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Seasonal Movement of King Eiders Breeding in Western Arctic Canada and Northern Alaska

D. Lynne Dickson

Prairie and Northern Region

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EXECUTIVE SUMMARY

Tracking the year-round movement of King Eiders using satellite telemetry technology has rapidly expanded our knowledge of a species that spends much of its life at sea. In this study, satellite transmitters were implanted in 86 King Eiders from two breeding sites in western arctic Canada (Victoria Island and Banks Island), as well as 10 eiders from a site in northern Alaska. Transmitters provided eider locations for a median of 13 months (range: 1-22 months).

Males departed the breeding area in late June (mean ± SD: 26 June ± 6 days), whereas females departed about a month later, following hatch. Most eiders initially moved to coastal waters near the breeding area, where they staged for 2-4 weeks prior to moult migration. However, the majority of males from Victoria Island flew a distance of about 700 km to the flaw lead in the southeastern Beaufort Sea after breeding. Males arrived at moulting areas in the second week of August on average (11 August ± 9 days), whereas females arrived at the end of August (30 August ± 11 days). Regardless of the difference in timing of migration, both sexes followed the same route across the Beaufort, Chukchi, and Bering seas. Over half of the eiders (44 of 80) moulted in the northern Bering Sea off the Chukotsk Peninsula: 8 moulted off St. Lawrence Island, 2 females remained on the breeding area, 3 males moulted in the Chukchi Sea, and the rest were scattered along both the Russian and Alaskan coasts of the Bering Sea.

Timing and duration of fall migration was highly variable. Some eiders (15%) did not migrate, and instead remained on the moulting area for winter. The rest departed from the moulting area over a 3-month period from 24 September to 16 December, and arrived on the wintering area over an even more protracted period from 8 October to 2 January. The area most heavily used during fall migration was the northern Bering Sea near St. Lawrence Island, where 75% of the eiders staged for 4 weeks on average (30 ± 19 days). The King Eiders spent winter in three separate regions: off the southeast Chukotsk Peninsula, off the Alaska Peninsula, and off the Kamchatka Peninsula.

By the end of the first week of April, most eiders had begun spring migration. The initial move consisted of a shift northward within the winter region. This was followed by departure from the winter region, which occurred in the second half of April (23 April ± 11 days). Spring migration lasted an average of 2.4 months, and consisted of rapid long-distance movements

followed by periods of 1-4 weeks of staging. Seven spring staging areas were identified, including the eastern Chukchi Sea and southeastern Beaufort Sea. The latter area was the most heavily used staging area for eiders destined for breeding areas in arctic Canada; the average length of stay in the southeastern Beaufort Sea was 26 ± 10 days, with peak numbers occurring from 13 May to 5 June. King Eiders arrived on the breeding grounds over a 3-week period from 6-27 June (n=30).

Females showed a high degree of breeding site fidelity. Excluding a suspected immature female, average distance apart in two consecutive years was 1.6 ± 1.1 km (n = 22). By contrast, distance between breeding sites in two consecutive years for males averaged over 1000 km (n = 22).

Males and females both returned to the same general area to moult over two consecutive years; mean distance apart was 18 ± 15 km (n = 13).

Breeding and wintering areas were diffusely connected. The eiders from two separate breeding areas (Victoria and Banks islands) used all three winter regions in similar proportions. Furthermore, in the second year, males from each winter region migrated to areas throughout the breeding range.

Results of this study add to the growing evidence that boundaries in the breeding area between the Pacific and Atlantic population of King Eiders are the Taymyr Peninsula in central Russia and the east side of Victoria Island in central arctic Canada (approximately 100-104° W).

Six key marine areas for King Eiders were identified: the southeastern Beaufort Sea, off the west coast of Banks Island, the eastern Chukchi Sea, Bristol Bay, Bering Sea off the southeast Chukotsk Peninsula, and Anadyr Bay.

Information obtained during this study will be useful in several ways, including: assessment of impact of resource development on King Eiders; development of regulations to ensure sustainable harvest; design of monitoring surveys; and identification of marine areas that require special protective status.

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INTRODUCTION

The King Eider (*Somateria spectabilis*) breeds in tundra habitat throughout much of the circumpolar region, including northern Russia, Canada, Alaska and Scandinavia. The limited amount of information on population delineation obtained to date suggests that there are two populations breeding in arctic Canada: a western (or Pacific) population that winters in the Bering Sea and north Pacific, and an eastern (or Atlantic) population that winters in the north Atlantic. Evidence suggests that the dividing line between the two populations occurs along the east side of Victoria Island and extends southward through Queen Maud Gulf Migratory Bird Sanctuary on the mainland (Dickson et al. 1997; Mehl et al. 2004). Along the boundary on the mainland, there is an area where both populations overlap (Mehl et al. 2004). The Pacific population, which is the focus of this study, breeds in moderate to high densities in northern Alaska, Banks Island, Victoria Island, and on the mainland south of Queen Maud Gulf (Barry 1986; Dickson et al. 1997; Raven and Dickson 2006; Larned et al. 2010; Groves and Mallek 2011a and 2011b; Groves et al. 2009a and 2009b). Over much of the rest of mainland western arctic Canada from the northern Yukon to Coronation Gulf, King Eiders are sparsely distributed (Barry 1986; Groves and Mallek 2011a and 2011b). Two exceptions are the outer Tuktoyaktuk Peninsula and Parry Peninsula, where there are low to moderate densities (Dickson et al. 1997). The scarcity of eiders on much of the mainland in western arctic Canada is perhaps due to the prevalence of taller, denser vegetation in those areas (Barry 1986).

The King Eiders that nest in northern Alaska and western arctic Canada declined by over 50% over a period of about 20 years from 1976 to 1996 (Suydam et al. 2000). The decline occurred for unknown reasons, thus raising concern about the lack of knowledge needed to manage and conserve the species. This concern was heightened due to renewed interest in offshore oil and gas development in the Beaufort Sea and eastern Chukchi Sea, two areas known to be part of the eider migration corridor between wintering areas west of the continent and breeding areas in northern Alaska and Canada (Barry 1986; Alexander et al. 1997; Suydam 2000). To assess the impact of expanded offshore oil and gas development on eiders, more information on their at-sea distribution and habitat preferences was needed. Year-round information on the location of eiders would further assist wildlife managers in assessing threats to the population, including hunting pressure and climate change.

This study used satellite technology to track the year-round movement of King Eiders tagged at two breeding areas in western arctic Canada, as well as a site in northern Alaska. The program objectives were as follows: 1) to determine specific migration routes and key staging areas for the western arctic population of King Eiders; 2) to determine timing of migration; 3) to document spatial relationships of migration corridors to pack ice, islands and other physical features in the Beaufort Sea; and 4) to identify wintering and moulting areas, and their affiliation with specific breeding areas.

The detailed movement of individual King Eiders is presented in both map and table format in progress reports written for each of the seven years of deployment of satellite transmitters. For this level of detail, see Dickson et al. (1998, 1999, 2000, 2001, 2006, 2007) and Dickson (2012). Dickson and Smith (in press) describe the location of eiders during spring migration in the southeastern Beaufort Sea in relation to ice, water depth and other physical features, and assess the threat of nearby oil and gas development to the eiders. Oppel et al. (2009) assess the importance of the eastern Chukchi Sea as a staging area for King Eiders during migration. The intent of this report is to provide a summary of year-round locations and timing of movement of King Eiders tagged in all seven years of the study. Key moulting, wintering and staging areas are identified, and dates when present in those areas are provided. Affiliations between wintering and breeding areas are assessed, as well as nest and moult site fidelity.

METHODS

Deployment of satellite transmitters

We captured and deployed satellite transmitters on 53 male and 43 female King Eiders in western arctic Canada and northern Alaska in seven years between 1997 and 2008 (Table 1, Figure 1). Eiders were captured using 2.6 m x 12.0 m mist nets with a mesh size of 127 mm. Two or three nets were strung together in a V- or U-shape and placed on the upwind side of a pond with eiders present. The nets were positioned just above the water to ensure no duck would drown if it tried to dive under the net. Two or three pairs of decoys were placed within 1 m of the downwind side of the net. Two or more observers crouched in a depression or behind a ridge downwind of the pond and waited for the eiders to return to the pond and approach the decoys.

Once the ducks were settled and near the nets, the observers flushed them into the nets by shouting and running towards them. The ducks were carried back to camp in cat cages fitted with a layer of wire mesh on the bottom to keep the birds clean and dry.

A veterinarian and assistant surgically implanted transmitters following the technique described by Korschgen et al. (1996). Different types of anaesthetics and analgesics were tried over the seven years in an attempt to maximize both ease of transporting equipment to a remote area and survival of the ducks (Table 2). Transmitters were implanted in the abdominal cavity with the antenna exiting dorsally near the base of the tail. Transmitters were anchored in place by stitching the eider's skin to a dacron collar fitted around the base of the antenna. Each individual was held in captivity for 2-3 hours following surgery to ensure recovery from anaesthesia. Blood samples were collected from each bird during surgery for genetics studies at the Alaska Biological Science Center in Anchorage, Alaska. All protocols were approved by the Animal Care Committee of the Canadian Wildlife Service (#PNR007).

The satellite transmitters, also known as Platform Terminal Transmitters or PTTs, were designed and produced by Microwave Telemetry Inc. of Columbia, Maryland. They were approximately 55 x 35 x 10 mm in size and weighed 38-43 g. This weight was < 3.5% of the minimum body mass encountered for the sample of King Eiders in this study. The majority of transmitters were programmed to send signals to Argos satellites over a 4-6 h period every 3-4 days from June to December, every 5-8 days during the winter, and every 3-4 days starting at the end of March and until the transmitters quit functioning. There were two exceptions: a three-times-daily transmission during moult migration in 2004, and a daily transmission during spring migration in 2008. The more frequent duty cycles (i.e., period of transmission followed by period of no transmission) were chosen to obtain more detailed information during the target periods of moult and spring migration, while the less frequent duty cycle during winter was chosen to preserve battery life when the birds were relatively stationary.

Location data were provided by Argos (both Standard and Service Plus/Auxiliary Location Processing), and included an assessment of accuracy (Service Argos, Inc. 2007). Locations accurate to within 1500 m were rated by Argos as class 1, 2 or 3, locations with an accuracy of > 1500 m were class 0, and those with no estimate of accuracy were class A, B or Z. Information relayed in the transmitter signals to the satellite also included body temperature and battery voltage. The latter two parameters were useful in determining why a transmitter ceased functioning. A drop in body temperature indicated that the bird was dead, whereas a sudden drop in voltage indicated that the battery was depleted.

Usually, several locations were received during each 4-6 h transmission period. The most accurate and plausible location of each individual eider within a transmission period was selected using software developed by David C. Douglas (Douglas 2006). First, any implausible locations were filtered out based on where a bird was during previous and subsequent locations. Then, locations were selected within each transmission period based on the highest Argos accuracy rating. If there was more than one location with the same accuracy rating (e.g., five locations with a class 3 accuracy rating in a 6-h transmission period), the location with the most messages that reached the satellite was selected.

Definition of seasonal movements

The data were divided into seasons based on migratory movement of the birds as follows: breeding, moult migration, moulting, fall migration, wintering, and spring migration.

Migration began when the bird left an area and did not return (Petersen and Flint 2002). The first distance travelled was usually > 50 km, although this was not always the case for moult migration. Thus, start of moult migration was defined as when the eider left the nesting area for the ocean and did not return (Phillips et al. 2007). Similarly, end of migration was the last of a series of directional movements and that movement was generally > 50 km. The exception was if a bird shifted southwards after 1 January, in which case it was considered part of winter movements rather than fall migration (Oppel et al. 2008). Spring migration ended when the bird moved onshore to a nesting area between early and late June. Some males remained offshore upon returning to the breeding area in the second year, so for those birds it was not possible to determine dates when spring migration ended and moult migration began.

Nest location was where the bird remained stationary at least 10 days during the nesting period (Petersen et al. 2006). Nesting period on Banks and Victoria islands was based on Cotter et al. (1997), and defined as follows: Banks Island males, 10 June to 5 July; Banks Island females, 10 June to 25 July; Victoria Island males and females, each 5 days later than on Banks

Island. The moulting area was defined as locations < 15 km apart over a period of > 20 days following moult migration (Oppel et al. 2008).

The date of departure on migration was the date that the bird was last seen on the nesting, staging, moulting or wintering area (Petersen et al. 1999). Similarly, the date of arrival was the date on which the bird was first seen in the area. The number of days of migration = date first seen at destination - date last seen at area of departure - 1 duty cycle. For example, the number of days of fall migration = date first seen on wintering area - date last seen on moulting area -1 duty cycle. The duration of stay on the nesting, staging, moulting or wintering area = last known date in the area - first known date in the area + 1 duty cycle (Petersen et al. 2006; Oppel et al. 2009). If there was a gap of > 10 days between locations at time of departure or arrival, that individual was not included in any analysis involving that date.

During migration, if a bird stopped and remained in an area for at least seven days (Petersen and Flint 2002), with no directional movement > 50 km, it was considered to be at a staging area.

Mapping

Moulting and nesting locations were mapped by using all values obtained during the relatively stationary period to calculate a centroid for each bird. Centroid locations were determined using the Mean Center tool within Spatial Statistics in ArcGIS (www.esri.com). The mean centre identifies the geographic centre for a set of points by averaging the x and y coordinates of all the locations within a particular dataset. The mean centre is used rather than the centroid of the minimum convex polygon because of the potential biases with the latter approach (Burgman and Fox 2003).

To examine the distribution of eiders on their wintering and staging areas, probability contours of 50% and 95% were created using the ArcGIS Spatial Analyst and Hawth's Tools (Beyer 2004). A density surface was first created using Spatial Analyst based on the eider locations and by accepting the default search radius. The Percent Volume Contour tool of Hawth's Tools was then used to create the 50% and 95% probability contours. A maximum of 10 locations per eider were used to map wintering areas, so that no single eider dominated the map. This was necessary due to auto-correlation among an individual's locations, plus the variable number of locations obtained for each eider. Most provided at least 10 locations, but some provided up to 4 times as many locations. Thus, for individuals with > 10 locations, a subset of 10 locations was randomly selected. Similarly, a maximum of 5 locations per bird were used to map staging areas.

Migration distances were measured by summing the orthodromes between locations obtained during migration; thus, they are minimum distances. Although most transmitters were programmed to transmit a location every 3-4 days during migration, locations were more frequent during moult migration in 2004 and spring migration in 2008. To avoid the problem of a few birds dominating the maps depicting the migration route, only one location every three days was used for those birds with a more frequent duty cycle. Furthermore, only eiders with PTTs that functioned throughout the migration period were used in the migration route maps.

Statistical analysis

T-tests and analysis of variance (1- or 2-way ANOVA) were used to examine whether timing of movement between nesting, moulting and wintering areas differed by sex or among breeding sites or winter regions. Tukey's HSD test was used as a *post-hoc* test. Differences in timing and duration of movement among years were not tested due to small sample sizes most years; also, capture sites differed among years, thus confounding the effect of year. A significance level of 0.05 was used in the analysis, and results were presented as mean ± SD.

RESULTS

Of the 96 surgeries performed to implant transmitters, 85 were successful. Although only 1 male died during the actual surgery, 8 additional males and 2 females died within 3 weeks of surgery, likely due to complications (Table 2). Nine of the surgery-related deaths occurred in the two years that propofal was used concurrently with bupivacaine and ketoprofen. Mortality was reduced substantially to 3% (2 of 65 surgeries) using isoflurane as the anaesthetic.

Transmitters started to send signals to Argos satellites within 24 hours of implantation. Excluding the 11 eiders that died, the median length of time that transmitters provided locations was 13 months (range: 1-22 months) (Table 3). Transmitter performance improved substantially through the 1990s. The median period of operation from 1997 to 1999 was only 5 months compared to 13 months from 2000 onwards. Similarly, the median number of locations received per transmitter in the 1990s was 26 compared to 108 locations per transmitter in later years. The best-performing transmitter provided 187 locations over a 19-month period. Another transmitter lasted longer, but for an unknown reason missed 4 months of transmissions during the first winter.

Moult migration

The mean date of departure of male King Eiders from the breeding grounds was 26 June ± 6 days (n = 43) (Table 4, Appendix A and B). Migration to the moulting areas in the Bering and Chukchi seas took an average of 42 ± 9 days, with peak arrival in the second week of August. Although 6 females departed breeding areas before 10 July, the mean departure date for most (34 of 40) was 31 July ± 10 days (n = 34), more than a month after the males (ANOVA, $F_{1,79} = 151.369$, $p < 0.001$). Females completed migration in a shorter period of time than males (32 ± 15 days; ANOVA, $F_{2,68} = 350.507$, $P < 0.001$), arriving at the moulting area an average of three weeks later than males on 30 August ± 11 days (ANOVA, $F_{1,68} = 69.47$, $P < 0.001$). Regardless of the difference in timing, males and females traveled a similar route across the Beaufort, Chukchi and Bering seas (Figure 2).

At the onset of moult migration, all females, regardless of the location of their breeding area, initially stopped for 2-4 weeks in nearby marine coastal waters (Figure 3, Table 5). Likewise, most of the males from Banks Island and Prudhoe Bay breeding areas staged for 3-4 weeks just offshore. Although some males from Victoria Island (6 of 21) staged in nearby Prince Albert Sound, the majority (71%) migrated directly to the eastern Beaufort Sea to stage off either the west coast of Banks Island or Cape Dalhousie. Once departed from the coastal waters adjacent to breeding areas, most females moved rapidly through the Beaufort and Chukchi seas to their moulting areas. Unlike the females, most males spent an additional 1-3 weeks either in the Beaufort Sea, eastern Chukchi Sea or in the Bering Sea off the Chukotsk Peninsula (Figure 4, Table 6).

Due to the difference in timing of moult migration between sexes, post-breeding King Eiders were present in the Beaufort Sea from mid spring to early fall (range: 5 June to 12

September, n = 75). The first to arrive were males from the Banks Island and Prudhoe Bay breeding areas (30 June ± 4 days and 27 June ± 7 days, respectively), and the last to depart were females from Victoria Island (26 August ± 7 days) (Table 7). Duration of stay in the Beaufort Sea varied from 31 ± 7 days for males from Banks Island to 9 ± 6 days for females from Victoria Island (Table 7).

Moult

Most (94%, n = 80) of the King Eiders moulted in the Bering Sea. The highest concentrations were located off the southeast coast of the Chukotsk Peninsula and in Anadyr Bay, but substantial numbers also occurred off St. Lawrence Island, off mainland Alaska between Nunivak Island and Kvichak Bay, and off Russia between Meynypil'gyno and Karagin Bay (Figure 5, Table 8). Males and females were not distributed evenly among the moulting areas (χ^2 = 12.65, n = 67, P = 0.005). Females were more common off the Chukotsk Peninsula, whereas males were more numerous in Anadyr Bay. Similarly, of the 13 eiders that moulted off Alaska in the Bering Sea, the males were in the vicinity of Kuskokwim Bay, whereas the females were all in Bristol Bay. Only 2 of the 39 females that we tracked throughout moult migration remained near the breeding areas to moult. Both were from Victoria Island, and one moulted in nearby Prince Albert Sound, whereas the other moulted off the west coast of Banks Island about 600 km from her breeding site.

Eiders from the Banks and Victoria island breeding areas were present on each moulting area in similar proportions, with no single moulting area dominated by eiders from either breeding area (χ^2 = 4.28, n = 62, P = 0.233) (Table 9, Figure 6). None of the eiders from Prudhoe Bay moulted off mainland Alaska; however, the sample size of eiders from that breeding area was small (n = 8).

Fall migration

Fall migration for most eiders consisted of a shift southward along either the Russian or Alaskan coast of the Bering Sea (Figure 7). About 15% of the eiders (3 males and 5 females) did not migrate, and instead remained on their moulting area throughout winter. With the exception of one eider that had moulted farther south along the Russian coast off Cape Olyutor, the non-migrants were all eiders that had moulted off the Chukotsk Peninsula. Excluding females that moulted near the breeding grounds, distance travelled during fall migration varied from 41 to 1970 km (mean: 743 ± 595 km, n = 52).

Timing and duration of fall migration were highly variable (Table 4). Eiders left the moulting area over a period of nearly three months from 24 September to 16 December. Mean date of departure for males was 20 October ± 19 days (n = 29), whereas females left two weeks later on average (5 November ± 17 days, n = 22). Although date of departure from the moulting area differed significantly between sexes, it did not vary with wintering destination (two-way ANOVA, $F_{1,43} = 5.90$, $P = 0.019$, and $F_{2,43} = 1.42$, $P = 0.252$, respectively). Date of arrival on the wintering area was even more variable, ranging from 8 October to 2 January, with significant differences among wintering areas (ANOVA, $F_{2,44} = 26.578$, $P < 0.001$), but not by sex (ANOVA, $F_{1,44} = 1.03$, $P = 0.316$). Eiders arrived in the northern most wintering area, off the Chukotsk Peninsula, earlier than off Alaska Peninsula (*post-hoc* test, $P < 0.001$), and the Kamchatka Peninsula (*post-hoc* test, $P = 0.002$). Mean dates of arrival by wintering area were as follows: 30 October ± 18 days (n = 16) off the Chukotsk Peninsula; 23 November ± 19 days (n = 10) off the Kamchatka Peninsula; and 8 December ± 13 days (n = 22) off the Alaska Peninsula.

The period of fall migration ranged from 2-82 days (Table 4). Although some eiders moved rapidly to wintering areas, others staged for an extended period of time in several locations in coastal regions of the Bering Sea (Figure 8). The most heavily used area was around St. Lawrence Island, where approximately 75% of the birds that migrated through the area stopped and remained an average of 30 ± 19 days (n = 19) (Table 10). About 40% of the eiders migrating along the Alaskan coast staged 28 ± 23 days (n = 17) on average in either Kuskokwim Bay or the north side of Bristol Bay. Eiders migrating southward along the Russian coast staged at several locations, including off Khatyrka and Cape Olyutor.

Winter

The eiders used three separate winter regions: off the Chukotsk Peninsula, off the Kamchatka Peninsula and off the Alaska Peninsula (Figure 9). Once fall migration was complete, none of the eiders moved between the regions. The three eiders from the Prudhoe Bay breeding area with transmitters that were still functioning all wintered off the Chukotsk

Peninsula. However, eiders from the other two breeding areas used all three winter regions in similar proportions ($\chi^2 = 3.788$, N = 61, p = 0.15) (Table 11, Figure 10). Likewise, males and females were present in similar proportions in each wintering region ($\chi^2 = 0.495$, N = 64, P = 0.781).

King Eiders that wintered in the northern Bering Sea were highly concentrated in the Sireniki polynia, a limited area of open water in winter that is surrounded by ice, and kept open throughout the winter by ocean currents and wind (Barber and Massom 2007). Eiders in the two more southerly regions off the Alaska and Kamchatka peninsulas were much more widely distributed (Figures 11a, b and c). Eiders off the Alaska Peninsula occurred primarily along the north side of the peninsula and Unimak Island, although 4 of the 26 eiders in that winter region spent at least part of the winter off Kodiak Island in the North Pacific.

Spring migration

King Eiders that wintered off the Kamchatka and Alaska peninsulas started to migrate northward as early as 4 February (mean: 11 March ± 23 days, n = 6 and 22 March ± 24 days, n = 15, respectively). Although distance travelled was > 50 km during this initial move, the birds remained within the region where they had wintered (as defined by Oppel et al. 2008), and the move was followed by a period when they were stationary, which lasted over 5 weeks on average. Birds that wintered farther north off the Chukotsk Peninsula began migrating northward along the coast 2-3 weeks later on average (9 April ± 12 days (n = 18); ANOVA, $F_{2,8} = 7.97$, P = 0.002). With the next northward movement, the birds departed their winter region for a staging area closer to the breeding grounds. This occurred in the fourth week of April (mean: 23 April ± 11 days, n = 43) (Table 4), and did not differ among winter regions (ANOVA, $F_{2,39} = 2.331$, P = 0.111), or between males and females (ANOVA, $F_{1,39} = 0.511$, P = 0.479). Date of departure also was not influenced by breeding ground destination: departure dates were the same for females migrating to Banks Island versus Victoria Island (ANOVA, $F_{1,17} = 1.40$, P = 0.253); likewise, departure dates were the same for males going to breeding areas in northern Russia versus North America (ANOVA, $F_{1,18} = 0.177$, P = 0.679).

All females returned to the breeding area where they had been the previous year (n = 23), whereas males migrated both east and west, with 6 going to northern Russia and 16 going to

North America (Figure 12). King Eiders arrived at their breeding areas over a 3-week period in mid-June (mean: 15 June ± 4 days, n = 30) (Table 4). Females returned to Banks Island 5 days earlier on average than those returning to the more distant Victoria Island (13 June ± 3 days, n = 12 versus 18 June ± 4 days, n = 9) (t-test, t = -3.646, df = 19, P = 0.002).

Spring migration occurred over a much longer period of time than either moult or fall migration (average of 71 ± 20 days (n = 25) compared to 37 ± 13 days (n = 71) and 21 ± 23 days (n = 46) for moult and fall migration, respectively). The spring migration period ranged from 1.5 to 4 months. The greater the distance travelled during spring migration, the longer the period of migration (Pearson's correlation: r = 0.71, t = 4.743, df = 22, P < 0.001). Spring migration consisted of rapid long-distance movements between staging areas where they would remain stationary for a period of 1-4 weeks. Seven staging areas were identified: 3 within the winter regions, 1 in the eastern Chukchi Sea (primarily off Ledyard Bay), 2 in the eastern Beaufort Sea (off the mainland and off the west coast of Banks Island), and 1 in the Siberian Sea off the eastern tip of Novaya Island (the latter location was preliminary due to the small sample size; only 4 of the 6 birds that migrated to Russia in the second year provided regular locations) (Figure 13). The distribution of eiders on each staging area is shown in Figures 14a to 14g. Aside from the three staging areas associated with the winter regions, those most heavily used were located in the eastern Chukchi Sea and southeastern Beaufort Sea (Table 12). Over 70% of the eiders migrating to breeding areas in North America stopped for at least one week in the eastern Chukchi Sea (mean length of stay: 12 ± 7 days, n = 39). Peak numbers occurred from 2-10 May. From there, those eiders destined for breeding areas in arctic Canada flew to the next staging area in the southeastern Beaufort Sea, where they all stopped. The average length of stay was 26 ± 10 days (range: 1-8 weeks, n = 37), and the peak period when they were present was from 13 May to 5 June. About a third of the eiders also staged off the west coast of Banks Island, where they stayed an average of 12 ± 7 days (n = 33) and peaked in number from 3-11 June. Only two of the eiders that staged off Banks Island were destined for breeding areas other than Banks Island: a male and female that migrated to Victoria Island. The departure of eiders from the Beaufort Sea for their breeding areas was more synchronous than their arrival (Table 13). Arrival occurred over a 6-week period starting in late April, whereas 80% of the eiders departed over a 1-week period from 9-16 June.

Transmitters programmed to provide a daily location during spring migration indicated that most eiders moved rapidly across the western Beaufort Sea from Point Barrow to Martin Point (a distance of about 450 km). The seven eiders with daily locations all moved through the western Beaufort Sea in < 1 day. Of an additional 9 eiders with either a 1- or 2-day gap in transmission, 3 stopped briefly (1-2 days) off the Alaska coast (off Smith Bay, Jones Island and Prudhoe Bay). Only 4 of the remaining 24 eiders that were tracked during spring migration were known to have stopped in the western Beaufort Sea. However, their transmitters only provided a location every 3-4 days. The few locations that were obtained while crossing the western Beaufort Sea suggest that the eiders follow the flaw lead rather than the coastline.

Nest site fidelity

All but one female returned to within 4 km of the breeding area used the previous year (mean: 1.6 ± 1.1 km, n = 22) (Appendix C1). The exception migrated to a breeding area on Victoria Island that was nearly 50 km from her location the previous year. However, in the first year her behaviour differed from other females. Rather than remain stationary until late July, she departed from her nesting area about a month earlier on 28 June, moved to a second site, remained there about a week, then moved to marine waters.

By contrast, males tended not to return to the same breeding area (Figure 15, Appendix C2). Distance between breeding sites in two consecutive years ranged from 3 to 3690 km (mean: 1172 ± 1249 km, n = 22). About a quarter of the males (6 of 22) migrated to breeding areas in northern Russia in the second year, and of the birds that returned to North America, only 25% (4 of 16) returned to the same island as in the previous year (i.e., Banks or Victoria island).

Moult site fidelity

King Eiders returned to the same general area to moult over two consecutive years (Figures 16a and b) (Appendix D). All were within 44 km of the site used the previous year; three were within 2 km; and the mean distance apart was 18 ± 15 km (n = 13). Distance between moult sites in two consecutive years did not differ between males and females (t-test, t = -0.195, df = 11, P = 0.849).

Winter site fidelity

Only one transmitter on a female provided enough locations throughout two winters to assess winter site fidelity. Although the centroid winter locations for two consecutive winters were 8 km apart, the eider shifted locations by roughly 100 km during each winter period. Thus, the wintering areas over the two consecutive years overlapped.

Extent of breeding range for males in second year

In spring, males marked on Banks and Victoria islands in the previous breeding season migrated to a wide range of breeding areas extending from the Taymyr Peninsula in central arctic Russia to Victoria Island, Canada (Figure 17). Furthermore, males from each winter region had a similar breeding range in the second year that included northern Russia, and Banks and Victoria islands.

DISCUSSION

Key marine areas for the Pacific population of King Eiders

Satellite tracking technology has greatly advanced our knowledge of the at-sea location of King Eiders. For the Pacific population, patterns have emerged that enable the identification of the marine areas that are crucial to their annual survival. The following is an assessment of those key areas based on the results of this study, as well as recent tracking of King Eiders from two other breeding areas in northern Alaska (Phillips et al. 2007; Oppel et al. 2008, 2009). Results of aerial surveys and other relevant observations are also considered in the assessment. Since all of the eiders tracked by satellite were originally marked in either western arctic Canada or northern Alaska, this assessment best applies to King Eiders that migrate to North America to breed. It does not take into consideration females that breed in Russia, and the sample size of males that migrated to Russia in the second year in this study was too small to assess staging areas used along the north coast of Russia. Tagging of eiders (especially females) at several sites in northern Russia from the Taymyr Peninsula eastward is highly recommended to complete this assessment of key marine areas for the Pacific population.

Several sites support a large proportion of the Pacific population of King Eiders at some point during their annual cycle. To help ensure a stable population, each of these areas should be considered for special protective status, whether that be a marine park, National Wildlife Area or more stringent control of resource development in the area.

Southeastern Beaufort Sea

Within Canada, the most crucial area for the Pacific population of King Eiders is the southeastern Beaufort Sea between the Alaska/Yukon border and Cape Bathurst. During spring migration, all eiders destined for breeding grounds in western arctic Canada stop in the early open water in the southeastern Beaufort Sea for an average of 4 weeks, with peak numbers occurring from mid-May to mid-June. Six years of aerial surveys between 1980 and 1993 similarly reported large numbers of King Eiders (over 80 000 in a single survey) in the flaw lead, with highest densities occurring off the Tuktoyaktuk Peninsula and Cape Bathurst (Alexander et al. 1997). Dickson and Smith (in press) noted that although the majority of King Eiders tracked by satellite were in the flaw lead, 36% were in cracks in the pack ice farther offshore. Few were in the landfast ice (5%), and none in the open water at shore. Average water depth where the King Eiders occurred was 30 m, and average distance to the mainland was 48 km.

The importance of the flaw lead to King Eiders as an energy source during spring migration is evident in years when unfavourable currents and winds close the open water lead, and tens of thousands of King Eiders die of starvation (Barry 1968; Fournier and Hines 1994). The presence of early open water for foraging in the southeastern Beaufort Sea is also likely crucial for successful reproduction. For many of the King Eiders destined for breeding areas in northern Canada, the southeastern Beaufort Sea is the last staging area before arrival on the breeding area. Therefore, it is the last opportunity for the eiders to accumulate body reserves needed to lay and incubate eggs (Oppel et al. 2011). King Eiders are heavily reliant on stored body reserves during their 23-day incubation period when their body mass decreases by 30% (Kellett and Alisauskas 2000). Although King Eiders do feed in the tundra ponds near their nest sites (Holcroft-Weerstra and Dickson 1997; Oppel et al. 2011), prey densities are low at that time of year. Thus, it is unlikely that a bird arriving in poor body condition could accumulate enough body reserves for successful reproduction (Oppel et al 2011).

Waters off Cape Dalhousie (and to a lesser extent off Cape Parry) are used again in July by males staging during moult migration (peak use from 9-24 July). The Cape Dalhousie staging area is more heavily used by eiders coming from breeding areas farther east: half of the males from Victoria Island staged off Cape Dalhousie, compared to only 18% from Banks Island.

West coast of Banks Island

The Beaufort Sea off the west coast of Banks Island is another important area for King Eiders. About a third of the eiders headed to breeding areas on Banks Island stage there during the first two weeks of June. Alexander et al. (1997) and Barry and Barry (1982) likewise reported seeing large numbers of King Eiders along the landfast ice edge in the flaw lead off Banks Island during aerial surveys in earlier years. Counts varied markedly from a few thousand to over 95 000, the latter count occurring in a year when the amount of open water off the mainland coast in the southeastern Beaufort Sea was very limited. Telemetry results suggest that this area is used primarily by local birds, since only 2 of the 12 eiders that staged there migrated farther east than Banks Island to breed. However, the large variation in counts obtained during aerial surveys suggests that in years when ice conditions are unfavourable in the southeastern Beaufort Sea, the area off the west coast of Banks Island becomes critically important not just to birds breeding on Banks Island, but also to eiders heading for breeding areas east of the Beaufort Sea (Barry and Barry 1982; Alexander et al. 1997). Local breeders stage in this area again for 2-4 weeks prior to moult migration: males are present in July and females in the first half of August.

Prince Albert Sound (locally important)

The north coast and east end of Prince Albert Sound are of local importance to eiders breeding in the Kagloryuak River valley on Victoria Island. All females and about 30% of the males stage for 3-4 weeks in those two areas of the sound following departure from the breeding area on moult migration. Males are present during the first three weeks of July, whereas females are most abundant in the first half of August. However, unlike the west coast of Banks Island, eiders do not stage in this area during spring migration, likely due to the lack of open water in the more productive areas of the sound at that time.

Eastern Chukchi Sea

The early open water off Ledyard Bay and Point Lay is an important spring staging area for King Eiders, including some of the eiders migrating to northern Russia to breed (Oppel et al. 2009; this study). Most of the birds destined for Canada stopped in the Ledyard Bay area and remained about two weeks on average, with peak numbers occurring in the first two weeks of May. Oppel et al. (2009) observed that birds destined for breeding areas in northern Alaska remained on the staging area about 10 days longer than those migrating to Canada. This is the last staging area for eiders heading to northern Alaska to breed (Phillips et al. 2007), whereas eiders migrating to breeding areas in Canada have another staging area in the southeastern Beaufort Sea where they can forage prior to breeding.

The eastern Chukchi Sea is also used as a staging area during moult migration. At that time of year, the most heavily used areas are the coastal waters extending from the east end of Ledyard Bay to just west of Icy Cape (Oppel et al. 2009; this study). Approximately half of the males from breeding areas in Canada staged there, while females tended to move through the area more quickly, with only about 20% stopping for a week or more. Eiders from breeding areas in northern Alaska arrive earlier and remain longer than those from Canadian breeding areas (Oppel et al. 2009). Including eiders from both northern Alaska and Canada, males occur in peak numbers in the second half of July and females in the second half of August (Oppel et al. 2009; this study). However, due to the staggered nature of moult/fall migration (first males, then females in the summer, followed by females and young in the fall), eiders are present in the area from late June to early November (Oppel et al. 2009).

Bristol Bay

The coastal waters off Alaska Peninsula and Unimak Island, as well as Kvichak Bay, are critically important to King Eiders during winter. Approximately 45% of the eiders tagged in Canada and northern Alaska wintered there (Phillips et al. 2006; this study). The eiders were present from late November to the fourth week in April. In the last month prior to departure from the region, the birds shifted from the south to the north side of Bristol Bay, including into Kvichak Bay. This distribution of birds with transmitters in mid-April concurs with results of aerial surveys for sea ducks conducted at that time of year (Larned and Bollinger 2011).

Western Beaufort Sea (locally important)

Although the Alaskan Beaufort Sea coast, particularly areas off the Harrison and Smith bays, is used by local breeders as a staging area during the post-nesting period (Phillips et al. 2007), it is less critical to King Eiders from breeding areas in Canada. During moult migration, some Canadian breeders (20% of females and 30% of males) do stage off the Alaskan coast at Harrison and Smith bays, but the majority migrate through in < 1 week. Aerial surveys of the Alaskan Beaufort coast in July showed a similar distribution of King Eiders, with most occurring off the Harrison and Smith bays (Fischer and Larned 2004). In spring, movement of Canadian breeders through the western Beaufort Sea is very rapid (typically < 3 days), and generally farther offshore along the flaw lead.

Bering Sea off the southeast Chukotsk Peninsula

The most critical area off the Russian coast for King Eiders from breeding areas in northern Alaska and Canada is the southeast coast of the Chukotsk Peninsula (Phillips et al 2006; this study). Nearly 30% of the eiders tracked in this study moulted between Cape Chukotsk and Mechigmen Bay (males present from mid-August to mid-October, and females from early September to early November), and nearly 40% wintered in the Sireniki polynia off Cape Chukotsk (late November to early April). Similarly, of the eiders tagged by Phillips et al. (2006) in northern Alaska, over 40% moulted and 15% wintered in the same areas off the Chukotsk Peninsula.

In addition, about a third of eiders that migrate along the west coast of the Bering Sea in spring use the early open water off Cape Nygligan and Cape Nunyagmo for staging during the second half of April.

Anadyr Bay

The north coast of Anadyr Bay is an important moulting area for males. Twenty-six percent of the eiders from breeding areas on Banks and Victoria islands moulted there (this study), as well as 16% of the eiders from northern Alaska (Phillips et al. 2006).

Other potentially critical areas

Other areas that could also prove critical to King Eiders with further investigation include:

- Olyutor Bay, where eiders both moult and winter;
- off St. Lawrence Island, where eiders moult and also stage during fall migration;
- Karagin Bay, used during moult and winter;
- the tip of the Kamchatka Peninsula, where eiders winter; and
- off the Russian coast near Khatyrka, where eiders moult and also stage in late winter (Phillips et al. 2006; Oppel et al. 2008; this study).

Choice of anaesthetic and analgesic

Most of the surgery-related deaths occurred when a combination of propofol, bupivacaine and ketoprofen were used to anesthetize the King Eiders. That combination of drugs resulted in 70% (7 of 10) mortality of males and 18% (2 of 11) mortality of females. Mortality of males was high in both years that we used those drugs (50% in 1998 on Victoria Island and 80% in 2000 on Banks Island), so that neither year nor capture site likely contributed to this high mortality rate. Mulcahy et al. (2003) likewise reported a high rate of mortality for male Spectacled Eiders when given the same drugs: 4 of 10 males died whereas 10 females all survived. Based on field examination of 5 male King Eiders from this study, plus results of histopathology of two of them, Mulcahy et al. (2003) concluded that deaths were caused by renal damage, and suggested that the impact was greater in males, likely due to differences in behaviour, hence body condition, just prior to nest initiation. At that time of year on the breeding grounds, females forage 3-4 times longer than males (foraging time of 30-47% for females compared to 9-13% for males) (Holcroft-Weerstra and Dickson 1997; Oppel et al. 2011). Given the high rate of mortality, especially of males, anesthetizing King Eiders with a combination of propofol, bupivacaine and ketoprofen is not recommended.

Long-term effect of transmitters on King Eiders

The transmitters might have affected the ability of males to obtain a mate in the year following implantation. In the second year of tracking, only 9 of the 18 males that were tracked throughout the nesting period were ever located in terrestrial habitat, 3 of which were present on land for only 2-4 days before returning to marine waters. The rest seemed to remain in marine waters throughout the breeding period, which suggests that over 50% of the males did not breed in the second year. Similarly, 10 of 23 males tagged with implanted transmitters in northern Alaska likely did not breed in the second year. These birds were all located off Cape Dalhousie and Cape Bathurst in the second year (Phillips and Powell 2006), which is suspect because the land adjacent to these sites supports only low densities of nesting King Eiders (Dickson et al. 1997; Groves and Mallek 2011b). In a study of Common Eiders in captivity, Latty et al. (2010) found that transmitters similar in size, shape and weight to the ones used in our study did affect the eider's dive performance, including speed of descent and ascent, and duration of dive. Latty et al. (2010) noted that this change in behaviour likely affected efficiency of foraging. Although these were captive birds, it seems logical that a similar effect would occur in wild birds. Thus, over time, birds with transmitters could become less fit, hence males would be less able to compete with other males for a mate.

Breeding site fidelity

Females from Banks and Victoria islands showed a high degree of breeding site fidelity, with all but one returning to within 4 km of the breeding area used the previous year. The exception was possibly a second-year bird prospecting, but not breeding in the first year that it was tracked. She departed the breeding site early, stayed briefly at a nearby site, then moved to the staging area at the coast. This is similar to the behaviour of second-year birds on the breeding grounds, as described by Oppel and Powell (2010). Our observation of high breeding-site fidelity in females concurs with other studies. Female King Eiders in northern Alaska returned to breeding sites within 15 km (average 4 km) of where they nested the previous year (Phillips and Powell 2006). Females from Karrak Lake (Nunavut) in the central Canadian arctic returned to within 3 km (average < 1 km) of where they nested the previous year (Kellett 1999). There is also growing evidence that females return to their natal breeding area. Oppel and Powell (2010) reported that 8 of 9 females tagged in northern Alaska returned to within 25 km of the lake where they were captured as ducklings two years earlier.

By contrast, adult male King Eiders usually do not return to the same breeding area. Only 2 of 22 males in this study were within 50 km of the breeding area used the previous year. The rest were scattered throughout the breeding range as far away as the Taymyr Peninsula in northern Russia. Males tagged on the breeding area in northern Alaska by Phillips and Powell (2006) showed a similar distribution throughout the breeding range in the second breeding season. Most King Eiders are paired as they enter the Beaufort Sea during spring migration, suggesting pair bonds are formed on the wintering area (Suydam et al. 2000). Thus, a male likely follows his mate to her natal breeding area.

Moult site fidelity

Both males and females returned to the same general area to moult over two consecutive years: 23% (3 of 13) likely moulted at the same site each year, and the rest were all within 44 km of the site used the previous year. Phillips and Powell (2006) reported a similar level of moult site fidelity for King Eiders from breeding areas in northern Alaska (17.1 ± 8.4 km apart, n=8). Unlike this study, which showed no difference between sexes in distance between moult sites in two consecutive years, Phillips and Powell (2006) noted males tended to return closer to the site where they had been the previous year. However, their sample sizes were small (2 females and 6 males).

Population delineation

Birds from breeding areas on Banks and Victoria islands used all three winter regions. Phillips et al. (2006) reported the same pattern for eiders that nested in northern Alaska (18% off Chukotsk, 35% off Kamchatka and 46% off the Alaska Peninsula, n=28). Furthermore, in the second year, males dispersed from each of the three winter regions to breed across the range from central arctic Russia to central arctic Canada. Given the extensive breeding range and three separate wintering areas used by this King Eider population, as well as the diffuse connection between wintering and breeding areas (Oppel et al. 2008), the King Eider might be able to adapt better to alterations to its habitat than species such as the Pacific Common Eider, which has breeding and wintering areas that are highly connected and more limited in extent (Petersen and Flint 2002; Dickson in press).

Evidence from satellite telemetry and banding studies suggest that the east side of Victoria Island is the eastern limit of the breeding range for King Eiders that winter in the Bering Sea and adjacent waters in the North Pacific. All eiders tagged with transmitters on central Victoria Island, including several pairs that subsequently nested on northeast Victoria Island, migrated west to winter (easternmost breeding location was 71.38°N and 104.80°W). Similarly, in the second year of tracking, northeast Victoria Island was the easternmost destination for eiders that wintered in the Bering Sea (Phillips and Powell 2006; this study). Several bands put on the Atlantic population of King Eiders off Greenland were recovered just east of Victoria Island on Prince of Wales Island, King William Island and the Boothia Peninsula, including one band recovered on southeast Victoria Island (summarized in Dickson et al. 1997). Stable isotope analysis and band returns from a study site on the mainland, south and about 25 km east of Victoria Island, showed that King Eiders breeding at Karrak Lake wintered both east and west of the continent (Mehl et al. 2004). This suggests that there is a band along the dividing line in central arctic Canada where both populations share the breeding range.

The western limit of the breeding range for King Eiders that winter in the Bering Sea and North Pacific is likely the Taymyr Peninsula, which was the farthest west that males migrated in the second year of both this study and Phillips and Powell (2006). This concurs with Bustnes et al. (2010), who noted the farthest east King Eiders from the northeast Atlantic wintering population bred was on the Taymyr Peninsula. The Taymyr Peninsula might be an area of overlap on the breeding range for the Atlantic and Pacific populations of King Eiders, as it is for Steller's Eider (Petersen et al. 2006); however, more information is needed to determine this.

Monitoring

Delineation of breeding, moulting and wintering areas is an important prerequisite to proper design of monitoring surveys and interpretation of the results. Although the two King Eider populations overlap to a small degree on the breeding range and they appear to be genetically very similar (Pearce et al. 2004), they essentially use separate geographic areas. Consequently, pressures (e.g., harvest, habitat loss) that affect their productivity and survival, and hence their population size, will likely be very different. Accordingly, it is important to design monitoring surveys that will provide population trend information for each population separately. In North America, this can be done by using the longitudinal band from 100°W to 105°W as the approximate boundary between the two populations.

Satellite telemetry not only provides spatial information, but also data on timing of movement, which can be used to select optimum dates to survey. Breeding pair surveys on the breeding grounds rely on the presence of males to obtain an accurate count, because the males are more visible than the females, especially when the females start to nest. Based on information obtained during this study on the time of arrival of females (assuming they are paired when arrive) and departure of males from each breeding area, the optimal time to survey for breeding pairs along the west coast of Banks Island is 16-24 June (based on mean date of arrival = 13 June ± 3 days, n = 12, and mean date of departure of males = 27 June ± 4 days, n = 17). In the Kagloryuak River valley on Victoria Island, optimum time to survey is 20-23 June (based on mean date of arrival = 18 June ± 4 days, n = 9, and mean date of departure of males = 25 June ± 6, n = 21). Satellite telemetry data indicate that arrival on the breeding grounds occurs over a 3-week period, and that arrival overlaps with departure of some males. Thus, a count obtained during a single aerial survey, even if perfectly timed, will be a minimum estimate. Furthermore, the count will vary among years depending on how synchronous the nesting is that year.

Harvest

To properly manage a harvested species, it is important to know how many are harvested throughout the year. Information obtained through satellite telemetry on the migration pattern of King Eiders has helped clarify geographic areas where harvest data should be collected. In Canada, the Pacific population of King Eiders is primarily harvested during spring migration at Holman, on western Victoria Island (Fabijan et al. 1997). In Alaska, they are harvested during spring and fall migration at several communities along the eastern Chukchi Sea coast, including Wainwright and Barrow, on the Yukon-Kuskokwim Delta and in Bristol Bay (Wentworth 2004). Harvest in Russia should also be considered. Results of this study suggest that nearly 70% of the eiders from breeding areas in western arctic Canada moult off the Russian coast (particularly off the south and east coasts of Chukotsk Peninsula), and > 50% wintered off Russia. Furthermore, males that use breeding grounds in North America also use breeding grounds in northern Russia. Therefore, harvest along the north coast of Russia should also be considered. Currently, most of the data available on the level of harvest of King Eiders in all three countries is out of date and the quality is insufficient to determine the effects of harvest on the population.

Environmental assessment

Knowing the location of a species population throughout its annual cycle is key to predicting pressures brought about by human activity, such as resource development. For example, telemetry has helped clarify the location, timing of use and relative importance of spring staging areas for King Eiders. Two of those staging areas, one in eastern Chukchi Sea off Alaska and the other in the southeast Beaufort Sea, overlap with offshore oil and gas development (Oppel et al. 2009; Dickson and Smith in press). Knowing where key areas for eiders are located and when birds are present will enable both government and industry to predict the level of risk of a proposed development and, if necessary, to develop measures to protect the eiders.

Impact of oil and gas development in the southeastern Beaufort Sea

One of the primary goals of this study was to obtain information on King Eider use of the southeastern Beaufort Sea in relation to oil and gas development in the region. Much has been learned that clarifies the potential risk to eiders. Although King Eiders are present in the southeastern Beaufort Sea from late April to November (Barry 1986; this study), the period when eiders are most vulnerable to offshore oil and gas development activity is during spring migration. At that time, the eiders are concentrated in areas of early open water associated with the flaw lead in the southeastern Beaufort Sea (Dickson and Smith in press). Results of this study suggest that most, if not all, King Eiders that breed in western and central arctic Canada stage in the southeastern Beaufort Sea for 2-4 weeks, with peak numbers occurring from mid-May to mid-June. For many of the eiders, it is the last stop prior to arrival on the breeding area, thus likely a key area to accumulate body reserves necessary for successful reproduction (Dickson and Smith in press). Disturbance, habitat degradation (e.g., contamination of benthic prey species), or direct mortality due to an oil spill at the spring staging area could have a catastrophic effect on Canada's western King Eider population. Oil spills are a major concern: eiders tend to aggregate in large flocks in spring, so even a small amount of oil could affect a large number of birds. It is unlikely that many birds could be successfully cleaned and rehabilitated, given the logistical difficulties of working in remote locations and ice-infested waters, and also given the low post-release survival rates reported elsewhere (Sharp 1996).

Movement westward through the southeastern Beaufort Sea on moult migration is generally more rapid, and the King Eiders that do stage (i.e., stop for > 6 days) tend to be at a greater distance from the current area of interest for oil and gas development (but see Phillips et al. (2007) for an analysis of the threat of oil and gas activity in the western Beaufort Sea during the post-breeding period for eiders breeding in northern Alaska). Males start to arrive in the

Beaufort Sea in late June. At that time, most are staging near their breeding grounds, thus they are concentrated either off Banks Island or off the north coast of Alaska. Males from Victoria Island start to arrive in the second week of July, and about half of these birds stage off Cape Dalhousie, where they are joined by some of the males (18%) from Banks Island. The length of stay off Cape Dalhousie ranges from 2-5 weeks. Although oil and gas activity is currently not taking place around Cape Dalhousie, wind and currents could conceivably carry oil to the area (Alexander et al. 1997). Once departed from Cape Dalhousie, males move rapidly to the Alaskan Beaufort Sea coast and beyond. Females enter the Beaufort Sea on moult migration about a month later than the males and stay for a shorter period of time. Few females likely stage in the southeast Beaufort Sea. Females from Victoria Island move through most rapidly, in < 10 days on average. Some females cross the Beaufort Sea in October after moult. This movement is perhaps very rapid (< 3 days, n = 1), although more data are needed to confirm this. Information is also needed on the timing of movement of juveniles from arctic Canada through the Beaufort Sea.

Conclusions

This study provides new information on the year-round movement of King Eiders that breed in western arctic Canada. The study identifies key areas and habitat for eiders outside the breeding range, links breeding, moulting and wintering areas, describes timing of movement, and provides insight into nest and moult site fidelity. These data will be useful to wildlife managers in several ways, including: identification of key marine areas that should be given special protective status, assessment of impact of resource development and other human activity, development of land use plans, assessment of harvest level, and design of monitoring studies.

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Table 1. Number of satellite transmitters (PTTs) deployed on King Eiders from 1997 to 2008 in western arctic Canada and northern Alaska.

			# of PTT deployed	
Location	Latitude and Longitude	Years	Male	Female
Victoria Island, NWT	70° 21' N; 110° 30' W	1997, 1998, 2003, 2004	25	20
Banks Island, NWT	72° 23' N; 125° 05' W	2000, 2008	23	18
Prudhoe Bay, AK	70° 15' N; 148° 25' W	1999	5	5
		All years	53	43

Table 2. Summary of surgery methods and related mortality from implanting satellite transmitters in King Eiders from 1997 to 2008.

	1997	1998	1999	2000	2003	2004	2008
Location	Victoria Is., NWT	Victoria Is., NWT	Prudhoe B., Alaska	Banks Is., NWT	Victoria Is., NWT	Victoria Is., NWT	Banks Is., NWT
Anaesthetic	ketamine & valium	propofal	isoflurane	propofal	isoflurane	isoflurane	isoflurane
Analgesic		*bupivacaine & ketoprofen*	*ketoprofen*	*bupivacaine & ketoprofen*			*bupivcaine: lidocaine (2:1)*
# surgeries	8 male 2 female	4 male 6 female	5 male 5 female	6 male 5 female	6 male 6 female	7 male 6 female	17 male 13 female
# deaths during surgery	0	0	0	0	0	1 male	0
# deaths within 3 weeks	0	2 male 1 female	0	5 male 1 female	0	0	1 male
# eiders with transmitters after 3 weeks	8 male 2 female	2 male 5 female	5 male 5 female	1 male 4 female	6 male 6 female	6 male 6 female	16 male 13 female

Table 3. Amount and quality of data obtained from the satellite transmitters, including period of operation, number of transmission cycles with at least one location, and percentage of locations classified by CLS-Argos Service as accurate to within 1500 m.

		Tracking period in days		Number of locations		% with location classes 1, 2 or 3	
Year	n[1]	Median	Range	Median	Range	Median	Range
1997	10	147	91 – 247	28	34 – 59	47	44 – 86
1998	7	275	82 – 421	26	15 – 82	60	20 – 77
1999	10	95	68 – 219	22	13 – 55	75	46 – 90
2000	5	422	408 – 440	80	76 – 108	78	28 – 90
2003	12	423	142 – 486	157	68 – 174	71	35 – 92
2004	12	395	138 – 427	40	15 – 104	56	39 – 92
2008	29	406	44 – 680	127	16 – 187	94	47 – 99

[1] Does not include transmitters on eiders that died within 3 weeks of surgery.

Table 4. Timing of movement of King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska from 1997 to 2008.

		Male						Female					
		Mean	SD in days	Range			n	Mean	SD in days	Range			n
Year 1	Depart nesting area	26-Jun	±6	13-Jun	-	09-Jul	43	26-Jul	±15	07-Jun	-	29-Aug	40
	Depart nearby staging	20-Jul	±9	29-Jun	-	04-Aug	26	14-Aug	±9	28-Jul	-	11-Sep	37
	Arrive moulting area	11-Aug	±9	23-Jul	-	26-Aug	38	30-Aug	±11	04-Aug	-	28-Sep	34
	Moult migration # days[1]	42	±9	17	-	63	38	32	±15	2	-	74	33
	Depart moulting area	20-Oct	±19	24-Sep	-	29-Nov	29	05-Nov	±17	05-Oct	-	16-Dec	22
	Arrive wintering area	20-Nov	±27	08-Oct	-	02-Jan	26	25-Nov	±19	17-Oct	-	19-Dec	22
	Fall migration # days	25	±26	2	-	82	26	16	±18	2	-	69	20
	Depart wintering area	21-Mar	±26	04-Feb	-	25-Apr	19	05-Apr	±14	10-Mar	-	27-Apr	20
	Depart wintering region	24-Apr	±7	07-Apr	-	11-May	22	21-Apr	±14	21-Mar	-	11-May	21
	Arrive nesting area	17-Jun	±5	10-Jun	-	27-Jun	9	15-Jun	±4	06-Jun	-	24-Jun	21
	Spring migration # days[2]	80	±28	49	-	121	8	67	±14	45	-	95	17
Year 2	Depart nesting area	26-Jun	±13	15-Jun	-	23-Jul	9	25-Jul	±10	01-Jul	-	08-Aug	15
	Depart nearby staging	12-Jul	±6	07-Jul	-	20-Jul	4	11-Aug	±6	05-Aug	-	22-Aug	9
	Arrive moulting area	05-Aug	±8	27-Jul	-	16-Aug	7	31-Aug	±9	21-Aug	-	15-Sep	6
	Moult migration # days[1]	39	±8	30	-	50	5	32	±5	27	-	38	6
	Depart moulting area						0	31-Oct	±0				2
	Arrive wintering area						0	14-Nov	±9	08-Nov	-	21-Nov	2
	Fall migration # days						0	11	±9	4	-	17	2

[1] Includes post-breeding period when eiders were staging at coast near breeding area.
[2] Includes period eiders were staging within winter region.

Table 5. Timing of use of staging areas in marine waters near breeding area at beginning of moult migration by King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

		Arrival[1]		Departure[1]		Period of stay (days)[1]			
Sex	Staging area	Mean	SD	Mean	SD	Mean	SD	# of eiders	% of eiders that staged ≥ 7 days
Males	Victoria Island	02-Jul	±9	22-Jul	±11	24	±11	21	29
	SW Banks Island	30-Jun	±4	21-Jul	±8	25	±7	17	94
	Alaskan Beaufort Sea	24-Jun	±6	12-Jul	±9	21	±4	5	80
Females	Victoria Island	29-Jul	±12	15-Aug	±7	21	±11	17	100
	SW Banks Island	30-Jul	±11	14-Aug	±7	17	±7	15	100
	Alaskan Beaufort Sea	31-Jul	±34	23-Aug	±17	28	±22	5	100

[1] Based on birds located in the staging area at least once.

Table 6. Location and timing of use of staging areas by King Eiders during moult migration following departure from marine waters adjacent to the breeding area.

Sex	Staging area	Arrival[1] Mean	Arrival[1] SD	Departure[1] Mean	Departure[1] SD	Period of stay (days)[1] Mean	Period of stay (days)[1] SD	# of eiders	% of eiders that staged ≥ 7 days
Males	Eastern Beaufort Sea	08-Jul	±12	26-Jul	±9	20	±11	39	44
	Off northern Alaska	28-Jul	±9	04-Aug	±8	10	±5	37	57
	Off Chukotsk Peninsula	04-Aug	±8	08-Aug	±7	7	±7	14	36
Females	Eastern Beaufort Sea	18-Aug	±7	21-Aug	±8	3	±2	34	6
	Off northern Alaska	22-Aug	±9	27-Aug	±9	8	±5	42	21
	Off Chukotsk Peninsula	27-Aug	±11	28-Aug	±10	5	±3	19	11

[1] Based on birds located in the staging area at least once.

Table 7. Timing of moult migration across the Beaufort Sea for King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

		Arrival			Departure			Duration of stay (days)			Staging areas	
	Breeding area	Mean	SD	n	Mean	SD	n	Mean	SD	n	Location	# that staged
Male	Victoria Is.	12-Jul	±15	20	01-Aug	±8	17	24	±15	16	west Banks Island	5
											C. Dalhouse/Bathurst	8
	Banks Is.	30-Jun	±4	17	27-Jul	±7	17	31	±7	17	west Banks Island	16
											Cape Bathurst	3
											Smith Bay	1
	Prudhoe B.	27-Jun	±7	5	11-Jul	±9	5	18	±8	5	Komakuk	2
											Camden Bay	2
											Smith Bay	1
	All	**05-Jul**	**±13**	**42**	**27-Jul**	**±10**	**39**	**26**	**±12**	**38**		
Female	Victoria Is.	18-Aug	±7	16	26-Aug	±7	15	9	±6	14	Smith Bay	1
	Banks Is.	30-Jul	±11	16	17-Aug	±7	16	22	±7	15	west Banks Island	17
											Smith Bay	1
	Prudhoe B.	31-Jul	34	5	24-Aug	±16	5	29	±25	5	Prudhoe Bay	1
											Jones Islands	1
											Harrison Bay	4
	All	**08-Aug**	**±17**	**37**	**22-Aug**	**±9**	**36**	**18**	**±13**	**34**		

Table 8. Location of moulting areas used by King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

	Number of eiders		% distribution of eiders		
Moulting area	Males	Females	Males	Females	All
SE Chukotsk Peninsula	9	14	22	36	29
Anadyr Bay	17	4	41	10	26
St. Lawrence Island	5	3	12	8	10
East Bering Sea	4	9	10	23	16
West Bering Sea	3	7	7	18	13
Chukchi Sea	3		7		4
Breeding area		2		5	2

Table 9. Affiliation between breeding and moulting areas for King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

		Percentage of eiders					
Breeding location	n	SE Chukotsk Peninsula	Anadyr Bay	St. Lawrence Island	SE Bering Sea	SW Bering Sea	Other
Victoria Island	37	22	30	8	14	19	8
Banks Island	33	39	24	9	18	6	3
Prudhoe Bay	8	25	25	25	0	12	12

Table 10. Location and timing of use of staging areas during fall migration for King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

	Arrival[1]		Departure[1]		Period of stay (days)[1]			
Staging area	Mean	SD	Mean	SD	Mean	SD	# migrating through area	% staging[2]
E Chukotsk Peninsula	12-Oct	±6	26-Oct	±20	18	±15	7	43
St. Lawrence Island	01-Nov	±16	28-Nov	±5	30	±19	19	74
Anadyr Bay	15-Oct	±20	02-Nov	±12	17	±14	6	50
Khatyrka	26-Oct	±14	01-Nov	±11	10	±7	8	38
Cape Olyutor	20-Nov	±7	24-Nov	±9	8	±6	7	43
Karagin Bay	09-Dec		22-Dec		17		5	20
Kushkokwim & Bristol bays	16-Nov	±20	11-Dec	±10	28	±23	17	41

[1] Based on birds located in the staging area at least once.
[2] Percentage of birds that stopped for ≥ 7 days.

Table. 11. Distribution of King Eiders from two different breeding areas amongst three separate wintering areas.

			Percent distribution on wintering area		
Breeding area	Year	n	off Chukotsk Peninsula	off Alaska Peninsula	off Kamchatka Peninsula
Victoria Island	1997	4		100	
	1998	3	66		33
	2003	11	27	36	36
	2004	11	36	36	27
	All years	**29**	**31**	**41**	**28**
Banks Island	2000	5		60	40
	2008	27	56	41	4
	All years	**32**	**47**	**44**	**9**
Combined	**All years**	**61**	**39**	**43**	**18**

Table 12. Location and timing of use of staging areas during spring migration for King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

	Arrival[1]		Departure[1]		Period of stay (days)[1]		# migrating	
Staging area	Mean	SD	Mean	SD	Mean	SD	through area	% staging[2]
Bristol Bay	16-Mar	±17	01-May	±13	52	±22	16	63
Khatyrka	19-Mar	±28	25-Apr	±6	36	±30	6	67
Chukotsk Peninsula	16-Apr	±11	28-Apr	±6	14	±11	44	30
E. Chukchi Sea	02-May	±9	10-May	±8	12	±7	39	72
SE. Beaufort Sea	13-May	±8	05-Jun	±8	26	±10	37	100
Banks Island	03-Jun	±7	11-Jun	±2	12	±7	33	36
Siberian Sea	02-May	±7	25-May	±6	27	±11	4	25

[1] Based on birds located in the staging area at least once.
[2] Percentage of birds that stopped for ≥ 7 days.

Table 13. Timing of spring migration across the Beaufort Sea for King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska, 1997-2008.

	Arrival			Departure			Duration of stay (days)		
	Mean	SD	n	Mean	SD	n	Mean	SD	n
Male	14-May	±11	17	11-Jun	±5	7	31	±10	7
Female	13-May	±8	23	10-Jun	±3	23	31	±8	22

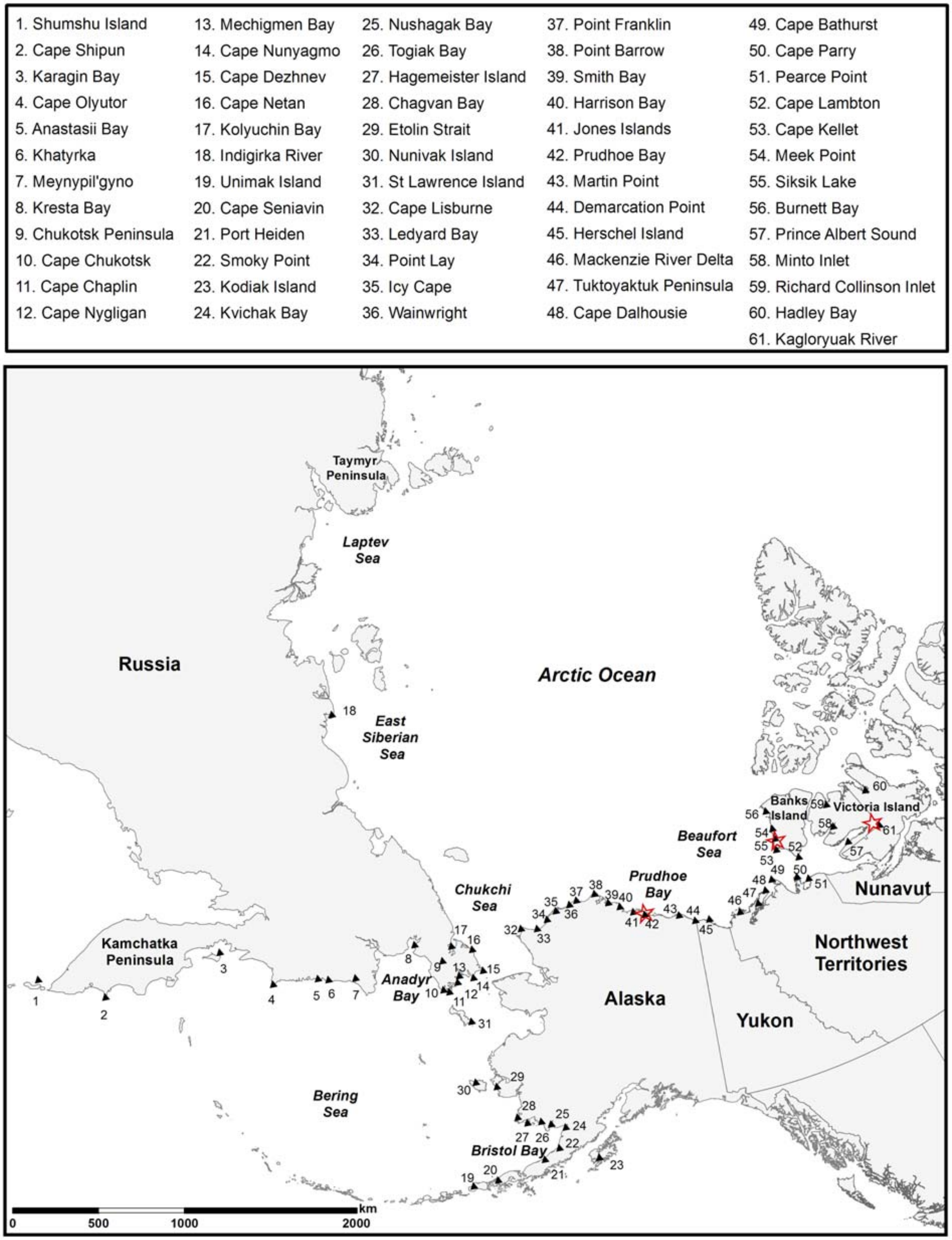
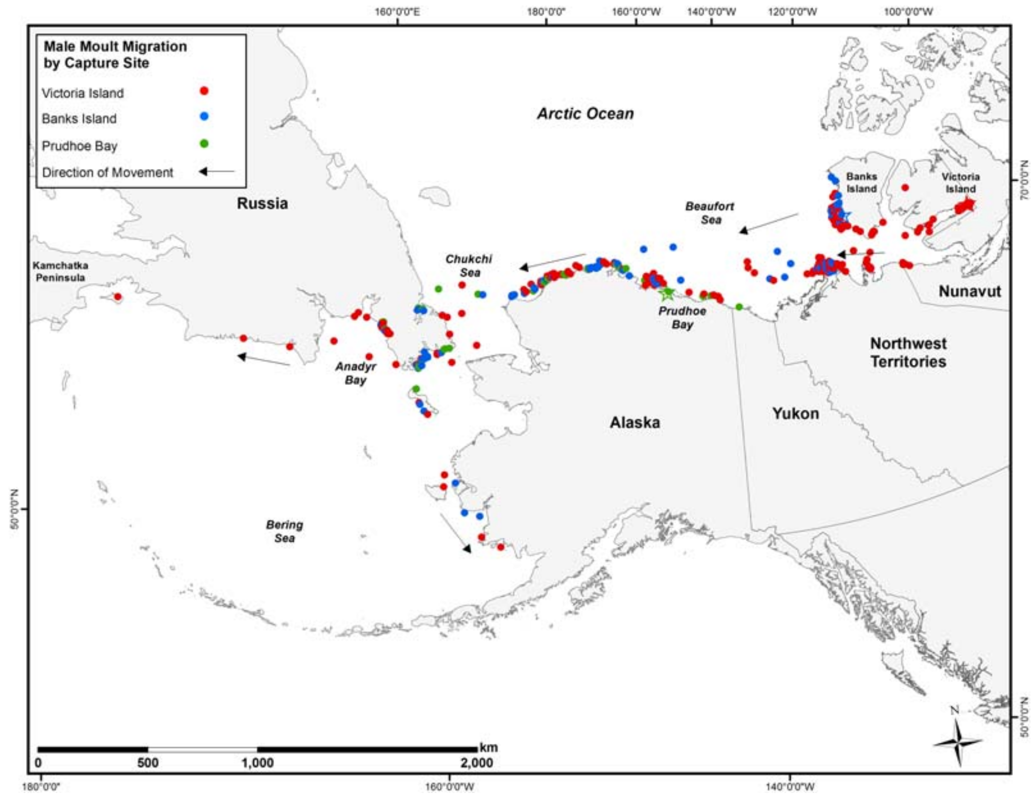


Figure 1. Location of King Eider capture sites (red stars) and place names mentioned in text.



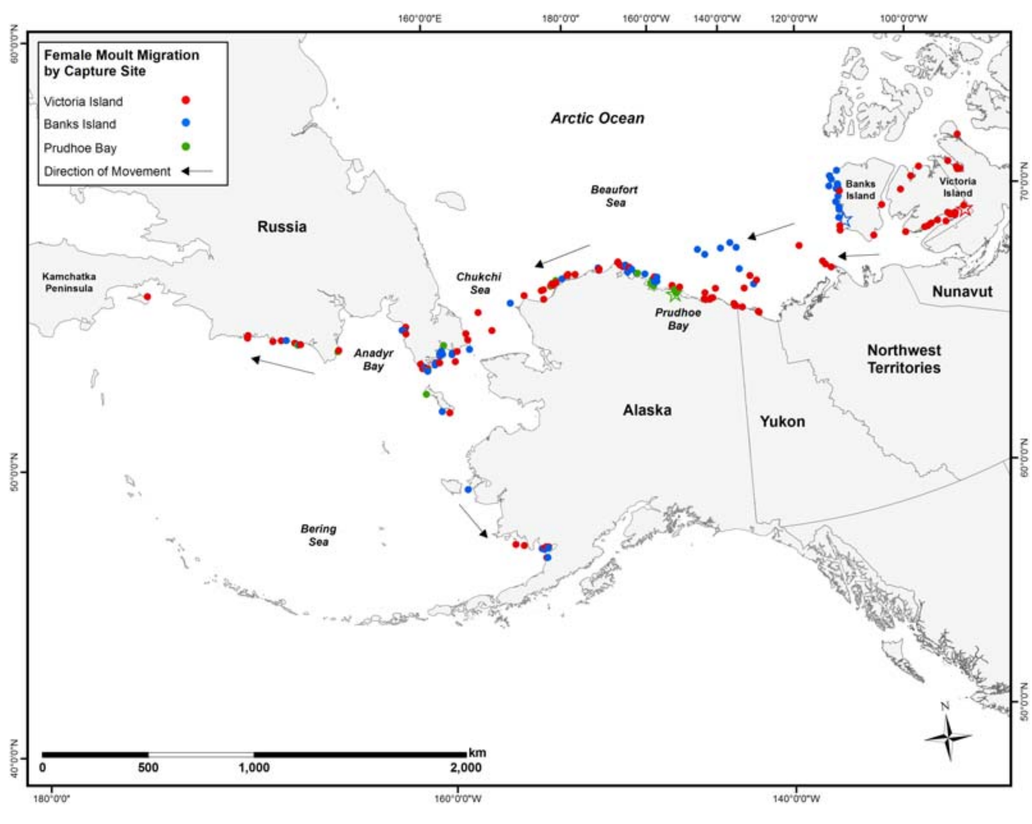


Figure 2. Moult migration route of 38 male and 32 female King Eiders from three different breeding areas. Each circle represents an eider location and stars represent capture sites.

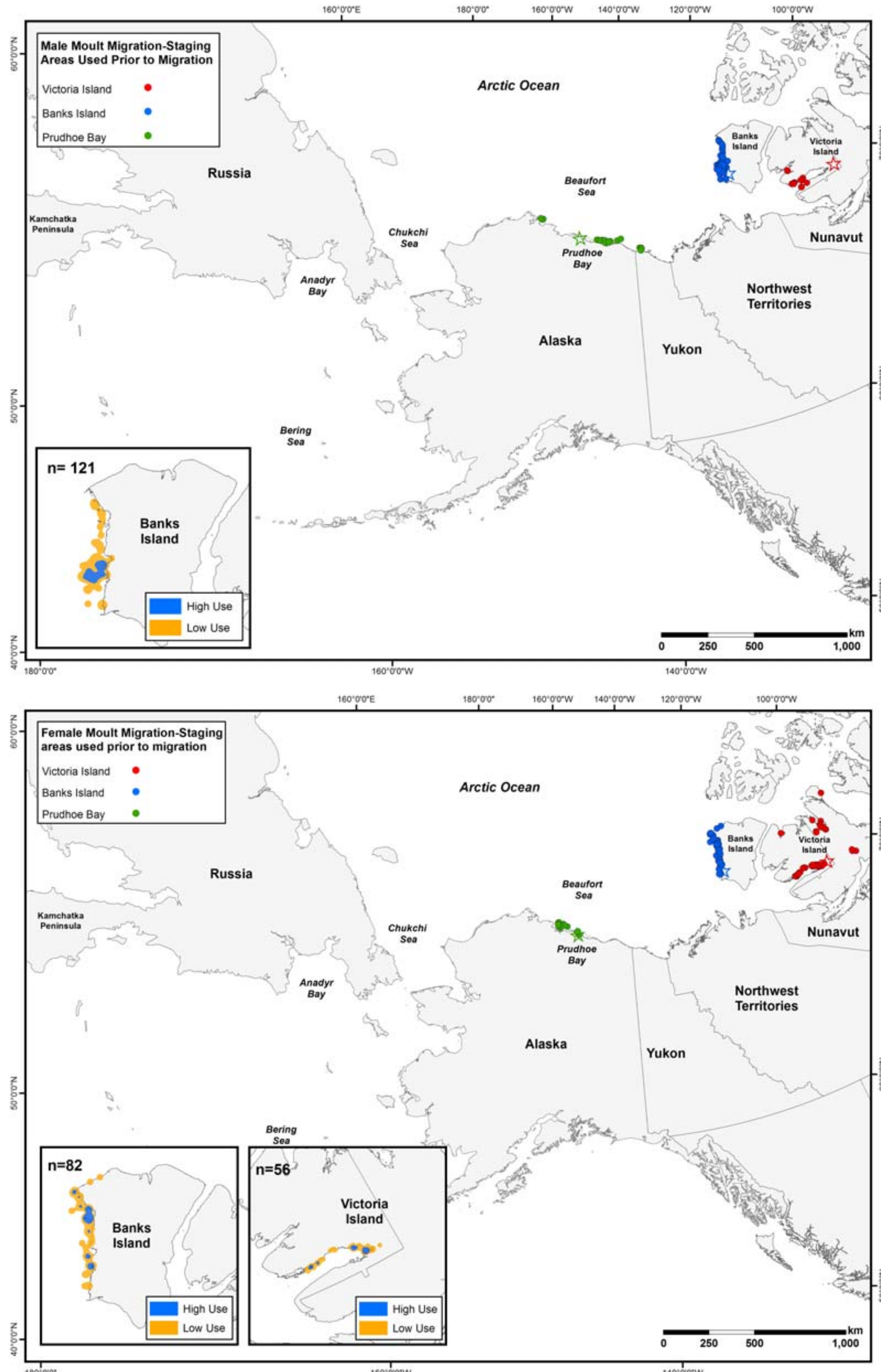


Figure 3. Staging areas used by King Eiders prior to moult migration. Colours refer to breeding areas where birds were captured. Inserts show distribution of eiders on staging areas: blue shading indicates high-use 50% volume contour; yellow shows 95% volume contour.

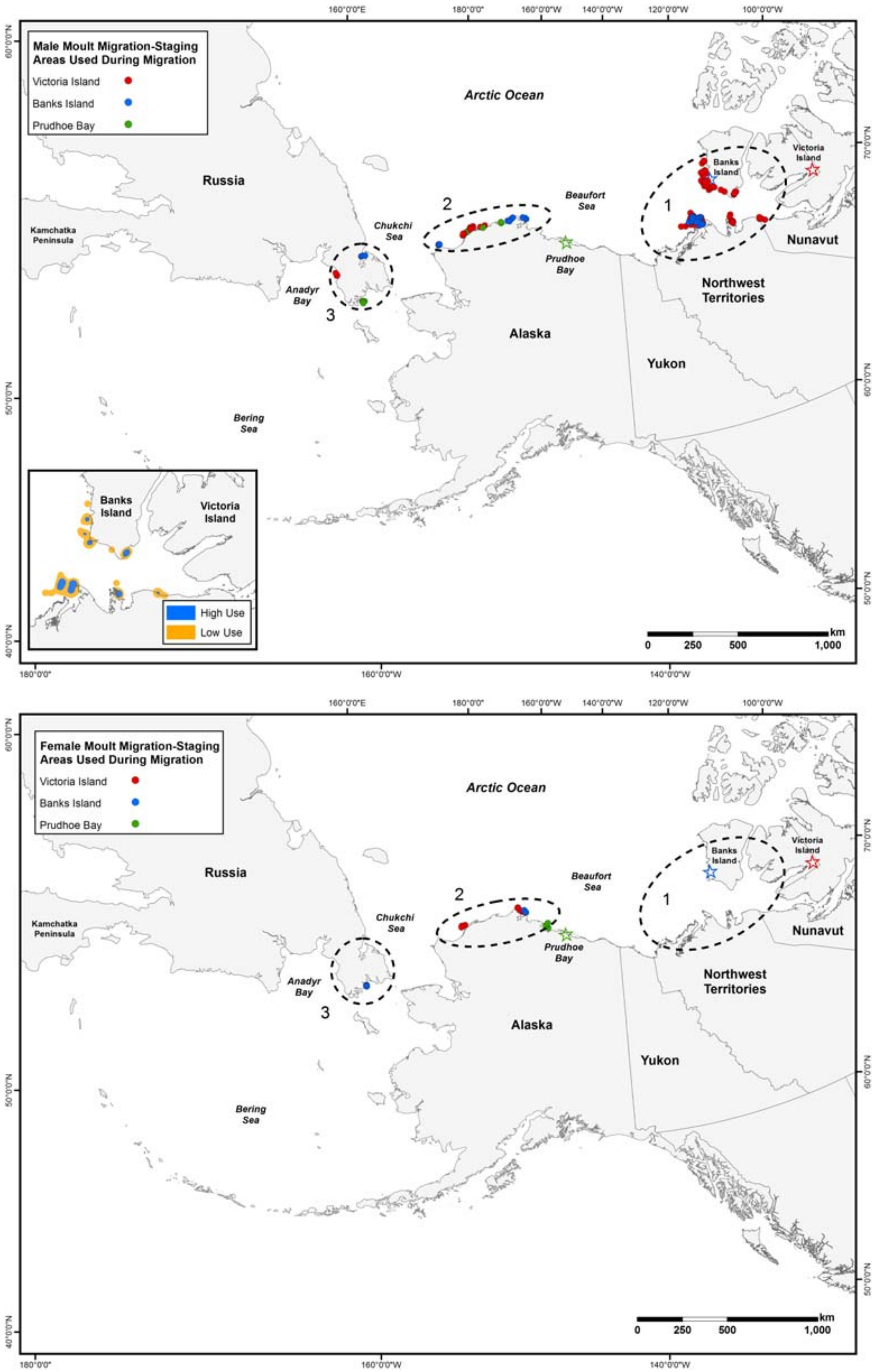


Figure 4. Staging areas used by King Eiders during moult migration: 1) eastern Beaufort Sea; 2) off northern Alaska; and 3) off Chukotsk Peninsula. Colours indicate breeding area where birds were captured. Insert shows distribution of male eiders on staging area #1 (n = 115 locations): blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

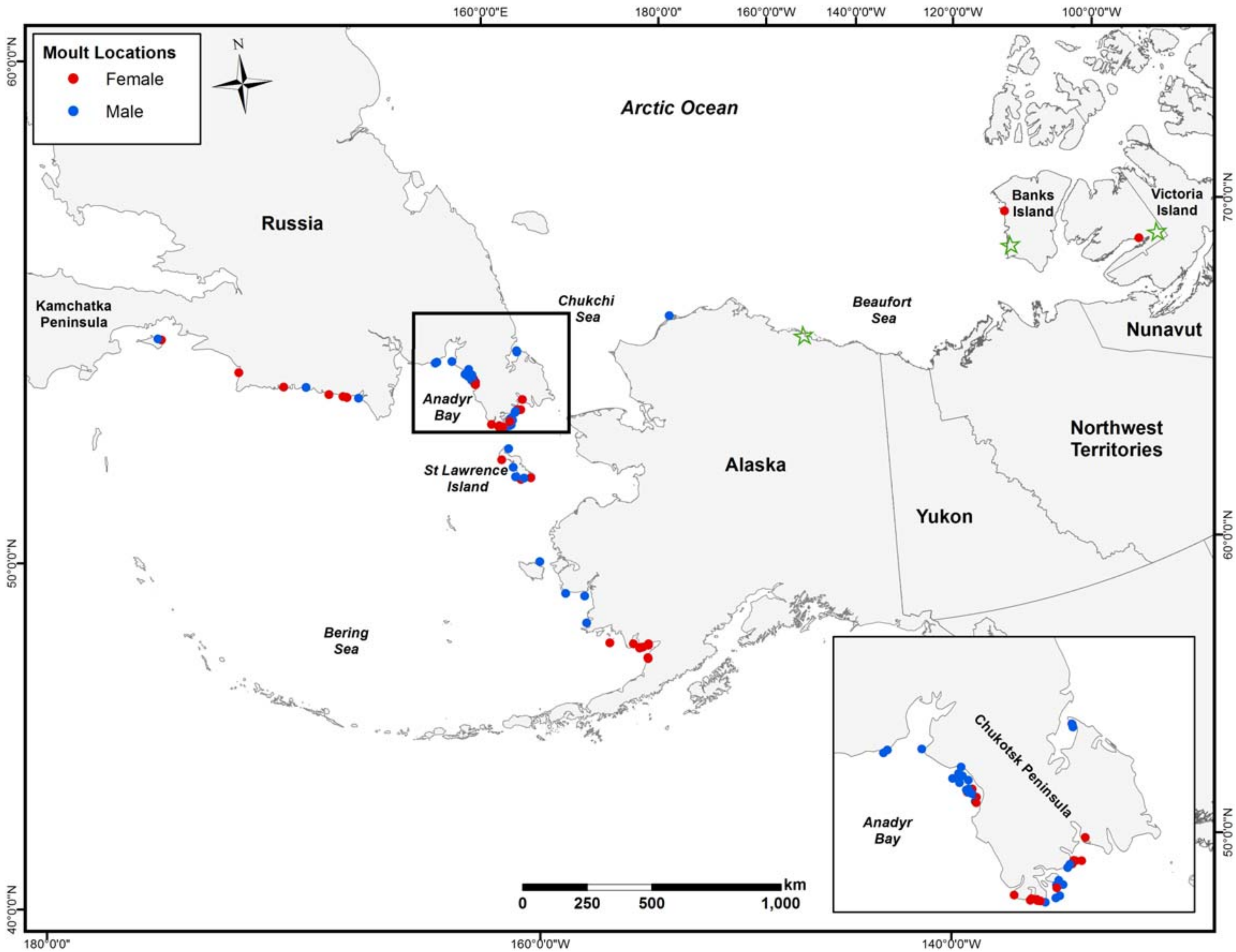


Figure 5. Moult locations of 41 male and 39 female King Eiders captured on breeding areas (green stars) in western arctic Canada and northern Alaska. Each circle represents the centroid of where an eider moulted.

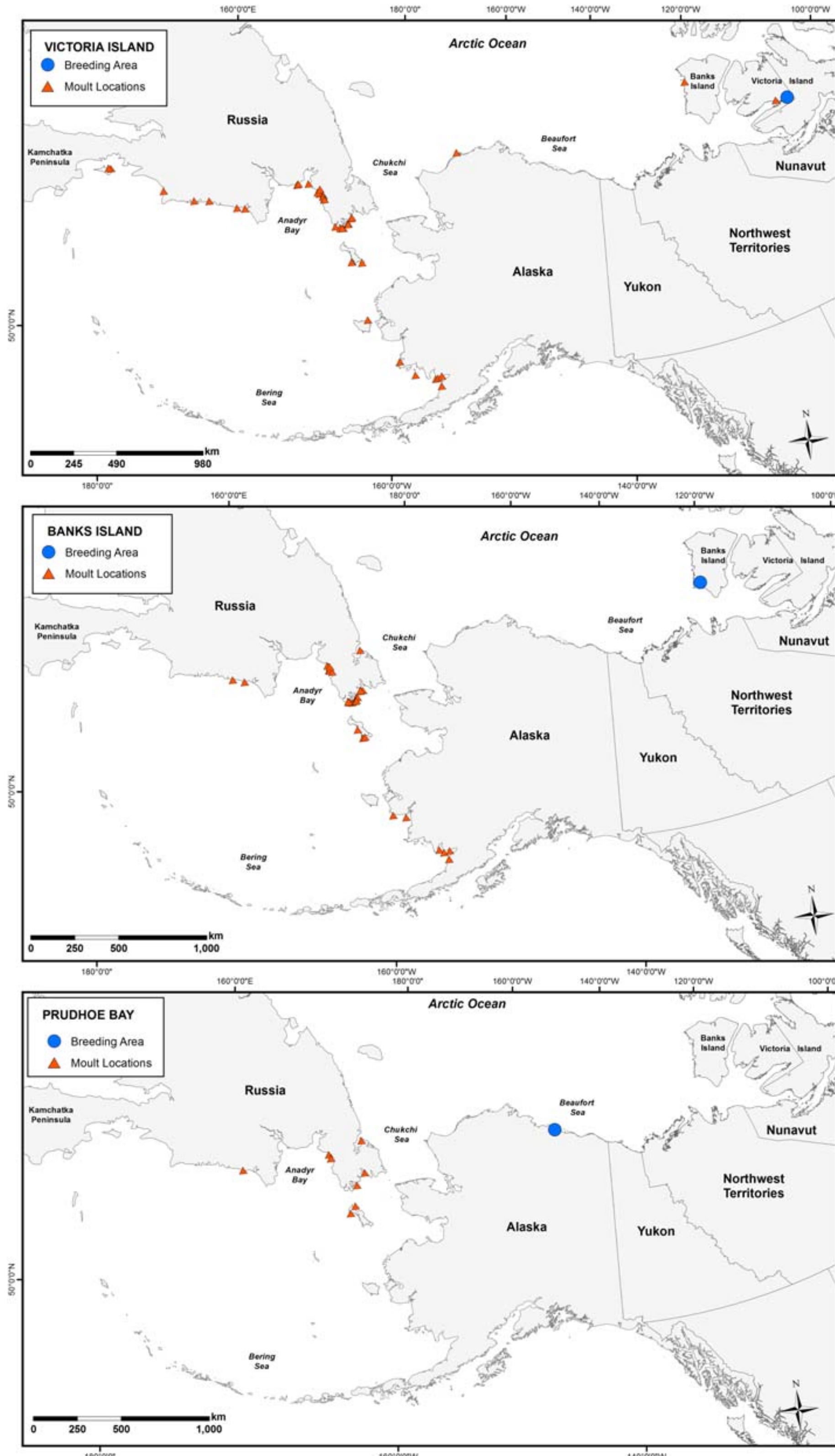


Figure 6. Comparison of moult locations used by King Eiders from three separate breeding areas: Victoria Island (n = 37), Banks Island (n = 33) and Prudhoe Bay (n = 8). Each triangle represents the centroid moult location of an eider.

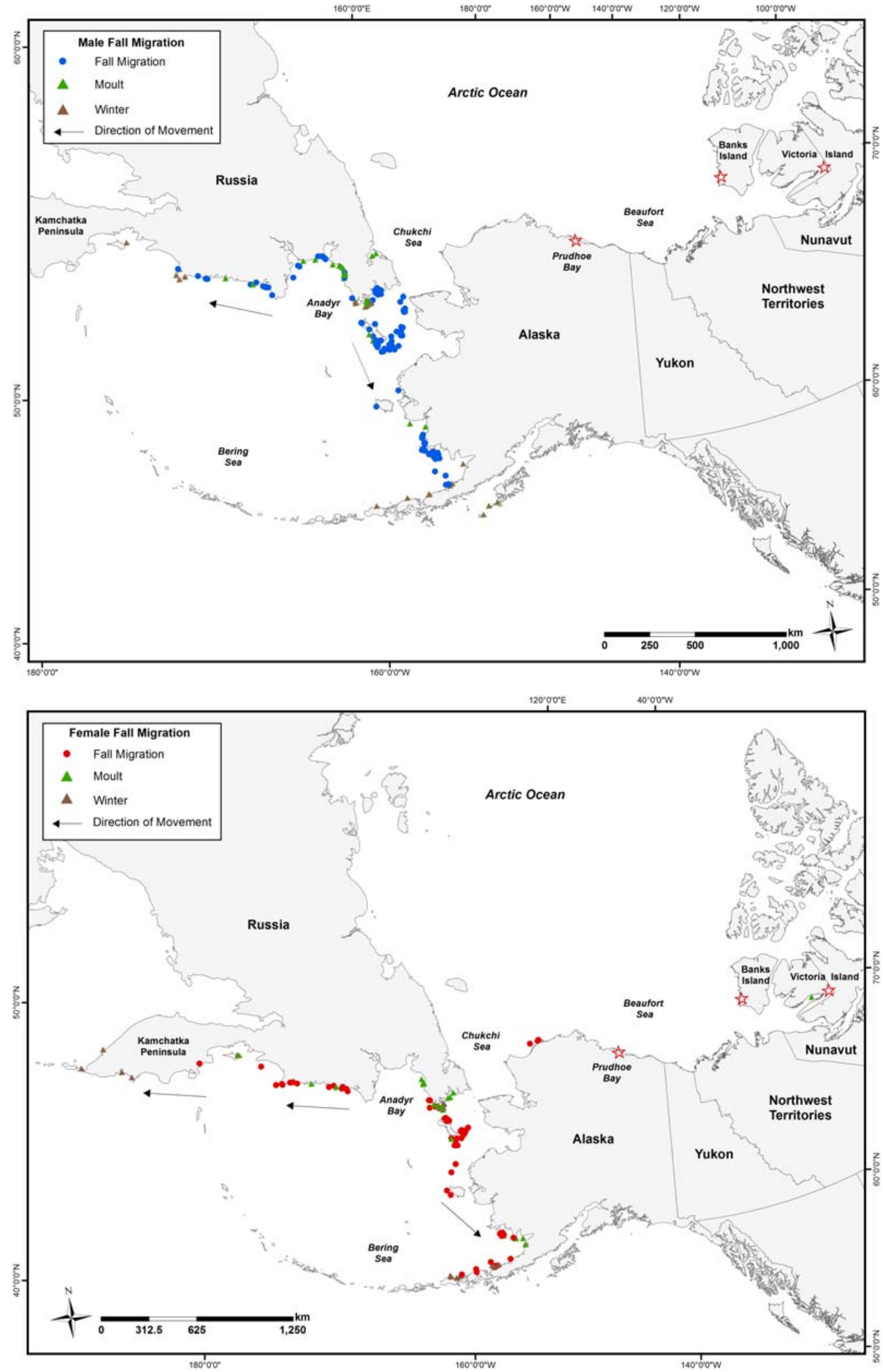


Figure 7. Fall migration of 26 male and 20 female King Eiders. Each circle represents an eider location during migration. Triangles represent moulting and wintering areas.

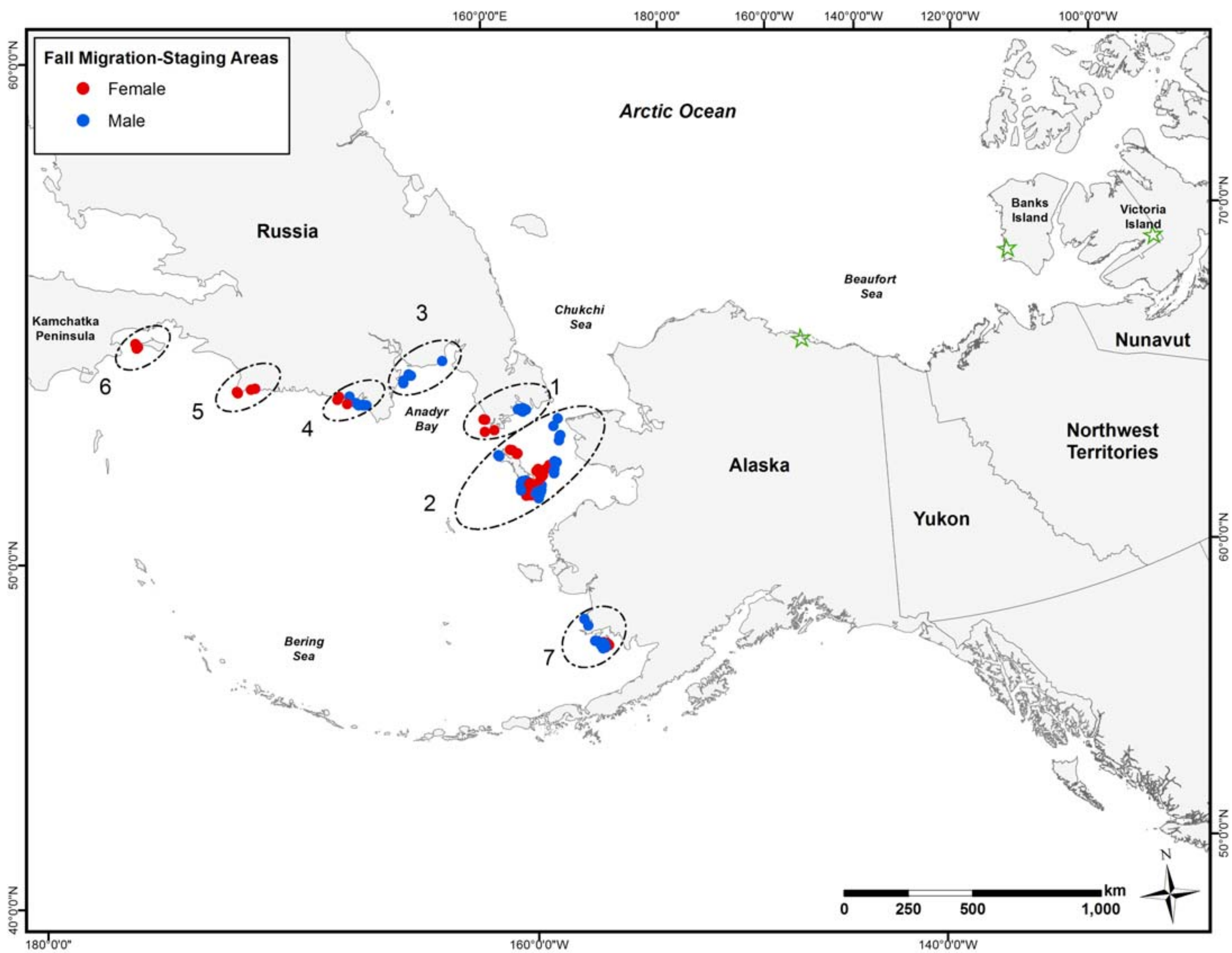


Figure 8. Staging areas used by King Eiders during fall migration: 1) the Chukotsk Peninsula; 2) St. Lawrence Island; 3) Anadyr Bay; 4) Khatyrka; 5) Cape Olyutor; 6) Karagin Bay; and 7) north Bristol Bay. Each circle represents an eider location.

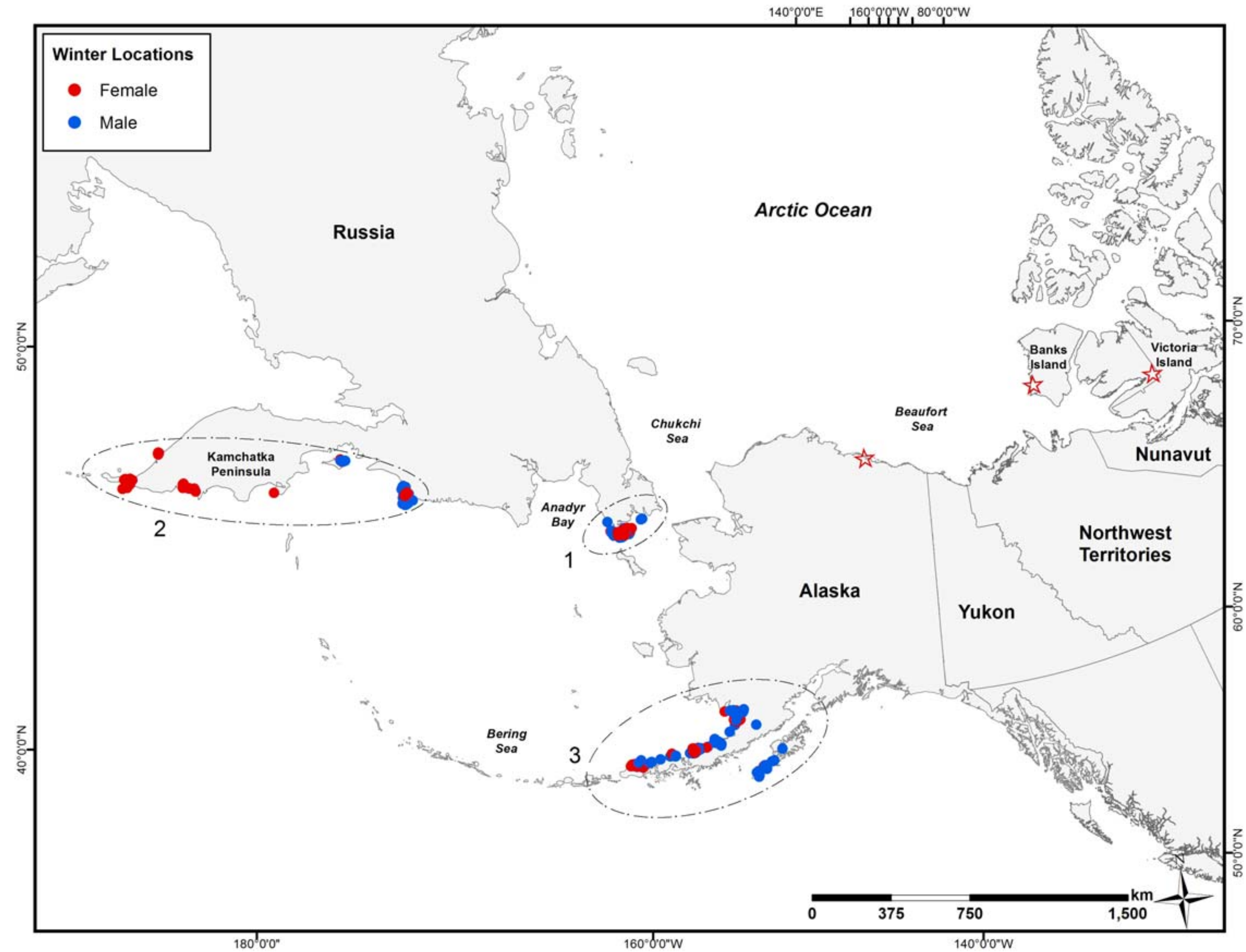


Figure 9. Winter locations of 24 male and 26 female King Eiders captured on breeding areas indicated with red stars. Each circle represents a centroid of where an eider was located during winter. There were three distinct winter regions: 1) off the Chukotsk Peninsula; 2) off the Kamchatka Peninsula; and 3) off the Alaska Peninsula.

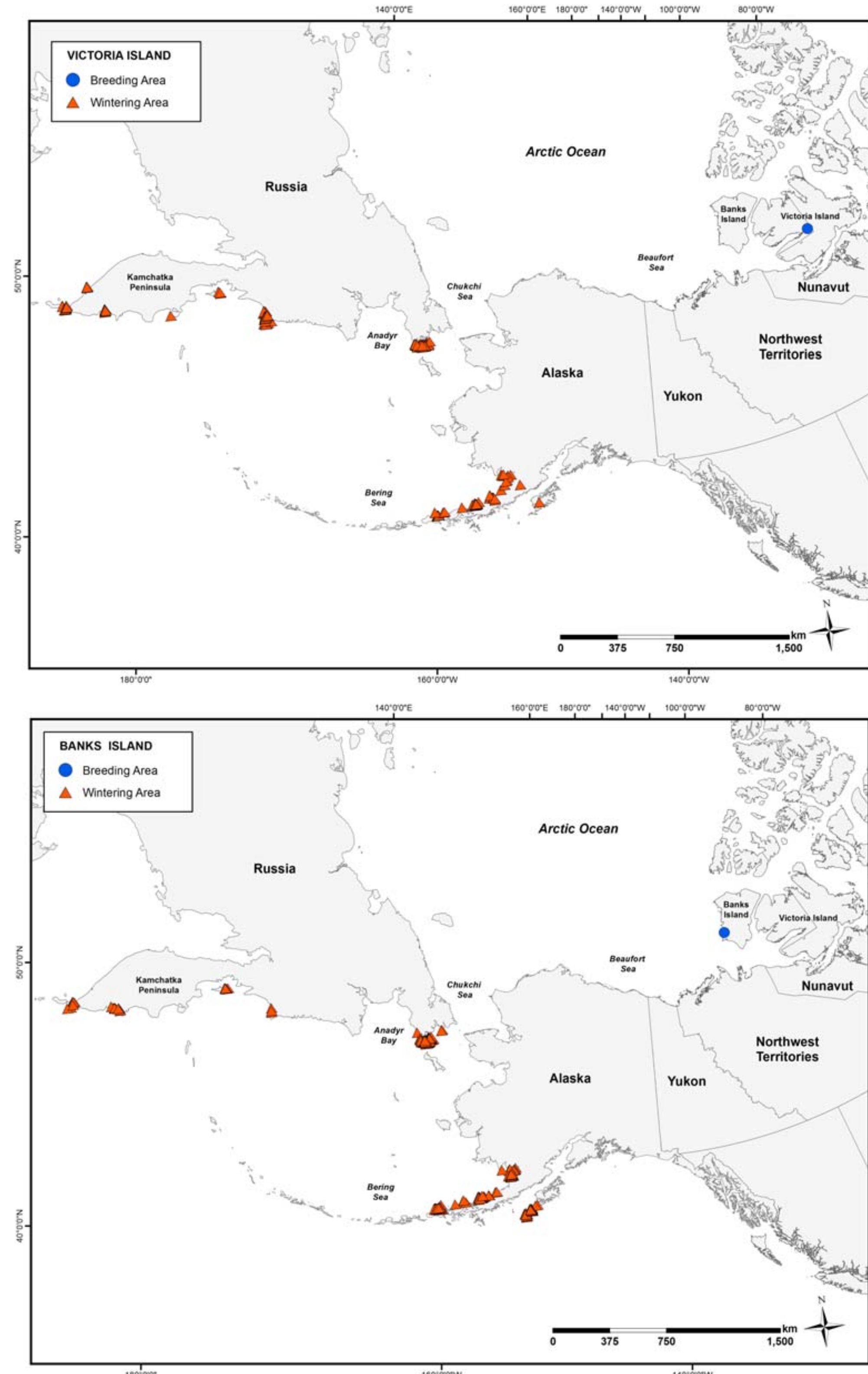


Figure 10. Comparison of winter sites used by King Eiders from breeding areas on Banks Island (n = 32) versus Victoria island (n =29). Each triangle is the centroid winter location of an eider.

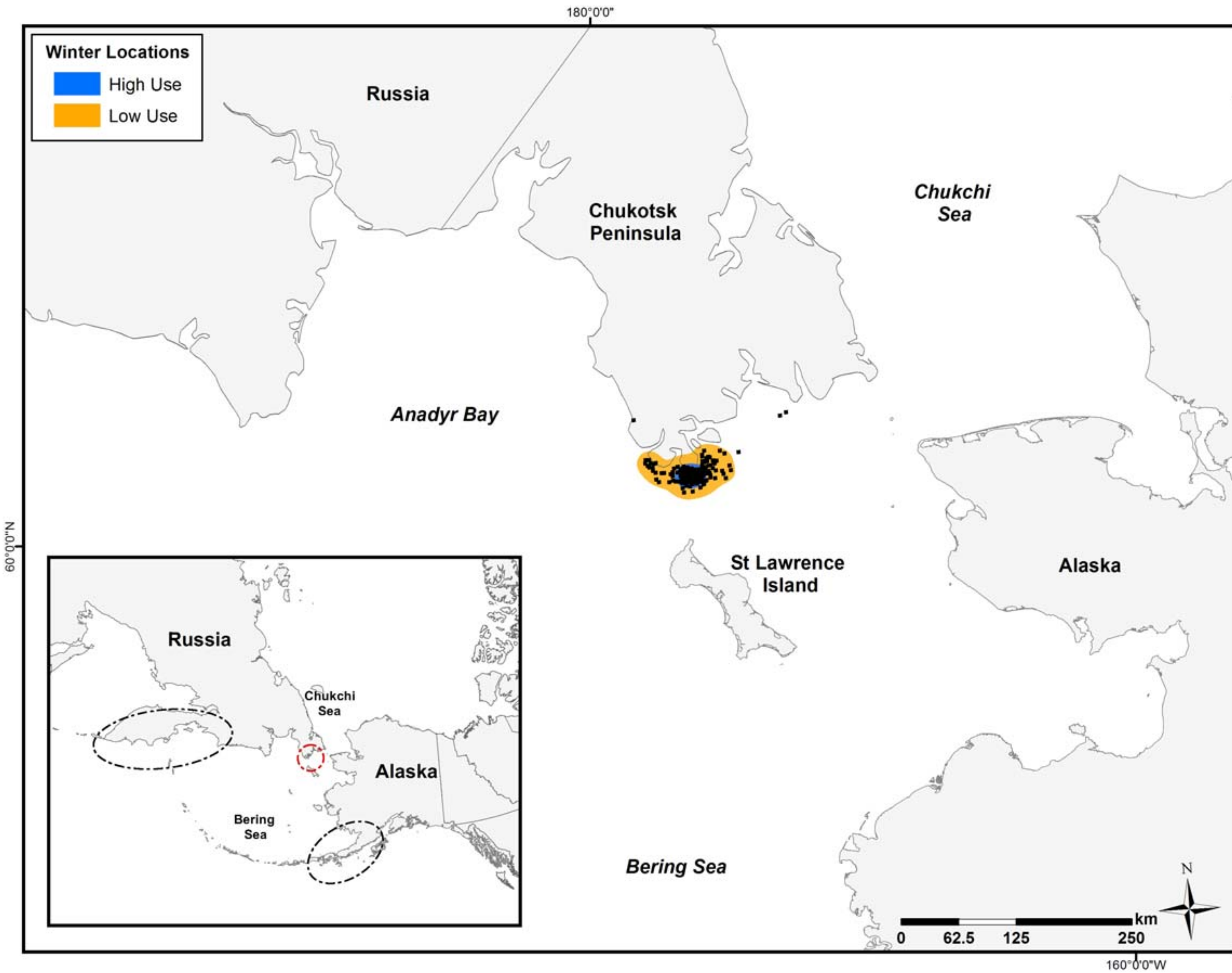


Figure 11a. Winter distribution of 10 male and 10 female King Eiders off the Chukotsk Peninsula (n = 199 locations). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

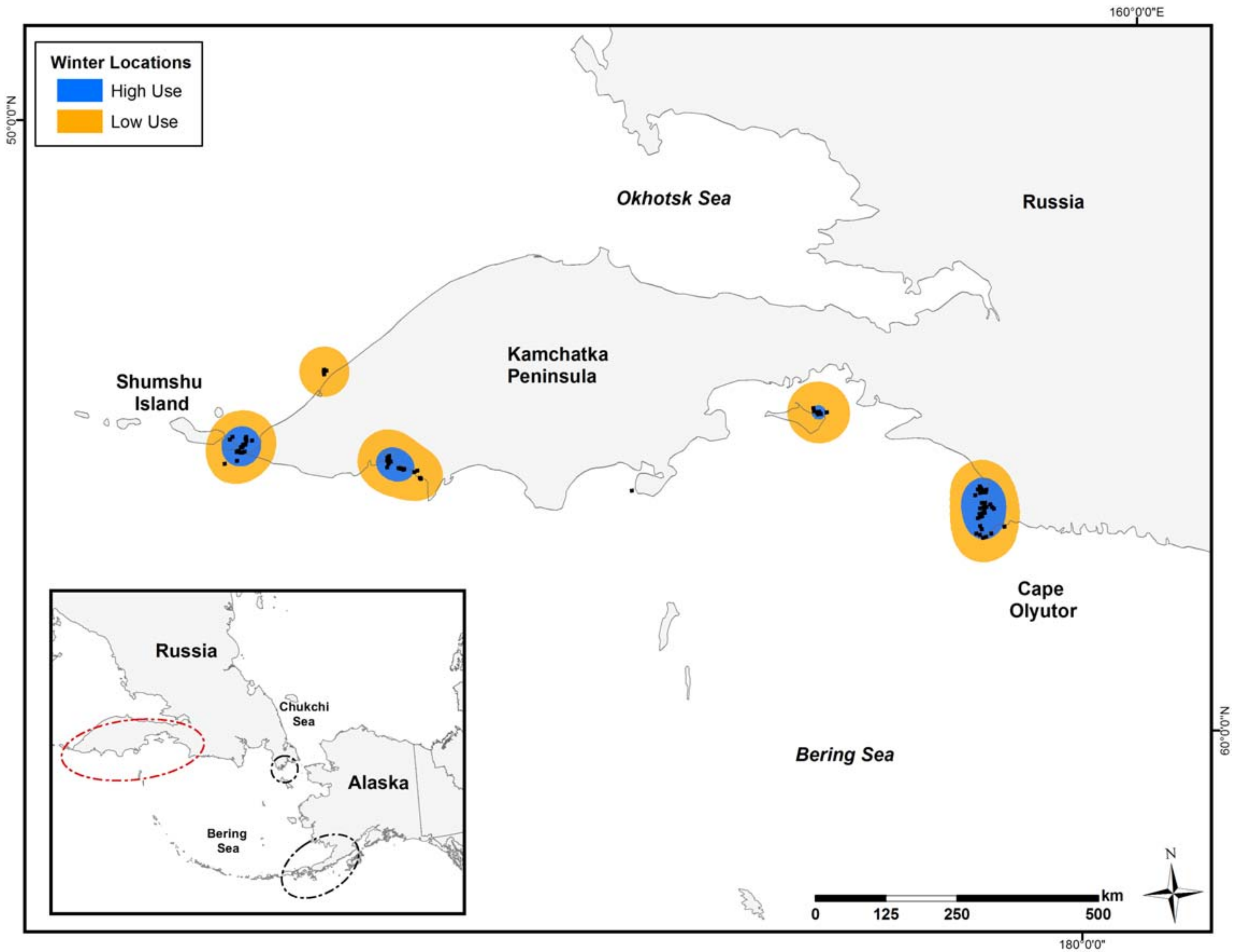


Figure 11b. Winter distribution of 4 male and 6 female King Eiders off the Kamchatka Peninsula (n = 94 locations). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

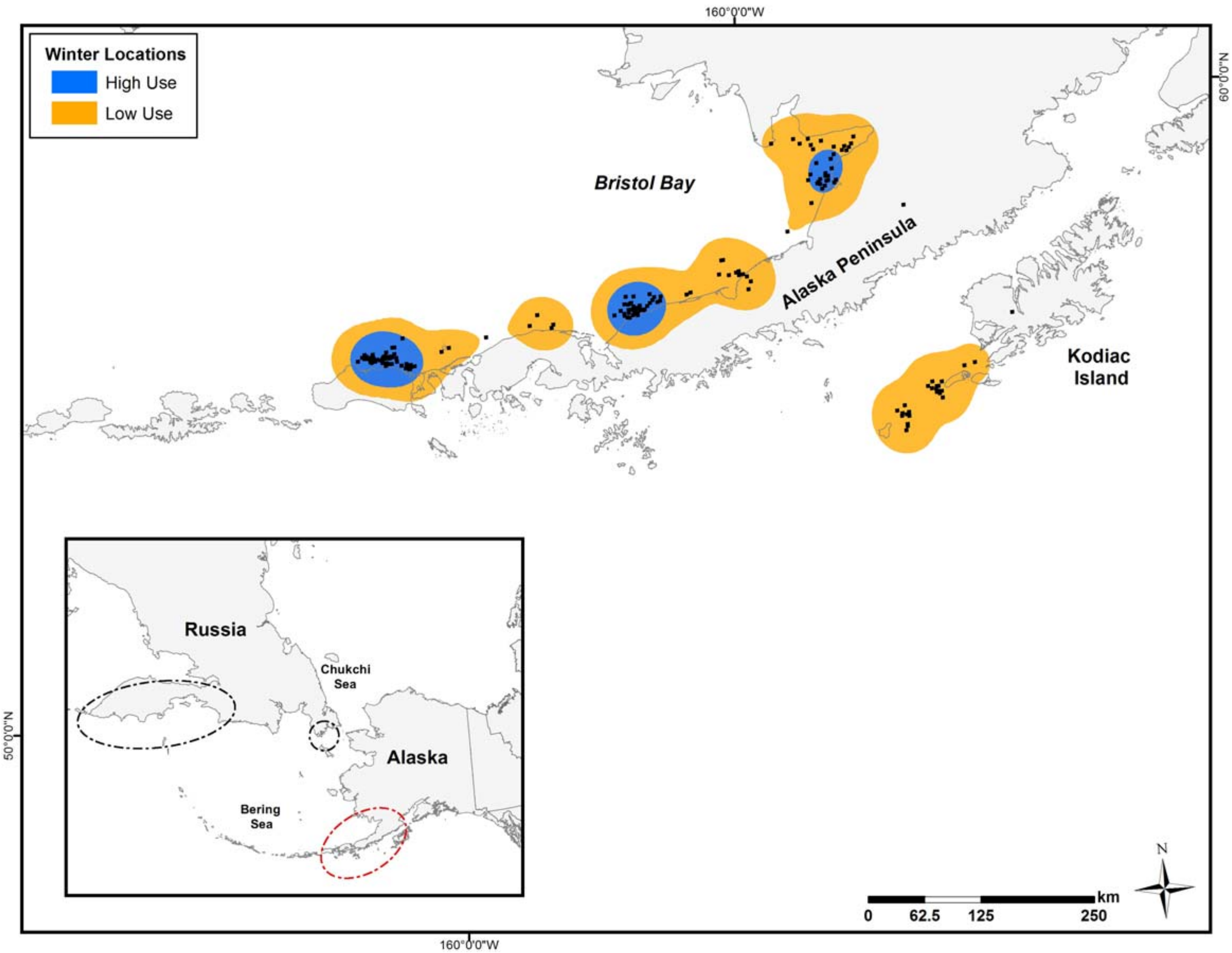


Figure 11c. Winter distribution of 10 male and 10 female King Eiders off the Alaska Peninsula (n = 188 locations). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

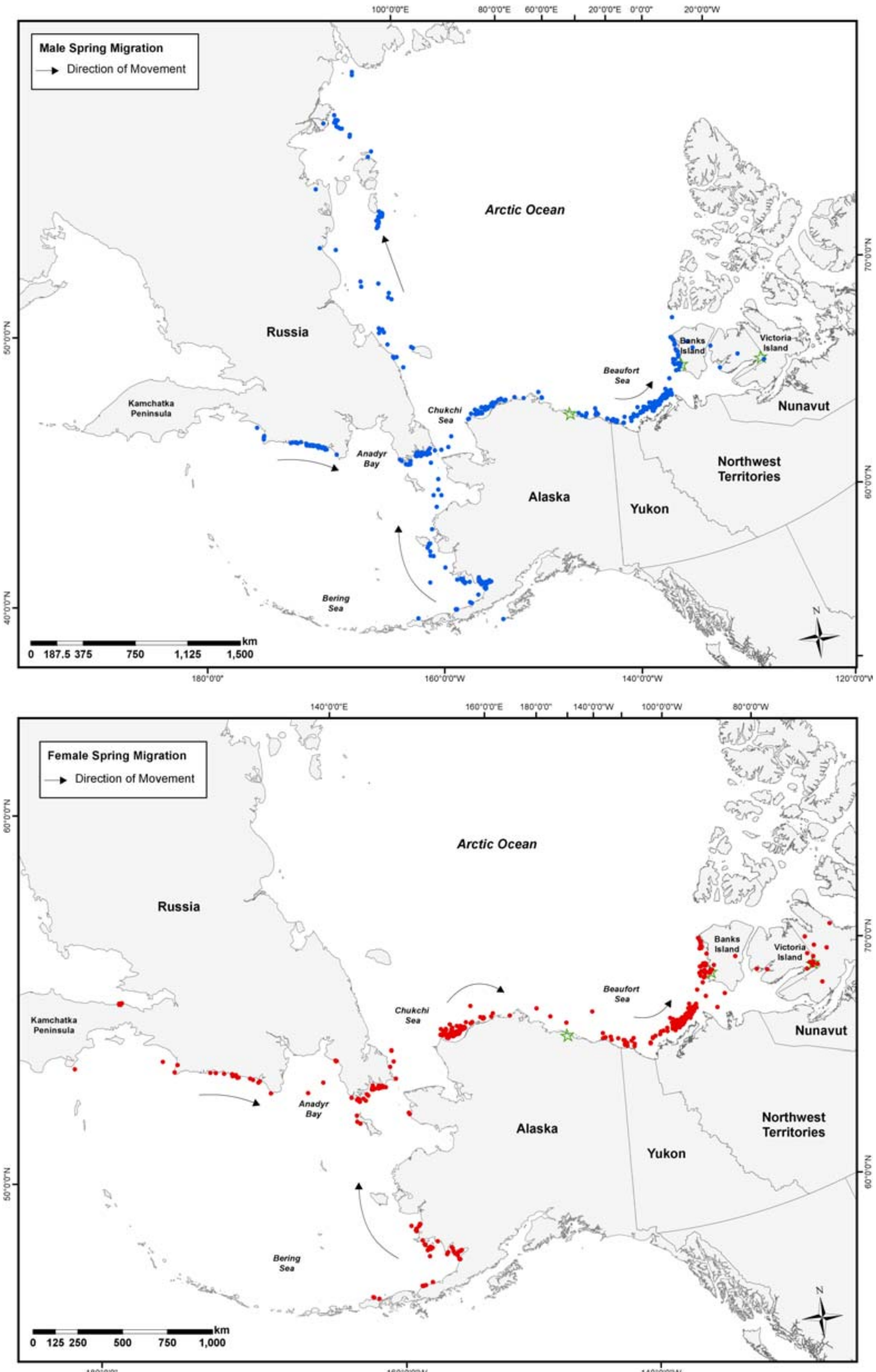


Figure 12. Spring migration of 19 male and 23 female King Eiders from wintering areas in the Bering Sea and North Pacific Ocean. Each circle represents an eider location. Stars represent capture sites the previous June.

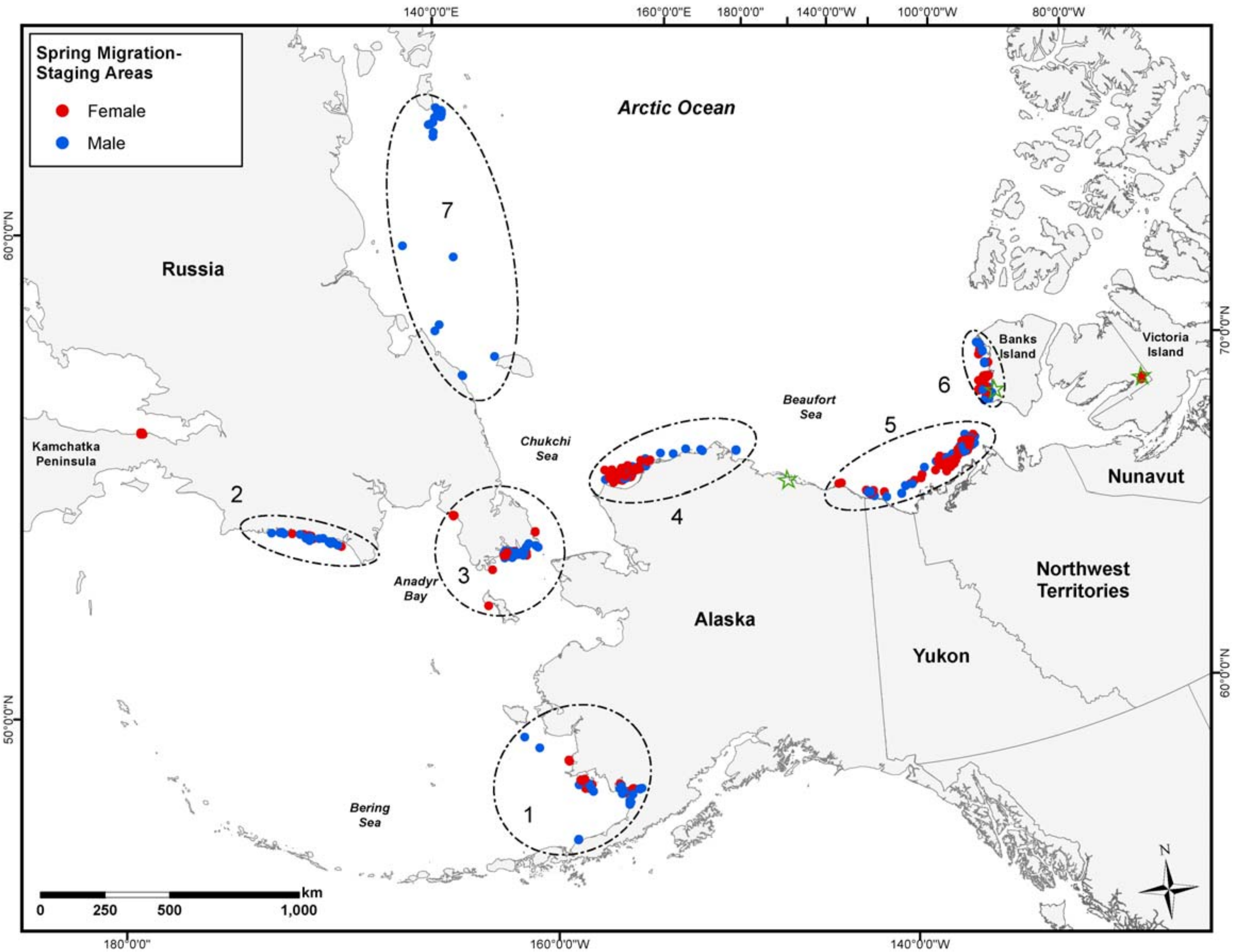


Figure 13. Staging areas used by King Eiders during spring migration: 1) Bristol Bay; 2) Khatyrka; 3) the Chukotsk Peninsula; 4) the east Chukchi Sea; 5) the southeast Beaufort Sea; 6) Banks Island; and 7) the Siberian Sea. Each circle represents an eider location.

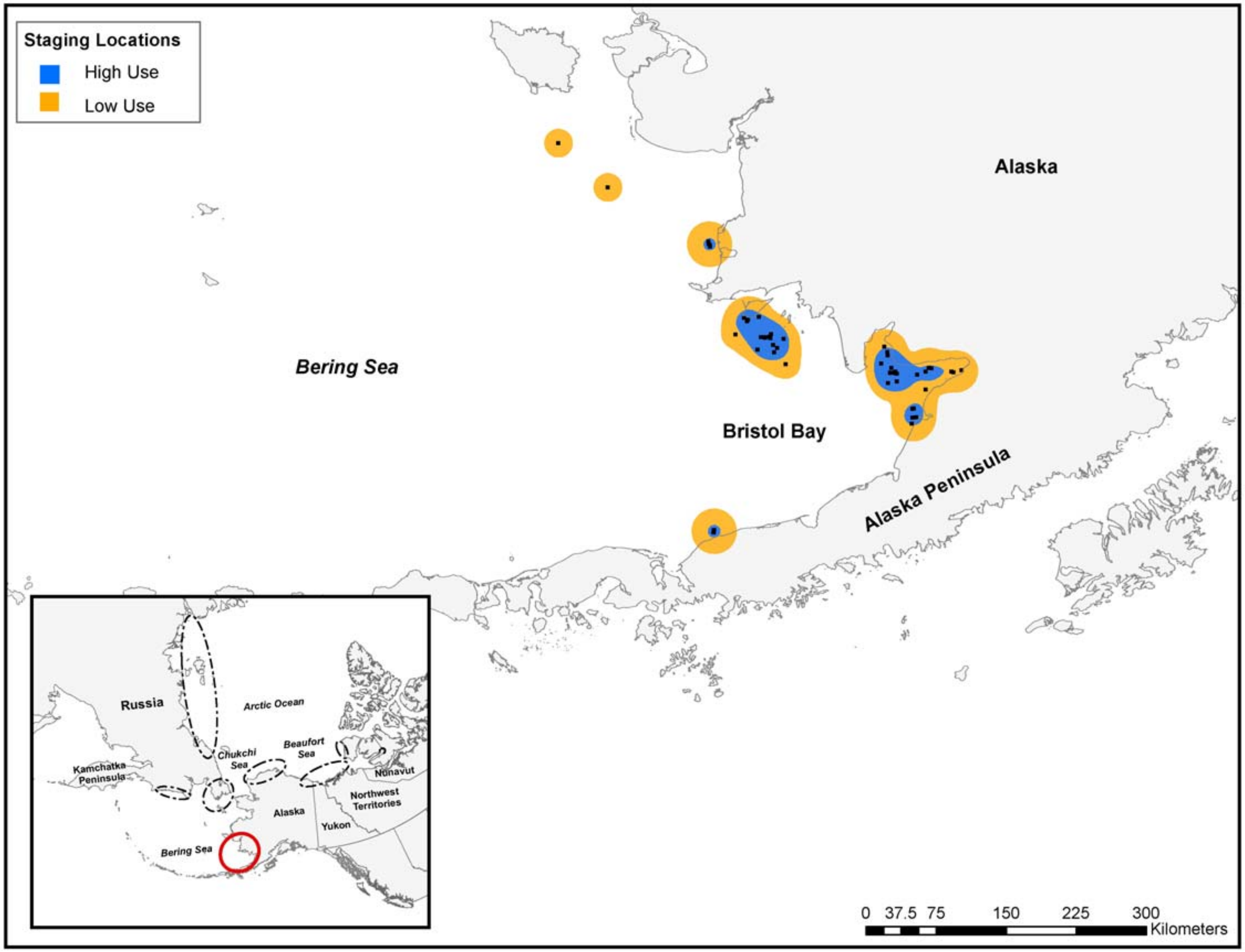


Figure 14a. Distribution of King Eiders on spring staging area in Bristol Bay (n = 12). Each dot represents an eider location (n = 55). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

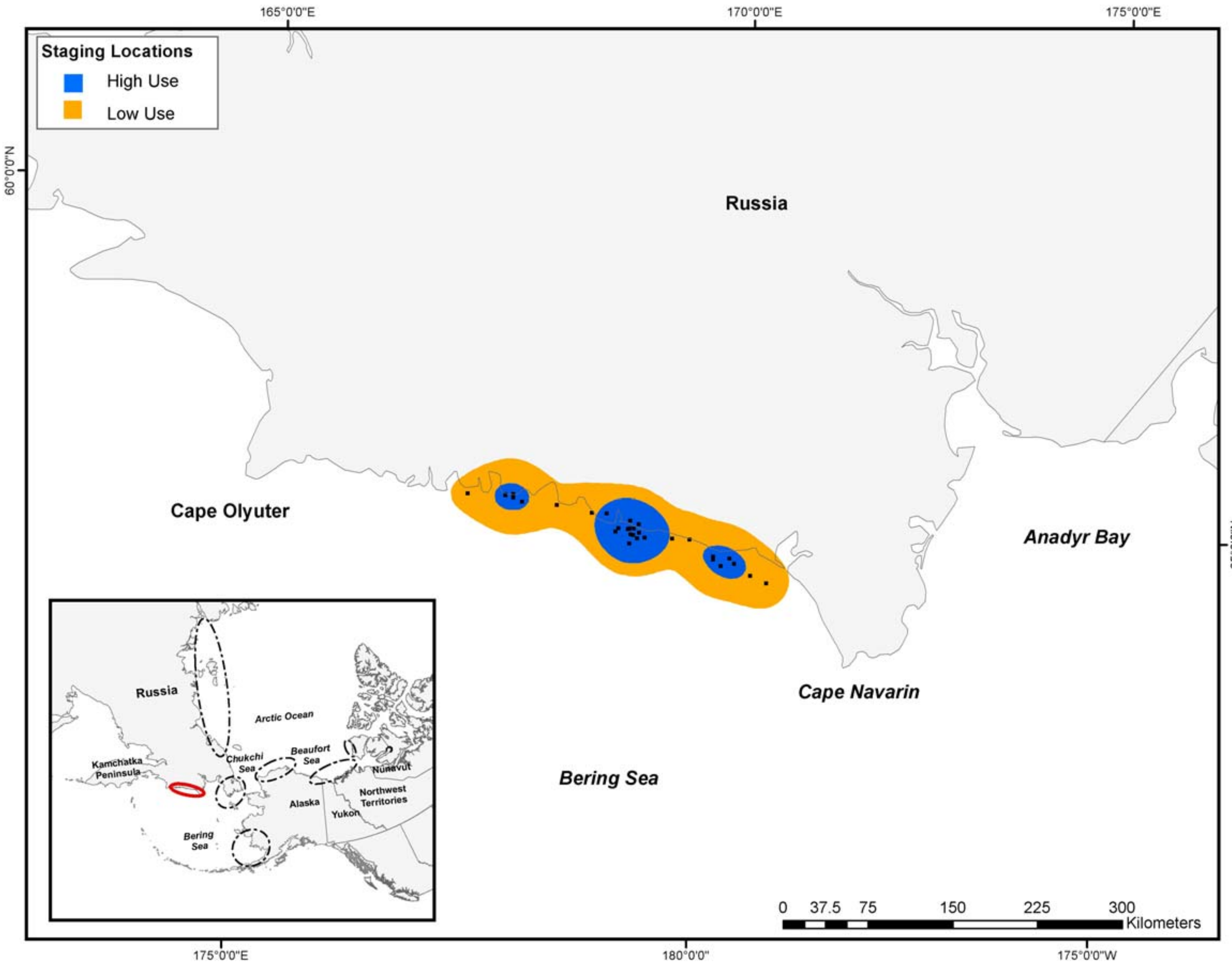


Figure 14b. Distribution of King Eiders on spring staging area off Khatyrka, Russia (n = 7). Each dot represents an eider location (n = 31). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

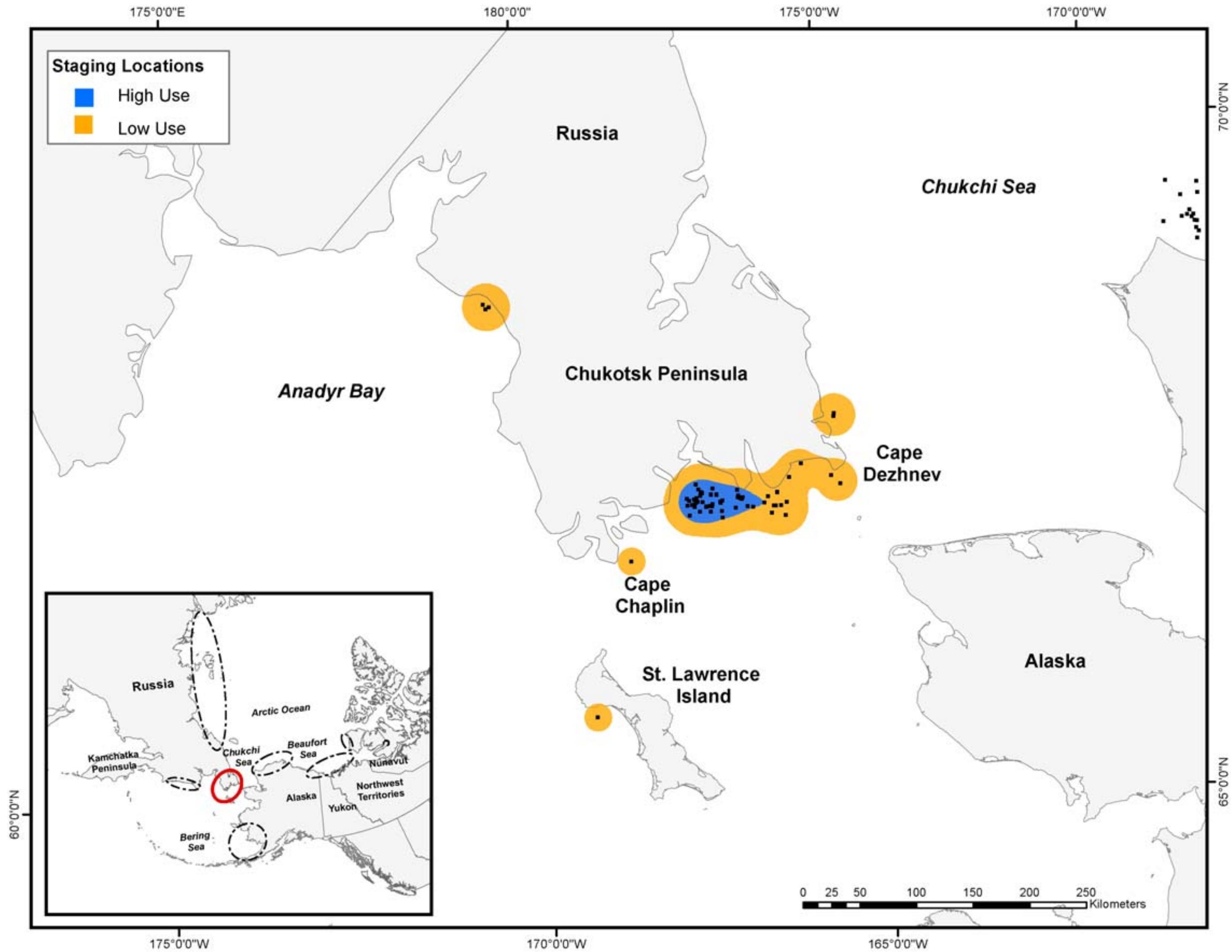


Figure 14c. Distribution of King Eiders on spring staging area off Chukotsk Peninsula (n = 15). Each dot represents an eider location (n = 62). Blue shading indicates high-use 50% volume contour; yellow shows the 95% probability contour.

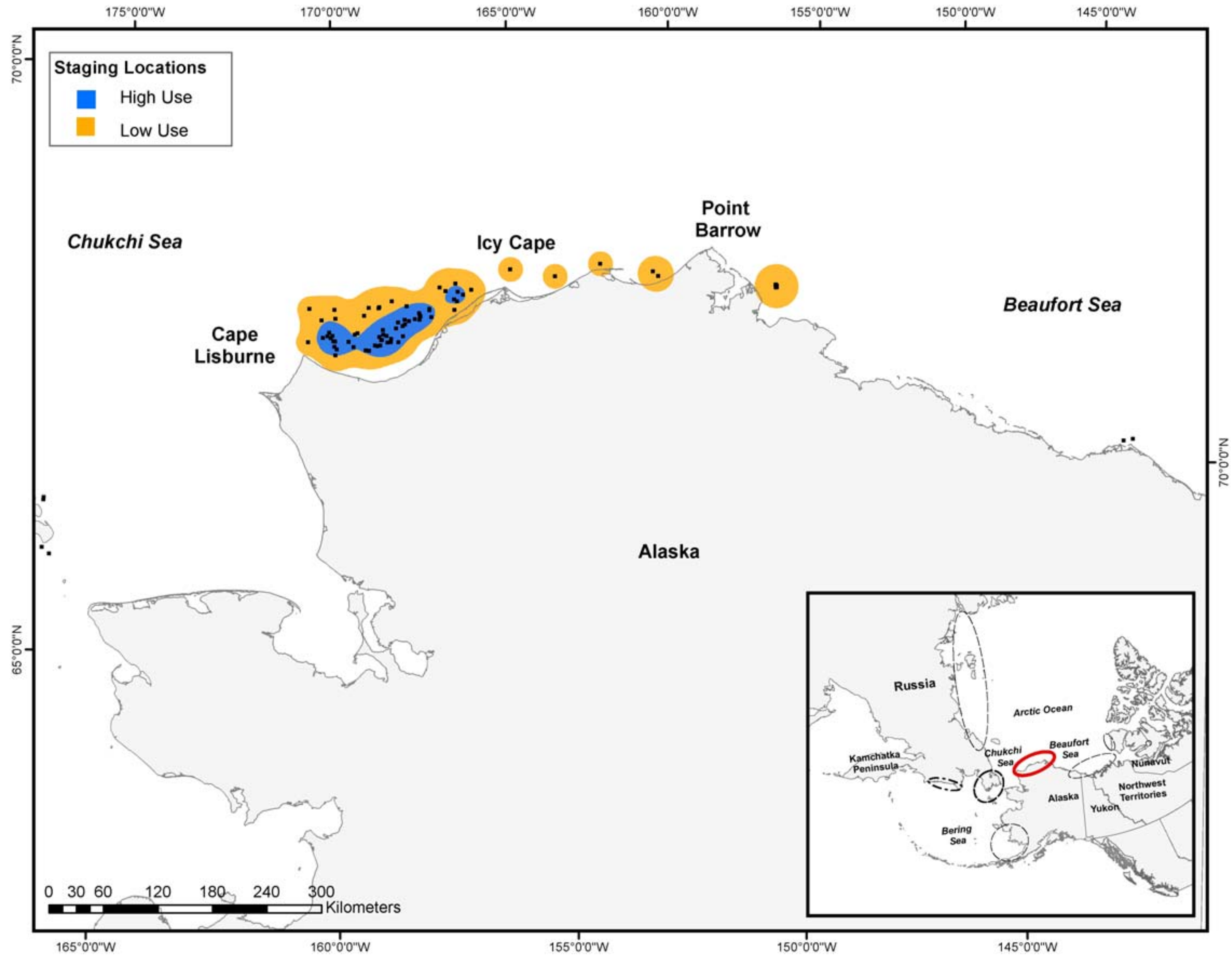


Figure 14d. Distribution of King Eiders on spring staging area off Alaska in the eastern Chukchi Sea (n = 19). Each dot represents an eider location (n = 74). Blue shading indicates high-use 50% probability contour; yellow shows the 95% volume contour.

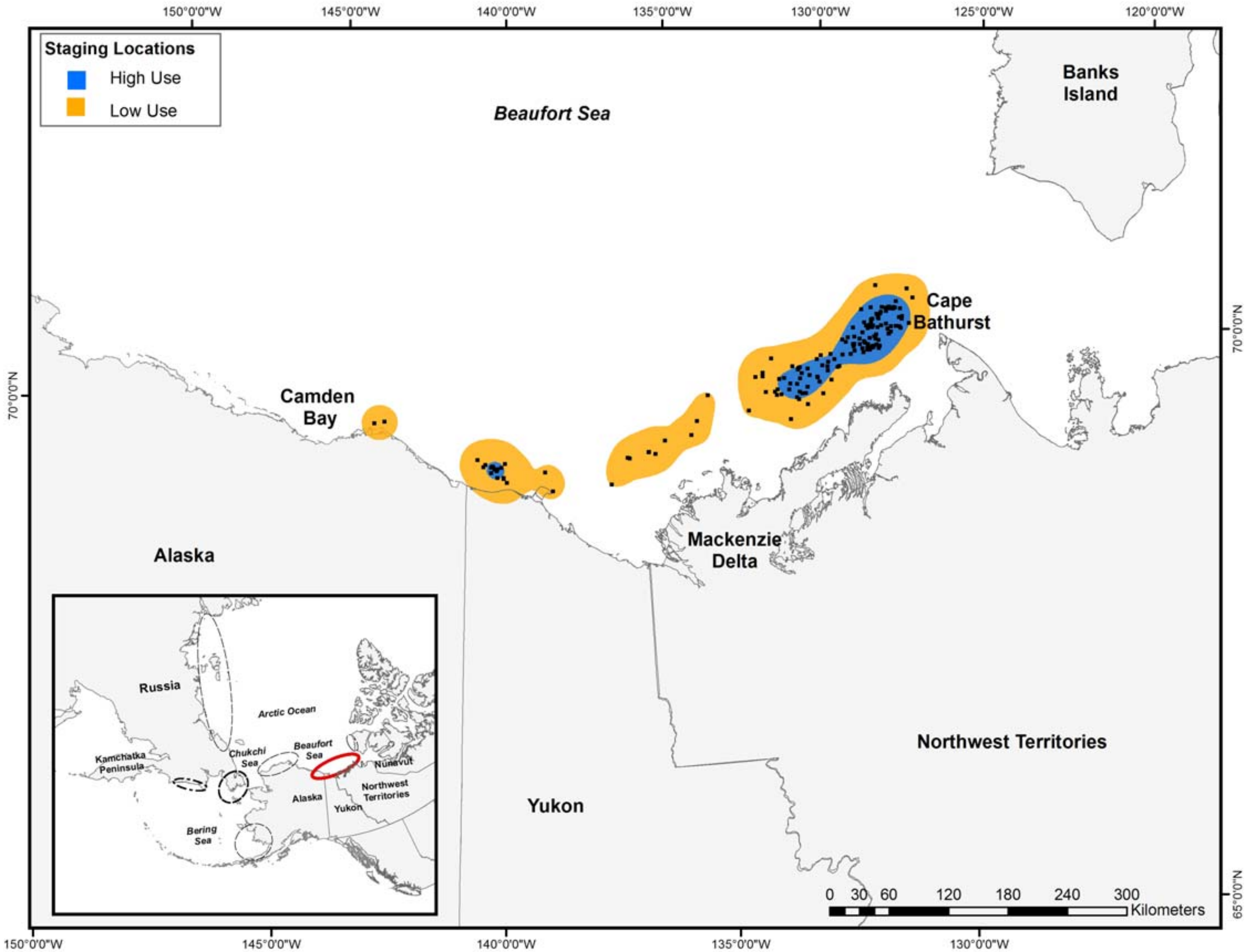


Figure 14e. Distribution of King Eiders on spring staging area in southeastern Beaufort Sea (n = 36). Each dot represents an eider location (n = 159). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

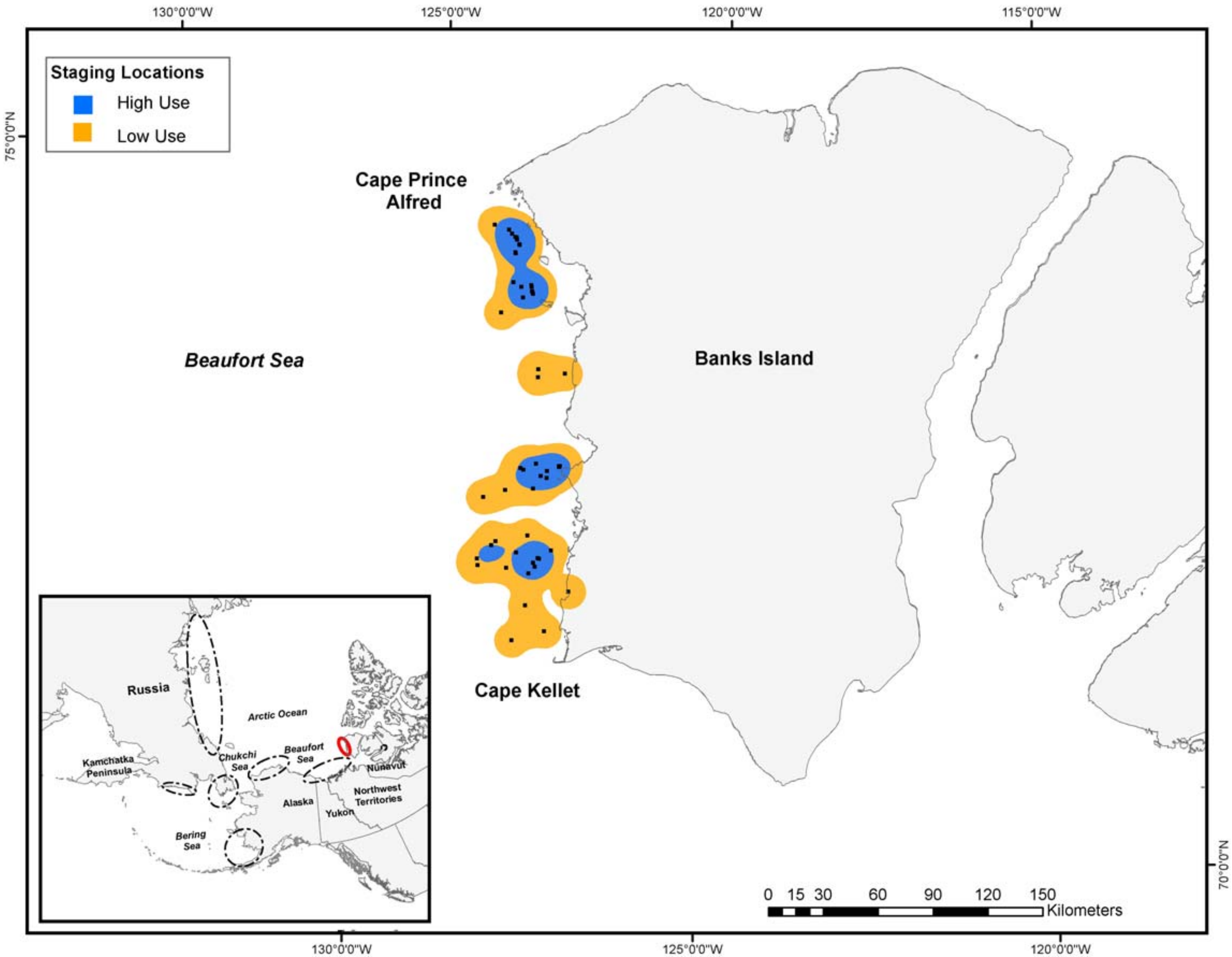


Figure 14f. Distribution of King Eiders on spring staging area in Beaufort Sea off the west coast of Banks Island (n = 12). Each dot represents an eider location (n = 51). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

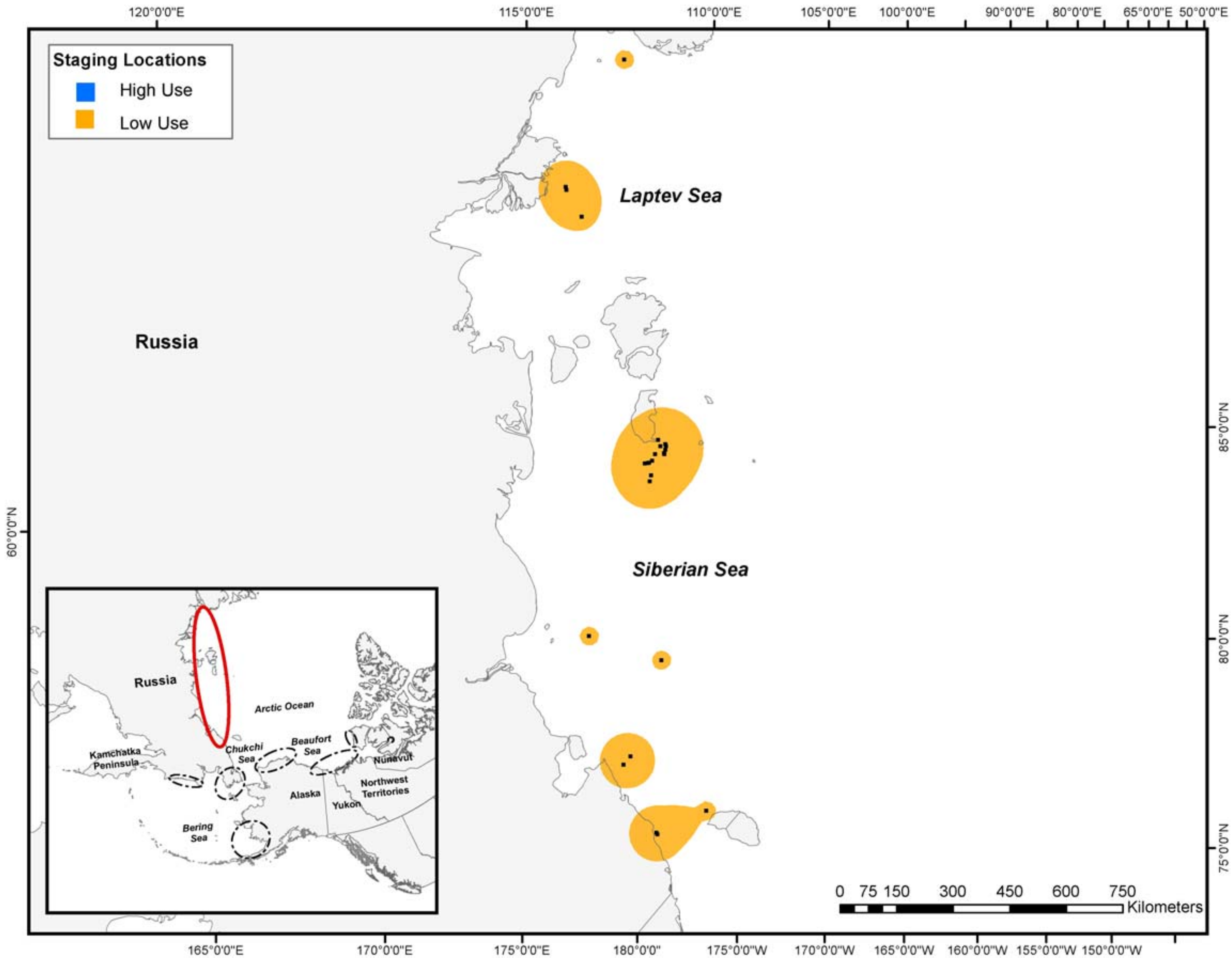


Figure 14g. Distribution of male King Eiders on spring staging area in Siberian Sea off the north coast of Russia (n = 5). Each dot represents an eider location (n = 25). Blue shading indicates high-use 50% volume contour; yellow shows the 95% volume contour.

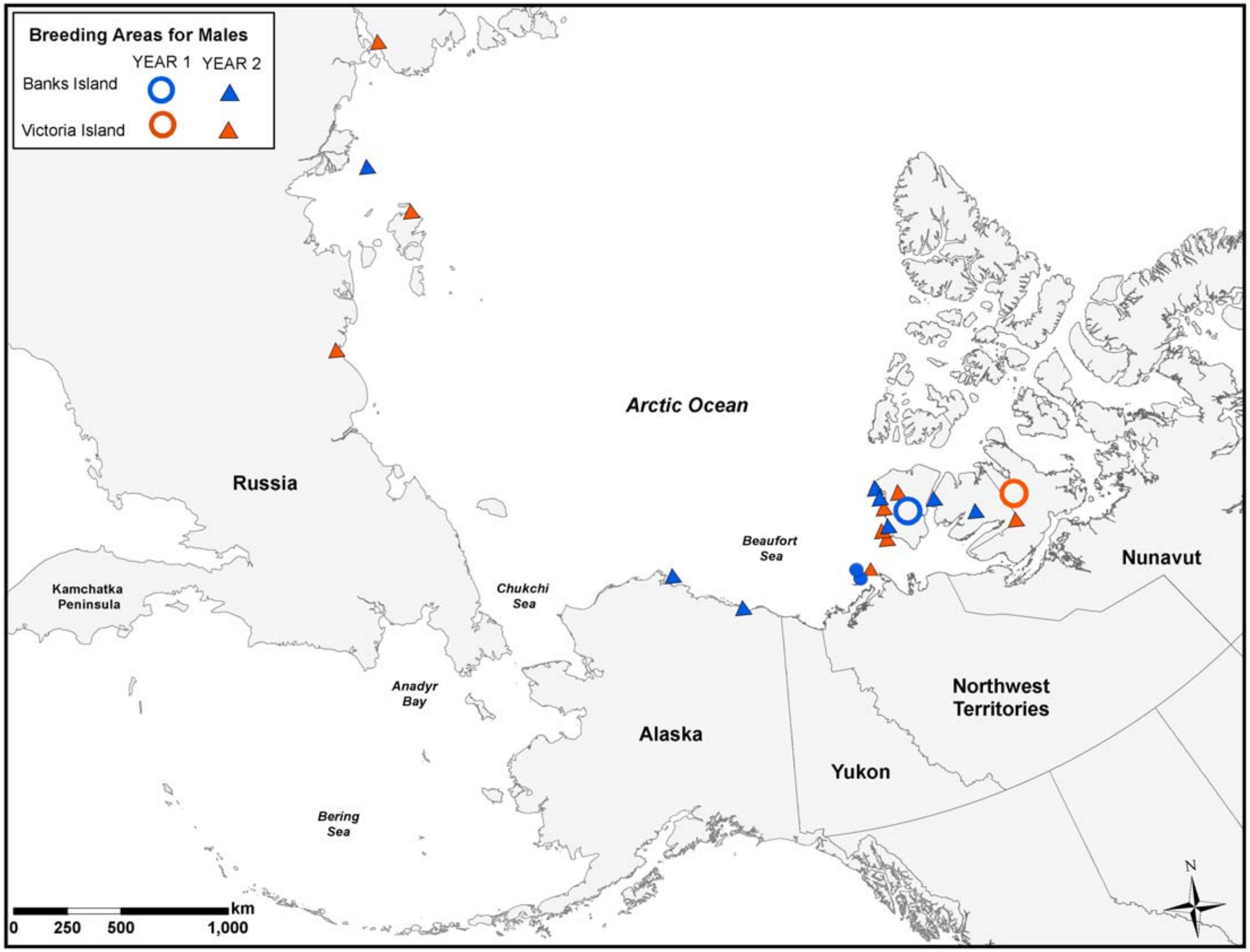


Figure 15. Locations of 20 male King Eiders in two consecutive breeding seasons. The open symbols represent the approximate breeding location of the eiders in the first year, and the solid symbols show the centroid location of each eider in the following breeding season. Half of the males remained in marine waters throughout the second breeding season.

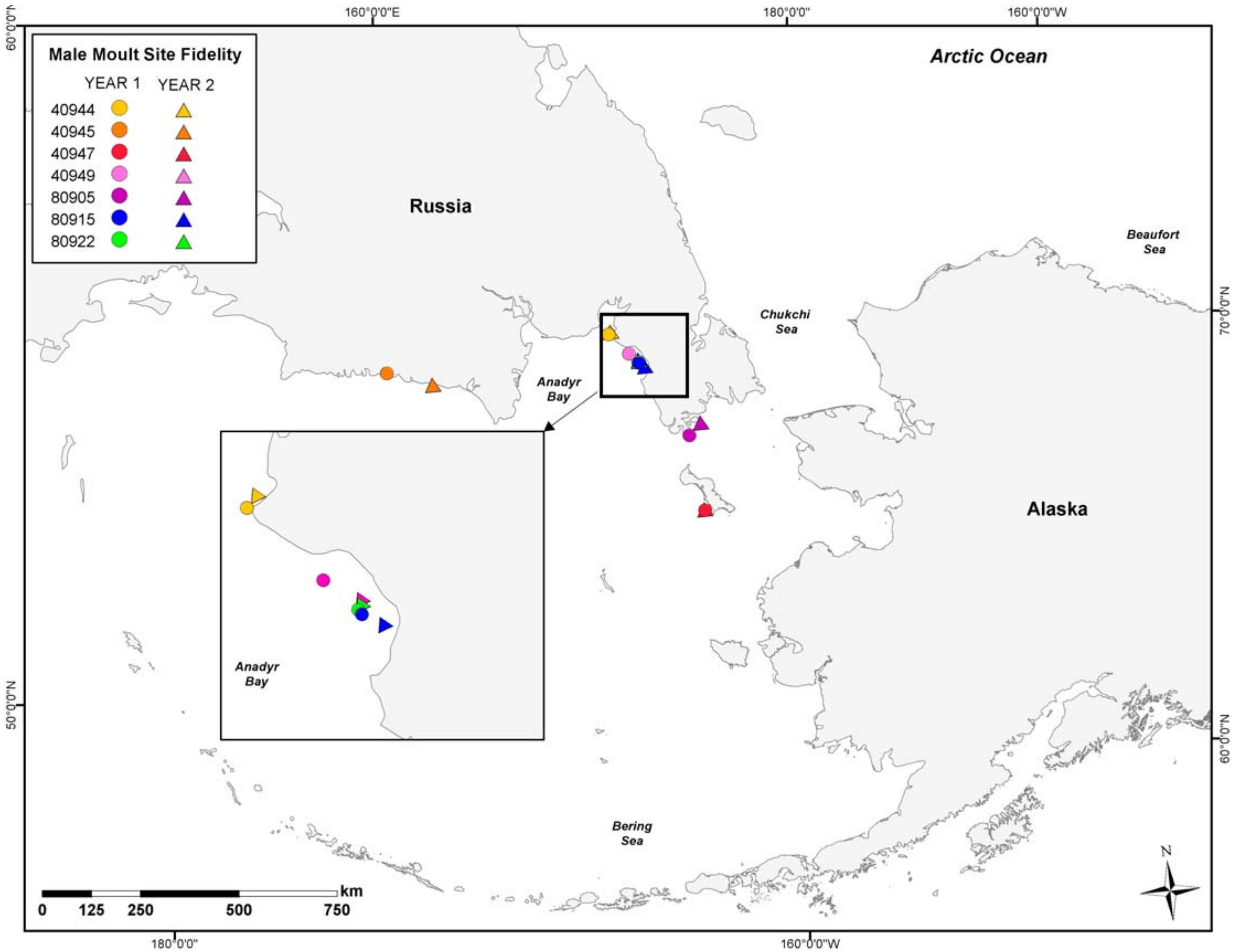


Figure 16a. Moult location of 7 male King Eiders in two consecutive years. The circles represent the centroid moult location in the first year, and the triangles show the centroid location in the subsequent year.

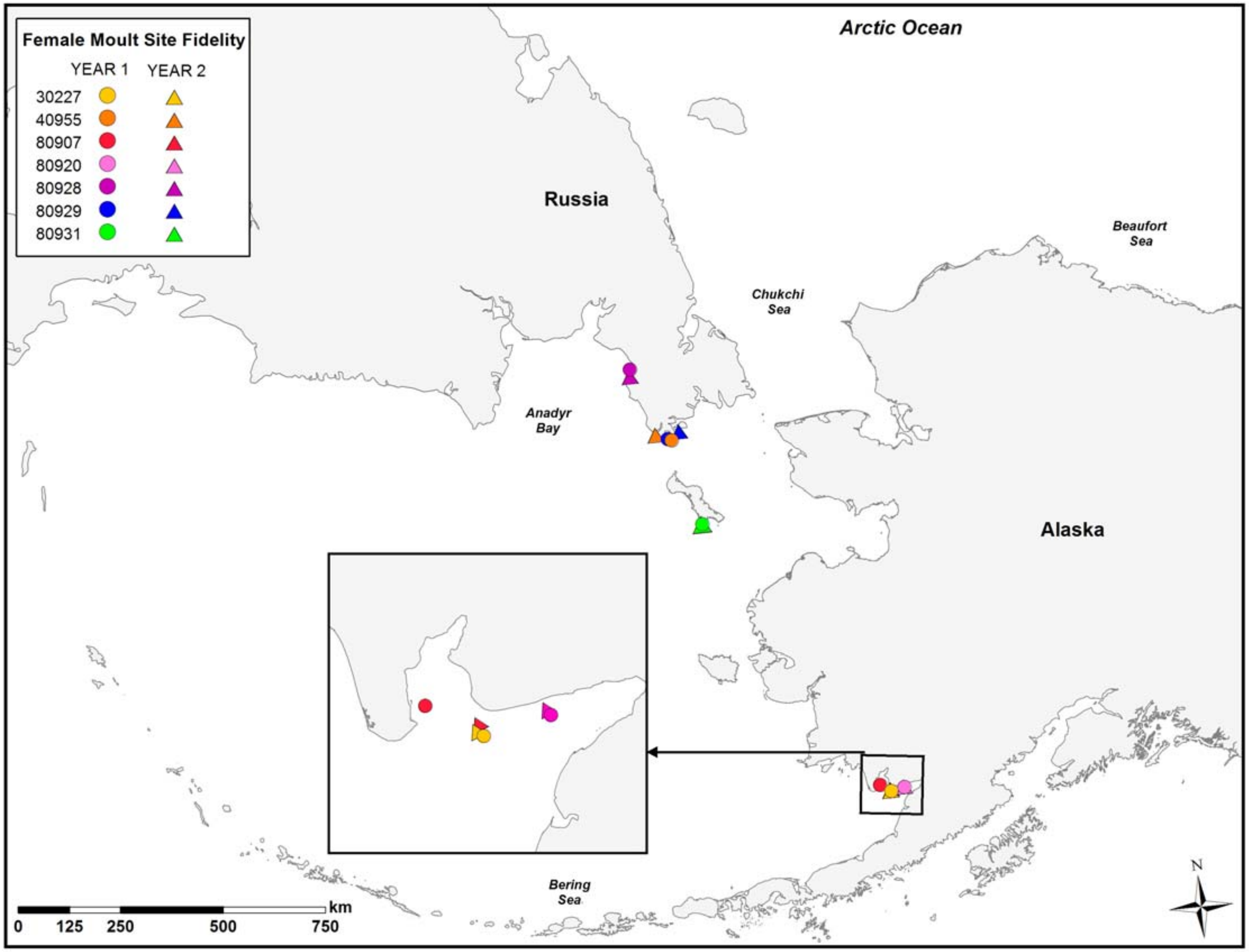


Figure 16b. Moult location of 7 female King Eiders in two consecutive years. The circles represent the centroid moult location in the first year, and the triangles show the centroid location in the subsequent year.

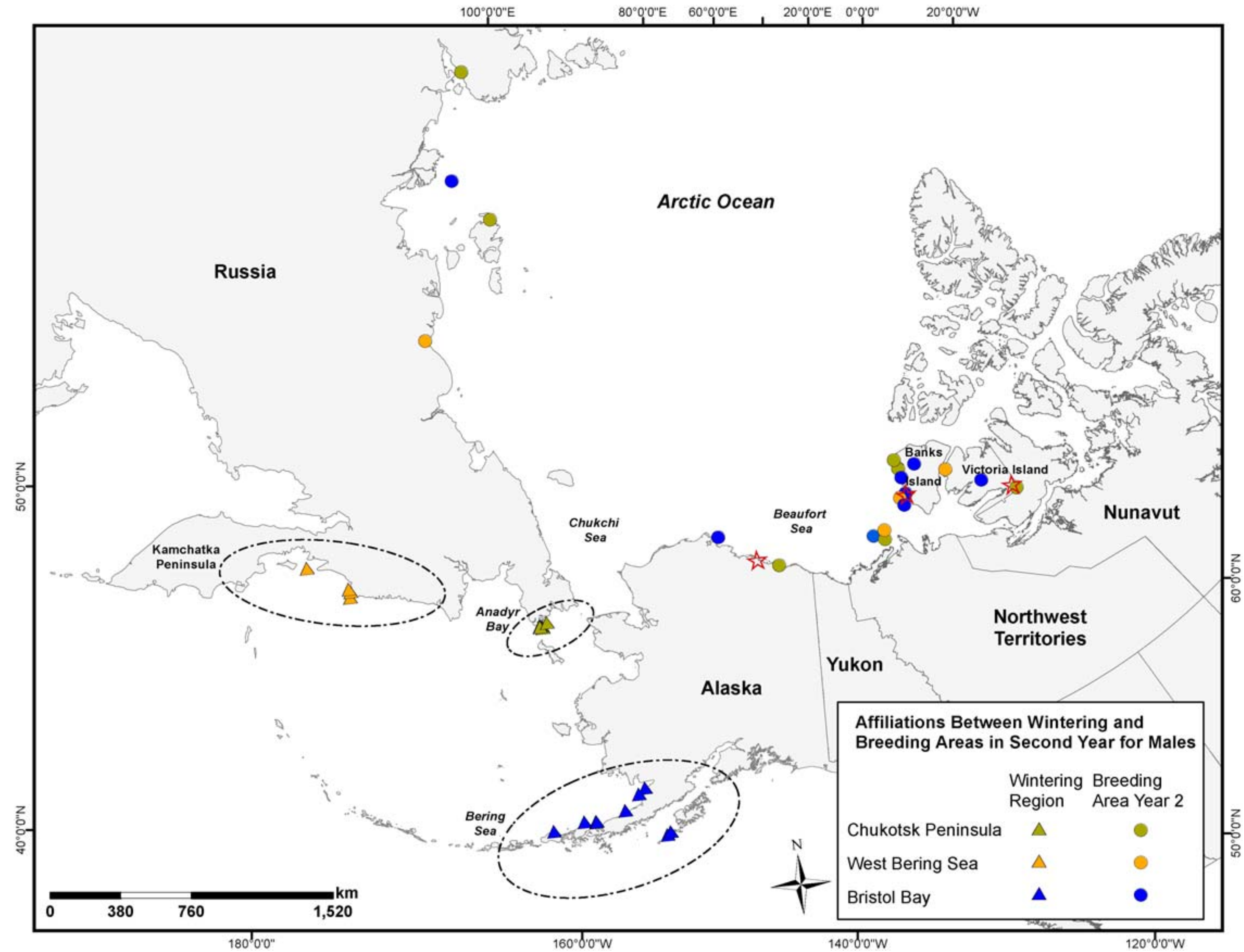


Figure 17. Breeding areas used by males in second year further define the affiliation between breeding and wintering areas. Triangles represent centroid locations of eiders during the winter, and the circles show where the eiders from each winter region were located in the subsequent breeding season (n = 19 males).

Appendix A. Timing of movement of King Eiders for each year that satellite transmitters were deployed on: Victoria Island, NWT, in 1997, 1998, 2003 and 2004; on Banks Island, NWT, in 2000 and 2008; and at Prudhoe Bay, Alaska, in 1999.

		Male					Female				
	Year PTT deployed	Mean	SD in days	Range		n	Mean	SD in days	Range		n
Depart nesting area Year 1	1997	23-Jun	±4	20-Jun	01-Jul	7	22-Jul	±18	10-Jul	04-Aug	2
	1998	17-Jun	±3	15-Jun	19-Jun	2	23-Jul	±14	28-Jun	01-Aug	5
	1999	24-Jun	±7	13-Jun	03-Jul	5	26-Jul	±34	07-Jun	29-Aug	5
	2000	27-Jun				1	06-Aug	±15	27-Jul	23-Aug	3
	2003	28-Jun	±9	18-Jun	09-Jul	6	30-Jul	±4	26-Jul	05-Aug	6
	2004	27-Jun	±2	25-Jun	29-Jun	6	24-Jul	±15	02-Jul	06-Aug	6
	2008	27-Jun	±5	18-Jun	08-Jul	16	25-Jul	±8	08-Jul	03-Aug	13
	All years	26-Jun	±6	13-Jun	09-Jul	43	26-Jul	±15	07-Jun	29-Aug	40
Depart nearby staging Year 1	1997					0	12-Aug	±6	08-Aug	17-Aug	2
	1998	24-Jul	±8	19-Jul	30-Jul	2	12-Aug	±9	05-Aug	25-Aug	4
	1999	09-Jul	±7	29-Jun	16-Jul	4	20-Aug	±20	28-Jul	11-Sep	5
	2000	18-Jul				1	19-Aug	±12	13-Aug	06-Sep	4
	2003					0	16-Aug	±3	14-Aug	23-Aug	6
	2004	11-Jul	±9	05-Jul	18-Jul	2	10-Aug	±8	28-Jul	18-Aug	5
	2008	22-Jul	±8	10-Jul	04-Aug	15	12-Aug	±4	07-Aug	20-Aug	11
	All years	20-Jul	±9	29-Jun	04-Aug	26	14-Aug	±9	28-Jul	11-Sep	37

Arrive moulting area Year 1	1997	16-Jul	±7	09-Aug	-	25-Aug	5	06-Sep	±4	03-Sep	-	09-Sep	2
	1998	12-Aug	±8	07-Aug	-	18-Aug	2	23-Aug	±14	04-Aug	-	07-Sep	4
	1999	31-Jul	±13	23-Jul	-	24-Aug	5	03-Sep	±18	23-Aug	-	24-Sep	3
	2000	01-Aug					1	30-Aug	±9	23-Aug	-	13-Sep	4
	2003	17-Aug	±6	11-Aug	-	26-Aug	6	07-Sep	±13	27-Aug	-	28-Sep	6
	2004	16-Aug	±8	08-Aug	-	26-Aug	4	04-Sep	±8	28-Aug	-	12-Sep	4
	2008	09-Aug	±6	27-Jul	-	20-Aug	15	23-Aug	±7	15-Aug	-	08-Sep	11
	All years	11-Aug	±9	23-Jul	-	26-Aug	38	30-Aug	±11	04-Aug	-	28-Sep	34
Moult migration # days Year 1	1997	49	±5	43	-	57	5	41	±12	33	-	50	2
	1998	51	±5	48	-	55	2	31	±23	2	-	57	4
	1999	34	±15	5	-	56	5	39	±30	20	-	74	3
	2000	32					1	21	±3	18	-	22	3
	2003	47	±9	37	-	63	6	35	±10	28	-	52	6
	2004	47	±7	38	-	56	4	38	±21	25	-	69	4
	2008	39	±6	28	-	49	15	27	±10	17	-	52	11
	All years	42	±9	17	-	63	38	32	±15	2	-	74	33
Depart moulting area Year 1	1997	16-Oct	±28	24-Sep	-	26-Nov	4						0
	1998						0	05-Oct					1
	1999	05-Oct	±6	01-Oct	-	10-Oct	2	05-Nov	±28	17-Oct	-	25-Nov	2
	2000	21-Oct					1	04-Nov	±9	26-Oct	-	12-Nov	3
	2003	17-Oct	±18	01-Oct	-	13-Nov	6	10-Nov	±5	06-Nov	-	15-Nov	3
	2004	10-Nov	±14	28-Oct	-	29-Nov	4	24-Nov	±22	29-Oct	-	16-Dec	4
	2008	19-Oct	±18	01-Oct	-	22-Nov	12	30-Oct	±12	14-Oct	-	18-Nov	9
	All years	20-Oct	±19	24-Sep	-	29-Nov	29	05-Nov	±17	05-Oct	-	16-Dec	22

Arrive wintering area Year 1	1997	10-Dec	±15	30-Nov	-	21-Dec	2						0
	1998						0	19-Dec					1
	1999	16-Oct	±4	13-Oct	-	19-Oct	2	21-Oct					1
	2000	06-Dec					1	23-Nov	±10	09-Nov	-	02-Dec	4
	2003	25-Nov	±30	18-Oct	-	31-Dec	6	02-Dec	±17	14-Nov	-	16-Dec	3
	2004	28-Nov	±12	16-Nov	-	13-Dec	4	06-Dec	±18	05-Nov	-	19-Dec	5
	2008	16-Nov	±30	08-Oct	-	02-Jan	11	18-Nov	±19	17-Oct	-	11-Dec	8
	All years	20-Nov	±27	08-Oct	-	02-Jan	26	25-Nov	±19	17-Oct	-	19-Dec	22
Fall migration # days Year 1	1997	42	±56	2	-	82	2						0
	1998						0	69					1
	1999	5	±1	1	-	6	2	2					1
	2000	42					1	12	±11	2	-	25	3
	2003	34	±28	2	-	73	6	19	±17	2	-	36	3
	2004	14	±17	2	-	40	4	9	±12	2	-	26	4
	2008	23	±24	2	-	71	11	16	±15	2	-	41	8
	All years	25	±26	2	-	82	26	16	±18	2		69	20
Depart wintering area Year 1	1997						0						0
	1998	03-Apr					1	23-Mar					1
	1999						0						0
	2000	22-Apr					1	16-Apr	±15	30-Mar	-	27-Apr	3
	2003	19-Mar	±31	12-Feb	-	07-Apr	3	01-Apr	±21	10-Mar	-	21-Apr	3
	2004	13-Mar	±35	08-Feb	-	19-Apr	3	01-Apr	±16	16-Mar	-	16-Apr	3
	2008	20-Mar	±25	04-Feb	-	25-Apr	11	05-Apr	±13	10-Mar	-	22-Apr	10
	All years	21-Mar	±26	04-Feb	-	25-Apr	19	05-Apr	±14	10-Mar	-	27-Apr	20

Depart wintering region													
	1997						0						0
Year 1	1998	04-May					1	11-May					1
	1999						0						0
	2000	22-Apr					1	16-Apr	±15	30-Mar	-	27-Apr	3
	2003	17-Apr	±5	07-Apr	-	22-Apr	6	15-Apr	±16	28-Mar	-	28-Apr	3
	2004	21-Apr	±3	19-Apr	-	24-Apr	3	12-Apr	±19	21-Mar	-	24-Apr	3
	2008	28-Apr	±6	16-Apr	-	11-May	11	26-Apr	±11	29-Mar	-	09-May	11
	All years	24-Apr	±7	07-Apr	-	11-May	22	21-Apr	±14	21-Mar	-	11-May	21
Arrive nesting area	1997						0						0
Year 1	1998						0	17-Jun					1
	1999						0						0
	2000	17-Jun					1	13-Jun	±4	11-Jun	-	16-Jun	2
	2003	14-Jun	±4	10-Jun	-	18-Jun	3	20-Jun	±3	17-Jun	-	24-Jun	4
	2004	18-Jun	±5	15-Jun	-	24-Jun	3	16-Jun	±4	13-Jun	-	23-Jun	4
	2008	21-Jun	±8	15-Jun	-	27-Jun	2	12-Jun	±3	06-Jun	-	17-Jun	10
	All years	17-Jun	±5	10-Jun	-	27-Jun	9	15-Jun	±4	06-Jun	-	24-Jun	21
Spring migration # days													
	1997						0						0
Year 1	1998						0	82					1
	1999						0						0
	2000	53					1	45					1
	2003	93	±40	64	-	121	2	74	±30	52	-	95	2
	2004	75	±37	49	-	101	2	71	±13	61	-	86	3
	2008	84	±28	61	-	115	3	65	±11	51	-	88	9
	All years	80	±28	49	-	121	8	67	±14	45	-	95	16

Depart nesting area Year 2	1997						0						0
	1998						0						0
	1999						0						0
	2000	17-Jun					1	18-Jul	±6	11-Jul	-	22-Jul	3
	2003	30-Jun	±20	18-Jun	-	23-Jul	3	31-Jul	±7	23-Jul	-	08-Aug	4
	2004	19-Jun	±7	15-Jun	-	27-Jun	3	30-Jul	±10	23-Jul	-	06-Aug	2
	2008	06-Jul	±10	29-Jun	-	13-Jul	2	23-Jul	±12	01-Jul	-	04-Aug	6
	All years	26-Jun	±13	15-Jun	-	23-Jun	9	25-Jul	±10	01-Jul	-	08-Aug	15
Depart nearby staging Year 2	1997						0						0
	1998						0						0
	1999						0						0
	2000	20-Jul					1	05-Aug	±1	05-Aug	-	06-Aug	2
	2003	07-Jul					1	16-Aug					1
	2004	09-Jul					1	06-Aug					1
	2008	13-Jul					1	13-Aug	±6	09-Aug	-	22-Aug	5
	All years	12-Jul	±6	07-Jul	-	20-Jul	4	11-Aug	±6	05-Aug	-	22-Aug	9
Arrive moulting area Year 2	1997						0						0
	1998						0						0
	1999						0						0
	2000						0	21-Aug					1
	2003	01-Aug	±8	27-Jul	-	14-Aug	4	15-Aug					1
	2004						0						0
	2008	10-Aug	±5	06-Aug	-	16-Aug	3	31-Aug	±6	26-Aug	-	06-Sep	4
	All years	05-Aug	±8	27-Jul	-	16-Aug	7	31-Aug	±9	21-Aug	-	15-Sep	6

Moult migration # days Year 2	1997						0						0
	1998						0						0
	1999						0						0
	2000						0	27					1
	2003	33	±3	30	-	35	3	38					1
	2004						0						0
	2008	47	±4	44	-	50	2	31	±3	28	-	35	4
	All years	39	±8	30	-	50	5	32	±5	27	-	38	6
Depart moulting area Year 2	1997												
	1998												
	1999												
	2000												
	2003												
	2004												
	2008							31-Oct	±0				2
	All years						0	31-Oct	±0				2
Arrive wintering area Year 2	1997												
	1998												
	1999												
	2000												
	2003												
	2004												
	2008							14-Nov	±9	08-Nov	-	21-Nov	2
	All years						0	14-Nov	±9	08-Nov	-	21-Nov	2

Fall migration # days	1997					
Year 2	1998					
	1999					
	2000					
	2003					
	2004					
	2008		11	±9	4 - 17	2
	All years	0	11	±9	4 - 17	2

Appendix B. Summary of movement of individual King Eiders tagged with satellite transmitters in western arctic Canada and northern Alaska from 1997-2008.

Appendix B1. Summary of movement of King Eiders tagged at the Kagloryuak River on Victoria Island, NWT, in 1997.

Sex	**PTT #**	**Nest location 1997**	**Depart nesting 1997**		**Depart nearby staging area**	**Arrive moulting 1997**		**Moult migration # of days**		**Moult locations 1997**	**Depart moulting 1997**		**Arrive winter 1997**		**Fall migration # of days**	
M	10594	Kagloryuak R.	20-Jun	*		09-Sep	**	50	**	Icy Cape						
M	10596	Kagloryuak R.	01-Jul			22-Aug		48		Karagin Bay	30-Sep	**				
M	10597	Kagloryuak R.	22-Jun			15-Aug		50		Anadyr Bay	24-Sep		21-Dec	*	82	*
M	11053	Kagloryuak R.	21-Jun			24-Aug	**	55	**	Anadyr Bay	09-Oct	**	05-Jan	**	49	**
M	11054	Kagloryuak R.	26-Jun			25-Aug		57		Chagvan Bay	26-Nov		30-Nov		< 4	
M	11055	Kagloryuak R.	23-Jun			12-Aug		46		Mechigmen Bay	11-Oct					
M	11056	Kagloryuak R.	23-Jun	**				99	**				21-Dec	**	< 150	**
M	11057	Kagloryuak R.	22-Jun	*		09-Aug		43		Anadyr Bay	05-Oct					
F	10595	Kagloryuak R.	10-Jul	*	08-Aug	03-Sep		50	*	Meynypil'gyno						
F	10598	Kagloryuak R.	04-Aug		17-Aug	09-Sep		33		Kvichak Bay						

PTT #	**Winter locations 1997/98**	**Depart winter 1998**
10594		
10596		
10597	Port Heiden	
11053	Sitkinak Strait	
11054	Cape Seniavin	
11055		
11056	Port Heiden	
11057		
10595		
10598		

* Gap of 7-10 days in locations received.
** Gap of > 10 days.

Appendix B2. Summary of movement of King Eiders tagged at the Kagloryuak River on Victoria Island, NWT, in 1998.

Sex	PTT #	Nesting arrival date 1998	Nest location 1998	Depart nesting 1998	Depart nearby staging area	Arrive moulting 1998	Moult migration # of days	Moult locations 1998	Depart moulting 1998	Arrive winter 1998
M	14655		Kagloryuak River	19-Jun	30-Jul	18-Aug	55	Anadyr Bay	15-Sep **	16-Dec
M	14656		Kagloryuak River	15-Jun *	19-Jul	07-Aug	48 *	Cape Nygligan	*no data September to June*	
F	14650	22-Jun *	Central Victoria	01-Aug	14-Aug	23-Sep **	41 **	Banks Island		
F	14651		Kagloryuak River	28-Jun	05-Aug	27-Aug	57	Kvichak Bay		
F	14657		Kagloryuak River	01-Aug		04-Aug	< 3	Prince Albert Sound	05-Oct	19-Dec
F	14658		Kagloryuak River	24-Jul *	07-Aug	26-Aug	28 *	St Lawrence Island		
F	14659		Kagloryuak River	29-Jul	25-Aug	07-Sep	37	Cape Chaplin		

PTT #	Fall migration # of days	Winter locations 1998/99	Depart winter 1999	Depart winter region[1]	Arrive nesting 1999	Spring migration # of days	Nesting location 1999
14655	67 **	Cape Chaplin	03-Apr *	04-May			
14656					10-Jun **		Taymyr Peninsula
14650							
14651							
14657	69 *	South Kamchatka Peninsula	23-Mar	11-May	17-Jun	82	Kagloryuak River
14658							
14659	No movement	Cape Chaplin					

* Gap of 7-10 days in locations received.
** Gap of > 10 days in locations received.
[1] Based on winter regions described in Oppel et al. (2008).

Appendix B3. Summary of movement of King Eiders tagged at Prudhoe Bay, Alaska, in 1999.

Sex	PTT #	Nest location 1999	Depart nesting 1999	Depart nearby staging area	Arrive moult 1999	Moult migration # of days	Moult locations 1999	Depart moulting 1999	Arrive winter 1999	Fall migration # of days	Winter locations 1999/00
M	14910	Prudhoe B.	13-Jun	29-Jun	25-Jul	39	Anadyr Bay				
M	14991	Prudhoe B.	28-Jun	12-Jul	29-Jul	28	Anadyr Bay	10-Oct *	19-Oct *	< 9	Cape Chaplin
M	15012	Prudhoe B.	03-Jul		23-Jul	17	Kolyuchin Bay	01-Oct *	13-Oct	6.0	Cape Chukotsk
M	15029	Prudhoe B.	23-Jun	16-Jul	26-Jul	30	Kayne Island				
M	15031	Prudhoe B.	23-Jun	12-Jul	24-Aug *	56 *	St. Lawrence Island				
F	15019	Prudhoe B.	07-Jun	28-Jul	24-Aug	74	St. Lawrence Island	17-Oct	21-Oct	< 4	Cape Chukotsk
F	15021	Prudhoe B.	29-Aug	11-Sep	24-Sep	23	Khatyrka	25-Nov			
F	15045	Prudhoe B.	27-Jul *	13-Aug	23-Aug	20 *	Mechigmen Bay				
F	15050	Prudhoe B.	24-Aug	10-Sep							
F	15067	Prudhoe B.	14-Jul	08-Aug *							

* Gap of 7-10 days in locations received.
** Gap of > 10 days in locations received.

Appendix B4. Summary of movement of King Eiders tagged at Siksik Lake on Banks Island, NWT, in 2000.

Sex	**PTT #**	**Nest location 2000**	**Depart nesting 2000**		**Depart nearby staging area 2000**	**Arrive moulting 2000**		**Moult migration # of days**		**Moult locations 2000**	**Depart moulting 2000**		**Arrive winter 2000**	
M	23870	Siksik Lake	27-Jun		18-Jul	01-Aug		32		Anadyr Bay	21-Oct		06-Dec	
F	30227	Siksik Lake	27-Jul		13-Aug	23-Aug		22		Kvichak Bay	05-Nov		09-Nov	
F	30228	Siksik Lake	31-Jul		13-Aug	27-Aug	*	22	*	Cape Chaplin	12-Nov		29-Nov	*
F	30273	Big River	24-Jul	**	13-Aug	27-Aug		25	**	Khatyrka	09-Nov	**	02-Dec	
F	30274	Big River	23-Aug		06-Sep	13-Sep		18		Khatyrka	26-Oct		23-Nov	

PTT #	**Fall migration # of days**		**Winter locations 2000/01**	**Depart winter 2001**		**Depart winter region**[1]		**Arrive nesting 2001**		**Spring migration # of days**		**Nest location 2001 (approximate)**[2]	**Depart nesting 2001**		**Depart nearby staging area**
23870	42		Kvichak Bay	22-Apr		22-Apr		17-Jun		53		Big River Delta	17-Jun		20-Jul
30227	< 4		Kvichak Bay	22-Apr		22-Apr		11-Jun		45		Siksik Lake	22-Jul		05-Aug
30228	11	*	Kvichak Bay	27-Apr		27-Apr		19-Jun	**	46	**	Big River Delta	21-Jul	*	
30273	15	**	Shumshu Island	29-Mar	**	29-Mar	**	16-Jun		72	**	Siksik Lake	11-Jul		06-Aug
30274	25		Cape Shipun	30-Mar		30-Mar									

PTT #	**Arrive moulting 2001**	**Moult migration # of days**	**Moult locations 2001**
23870			
30227	21-Aug	27	Kvichak Bay
30228			
30273			
30274			

* Gap of 7-10 days in locations received
** Gap of > 10 days in locations received.
[1] Based on winter regions described by Oppel et al. (2008).
[2] Brackets indicate bird remained offshore during nesting period, meaning that breeding location is approximate.

Appendix B5. Summary of movement of King Eiders tagged at Kagloryuak River on Victoria Island, NWT, in 2003.

Sex	PTT #	Nest location 2003	Depart nesting 2003	Depart nearby staging	Moult migration # of days	Arrive moulting 2003	Moult locations 2003	Depart moulting 2003	Fall migration # of days	Arrive winter 2003	Winter location 2003/04
Male	40944	East Victoria Island	08-Jul	02-Aug	45	26-Aug	Kresta Bay	13-Nov	42*	31-Dec*	Cape Seniavin
	40945	Kagloryuak River	24-Jun		48	13-Aug	Anastasii Bay	01-Oct	21	26-Oct	Cape Olyutor
	40946	Kagloryuak River	09-Jul	29-Jul	37	17-Aug	St. Lawrence Island	05-Oct	73	21-Dec	Cape Seniavin
	40947	Kagloryuak River	01-Jul		41	13-Aug	St. Lawrence Island	05-Oct	59	08-Dec	Kvichak Bay
	40948	Kagloryuak River	18-Jun		63	24-Aug	Anadyr Bay	06-Nov	9	19-Nov	Cape Olyutor
	40949	Kagloryuak River	22-Jun		47	11-Aug	Anadyr Bay	14-Oct	< 4	18-Oct	Cape Chaplin
Female	40950	East Victoria Island	29-Jul	16-Aug	31	01-Sep	Cape Chaplin	06-Nov	36	16-Dec	Cape Seniavin
	40951	Central Victoria Island	03-Aug	16-Aug	52	28-Sep	Anastasii Bay	15-Nov	18	08-Dec	Karagin Bay / Shumshu Island
	40952	Kagloryuak River	26-Jul	14-Aug	29	27-Aug	Kvichak Bay	-	*end*	-	-
	40953	Kagloryuak River	27-Jul	14-Aug	29	27-Aug	Anadyr Bay	10-Nov	< 4	14-Nov	Cape Chukotsk
	40954	Central Victoria Island	05-Aug	15-Aug	28	05-Sep	Cape Olyutor	-	No movement	-	Cape Olyutor
	40955	Kagloryuak River	01-Aug	23-Aug	44	18-Sep	Cape Chukotsk	-	No movement	-	Cape Chukotsk

Appendix B5 continued.

PTT #	Depart winter 2004	Depart winter region[1]	Spring migration # of days	Arrive nesting 2004	Nest location 2004 (approximate)[2]	Depart nesting 2004	Depart nearby staging	Moult migration # of days	Arrive moulting 2004	Moult locations 2004
40944	12-Feb*	19-Apr	121*	18-Jun	Northwest Banks Island	18-Jun	07-Jul	35	28-Jul	Kresta Bay
40945	10-Mar**	17-Apr	82**	10-Jun	Indigirka River	23-Jun	-	30*	30-Jul*	Khatyrka
40946	23-Feb**	19-Apr	*end*	-	-	-	-		-	-
40947	7-Apr*	7-Apr*		-	(West Banks Island)	-	-		14-Aug	St. Lawrence Island
40948	Before 14-Feb**	22-Apr		-	(Cape Dalhousie)	-	-		-	-
40949	5-Apr*	19-Apr	64*	15-Jun	Kotel'nyy Island	19-Jun	-	34	27-Jul	Anadyr Bay
40950	19-Mar**	19-Mar**	75**	04-Jul**	East Victoria Island	4 Jul**	-	*end*	-	-
40951	10-Mar*	28-Mar*	95*	20-Jun	Central Victoria Island	02-Aug	-	*end*	-	-
40952				-	-	-	-		-	-
40953	31-Mar**	31-Mar**	69**	24-Jun*	Kagloryuak River	23-Jul*	-	*end*	-	-
40954	4-Apr*	28-Apr	70*	20-Jun	Central Victoria Island	08-Aug	-	*end*	-	-
40955	21-Apr	21-Apr	52	17-Jun	Kagloryuak River	01-Aug	16 Aug*	38*	15-Sep*	Cape Chukotsk

* Gap of 7-10 days in locations received.
** Gap of > 10 days in locations received.
[1] Based on winter regions described by Oppel et al. (2008).
[2] Brackets indicate bird remained offshore during nesting period, so that breeding location is approximate.

Appendix B6. Summary of movement of King Eiders tagged at Kagloryuak River on Victoria Island, NWT, in 2004.

Sex	PTT #	Nest location 2004	Depart nesting 2004	Depart nearby staging	Moult migration # of days	Arrive moulting 2004	Moult locations 2004	Depart moulting 2004	Fall migration # of days	Arrive winter 2004	Winter location 2004/05
Male	50120	Kagloryuak River	28-Jun	-	38	08-Aug	Kayne Island	29-Nov	<3	2-Dec	Cape Chaplin
	50121	Kagloryuak River	28-Jun	-	56	26-Aug	Anadyr Bay	03-Nov	10	16-Nov	Cape Olyutor
	50124	Kagloryuak River	25-Jun	18-Jul	45	13-Aug	Anadyr Bay	18-Oct**	<66**	23-Dec**	Cape Chaplin
	50127	Kagloryuak River	29-Jun	-	48	20-Aug	Nunivak Island	28-Oct*	40*	13-Dec	Kodiak Island
	50128	Kagloryuak River	26-Jun	5-Jul	89**	?	?	?	73**	14-Dec**	Unimak Island
	50130	Kagloryuak River	29-Jun	-	57**	2-Sep**	Meynypil'gyno	14-Nov	5	24-Nov	Cape Olyutor
Female	50122	Central Victoria Island	30-Jul	9-Aug	26	29-Aug	Cape Chukotsk	07-Dec	< 4	11-Dec	Cape Chaplin
	50123	Kagloryuak River	8-Jul	28-Jul	46**	3-Sep**	Anadyr Bay	29-Oct*	< 7	05-Nov*	Cape Chaplin
	50125	Kagloryuak River	5-Aug	15-Aug	33	10-Sep	Karagin Bay	16-Dec	< 3	19-Dec	Kamchatka Peninsula
	50126	Kagloryuak River	2-Jul	13-Aug*	69	12-Sep	Hagemeister Island	17-Nov**	16**	13-Dec*	Unimak Island
	50129	Kagloryuak River	06-Aug	16-Aug**	48**	4-Oct**	Kvichak Bay	after 7-Nov**	-	-	-
	50131	Kagloryuak River	31-Jul	18-Aug	25	28-Aug	Cape Chukotsk	15-Nov	26	14-Dec	Unimak Island

Appendix B6 continued.

PTT #	Depart winter 2005	Depart winter region[1]	Spring migration # of days	Arrive nesting 2005	Nest location 2005 (approximate)[2]	Depart nesting 2005	Depart nearby staging	Moult migration # of days	Arrive moulting 2005	Moult locations 2005
50120	19-Apr	19 Apr	49*	15 Jun*	Kagloryuak River	15 Jun	-	-	-	-
50121	8- Feb*	24 Apr	-	-	(Cape Kellet)	-	-	-	-	-
50124	-	-	-	-	-	-	-	-	-	-
50127	Before 26-Mar**	22-Apr*	107**	16-Jun*	Cape Kellet	16- Jun	10-Jul**	51**	before 23-Aug**	Nunivak Island
50128	9-Mar	5-Apr**	101*	24-Jun*	Cape Kellet	27-Jun	9-Jul*		-	-
50130	-	-	-	-	-	-	-	-	-	-
50122	16-Apr*	23-Apr	61*	23-Jun*	Central Victoria Island	-	-	-	-	-
50123	02-Apr*	16-Apr**	66*	15-Jun*	Kagloryuak River	23-Jul	6-Aug	-	-	-
50125	07-Mar**	21-Mar	92**	15-Jun	Kagloryuak River	6-Aug	-	-	-	-
50126	-	-	-	-	-	-	-	-	-	-
50129	-	-	-	-	-	-	-	-	-	-
50131	16-Mar	24-Apr	86	13-Jun	Kagloryuak River	-	-	-	-	-

* Gap of 7-10 days in locations received.
** Gap of > 10 days in locations received.
[1] Based on winter regions described by Oppel et al. (2008).
[2] Brackets indicate bird remained offshore during nesting period, meaning that breeding location is approximate.

Appendix B7a. Summary of movement of male King Eiders tagged at Siksik Lake on Banks Island, NWT, in 2008 (see App. 7b for movement of females).

PTT #	Nest location 2008	Depart nesting 2008	Depart nearby staging area	Arrive moulting 2008	Moult migration # of days	Moult locations 2008	Depart moulting 2008	Fall migration # of days
Males								
80903	Siksik Lake	28-Jun	27-Jul	12-Aug	42	Anadyr Bay	09-Oct	< 4
80905	Central Banks Island	27-Jun	10-Jul	10-Aug	41	Cape Chaplin	05-Oct	23
80906	Siksik Lake	18-Jun	24-Jul	09-Aug	49	Anadyr Bay	01-Oct	4
80908	Siksik Lake	25-Jun	20-Jul		*end*			
80909	Siksik Lake	23-Jun	22-Jul	11-Aug	46	St. Lawrence Island	07-Oct	*end*
80911	Siksik Lake	28-Jun	26-Jul	14-Aug	44	Cape Chaplin		
80914	Siksik Lake	29-Jun	02-Aug	20-Aug	49	Etolin Strait	18-Oct	71 *
80915	Siksik Lake	27-Jun	10-Jul	01-Aug	32	Anadyr Bay	05-Nov	49
80917	Siksik Lake	26-Jun	12-Jul	27-Jul	28	Kolyuchin Bay	10-Oct	32
80918	Siksik Lake	30-Jun	19-Jul	07-Aug	35	Cape Chaplin		
80921	Siksik Lake	25-Jun		09-Aug	42	St. Lawrence Island	22-Nov	4
80922	Siksik Lake	28-Jun	26-Jul	04-Aug	34	Anadyr Bay	12-Oct	10
80923	Siksik Lake	08-Jul	04-Aug *	19-Aug	38	Etolin Strait	22-Oct	49
80925	Siksik Lake	02-Jul	24-Jul	06-Aug	32	Anadyr Bay	11-Oct	7
80927	Siksik Lake	02-Jul	02-Aug	11-Aug	37	Cape Chaplin		
80930	Siksik Lake	22-Jun	11-Jul	08-Aug	44	Cape Chaplin	20-Nov	4

Appendix B7a continued.

PTT #	Arrive winter 2008		Winter locations 2008/09	Depart winter 2009		Depart winter region[1]	Arrive nesting 2009	Spring migration # of days		Nest locations 2009 (approximate)[2]	Depart nesting 2009
Males											
80903	13-Oct		Cape Chaplin	25-Apr		27-Apr	27-Jun	61		(Martin Point)	13-Jul
80905	31-Oct		Cape Chaplin	14-Apr		26-Apr				(Cape Dalhousie)	
80906	08-Oct		Cape Chaplin	30-Mar	*	26-Apr		*end*		(Burnett Bay)	
80908											
80909											
80911			Cape Chaplin	11-Mar	*	30-Apr		*end*		(Taymyr Peninsula)	
80914	02-Jan	*	Port Heiden	04-Feb	*	02-May				(Lena River Delta)	
80915	27-Dec		Port Heiden	31-Mar	*	28-Apr		76	*	(East of Minto Inlet)	
80917	14-Nov		Cape Chukotsk	15-Apr		29-Apr		*end*		(Novaya Sibir Island)	
80918			Cape Chaplin	*end*							
80921	29-Nov		Unimak Island	08-Mar	*	05-May				(Cape Dalhousie)	
80922	25-Oct		Karagin Bay	16-Feb	*	26-Apr	15-Jun	115	*	Prince Albert Peninsula	29-Jun
80923	13-Dec		Kodiak Island	*end*							
80925	21-Oct		Cape Chukotsk	*end*							
80927			Cape Chaplin	27-Mar	*	16-Apr				(Burnett Bay)	
80930	27-Nov		Kodiak Island	02-Mar	*	11-May				(Smith Bay)	

Appendix B7a continued.

PTT #	Depart nearby staging area	Arrive moulting 2009	Moult migration # of days	Moult locations 2009	Depart moulting 2009	Arrive winter 2009	Fall migration # of days
Males							
80903			*end*				
80905		06-Aug		Cape Chaplin	*end*		
80906							
80908							
80909							
80911							
80914			*end*				
80915		10-Aug	50	Anadyr Bay	*end*		
80917							
80918							
80921			*end*				
80922	13-Jul	16-Aug	44	Anadyr Bay	*end*		
80923							
80925							
80927			*end*				
80930			*end*				

* Gap of 7-10 days in locations received.

** Gap of > 10 days in locations received.

[1] Based on winter regions described by Oppel et al. (2008).

[2] Brackets indicate bird remained offshore during nesting period, so that breeding location is approximate.

Appendix B7b. Summary of movement of female King Eiders tagged at Siksik Lake on Banks Island, NWT, in 2008 (see App. 7a for movement of males).

PTT #	Nest location 2008	Depart nesting 2008	Depart nearby staging area	Arrive moulting 2008	Moult migration # of days	Moult locations 2008	Depart moulting 2008	Fall migration # of days
Females								
80902	Siksik Lake	28-Jul	07-Aug	17-Aug	17	Cape Nygligan	27-Oct	< 6
80904	Central Banks Island	01-Aug	20-Aug	29-Aug	25	Cape Chukotsk		
80907	Siksik Lake	03-Aug	11-Aug	01-Sep * *	20 * *	Nushagak Bay	25-Oct	38 * *
80910	Siksik Lake	19-Jul	10-Aug	22-Aug	31	Anadyr Bay	14-Oct	< 3
80912	Siksik Lake	17-Jul	30-Jul * *	15-Aug	26	Cape Nygligan	14-Oct * *	< 16 * *
80913	Siksik Lake	15-Jul	13-Aug	08-Sep	52	Kvichak Bay	18-Nov	< 3
80916	Siksik Lake	02-Aug	17-Aug	24-Aug	19	Cape Nygligan	03-Nov	26
80920	Siksik Lake	26-Jul	11-Aug	24-Aug	26	Kvichak Bay	29-Oct	29
80924	Siksik Lake	02-Aug	11-Aug * *	02-Sep * *	24 * *	Cape Chukotsk		
80926	Siksik Lake	03-Aug	15-Aug *	28-Aug	21	Cape Nygligan	27-Oct * *	< 35 * *
80928	Siksik Lake	08-Jul	12-Aug	19-Aug	39	Anadyr Bay	02-Nov	< 4
80929	Siksik Lake	22-Jul	10-Aug	19-Aug	25	Cape Chaplin	19-Oct	41
80931	Siksik Lake	28-Jul	13-Aug	23-Aug	23	St. Lawrence Island	17-Nov	21

Appendix B7b continued.

PTT #	Arrive winter 2008		Winter locations 2008/09	Depart winter 2009		Depart winter region[1]		Arrive nesting 2009	Spring migration # of days		Nest locations 2009 (approximate)[2]	Depart nesting 2009	
<u>Females</u>													
80902	02-Nov		Cape Chukotsk	28-Mar	*	26-Apr		15-Jun	74	*	Siksik Lake	*end*	
80904			Cape Chaplin	19-Apr		28-Apr		15-Jun	55		Central Banks Island	*end*	
80907	10-Dec[2]	* *	Off Alaska Peninsula[2]			27-Apr		15-Jun	127	* *	Siksik Lake	04-Aug	* *
80910	17-Oct		Cape Chaplin	11-Apr		28-Apr		17-Jun	65		Siksik Lake	13-Jul	* *
80912	30-Oct	* *	Cape Chukotsk	14-Apr		28-Apr			*end*				
80913	21-Nov		Port Heiden	*end*									
80916	02-Dec		Unimak Island	10-Mar	*	07-May		10-Jun	88	*	Siksik Lake	01-Jul	
80920	30-Nov		Port Heiden	02-Apr	*	09-May		11-Jun	66	*	Siksik Lake	29-Jul	
80924			Cape Chaplin	*end*									
80926	01-Dec	* *	Cape Chukotsk	14-Apr		21-Apr	*	14-Jun	59		Siksik Lake	01-Aug	
80928	06-Nov		Cape Chukotsk	22-Apr		27-Apr		13-Jun	51		Siksik Lake	19-Jul	
80929	02-Dec		Unimak Island	29-Mar	*	29-Mar	*	13-Jun	72	*	Siksik Lake	26-Jul	
80931	11-Dec		Unimak Island	31-Mar	*	28-Apr		06-Jun	63	*	Siksik Lake	04-Aug	

Appendix B7b continued.

PTT #	Depart nearby staging area	Arrive moulting 2009	Moult migration # of days	Moult locations 2009	Depart moulting 2009	Arrive winter 2009	Fall migration # of days	Winter locations 2009/10
<u>Females</u>								
80902								
80904								
80907		08-Sep	**	Nushagak Bay	31-Oct	21-Nov	17	Unimak Island
80910			*end*					
80912								
80913								
80916			*end*					
80920	09-Aug	04-Sep	34	Kvichak Bay	*end*			
80924								
80926	16-Aug		*end*					
80928	09-Aug	26-Aug	35	Anadyr Bay	31-Oct	08-Nov	4	Cape Chaplin
80929	12-Aug	26-Aug	28	Cape Chaplin	*end*			
80931	22-Aug	06-Sep	29	St. Lawrence Island	*end*			

* Gap of 7-10 days in locations received.
** Gap of > 10 days in locations received.
[1] Based on winter regions described by Oppel et al. (2008).
[2] Exact winter location of 80907 in 2008 unknown, because no locations were received between 10 Dec. 2008 and 6 Apr. 2009.

Appendix C1. Distance between breeding sites used in two consecutive years by female King Eiders tagged with satellite transmitters in western arctic Canada. Breeding site location obtained by calculating centroid of locations received during applicable period when bird was relatively stationary.

Sex	Year captured	PTT #	Distance apart (km)	Location Year 1	Location Year 2
Female	1998	14657	3.1	Victoria	Victoria
Female	2000	30273	3.4	Banks	Banks
Female	2000	30227	0.1	Banks	Banks
Female	2000	30228	4.0	Banks	Banks
Female	2003	40950	0.9	Victoria	Victoria
Female	2003	40951	1.3	Victoria	Victoria
Female	2003	40953	2.7	Victoria	Victoria
Female	2003	40954	2.8	Victoria	Victoria
Female	2003	40955	2.6	Victoria	Victoria
Female	2004	50122	0.6	Victoria	Victoria
Female	2004	50123	48.7	Victoria	Victoria
Female	2004	50125	1.1	Victoria	Victoria
Female	2004	50131	1.9	Victoria	Victoria
Female	2008	80902	0.8	Banks	Banks
Female	2008	80904	0.2	Banks	Banks
Female	2008	80907	2.2	Banks	Banks
Female	2008	80910	1.4	Banks	Banks
Female	2008	80920	0.8	Banks	Banks
Female	2008	80926	0.8	Banks	Banks
Female	2008	80928	0.6	Banks	Banks
Female	2008	80929	1.5	Banks	Banks
Female	2008	80931	0.8	Banks	Banks
Female	2008	80916	1.2	Banks	Banks

Appendix C2. Distance between the location of male King Eiders in two consecutive breeding seasons. Each location was obtained by calculating the centroid of locations received during the breeding season when the bird was relatively stationary.

Sex	Year captured	PTT #	Distance apart (km)	Location Year 1	Location Year 2[1]
Male	1998	14656	3690	Victoria	Taymyr Peninsula
Male	2000	23870	3	Banks	Big River Delta
Male	2003	40944	633	Victoria	NW Banks Island
Male	2003	40945	3247	Victoria	Indigirka River
Male	2003	40947	604	Victoria	(West Banks Island)
Male	2003	40948	742	Victoria	(Cape Dalhousie)
Male	2003	40949	3157	Victoria	(Kotel'nyy Island)
Male	2004	50120	31	Victoria	Kagloryuak River
Male	2004	50121	607	Victoria	(Cape Kellet)
Male	2004	50127	590	Victoria	Cape Kellet
Male	2004	50128	589	Victoria	Cape Kellet
Male	2008	80903	778	Banks	(Martin Point)
Male	2008	80905	409	Banks	(Cape Dalhousie)
Male	2008	80906	185	Banks	(Burnett Bay)
Male	2008	80911	3300	Banks	Taymyr Peninsula[2]
Male	2008	80914	2963	Banks	(Lena River Delta)
Male	2008	80915	412	Banks	East of Minto Inlet
Male	2008	80917	2150	Banks	Novaya Sibir Island[2]
Male	2008	80921	270	Banks	(Cape Dalhousie)
Male	2008	80922	249	Banks	Prince Albert Peninsula
Male	2008	80927	138	Banks	(Burnett Bay)
Male	2008	80930	1035	Banks	(Smith Bay)

[1] Brackets indicate breeding location is approximate, because the bird was offshore.

[2] Breeding location is approximate, because the bird was likely still migrating on the date the transmitter quit functioning.

Appendix D. Distance between moulting sites used over two consecutive years by King Eiders tagged with satellite transmitters in western arctic Canada. Moulting site location obtained by calculating centroid of locations received during applicable period when bird was relatively stationary.

Sex	Year captured	PTT#	Distance apart (km)	Location Year 1	Location Year 2
F	2000	30227	4	Kvichak Bay	Same
F	2003	40955	42	Cape Chukotsk	Same
F	2008	80907	27	Nushagak Bay	Same
F	2008	80920	2	Kvichak Bay	Same
F	2008	80931	10	St. Lawrence Island	Same
F	2008	80928	15	Anadyr Bay	Same
F	2008	80929	31	Cape Chaplin	Same
M	2003	40949	29	Anadyr Bay	Same
M	2003	40944	9	Kresta Bay	Same
M	2003	40947	2	St. Lawrence Island	Same
M	2008	80905	44	Cape Chaplin	Same
M	2008	80922	2	Anadyr Bay	Same
M	2008	80915	16	Anadyr Bay	Same