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ABSTRACT

In summer 2002, we completed the fourth season of a combined research program designed to assess the breeding ecology of Pacific Common Eiders (*Somateria mollissima v-nigra*) and molting ecology of Long-tailed Ducks (*Clangula hyemalis*) along the Beaufort Sea Coast of Alaska. An aerial survey component of the study was completed in 2000 and presented as a separate report. Our study area was split into an *industrial* area (the 'Western Area') and an undeveloped *control* area (the 'Eastern Area') based on a previous study design. Nesting effort by Common Eiders has declined each year of the study and was particularly low in 2002 (likely due to late ice breakup). Hatching success was extremely low in both the Eastern and Western Areas, due to predation by Arctic Foxes and Glaucous Gulls. Hatching success has varied considerably through the course of the study but has always been below that Pacific Common Eiders breeding on the Yukon-Kuskokwim (Y-K) Delta. No Common Eider broods tracked by radio-telemetry in 2000 and 2001 were known to fledge. Our mark-recapture study of adult female survival has been limited by low nesting effort and nest survival. We used radio-telemetry to study movement, habitat use, and feeding activity of molting Long-tailed Ducks. Analysis of triangulation data in 2000 and 2001 show that in general Long-tailed Ducks follow a diurnal pattern of feeding in the lagoons during the day and roosting along the barrier islands at night. Analysis of larger scale movement data collected by automated Data Collection Computers (DCC) in 2000-2002 shows a high degree of variability within and among areas and years. In 2002, movement between DCC sites was more likely in the Western Area than the Eastern Area and short distance movements (5km) were likely than longer movements. Weather (esp., wind) is suspected to play an important role in Long-tailed Duck movement, but not in feeding patterns. A study of body composition of molting Long-tailed Ducks was finished in 2002 as a Master's thesis at Auburn University and is a separate stand-alone report. Common Eiders and Long-tailed Ducks had lower concentrations of Pb in their blood than levels reported from sea ducks in the Y-K Delta. Se levels in eggs of Common Eiders were higher than other eider populations, but below toxic levels. The prevalence of the adenovirus isolated during a mortality event in 2000 was lower in 2001, but evidence of virus exposure remains higher in the Eastern Area. Further analyses of all data sets and planning for summer 2003 are ongoing.

GENERAL INTRODUCTION

The Alaskan Arctic Coastal Plain is home to the largest oil and natural gas discovery in North America (Gilders and Cronin 2000). Located primarily between the Colville and Sagavanirktok rivers on the North Slope of Alaska, this development spans an area approximately 30 x 100 km in size, with facilities occupying some 8,793 ha (Gilders and Cronin 2000). Recent expansion of oil and gas development into the near shore waters of the Beaufort Sea has raised concerns that wildlife using these waters (and the nearby barrier islands) may be at risk to disturbance and oil spills (US Army Corps of Engineers 1998). Of particular concern are more than one hundred thousand sea ducks and other marine birds that use the Beaufort Sea each summer (Johnson and Herter 1989, USFWS 1999). Impacts on sea ducks may be especially important given their recent declines in Alaska and along the Arctic Coastal Plain (Goudie et al. 1994, Suydam et al. 2000, USFWS 1999).

In 1999, the Mineral Management Services, in collaboration with the U.S. Geological Survey, began studies to describe the abundance and distribution of Long-tailed Ducks (*Clangula hyemalis*), eiders (*Somateria* spp.), and other marine birds in lagoons and offshore areas located adjacent to and away from industrial development. This study consisted of nearshore and offshore aerial surveys, and intensive ground-based studies focused on breeding Common Eiders (*Somateria mollissima v-nigra*) and molting Long-tailed Ducks. These latter studies monitor eiders and Long-tailed Ducks in more detail, and evaluate how species utilizing the lagoons during different stages of their breeding cycle may be affected differentially by industrialization. Here, we summarize ground-based results from the third season of Common Eider research and the fourth season of Long-tailed Duck research. The aerial survey results were completed and are presented separately (Fischer et al. 2001).

The objectives of the ground-based studies include:

Common Eiders

- 1) Document nesting activity by birds on barrier islands, particularly Common Eiders, and to compare these data to historic data summarized by Noel and Johnson (2000).
- 2) Examine life-history parameters (e.g., annual survival, productivity, and site fidelity) of Common Eiders in relation to the proximity of oil development and in comparison with Common Eiders breeding in other locations.
- 3) Develop a population growth model by incorporating levels of productivity and annual survival.
- 4) Use genetic markers to determine the geographic extent of discrete demographic units among Pacific Common Eiders.

- 5) Determine the prevalence of viruses and concentrations of selected contaminants in blood and eggs of nesting Common Eiders, and evaluate these parameters in relation to the proximity of oil development and year of study.

Long-tailed Ducks

- 1) Examine within-season site fidelity, local movement and feeding patterns of Long-tailed Ducks in relation to season, time of day, weather, and proximity to oil development.
- 2) Compare the duration and timing of the flightless period of molting Long-tailed Ducks in relation to the proximity of oil development.
- 3) Compare the dynamics of muscle mass and body composition of molting Long-tailed Ducks in relation to the proximity of oil development.
- 4) Determine the prevalence of viruses and concentrations of selected contaminants in molting Long-tailed Ducks, and compare results between 2000, when mortality of Long-tailed Ducks was observed near one of our two study areas (i.e., Flaxman Island), and subsequent years, when no mortality was observed.

STUDY AREA

This study was conducted at Simpson Lagoon (formed by the barrier island complex between Spy and Stump Islands), an unnamed lagoon to the east (formed by the Stockton, Maguire, and Flaxman island complexes), and the near-shore waters between these two lagoons (Figure 1). Simpson lagoon lies adjacent to oilfield production facilities (including Milne Point and Northstar) and is thus considered the *industrial* site (hereafter, the 'Western Area'). The lagoon to the east (the 'Eastern Area') is considered to be a comparable *control* site. In 2002, we moved our field camps from the barrier island sites used in previous years (i.e., Bodfish Island on the Eastern Area and Flaxman Island on the Western Area) to nearby mainland sites ('Gwydyr Bay Camp' on the Eastern Area and 'Pt. Thomson Camp' on the Western Area). Both of these new sites are on existing gravel pads (Gwydyr Bay South #1 and Pt. Thomson Unit #3), in locations that provide good access to our study sites with good protection for our boats. At each site we have placed a 20ft steel Conex shipping unit. These Conexes serve as secure onsite storage for our equipment during the winter (this eases our logistics significantly) and serves as a base of operations during the field season. This summer we removed all evidence of our presence on Bodfish and Flaxman Islands. We travel within the lagoon system in a Cessna 185 airplane with wheels (prior to ice break-up), and in 16 and 18-foot aluminum boats, and smaller inflatable rafts. In 2000 and 2001 we used an ATV to travel between Bodfish and West Long Islands. The study area includes the barrier islands that protect the lagoons and the adjacent waters of the lagoons and Beaufort Sea. Our 'control' area is not a true control in the sense that some limited development has occurred in the area. However, the development of

the Northstar oil production facility in the Simpson Lagoon in the winter of 1999 increased the absolute difference in disturbance levels between areas.

BREEDING ECOLOGY OF COMMON EIDERS

The Pacific race of Common Eiders (*Somateria mollissima v-nigra*) is of particular interest to resource managers for several reasons. First, along the North Slope of Alaska, Common Eiders nest and raise their broods almost exclusively on barrier islands (Johnson 2000). These islands may be impacted by existing and future offshore oil development. Two of the most productive islands, Egg and Stump, are bisected by an underwater oil pipeline or lie adjacent to the Northstar oil production facility. Accordingly, an understanding of the distribution of Common Eider nests across islands is essential to understand the potential impacts of an oil spill and to lessen the effects of future offshore oil development. Our first objective addresses this need by documenting nesting effort on several barrier islands located in the Eastern and Western Areas. Our nest records also provide continuity with the existing history of nest data collected by various non-governmental and governmental agencies over the years (see Noel and Johnson 2000).

Managers are also concerned about Common Eiders because of their recent decline in numbers (Hodges et al. 1996, Suydam et al. 2000). The Beaufort Sea population of Common Eiders is estimated to have declined by 53% from approximately 156,000 birds in 1976 to 72,600 birds in 1996 (Suydam et al. 2000). Reasons for this decline are unknown, but may be related to poor productivity and low adult survival. Clutch size, hatching success, and fledging success are important parameters for determining recruitment in waterfowl populations (Johnson et al. 1992). Coulson (1984) concluded that recruitment had a strong influence on Common Eider population dynamics in Britain. Milne (1974) demonstrated considerable annual variation in the proportion of ducklings surviving to fledging and linked years of high duckling survival to subsequent increases in population size. Estimates of the proportion of Common Eider ducklings surviving to fledging vary from 10% in Scotland to 24% in Nova Scotia (Milne 1974, Mendenhall and Milne 1985). Estimates of the number of ducklings fledged per female varied from 0.47 in the Netherlands to 0.89 in Finland (Hilden 1964, Swennen 1983). Thus, brood rearing may be a bottleneck in annual productivity, and low duckling survival may be a major determinant of recruitment. Information on adult annual survival is absent for North America but presumed to be high (Suydam et al. 2000). Estimates of adult mortality in Europe, however, vary from less than 10 to 39% per year (Boyd 1962, Paludan 1962, Swennen 1972). Thus low adult survival may also be contributing to the population decline. Accordingly, the second and third objectives of this study are to estimate productivity and adult survival of eiders and, using this information, develop a model to indicate whether the Beaufort Sea population of eiders is increasing or decreasing. Additionally, comparisons of productivity measures will be made between the Eastern and Western Areas.

We use a mark-recapture program to determine adult survival rates and to document nest site fidelity and local movements by females across years. High nest-site fidelity to particular islands has been documented previously (Cooch 1965, Reed 1975), as has

high natal philopatry by female young (Hollmén, unpubl. data). In concert, these life history traits have the potential to make eider colonies discrete demographic units, thus making colonies potentially vulnerable to oil spills. For example, if eider colonies on particular islands are distinct demographic units then recovery from the extirpation of eiders from one or more islands (e.g., due to an oil spill or some other human or natural event) would require re-colonization from other populations. Strong site fidelity and natal philopatry could make this a slow process. With our fourth objective we expect to determine the level of genetic isolation among Common Eider colonies.

BREEDING ECOLOGY OF COMMON EIDERS: METHODS

In all years of the study, we searched all islands from Brownlow Point through the Maguire Islands (Eastern Area) and from Stump to Spy Island (Western Area). Teams of observers searched islands by systematically examining all potential nesting cover in sufficient detail to detect nests not attended by females. Nest searches began as soon as incubation was detected during spot checks of suitable nesting habitat.

We recorded the exact location (determined by GPS) and habitat information (i.e., landform, distance to water, height above water, density, and size of driftwood within one meter) for all nests. Active nests were marked with a lathe placed 5m North of the nest bowl. We numbered and candled each egg to determine viability and stage of incubation (Weller 1956). Nests were revisited at irregular intervals to determine success. During each visit to a nest, we recorded the presence of the female, condition and number of eggs, and stage of incubation. After hatch, we visited nests and determined egg fates from nest contents. We subtracted depredated and unhatched eggs from the number of eggs laid into the nest to determine the number of ducklings produced. We calculated nest initiation dates by subtracting the estimated age of embryos, as determined by candling, plus the number of eggs laid into the nest, from the date of discovery. Alternatively, we back-calculated from known hatching dates to determine nest initiation. We used a 26-day incubation period and assumed one egg was laid each day prior to the start of incubation.

We used only nests with signs of embryonic development in the determination of nest initiation date and clutch size. We defined clutch size as the number of eggs laid into a nest, partial depredation as the number of eggs missing from nests that remained active, and successful nests as those in which at least one egg hatched. For all nests with known fates we determined the number of successful, depredated, abandoned, or destroyed (e.g., by ice, or flooding) nests. We used a Mayfield approach to estimate daily nest survival rates and nest success (Johnson 1979). Analysis of nest success did not include nests that were depredated, destroyed, abandoned, or hatched when first discovered.

We trapped females on nests before hatch using dipnets or a string-activated bownets (Sayler 1962). Captured females were weighed, the lengths of the culmen and total tarsus were measured, and blood and cloacal samples were collected. Birds were marked with metal U.S. Fish and Wildlife Service tarsus bands and in most instances with numbered colored tarsal bands. In 2000 and 2001, a sub-sample of females was

fitted with a 15-g subcutaneously anchored radio transmitter (Pietz et al. 1995), these females were then tracked to determine brood fate. Initial brood size was assumed to be equal to the number of eggs present in the nest on the last visit prior to hatch.

Brood fate was assessed by ground-based tracking in 2000 and a combination of aerial and ground-based tracking in 2001. Searches were conducted as weather and pilot availability allowed (all females were sought at least four times). Birds detected from the air were subsequently located from the ground to determine brood fate. Aerial searches were conducted along the mainland and barrier islands in the Western Area only, as no Common Eiders were equipped with radios in the Eastern Area in 2001. When a female was located, we determined whether the female had young and if so, how many. Females not detected from the air were assumed to have lost their brood. Our estimate of duckling survival rates is based on all visits combined over the entire study.

In 2002, we initiated a study of Common Eider genetics and population structure. We collected blood samples from captured females and feather samples from nests. These samples, as well as samples collected from other Common Eider populations in the Yukon-Kuskokwim (Y-K) Delta, AK and the Kent Peninsula, NWT, Canada were genotyped at five microsatellite DNA loci and compared for levels of genetic differentiation within and among populations.

BREEDING ECOLOGY OF COMMON EIDERS: RESULTS

In 2002, we found a total of 358 nests of all species (including 327 eider nests) across study areas. Of the eider nests, one was a King eider, 208 were Common Eider, and 118 were of unknown eider species (because neither females nor intact eggs were present; based on habitat characteristics these were likely Common Eider nests). A summary of nest counts by species and year is given in Table 1. Each year since the start of the study we have increased the nest search area. In the Eastern Area, we added the eastern portion of Stump Island to our search in 2001 and 2002. In the Western Area, we added five, small, sand spit islands adjacent to the mainland near Pt. Thomson in 2002. Although we have not systematically searched for nests on these sand spit islands in previous years, we believe this to be the first year of the study in which eiders have nested on them; ice break up was delayed this year and these islands provided the only nesting habitat with adjacent open water. We report nest counts for areas searched in all years separately from areas added in subsequent years. Of nests located in 2002, recently added areas accounted for 100 Common Eider, one King eider, and 32 unknown eider nests (Table 1). When we examine only the areas searched in all three years, we see a steady decrease in the total number of eider nests found in each year of the study (2000: 470, 2001: 301, 2002: 194). Similarly, the number of Glaucous gull nests has decreased since 2000 (2000: 66, 2001: 43, 2002: 12). A summary of 2002 nest counts by species and island is presented in Table 2.

Eider nests in the Eastern Area tended to be farther from water than in the Western Area (Eastern= 30.2m±3.2, $X \pm SE$, n=119; Western= 20.5m±0.9, n=208; Cochran

unequal variance t-test=2.88, $P < 0.05$). Nests in the Eastern Area tended to be lower, relative to the water line (Likelihood ratio $X^2 < 0.0001$) and they tended to have less driftwood within 1m (Likelihood ratio $X^2 < 0.01$). However, driftwood around the nests was larger than in the Western Area (Likelihood ratio $X^2 < 0.0001$). The height of driftwood and other vegetation northeast of nests (i.e., towards the prevailing wind direction) did not differ between areas (Eastern= $9.7\text{cm} \pm 1.2$, $X \pm SE$, $n=119$; Western= $11.9\text{cm} \pm 0.7$, $n=208$; Cochran unequal variance t-test= 1.58, $P=0.12$).

The distribution of nest initiation dates differed between the study areas (Wilcoxon Two-Sample Test = 4904, two-sided t approximation $P < 0.05$) with the initiation period earlier and more spread out in the Western Area than the Eastern Area (Figure 2). Initiation dates in 2002 were substantially later than previous years, likely due to the particularly late ice breakup (median initiation date: 2002: 1-Jul, 2001: 24-Jul, 2000: 26-Jul). As in previous years, clutch size declined with nest initiation date in 2002 (0.05 ± 0.02 eggs per day $F_{1,111}=4.38$, $P < 0.05$). Average clutch size was larger in the Eastern Area (Eastern= 3.8 ± 0.2 , $X \pm SE$, $n=61$ nests; Western= 2.6 ± 0.2 , $n=51$; Wilcoxon Two-Sample Test = 2230, two-sided t approximation $P < 0.05$)

As we have documented in previous years, the distribution of Common Eider nests was not uniform through the study areas (Figures 3a & 3b, Table 2). Both study areas had small areas of high nesting densities, especially on Spy, Egg, Stump, and Duchess Islands. In all three years, the concentration of Glaucous Gull nests has been greater in the Western Area and tends to occur where large colonies of eiders are present. In 2002 we located no gull nests in the Eastern Area. This is likely due to the overall lower nesting effort seen in 2002 (Tables 1 & 2).

In the Eastern Area, we located 85 active Common Eider nests. Of those, 21 hatched, 37 were depredated, 19 flooded, and 8 had unknown fates. In the Western Area we located 123 nests. Only 12 hatched, 98 were depredated, 4 flooded, 2 were abandoned, and 7 had unknown fates. Unknown eider nests are nests that were depredated (or likely depredated) when located. Based on the habitat, we suspect most were Common Eider nests. Arctic foxes (*Alopex lagopus*) and Glaucous gulls were the principal nest predators on the study area. On 3-Jul a fox was observed on West Egg Island. The single fox, followed closely by many gulls, destroyed every active eider ($n=29$) and gull ($n=6$) nest on the island in less than four hours. A fox was also seen on East Long, West Long, Pingok Islands and tracks were seen on East Egg, Cottle, Bodfish, and Bertoncini Islands. In the Eastern Area, fox sign was noted on Flaxman Island only (an island not traditionally used by nesting Common Eiders), thus we suspect the gulls were the primary nest predators on this area. In contrast, in 2001 foxes destroyed most nests on the Western Area, but not the Eastern Area. Nest success estimates for Common Eiders, using the Mayfield method were similar between study areas in 2002 and are very low (Table 3).

We captured a total of 44 female Common Eiders and one King eider during the nesting period in 2002. All but one were marked with U.S. Fish and Wildlife metal bands and 38 of these were marked with uniquely numbered plastic tarsal bands to facilitate future identification without recapture. Females weighed an average of $1727\text{g} \pm 28.6$; weights

did not vary between areas ($t=1.17$, $df=42$, $p=0.249$). There were six recaptures from previous years (three in each area). In the Eastern Area, two recaptures were nesting females on the sand spit islands near Pt. Thomson. Those hens were originally captured in 2000, while nesting on the Maguire Islands. Our banding effort is summarized in Table 4.

In 2000 and 2001, we fitted nesting female Common Eiders with 15-g subcutaneously anchored radio transmitters. Subsequently, we followed those females to assess fledging success of broods. During the course of this study, we fitted 65 females with transmitters in the Western Area (2000: 30; 2001: 35) and 31 females in the Eastern Area (2000 only, due to total nest failure in 2001). Because of difficulties with ground-based tracking in 2000, we were only able follow broods in the Eastern Area, only one brood survived as late as 12-Aug. In 2001, we conducted five aerial searches for radio-marked females (6-Aug, 14-Aug, 15-Aug, 8-Sep, and 26-Sep) on the Western Area. We confirmed brood failure for all but two the marked females, the fates of those two broods could not be reliably classified. It is most likely that they failed as well.

For a preliminary examination of the genetic structure of Common Eider populations, thirty individuals from the Beaufort Sea, Kent Peninsula (Canada), and Y-K Delta populations were genotyped at five microsatellite DNA loci. Data were analyzed in Fstat (Goudet 1995, 2001), GENEPOP (Raymond and Rousset 1995), and Structure (Pritchard et al. 2000) genetic data analysis programs. There were no significant deviations from Hardy-Weinberg equilibrium across or within populations. All loci were in Hardy-Weinberg equilibrium except for one locus in the Y-K Delta population. Mean observed heterozygosity per locus ranged from 52.5% to 65.0% for each population. The overall F_{ST} (0.017) was not significantly greater than zero suggesting no population subdivision. However, there were significant differences between pairwise F_{ST} values between Kent Peninsula and Y-K Delta populations and Beaufort Sea and Y-K Delta populations (Table 5). Population models generated in Structure support a two-population system among sampled sites supporting the pairwise F_{ST} results.

BREEDING ECOLOGY OF COMMON EIDERS: DISCUSSION

Nesting Effort

The number of Common Eider and Glaucous Gull nests initiated in 2002 was much lower than in 2000 and 2001. The late ice breakup in the lagoon system may have contributed to the diminished nesting effort. Based on long-term nest census data, it does appear that substantial variation in nesting effort is common on the barrier islands of the Beaufort Sea (Noel and Johnson 2000). Because the methods, duration, and overall effort of our nest search was the same in all three years, we do not run into the common problem of comparing inconsistently gathered data across years. However, in other nest search studies a correlation between low nesting success and the probability of nest detection has been noted (Flint, unpubl. data). Nests destroyed prior to their first discovery, can be difficult to detect and identify as a nest from the current year. Nonetheless, we are confident that there was indeed a reduced nesting effort in 2002.

Nest Initiation and Clutch Size

Timing of nesting differed significantly between areas. Nests appeared to have been initiated slightly earlier and over a longer period of time in the Western Area. A similar, though non-significant, pattern was seen in the distribution of nest initiation dates in 2001. Both 2000 and 2001 were considered years of late ice breakups, yet ice breakup in 2002 was even later. Consequently, median initiation date was delayed in 2002 and fewer eiders nested. Among nesting Common Eiders clutch size did not vary from previous years. Across years, we have not seen a consistent pattern of variation in clutch size. In 2002, the average clutch size was greater in the Eastern Area, in 2001 there was no difference, and in 2000 Western Area clutches were larger. There may be differences in natural forage available to Common Eiders across areas and years that could explain this shift in clutch size. Additional data are needed to test this hypothesis.

Nest Success

As in 2001 (but unlike 2000), we found geographic variation in nest success between study areas. The Western Area had 12 nests hatch, while 21 nests hatched on the Eastern Area. During the three years of this study we have seen dramatic variation in daily and nest survival rates (Table 3). This has largely been due to catastrophic nest predation. Arctic fox predation led to the complete nest failure in Eastern Area in 2001 and much of the nest loss in the Western Area in 2002. While the ice pack is intact foxes can access the islands. Typically, as the ice pack begins to breakup foxes leave the islands. However, in years of late breakup, eiders may begin laying while foxes still have access to islands. Arctic foxes will eat or cache any egg they discover, thus one or two foxes can readily destroy all nests on an island (or island complex). Furthermore, we have observed gulls following a fox during a predation event and depredating eggs as hens were flushed by the fox. Clearly, the timing of breakup, the presence of foxes and laying eiders, and other natural events all affect the nesting success on each island differently each year.

Brood Success

Our study of duckling survival in 2000 and 2001 was compromised by methodological problems. Most significantly, poor weather conditions limited our opportunities to track radio-equipped females from both the air and ground. Additionally, the complete nest failure in the Eastern Area in 2001 limited the number of females that we could follow. Nonetheless, we found exceptionally low fledging success through the course of the study: in 2000 only one of 31 Eastern Area broods survived as late as 12-Aug; in 2001 of 21 Western Area broods 19 were confirmed failures and the remaining two were suspected failures. The evidence of colossal brood failure is supported (at least anecdotally) by field observations in 2000-2002. Each year we encounter broods shortly after peak hatch, however by the time duckling should be fledging we no longer encounter broods. We have no direct data explaining duckling loss, however two ducklings collected in the Western Area in 2000 were infected with a reovirus similar to one implicated in a massive die off of Common Eider ducklings in Finland (Hollmén et al

2002). Samples collected in 2002 to test for viruses are presently being analyzed (see Contaminants and Virus Exposure section).

Adult Survival and Site Fidelity

Nest predation and low nesting effort in 2001 and 2002 have limited our ability to capture and recapture a sufficient number of nesting adult females to make reasonable estimates of adult survival and site fidelity. Accordingly, we plan to continue our trapping effort in coming years. Additionally, we plan to capture eiders on the Western Area during the pre-breeding period and we will collect feathers from nests to use for genetic identification of nesting females. Also notable in 2002, was the discovery of nesting Common Eiders on the sand spit islands near the mainland around Pt. Thomson in the Western Area. Of particular interest was the confirmation (from recapture data) that at least two of these females nested on barrier islands in 2000. Ice breakup patterns are highly variable; in 2002 breakup was particularly delayed and these islands provided the only nesting habitat with adjacent open water. We believe that the low nesting effort that we saw this year was a result of females choosing not to nest on ice bound barrier islands. That many eiders used the sand spit islands this year suggests that alternative habitats can be important for nesting Common Eiders when environmental conditions prevent nesting in preferred habitats. The apparent lower nesting effort in recent years of delayed break-up may be associated with displacement of birds to alternative nesting areas. Whether or not displaced females will return in subsequent years, or show fidelity to the new nesting areas, are unknown.

Population Model

To properly develop a population model, information on adult female survival and productivity is needed. We anticipate needing at least one more year of recapture data to produce even preliminary estimates of adult female survival. Given the late ice breakup during the three years of the study, it would be valuable to gather one (preferably two) more years of data on Common Eider hatching and fledging success so that estimates of the variation in these parameters can be obtained.

Status of Breeding Common Eiders in the Beaufort Sea

During the three years of this study, Common Eiders breeding along Alaska's North Slope have shown exceptionally poor success in most components of production (i.e., nesting effort, clutch size, hatch success, and fledging success). For comparison, we present summary data from Pacific Common Eiders breeding at two sites on the Yukon-Kuskokwim (Y-K) Delta, AK in 2002 (unpublished data from H. Wilson); Y-K Delta Common Eiders have consistently higher productivity. Average clutch sizes from the Y-K Delta sites were 5.2 and 4.9, approximately two eggs/nest more than average clutch sizes in our study. Hatch success estimates on the Y-K Delta sites were 53.7% and 45.2%. During our study hatch success estimates have ranged from 31.5% to 1.4% (3.8% in 2002). In a 1997 study, fledging success was 27.1% on the Y-K Delta (Flint et al 1998). North Slope brood success has been essentially zero during our study. Using these data to calculate a rough index of productivity, we estimate that production on the

Y-K Delta ranges from 0.63 to 0.73 fledglings/nest/year. In contrast, using maximum estimates, North Slope production is 0.09 fledglings/nest/year.

Common Eiders are long-lived birds that breed and over-winter in particularly harsh and variable environments. It is certainly possible that this study has spanned a particularly poor breeding period. Only through additional years of study will we be able to determine this. Regardless, our data point to a need for concern about the future of this population of Common Eiders.

BREEDING ECOLOGY OF COMMON EIDERS: Nest Observation Study

Nesting success of Common Eiders is commonly determined by multiple nest visits to assess fates through the nesting period. This method requires regularly flushes hens from their nests. In areas with avian egg predators, an inadvertent increase predation and biases in hatching success estimates may result from disturbances caused by investigators. On Vlieiland, human disturbance was credited with the loss of 20% of the eider clutches due to gull predation (Swennen 1983). Kumerloeve (1956) noted a loss of 43-85% of eider clutches due to nest predation or loss related to frequent human disturbance. Götmark and Åhlund (1984) tested whether avian predators are attracted to islands where observers flush incubating common eiders. They found that gulls were attracted, but that nest predation did not increase. They attributed this lack of increased predation to the fact that eiders nested in a heavily vegetated environment. They suggested that observer-induced predation of eggs and chicks may be more extensive for those species nesting in conspicuous and open environments. In our study area, the principal avian egg predators are Glaucous Gulls. In the 1970s Schamel studied Common Eiders on Egg Island. He found that over 70% of all egg losses were due to gull predation during the egg laying period (when female attendance is low). Once incubation began all remaining nests were successful (Schamel 1974).

In 2000 and 2001, we visited nests in early and late incubation to record measures of productivity. We recognize that our estimates of nest success may be biased low by increased predation pressure due to observer disturbance. It is essential to obtain reliable estimates of nesting effort and hatching success to develop a good population model. Therefore in 2002, we began a study to compare how two different nest visitation regimes affect nest fate. The two treatments were: (1) nest visitations on all islands except Egg Island as we have in previous years, and (2) no nest visits on Egg Island, with nest success determined by observations from blinds. Egg Island has had on average 57 active eider nests over the past 18 years with approximately 25 (n=3 years) Glaucous Gull nests (Noel et al. 2001)

Data from our blind observations include detailed life history characteristics of Common Eiders that we have not been able to gather previously. We designed our study so that our data will be comparable to data from two on-going long-term studies run by the Canadian Wildlife Service in the Canadian Arctic. Our objectives with this study are: to compare the two methods of assessing hatching success, to estimate our human observer effect, and to obtain data on nesting characteristics for comparison with other Common Eider populations.

Methods: Blind Observation

In late May (well before the arrival of eiders to the breeding grounds), we erected two 8ft high observation blinds on Egg Island. Blinds were placed adjacent to areas known, from previous years, for high nesting densities. From each blind a distinct aggregation of nests could be observed. The blinds were reached via 60 m long tunnels extending away from the nesting colony. This allowed us to approach and enter the blinds with minimal disturbance to birds on the island.

We performed four-hour observations daily and advanced the start time by four hours each day so that we covered all hours multiple times. With this method, we could detect diurnal patterns in nest attendance, behavior, and predator activity. Each blind had four viewing windows facing a different direction. We divided our observation periods so that each window was used for one hour. During each hour the first 45 minutes were dedicated to nest attendance observations. The last 15 minutes were dedicated to predator counts.

At the beginning of each nest attendance watch, observers checked for attendance on all previously located nests and recorded any newly established nests. Observers recorded the time of all nest attendance breaks and interactions among eiders and gulls. At the end of the 45 minute period, the amount of time each incubating hen attended her nest was noted. Nests that were not occupied on successive days were deemed failed and we considered incubation to have begun when nests were occupied on three consecutive days of observation.

During predator watches, the number of gull and jaeger patrols was recorded. We defined patrols as systematic searching while following a relatively regular route. A patrol was considered to be a single pass (on the ground or air) through the observed quadrant, thus one gull could make several patrols during an observation.

Results

A total of 43 Common Eider nest were initiated within the blind observation area (a small group of nests at the western extreme of Egg Island was too far from our blinds for observations). Of these only 28 (65.1%) survived to incubation. The nest initiation period ranged from shortly before 15 Jun to June 29. Common Eider hens began incubating between 17 June and 1 Jul. Males were observed attending hens at 17 nests (39.5 %). On average males were observed 1.5 ± 0.2 times per nest. The observation area also hosted 14 Glaucous Gull nests. Ten of these nests (71.4 %) were actively incubating. The majority of gull nests were found on the first day of observation 15 Jun (64.3 %, n=9) and were likely initiated previously. Four gull nests hatched between 29 Jun and 5 Jul. Data from avian predator watches are summarized in Table 6.

On 3 Jul, an Arctic Fox was observed on Egg Island. The fox, followed by a large concentration of Glaucous Gulls, depredated all nests on the island with the exception of one gull nest. After this event, we discontinued observations as there were no further

nesting or re-nesting attempts by eiders or gulls. We were unable to compare hatching success obtained through blind observations versus those attained from traditional nest visitations as no eiders survived the fox predation event.

MOLTING ECOLOGY OF LONG-TAILED DUCKS

Between mid-July and mid-September 10-30,000 Long-tailed Ducks use the lagoons along the Beaufort Sea for a post-nuptial molt (Johnson and Richardson 1981, Bartels et al. 1983, Wilbor 1999). At this time, Long-tailed Ducks are the most abundant and widespread waterbird in the nearshore areas of the Beaufort Sea (Schroger 1947, Gollop and Richardson 1974, Johnson and Richardson 1981, Johnson and Herter 1989). During this molt period, birds are flightless for 3-4 weeks, making them vulnerable to human disturbance, weather events, and predation (Johnson and Richardson 1982). Within the lagoons invertebrates (esp., mysids and amphipods) are an abundant food source during an energetically costly time (Johnson 1984). Howell (see Body Condition of Molting Long-tailed Ducks section) found that Long-tailed Ducks obtain the energy for molt from feeding on the molting grounds (as opposed to using stored reserves). Because of their numbers and potential susceptibility to disturbance, Johnson and Gazey (1992) identified Long-tailed Ducks as an indicator species for monitoring the affects of oilfield related activities in the Beaufort Sea.

Industrial development associated with oil and gas exploration and extraction has resulted in increased industrial activity in the Beaufort Sea lagoons. These activities include increased sea and air traffic, and changes in habitat due to development of temporary and permanent structures. The Outer Continental Shelf Lands Act requires monitoring to identify changes in quality and productivity associated with exploration for and extraction of oil and gas in and adjacent to nearshore areas (Johnson and Gazey 1992). Offshore industrial development in the Northstar Unit of the Beaufort Sea began during the winter of 1999. In addition, underwater seismic activity, conducted in 2001, may continue in other areas. The additional air and boat traffic may result in increased levels of stress during a time of energetic demand. Additionally, there is at least a 15% chance of $\geq 1,000$ barrel oil spill during the expected 15-year lifespan of the industrial developments (U.S. Army Corps of Engineers 1998). Long-tailed Ducks may be especially vulnerable to these disturbances during the flightless period.

Knowledge of the distribution, movements, and residence times of ducks within the lagoons, as well as their behavior, is important to predict potential effects of pollution and disturbance from oil exploration on Long-tailed Ducks using the coastal lagoon system. Effects of disturbance could be as subtle changes in behavior, or as major as disuse of molting sites. Our objective is to document local movement, site tenacity, and feeding patterns of Long-tailed Ducks in response to season, time of day, and experimental disturbance.

MOLTING ECOLOGY OF LONG-TAILED DUCKS: METHODS

Capture

Following the methodologies developed in 1999 for the capture of molting Long-tailed Ducks (Petersen et al. 1999), we captured ducks with large corrals set at known roosting beaches. During 2000-2002, ducks were trapped in the Western Area at several locations: Bertoncini, Cottle, and West Long Islands (collectively, the 'Bodfish Capture Area') and East Spy and Leavitt Islands (the 'Leavitt Capture Area'). In the Eastern Area, trapping was performed at Northstar Island (the 'Maguire Capture Area') and Flaxman Island (the 'Flaxman Capture Area'). All captured ducks were marked with metal U.S. Fish and Wildlife Service tarsus bands, weighed, and measured (culmen, tarsus, 9th primary). We collected blood for genetic, contaminant, and disease analyses from a sub-sample of ducks. We fitted a sub-sample of males with 15-gram subcutaneously anchored radio transmitters (Pietz et al. 1995). Transmitters emitted 60 signals per minute and were equipped mortality sensors. Signals could be detected from radio telemetry towers at a range of approximately 2.5 km. In 2000, an additional sub-sample of ducks was collected for analysis of changes in body composition relative to molt stage and disturbance.

Radio Telemetry

During 2000-2002, we used two radio telemetry techniques to monitor the movements and activity of male Long-tailed Ducks around the capture areas. In 2000 and 2001, we used triangulation to study diurnal movement patterns, habitat use, and feeding activity. In 2000-2002, we used an array of automated Data Collection Computers (DCC) to follow movements through the lagoon and to monitor feeding activity. For both telemetry techniques we mounted two 4-element yagi antennas on 25ft 'towers' and connected them to radio receivers. On 'triangulation towers' both antennas were mounted parallel to each other on rotating towers. The two antennas on 'DCC towers' were mounted so that each pointed toward an area likely to be visited by Long-tailed Ducks (e.g., roosting and feeding sites). DCCs record only the number of signals per transmitter within the detection range, so no directional data is collected by this method. Also in 2001, we searched for transmitter signals from the air using a Cessna 185 airplane on several occasions.

Triangulation

Observers monitored each transmitter simultaneously from two or three triangulation towers within each capture area (i.e., Bodfish, Maguire, Flaxman). We used a two-tower approach in 2000 and a three-tower approach in 2001. Figure 4 and Table 7 show the locations and sampling regime of DCC towers during 2000 and 2001. At the top of every hour, observers listened for transmitters sequentially until all radios in the area were monitored. For each transmitter, observers recorded two bearings that bracketed the strongest signal, thus incorporating a margin of error around the duck's true location. In addition to directional data, observers recorded feeding activity based on the pattern of radio signals. Long-tailed Ducks feed by diving below the surface of the water where their transmitter signals attenuate. Consequently, signals from feeding ducks are marked by 10-30 second breaks in transmission, whereas signals from roosting ducks are continuous. At least once per day observers monitored the frequencies of birds captured at neighboring capture areas to investigate larger scale

movements of ducks. When new birds were detected, they were added to the list for hourly monitoring.

When a duck was detected from two or three towers in the same hour, the individual's location (X, Y position in UTM coordinates) was calculated by triangulation (White and Garrott 1990). In ArcView, we overlaid the calculated Long-tailed Duck locations on a GIS coverage of the coastline and lagoon system. A preliminary plot of all duck locations placed several ducks in improbable areas (e.g., on land or several kilometers out in the ocean); these locations were excluded from further analysis as were locations with excessively large associated error. The remaining locations were then subdivided into the following habitat classes: barrier islands (within 300m), mainland (within 300m), and lagoon (greater than 300 m from land). An example of this work is presented in Figure 5. Map1 contains only points generated from triangulation by three towers, whereas Map2 contains points generated from triangulation by two and three towers. Note that the same relative concentration of points in each habitat is present in both maps. We then examined diurnal and seasonal patterns of feeding activity and habitat use at each capture site. In 2000, major storm on 10 Aug cut short our triangulation study, therefore the seasonal patterns are only presented for 2001 data.

Automated DCC

The DCCs are automated data loggers that record the pulse rate of transmitters within the detection range of the antenna tower. Figure 6 and Table 8 show the locations and sampling regime of DCC towers during 2000-2002. DCCs were programmed to listen for each radio transmitter for 45 seconds, then switch to the next, and to repeat the cycle once all transmitters were scanned. In this way, transmitters were monitored 2-3 times per hour continuously through the study period. Our transmitters emitted 60 pluses per minute, so we considered records of 40 pulses or less (during a 45 second scan) to represent a feeding duck, records with 41-50 pulses were considered to represent a roosting duck, and records with more than 50 pulses were discarded as erroneous. High pulse rates may have been caused by competing radio frequencies from two or more ducks close to the radio towers, interference from other radio sources (i.e. marine radio) or low battery signals in the receiver or DCC unit.

Because DCC antennas were stationary and could only detect the presence of ducks within 2.5 km, we used DCC records to indicate the presence or absence of radio-equipped ducks near the towers. Thus we defined the area around each tower as a unique area and describe the fidelity of individuals to these areas. We used two approaches to analyze these data. First, we used standard Cormack-Jolly-Seber models to estimate the overall rate of fidelity. These models examine the 'capture history' of individuals and typically estimate two parameters: survival rate and recapture rate. The recapture parameter accounts for the fact that not all marked individuals are typically encountered at every 'observation' and is defined as the probability of recapturing or observing a marked individual given that it is present on the study area. However, in our case, our areas were defined by the coverage of our antennas. Thus, the recapture rates accounts for individuals on the fringe of the antenna range or individuals that left the areas for a period of time then returned. The survival parameter is related to the

proportion of individuals that disappear from the area and are never re-encountered. These individuals either died or permanently emigrated from the area. Because our study was of a short duration, we assumed that survival was 100% and that the apparent 'mortality' from a mark-recapture model was actually permanent emigration. Hereafter we refer to this parameter as the emigration rate. We examined models that estimated emigration and recapture probability on a daily basis (i.e., individual days were the period of observation); however, we lacked sufficient data to examine if this daily rate varied through time. We fit models that allowed the emigration and recapture rates to differ among areas. This analysis estimates the daily rate of emigration. The probability of emigration for the flightless period was estimated by raising this daily rate to the power of a 21-day flightless interval.

The second analysis used multi-state mark-recapture approaches to estimate the transition or movement probabilities among areas. This approach is similar to the one described above, however it incorporates additional parameters that estimate the probability of individuals changing 'states'. In this case, 'states' were defined as specific monitoring areas. Thus, this model has the ability to estimate the specific probability of individuals moving from one area to another. For this analysis, we lacked sufficient sample size to estimate the emigration and detection probabilities for each area separately. Therefore, we estimated overall emigration and detection probabilities and fixed these values in subsequent analyses. We then applied multi-state models to estimate the transition probabilities among the different areas. It is important to realize that a single individual can contribute to more than one transition probability. That is, once an individual changes areas, it is subsequently assumed to be a member of that population and any further movements will contribute to subsequent transition probabilities. Thus, if an individual moves from area A to area B then back to area A, it will contribute to both the probability of movement from A to B and from B to A.

MOLTING ECOLOGY OF LONG-TAILED DUCKS: RESULTS

Capture

A summary of the capture history (2000-2002) of Long-tailed Ducks for these radio telemetry studies is presented in Table 9. In the Eastern Area during 7-11 Aug 2002, we captured additional Long-tailed Ducks in locations away from the radio telemetry study site. These ducks were captured for a Sea Duck Joint Venture endorsed project entitled: Characterization of the Beaufort Sea Flyway: Long-tailed Ducks and Common Eiders. We captured and banded 248 molting Long-tailed ducks (208 males and 40 females). Thirty of the females were surgically implanted with satellite transmitters. The movements of these females are being followed remotely through the year. These data will be used to characterize the use of the Beaufort Sea by molting Long-tailed Ducks and to identify their wintering, staging, and nesting areas.

Radio Telemetry

Triangulation

Our results show a strong diurnal pattern of feeding activity in all areas with ducks tending to roost at night and feed during the day (Figure 7). In general, there was a similar diurnal pattern of habitat use with ducks tending use the island habitat more at night and the lagoons during the day. At the Flaxman Capture Area in 2001, however, there was no diurnal pattern of habitat use (Figure 8). Feeding activity and habitat use changed through the course of the study in 2001. During the third week, the proportion of feeding ducks decreased, as did the proportion of ducks using the lagoon habitat. These results were most evident at the Flaxman Capture Area (Figure 9).

Automated DCC Monitoring

Site tenacity

In Table 10 we present the probabilities of radio-marked Long-tailed Ducks remaining by one DCC through the entire 21-day flightless period. These estimates were derived with a Cormack-Jolly-Seber mark-recapture model. The results show a remarkable amount of variation in site tenacity within and among years and DCC locations. In 2000, radio marked birds had a very high probability (>85%) of remaining at one site through the flightless period. In 2001, we were only able to estimate probabilities for the Eastern Area and they were much lower (<50%). In 2002, Eastern Area estimates were high (72-96%) again, whereas Western Area estimates were particularly low (0.5-32%).

To examine the movements of radio-marked ducks between DCC sites in 2002, we used multi-state and Cormack-Jolly-Seber models to estimate daily movement probabilities (Table 11). At all sites except Pingok, the probability of permanently emigrating from a site (i.e., never being detected at that DCC again) is less than 10%. The probability of movements among DCC sites appears to be related to the distance between DCCs. The transitions with the highest probabilities (i.e., Bodfish to Cottle, Cottle to Bodfish, and Cottle to West Long) are between the most closely spaced DCCs (see Table 12 for distances among DCC locations). The only other transitions with substantial probabilities (i.e., Bodfish to West Long and Pingok to West Long) involved westerly movements.

Feeding activity

Our DCC data also show feeding activity of Long-tail Ducks. A clear diurnal pattern of feeding during the day and roosting at night is evident in these data (Figure 10). These results are consistent with results from triangulation and DCC monitoring in 2000 and 2001.

Aerial Telemetry

In 2001, aerial telemetry flights on 14-15 August located all but three of the 20 Long-tailed Ducks that were not being detected at that time. These three radios were never heard during the study and are presumed non-functional. Aerial searches of the study areas on 7-8 September, approximately two weeks after researchers had quit collecting data using triangulation towers and DCCs, located 16 of 40 and 44 of 62 radio-equipped ducks in the Western and Eastern areas, respectively. These numbers had dropped to 4 of 40 (Western) and 19 of 62 (Eastern) by 26 September. Aerial searches indicated Long-tailed Ducks remained primarily along the barrier islands, although several ducks in each area appeared to have moved toward the mainland. Additionally, ducks were detected near the Canning River in the Eastern Area and near Thetis Island in the Western Area. Two radios were detected emitting mortality signals. In subsequent ground searches we were unable to locate these ducks, it is suspected they were scavenged or washed into the ocean.

MOLTING ECOLOGY OF LONG-TAILED DUCKS: DISCUSSION

The use of radio transmitters during the two years of this study has provided some of the first direct information on daily movements, site tenacity, and feeding behavior of individual Long-tailed Ducks in the Beaufort Sea lagoon system. The majority of studies in the past have relied on aerial surveys or observations from island shorelines to record such movements (Johnson and Richardson 1981, Johnson 1982, Johnson and Gazey 1992). Only two other studies of radio-marked Long-tailed Ducks have been conducted in the Beaufort Sea (Bartels et al. 1983, Brackney et al. 1985). These studies, conducted at Tapkauruk Lagoon and Simpson Cove, tracked 44 Long-tailed Ducks through molt. The use of very large transmitters (28-g) attached with wing harnesses, however, led to the loss of 28 ducks and likely biased the behavior of the surviving birds. With our use of much smaller radios (15-g) it appears that we have avoided this problem.

Radio Telemetry

Both triangulation and DCC data indicate that Long-tailed Ducks mostly occupied areas near barrier islands and in the lagoons. Transmitter detection distance, however, may have limited our ability to detect birds that moved to the mainland, ventured far into the ocean, or traveled along the barrier islands outside our study areas. Aerial searches confirmed this latter occurrence on several occasions. These searches also indicated that Long-tailed Ducks stayed in the barrier island lagoon system into September, well past the time when they regained flight.

Triangulation

Our triangulation data show similar patterns of activity and habitat use by Long-tailed ducks at the Bodfish and Maguire Capture Areas. Ducks in the Flaxman Capture Area, however, tend to show somewhat different patterns. This would not be expected if there were industry related effects on their activities and habitat use, because the Bodfish

Capture Area is the 'industrialized' area, while the Maguire and Flaxman Capture Areas are both 'control' areas. Rather, we suspect that other environmental conditions (e.g., relative abundance of food, wind protection) are more important determinants of Long-tailed Duck activity and habitat use. The decline in the proportion of ducks feeding in the lagoons during the third week is likely due to newly flighted ducks leaving the protected lagoons during the day to feed and returning at night to roost.

Automated DCC Monitoring

Site tenacity

Our results from three years of DCCs monitoring movements through the lagoon system show an intriguingly high amount of variation within and among years and areas. Interestingly, the year with the highest probability of ducks remaining at one DCC for the entire flightless period (i.e., 2000) was the year when we experimentally disturbed Long-tailed Ducks with boats at two of the three DCC locations (Cottle and Flaxman). In the Eastern Area, the probabilities of site tenacity in 2001 were dramatically lower than 2000 and 2002. Some of this variation in site tenacity may be related to weather conditions (esp., prevailing wind direction). During most of August 2001, we experienced strong prevailing winds from the southwest. Many ducks may have moved beyond the detection range of our DCCs to gain protection from the wind. We are continuing to look into the relation between weather and duck movements.

In 2002, we collected our largest and most consistent set of DCC data, thus were able to examine 2002 data in greater detail. Long-tailed Ducks in the Western Area appear to move more readily among DCC sites. We would predict this based simply on the more contiguous arrangement of islands in the Western Area (Figure 1). Movements between DCC sites was most likely when distances were short and when movements were in a westerly direction. This latter aspect may be a result of following prevailing winds.

Feeding

Our feeding activity data from DCC monitoring in 2002, as well as triangulation and DCC monitoring in 2000 and 2001, clearly indicate that Long-tailed Ducks maintain a consistent diurnal feeding pattern. Remarkably, this pattern occurs even though during the first half of the molt period there is sufficient light for feeding 24 hours per day.

Conclusions

During three years of radio-telemetry studies we have seen no indication of effects of oil field activity on the movements or feeding of Long-tailed Ducks in the lagoons of the Beaufort Sea. Rather, the primary conclusion that can be drawn from these studies is that movements by molting Long-tailed ducks are highly variable (likely due to highly variable environmental conditions). Whereas, feeding activity shows a fairly consistent diurnal pattern. The consistency of feeding is expected because of the need to meet

the nutritional demands of molt (see Body Condition of Molting Long-tailed Ducks section).

BODY CONDITION OF MOLTING LONG-TAILED DUCKS

To address questions regarding the potential effects of disturbance, we initiated a study of the body condition and mass dynamics of molting long-tailed ducks. This study was conducted as a Masters student project out of Auburn University. The resulting thesis is posted as a stand-alone report: Molt dynamics of male Long-tailed Ducks on the Beaufort Sea. A brief summary of this project follows.

Body condition and mass dynamics are of particular interest in understanding the nutritional costs associated with molt. We examined body mass and nutrient reserve dynamics during the flightless wing molt as indicators of potential impact of industrial disturbance on molting Long-tailed Ducks. Flightless birds were collected from each study location in 1999 and 2000. Proximate analyses suggest that, at least initially, long-tailed ducks rely on stored reserves to meet the demands of feather re-growth. Protein levels gradually declined then increased in the latter half of molt, whereas lipid levels declined continuously throughout the flightless period. We found no support for a negative influence of experimental disturbance on body condition. The fact that birds were able to increase protein reserves during the period of feather growth, suggests that Long-tailed Ducks were able to more than meet the nutritional requirements for maintenance and feather growth from the environment.

Mass dynamics were investigated to determine how they affected flight performance. We found that wing loading, power loading, and wing power loading all increased substantially at the onset of molt. These loadings declined as birds simultaneously lost weight and increased wing surface area as primaries re-grew. These loadings remained relatively constant after flight was re-attained. That is body mass began to increase simultaneously with wing surface area resulting in relatively constant loading. Thus, it appears that the initial mass loss observed in molting Long-tailed Ducks may not be indicative of nutritional stress, but may be an adaptation allowing re-attainment of flight before primary growth is complete. Changes in mass of specific muscles (i.e., breast muscles) and overall protein levels supports the conclusion that mass dynamics during molt are an adaptation to minimize the flightless period.

We also examined the molt of body feathers by male Long-tailed Ducks during the flightless period. Wing and tail feathers are molted simultaneously with the pre-basic molt of body feathers. Molt occurred in a staggered pattern across eight regions of the body (i.e., head and neck, back and rump, greater coverts, lesser coverts, flank and sides, breast, belly, and tail). While the staggered pattern of molt could be interpreted as an adaptation to minimize energetic and nutritional demands during the flightless period, the fact that body molt occurred coincident with wing molt suggests that birds were not nutrient limited during the flightless period.

CONTAMINANTS AND VIRUS EXPOSURE

Contaminants such as chlorinated hydrocarbons and trace metals are now known to be widely distributed in arctic and subarctic ecosystems that have previously been considered pristine (Anthony et al. 1999; Estes et al. 1997; Hargrave et al. 1992). Organochlorine compounds are resistant to degradation and are distributed to the poles through the atmosphere after evaporation or sublimation from points of release, aided by net heat currents from equatorial regions (Goldberg 1975; Ottar 1981). Metals enter the marine environment from natural geologic sources and from discharges of anthropogenic sources (Law 1996). In marine ecosystems, the highest concentrations of contaminants occur in coastal regions (Harrison and Peak 1995), where trace elements and organics bind to and accumulate in sediments. The availability and uptake of persistent contaminants from sediments by forage species can lead to bioaccumulation, a species-dependent process associated with feeding ecology, potentially resulting in toxicity (Barron 1995).

At the regional level, contaminants may enter arctic environments through releases associated with mining and the use and transport of oil and gas resources. This latter source has been of particular concern in the area of the Beaufort Sea coast because of the presence of large oil and gas resources and the resultant high level of activity of the oil industry in federal and state leasing areas. Several monitoring studies have reported the presence of contaminants in the Beaufort Sea. Findings of the Minerals Management Service Beaufort Sea Monitoring Program (BSMP) indicated that concentrations of some trace elements, particularly barium and chromium, as well as levels of saturated and aromatic hydrocarbons, were higher in sediments from the Beaufort Sea in comparison to other outer continental shelf sediments (Beohm et al. 1990). Concentrations of saturated hydrocarbons in tissues of bivalves (*Astarte* sp., *Cyrtodaria* sp., *Macoma* sp., and *Portlandia* sp.) were comparable to levels in sediments, although total polycyclic aromatic hydrocarbons were somewhat lower than in sediments (Beohm et al. 1990). The National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program (NSTP) found that sediment concentrations of arsenic, mercury, nickel, and silver were higher at Oliktok Point on the Beaufort Sea than at the reference area, Lutak Inlet in southeast Alaska (Meador et al. 1994). In the western Beaufort Sea, concentrations of arsenic and nickel were higher than the average for U.S. sediments and the occurrence of certain naphthalenes indicated the presence of crude oil (Valette-Silver et al. 1997). Concentrations of polycyclic aromatic hydrocarbons (PAHs) in Beaufort Sea sediments are higher than expected for a pristine area, making the region particularly sensitive to additional anthropogenic inputs of PAHs (Yunker and MacDonald 1995).

Waterfowl in arctic environments are exposed to a variety of contaminants directly from anthropogenic inputs and from bioaccumulation through the food chain. High levels of cadmium and selenium have been reported from sea ducks, including eiders and Emperor Geese (*Chen canagica*) in several areas of Alaska (Franson et al. 2002; Grand et al. 2002; Henny et al. 1995). On Alaska's North Slope, mean selenium concentrations of up to 15 ppm wet weight and detectable levels of arsenic, barium, cadmium, lead, and mercury have been found in the blood of adult eiders (Margaret Petersen, personal communication). Few data are available concerning organic

contaminants in waterfowl in Alaska, although organochlorines were found in Alaskan seabird eggs collected in the mid-1970s (Ohlendorf et al. 1982) and in eggs of Bald Eagles (*Haliaeetus leucocephalus*) collected from the Aleutian archipelago in the 1990s (Anthony et al. 1999).

Little is known about infectious diseases in sea ducks, but recent findings suggest that exposure to viruses should be considered among the factors potentially contributing to population declines of Common Eiders and Long-tailed Ducks in the Beaufort Sea. Viruses belonging to the family Reoviridae and Adenoviridae have been associated with Common Eider (*Somateria mollissima mollissima*) mortality in the Baltic Sea (Kilpi et al. 1999; Hollmén et al. 2002). In 2000, we isolated a reovirus, similar to those found in eiders in the Baltic Sea, from two Common Eider ducklings found dead near Prudhoe Bay, Alaska. Follow-up serology indicated that about 18% of Common Eider females nesting at two locations in the Beaufort Sea had been exposed to the reovirus. Also in 2000, dead Long-tailed Ducks were observed at one of their molting areas in the Beaufort Sea and an adenovirus was isolated from tissues of carcasses collected during the die-off. The prevalence of antibodies to the virus and the occurrence of live virus in sera and cloacal swabs, respectively, that we collected from live Long-tailed Ducks were significantly higher at the mortality site as compared to a reference area, where no mortality was observed.

Reoviruses cause severe illness and up to 50% mortality in domestic ducklings (Heffels-Redmann et al., 1992), arthritis, respiratory and enteric illness, and malabsorption syndrome in chickens (Rosenberger and Olson 1997), and also have been associated with immune system compromise (Rinehart and Rosenberger 1983; Montgomery et al. 1986). Adenoviruses have been associated with enteritis and a variety of other disease syndromes in several avian species, and some are known to induce immunosuppression in the infected host (McFerran and McAdair 1977; Pierson and Domermuth 1997). Experimental studies of the reoviruses and adenoviruses isolated from sea ducks have provided evidence of both direct pathologic effects on organs, and of potential immunosuppressive effects (Hollmén et al. 2002 and unpubl. data).

Objectives:

- 1) Determine concentrations of selected contaminants in blood and eggs of nesting Common Eiders, and blood of molting Long-tailed Ducks.
- 2) Monitor the prevalence of viruses in nesting Common Eiders and molting Long-tailed Ducks, and compare the results collected in 2000, when mortality of Long-tailed Ducks was observed at our study areas near Flaxman Island, and 2001, when no mortality was observed.
- 3) Further characterize the adenovirus isolated in 2000 by conducting an experimental inoculation trial in Long-tailed Ducks.

CONTAMINANTS AND VIRUS EXPOSURE: METHODS

Common Eider eggs were submitted to En Chem, Inc. (Madison, WI) for contaminants analysis by inductively-coupled plasma/mass spectrometry (ICP/MS) emission spectroscopy, cold vapor atomic absorption spectrometry (CVAA), and gas chromatography/mass spectrometry (GC/MS). Twenty eggs were individually analyzed for trace elements and persistent organic pollutants, a subset of 10 was analyzed for polyaromatic hydrocarbons, and four eggs were composited for quality assurance/quality control spikes and duplicates. The eggs were collected at the Eastern and Western study sites in the Beaufort Sea in 2000, and had been stored frozen at -20C in pre-cleaned glass jars (I-Chem, Nalge Nunc International, Rochester, NY). Whole blood samples for trace element analysis were collected from 20 Common Eiders and 20 Long-tailed Ducks at each of the two study areas. Blood samples were analyzed at RTI International (Research Triangle Park, NC) for trace elements by ICP/MS and CVAA.

Serum samples collected from nesting Common Eiders and molting Long-tailed Ducks in 2001 were tested for viral antibodies using a standard virus neutralization assay (Hollmén et al. 2000). Cloacal swabs were processed for virus isolation as follows: samples were centrifuged at 800 g for 15 min and supernatants from each sample were inoculated into Muscovy Duck (*Cairina moschata*) embryo fibroblast monolayers, incubated at 37 C, and followed daily for viral cytopathic effects for 7 days. If cytopathology was not detected, the samples were freeze-thawed and passaged to new cell cultures before determined to be negative. Positive cultures were evaluated by negative staining transmission electron microscopy.

Long-tailed Ducks housed in an isolation facility at the National Wildlife Health Center were used to test the pathogenicity of the adenovirus isolated from tissues of Long-tailed Ducks found dead in 2000. Pre-inoculation blood samples and cloacal swabs were collected from all ducks and they were divided into treatment (inoculated with virus and in-contact controls) and control groups. Serum antibody response and virus shedding was followed by periodic collection of blood samples and cloacal swabs. At the end of the study, tissues were collected for virus isolation and histopathology.

During the 2002 field season, blood samples (via jugular venipuncture) and cloacal swabs were collected from 44 incubating Common Eider females and 215 (146 males, 69 females) molting Long-tailed Ducks at the two study sites (Table 13). Blood samples were split between heparinized tubes and tubes without anticoagulant (VACUETTE®, Greiner Mediatech, Inc., Bel Air, MD) for tests requiring whole blood and serum, respectively. Portions of heparinized whole blood were collected for lead and selenium analysis. Whole blood without anticoagulant was allowed to clot and serum was harvested. Cloacal swabs from incubating Common Eider females and molting Long-tailed Ducks were collected in transport media (Hanks' balanced salt solution with 0.5% gelatin and 1,500 IU penicillin, 1,500 µg streptomycin, 100 µg gentamicin, and 100 IU mycostatin per ml). Blood, serum, plasma, and cloacal swabs were frozen in the field in a gaseous phase liquid nitrogen dry shipper.

CONTAMINANTS AND VIRUS EXPOSURE: RESULTS

Contaminants in Blood and Eggs

Trace element analysis has been completed for both blood and eggs; analysis of persistent organic pollutants in eggs is pending. Ni and Be were not detected in any of the blood samples. Al, As, B, Ba, and Cd were detected in 5% to 95% of the ducks at the Eastern Area and in 0% to 95% of the ducks at the Western Area and all other trace elements were detected in 100% of the ducks from both sites (Table 14).

Concentrations of Pb and Hg in blood samples were generally low (maximum Pb of 0.68 parts per million [ppm] dry weight in Common Eiders and 0.35 ppm dry weight in Long-tailed Ducks; maximum Hg of 1.19 ppm dry weight in Common Eiders and 1.18 ppm dry weight in Long-tailed Ducks). Se concentrations, however, were relatively high (maximum of 72.7 ppm dry weight in Common Eiders and 93.0 ppm dry weight in Long-tailed Ducks). Wet weight concentrations in ppm are approximately one-fifth of dry weight for Common Eiders and one-fourth of dry weight for Long-tailed Ducks. We found no evidence of increased trace element exposure at the Western (industrial) area, but Cr, Sr, and V were higher in Long-tailed Ducks at the Eastern (control) area. Concentrations of several trace elements (Cu, Cr, Hg, V, Pb, and Zn) were greater in blood of Common Eiders than Long-tailed Ducks, while Se was significantly higher in Long-tailed Ducks than Common Eiders. Ag, Be, Co, Mo, Sb, and Tl were not detected in any of the Common Eider eggs. Concentrations of potentially harmful trace elements (such as Se, Hg, and Pb) were low (0.3 ppm to 2.3 ppm dry weight).

Evidence of Virus Exposure in Field Samples

In Long-tailed Ducks sampled in 2001, seroprevalence to the adenovirus was 20% at the Eastern Area (n = 68) and 0% at the Western study site (n = 36). The frequency of adenovirus isolations from Long-tailed Duck cloacal swabs was 6% at the Eastern Area (n = 67) and 0% at the Western site (n = 39). Thirty percent of Common Eider hens captured at the Western study site (n=20) had serologic evidence of exposure to the adenovirus and a reovirus.

Adenovirus Inoculation Study

All inoculated ducks developed a rapid, marked antibody response to the virus and shed viruses from their cloacas for about two weeks. Levels of circulating antibodies dropped to relatively low levels after 3 weeks post inoculation, and chronically infected individuals shed viruses from their cloacas intermittently throughout the 3.5-month study. No mortality occurred in the infected ducks in captivity, but clinical signs (watery feces, blood in feces) were indicative of an intestinal disease. Inoculated birds developed lesions in the upper intestinal tract and viruses were isolated from a wide variety of tissues.

CONTAMINANTS AND VIRUS EXPOSURE: DISCUSSION

Our contaminants results indicate that Common Eiders and Long-tailed Ducks sampled in the Beaufort Sea have lower concentrations of lead in their blood than the levels that have been reported from sea ducks in some other areas of Alaska, such as the Yukon-

Kuskokwim Delta (YKD). Selenium concentrations may be naturally higher in tissues of marine birds than those that inhabit fresh water environments. Se concentrations in eggs of Common Eiders nesting on the Beaufort Sea were higher than those found in eggs of Common Eiders in the Baltic Sea and Spectacled Eiders on the YKD, but were still below toxic levels (Heinz 1996; Franson et al. 2000, Grand et al. 2002). Although our results suggest that relatively little selenium is transferred from Common Eider females nesting in the Beaufort Sea to their eggs, the effects of selenium on sea duck physiology and reproduction deserves further study.

Findings from serum samples and cloacal swabs indicate that the activity of the adenovirus among molting Long-tailed Ducks was much lower in 2001 than in 2000, when the mortality event occurred at the Eastern study area. However, evidence of virus exposure remains higher at the Eastern Area one year after the 2000 mortality event. Long-tailed ducks experimentally infected with the adenovirus shed viruses for as long as 3.5 months, suggesting that some ducks may act as carriers and transmit viruses to susceptible individuals in the wild. Serologic evidence of adenovirus exposure has recently been detected in other North American sea ducks, including Common Eiders at our study areas in the North Slope, but the interrelationships of viruses from different species and their potential to cause disease remains unknown. Our finding of reovirus antibodies in Common Eiders indicates that eiders are exposed to at least two species of viruses in our study areas in the North Slope.

Contaminants and Virus Exposure: Future Work

- 1) Complete and submit draft manuscript on identification and characterization of the adenovirus from Long-tailed Ducks.
- 2) Prepare and submit draft manuscript on contaminants in blood and eggs of Common Eiders and blood of Long-tailed Ducks.
- 3) Test samples collected from Common Eiders and Long-tailed Ducks in 2002 for evidence of virus exposure.
- 4) Continue development of a polymerase chain reaction (PCR) test that will enhance and simplify the detection of avian adenoviruses, specifically the virus isolated from Long-tailed Ducks in 2000. This will streamline the testing procedure and allow us to gather additional data to evaluate the epidemiology and potential ecological effects of the virus in sea ducks.
- 5) Evaluate serum biochemistry parameters in relation to evidence of virus infection, condition, and exposure to contaminants.

OVERALL SYNTHESIS REGARDING THE EFFECTS OF DISTURBANCE

The final results and analyses from two years of aerial surveys of marine in birds in the lagoon system of the Beaufort Sea have been completed and are presented in a separate report (Fischer et al, 2001). Overall, our ground-based observations support

the aerial survey results and allow further insight into some established patterns. In aerial surveys, Common Eiders were found predominantly around the barrier islands that we have documented as important nesting habitat. More eiders were counted in the Eastern Area than the Western Area during aerial surveys. By contrast, in our nest searches we found approximately equal numbers of nesting eiders between areas in 2000 (a year with relatively high nesting success) and we found substantially more nests in the Western Area during 2001 (a year when nesting success was highly variable). Thus, we suggest that the distribution of Common Eiders observed during aerial surveys in mid-July is influenced by the pattern of nesting success. Successful breeding females, accompanied by broods, are expected to remain near their nesting locations. Whereas, broodless females (non-breeders and failed breeders) may fly to areas with better foraging conditions. It appears that broodless eiders prefer the area around the Stockton Islands. Most likely this preference is related to local foraging conditions around these islands. Large concentrations of eiders are most likely to occur in years of poor nesting success when females can move long distances to optimal foraging areas. In years of good productivity, Common Eiders are likely to be distributed more evenly among the barrier islands. Thus, the vulnerability of Common Eiders to disturbance and industrial activity or accidents (i.e., oil spills) in mid-July is dependent on geographic variation in productivity.

In aerial surveys, the highest densities of Long-tailed Ducks were found along the lagoon side of the barrier islands. Somewhat lower densities were observed on the mid-lagoon transects. Our ground based data support this overall pattern and demonstrate that the distribution of Long-tailed Ducks within the lagoon is a function of time of day and behavior. Our data show that Long-tailed Ducks are most likely to be concentrated in roosting flocks close to the barrier islands late in the evening and at night. During the day, Long-tailed Ducks disperse into the mid-lagoon areas to forage, and consequently are likely to be in loose feeding (i.e., diving) flocks. The reduced density of birds observed on mid-lagoon transects is likely influenced by the time at which the survey is flown. Also, observability (i.e., detection probability) likely varies among transects. In the Eastern Area, Long-tailed Ducks were commonly observed near the mainland coast. We captured and radio-marked Long-tailed Ducks at roost sites on the barrier islands, only. Our triangulation data show that these birds rarely used the mainland side of the lagoon, suggesting the presence of segregated sub-populations of Long-tailed Ducks within relatively small regions of the lagoon system.

The aerial surveys found no evidence of an industrial effect on the distribution of marine birds between areas in the lagoons of the Beaufort Sea. The results of ground-based monitoring, to this point, agree with these conclusions. Rather, it is suggested that stochastic natural events have a larger influence on birds in the lagoon system than humans. During our study we have documented that the distribution and breeding success of Common Eiders is strongly affected by the timing of ice breakup (effects include initiation date, clutch size, and predation), the loss of nesting habitat from a major storm in August 2000, nest predation, and disease. In 2001, a year with extreme variation in nesting success, the highest success was in the industrialized area. The distribution and movements of molting Long-tailed Ducks, also, appears to be most

strongly influenced by natural events such as time of day, prevailing wind conditions, the distribution of protected coves, and possibly disease.

Direct small-scale disturbances (e.g., boating, aircraft overflights, and land-based activity) were not shown to affect marine bird distribution during the aerial surveys. Likewise, our ground-based monitoring has not yielded evidence of such disturbance effects. Our disturbance experiment during the 2000 season did not reveal any differences in overall activity or body condition between treatments, but difficulties with collecting birds in late August decreased the power of our analyses. Furthermore, the movements of Long-tailed Ducks during the seismic study in 2001 have not been clearly related to disturbance. Thus, overall we find little support for an effect of human activity on the distribution or behavior of molting Long-tailed Ducks. In fact, the virus we identified in 2000 is more likely than disturbance to influence the overall distribution and long-term trends of Long-tailed Ducks in the lagoons of the Beaufort Sea.

Although our results do not provide direct evidence of human or industrial impacts on waterfowl in the Beaufort Sea lagoon system, there is evidence of long-term declines in Common Eiders and Long-tailed Ducks in the area (Suydam et al. 2000; Fischer et al. 2001). It is possible that the presence of human development in the area has indirectly affected Common Eiders and Long-tailed Ducks. One likely example of an indirect effect is nest predation by Arctic Foxes and Glaucous Gulls. The populations of foxes and gulls may be sustained at particularly high levels due to scavenging opportunities associated with human habitation (e.g., litter and garbage dumps). Clearly, larger populations of nest predators in the area increase the likelihood of nest predation. Further, our body condition data suggest that molting Long-tailed Ducks have almost no fat reserves remaining by the end of molt. Thus, while we have not documented a disturbance effect, clearly the importance of this area to breeding and molting sea ducks has been demonstrated and we suggest that there remains a substantial potential for negative human impacts on Common Eiders and Long-tailed Ducks.

Currently, we are pursuing further analyses of the data we have gathered. In particular, we are focusing on spatial and temporal analyses Common Eider and Long-tailed duck habitat usage and movement. Additional analysis of data from the seismic study is ongoing. Also, we are planning and preparing ahead for the 2003 field season.

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Table 1. Number of nests found by species and study area 2000-2002.

Species	Number of nests found					
	Eastern Area ¹			Western Area ²		
	2000	2001	2002	2000	2001	2002
Common Eider	228	92	52 (33)	218	110 (134)	56 (67)
King Eider	1	0	0	6	2	0 (1)
Unknown Eider ³	0	49	28 (6)	17	58 (17)	58 (26)
Long-tailed Duck	2	0	0	2	0	0
Northern Pintail	4	0	0	0	0	0
Black Brant	0	0	0	4	5 (3)	2
Canada Goose	2	0	0	0	0	0
White-fronted Goose	0	0	0	0	1	0
Arctic Tern	0	2	0	3	2	1
Glaucous Gull	19	12	0	47	31 (60)	12 (16)
Total	256	155	80 (39)	297	209 (214)	129 (110)

¹ In the Eastern area, the search area increased in 2002 to include five, small, sand spit islands adjacent to the mainland. The numbers of additional nests found in the expanded area are enclosed in parentheses.

² In the Western area, the search area increased in 2001 to include East Stump Island. The numbers of additional nests found in the expanded area are enclosed in parentheses.

³ Indicates nests where no eggs or females were observed to help differentiate between eider species. Based on habitat characteristics, the majority of these nests are likely Common eider.

Table 2. Number of nests by species and island on the Eastern and Western Area, 2002.

Species	Western Area												Total
	Spy	Leavitt	Pingok	Bert- oncinii	Bodfish	Cottle	West Long	East Long	West Egg	East Egg	West Stump	<i>East Stump</i>	
Arctic Tern	1	0	0	0	0	0	0	0	0	0	0	0	1
Black Brant	0	0	0	0	0	0	0	0	2	0	0	0	2
Common Eider	2	0	0	0	0	0	1	5	42	5	1	67	123
Unknown Eider	13	2	0	0	0	1	3	19	15	3	2	26	84
King Eider	0	0	0	0	0	0	0	0	0	0	0	1	1
Glaucous Gull	0	0	0	0	0	0	1	1	9	1	0	16	28
Total	16	2	0	0	0	1	5	25	68	9	3	110	239

Species	Eastern Area												Total
	Brown- low Pt	Flaxman	Mary Sachs	North- Star	Duchess	Alaska	Chal- lenge	<i>Pt Thomso n #1</i>	<i>Pt Thomso n#2</i>	<i>Pt Sweene y</i>	<i>Camp #1</i>	<i>Camp #2</i>	
Arctic Tern	0	0	0	0	0	0	0	0	0	0	0	0	0
Common Eider	0	0	1	7	37	4	3	10	3	1	2	17	85
Unknown Eider	0	0	4	3	17	4	0	0	0	0	0	6	34
Glaucous Gull	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	5	10	54	8	3	10	3	1	2	23	119

*Islands in *italics* were not sampled in all three years. In the Eastern area, *East Stump Island* was sampled in 2001 & 2002. *Italicized* islands in the Western area are small sand spit islands adjacent to the mainland, sampled only in 2002.

Table 3. Estimates of nesting success for Common Eiders 2000-2002.

	Eastern Area			Western Area		
	2000	2001	2002	2000	2001	2002
Number of nests	193	67	85	190	220	123
Exposure Days	2385	501	619	2803	2623	1087
No. Hatched	48	0	21	47	90	12
Daily Survival Rate	0.9392	0.8663	0.8966	0.9489	0.9622	0.8979
Hatching success	0.1523	0.0135	0.0379	0.2078	0.3152	0.0395
95% CI	0.11-0.20	0.005-0.04	0.014-0.081	0.15-0.27	0.25-.40	0.019-0.073

Table 4. Banding effort for female Common Eiders 2000-2002.

	Eastern Area			Western Area		
	2000	2001	2002	2000	2001	2002
Total Captures	47	0	30	66	53	13 ¹
First time Captures	47	0	27	66	46	10
Recaptures	-	0	3	-	7	3

¹ Additionally, we banding one nesting King Eider

Table 5. Pairwise F_{ST} values and p -values for each population pair after 3000 permutations.

Populations	F_{ST}	p -value*
Kent Pen. & Beaufort Sea	-0.013	0.9673
Kent Pen. & Y-K Delta	0.033	0.0007
Beaufort Sea & Y-K Delta	0.032	0.0010

* Adjusted p -value significance level after multiple comparisons is 0.017.

Table 6. Avian predator patrols during observations of nesting Common Eiders on Egg Island.

	Egg Island Observation Blind	
	West Blind	East Blind
No. predator watches	88	88
Mean (\pm) no. of ground gull patrols (min-max, total)	1.1 \pm 0.2 (0 – 7, 87)	1.1 \pm 0.2 (0 – 6, 86)
Mean (\pm) no. of aerial gull patrols (min-max, total)	3.3 \pm 0.5 (0 - 16, 261)	3.4 \pm 0.8 (0 - 50, 270)
Mean (\pm) no. of ground jaegar patrols (min-max, total)	0	0
Mean (\pm) no. of ground jaegar patrols (min-max, total)	0.08 \pm 0.06 (0 – 5, 7)	0.01 \pm 0.01 (0 - 1, 1)

Table 7. Sampling effort and results of radio-equipped Long-tailed Ducks monitored by triangulation in the Eastern and Western Areas, 2000-2001.

		Western Area		Eastern Area	
		Bodfish	Maguire	Flaxman	
2000	Sampling (days)	11	7	10	
	Sampling (hours)	129	47	91	
	Number of Radios	18	25	25	
	Total Fixes	872	492	933	
2001	Sampling Dates (range)	10-23Aug	6-18Aug	1-23Aug	
	Sampling (days)				
	3 Tower Triangulation	11	10	15	
	2 Tower Triangulation	3	-	-	
	Sampling (hours)				
	3 Tower Triangulation	130	84	150	
	2 Tower Triangulation	38	3	12	
	Number of Radios	40*	31	32	
Total Fixes	672	951	1590		

*radios from both the Leavitt and Bodfish capture areas were monitored 16-23Aug

Table 8. Sampling results for radio-equipped Long-tailed Ducks monitored by Data Collection Computers (DCC) on the Eastern and Western Areas, 2000-2002.

Year	DCC sites:	Western Area									Eastern Area	
		Bodfish Island	Cottle Island	E. West Long Island	W. West Long Island	F-Pad	Oliktok Point	Pingok Island	E. Spy Island	W. Spy Island	Flaxman Island	Maguire Island
2000	Sampling (days)		12								15	8
	Sampling (hours)		272.0								337.7	170.8
	No. radios monitored		20								26	26
	No. radios detected		19								26	24
	Fixes/radio (\pm SE)		735.9 \pm 107.4								1141.3 \pm 116.8	493.5 \pm 60
	Range of fixes/radio		23 - 1518								12 - 1929	4 - 758
	Total Fixes		13982								29673	11843
2001	Sampling (days)	29	14	4	1	35	31	28	34	32	18	16
	Sampling (hours)	649.7	229.5	61.0	4.5	690.7	659.2	623.6	762.2	654.4	321.8	343.7
	No. radios monitored	40	40	40	40	40	40	40	40	40	63	63
	No. radios detected	18	14	1	1	6	3	28	30	15	36	27
	Fixes/radio (\pm SE)	132.2 \pm 55.1	26.5 \pm 11.6	48	6	5.2 \pm 1.7	3.3 \pm 1.3	215.3 \pm 48.2	135.5 \pm 34.0	26.1 \pm 6.3	144.4 \pm 20.8	118 \pm 21.9
	Range of fixes/radio	4 - 737	2 - 170			2 - 11	2 - 6	5 - 995	2-699	2-100	2-446	2-395
	Total fixes	2380	371	48	6	31	10	6027	4066	391	5186	3202
2002	Sampling (days)	37	37		34			30	37	6	15	14
	Sampling (hours)	876.7	877.5		796.4			734.7	874.6	114.5	338.5	306.3
	No. radios monitored	59	59		59			59	59	59	59	59
	No. radios detected	39	31		41			21	17	2	9	33
	Fixes/radio (\pm SE)	62.1 \pm 17.5	76.2 \pm 16.6		73.5 \pm 20.8			21.5 \pm 7.6	48.9 \pm 25.2	50 \pm 24	106.9 \pm 21.7	101.6 \pm 16.4
	Range of fixes/radio	2 - 645	2 - 430		2 - 755			2 - 130	2-389	26-74	2-186	2-322
	Total fixes	2423	2363		3015			451	831	100	962	3352

Table 9. Number of Long-tailed Ducks captured and fitted with radio transmitters at capture sites in the Eastern and Western Areas, 2000 - 2002.

Year	Capture Area	Western Region				Eastern Region		
		Spy Island	Leavitt Island	Bertoncini Island	Cottle Island	West Long Island	Maguire Island	Flaxman Island
2000	Number Captured				45		119	129
	Number (%) of Males				37 (82.2)		114 (95.8)	129 (100)
	Number Radioed				20		26	26
	Capture Dates				Jul 28, 31; Aug 4, 6, 7		Jul 31	Jul 29, 30
2001	Number Captured		30	9	1	6	82	124
	Number (%) of Males		26 (96.8)	9 (100)	1 (100)	1 (16.7)	70 (85.4)	124 (100)
	Number Radioed		29	9	1	1	32	31
	Capture Dates		Jul 30	Jul 29; Aug 3, 9	Aug 1	Aug 5, 7	Jul 30	Jul 28
2002	Number Captured	11		70	19	29	80	86
	Number (%) of Males	10 (90.9)		68 (97.1)	17 (89.5)	26 (89.7)	76 (95)	69 (80.2)
	Number Radioed	10		19	17	13	32*	30*
	Capture Dates	Aug 3		Aug 6	Jul 30	Aug 1	Jul 28 & Aug 4	Aug 1 & 2

* A bird in each location were radio-tagged with a radio-transmitter emitting the same frequency. These two individuals were removed from subsequent data analysis.

Table 10. Probability (%) of a bird remaining within the detection zone of a single Data Collection Computer (DCC) for a 21-day sampling period.

	2000	2001*	2002
Western Area			
West Long			32.0
Cottle	89.4		17.0
Bodfish			21.7
Pingok			0.5
East Spy			21.7
Eastern Area			
Maguire	86.1	35.0	71.8
Flaxman	95.5	48.9	96.0

* Because of sampling gaps, we did not estimate probabilities for the Western Area in 2001.

Table 11. Daily probability (%) of movement between the detection zone of one Data Collection Computer (DCC) and another, in the Western Area 2002.

From	To				
	West Long	Cottle	Bodfish	Pingok	East Spy
West Long	94.7 ¹	5.0 ²	0.07	0	0
Cottle	13.1	91.9	18.0	0	0
Bodfish	10.7	18.3	93.0	1.9	0
Pingok	7.7	0	0	77.8	0
East Spy	0	0	0	0	93.0

¹ Values along the diagonal are the daily probabilities of not *permanently* emigrating from a site. Because some ducks move to other sites and then return (i.e., non-permanent emigration) rows can sum to >100%. Estimates based on Cormak-Jolly-Seber model.

² Values off the diagonal were estimated with a multi-state transition model.

Table 12. Distances (km) between Data Collection Computer (DCC) towers in the Eastern and Western Areas, 2002.

DCC	West Long	Cottle	Bodfish	Pingok	Flaxman
Western Area					
East Spy	28.8	24.6	19.3	7.1	
Pingok	22.2	17.9	12.5		
Bodfish	9.8	5.4			
Cottle	4.6				
Eastern Area					
Maguire					12.7

Table 13. Samples collected from Long-tailed Ducks and Common Eiders at the Eastern and Western Areas, 2002.

Long-tailed Ducks						
Location	No. individuals sampled	Samples collected				
		Cloacal swab	Serum	Plasma	Whole blood	
Western						
males	74	37	57	0	40	
females	8	6	6	0	8	
Eastern						
males	72	30	49	12	30	
females	61	41	57	0	41	
Totals						
males	146	67	106	12	70	
females	69	47	63	0	49	
Grand total	215	114	169	12	119	
Common Eiders						
Location	No. individuals sampled	Samples collected				
		Cloacal swab	Serum	Plasma	Whole blood	
Western	13	13	8	0	4	
Eastern	31	31	31	0	31	
Total	44	44	39	0	35	

Table 14. Lower limits of detection (LLD) in parts per million (ppm) dry weight and frequency of detection of 19 trace elements in blood samples collected from Common Eiders and Long-tailed Ducks at the Eastern and Western study areas (n = 20 COEI and 20 LTDU at each site) in 2000.

Element	LLD	Frequency (%) of blood samples above the detection limit for each element			
		Eastern area		Western area	
		COEI	LTDU	COEI	LTDU
Al	2.5	15	10	0	5
As	0.4	5	50	0	15
B	0.25	40	100	35	55
Ba	0.025	40	45	50	60
Be	0.025	0	0	0	0
Cd	0.005	95	20	95	15
Cr	0.25	100	100	100	100
Cu	0.025	100	100	100	100
Fe	2.5	100	100	100	100
Hg	0.012	100	100	100	100
Mg	2.5	100	100	100	100
Mn	0.01	100	100	100	100
Mo	0.025	100	100	100	100
Ni	0.25	0	0	0	0
Pb	0.025	100	100	100	100
Se	0.25	100	100	100	100
Sr	0.04	100	100	100	100
V	0.025	100	100	100	100
Zn	0.5	100	100	100	100

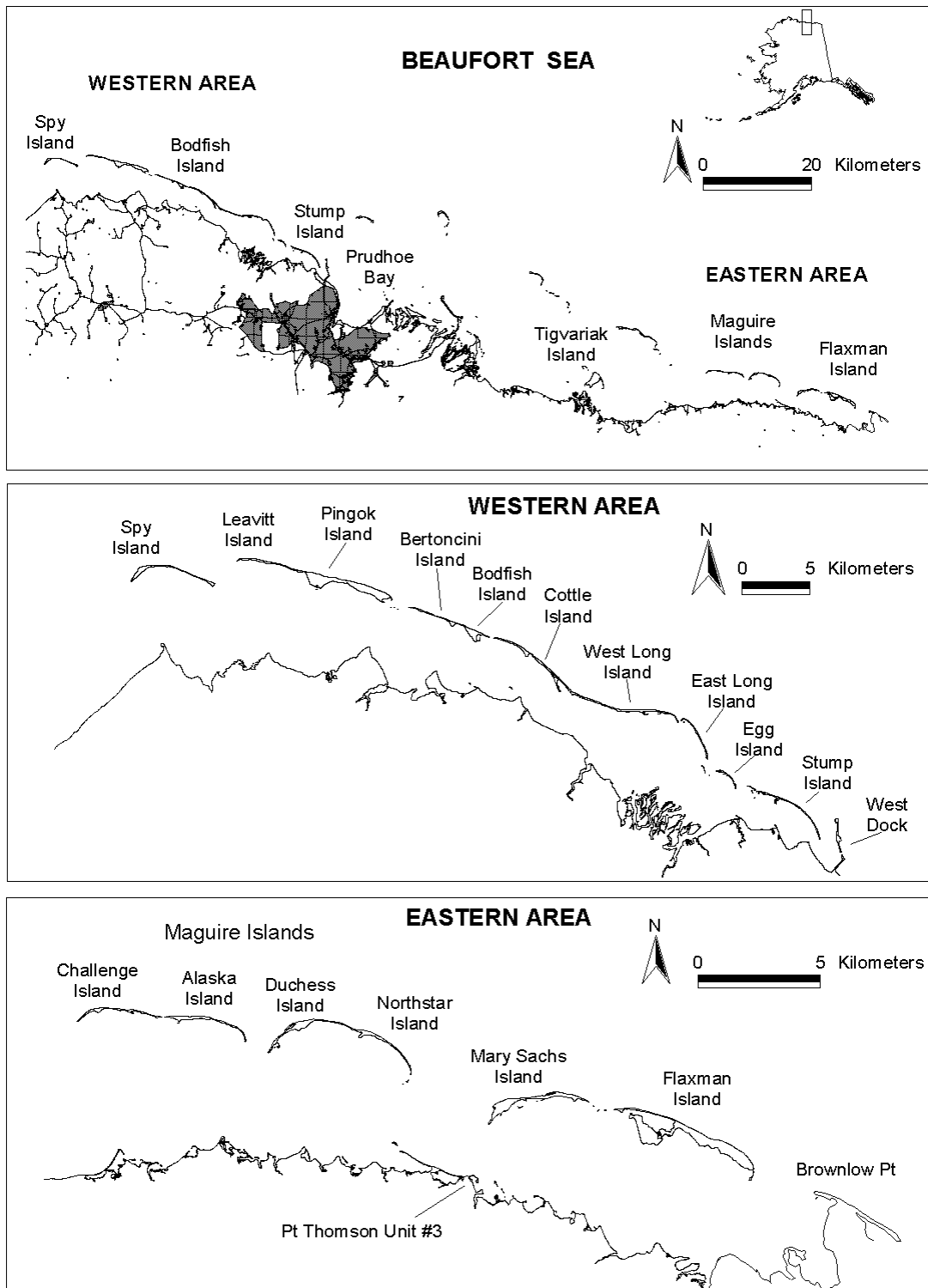


Figure 1. Location of Common Eider and Long-Tailed Duck Study along the Beaufort Sea, Alaska. 2000-2002.

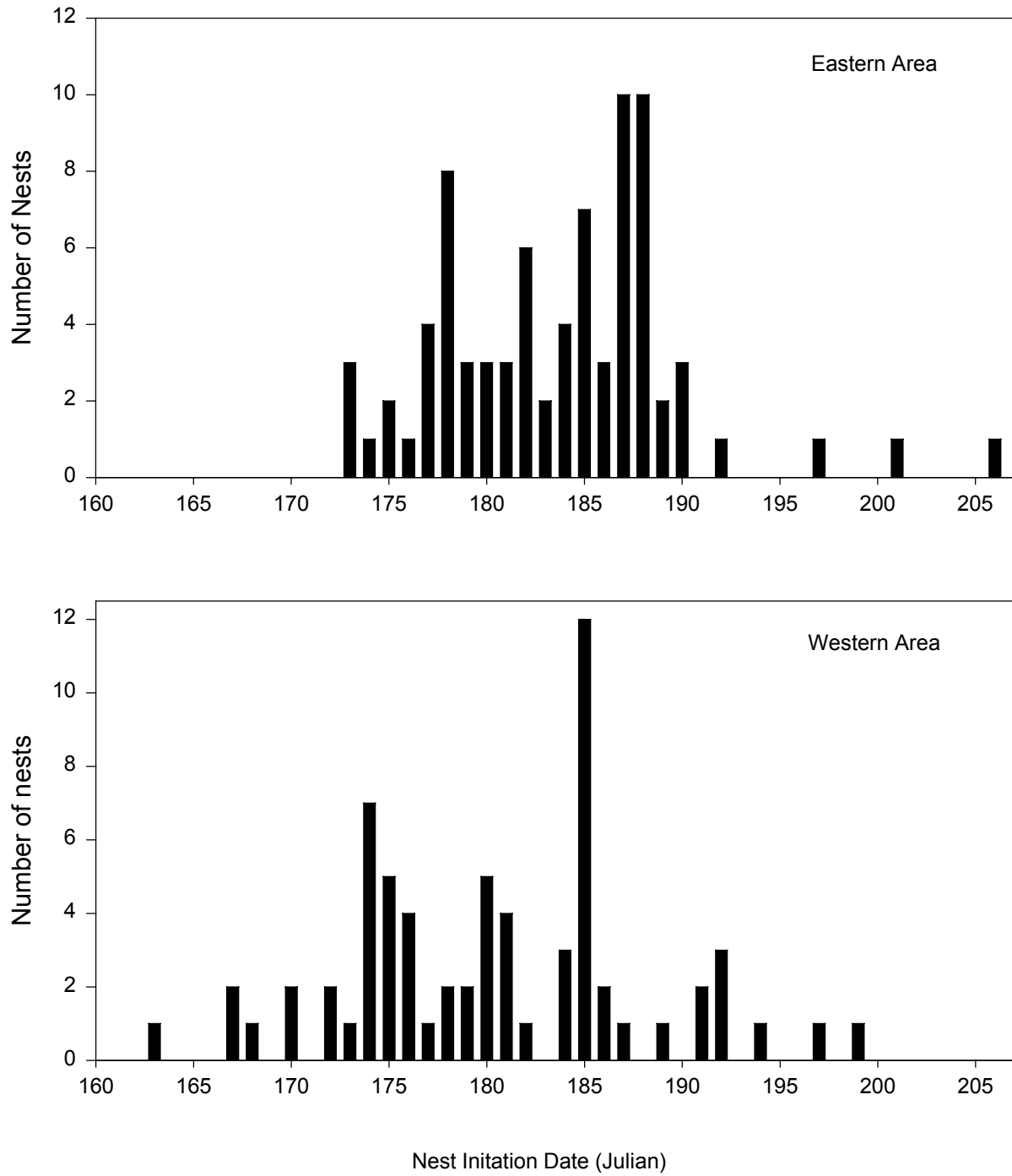


Figure 2. Distribution of Common Eider nest initiation dates on the Eastern and Western areas 2002.

EASTERN AREA

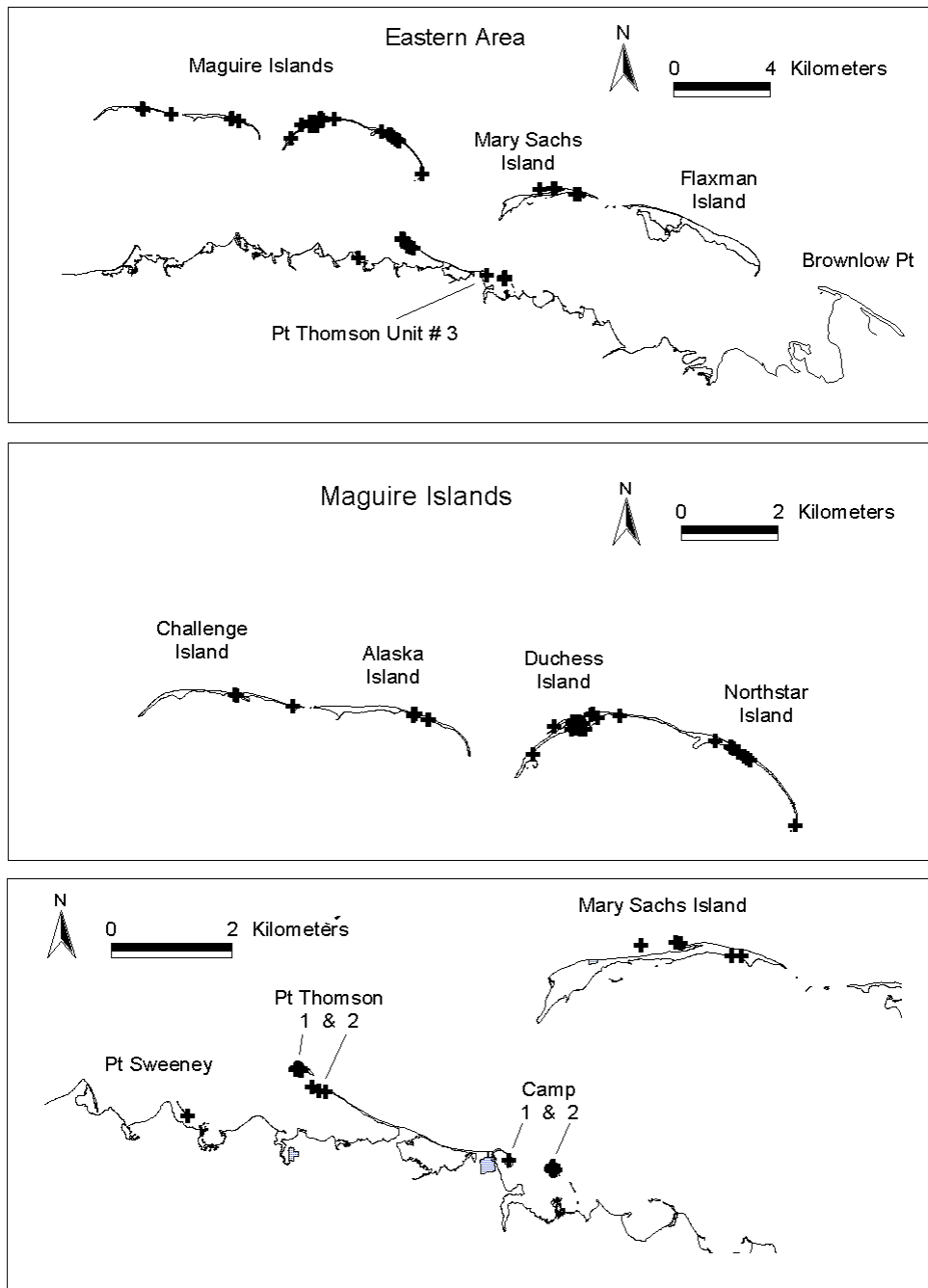


Figure 3a. Locations of Common Eider nests on the Eastern area, 2002.

WESTERN AREA

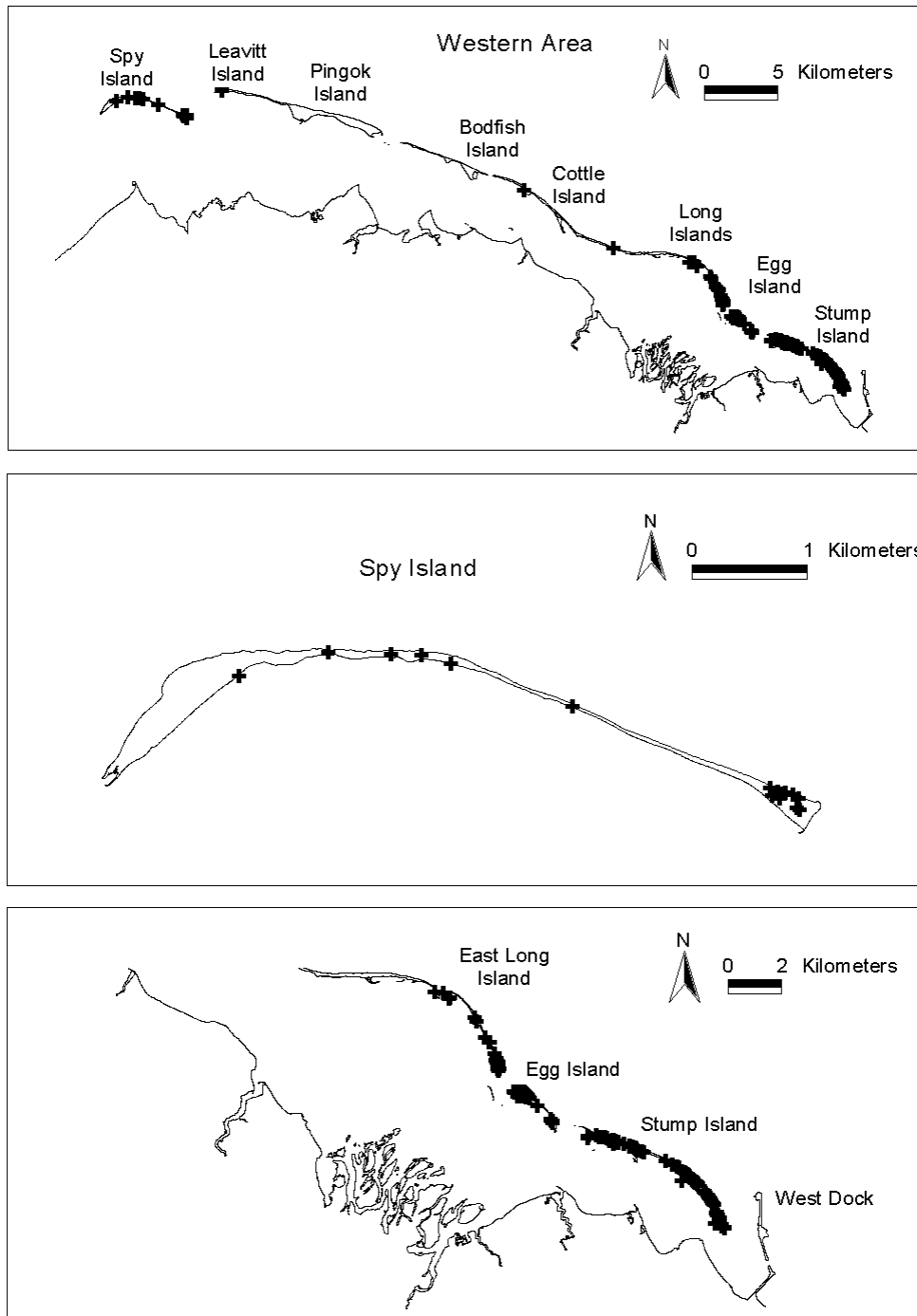


Figure 3b. Locations of Common Eider nests on the Western area, 2002.

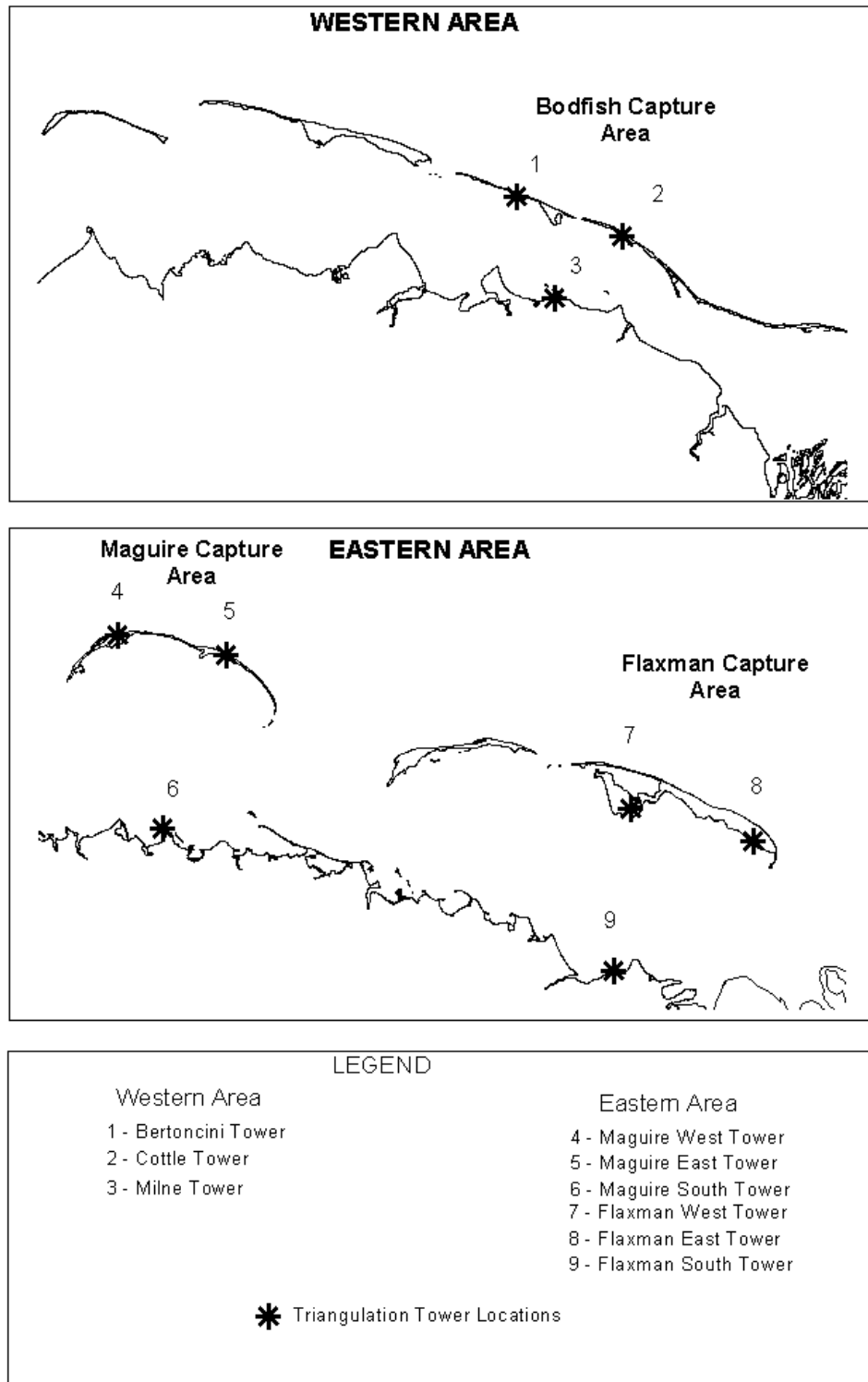


Figure 4. Locations of triangulation towers Eastern and Western areas, 2000-2001.

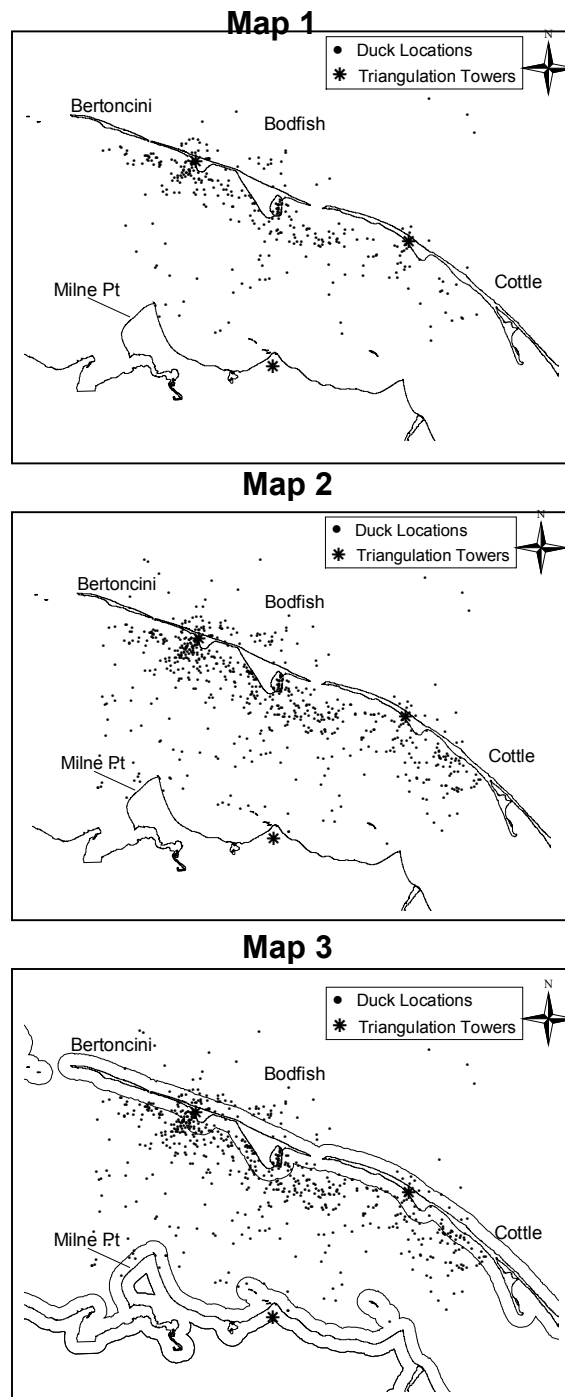


Figure 5. Sample of maps generated from triangulation data from the Bodfish area. Map 1 shows duck locations calculated using records in which a bird was heard by observers at three towers simultaneously. Map 2 shows duck locations calculated using records in which a bird was heard by observers at two or three towers simultaneously. Map 3 shows duck locations superimposed on 300 m buffer around all landforms.

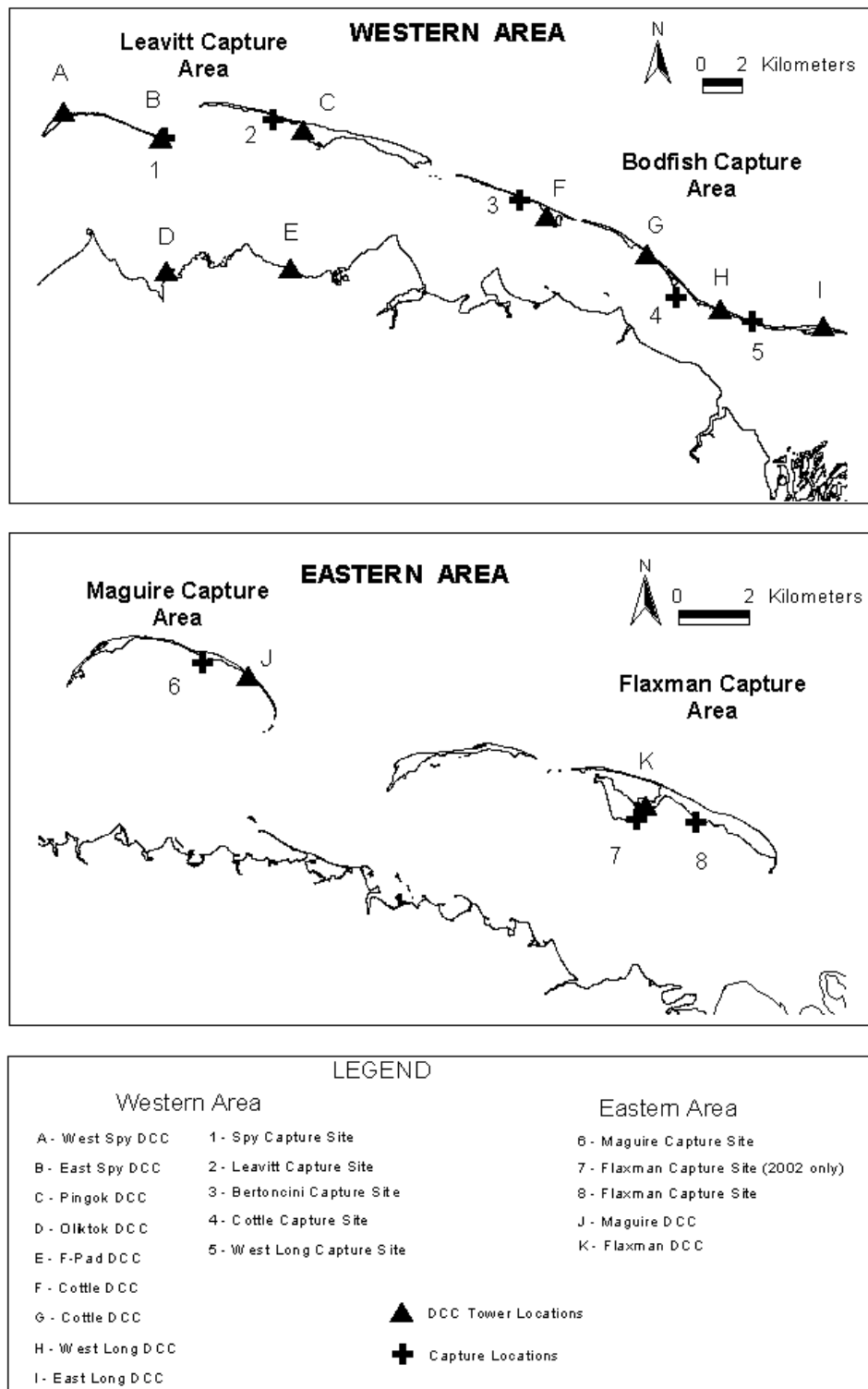


Figure 6. Locations of Data Collection Computers (DCC) and Long-tailed Duck Capture sites in the Eastern and Western areas, 2000-2001.

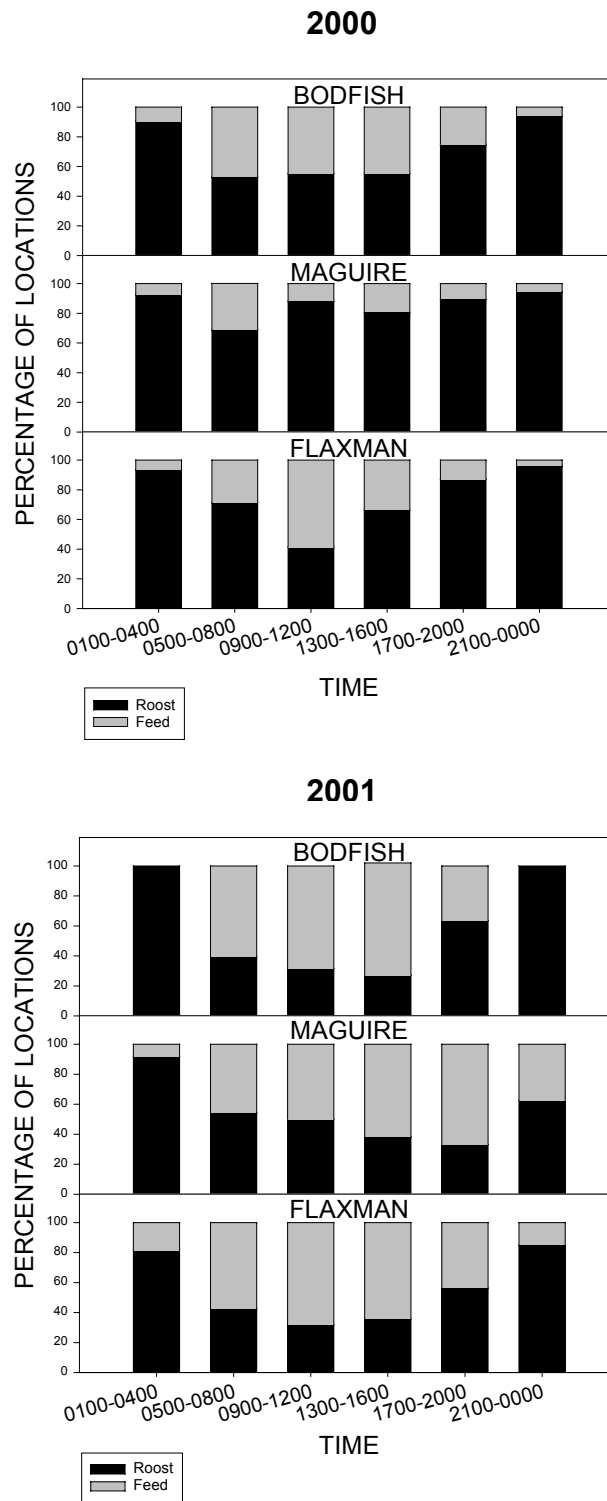


Figure 7. Diurnal pattern of feeding and roosting, as determined by triangulation, 2000 & 2001.

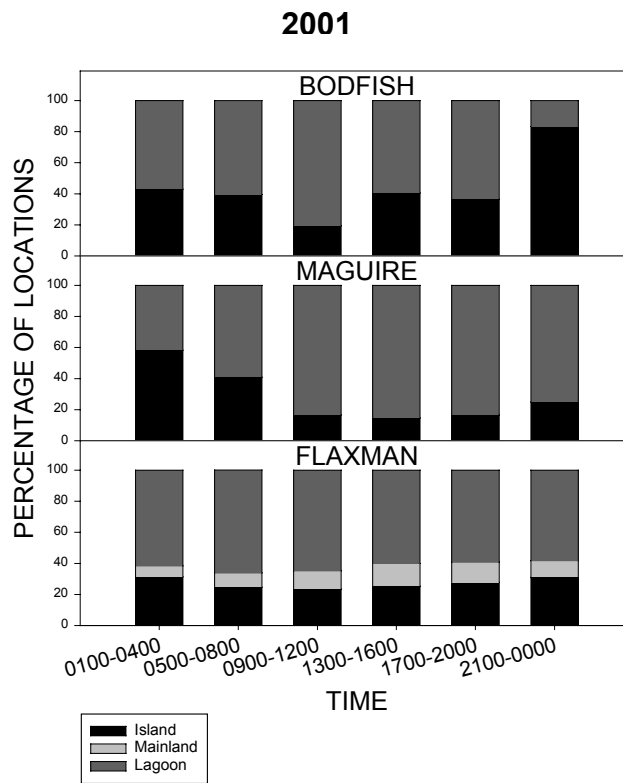
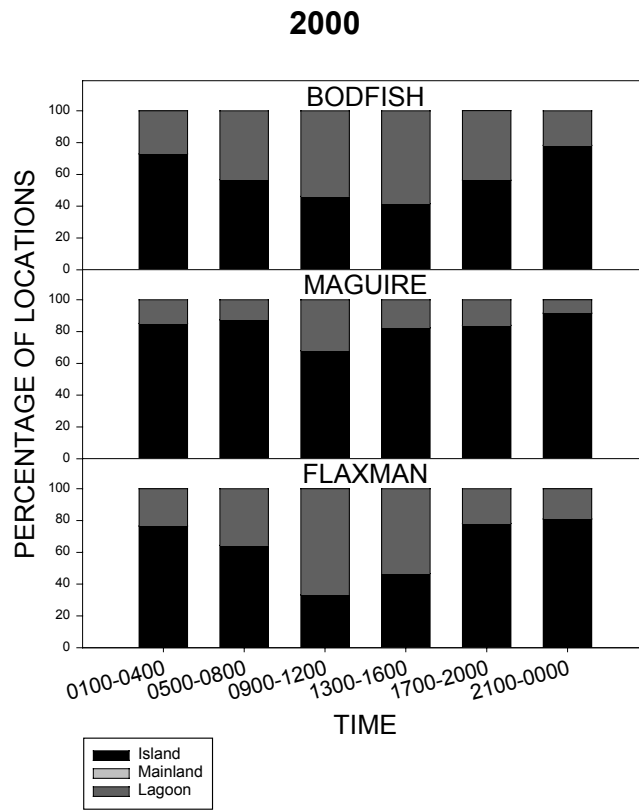


Figure 8. Diurnal pattern of habitat use, as determined by triangulation, 2000 & 2001.

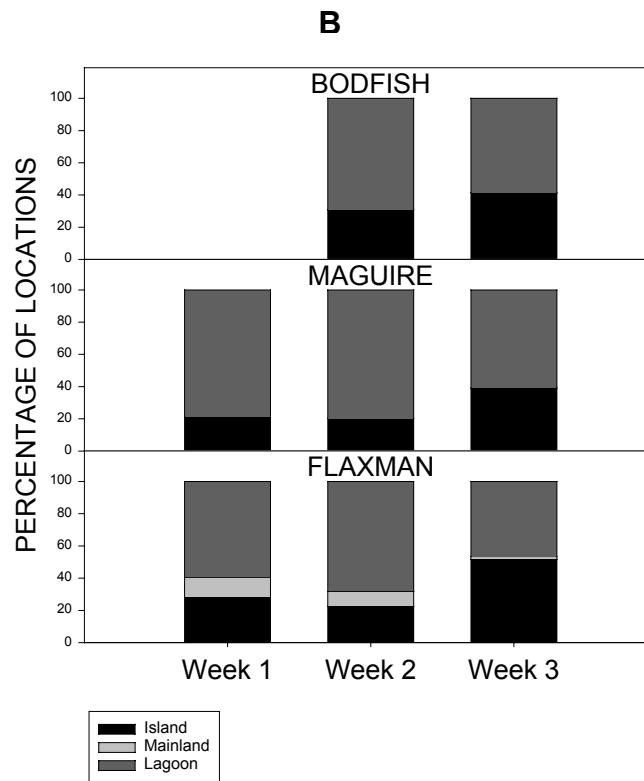
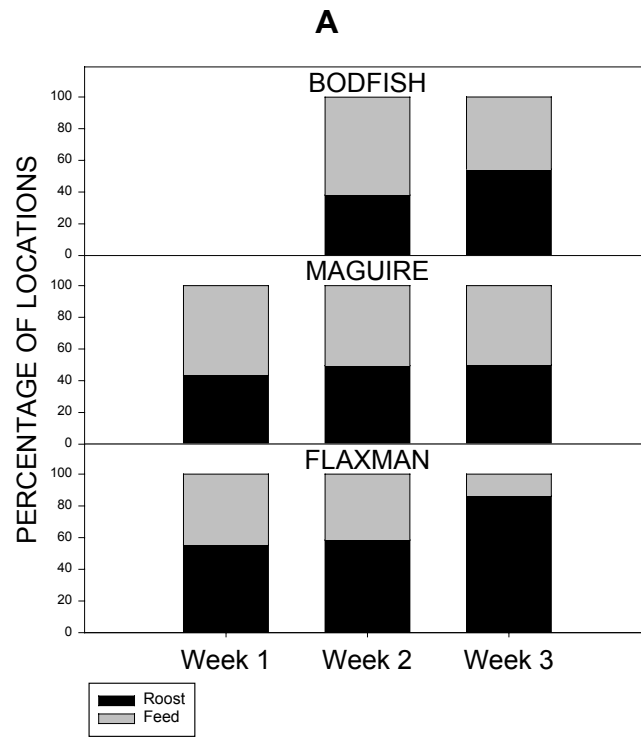


Figure 9. Weekly pattern of feeding and roosting (A) and habitat use (B), 2001. (Week 1 = 1-7 Aug, Week 2 = 8-14 Aug, Week 3 = 15-20 Aug)

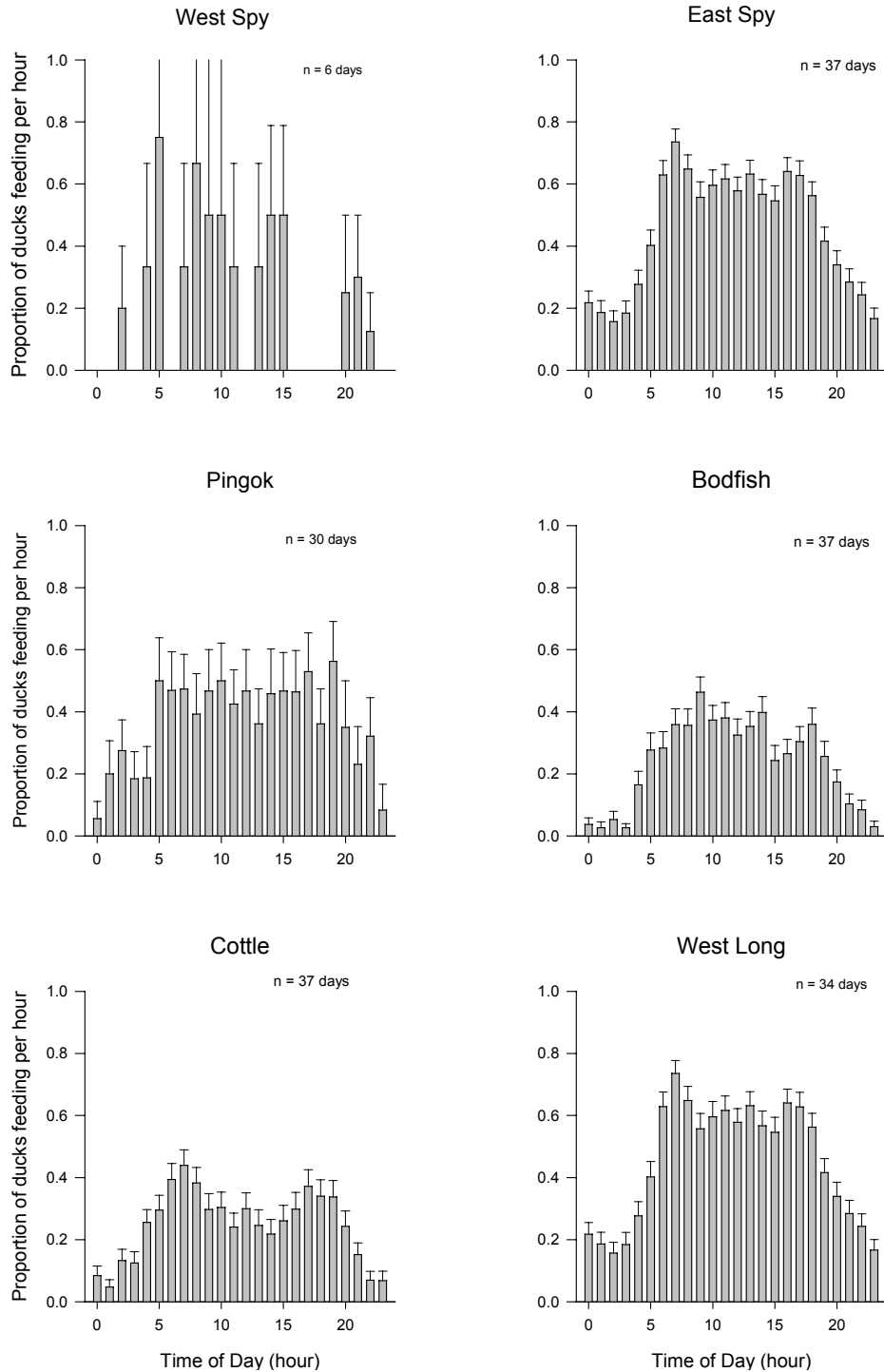


Figure 10a. Average proportion (+SE) of Long-tailed Ducks feeding per hour at each DCC site in the Western Area, 2002. Data based on pulse rates collected by Data Collection Computers (DCC). The number of days sampled is indicated.

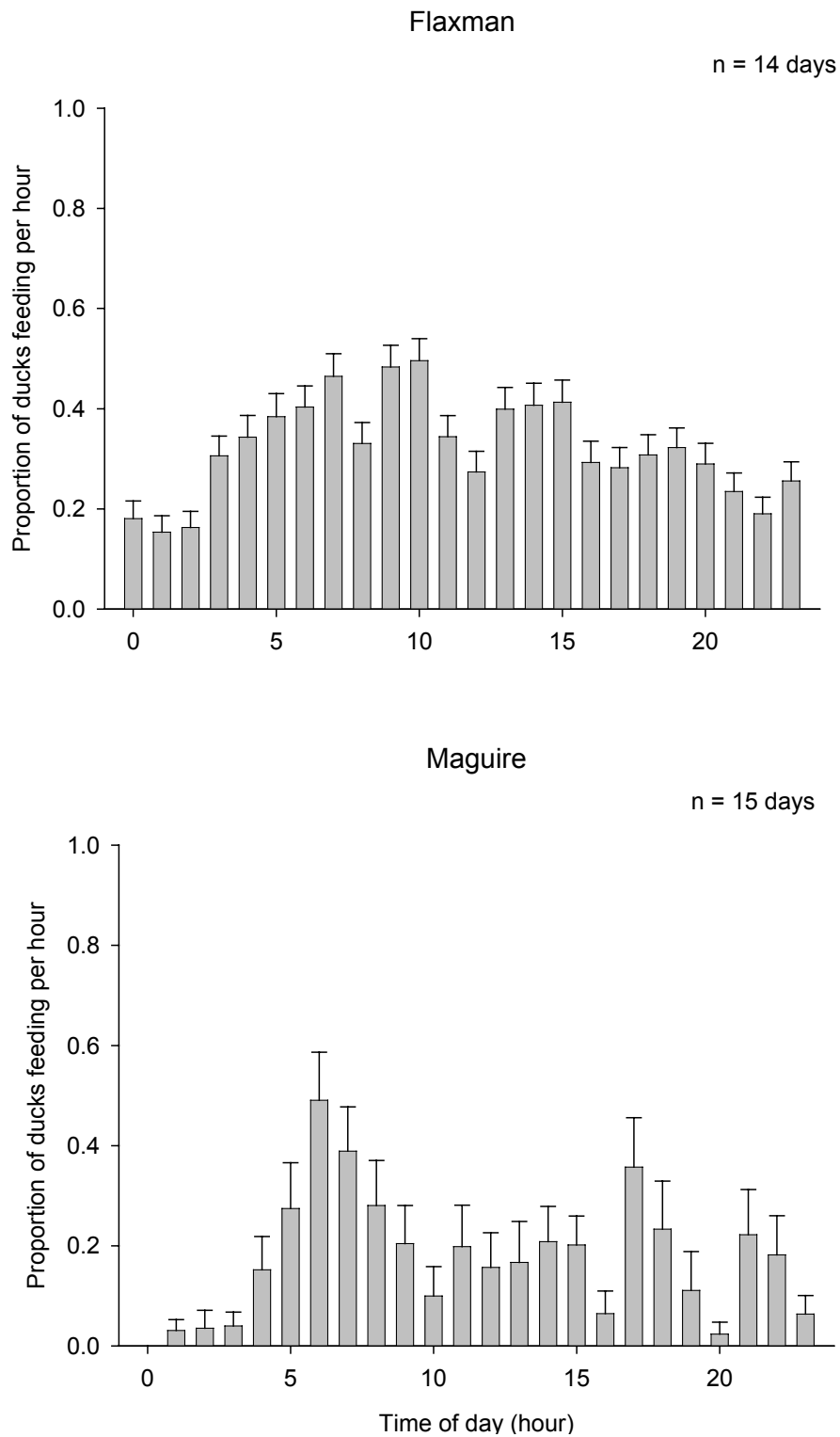


Figure 10b. Average proportion (+SE) of Long-tailed Ducks feeding per hour at each DCC site in the Eastern Area, 2002. Data based on pulse rates collected by Data Collection Computers (DCC). The number of days sampled is indicated.