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Reproductive Ecology and Habitat Use of Pacific Black Scoters (*Melanitta nigra americana*) Nesting on the Yukon-Kuskokwim Delta, Alaska

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Abstract.—Abundance indices of Black Scoters (*Melanitta nigra americana*) breeding in Alaska indicate a long-term population decline without obvious cause(s). However, few life history data are available for the species in North America. In 2001-2004, information was collected on nesting habitat and reproductive parameters (i.e. components of productivity) from a population of Black Scoters nesting on the Yukon-Kuskokwim Delta, Alaska. A total of 157 nests were found over four years. Primarily, nests were among dense vegetation in shrub edge habitat, predominantly dwarf birch (*Betula glandulosa*) and Alaska spiraea (*Spiraea beauverdiana*), an average of 58 m from water. Females initiated nests from 11 June and 17 July across years. Clutch size averaged 7.5 eggs and did not vary annually. Nest success was highly variable among years and ranged from 0.01 to 0.37. Duckling survival to 30 days old varied among years, and ranged from 0.09 - 0.35. Nest success was poor in three of four years, likely due to predation by Red Fox (*Vulpes vulpes*). Black Scoters appear to have low but variable productivity, consistent with life-history patterns of other sea duck species. Information gained will direct future demographic research on Black Scoters, and highlights knowledge gaps impeding management strategies needed for population recovery. *Received 10 June 2009, accepted 17 December 2009.*

Key words.—Alaska, Black Scoter, duckling survival, habitat selection, initiation date, *Melanitta nigra*, nest success, sea duck, Yukon-Kuskokwim Delta.

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Black Scoters (*Melanitta nigra*) are sea ducks distributed throughout the palearctic (*M. n. nigra*) and nearctic (*M. n. americana*) regions. In North America, two geographically distinct populations are recognized and distinguished by their allopatric Pacific and Atlantic distributions (Bordage and Savard 1995). The Pacific population breeds primarily in three regions of western coastal Alaska that include the Bristol Bay Lowlands, the Yukon-Kuskokwim Delta (YKD) and Kotzebue Sound. Indices based on counts of breeding scoters in Alaska (i.e. Black, Surf [*M. perspicillata*] and White-winged [*M. fusca*]) from the North American Waterfowl Breeding Pair Survey have indicated a substantial decline (estimated -40% population size change from 1957-1994; Hodges *et al.* 1996) in recent decades; specifically, in the upland tundra strata where Black Scoters predominate, the average annual rate of decline was -2.2% from 1977-1998. Factors that may contribute to the decline are unknown, largely because little biological information is available for the species. Biological data has been difficult to collect because Black Scoters breed in remote locations at low densities and winter offshore in areas that are seldom accessible. Moreover, Black Scoters nest later than most waterfowl species (Bordage and Savard 1995) and are rarely encountered during studies of other waterfowl; few

nests have been previously found in North America (Bordage and Savard 1995).

The YKD is used by a major proportion (~50%) of Black Scoters breeding in Alaska (Stehn *et al.* 2006). Opportunistic observations identified an area on the YKD where Black Scoters appeared sufficiently abundant to facilitate a multi-year breeding ecology study; in particular, the study was focused on two objectives that are listed as priority management needs (SDJV Management Board 2008). The first objective was to characterize nesting habitat at a finer scale (e.g. third-order selection; Johnson 1980) than is currently described by aerial observation (i.e. tundra strata; Hodges *et al.* 1996). The second objective was to obtain estimates of components of productivity that included clutch size, nest survival and duckling survival.

Historic descriptions of nest site attributes were limited to anecdotal evidence from only a few scattered nests on the YKD (e.g. tall and short graminoid habitat near tidal sloughs and rivers; Bellrose 1980; Bordage and Savard 1995), underscoring a need for more detailed baseline information. Distinctive cues to nesting habitat are necessary for further study of Black Scoter breeding ecology on a landscape level. Locating nests for this species, as for many other sea ducks, is largely accomplished through ground based searches (e.g. Grand and Flint 1997; Wilson *et al.* 2007; Schamber *et al.* 2009).

Annual productivity is an important component of recruitment (Johnson *et al.* 1992) and has potential to influence population growth (Hoekman *et al.* 2002; Flint *et al.* 2006a). Current trend estimates of Black Scoters are derived from long-term aerial surveys in Alaska. However, interpretation of population trends is limited without congruent demographic information that allows managers to differentiate among potential causes of apparent trends. Given some indication of causal effects, managers can alter extrinsic factors linked to demographic rates in order to increase population abundance; for example, removal of predators can enhance productivity of waterfowl (Garrettson and Rohwer 2001; Pearse and Ratti 2004). Thus, estimates of annual productivity of Black Scoters are necessary to help identify factors limiting their population and develop management strategies to reverse the current population trajectory.

METHODS

Study Area

The study was conducted at Aropuk Lake (AL; 61°07'N, 163°53'W) on the YKD (Fig. 1) from 2001 through 2004; the selection was based on historic aerial survey distributions of pre-breeding pairs and broods (B. J. McCaffery pers. comm.; Yukon Delta National Wildlife Refuge). The area was ~155 km^2 along the western portion of AL, most of which is in the Clarence Rhode National Natural Landmark. AL is a shallow freshwater lake of ~150 km^2 and connects to a large tidal inlet through a series of channeled lakes approximately 70 km inland from the Bering Sea coast. Timing of snow and ice melt varies annually, but typically occurs in early to mid-May. Accordingly, annual water levels of AL also are variable dependent upon the total spring snowmelt. The maximum lake depth in spring is ~2.5 m, but the lake typically undergoes a significant draw-down over the summer months. AL is not influenced by tidal changes, although wind-driven fluctuations in water level are common and often cause extremely shallow to dry conditions along the upwind side of the lake's fringe. Ambient air temperatures during the summer months fluctuate between 5 and 30°C.

Habitat surrounding AL is characterized by three general types: 1) dry upland tundra interspersed by variably sized lakes; 2) lower elevation, wet graminoid/forb marshes interconnected by an extensive system of drainages; and 3) dense, dwarf shrub vegetation that varies in breadth from 2-20 m and delineates the transitional edge (e.g. along palsa sides, drainages and lake margins) between dry (upland tundra) and wet (marsh) habitats. Dry upland habitat consists of lichens (*Cladonia* spp.), moss (*Aulacomnium, Hylocomium*), Cloudberry (*Rubus chamaemorus*), Crowberry (*Empetrum*

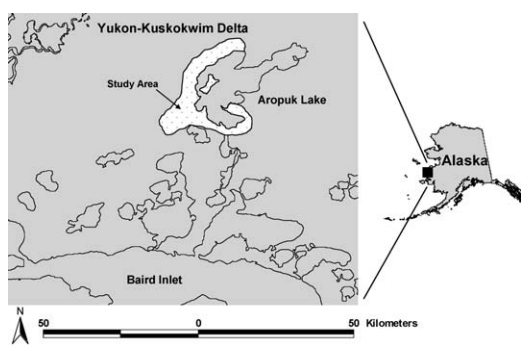

Figure 1. Location of Aropuk Lake study area for breeding ecology study of Black Scoters on the Yukon-Kuskokwim Delta, Alaska, USA. The stippled areas denote the ~155 km^2 area where the study was conducted.

nigrum), Bearberry (*Arctostaphylos rubra*), Bog Cranberry (*Oxycoccus oxycoccus*), Arctic Sweet Coltsfoot (*Petasites frigidus*) and Labrador Tea (*Ledum groenlandica*). In shrub edge habitat, vegetation consists primarily of Alaska Spiraea (*Spiraea beauverdiana*), Dwarf Birch (*Betula glandulosa*), Willow (*Salix* spp.), Red Alder (*Alnus rubra*) and dwarf Dogwood (*Cornus canadensis*). Finally, marsh habitat and associated drainages are quite varied with regard to vegetation composition. Dominant vegetation includes low-lying, wet sedges (*Carex* spp.) and grasses (*Calamagrostis* spp.), but also emergent plants that include Marsh Cinquefoil (*Potentilla palustris*), Sphagnum Moss (*Sphagnum cymbilifolium*), Field Horsetail (*Equisetum arvense*) and Buckbean (*Menyanthes trifoliata*). Portions of this habitat also have areas with higher elevations that allow shrubs, such as Alaska Spiraea, Dwarf Birch and Willow to exist.

Nesting Habitat

In 2003 and 2004, a random plot design was used to quantify third-order habitat selection (the selection of habitat within a home range; Johnson 1980) of Black Scoters. ArcView GIS 3.3 software (Environmental Systems Research Institute, Redlands, California, USA) was used to generate and randomly distribute 30 plots (400 × 800 m) each year on a geo-referenced raster image of the AL study area. The random design allowed unbiased representation of ≥1 of the AL broad habitat classifications in each plot. Observers located plot boundaries on the ground and searched each habitat type with equal intensity for Black Scoter nests. For each nest found, observers collected habitat data and nesting information (see below). Nesting habitat was described by: 1) recording broad habitat type (i.e. dry upland tundra, edge shrub or marsh), 2) recording percent cover of the four dominant vegetation species within a 1 m lateral radius of the nest bowl, and 3) visually approximating distance to the nearest water. All GPS locations of nests were plotted on the study area image. ArcView was used to generate random points in plots that contained Black Scoter nests and recorded habitat type where points were located.

Nesting

In 2001, nests were searched for on foot, beginning in mid-June around lakeshores and drainages in graminoid micro-habitat, following historic habitat descriptions (Bellrose 1980; Bordage and Savard 1995). However, ~2 weeks of searching this habitat failed to yield any Black Scoter nests. In late June, a Black Scoter hen was inadvertently flushed out of dense vegetation in shrub edge habitat ~70 m from the nearest pond, and subsequently her nest of three undeveloped eggs was located. Ensuing searches were focused in the shrub edge habitat and further refined the search technique that was used to locate nests in 2001-2004. From mid-June until late July, six to eight observers worked in tandem to systematically search shrub edge habitat within the study area. Paired observers aligned themselves along opposing sides of drainages and connected water bodies, and moved on foot through shrubs to search for nests. Because nests were difficult to discover visually, observers used a 1.5 m pole to disturb vegetation across the breadth of edge habitat with the intent of flushing attending females to increase nest detection. A Black Scoter nest was defined as a depressed bowl that contained either eggs or identifiable down and contour feathers. All drainages and connecting pond/lake edges were searched for nests within the study area at least twice each year.

When a nest was found, the position was recorded using a handheld global positioning system (GPS) unit and a color infrared photo of the study area. In addition, the date the nest was found, number of eggs present, stage of embryonic development in eggs (as determined by candling; Weller 1956), and nest status (i.e. laying, incubating, failed or hatched) were recorded. As well, habitat data were recorded as described above. Clutch size was defined as the number of eggs surviving to incubation. Nests were considered successful if ≥1 egg hatched, indicated by the presence of either ducklings or egg membranes in the nest bowl. Nest initiation dates were calculated for nests found during egg-laying by subtracting 1 d from the date found for each egg laid. However, nest initiation dates for nests that were found during incubation were calculated in two ways, dependant upon nest fate for nests that: 1) hatched, initiation dates were calculated by subtracting an assumed average 27 d incubation period (calculated from successful nests as days between cessation of egg laying and hatch, based on candling and nest visits) plus clutch size (i.e. 1 egg = 1 d) from hatch date; and 2) failed, date was calculated by subtracting the estimated age of eggs (based on stage of embryonic development) plus clutch size from date found. Nests that were potentially abandoned due to observer activity (N = 6), dump nests (N = 1; 13 eggs) and those found after hatching or failure (N = 40) were excluded from all analyses. In 2001 and 2002, nests found during laying or incubation were revisited at 7 d intervals until nests either failed or hatched. Observer effects (e.g. higher predation rates) were assumed minimal because of infrequent nest visits (Olson and Rowher 1988); however, due to small sample size, this potential bias was unable to be assessed. Nest success was extremely low in three of four years of this study (see results). Thus, in 2003 and 2004 disturbance to nesting females was minimized by delaying the first revisit to an estimated 21 d of incubation; nests were revisited at this stage to determine nest status (incubating or failed) and to more precisely estimate hatch date by candling eggs. Nests were also revisited a final time near hatch. Daily nest survival was monitored by recording incubation temperature using HOBO® temperature data loggers (Flint and MacCluskie 1995). When nests were first discovered, data loggers were buried in watertight containers approximately 1.5 m outside the nest bowl. A 2 m length of thermistor cable with a temperature probe was connected to the loggers and the probe placed amongst the eggs inside the nest bowl. Temperature data were uploaded to a computer and were visually inspected for failed nests. Nest failure was assumed to have occurred on the date that temperatures began to consistently record ambient temperature.

The apparent low nest success was likely due to high predation rates; therefore, cameras and micro-switch triggers were placed at a sample of nests to capture predation events (Anthony *et al.* 2006). In 2002, cameras that were tethered to a false-egg trigger placed among the eggs in the nest bowl were hidden near 22 Black Scoter nests. Additionally, in 2003, 23 artificial nests were constructed at former nest locations (2001-2002) using down collected from Black Scoter nests in 2002. At each nest, a camera was hidden and the false-egg trigger was placed in the nest bowl along with six farm-laid duck

eggs. Artificial nests were revisited at 7 d intervals in 2003 to record nest status, similar to the visitation schedule in 2001-2002. All photos were inspected from each camera for evidence of a nest predator.

Within three days of eggs hatching in each year, females were trapped on their nest using dip-nets and were fitted with a USGS metal tarsal band and an external prong-glue VHF transmitter to assess duckling survival (Pietz *et al.* 1995). Nests were inspected after broods departed and the number of egg membranes remaining in the nest bowl was counted to determine initial brood size. Radio-marked females were relocated every three days and the number of ducklings remaining in each brood was counted until 30 days after hatch. Radio-marked females were relocated using hand-held yagi-antennas while they remained on the study area and from fixed-wing aircraft if they had moved outside of the study area. Random variation in error was assumed to be associated with brood counts (Flint *et al.* 1995). Additionally, the mean number of ducklings per hen was used as the duckling count for three radio-marked broods that were observed in a crèche. The behavior or survival of hens was assumed to have been unaltered by the use of radio-transmitters (Paquette *et al.* 1997); which otherwise may have artificially lowered duckling survival.

Analyses

Habitat. A chi-square test of homogeneity in SAS (v.8.0, SAS Institute 2003; PROC FREQ) was used to test for equal proportions of plot nests and random points in the three habitat types. In addition, the proportion of habitats within plots was calculated using the Spatial Analyst extension in ESRI® ArcMap™ 9.2 and a test of homogeneity was used to test for equal proportions of habitat that contained random points and available habitat. Dominant nest site vegetation is presented as the proportion of species over total coverage at each nest across years (Grand *et al.* 1997). A general linear model in SAS (PROC GLM) was used to examine annual variation in distance of nests from water.

For analyses of nest survival and duckling survival, Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham and Anderson, 2002) was used to rank models within a candidate model set. Model weights (w_i) were calculated as evidence of relative model importance. Additionally, the sum of AIC_c weights was used for all models that included a parameter of interest (hereafter; parameter weight) as the basis for statistical inference regarding individual parameters. To account for model-selection uncertainty among model sets, model-averaged estimates were calculated across all candidate models within a set. Standard errors were estimated for model-averaged estimates by performing 500 bootstrap-resample simulations of the data in SAS.

Nesting. General linear models in SAS were used to examine annual variation in initiation dates and clutch sizes. Only two factors, year and initiation date, were considered when constructing models of clutch size because of sample size limitations in the data set. Thus, all permutations of the global model which included year + year x initiation date, as well as an equal means model (null) were compared. AIC_c was used to select the most parsimonious model among models in the candidate set.

Daily survival rate of nests (DSR_{NS}) was estimated using the nesting model (Dinsmore *et al.* 2002) in program MARK (v. 4.3, White and Burnham 1999), and nest success was calculated as the product of DSR_{NS} across the nesting period of 35 d (average 8 d laying + 27 d incubation). The fit of five candidate models was compared using AIC_c to examine temporal variation in DSR_{NS} across the nesting period (i.e. initiation through hatch) among years. Models were considered for which each year's DSR_{NS}: 1) was constant over the nesting interval (*S.* - i.e., Mayfield nest success); 2) was time invariant, but varied among years (S_{YEAR}); 3) included a linear trend across the nesting interval ($S_{YEAR+AGE}$); or 4) showed a quadratic trend over the nesting interval ($S_{YEAR+AGE+AGE^2}$) (Dinsmore *et al.* 2002). The fifth model included an initiation date covariate ($S_{YEAR+AGE+ID}$) added to the best model of those initially considered; a seasonal decline in nest success was detected in other sympatric nesting ducks on the YKD (Flint and Grand 1996; Grand and Flint 1997; Flint *et al.* 2006a; Schamber *et al.* 2009). A logit-link function was used to constrain estimates of DSR_{NS} between 0 and 1 (Lebreton *et al.* 1992). Also, a variance inflation factor ($\hat{c}$) was not estimated because MARK does not include a goodness-of-fit test for nest survival data (Dinsmore *et al.* 2002).

Duckling survival. The known-fates model in program MARK with a logit-link was used to examine duckling DSR_{DS}, and duckling survival was calculated as the product of DSR_{DS} across 30 days. Two factors, year and duckling age, were considered in comparative models: 1. DSR_{DS} varied with year and was invariant with age (S_{YEAR}); 2. DSR_{DS} varied with year and exhibited a geometric trend (see below) with age ($S_{YEAR+GAGE}$); and 3. DSR_{DS} was constant among years and showed a geometric trend with age (S_{GAGE}). The fit of a hatch date covariate to the best model ($S_{YEAR+GAGE}$) was tested because later hatching ducklings tend to survive less well (Grand and Flint 1996; Flint *et al.* 2006b). Models where DSR_{DS} showed a linear trend over duckling age were not considered; rather, it was assumed that DSR_{DS} changed in a geometric manner (Gunnarsson *et al.* 2004; 2006). However, the slope that best fit the data was assessed using the equation, $DSR_{DS} = A \times (1 - x^2)$, where A = age at which DSR asymptotes (assumed to be 30 days), x = a constant non-linear slope parameter varying from 0.5 to 0.9 and a = duckling age varying from 1 to 30 (Gunnarsson *et al.* 2004; 2006). Because MARK does not support goodness-of-fit tests for known-fate models, the lack of independence among brood mates was accounted for by estimating the amount of over-dispersion (i.e. $\hat{c}$) in the sample using Winterstein's (1992) second goodness-of-fit test. The test was calculated as the ratio of the sum of individual chi-square statistics from each broods' observed and expected number surviving (based on the annual 30-day survival estimates) to the total number of broods across years (Chouinard and Arnold 2007).

RESULTS

Nesting Habitat

Seventeen Black Scoter nests were located on random plots: three in 2003 and 14 in 2004. Thus, a total of 17 random locations

were generated that were paired with nests found within plots. Of these, ten points occurred in upland habitat, three in shrub edge and four in marsh. Random points were distributed among habitat types in equal proportion to habitat availability (χ^2_2 = 0.25, P > 0.88); which was 63% upland tundra, 13% shrub edge and 24% marsh. Black Scoter nests were distributed disproportionate to random points (χ^2_2 = 17.26, P < 0.01), suggesting non-random habitat selection. No nests were located in upland tundra, but 14 nests were found in shrub edge and three nests were located in marsh; however, nests in marsh habitat also were associated with shrubs.

Qualitative measures of nest site characteristics indicated that females preferred sites located in shrub edge habitat among dense shrubs associated with palsa sides, drainages, dry lake basins and lakeshores. In the four years of the study, 148 nests were located in shrub edge habitat and nine nests within marsh habitat; eight nests within marsh habitat were located in shrubs, and one nest was in tall grass. Vegetation at nest sites was composed predominantly of two species of shrubs: Alaska Spiraea (0.32 ± <0.01 [SE]) and Dwarf Birch (0.31 ± <0.01), but also included grasses (0.12 ± <0.01) and Willow (0.08 ± <0.01). The remaining 17% of nesting cover was comprised of 18 other understory plant species; each plant species was <0.04 of total cover. Mean distance (58.00 m; 95% CL: 47.00 m, 69.00 m) from nests to the nearest water body was similar among years (F_3 = 1.68, P = 0.17); although females nested farther from water in 2001 (77.00 m ± 11.69 [SE]) than in 2004 (45.00 m ± 10.20; P = 0.04). Most females nested at a distance from water between 10 to 150 m; however, some females nested as close as 0.05 m (N = 5) and as far as 300 m (N = 5).

Initiation Date, Clutch Size and Predator Identification

One hundred and fifty seven Black Scoter nests were located at AL (2001-2004; ~40 h of searching × nest^{-1}), but only nests found active in each year were used to calculate initiation dates, clutch size, and to estimate nest success. Mean nest initiation dates varied among years (F_3 = 11.27, P < 0.01); birds initiated nests significantly later in 2001 than in 2002-2004 (Table 1). The most parsimonious model of clutch size variation included only initiation date (clutch size declined with date by 0.05 ± 0.01[SE] eggs day^{-1}) and received strong support (w_i = 0.83); however, the model poorly fit the data (r^2 = 0.10). Little support was found for annual variation in clutch size (parameter weight = 0.15; Table 2). Mean clutch size across years was 7.5 eggs (95% CL: 7.2, 7.6; Table 1). Clutch sizes ranged from four to ten eggs (with the exception of a single 13 egg clutch, which was considered a dump nest); however, most clutches contained seven to nine eggs.

Of the 45 nests monitored with cameras, 35 were depredated (17 in 2002 and 18 in 2003) with all eggs removed. Only seven of 45 cameras yielded a discernible image of a predator; all were Red Fox (*Vulpes vulpes*).

Table 1. Means and 95% CLs of productivity components that included initiation date, clutch size, nest success, and duckling survival from a breeding ecology study of Black Scoters nesting at Aropuk Lake on the Yukon-Kuskokwim Delta, Alaska.

	Year			
ATTRIBUTE	2001	2002	2003	2004
Active Nests	25	30	28	34
Initiation Date	30 June:28 June, 3 July	21 June:18, 23 June	23 June:21, 25 June	24 June:22, 26 June
Clutch Size	7.8:7.3, 8.3	7.3:6.9, 7.7	7.4:7.0, 7.8	7.4:7.1, 7.8
Nest Success	0.08:0.00, 0.17	0.05:0.02, 0.08	0.02:0.00, 0.05	0.37:0.20, 0.54
Duckling Survival	0.28:0.17, 39	0.09:0.02, 0.16	0.35:0.18, 0.52	0.15:0.12, 0.18

Table 2. Akaike Information Criterion (AIC_c) adjusted for small sample for models of clutch size, nest survival, and duckling survival of Black Scoters on the Yukon-Kuskokwim Delta, Alaska. Also included are the number of model parameters (K), the difference in AIC_c score between each model and the best model (Δ_i), the likelihood of each model in a set (w_i), and model fit (r^2).

Model	K	AIC_c	Δ_i	w_i	r^2
Clutch Size					
initiation date	3	8.38	0.00	0.83	0.10
year, initiation date	6	11.80	3.41	0.15	0.13
null	2	17.27	8.89	<0.01	0.00
year, initiation date, year*initiation date	9	17.54	9.16	<0.01	0.14
year	5	23.60	15.22	<0.01	<0.01
Nest Survival					
year, nest age	5	380.87	0.00	0.39	
year	4	381.71	0.83	0.26	
year, nest age, initiation date	6	382.46	1.59	0.18	
year, nest age, quadratic nest age	6	382.73	1.85	0.15	
constant DSR	1	394.62	13.74	<0.01	
Duckling Survival					
year, geometric age trend, hatch date	6	260.04	0.00	0.51	
year, geometric age trend	5	260.68	0.64	0.37	
constant DSR, geometric age trend	2	263.09	3.05	0.11	
year	4	281.29	21.25	<0.01	

Nest Survival

Few nests survived to hatch in 2001-2003 (six, seven and two, respectively), but nearly half (15) survived in 2004. In the analysis of nest survival, the strongest support was found for a DSR_{NS} model of ($S_{YEAR+AGE}$; Table 2). In this model, DSR_{NS} increased with nest age (0.03 ± 0.01 [SE]); however, the effect size was poorly estimated (95% CL: -0.01, 0.06). Three lower ranked models (S_{YEAR}), ($S_{YEAR+AGE+ID}$), and ($S_{YEAR+AGE+AGE^2}$) also received strong support (ΔAIC_c<2.0) to compete with the top model (Table 2). However, evidence was weak for an initiation date effect (parameter weight = 0.18) or a non-linear trend in nest age (parameter weight = 0.15). A model of constant DSR_{NS} ($S_.$) received weak support (parameter weight <0.01) (Table 2), but estimated Mayfield nest success in each year as 0.07 (95% CL: 0.01, 0.18), 0.04 (0.01, 0.11), 0.01 (<0.01, 0.06), and 0.35 (0.16, 0.55) for 2001-2004, respectively. Nest success (DSR_{NS}^{35}) was calculated for each year based on model-averaged estimates of DSR_{NS}. Nest success was below 0.10 in 2001-2003, but was >0.35 in 2004 (Table 1).

Duckling Survival

Survival was monitored for 42 ducklings from six broods each in 2001 and 2002, twelve ducklings from two broods in 2003, and 42 ducklings from seven broods in 2004. Three broods, with ≥1 surviving duckling, survived to 30 days post-hatching in 2001, two broods survived in 2002 and 2004, and only one brood survived in 2003. Some evidence was found for lack of independence in survival among brood mates ($\hat{c}$ =1.58), and therefore, model selection criteria ($QAIC_c$) and sampling variance of all models were adjusted accordingly. In the analysis of variation in duckling survival, the best DSR_{DS} model ($S_{YEAR+GAGE+HD}$) received relatively strong support (w_i = 0.51; Table 2). In this model, DSR_{DS} showed a geometric trend of 0.05 and declined with date (-0.06 ± 0.03 [SE]), but effect size of hatch date was poorly estimated (95% CIs: -0.12, 0.01). The second-best model ($S_{YEAR+GAGE}$) competed well with the top model (ΔAIC_c <2.0; Table 2), providing further evidence for annual variation in DSR_{DS} and a geometric trend with duckling age. However, weak support was found for a DSR_{DS} model of S_{GAGE} (w_i = 0.11)

or S_{YEAR} (w_i <0.01; Table 2). Model-averaged 30-day duckling survival was highly variable among years; ranging from 0.08 to 0.34 (Table 1).

DISCUSSION

Black Scoters at AL preferred to nest away from water in habitat that provided nests with relatively high concealment. Thus, in the broad sense, they select sites similar to White-winged Scoters (Traylor *et al.* 2004; Safine and Lindberg 2008). However, in contrast to White-winged Scoters nesting in Alaska, which showed no evidence of nest site preference (Safine and Lindberg 2008), Black Scoters appeared to prefer a specific habitat type for nesting. Using a quantitative approach (i.e. nest plots), a high percentage (82%) of nests was found in shrub edge habitat in disproportion to habitat availability. The percentage of total nests found in shrub edge habitat was even higher (94%) but this was a product of unequal search intensity across habitat types. Black Scoters appeared to avoid dry upland tundra, which offers very little overhead or lateral concealment. A small number (N = 9) of nests were found in marsh habitat, although most (N = 8) of those nests were found in association with the same shrub species found in the edge habitat. Females nesting within shrub edge or marsh habitat preferred sites composed of ~70% woody, dense vegetation (i.e. spiraea, dwarf birch, willow) suggesting that concealment was important. The proximity of nests to water was highly variable, but on average was closer than was found for White-winged Scoters (Traylor *et al.* 2004; Safine and Lindberg 2008).

As suggested for White-winged Scoters (Traylor *et al.* 2004), Black Scoters likely selected solitary, well-concealed nest sites to increase the probability of nest survival (Crabtree *et al.* 1989; Clark and Shutler 1999) by lowering predation risk (Filliater *et al.* 1994). Nests at AL were highly dispersed (~1 nest × [2.6 km^2]$^{-1}$) and often located in areas less commonly patrolled by predators (e.g. near water; Brown and Fredrickson 1989), likely making active nest searches by predators less profitable. In addition, concealed nest sites appeared to be less vulnerable to predatory birds (e.g. gulls, jaegers) because dense nesting cover may have created a visual barrier to avian predators (Clark and Nudds 1991); which is consistent with evidence from nest remains at AL (Sargeant *et al.* 1998) that egg loss was unattributable to birds (see below). However, nest concealment was less likely to provide safety against terrestrial predators that may have relied on olfactory cues to detect cryptic nests (Colwell 1992) because Red Fox appeared to be responsible for most nest failure at AL.

Initiation dates were similar to earlier reports from the YKD (Bellrose 1980) and from Quebec, Canada (Savard and Lamothe 1991). Black Scoters were the latest waterfowl species to initiate nests on the YKD. Reasons for their delayed nesting chronology are unknown; but future study should focus on reproductive investment as a possible explanation.

Mean clutch size was similar to the clutch size reported for a small sample (N = 20) of nests found elsewhere on the YKD (7.7 ± 1.4 [SD]; Bordage and Savard 1995), but was smaller by ~1 egg on average than clutch sizes described for *M. n. nigra* in Iceland (8.7 ± 0.7 [SE]; Bengtson 1972). However, clutch size in this study may have been underestimated because partial clutch loss could not fully be accounted for. Approximately 15% of nests had clutches of <7 eggs and some fraction of these nests were likely partially depredated before nest discovery or contained a continuation clutch (partial clutch in successive nests resulting from egg loss during egg-laying in preceding nests). In contrast, Bengtson (1972) reported a separate clutch size ($\bar{x}$ = 6.1) for females that renested; however, because Black Scoters initiate nests late and therefore likely have a low renesting propensity, most of these nests were probably partial clutches. Thus, if clutch sizes from renests were included in calculations, mean clutch size in Bengtson's (1972) study would be similar to the estimate in this study. The inability to account for partial egg loss may also explain, in part, the seasonal decline in clutch size that was estimat-

ed in this study. However, this seasonal pattern was consistent with that observed in most other waterfowl species (Johnson *et al.* 1992).

Nest success of Black Scoters at AL varied among years and was similar to the annual variation in nest success found for Black Scoters in Iceland and sympatric nesting sea ducks on the YKD (Bengtson 1972; Grand and Flint 1997; Wilson 2006; Schamber *et al.* 2009). However, annual Mayfield estimates were much lower than those reported for Black Scoters in Iceland across nine years (range: 57.2-88.9; Bengtson 1972). At AL, predation was the apparent cause for most nest failure (~94%) of Black Scoters in all years, similar to that found for other sea ducks nesting on the YKD (Grand and Flint 1997; Wilson 2006; Schamber *et al.* 2009). Potential nest predators found at AL included: Red Fox, Mink (*Mustela vison*), Parasitic Jaeger (*Stercorarius parasiticus*), Glaucous Gull (*Larus hyperboreus*) and Mew Gull (*L. canus*). However, based on evidence at failed nests (Sargeant *et al.* 1998) Red Fox were the primary predator of Black Scoter nests. All eggs of the clutch were removed from all depredated nests in the study, which is characteristic of canids; in particular, Red Fox typically cache the entire clutch nearby the nest site, and very rarely eat eggs at the nest bowl (Sargeant *et al.* 1998). In addition, cameras placed at occupied nests only documented predation events by Red Fox. While evidence from depredated nests and photos are not definitive, and therefore, other species as predators cannot be excluded, the evidence strongly suggests that Red Fox were the most important nest predator of Black Scoters at AL and likely were responsible for much of the annual variation in nest success. For example, nest success was <0.10 in 2001-03, but increased significantly in 2004 possibly because of a natural reduction in Red Fox abundance; the carcasses of six Red Fox were found in the study area, which may have been indicative of a localized epizootic outbreak of rabies virus (Castrodale and Ritter 2003). Annual variation in nest success at AL may be correlated with apparent annual variation in local fox abundance.

Because nest success was poor in the first two years of the study, the effects of observers may have biased nest success estimates; nest success increased in a subsequent year when visitation frequency was reduced. Nest searching occurred through dense vegetation in shrub edge habitat that may have left physical pathways (Olson and Rohwer 1988) and scent trails (Götmark 1992) that could be followed by Red Fox. However, tracking these observer markers may have been unprofitable for predators because nests occurred at very low densities in the study area and required a significant time investment to locate; therefore, these trails likely were spatially and temporally difficult to follow. Further, 25% of nests were found depredated, suggesting that Red Fox was a successful predator in the absence of observers. Nonetheless, the possibility that nest success estimates were biased cannot be excluded; thus, results from this study should be interpreted cautiously and investigators are advised to consider potential observer impacts in future studies of Black Scoters.

The range of annual variation in duckling survival of Black Scoters was lower than that reported for ducklings across four years at Iceland (~35-60%; Bengtson 1972). Duckling survival averaged across years was higher than for sympatric nesting Long-tailed Ducks ([*Clangula hyemalis*] 0.10; Schamber *et al.* 2009) and was similar to or lower than estimates for other sea ducks on the YKD (Common Eiders [*Somateria mollissima*] 0.19; Flint *et al.* 1998, Spectacled Eiders [*S. fischeri*] 0.34; Flint and Grand 1997). However, estimates of Black Scoter duckling survival may be biased low if the assumption of no-effect from radio-transmitters was incorrect and the behavior or survival of hens was altered (Paquette *et al.* 1997); although data were insufficient to assess this potential bias in the study.

While numerous ecological factors likely contribute to duckling mortality (Johnson *et al.* 1992), these are difficult to determine and at AL mortality factors are unknown. However, a model of higher duckling mortality at young ages fits the data well, and agrees with the observed pattern in other ducks on

the YKD (Grand and Flint 1996; Flint and Grand 1997; Flint *et al.* 2006a; Schamber *et al.* 2009) and elsewhere (Hill and Ellis 1984; Savard *et al.* 1991; Hoekman *et al.* 2004). Thus, factors that influence mortality of young ducklings may be most important to duckling survival. As with many other waterfowl species (Talent *et al.* 1983; Flint *et al.* 2006b; Traylor and Alisauskas 2006), predation was likely a leading proximate cause of young duckling mortality at AL. Most mortality occurred when ducklings were small-sized, and therefore, ducklings were potentially vulnerable to multiple predator species (e.g. gulls, jaegers, mink, and fox). Predation risk and the array of possible predators are likely negatively associated with duckling size and age (Flint *et al.* 2006b); that is, larger, older ducklings may be at less risk to specific predator guilds (e.g. Larids). Also, predation risk may have been higher for young Black Scoter ducklings during brood movements from solitary nest sites to upland rearing-habitat immediately after hatch. Broods often traveled long distances (average 1.7 km by 10 days-of-age) across relatively open habitat, e.g. nearby drainages, which may have increased ducklings' exposure to predators. Brood movements have been associated with reduced duckling survival in other waterfowl studies (Ball *et al.* 1975; Rotella and Ratti 1992; Yerkes 2000); although this finding was not universal (Dzus and Clark 1997; Pöysä and Paasivaara 2006). As well, studies have hypothesized that other intrinsic or extrinsic factors such as maternal condition (Paasivaara and Pöysä 2007), inclement weather (Traylor and Alisauskas 2006), and variation in food resources (Gunnarsson *et al.* 2004) may compound the effects of predation or directly influence duckling mortality; but results are often inconsistent among studies (Johnson *et al.* 1992), which underscores the complexity of investigating duckling survival. Determining causal factors of duckling mortality at AL was hampered by an inability to model possible underlying correlates of duckling survival, and therefore, further study is needed to delineate ecological factors that may influence the survival of Black Scoter ducklings.

In this study, Black Scoters selected nest sites that provided high concealment and were frequently far from water, likely to lower predation risk. However, predation by Red Fox appeared to be the leading cause of high nest failure. Further, the estimated high mortality of young ducklings at AL likely also was due to high apparent predation rates. Accordingly, Black Scoters appear to have low, but variable productivity consistent with life histories of other sea duck species (Alisauskas *et al.* 2004; Schamber *et al.* 2009). Unfortunately, the lack of information on annual survival of adults precludes development of a simple population model that would provide an assessment of the relative influence of productivity on population growth. Notably, methods other than mark-recapture to estimate adult annual survival of Black Scoters should be explored because of difficulties marking a sufficient sample of individuals across years. The absence of a population model limits the development of management strategies that address the apparent decline in the Pacific population of Black Scoters. However, population models of sympatric nesting ducks have indicated that simultaneous changes to productivity and adult survival may be needed to change population trajectories (Flint *et al.* 1998; Flint *et al.* 2006a; Schamber *et al.* 2009). Therefore, management actions designed to increase productivity of Black Scoters in years with poor nest success or extremely low duckling survival would, in effect, reduce parameter variation and increase parameter means, thereby having a positive influence on population trends.

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