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The population of dusky Canada geese (*Branta canadensis occidentalis*; hereafter, dusky geese) nesting on the western Copper River Delta (CRD) in south-central Alaska has been in decline since the late 1970s. In an effort to alleviate mammalian predation, increase nest success, and avoid a listing under the U.S. Endangered Species Act, an artificial nest island (island) program was implemented on the western CRD in 1983. The installation of new islands on the CRD is the sole management action of the Pacific Flyway Council on the breeding grounds, but no comprehensive evaluation of the program has been published. I examined general trends in island use and nest success over time for three island types (donut islands, fiberglass floater islands, and sandbag islands) from 1984-2005. I used data from the island program to identify factors associated with dusky Canada goose nesting (hereafter, use) and nest success on islands from 1996-2005. I generated a series of candidate models and used logistic regression with model selection techniques to determine how variables representing pond characteristics, vegetative characteristics, interactions with conspecifics and larid species, the previous year's island status, and the distance to predator corridors were associated with island use and nest success for each year. Use of islands by dusky geese nesting on the western CRD increased between 1987 and 2005 from a low of 10% in 1987 to 44% in 2005. There was annual variability in factors associated with island use; however, use of islands was most consistently and strongly associated with the previous year's island status. The odds of a nest being placed on an island that contained a successful nest the previous year

were 2.91 to 6.62 times greater than for islands not used the previous year. There was also evidence for an increased likelihood of island use further from shore and for islands with up to 55% aerial shrub cover and shrubs up to 1 m tall. Nest success was consistently high, indicating islands have long term potential for increasing dusky goose nest success on the Copper River Delta. Compared to island use, my analysis of nest success and habitat features resulted in many more competitive models (average 10 v. 2 per year) with fewer strong (95% confidence intervals for parameter estimates excluded zero) associations between explanatory variables and nest success. Explanatory variables representing vegetative characteristics, interactions with conspecifics and larid species, and the distance to predator corridors had a relatively low capacity to explain nest success on artificial islands. However, there was some evidence for an increased likelihood of nest success on islands further from shore with shorter shrubs. Lower variability in factors associated with island use is likely because factors associated with nest site selection are controlled by decisions of the nesting goose. The importance of previous year's island status on island use likely reflects high site fidelity by breeding adult geese, with fidelity being higher for birds that have successful nests. Alternately, dusky geese use cues from the previous year's nesting activity when prospecting for island nest sites. In contrast, nest success is dependent on a more complex combination of factors that vary within and among years outside the control of a nesting goose. Inter-annual variation in the timing and magnitude of eulachon (*Thaleichthys pacificus*) spawning runs on large sloughs of the CRD and prey-switching by important dusky goose nest predators may have considerable influence on dusky goose nest success on islands, similar to mainland-nesting dusky geese. The inability to control for eulachon presence and abundance may have confounded my analysis of habitat features important to nest success. Therefore, factors such as presence of alternate prey (and predator abundance) may be more important to dusky goose nest success on islands than habitat features. Current use of available nest islands is at a program high of 44% and nest success also remains high (63%); suggesting the artificial nest island program is valuable for dusky geese. However, the contribution of island-nesting dusky geese to the dusky goose population on the Copper River Delta is unclear. There is a need for a population model that incorporates all recent information on dusky goose reproductive ecology to determine if artificial nest islands can increase dusky goose population size, and if so, how many islands are needed.

Factors Associated with Dusky Canada Goose Nesting and Nest Success on Artificial Nest Islands of the Western Copper River Delta

by
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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Nicole Marie Maggiulli, Author

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Factors Associated with Dusky Canada Goose Nesting and Nest Success on Artificial Nest Islands of the Western Copper River Delta

CHAPTER 1

INTRODUCTION

The dusky Canada goose (*Branta canadensis occidentalis*, hereafter, dusky goose) is a moderately large subspecies of Canada goose characterized by dark brown plumage and distinguished from other subspecies of Canada goose in the field by color and size (Johnson et al. 1979). For management purposes, the U.S. Fish and Wildlife Service and Pacific Flyway Council define the dusky goose population as all Canada geese breeding on the Copper River Delta (CRD) in south-central Alaska and on Middleton Island in the Gulf of Alaska (Pacific Flyway Council 2008). Dusky geese migrate between their breeding grounds in Alaska and wintering grounds in the Willamette Valley of Oregon and the lower Columbia River Valley in northwestern Oregon and southwestern Washington (Pacific Flyway Council 2008).

Prior to 1964, the dusky goose population fluctuated between less than 10,000 in the early 1950s to roughly 18,000 in 1961 (Pacific Flyway Council 1973, Pacific Flyway Council 2008). Dusky geese primarily nested on the outer portion of the western CRD, above the mean high tide level in a vegetation community dominated by sedges, grasses, forbs and low shrubs (Trainer 1959). During this time dusky goose nest success was high (~89%) and nest losses were mainly attributed to flooding and avian predation, primarily gulls (Trainer 1959). Mammalian predators including coyote (*Canis latrans*), brown bear (*Ursus arctos*) , black bear (*Ursus americanus*), red fox (*Vulpes vulpes*), mink (*Mustela vison*), weasel (*Mustela* spp.), and river otter (*Lutra canadensis*) were only occasionally observed in core dusky goose nesting areas (Trainer 1959). Harvest pressure in Oregon and Washington was high and harvest mortality often exceeded recruitment, which likely limited population size (Chapman et al. 1969).

On 27 March 1964 the Great Alaska Earthquake, measuring 8.4-8.6 on the Richter scale, elevated the CRD as much as two meters (Thilenius 1990). The change in elevation dried the CRD, which initiated succession of the plant community (Thilenius 1990, Bromley and Rothe 2003). Intertidal areas dominated by grasses and sedges and used by nesting dusky geese began a transition to habitat dominated by shrubs and trees including willow (*Salix* spp.), sweetgale (*Myrica gale*), alder (*Alnus* spp.), and Sitka spruce (*Picea sitchensis*) (Crow 1971, Thilenius 1990, Boggs and Shephard 1999). Despite these habitat changes, dusky geese continued to use the outer CRD as their core nesting area and adjusted to nesting in a higher percentage of shrubs (Bromley 1976, Campbell 1990).

Post-earthquake habitat succession and the drying of wet areas on the CRD corresponded with an increase in the diversity and abundance of predators on dusky goose nesting grounds (P. E. K. Shepherd 1965 unpublished report, Bromley and Rothe 2003, Anthony et al. 2004). Two years after the earthquake, nest losses to predators in one area of the CRD increased by 28% (average nest success ~59%) (Shepherd 1965). Avian predators were still thought to be the most important, but determining which species was most important was difficult and mammal abundance in the region had increased (Bromley 1976). By the mid-1980s, brown bears accounted for half of nest predation events, and annual nest success averaged 43% (Campbell 1991). Subsequent translocation of brown bears decreased bear related depredation, but that appeared to be compensated by increased predation by parasitic jaegers (*Stercorarius parasiticus*) and glaucous-winged gulls (*Larus glaucescens*) (Campbell 1988). More recently, bald eagles (*Haliaeetus leucocephalus*) have been the major nest predator (Anthony et al. 2004) and this research suggests that bald eagles may have been responsible for some of the dusky goose nest losses attributed to brown bears in the 1980s (Campbell and Griese 1987, Campbell 1991). Dusky goose annual nest survival from 1997-2000 averaged 26% (Grand et al. 2006). After an initial increase in dusky goose abundance following the earthquake, the dusky goose population declined to fewer than 9,000 birds in 1987, the lowest population estimate since the 1950s, with the decline primarily attributed to low recruitment caused by an increase in dusky goose nest and gosling predators on the CRD (Figure 2 in Pacific Flyway Council 2008).

Management on the wintering grounds had initially focused on protecting key habitats. For example, in the mid-1960s the U.S. Fish and Wildlife Service created Ankeny, Finley, Baskett Slough, and Ridgefield National Wildlife Refuges in the Willamette and Lower Columbia River Valleys (Pacific Flyway Council 1973, Pacific Flyway Council 1985, Pacific Flyway Council 1997). Beginning in 1983, the Pacific Flyway Council drastically reduced hunter harvest of dusky geese (Pacific Flyway Council 1985), in an effort to offset declining productivity on the breeding grounds. Prior to 1984, dusky goose harvest often averaged over 25% of the population (Pacific Flyway Council 1997). Current harvest regulations in Oregon and Washington maintain a combined dusky goose harvest quota of 200 dusky geese, less than two percent of the population in most years (Pacific Flyway Council 1997). However, a long-term solution required actions to increase nest success and gosling survival.

In 1983 the U.S. Forest Service (USFS), the federal agency that owns and manages the CRD, Alaska Department of Fish and Game, and Ducks Unlimited initiated an artificial nest island program for dusky geese to improve recruitment on the western CRD (Babler et al. 1998). Canada geese in other regions of North America use artificial nest islands (hereafter called islands) (Craighead and Stockstad 1961, Brakhage 1965, Will and Crawford 1970, Giroux et al. 1983, Rienecker 1971) and nest success is generally higher than mainland nesting geese (Craighead and Stockstad 1961, Brakhage 1965, Will and Crawford 1970). Six different types of islands were designed and installed in ponds and beaver sloughs on the western CRD between 1983 and 1992. Monitoring and maintenance of islands has been conducted annually since 1984. Since 1984, the number of islands has ranged from 40 to 525.

From 1984-1994 apparent nest success averaged 59%; in contrast, apparent nest success for mainland-nesting dusky geese (i.e., those not nesting on islands) during the same time period averaged only 22% (Babler et al. 1998). Although nest success was higher on islands, success varied considerably among years and use of islands by dusky geese was relatively low compared to other programs (Brakhage 1965, Will and Crawford 1970, Rienecker 1971, Giroux et al. 1983), averaging 15% of available islands (Babler et al. 1998). Identifying factors that influence use of islands and nest success on islands may improve the management of this program and will help improve goose recruitment.

Several studies have investigated how habitat features can influence use and nest success on artificial nest islands. In Michigan, Utah, and Canada use was related to vegetative cover on islands (Kaminski and Prince 1977, Giroux 1981, Reese et al. 1987), elevation of islands above the water (Kaminski and Prince 1977), water depth around islands (Giroux 1981, Reese et al. 1987), and distance of islands to shore (Giroux et al. 1983, Reese et al. 1987). Nest success for geese on islands in Illinois and Canada was related to water depth (Vermeer 1970), distance to shore (Giroux 1981, Cline 2004), and water body size (Cline 2004). Most of these studies were conducted at temperate latitudes in man-made lakes. The extent to which these factors influence island use and nest success in a northern ecosystem with little alteration by man is unclear. Furthermore, as these habitat features presumably were important because they influenced detection and access of nests by predators, it is not clear that results from these studies are applicable to the CRD. Research on dusky geese nesting on the mainland of the western CRD found a relationship between vegetation characteristics around the nest and nest success (Miller et al. 2007). However, it is not clear those relationships apply to dusky geese nesting on islands.

In this study, I conduct a retrospective analysis of nest island data for dusky geese on the CRD to test hypotheses about factors that influence use and success on islands and guide management of the nest island program on the CRD. Chapter 2 reviews nest island literature for Canada geese and summarizes factors correlated with use and nest success on these islands. I use those studies along with discussions with other goose researchers and my own observations on the CRD to develop testable hypotheses. Chapters 3, 4, and 5 report the details of my analysis and interpretation of the major results.

CHAPTER 2

FACTORS INFLUENCING CANADA GOOSE USE OF AND NEST SUCCESS ON ISLANDS: A LITERATURE REVIEW

Introduction

Canada geese readily place their nests on islands (e. g., Geis 1956, Ewaschuk and Boag 1972, Giroux 1981). Nest success is typically higher on islands than the mainland (Craighead and Stockstad 1961, Cline 2004, Miller et al. 2007) and this difference is usually attributed to a decreased susceptibility to mammalian predation (Vermeer 1970). Consequently, managers frequently use artificial islands to increase nest site availability (Yocom 1952, Brenner and Mondok 1979, Giroux 1981, Reese et al. 1987, Lokemoen and Woodward 1992) and increase goose nesting success (Brakhage 1965, Giroux 1981, Lokemoen and Woodward 1992, Babler et al. 1998). Many studies have investigated factors that influenced use of islands for nesting (hereafter, use) and nest success on islands, but there has been no comprehensive review of this work for geese. In this chapter I review the literature dealing with goose use of natural and artificial nest islands to identify patterns that can guide management of nest island programs and generate ecological hypotheses that provide causal explanations for patterns in the data.

I reviewed 24 papers on Canada geese and eight papers on Canada geese and ducks that included research conducted between 1943 and 2004 in 16 states and three provinces in the United States and Canada (Table 2.1). I included studies from natural and artificial islands and islands (structures) small enough to support one nest (i.e. elevated nest baskets, tubs, platforms and floating structures) or many nests. Artificial nest structures (ANSs) ranged in size from 0.2 m^2 (Brakhage 1965) to 2.7 m^2 (Babler et al. 1998) for seven of the thirteen studies that reported ANS size. The size of earthen islands ranged from 2 m^2 (Johnson et al. 1978) to 259,000 m^2 (Zoellick et al.

2004) for eleven of the twenty-two studies. In many instances I report on trends for ANSs separate from earthen islands. Earthen islands were typically much larger than ANSs and could support more than one nesting goose. Nest density on earthen islands varied from 0.05 to 10.1 nests/ha (Geis 1956, Hammond and Mann 1956, Klopman 1958, Vermeer 1970, Giroux 1981, Lokemoen and Woodward 1992). Use of ANSs by geese may be favored in areas where natural nesting habitat is saturated (Rienecker 1971). However, a study of elevated nest platform use in Flathead Valley, Montana, found no relationship between platform use and the density of nesting geese near platforms (nest density range = 0.2 – 2.0 nests/ha; Craighead and Stockstad 1961).

Nest Island Use

Goose use of ANSs averaged 36 (± 7 % SE; n = 11 studies) with a range from 3% to 67% (Table 2.2). The authors of one study posited use was low because of interactions between nesting pairs and large fluctuations in the water levels of man-made ponds and lakes (Brenner and Mondok 1979). Yocom (1952) felt high use was caused by loss of traditional nesting sites (old osprey nests in snags) during a fire. Several studies have reported increased use of ANSs and earthen islands over time (Craighead and Stockstad 1961, Rienecker 1971, Giroux et al. 1983, Stolley et al. 1999, Dow 1943, Giroux 1981, Gosser and Conover 1999). Some studies have also observed nest site fidelity to islands (Geis 1956, Craighead and Stockstad 1961, Brakhage 1965, Vermeer 1970, Giroux et al. 1983). Most studies report that pond features or island characteristics are associated with goose use of islands. The following review of nest island use by geese will include a discussion of the associations between use and variables representing pond features and island characteristics reported in the literature.

Island Characteristics

The spacing of ANSs determines the distance between single goose nests, whereas the spacing of larger earthen islands determines the distance between clusters of goose nests. The distance between single goose nests on ANSs and earthen islands ranges from 46 to 193 m apart (Sherwood 1968, Giroux 1981, Giroux et al. 1983, Reese et al. 1987, Lokemoen 1993). In one study of small earthen islands (1.8 – 12.6 m^2) the distance between islands with nests was greater than between islands without nests (mean 154 v. 83 m), which the authors attributed to territorial behavior (Reese et al. 1987). However, there was no difference between rock islands used and unused by geese, but the authors suggested islands were adequately spaced (average = 193 m; Giroux et al. 1983). The spacing of nests on larger earthen islands (8,094 – 251,000 m^2) was uniform and attributed to territorial behavior (Vermeer 1970).

Six studies reported information on island use related to island and structure size; results vary considerably. In three studies of ANSs, geese preferred larger structures (Rienecker 1971, Giroux et al. 1983, Babler et al. 1998). For example, the mean diameter of man-made islands that were used by geese in Canada was 1.5 m compared to 1.2 m for unused (Giroux et al. 1983), and geese in Alaska preferred islands greater than 2.0 m^2 but avoided islands 1.5 m^2 or less (Babler et al. 1998). However, in another study of small man-made islands in Utah, geese seemed to use islands of intermediate size, using islands 1.5 to 4.0 m in diameter, although almost a quarter of the available islands were smaller or larger (Reese et al. 1987). In two studies of geese nesting on muskrat lodges, one found that use was independent of lodge size (mean = 0.9 used, mean = 0.8 unused; Reese et al. 1987); whereas, the second found lodge crown diameter was the most important indicator of use (mean = 1.6 m for used vs. mean = 0.9 m for unused; Kaminski and Prince 1977). These studies suggest that geese use structures and small islands (muskrat lodges) with a minimum of 1.0 m in diameter but diameters of 1.5 m and greater may be best.

Direct comparisons of use on ANSs versus larger earthen islands are difficult, in part because the smaller earthen islands are larger than the largest ANSs. For earthen islands, nest density may be a better measure of island attractiveness. Goose nest density tends to be higher for smaller earthen islands (Geis 1956, Hammond and Mann 1956, Vermeer 1970, Duebbert 1982, Zoellick et al. 2004). A multiple regression analysis of habitat variables related to mean goose nest density on large earthen islands (mean = 60,000 m^2) found mean goose nest density significantly decreased as island size increased (Zoellick et al. 2004). Similarly, goose nest density was lowest for the largest island (0.1 nest/ha on a 250,905 m^2 island v. 3.2 nests/ha on a 64,750 m^2 island) in a study in Alberta (Vermeer 1970). Goose densities were higher on small earthen islands in North Dakota (8.1-32.4 nests/ha on 1,214– 4,047 m^2 islands) and the authors suggested islands 4.6 to 9.1 m wide usually had higher use than larger islands (Hammond and Mann 1956). Smaller earthen islands in Montana (average = 2.7 nests/ha on 2,023 – 8,094 m^2 islands, average = 0.2 nests/ha on 80,937 – 121,406 m^2 islands; Geis 1956) and in North Dakota (5,000 – 10, 000 m^2 islands; Duebbert 1982) also had greater nest densities.

Geese will naturally place nests high above the ground in old nests of osprey, red-tailed hawk, bald eagles and herons (Yocom 1952, Geis 1956, Craighead and Stockstad 1961); thus, it is possible island height might influence island use. While ten studies report data on nest height and nine suggest use is higher on elevated nest sites, few provide quantitative details that suggest there is an ideal nest site elevation (Dow 1943, Craighead and Craighead 1949, Yocom 1952, Craighead and Stockstad 1961, Brakhage 1965, Will and Crawford 1970, Rienecker 1971, Kaminski and Prince 1977, Giroux et al. 1983, Reese et al. 1987). In one study, nest platform use was almost twice as high for platforms 6.4 to 13.7 m above rivers, shorelines, and islands than for platforms placed lower or higher; however, platforms on islands were more frequently used at lower heights than platforms above rivers or shorelines (Craighead and Stockstad 1961). In contrast, there was no correlation between tub height (range: 0.3 – 6.1 m tall) and use in Missouri (Brakhage 1965) or the height of used and unused man-made rock islands in Canada (Giroux et al. 1983). In the latter study, the author suggested all islands were of adequate minimum height (mean = 0.8 m used islands). Reese et al. (1987) suggested geese only nested on islands 0.5 m or higher in Utah. The value of elevated sites is likely increased security for adults and nests (Dow 1943, Craighead and Craighead 1949, Kaminski and Prince 1977, Giroux et al. 1983, Reese et al. 1987). Finally, it was not height, but slope of island sides that was the highest predictor for discriminating between used and unused islands (mean = 15.7% slope used, mean = 8.4% slope unused) in one study in Michigan (Kaminski and Prince 1977).

Vegetative cover on islands was not an important selection factor for island nesting geese in most studies (Miller and Collins 1953, Geis 1956, Hammond and Mann 1956, Craighead and Stockstad 1961, Lokemoen 1993). In three studies geese were observed nesting on islands with no vegetative cover (Miller and Collins 1953, Hammond and Mann 1956, Reese et al. 1987). However, vegetative cover may influence nest density on larger islands because increased cover may reduce encounters with conspecifics. For example, in one study artificial earthen islands (island size: 1,600 – 66,000 m^2) with an average of 95% grass and forb cover were more likely to have two nests than one (Giroux 1981). In general, shorter, less dense vegetation with an average height of about 0.5 m seems to be used most often by geese nesting on earthen islands (Craighead and Craighead 1949, Sherwood 1968, Giroux 1981, Reese et al. 1987). Vegetation density on used islands was significantly lower than on islands not used (average 17.1%, used), and this was one of the two most important parameters measured distinguishing used and unused islands (Kaminski and Prince 1977). In the same study, the average height of vegetation was similar between used (1.7 m) and unused (2.0 m) islands (Kaminski and Prince 1977). These studies suggest geese prefer the visibility afforded by reduced vegetative cover and easier access to the island from the water. However, three studies suggest vegetative cover or the availability of vegetation materials at the nest site are indicators of island use (Giroux 1981, Giroux et al. 1983, Babler et al. 1998). Geese in two studies in Canada only nested on artificial rock islands with artificial or natural vegetation available (Giroux et al. 1983), and selected islands with greater forb and grass cover (Giroux 1981). In addition, geese in Alaska selected greater than 50% aerial shrub cover on islands and avoided islands with 10% cover or less (Babler et al. 1998).

Finally, several studies of ANSs recommended that loafing sites for ganders should be provided with ANSs (Yocom 1952, Brakhage 1965, Rienecker 1971, Ball

1990, Babler et al. 1998). Floating logs, large rocks, stumps, and matted vegetation wads placed near ANSs allow active participation of the gander in nest site protection. One study reduced gander territory size when loafing sites were placed near nesting tubs, decreasing territorial strife among tub nesters (Brakhage 1965). Another study recommended providing loafing sites for the gander when elevated ANSs are further than 91 m from shore but warns to avoid facilitating territorial strife, loafing sites should not be large enough to support a goose nest (Rienecker 1971).

Pond characteristics

Fewer studies have considered how pond size characteristics influence island use. One study found 92% of nesting pairs on islands were in wetlands with at least two hectares of open water (Kaminski and Prince 1977) and another source suggested geese inhabit large water bodies first (Ball 1990). Water depth surrounding islands used by nesting geese ranged from 0.4 m to 7.0 m (Giroux 1981, Giroux et al. 1983, Reese et al. 1987). Mean water depths reported for islands used by geese varied among studies from 0.37 m (Giroux et al. 1983) to 0.69 m (Giroux 1981) to 1.3 m and 7.0 m (Reese et al. 1987). Geese used earthen islands in deeper water impoundments for nesting in Canada, with an average water depth of 0.69 m (Giroux 1981). Water depth surrounding small, artificial rock islands used by nesting geese did not differ from unused islands in Canada, with an average of 0.37 m water depth (Giroux et al. 1983). In Ogden Bay, Utah, geese used small artificial islands with an average of 1.3 m water depth and muskrat lodges with an average of 7.0 m water depth for nesting (Reese et al. 1987).

Geese generally use ANSs farther from the mainland shore with suggested distances for island placement ranging from 15 m to greater than 150 m (Sherwood 1968, Rienecker 1971, Duebbert 1982, Giroux et al. 1983, Reese et al. 1987, Babler et al. 1998). Geese preferred island sites greater than 20 m from shore and avoided island sites 10 m from shore or less in Alaska (Babler et al. 1998), and used rock islands further from shore (44.6 m v. 17.1 m) in Canada (Giroux et al. 1983). Two studies reported no difference in the distance to shore between earthen islands used and unused for nesting by geese; however, the majority of islands averaged 50 m or greater from shore (Kaminski and Prince 1977, Reese et al. 1987).

Nest Success

Geese typically experience greater nest success on islands than on the mainland (Will and Crawford 1970, Johnson et al. 1978, Babler et al. 1998, Stolley et al. 1999, Cline 2004, Peters et al. 2004). Nest success is known to increase with age in geese (Brakhage 1965) and two studies suggested experienced geese used artificial nest platforms more than young birds (Stolley et al. 1999, Peters et al. 2004). However, another study found no difference in female age between island and mainland nesting geese and no significant difference between nest success on islands (65%) and the mainland (55%) (Gosser and Conover 1999).

Nest success, defined as the successful hatching of at least one egg, on ANSs and earthen islands averaged 70 (± 3% SE; n = 23 studies) with a range from 48% (Klopman 1958) to 98% (Rienecker 1971) (Table 2.3). Nest success for earthen islands was somewhat less (65 ± 3%, n = 13) than for ANSs (77 ± 4%, n = 10). Four studies reported larger average clutch size for geese nesting on ANSs and earthen islands than mainland ground-nesters (Craighead and Stockstad 1961, Brakhage 1965, Gosser and Conover 1999, Peters et al. 2004). In three of those studies, geese nesting on ANSs also had greater hatching success than geese nesting on the ground (Craighead and Stockstad 1961, Brakhage 1965, Peters et al. 2004), and in two of the studies geese nesting on earthen islands and structures produced more goslings per nesting attempt than geese on the mainland (Gosser and Conover 1999, Peters et al. 2004).

Causes of nest failure on islands include depredation (Dow 1943, Geis 1956, Vermeer 1970, Giroux 1981, Giroux et al. 1983, Babler et al. 1998, Zoellick et al. 2004), desertion (Miller and Collins 1953, Craighead and Stockstad 1961, Brakhage 1965, Vermeer 1970, Ewaschuk and Boag 1972, Gosser and Conover 1999) and flooding (Craighead and Craighead 1949, Klopman 1958). The number of studies of islands and ANSs where goose nests were lost mainly to desertion (Miller and Collins 1953, Craighead and Stockstad 1961, Brakhage 1965, Rienecker 1971) is similar to the number lost mainly to predation (Dow 1943, Vermeer 1970, Giroux 1981, Giroux et al. 1983); losses to flooding appear to be negligible (Craighead and Craighead 1949, Klopman 1958).

A diversity of mammalian and avian species depredate goose nests on ANSs and on islands, including: brown bears (Cordova Ranger District, unpublished data), coyotes (Dow 1943, Naylor 1953, Zoellick et al. 2004), red foxes (Klopman 1958), badgers (*Taxidea taxus*) (Zoellick et al. 2004), striped skunks (*Mephitis mephitis*) (Dow 1943, Naylor 1953), raccoons (*Procyon lotor*) (Johnson et al. 1978, Zoellick et al. 2004), mink (Geis 1956, Johnson et al. 1978, Zoellick et al. 2004), bald eagles (Cordova Ranger District, unpublished data), corvids (*Pica hudsonia*, *Corvus* spp.) (Dow 1943, Craighead and Craighead 1949, Naylor 1953, Geis 1956, Stolley et al. 1999), and larids (*Larus* spp., *Stercorarius parasiticus*) (Naylor 1953). Mammalian predators are typically the main cause of nest destruction on islands, but the identification of nest predators is difficult, so the extent of damage caused by mammalian predators versus avian predators is unclear in many cases.

Causes of desertion include human disturbance (Craighead and Stockstad 1961), inter- and intra-specific competition (Dow 1943, Miller and Collins 1953, Klopman 1958, Vermeer 1970, Ewaschuk and Boag 1972, Giroux 1981), and predators (Craighead and Stockstad 1961). Encounters with white pelicans (*Pelecanus erythrorhynchos*) and herring gulls (*Larus argentatus*) can also lead to nest desertion by geese (Klopman 1958). Nest success was greater for single pairs nesting on artificial earthen islands (80%) than for geese nesting on islands with greater than one nest (53%) (Giroux 1981). On one island, there was a significantly greater distance between successful (49 m) vs. unsuccessful nests (40 m) (Ewaschuk and Boag 1972). Island and pond characteristics reported to influence nest success include: island size, vegetative cover, freeboard, pond area, water depth, and distance to shore.

Island characteristics

Nest success on ANSs and earthen islands may be associated with island size (Hammond and Mann 1956, Zoellick et al. 2004). Larger islands are easier to detect and board than smaller islands in most areas and may house resident goose predators. In one study of geese nesting on earthen islands on the Snake River, mammalian predation of goose nests increased with island size (size range: 7,000 m^2 to 259,000 m^2, average = 60,000 m^2; Zoellick et al. 2004). However, in another study island size did not have a strong association with nest survival, but the size of islands in this study was smaller (10 m^2 to 17,480 m^2; Cline 2004).

Vegetative cover on islands can conceal nests from predators and reduce intraspecific interactions between geese nesting in close proximity (Ewaschuk and Boag 1972). A study of geese nesting on the ground in south-central Alaska found higher female survival in nest sites surrounded by a high proportion of low density shrubs, and greater daily nest survival associated with tall shrub sites early in the nesting season (Miller et al. 2007). These results suggest that vegetative characteristics influencing depredation of female geese and depredation of nests are different with visibility important for adult survival and vegetative barriers important for nest survival (Miller et al. 2007). In another study successful goose nests were found on islands with greater vegetative cover (forb and grass, average = 58.2%), and this was attributed to the vegetative barrier provided from conspecifics (Giroux 1981). Unlike ducks, it seems that geese prefer visibility afforded by reduced vegetative cover at the nest site, but vegetative cover near the nest can reduce territorial interactions and possibly enhance nest success on larger islands that can support more than one nest. Gander visibility of the nest site is also enhanced, possibly increasing the detection of predation events (Stolley et al. 1999).

Visibility at the nest site is also enhanced by freeboard, or height of the island above the surface of the water. Freeboard is crucial for nest islands to accommodate rising water conditions and avoid flooding of the nest (Yocom 1952, Hammond and Mann 1956, Rienecker 1971). In one study of geese nesting on earthen islands, flooding was responsible for 50% of nest losses (Klopman 1958). Floating or elevated ANSs are usually protected from flooding losses. Islands protruding further out of water may be more easily detected by predators, particularly avian predators, so there are trade-offs for island freeboard among reducing the risk of flooding, increasing visibility for geese, and decreasing detection by predators.

Pond characteristics

The relationship between nest success and pond area is unclear. One reference suggests large saline lakes or open freshwater wetlands are the safest locations for waterfowl nests (Lokemoen 1993), but a study on earthen islands in Illinois found strong evidence for decreased nest survival with increased water body size (Cline 2004). Water depth was an important factor limiting mammalian predation on islands in some studies (Sherwood 1968, Vermeer 1970). Seasonal decreases in water depth (~30 cm to dry) on Lake Dowling in Alberta increased the susceptibility of island nesting geese to predation, particularly by coyotes, and predation was responsible for the loss of 50.4% of nests on one island (Vermeer 1970). An island far from shore but in shallow water (< 0.3 m deep) in Michigan did not deter a coyote from wading and swimming over 180 m to reach the island (Sherwood 1968). The literature suggests water depths of 0.3 to 0.7 m or greater are ideal for waterfowl nest success (Sherwood 1968, Giroux 1981). However, one study recommends water depth surrounding islands of 0.30 to 0.46 m to isolate the island but avoid damage from waves (Hammond and Mann 1956).

Water depth surrounding goose nest islands may be an important mammalian predator deterrent in some areas, but in several studies coyotes have been observed swimming to islands with goose nests (Sherwood 1968, Giroux 1981), and destroying multiple nests in at least one instance (Dow 1943). Red foxes have been observed swimming between wooded earthen islands in Dog Lake, Manitoba (Klopman 1958). Mammalian predators can also cross ice sheets to depredate goose nests on islands in frozen ponds (Klopman 1958). Skunks have also been observed swimming over 200 m to islands (Giroux 1981).

Distance from shore should deter mammalian predation of goose nests because predators will have to wade or swim longer distances for nests. Successful nests were found on islands further from shore (average = 54 m) in one study (Giroux 1981) and there was strong evidence for low nest survival on earthen islands in Illinois close to shore in large water bodies (Cline 2004). A high percentage of goose nests lost in another study were within 61 m from shore (Sherwood 1968). The literature suggests placing nest islands 61 m from shore or greater to provide protection from mammalian predation (Giroux 1981, Duebbert 1982, Lokemoen 1993). Finally, for islands in rivers, success may increase as river flows increase (Zoellick et al. 2004).

Predator control

Islands less than 15,000 m^2 usually lack resident predators (Lokemoen and Woodward 1992, Lokemoen 1993). On floating islands, mink can be a problem because they are attracted to floating rafts (Reynolds et al. 2004). A couple studies attempted to remove mammalian predators from earthen islands to alleviate goose nest predation (Sherwood 1968, Lokemoen and Woodward 1992). However, the data was equivocal as one study reported lower nest success on islands with mammalian predators trapped (Lokemoen and Woodward 1992), but another study reported an 11% increase after live-trapping targeted at raccoons and coyotes (Sherwood 1968).

Conclusions

Use of earthen islands and ANSs for nesting by geese may be influenced by a variety of factors which appear to be site- and sometimes study-specific. However, disagreement between studies may, in part, be due to how data were collected. No study conducted controlled experiments that would permit strong inferences and quantify relationships between key habitat characteristics and use and success. Such controlled experiments are needed. Managers should be cautious when applying the results of any single study to the design of future nest island programs. While it is difficult to use past research to make specific recommendations about how to design and place islands, there were some patterns that emerged from this review.

Geese tend to use elevated islands and ANSs at least 1.0 m in diameter with reduced vegetative cover. This combination of factors provides space for the nest and some security for incubating females and nests. When increased vegetative cover was preferred, vegetation primarily consisted of grasses and forbs, which are likely shorter and more ephemeral than woody shrub species. This suggests a goose's choice of nest site vegetation on islands may not be related to grass and forb cover at all because these plant species are likely underdeveloped at the time of nest site selection in the early spring. Geese nesting on islands preferred a site provided for gander loafing, particularly if the island was far from shore. Geese tend to nest on islands further from shore (>50 m) and in deeper waters, but it is unclear if these attributes are selected by geese.

Nest success on islands and ANSs tends to be greater for geese nesting on islands further from shore and in deeper waters, but exact distances and depths are unclear. This finding is intuitive because mammalian predators will have to swim long distances and exert more energy to depredate nests further from shore in deeper waters, likely discouraging the desire to depredate the nest. However, ideal island distance to shore and surrounding water depth are probably dependent on the diversity, abundance, and foraging habits of nest predators on the study site.

Vegetation is an important barrier that protects nests from predators and conspecifics, but there is a trade-off between the nest protection provided by increased vegetative cover and the vigilance of the female goose facilitated by reduced vegetation. In addition, desertion was a major cause of nest loss for both earthen island nesting geese and geese nesting on ANSs, so islands should be well spaced to avoid facilitating depredation and confrontations with other geese. In general, geese nesting on ANSs are less likely to interact with conspecifics than geese nesting on larger earthen islands and may be further removed from depredation events than geese nesting on earthen islands because of smaller island size and increased elevation of some structures. This could account for the higher average nest success on ANSs versus earthen islands.

TABLES

Table 2.1. Canada goose (*Branta canadensis*) nest island studies and locations included in the literature review.

Island type[a]	Species and subspecies studied	State or Canadian Province	Source
Earthen	Canada goose (*B. canadensis*)	California	Dow 1943
Earthen	Canada goose	Wyoming	Craighead and Craighead 1949
Earthen	Western Canada goose (*B. c. moffitti*)	California	Miller and Collins 1953
Earthen	Western Canada goose	California	Naylor 1953
Earthen	Western Canada goose	Montana	Geis 1956

Table 2.1 continued…

Table 2.1 continued…

Island type[a]	Species and subspecies studied	State or Canadian Province	Source
Earthen	Canada goose, mallard (*Anas platyrhynchos*), gadwall (*A. strepera*), blue-winged teal (*A. discors*), lesser scaup (*Aythya affinis*), redhead (*Aythya americana*)[b]	North Dakota	Hammond and Mann 1956
Earthen	Hudson Bay Canada goose (*B. c. interior*)	Manitoba	Klopman 1958
Earthen	Giant Canada goose (*B. c. maxima*)	Michigan	Sherwood 1968
Earthen	Canada goose	Alberta	Vermeer 1970
Earthen	Canada goose	Alberta	Ewaschuk and Boag 1972

Table 2.1 continued…

Table 2.1 continued…

Island type[a]	Species and subspecies studied	State or Canadian Province	Source
Earthen	Canada goose, mallard	North Dakota	Johnson et al. 1978
Earthen	Canada goose, mallard, gadwall, lesser scaup[c]	Alberta	Giroux 1981
Earthen	Canada goose, mallard, gadwall[d]	North Dakota	Duebbert 1982
Earthen	Canada goose, gadwall, mallard [e]	North and South Dakota, Montana	Lokemoen and Woodward 1992
Earthen	Giant Canada goose	Connecticut	Gosser and Conover 1999
Earthen	Giant Canada goose	Illinois	Cline 2004
Earthen	Canada goose, mallard	Idaho	Zoellick et al. 2004

Table 2.1 continued…

Table 2.1 continued…

Island type[a]	Species and subspecies studied	State or Canadian Province	Source
Earthen and muskrat lodges	Giant Canada goose	Michigan	Kaminski and Prince 1977
Earthen and muskrat lodges	Western Canada goose	Utah	Reese et al. 1987
Elevated baskets and washtubs	Western Canada goose	Washington	Yocom 1952
Elevated tubs	Giant Canada goose	Missouri	Brakhage 1965
Elevated fiberglass herbicide tanks	Giant Canada goose	Minnesota	Atkins and Fuller 1979
Elevated nest platforms	Canada goose	Montana	Craighead and Stockstad 1961
Elevated nest box and floating platforms	Canada goose	Colorado	Will and Crawford 1970
Floating and elevated platforms	Canada goose	California	Rienecker 1971

Table 2.1 continued…

Table 2.1 continued…

Island type[a]	Species and subspecies studied	State or Canadian Province	Source
Elevated nest box and floating platforms	Canada goose	Colorado	Will and Crawford 1970
Floating rafts	Canada goose, mallard, blue-winged teal	Pennsylvania	Brenner and Mondok 1979
Round straw and hay bales, culverts, and floating and pole-mounted baskets	Giant Canada goose, mallard	North and South Dakota, Montana	Johnson et al. 1994
Floating, elevated and stationary structures	Dusky Canada goose (*B. c. occidentalis*)	Alaska	Babler et al. 1998
Rock islands and round straw bales	Canada goose	Alberta, Saskatchewan, Manitoba	Giroux et al. 1983
Artificial nest platforms	Canada goose	Utah	Stolley et al. 1999

Table 2.1 continued…

Table 2.1 continued…

Island type[a]	Species and subspecies studied	State or Canadian Province	Source
Artificial nest structures	Canada goose	Pennsylvania	Jacobs and Dunn 2004
Artificial nest structures	Canada goose	Pennsylvania	Peters et al. 2004

[a] Earthen islands include islands created naturally and artificially.
[b] A smaller number of blue-winged teal, American wigeon (*Anas americana*), northern shoveler (*A. clypeata*), canvasback (*Aythya valisineria*), and ruddy duck (*Oxyura jamaicensis*) nests were also observed on islands in this study.
[c] A smaller number of northern pintail (*Anas acuta*), blue-winged teal, green-winged teal (*A. crecca*), cinnamon teal (*A. cyanoptera*), northern shoveler, American wigeon, redhead, white-winged scoter (*Melanitta fusca*), and ruddy duck nests were also observed on islands in this study.
[d] A smaller number of lesser scaup, American wigeon, blue-winged teal, northern shoveler, northern pintail, redhead, and canvasback nests were also observed on islands in this study.
[e] A smaller number of lesser scaup, blue-winged teal, northern shoveler, northern pintail, redhead, American wigeon, green-winged teal, and ruddy duck nests were also observed on islands in this study

Table 2.2. Mean percent use (± SE) of artificial nest structures by Canada geese (*Branta canadensis*) in eleven states and three provinces of the United States and Canada.

Percent use[a]	*n*[b]	Years[c]	Source
67	18	1	Yocom 1952
13 ± 3	367	5	Craighead and Stockstad 1961
58[d]	309	4	Brakhage 1965
64 ± 5	387	2	Will and Crawford 1970
37 ± 8	279	4	Rienecker 1971
38[d]	16	4	Atkins and Fuller 1979
3 ± 1	88	3	Brenner and Mondok 1979
22[d]	496	3	Giroux et al. 1983
18 ± 1	544	3	Johnson et al. 1994
14 ± 1	2,288	11	Babler et al. 1998
65 ± 6	34	2	Stolley et al. 1999
Overall Mean			
36 ± 7			

[a] Percentage of the available nest structures used for nesting by Canada geese averaged over all study years.
[b] A sum of the available nest structures over all study years.
[c] The number of study years averaged over for percent nest structure use.
[d] Percent use of structures combined over all years, not an average.

Table 2.3. Mean percent nest success (± SE) for Canada geese (*Branta canadensis*) on artificial nest structures and islands in twelve states and three provinces of the United States and Canada.

Island Type/Success[a]	*n*[b]	Years[c]	Source
Nest Structures			
63 ± 18	49	5	Craighead and Stockstad 1961
73 [d]	179	3	Brakhage 1965
76 [e]	260	2	Will and Crawford 1970
98[f]	104	4	Rienecker 1971
85 ± ? [g]	107	3	Giroux et al. 1983
85 ± 2	24	3	Johnson et al. 1994
65 ± 6	388	11	Babler et al. 1998
87 ± 3	22	2	Stolley et al. 1999
63 ± 6	40	2	Jacobs and Dunn 2004
70 [h]	106	1	Peters et al. 2004
Earthen Islands			
64	93	1	Naylor 1953
62 ± 11	423	2	Geis 1956
48 ± 13	104	2	Klopman 1958
54 ± 27[i]	178	1	Vermeer 1970
52 ± 13	334	3	Ewaschuk and Boag 1972
75 [j]	8	5	Johnson et al. 1978
70 ± ?	144	3	Giroux 1981
83 ± 9	68	2	Duebbert 1982
76	30	1	Giroux et al. 1983
76 ± 6	115	2	Lokemoen and Woodward 1992

Table 2.3 continued…

Table 2.3 continued…

Island Type/Success[a]	n[b]	Years[c]	Source
65 [k]	161	11	Gosser and Conover 1999
50 ± 2	1,220	3	Cline 2004
66 ± 4	841	3	Zoellick et al. 2004

[a] The percentage of nests on nest structures and islands with at least one hatched egg.
[b] A sum of the number of nests on nest structures and islands over all study years.
[c] The number of study years averaged over for percent nest success.
[d] Nest success for all nests built in tubs over three years (1961-1964).
[e] Nest success for all nests built on structures over two years (1967-1968).
[f] Nest success for all nests built on platforms over four years (1967-1970).
[g] The standard error or data to calculate the standard error was not provided.
[h] Product Mayfield nest success calculated with different nest survival rates for laying and incubation and without the assumption of constant nest survival throughout the nesting period.
[i] The average and standard error for two earthen islands in one year.
[j] Nest success for all nests built on islands over 5 years (1972-1976).
[k] Nest success for all nests built on islands over eleven years (1982-1990, 1995-1996).
[l] Overall mean and standard error for nest structures and islands

CHAPTER 3

MATERIALS AND METHODS

Hypotheses and Predictions

I developed hypotheses and predictions about factors that may explain dusky goose use of islands for nesting (hereafter, use) and nest success on islands based on the literature (Chapter 2) and personal observations on the western CRD. Hypotheses are grouped by four factors known to influence nest site selection and nest success: predation, weather, nest fate in the previous year, and interactions with conspecifics.

Hypothesis 1: Use of islands and nest success on islands will be associated with habitat characteristics that influence detection of and access to islands by predators.

Prediction: Use of islands and nest success on islands will be positively correlated with the distance between the island and the nearest shore. Distance of an island from shore should influence island detection by mammals and possibly deter mammalian predation because predators must wade or swim longer distances to depredate nests. Nest success for island nesting Canada geese in Alberta and Illinois was greater for geese nesting on islands further from shore (Giroux 1981, Cline 2004).

Prediction: Use and nest success on islands will be negatively correlated with pond area. This prediction is based on results from a study in Illinois where this pattern was attributed to nest isolation; larger ponds usually had more islands, and larger islands with multiple nests per island (Cline 2004). These characteristics may have attracted more predators and resulted in increased failure due to conspecifics. It is not clear this relationship would hold on the CRD where nests are generally at low density and each island supported only one nest. This prediction seems counter intuitive to the previous prediction; however, correlation analyses indicated that pond area and island distance to shore were not highly correlated, with Pearson's correlation coefficients of < 0.70. In addition, strong winds can build powerful waves on large ponds, potentially flooding nests on islands.

Prediction: Use of islands and nest success on islands will be positively associated with distance from the island to the nearest large slough. Large sloughs are major feeding corridors for bald eagles during eulachon spawning (Bromley 1976, Marston et al. 2002, Moffitt et al. 2002) and large mammalian predators like brown bears (*Ursus arctos*) use large slough banks as travel corridors on the western CRD (Bromley 1976, Campbell 1988, Campbell 1991). Eulachon are a small, anadromous forage fish in the smelt family (Osmeridae) with the highest lipid level (mean = 19.0 ± 0.52 %; Iverson et al. 2002) of any forage fish in the north-eastern Pacific Ocean (Payne et al. 1999, Iverson et al. 2002). During spawning runs up CRD sloughs they can occur in large concentrations providing a high-quality food source for aggregations of avian and mammalian predators (Marston et al. 2002, Willson and Marston 2002, Sigler et al. 2004). Eulachon spawning on the western CRD typically coincides with the dusky goose incubation period in mid-late May (Trainer 1959, Bromley 1976, Miller et al. 2006), but spawning often occurs in sporadic pulses on the CRD between late January and early July (Moffitt et al. 2002). A study of dusky geese nesting on the mainland of the western CRD in the mid-1970s found higher nest success for nests further from sloughs (Bromley 1976).

Prediction: Use of islands will be highest with moderate aerial shrub cover and moderate shrub height and nest success on islands will be positively associated with aerial shrub cover and shrub height. Dusky geese nesting on the CRD in the mid-1970s preferred moderate density shrub cover (average = 3.2; qualitative scale of 1 to

5, with 5 as the most dense) within 0.5 m of the nest site and experienced slightly increased nest success with higher cover density near the nest site (Bromley 1976). Dusky geese nesting on the western CRD between 1997 and 2002 had higher female survival in nest sites surrounded by a high proportion of low density shrubs (0-20% canopy cover) within 50 meters of the nest site, but higher daily nest survival associated with mainland nest sites with tall shrubs (> 2 m) and on islands in the early nesting season (Miller et al. 2007).

Prediction: Dusky goose nest success on islands is negatively associated with the distance to the nearest larid colony or nest. Colonial nesting gulls and terns actively defend their nests and colonies against potential predators (Hatch 2002, Moskoff and Bevier 2002); consequently, they can provide protection for other avian species nesting in their colonies (Larson 1960, MacInnes 1962, Vermeer 1968, Vermeer et al. 1992, Nguyen and Abraham 2006). On the western CRD, mew gulls (*Larus canus*), Arctic terns (*Sterna paradisaea*) and Aleutian terns (*Sterna aleutica*) nest colonially (Isleib and Kessel 1973, Lang 2005) and parasitic jaegers (*Stercorarius parasiticus*) often nest in close proximity to these colonies. These relatively small-bodied species are infrequent predators of dusky goose eggs (Anthony et al. 2004).

Hypothesis 2: Use of islands and nest success on islands will be associated with the impact of prevailing winds during the breeding season.

Prediction: Use of islands and nest success on islands will be negatively associated with the distance from the island to the nearest shore in the direction of the prevailing winds. The western CRD has prevailing winds coming from the east-southeast direction (Bishop et al. 2000). Fetch determines the amount of stress an island will incur due to wind and wave action in the pond. As fetch increases, wave energy increases, possibly increasing the risk of nest flooding.

Hypothesis 3: Use of islands will be associated with dusky goose nest fate on the island in the previous year.

Prediction: Use of islands will be higher for islands that supported successful nests the previous year. Nesting Canada geese display a high degree of site fidelity (Geis 1956, Craighead and Stockstad 1961, Brakhage 1965, Vermeer 1970, Giroux et al. 1983) and fidelity for geese is greater following a successful nest (Lindberg and Sedinger 1997).

Hypothesis 4: Use of islands and nest success on islands will be associated with the presence of conspecifics nesting near islands.

Prediction: Use of islands and nest success on islands will be positively associated with the density of breeding dusky geese near the island. Dusky goose nest densities vary within the western CRD (Butler et al. 1994, U. S. Fish and Wildlife Service 2006 unpublished data). High densities of nesting geese can attract other geese (Rienecker 1971) and alert conspecifics of nearby predators (Miller et al. 2007). In addition, the availability of alternate nests near islands for predators to depredate probably results in increased nest success for island-nesting geese because depredating island nests likely involves expending more energy. Dusky geese nesting on the western CRD had higher nest survival in areas of higher goose nest densities (Miller et al. 2007). It is also possible that areas of high goose nest density reflect some unmeasured aspect of habitat quality that is important to nest site selection and success.

Study Area

My study was conducted on the Copper River Delta, the largest Pacific coastal wetland in North America, encompassing 283,380 ha, including 150,000 ha of wetlands with extensive freshwater influences from glacial runoff and precipitation and a bar-built estuarine structure (Thilenius 1990). The CRD experiences a maritime climate with cool summers and mild winters and average annual precipitation of 237 cm (Bishop et al. 2000). The nest island project area encompassed 10,800 ha of uplifted marsh near the outer coastal region of the western CRD (Figure 3.1). This region is characterized by small freshwater ponds, many engineered by beavers (*Castor canadensis*), and dissected by a network of small and large sloughs (Babler et al. 1998).

Methods

United States Forest Service (USFS) personnel have managed the nest islands annually since program inception in 1983. Monitoring intensity varied across years; all islands were visited each year from 1984 to 1988 and from 1996 to present, and once every two years from 1989 to 1995. During years when checked, each island was visited between 7 May and 29 June by airboat, kayak, or on foot to determine use and nest success. During the first visit the island was categorized as available or unavailable. Unavailable islands 1) had sunk, 2) been blown to shore, 3) were missing a sod mat, 4) were flooded, or 5) were located in a dry pond. Islands were classified as used or not used based on signs at the nest that included the presence of the incubating adult, young in the nest, egg shell remains, and nest characteristics (presence of nest bowl and down). Dusky goose nest fate (successful or failed) was determined by signs at the nest. A successful nest contained at least one egg shell membrane in the bottom of the nest. Failed nests contained no membranes and usually some number of wholly or partially destroyed and scattered eggs. Nests were also classified as failed if there were no eggs in an otherwise intact nest bowl or if nests were abandoned. If a nest was active during the first visit, eggs were floated to determine incubation stage (Westerskov 1950) and the nest was visited again after its scheduled hatch date to determine fate.

During the first nest visit, USFS staff also recorded information on habitat and island characteristics including: 1) percent aerial shrub cover on the island (AC) comprised of willow (*Salix* spp.), alder (*Alnus* spp.) and sweetgale (*Myrica gale*); 2) average height of shrubs on the island (SH, m, only collected from 1995-present); and 3) causes of nest destruction. All variables were estimated by USFS biologists and field technicians. New technicians were trained with experienced technicians during the first day of monitoring (Babler et al. 1998).

Data Analysis

My analysis only included islands defined as available by USFS staff during field visits; availability ranged from 81-100% of islands deployed on the CRD during any single year. I also limited my analysis to three of the six island types that had been placed in the study area: dusky donut islands, fiberglass floater islands, and sandbag islands. The remaining three types: barrel-platform islands, rebar-platform islands, and fiberglass-dish islands, were all stationary islands that suffered major damage from ice and their use was discontinued early in the program (Babler et al. 1998).

Prior to analysis, I compared field data cards against the digital dataset to estimate data entry quality. I reviewed data for donut and sandbag islands that were available for six years or greater and data for all available floater islands. I proof-read five variables (AC, SH, species use, dusky goose nest presence, and nest fate) for a random sample of 10% of all available island records for each year from 1984-2005. The average number of incorrect entries (± SE) for species use, dusky goose nest presence and nest fate was 1.9 ± 0.7%. However, the average number of incorrect entries for SH was much larger 75 ± 8%. Based on this sample, I proof-read all the data for any variable in a year when I found incorrect entries exceeded 5%. I also computed summary statistics for explanatory variables each year to look for outliers. I investigated potential outliers for all variables, but I only removed entries that were likely recording errors. Outliers only occurred for one variable, average shrub height. I deleted records with values of ≥ 3.0 m if these entries changed the outcome of analyses.

I calculated percent use and apparent nest success (the proportion of dusky goose nests with ≥ 1 egg hatched) for each year and graphed both variables with time

(1984–2005) to look for temporal patterns. Nest success estimates based on apparent nest success are usually biased high because successful nests are more likely to be detected than failed nests (Mayfield 1961); however, our apparent nest success estimates should be relatively unbiased because all nest locations were known *a priori* (Mayfield 1961, Jehle et al. 2004). I calculated the percent use for each island and the percent of years an island was used when available (1986 and 2005), for all islands available for at least five years. I graphed trends in use and nest success for all island types combined and separately. I compared trends in use and nest success over time using simple linear regression (PROC GLM; SAS v. 9.1) and by island type using analysis of covariance (PROC MIXED; SAS v. 9.1) after meeting assumptions of normality and equal variances. Next I compared use and nest success between islands located in the two major categories of wetlands (sloughs vs. ponds) using logistic regression (PROC GENMOD; SAS v. 9.1). I used odds ratios and likelihood ratio 95% confidence intervals to evaluate the strength of evidence for associations among wetland type and island use and nest success.

I used ten years of data (1996-2005) to investigate habitat and island features correlated with island use and nine years of data (1997-2005) to investigate habitat and island features correlated with island nest success. I restricted my analysis to a recent block of years in an attempt to control for changes in plant community composition on the CRD following the 1964 earthquake (Thilenius 1990). I also wanted years where all islands were monitored annually and where data was gathered for all my explanatory variables. I did not analyze data from 1996 for island nest success because USGS field technicians were not camped on the CRD and thus unable to confirm that larid colonies were in the same locations. In addition to variables collected during field checks of nests, I used a geographical information system (GIS) to measure distance of the nest island to shore (DTS; m); the distance from the island to the nearest large slough including: Tiedeman, Alaganik, Pete Dahl, Pete Dahl Cutoff, Wahalla and Gus Stevens Sloughs (DTLS; m); pond size (PSIZE, ha); the distance from the island to the nearest mainland shore in the east-southeast (112.5°)

direction (FETCH, m); the distance from the island to the nearest larid colony or nest (DTLAR, m; colonies included mew gulls and Arctic terns, and nests included primarily mew gulls and Arctic terns, with some parasitic jaegers and Aleutian terns); and the average number of breeding dusky geese per square kilometer (BDD, number/km^2). The locations of gull and tern colonies came from surveys conducted from 2001-2003 (Miller 2004). I assumed larid colonial locations were relatively stable from the period of 1997–2005 based on observations by USGS field technicians and biologists camped near the colonies and information on the nest site fidelity of mew gulls and Arctic terns from the literature (Hatch 2002, Moskoff and Bevier 2002). I assigned BDD within the vicinity of each island based on density contours generated in a GIS from five year aggregations of annual aerial surveys of breeding dusky goose pairs conducted by USFWS in the spring from 1986-2005 (U. S. Fish and Wildlife Service 2006, unpublished data). I categorized the previous year's island status (PRYR) as: 1 = island not used (NOT USED); 2 = island used, nest successful (SUCCESSFUL); 3 = island used, nest failed (FAILED); 4 = island used, nest fate unknown or island not available (UNAVAILABLE).

I generated univariate statistical hypotheses for associations between island use and nest success with explanatory variables based on my predictions (Table 3.1; based on Franklin et al. 2000). I tested explanatory variables for multicollinearity (Allison 1999) using Pearson's correlation coefficients (PROC CORR in SAS software v. 9.1), and only included explanatory variables with Pearson's correlations less than 0.70 in models (Burnham and Anderson 2002). I tested for relationships between dependent and explanatory variables using logistic regression (PROC GENMOD, SAS v. 9.1) and Akaike's Information Criterion (AIC) model selection techniques. I used AIC corrected for small sample sizes (AIC_c) for all analyses (Burnham and Anderson 2002). In the analysis of island use, I tested for a linear relationship with six explanatory variables and quadratic relationships for aerial shrub cover ($AC + AC^2$) and average shrub height ($SH + SH^2$). In the analysis of island nest success, I tested for a linear relationship with all eight explanatory variables.

Canada geese can exhibit high nest site fidelity (e.g., Craighead and Stockstad 1961, Brakhage 1965, Bromley 1976, Giroux et al. 1983); thus, dusky geese that were successful on an island in one year often return to that island the next year. Ignoring this fact and treating each nest attempt as independent can lead to biased test statistics and standard errors (Allison 1999). One option was to use a repeated measures analysis; however, the identity of pairs using an island was unknown. In addition, no hypotheses were posed in relation to time-dependent trends. Consequently, I chose to analyze years separately.

With two exceptions, I modeled all subsets of four-variable, three-variable, two-variable and one-variable additive models for island use (n = 42 models; Appendix 3.1), and all subsets of three-variable, two-variable and one-variable additive models (n = 93; Appendix 3.2) for nest success. More complex models were not included because of sample size constraints and a desire to keep results interpretable. BDD was included only as a univariate model in the analysis of island use because I predicted that if island use is associated with the density of breeding conspecifics near the island that geese would not base their island use decisions on habitat or island characteristics, but solely on other geese. Similarly, I only included PRYR as a univariate model in my analysis of island use because I predicted that if previous year's island status was associated with island use that geese would base their island use decisions solely on the use and nest fate of islands in the previous year. I also included the null model (intercept-only model) and full model (with all variables) in each model set (Burnham and Anderson 2002).

The best approximating model was the model with the lowest AIC_c value; models with ΔAIC_c values less than two were considered competitive; and Akaike model weights (w_i) and variable importance weights for competitive models were used to evaluate and rank models (Burnham and Anderson 2002). I used variable coefficients (β) and likelihood ratio 95% confidence intervals to evaluate the direction and strength of associations between the response variable and the continuous explanatory variables (Burnham and Anderson 2002), and I used odds ratios to evaluate the direction and strength of evidence for categories of PRYR in relation to islands not used the previous year (PRYR, NOT USED). Strength of evidence was considered weak if 95% confidence intervals for variable coefficients included zero or 95% confidence intervals for odds ratios included one. In order to enhance the visualization of non-linear (e.g., quadratic) and strong relationships and to help generate management recommendations, I graphed the relationships between the odds of island use and nest success for continuous variables in best approximating models for variables with consistent associations with use and nest success across years and 95% confidence intervals for parameter estimates that did not include zero, focusing on variables that can be manipulated by managers.

I conducted a second analysis where the response variable was the proportion of years an island was used by a dusky goose, restricting my analysis to include only islands that were available for nine consecutive years from 1997-2005 (n = 189). The response variable was a proportion with ten possible values. Explanatory variables included those that did not vary annually (DTS, DTLS, DTLAR, FETCH, PSIZE). I corrected for overdispersion and used small sample AIC (AIC_c) quasi-likelihood estimation, called $QAIC_c$ (Burnham and Anderson 2002), to find the best approximating model. I examined all subsets of four-variable, three-variable, two-variable and one-variable models and the null model and full model (n = 32 models; Appendix 3.3). I estimated the overdispersion parameter from the full model as the goodness-of-fit Pearson chi-square divided by its degrees of freedom (Burnham and Anderson 2002). The best approximating model and the direction and strength of relationships were determined as above. All means are reported ± SE.

FIGURES

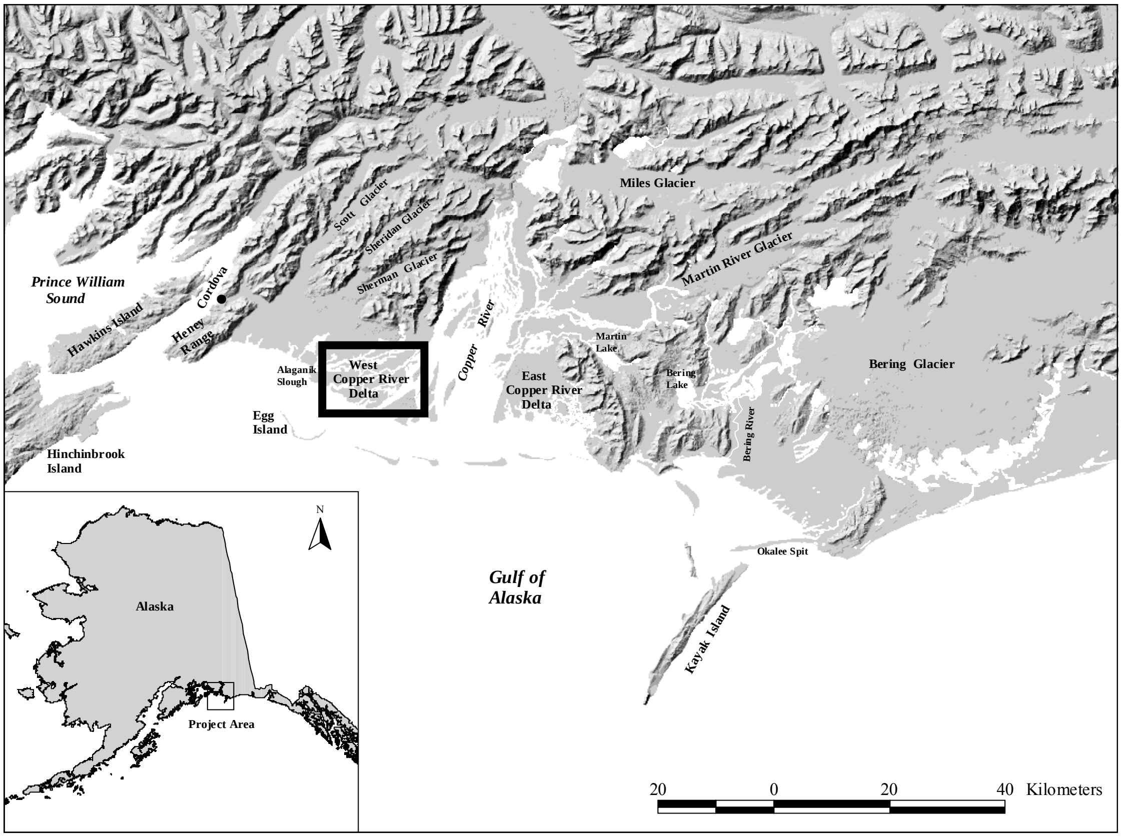

Figure 3.1. Artificial nesting islands for dusky Canada geese were placed in wetlands on the western Copper River Delta (area designated by square), Alaska, USA (adapted from Pacific Flyway Council in press).

Table 3.1. Descriptions of univariate model structures and statistical predictions for the logistic regression analyses of artificial nest island use by dusky Canada geese and nest success with explanatory variables of island and habitat characteristics on the western Copper River Delta, Alaska USA.

Model[a]	Model Structure	Univariate Predictions Associated with Artificial Nest Island Use and Nest Success	Expected Result
Island Use			
BDD	$\beta0 + \beta1(BDD)$	Increased likelihood of nest island use with an increase in density of breeding dusky geese	$\beta1 > 0$
FETCH	$\beta0 + \beta1(FETCH)$	Increased likelihood of nest island use with a decrease in fetch	$\beta1 < 0$
PSIZE	$\beta0 + \beta1(PSIZE)$	Increased likelihood of nest island use with a decrease in pond area	$\beta1 < 0$
DTS	$\beta0 + \beta1(DTS)$	Increased likelihood of nest island use with an increase in distance to the nearest shore	$\beta1 > 0$
DTLS	$\beta0 + \beta1(DTLS)$	Increased likelihood of nest island use with an increase in distance from the nearest large slough	$\beta1 > 0$
$AC + AC^2$	$\beta0 + \beta1(AC) + \beta2(AC^2)$	Highest likelihood of nest island use at a moderate percentage of aerial shrub cover	$\beta1 > 0, \beta2 < 0$
$SH + SH^2$	$\beta0 + \beta1(SH) + \beta2(SH^2)$	Highest likelihood of nest island use at moderate average shrub height	$\beta1 > 0, \beta2 < 0$
PRYR	$\beta0_{NOT\ USED} + \beta1(PRYR_{SUCCESSFUL})$	Increased likelihood of nest island use when the island had a successful dusky goose nest the previous year relative to islands not used the previous year	$\beta1 > 0$

Table 3.1 continued…

Table 3.1 continued…

Model	Model Structure	Univariate Predictions Associated with Artificial Nest Island Use and Nest Success	Expected Result
Nest Success			
BDD	$\beta0 + \beta1(BDD)$	Increased likelihood of nest island use with an increase in density of breeding dusky geese	$\beta1 > 0$
FETCH	$\beta0 + \beta1(FETCH)$	Increased likelihood of nest success with a decrease in fetch	$\beta1 < 0$
PSIZE	$\beta0 + \beta1(PSIZE)$	Increased likelihood of nest success with a decrease in pond area	$\beta1 < 0$
DTS	$\beta0 + \beta1(DTS)$	Increased likelihood of nest success with an increase in the distance to the nearest shore	$\beta1 > 0$
DTLS	$\beta0 + \beta1(DTLS)$	Increased likelihood of nest success with an increase in the distance to the nearest large slough	$\beta1 > 0$
DTLAR	$\beta0 + \beta1(DTLAR)$	Increased likelihood of nest success with a decrease in the distance to the nearest known larid colony or nest	$\beta1 < 0$
AC	$\beta0 + \beta1(AC)$	Increased likelihood of nest success with an increase in percent aerial shrub cover	$\beta1 > 0$
SH	$\beta0 + \beta1(SH)$	Increased likelihood of nest success with an increase in shrub height	$\beta1 > 0$

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; BDD = indicated number of breeding dusky geese per square kilometer near the island; $PRYR_{SUCCESSFUL}$ = the island had a successful nest the previous year; $\beta0_{NOT\ USED}$ = islands not used the previous year as the reference group; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); DTLAR = distance from the island to the nearest known larid nest or colony.

CHAPTER 4

RESULTS

The number of islands monitored on the CRD fluctuated between 37 and 525 from 1984 to 2005 with a total of 897 islands placed on the CRD over time. Of those, 96% were placed in ponds, the remainder in sloughs. Use of islands differed by wetland type. Dusky geese were 6.18 times more likely (95% Confidence Interval (CI): 3.08-14.69) to use an island in a pond than a slough; however, average annual nest success was similar between islands in sloughs (71 ± 18%, *n* = 7) and islands in ponds (64 ± 1%, *n* = 1340; odds ratio = 0.71, 95% CI: 0.10–3.28). Over half of the islands available for five years or greater were used less than 30% of the time (Figure 4.1). Combining island types (fiberglass floaters, sandbags, and dusky donuts), annual island use averaged 25 ± 2%. No transformations of variables were needed for analyses of use and nest success over time after examining histograms of the distribution of residuals and plots of residuals versus predicted values. Use of islands has increased since 1985 ($F_{1,20}$ = 12.19, p = 0.002; Figure 4.2) and the increase was most evident for fiberglass floater and sandbag islands ($F_{2,54}$ = 8.44, p ≤ 0.001; Figure 4.3). Combining island types and years, apparent nest success averaged 64 ± 4%. Nest success showed no obvious trend with time ($F_{1,20}$ = 0.35, p = 0.56; Figure 4.4) for any island type ($F_{2,51}$ = 0.02, p = 0.98; Figure 4.5). Thus, I combined all nest island types for subsequent modeling and because sample size was small, I deleted islands placed in sloughs for all subsequent analyses.

Island Use

My analyses of island use from 1996 to 2005 included 378 islands and 1,056 nests (Table 4.1). Annual use of islands averaged 33 ± 1% from 1996-2005. None of the explanatory variables had Pearson's correlations greater than 0.70 and only 1.0 ± 0.4% of variables had correlations between 0.50 and 0.70. The number of competitive models explaining variation in island use varied from one to four for each year with an average of 1.90 ± 0.35; the null model was never competitive. The univariate model with PRYR was the best approximating model of island use for five of ten years, followed by the full model in three of ten years (Table 4.2). Best approximating models had a wide range of model weights (w_i = 0.25 – 0.99, average = 0.66 ± 0.10). PRYR had the highest variable importance weight for six of the ten years, followed by SH and AC (three of ten years), and DTS for one of ten years (Table 4.3).

Parameter estimates for explanatory variables in the best approximating and competitive models for each year revealed some consistent relationships with island use (Table 4.4). Islands used the year before were more likely to be used the following year and this trend was strongest for islands with successful nests the previous year (Table 4.5). The odds of a nest being placed on an island that contained a successful nest the previous year were 2.91 to 6.62 times the odds of use for islands not used the previous year (Table 4.5) after accounting for the other variables in the models. Parameter estimates for continuous explanatory variables in best and competitive models had consistent relationships with island use within the same year, but only DTS and DTLS had the same relationships with island use across years. Island use always increased as distance to large slough decreased; whereas, use increased as DTS increased. The relationship was stronger for DTS as the 95% confidence interval for the parameter estimate did not include zero in four of five years v. one of five years for DTLS (Table 4.6). In four years, the 95% confidence intervals for the parameter estimates of DTS in the best approximating models of island use excluded zero, and indicated nest success increased as distance to shore increased; graphs suggest the odds of nest success increase rapidly when DTS exceeds 50 m (Figures 4.6 - 4.9).

In all four years when AC occurred in competitive models, the parameter estimates of AC were always positive and parameter estimates of AC^2 were always negative. In one of four years, use increased up to 35% AC, in another year use increased up to 55% (Figure 4.10), and the remaining two years indicated that use increased as AC increased. In one of four years the confidence intervals for the parameter estimates of AC and AC^2 did not include zero (Figure 4.10). In four of six years that SH occurred in competitive models, a quadratic relationship was supported (parameter estimates of SH were positive and parameter estimates of SH^2 were negative). In three of six years use declined after SH of 1.0 m for SH (e.g. Figure 4.11), in one year use declined after SH of 1.6 m, and in the other two years use increased as SH increased. In one of six years the confidence intervals for the parameter estimates of SH and SH^2 did not include zero (Figure 4.11). The relationships between island use and PSIZE, island use and BDD, and island use and FETCH were equivocal, with both positive and negative parameter estimates for each variable across years (Table 4.4) and confidence intervals that never excluded zero.

To control for the strong effect of previous year's island status, I reran the models including only the first time an island was available (n = 380 islands, 63 nests, 29 models; Appendix 4.1). I excluded SH because it was not collected before 1995. None of the explanatory variables had Pearson's correlations greater than 0.50. Seven models were competitive; however, the null model was included in this set (Table 4.7), suggesting none of the explanatory variables had much influence on island use. The analysis for percent island use over nine consecutive years had no explanatory variables with Pearson's correlations greater than 0.50. Four models were competitive in explaining percent island use (n = 189 islands, 599 nests, 32 models). However, the null model was almost competitive and had a similar model weight (w = 0.033) to the best model (Table 4.8), indicating none of the explanatory variables influenced percent island use.

Nest Success

My nest success analysis of dusky goose nest success from 1997 to 2005 included 303 islands and 947 nests (Table 4.1). Annual apparent nest success averaged 64 ± 1%

from 1997-2005. None of the explanatory variables had Pearson's correlations greater than 0.70 and only 2 ± 0.5% of variables had correlations between 0.50 and 0.70. The best approximating model of nest success differed among years and multiple models were competitive each year (10 ± 2, range 2-20; Table 4.9, Appendices 4.2 - 4.10). In three years, the null model was either the best model (2000) or competitive (1997 and 2003). Considering only years where the null was not competitive, model weights for the best approximating models were generally low (0.16, ± 0.04, range 0.06 – 0.35). All eight variables appeared in at least one best approximating model; however, occurrence varied with BDD and DTLAR included in the best approximating or competitive model in all six years, followed by AC (5 of 6 years); DTLS, FETCH, and SH (4 of 6 years); and DTS and PSIZE (3 of 6 years). The variable with the highest variable importance weight varied among years (Table 4.10), but was highest on average for BDD followed closely by SH (Table 4.11).

Parameter estimates of explanatory variables revealed consistent relationships with nest success within a year, but only SH and DTS had consistent relationships with nest success across years (Table 4.12). Nest success always declined as shrub height increased and increased as DTS increased. In two of four years the 95% confidence intervals for the parameter estimates of SH did not include zero, and confidence intervals did not include zero for one of three years for DTS (Table 4.13). In 1999 and 2004, the 95% confidence intervals for the parameter estimates of SH in the best approximating models excluded zero, and indicated a negative association between SH and island nest success with a rapid decrease in nest success as SH increased in both years (Figures 4.12 and 4.13). In 1998, the 95% confidence interval for the parameter estimate of DTS in the best approximating model excluded zero, and revealed a positive association between DTS and island nest success, with a rapid increase in the odds of nest success from DTS of 40 m and greater (Figure 4.14). Parameter estimates for BDD were both positive and negative and confidence intervals did not include zero in three of six years (Table 4.13), with support for both positive and negative associations with nest success. Parameter estimates for AC, DTLAR, DTLS, PSIZE, and FETCH were both positive and negative (Table 4.12). The confidence intervals for the parameter estimates of AC, DTLAR, and DTLS did not include zero in only one year for each variable (Table 4.13); confidence intervals included zero in all years for PSIZE and FETCH.

FIGURES

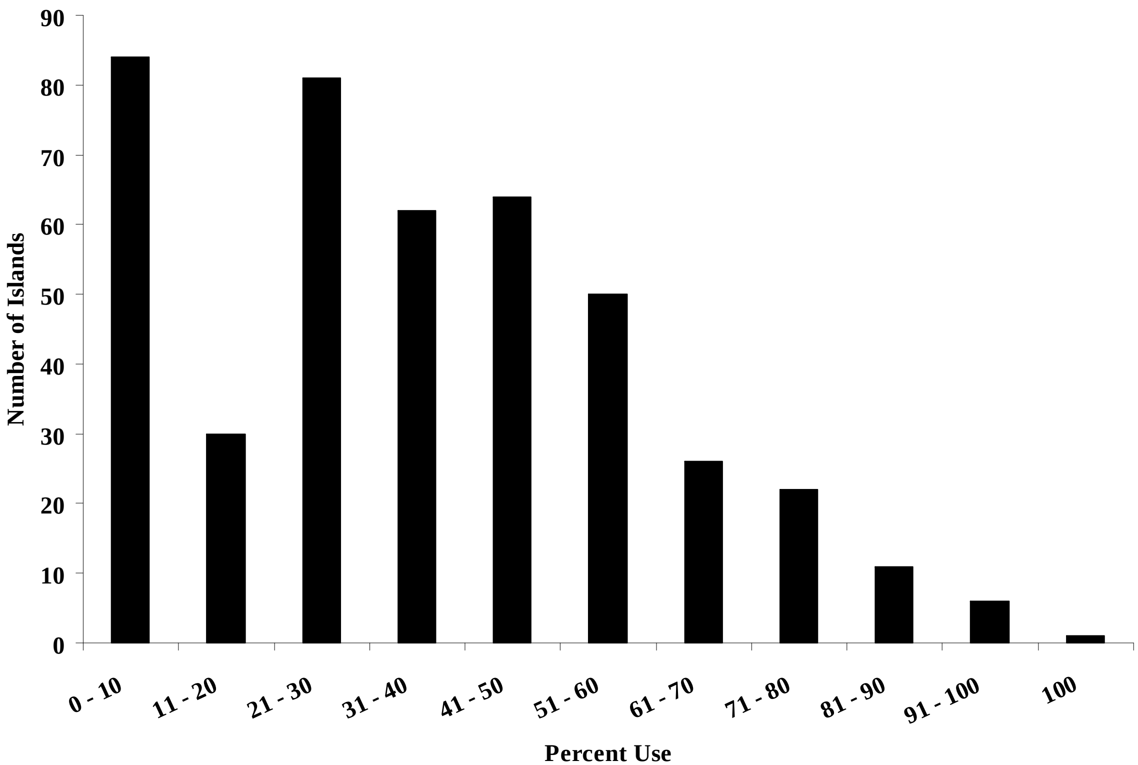

Figure 4.1. Percent of years an artificial nest island was used when available per individual artificial nest island between 1986 and 2005 for artificial nest islands available for at least five years on the western Copper River Delta, Alaska, USA.

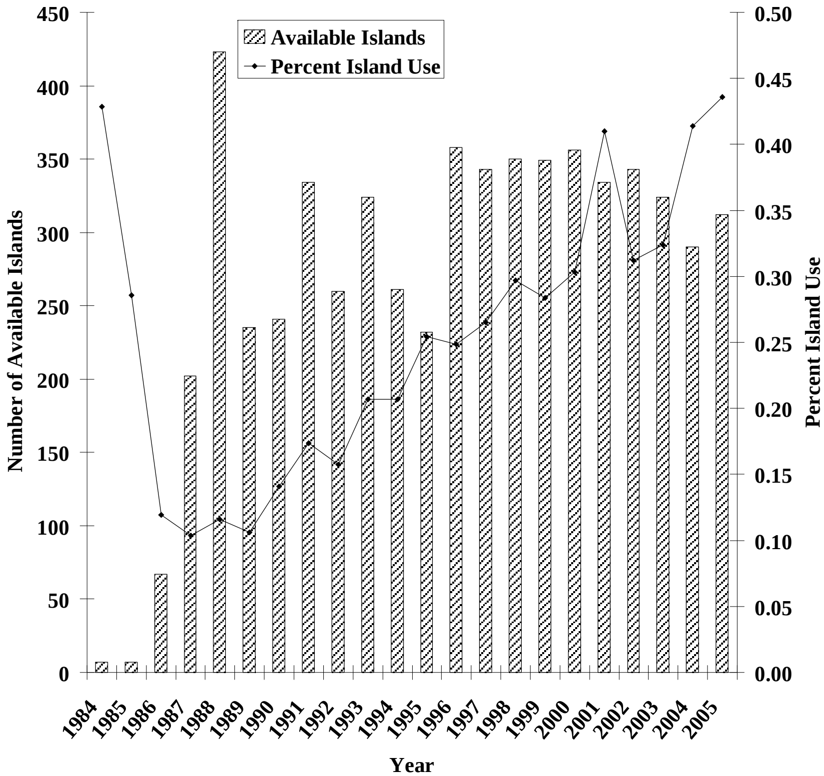

Figure 4.2. Relationship between proportion of islands used by breeding dusky Canada geese, number of islands available, and year for artificial nest islands located on the western Copper River Delta, Alaska, USA (Percent island use: slope = 0.0102 ± 0.0029 SE, r^2 = 0.38).

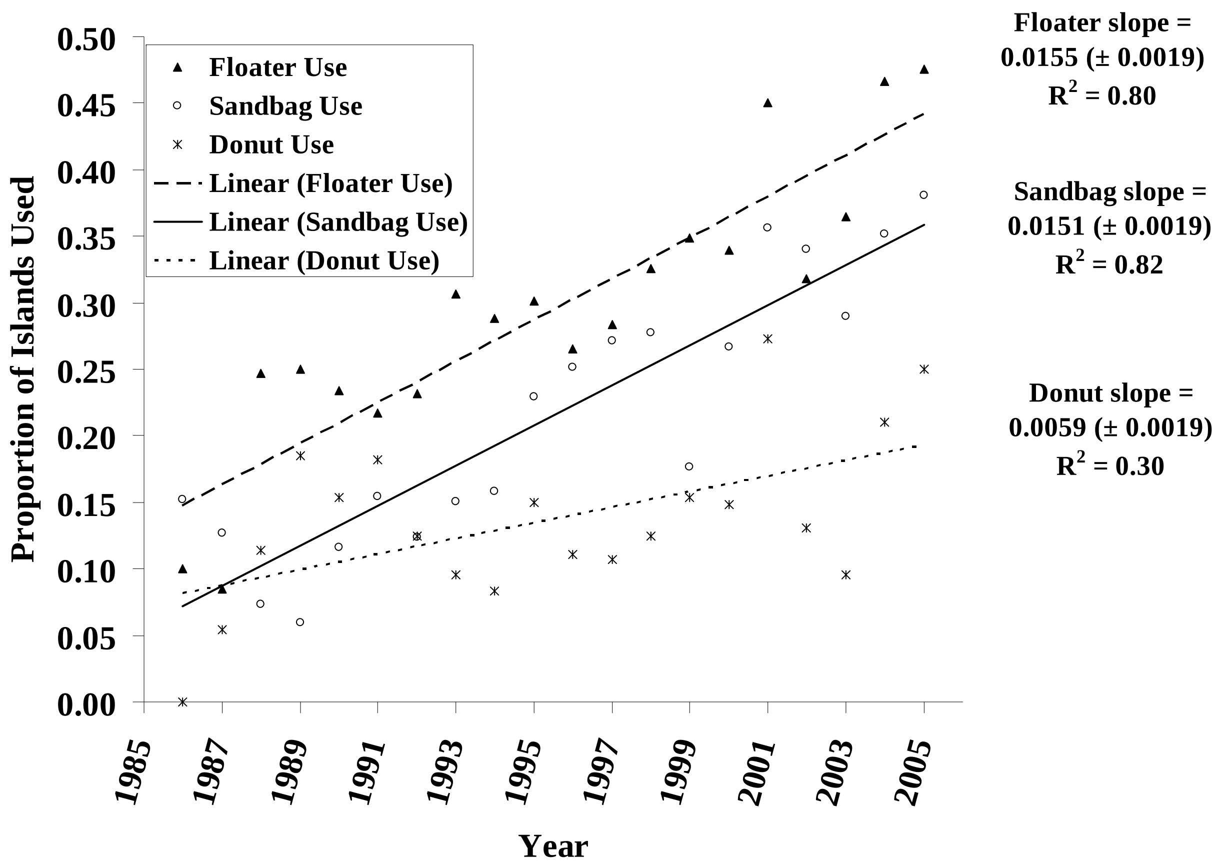

Figure 4.3. Relationship between proportion of islands used by breeding dusky Canada geese and year for three types of artificial nest islands used by breeding dusky Canada geese located on the western Copper River Delta, Alaska, USA (all slopes ± SE).

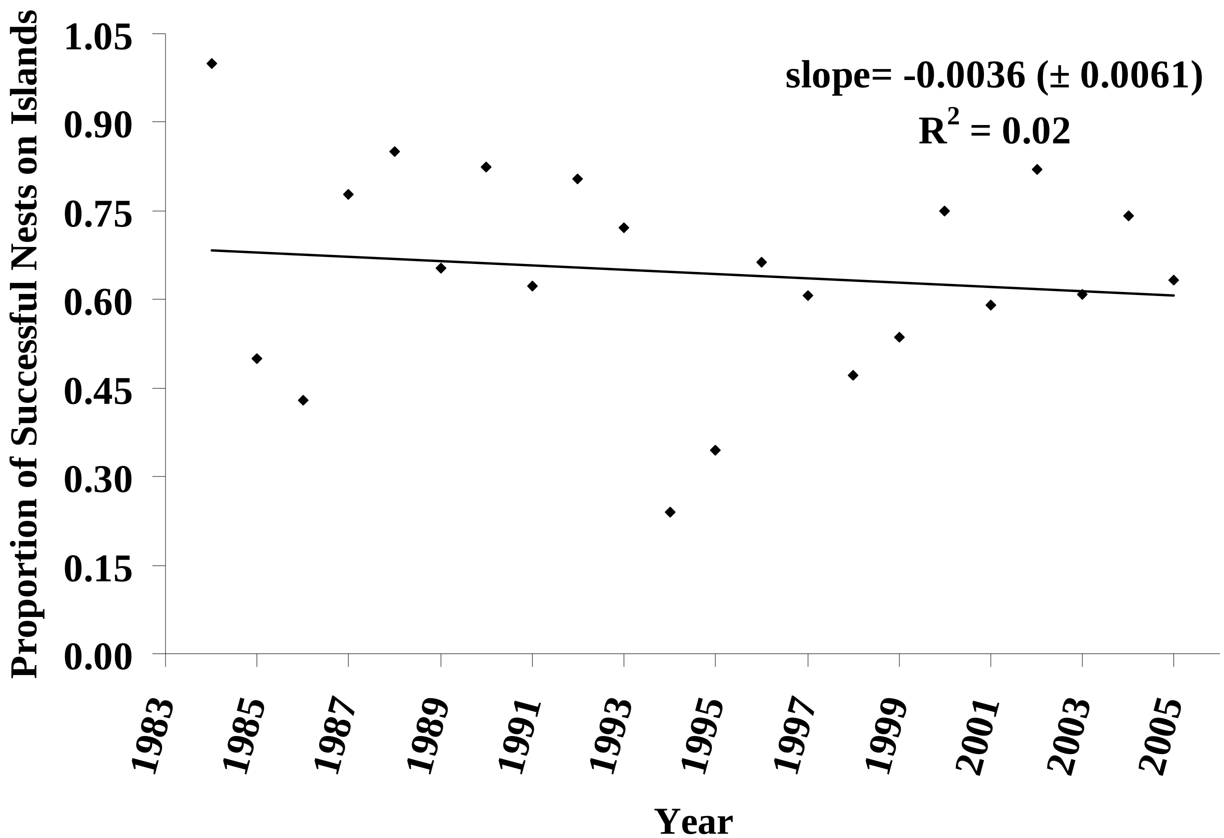

Figure 4.4. Relationship between apparent nest success and year for dusky Canada geese nesting on artificial nest islands on the western Copper River Delta, Alaska, USA (slope ± SE).

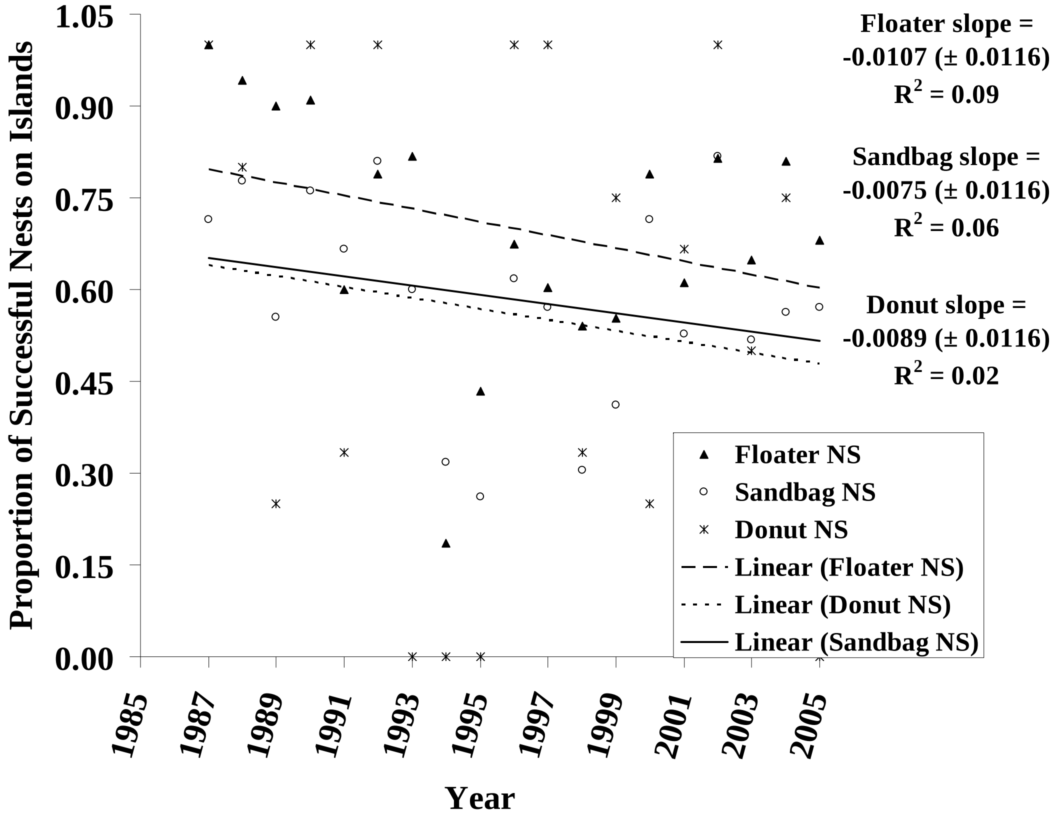

Figure 4.5. Relationship between apparent nest success and year for dusky Canada geese nesting on three types of artificial nest islands on the western Copper River Delta, Alaska, USA (all slopes ± SE).

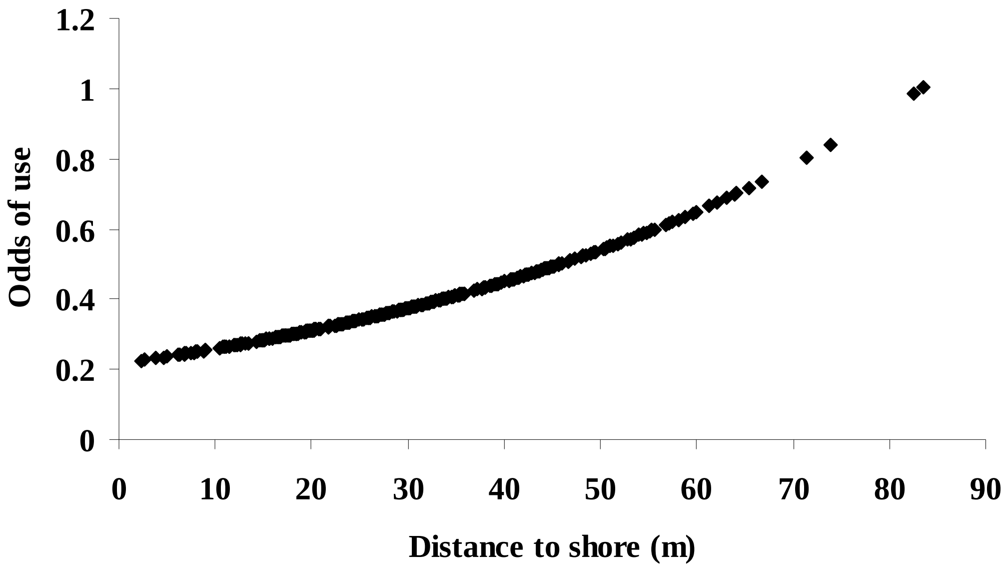

Figure 4.6. The odds of a dusky Canada goose using an artificial nest island for nesting versus distance of the island to the nearest shore in 1998 for the best approximating logistic regression model of island use by dusky geese for nesting, holding the other variables in the model at average values.

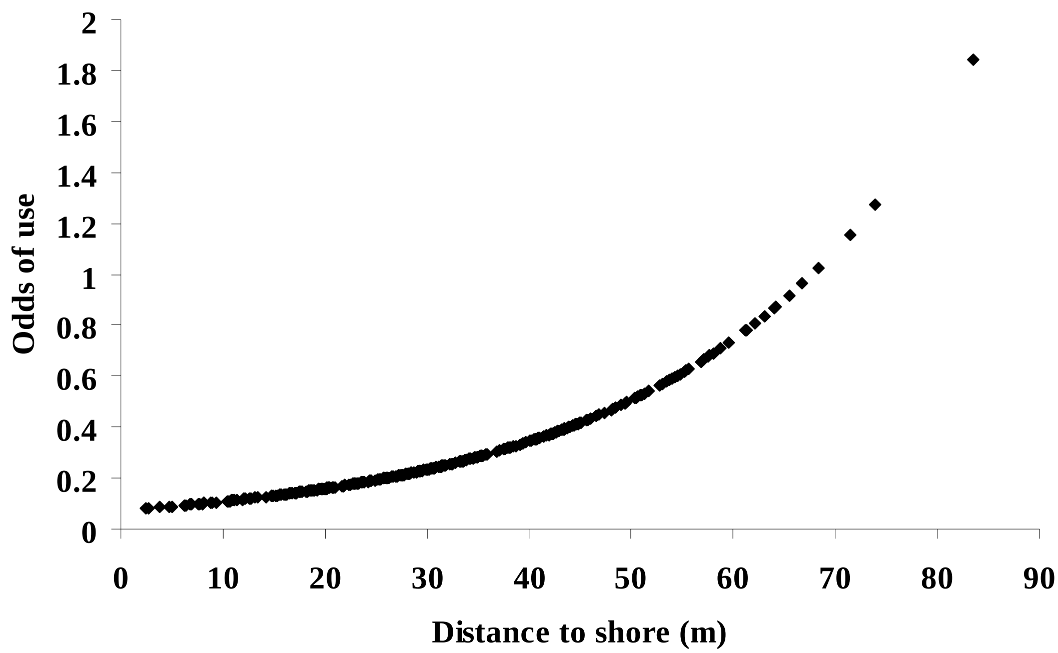

Figure 4.7. The odds of a dusky Canada goose using an artificial nest island for nesting versus distance of the island to the nearest shore in 1999 for the best approximating logistic regression model of island use by dusky geese for nesting, holding the other variables in the model at average values.

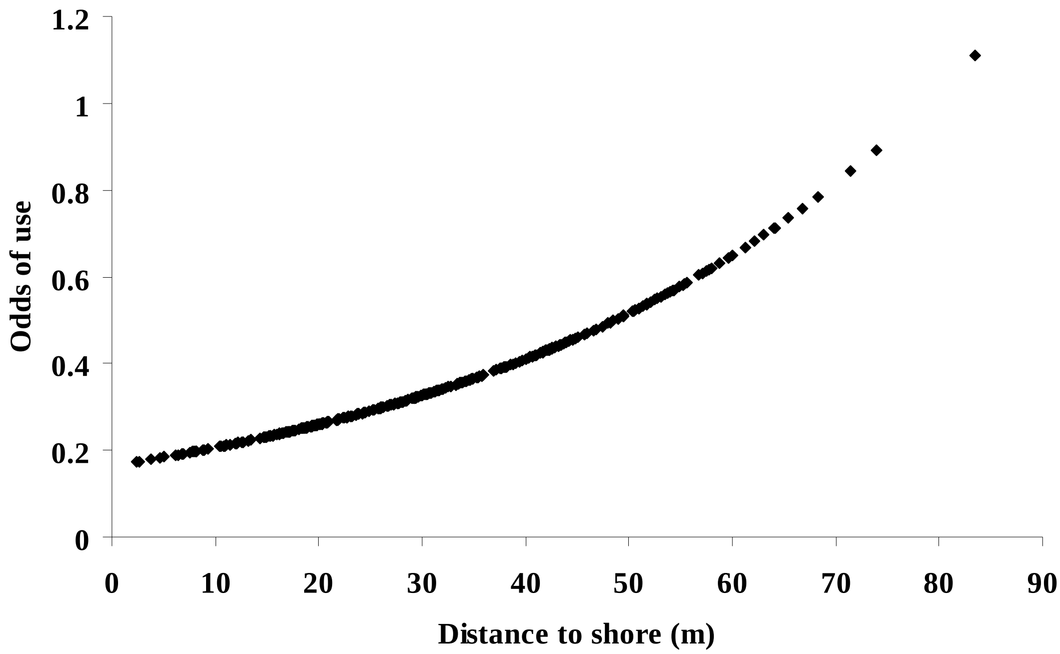

Figure 4.8. The odds of a dusky Canada goose using an artificial nest island for nesting versus distance of the island to the nearest shore in 2000 for the best approximating logistic regression model of island use by dusky geese for nesting, holding the other variables in the model at average values.

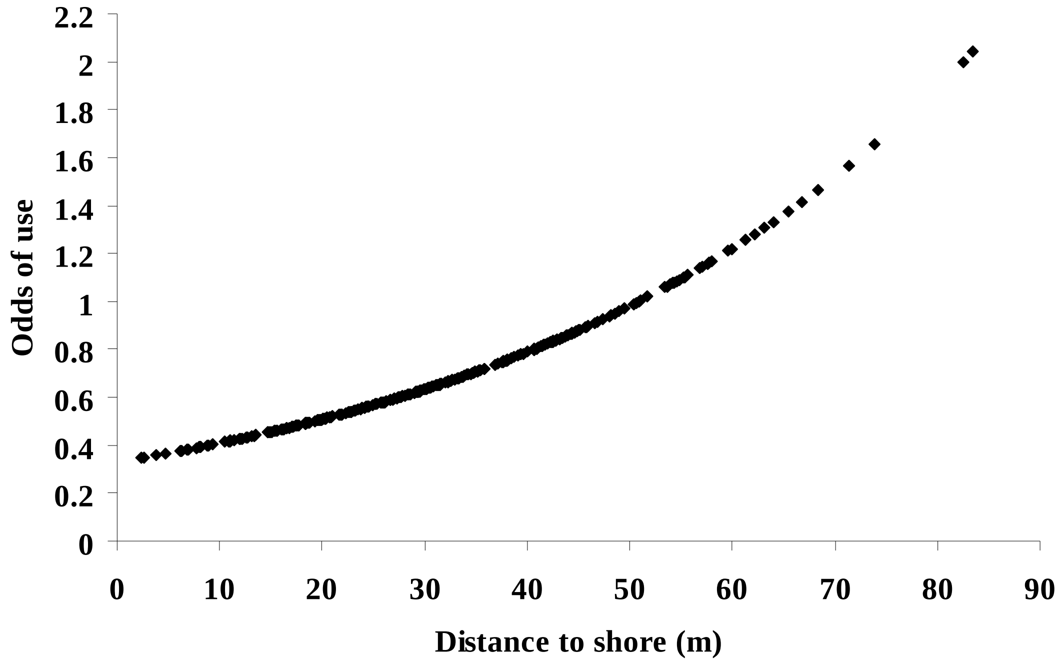

Figure 4.9. The odds of a dusky Canada goose using an artificial nest island for nesting versus distance of the island to the nearest shore in 2003 for the best approximating logistic regression model of island use by dusky geese for nesting, holding the other variables in the model at average values.

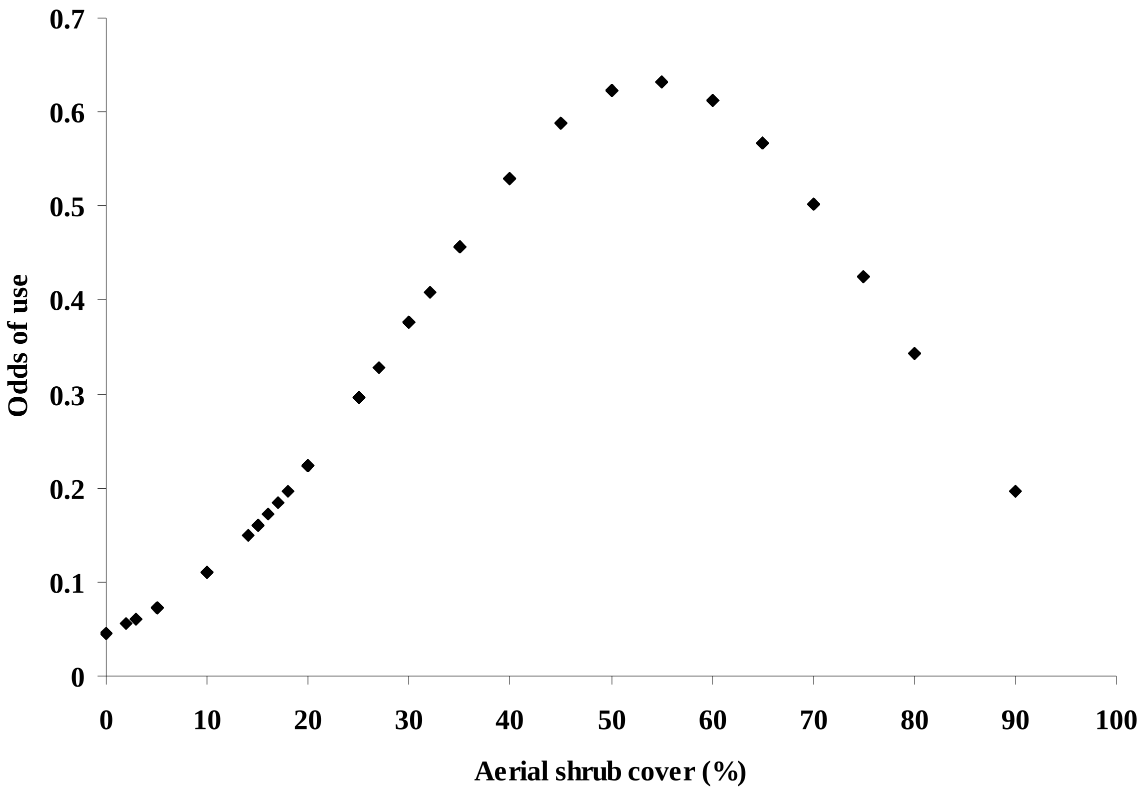

Figure 4.10. The odds of a dusky Canada goose using an artificial nest island for nesting versus aerial shrub cover on the island in 1999 for the best approximating logistic regression model of island use by dusky geese for nesting, holding the other variables in the model at average values.

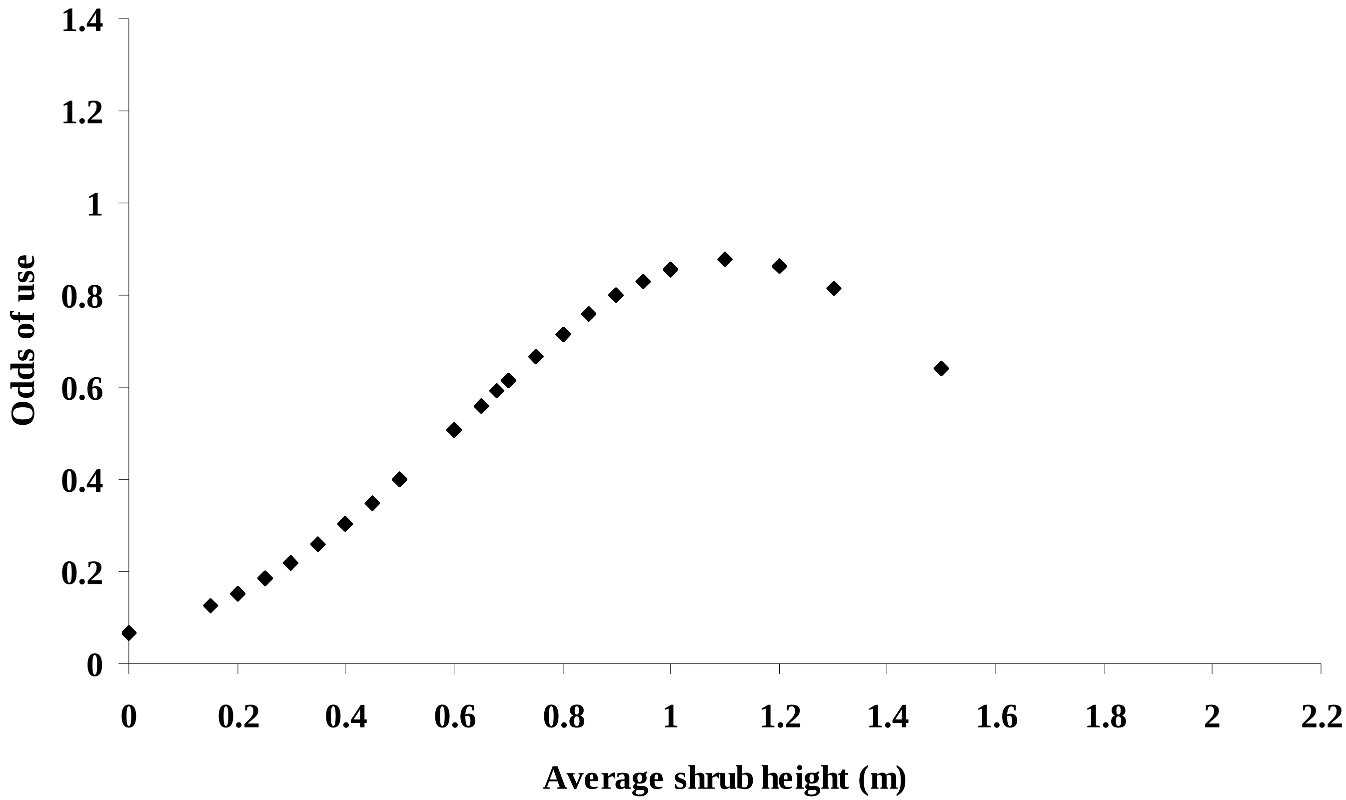

Figure 4.11. The odds of a dusky Canada goose using an artificial nest island for nesting versus average shrub height on the island in 1998 for the best approximating logistic regression model of island use by dusky geese for nesting, holding the other variable in the model at the average value and excluding the data entry for average shrub height = 3.0 m.

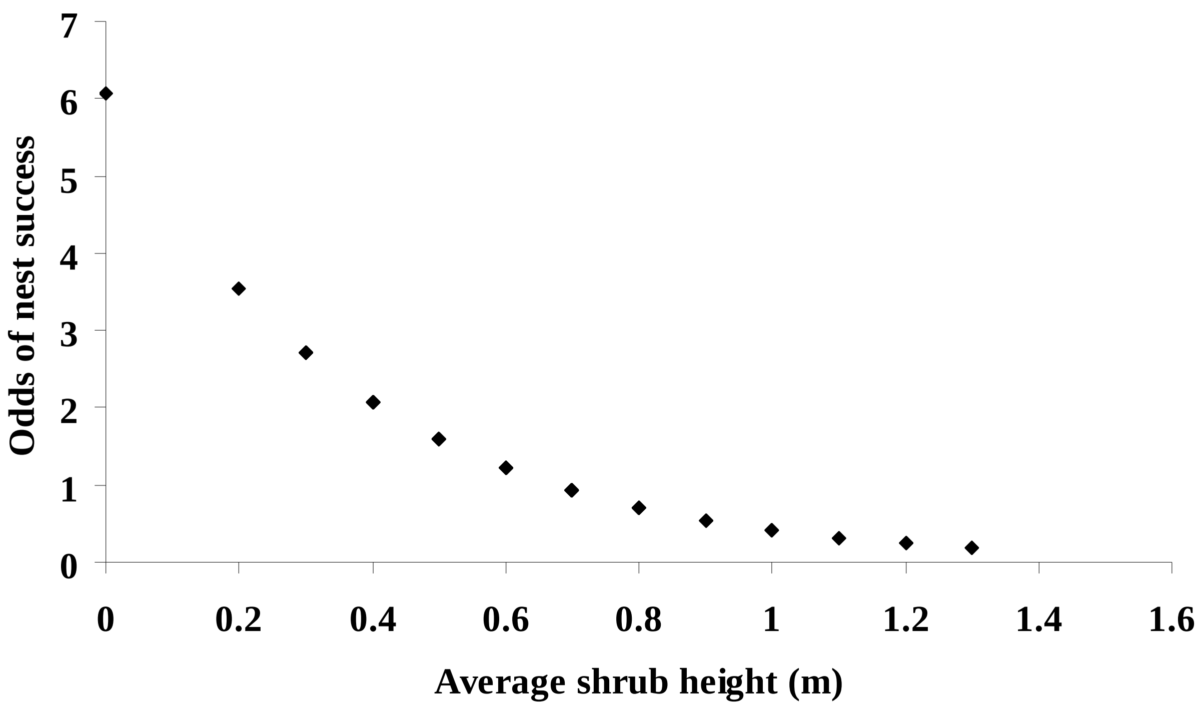

Figure 4.12. The odds of dusky Canada goose nest success on an artificial nest island versus average shrub height on the island in 1999 for the best approximating logistic regression model of dusky Canada goose island nest success.

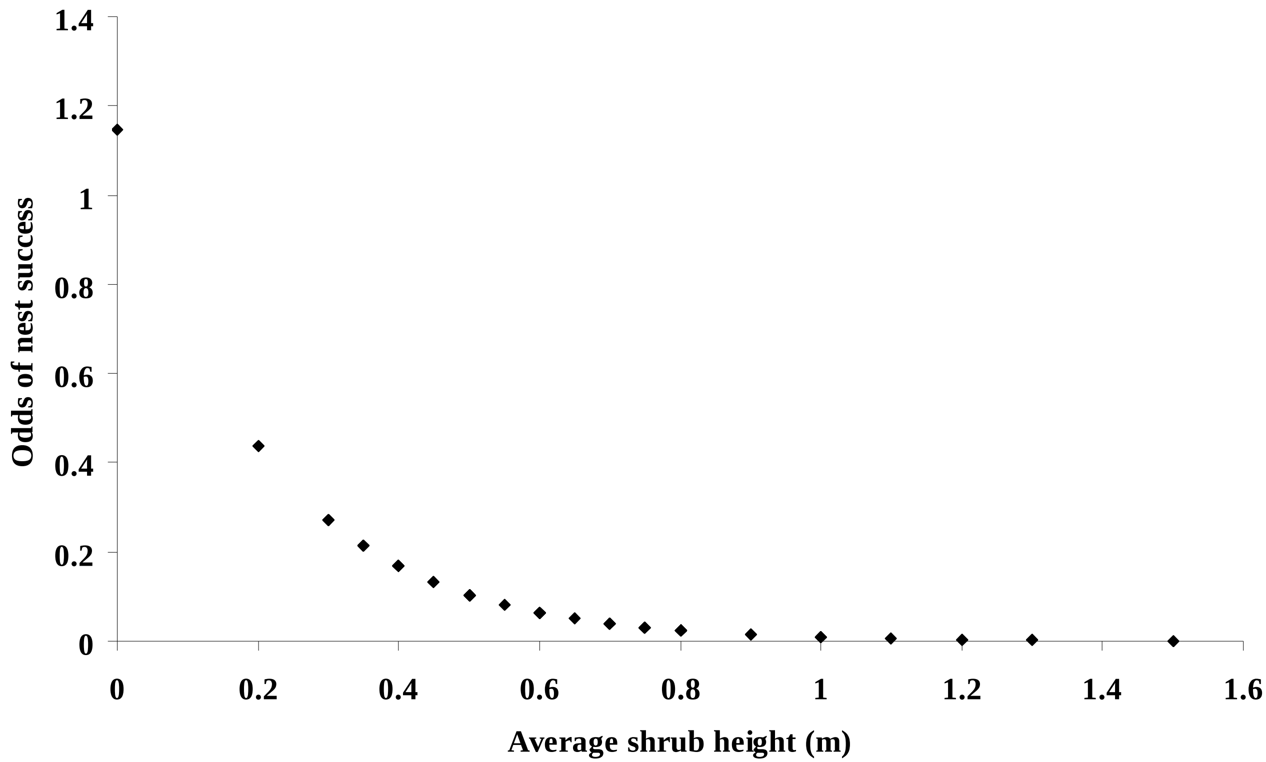

Figure 4.13. The odds of dusky Canada goose nest success on an artificial nest island versus average shrub height on the island in 2004 for the best approximating logistic regression model of dusky Canada goose island nest success, holding the other variables in the model at average values.

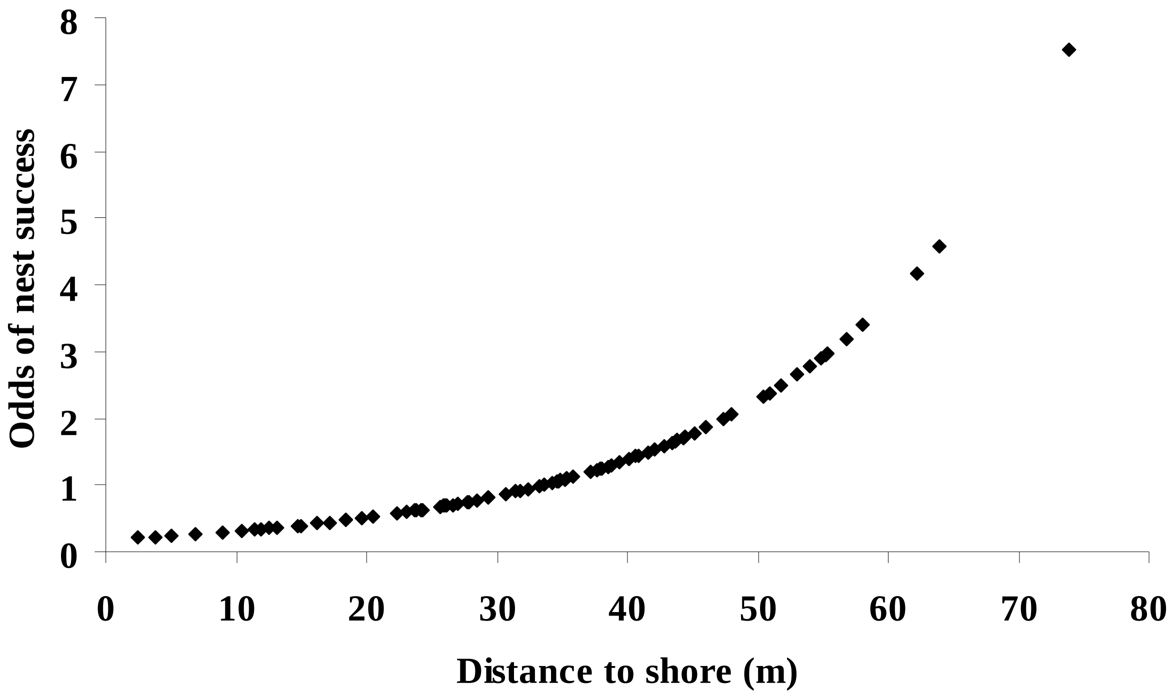

Figure 4.14. The odds of dusky Canada goose nest success on an artificial nest island versus distance of the island to the nearest shore in 1998 for the best approximating logistic regression model of dusky Canada goose island nest success, holding the other variable in the model at the average value.

Table 4.1. Summary of explanatory variables in candidate models of dusky Canada goose use and nest success of artificial nest islands on the western Copper River Delta, Alaska, USA.

Response Variable			
Island Use[a]		Nest Success[b]	
Variable[c]	Mean ± SE (range)	Variable[c]	Mean ± SE (range)
FETCH	67.9 ± 1.0 (2.9-599.9)	FETCH	67.9 ± 1.7 (7.5-599.9)
BDD	11.0 ± 0 (4-21)	BDD	11.0 ± 0.1 (4-21)
DTS	31.1 ± 0.3 (2.4-83.5)	DTS	33.3 ± 0.5 (2.4-83.5)
AC	40.0 ± 0 (0-100)	AC	45.0 ± 0.7 (0-100)
SH	0.6 ± 0 (0-3.0)	SH	0.6 ± 0.01 (0-2.0)
PSIZE	4.0 ± 0.1 (0.1-35.5)	PSIZE	4.3 ± 0.18 (0.1-35.5)
DTLS	713.2 ± 8.2 (72.8-2095.3)	DTLS	690.1 ± 14.6 (72.8-2095.3)
		DTLAR	1597.6 ± 41.5 (0.0-5150.7)

Table 4.1 continued…

Table 4.1 continued…

[a] 3,158 entries, 378 islands, 1,056 nests, 1996-2005.
[b] 947 entries, 303 islands, 947 nests, 1997-2005.
[c] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; BDD = indicated number of breeding dusky geese per square kilometer near the island; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle). DTLAR = distance from the island to the nearest known larid nest or colony.

Table 4.2. Modeling results looking for factors influencing use of artificial nest islands by nesting dusky Canada geese on the western Copper River Delta, Alaska, USA (1996-2005).

Year	*n*[a]	Best and Competitive Models[b]	ΔAIC_c	w_i[c]
1996	225	SH SH^2 DTLS PSIZE	0.00	0.25
		SH SH^2 DTLS	0.08	0.24
		SH SH^2 DTLS FETCH	1.72	0.10
		SH SH^2 DTLS DTS	2.16	0.08
		SH SH^2 PSIZE	2.51	0.07
		SH SH^2 PSIZE FETCH	2.88	0.06
		SH SH^2	3.22	0.05
		SH SH^2 DTLS PSIZE FETCH DTS AC AC^2 PRYR BDD	3.44	0.04
1997	335	PRYR	0.00	0.98
1998	343	SH SH^2 DTS	0.00	0.30
		SH SH^2 DTS PSIZE	1.62	0.13
		SH SH^2 DTS DTLS	2.01	0.11
		SH SH^2 FETCH DTS	2.06	0.11
		SH SH^2	2.93	0.07
		SH SH^2 AC AC^2	3.09	0.06
1999	346	AC AC^2 DTS DTLS PSIZE FETCH PRYR SH SH^2 BDD	0.00	0.55
		AC AC^2 DTS DTLS	1.31	0.28
		AC AC^2 DTS	3.59	0.09
2000	343	DTS AC AC^2 FETCH PSIZE DTLS SH SH^2 PRYR BDD	0.00	0.28
		DTS AC AC^2	0.15	0.26
		DTS AC AC^2 FETCH	1.00	0.17
		DTS AC AC^2 PSIZE	1.15	0.16
		DTS AC AC^2 DTLS	2.19	0.09
2001	326	PRYR	0.00	0.99
2002	341	PRYR SH SH^2 DTLS AC AC^2 PSIZE FETCH DTS BDD	0.00	0.91
2003	301	PRYR	0.00	0.60
		PRYR SH SH^2 DTS PSIZE DTLS FETCH AC AC^2 BDD	0.83	0.40
2004	287	PRYR	0.00	0.90
2005	310	PRYR	0.00	0.89

Table 4.2 continued…

Table 4.2 continued…

[a] Number of available artificial nest islands by year.
[b] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; BDD = indicated number of breeding dusky geese per square kilometer near the island; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PRYR = the status of nest island use and nest success in the previous year (4 categories: island not used; island used, nest successful; island used, nest failed; island used, nest unknown fate or island not available).
[c] Model weights provide the strength of evidence for a particular candidate model relative to the rest of the models examined.

Table 4.3. Variable importance weights (VIW) for variables in best approximating and competitive annual models (1996-2005) of dusky Canada goose use of artificial nest islands for nesting on the western Copper River Delta, Alaska, USA.

Year	Variables[a] (VIW)[b]
1996	SH (0.98), DTLS (0.73), PSIZE (0.39), FETCH (0.24)
1997	PRYR (0.99)
1998	SH (0.91), DTS (0.73), PSIZE (0.21), DTLS (0.19)
1999	AC (1.00), DTS (1.00), DTLS (0.83), PSIZE (0.59), FETCH (0.58), BDD (0.55), PRYR (0.55), SH (0.55)
2000	DTS (0.99), AC (0.96), FETCH (0.46), PSIZE (0.45), DTLS (0.38), SH (0.32), PRYR (0.28), BDD (0.28)
2001	PRYR (1.00)
2002	PRYR (0.95), SH (0.94), DTLS (0.93), AC (0.93), PSIZE (0.93), FETCH (0.93), DTS (0.92), BDD (0.91)
2003	PRYR (1.00), AC (0.40), BDD (0.40), DTLS (0.40), DTS (0.40), FETCH (0.40), PSIZE (0.40), SH (0.40)
2004	PRYR (0.99)
2005	PRYR (0.99)

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; BDD = indicated number of breeding dusky geese per square kilometer near the island; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PRYR = the status of nest island use and nest success in the previous year (4 categories: island not used; island used, nest successful; island used, nest failed; island used, nest unknown fate or island not available).
[b] The sum of all the model weights for all models examined including the variable of interest.

Table 4.4. Relationships between explanatory variables and artificial nest island use by nesting dusky Canada geese on the western Copper River Delta, Alaska, USA, and results relative to predicted relationships based on best approximating and competitive models of island use by dusky Canada geese modeled separately by year from 1996-2005.

Variable	Direction of Association	Supports prediction?
Previous year's island status	+, successful	Yes
Distance to shore	+	Yes
Aerial shrub cover	moderate and +	Yes and No
Shrub height	moderate and +	Yes and No
Pond size	- and +	Yes and No
Fetch	- and +	Yes and No
Breeding dusky density	+ and -	Yes and No
Distance to large slough	-	No

[a] Previous year's island status = the status of nest island use and nest success in the previous year (4 categories: island not used; island used, nest successful; island used, nest failed; island used, nest unknown fate or island not available); Distance to shore = distance from the island to the nearest shore; Aerial shrub cover = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; Average shrub height = average shrub height on the island (meters); Pond size = area of the island pond; Fetch = distance from the island to shore in the direction of the prevailing wind (112.5° angle); Breeding dusky density = indicated number of breeding dusky geese per square kilometer near the island; Distance to large slough = distance from the island to the nearest large slough.

Table 4.5. Influence of previous year's island status (year *i*) on the odds of an island being used the subsequent year (*i*+1) by dusky Canada geese nesting on the western Copper River Delta, Alaska (1996-2005). Results reported for years when previous year's island status appeared in competitive models. Islands not used in year *i* served as the reference condition for calculations.

Year	Previous Year's Island Status[a]	Odds Ratio[b]	95% CI[c]
1997	UNAVAILABLE	1.49	0.76 – 2.86
	SUCCESSFUL	4.98	2.56 – 9.84
	FAILED	1.61	0.63 – 3.80
1999	UNAVAILABLE	1.22	0.46 – 3.03
	SUCCESSFUL	4.02	1.93 – 8.54
	FAILED	2.33	1.09 – 4.96
2000	UNAVAILABLE	1.01	0.20 – 4.10
	SUCCESSFUL	2.91	1.48 – 5.75
	FAILED	1.83	0.89 – 3.69
2001	UNAVAILABLE	2.10	0.48 – 9.11
	SUCCESSFUL	3.87	2.24 – 6.82
	FAILED	1.78	0.75 – 4.17
2002	UNAVAILABLE	1.89	0.80 – 4.36
	SUCCESSFUL	3.52	1.93 – 6.49
	FAILED	0.85	0.38 – 1.79
2003	UNAVAILABLE	3.04	0.58 – 14.32
	SUCCESSFUL	6.62	3.76 – 11.88
	FAILED	2.58	0.90 – 6.99
2004	UNAVAILABLE	1.77	0.79 – 3.94
	SUCCESSFUL	3.56	1.87 – 6.95
	FAILED	3.82	1.78 – 8.53
2005	UNAVAILABLE	2.33	1.14 – 4.81
	SUCCESSFUL	3.56	2.05 – 6.29
	FAILED	1.60	0.71 – 3.54

Table 4.5 continued…

Table 4.5 continued…

[a] UNAVAILABLE= previous year's dusky Canada goose (goose) nest fate on island was unknown or the island was not available in the previous year; SUCCESSFUL = previous year's goose nest on island was successful; FAILED = previous year's goose nest on island failed
[b] Odds ratios >1 indicate positive relationship with island use; <1 indicate negative relationship with island use.
[c] All confidence intervals are likelihood ratio, and confidence intervals not including 1.00 indicate evidence of effects.

Table 4.6. Best approximating or competitive models and parameter estimates (β) with 95% confidence intervals for continuous explanatory variables with evidence of linear relationships with use of artificial nest islands by dusky Canada geese for nesting on the western Copper River Delta, Alaska, USA, from 1996-2005.

Year	Model[a,b]	Variable	β[c]	95% CI[d]
1996	SH SH^2 DTLS PSIZE	DTLS	-0.0007	-0.0014 to -0.0001
1998	SH SH^2 DTS	DTS	0.0184	0.0022 to 0.0349
1999	AC AC^2 DTS DTLS PSIZE FETCH PRYR SH SH^2 BDD	DTS	0.0386	0.0179 to 0.0602
2000	DTS AC AC^2 FETCH PSIZE DTLS SH SH^2 PRYR BDD	DTS	0.0229	0.0031 to 0.0432
2003	PRYR SH SH^2 DTS PSIZE DTLS FETCH AC AC^2 BDD	DTS	0.0219[d]	0.0003 to 0.0443

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; BDD = indicated number of breeding dusky geese per square kilometer near the island; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PRYR = the status of nest island use and nest success in the previous year (4 categories: island not used; island used, nest successful; island used, nest failed; island used, nest unknown fate or island not available).

[b] Parameter estimates based on this best approximating or competitive model.

[c] Parameter estimates > 0 indicate positive relationship with island use; < 0 indicate negative relationship with island use.

[d] All confidence intervals are likelihood ratio and confidence intervals not including zero indicate evidence of effects.

Table 4.7. Modeling results looking for factors influencing use of artificial nest islands during the first year they are available to nesting dusky Canada geese on the western Copper River Delta, Alaska, USA (1984-2002). Results indicate no clear relationship between explanatory variables and island use.

Best and Competitive Models[a]	ΔAIC_c	w_i[b]
DTLS	0.00	0.146
DTLS PSIZE	0.48	0.115
NULL	1.51	0.069
DTLS PSIZE FETCH	1.86	0.058
DTLS DTS	1.92	0.056
DTLS AC AC^2	1.94	0.056
DTLS FETCH	1.99	0.054
DTLS PSIZE AC AC^2	2.41	0.044
BDD_FWS	2.42	0.044
PSIZE	2.42	0.044
DTLS PSIZE DTS	2.44	0.043
FETCH	3.41	0.027
DTS	3.50	0.025
PSIZE FETCH	3.61	0.024
AC AC^2	3.67	0.023
DTLS DTS FETCH	3.85	0.021
DTLS PSIZE FETCH DTS	3.89	0.021
DTLS FETCH AC AC^2	3.92	0.021
DTLS AC AC^2 DTS	3.96	0.020

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; DTLS = distance from the island to the nearest large slough; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model.
[b] Model weights provide the strength of evidence for a particular candidate model relative to the rest of the models examined.

Table 4.8. Modeling results looking for factors influencing percent use of artificial nest islands available for nine consecutive years (1997-2005) by nesting dusky Canada geese on the western Copper River Delta, Alaska, USA. Results indicate no clear relationship between explanatory variables and percent island use.

Best and Competitive Models[a]	ΔAIC_c	w_i[b]
DTS	0.00	0.039
DTS PSIZE	1.49	0.036
DTS DTLS	1.80	0.036
DTS FETCH	2.03	0.035
DTS DTLAR	2.07	0.035
PSIZE	2.07	0.035
NULL	3.31	0.033
DTS DTLS PSIZE	3.36	0.033
DTS PSIZE FETCH	3.41	0.033
DTS PSIZE DTLAR	3.53	0.033
DTS DTLS FETCH	3.86	0.032
DTS DTLS DTLAR	3.89	0.032

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; DTLS = distance from the island to the nearest large slough; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); DTLAR = distance from the island to the nearest known larid nest or colony; NULL = intercept-only model.

[b] Model weights provide the strength of evidence for a particular candidate model relative to the rest of the models examined.

Table 4.9. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands of the western Copper River Delta, Alaska, USA (1997-2005).

Year	n^a	Best Model[b]	w_i^c	Competitive Models[d]	Null $< 2\ \Delta AIC_c$	Nest Success (%)
1997	77	DTLS BDD PSIZE	0.04	14	yes	62
1998	85	DTS DTLAR	0.10	6	no	48
1999	96	SH	0.12	8	no	53
2000	104	NULL	0.04	19	yes	74
2001	128	BDD	0.06	12	no	58
2002	104	BDD DTLS	0.09	9	no	82
2003	97	FETCH	0.06	13	yes	59
2004	120	SH BDD AC	0.35	2	no	74
2005	136	DTLS DTLAR BDD	0.22	1	no	63

Table 4.9 continued…

Table 4.9 continued…

[a] Number of available artificial nest islands with dusky goose nests by year.
[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model.
[b] Model weights provide the strength of evidence for a particular candidate model relative to the rest of the models examined.
[c] Number of models competitive in addition to the best model.

Table 4.10. Variable importance weights (VIW) for variables in best approximating and competitive models (1997-2005) of dusky Canada goose nest success on artificial nest islands of the western Copper River Delta, Alaska, USA.

Year[a]	Variable[b] (VIW)[c]
1998	DTS (0.78), DTLAR (0.58), PSIZE (0.31), BDD (0.22), FETCH (0.22), AC (0.18)
1999	SH (0.97), FETCH (0.29), DTS (0.23), PSIZE (0.21), AC (0.18), BDD (0.18), DTLAR (0.17), DTLS (0.15)
2001	BDD (0.77), SH (0.33), DTLS (0.32), AC (0.27), DTLAR (0.23), DTS (0.18), FETCH (0.18)
2002	BDD (0.92), DTLS (0.35), AC (0.32), SH (0.22), PSIZE (0.18), FETCH (0.15), DTLAR (0.14)
2004	SH (1.00), BDD (0.89), AC (0.45), DTLAR (0.20)
2005	DTLS (0.85), DTLAR (0.78), BDD (0.44)

[a] Only included years where the null model was not competitive (excludes 1997, 2000, and 2003).
[b] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.
[c] The sum of all the model weights for all models examined including the variable of interest.

Table 4.11. Summary of the frequency of explanatory variables appearing in best and competitive models of dusky Canada goose nest success on artificial nest islands of the western Copper River Delta, Alaska, USA; with the number of best and competitive models that contained that variable, the proportion of years each variable occurs in best approximating and competitive models, and the average variable importance weight (VIW) for each variable from 1997-2005.

Variable[a]	Number of Models with Variable[b]	Years in Competitive Model (%)	Mean VIW ± SE
BDD	30	100%	0.57 ± 0.14
DTLAR	14	100%	0.35 ± 0.11
AC	10	83%	0.25 ± 0.05
DTLS	13	67%	0.31 ± 0.12
SH	19	67%	0.46 ± 0.17
FETCH	5	67%	0.17 ± 0.03
DTS	10	50%	0.26 ± 0.10
PSIZE	3	50%	0.18 ± 0.03

[a] BDD = indicated number of breeding dusky geese per square kilometer near the island; DTLS = distance from the island to the nearest large slough; SH = average shrub height on the island (meters); DTLAR = distance from the island to the nearest known larid nest or colony; DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle).
[b] A total of 44 models, only including years where the null model was not competitive (excludes 1997, 2000, and 2003).

Table 4.12. Relationships between explanatory variables and nest success for dusky Canada geese on artificial nest islands of the western Copper River Delta, Alaska, USA, and results relative to predicted relationships based on best approximating and competitive models of dusky Canada goose island nest success modeled separately by year from 1997-2005.

Variable	Direction of Association	Supports prediction?
Distance to shore	+	Yes
Shrub height	-	No
Breeding dusky density	+ and -	Yes and No
Distance to larid colony or nest	- and +	Yes and No
Distance to large slough	+ and -	Yes and No
Pond size	- and +	Yes and No
Fetch	- and +	Yes and No
Aerial shrub cover	+ and -	Yes and No

[a] Distance to shore = distance from the island to the nearest shore; Average shrub height = average shrub height on the island (meters); Breeding dusky density = indicated number of breeding dusky geese per square kilometer near the island; Distance to larid colony or nest = distance from the island to the nearest known larid nest or colony; Distance to large slough = distance from the island to the nearest large slough; Pond size = area of the island pond; Fetch = distance from the island to shore in the direction of the prevailing wind (112.5° angle); Aerial shrub cover = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow.

Table 4.13. Parameter estimates (β) and their 95% confidence intervals for explanatory variables in best approximating and competitive models with evidence of linear relationships with nest success of dusky Canada geese on artificial nest islands of the western Copper River Delta, Alaska, USA, from 1997-2005.

Year[a]	Best Model[b]	Variable[c]	β[d]	95% CI[e]
1998	DTS DTLAR	DTS	0.0500	0.0183 to 0.0857
1999	SH	SH	-2.6839	-4.6476 to -0.9486
2001	BDD	BDD	0.1355	0.0297 to 0.2466
2002	BDD DTLS	BDD	-0.2608	-0.4813 to -0.0801
2004	SH BDD AC	SH	-4.8069	-7.5868 to -2.4192
		BDD	0.1796	0.0463 to 0.3226
		AC	0.0359	0.0002 to 0.0752
2005	DTLS DTLAR BDD	DTLS	-0.0009	-0.0017 to -0.0002
		DTLAR	0.0004	0.0001 to 0.0008

[a] Only including years where the null model was not competitive (excludes 1997, 2000, and 2003).
[b] Parameter estimates based on this best approximating model.
[c] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.
[d] Parameter estimates > 0 indicate positive relationship with island use; < 0 indicate negative relationship with island use.
[e] All confidence intervals are likelihood ratio, and confidence intervals not including zero indicate evidence of effects.

CHAPTER 5

DISCUSSION AND CONCLUSIONS

Island Use

Use of islands by dusky geese nesting on the western CRD increased between 1986 and 2005 from a low of 10% in 1987 to 44% in 2005 (Figure 4.2). The high use of islands in 1984 and 1985 may have been due to small sample sizes (fewer than 10 islands were available each year). However, there is no clear relationship between use and the number of islands available over time (which did not vary linearly with time; Figure 4.1); suggesting islands were positioned in prime nesting habitat in 1984 and 1985. Natural islands existed prior to 1984 (Babler et al. 1998), but it is unclear how many were suitable for nesting and the extent of dusky goose nesting on these islands. Use of nest islands may be limited because of failure to provide gander loafing sites (Brakhage 1965, Rienecker 1971, Babler et al. 1998), beaver and muskrat damage to islands (Babler et al. 1998), the limited availability of islands during nest site selection due to snow and ice cover (Bromley 1976, Campbell 1990, Bromley and Rothe 2003), or because nest sites on the western CRD are not limited (Babler et al. 1998). However, the steady increase in use of islands with time suggests these factors are not currently creating substantial obstacles to island use.

Increased use of islands over time has been reported in other studies of Canada geese (Craighead and Stockstad 1961, Rienecker 1971, Giroux 1981, Giroux et al. 1983) and has been attributed to a “normal process of learning” (Rienecker 1971, Giroux et al. 1983), imprinting of the offspring of island-nesting geese to islands (Giroux et al. 1983), increased population size due to immigration, or increased local breeding productivity (Giroux 1981). Additionally, breeding and non-breeding dusky geese may be searching for high quality nest sites during, after, or immediately preceding the breeding season (i.e., nest prospecting) and cues provided by previously used islands may be attracting birds. This activity is known in cavity-nesting ducks (Eadie and Gauthier 1985, Zicus and Hennes 1989), but the extent of prospecting in Canada geese is unknown. Dusky geese on the western CRD have been seen examining old nest sites on arrival to nesting grounds in the spring; however, the identity of these birds (e.g., first time breeders v. established pairs returning to previous nest sites) was unknown (Bromley 1976). Groups of non-breeding Canada geese in Missouri exhibited behavior that could be a form of prospecting when they were observed inspecting nest tubs after breeding females had departed with goslings (Brakhage 1965). Determining which mechanism is most important for the trend will require tracking individually marked birds over time. Regardless of the explanation, I predict a continued increase in island use on the CRD as data in Figure 4.2 do not suggest use has started to level off.

My predictions for the relationships between habitat variables and island use were supported in most years (Table 4.4). However, there was annual variability in factors associated with island use, and evidence for both simple (single variable best models) and complex (full model as the best model) explanations for the variability in island use. Use of islands for nesting was most consistently and strongly associated with the previous year's island status. Islands with a successful nest the previous year were most likely to be used by dusky geese in the subsequent year (Table 4.5). In another study, Canada geese using hay bale island structures in Canada were more likely to use a bale for nesting if it was used in the previous year (Giroux et al. 1983). Like the trend with island use by year (Figure 4.2), the importance of previous year's island status likely reflects high site fidelity by breeding adult geese, with fidelity being higher for birds that have successful nests (Lindberg and Sedinger 1997). Nesting dusky geese on the western CRD do show strong fidelity to breeding territories; in one study 77.1% of pairs (n = 36 pairs) returned to sites on or adjacent to their previous territory (Bromley 1976). The high degree of homing exhibited by geese may restrict their pioneering activities (Bromley 1976), providing another explanation for unused islands. However, 23% of those pairs moved some distance, suggesting that site fidelity may not be to a specific location but to a particular nest site type (mainland v. island), as documented in Missouri for Canada geese nesting in tubs (Brakhage 1965). Alternately, dusky geese use cues from the previous year's nesting activity, such as the presence of egg shell membranes, when prospecting for island nest sites (Eadie and Gauthier 1985, Zicus and Hennes 1989). If site fidelity is the primary explanation, then efforts to increase nest success will help increase island use. If signs of old nests are important cues for prospecting geese, then artificially creating "successful" nests on unused islands may increase use. I suspect some combination of both mechanisms is important.

Use analyses supported my prediction for the association between distance to shore and island use, and evidence for this effect was strong in four of ten years. Dusky geese used islands located further from shore, suggesting that mammalian predators remain an important nest predator on the western CRD, particularly on islands. In one of ten years there was evidence that moderate average shrub height was associated with island use and in one of ten years that moderate aerial shrub cover was associated with island use. This evidence suggested that dusky geese use islands with a moderate percentage of shrub cover, moderate shrub height, and with tall shrubs. Use of islands consistently increased with shrub height up to 1.0 m, however, above shrub heights of 1.0 m trends varied with year. More data for islands with a greater range of shrub heights are needed to resolve this uncertainty.

Contrary to my prediction, dusky geese tended to use islands closer to large sloughs, and there was evidence for this effect in one of ten years. This may be an artifact of reduced snow and ice cover on islands closer to large sloughs, making them available for use earlier in the nesting season than islands further from large sloughs. Dusky geese may also nest closer to large sloughs so they have a quick escape route to brood-rearing areas for goslings post-hatch. Alternatively, a previous author reported this relationship and suggested it was caused by older more experienced birds nesting nearer large sloughs where material used to build nests was more abundant (Bromley 1976). Vegetation has increased dramatically on the western CRD since the 1964 Earthquake and nesting material is likely no longer limited, but the pattern may persist because of long-term site fidelity of adult geese and imprinting of offspring to natal nest sites. If true, I predict this pattern will diminish with time.

Pond size, fetch and the density of breeding dusky geese near the island had weak relationships with island use across years. In general, pond size was negatively associated with island use, as predicted, but 95% confidence intervals of the parameter estimates for pond size always included zero, suggesting pond size is not a strong selection factor for island-nesting dusky geese. Island use had mixed relationships with fetch across years and the 95% confidence intervals of the parameter estimates for this variable always included zero. This suggests that concerns of wind and wave damage are unimportant for nest site selection by dusky geese or that variability in weather conditions from year-to-year make it difficult to select nesting locations based on weather-related factors. Persistent maintenance efforts and attempts to anchor islands on the leeward shore (Babler et al. 1998) have also likely increased island protection from prevailing winds. Relationships between the density of breeding dusky geese and island use were generally positive, as predicted, but 95% confidence intervals for parameter estimates always included zero and the univariate model was never competitive. This suggests that the density of breeding dusky geese near the nest site is not a strong selective factor for island-nesting dusky geese or that the data used to compile the densities was not on a fine enough scale to detect a relationship.

Analyses of percent use of islands available for nine consecutive years and for the first year that islands were available did not clarify any of my results. Habitat characteristics of islands available for nine consecutive years were not related to percent island use. In addition, island site selection in the first year of availability was not related to the habitat characteristics tested in these analyses. These results suggest that island use is related to fidelity to nest site type (mainland v. island), dusky geese select nest sites based on factors not tested in these analyses, or simply that dusky geese initially nest on the first site that is available.

Nest Success

Apparent nest success for dusky geese is higher on islands compared to the mainland on the western CRD (Fode et al. 2006, Grand et al. 2006, Miller et al. 2007), but comparable to estimates of nest success for previous studies of nest islands (Chapter 2). The range of nest success estimates for dusky geese on islands of the western CRD in another study (roughly 55 – 73%; Miller et al. 2007) are similar to my data (47 – 82%). In general, consistently high nest success since 1984 indicates islands have long term potential for increasing dusky goose nest success on the CRD. Recent work attributed 72% of dusky goose nest losses to bald eagles (Anthony et al. 2004). The location and appearance of islands makes them easy for eagles to detect (N. Maggiulli personal observation), but floating islands are small, unstable, and covered by low lying shrubs. These characteristics likely discourage eagles from landing on islands (Miller et al. 2007). If true, the identity of predators or methods of depredation likely differ between islands and the mainland. Additional research to determine predators frequenting islands and modes of depredation (e.g., Anthony et al. 2004, Anthony et al. 2006) may lead to additional suggestions for how to improve island nest success.

Compared to island use, my analysis of nest success and habitat features resulted in many more competitive models (average 10 v. 2 per year) with fewer strong associations between explanatory variables and nest success. Each explanatory variable occurred in at least one best model; however, the large number of competitive models each year, the low model weights assigned to each of these models, the tendency for confidence intervals around the parameter estimates to include zero, and the inclusion of the null model in the competitive model set for three years suggests my explanatory variables generally had a relatively low capacity to explain nest success on artificial islands. However, after evaluating 44 competitive models for the six years that did not have the null model in the competitive set, there was evidence in at least one year for relationships between nest success and the density of breeding dusky geese near the island, aerial shrub cover, and distance to shore and the relationships were consistent with my predictions (Table 4.12). In those instances, nest success was higher on islands near more breeding geese, further from shore, with a higher percentage of shrub cover. However, relationships between explanatory variables and nest success in two years for each of the following variables suggested nest success was higher on islands with shorter shrubs, closer to large sloughs (the case in one year), near a lower density of breeding geese, and further from a larid colony or nest, inconsistent with my predictions (Table 4.12). The negative relationship with breeding dusky density may reflect increased predator awareness of islands near more breeding geese because of increased activity in those areas and a limited abundance of alternate prey making predators more desperate to acquire food in some years. However, the possibility that dusky geese nesting on islands were included in counts of breeding dusky geese during aerial dusky goose breeding surveys may have confounded the relationship between breeding dusky density and nest success.

Nest success was higher farther from shore, as predicted. The water barrier, instability of floating islands, and limited variability of shrub height (Table 4.1) on these islands of the western CRD, may preclude the need for tall shrubs to protect nests on islands (Miller et al. 2007). However, it is possible that nest success is related to shrub height on islands but this relationship is more complex, depending on the presence of alternate prey (eulachon) and predator activities (Miller et al. 2007). Therefore, further study of inter- and intra-annual variation in the presence of alternate prey and predator activities on the CRD, their impact on nest success, and for a greater range of shrub height values on islands may provide more clarity for the relationships between nest success and shrub height.

In one year support for increased nest success closer to larid colonies or nests was similar to another study on the western CRD; that study found a negative correlation with the distance to the nearest aggressive species colony, including Arctic terns and mew gulls, but the relationship was inconsistent across years (Miller et al. 2007). However, associations between the distance to the nearest larid colony and nest success were not consistent across years, suggesting that the location of larid colonies were not consistent from 1997-2005, per my assumptions; that there may be a threshold distance from a larid colony, and beyond this distance colony defense is absent (Miller 2004, Miller et al. 2007); or that the variable has little influence on dusky goose nest success on artificial nest islands. In addition, one year of strong support for increased nest success further from large sloughs suggests that predator activity may be higher closer to large sloughs. However, the relationship between nest success and the distance to large sloughs was not consistent across years. This suggests the variable has little influence on dusky goose nest success on artificial nest islands, or alternatively, that the average distance from islands used in nest success analyses to large sloughs (690 m) is probably insufficient to avoid nest detection by bald eagles (Buehler 2000). The relationship between fetch and nest success was equivocal, likely due to variable weather conditions among years.

Synthesis

Overall, the strength of associations between use and my explanatory variables was higher for island use than nest success. Lower variability in factors associated with island use is likely because factors associated with nest site selection are controlled by decisions of the nesting goose, such as visibility at the nest site (Chapter 2). While this process is little understood in geese, nest site choice by adults may be determined by a few heuristic rules that do not vary appreciably among years (e.g., if successful the previous year, return to that site if it is available; if not successful, pick site with different characteristics). In contrast, nest success is dependent on a more complex combination of factors that vary within and among years outside the control of a nesting goose. For example, recent work has shown that inter-annual variation in the timing of eulachon (*Thaleichthys pacificus*) spawning runs on large sloughs of the CRD has considerable influence on dusky goose nest success (Miller et al. 2006).

The inability to control for eulachon abundance may have confounded my analysis of habitat features important to nest success. This suggests factors like presence of alternate prey (and maybe predator abundance) are more important to dusky nest success on islands than habitat features, a conclusion shared in a recent paper (Miller et al. 2007). For example, in 2000, island use was higher for islands further from large sloughs with a high percentage of tall shrubs. In addition, the null model was the best model for nest success in this year. The low availability of spawning eulachon observed in Alaganik Slough in 1999 (Meyers et al. 1999) may have led bald eagles and mammalian predators to prey-switch to dusky goose nests the previous year, affecting island use decisions in 2000 because of increased predation risk on some island sites in the previous year. Nest site selection based on predator-prey dynamics explains a likely departure from nest site fidelity, resulting in the small influence of previous year's island status on island use and an increased emphasis on variables related to predation in 2000 (distance to shore and shrub cover; Tables 4.2 and 4.3). In addition, weak eulachon spawning runs in 2000 (Meyers et al. 2000) may have contributed to unexplained variation in nest success for 2000. In years of negligible eulachon spawning runs, predators may alter their behavior to target dusky goose nests, with the impact being largest on nests near large sloughs. This is consistent with my results finding higher nest success further from large sloughs in 1999 and 2000, both years of low eulachon abundance (Meyers et al. 1999, Meyers et al. 2000). Furthermore, if eulachon abundance has a large influence on nest fate, and nest fate has a large influence on nest site choice in subsequent years, then eulachon abundance in year i influences nest site selection in year i+1. If this is true, then in years when the previous year's island status did not appear in best models of island use (1996, 1998), dusky geese could have selected nest sites based on eulachon abundance in 1995 and 1997. However, observations of eulachon spawning in Alaganik Slough suggest moderate eulachon abundance (S. Babler 1999, U.S. Forest

Service, unpublished report) in 1995 and a high eulachon abundance in 1997 (Youkey et al. 1997). However, these reports (Youkey et al. 1997, Babler 1999, Meyers et al. 1999, Meyers et al. 1999) are based solely on qualitative evidence and, in general, data on eulachon presence and abundance on the western CRD is extremely limited (N. Maggiulli, personal observations).

The timing of eulachon spawning varies considerably within and among years (Moffitt et al. 2002) and bald eagles aggregate near eulachon spawning runs (Bowman 1999, Marston et al. 2002, N. Maggiulli personal observations). Currently, there are no quantitative estimates of spawning eulachon or bald eagle abundance on the CRD beyond rough estimates of eulachon abundance from subsistence and commercial fisheries of the past (Moffitt et al. 2002); bald eagle counts from a single study conducted along Alaganik Slough from 2001-2003 (Miller et al. 2007); and evidence that bald eagle numbers are increasing along Prince William Sound and coastal, southeast Alaska (Bowman 1999). Eulachon populations have declined from northern California to southeast Alaska since the mid-1990's (Hay and McCarter 2000), and the status of eulachon that spawn on the CRD is unknown but is likely in decline. The cause of the eulachon decline has mainly be attributed to humans from bycatch by the shrimp trawl fishery, habitat alteration, and climate change (Hay and McCarter 2000). The abundance of spawning eulachon likely influences predation on dusky goose nests and without data on eulachon presence or abundance on the CRD, the ability to effectively manage for dusky goose productivity will be greatly reduced. Therefore, I suggest collecting quantitative data on the timing, abundance, and location of spawning eulachon on the western CRD and the numerical response of bald eagles to these spawning runs so these data can be incorporated into further analyses of factors that may influence nest success on artificial nest islands. Managing to reverse the decline in dusky goose productivity attributed to a natural disaster may seem out of place as a management tool on the relatively untouched wetlands of the western CRD, but considering the intense harvest pressure humans ensued on wintering dusky geese prior to the earthquake (Chapman et al. 1969) and more recent declines in eulachon attributed to humans that likely are impacting predation pressure on dusky geese, the artificial nest island program earns its current place in dusky goose management on the breeding grounds.

Total dusky goose population size on the CRD was relatively constant over the years of my study (Pacific Flyway Council 2008). Assuming gosling survival is independent of nest location (island v. mainland), the increasing use of islands and relatively constant nest success indicates dusky goose production attributable to islands is increasing. Understanding the overall impact of the nest island program on dusky goose production depends on quantifying the contribution of islands. An unpublished model constructed in the mid-1990s predicted that islands might comprise 13% of dusky goose production by 2004 (D. Youkey 1995, U. S. Forest Service, unpublished report). An update of this model is needed. More generally, the artificial nest island program on the CRD is the only management tool used to increase dusky goose nest success. There is a need for a new population model that incorporates all recent information on dusky goose reproductive ecology to determine if artificial nest islands can increase dusky goose population size, and if so, how many islands are needed.

Management Implications

Current use of available nest islands is at a program high of 44% (Figure 4.2). Current nest success on islands also remains high (63%; Figure 4.4) relative to dusky geese nesting on the mainland (Grand et al. 2006). Relocation of islands should focus on ponds where nests can be placed greater than 40 m from shore, and on maintaining 50% or greater aerial shrub cover near 1 m tall. I also recommend conducting an adaptive experiment to determine if placement of artificial nests on unused islands can help increase use more quickly than the current trend. I do not recommend placing nest islands in sloughs or considering distance to large slough, distance to larid colonies, fetch, and the adjacent density of nesting dusky geese when placing nest islands at this time.

BIBLIOGRAPHY

Allison, P. D. 1999. Logistic regression using the SAS® system: theory and application. 2006, Reprint. SAS Institute Inc., Cary, North Carolina, USA.

Anthony, M., J. B. Grand, T. F. Fondell, and B. F. J. Manly. 2004. A quantitative approach to identifying predators from nest remains. Journal of Field Ornithology 75:40-48.

Anthony, R. M., J. B. Grand, T. F. Fondell, and D. A. Miller. 2006. Techniques for identifying predators of goose nests. Wildlife Biology 12:249-256.

Atkins, T. D., and T. L. Fuller. 1979. An improved nesting structure for Canada geese. Wildlife Society Bulletin 7:192-193.

Babler, S., D. Youkey, and J. A. Crouse. 1998. Eleven years of artificial nest islands for dusky Canada geese on the Copper River Delta, Alaska. USDA Forest Service, Chugach National Forest, Unpublished Report, Cordova, Alaska, USA.

Ball, I. J. 1990. Artificial nest structures for Canada geese. U. S. Fish and Wildlife Service, Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.2.12, Washington, D.C., USA. <http://www.nwrc.usgs.gov/wdb/pub/wmh/13_2_12.pdf>

Bishop, M. A., P. M. Meyers, and P. F. McNeley. 2000. A method to estimate migrant shorebird numbers on the Copper River Delta, Alaska. Journal of Field Ornithology 71:627-637.

Boggs, K., and M. Shephard. 1999. Response of marine deltaic surfaces to major earthquake uplifts in southcentral Alaska. Wetlands 19:13-27.

Bowman, T. 1999. Restoration notebook: bald eagle (*Haliaeetus leucocephalus*). 1999. Exxon Valdez Oil Spill Trustee Council, Anchorage, Alaska, USA.

Brakhage, G. K., 1965. Biology and behavior of tub-nesting geese. Journal of Wildlife Management 29:751-771.

Brenner, F. J., and J. J. Mondok. 1979. Waterfowl nesting rafts designed for fluctuating water levels. Journal of Wildlife Management 43:979-982.

Bromley, R. G., and T. C. Rothe. 2003. Conservation assessment for the dusky Canada goose *(Branta canadensis occidentalis* Baird). USDA Forest Service General Technical Report PNW GTR-591, Portland, Oregon, USA.

Bromley, R. G. H. 1976. Nesting and habitat studies of the dusky Canada goose (*Branta canadensis occidentalis* Baird) on the Copper River Delta, Alaska. Thesis, University of Alaska, Fairbanks, Alaska, USA.

Buehler, David A. 2000. Bald eagle (*Haliaeetus leucocephalus*). Account 506 *in* A. Poole, editor. The birds of North America online, Cornell Lab of Ornithology, Ithaca, New York, USA. <http://0-bna.birds.cornell.edu.oasis.oregonstate.edu:80/bna/species/506>.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer Science+Business Media, Inc., New York, New York, USA.

Butler, W. I., Jr., R. A. Stehn, and G. R. Balogh. 1994. GIS for mapping waterfowl density and distribution from aerial surveys. Wildlife Society Bulletin 23:140-147.

Campbell, B. H. 1990. Factors affecting the nesting success of dusky Canada geese (*Branta canadensis occidentalis*) on the Copper River Delta, Alaska. The Canadian Field-Naturalist 104:567-574.

Campbell, B. H. 1991. Activities of brown bears on the Copper River Delta, Alaska and their impact on nesting dusky Canada geese. Northwestern Naturalist 72:92-99.

Campbell, B. H. 1991. Longevity records for the dusky Canada goose (*Branta canadensis occidentalis*). Northwestern Naturalist 72:34.

Campbell, B. H, T. C. Rothe, and D. H. Rosenberg. 1988. Annual report of survey-inventory activities, Part XIII. Waterfowl, Vol. XVIII. Alaska Department of Fish and Game, Federal Aid to Wildlife Restoration Progress Report Project W-22-6, Job 11.0, Juneau, Alaska, USA.

Chapman, J. A., C. J. Henny, and H. M. Wight. 1969. The status, population dynamics and harvest of dusky Canada goose. Wildlife Monographs 18:7-48.

Cline, M. L. 2004. Productivity of giant Canada geese (*Branta canadensis maxima*) in northeastern Illinois. Thesis, Southern Illinois University, Carbondale, Illinois, USA.

Craighead, F. C., Jr., and J. J. Craighead. 1949. Nesting Canada geese on the upper Snake River. Journal of Wildlife Management 13:51-64.

Craighead, J. J., and D. S. Stockstad. 1961. Evaluating the use of aerial nesting platforms by Canada geese. Journal of Wildlife Management 25:363-372.

Crow, J. H. 1971. Earthquake-initiated changes in the nesting habitat of the dusky Canada goose. Pages 130-136 *in* The great Alaska earthquake of 1964: biology. Committee on the Alaska Earthquake of the Division of Earth Sciences, National Research Council, National Academy of Sciences, Washington, D.C., USA.

Dow, H., and S. Fredga. 1985. Selection of nest sites by a hole-nesting duck, the goldeneye (*Bucephala clangula*). Ibis 127:16-30.

Duebbert, H. F. 1982. Nesting of waterfowl on islands in Lake Audubon, North Dakota. Wildlife Society Bulletin 10:232-237.

Eadie, J. M. A., and G. Gauthier. 1985. Prospecting for nest sites by cavity-nesting ducks from the Genus *Bucephala*. The Condor 87:528-534.

Ewaschuk, E., and D. A. Boag. 1972. Factors affecting hatching success of densely nesting Canada geese. Journal of Wildlife Management 36:1097-1106.

Fode, J., P. Meyers, and D. Logan. 2006. Artificial nest island program for dusky Canada geese on the Copper River Delta, Alaska: final report. U. S. Forest Service, Chugach National Forest, Cordova, Alaska, USA.

Fondell, T. F., J. B. Grand, D. A. Miller, and R. M. Anthony. 2006. Renesting by dusky Canada geese on the Copper River Delta, Alaska. Journal of Wildlife Management 70:955-964.

Franklin, A. B., D. R. Anderson, R. J. Gutierrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern

California. Ecological Monographs 70:539-590.

Geis, M. B. 1956. Productivity of Canada geese in the Flathead Valley, Montana. Journal of Wildlife Management 20:409-419.

Giroux, J., D. E. Jelinski, and R. W. Boychuk. 1983. Use of rock islands and round straw bales by nesting Canada geese. Wildlife Society Bulletin 11:172-178.

Giroux, J. F. 1981. Use of artificial islands by nesting waterfowl in southeastern Alberta. Journal of Wildlife Management 45:669-679.

Gosser, A. L., and M. R. Conover. 1999. Will the availability of insular nesting sites limit reproduction in urban Canada goose populations? Journal of Wildlife Management 63:369-373.

Grand, B., M. Anthony, and T. Fondell. 1998. Renesting, nest depredation, and gosling survival of dusky Canada geese on the Copper River Delta, Alaska. U. S. Geological Survey, Alaska Biological Sciences Center, Unpublished Report, Anchorage, Alaska, USA.

Grand, J. B., T. F. Fondell, D. A. Miller, and R. M. Anthony. 2006. Nest survival in dusky Canada geese (*Branta canadensis occidentalis*): use of discrete time models. Auk 123:198-210.

Hammond, M. C., and G. E. Mann. 1956. Waterfowl nesting islands. Journal of Wildlife Management 20:345-352.

Hatch, J. J. 2002. Arctic tern (*Sterna paradisaea*). Account 707 *in* A. Poole, editor. The birds of North America online, Cornell Lab of Ornithology, Ithaca, New York, USA. <http://0-bna.birds.cornell.edu.oasis.oregonstate.edu:80/bna/species/707>.

Hay, D., and P. B. McCarter. 2000. Status of the eulachon *Thaleichthys pacificus* in Canada. Canadian Stock Assessment Secretariat 2000/145:1-56.

Isleib, M. E. and B. Kessel. 1973. Birds of the North Gulf coast- Prince William Sound region, Alaska. Reprint, 1992. Biological Papers of the University of Alaska, University of Alaska Press, Fairbanks, Alaska, USA.

Iverson, S. J., K. J. Frost, and S. L. C. Lang. 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: factors contributing to among and within species variability. Marine Ecology Progress Series 241:161-181.

Jacobs, K. J., and J. P. Dunn. 2004. Canada goose nesting ecology and gosling survival at Pymatuning Wildlife Management Area, Pennsylvania. Pages 85-91 *in* T. J. Moser, R. D. Lien, K. C. VerCauteren, K. F. Abraham, D. E. Andersen, J. G. Bruggink, J. M. Coluccy, D. A. Graber, J. O. Leafloor, D. R. Lukkonen, and R. E. Trost, editors. Proceedings of the 2003 International Canada Goose Symposium, Madison, Wisconsin, USA.

Jehle, G., A. A. Yackel Adams, J. A. Savidge, and S. K. Skagen. 2004. Nest survival estimation: a review of alternatives to the Mayfield estimator. The Condor 106:472-484.

Johnson, D. H., D. E. Timm, and P. F. Springer. 1979. Morphological characteristics of Canada geese in the Pacific Flyway. Pages 56-80 *in* R. L. Jarvis and J. C. Bartonek, editors. Management and Biology of Pacific Flyway Geese. Portland, Oregon, USA.

Johnson, R. F., Jr., R. O. Woodward, and L. M. Kirsch. 1978. Waterfowl nesting on small man-made islands in prairie wetlands. Wildlife Society Bulletin 6:240-243.

Johnson, R. R., K. F. Higgins, I. J. Ball, and S. C. Kohn. 1994. Waterfowl productivity and use of nesting structures in the prairie pothole region. Prairie Naturalist 26:187-194.

Kaminski, R. M., and H. H. Prince. 1977. Nesting habitat of Canada geese in southeastern Michigan. The Wilson Bulletin 89:523-531.

Klopman, R. B. 1958. The nesting of the Canada goose at Dog Lake, Manitoba. The Wilson Bulletin 70:168-183.

Lang, A. 2005. The birds of Cordova and the Copper River Delta: a checklist. Cordova, Alaska, USA.

Larson, S. 1960. On the influence of the Arctic fox (*Alopex lagopus*) on the distribution of Arctic birds. Oikos 11:276-305.

Lindberg, M. S., and J. S. Sedinger. 1997. Ecological consequences of nest site fidelity in black brant. The Condor 99:25-38.

Lokemoen, J. T. 1993. Increasing waterfowl nesting success on islands and peninsulas. U. S. Fish and Wildlife Service, Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.2.11, Washington, D.C., USA.

Lokemoen, J. T. and R. O. Woodward. 1992. Nesting waterfowl and water birds on natural islands in the Dakotas and Montana. Wildlife Society Bulletin 20:163-171.

MacInnes, C. D. 1962. Nesting of small Canada geese near Eskimo Point, Northwest Territories. Journal of Wildlife Management 26:247-256.

Marston, B. H., M. F. Willson, and S. M. Gende. 2002. Predator aggregations during eulachon (*Thaleichthys pacificus*) spawning runs. Marine Ecology Progress Series 231:229-236.

Mayfield, H. F. 1961. Nesting success calculated from exposure. Wilson Bulletin 73:255–261.

Meyers, P., E. Cooper, S. Babler, and D. Logan. 1999. Artificial nest island program for dusky Canada geese on the Copper River Delta, Alaska: final report. U. S. Forest Service, Chugach National Forest, Cordova, Alaska, USA.

Meyers, P., E. Cooper, J. Fode, S. Babler, and D. Logan. 2000. Artificial nest island program for dusky Canada geese on the Copper River Delta, Alaska: final report. U. S. Forest Service, Chugach National Forest, Cordova, Alaska, USA.

Miller, A. W., and B. D. Collins. 1953. A nesting study of Canada geese on Tule Lake and lower Klamath National Wildlife Refuges, Siskiyou County, California. California Fish and Game 39:385-396.

Miller, D. A. 2004. Factors related to temporal and spatial variation in nest survival for dusky Canada geese on the Copper River Delta, Alaska. Thesis, Auburn University, Auburn, Alabama, USA.

Miller, D. A., J. B. Grand, T. F. Fondell, and M. Anthony. 2006. Predator functional response and prey survival: direct and indirect interactions affecting a marked prey population. Journal of Animal Ecology 75:101-110.

Miller, D. A., Grand, J. B., Fondell, T. F. and Anthony, R. M. 2007. Optimizing nest survival and female survival: consequences of nest site selection for Canada geese. The Condor 109:769-780.

Moffitt, S., B. Marston, and M. Miller. 2002. Summary of eulachon research in the Copper River Delta, 1998-2002: report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Regional Information Report No. 2A02-34, Anchorage, Alaska, USA.

Moskoff, W., and L. R. Bevier. 2002. Mew gull (*Larus canus*). Account 687 *in* A. Poole, editor. The birds of North America online, Cornell Lab of Ornithology, Ithaca, New York, USA. <http://0-bna.birds.cornell.edu.oasis.oregonstate.edu:80/bna/species/687>.

Mowbray, T. B., C. R. Ely, J. S. Sedinger, and R. E. Trost. 2002. Canada goose (*Branta canadensis*). Account 682 *in* A. Poole, editor. The birds of North America online, Cornell Lab of Ornithology, Ithaca, New York, USA. <http://0-bna.birds.cornell.edu.oasis.oregonstate.edu:80/bna/species/682>.

Naylor, A. E. 1953. Production of the Canada goose on Honey Lake Refuge, Lassen County, California. California Fish and Game 39: 83-94.

Nguyen, L. P., K. F. Abraham, K. F., and E. Nol. 2006. Influence of Arctic terns on survival of artificial and natural semipalmated plover nests. Waterbirds 29:100-104.

Pacific Flyway Council. 1973. Guidelines for management of the dusky Canada goose. Dusky Canada Goose Subcommittee, Pacific Flyway Study Committee, [c/o U. S. Fish and Wildlife Service], Portland, Oregon, USA.

Pacific Flyway Council. 1985. Pacific Flyway management plan for the dusky Canada goose. Dusky Canada Goose Subcommittee, Pacific Flyway Study Committee, [c/o U. S. Fish and Wildlife Service], Portland, Oregon, USA.

Pacific Flyway Council. 1997. Pacific Flyway management plan for the dusky Canada goose. Dusky Canada Goose Subcommittee, Pacific Flyway Study Committee, [c/o U. S. Fish and Wildlife Service], Portland, Oregon, USA.

Pacific Flyway Council. 2008. Pacific Flyway Management plan for the dusky Canada goose. Dusky Canada Goose Subcommittee, Pacific Flyway Study Committee, [c/o U. S. Fish and Wildlife Service], Working Draft, version 3, Portland, Oregon, USA.

Payne, S. A., B. A. Johnson, and R. S. Otto. 1999. Proximate composition of some north-eastern Pacific forage fish species. Fisheries Oceanography 8:159-177.

Peters, M. L., M. J. Sebetich, J. P. Dunn. 2004. Canada goose reproductive success and recruitment in southeastern Pennsylvania. Pages 223-230 *in* T. J. Moser, R. D. Lien, K. C. VerCauteren, K. F. Abraham, D. E. Andersen, J. G. Bruggink, J. M. Coluccy, D. A. Graber, J. O. Leafloor, D. R. Lukkonen, and R. E. Trost, editors. Proceedings of the 2003 International Canada Goose Symposium, Madison, Wisconsin, USA.

Reese, K. P., J. A. Kadlec, and L. M. Smith. 1987. Characteristics of islands selected by nesting Canada geese (*Branta canadensis*). The Canadian Field-Naturalist 101:539-542.

Reynolds, J. C., M. J. Short, and R. J. Leigh. 2004. Development of population control strategies for mink (*Mustela vison*), using floating rafts as monitors and trap sites. Biological Conservation 120:533-543.

Rienecker, W. C. 1971. Canada goose nest platforms. California Fish and Game 57:113-123.

SAS Institute. 2002-2003. Version 9.1.3. SAS Institute, Cary, North Carolina, USA.

Sherwood, G. A. 1968. Factors limiting production and expansion of local populations of Canada geese. Pages 73-85 *in* R. L. Hine and C. Shoenfeld, editors, Canada Goose Management: current continental problems and programs, Dembar Educ. Res. Serv., Madison, Wisconsin, USA.

Sigler, M. F., J. N. Womble, J. J. Vollenweider. 2004. Availability to Steller sea lions (*Eumetopias jubatus*) of a seasonal prey resource: a prespawning aggregation of eulachon (*Thaleichthys pacificus*). Canadian Journal of Fisheries and Aquatic Sciences 61: 1475-1484.

Stolley, D. S., J. A. Bissonette, and J. A. Kadlec. 1999. Limitations on Canada goose production at Fish Springs National Wildlife Refuge. Great Basin Naturalist 59:245-252.

Thilenius, J. F. 1990. Woody plant succession on earthquake-uplifted coastal wetlands of the Copper River Delta, Alaska. Forest Ecology and Management 33/34:439-462.

Trainer, C. E. The 1959 western Canada goose (*Branta canadensis occidentalis*) study of the Copper River Delta, Alaska, U. S. Bureau of Sport Fisheries and Wildlife, Annual Waterfowl Report, Juneau, Alaska, USA.

Vermeer, K. 1968. Ecological aspects of ducks nesting in high densities among larids. The Wilson Bulletin 80:78-83.

Vermeer, K. 1970. A study of Canada geese (*Branta canadensis*) nesting on islands in southeastern Alberta. Canadian Journal of Zoology 48:235-240.

Vermeer, K., K. H. Morgon, and G. E. J. Smith. 1992. Black oystercatcher habitat selection, reproductive success, and their relationship with glaucous-winged gulls. Colonial Waterbirds 15:14-23.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. Journal of Wildlife Management 14:56-67.

Will, G. C., and G. I. Crawford. 1970. Elevated and floating nest structures for Canada geese. Journal of Wildlife Management 34:583-586.

Willson, M. F., and B. H. Marston. 2002. Fishing success of gulls at a southeast Alaska smelt run. Journal of Field Ornithology 73:91-96.

Yocom, C. F. 1952. Techniques used to increase nesting of Canada geese. Journal of Wildlife Management 16:425-428.

Zicus, M. C., and S. K. Hennes. 1989. Nest prospecting by common goldeneyes. The Condor 91:807-812.

Zoellick, B. W., H. M. Ulmschneider, B. S. Cade, and A. W. Stanley. 2004. Isolation of Snake River islands and mammalian predation of waterfowl nests. Journal of Wildlife Management 68:650-662.

APPENDICES

Appendix 3.1. Candidate models used in the logistic regression analysis of factors influencing artificial nest island use by nesting dusky Canada geese on the western Copper River Delta, Alaska, USA, from 1996-2005.

Model	Candidate Models[a]
1	NULL
	One-variable models
2	BDD
3	DTLS
4	DTS
5	FETCH
6	PRYR
7	PSIZE
	Two-variable models
8	AC AC^2
9	SH SH^2
10	DTS DTLS
11	DTS PSIZE
12	FETCH DTLS
13	FETCH DTS
14	FETCH PSIZE
15	PSIZE DTLS
	Three-variable models
16	DTLS AC AC^2
17	DTLS SH SH^2
18	DTS AC AC^2
19	DTS PSIZE DTLS
20	DTS SH SH^2
21	FETCH AC AC^2
22	FETCH DTS DTLS
23	FETCH DTS PSIZE
24	FETCH PSIZE DTLS
25	FETCH SH SH^2
26	PSIZE AC AC^2
27	PSIZE SH SH^2

Appendix 3.1 continued…

Appendix 3.1 continued…

Model	Candidate Models
	Four-variable models
28	AC AC^2 DTS DTLS
29	AC AC^2 DTS PSIZE
30	AC AC^2 FETCH DTLS
31	AC AC^2 FETCH DTS
32	AC AC^2 FETCH PSIZE
33	AC AC^2 PSIZE DTLS
34	AC AC^2 SH SH^2
35	FETCH DTS PSIZE DTLS
36	SH SH^2 DTS DTLS
37	SH SH^2 DTS PSIZE
38	SH SH^2 FETCH DTLS
39	SH SH^2 FETCH DTS
40	SH SH^2 FETCH PSIZE
41	SH SH^2 PSIZE DTLS
	Full Model
42	PRYR FETCH BDD DTS AC AC^2 SH SH^2 DTLS PSIZE

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; BDD = indicated number of breeding dusky geese per square kilometer near the island; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PRYR = the status of nest island use and nest success in the previous year (4 categories: island not used; island used, nest successful; island used, nest failed; island used, nest unknown fate or island not available); NULL = intercept-only model.

Appendix 3.2. Candidate models used in the logistic regression analysis of factors influencing dusky Canada goose nest success on artificial nest islands of the western Copper River Delta, Alaska, USA, from 1997-2005.

Model	Candidate Models[a]
1	NULL
	One-variable models
2	AC
3	BDD
4	DTLAR
5	DTLS
6	DTS
7	FETCH
8	PSIZE
9	SH
	Two-variable models
10	AC DTLS
11	AC PSIZE
12	AC SH
13	BDD AC
14	BDD DTLAR
15	BDD DTLS
16	BDD DTS
17	BDD PSIZE
18	BDD SH
19	DTLAR AC
20	DTLAR DTLS
21	DTLAR PSIZE
22	DTLAR SH
23	DTS AC
24	DTS DTLAR
25	DTS DTLS
26	DTS PSIZE
27	DTS SH

Appendix 3.2 continued…

Appendix 3.2 continued…

Model	Candidate Models
28	FETCH AC
29	FETCH DTLAR
30	FETCH DTLS
31	FETCH DTS
32	FETCH PSIZE
33	FETCH BDD
34	FETCH SH
35	PSIZE DTLS
36	SH DTLS
37	SH PSIZE
	Three-variable models
38	AC PSIZE DTLS
39	AC SH PSIZE
40	BDD AC DTLS
41	BDD AC PSIZE
42	BDD AC SH
43	BDD DTLAR AC
44	BDD DTLAR DTLS
45	BDD DTLAR PSIZE
46	BDD DTLAR SH
47	BDD DTS AC
48	BDD DTS DTLAR
49	BDD DTS DTLS
50	BDD DTS PSIZE
51	BDD DTS SH
52	BDD PSIZE DTLS
53	BDD SH DTLS
54	BDD SH PSIZE
55	DTLAR AC DTLS
56	DTLAR AC PSIZE
57	DTLAR AC SH
58	DTLAR PSIZE DTLS
59	DTLAR SH DTLS
60	DTLAR SH PSIZE

Appendix 3.2 continued…

Appendix 3.2 continued…

Model	Candidate Models
61	DTS AC DTLS
62	DTS AC PSIZE
63	DTS AC SH
64	DTS DTLAR AC
65	DTS DTLAR DTLS
66	DTS DTLAR PSIZE
67	DTS DTLAR SH
68	DTS PSIZE DTLS
69	DTS SH DTLS
70	DTS SH PSIZE
71	FETCH AC DTLS
72	FETCH AC PSIZE
73	FETCH AC SH
74	FETCH BDD AC
75	FETCH BDD DTLAR
76	FETCH BDD DTLS
77	FETCH BDD DTS
78	FETCH BDD PSIZE
79	FETCH BDD SH
80	FETCH DTLAR AC
81	FETCH DTLAR DTLS
82	FETCH DTLAR PSIZE
83	FETCH DTLAR SH
84	FETCH DTS AC
85	FETCH DTS DTLAR
86	FETCH DTS DTLS
87	FETCH DTS PSIZE
88	FETCH DTS SH
89	FETCH PSIZE DTLS
90	FETCH SH DTLS
91	FETCH SH PSIZE
92	SH PSIZE DTLS
	Full Model
93	FETCH BDD DTS DTLAR AC SH PSIZE DTLS

Appendix 3.2 continued

Appendix 3.2 continued…

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model

Appendix 3.3. Candidate models used in logistic regression analyses of explanatory variables predicted to be associated with the percent use of artificial nest islands available for nine consecutive years (1997-2005) by nesting dusky Canada geese on the western Copper River Delta, Alaska, USA.

Model	Candidate Models[a]
1	NULL
	One-variable models
2	FETCH
3	DTS
4	PSIZE
5	DTLS
6	DTLAR
	Two-variable models
7	FETCH DTS
8	FETCH PSIZE
9	FETCH DTLS
10	FETCH DTLS
11	DTS PSIZE
12	DTS DTLS
13	DTS DTLAR
14	PSIZE DTLS
15	PSIZE DTLAR
16	DTLS DTLAR
	Three-variable models
17	FETCH DTS PSIZE
18	FETCH DTS DTLS
19	FETCH DTS DTLAR
20	FETCH PSIZE DTLS
21	FETCH PSIZE DTLAR
22	FETCH DTLS DTLAR
23	DTS PSIZE DTLS
24	DTS PSIZE DTLAR
25	DTS DTLS DTLAR
26	PSIZE DTLS DTLAR
	Four-variable models
27	FETCH DTS PSIZE DTLS
28	FETCH DTS PSIZE DTLAR

Appendix 3.3 continued…

Appendix 3.3 continued…

Model	Candidate Models
29	FETCH DTS DTLS DTLAR
30	FETCH PSIZE DTLS DTLAR
31	DTS PSIZE DTLS DTLAR
	Full Model
32	FETCH DTS PSIZE DTLS DTLAR

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; DTLS = distance from the island to the nearest large slough; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); DTLAR = distance from the island to the nearest known larid nest or colony; NULL = intercept-only model.

Appendix 4.1. Candidate models used in logistic regression analyses of explanatory variables predicted to be associated with the first year an artificial nest island was available for use by nesting dusky Canada geese on the western Copper River Delta, Alaska, USA, from 1984-2002.

Model	Candidate Models[a]
1	NULL
	One-variable models
2	FETCH
3	BDD
4	DTS
5	PSIZE
6	DTLS
	Two-variable models
7	FETCH DTS
8	FETCH PSIZE
9	FETCH DTLS
10	DTS PSIZE
11	DTS DTLS
12	PSIZE DTLS
13	AC AC^2
	Three-variable models
14	FETCH DTS PSIZE
15	FETCH DTS DTLS
16	FETCH AC AC^2
17	FETCH PSIZE DTLS
18	DTS AC AC^2
19	DTS PSIZE DTLS
20	PSIZE AC AC^2
21	DTLS AC AC^2
	Four-variable models
22	FETCH DTS PSIZE DTLS
23	AC AC^2 FETCH DTS
24	AC AC^2 FETCH PSIZE
25	AC AC^2FETCH DTLS
26	AC AC^2 DTS PSIZE
27	AC AC^2DTS DTLS
28	AC AC^2 PSIZE DTLS
	Full model
29	FETCH BDD DTS AC AC^2 PSIZE DTLS

Appendix 4.1 continued…

Appendix 4.1 continued…

[a] DTS = distance from the island to the nearest shore; PSIZE = area of the island pond; DTLS = distance from the island to the nearest large slough; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model.

Appendix 4.2. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 1997 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
DTLS BDD PSIZE	0.00	0.04
DTS	0.28	0.04
DTLS BDD	0.29	0.04
DTLS	0.29	0.04
DTLS BDD DTS	0.63	0.03
NULL	0.64	0.03
FETCH	0.64	0.03
PSIZE	0.66	0.03
DTLS PSIZE	0.77	0.03
DTLS DTS	0.80	0.03
DTLS BDD FETCH	1.25	0.02
BDD DTS	1.45	0.02
DTLS FETCH	1.60	0.02
BDD PSIZE	1.74	0.02
PSIZE DTS	2.03	0.02
BDD	2.12	0.01
DTS AC	2.15	0.01
DTLS SH	2.15	0.01
DTLS BDD SH	2.17	0.01
DTS FETCH	2.29	0.01
PSIZE FETCH	2.32	0.01
SH	2.37	0.01
DTLS AC	2.38	0.01
DTLS BDD AC	2.41	0.01
DTS SH	2.42	0.01
DTS DTLAR	2.44	0.01
DTLS DTLAR	2.46	0.01
DTLS BDD DTLAR	2.51	0.01
DTLS PSIZE DTS	2.56	0.01
PSIZE SH	2.58	0.01
BDD FETCH	2.62	0.01
DTLAR	2.67	0.01
DTLS PSIZE FETCH	2.68	0.01
DTLS DTS AC	2.68	0.01
AC	2.71	0.01

Appendix 4.2 continued…

Appendix 4.2 continued…

Best and Competitive Models	ΔAIC_c	w_i
PSIZE DTLAR	2.77	0.01
DTLS PSIZE SH	2.79	0.01
PSIZE AC	2.82	0.01
DTLS PSIZE DTLAR	2.84	0.01
DTLS DTS FETCH	2.90	0.01
DTLS PSIZE AC	2.94	0.01
DTLS DTS SH	2.99	0.01
DTLS DTS DTLAR	3.02	0.01
BDD PSIZE DTS	3.09	0.01
BDD PSIZE FETCH	3.22	0.01
BDD DTS AC	3.37	0.01
FETCH AC	3.42	0.01
BDD DTS FETCH	3.43	0.01
FETCH SH	3.53	0.01
DTLS FETCH AC	3.59	0.01
FETCH DTLAR	3.61	0.01
BDD DTS SH	3.65	0.01
BDD DTS DTLAR	3.67	0.01
BDD PSIZE SH	3.69	0.01
DTLS FETCH SH	3.74	0.01
DTLS FETCH DTLAR	3.80	0.01
BDD PSIZE DTLAR	3.80	0.01
SH AC	3.84	0.01
BDD SH	3.88	0.01
DTS SH AC	3.91	0.01
BDD PSIZE AC	3.96	0.01

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model.
[b] Model weights provide the strength of evidence for a particular candidate model relative to the rest of the models examined

Appendix 4.3. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 1998 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
DTS DTLAR	0.00	0.10
DTS DTLAR PSIZE	0.39	0.09
DTS DTLAR AC	0.98	0.06
DTS DTLAR FETCH	1.02	0.06
DTS DTLAR BDD	1.17	0.06
DTS	1.80	0.04
DTS BDD	1.94	0.04
DTS DTLAR SH	2.17	0.04
DTS DTLAR DTLS	2.20	0.03
DTLAR PSIZE	2.43	0.03
DTS FETCH	3.12	0.02
DTS BDD AC	3.13	0.02
DTS PSIZE	3.16	0.02
DTS AC	3.17	0.02
DTLAR PSIZE FETCH	3.28	0.02
DTLAR PSIZE SH	3.44	0.02
DTS BDD FETCH	3.71	0.02
DTS PSIZE BDD	3.88	0.01
DTS SH	3.93	0.01
DTS DTLS	3.94	0.01
DTS BDD DTLS	3.98	0.01

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.

Appendix 4.4. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 1999 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
SH	0.00	0.11
SH FETCH	0.77	0.08
SH AC	1.52	0.05
SH PSIZE	1.58	0.05
SH FETCH DTS	1.62	0.05
SH DTS	1.67	0.05
SH BDD	1.80	0.05
SH DTLS	1.94	0.04
SH DTLAR	2.02	0.04
SH DTS PSIZE	2.30	0.04
SH FETCH AC	2.64	0.03
SH FETCH DTLS	2.74	0.03
SH FETCH DTLAR	2.75	0.03
SH FETCH BDD	2.77	0.03
SH FETCH PSIZE	2.78	0.03
SH DTS AC	3.07	0.02
SH PSIZE AC	3.10	0.02
SH PSIZE DTLAR	3.37	0.02
SH AC BDD	3.41	0.02
SH PSIZE DTLS	3.53	0.02
SH AC DTLAR	3.53	0.02
SH DTS BDD	3.56	0.02
SH PSIZE BDD	3.56	0.02
SH DTS DTLS	3.72	0.02
SH BDD DTLS	3.77	0.02
SH DTS DTLAR	3.82	0.02
SH BDD DTLAR	3.93	0.02
SH DTLAR DTLS	4.05	0.02

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.

Appendix 4.5. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 2000 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
NULL	0.00	0.04
FETCH DTLAR	0.06	0.04
FETCH DTS	0.16	0.04
FETCH	0.38	0.03
FETCH DTLAR DTS	0.77	0.03
DTLAR	0.86	0.03
DTS	1.10	0.02
DTLS	1.40	0.02
AC	1.42	0.02
FETCH DTLAR DTLS	1.50	0.02
BDD	1.52	0.02
FETCH DTLAR AC	1.54	0.02
FETCH AC	1.54	0.02
PSIZE	1.70	0.02
FETCH DTLS	1.71	0.02
FETCH DTS DTLS	1.78	0.02
SH	1.84	0.02
FETCH DTS AC	1.90	0.02
FETCH DTLAR SH	1.92	0.02
DTS PSIZE	1.93	0.02
FETCH DTS BDD	2.11	0.01
DTLAR PSIZE	2.11	0.01
FETCH DTS SH	2.15	0.01
FETCH DTLAR BDD	2.17	0.01
FETCH DTLAR PSIZE	2.18	0.01
FETCH BDD	2.20	0.01
FETCH DTS PSIZE	2.32	0.01
FETCH SH	2.38	0.01
DTLAR DTLS	2.39	0.01
FETCH PSIZE	2.39	0.01
DTLAR DTS	2.51	0.01
DTLAR AC	2.54	0.01
DTLAR SH	2.55	0.01
DTLAR BDD	2.65	0.01
DTS BDD	2.65	0.01

Appendix 4.5 continued…

Appendix 4.5 continued…

Best and Competitive Models	ΔAIC_c	w_i
DTS DTLS	2.70	0.01
DTLS BDD	2.74	0.01
AC SH	2.86	0.01
DTS SH	2.87	0.01
DTS AC	2.89	0.01
DTLS AC	2.97	0.01
AC BDD	3.02	0.01
DTLAR DTS PSIZE	3.04	0.01
FETCH DTLS AC	3.05	0.01
AC PSIZE	3.14	0.01
DTLS PSIZE	3.15	0.01
FETCH AC SH	3.20	0.01
DTLS SH	3.35	0.01
BDD SH	3.37	0.01
FETCH DTLS BDD	3.41	0.01
FETCH AC BDD	3.47	0.01
PSIZE BDD	3.47	0.01
FETCH AC PSIZE	3.53	0.01
PSIZE SH	3.63	0.01
DTS DTLS PSIZE	3.66	0.01
DTLAR DTLS PSIZE	3.69	0.01
FETCH DTLS PSIZE	3.73	0.01
DTS PSIZE SH	3.80	0.01
FETCH DTLS SH	3.81	0.01
DTLAR AC PSIZE	3.84	0.01
DTLAR AC SH	3.85	0.01
DTS AC PSIZE	3.87	0.01
DTLAR PSIZE SH	3.90	0.01
DTS PSIZE BDD	3.94	0.01
DTLAR DTLS BDD	3.99	0.01

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model.

Appendix 4.6. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 2001 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
BDD	0.00	0.06
BDD SH	0.23	0.06
BDD AC	0.41	0.05
BDD DTLS AC	0.64	0.05
BDD DTLS	0.67	0.04
BDD SH DTLS	0.94	0.04
BDD DTLAR	1.18	0.03
BDD SH DTLAR	1.33	0.03
BDD DTLS DTLAR	1.34	0.03
BDD DTS	1.58	0.03
BDD FETCH	1.76	0.03
BDD SH AC	1.91	0.02
BDD AC DTLAR	1.95	0.02
BDD PSIZE	2.09	0.02
BDD SH DTS	2.13	0.02
BDD DTLS DTS	2.16	0.02
BDD SH FETCH	2.22	0.02
BDD AC DTS	2.29	0.02
BDD AC FETCH	2.32	0.02
BDD SH PSIZE	2.36	0.02
BDD AC PSIZE	2.53	0.02
BDD DTLS FETCH	2.55	0.02
SH	2.74	0.02
SH DTLS	2.77	0.02
BDD DTLAR FETCH	2.78	0.02
BDD DTLS PSIZE	2.80	0.02
BDD DTS FETCH	2.92	0.01
BDD DTS DTLAR	3.00	0.01
BDD DTLAR PSIZE	3.30	0.01
SH DTLS DTLAR	3.63	0.01
BDD DTS PSIZE	3.66	0.01
BDD FETCH PSIZE	3.68	0.01
DTLS AC	3.78	0.01

Appendix 4.6 continued…

Appendix 4.6 continued…

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.

Appendix 4.7. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 2002 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
BDD DTLS	0.00	0.09
BDD	0.30	0.08
BDD AC SH	0.44	0.07
BDD AC	0.69	0.07
BDD DTLS AC	0.98	0.06
BDD DTLS PSIZE	1.49	0.04
BDD DTLS SH	1.83	0.04
BDD SH	1.88	0.04
BDD DTLS FETCH	2.00	0.03
BDD DTLS DTLAR	2.04	0.03
BDD PSIZE	2.06	0.03
BDD DTLS DTS	2.16	0.03
BDD DTS	2.36	0.03
BDD FETCH	2.41	0.03
BDD DTLAR	2.42	0.03
BDD AC PSIZE	2.53	0.03
BDD AC FETCH	2.74	0.02
BDD AC DTLAR	2.83	0.02
BDD AC DTS	2.85	0.02
BDD SH PSIZE	3.73	0.01
BDD PSIZE DTS	3.76	0.01
BDD SH DTS	3.94	0.01
BDD SH DTLAR	4.03	0.01
BDD SH FETCH	4.05	0.01

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.

Appendix 4.8. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 2003 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
FETCH	0.00	0.06
FETCH SH	0.03	0.05
SH DTS	0.72	0.04
FETCH SH DTS	1.15	0.03
FETCH SH PSIZE	1.20	0.03
FETCH SH BDD	1.33	0.03
FETCH BDD	1.43	0.03
FETCH PSIZE	1.48	0.03
FETCH DTS	1.80	0.02
SH PSIZE	1.82	0.02
NULL	1.97	0.02
FETCH DTLS	1.98	0.02
SH	2.02	0.02
FETCH SH AC	2.03	0.02
DTS	2.05	0.02
FETCH AC	2.07	0.02
FETCH DTLAR	2.07	0.02
FETCH SH DTLAR	2.16	0.02
FETCH SH DTLS	2.17	0.02
SH DTS BDD	2.25	0.02
PSIZE	2.25	0.02
SH DTS PSIZE	2.50	0.02
FETCH PSIZE BDD	2.54	0.02
SH PSIZE BDD	2.75	0.01
SH DTS AC	2.75	0.01
SH DTS DTLAR	2.81	0.01
SH DTS DTLS	2.89	0.01
FETCH DTS BDD	3.30	0.01
PSIZE BDD	3.43	0.01
FETCH BDD DTLS	3.44	0.01
FETCH BDD DTLAR	3.49	0.01
FETCH PSIZE AC	3.51	0.01
FETCH PSIZE DTLS	3.51	0.01
FETCH BDD AC	3.55	0.01
FETCH DTS PSIZE	3.61	0.01
FETCH PSIZE DTLAR	3.65	0.01

Appendix 4.8 continued…

Appendix 4.8 continued…

Best and Competitive Models[a]	ΔAIC_c	w_i
BDD	3.69	0.01
DTLS	3.69	0.01
BDD SH	3.69	0.01
DTS PSIZE	3.71	0.01
BDD DTS	3.72	0.01
SH AC	3.79	0.01
SH PSIZE AC	3.84	0.01
FETCH DTS AC	3.84	0.01
FETCH DTS DTLS	3.87	0.01
SH PSIZE DTLS	3.89	0.01
DTLAR	3.90	0.01
FETCH DTS DTLAR	3.91	0.01
SH DTLS	3.99	0.01
SH PSIZE DTLAR	4.00	0.01
SH DTLAR	4.01	0.01
DTS DTLS	4.02	0.01
DTS AC	4.02	0.01
AC	4.05	0.01

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island; NULL = intercept-only model.

Appendix 4.9. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 2004 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
SH BDD AC	0.00	0.35
SH BDD DTLAR	1.56	0.16
SH BDD	1.74	0.14
SH BDD FETCH	3.33	0.07
SH BDD PSIZE	3.62	0.06
SH BDD DTS	3.75	0.05
SH BDD DTLS	3.80	0.05

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.

Appendix 4.10. Modeling results looking for factors influencing dusky Canada goose nest success on artificial nest islands in 2005 on the western Copper Delta, Alaska, USA.

Best and Competitive Models[a]	ΔAIC_c	w_i
DTLS DTLAR BDD	0.00	0.22
DTLS DTLAR	1.18	0.12
DTLS DTLAR PSIZE	2.06	0.08
DTLS DTLAR DTS	2.19	0.07
DTLS DTLAR SH	2.89	0.05
DTLS DTLAR FETCH	3.00	0.05
DTLS DTLAR AC	3.30	0.04
DTLAR BDD	3.96	0.03
DTLS BDD	3.99	0.03

[a] DTS = distance from the island to the nearest shore; FETCH = distance from the island to shore in the direction of the prevailing wind (112.5° angle); PSIZE = area of the island pond; AC = percent aerial shrub cover of the island, consisting of sweetgale, alder and/or willow; SH = average shrub height on the island (meters); DTLS = distance from the island to the nearest large slough; DTLAR = distance from the island to the nearest known larid nest or colony; BDD = indicated number of breeding dusky geese per square kilometer near the island.