Exxon Valdez Oil Spill
Restoration Project Final Report

Using Satellite Telemetry to Monitor Movements of Surf Scoters (*Melanitta perspicillata*) Captured in Prince William Sound, Alaska

Restoration Project 00273
Final Report Volume 1

This final report has been prepared for peer review as part of the *Exxon Valdez* Oil Spill Trustee Council restoration program. Peer review comments from previous annual reports have been addressed in this final report.

***NOTE regarding this final report:**

This report is being released by EVOSTC. It has been peer reviewed and the format has been standardized for cataloging by ARLIS. However, the authors may not have reviewed this draft and some of the pages may have a "DRAFT" watermark.

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Study History: Restoration Project 00273 continues studies initiated in 1998 (Rosenberg and Petrula 1999) and continued in 1999 (Rosenberg and Petrula 2000). The goal of this study is to monitor movements of white-winged scoters using satellite telemetry to increase our understanding of scoter ecology. White-winged scoters, a sea duck, are an important subsistence resource to the indigenous people of Prince William Sound. Scoter numbers, however, have reportedly declined for unknown reasons. Additional scoters were killed during the *Exxon Valdez* oil spill. The decline is a concern to both waterfowl managers and subsistence consumers. This report describes results of these studies.

Abstract: We used satellite telemetry to identify seasonal movements, nesting, molting and wintering areas for surf scoters (*Melanitta perspicillata*) captured in Prince William Sound, AK during April-May 1998-2000. Satellite transmitters were surgically implanted in 36 surf scoters (20 males and 16 females). Transmitters were expected to operate until approximately February the following year. Because of high post-release mortality (>50%) and poor transmitter performance we can only verify that 14 surf scoters left Prince William Sound. Movements of seven birds were monitored until the following winter.

Surf scoters departed Prince William Sound between 12 May and 15 June (median = 23 May). Non-breeding males (n = 4) traveled directly to molting locations along the Kuskokwim shoals. Winter locations were identified for 3 of these birds (Kashvik and Katmai bays, Alaska Peninsula; Baranof Island, Sitka Sound; Montague Island, Prince William Sound). Eleven scoters traveled from Prince William Sound to breeding areas in interior Alaska (4 females) and northern Canada (4 females, 3 males). Molting locations were identified for 2 females (Prince William Sound) and 2 males (Norton Sound, Kotzebue Sound). Wintering locations were identified for 2 females (Prince William Sound; Strait of Georgia, British Columbia) and 2 males (Prince William Sound).

The broad distribution of our birds during the summer indicates that the potential breeding and molting range for surf scoters encompasses a large geographic area. An unknown proportion of surf scoters from the Pacific Northwest nest and molt sympatrically with Prince William Sound birds. Consequently, delineating population units for management purposes may be difficult.

Key Words: Alaska, Kuskokwim shoals, migration, molt, Northwest Territories, Prince William Sound, satellite telemetry, scoter, sea duck, surf scoter.

Project Data: *Description of data* – Location and sensor data were recorded for each satellite transmitter. *Format* – Location and sensor data are in Microsoft Excel and DBASE IV spread sheet format. GIS coverage of Alaska and Canada showing scoter locations are presented in ArcView format. *Custodian* - Archived at ADF&G regional headquarters in Anchorage. Contact Dan Rosenberg at ADF&G, 525 W 67 Ave, Anchorage, Alaska 99518 (907-267-2453) (dan_rosenberg@fishgame.state.ak.us) or Mike Petrula (907-267-2159) mike_petrula@fishgame.state.ak.us) for information. Project information can be viewed at http://www.wildlife.alaska.gov/index.cfm?adfg=waterfowl.scoter_home

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EXECUTIVE SUMMARY

Sea duck populations in Alaska have reportedly declined over the last few decades. A precipitous decline in several species has raised concern. The lack of information available to researchers and managers pertaining to sea duck ecology, and inadequate methods of inventory and monitoring limits our ability to identify probable reasons for the decline. Identifying staging, nesting, molting, and wintering areas is a crucial first step in understanding sea duck biology and population dynamics.

Surf scoters (*Melanitta perspicillata*) are sea ducks, some of which migrate through or spend the winter in Prince William Sound and lower Cook Inlet, AK. Scoters are an important subsistence resource for communities in these areas and comprise a large proportion of their sea duck harvest. The decline in scoter numbers is a concern to managers and consumers.

We used satellite telemetry to track scoter movements and to identify seasonally important habitats. We used floating mist nets and decoys to catch scoters in Prince William Sound during the spring at Stockdale Harbor (April-May 1998), near St. Matthew's Bay (April-May 1999), and in Orca Inlet (mid-April 2000). A veterinarian implanted the satellite transmitters in the abdominal cavity of the birds. In 1998 and 1999, surgeries were performed on the vessel and birds were released at the capture site approximately 5 hours after the procedure. In response to high post-release mortality in 1998 and 1999, birds in 2000 were transported via fixed winged aircraft to the Alaska SeaLife Center in Seward where they were held in captivity for 5-9 days pre– and 12-21 days post-surgery. Birds were flown back to the capture site and released. No birds died during surgery.

Satellite transmitters contained sensors that recorded internal body temperature and battery voltage. Ambient temperature readings indicated the bird died. Transmitters were programmed to transmit more frequently during anticipated periods of activity (i. e. migration). Signals were analyzed using Argos Data Collection and Location Systems.

Satellite transmitters were deployed in 36 surf scoters (20 males and 16 females) during the study. Ambient readings from the temperature sensor indicated that 18 scoters (11 males, 7 females) died soon (< 21 days) after release, and 3 males died in captivity. A female survived until 30 January, but accurate locations were not received after 4 June, therefore we can only verify that 14 birds departed Prince William Sound. Four transmitters subsequently failed, 3 females died 13, 47 and 58 days after leaving Prince William Sound, and one transmitter went off the air for unknown reasons. Consequently, movements of only seven birds were monitored until the following winter.

Surf scoters departed Prince William Sound between 12 May and 15 June (median = 23 May). Four non-breeding males traveled west along the coast stopping in lower Cook Inlet and Bristol Bay before settling on the Kuskokwim shoals where we believe they remained during the flightless period (molt). We determined wintering locations for 3 of these birds (Kashvik and Katmai bays, Alaska Peninsula; Baranof Island, Sitka Sound; Montague Island, Prince William Sound).

Four females traveled north into interior Alaska during the breeding season. One (12753) spent 28 days (27 May-23 June) approximately 55km south of Arctic Village near the confluence of the Wind and east fork of the Chandalar rivers (Arctic National Wildlife Refuge), and another (27598) spent 58 days (23 May-19 July) approximately 15km south-east of Lake Louise. Both returned to Prince William Sound where we believe they molted. One (27598) wintered in Prince William Sound, and we suspect the other wintered in the Strait of Georgia near Vancouver Island, British Columbia. We did not receive location data after 5 July for the other 2 females that moved to interior Alaska. One (12754) spent 30 days (2 June-1 July) approximately 53km south of Lake Minchumina, and the other (12943) was located for brief periods (9-19 June) at 2 locations within 35km of Lake Minchumina before going off the air.

Seven scoters (3 males, 4 females) traveled through Alaska and spent time in northwest Canada (Northwest Territories; Yukon Territory) during the breeding season. Three females died and one went off the air on or before 22 July, consequently we cannot report molting and wintering locations for these birds. Female (10928) traveled from Prince William Sound to the Horton River drainage south of Paulatuk, Northwest Territories in approximately 6 days (25-30 May). It spent 25 days (2-27 June) in a centralized location between the Horton and Anderson rivers before temperature readings indicated that it had died. Female 29996 traveled from Prince William Sound to the Porcupine River near Canyon Village in approximately 5 days where it remained from 30 May-8 June. It then traveled 300km to the Northwest Territories near Inuvik where it spent 37 days (11 June-17 July. The bird died on 22 July at a location along the Snake River drainage, Yukon Territory, approximately 310km south of its previous location. Before it died, female (12991) was last located (26-31 May) near the Mountain River area, Mackenzie River drainage, Northwest Territory. Female (12772) initially flew west after leaving Prince William Sound, similar to the route taken by non-breeding males. In early June, however, she traveled through interior Alaska on the way to the Northwest Territories. Our last data for this bird was of poor quality but indicated that from 1-16 July she was located north of the Smith Arm of Great Bear Lake near Colville and Aubry Lakes.

We have conclusive location data for 2 of the 3 male surf scoters that traveled inland to breeding areas in northwestern Canada. After spending approximately 10 days (21-29 May) near the confluence of the Kantishna and Toklat rivers (interior Alaska), male (23893) traveled to a large lake system located north of Old Crow (Yukon Territory) where it remained for approximately 20 days (31 May-19 June) before traveling to Kotzebue Sound, Alaska where we believe it molted before returning to Prince William Sound. Male (23888) was located in the Northwest Territories 3 days after departing Prince William Sound. It remained near the Dahadinni River area, south of Bracket Lake for approximately 15 days (18 May-3 June) before traveling in a westerly direction along the Beaufort Sea coast, eventually molting in Kotzebue Sound, Alaska. The transmitter for this bird failed in early August, but on 14 December it was shot by a hunter near Main Bay (Prince William Sound), approximately 100km west of the capture site. After wintering in Prince William Sound, male 2246 traveled through Alaska to the Northwest Territories. This was the second spring migration recorded for this bird; the previous year it followed a coastal route. Our last location was on 17 July near Herschel Island, Yukon Territory.

Surf scoters appear to have a high degree of fidelity to wintering locations. That 3 birds used locations other than Prince William Sound during the winter following capture suggests that spring migrants from other wintering locations were included in our sample.

The 2 geographic regions (interior Alaska, northwest Canada) used by surf scoters during the breeding season encompasses a large area but is confined to the boreal forest ecoregion. Because an unknown proportion of surf scoters from the Pacific Northwest nest and molt sympatrically with Prince William Sound birds, and most likely birds from other locations in Alaska, we cannot determine a bird's winter origin based on where it nests or molts. Similarly, we cannot predict where a surf scoter might nest or molt based on its winter origin. Consequently, delineating population units for management purposes may be difficult.

In spite of the small sample size, our pioneering work has produced unique and revealing information on surf scoter movements unattainable with conventional marking and telemetry methods. We regret that many birds died soon after release during this study. However, satellite telemetry is the only effective way to monitor movements of birds over vast and remote areas, when rapid movement between distant regions is typical. The chronology of surf scoter movements is becoming more apparent and important seasonal habitats are being delineated with more precision due to results of this and similar satellite telemetry studies. We suggest that additional experimentation be conducted on surf scoters to determine the causes of post-release mortality.

Photographs of the capture, surgery, satellite transmitter, and color maps of surf scoter movements are at http://www.wildlife.alaska.gov/index.cfm?adfg=waterfowl.scoter_home.

INTRODUCTION

The current status for many of Alaska's 15 sea duck (Mergini) species is uncertain (U.S.Fish and Wildlife Service 1999). For several species, however, abundance appears to have declined in the last few decades and there is concern for many others (Kertell 1991, Stehn et al. 1993, Goudie et al. 1994, Hodges et al. 1996, U.S. Fish and Wildlife Service 1999). The uncertainty in the status of some populations results from the inherent difficulties associated with assessing population trends, and the lack of a standardized inventory and monitoring program designed specifically for sea ducks (U.S.Fish and Wildlife Service 1999). Further, little is known about sea duck ecology compared to dabbling (Anatini) and diving ducks (Aythyini). Because sea ducks are widely dispersed throughout remote areas and winter study in the marine environment is difficult, little information is available on population trends, productivity, survival, and harvest.

The best available evidence indicates that scoter (*Melanitta* spp.) numbers in Alaska have declined by as much as 40% since 1977 (Hodges et al. 1996). In Prince William Sound (PWS), the estimated population of wintering scoters declined from 56,600 to 14,800 birds between the early 1970’s and 1989; the year of the *Exxon Valdez* oil spill (Klosiewski and Laing, 1994). The summer population (July) of scoters during this period also declined from 13,000 to 5,400 birds (Klosiewski and Laing, 1994). The number of scoters in PWS has increased since the spill (Agler and Kendall 1997, Lance et al. 2001) but remains below historic levels.

The cause for the large decline in scoter numbers in PWS between the early 70’s and 1989 is not known, but long-term oscillations in ocean temperatures in the Gulf of Alaska (Piatt and Anderson 1996) and effects from exposure to contaminants, particularly oil, have been proposed agents. An estimated 1,000 scoters died as a direct result of the *Exxon Valdez* oil spill (John Piatt, pers. comm.). A white-winged (*Melanitta fusca*) scoter die-off near Cape Yakataga in southeast Alaska during 1990-1992 (Henny et al. 1995) raised concern that contaminants were present in the environment. Although no definitive cause could be identified, elevated levels of cadmium were detected in the birds, but no source of contamination could be identified. Surf scoters (*Melanitta perspicillata*) are vulnerable to oil spills (Piatt et al. 1990) because they are more associated with intertidal areas in PWS than other scoter species (Patten et al. 1998), and intertidal areas were most impacted by oil (Highsmith et al. 1996, Short and Babcock 1996). They feed primarily on bivalves, especially mussels (Crow 1978, Vermeer 1981), but in spring they may switch to a diet composed primarily of herring roe (Vermeer 1981, Goudie et al. 1994, Bishop et al. 1995). Mussels and intertidal sediments in PWS showed increases in petroleum hydrocarbon concentrations directly attributable to *Exxon Valdez* oil (Short and Babcock 1996), and oil in mussel beds in PWS and the Kenai Peninsula persisted for several years after the spill (Babcock et al. 1996). PWS herring stocks suffered a dramatic decline in 1993 and stocks have remained depressed (Sharp et al. 2000), subsequently reducing the amount of available roe in the spring. Additionally, increasing sea otter populations since the mid 1900's may have led to increased competition for food between scoters and otters (Stratton 1981).

Exposure of sea ducks to contaminants or other mortality factors may occur anywhere in a bird's annual migratory cycle. The difficulty of detecting causes of population declines, especially for species with a broad geographic range, is confounded by a lack of specific information on affiliations between breeding, molting, and wintering areas (Henny et al. 1991). Unfortunately, scoters are among the least studied of North American waterfowl (Bellrose 1976, Savard and Lamothe 1991, Savard et al. 1998). Although some breeding (Gabrielson and Lincoln 1959, Godfrey 1986) and molting (Johnson and Richardson 1982, Dau 1987) areas have been identified, the link between these areas with wintering locations has not been identified.

Not until we begin to understand the basics of sea duck biology will we be able to understand the factors that influence their numbers. Identifying migration routes, the chronology of movements, and important staging, nesting, molting and wintering locations is an important first step in determining affiliations among these areas and would allow us to direct sampling and monitoring efforts at specific population segments. Traditional marking of birds with metal leg bands has not been an informative exercise because so few sea ducks are banded and the harvest is small. The potentially vast geographic range of these birds makes conventional telemetry impractical and costly.

Satellite transmitters have been used effectively in other studies designed to monitor movements of sea ducks (Petersen et al. 1995, Dickson et al. 1998, Savard et al. 1999, Robert et al. 2000), and we employ this evolving technology to monitor movements of surf scoters wintering in PWS. Our objectives are to identify nesting and molting locations, describe the chronology of movements and routes taken between seasonal habitats, and exam if affiliations exist among wintering, breeding and molting locations.

STUDY AREA AND METHODS

Prince William Sound, Alaska (PWS) (ca. 60°30'N, 147°00'W) is a large estuarine embayment of the northern Gulf of Alaska characterized by fjord-like ports and bays surrounded by steeply rising mountains (Fig. 1). Highly irregular in shape, it is approximately 160km east to west and 140km north to south. Tides can exceed 4.5m and water depth can reach 870m. The general physiography, climate, oceanography, and avian habitats of PWS are described by Isleib and Kessel (1973). Surf scoter numbers in PWS during the winter since the spill have been estimated to be between 4,500-24,500 birds (Stephensen et al. 2001).

We captured scoters at the northern tip of Montague Island near Graveyard Point (60.362°N, 147.218°W) from 31 April-3 May 1998, in St. Matthew's Bay (60.734°N, 146.356°W) from 26 April-5 May 1999, and in Orca Inlet (60.513°N, 145.886°W) from 11-15 April 2000 (Fig. 1). Capture sites were about 82km southwest, 37km northwest, and 4km west of Cordova, Alaska respectively. Birds captured on Montague Island and in St. Matthews Bay were concentrated on herring spawn. Herring spawn was not present in Orca Inlet, yet several thousand sea ducks were utilizing the area.

Equipment, Field Procedures and Data Collection

Sea ducks were captured over water using decoys and floating mist nets (Kaiser et al. 1995, Sea Duck Joint Venture, www.seaduckjv.org). Captured birds were placed in small pet carriers with raised mesh floors and transported by skiff to a nearby vessel where we recorded morphological measurements and applied a USFWS metal leg-band. Blood was also sampled for future genetic work.

We used PTT-100 implant transmitters (Microwave Telemetry Inc., Columbia MD). Surgical procedures were performed by an experienced veterinarian and followed protocols developed by Korschgen et al. (1996) with some modifications (Mulcahy and Esler 1999, Robert et al. 2000). Standard aseptic surgical techniques were practiced. Anesthesia was induced and maintained with isoflurane gas (Aerrane, Ohmeda) delivered in oxygen. Pre-surgical preparation included plucking feathers along the ventral midline (about 3.0cm long by 2cm wide) between the distal end of the keel and the pubic bone to expose the incision site in the coelomic cavity (a practice that has since been discontinued). Another 1-cm^2 patch of feathers was plucked at a dorsal position nearest the intersection of the pubis and synsacrum. Here, an incision was made for the antenna exit. The abdominal air sac was breached and the antenna was passed through a trochar inserted dorsally. The transmitter was inserted into the right abdominal air sac and all incisions closed with absorbable sutures. Scoters that received satellite transmitter implants were selected based on body size and breeding status. Large bodied birds determined to be part of a breeding pair were preferred over smaller, lone individuals. Only adult (ASY) scoters received transmitters.

In 1998 and 1999, surgeries were performed on a vessel near the capture site. Birds were returned to pet carriers following surgery and allowed to recover from anesthesia for 2–5 hours before being released on the water within 0.5km of their capture site. Because we experienced high rates of post-release mortality in 1998 and 1999, we transported birds in 2000 (fixed-winged aircraft) to the Alaska SeaLife Center in Seward where they were held in captivity for 5-9 days pre– and 12–21 days post-surgery. When captive birds remained dry at the ventral incision site, had normal hematocrits, total plasma solids and leukocytes (buffy coat), gained mass, and exhibited no signs of trauma or lethargy, they were flown back to the capture site and released.

Transmitter design changed over the course of the study because of changes in battery configuration (Rosenberg and Petrula 2000). Transmitters were expected to operate until February the following year. We used transmitters that weighed 39-41g in all years except for males in 1999 that received transmitters (50-51g) with a larger battery source in an attempt to lengthen the period of data collection. Mean (± SD) body mass of male and female surf scoters receiving transmitters was 1146.2 ± 74.1g (n = 20) and 994.4 ± 63.5g (n = 16), respectively. Transmitter to body weight ratio ranged from 3.6%-4.4% for females, and 3.2%-4.1% for males carrying the 36g transmitter, and 4.1%-4.5% for males (n = 10) that carried the heavier transmitter. A 21.6cm long Teflon-coated multi-strand stainless steel antenna exited from the posterior dorsal end of the transmitter and protruded 2cm before bending at a 90^o angle. All satellite transmitters were reinforced to withstand external pressure and were equipped with temperature and battery voltage sensors. Transmitters were programmed to transmit one pulse every 60s for 6-8 consecutive hours. Off times varied from a minimum of 48 hours during spring and summer to a maximum of 120 hours during fall and winter.

Locations were obtained through Argos Data Collection and Location Systems (Service Argos, Inc. Landover MD). We used standard and auxiliary location data processing services (Argos 1996). We used a filtering algorithm (David Douglas USGS-BRD) based on travel distance, travel rate, and redundancy from previous or subsequent locations to remove autocorrelated and aberrant locations. We mapped the best location per 6-8 hour on-period for each bird. Locations with class code Z (n = 1) were scrutinized for plausibility.

The ultimate fate of the satellite transmitter or birds was classified as: 1) “dead” when sensor data indicated ambient temperature; 2)“off air” when no data (sensor or location) was received; 3)“failed” when sensor data indicated the bird was alive, but location data was not received.

Photographs of the capture, surgery, and satellite transmitter can be viewed on the Internet at the following site: http://www.wildlife.alaska.gov/index.cfm?adfg=waterfowl.scoter_home

RESULTS

Floating mist nets were an effective trapping technique for capturing sea ducks in PWS. The presence of several thousand sea ducks provided us with ample opportunities. We captured 135 surf scoters, 201 white-winged scoters, 25 black scoters, 23 harlequin ducks, and 22 long-tailed ducks.

Thirty–six satellite transmitters were deployed in surf scoters (20 males and 16 females) during the study. Ambient readings from temperature sensors indicated that 18 birds (11 males, 7 females) died in PWS soon (< 21 days) after release, and 3 males died in captivity. We did not receive accurate location data for another bird (12752) after 4 June even though it survived until 30 January, therefore we can only verify that 14 birds (39%; 8 females, 6 males) departed PWS in the spring. Our sample size was gradually reduced when 3 females died 13, 47, and 58 days after leaving PWS (Table 1).

Transmitter Performance

Transmitter performance (signal quality, longevity) was variable, consequently the number and accuracy of locations varied among surviving birds (Table 1). Three transmitters stopped providing location data in July (12772, 12943) or August (14019), approximately 67-119 days after deployment, and prior to the expected life of the batteries. Before losing complete contact with these transmitters, we received temperature sensor data, indicating the birds were alive for 1 (14019), 3 (12772), and 5 (12943) months after the last location was received. Consequently, as was the case for 12752 (see above), the lack of location data was not the result of the bird’s death but was probably the result of transmitter malfunction or antenna damage. We know transmitter 23888 failed in early August, 103 days after deployment, because the bird was shot by a hunter the following December, 126 days after we received our last data for this bird. We cannot determine if the lack of data after late July for another transmitter (12754) was the result of transmitter failure or the bird’s death.

Our longest active transmitter (2246) lasted through most of the bird’s second summer after release (440 days), but we received relatively few locations; locations were of poor quality (37%; 1, 2, and 3 class code), and received infrequently (only 44% of expected transmission cycles; Table 1). Our best performing transmitter (23893) was active for 258 days; locations were relatively accurate (64%; 1, 2, and 3 class code), abundant (>9 locations per transmission cycle, on average), and dependable (100% of expected transmission cycles; Table 1).

Scoter Movements and Activity

Prior to spring departure, scoter locations were primarily concentrated in eastern PWS. Several birds were detected for brief periods in northern (Port Valdez, Unakwik Inlet), southern (southern Montague Island, Port Bainbridge), and western (Passage Canal, College Fiord) PWS (Fig. 1). Surf scoters left PWS between 12 May and 15 June (median = 23 May). We identified 3 summer destinations for surf scoters after leaving PWS; 4 males took a coastal route to western Alaska; 4 females traveled north to interior Alaska; and 4 females and 3 males traveled through Alaska to northern Canada (Northwest Territories, Yukon Territory). We grouped birds by summer destination and identified stopover locations, subsequent molting and wintering locations, and the ultimate fate of the transmitter or bird.

Western Alaska Coast: After leaving PWS, four males (2244, 2246, 10929, 14019) traveled west along the coast before settling in Kuskokwim Bay (Fig. 2). Stopover locations included areas on the east (Kachemak Bay) and west side (Kamishak Bay, Iniskin Bay, Chinitna Bay) of lower Cook Inlet, and Bristol Bay regions (Kvichak Bay, Nushagak Bay, Lake Aleknagik, Togiak Bay; Fig. 2). Longer lengths of stay were recorded at stopover areas on the west side of lower Cook Inlet (4-17 days) than other locations (1-4 days). Birds accessed Cook Inlet from PWS by traveling around the southern tip of the Kenai Peninsula, or through Portage Pass (Fig. 2). Because we did not receive spring locations in lower Cook Inlet south of Kamishak Bay, we suspect birds accessed Bristol Bay by crossing the Alaska Peninsula through a pass in the Aleutian Range near Iliamna Lake (Fig. 2). We suspect they were non-breeding males because they did not travel inland for extensive periods during the summer.

We are confident that three birds (2244, 10929, and 14019) molted along the Kuskokwim shoals because they spent most of July and part of August centrally located in that area (Fig. 2). Male 2246 also spent time on the Kuskokwim shoals, but because locations were not received between 18 July and 5 October we cannot verify its molting location (Fig. 2). The transmitter should have been providing locations approximately every 3 days during this period.

All birds departed Kuskokwim Bay after the molt (Fig. 2). Male 2244 left in early September and traveled to the east side of the Alaska Peninsula and remained near Kashvik and Katmai bays, Shelikof Strait until the transmitter expired in mid-March. Male 10929 also left Kuskokwim Bay in early September but traveled across the Gulf of Alaska to Baranof Island, Sitka Sound and remained there until the transmitter expired in late January (Fig. 2). We suspect male 2246 returned to PWS earlier than our first location indicated (5 October), but data gaps prevent us from being certain. It remained in PWS during the winter, mostly near the south-west tip of Montague Island. Male 14019 went off the air in late August near Kaghasiuk Lake, Yukon Delta NWR (60.958^{o}N, 163.879^{o}W) consequently we do not know where it spent the winter (Fig. 2).

Interior Alaska: Four females (12753, 12754, 12943, 27598) traveled north into interior Alaska during the breeding season (Fig. 3). We received good quality location data for two of these birds (12753, 27598).

After leaving PWS, female (12753) spent 5 days on Yukon Flats NWR (66.097°N, 145.682°W), before traveling further north where it spent 28 days (27 May-23 June) approximately 55km south of Arctic Village (Table 2) near the confluence of the Wind and east fork of the Chandalar Rivers (Arctic NWR). Female 27598 traveled directly from PWS to an area approximately 15 km south-east of Lake Louise (Table 2) where it remained for 58 days (23 May-19 July). Both returned to PWS by late July. Female 27598 molted and spent the winter in PWS. We suspect 12753 also molted in PWS then traveled to the Straits of Georgia near Vancouver Island, BC. for the winter (Fig. 3).

We did not receive location data after 5 July for the other two females that moved to interior Alaska. Female 12754 spent 30 days (2 June-1 July) approximately 53km south of Lake Minchumina near Burnt Lake (Table 2), and 12943 was located for brief periods (9-19 June) at 2 locations (Chilchukabena and Jim Lakes) within 35km of Lake Minchumina before going off the air (Fig. 3).

Northwest Canada: Seven scoters (3 males, 4 females) traveled through Alaska and spent time in northwest Canada (Northwest Territories; Yukon Territory) during the breeding season.
Travel to breeding destinations was fairly direct, consequently stopover locations were difficult to detect for most birds. Only Tetlin NWR (near Tetlin Lake) was used as a stopover location by more than one bird (n = 3; Fig. 4 and Fig. 5).

Females traveling to northwest Canada either died, or their radio failed before leaving breeding areas. Female 10928 traveled from PWS to the Horton River drainage south of Paulatuk, NWT in approximately 6 days (25-30 May; Fig. 4). It spent 25 days (2-27 June) in a centralized location between the Horton and Anderson rivers near Bekere Lake (Table 2) before temperature readings indicated that it had died. Female 29996 traveled from PWS to the Porcupine River near Canyon Village, AK (67.180°N, 142.090°W) in approximately 5 days where it remained from 30 May-8 June. It then traveled approximately 300km to the NWT near Inuvik (Table 2) where it spent 37 days (11 June-17 July). The bird died on 22 July, at a location along the Snake River drainage, YT (65.221°N, 134.944°W), approximately 310km south of its previous location (Fig. 4). Female 12991 was located near Tetlin NWR on 21 May, and in the Yukon Territory (66.716°N, 137.039°W) on 24 May; 6 days after leaving PWS. It died on 31 May near the Mountain River area, Mackenzie River drainage, NWT (65.443°N, 129.613°W; Fig.4). Female 12772 initially flew west after leaving PWS, similar to the route of non-breeding males, stopping at Iniskin Bay (lower Cook Inlet), Hagemeister Strait (Bristol Bay) and on the Yukon Delta NWR, AK (61.010°N, 162.265°W; Fig. 4). In early June it began an easterly migration through interior Alaska on the way to the NWT stopping on the Koyukuk NWR, AK (65.879°N, 157.810°W), near Old Crow, YT (67.176°N, 140.368°W), and near the Mackenzie River Delta, NWT (68.243°N, 136.484°W; Fig. 4). Our last data for this bird was of poor quality but indicated that from 1-16 July it was located north of the Smith Arm, Great Bear Lake near Colville and Aubry Lakes, NWT (67.642°N, 126.806°W; Fig. 4).

We have conclusive location data for 2 of the 3 male surf scoters that traveled inland to breeding areas in northwestern Canada. After spending the summer of 1998 in Kuskokwim Bay and wintering in PWS (Fig. 2), male 2246 traveled through Alaska to the NWT during the spring in 1999 (Fig. 5). We only received 5 locations between the time it departed PWS (13 May) and when we lost complete contact (20 September). We are fairly certain that it spent approximately 10 days in the vicinity of Tetlin Lake, Tetlin NWR, AK. (Fig. 5). Our last location (17 July) placed the bird on the coast near Herschel Island, YT (69.503^{o}N, 139.231^{o}W; Fig. 5). We do not have data to describe what transpired between those locations.

Two male surf scoters (23893, 23888) traveled inland from PWS to breeding areas in northwestern Canada before migrating to molting sites along the coast of northwestern Alaska (Fig. 5). Male 23893 spent approximately 10 days (21-29 May) near the confluence of the Kantishna and Toklat rivers (64.083^{o}N, 150.573^{o}W; interior Alaska), then traveled to a large lake system located north of Old Crow, YT (Table 2) where it remained for about 20 days (31 May-19 June) before traveling to Kotzebue Sound, Alaska (Fig. 5). This male may have accompanied a female to a nesting area and left for the coast with the onset of incubation. Based on the time subsequently spent in Norton Sound we believe the bird molted there before returning to PWS for the winter. From 24 September until our last location (12 January) the bird traded between Montague Island (southern PWS) and Port Wells (northwest PWS; Fig. 5).

Male 23888 was located in the NWT, Canada 3 days after departing PWS (Fig. 5). It is possible that he also accompanied a female to a nesting area near the Dahadinni River, south of Bracket Lake (Table 2) where it remained for approximately 15 days (18 May-3 June) before traveling in a westerly direction along the Beaufort Sea coast, eventually molting in Kotzebue Sound, Alaska. The transmitter for this bird failed in early August, but on 14 December it was shot by a hunter near Main Bay (PWS), approximately 100km west of the capture site. A necropsy on 17 December indicated that the bird appeared healthy (Dan Mulcahy, DVM, Pam Tuomi, DVM, pers. comm.).

DISCUSSION

The large sample of surf scoters captured during the study enabled us to select heavier and, in most cases, paired birds for satellite implants. We presumed that birds possessing both characteristics would be more likely to survive and travel to breeding areas than would lighter, lone individuals. Among the 14 birds leaving PWS in the spring, 8 females and 1 male were paired at capture. Seven paired females traveled directly from PWS to potential breeding areas in interior regions, but the paired male followed a coastal route to the Kuskokwim shoals molt site. One of the 5 unpaired males at capture traveled to a potential breeding area.

That many surf scoters died early during the study indicates that other factors are more critical to survival of surgery birds than weight alone. In 2000, we attempted to increase post-surgery survival by holding birds in captivity at the Alaska SeaLife Center for longer periods before release. Our hypothesis was that post-operative birds were vulnerable to predators, or susceptible to hypothermia and infection. Husbandry techniques, however, for maintaining sea ducks were not well developed at the time and holding birds in captivity presented some unexpected complications. The end result was that post-release survival rates was no higher for captive birds than birds released soon after surgery. We did, however experience higher post-release survival rates for white-winged scoters held during the same period and for the same purpose (satellite study; see Volume 2). Surf scoters may not be good candidates for satellite implants at winter locations in northern latitudes given current technology.

The satellite transmitters used during the study did not perform up to our expectations. Three transmitters (12772, 12943, 14019) did not provide location data 67, 79 and 119 days after release even though the birds were alive. One transmitter (23888) failed completely, and two of our longer-lived transmitters (2246, 12753) provided infrequent location data (Table 1). The combination of high mortality and poor transmitter performance resulted in our tracking a small number of birds from PWS and generated inconclusive data for several that did leave. Consequently, our sample size was smaller than expected, and we were only able to monitor movements of 7 birds until the winter following capture.

A primary objective of the study was to capture surf scoters that winter in PWS and use satellite telemetry to identify their nesting and molting locations and describe potential affiliations among these areas. We are therefore attempting to associate a location with a specific activity even though the bird is not under direct observation. Consequently, we must employ previous knowledge of surf scoter breeding and molt chronology, and seasonal distribution to corroborate our conclusions. Whether an individual attempts to breed in a location we define as a nesting area is not known, but we assume the bird traveled there for that purpose. Identifying molting areas is simplified because birds lack mobility for approximately 1 month. Determining wintering areas depends to a greater extent on the longevity of the transmitter and the quality and quantity of location data. Since the completion of our project, studies using implantable satellite transmitters have been initiated at four locations along the Pacific coast (Baja San Quitin, Mexico, San Francisco Bay, CA., Puget Sound, WA., and Straits of Georgia, BC.) to track movements of surf scoters. Results from these projects are preliminary, but we refer to them here to aid in the interpretation of our results.

Wintering Locations

We cannot be certain that birds trapped during April-May in PWS were winter residents. Depending on latitude, surf scoters along the Pacific coast depart winter locations for breeding areas from as early as mid-April (San Francisco Bay, CA.) to early May (Puget Sound, WA.) (Susan Wainwright-De La Cruz, USGS-BRD, pers. comm.). Therefore, the possibility exists that spring migrants were included in our sample, their true winter origin being unknown. If that is the case, any conclusions addressing potential affiliations among PWS wintering, to breeding and molting locations would be incorrect. That only 1 of 52 surf scoters carrying satellite transmitters deployed at locations along the Pacific coast used PWS during early spring (Dan Esler SFU, pers. comm.) suggests that it is unlikely that birds from these areas were included in our sample. Most scoters wintering in the Pacific Northwest appear to access interior breeding locations by leaving the coast > 600km southeast of PWS (Sea Duck Joint Venture, www.seaduckjv.org/ststoc.html). However, sample sizes are relatively small in these studies and surf scoters occur along the Gulf Coast of Alaska during the winter in locations other than PWS, particularly southeast Alaska (Conant and Groves 2001). We do not know the chronology of movements or routes taken during the spring by birds from these locations.

There appears to be a relatively high return rate by surf scoters carrying satellite and VHF radios to wintering areas on the Pacific (Susan Wainwright-De La Cruz, USGS-BRD, Dave Nysewander, Dan Esler pers. comm.) and Atlantic coasts (Perry et al. 2004). With few exceptions, marked scoters returned to the general vicinity of their initial capture suggesting strong fidelity to wintering locations. That most birds in these studies returned by mid-December (Dave Nysewander, pers. comm.) indicates that even though our transmitters did not operate throughout the entire winter period the wintering areas we identified (n = 7; Table 2) were most likely the final winter destinations for scoters prior to spring migration. Therefore 4/7 birds in our study were probably winter residents of PWS, and 3 migrated to PWS from other areas (Straits of Georgia, BC., Shelikof Straight and Sitka Sound, AK) during the spring, perhaps in response to herring spawn, or to use PWS as a gateway to interior regions.

Summer Destinations

Breeding Areas: We broadly defined 2 geographic regions (interior Alaska, northwest Canada) as potential breeding areas used by surf scoters during the summer. Although we have no empirical evidence that transmitted birds actually attempted to breed, our satellite locations are within known breeding areas and the timing of arrival coincides with dates reported in the literature (Bellrose 1976, Johnson and Herter 1989, Savard et al. 1998). We know that it is possible for female scoters to lay eggs their first nesting season after receiving a satellite transmitter (USGS-BRD, http://www.werc.usgs.gov/scoter/2005/nest.html). However, we do not know the behavioral or physical effects surgically implanted transmitters had on the potential breeding birds in our study.

The closest breeding location to the PWS capture site was approximately 200km to the north near Lake Louise, AK (Fig. 3), and the furthest was in northern Northwest Territories, Canada, approximately 1,300km from the capture site (Fig. 4). The broad distribution of our birds during the summer indicates that the potential breeding range for surf scoters encompasses a large geographic area but is within the boreal forest ecoregion.

Wintering surf scoters from other study areas along the Pacific coast nested sympatrically with PWS birds in northwestern Canada, but were not as likely to nest in Alaska (Sea Duck Joint Venture, www.seaduckjv.org/ststoc.html). However, a female from both the Strait of Georgia, BC. and San Francisco Bay wintering populations spent the breeding season near Arctic Village, AK (Susan Wainwright-De La Cruz, Erika Lok, pers. comm.), approximately 45km southwest of a breeding area used by one of our birds (12753; Fig. 3). Based on where 12753 spent the winter following capture, it was more likely a spring migrant from British Columbia than a winter resident of PWS.

One female (12772) combined a coastal and interior route to travel to the Northwest Territories (Fig. 4). Given the circuitous route and limited data it is difficult to predict whether this bird was a potential breeder but given the chronology of movements we find it unlikely. Nevertheless, it is interesting that such an atypical route should be taken and indicates that we have more to learn about surf scoter migration strategies.

Molting Areas: Molting locations used by surf scoters in our study were all on the coast and, at least for males, quite distant from wintering locations. The Kuskokwim shoals was used by 4 male surf scoters during the flightless period (Fig. 2). Because these birds did not travel inland during the spring, but remained for the most part on the coast, we suspect they were non-breeding birds. The Kuskokwim shoals was designated a critical habitat area for staging and molting Steller's eiders. That it is used during the spring by many other sea ducks as well signifies the importance of this area to waterfowl (Larned 2005).

We identified 3 additional molting areas used by surf scoters (PWS, Norton Sound, Kotzebue Sound). We can only be certain that 1 (27598) of 2 females returning to PWS in late July remained there during the molt. We suspect that 12753 molted in PWS, but because we did not receive data between its last location in PWS (28 July) and when it was detected along the southern coast of BC. (5 Dec), we can only speculate on where it spent the flightless period (Fig. 3). That both females returned to PWS in late July indicates that they did not rear a brood to fledging. Stephensen et al. (2001) estimated up to 6,000 surf scoters utilizing PWS in July.

After leaving interior breeding locations, 2 males traveled to northwestern Alaska and molted in either Kotzebue Sound (23888) or Norton Sound (23893; Fig. 5). The molt migration of 23888 along the Beaufort Sea coast followed a pattern described by Johnson and Richardson (1982). That at least one male carrying a satellite transmitter from both Puget Sound and the Strait of Georgia followed a similar route (Sea Duck Joint Venture, www.seaduckjv.org/ststoc.html) indicates that a proportion of the Pacific Northwest wintering population also uses northwestern Alaska during the molt.

Affiliations Among Nesting, Molting, and Wintering Areas

Although many surf scoter nesting, molting, and wintering areas have been identified prior to this study, the affiliations between these areas were unknown. Using satellite telemetry we were able to link wintering sites, with breeding and molting locations for some birds. Surf scoters wintering in Alaska and along the Pacific coast, however, disperse over a broad geographic area during the breeding and molting periods, and overlap in habitat occurs during these summer months. Because an unknown proportion of surf scoters from the Pacific Northwest nest and molt sympatrically with PWS birds, and most likely birds from other locations in Alaska, we cannot determine winter origins based on where they nest or molt. Similarly, we cannot predict where a surf scoter might nest or molt based on its winter origin. Consequently, delineating population units for management purposes may be difficult. Satellite technology, however, has enabled us to predict with greater certainty where an individual bird will spend the summer regardless of wintering location. Satellite telemetry has narrowed the geographic range of potential breeding and molting areas for the wintering aggregations under study. We can now more precisely delineate frequently used nesting and molting locations in albeit a spacious geographic area.

CONCLUSIONS

In spite of the small sample size, our pioneering work has produced unique and revealing information on surf scoter movements unattainable with conventional marking and telemetry methods. We have since been consulted by several federal and state agencies regarding our work, and our floating mist net design is being used in many sea duck trapping efforts. The chronology of surf scoter movements is becoming more apparent and important seasonal habitats are being delineated with more precision due to results of this and similar satellite telemetry studies. Ground based studies designed to quantify vital rates for the breeding component of the population can be more effective because they can be initiated with certainty in areas of high bird use. The timing of aerial surveys designed specifically to monitor sea duck abundance can be adjusted based on the chronology of movements of birds carrying satellite transmitters

Satellite telemetry is the only effective way to monitor movements of birds over vast and remote areas, when rapid movement between distant regions is typical. We have identified migration patterns and located several areas used by surf scoters that had not been previously described. Granted, our data, at best, explains the movements of surf scoters during one annual cycle. Data from longer-lived satellite transmitters, deployed in recent years, indicates a propensity for winter site fidelity and hints towards the possibility of fidelity to summer locations as well (Susan Wainwright-De La Cruz, pers. comm.). Consequently, we might not expect annual variability in site selection by individual birds. That one of our males (2246; Fig. 2 and Fig. 5) chose different routes in successive years after leaving PWS suggests that breeding scenario (breeding vs. non-breeding) influences direction of travel and subsequent habitat use and site selection.

We regret the death of our study birds. We do not know why >50% of our surf scoters implanted with satellite transmitters died soon after release even though they were in good physical condition (Dr. D. M. Mulcahy pers. comm.). Post-release mortality observed during this study was greater than other sea duck satellite implant studies using similar surgical procedures: spectacled eiders (Petersen et al. 1995); king eiders (Dickson et al. 1998); white-winged scoters (authors unpublished data); Barrow's goldeneyes (Robert et al. 2000); and harlequin ducks (Mulcahy and Esler 1999). Differences in time of year, temperature, predator density, and species-specific behavior may have been responsible for differences in survival rates between these and our study. Even after a Herculean effort and substantial expense we could not reduce post-release mortality by holding surf scoters in captivity. Some captive birds failed to maintain waterproofing. Feather loss at the incision site, irritation at the incision or antenna exit site, seepage from incisions, and infections may have all been contributing mortality factors. Post-surgical complications develop, but with abundant predators birds have less opportunity to recover. Nonetheless, we believe that the experience gained during our first attempt at maintaining captive birds would facilitate our success in the future.

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Table. 1. Release date, days active, fate, and satellite transmitter performance indicators for surf scoters captured in Prince William Sound, AK during April-May (1998-2000).

							Percent locations by class codes[g]			
PTT[a]	Sex	Date released[b]	Days active[c]	Fate[d]	No. Obs./Exp. duty cycles[e]	No. of locations[f]	1-2-3	A-B	0	Z
2244	male	30 April 98	317	off-air	68/81	213	23.0	44.6	30.1	2.3
2246	male	3 May 98	440	off-air	46/104	134	37.3	41.8	16.4	4.5
10928	female	2 May 98	54	died	19/19	81	46.9	40.7	12.4	0.0
10929	male	30 April 98	266	off-air	57/72	173	31.2	53.8	15.0	0.0
12753	female	28 April 99	242	off-air	27/77	129	46.5	32.6	20.2	0.7
12754	female	1 May 99	66	off-air	23/29	44	20.5	72.7	6.8	0.0
12772	female	28 April 99	79	failed	29/34	109	24.8	54.1	19.3	1.8
12943	female	29 April 99	67	failed	23/30	62	32.3	53.2	12.9	1.6
23888	male	29 April 99	103	failed	39/39	343	50.7	31.5	17.2	0.6
23893	male	29 April 99	258	off-air	84/84	810	64.4	19.1	16.3	0.2
14019	male	27 April 99	119	failed	43/45	252	46.4	32.9	19.5	1.2
12991	female	2 May 00	28	died	10/10	71	35.2	30.9	29.6	4.2
27598	female	2 May 00	276	off-air	73/100	282	24.5	53.9	20.5	1.1
29996	female	2 May 00	80	died	29/29	112	25.9	48.2	23.2	2.7

[a] Satellite transmitter (platform transmitter terminal) identification number.

[b] Scoters in 2000 were captured in mid-April and held in captivity until release date.

[c] Number of days between release date and the date of last location while the bird was alive.

[d] Temperature sensor readings indicated a dead bird. Transmitters that went off-the-air did so because they either failed prematurely, the bird died and we could not detect it, or they reached their life expectancy. Failed transmitters provided no location data.

[e] Number of duty cycles receiving at least one location/number of duty cycles expected during the active period.

[f] All locations received during the active period. Duty cycles varied among years.

[g] Accuracy for class codes 1, 2, and 3 locations is <1000m, class code 0 >1000m, no estimate of accuracy for class codes A, B, and Z.

able. 2. Likely breeding, molting and wintering locations determined with satellite telemetry for surf scoters captured during April-May in Prince William Sound, AK. (1998-2000).

PTT[a]	Sex	Capture location	Breeding Area	Molting Area	Wintering Area
2244	male	Montague Island	none	Kuskokwim shoals, AK	Shelikof Strait, AK
2246	male	Montague Island	none	Kuskokwim shoals, AK*	Prince William Sound, AK
10928	female	Montague Island	near Bekere Lake, NWT (68.821N x 126.363W)	unknown	unknown
10929	male	Montague Island	none	Kuskokwim shoals, AK	Sitka Sound, Baranof Is., AK
12753	female	St Mathew's Bay	near Arctic Village, AK (67.726N x 146.297W)	Prince William Sound, AK*	Straits of Georgia, BC.
12754	female	St Mathew's Bay	near Burnt Lake, AK (63.390N x 152.457W)	unknown	unknown
12772	female	St Mathew's Bay	unknown	unknown	unknown
12943	female	St Mathew's Bay	near Lake Minchumina, AK	unknown	unknown
23888	male	St Mathew's Bay	near Bracket Lake, NWT (63.980N x 124.489W)	Kotzebue Sound, AK	Prince William Sound, AK
23893	male	St Mathew's Bay	north of Old Crow, YT (68.277N x 140.588W)	Norton Sound, AK	Prince William Sound, AK
14019	male	St Mathew's Bay	none	Kuskokwim shoals, AK	unknown
12991	female	Orca Inlet	unknown	unknown	unknown
27598	female	Orca Inlet	near Lake Louise, AK (62.247N x 146.164W)	Prince William Sound, AK	Prince William Sound, AK
29996	female	Orca Inlet	near Inuvik, NWT (67.965N x 135.162W)	unknown	unknown

[a] Satellite transmitter (platform transmitter terminal) identification number.

* Location can not be confirmed with certainty.

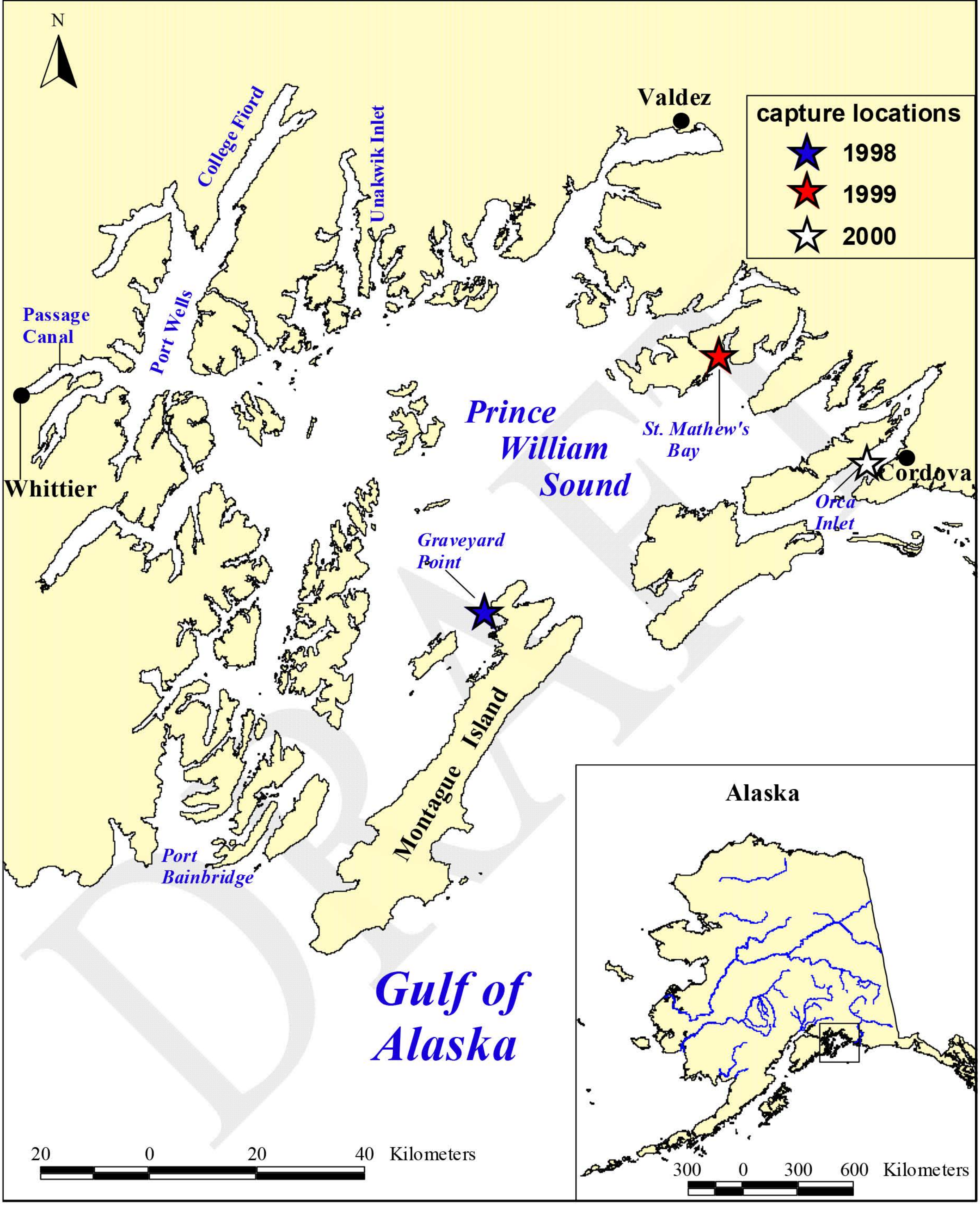

Fig. 1. Map of Prince William Sound, AK and locations of surf scoter trapping efforts during April-May (1998-2000).

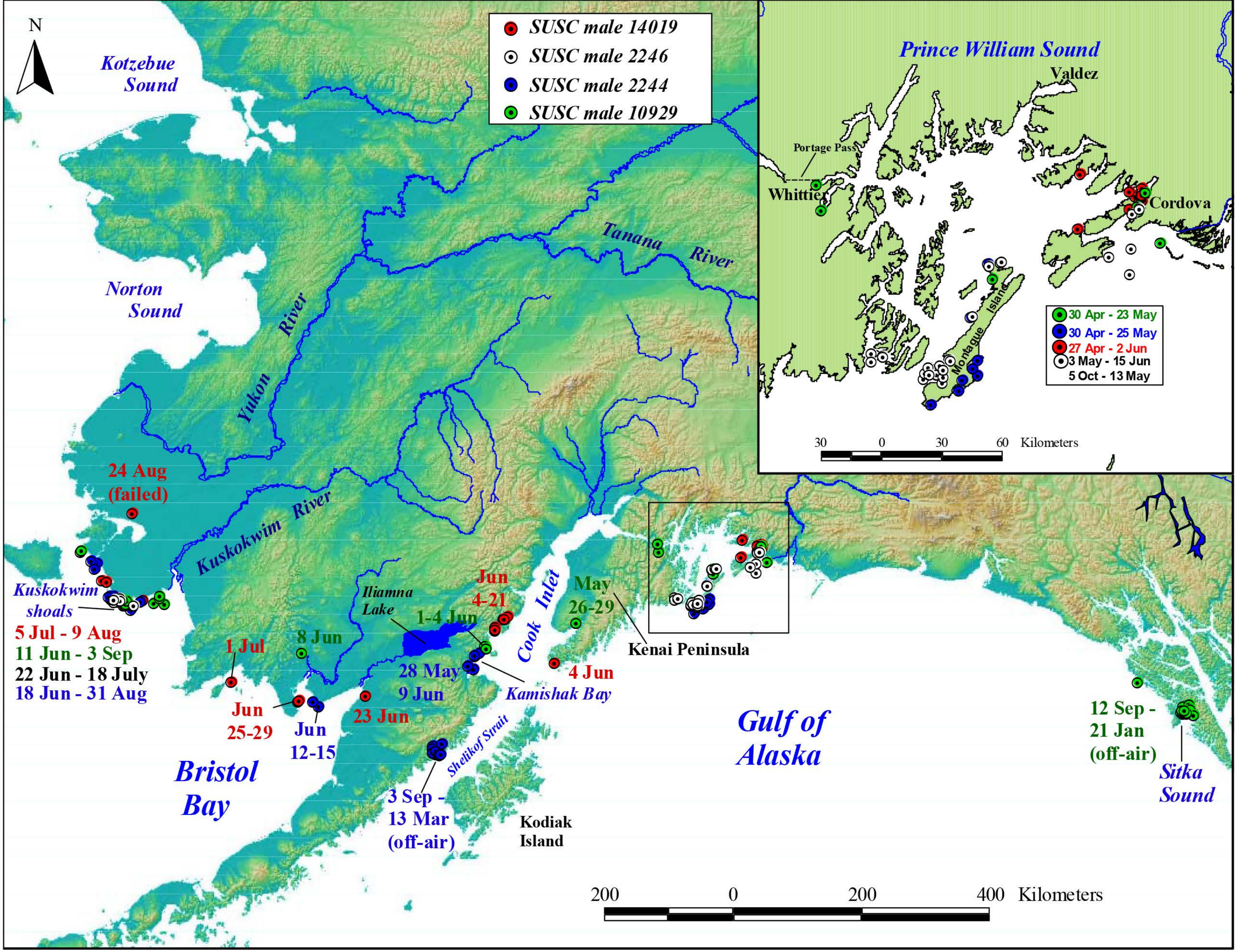

Fig. 2. Movement of male surf scoters from Prince William Sound, AK to molting and wintering locations.

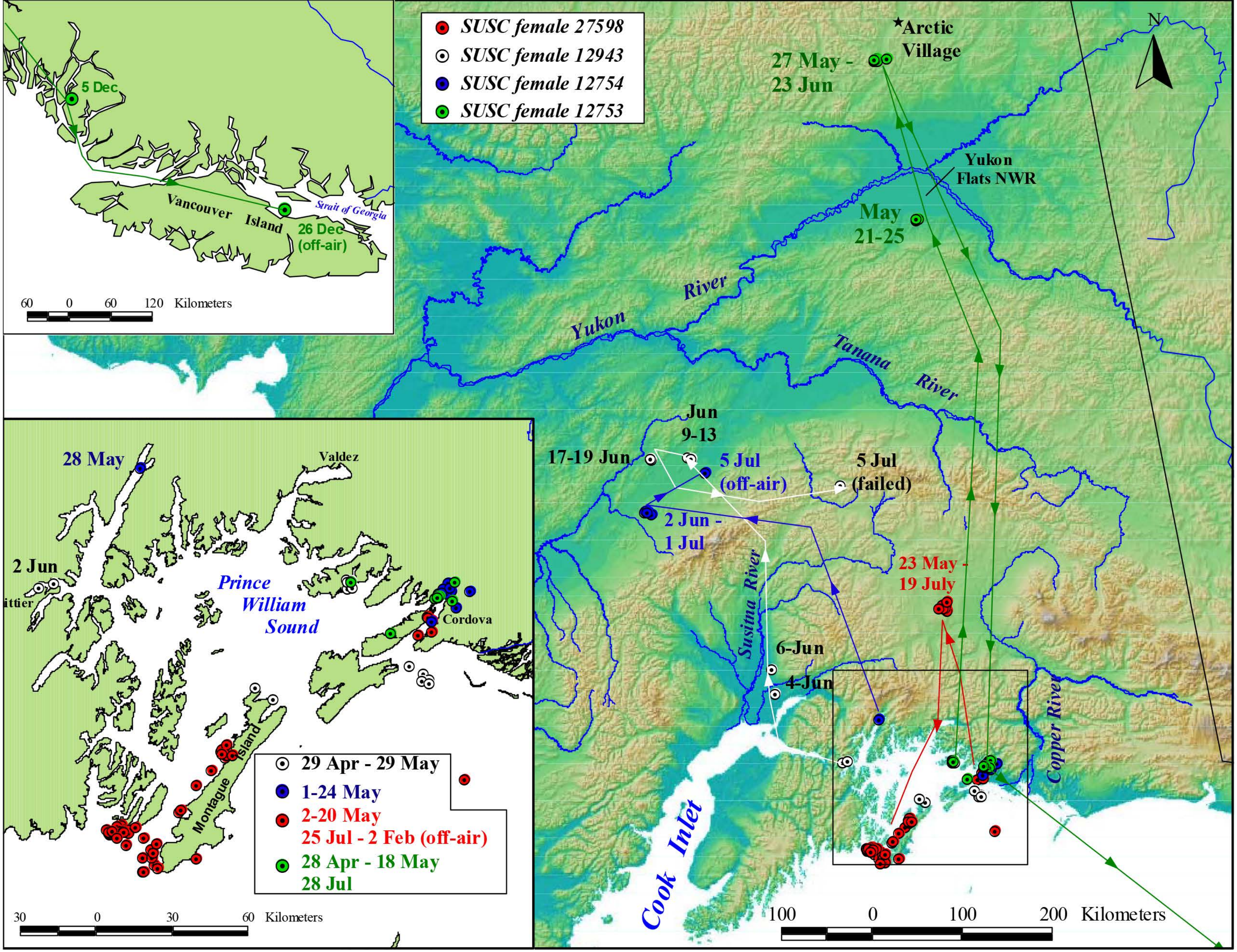

Fig. 3. Movements of female surf scoters from Prince William Sound, AK to breeding, molting and wintering locations. Lines depict general direction of travel.

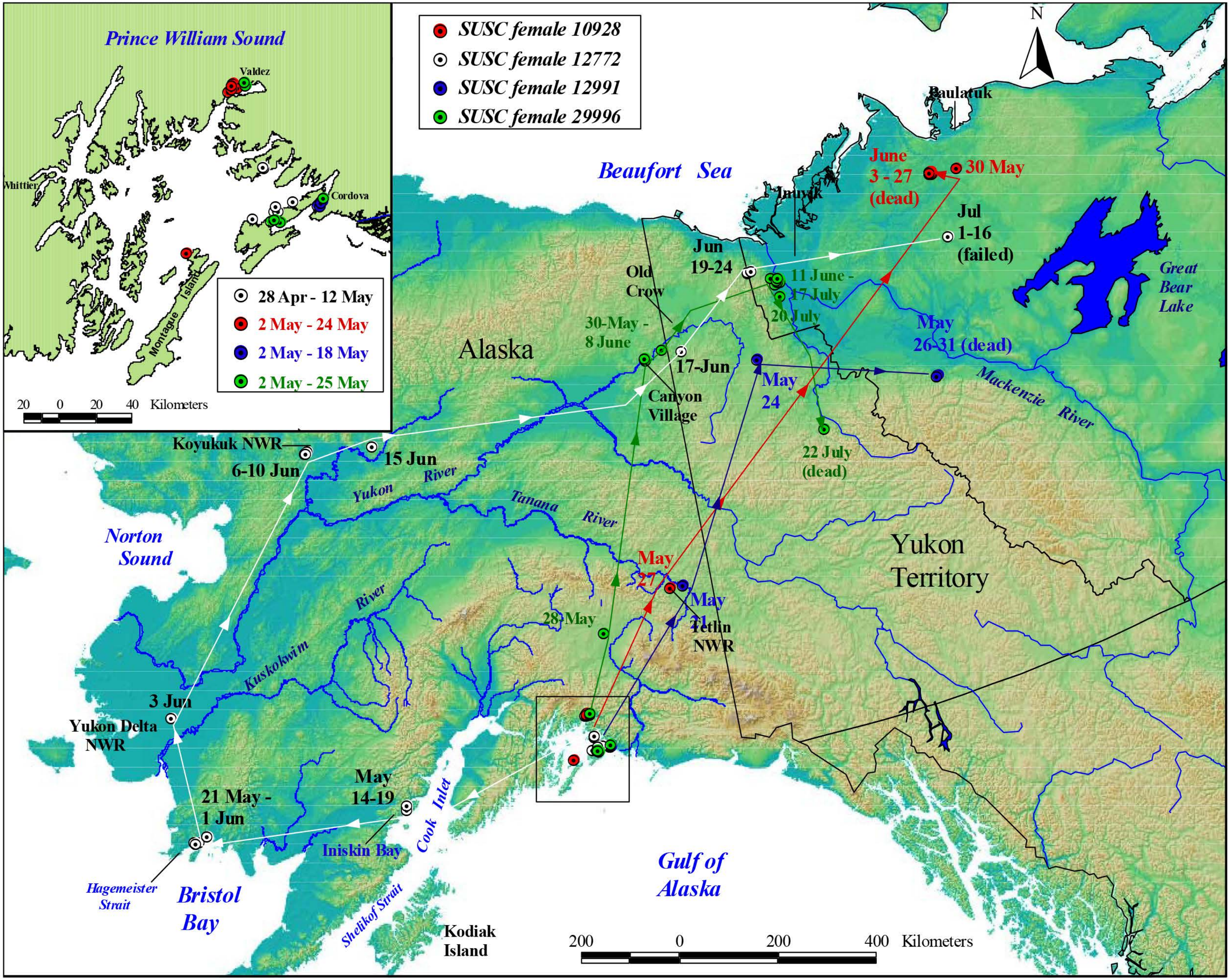

Fig. 4. Movements of female surf scoters from Prince William Sound, AK to breeding areas in northern Canada. Lines depict general direction of travel.

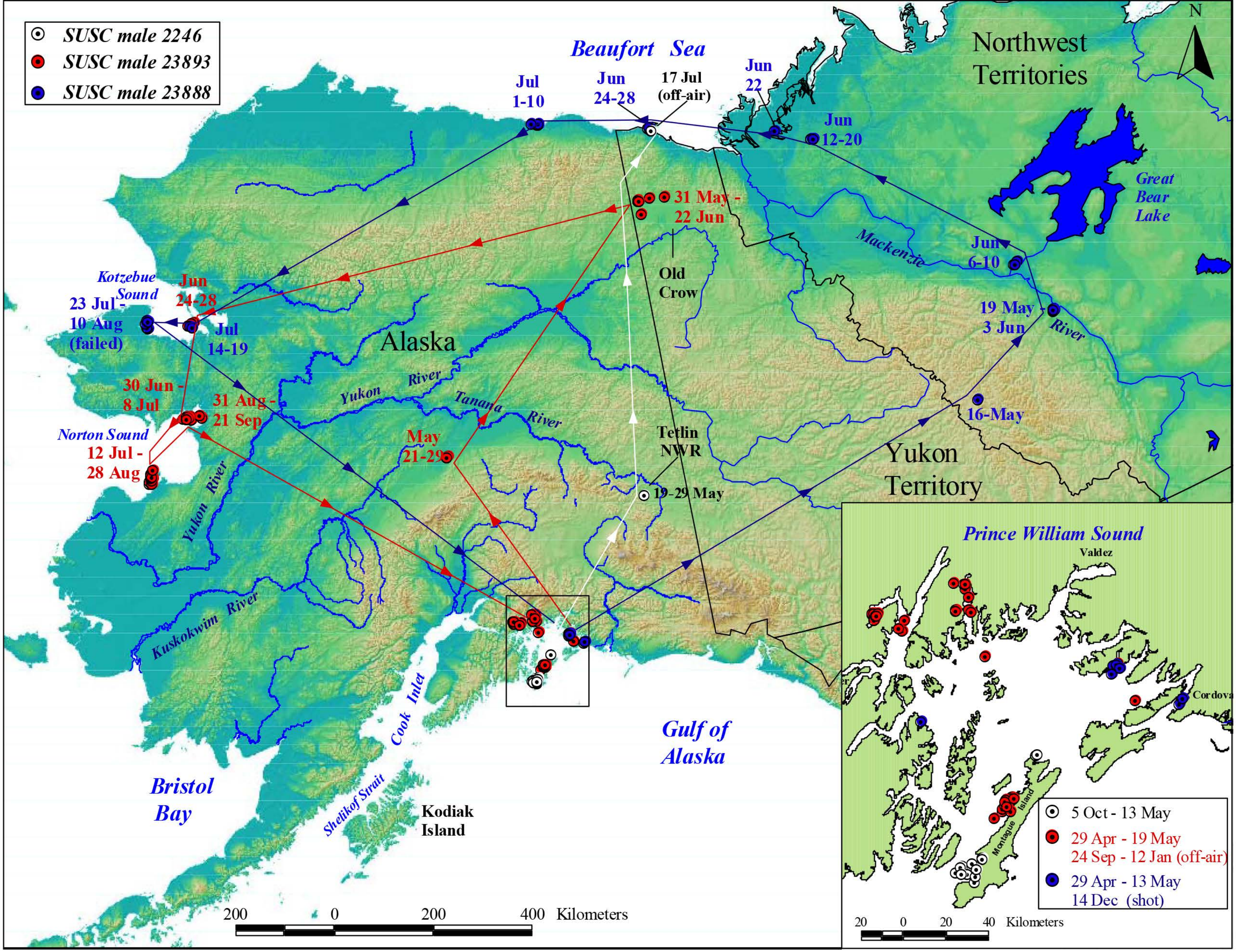

Fig 5. Movements of male surf scoters from Prince William Sound, AK to breeding, molting and wintering locations. Lines depict general direction of travel.

Exxon Valdez Oil Spill
Restoration Project Final Report

Seasonal Movements of White-Winged Scoters (*Melanitta fusca*) from Prince William Sound, Alaska

Restoration Project 00273
Final Report Volume II

This final report has been prepared for peer review as part of *Exxon Valdez* Oil Spill Trustee Council restoration program. Peer review comments from previous annual reports have been addressed in this final report.

****NOTE regarding this final report:***

This report is being released by EVOSTC. It has been peer reviewed and the format has been standardized for cataloging by ARLIS. However, the authors may not have reviewed this draft and some of the pages may have a "DRAFT" watermark.

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March 2019

Exxon Valdez Oil Spill
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March 2019

Seasonal Movements of White-Winged Scoters (*Melanitta fusca*) from Prince William Sound, Alaska

Restoration Project 00273
Final Report Volume II

Study History: Restoration Project 00273 continues studies initiated in 1998 (Rosenberg and Petrula 1999) and continued in 1999 (Rosenberg and Petrula 2000). The goal of this study is to monitor movements of white-winged scoters using satellite telemetry to increase our understanding of scoter ecology. White-winged scoters, a sea duck, are an important subsistence resource to the indigenous people of Prince William Sound. Scoter numbers, however, have reportedly declined for unknown reasons. Additional scoters were killed during the *Exxon Valdez* oil spill. The decline is a concern to both waterfowl managers and subsistence consumers. This report describes results of these studies.

Abstract: We used satellite telemetry to track the movements of white-winged scoters (*Melanitta fusca*) wintering in the Gulf of Alaska to determine timing and routes of migration and affiliations among wintering, breeding, and molting areas. This was the first successful satellite telemetry project to monitor the movements of white-winged scoters. We captured birds in Prince William Sound in April and May of 1999 and 2000. We monitored movements of 13 females and 9 males. Spring departure dates varied by year and breeding status. Five males and 11 females migrated to breeding areas in the 1) Yukon Flats National Wildlife Refuge, Alaska (n = 1 male); 2) Old Crow Flats, Yukon Territory (n = 2 females) and 3) Northwest Territories (n = 9 females, 4 males). We monitored 16 birds to coastal molting areas. Five birds went directly from wintering to molting areas. Molting areas were broadly distributed in the Beaufort Sea, Gulf of Alaska, and Bering Sea and primarily distinct from nesting and wintering areas. Eight of 12 breeding birds molted in the Beaufort Sea. Nine breeding birds (82%) returned to Prince William Sound. We identified an affiliation between wintering areas in the Gulf of Alaska and breeding and molting areas in the Northwest Territories.

Key Words: Alaska, Gulf of Alaska, Prince William Sound, Bering Sea, Northwest Territories, migration, breeding, molting, philopatry, population affiliation, satellite telemetry, scoter, sea duck, white-winged scoter.

Project Data: *Description of data* – Location and sensor data was recorded for each satellite transmitter. *Format* – Location and sensor data are in Microsoft Excel and DBASE IV spread sheet format. GIS coverage of Alaska and Canada showing scoter locations are presented in ArcView format. *Custodian* - Archived at ADF&G regional headquarters in Anchorage. Contact Dan Rosenberg at ADF&G, 525 W.67th Ave., Anchorage, Alaska 99518 (907-267-2453) (dan_rosenberg@fishgame.state.ak.us) or Mike Petrula (907-267-2159) mike_petrula@fishgame.state.ak.us) for information. Project information can be viewed at http://www.wildlife.alaska.gov/index.cfm?adfg=waterfowl.scoter_home.

Citation:
Rosenberg, D. H., M. J. Petrula, and D.D. Hill. 2019. Seasonal movements of white- winged scoters (*Melanitta fusca*) from Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Restoration Project Final Report (Restoration Project 00273 Vol. II), *Exxon Valdez* Oil Spill Trustee Council, Anchorage, Alaska.

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EXECUTIVE SUMMARY

We used satellite telemetry to track the movements of white-winged scoters (*Melanitta fusca*) wintering in Prince William Sound to determine timing and routes of migration and affiliations among wintering, breeding, and molting areas. Satellite transmitters allow researchers to determine large-scale movements of individual animals and link this information with life history data gathered at smaller spatial scales. This was the first successful satellite telemetry project to monitor the movements of white-winged scoters.

The migratory patterns of white-winged scoters are poorly understood. In North America, breeding white-winged scoters are widely dispersed over vast and remote areas throughout the boreal forests of Alaska and western Canada where they prefer to nest near permanent lakes. In western North America, post-breeding males and most females return to the coast to molt over a broad area from the Beaufort Sea to the Gulf of Alaska and west to the Aleutian Islands. The Pacific population winters in marine nearshore waters from eastern Kamchatka to Japan and from the Aleutian Islands, throughout the GOA, and south to Baja California.

Scoter populations in North America have been declining. Collectively breeding populations of all three North American species of scoters (white-winged, surf, black) have steadily declined by as much as 40% in Alaska and about 58% in North America since the late 1970's. Between 1973 and 1990, the estimated population of white-winged scoters wintering in Prince William Sound in the northern Gulf of Alaska declined over 80% from 24,000 to 3,300 birds. About 1,000 scoters (all species) died as a direct result of the *Exxon Valdez* oil spill in 1989. Population estimates for white-winged scoters in PWS are imprecise; apparently increasing since the spill but likely remaining well below historic levels. Scoters are an important food source for indigenous peoples of Prince William Sound and other areas affected by the *Exxon Valdez* oil spill.

Understanding the cause of these declines is hindered by a lack of information on the timing of movements and affiliations between wintering, breeding and molting areas. The underlying mechanisms for population change may occur anywhere in a bird's annual life cycle and we know little about seasonal movements and range affiliations throughout the annual cycle of white-winged scoters. This makes it difficult to effectively monitor population status and trends and develop conservation strategies.

We tested whether white-winged scoters from specific wintering areas are randomly distributed throughout the breeding and molting range or utilize more narrowly defined geographical "units" within the broader species distribution. Our objectives were to 1) identify breeding, molting, and staging areas, 2) identify affiliations among wintering, breeding, and molting areas, and 3) determine timing of movements and migration routes between seasonal use areas.

We captured 120 white-winged scoters in 2 areas of Prince William Sound in April and May of 1999 and 2000. Prince William Sound is characterized by fjord-like ports and bays surrounded by steeply rising mountains. Highly irregular in shape, it is approximately 160 km east to west and 140 km north to south.

We captured birds over open water using decoys and floating mist nets. In 1999, we implanted 13 birds with satellite transmitters (5 males, 8 females) and in 2000 we implanted 18 birds (9 males, 9 females). The transmitter was inserted into the coelomic cavity by an experienced veterinarian using standard aseptic surgical techniques including anesthesia. In 1999 surgery was performed on-site and birds were released within 2–5 hours of surgery. Responding to high rates of post-release mortality in 1999 we temporarily held birds pre– and post-surgery in outdoor pools at the Alaska SeaLife Center in Seward, AK in 2000. All birds were released at the capture sites.

We used Service Argos Inc., compatible PTT-100 implant transmitters. Transmitters were equipped with temperature and battery voltage sensors. The amount of data we received was limited by transmitter battery life. To conserve limited battery life transmitters were programmed for various on/off (duty) cycles based on predicted periods of seasonal movements. Signals were analyzed using Argos Data Collection and Location Systems processing. Locations were mapped using ArcView® GIS software. Individual transmitter performance (number of transmissions, location quality, and longevity) varied significantly, providing location data from 35 to 308 days (mean = 203, SD = 73).

We monitored movements of 13 females and 9 males. Departure dates varied by year and breeding status. Spring migrants departed Prince William Sound between 27 May and 3 June in 1999 (median = 31 May). In 2000 breeding birds departed between 18 –27 May (median = 24 May) and nonbreeders between 14 June and 8 July. Birds used three widely separated breeding areas within the boreal forests of western Canada and Alaska. Five males and 11 females migrated to breeding areas in the 1) Yukon Flats National Wildlife Refuge, Alaska (n = 1 male); 2) Old Crow Flats, Yukon Territory (n = 2 females) and 3) Mackenzie, Anderson, and Horton River basins, Northwest Territories (n = 9 females, 4 males). Birds arrived on the breeding grounds between 25 May and 13 June. Birds arrived earlier in 2000 than in 1999. The core breeding area in the Northwest Territories encompassed approximately 45,000 km^2 in the open boreal forest. Females remained at breeding areas longer than males and longer stays may indicate that some possibly nested successfully. Nonbreeding birds took a coastal route, traveling directly to coastal molting areas in the Bering Sea or the northern Gulf of Alaska

We monitored 16 birds to coastal molting locations. Molting areas were primarily distinct and distant from nesting and wintering areas and distributed over a broad geographical area from the Beaufort Sea to the Gulf of Alaska and Bering Sea. Molting, like breeding, occurred in relatively few areas compared to the molting range of white-winged scoters in North America. Some females molted in breeding areas while others migrated almost 2,000km to discreet molting sites. The majority of breeding birds molted in the Beaufort Sea while a minority used the southern Bering Sea and northern Gulf of Alaska. Nonbreeding birds used only the southern Bering Sea and northern Gulf of Alaska.

We monitored the movements of 15 birds to wintering areas. Ten birds returned to Prince William Sound and one wintered nearby in Icy Bay in the Northern Gulf of Alaska. Icy Bay was the farthest east any bird wintered. At minimum three birds wintered on the Alaska Peninsula. A female wintered the farthest west, by Cape Sagak, Umnak Island, in the Aleutian Islands, about

1800km west of Prince William Sound. All but two birds migrated southwest from molting (or breeding) areas to wintering areas.

We documented strong evidence for winter site fidelity in breeding males and females. Of 11 breeding birds that we were able to monitor into the following winter, nine (82%) returned to PWS. All breeding males and 75% of breeding females returned. All birds (n = 8) that molted in the Northwest Territories returned to Prince William Sound. Nonbreeding birds had lower return rates and may represent dispersal. This is the first-time winter site fidelity has been documented for white-winged scoters.

The majority of the core nesting area we identified in the Northwest Territories is surveyed annually as part of the Continental Waterfowl Breeding Population Habitat Survey conducted each May since 1955. Most scoter population estimates are derived from this survey. Prince William Sound birds used only three of these strata and primarily the eastern third of stratum 14 in the Northwest Territories. Numbers of scoters in stratum 14 have been declining since the late 1970's.

We identified affiliations of white-winged scoters from wintering areas with breeding and molting areas in Alaska and western Canada. Most significantly we identified an affiliation between Prince William Sound and a breeding area in the Mackenzie, Anderson, and Horton River basins in the Northwest Territories and a molting site in Liverpool Bay in the Beaufort Sea. This is the first time precise migratory connectivity and habitat affiliations have been documented for white-winged scoters. Breeding and molting areas were nearly distinct from those used by birds wintering farther south along the coasts of British Columbia and Washington State. More evidence is needed before we can solidify the spatial and temporal scale of this affiliation, but this type of association will help researchers and managers investigate, assess, or identify future resource related concerns. We also identified a link between molting birds near Cape Yakataga and Cape Suckling, the site of an historic scoter die-off, with staging and perhaps wintering areas in Prince William Sound.

This information will provide a basis for future population delineation and improved monitoring efforts and allow managers to associate changing habitat and environmental conditions, harvest levels, and development proposals with distinct population segments. We present this as a small step toward identifying the mechanisms of population change. We also hope it will be useful to regional planners. Much additional effort among many disciplines is required before we can draw conclusions about population structuring at both smaller and larger spatial scales. However, we emphasize the importance of further defining and refining seasonal affiliations so we can comprehensively assess mortality factors throughout the annual cycle.

INTRODUCTION

We used satellite telemetry to track the movements of white-winged scoters (*Melanitta fusca*) wintering in the Gulf of Alaska (GOA) to determine timing and routes of migration and affiliations among wintering, breeding, and molting areas. Satellite transmitters allow researchers to determine large-scale movements of individual animals and link this information with life history data gathered at smaller spatial scales (Huntington et al 2004).

Three species of scoters breed and winter in North America: The Black Scoter (*Melanitta nigra*), Surf Scoter (*M. perspicillata*), and White-winged Scoter (*M. fusca*). Collectively, scoters are among the least studied of North American waterfowl (Godfrey 1986, Savard and Lamothe 1991, Henny et al. 1995) and relatively little is known about their life history, ecology, and seasonal distributions (Bellrose 1976, Herter et al. 1989, Goudie et al. 1994).

In North America, breeding white-winged scoters are widely dispersed over vast and remote areas throughout the boreal forests of Alaska and western Canada (Gabrielson and Lincoln 1959, Godfrey 1986) where they prefer to nest near permanent lakes (Brown and Brown 1981). Highest densities are in the Northwest Territories (NWT) of Canada and northeast Alaska (Palmer 1976, Bellrose 1980). As with other sea ducks, male scoters abandon incubating females in early summer and congregate at communal molting sites, which are often distinct from wintering areas (Salomonsen 1968). In western North America, post-breeding males and most females return to the coast to molt over a broad area from the Beaufort Sea to the GOA and west to the Aleutian Islands (Palmer 1976, Bellrose 1980, Johnson and Richardson 1982, Herter et al 1989, Alexander et al. 1988, Henny et al. 1995).

The migratory patterns of white-winged scoters are poorly understood (Alberta Sustainable Resource Development, 2002). Breeding birds from Saskatchewan migrate to both the Atlantic and Pacific coasts to winter (Houston and Brown 1983), but no clear demarcation exists on the breeding grounds between Atlantic and Pacific populations. Band recoveries suggest that birds breeding farther north and east are more likely to migrate to the Atlantic coast and conversely, those breeding farther south and west are more likely to migrate to the Pacific coast (Bellrose 1976). The Pacific population winters in marine nearshore waters from eastern Kamchatka to Japan (Kistchinski 1973) and from the Aleutian Islands, throughout the GOA, and south to Baja California (Palmer 1976).

While the general distribution of scoters has been documented, population estimates are hindered by the lack of differentiation among the three species during Continental surveys (Smith 1995). Collectively breeding populations of all three species have steadily declined by as much as 40% in Alaska and about 58% in North America since the late 1970’s (Hodges et al. 1996, Canadian Wildlife Service 2000, S. Slattery, Ducks Unlimited Canada, pers. comm.).

Between 1973 and 1990, the estimated population of white-winged scoters wintering in Prince William Sound (PWS), in the northern GOA, declined over 80% from 24,000 to 3,300 birds (Klosiewski and Laing 1994). About 1,000 scoters (all species) died as a direct result of the *Exxon Valdez* oil spill in 1989 (John Piatt, pers. comm.). Population estimates for white-winged scoters in PWS are imprecise; apparently increasing since the spill but likely remaining below historic levels (Lance et al. 2001, Stephensen et al. 2001).

Understanding the cause of these declines and delineating the population segment(s) most affected is hindered by a lack of information on the timing of movements and affiliations between wintering, breeding and molting areas (Sea Duck Joint Venture Management Board 2001). The underlying mechanisms for population change (e.g. contaminants, habitat loss, harvest, food abundance, increased predation, climate change) are difficult to identify because they may occur anywhere in a bird's annual life cycle. In a migratory species, especially one with a broad range, identifying mechanisms of population change is confounded by a lack of specific information on affiliations between breeding, molting, and wintering areas (Henny et al. 1991, Webster et al. 2002), making it difficult to interpret surveys or the results of local research projects. Resource managers must define and focus efforts on specific geographic or biological "management units' (e.g. "subpopulations", "population segments") in order to identify constraints to population growth or viability (Moritz 1994). This requires knowledge of a species spatial and temporal distribution (migratory patterns) throughout annual cycles (Esler 2000).

Scoters are an important food source for indigenous peoples of North America, both currently and historically. Scoters comprise a significant portion of the waterfowl subsistence harvest in coastal and interior Alaska, including PWS (Birket-Smith 1953, Stratton 1981, Stratton and Chisum 1986, Scott et al. 1996, Wolfe et al. 1990.) and the Northwest Territories of Canada (Gwich'in Elders 1997). Bones from scoters are the most abundant avifaunal remains found at archeological sites in PWS over a 2,250-year period (Linda Yarborough, USFS, pers. comm.). In spite of their importance to the culture and subsistence lifestyles of the communities affected by the *Exxon Valdez* oil spill (Rosenberg and Petrula 1999, Huntington et al. 2004), we know little about seasonal movements and range affiliations throughout the annual cycle. This makes it difficult to understand and effectively regulate multi-season harvests across many jurisdictions.

Identifying migratory connectivity (Webster 2002) for white-winged scoters is necessary to interpret (or design) population surveys and a first step to detect causes of population change (Henny et al. 1991). A white-winged scoter die-off occurred during the molt near Cape Yakataga and Cape Suckling in the eastern GOA during 1990-1992 (Henny et al. 1995) but no definitive cause was identified. The lack of specific information on locations and movements of birds prior to their death increased the difficulty of identifying the cause of mortality (Henny et al. 1995) and the relationship to long-term population declines.

Scoters are difficult to band in large numbers and they have relatively low rates of harvest, making traditional banding studies impractical. There have been only 142 recoveries of 4,006 white–winged scoters banded in North America from 1923 to 2001

(Alisauskas et al. 2004). Most recoveries were at the banding location (Powell 2000) although bands from breeding areas in western Canada were recovered in the Atlantic, Pacific, and Mississippi flyways (Bellrose 1980, Houston and Brown 1983). Similarly, the wide range, remote locations, and at-sea habits of scoters make color marking and VHF telemetry impractical. Satellite telemetry offers the best approach to obtain information about seasonal distribution, migration routes, and timing of movements for birds that migrate over vast and remote regions.

We tested whether white-winged scoters from specific wintering areas are randomly distributed throughout the breeding and molting range or utilize more narrowly defined geographical “units” within the broader species distribution. Our objectives were to 1) identify breeding, molting, and staging areas, 2) identify affiliations among wintering, breeding, and molting areas, and 3) determine timing of movements and migration routes between seasonal use areas. In concert with other studies we hope this information will help develop a better understanding of population delineation and improve the design and interpretation of population surveys.

STUDY AREA AND METHODS

Study Area

Prince William Sound, Alaska (PWS) (ca. 60.5^{o}’N, 147.0^{o}W), a large estuarine embayment of the northern GOA is characterized by fjord-like ports and bays surrounded by steeply rising mountains. (Fig. 1). Highly irregular in shape, it is approximately 160 km east to west and 140 km north to south. Tides can exceed 4.5m and water depth can reach 870m. Isleib and Kessel (1973) described the general physiography, climate, oceanography, and avian habitats of PWS. An estimated 3,000 –24,000 white-winged scoters wintered in PWS since the spill (Stephensen et al. 2001).

We captured white-winged scoters in St. Matthew’s Bay (60.7^{o}N, 146.4^{o}W) from 26 April to 5 May 1999 and in Orca Inlet (60.5^{o}N, 145.9^{o}W) from 11– 15 April 2000 (Fig. 1). Capture sites were about 37km northwest and 4km west of Cordova, Alaska respectively. Birds captured in St. Matthews Bay were attracted there by herring roe (spawn), which provided an abundant and easily accessible food source. Herring spawn was not present in Orca Inlet.

Equipment and Field Procedures

Birds were captured over open water using decoys and floating mist nets (Kaiser et al. 1995). Upon removal from nets birds were placed in small pet carriers with raised mesh liners and transported by skiff to a vessel anchored nearby. In 1999 we surgery was performed on the vessel. In 2000, birds were transported by float plane to the Alaska SeaLife Center (ASLC) in Seward, AK for surgery and observation. Responding to high rates of post-release mortality in 1999 (see Results); we held birds at the ASLC the following year. Birds were held for 5–9 days pre– and 12–21 days post-surgery.

In 1999 we implanted 13 birds (5 males, 8 females) and in 2000 we implanted 18 birds (9 males, 9 females). Surgical procedures were performed by an experienced veterinarian and followed protocols developed by Korschgen et al. (1996) with some modifications (Mulcahy and Esler 1999, Robert et al. 2000). At minimum, one veterinarian and one trained anesthetist performed the operation. Standard aseptic surgical techniques were practiced. Anesthesia was induced and maintained with isoflurane gas (Aerrane, Ohmeda) delivered in oxygen. Presurgical preparation included plucking feathers along the ventral midline (about 3.0 cm long by 2cm wide) between the distal end of the keel and the pubic bone to expose the incision site in the coelomic cavity (a practice that has since been discontinued). Another 1-cm^2 patch of feathers was plucked at a dorsal position nearest the intersection of the pubis and synsacrum and an incision was made for the antenna exit. The abdominal air sac was breached and the antenna was passed through a trochar inserted dorsally. The transmitter was inserted into the right abdominal air sac and all incisions closed with absorbable sutures. The transmitter was attached to the duck at a single point by a suture through the skin, body wall, and Dacron collar at the base of the antenna.

The large number of white-winged scoters we captured in PWS in 1999 and 2000 (n = 120) enabled us to generally select birds for satellite telemetry that were heavier, in definitive plumage (Palmer 1976) and, in most cases, appeared to be paired. We presumed that birds possessing these characteristics would be in superior condition and more likely to travel to breeding areas than lone individuals. Only birds aged as After Second Year (Gustafson et al. 1997) based on plumage characteristics (Palmer 1976) were selected for implants. In 2000, we measured bursal depth to further differentiate age-classes (Mather and Esler 1999). We divided birds into three age classes based on calendar year (Gustafson et al. 1997) following protocols of Mather and Esler (1999). If the bursa was absent or ≤ 3mm we classified the bird as after-third-year (ATY). Birds with bursa depths from 4–10mm were classified as third-year (TY), and if bursa depth was >10mm we classified the bird as second-year (SY) regardless of plumage.

Mean (± SD) body mass of female and male white-winged scoters implanted with transmitters was 1487.9 ± 107.0g (n = 17) and 1671.8 ± 85.7g (n = 14) respectively. Mean (± SD) body mass of all females and males captured was 1464.0 ± 118.1g (n = 48) and 1648.3 ± 114.9g (n = 71) respectively. Transmitter to body weight ratio ranged from 2.2 percent of body weight for the largest bird, an 1800g male, to 3.6 percent for a 1400g female.

Following surgery birds were returned to pet carriers and allowed to recover from anesthesia for 2–5 hours before release to the water within 0.5km of their capture site (1999) or returned to protected outdoor pools at the ASLC (2000). Once the latter birds remained dry at the ventral incision site; had normal hematocrits, total plasma solids, and leukocytes (buffy coat); gained mass, and exhibited no signs of trauma or lethargy, they were released at their capture sites.

We used Service Argos Inc., compatible PTT-100 implant transmitters (Microwave Telemetry Inc., Columbia MD). Transmitter design changed over the course of the study due to changes in battery model and configuration. This resulted in transmitter weights varying from 50–51g in 1999 to 39–41g in 2000. Transmitter dimensions were 58mm long, 33mm wide, and from 9 to 14mm thick. A 21.6cm long Teflon-coated multi-strand stainless steel antenna exited from the posterior dorsal end of the transmitter and protruded 2cm before bending at a 90^{o} angle. All satellite transmitters were reinforced to withstand external pressure and were equipped with temperature and battery voltage sensors.

Data Acquisition and Analysis

The amount of data we received was limited by transmitter battery life. Birds require small transmitters. This limits battery size, which limits transmitter life. To conserve limited battery life transmitters were programmed for various on/off (duty) cycles based on predicted periods of seasonal movements. All transmitters remained on for 6 consecutive hours. Off times varied from a minimum of 48 hours (spring migration) to a maximum of 120 hours (winter). We increased data collection during spring and summer at the expense of fall and winter.

Signals were analyzed using Argos Data Collection and Location Systems (Service Argos, Inc. Landover MD). We accepted all Argos Standard Location Processing with class codes 1, 2 or 3 (Service Argos 1996). When standard processing criteria were not met during a transmission cycle (generally fewer than 4 signals during a satellite overpass), we used Argos Auxiliary Location Processing (class codes A, B). We removed aberrant locations associated with Class codes A, B, and 0 which is typical for data obtained through the Argos ‘Doppler’ system (Fancy et al. 1988) by using qualitative and quantitative criteria based on travel distance, travel rate, and redundancy from previous or subsequent locations (Ely et al. 1997, David Douglas USGS filtering algorithm). Through this filtering process we attempted to eliminate all locations lacking biological plausibility (Ely et al. 1997). Locations were mapped using ArcView® GIS software. Birds that died (verified by temperature sensor) or stopped transmitting signals within 30 days of release were not included in the analysis.

We presumed seasonal status (spring departure, breeding, molting, wintering, migration) by correlating dates and patterns of movement with geographical locations and published information, historical accounts, and surveys. A breeding area was assigned to a bird if it spent a minimum of 9 days at an interior location during the breeding season before departing to a molting area. If a bird spent time at two or more locations we used the latter. It was not intended as an indication of breeding status.

We used the best location in each duty cycle for mapping and distance calculations. We selected from all plausible locations to determine migration routes. We estimated dates of spring migration from PWS by using the median date between two sequential locations (last date in PWS and first date outside PWS) and rounding towards the first location in the sequence. We followed this pattern throughout migration (e.g. median date between last location at breeding area and first location after breeding area to indicate last date at breeding area). We did not estimate arrival and departure dates between seasonal use areas if we did not receive a location for a minimum of 8 consecutive days between movements.

Methods used in this study were approved by the *Exxon Valdez* Oil Spill Trustee Council and the Institutional Animal Care and Use Committee of the Alaska SeaLife Center. Capture and handling of birds followed Ornithological Council guidelines (1997).

RESULTS

We captured 120 white-winged scoters. We monitored movements of 13 females and 9 males from PWS (Table 1). Individual transmitter performance (number of transmissions, location quality, and longevity) varied significantly. Individual transmitters provided location data from 35 to 308 days (mean = 203, SD = 73) and the total number of locations per individual ranged from 30 – 814 (mean = 349.9, SD = 250.4). In 1999, we received 2,339 locations from 7 birds and in 2000 we received 5,358 locations from 15 birds. We used 16.3% of all locations in our analysis. Sample size at a given staging, breeding, molting, or wintering area varied throughout the study as transmitter performance and individual migration patterns varied. We were not able to track a bird throughout a full year, but we were able to track most birds to breeding and molting areas and back to wintering areas (Table 1).

Spring Migration

Departure from Prince William Sound

All 22 birds departed PWS. We observed two different migration patterns in spring. Breeding birds traveled inland, departing PWS in a northeasterly direction with the majority of birds migrating to breeding areas in the NWT, Canada (Fig. X). Nonbreeding birds from PWS took a coastal route, traveling westerly or easterly to coastal molting areas in the Bering Sea of western Alaska or the northern GOA (Fig. X).

Departure dates from PWS varied by year and breeding status (Table 2). Spring migrants departed PWS between 27 May and 3 June in 1999 (median = 31 May). Departure dates for the two males not migrating to breeding areas were within the range of the five females that migrated to breeding areas. In 2000, 12 of 15 birds departed PWS between 18 –27 May (median = 24 May) and the remaining three birds (nonbreeders) between 14 June and 8 July (Table 2). Unlike earlier migrants that went to breeding areas, the latter three birds migrated to coastal molting areas (see *Coastal Routes*, below).

Migration Routes

Spring migration to breeding areas was fairly rapid and direct. Transmitters were programmed to receive location data six out of every 54 hours, affording us few opportunities to monitor birds during migration and identify routes and brief stopover points. In addition, we received fewer messages and poorer quality messages during periods when birds were flying.

We received enough locations from seven birds to suggest a general migration route. Birds migrated northwest from PWS, through the Copper River basin, circumnavigating the northwest side of the Wrangell Mountains via the upper Copper River Valley and proceeding east and crossing the Alaska Range through the Nabesna River Valley or Mentasta Mountains to wetlands in the upper Tanana River Valley (Tetlin). A female died during spring migration near the outlet of Tetlin Lake soon after her estimated arrival on 28 May 1999.

Old Crow and Yukon Flats. Birds heading to breeding areas in the Yukon Flats and Old Crow proceeded north from Tetlin (Table 1). Three birds arrived east of Ft. Yukon (66.6°N, 145.3°W) by 29 May (Figs 2A, 3D,5C), two days later than observed in 1962, a year when the Yukon River breakup was later than normal (Lensink 1962). Birds staged for about one week in the vicinity of the confluence of the Black and Porcupine Rivers in the Yukon Flats. We cannot determine the route from Tetlin to the Black River, though birds likely crossed the Yukon-Tanana uplands (Wahrhaftig 1965), a minimum flight distance of about 410km or proceeded northeast into the Yukon River drainage and then followed it to the northwest. From here birds proceeded further east on the Yukon Flats (Fig. 5C), or followed the Porcupine River to the Old Crow Flats (Fig. 2A, 3D) (Irving 1960)

Northwest Territories. Birds migrating to the NWT (Table 1, Fig. 2B–D; 3A,B,D; 4A–D; 5A–C; 6A,B) traveled east from Tetlin to the Stewart River Valley in the Yukon Territory, then northeast between the Ogilve and Wernecke Mountains to the Peel River basin. From here birds proceeded east, crossing the Mackenzie River near Fort Good Hope (66.3°N, 128.6°W). We have several scattered locations between the Peel and Mackenzie Rivers in late May prior to birds moving further east to breeding areas.

Coastal Routes. Four males and one female went from wintering to molting areas without stopovers at breeding areas (Figs. 3C, 7A–D). The migration of nonbreeders was generally more prolonged than the rapid and direct migration of birds to breeding areas. All nonbreeding birds migrated to the southern Bering Sea or northern GOA. Individual migrations varied. A male staged in lower Cook Inlet (Kamishak Bay) before traveling further west to Togiak Bay in the southern Bering Sea (Fig. 7C). A second male remained in lower Cook Inlet to molt (see Molting Areas below) (Fig 7B). The female traveled west through Cook Inlet but sporadic data prevented us from being more detailed about the timing and locations of her movements. By 31 July she had arrived along the west coast of the Nushagak Peninsula (Fig. 3C). The fourth bird, a nonbreeding male, took the most direct route to the molting area, migrating from PWS to Cape Newenham within six days (Fig 7A). Only one bird migrated east. This nonbreeding male took the shortest migration route of any bird (226km), flying from PWS to a staging area at the mouth of Icy Bay in the northeastern GOA (Fig. 7D).

Breeding Areas

Five males and 11 females from PWS migrated to breeding areas in the 1) Yukon Flats National Wildlife Refuge, Alaska (Yukon Flats) (n = 1 male); 2) Old Crow Flats, Yukon Territory (n = 2 females) and 3) Mackenzie, Anderson, and Horton River basins, NWT (n = 9 females, 4 males) (Table 1, Fig. 8). Although we have no empirical evidence of our transmitted birds actually nesting, our satellite locations are within known breeding areas (Palmer 1976, Bellrose 1980, Brown and Fredrickson1997).

Arrival Dates

Birds arrived on the breeding grounds between 25 May and 13 June (Table 2). Birds arrived earlier in 2000 than in 1999. The estimated median arrival date at breeding areas in 1999 for four females was 6 June. The estimated median arrival date in 2000 was 31 May for seven females and five males (Table 2). The two Old Crow breeders arrived between 5– 8 June, later than Irving (1960) observed in 1957 and likely due to a latter spring thaw in 2000 (S. Haszard, pers. comm.). The only Yukon Flats breeding bird, a male, arrived on approximately 2 June, preceding the dates for mean nest initiation (Safine 2005). We do not have historical data from the NWT breeding areas to compare with our estimated dates of arrival.

Northwest Territories Core Breeding Area

PWS birds used breeding areas primarily in the lower Mackenzie and Great Bear sub-basins of the Mackenzie River (Mackenzie River Basin Board 2004) and further north in the basins of the Horton and Anderson Rivers (Table 1, Figs. 2B–D; 3A,B,D; 4A–D; 5A–C; 6A,B). The core breeding area in the NWT encompassed a triangular area of approximately 45,000 km^2 in the open boreal forest, with the triangle tapering in width from south to north (Fig. 8). The area was bordered to the southeast (65.7^{o}N, 123.3^{o}W) by the Great Bear Lake, to the southwest (65.9^{o}N, 127.6^{o}W) near Fort Good Hope and the Mackenzie River and to the north (68.9^{o}N, 127.5^{o}W), west of Sadere Lake between the headwaters of the Anderson and Horton Rivers. The size of this core breeding area is approximately 3 times the area of PWS. All breeding birds in the NWT were within the boundaries we described for the core breeding area with one exception, a female, who "nested" 175km to the west (Fig. 2D).

Time at Breeding Areas

As is typical for sea ducks, females remained at breeding areas longer than males (Table 2) and longer stays may indicate that some possibly nested successfully. White-wing scoter females commonly combine broods (crèching) when ducklings are less than 1 week old (Brown and Brown 1981) and the combined egg laying and incubation period is from 37–44 days (Brown 1977, Brown 1981). Thus, five females were present at a breeding site long enough (minimum 62 days) to have nested successfully (Figs. 2B,C; 3A,D; 4D). A sixth female was at the breeding site for 47 days (Fig. 2A). Four of these females used the core breeding area in the NWT and two used Old Crow Flats.

We permanently lost contact with 2 females while at breeding areas after 39 and 62 days. We do not know if the birds died or the transmitter failed. Body temperatures were normal in both birds when we received our last transmission of data.

Molting Areas

We were able to monitor 16 birds to coastal molting locations (Table 3). Molting areas were primarily distinct and distant from nesting and wintering areas and distributed over a broad geographical area. We divided molt chronology between birds that migrated to molting areas from breeding areas and nonbreeders that migrated from wintering to molting areas without stopovers at breeding areas (Table 3). We identified three general areas used by molting scoters. The majority of breeding birds molted in the Beaufort Sea while others used the southern Bering Sea and northern GOA (Table 1, Fig 9). Nonbreeding birds used only the southern Bering Sea and northern GOA (Figs. 3A–D, 7A). Nonbreeding birds generally arrived at molting sites earlier than breeding birds (Table 3). In addition to coastal molting sites, two females molted on breeding lakes in the NWT (Figs. 2B, 4D).

The time each individual spent at breeding areas varied greatly, thus the advent of molt migration varied for each individual and occurred over an extended time period (Tables 2 and 3). Once initiated, molt migration was fairly direct and most birds generally arrived at molting sites within 9 days of departing breeding areas with some exceptions (see below). Birds with distinct molting areas (i.e. separate from breeding or wintering areas) spent an average of 83 days at molting areas (Table 3). Following molt, scoters generally remained at or near the same location before migrating to wintering areas.

Breeding birds from the NWT tended to molt in the NWT (Beaufort Sea) but we did not observe any absolute affiliations between breeding and molting areas. In addition to the Beaufort Sea, NWT birds molted in the northern GOA and the southern Bering Sea (Nelson Lagoon, 56.0^{o}N, 160.8^{o}W). The two females from Old Crow dispersed southwesterly to molting sites in the northern GOA (PWS) and the southern Bering Sea (Kuskokwim Bay). The lone Yukon Flats bird, a male, migrated northeasterly to join NWT birds in the Beaufort Sea.

Beaufort Sea.

Eight of twelve breeding birds molted in the Beaufort Sea, including seven of nine birds that nested in the NWT (Table 1, Fig. 9). The primary molting site for breeding birds was Liverpool Bay ((70.3^{o}N, 128.4^{o}W) off the coast of the NWT (3 Females, 2 Males) (Fig 9). Another male and female were present in Liverpool Bay but we lost data reception before we could confirm molting. An additional male molted to the east in Franklin Bay near the northern tip of the Parry Peninsula (70.1^{o}N, 124.5^{o}W) (Figs. 5B, 9). This was the most easterly molting site used by one of our birds. All birds that molted in the Beaufort Sea arrived from breeding areas in the NWT with one exception. The lone male from the

Yukon Flats also molted in Liverpool Bay (Fig. 5C). Nonbreeding birds did not molt in the Beaufort Sea.

Molt migration from breeding areas was relatively short and direct though a few birds staged at tundra and coastal locations before arriving at molting areas. A female migrated to the Beaufort Sea coast at Darnley Bay (69.6°N, 123.9°W) before moving 170km west to Liverpool Bay (Fig. 4C). Darnley Bay was the most easterly coastal staging area used by one of our white-winged scoters.

Two birds, 1 female and 1 male each spent about two weeks in the core breeding area near Lac Maunoir (67.5°N, 125.0°W) in the headwaters of the Anderson River from late May to early June before moving approximately 320 km northwest to coastal tundra locations on the Nicholson and Tuktoyaktuk peninsulas respectively (Figs. 4A, 5A). The female spent 32 days southeast of Nicholson Peninsula between Wood Bay and Liverpool Bay before moving to a molting area in Liverpool Bay. The male spent three weeks on the tundra before we lost all contact (lost transmission). During that period we documented one brief round trip to a known molting site in Liverpool Bay. Arner et al. (1985) observed an influx of white-winged scoters on the Tuktoyaktuk Peninsula in late June but observed no evidence of nesting. A lack of nesting on the Arctic coastal plain of western Canada was supported by Porslid (1943) and Salter et al. (1980). Thus, we don't believe birds attempted to nest at these locations but staged before continuing their migration to molting areas, most likely in Liverpool Bay.

Satellite data confirmed the presence of a female in Liverpool Bay on 2 October and based on her next location she possibly remained until 5 October. This is the latest departure date we can reliably estimate for the Beaufort Sea.

Bering Sea

Five birds molted in the southern Bering Sea. Birds arrived in the Bering Sea from wintering and breeding areas. Molting sites were widely dispersed from Kuskokwim Bay on the north to Nelson Lagoon in the southwest a direct distance of about 450km.

Two breeding females from the Anderson River drainage, NWT, and Old Crow Flats molted in Nelson Lagoon and Kuskokwim Bay respectively (Figs. 3A,D). The molt migration from the Anderson River drainage to Nelson Lagoon was the longest we identified. This bird flew the 1903km from the breeding area to the south side of the Alaska Peninsula within 72 hours. After staging for at most one week, just northeast of Yantarni Bay, it flew another 303km northwest across the Alaska Peninsula to Nelson Lagoon. Nelson Lagoon is the most southwesterly molting site we identified and is approximately 2,342 km from our most easterly site in Franklin Bay. The Old Crow female remained 111 days in Kuskokwim Bay, the longest a breeding bird spent at a coastal molting site that was distinct from its wintering area. She finally departed the molting area after 27 November for a wintering area further west in the Aleutian Islands (see Winter Areas, below).

Three birds, all nonbreeders, molted in disparate locations from Cape Newenham (north side) to the west coast of the Nushagak Peninsula (Figs. 3C, 7A,C). After molting at Cape Newenham the bird moved north into Kuskokwim Bay where it remained through 29 November when we lost contact. The bird spent a minimum of 156 days in the Bering Sea from its arrival at Cape Newenham about 27 June until we lost contact. Unfortunately we do not know where it wintered.

Gulf of Alaska

Two breeding birds and two nonbreeding birds molted in the northern GOA. Molting areas were widely dispersed from Cook Inlet to Cape Yakataga (Figs. 2A, 6A, 7B,D). A female from the Old Crow Flats molted in Knowles Bay in northeastern PWS (Fig X). It arrived in Knowles Bay on approximately 26 July and remained until 24 September. A male from the NWT migrated to Cape Suckling by 10 July. We next located it in Controller Bay, 60km northwest, in late August (Fig. 6A). We lost contact (i.e. did not receive data) with this latter bird for over 6 weeks and could not confirm where it molted. We believe it likely molted in the northern GOA, probably near Cape Suckling, a known molting area, (Henny et al. 1995), based on July and August locations. Two nonbreeding birds, both males, molted at Cape Yakataga (Fig. 7D) and lower Cook Inlet (Chinitna Bay) (Fig. 7B) respectively. The former bird remained at Cape Yakataga from 20 June through 28 August and the latter bird resided in Chinitna Bay from 13 June until 27 August.

Migration to Wintering Areas

We monitored the movements of 15 birds to wintering areas (Tables 1 and 3). Birds not included in Table 3 had the same molting and wintering areas. Ten birds returned to PWS and one wintered in the Northern GOA (Icy Bay) (Table 1) (Fig. 7D). Icy Bay was the farthest east any bird wintered. At minimum three birds wintered on the Alaska Peninsula (see Other Wintering Areas, below), two on the north side (Bering Sea) and one on the south side (GOA). A female wintered the farthest west, by Cape Sagak, Umnak Island (52.8^{o}N, 169.2^{o}W), in the Aleutian Islands (Fig. 3D). Umnak Island is about 1800km west of PWS. All but two birds migrated southwest from molting (or breeding) areas to wintering areas.

Prince William Sound

Breeding birds (birds that migrated from PWS to breeding areas) exhibited a high rate of return to PWS. Of 11 breeding birds that we were able to monitor into the following winter, nine (82%) returned to PWS (Table 1). All breeding males returned while 75% of breeding females returned. All birds (n = 8) that molted in the NWT returned to PWS (Table 1).

The first breeding bird returned to PWS on 25 July (estimated – see methods). This female, returning from Old Crow Flats was the only bird to molt in PWS (Knowles Bay) (Fig. 2A). Birds molting in the NWT returned much later. The first bird to return from the

NWT, a female, arrived on 15 September after molting on a breeding area lake. The first coastal molting bird, a male from the Beaufort Sea, returned on 21 September. Excluding the first bird that returned in July, the average date of return to PWS was 27 September and the median date was 1 October. All birds returned by 11 October. We estimated peak return occurred between 29 September and 7 October.

The return migration to PWS was generally rapid and direct, usually occurring within a few days to a week. Birds from the NWT all returned via inland routes, following river valleys within the Yukon and Mackenzie River basins. Our data suggests three birds possibly returned to PWS from the NWT by traveling on the eastside of the Wrangell Mountains but location data were not sufficient. Return routes likely varied among flocks.

In 1999, a female possibly remained in Liverpool Bay until 5 October (see Molting Areas, above). It was next located in the Black River drainage in the interior of northeast Alaska (66.1^{o}N 142.6^{o}W) the evening of 5 October before returning to PWS by 8 October. This bird migrated 1,334km from the Beaufort Sea to PWS in a maximum of 147 hours and possibly within 48 hours (Fig. 3B). Another female, in what we believe is atypical, returned to PWS via southeast Alaska after having molted on a freshwater lake in the NWT (Fig. 2B). She departed the NWT sometime after 14 September and traveled through the upper Mackenzie River Valley to Lynn Canal, arriving no later than 19 September. She staged for about two weeks at the south end of Baranof Island before returning to PWS within the first few days of October.

Among five nonbreeders, only one bird, a male, returned to PWS (via Cook Inlet) on 4 September after molting in Togiak Bay (Fig. 7C). This bird returned before all but one breeding bird (see above). This was the only bird to migrate east from a molting to wintering area. Thus, it was the only bird to return to PWS among the two breeders and four nonbreeders molting from Cook Inlet west (Table 1).

After returning to PWS birds dispersed from Sheep Point east to Glacier and Perry islands and south to Green Island (Figs. 2A,B; 4A,D; 5B, 7C).

Other Wintering Areas

Icy Bay in the northern GOA was the most easterly wintering location for one of our birds (Fig. 7D). Prior to moving to Icy Bay this nonbreeding male molted at Cape Yakataga then moved west and staged from mid-September to early December outside of barrier islands in the Copper River Delta. It arrived in Icy Bay in mid-December and remained there until mid-February 2001when we lost contact.

Three birds wintered on the Alaska Peninsula (Figs.3A,C; 7B). We lost contact with another bird, a male, while still in Kuskokwim Bay on 29 November 2000 (Fig. 7A.). We suspect, if still alive, it wintered in the Bering Sea or further west. A female, having molted in Port Moller remained there until we lost contact in late November 1999 (Fig.

3A). We tentatively identified this as her wintering area but she may have moved subsequently.

The second female, a nonbreeder wintering on the north side of the Alaska Peninsula, moved among several locations throughout the winter (Fig. 3C). She was one of two birds without a definitive southwesterly migration from the molting to wintering area. After molting by the Nushagak Peninsula she moved to the north side of Hagemeister Island (mid-October to mid-December, 2000), then returned to her molt site, remaining until early January 2001. She then proceeded west along the Alaska Peninsula by Port Moller where she remained until early February before moving northeast to the mouth of Ugashik Bay where she remained until early March 2001. Our last location before losing contact was of poor quality, but plausible and intriguing. It placed the bird on Becharof Lake, on the Alaska Peninsula, southeast of Ugashik in mid-March. We will never know if this bird was migrating east, perhaps back to PWS or continuing a series of winter movements. She illustrates the fascinations and frustrations inherent in satellite telemetry studies.

One bird wintered on the south side of the Alaska Peninsula in Chiginagak Bay (Cape Providence) (Fig. 7B). After molting and staging in lower Cook Inlet, this nonbreeding male traveled west along the south side of the Alaska Peninsula spending two months in the fall at Puale Bay before arriving in Chiginagak Bay in late October. We lost contact with this bird in mid-December while still in Chiginagak Bay. We identified this as its wintering area, recognizing the possibility of additional winter movements.

Finally, a female that bred near Old Crow and molted in Kuskokwim Bay, wintered the farthest west, by Cape Sagak, Umnak Island (52.8^{o}N, 169.2^{o}W), in the Aleutian Islands (Fig. 3D). She departed Kuskokwim Bay after 27 November, migrated west by Port Moller on 30 November and arrived at Umnak Island the first week of December. She remained there until 28 January 2001 when we lost contact.

Age Classes

Distribution of age classes based on bursal depth among the eight females and seven males we monitored from PWS in 2000 were as follows: After Third Year (ATY) n = 6 Females, 5 Males; Third Year (TY) n =1 Female, 1 Male; and Second Year (SY) n = 1 Female, 1 Male.

All but one bird classified as ATY went to a breeding area. A female, the one exception, flew directly to a molting area in western Alaska. Of the two TY birds, the female migrated to a breeding area while the male flew directly to a molting area (Figs. 4A, 7A). Of the two birds classified as SY, the female migrated to a breeding area in the NWT where she remained to molt, staying until mid-September (Fig. 2B). The male flew directly to a molting area east of PWS (Fig. 7D). Both birds classified as SY by bursal depth had acquired definitive plumage (Palmer 1976). The bursa depths of two TY birds were at the lower range for that category.

Mortality and Transmitter Longevity

Of the 13 birds we implanted in 1999, two males and three females died within 14 days of surgery (38% mortality). A third male died at 16 days post-release. Finally, a fourth female died during spring migration near the outlet of Tetlin Lake (63.0°N, 142.7°W) approximately 35 days after capture. A subsistence hunting camp was present in this location and we suspect she was shot. We did not confirm mortality in any other birds. During July and August 1999 we stopped receiving transmissions from two females (Fig. X). The fate of the birds could not be determined but the internal temperature sensor indicated the birds were alive at the time of the last transmission. The remaining transmitters failed between 23 November and 25 December 2000.

Of the 18 birds we implanted in 2000, two birds died in captivity (11%). A male died 9 days post-surgery and we euthanized a female 21 days post-surgery. Cause of mortality in the former was not determined. The latter likely resulted from a bacterial granuloma (introduced during surgery) with additional stresses from ureter tremtodiasis (J. Raymond, DVM, NWZooPath, histopathology report). A third male died when attacked by a bald eagle (*Haliaetus* l*eucocephalus*) immediately after release. In July and August 2000 we lost transmission from two males and one female (Figs. 4B, 5A, 6A). As with the 1999 birds, the temperature sensor indicated the birds were alive as of the last transmission. The remaining transmitters failed between 7 November 2000 and 31 March 2001. Individual transmitter performance varied by the quality and quantity of signals we received throughout the study.

DISCUSSION

Using satellite telemetry we described migration patterns and linked PWS wintering areas with breeding sites in the Northwestern Canada and molting sites in the Beaufort and Bering seas and GOA. This is the first successful attempt to use satellite telemetry to document movements of white-winged scoters. We compared movements of PWS birds with satellite transmitted white-winged scoters marked in wintering areas in 1) southeast Alaska (n = 2) (authors, unpublished data), 2) British Columbia (BC) (n = 23) (Sea duck Joint Venture 2006), 3) Washington State (WA) (n =14) (D. Nysewander and J. Evenson, WDF&W, unpublished data), and 4) a breeding area on the Yukon Flats in interior Alaska (n = 7) (authors, unpublished data).

Sample sizes are small but precision is high and we felt it important to try and incorporate all this data recognizing the usual caveats associated with small sample sizes both spatially and temporally (Lindberg and Walker, in press). Comparisons with southeast and interior Alaska are especially provisional. However, scoters migrate in flocks of 10 to one hundred or more birds (Murie 1959, Irving 1960, Salter 1972, Mauer and Wilbor1989) and each transmitted bird potentially represents many birds.

Spring Migration

Inland migration

White-winged scoters have often been observed during spring migration (Johnson and Herter 1989), but migration routes have not been described, as observers could not associate piecemeal observations with both origins and destinations. Isleib and Kessel (1973) observed white-winged scoters departing PWS in spring flying northward directly over mountain ranges and Irving (1960) observed migrants moving northward in the upper Copper River Valley and others following the Porcupine River to the Yukon Territory.

We described partial migration routes from PWS to nesting areas in Old Crow, YT and the NWT. While the information is incomplete, the southern portions of these routes (at minimum) are largely distinct from migrants from southeast Alaska (authors, unpublished data), and the Pacific coasts of BC (Sea duck Joint Venture 2006), and WA (D. Nysewander and J. Evenson, WDF&W, unpublished data). These latter birds all traveled inland east of Cape Spencer (58.2^{o}N, 136.6^{o}W) and over 600km east of PWS.

The timing of migration we observed was consistent with earlier observations in late May (Murie 1959, Lensink 1962, Campbell and Shepard 1973, Salter et al. 1974). We did not confirm spring staging areas, but our data suggest birds briefly staged near the confluence of the Black and Porcupine Rivers and between the Peel and Mackenzie Rivers in late May while waiting for more favorable weather conditions and advances in spring phenology.

Coastal migration

Several birds migrated directly to molting areas. These birds followed coastal routes, both east and west from PWS and generally departed later than inland migrants. Immature birds undergo pre-molt migrations directly from the winter area to the molting area (Salomonsen 1968) but little is known about older nonbreeding birds. Our sample of bursal measurements and number of coastal migrants was too small to draw conclusions about age class distribution between inland and coastal migrants but an ATY female and a TY male bypassed the breeding area.

The few coastal migrants made it difficult to identify patterns. Spring migration was not unidirectional. One male migrated east from PWS to molt near Cape Yakataga, a much shorter distance by about 80%, than the route to westerly molting areas in the southeastern Bering Sea. Some westerly migrants passed through lower Cook Inlet, possibly timed to coincide with late herring spawn events (Nature Conservancy 2003). Spring migration through this area has not been well documented but fisheries researchers have reported several thousand white-winged scoters plus other sea ducks during peak herring spawn events in mid-May (Ted Otis, pers. comm.). One bird remained in Cook Inlet to molt while others proceeded to Bristol Bay likely taking overland routes across the Alaska Peninsula.

One nonbreeding male migrated west past Cape Pierce (58.8°N, 159.6°W) in western Alaska along a route where Herter et al. (1989) estimated 51,200 pre-molting white-winged scoters, primarily adult males. Two other PWS birds, a male and female remained southeast of Cape Pierce. All three birds arrived in the area past peak herring spawn in the Togiak district though possibly in time for late spawning events (ADF&G 2000). A distributional response of sea ducks to herring spawn has been established on wintering areas in PWS and BC (Bishop and Green 1981, Boyd, 2003) but the response among migrants is not well known.

We preferred to catch birds that strictly wintered in PWS rather than migrants. Isleib and Kessel (1973) observed numerous spring migrants along the outer coasts of PWS but did not mention an influx of birds staging in PWS. We have no record of migrants from southwest Alaska traveling through or staging in PWS in spring (authors unpublished data) consistent with observations of migrants from western Alaska traveling inland (Murie 1959). Nor did birds from BC, WA, or southeast Alaska migrate through PWS (see above). In fall, thousands of scoters stage along the coast to the southeast of PWS between Cape Suckling and Cape Yakataga (Conant and Groves 2001). If these birds remained there to winter they would provide a potential source of spring migrants. We transmitted one and possibly two birds that wintered in this area the following year and we suspect late winter or spring migrants from these nearby coastal wintering areas move to PWS and join wintering birds.

Breeding

Breeding Areas

PWS birds used three widely separated breeding areas within the boreal forests of western Canada and Alaska (Fig. 5C, 8), (Palmer 1976, Bellrose 1980) with the majority of breeding concentrated in the NWT (Fig. 8). These areas were nearly distinct from breeding areas used by birds from coastal BC (Sea Duck Joint Venture 2006) and WA (D. Nysewander and J. Evenson, WDF&W, unpublished data). The longitudinal divide, with some overlap occurred along the western arms of Great Bear Lake in the NWT (ca. 123.3°W). This marked the approximate western extent of the breeding range for BC and WA populations and the eastern extent for PWS birds. From here, the breeding range of BC and WA birds extended far to the south and east while PWS birds extended west. Birds from southeast and southwest Alaska extended into the range of PWS birds from the east and west respectively. Population affiliations may occur within regions (e.g. within the core breeding area) at smaller spatial scales than we were able to detect.

Relationship to North American Waterfowl Population Surveys

The majority of the core nesting area we identified in the NWT is surveyed annually as part of the Continental Waterfowl Breeding Population Habitat Survey (WBPHS) conducted each May since 1955 (Smith 1995). Most scoter population estimates are derived from this survey. The WBPHS divides the U.S. and Canada into over 50 habitat strata. PWS birds used only three of these strata during the breeding season (from west to east with increasing in frequency): stratum 4 (Yukon Flats, Alaska), stratum12 (Old Crow Flats, YT), and stratum14 (NWT forest tundra), (Smith 1995). White-winged scoters are the most abundant scoter in each of these strata (Irving 1960, Lensink 1962, Haszard 2001). The Yukon Flats was used by only one male, possibly an anomaly for PWS birds, or at least not representative of breeding females and Old Crow was used by just two females. PWS birds were most represented in Stratum 14.

Stratum 14 encompasses 127,484 km^2 (Smith 1995) or about triple the size of the core breeding area we described for PWS and supports 30% of the surveyed continental scoter breeding population (S. Slattery, Ducks Unlimited, Canada, pers. comm.). Most of the core breeding area lies within the eastern third of stratum 14, while the most southerly and easterly portions lie outside the boundary of the WBPHS. In the western portion of stratum 14 PWS birds mixed with white-winged scoters from southeast and southwest Alaska (authors, unpublished data). Unfortunately, we cannot use the WBPHS to assess changes in PWS populations without population assessment at smaller spatial scales and population surveys capable of identifying shorter-term trends in individual species. The many shortcomings of the WBPHS preclude good assessment of scoter population trends, especially in the short-term (Smith 1995, Alberta Sustainable Resource Development 2002). We have presented the beginnings of this long, multi-disciplined process and eventually we hope the results of population delineation studies will guide the timing and locations of surveys.

Molting

Several authors observed post-breeding movements or identified molting areas in coastal Canada and Alaska (Johnson and Herter 1989, Herter et al 1989, Alexander et al 1988, Salter et al. 1980, Johnson and Richardson 1982, Henny et al 1995, Mauer and Wilbor1989), but this study is the first to link molting locations with specific breeding and wintering areas. We identified links to several coastal molting areas in northern Canada and western Alaska. Most conclusive among these is the affiliation, though not absolute, of PWS wintering birds to breeding and molting areas in the NWT. Molting areas used by PWS birds were apparently discrete from molting areas used by female white-winged scoters from BC and WA (Sea Duck Joint Venture 2006, D. Nysewander and J. Evenson, WDF&W, unpublished data). Wintering and breeding birds may have affinity to certain molting areas, but individual molting areas likely support aggregates of flocks (scale of large bays, e.g. Liverpool Bay, Kuskokwim Bay) from several widely separated breeding and wintering areas. Fidelity to these sites as well as further structuring at smaller spatial scales is unknown.

Beaufort Sea

Only birds that occupied breeding areas in the NWT and Yukon Flats molted in the Beaufort Sea, primarily in Liverpool Bay (Fig. 9). Liverpool Bay contains 3 of 6 key scoter molting areas between Herschel Island, YT and Cape Bathurst, NWT (Barry 1976, Alexander et al. 1988, Dixon and Gilchrist 2002) and the number of molting sea ducks in these areas is thought to have declined considerably since the early 1970's (Barry 1974, Alexander et al. 1988, Johnson and Herter 1989). Post-breeding birds originating from wintering areas in southwestern and southeast Alaska (authors, unpublished data) also molted in Liverpool Bay so it is not unique to PWS birds, but we suspect a high proportion of PWS breeding birds used Liverpool Bay. One male each from BC and (Sea Duck Joint Venture 2006) and WA (D. Nysewander and J. Evenson, WDF&W, unpublished data) staged here but molting was not confirmed, and these birds were atypical of other birds from these areas.

Bering Sea

Birds were widely dispersed from Kuskokwim Bay to Nelson Lagoon (56.2°N, 159.3°W) on the north side of the Alaska Peninsula indicating many suitable molt sites in this region for breeders and nonbreeders. Only one bird, a female, migrated here from the NWT, so any affinity with PWS breeding birds may be low. Most birds molted from the Nushagak Peninsula to Kuskokwim Bay. No fall survey data is available for this area. Few white-winged scoters molted north of Kuskokwim Bay (Dau 1987) so the destination of the 51,200 pre-molting white-winged scoters observed by Herter et al. (1989) remains a mystery. The area between the Nushagak Peninsula and Kuskokwim Bay is a likely priority for future surveys during summer and fall.

One bird molted and later staged on the north side of the Alaska Peninsula near Nelson Lagoon in autumn of 1999 (Fig. 3A). Fewer than 1,000 white-winged scoters including 285 in near Port Moller/Nelson Lagoon were counted along the north side of the Alaskan Peninsula in early October 1999 when this bird was present (Mallek and Dau 2000). Over twenty years earlier, Gill et al. (1981) observed 1,000 molting white-winged scoters just in the Port Moller/Nelson Lagoon area in early August; 2,000 birds in late September; and several thousand in late October (Byrd reported in Gill et al 1981).

Gulf of Alaska

From 1990–1992, at minimum several hundred molting white-winged scoters died at Cape Suckling and Cape Yakataga. No definitive causes for the mortality could be identified (Henny et al. 1995). During these investigations which continued into 1993, observers estimated maximum numbers of living scoters as follows: 1,000 at Cape Suckling, 1,870 between Cape Suckling and Cape Yakataga, and 1,200 at Cape Yakataga. Species were not differentiated but based on carcass counts white-winged scoters represented the large majority of these offshore observations. Investigators were frustrated by a lack of knowledge about migration patterns of these birds prior to their death (Henny et al. 1995). The movements we described for Cape Yakataga and Cape Suckling birds would have given investigators the benefit of a starting point. And will help researchers focus sampling and population monitoring efforts in the event of future die-offs.

Birds from other Pacific wintering areas did not molt in the northern GOA although two birds from WA passed through the area during migration, in June and August respectively (D. Nysewander and J. Evenson, WDF&W, unpublished data). Additional surveys are needed to identify the importance of the various molt sites we have described. These sites likely support all three species of scoters so differentiation is necessary to assess relative abundance.

Winter Fidelity

We assumed birds returning to PWS in late fall and early winter remained until the following spring but at best, we received location data for about 11 months. Once a bird returned to PWS we have no record of it migrating elsewhere.

Winter site fidelity has been documented for members of several waterfowl taxa including sea ducks (see Anderson et al. 1992, Robertson and Cooke 1999) but not specifically for white-winged scoters. Site fidelity is most advantageous in stable environments (Esler et al. 2002); familiarity of local habitat conditions and availability of mates are other possible selective factors (Anderson et al. 1992, Robertson and Cooke 1999). Site fidelity can be an evolutionary precursor to the formation of unique population segments.

We believe the high return rate to PWS among breeding birds indicates winter site fidelity in white-winged scoters. Dispersal may be more common among unpaired males especially in birds, like scoters, with male biased sex ratios. Regardless, relative levels of philopatry and dispersal may vary among years, locations, age, sex, and breeding status and it is premature to infer at what spatial and temporal scale winter site fidelity operates in PWS.

Current marine boat surveys in PWS indicate large annual variations in winter populations (Sullivan et al. 2005). Whether these surveys reflect relatively low or variable rates of intra-annual winter site fidelity; a high and varying percentage of dispersal by nonbreeding birds or production by breeding birds; or poor design for sampling scoters is unknown. We need to better quantify interannual rates of winter site fidelity and dispersal by age and breeding status and understand winter movements and distribution before we can design optimal surveys or interpret existing surveys.

Mortality

The most serious problem we encountered in this study was the high rate of mortality that occurred within two weeks of surgery in 1999. By holding birds in captivity in 2000 we increased survival. In both years scoters were in good physical condition and responded well to surgical procedures (Dr. D. M. Mulcahy pers. comm.) but in 1999, post-release mortality was greater than other sea duck satellite implant studies using similar surgical procedures: spectacled eiders (Petersen et al. 1995); king eiders (Dickson et al. 1998); white-winged scoters (authors unpublished data); Barrow's goldeneyes (Robert et al. 2000); and harlequin ducks (Mulcahy and Esler 1999.).

The primary difference between this study and others (excluding harlequin ducks) is that we implanted birds in late winter in the GOA. Surgical implants for the first three studies (spectacled eiders, king eiders, white-winged scoters) were conducted on the breeding grounds. Behavioral differences may be attributable to increased survival of harlequin ducks which feed near shore and are comfortable on land (Robertson and Goudie 1999) and behavioral and geographic differences may be factors when comparing Barrow's Goldeneyes. Our mortality rates were more comparable to those reported for alcids (murres) implanted with satellite transmitters (Hatch et al. 2000). These birds were also captured and released in marine waters of Alaska and feed at deeper depths.

In simplest terms, the relatively high mortality of post-operative scoters primarily resulted from altered behavior after surgery which increased vulnerability to predators. In 1999, we observed post-operative birds isolated from flocks showing signs of lethargy and appearing less capable of diving for food or responding to an avian threat. In 2000, we were able to examine birds post-surgery. We observed irritation at the incision and antenna exit site, seepage from incisions, and possible infections. Some captive birds failed to maintain waterproofing. Had these birds not been allowed to recover from surgery in a protected environment we would have expected higher mortality rates.

PWS is a predator rich environment with about 6,000 bald eagles (Bowman et al. 1997). In addition to witnessing a bald eagle capture a transmitted bird, eagles were frequently observed near the trap site disturbing flocks of sea ducks and we recovered several transmitters from under eagle roost trees although we do not know if these were predated or scavenged. With or without predators post-surgical complications developed but in 1999, birds had less opportunity to recover.

We implanted birds in late winter because we hoped to monitor birds for most of their annual cycle culminating in a return to wintering areas. Late winter may be a particularly stressful period in the annual cycle of sea ducks in northern latitudes. Limited daylight hours during winter and prolonged and severe storm events may limit winter foraging. If birds are energetically compromised and surgical effects constrain a bird from diving for food, then energetic processes may be further altered. Esler et al. (2000) found lower survival rates in harlequin ducks as winter progressed. Birds may have difficulty compensating for the additional stresses of capture and surgery at this time of year. Storms immediately before capture or soon after release seem to increase mortality rates. Behavioral and physiological changes prior to migration may also affect survival.

By holding birds in captivity pre- and post-surgery we allowed birds to first acclimate to captivity and then recover in a sheltered environment that improved survival in spite of additional stressors created by transporting and holding birds. However, it added considerable cost to the project. Since we conducted this study, technological improvements (battery life, power consumption, and programming) have extended transmitter life. These provide greater flexibility in project planning. We can now capture birds in any season and monitor them for one to two annual cycles. For studies focusing on wintering birds, implanting birds in autumn, soon after their return may increase survival rates. Once affiliations are established, winter objectives may be accomplished by marking birds at other seasons. We had better success marking scoters at breeding areas where warmer air and water temperatures, fewer predators, easier access to food and better escape cover likely led to increased survival (authors unpublished data). Our small sample sizes and year and location variability preclude statistical comparisons.

CONCLUSIONS

Scoters are widely dispersed throughout remote areas and we had little knowledge of the migration patterns, affiliations between seasonal use areas, and fidelity to wintering, molting, and breeding areas. This made it extremely difficult to obtain and interpret information on population trends, productivity, survival, and harvest. This was the first project to successfully use satellite telemetry to identify the timing and routes of migration, affiliations between seasonal use areas and winter fidelity in white-winged scoters.

Migration Patterns and Seasonal Use Areas

Migration

Migration between seasonal use areas was generally rapid and direct occurring within a few days to a week or more. We described a general spring migration route from PWS to the Yukon Flats, Old Crow Flats, and NWT that filled in knowledge gaps and provided additional context to earlier observations. Refining these routes may provide additional opportunities to study migration and link information to PWS wintering populations. The timing of spring migration was consistent with historical accounts. Timing and routes of migration were different between breeding and nonbreeding birds.

Breeding

Most PWS birds (81%) used breeding areas in the NWT where numbers may have declined by as much as 56% from 1977 to 1996 (Dixon and Gilchrist 2002). Comprehensive surveys and research efforts conducted within the NWT core breeding area may serve to describe productivity and population trends for PWS birds and be a useful starting point to investigate population delineation at smaller spatial scales. As population affiliations are identified new survey designs (Mallek 2001) need to be incorporated that reflect the distribution of known population segments. If affiliations can be established, winter surveys in PWS may be advantageous for assessing abundance and trends (see Winter Fidelity below).

Molting

Molt sites of PWS scoters were widespread and primarily distinct from breeding areas. We identified coastal molting areas in the Beaufort Sea, the southern Bering Sea, and the northern GOA. Liverpool Bay in the Canadian portion of the Beaufort Sea, NWT was the primary molting site for breeding birds. We identified a link between a core breeding area in the NWT and molting areas in Liverpool Bay. Population structuring may occur at smaller scales in specific bays (i.e. smaller bays within Liverpool Bay) but this has not been investigated.

Nonbreeding birds bypassed breeding areas and migrated along the coast to molting areas in the southern Bering Sea or northern GOA. Most of these areas have not been surveyed during the molt and we do not know the significance of many of these sites, the annual fidelity to these sites, or the strength of affiliations with PWS. We suspect molting sites are aggregates of birds from several breeding and wintering areas. We identified a link between molting birds near Capes Yakataga and Suckling in the northern GOA with staging and perhaps wintering areas in PWS.

Affiliations

We identified affiliations of white-winged scoters from PWS with breeding and molting areas in Alaska and western Canada. Identifying these affiliations is especially important in a species like white-winged scoters due to their high rates of female philopatry to natal areas (Brown and Brown 1981) and their low rates of annual recruitment (Brown and Fredrickson 1997).

Most significantly we identified an affiliation between PWS and a breeding area in the Mackenzie, Anderson, and Horton River basins in the NWT and a molting site in Liverpool Bay, NWT. This is the first time precise migratory connectivity and habitat affiliations have been documented for white-winged scoters. Breeding and molting areas were nearly distinct (i.e. small geographic and numerical overlap) from those used by birds wintering further south along the coasts of BC and WA. More evidence is needed before we can solidify the spatial and temporal scale of this affiliation, but this type of association will help researchers and managers investigate, assess, or identify future resource related concerns.

Philopatry

We documented strong evidence for winter site fidelity in breeding males and females. Birds using breeding and molting areas in the NWT had a high return rate to PWS the following winter. Nonbreeding birds had lower return rates and may represent dispersal. This is the first-time winter site fidelity has been documented for white-winged scoters. The strength of philopatry to wintering and molting areas is unknown.

Management and Research Implications

Factors affecting distribution, and ultimately population dynamics, may occur anywhere within a bird’s annual cycle and may result from a variety of complex and interacting events and processes. Testing hypotheses regarding the relationship between migratory connectivity and its behavioral and evolutionary effects requires knowledge of geographical patterns of movements of migratory birds (Webster et al. 2002). While there are several valuable methods to study migratory connectivity, satellite telemetry provides the greatest precision to define migratory pathways and affiliations between breeding, molting, and wintering areas (Webster al 2002).

We have taken the first step in this lengthy process by providing key focal points for research and management studies directed at declines in PWS populations. The mechanisms causing population change are poorly understood. Many causes for past population declines and impediments to future growth or stability have been speculated for the geographical areas we affiliated with PWS birds. These range from changes at global to local levels and all are difficult to test and quantify. For coastal areas these include: changes in ocean temperatures (Piatt and Anderson 1996, Grebmeier et al. 2006), coastal development (Dixon and Gilchrist 2002), exposure to contaminants including oil spills (Vermeer and Peakall 1979, Piatt et al. 1990, Henny et al. 1991, Olendorf et al. 1991, Henny et al. 1995), declines in herring stocks (Sharp et al. 2000), and increased competition from sea otters (Stratton 1981), while climate change and industrial development (Cohen 1997, Rouse et al. 1997, Mackenzie River Basin Board 2004) are leading candidates for altering habitats and affecting wildlife population dynamics in the NWT. If we are to narrow the range of possibilities, we need to identify affiliations and focus local research projects and monitoring efforts in areas with known connectivity.

Our efforts establish a basis for future population delineation and improved monitoring efforts. We present this as a small step toward identifying the mechanisms of population change. We also hope it will be useful to regional planners. Much additional effort among many disciplines is required before we can draw conclusions about population structuring at both smaller and larger spatial scales. However, we emphasize the importance of further defining and refining seasonal affiliations so we can comprehensively assess mortality factors throughout the annual cycle.

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Table 1. Summary of year (1=1999, 2=2000), sex (F= female, M=male), capture location (CL); and general location of breeding, molting, and wintering areas; and last location and date we received data for individual white-winged scoters captured in Prince William Sound, Alaska (PWS) and implanted with satellite transmitters in 1999 and 2000.

Year	Bird ID	Sex	CL[1]	Breeding Area[2]	Molting Area	Winter Area	Last Location	Last Date (M/D/Y)
1	20375	F	SMB	Carcajou Lake, NWT	NA[3]	NA	Breeding Area	8/8/99
1	23887	F	SMB	Anderson River, NWT	Port Moller, AK	Port Moller, AK[4]	Port Moller, AK	11/28/99
1	23890	F	SMB	Anderson River, NWT	Liverpool Bay, NWT	Port Fidalgo, PWS	PWS	12/25/99
1	23894	F	SMB	Mackenzie River, NWT	Liverpool Bay, NWT[4]	NA	Liverpool Bay NWT	7/24/99
1	20376	M	SMB	Nonbreeder	Cook Inlet, AK	Chiginagak Bay, AK	Chiginagak Bay, AK	12/22/99
1	24124	M	SMB	Nonbreeder	Togiak Bay, AK	Naked Island, PWS	PWS	11/23/99
2	20377	F	OI	Old Crow, YT	Knowles Bay, PWS	Sheep Pt., PWS	PWS	1/17/01
2	23889	F	OI	Lac Maunoir, NWT	Liverpool Bay, NWT	Naked Island, PWS	PWS	2/2/01
2	27596	F	OI	Tadek Lake, NWT	NA	NA	Tadek Lake, NWT	7/9/00
2	27597	F	OI	Great Bear Lake, NWT	Liverpool Bay, NWT	Simpson Bay,PWS	PWS	1/16/01
2	27599	F	OI	Nonbreeder	Nushagak Peninsula, AK	Bristol Bay, AK	Becharof Lake, AK	3/15/01
2	30046	F	OI	Great Bear Lake, NWT	Great Bear Lake, NWT	Glacier Isl., PWS	PWS	12/22/00
2	30048	F	OI	Tadenet Lake, NWT	Tadenet Lake, NWT	Green Isl., PWS	PWS	1/14/01
2	30049	F	OI	Old Crow, YT	Kuskokwim Bay, AK	Umnak Isl., AK	Umnak Isl., AK	1/28/01
2	12992	M	OI	Lac Maunoir, NWT	Liverpool Bay, NWT[4]	NA	Liverpool Bay, NWT	7/6/00
2	23888	M	OI	Yukon Flats, AK	Liverpool Bay, NWT	Knowles Bay, PWS	PWS	11/8/00
2	29992	M	OI	Great Bear Lake, NWT	Liverpool Bay, NWT	Glacier Isl., PWS	PWS	3/31/01
2	29994	M	OI	Great Bear Lake, NWT	Franklin Bay, NWT	Smith Isl., PWS	PWS	1/2/01
2	29995	M	OI	Nonbreeder	Cape Yakataga, AK	Icy Bay, AK	Icy Bay, AK	2/17/01
2	30047	M	OI	Great Bear Lake, NWT	Cape Suckling[4]	NA	Kayak Island, AK	8/27/00
2	30051	M	OI	Nonbreeder	Cape Newenham, AK	NA	Cape Newenham, AK	11/29/00

[1] St. Matthews Bay, PWS (SMB), Orca Inlet, PWS (OI)

[2] Northwest Territories, Canada (NWT), Yukon Territory, Canada (YT)

[3] Data not available (NA)

[4] Presumed affiliation. Transmitter failed prior to verification.

able 2. Median departure date (range) from coastal capture areas in Prince William Sound (PWS) (1999, 2000) by reproductive status (RS) and median arrival dates (range) and duration by sex (Female/Male) at breeding areas. Mean arrival dates for nonbreeding birds (NB) going directly to coastal molting areas are not included (refer to Table 3).

Year	RS[1]	PWS Capture Location	#F/#M[2]	Winter Area Median Departure Date (Range)	#F/#M[2]	Breeding Area Median Arrival Date (Range)	#F/#M[2]	Breeding Area Mean No. Days (Range)
1999	B	St. Matthew's Bay, 60.8°N, 146.3°W	5/0	31 May (27 May – 3 Jun)	3/0	6 Jun (3–13 Jun)	3/0	51 (34-72)[3]
	NB		0/2	1 June (31 May – 2 Jun)	0/2	—	—	—
2000	B	Orca Inlet 60.5°N, 145.9°W	7/5	24 May (18–27 May)	7/5	31 May (25 May – 8 Jun)	5/3	66 (15-107)/27 (16-44)
	NB		1/2	25 June (14 Jun – 8 Jul)	1/2	—	—	—

[1] Migrated to inland breeding area (B) or remained on marine waters (NB) after departing wintering area.
[2] F (Female), M (Male).
[3] A fourth female spent 62 days at a breeding area before we lost transmission.

Table 3. Median arrival and departure dates and duration at molting areas and arrival dates at wintering areas by sex (Female/Male) and reproductive status (RS) for birds captured in late-winter in Prince William Sound (1999, 2000). Birds that bred and molted or molted and wintered in the same area are excluded from molting and winter arrival date and duration calculations.

		Molting Area					Winter Area	
RS	Year	F/M	Arrival	F/M	Departure	Mean # days (range)	F/M	Arrival[1]
Breeding	1999	3/0	25 Jul (9 Jul-23 Aug)	1/0	4 Oct	69	1/0	7 Oct
	2000	4/4	20 Jul (14 Jul – 9 Aug)/ 30 Jun (21 Jun- 25 Jul)	3/1	29 Sep (15 Sep – 28 Nov)/ 28 Sep[2]	87[3] (75-111)/ 95	5/3	25 Sep (15 Sep – 1 Dec)[4]/ 1 Oct (21 Sep- 11 Oct)
Non-breeding	1999	0/2	16 Jun (13-20 Jun)	0/2	30 Aug (29 Aug – 1 Sep)	74 (72-76)	0/2	4 Sep (3 Sep – 4 Sep)
	2000	1/2	NA[5]/20 Jun (14 – 25 Jun)	1/2	11 Oct/4 Sep (28 Aug – 12 Sep)	72[6]/77 (75-79)	1/1	11 Oct/29 Aug

[1] Does not include 2 females that molted at breeding area.

[2] Poor location data before and after departing molting area allowed calculations for only one male.

[3] Does not include birds that molted and wintered in same area.

[4] Two birds from returning from the Northwest Territories were estimated to return to the northern Gulf of Alaska by 10 July (male) and 27 July (female) to molt and winter. The male is not included in the table due to poor transmitter performance.

[5] A non-breeding female was present in Bristol Bay on 31 July, the first location data since 16 July.

[6] Minimum estimate.

Figure 1. Map of Prince William Sound, Alaska showing capture locations in 1999 and 2000 for white-winged scoters implanted with satellite transmitters.

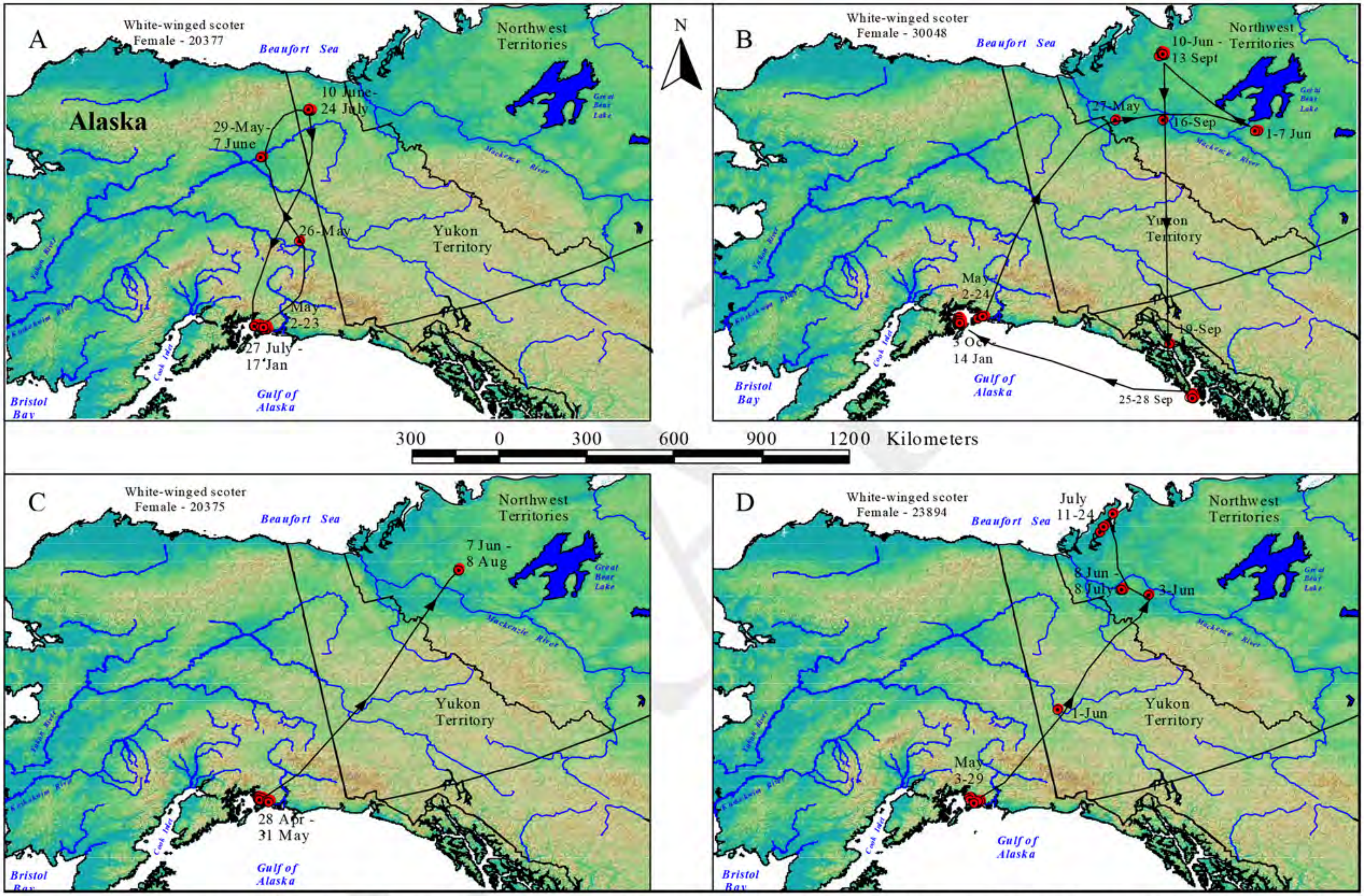

Figure 2. Movements of female white-winged scoters 20377, 30048, 20375, and 23894 marked with satellite transmitters from Prince William Sound, AK. Lines are not intended to depict actual routes.

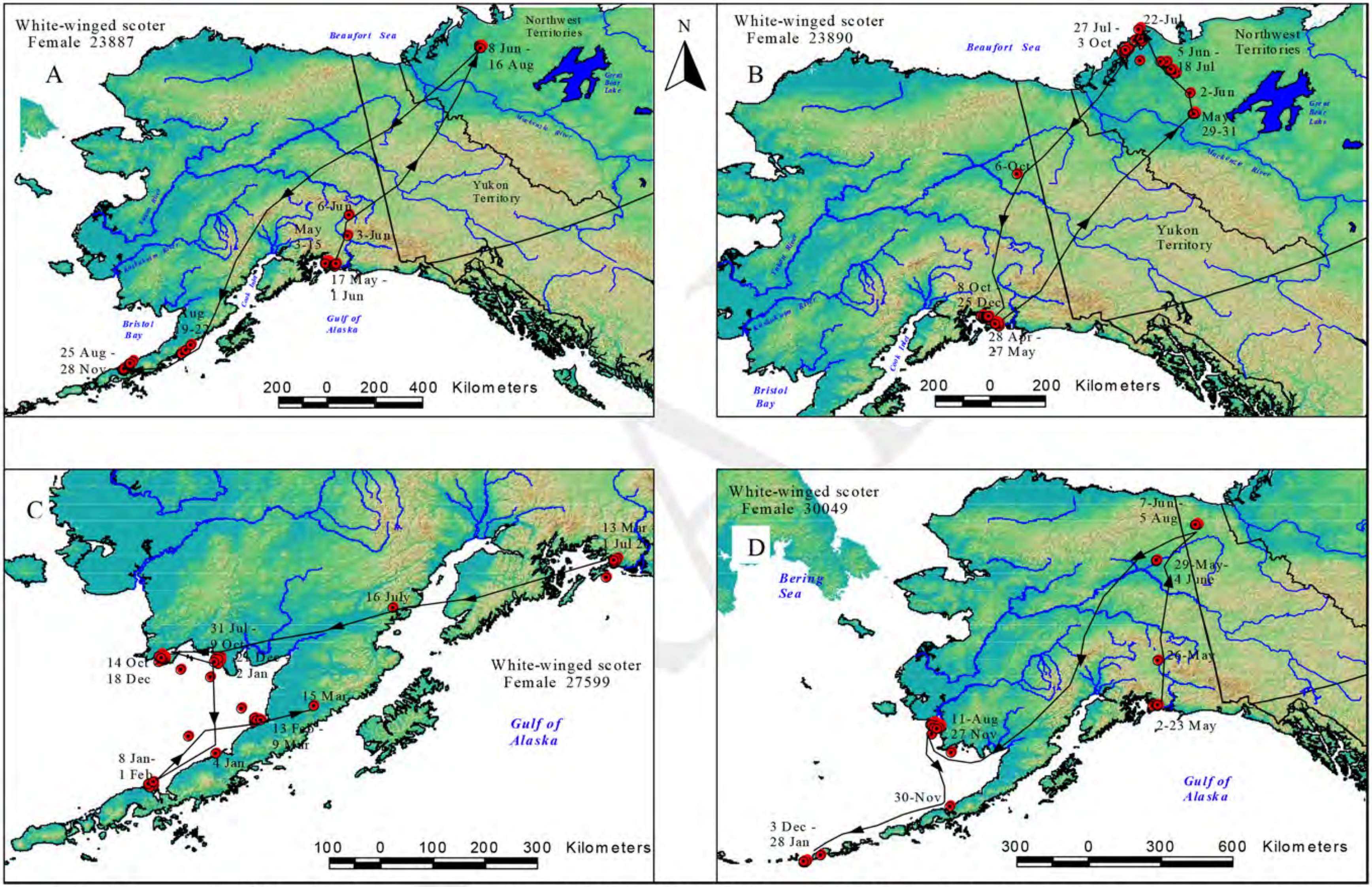

Figure 3. Movements of female white-winged scoters 23887, 23890, 27599, and 30049 marked with satellite transmitters from Prince William Sound, AK. Lines are not intended to depict actual routes.

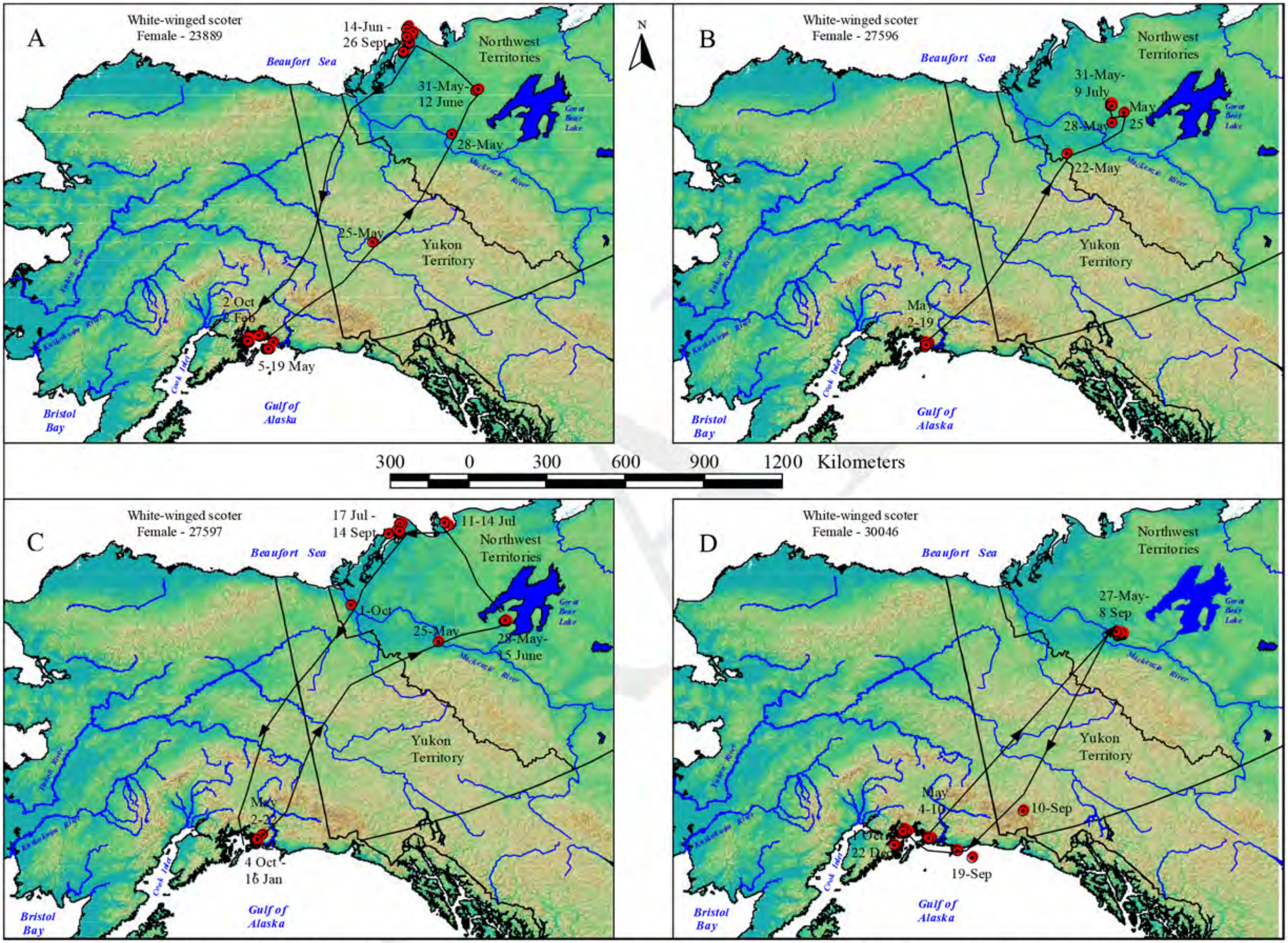

Figure 4. Movements of female white-winged scoters 23889, 27596, 27597, and 30046 marked with satellite transmitters from Prince William Sound, AK. Lines are not intended to depict actual routes.

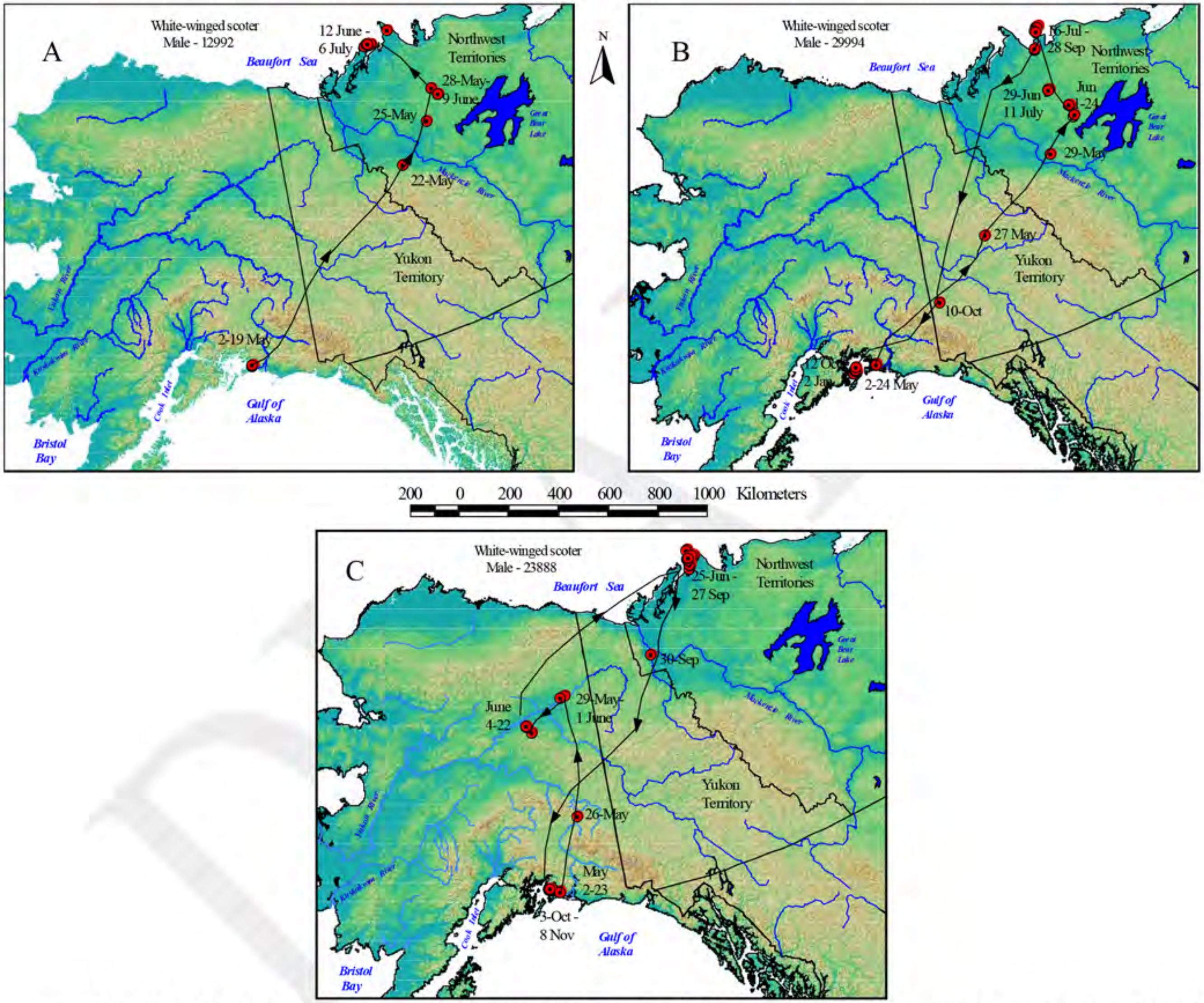

Figure 5. Movements of male white-winged scoters 12992, 29994, and 23888 marked with satellite transmitters from Prince William Sound, AK. Lines are not intended to depict actual routes.

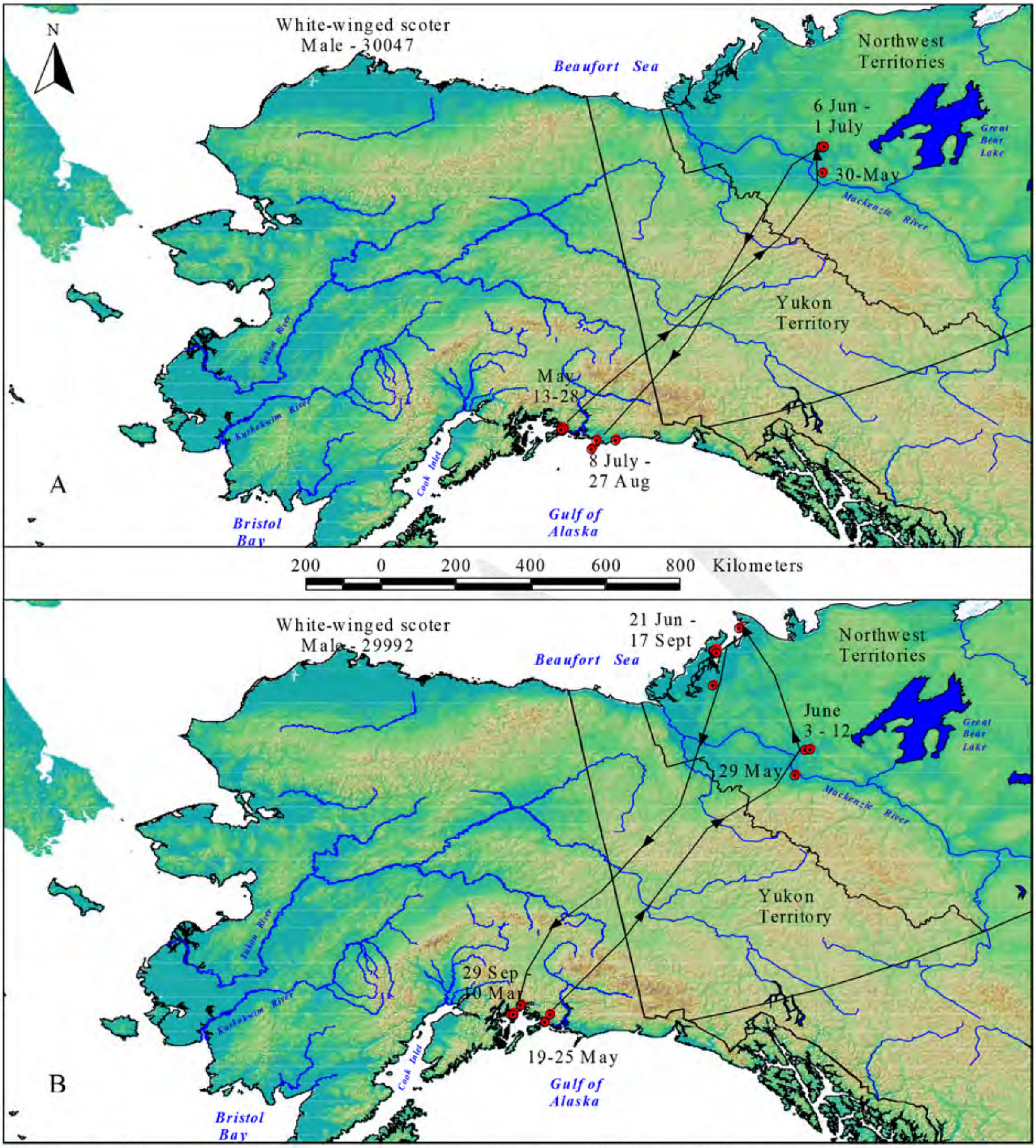

Figure 6. Movements of male white-winged scoters 30047 and 29992 marked with satellite transmitters from Prince William Sound, AK. Lines are not intended to depict actual routes.

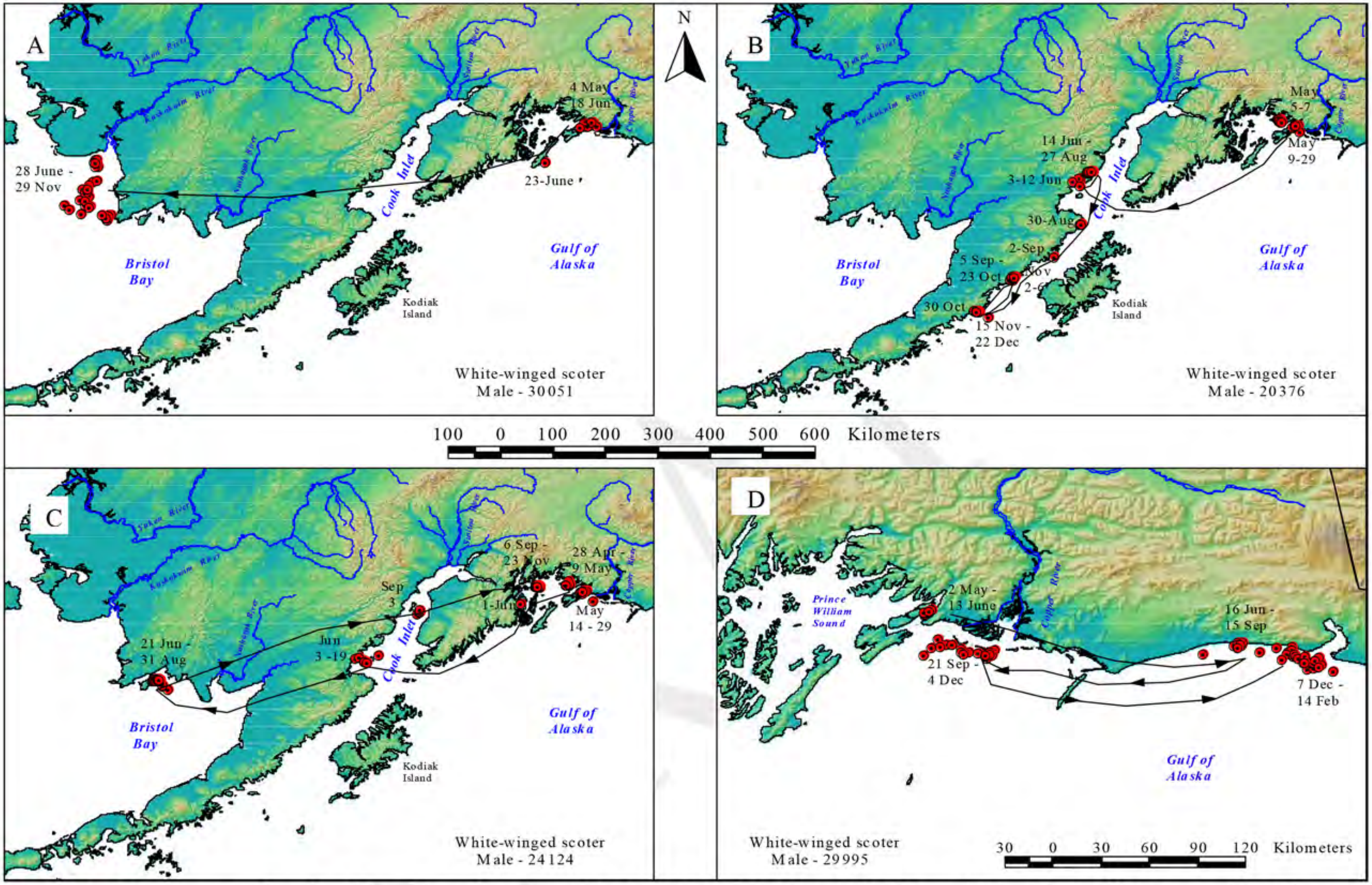

Figure 7. Movements of male white-winged scoters 30051, 20374, 24124 and 29995 marked with satellite transmitters from Prince William Sound, AK. Lines are not intended to depict actual routes

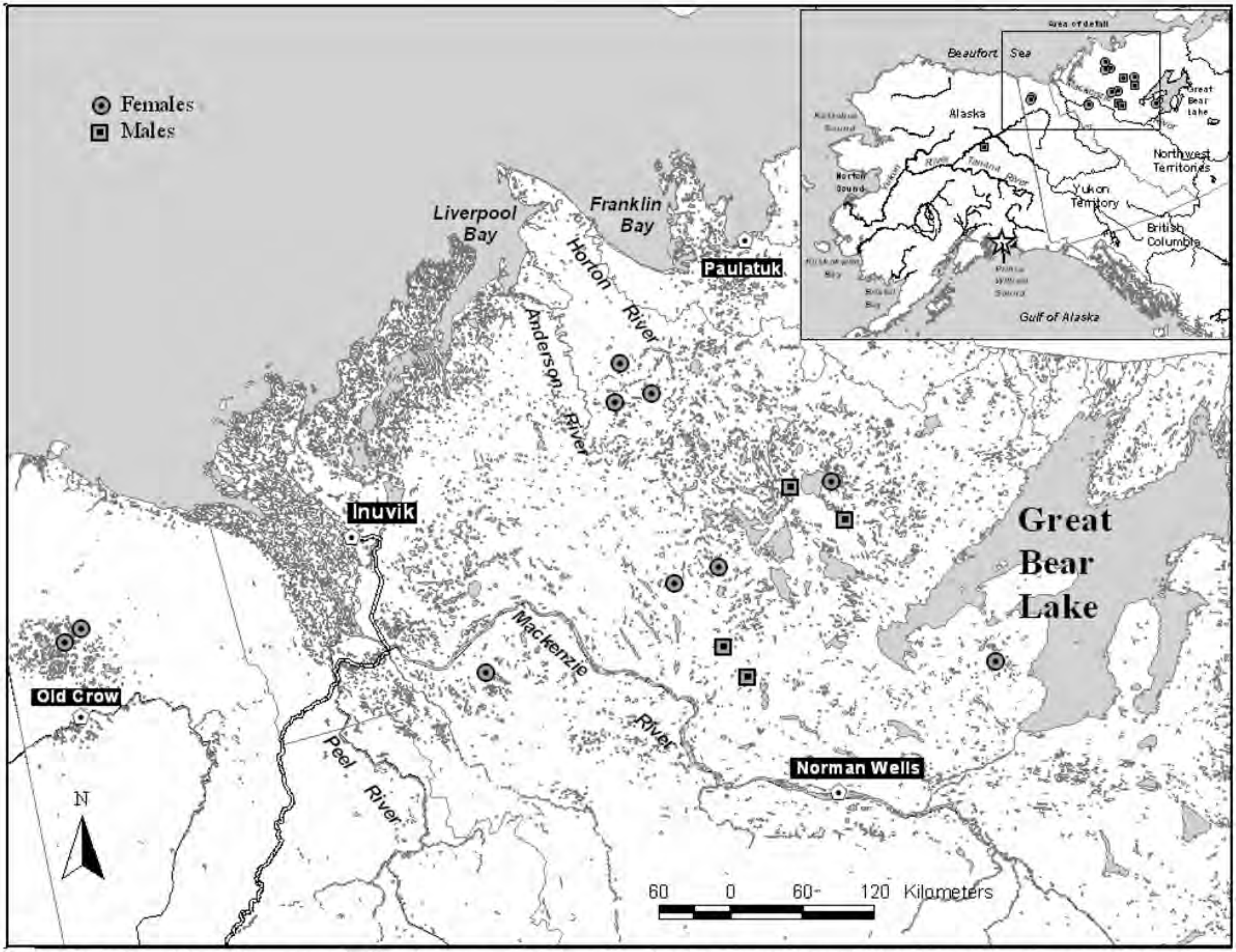

Figure 8. Map of breeding areas in Northwest and Yukon Territories, Canada used by white-winged scoters from Prince William Sound, Alaska. One male settled further east in the Yukon Flats, Alaska and is not depicted.

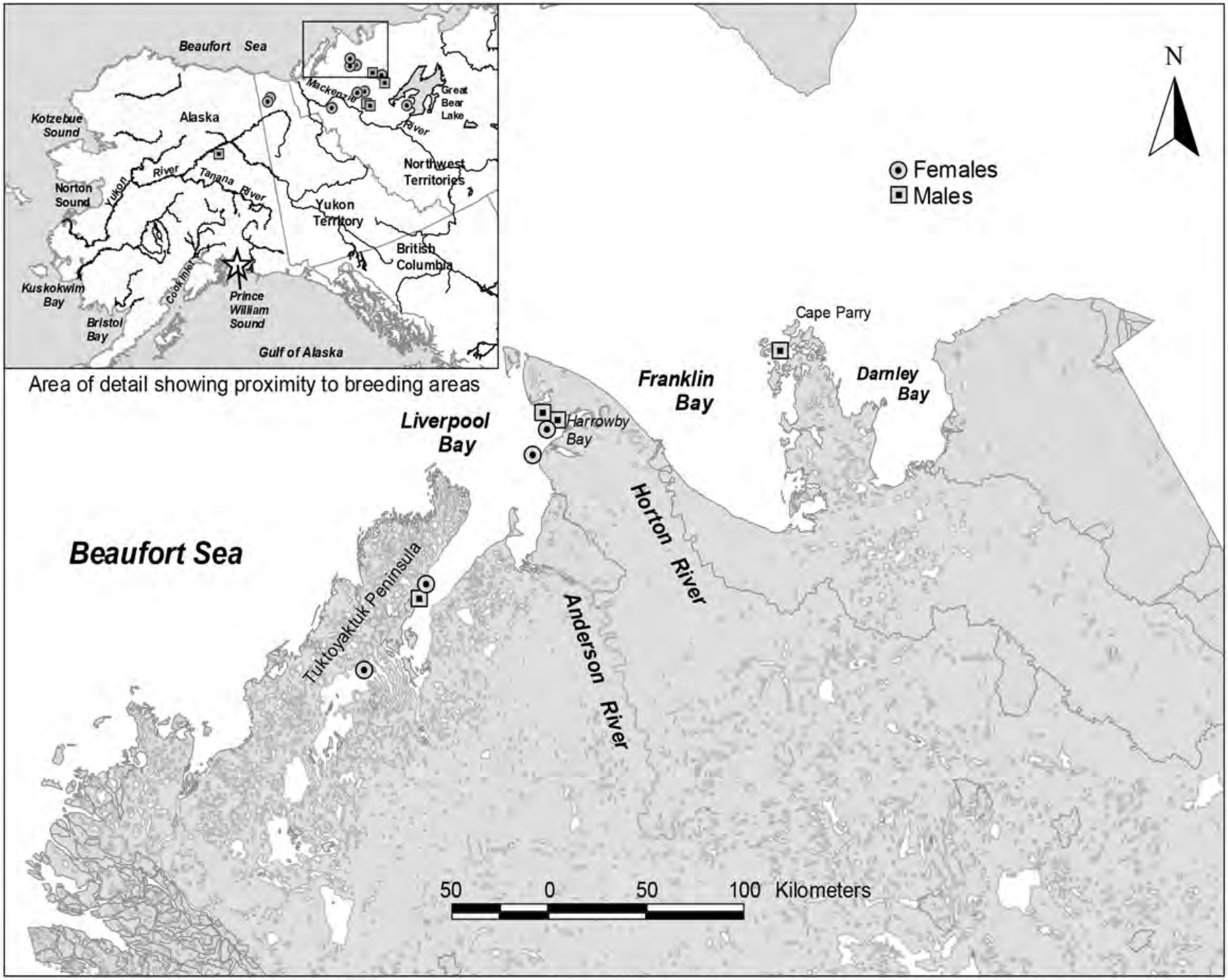

Figure 9. Map of molting areas in the Beaufort Sea, Northwest Territories, Canada used by white-winged scoters from Prince William Sound, Alaska. Additional molting sites were located in the Bering Sea and Gulf of Alaska.