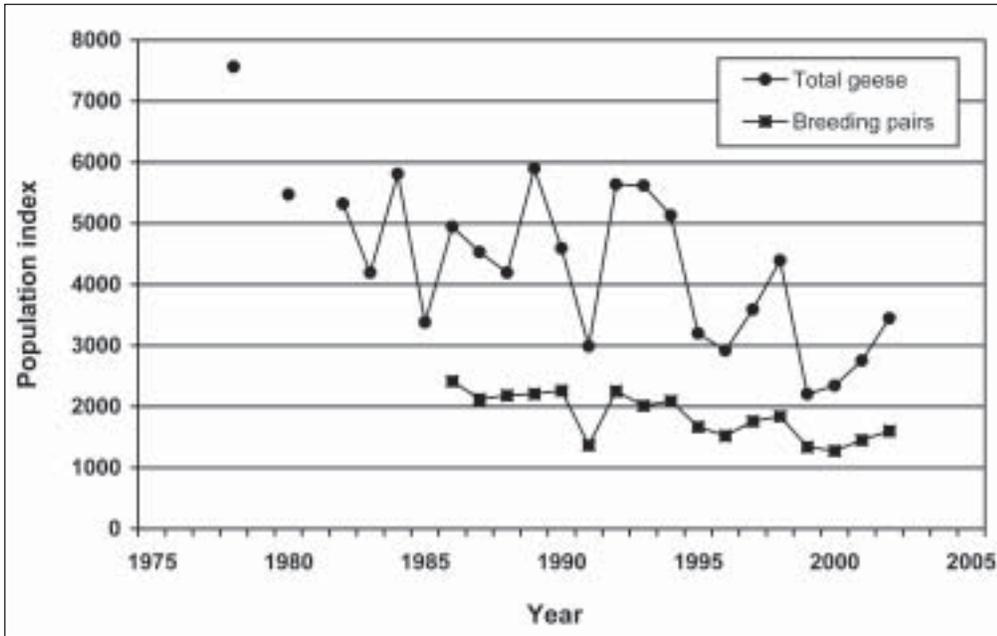


Figure 8—Estimates of total geese and breeding pairs of dusky Canada geese from spring aerial surveys on the Copper River Delta, Alaska, 1974-2002.

Population Trend

Midwinter indices from 1947 to the present show an increasing population until the mid-1970s (fig. 7). Jarvis and Cornely (1988), based on 3-year moving averages of midwinter counts, concluded that the dusky population declined 8.3 percent per year from 1975 through 1984, with most of that decline occurring since 1979. Based on the midwinter counts, this decline continued through 1990, with widely fluctuating population estimates since that time (Drut et al. 1998, Pacific Flyway Council 1997). Some of the variability in recent years, however, may be attributed to uneven sampling of marked duskys as discussed above (Drut and Trost 1999). Estimates from at least recent years reflect a combination of both CRD and island geese, obscuring the trend of the CRD population. These data are consistent with a rapidly increasing population of island geese since the late 1980s.

Similar to midwinter indices, breeding ground surveys (fig. 8) reflected a 50-percent linear decline from 1978 to 1990 on the CRD (Conant and Dau 1990), with a further decline in 1991 (Butler

1991). In an independent analysis considering both breeding population estimates and annual estimates of young produced, Stehn (1992) confirmed an average annual rate of population decrease from 1978 to 1991 of 7 to 8 percent per year. The population rebounded in 1992, however, to a level similar to that of 1984 (Butler 1992, Conant and Dau 1990). In recent years, lower indices during 1995 and 1996 were offset by modestly higher indices during 1997 and 1998 (Eldridge et al. 1998), but both breeding pair and total goose indices have declined further and reached all-time lows in 1999 (Eldridge and Dau 2002). Assuming the early breeding ground surveys were equivalent to the current operational survey, a significant population decline occurred from 1978 through 1985; since then, however, the CRD component of the population has fluctuated substantially after the late 1980s, but has continued a gradually declining trend over the past 10 years (fig. 8). Short-term increases in total geese during 1992-94 and 2001-02 followed periods with relatively good production (table 10) but have not been reflected in subsequent increases in breeding pairs.

Productivity and Recruitment

Productivity of dusky on the CRD has changed over the nearly three decades of study, with the major change happening within the period covered by the first method of measurement, so that the change is unlikely to be an artifact of different methods. During 1979, low nest success resulted in low productivity, and although moderate levels of production occasionally have occurred since then, consistent high production documented during the 1970s has not recurred (tables 9 and 10). Over the long term, assuming productivity estimates did not vary from changes in methods, production declined from the 1970s (\bar{x} = 26.8 percent young, sd = 13.2 percent, n = 9 years) to the 1980s (\bar{x} = 15.4 percent young, sd = 6.7, n = 10), with little or no change during the 1990s (\bar{x} = 14.3 percent young, sd = 7.5, n = 9). Production in 2000-2002 (\bar{x} = 26.7 percent young, sd = 3.4, n = 3) has been the best since the late 1970s, but the duration of this success and effect on recruitment are yet to be seen. Sheaffer (1993) estimated that production of at least 20 percent young would be needed to maintain a stable population. The flyway management plan has adopted that goal (Pacific Flyway Council 1997). These levels of production, however, have only occurred in 8 of the past 20 years (table 10).

In the 1990s, a sustained pattern of low production and population decline raised concerns that maturing age structure could reduce reproductive potential. Campbell and Griese (1987) estimated that over 85 percent of dusky were of breeding age, with 70 percent in the category of prime breeders aged 6 to 14 years. Longevity was subsequently noted to be at least 19 years, with evidence of breeding at 17 years (Campbell 1991b). Chapman et al. (1969) concluded that, to maintain the population when annual mortality averaged 46 percent, at least 50 to 66 percent of 2-year-old dusky must nest annually. Sheaffer (1993) assumed 80 percent of 2-year-olds nested with nest success of 30 percent, compared to 40 percent for geese age 3 or older. In recent years, however, young age cohorts of dusky have been

small, and realized nest success for all ages combined has only reached 30 percent during 1990-92 (table 9) and perhaps during 2000-2002 (see table 10).

Survival and Mortality

Hansen (1962) was the first to estimate mortality rates of dusky. Using the composite dynamic method, he estimated average annual mortality rates of 28.9 percent for adults and 56.9 percent for juveniles during 1952-60. Similarly, Chapman et al. (1969) analyzed data for 1952-65, yielding average annual mortality rate estimates of 34.6 percent for adults, 37.7 percent for yearlings, and 57.4 percent for juveniles. In recognition that the composite dynamic method can yield underestimates of survival rates (Seber 1972), Sheaffer (1993: 21) reanalyzed and estimated survival rates for several periods during 1953 through 1990 for normal, leg-banded-only dusky, determining average annual adult survival rates of 65.8 to 77.2 percent and rates of 30.7 to 42.5 percent for immatures (table 12). Both Chapman et al. (1969) and Sheaffer (1993) noted that adult survival rates increased over time in tandem with incremental restrictions in harvest regulations. Sheaffer (1993) also examined survival estimates based on resightings of marked birds during 1983-90, and calculated a mean annual adult survival rate of 78.8 percent (se = 6.4 percent, range = 73 to 85 percent). Survival rates based on resightings were not significantly different than rates estimated from leg band recoveries for the same period.

Following population modeling to simulate what was known of the dusky population from the early 1950s through 1989, Chapman et al. (1969) and Sheaffer (1993) concluded that large harvests were supportable by the population during the 1960s because the average recruitment rate was high. Subsequently, as recruitment rates declined during the 1980s, the population could not continue to increase despite modest increases in adult survival rates (Sheaffer 1993). Ultimately, low rates of recruitment accompanied by moderate adult survival rates resulted in population decline.

Table 12—Average annual survival rates of adult and juvenile dusky Canada geese during selected periods from 1953 to 1990

Period	Adults		Immatures	
	Survival rate	SE ^a	Survival rate	SE ^a
1953 - 1960	0.658	0.017	0.386	0.029
1965 - 1968	.693	.045	.425	.060
1974 - 1978	.694	.030	.307	.038
1983 - 1990	.772	.044	—	—

Source: Sheaffer 1993.

^a Standard error.

That is, as recruitment rates declined, population size became relatively more sensitive to small changes in adult survival. As severe restrictions were placed on hunting during the mid to late 1980s, adult survival increased and the population apparently stabilized.

Sheaffer (1993) concluded that the chances for the population to increase were favorable if recruitment and survival rates remained at or above levels typical of the late 1980s and early 1990s; she also noted that the population was likely to experience greater variation in recruitment rates. Relative to the previous period of the same duration, production of young seems to have been more variable and slightly higher during 1990 through 1993 (see table 10), a period characterized by an apparent rebound in the dusky population (figs. 7 and 8).

Limiting Factors

Predators and Depredation

Depredation of geese and eggs—Predators of geese and goose eggs on the CRD during the reproductive season include brown bears, coyotes, wolves (*Canis lupus*), red fox (*Vulpes fulva*), river otter (*Lutra canadensis*), mink (*Mustela vison*), bald eagles (*Haliaeetus leucocephalus*), northern harriers (*Circus cyaneus*), short-eared owls (*Asio flammeus*), glaucous-winged gulls (*Larus glaucescens*), herring gulls (*Larus argentatus*), mew gulls (*Larus canus*), parasitic jaegers (*Stercorarius parasiticus*), common ravens (*Corvus corax*), northwestern crows (*Cor-*

vus caurinus), and possibly magpies (*Pica pica*). Depredation occurs on nesting adults, eggs, goslings, and molting geese; the known level of intensity, however, varies widely throughout the season in association with the stages of reproduction and vulnerability of the birds. Further, the amount of depredation has increased over years. During initial studies when adult geese and goslings were being banded in the 1950s, several workers reported the presence of predators. Olson (1953, 1954a) noted that the potential for nest depredation was high because bears could literally travel along the slough banks and go from nest to nest. Despite the ease of access, and the documented presence of most of the known predators on the nesting grounds, loss of nests was minimal (e.g., Elkins 1952). Both Courtright (in Olson 1954a, 1954b) and Trainer (1959) found low rates of nest depredation. Hanson (1962), referring to those studies, noted that there were so few predators after incubation was completed that juvenile mortality was considered negligible. Shepherd (1966), however, expected that depredation, particularly by mammals, would increase after and because of the 1964 earthquake.

Depredation on adults—Little depredation of geese is known to occur in early spring. During arrival on the CRD when geese are concentrated in the upper delta and on tidal flats in snow-free areas, flocks of foraging geese are sensitive to bald eagles that frequently circle overhead flushing geese, indicating at least the possibility of depredation attempts at that time. As geese disperse, become territorial, begin to lay eggs, and

Table 13—The number and density of dusky Canada goose carcasses and kill sites determined during nest searches on the Copper River Delta, Alaska 1980-1995

Year	Number of goose carcasses and kill sites	Density (carcasses/km ²)	Source
1980	7	1.6	Sellers 1980
1983	3	.7	Campbell 1984
1984	4	.9	Campbell and Rothe 1985
1985	17	3.8	Campbell and Rothe 1986
1986	34	7.9	Campbell et al. 1987
1987	15	3.5	Campbell et al. 1988
1988	26	10.6	Campbell and Rothe 1989
1989	16	6.5	Campbell and Rothe 1990
1990	8	3.2	Campbell 1990a
1991	18	7.3	Campbell 1991c
1992	7	2.9	Campbell et al. 1992
1994	24	3.8	Crouse 1995
1995	11	2.6	Crouse et al. 1995

become associated with nests, the adults become more susceptible to depredation. Geese may be vulnerable to predators while distracted during territorial disputes, or they may attempt to defend nests from predators and be killed in the process. Olson (1954a) found the remains of adult geese at each of four artificial nesting platforms established the previous year and concluded that dusky using these sites may have been more vulnerable to coyotes and bald eagles. Possibly, for geese nesting in thick cover increasingly typical of the CRD, the birds are unable to efficiently detect the approach of predators (Bromley 1976). During intensive nesting studies, early investigators reported no incidents of depredation on nesting adults (Trainer 1959). In five seasons over the period 1974-79, Bromley (1976, and pers. obs. 1977-79) found one adult male and one adult female dusky carcass resulting from depredation by bald eagles and an additional four carcasses that were probable eagle kills. The annual incidence of adult mortality during nesting increased in later years (table 13), with responsible predators including bald eagles, coyotes, brown bears (Campbell 1991c, 1992b; Campbell and Rothe 1986, 1989; Campbell et al. 1987; Crouse 1995;

Crouse et al. 1995; Sellers 1980; Timm 1982), and occasionally wolves (Stephenson and Van Ballenberghe 1995). In the latter case, however, waterfowl were not a major component in the diet of wolves (Carnes et al. 1996). Based on remains of adult geese and their nests, bald eagles were responsible for depredating at least 17 nesting geese in 1998 (Grand et al. 1998). They concluded that bald eagles are currently a more important predator than was previously thought.

Remains of flightless dusky (based on stage of wing molt in carcass remains) have been found occasionally at mink and red fox dens (Bromley 1976). Brown bears have been observed from a distance engaging in behavior suspected to be running down and consuming molting geese and their young (Bromley 1976, Timm in Bromley 1976). Trainer (1959) found fresh remains of an adult-sized goose in the stomach of an adult coyote taken near Copper (Alaganik) Slough on the CRD on 28 August. Wolves on the CRD are known to prey occasionally on molting geese (Stephenson and Van Ballenberghe 1995).

Depredation on eggs—Eggs were generally not vulnerable to depredation by gulls and jaegers

when they were attended by geese (Bromley 1976). During laying and incubation recesses, however, when geese leave eggs unattended (though covered with nest material and down) as they forage away from the nest, eggs are vulnerable to predators. Avian predators such as glaucous-winged gulls are particularly adept at quick thefts and can carry an egg away from the nest. In addition, geese may be suddenly disturbed from their nests by large predators such as bears or canids, leaving the eggs exposed and vulnerable to all predators. Although data are few for the 1950s, egg and nest losses to predators were low during 1954 and 1959, and thought to be almost exclusively due to gulls and jaegers (Shepherd 1966, Trainer 1959). From the 1964 earthquake until about 1978, however, the rate of egg loss to both mammalian and avian predators progressively increased from less than 10 percent to greater than 50 percent (table 9).

During most dusky goose nest studies over the years, investigators routinely have covered nests with nest material and down as soon as nests were found, which apparently compensated for disturbance that might otherwise have resulted in higher nest loss. Bromley (1976: 37) tested for human effects by using two methods and found no difference between control and experimental nests. Similarly, from 1983 through 1989, Campbell et al. (1987, 1988) and Campbell and Rothe (1989, 1990) annually compared the fate of nests checked repeatedly to those located only after nesting was completed; no visitation effect was evident.

Although the rate of egg loss was rising after the 1964 earthquake, beginning in 1979, the annual rate of egg depredation rose dramatically (table 9) as illustrated by losses noted by Courtright (in Olson 1954a), Shepherd (1966), and Bromley (1976) compared to data in Bromley (1979) and Campbell (1990a). Beginning in 1982 (Campbell 1990a), nest depredation was classified as avian, unknown mammal, canid, or bear based on evidence as defined in Darrow (1938), Sooter (1946), and Rearden (1951). From 1982 through 1987, over half of nest losses were caused by bears (Campbell 1991c). Additional loss was

caused by canids, primarily coyotes (about 20 percent of annual losses), and by avian predators that on average accounted for 16 percent of losses, although proportions of losses attributed to specific predators differed greatly between years (Campbell 1990a). The accelerated rate of nest loss from mammalian predators coincided with a substantial increase in the number of adult goose carcasses found at nest sites during the mid-1980s (table 13).

Bears observed on the nesting grounds (presumably the individuals responsible for the nest loss) were predominantly immature animals and sows with cubs (Bromley 1976, Campbell 1991c, Mickelson et al. 1980). Bears moved onto the outer delta (primary nesting area) to graze on emerging grasses and sedges when geese were initiating nests; Campbell (1991c) suggested this was coincident with early spring phenology. Although he concluded that bears substantially influenced annual production of goslings, an experimental removal of 40 to 60 percent of brown bears on the west CRD during nesting in 1987 did not result in increased nest success of geese (Campbell et al. 1988). Rather, other forms of nest loss increased, most notably a doubling of avian depredation on goose nests.

From 1987 to 1998, nest losses to predators remained high (Campbell and Rothe 1989, 1990; Campbell et al. 1992; Crouse et al. 1997; Grand et al. 1998; Youkey 1998) and have included occasional depredation by wolves (Stephenson and Van Ballenberghe 1995). Loss to mammalian predators, however, has declined since 1990, perhaps partially in response to widely flooded areas and wetter habitat caused by beaver activity (Campbell 1992b).

As loss of nests to mammalian predators has declined, loss to avian predators has increased, and new evidence is emerging that bald eagles are currently a significant predator on eggs and geese. In 1997 and 1998, Grand and Anthony (1997) and Grand et al. (1998) used remote video cameras at goose nests to document predators at four destroyed nests each year. In all cases, bald eagles were the predators caught on camera destroying eggs. Of 193 depredated dusky nests in

1997 screened through evidentiary filters following Sargeant et al. (1998), Grand and Anthony (1997) attributed 88 (46 percent) exclusively to eagles, none exclusively to other avian predators, 2 to bears, 1 to mink, and 4 to canids; 98 (51 percent) could not be assigned to any one predator. Data were similar for 311 nests lost in 1998: Grand et al. (1998) attributed 165 (53 percent) exclusively to eagles, none to other avian predators, 1 to mink, and 1 to bears; 146 (47 percent) were not classified. These studies are continuing. Bernatowicz et al. (in press) found that 97 percent of relocations of radio-marked territorial eagles were within 2 km of their nest sites, indicating that these birds likely conducted most of their foraging close to their nests. As noted above, ongoing plant succession on the CRD is causing an increase in the availability of eagle nest sites on the nesting area of geese.

The temporal pattern of nest depredation within a season also has significance to the productivity of dusky geese. Most nest losses to predators occur early in the nesting season—during egg laying and early incubation. Thus, although relatively low in absolute numbers, renests and late-initiated nests have higher daily survival rates than early nests (Grand et al. 1998). There is an obvious increase in predator numbers and activities associated with the start of the eulachon (*Thaleichthys pacificus*) run on the CRD, and some observers have suggested that the availability of eulachon, as alternative prey, causes a decline in depredation of nests and adult geese midnesting (Babler 1999, Grand 1999). The relation of the timing of the eulachon run, which differs annually, to the timing of goose nesting (also differs annually) may determine when the usually high rate of early nest depredation subsides. For example, if nest initiation is late and the eulachon run is early, the most intensive period of nest loss would end quite soon and result in greater nest success than if nesting began early and the eulachon run was late.

Depredation on goslings—There is evidence that goslings are killed by glaucous-winged gulls (Bromley 1976), bald eagles (Bromley 1976, Grand and Anthony 1997, Mickelson et al. 1980),

mink (Bromley 1976, Grand and Anthony 1997), red fox (Bromley 1976), coyotes (Olson 1954a), wolves (Grand and Anthony 1997, Stephenson and Van Ballenberghe 1995), and brown bears (Bromley 1976, Timm in Bromley 1976, Trainer 1959). Grand et al. (1998) studied the causes of dusky Canada goose gosling mortality in 1997 and 1998 (table 14); small carnivorous mammals and eagles each accounted for about one-quarter of the observed mortalities. In an examination of the stomach contents of 38 glaucous-winged gulls collected in July and August, Olson (1954b) found only 1 that contained the remains of waterfowl.

Predator numbers and trends—

Brown bear—Since the 1800s, brown bears have probably increased in the region of the CRD (Morgan 1989). Although bears had no effect on rates of nest loss during the two seasons of study before 1964, all biologists working on the CRD during the 1950s mentioned the presence of brown bears. Brown bear tracks were common on the delta in 1953 (Olson 1953), and bears were not uncommon in 1954 (Olson 1954a). Klein (1955) noted that bears were commonly seen on the flats during his work 13-31 July 1955. In 1959, brown bears were common to the wooded upland area of the delta, but were observed only occasionally beyond the limits of the shrubs and trees; nevertheless, a subadult brown bear was collected on the nesting area of the outer delta on 23 June (Trainer 1959). Shepherd (1966) reported his impression that bears had increased in abundance since before the earthquake, noting the high population of microtine rodents (e.g., voles: *Microtus* spp. and *Clethrionomys* spp.) in 1965 as a possible attraction, and he speculated that bears might continue to increase.

Campbell (1984) conducted an intensive study of brown bears on the CRD, and estimated that a minimum of 22 to 27 bears used the outer delta during May and June that year. Similarly, Mickelson (1984) interviewed local residents and, after adding his personal experience, speculated that 20 to 30 brown bears were annually present on the nesting grounds of the western CRD. Studies by Campbell (Campbell and Rothe

Table 14—Dusky Canada goose gosling mortalities attributed to types of predators on the Copper River Delta, Alaska, 1997 and 1998

Cause of mortality	1997		1998		Total	
	Number	Percent	Number	Percent	Number	Percent
Unknown	9	26	11	34	20	30
Small mammals	8	24	10	31	18	27
Eagle	9	26	8	25	17	26
Avian	5	15	2	6	7	11
Wolf	3	9	1	3	4	6
Subtotal	34		32		66	
Missing	7		9		16	
Total	41		41		82	

Source: Grand et al. 1998.

1986, Campbell et al. 1987) yielded estimates of at least 33 bears in 1985 and 35 to 48 in 1986. Bear numbers in Alaska Game Management Unit 6C (western CRD) were estimated at 60 to 85 in the mid-1980s (Campbell and Griese 1987), and 100 to 106 during 1989 to 1992 (Nowlin 1995), illustrating an increase over a period of dramatic successional changes in habitats on the nesting area. During 1993 to 1997, estimates of the bear population increased each year to 120 bears in 1997 (Crowley 1999b). In his telemetry study on the CRD, Campbell (1991a) demonstrated great mobility among bears and recorded some aspects of goose nest predation by sex and age class of bears and other factors affecting the impact of bears on breeding dusky geese.

Canids—Although the red fox was considered abundant in the 1950s with about 50 to 60 trapped on the delta annually (Mickelson 1984), there were so few in the 1980s that Campbell and Griese (1987) did not consider them in a review of predators of geese. In contrast, coyotes were considered a common and important predator (Campbell 1990b, Campbell and Griese 1987). Indeed, more numerous coyotes may play a role in discouraging red foxes from the CRD (Sargeant et al. 1984, Voight and Earle 1983). During the 1950s and 1960s, aerial gunners and trappers took 30 to 40 coyotes per year from the CRD (Campbell and Griese 1987, Mickelson 1984); however, harvest declined thereafter because of low fur prices. Coyote populations seem

closely associated with microtine rodent numbers, likely increasing substantially when vole (*Microtus oeconomus*) numbers irrupt on the CRD (Campbell 1991c). Based on frequent but incidental observations during intensive study of wolves on the CRD, Carnes et al. (1996) concluded that coyotes were abundant during the 1990s. Because of high interest in harvest of wolves on the western CRD (see below), humans may have enhanced the success of coyotes (Carnes et al. 1996), a more active and common goose predator. Where both species occur, wolves tend to displace coyotes and there is typically an inverse relation between their densities (e.g., Mech 1970). Reduction of wolves on the CRD may have promoted expansion of coyotes. There likely has been an overall increase in coyotes on the western CRD since the 1950s, partly in response to reduced harvest by humans, and possibly in response to the successional increase of brushy habitats in goose nesting areas.

Wolves became established in the 1980s on the western CRD (Stephenson et al. 1993), in association with the successful introduction of moose (*Alces alces*) during 1949-58 (MacCracken 1992), and with the termination of predator control programs (Crowley 1999a). Although wolf numbers initially increased to two packs totaling 7 to 20 animals in the 1980s, subsequent harvest and illegal take have reduced them to low density (Carnes et al. 1996). Although few in number,

wolves have had a regular presence on the western CRD during the past 20 years. Thus, because there were no wolves present earlier, the goose nesting area has experienced, in effect, an increase in wolves.

Avian predators—Glaucous-winged gulls and parasitic jaegers were common on the western CRD in 1954 (Olson 1954a), and Klein (1955) found gulls and jaegers abundant the following year. Trainer (1959) considered the glaucous-winged gull to be common, and the mew gull to be abundant; parasitic jaegers were present but not considered an important predator. About 250 jaegers were estimated to be on the entire CRD in May and June 1963 (Isleib and Kessel 1973). Mickelson et al. (1980) estimated 12 to 13 pairs on the eastern CRD, and Mickelson (1984) speculated there could be 10 to 25 pairs annually on the western CRD. There are no current estimates of numbers or trends for mew gulls and parasitic jaegers on the CRD. Glaucous-winged gulls increased in the region during the 1970s. Mickelson (1984) estimated 5,600 pairs on Egg Island, just offshore of the western CRD, in 1975. In 1979, Patten (1980) recorded 10,000 pairs on the island, making it the largest glaucous-winged gull colony in the world. Patten and Patten (1979) estimated that these gulls were increasing at the rate of 4 percent per year in the 1970s.

Common ravens occur on the nesting grounds but are not numerous. Trainer (1959) reported that they moved out onto the delta after the goose nesting season; however, Bromley (1976) and Youkey (1995) reported them as occasional egg predators during the nesting season. If ravens are more closely associated with the wooded areas than the nonforested parts of the delta, they likely have increased on the nesting grounds over the past 20 years as the amount of forested, closed habitat has increased on the outer delta.

Bald eagles commonly nested on the inland portion of the western CRD during the 1950s but usually were seen only passing overhead on the outer delta (Trainer 1959). In late May or early June, however, an annual spring run of eulachon, a candlefish, attracts large numbers of gulls and

eagles to the primary nesting grounds of the geese (Bromley 1976, Grand and Anthony 1997, Trainer 1959).

In response to bounties offered on eagles to protect fisheries, about 100,000 eagles were killed in southeast Alaska from 1917 to 1953; many of these likely were taken in the PWS region because high eagle numbers overlapped with human activity there (Schempf 1999). Before the *Exxon Valdez* oil spill in PWS in March 1989, there were no population data for bald eagles in the region. Since the spill, population estimates and trends have been measured for several years to assess the effects of the spill. After an initial decline in productivity in western PWS during the 1989 reproductive season (Bernatowicz et al. 1996), eagle production recovered, and the PWS population has since increased at an average rate of 2.0 to 3.7 percent per year (Bowman et al. 1995, 1997).

An eagle survey of the western CRD in 1990, uncorrected for detection rates, yielded documentation of 112 bald eagle nests, 64 of them occupied, and several of them in atypically small, young Sitka spruce (*Picea sitchensis* (Bong.) Carr.) (Bowman 1999). Because of rapid plant succession during the 1990s, new nest sites are becoming available every year as trees appropriate in stature for nesting eagles mature on the outer delta. Because nest sites appear limiting for eagles on the delta (Bowman 1999), it is likely that the nesting population on the western CRD will continue to expand. As an example, where there were no trees on a high-density goose nesting study area of a few km² during 1976 (Bromley 1976), trees of sufficient stature hosted at least three recently established bald eagle nests in 1998 (Grand 1999).

In summary, bald eagles probably have increased steadily since the end of the eagle control program in 1953. The PWS population increased at a rate of 2.0 to 3.7 percent per year from 1989 through 1995 (Bowman et al. 1997). More specifically, as new nesting habitat has developed on the CRD after the 1964 earthquake, the eagle population is expanding on the goose nesting area.

Other predators—There has been no documentation of numbers or population trends of other predators on the western CRD.

Predator management—Predator management is expensive and controversial, yet some managers have suggested it is the most obvious and feasible solution to severe depredation of dusky goose nests on the CRD (Campbell 1990a). The discussion above indicates that the array of predatory agents on the delta has changed and likely will change further over time, as rapid and substantial succession in an already dynamic system causes predatory species and their primary and alternate prey to fluctuate in numbers and availability. Further, there may be changes in relative vulnerability of dusky geese to specific predators among life history stages—which agents prey on adult geese, eggs, and young. The suitability of predator management as a means to sustain and enhance the dusky goose population requires an understanding of the status and direction of ecological factors, and consideration of both public resource objectives and social concerns (Campbell and Griese 1987, Pacific Flyway Council 1997).

Based on a review of predator management options for the CRD and the public involvement process (Campbell and Griese 1987), the Alaska Department of Fish and Game rejected control of brown bears, by increased public hunting or control by state personnel, as a reasonable management alternative. Public opposition to bear control and to reduction of public use and enjoyment of bears were factors, but also, because of their life history characteristics, brown bear populations are difficult to manage precisely (Miller 1990, 1997). Removal or protection of only a few females can mean the difference between an increasing bear population or a decline with the possibility of consequential and undesirable changes in population structure that may require decades of intensive management to correct (Miller 1990, Taylor et al. 1987).

Based on high rates of nest depredation by bears in the 1980s, Campbell and Griese (1987) suggested that control of bear numbers would result in increased nesting success of geese. In a test of

this hypothesis, 16 bears were translocated from the delta 150 km east to Cape Yakataga in spring 1987 before the peak of nest initiation. At least six of these bears eventually returned to their original home ranges on the CRD, including four that returned before the peak of hatch was over (Campbell 1999, Campbell et al. 1988). Nest success did not increase, but unusual circumstances confounded interpretation of experimental results. Rainfall was exceptionally high during the nesting season, and the level of nest flooding and abandonment was higher than normal (table 9). In addition, the potential reduction in nest losses from bears was offset by avian predation that reached an unprecedented level. Thus, investigators concluded that to be consistently effective, predator control would need to encompass bears, avian predators, and possibly coyotes (Campbell et al. 1988).

Hunting is an effective means of managing brown bears on the CRD, but requires careful administration (Campbell and Griese 1987). Regulations for brown bears were restricted in 1968, yielding a lower harvest of bears in the region (table 15). Hunters were allowed to take only one bear every 4 years, rather than one per year. Whereas an average of four bears were harvested annually on the western CRD in the 1960s, the average harvest declined to 3.1 per year during the 1970s (table 15). The harvest rate began to increase, however, during the 1980s and, by the 1990s, reached the level of the 1960s (table 15). In 1997, regulations were liberalized to reduce predation on moose calves on the eastern CRD; hunters again were allowed one bear every year, rather than every 4 years. The current conservative strategy for brown bear harvest on the CRD has guidelines that constrain annual harvests to < 5 percent of the population, composed of no more than 40 percent females. The strategy supports a management objective of maintaining about 100 brown bears on the CRD. The current brown bear population in Unit 6C (western CRD) provides for a maximum annual harvest of six bears (Crowley 1999b).

Testing the effectiveness of taste aversion conditioning as an attempt to dissuade nest predators, particularly bears and coyotes, from taking goose

Table 15—Harvest of brown bears on Alaska Game Management Unit 6C, the western Copper River Delta, 1961-2000

Year	Number of bears harvested			
	Females	Males	Unknown	Total
1961	1	0	0	1
1962	0	1	0	1
1963	1	1	0	2
1964	0	3	0	3
1965	3	6	0	9
1966	2	3	0	5
1967	1	6	2	9
1968	2	7	1	10
1969	0	2	0	2
1970	2	0	0	2
1960s mean:	1.2	2.9	0.3	4.4
1971	1	3	0	4
1972	0	1	0	1
1973	1	3	0	4
1974	1	0	0	1
1975	3	4	0	7
1976	0	1	0	1
1977	0	3	0	3
1978	1	3	0	4
1979	2	2	0	4
1980			2	2
1970s mean:	1.0	2.2	0	3.1
1981	1	2	0	3
1982	2	2	0	4
1983	2	5	0	7
1984	1	3	0	4
1985	3	0	0	3
1986	1	3	0	4
1987	2	4	0	6
1988	3	2	0	5
1989	1	4	0	5
1990	0	2	0	2
1980s mean:	1.6	2.7	0.0	4.3
1991	3	5	0	8
1992	1	1	0	2
1993	0	0	0	0
1994	3	3	0	6
1995	3	2	0	5
1996	1	4	0	5
1997	2	4	0	6
1998	1	2	0	3
1999	1	5	0	6
2000	2	2	0	4
1990s mean:	1.7	2.8	0.0	4.5

Note: Annual harvest for the regulatory year includes hunts in fall and following spring.

Source: Alaska Department of Fish and Game 2000, Nowlin 1995, Crowley 1999b.

eggs also has been suggested (Campbell and Griese 1987). Because this type of research would be expensive with uncertain benefits to the dusky goose population, trials have not been conducted but may be warranted in the future (Pacific Flyway Council 1997).

Campbell and Griese (1987) also recommended liberalization of hunting and trapping regulations for coyotes in Game Management Units 6C and 6B on a trial basis, with monitoring of coyote harvests and coyote population trends. If the coyote population failed to respond, they recommended removal of coyotes by trappers sponsored by Alaska Department of Fish and Game. In 1987, the Alaska Board of Game encouraged increased harvests of coyotes on the CRD by liberalizing seasons and bag limits for hunting and trapping and permitting night lighting as a legal method of take in Unit 6. Because of the low value and poor quality of coyote fur from the CRD, there was little interest by hunters and trappers in pursuing this opportunity. In 1993, these regulations were retracted, and the harvest remains low at about 20 per year (Crowley 1999a).

The suspected relation of early nest success to the timing of the eulachon run remains undocumented. If it proves accurate, one important implication might be that predator management efforts could effectively be focused during an annually variable but relatively brief period from initiation of nesting to the beginning of the eulachon run. In a best-case scenario, simply providing food to nesting eagles on high-density goose nesting areas until the eulachon run begins may significantly increase nest success of geese.

Considerable thought has been given to predator management on the breeding grounds, and the current view of managers is that, although direct predator control is not warranted now, experimental and operational controls are deemed necessary if the dusky population declines rapidly from the present level. The increasingly intensive management options planned in the event of significant population declines, as presented in the flyway management plan (Pacific Flyway Council 1997), are designed to incorporate the results of depredation studies presently underway.

Hunting Mortality

There is good evidence that hunting mortality can be a limiting factor for the dusky population. Dusks are known to be vulnerable to hunting and may be heavily harvested (Chapman et al. 1969, Hansen 1962, Jarvis and Cornely 1988). They frequent small fields, which provides better access to the birds by hunters, they approach fields at lower altitudes with less circling before landing, and they feed with smaller numbers of other geese than do other races of Canada geese (Havel and Jarvis 1988); they are known to be 2.7 to 3.0 times more vulnerable to hunting than are Taverner's Canada geese (Jarvis and Cornely 1988, Simpson and Jarvis 1979). Kebbe (1958) noted that the dusky population wintering in western Oregon ranged from 3,800 to 7,500 during 1947-55, but that with reductions in bag limits and season length during the subsequent 3 years, dusks progressively increased from 8,400 the first year to 14,500 the third year. About two-thirds of the annual harvest of dusks occurred in Oregon through the mid-1980s (Chapman et al. 1969, Hansen 1962, Timm et al. 1979). After regulations were restricted in 1985, however, the Oregon proportion of the dusky harvest declined to less than 40 percent (see table 7), illustrating that a large degree of harvest control can be achieved within one jurisdiction.

Based on 1,129 leg band recoveries from 3,943 dusks banded during 1951-60, Hansen (1962) estimated mortality rates of 57 percent for juveniles and 29 percent for adults. Through examination of Oregon's hunting season length, bag limits, and midwinter population estimates during this same period, he concluded that hunting restrictions during the mid-1950s yielded reduced direct band recovery rates and a subsequent increase in the winter inventory. Through an analysis of age ratios in the weekly harvest, Hansen (1962) observed that the kill of adults increased sharply after 26 December. He suggested that by curtailing the harvest after this date the population could be increased, providing for a larger harvestable surplus within a few years, particularly if some winter refuge were provided.

Before the establishment of new federal wildlife refuges, hunt clubs strongly influenced the distribution and harvest of wintering dusks in Oregon (Chapman et al. 1969, Hansen 1962). Chapman et al. (1969) report that, in the absence of a public refuge program, the harvest could have been much greater had the hunt clubs not provided refuge and regulation of the take. By the late 1960s, however, refuges had assumed this role (Chapman et al. 1969, Hansen 1968).

Chapman et al. (1969) updated and extended Hansen's (1962) work for 1952-66, for which they estimated a mean annual population mortality of 45.6 percent, a rate that requires maximum productivity to be sustainable. Chapman et al. (1969) also concluded that neither the capacity of the nesting grounds nor the wintering grounds were limiting at that time. During this time, Henny (1967) estimated that natural mortality accounted for only 5.6 percent of annual mortality, with the remainder attributable to hunting. Winter refuge was provided in the mid-1960s (Chapman et al. 1969), the bag limit in Oregon was reduced to two by 1971, and season length was varied according to the size of the fall flight estimate (Pacific Flyway Council 1997). The postseason population increased from 10,000 to 17,795 during 1952-65 and to 22,000 to 25,500 during 1976-80.

Cornely et al. (1985) estimated that the adult component of the annual harvest averaged 55.8 percent (range: 46.7 to 64.1 percent) during 1975-84, compared to 32 percent (range: 22.3 to 38.5 percent) during 1964-66 (Chapman et al. 1969). Simpson and Jarvis (1979) estimated a population kill rate (retrieved harvest + wounding loss) of 38 percent in the 1977-78 season. From 1971 to 1983, winter population mortality rates were highly variable, from 16.9 to 47.7 percent (\bar{x} = 26.1 percent) over the 13 years (Jarvis and Cornely 1988). On examining results in detail, these authors noted that average winter population mortality of 24 percent from 1971 to 1978 was close to average annual recruitment of 28 percent (range: 10 to 50 percent), whereas from 1979 to 1984, average winter mortality of 30 percent greatly exceeded average recruitment of 19 percent (range: 15 to 24 percent). Thus, low re-

cruitment from 1979 through 1984, in concert with high rates of mortality (largely from hunting), resulted in declining numbers of dusks (Jarvis and Cornely 1988).

Beginning in 1984, hunting restrictions were applied to give extra protection to dusks in order to arrest their decline. Seasons were delayed in Alaska to allow the departure of dusks from the state before the hunting season, and bag limits and seasons were reduced in both Washington and Oregon (Pacific Flyway Council 1997). In 1985, hunting was limited to a quota of 300 dusks, reduced to 200 in 1995, with the Canada goose season to be closed in western Oregon and southwestern Washington when the quota was reached. This approach was successful, yielding annual harvests of only 130 to 278 dusks since 1985. A quota of 250 is in effect today. Campbell and Giese (1987) estimated annual hunting mortality of about 3.5 percent, and Sheaffer (1993) found no difference in monthly or period survival rates of dusks between harvest and nonharvest periods. In conclusion, hunting can and has limited the dusky Canada goose population, but, through the successful implementation of effective hunting regulations, it is unlikely that it is currently limiting the population.

Breeding Habitat and Recruitment

Habitat changes on the CRD accelerated by the uplift in 1964 have led to an increasing diversity of predators with greater predatory effectiveness, leading to lower nest success of geese. As reviewed earlier, studies of nest success have indicated that rates of depredation are similar in the various types of habitat used by nesting geese; that is, nests in each habitat type are preyed upon in proportion to the number of nests located there (Campbell 1990b, Crouse et al. 1997). Thus, although the predatory agents largely responsible for nest loss have changed over time, nests seem to be similarly susceptible to destruction regardless of the habitat type in which they are found.

In a major effort to explore the possibility of decreasing nest depredation on dusks, personnel of the Chugach National Forest, USDA Forest Service, experimented with different types and

locations of artificial nesting islands (ANI) on the western CRD from 1983 to 1994 (Babler et al. 1998). Based on monitoring of 861 ANI, they were able to determine the preferences of geese in terms of size of the ANI, height above water, aerial cover (shrubs), and distance from shore. Further, they recommended the two best types of ANI, considering use by geese and cost of construction and maintenance. Geese preferred ANI that were 2 to 2.5 m² in diameter, with freeboard of >15 to 20 cm, aerial shrub cover of 50 to 60 percent, and located 20 to 40 m from shore. The two types of ANI recommended were fiberglass floaters and sandbag islands (Babler et al. 1998). These investigators recommended continuation of the ANI program, with specific suggestions for improving efficiency in the program, and they listed appropriate actions to be taken should the population decline below 8,000 geese.

Over the history of the ANI program from 1984 to 2000, use of ANI by nesting geese ranged from 9 to 32 percent; however, 28 percent of fiberglass floater islands were used (Meyers et al. 2000). These rates are much lower than rates measured in other areas to the south (Babler et al. 1998) and may reflect a low preference for islands by dusks, or low survival of platform-born young that would be predisposed to nest at these sites. From 1984 to 2000, annual nest success of ANI nests with known fates averaged 64 percent and depredation averaged 27 percent, whereas nest success averaged 29 percent and depredation 57 percent at natural sites, demonstrating that ANI were effective at achieving reduced rates of nest loss for geese (Meyers et al. 2000).

A current trend of particular interest is the tendency for eagles to establish new nest sites in maturing cottonwood (*Populus balsamifera* L.) and spruce trees on the nesting grounds of the outer delta (Grand 1999). Most of the 112 nests found during the 1990 survey were located on the upper delta. Assuming that the cottonwoods and spruce required for nesting habitat of eagles develop on the outer delta (MacCracken 1992, Thilenius 1990b, Witten 1995), many more nest sites may become available on the nesting grounds. Given the tendency of adult eagles to remain within 2 km of their nest sites during nest-

ing, and a nesting chronology with egg laying in mid to late April through early May (Bowman 1999), overlapping with dusks, these efficient predators will become increasingly active on the high-density nesting areas of the geese. Their depredation on nesting female geese as well as on goose eggs has the potential to greatly increase their effect on the dusky goose population.

Natural changes continuing on the CRD will lead to changes in habitat that will affect the types of depredation on nesting geese and their eggs. Colonization of the area by beaver in the mid-1980s caused the creation of many ponds and extensive areas of wet habitat, perhaps deflecting mammalian predators from many dusky nest sites (Campbell and Rothe 1989, Campbell et al. 1988). Nevertheless, avian depredation increased concurrently with decreasing depredation from mammals (Campbell et al. 1988), leading to little change in the net rate of nest loss. Undoubtedly some habitat changes will occur on the CRD that are unpredictable and will cause similarly unpredictable chains of events to occur that may be beneficial or detrimental to goose productivity. Ongoing studies and monitoring activities will help provide for early detection and adaptive management actions to take advantage of opportunities or attempt to mitigate detrimental habitat changes as they occur.

Summary of Ecology and Ecosystem Dynamics With Regard to Foreseeable Environmental Conditions

Ecology and Ecosystem Dynamics

The dusky Canada goose is an evolutionarily young race of Pacific Flyway goose, adapted to nest in coastal Alaska and to winter in the mild, wet climate of the Pacific Northwest. On wintering grounds during late winter and early spring, mature individuals feed in rich agricultural croplands to gather peak lipid reserves that subsequently play an important role in meeting energy requirements of geese through migration, prenesting, egg laying, and incubation. Beginning in early to mid April, they migrate about 2,600 km

along a route largely characterized by rugged fjords with occasional small river deltas and arrive in mid to late April to nest on the CRD in south-central Alaska. The prelaying period on the nesting grounds is at least 13 days, allowing birds to uniquely time egg formation according to annual spring phenology. Geese time their nesting to coincide with snowmelt and early availability of new-growth vegetation, typically early to mid May, although the range of nest initiation dates has ranged from late April to early June. Annual nest success is highly variable, affected primarily by spring weather conditions and nest depredation. Within the nesting season, the rate of nest loss to predators is high during laying and early incubation, but relatively low during the late nesting period. Dusks lay a clutch of about five eggs, incubate them 27 days, and typically fledge young early to mid August. Adult geese begin molt as early as the first week in July, with most regaining flight by early to mid August. A postmolt dispersal results in a shift in distribution to new feeding areas on the CRD, often from the western CRD to the eastern CRD. Fall departure begins in early September and peaks in early October, generally after a staging period near the nesting grounds during September. Geese begin arriving on wintering grounds in southwestern Washington and western Oregon in late September, with peak arrival at the southern terminus in the southern Willamette Valley in early to mid November.

The summer habitat of the geese is located in a highly dynamic region, influenced by tectonic, glacial, riverine, and tidal forces. Before 1964, the nesting grounds of the geese were characterized by extensive areas of salt marsh on the outer CRD, maintained by regular tide cycles and by storm tide surges. Although the population of geese was fairly low before the 1964 earthquake, perhaps 7,000 to 10,000 on average, the birds were highly productive, with only a small percentage of eggs lost to tidal flooding and even fewer to predators. During the 1950s and 1960s, the population supported a large annual harvest, mainly on their wintering grounds. Hunting mortality was the primary factor limiting the population of dusks at that time. The severe earthquake

of 1964 uplifted the CRD 1.8 to 3.4 m in an apparently long-lasting cycle of uplift and subsidence. Postquake studies have revealed that the delta had been similarly uplifted at least four times previously, with a frequency interval of 600 to 900 years. Buried forest horizons from dry periods provide an indication of what can be expected on the nesting grounds, (i.e., accelerated succession from open, graminoid marsh habitat toward extensive shrub and closed spruce-cottonwood forest habitat). In fact, much of the succession has already transpired and is quite obviously ongoing. There are now trees large enough to support bald eagle nests in the midst of the nesting grounds of geese.

Associated with habitat changes, predator numbers and diversity have increased on the nesting grounds, leading to increased rates of eggs and nesting adults lost to predators, and thus to declining productivity. Brown bears, coyotes, and bald eagles were present before the earthquake, but their activity was apparently deterred by wet (and possibly salty) habitat and extensive inundation of the nesting grounds by high spring tides. In the absence of tidal inundation, however, and given increasing shrub and forest habitat, these species are currently considered effective predators on the geese and their eggs. The lowered recruitment rate of dusks combined with a high mortality rate of both adults and young caused the population to decline. The population recently may have become stabilized because of a near cessation of harvest and a high rate of survival of adults.

During the past 25 years, large numbers of several other races of Canada geese and increasing numbers of island geese have begun to winter sympatrically with dusks. Because some of these races are similar-looking birds, it is not feasible to specifically estimate the population size and harvest of the CRD subpopulation of dusks. Protection of dusks in the face of burgeoning numbers of other geese and an associated leap in complaints of agricultural depredation has become increasingly complex. Ongoing innovative and effective management measures are being developed to minimize the harvest of dusks and to increase the reliability of inventories in the

overwhelming presence of other Canada geese. Thus, establishment of refuges and intensive management efforts on the wintering grounds assure the security of dusks at that stage of their life history.

Short-Term Outlook

The accelerated rate of succession on the outer CRD almost certainly will continue for some time (Boggs 2000, Thilenius 1995, Witten 1995), increasing the extent of closed habitats that were atypical on preearthquake nesting areas. The productivity of geese likely will remain low, although the predators responsible for nest destruction may change over time according to the changing suitability of successional habitats for predator species. For example, numbers of nesting bald eagles will continue to increase on the nesting grounds of the geese as spruce and cottonwood trees mature to sizes that can support bald eagle nests. Nesting geese and their eggs likely will be vulnerable and potentially suffer increasing rates of loss to eagles. Perhaps at some point, increasing vegetative cover will begin to protect geese from eagle depredation. The pattern observed to date, however, is that there always will be the possibility of another predator species emerging as the most effective agent for that stage of succession.

Although new habitat similar to preearthquake conditions is developing on the outer marsh in the previously subtidal zone, rate of development is so slow that extensive, high-quality new nesting habitat is not expected in the short term. Geese likely will use new habitat as it develops. Until it is sufficiently extensive to support a dispersed nesting population, however, rates of nest loss in new marsh likely will be similar to that of the old marsh.

The ANI program of the USDA Forest Service is expected to continue and may help to boost production of geese to a small but possibly significant degree. With 17 years of experience researching and testing the preferences and requirements of nesting geese and maintenance requirements of different designs of ANI, the Forest Service is in an excellent position to carry

on an effective and efficient program to enhance nest success and production. Given the dynamic nature of the system, an ongoing monitoring and evaluation program will be a necessary part of this management effort.

Given that geese will be facing the consequences of low annual productivity from high rates of depredation on eggs, young, and possibly nesting adults, harvest rates will have to be maintained at low levels. Currently low and minimal rates of harvest are essential and must be viewed as an ongoing management requirement into the foreseeable short-term future.

Medium-Term Outlook— Implications of Source-Sink Metapopulation Dynamics

The concept of metapopulations can be useful in wildlife conservation (McCullough 1996), although it may be rare that conditions defining them are met in the real world. Metapopulations are systems of local populations connected actually or potentially by dispersing individuals (Eriksson 1996, Levins 1968). More rigorously defined, a metapopulation is spatially structured, with small subpopulations relative to others, subpopulation dynamics are asynchronous, and dispersal is sufficient to ensure recolonization, but not so great as to erode local asynchrony (reviewed in Wiens 1996). Although dispersal between subpopulations of dusks already may occur, there is no direct evidence of individuals from one subpopulation dispersing to breed in another, and genetic differences similarly reflect a low degree of interaction. Nevertheless, the potential exists for exchange between CRD and island geese, and for recolonization after local extirpation. As discussed earlier, the dusky subpopulations have common wintering grounds and regionally adjacent nesting grounds. Nevertheless, dispersal, the key component of metapopulations, is difficult to study and rarely known (Gutierrez and Harrison 1996, McCullough 1996, Wiens 1996).

As a special case of metapopulations, CRD geese apparently now compose a **sink** population, where reproduction is insufficient to maintain

the population because of high local mortality. In contrast, island geese, certainly from the Middleton Island breeding site, are more productive and may be, or may become, a **source** population, where emigration potentially leads to dispersal to the CRD population (Pulliam 1988). Pulliam (1988) has suggested that this can occur to such an extent in some species that sink populations can be maintained by source populations over the long term. Because strategies enhancing population parameters in the natural population seem to be most effective when directed at healthier subpopulations (Wootton and Bell 1992), studies and management of survival, productivity, and dispersal of island geese (a potential source population) may be warranted.

As a source population, island geese eventually may contribute sufficient numbers of individuals to sustain the CRD subpopulation. Ultimately, the CRD population either will persist until it again becomes a source by adapting to the new habitat or when sufficient new salt marsh develops, or it will dwindle and disappear. As natural restoration of habitat occurs through processes described earlier, however, the CRD population may be reestablished through dispersal from the source population until CRD geese can once again sustain themselves or even increase. In this process, small, seemingly meaningless changes in rates of dispersal, reproduction, and survival may gain importance over time, eventually having significant implications to subpopulation dynamics. Regardless of which or to what degree each scenario occurs, management will have the opportunity to protect and enhance these natural interactions by using knowledge of dispersal, interbreeding of subpopulations, and survival and reproductive rates by location over time.

Long-Term Outlook

The long-term cycle of dramatic uplift followed by gradual subsidence of the CRD over intervals of 600 to 950 years has been well documented and indicates that a new iteration began with the 1964 earthquake. Although the short-term future habitat conditions and associated high rates of depredation on the CRD will be a challenge for dusky Canada geese, the gradually developing

new marsh with eventual subsidence of the old marsh and subsequent reversion to salt marsh promise a more rewarding long-term prognosis for dusky, at least on a geological time scale. Boggs (2000) suggested that eventually there may be a net increase in marsh habitat on the CRD because the trend in past episodes has been for a net gain in the total extent of salt marsh with each cycle.

To take advantage of the eventual increase in habitat, however, dusky must survive and remain viable as a population over the long term, viewed from the context of a human time scale. Long-term survival seems possible for several reasons. For example, despite a modest population of possibly 2,000 birds, until the recent irruption of the Middleton Island population, itself now about 2,000, island Canada geese have persisted over time, indicating a population resiliency useful under these conditions. There are also small pockets of dusky (e.g., Bering Glacier area) that persist in the absence of specially directed conservation effort.

One further example is the Vancouver Canada goose, a largely nonmigratory race (Ratti and Timm 1979) that occupies forest habitat and tidal areas of southeastern Alaska. Geese of this race nest in coastal temperate rain forests of Sitka spruce, western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and lodgepole pine (*Pinus contorta* Dougl. ex Loud.). Nest sites are located in heavily forested areas at the base of trees, on tree stumps and snags, and even on moss-covered tree limbs (Lebeda 1980, Lebeda and Ratti 1984, Ratti in Timm and Havens 1973). Males use roost sites on tree limbs far above the forest floor during incubation, and both broods and molting geese use forest as escape terrain when disturbed (Lebeda and Ratti 1984). The principal food for Vancouver Canada geese is American yellow skunk cabbage (*Lysichiton americanum* Hult. & St. John), a common plant in the understory. In summary, this race of Canada geese has become uniquely adapted to a forested environment. Although crows, ravens, bald eagles, river otters, and brown bears are present, they typically frequent more open areas, leading Lebeda and Ratti (1984) to speculate that dense forest vegetation

characteristic of nest sites decreased the vulnerability of these nests to predators, a condition not available in the narrow fringes of traditional, open habitat at the forest edge.

By remaining on their traditional nesting grounds despite dramatic and rapid plant succession with subsequent changes in the structure of vegetation, dusky Canada geese are being forced to use increasingly shrubby and forested nesting habitat. There may now be generations of dusks that have only experienced this type of habitat, and these geese may already be increasing their nesting range on the upper CRD, moving inland into habitat similar to what now occurs on the traditional parts of their range. This may be how Vancouver Canada geese evolved their nesting and brood-rearing habits, if not on the CRD, then at some similar location and situation in the geologically dynamic region of coastal Alaska. In their forested habitat, an environment likely similar to that toward which the CRD is headed, Vancouver Canada geese experienced 56 percent nest success (Lebeda and Ratti 1984). Although measured only 1 year, this rate of success is much higher than the rate dusks now normally experience. Thus, the persistence and viability of their population and their unique adaptations make Vancouver a positive example of one possible direction for the long-term future of dusks.

In contrast, as the nesting and brood-rearing habitat of dusks continues to become less suitable as succession proceeds, the population may decline gradually if they are not able to adapt. Given a rapid invasion of Sitka spruce and cottonwoods on the nesting grounds, and the presence of abundant potential prey during spring and summer, bald eagles can be expected to respond by establishing a high density of nest sites. Nest success of geese and survival of nesting adults might decline. Thus, for geese, the presently low rate of recruitment would decline further, while population mortality rates may remain at their present levels, or even increase, leading to a net loss to the population. If minimal annual recruitment consistently occurs over time, the average age of surviving adults would increase, with an eventual drop in reproductive potential. At some point, an abrupt decline would likely occur. To prevent or

mitigate this scenario, efforts are warranted to promote high adult survival rates, and to support successful reproduction to the extent feasible.

Knowledge Gaps and Information Needs—Relationship to Management

As indicated in the annotated bibliography of work on dusky geese (Campbell and Cornely 1992), there is a substantial body of research and survey information on these birds, and much of it has been incorporated directly into management programs. The Pacific Flyway management plan details the current management and research procedures to be implemented at three action levels tied to dusky goose population size estimated from the CRD and Middleton Island (Pacific Flyway Council 1997). As a result of this biological review, the following topics are mentioned to supplement or underscore the planned procedures in the flyway plan, and most are specifically directed toward the CRD subpopulation, or to sorting out subpopulations. Also, a few of the items highlighted below are actually next-step suggestions flowing logically from progress already achieved on initiatives listed in the plan. The following recommendations, therefore, should not be viewed as an exhaustive list of information needed for the routine management of dusks; for this, the flyway plan should be consulted.

Taxonomy and Classification

The recent progress of research in the field of genetics has been great but has created dilemmas for wildlife managers. Although differences between many species and subspecies are clear, in species such as the Canada goose there are now easily detected but often minor genetic differences between groups of breeding birds that are only modestly separated geographically or evolutionarily. The situation with dusky Canada geese provides a typical example. As recommended in the flyway management plan, considerable work has been conducted to elucidate relations between populations of Canada geese in the Pacific Flyway (e.g., Pearce et al. 1998, Shields and Connor 1998), and more work is ongoing.

Because of the close relationships among groups of Canada geese breeding in southern Alaska and coastal British Columbia, and because of the large body of new information both accumulated and pending, a coordinated and joint review of the current taxonomic designations of breeding groups by both researchers and managers in the near future will help to appropriately delineate populations for uniquely focused management attention.

Distribution

Despite extensive knowledge within the CRD, western Oregon, and southwestern Washington, little is known of the numbers and locations of dusky winters in British Columbia. These geese are not currently included in annual mid-winter population estimates. The degree to which these birds represent a segment of the population associated with a particular part of the breeding grounds, and variation in the size of this segment are unknown. Characteristics of migration remain even less understood. The exact migration route dusky winters take to and from their wintering grounds, the habitats they use, and when and to what extent they use them remain poorly understood.

Breeding Population Estimates

Because of the rapidly increasing and changing numbers of similar-looking Canada geese on the wintering grounds, and the problems this presents for developing reliable population estimates of dusky winters, the value of a method to reliably estimate breeding population size is greatly elevated. Breeding population estimates currently constitute indices, rather than absolute numbers, because they are uncorrected for visibility bias. This problem is confounded by the inconsistent results obtained during assessment of visibility bias when using helicopters. Possible sources of this inconsistency are the changing nature of the environment caused by accelerated plant succession and the relatively dense cover now occurring on the CRD. Expansion of aerial survey estimates with factors derived from nest densities (Stehn 1991) seems to hold the most promise. For dusky winters, this method is complicated by the unknown and variable extent of annual re-nesting

that occurs. The degree of re-nesting and the causes of re-nesting need to be assessed carefully before they are incorporated into estimations of the breeding population.

Exchange Between Copper River Delta Geese and Island Geese

As a metapopulation, there is some chance that the CRD subpopulation of dusky winters will be supported by dispersal from island geese, and that CRD dusky winters will contribute, at least genetically, to island geese. Although exchange is now apparently low, over time any dispersal phenomena that lead to greater reproductive success and survival beyond what would have occurred without dispersal will be magnified. Dispersal may be occurring because CRD geese and island geese winter sympatrically and nest in adjacent regions. Dispersal could assist the long-term viability of dusky winters, ensuring either the persistence of geese on the CRD or the eventual recolonization of the CRD after favorable habitat conditions are naturally restored. To enhance this potential, managers should attempt to detect and measure dispersal between subpopulations, and be prepared to take management action to protect this exchange and the potential for increased productivity and survival of dusky winters that may result. Because island geese may be an important source population, a wise course would be to determine monitoring and management needs for ensuring their conservation over the long term. If numbers of CRD geese become critically low, consideration could be given to transplanting island geese from forested locations to the CRD.

Population Age Structure

The reproductive potential of a population is higher with a majority of young to middle-aged adults than with a population consisting largely of old adult birds. Relatively low recruitment rates have now characterized the dusky Canada goose population for about 20 years. Adult survival has been high for at least 15 years. To be able to predict the future prospects for the population, and to be prepared for management needs as they arise, the age structure of the population is an

important component that needs to be evaluated. Given the active banding program that has been conducted with the dusky population for many years, and given the ongoing commitment to regular banding quotas at certain intervals, data may be already in hand to assess aging of the population.

Depredation

Knowledge of the predators that currently are responsible for loss of eggs, nesting adults, and goslings on the breeding grounds is required. Real data on this question are extremely difficult to accumulate yet may be essential should there be periods when management is needed to boost nest success. Answers to related questions, such as when and where does depredation occur and not occur, and what conditions influence the degree of depredation, will lead to both further understanding of potential management options and effective use of advantageous opportunities.

Depending on the successional stage on the nesting grounds, the species, effectiveness of depredation, and population status of predators will vary. For bald eagles, knowledge of their rate of colonization for nesting, their hunting range, and their proclivity for dusky and eggs is needed. Their efficiency of depredation may differ by habitat type.

Further, the relation of the eulachon run to the degree and timing of nest depredation, when the spring eulachon run occurs in relation to the timing of nesting by geese, and whether the factors influencing the timing and size of the run are the same as those influencing spring phenology and associated nesting chronology of geese require elucidation. Perhaps the presence of eulachon buffers geese from depredation, or increases depredation by attracting predators to the nesting grounds.

Finally, evidence indicates that high nest loss occurs early in the nesting period and declines steeply during late nesting. Proactive, small-scale testing of techniques to control nest depredation during this narrow window of time deserves consideration, and should be considered during brood-rearing if appropriate.

Adult Mortality on Nesting Grounds

Knowledge of mortality rates of breeding adults by phase of reproduction is key to understanding limitations to production, and for directing management initiatives. Current research includes assessing predators responsible for adult mortality during nesting, and for determining adult and gosling mortality during brood-rearing. However, a quantitative assessment of mortality rates of breeding adults before and during nesting will help ensure effective use of management effort.

Why Is Use of Artificial Nesting Islands So Low?

The current annual use of less than 30 percent of artificial nest islands by dusky is much lower than is typical of Canada geese elsewhere in North America. Understanding whether this is attributable to unique habits of dusky geese, characteristics of the structures, or other environmental factors is important to increase the potential contribution of artificial islands to production, or at least allow a thorough evaluation of the program.

Quality of Breeding Habitat Given Accelerated Plant Succession

Duskys typically arrive on their breeding grounds and feed vigorously to increase their nutritional condition and to form eggs during the prelaying and laying period. Because habitat changes have been extreme, however, it is unknown if sufficient quantity and quality of habitat exists for duskys to meet their energy and nutritional requirements for reproduction at a rate similar to that of the past. Comparison of clutch size in recent years to data from earlier times may shed some light here. Similarly, comparison of constancy of incubation and frequency and duration of recesses between contemporary and past periods would be useful. At the higher survival rates typical of adult geese in the near absence of hunting, they may maintain sufficient reproductive potential for population maintenance. This potential, however, may be much lower than it was when higher quality habitat existed 10 to 30 years ago.

New Marsh Development and Old Marsh Plant Succession

The rate of new marsh development has been monitored, and this monitoring should be continued. Monitoring also should include a periodic assessment of the use of, and productivity in, the new marsh by dusks. To develop a predictive capability for long-term assessment, however, the rates of subsidence and silt deposition (and accretion) need to be determined. Knowing these rates will improve the ability of land managers to predict rates of new marsh expansion and changes in the rate, timing, and direction of plant succession on the delta.

Winter Foraging Ecology

Because of the increasing numbers of other Canada geese wintering sympatrically with dusks, there remains a need for detailed information on the winter foraging ecology of this race. The carrying capacity of the Willamette Valley for Canada geese is being approached, at least in terms of human tolerance to geese. As crop depredation complaints and the overall density of geese increase, new pressures will be brought to bear on dusks. These include conversion of grassland foraging habitat to pulpwood production (Fleagle 1991) and other uses, hazing from croplands and redistribution to other habitats, as well as proposals to expand hunting to move or reduce goose populations. Detailed insights on foraging characteristics and needs of dusks in this changing environment will support the effectiveness of management efforts to meet their requirements and ensure that they reach

English Equivalents

When you know:	Multiply by:	To find:
Millimeters (mm)	0.0394	Inches
Centimeters (cm)	.394	Inches
Meters (m)	3.28	Feet
Square meters (m ²)	10.76	Square feet
Kilometers (km)	.6215	Miles
Hectares (ha)	2.471	Acres
Square kilometers (km ²)	.386	Square miles
Kilograms (kg)	2.205	Pounds

ideal physiological condition before spring migration and the onset of reproduction.

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