Exxon Valdez Oil Spill
Restoration Project Annual Report

Scoter Life History and Ecology: Linking Satellite Technology with Traditional Knowledge

Restoration Project 99273
Annual Report

This annual report has been prepared for peer review as part of *Exxon Valdez* Oil Spill Trustee Council restoration program for the purpose of assessing project progress. Peer review comments have been addressed in this annual report.

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Scoter Life History and Ecology: Linking Satellite Technology with Traditional Knowledge

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Study History: Restoration Project 99273 continues studies initiated in 1998 (RP 98273). The goal of the study is to monitor movements of surf and white-winged scoters using satellite telemetry, and to incorporate traditional knowledge into our understanding of scoter ecology. Scoters, a sea duck, are an important subsistence resource. Scoter numbers, however, have reportedly declined for unknown reasons. The decline is a concern to both waterfowl managers and subsistence consumers. This report describes results of the study's second year.

Abstract: We used satellite telemetry to identify migration patterns and seasonal distribution of scoters. We captured 215 sea ducks (87% scoters) near St. Matthew's Bay, Prince William Sound (PWS) during early spring 1999. We surgically implanted satellite transmitters in 28 scoters (18 surf and 10 white-winged). Scoters departed PWS by 4 June. Three male scoters (1 surf, 2 white-winged) traveled west and remained on the coast of Alaska throughout the summer. We suspect these were non-breeding males. We identified 2 areas used by scoters during the nesting season (interior Alaska, northern Canada). Four females and three males spent a large portion of the summer in northern Canada. Limited location data for 3 female surf scoters suggests that they remained in interior Alaska during the breeding season. We identified 7 areas used by scoters during the wing molt, all located on the coast. After the molt, 4 scoters (2 surf, 2 white-winged) returned to PWS, a female surf scoter traveled to Vancouver Island, a male white-winged scoter remained in Shelikof Strait, and a female white-winged scoter traveled to Port Moller. The extensive movements exhibited by scoters during this study could not have been observed without the use of satellite telemetry.

Key Words: Alaska, capture, directional finder, lower Cook Inlet, migration, Prince William Sound, satellite telemetry, scoter, sea duck, surf scoter, traditional knowledge, 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, 333 Raspberry Road, 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.state.ak.us/adfg/wildlife/waterfwl/scoter/surf.htm.

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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.

Scoters are sea ducks, some of which migrate through or spend the winter in Prince William Sound (PWS) and lower Cook Inlet (LCI). 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.

In 1998, we initiated this study to integrate traditional ecological knowledge, scientific methods and modern technology to begin to understand scoter ecology. We report on the second-year of this three-year study. As in the first year, we used satellite telemetry to track scoter movements throughout most of the year to identify important habitat areas. We captured scoters in PWS, Alaska near the mouth of St. Matthew's Bay, Port Gravina during the spring in 1999. We used floating mist nets and decoys to catch sea ducks. Ducks were captured as they flew into the net. A captured bird was immediately removed from the net, placed in a small kennel and taken to a nearby vessel.

Once aboard the vessel, birds were weighed, morphological measurements were taken, blood was sampled, and a USFWS leg band was attached. The bird was anesthetized and prepared for surgery. A veterinarian (Dr. D. M. Mulcahy) implanted the satellite transmitter in the abdominal cavity of the bird. Respiration rate, body temperature, and heart rate of the bird were monitored during surgery. No birds died during surgery. Each bird was held for approximately 5 hours after surgery and then released on the water.

Two models of implantable satellite transmitters were used in the study. Each transmitter contained a sensor that recorded the bird's internal temperature and a sensor that recorded battery voltage. Transmitters were programmed to transmit at various duty cycles depending on expected bird activity and movements. Signals were analyzed using Argos Data Collection and Location Systems.

We captured and banded 215 sea ducks during 7 days of effort. Satellite transmitters were surgically implanted in 18 surf and 10 white-winged scoters. Nine transmitters were recovered in the field from birds that died soon after release. Of these, 3 were cold sterilized and re-implanted in scoters (1 surf and 2 white-winged) captured in St. Matthew's Bay. Seventeen birds (12 within 10 days of release) were known to have died and 1 bird is suspected of dying. Except for one hunter-shot bird, we do not know the specific cause of death.

Signal quality and longevity ratings varied among transmitters that remained on the air for >30 days, consequently the number and accuracy of locations varied among birds. Better performing

transmitters provided more locations, with greater accuracy, for a greater proportion of the expected transmission cycles.

All scoters departed PWS by 4 June. Three male scoters utilized coastal areas exclusively during the monitoring period, consequently we do not believe they attempted to breed. All non-breeding males traveled west to LCI after departing PWS. A white-winged scoter remained in LCI for the wing molt then traveled to the southeastern coast of the Alaska Peninsula. Two males traveled to molting sites in western Alaska. A white-winged scoter molted in Togiak Bay before returning to PWS. A surf scoter molted in Kuskokwim Bay before we lost contact with the transmitter.

Two male surf scoters traveled to northern Canada after departing PWS. One male spent time during the nesting season near Old Crow, Yukon Territory before traveling to Norton Sound where it remained to molt. Another male spent time during the nesting season near the Mackenzie River, Northwest Territories (NWT), before molting in Kotzebue Sound. It is possible that these males accompanied females to nesting areas and left for the coast at the onset of incubation. Both males returned to PWS after the molt.

Four of 5 female white-winged scoters were located in the NWT during the nesting season. We are not certain if these females nested. Three females returned to the coast to molt; one transmitter failed prior to the molt. One female traveled approximately 1,950 km to the south coast of the Alaska Peninsula where it molted and remained for the winter (Port Moller). Another female molted in Liverpool Bay, NWT before returning to PWS. The third female was last located in the Eskimo Lakes region, NWT before going off the air.

Satellite transmitters implanted in female surf scoters received relatively low evaluation ratings, resulting from infrequently received transmissions and minimal location data. This limits our ability to describe detailed movements, and to identify stationary periods. With one exception, we did not receive location data for female surf scoters after 16 July (approximately 80 days after release), and for one female we never received reliable location data (poor signal quality) for areas outside of PWS.

Three of 5 female surf scoters were located in interior Alaska during the nesting season and one traveled to northern Canada. The numerous lakes and drainages in these areas provide suitable nesting habitat for scoters. One female returned to PWS before traveling further south to Vancouver Island, British Columbia.

Photographs of the capture, surgery, satellite transmitter, and color maps illustrating surf scoter movements can be viewed at http://www.state.ak.us/adfg/wildlife/waterfwl/scoter/surf.htm.

INTRODUCTION

The current population status for many of Alaska's 15 sea duck (Mergini) species is uncertain (U.S.Fish and Wildlife Service 1999). Populations of several species, however, appear 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 of sea ducks results from the inherent difficulties associated with assessing population trends, and the lack of a standardized inventory and monitoring protocol designed specifically for sea ducks (U.S.Fish and Wildlife Service 1999). Further, little is known about the ecology and life history processes of sea ducks compared with those of dabbling (Anatini) and diving ducks (Aythyini). Sea ducks are widely dispersed throughout remote areas, conducting a winter study in the marine environment is difficult, and in some part, sea ducks have been neglected because of a lack of interest. This makes it extremely difficult to obtain and interpret information on population trends, productivity, survival, and harvest.

The best available evidence indicates that scoter (*Melanitta spp.*) populations have declined. Surf scoters (*M. perspicillata*), black scoters (*M. nigra*), and white-winged scoters (*M. fusca*) all occur in Prince William Sound (PWS) and lower Cook Inlet (LCI) with surf scoters being the most abundant (Isleib and Kessel 1973). Surf scoters occur as both a year-round residents and migrants. Some nonbreeders remain in PWS during the summer. It has been estimated that scoters in Alaska have declined by as much as 40% since 1977 (Hodges et al. 1996). Between 1972-1973 and 1989, the estimated population of scoters wintering in PWS declined from 56,600 to 14,800 birds. Summer populations (July) declined from 13,000 to 5,400 birds during the same period (Klosiewski and Laing, 1994). Surf Scoters declines by an estimated 83% and white-winged scoters declined by 20 percent (Agler et al. 1999). An estimated 1,000 scoters died as a direct result of the *Exxon Valdez* oil spill (John Piatt, pers. comm.). The number of scoters in PWS has increased since the spill (Agler and Kendall 1977, Irons et al. in review) but remains below historic levels.

Scoters are an important subsistence resource to the people living in the communities of PWS and LCI (James Fall, ADF&G, pers. comm., Gary Kompkoff, Tatitlek IRA, pers. comm.). Native inhabitants of PWS have used scoters (locally known as black ducks) as a subsistence resource for centuries. Bones from surf scoters, black scoters, and white-winged scoters are the most abundant avifaunal remains found at archeological sites in PWS over a 2,000-year period (Linda Yarborough, USFS, pers. comm.). Currently, scoters comprise the majority of the sea duck harvest in the communities of Tatitlek, Chenega Bay, Port Graham, and Nanwalek (Scott et al. 1996). Residents of the communities affected by the *Exxon Valdez* Oil Spill remain concerned about the abundance of their traditional food resources and maintaining their cultural ties to traditional use of fish and wildlife (*Exxon Valdez* Oil Spill Trustee Council, 1999).

The large decline in scoter numbers in PWS between 1972-1973 and 1989 may be a result of long-term oscillations in ocean temperatures in the Gulf of Alaska (Piatt and Anderson 1996) or effects from exposure to contaminants. Scoters are among the species most vulnerable to oil spills (Piatt et al. 1990); several studies have shown scoters and other sea ducks to bioaccumulate trace metals and organochlorines from their environment (Vermeer and Peakall 1979, Henny et al. 1991, Olendorf et al. 1991, Henny et al. 1995). Among the three scoter species, surf scoters are most associated with intertidal areas in PWS (Patten et al. 1998). 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). A white-winged scoter die-off occurred in the Cape Yakataga area in southeast Alaska during 1990-1992 (Henny et al. 1995). Although no definitive cause could be identified, elevated levels of cadmium were detected in the birds, but no source of contamination could be identified.

PWS herring stocks suffered a dramatic decline in 1993 and stocks have remained depressed (Morstad et al. 1997). Increasing sea otter populations since the mid-1900's may have led to increased competition for food between scoters and otters (Stratton 1981). Quite likely, any decline results from a combination of factors such as food and habitat changes, contaminants, or climate change. Climate and ecosystem changes or human activities, such as hydroelectric development (Savard and Lamothe 1991) or introductions of exotic species (Bordage and Savard 1995) on breeding or molting areas can also have profound affects on abundance or distribution of a population.

Scoters are among the least studied of North American waterfowl (Bellrose 1976, Savard and Lamothe 1991, Henny et al. 1995, Savard et al. 1998). Little is known about the ecology, breeding areas, molting areas, and migration routes of these species anywhere in North America (Bellrose 1976, Herter et al. 1989, Goudie et al. 1994, Savard et al. 1998). Although scoters are known to breed throughout much of Alaska and Canada (Gabrielson and Lincoln 1959, Godfrey 1986), nothing is known about specific populations and the affiliations between winter, breeding, and molting areas. The few studies that have identified molting sites have not made the link between these and winter and breeding areas (Johnson and Richardson 1982, Dau 1987).

Exposure of migratory waterfowl to contaminants or other mortality factors may occur anywhere in a bird's annual cycle. The difficulty of detecting causes of population declines in a migratory species, especially one with a broad range, is confounded by a lack of specific information on affiliations between breeding, molting, and wintering areas (Henny et al. 1991).

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 important staging, nesting, molting and wintering areas and understanding the links between these areas would allow us to direct sampling and monitoring efforts at specific population segments. Traditional marking of birds with metal leg bands has little success with sea ducks because so few birds are killed in the harvest. The potentially vast geographic range of these birds makes conventional telemetry impractical and costly. Satellite telemetry studies offer the best method for identifying migration routes, staging areas, and breeding, molting, and wintering sites. Satellite transmitters have been used effectively in other studies designed to monitor movements of sea ducks (Petersen et al. 1995, Dickson et al. 1998, Robert et al. 2000, Savard et al. 1999).

In summary, little is known about the ecology, breeding areas, molting areas, and migration routes of scoters anywhere in North America. Population trends in scoters are uncertain, but appear to be declining in most regions. Affiliations between breeding and wintering areas are unknown, compounding meaningful integration of survey data. The susceptibility of seaducks to contaminants is a concern to resource managers and subsistence consumers. Determining distribution is the first step in assessing breeding, wintering, and molting ecology. Potential breeding and molting sites range throughout Alaska and western Canada.

In 1998, we initiated a study that integrates traditional ecological knowledge, scientific methods, and modern technology to begin to understand scoter ecology. This paper reports on the second year of this three-year study. As in 1998, we used satellite telemetry to track scoter movements throughout most of the year, and identify critical habitat areas.

STUDY AREA AND METHODS

Capture

During the herring spawn in Prince William Sound (April, May), sea ducks gather in large flocks to feed on roe. An aerial reconnaissance survey of historical spawning areas in Prince William Sound indicated that several thousand sea ducks were concentrated in Port Gravina. We used floating mist nets to capture sea ducks in Port Gravina near the mouth of St. Matthew's Bay (60.734N x 146.356W) from 26 April to 5 May 1999 (Fig. 1). Each trap consisted of two mist nets (3m or 1.5m by 18m) hung between three masts (3.05m or 1.8m by 1.9cm dia.) made of aluminum conduit. Each mast was attached to a hub consisting of four aluminum poles (1.8m by 1.9cm dia.) connected at one end forming a + pattern. Attached at the distal end of each pole was a closed-cell, foam float painted to resemble a scoter. The trap was erected on the beach and towed into place by skiff, and placed up to 100m from shore. Two additional lines, the length of the net, connected each hub to relieve tension on the net when towed. One end of the trap was secured to the shore with a line and the other end was anchored to the sea floor. We placed decoys near the nets to lure ducks. Ducks were captured when they flew or swam into the net. Three traps were used during our capture effort. An observer on-shore, or in a skiff, was stationed near each trap site to monitor nets at all times. A captured bird was immediately removed from the net, placed in a small kennel and taken to a nearby vessel.

Surgery

Once aboard the vessel, the bird was weighed, morphological measurements were taken, blood was sampled, and a USFWS metal band was attached to a leg. 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. Bird's were anesthetized and prepared for surgery. A veterinarian (D. M. Mulcahy, D.V.M.) implanted the satellite transmitter in the abdominal cavity of the bird (Korschgen et al. 1996). The 21.6cm stainless steel antenna exited the bird caudally, near the base of the tail. Respiration rate, body temperature and heart rate of the bird were monitored during surgery. No birds died during surgery. Each bird was held for approximately 5 hours after surgery and then released on the water.

Description of Satellite Transmitters

We used 2 types of satellite transmitters designed for surgical implantation (Microwave Telemetry, Inc). One model weighed approximately 36 grams, and measured 10mm x 55mm x 35mm (n = 10). The second model weighed approximately 52 grams (n = 18) and was of similar dimensions but had a 5mm x 31mm x 24mm rectangular protrusion on the left side. A newly designed power source, expected to increase transmitter life, accounted for the additional mass and larger size. Because of their smaller body size, only female surf scoters received the lighter transmitter package. All satellite transmitters were reinforced to withstand external pressure and were equipped with temperature and battery voltage sensors. The temperature sensor recorded the birds internal body temperature. Temperature sensor readings below normal body temperature (41^0 C) indicated the bird died.

Satellite transmitters were programmed to transmit at various duty cycles depending on expected bird activity and movements. The smaller transmitters were programmed with 4 duty cycles and the larger transmitters were programmed with 5 duty cycles (Table 1). Five hundred hours of transmission was the expected life for the lighter transmitters, > 500 hours for the heavier transmitters (P. Howey, Microwave Telemetry, pers. comm.). All transmitters were programmed to transmit continuously when the internal sensor recorded temperatures < 20^0 C (ca. ambient). This allowed us to use a UHF pulse directional finder (ISEM-Gonio 400P Cospas-Sarsat ground receiver) to recover transmitters from birds that died in PWS soon after release, regardless of duty cycle.

Signals were analyzed using Argos Data Collection and Location Systems. Four polar-orbiting satellites receive signals from the transmitter. Sensor data was transmitted every 60 seconds during the on cycle in frames of 4, 8 bit messages (i. e. a total of 32 bits per transmission). The bird's location was calculated from a Doppler shift in signal frequency (Fancy et al. 1988). We used Agros "standard" and "auxiliary" location data processing services. The accuracy of "standard locations" (class codes 1, 2, and 3) is generally <1000m and requires that the satellite receives at least 4 messages during a pass over the transmitter. Location accuracy for "standard locations" with class code 0 is >1000m with no maximum limit. The accuracy of "auxiliary locations" (class codes A and B) can not be calculated because the normal system specifications are relaxed to provide locations calculated from 2 or 3 messages. The lack of an estimate of accuracy, however, does not necessarily mean that "auxiliary locations" are inaccurate. Argos locations with class code Z are considered invalid and were rejected. Class code Z messages are informative because they confirm that the transmitter is still active, and temperature sensor data enables us to determine the status of the bird (dead or alive).

We accepted all "standard locations" with class codes 1, 2 and 3 and used them to map scoter movements. When class codes 1, 2 and 3 were not obtained during a transmission cycle, we used locations with class codes A, B or 0. We accepted or rejected locations with these class codes based on their proximity to previously and subsequently accepted locations. We only accepted one location with class code A, B or 0 per transmission period to map scoter movements.

Satellite Transmitter Performance Evaluation

We evaluated the performance of the satellite transmitters used during this study by assigning them ranks based on signal quality and transmitter life. Identifying transmitters that performed well provides a standard for which other transmitters can be compared, and may prove useful in comparing transmitter performance among years, among studies using different study animals, conducted in different geographic locations, and using different transmitter designs.

Signal quality was measured in 4 ways:

1) **transmission consistency** – The proportion of actual transmission cycles in which data was received. Data refers to either location and sensor data, or sensor data alone. The number of expected transmissions was calculated based on programmed duty cycles and the actual life of the transmitter, or if the bird died, the period the bird was known to be alive. If we received data for each expected transmission cycle, the transmitter would receive a score of 1.00.
2) **location accuracy** – The proportion of transmission cycles in which data was received that included at least one location with a quality code of 1, 2 or 3 (standard locations). Standard locations have an accuracy of <1000 m and are preferred to the less accurate auxiliary locations. If we obtained one location with a quality code of 1, 2, or 3 for each received transmission cycle, the transmitter would receive a score of 1.00.
3) **location deficiency** – The proportion of transmission cycles in which no valid location data (class codes 1, 2, 3, A, B, 0) was provided. Location data are not always obtained during the satellite's pass over the transmitter, and on occasion only invalid locations are provided (class code Z). Sensor data, however, are usually provided because it only requires that one message pulse reach the satellite. If we obtained no valid location data for each received transmission, the transmitter would receive a score of 1.00. Thus, for this category, the higher the score the poorer the performance.
4) **abundance of accurate locations** – The average number of locations with class code 1, 2 or 3 received for each transmission cycle that included at least one location with a class code 1, 2, or 3. If we received 100 locations with class code 1, 2, or 3 for 25 transmission cycles each containing at least one location with class code 1, 2, or 3, then the transmitter average would be 4.0 locations.

A number of physical factors (e. g. antenna orientation, geographic location, bird activity), other than individual variation in transmitter components, can influence the quantity and quality of data received. We discuss these factors with respect to our results.

Transmitter longevity is the number of days from the date of deployment until the last date data was received, or if the bird died, the last day the bird was known to be alive. We do not know the specific reason why transmitters stopped transmitting. We suspect that short-lived transmitters failed because of component defect, or the bird died but we could not detect its death. Transmitters in dead birds are susceptible to damage by predators or scavengers, and they may be carried to areas where reception is not possible (burrows, dropped in water). For longerlived transmitters, possible reasons for transmission failure would include exhausted battery life, component failure, or antenna damage.

Kachemak Bay Capture Effort

To increase the geographic scope of the study, we attempted to catch scoters in Kachemak Bay (KB) located on the eastern shore of lower Cook Inlet (LCI). Several thousand scoters were observed in the nearshore waters of KB during March 1999 (Petrula and Rosenberg 2000). An aerial reconnaissance survey of KB during our trapping effort in mid-April, 1999 indicated that <500 scoters (mostly surf) were present. The majority of scoters were observed near Halibut Cove. During 3 days of effort we trapped 15 sea ducks (12 harlequin ducks, 3 white-winged scoter females). No transmitters were deployed because the white-winged scoters were all sub-adults.

Photographs of the capture, surgery, and satellite transmitter can be viewed on the Internet at the following site: http://www.state.ak.us/adfg/wildlife/waterfwl/scoter/surf.htm.

RESULTS

Capture and Surgery

We captured and banded 215 sea ducks (87% scoters) in PWS during 7 days of effort (Table 2). Satellite transmitters were surgically implanted in 18 surf scoters (10 females, 8 males) and 10 white-winged scoters (6 females, 4 males) (Table 3). No birds died during surgery. Nine transmitters were recovered in the field from birds that died soon after release (Table 3). Of these, 3 were cold sterilized and re-implanted in scoters (1 surf and 2 white-winged) captured in St. Matthew's Bay (Table 3).

Transmitter Performance

We evaluated the performance of 15 satellite transmitters (Table 5). Only transmitters in live birds that remained on the air for > 30 days were used in the evaluation. We evaluated transmission quality and longevity separately. Both, however, need to be considered when comparing performance among transmitters. Transmitters may provide ample location data but last for a short period, or a transmitter may have a long lifetime but provide little location data. Longevity alone is not a meaningful measure of transmitter performance, per se, because we are not always certain whether the loss of transmission is caused by component failure or signal obstruction. When a bird dies the transmitter may be situated in a location or orientation that blocks transmission to a satellite. In these cases a death may go undetected and we have no means of assessing transmitter life. We know that one bird (14021) died before the transmitter failed (see below). Conversely, we know that one transmitter failed before the bird died (23888).

Quality and longevity ratings varied among transmitters, consequently the number and accuracy of locations varied among birds (Table 5). Obviously, the better performing transmitters provided more locations, with greater accuracy, for a greater proportion of the expected transmission cycles (Table 5). For the best performing transmitter (23893), we received location data for each expected transmission cycle, 99% of which contained an average of 6.3 locations with accuracy of < 1000 m (class codes 1, 2, or 3) (Table 5). Seven other transmitters (ranked 2-7) also performed well with regard to overall signal quality (Table 5). All 8 of the higher ranked transmitters were the heavier (52 g) model. Conversely, seven transmitters, while relatively long-lived, ranked 8-13 in overall quality by providing substantially fewer and less accurate locations (Table 5). Five of these seven transmitters were the lighter (36 g) model. Lighter transmitters were only implanted in female surf scoters.

Transmitter 23888 failed after 10 August. We acquired the frozen carcass of male surf scoter 23888 with both the bird and transmitter intact. A necropsy (see below) was performed on the carcass and the transmitter was shipped to the manufacturer to determine the cause of transmitter failure. Body fluid leaked into the transmitter either through the antenna exit or via a crack in the housing (Paul Howey, Microwave Telemetry, Inc., pers. comm.)

Mortality

Seventeen birds surgically implanted with satellite transmitters were known to have died and 1 bird is suspected of dying (Table 4). Of the birds known to have died, 12 died within 10 days of release and 2 died between 18 and 22 days after release (Table 4). We do not know the specific cause of death. Of the 9 transmitters recovered in the field from dead birds, 3 were located in open areas (beach, meadow) and 6 transmitters were located under conifer canopy. All were recovered in PWS < 70 km (straight-line distance) from the capture and release site (Fig. 2) and all were < 100m from shore. In all cases, feathers, at most, were the only visible remains of the bird. Consequently, postmortem examinations were impossible.

Two birds died after departing PWS. A female white-winged scoter (14021) died near Tetlin, Alaska approximately 33 days after release (Table 4). The bird died near the outlet of Tetlin Lake. A nearby subsistence hunting camp was occupied at the time of the bird's death (Craig Gardner, ADF&G, pers. comm.), although we have no evidence the bird was shot. A male surf scoter (23888) was shot by a hunter near Main Bay, PWS on 14 December 1999 (Table 4). Our last location for this bird was from Kotzebue Sound on 10 August 1999.

We lost contact with a female surf scoter (12773) 4 days after release (Table 4). We received sensor data 76 days later indicating that the bird died. We did not receive any subsequent location data. We suspect death occurred soon after release and the transmitter was situated in a location or orientation usually concealed from orbiting satellites.

In addition to these birds, we lost contact with a female surf scoter (12774) approximately one week after release (Table 4). We suspect that the transmitter failed or the bird died and the transmitter was destroyed or permanently concealed from orbiting satellites.

Scoter Movements and Activity

After release, scoter activity was primarily concentrated in eastern PWS either near the capture site or in Orca Inlet (Fig. 1). All scoters in the study departed PWS by early June (Table 6). The earliest departure date was approximately 12 May and the latest was approximately 4 June (median = 29 May). Eleven of 15 scoters (73%) were last detected on the eastern side of PWS (9 in Orca Inlet) while 4 scoters traveled to western or northern PWS before migrating elsewhere (Table 6).

White-winged Scoter Males

Two white-wing scoter males utilized coastal areas exclusively. Because they did not travel inland we believe they did not attempt to breed. Both males traveled west to lower Cook Inlet (LCI) after departing PWS. White-winged scoter 20376 remained in LCI for 83 days (5 June to 27 August) (Fig.3). We believe he molted in Chinitna Bay (LCI) before traveling south along the eastern shore of the Alaskan Peninsula spending appreciable amounts of time near Cape Aklek (Puale Bay) and then Cape Providence (Chiginagak Bay) where we believe he remained for the winter (Fig. 3). He was one of two white-winged scoters (the other a female) that wintered along the Alaska Peninsula. The transmitters failed before we could determine if these birds migrated back to PWS the following spring.

White-winged scoter (24124) continued west after departing LCI. He traveled to Togiak Bay and remained there throughout the summer (Fig. 3). We believe he molted near Hagemeister Island before returning to PWS in early September. He remained near Naked Island from 6 September until our last location on 23 November (Fig. 3). We believe he remained in PWS throughout the winter. He was one of two white-winged scoters (the other a female) that returned to PWS.

Surf Scoter Males

Male surf scoter (14019) followed a pattern similar to white-wing male 24124. He also spent about 17 days in LCI before traveling to Togiak Bay in late-June. Unlike white-wing male 24124 he continued northwest to Kuskokwim Bay where we believe he molted (5 July to 9 August). The last location for this bird (class code A) was received on 24 August indicating that he was in Baird Inlet (Fig. 4). Because he did not travel inland we believe he never attempted to breed.

Two male surf scoters (23893, 23888) traveled inland from PWS to known breeding areas in northwestern Canada before migrating to molting sites along the coast of northwestern Alaska. Male (23893) spent about 10 days (21-29 May) near the confluence of the Kantishna and Toklat rivers (interior Alaska), then traveled to a large lake system located north of Old Crow (Yukon Territory). He remained there for about 20 days (31 May to 19 June) before traveling to Kotzebue Sound, Alaska (Fig. 4). 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 he molted there before returning to PWS. From 24 September until our last location (12 January) he traded between Montague Island (southern PWS) and Port Wells (northwest PWS) (Fig. 1).

Male (23888) was located in the NWT, Canada 3 days after departing PWS (Fig. 4). It is possible that he also accompanied a female to a nesting area near the Mackenzie River where he remained for approximately 15 days (18 May to 3 June) (Fig. 4). He then traveled in a westerly direction along the Beaufort Sea coast, eventually molting in Kotzebue Sound, Alaska (Fig. 4). We lost contact with this bird in early August. A sport hunter shot him on 14 December near Main Bay, PWS, approximately 100 km west of the capture site (Fig. 4). A necropsy on December 17, 1999 detected *Escherichia coli* in the fibrous sac encapsulating the transmitter. This may have been introduced when shot, during the necropsy, or during surgery. Otherwise, the bird appeared healthy (Dan Mulcahy, DVM, Pam Tuomi, DVM, pers. comm.).

White-winged Scoter Females

Four of five female white-winged scoters migrated to the NWT, Canada, after departing PWS. The fifth female (14021) died near Tetlin, Alaska (63.038N, 142.627W) approximately 90 km west of the Canadian border (Fig. 5). Based on the similar direction of travel observed for our other white-winged females, it is likely that 14021 was also enroute to the NWT. Movements to coastal molting and wintering sites were more diverse.

Female (23887) was located in northern NWT, approximately 1,250 km from the capture site, 7 days after departing PWS (Fig. 5). We believe she nested in a low-lying lake system located north of the Anderson River and west of Tadener Lake (68.645N, 127.830W). She remained at this location from 8 June to 16 August (70 days) (Fig. 5). Three days later (19 August) she was located approximately 1,950 km to the southwest near Yantarni Bay on the south coast of the Alaska Peninsula (Fig. 5). She then moved to Port Moller where we believe she molted and remained from 25 August until the last location on 28 November.

Female (23890) was first located in the NWT 2 days after departing PWS, a distance of approximately 1,150 km (Fig. 5). During the expected nesting period, she was also located in an area north of the Anderson River (68.895N, 127.445W) (Fig. 5). Because she remained in this area for approximately 33 days and location data indicates slight movements, we are not sure if she attempted to nest. She then moved north to molt in the nearshore waters of the Beaufort Sea (Liverpool Bay), NWT before returning to PWS for the winter (Fig. 5). From 8 October until our last location on 25 December she remained, for the most part, in Port Fidalgo (Fig. 1).

Our only location data for female (20375) indicated that from 7 June until our last location on 8 August she remained near Carcajou Lake, a low-lying area between the Mackenzie River and Colville Lake (67.200N, 128.149W) (Fig. 5). We are not certain if she remained here to nest.

Like the other white-winged scoter females, 23894 departed PWS at the end of May for the NWT. She crossed the upper Yukon River (63.415N, 139.459W) on 1 June. Due to poor signal quality we do not know if she stopped there on her northward migration. She arrived in the Mackenzie River valley by 3 June. Although infrequent and of poor quality, the location data indicates that she remained in a low-lying area just south of the Mackenzie River for 30 days (8 June to 8 July) (67.048N, 132.030W). On 11 July she traveled further north to the Beaufort Sea

(Eskimo Lakes region) where she remained until we received our last location on 24 July (Fig. 5).

Surf Scoter Females

Satellite transmitters implanted in female surf scoters received relatively low evaluation ratings, resulting from infrequently received transmissions and minimal location data (Table 5). This limits our ability to describe movements and identify stationary periods. With the exception of female (12753), we did not receive location data for female surf scoters after 16 July (approximately 80 days after release) (Table 2), and for female (12752) we rejected location data (poor quality) for points beyond PWS (Fig. 6).

Three of 5 female surf scoters (12754, 12943, and 12753) traveled to interior Alaska immediately after departing PWS (Fig. 6). Female (12754) spent an appreciable amount of time (2 June to 1 July) near a low-lying lake complex (Carey, Burnt and Albert lakes) north of the Swift Fork of the Kuskokwim River near the western boundary of Denali National Preserve (Fig. 6). She may have attempted to nest there. Unfortunately, our last location for this bird was received on 5 July. Female (12753) may have attempted to nest (27 May to 23 June) near a lake complex just south-west of the confluence of the Windy River and Chandalar River (East Fork) (Fig. 6). We then lost track of her for over a month until she was located back in PWS on 28 July. Our last location for this bird (26 December) indicated that she continued south and presumably wintered off Vancouver Island, Canada in the Strait of Georgia (Fig. 6). Infrequent and poor quality location data suggests that female (12943) spent time near Lake Minchumina (Fig. 6). Numerous lakes and drainages in the area may provide suitable nesting habitat. Our last location for this bird was 5 July.

After departing PWS, female surf scoter (12772) initially followed a westerly coastal route, more typical of non-breeding males (Fig. 6). In early June, however, she began a trek through interior Alaska on her way to the NWT. Poor quality location data indicates that from 1 July to 16 July she was located north of the Smith Arm of Great Bear Lake near Colville and Aubry lakes. Large lakes in the area may provide molting or breeding habitat. We did not receive locations for this bird after 16 July.

DISCUSSION

Capture

Floating mist nets worked well for capturing scoters (n=188) in PWS. The presence of several thousand sea ducks, however, provided us with ample opportunities. This was not the case in Kachemak Bay (KB) where the low abundance of scoters was reflected in our poor capture success (n=15 ducks). A trapping effort in KB would be more successful if conducted earlier in the year (March) when scoters are significantly more abundant (Petrula and Rosenberg 2000) than what we observed in mid-April.

The large sample of surf (n=90) and white-winged (n=77) scoters captured in PWS enabled us to select birds for satellite telemetry that were heavier (superior condition) and, in most cases, paired with a mate. We presumed that birds possessing both characteristics would be more likely to travel to breeding areas than would lighter, lone individuals. Three male scoters that were paired with a female at capture failed to travel inland to potential nesting areas (Fig 3 and Fig. 4).

Transmitter Performance

The maximum time a transmitter functioned was for 284 days. The amount of data we can receive is limited by transmitter battery life. Birds require small transmitters. This limits battery size, which limits transmitter life. The length of duty cycles is a compromise between frequency of data collection and transmitter life. We attempted to adjust duty cycles based on the life history of the bird. Thus, during periods when birds were expected to migrate duty cycles were shorter while during stationary periods (e.g. molt) duty cycles were longer. Regardless, we were not able to track a bird throughout a full year. We were able to track most birds to breeding and molting areas and back to the wintering grounds. However, the performance of transmitters (number of transmissions, signal quality, and longevity) varied significantly.

Based on our criteria for evaluating satellite transmitter performance (Table 5), variation in quality existed among the 15 transmitters we compared. Transmitters with quality ranks 1 to 7 (n=8) significantly outperformed transmitters ranked 8 to 13 (n=7) (Table 5). Seventy-one percent (5 of 7) of the worst performing transmitters were the lighter model. These were implanted only in female surf scoters. None of the lighter transmitters received a high quality rank. Conversely, the lighter transmitters (with one exception) received relatively high ranks for longevity (Table 5). The most apparent reason for the dissimilarity between transmitter performance is that fewer messages are being received by orbiting satellites from poor performing transmitters. Messages are either not being sent by the transmitter (indicating transmitter malfunction), or the message is weakened or obstructed and not being received by the satellite.

Physiographic variation in scoter habitat is probably not responsible for our observed differences in signal quality. Physical obstruction of a transmitted message is not likely in areas dominated by open water (sea, lake, wetland), especially in high latitude areas where the likelihood of having a satellite in view is greater than in lower latitudes (Fancy et al. 1988). The only exception may be when females are on nests adjacent to or under an obstruction (trees, logs, rocks etc.). Nor do we believe that differences in bird activity (diving, flying) would cause the differences we observed in the number of messages reaching orbiting satellites.

Antenna orientation will affect satellite reception. A 90° angle from horizontal is the preferred antenna orientation and lesser angles will attenuate signal strength (Paul Howey, Microwave Telemetry, pers. comm). However, we do not know if antenna angle is solely responsible for the differences we observe in signal quality. We plan to test this relationship in the future. As Argos compatible transmitters are complex devices, other factors may be responsible but these are outside our purview.

Nesting, Molting, and Wintering Areas

Although many 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 in the Gulf of Alaska with breeding sites in northwestern Canada and interior Alaska, and molting sites in western Alaska. Satellite telemetry is the only effective way to monitor movements over such a vast and remote area where birds rapidly move between distant locals. In the process we have also identified migration patterns and located several areas used by scoters for various life stages that had not been previously described.

We identified 2 geographic areas used by scoters during the nesting season; northern Canada and interior Alaska. Four white-winged scoter females and 3 surf scoters (2 males, 1 female) traveled to northern Canada (Yukon Territory, NWT) (Figs. 3 to 6). Most of our locations for these birds were concentrated in areas north of the Mackenzie River and west of Great Bear Lake (NWT) and near Old Crow (Yukon Territory). Both regions are composed of extensive river and lake systems. Three female surf scoters were located in interior Alaska (Yukon and Kuskokwim river drainages) during the nesting season in boreal forested areas also dominated by low-lying lakes and river drainages (Fig. 6).

Although we have no empirical evidence of our transmitted birds actually nesting, our satellite locations are within known breeding areas for both species and the timing of arrival coincides with scoter breeding habits (Bellrose 1980, Brown and Fredrickson 1997, Savard et al. 1998). 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, two (and possibly 3) of four females were present at a breeding site long enough to have nested successfully (Fig. 5). The southerly migration of female 23887 to the Alaska Peninsula may have occurred after she reared a brood in the NWT.

Two male surf scoters (23888, 23893) were on the breeding grounds in the YT and NWT for about 18 days. These birds may have also bred (Fig. 4). Surf scoters have one of the shortest pair bonds among waterfowl and paired males abandon females about 3 weeks after arrival at breeding lakes (Savard et al. 1998).

Due to poor or no locations we were unable to determine if surf scoter females attempted to nest. The best location data was from female 12753 (Fig. 6). She remained inland for a minimum of 26 days and a maximum of 60 days. While the former is much less than the combined egg-laying and incubation period for surf scoters (Savard et al. 1998), the latter would have given her sufficient time to hatch a brood.

Based on periods of stationary activity, we were able to identify molting areas for 7 scoters. Inadequate location data precluded identifying molting areas for other birds. All birds molted in coastal areas. We identified ties to several coastal molting areas in northern Canada and western Alaska. While several authors have described post-breeding movements, molt migrations, or molting areas in northwestern Canada and Alaska (Porslid 1943, Salter et al. 1980, Johnson and Richardson 1982, Dau 1987), this study is the first to link these populations to specific breeding or wintering areas. As in 1998 (Rosenberg and Petrula 1999) the coast of western Alaska appears to be the predominant molting site for male scoters. This year we also identified a molting site in Cook Inlet (20376) (Fig. 3).

We tracked 7 post-molting scoters (4 white-winged scoters, 3 surf scoters) to wintering areas. Two white-winged scoters (1 male, 1 female) returned to PWS and two wintered on the Alaska Peninsula. The transmitters failed before we could determine if these later birds returned to PWS the following spring. In 1998, we identified surf scoters wintering on the south side of the Alaska Peninsula (Rosenberg and Petrula 1999).

Two surf scoters (both males) returned to PWS after the molt while one female wintered in British Columbia (BC). This pattern of dispersal suggests that birds from wintering areas other than PWS, migrate to PWS during early spring, perhaps in response to the food source (roe) provided by spawning herring. Therefore, during our spring capture both winter residents and migrants are present. This contradicts Bishop and Green's (1999) observation that the PWS breeding population of over-wintering scoters had departed by mid-April and was replaced by an influx of migrants. The return to wintering areas in PWS by both surf and white-winged scoters may indicate fidelity to wintering sites although this has not been documented for scoters.

At best, we received location data for about 8.5 months. Therefore, we are not certain if birds that returned to wintering areas remained until the following spring. However, based on our limited 1998 data (Rosenberg and Petrula 1999) we believe birds are present on the wintering grounds by early fall and remain there until spring.

The female surf scoter that wintered in British Columbia, Canada, was our longest migrant. She traveled to the Strait of Georgia near Vancouver Island, BC (Fig. 6). We lost track of this bird between July 28 when it was in PWS and December 5 when it was in Queen Charlotte Strait, BC. As post-breeding surf scoters return to the Strait of Georgia in late October or early November (Savard 1989), this bird may have been in the vicinity for about 1 month before we received a location.

Migration Routes

The few locations we received during migration make it difficult to delineate specific routes. As the number of failed transmitters increased with time, we received progressively less location data by the time birds migrated to molting and then wintering areas. This further limited our ability to detect movements. However, the limited data we received suggests several patterns. Non-breeding male surf and white-winged scoters traveled westerly to molting areas in western Alaska with stopover points in LCI (Kamishak Bay). This was similar to what we observed in 1998 (Rosenberg and Petrula 1999). These flights were less direct than breeding birds.

White-winged scoters flew northeast from PWS to breeding areas. Birds generally made the flight to the NWT via the Copper River-Nelchina, Tanana, and Yukon basins. Unlike the prolonged westerly molt migration of non-breeders, migration to breeding areas was rapid and direct. Few stopover points were recorded. This may be because most birds migrated non-stop to the vicinity of the nesting area or because we only receive location data six out of every 54 hours. The one non-breeding male surf scoter also had a prolonged flight to its western Alaska molt site while breeding birds, with one exception (12772), took relatively direct flights to nesting areas. Otherwise, spring migration patterns in surf scoters are inconclusive due to a combination or poor transmitter performance and great variability in routes.

The molt migration of male surf scoter 23888 (Fig. 4) along the Beaufort Sea coast followed a pattern described by Johnson and Richardson (1982). Until now, we were unaware of the origin and destination of any of the birds observed by these authors. As in 1998 (Rosenberg and Petrula 1999), Kamishak Bay was a-stopover point for males on route to western Alaska molting sites. Four of 6 birds we tracked to wintering areas returned to PWS. Three of the PWS returnees molted in western Alaska.

Mortality

The most serious problem we encountered in this study was the high rate of mortality that occurred within two weeks of surgery (Table 4). We are not certain why scoters implanted with satellite transmitters died soon after release. Scoters were in good physical condition and responded better than 3 other species of diving ducks to identical surgical procedures (Dr. D. M. Mulcahy pers. comm.). The initial mortality observed in this study was much greater than other satellite implant studies conducted with seaducks using similar surgical procedures: spectacled eiders (Petersen et al. 1995); king eiders (Dickson et al. 1998); white-winged scoters (D. Rudis, USFWS, pers. comm); Barrow's goldeneyes (Robert et al. 2000); and harlequin ducks (S. Brodeur, CWS, pers. comm.). Thus, mortality is not believed to be a direct consequence of capture, handling, or surgery. The surgical implants for the first three studies (spectacled eiders, king eiders, white-winged scoters) were conducted on the breeding grounds. For the latter two studies implants were done on the wintering grounds in eastern Canada. 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.

We suspect that the relatively high mortality of post-operative scoters is indirectly related to surgery by increasing their vulnerability to the many predators that inhabit the marine environment, particularly bald eagles. Bald eagles were frequently observed near the trap site disturbing flocks of sea ducks with over-flights. Post-operative birds may be less likely or slower to flush from an avian threat, making them more conspicuous and vulnerable to potential predators. Hypothermia may result from the abdominal incision. We observed one post-operative surf scoter hauled-out near the release site. This behavior is rarely observed in surf scoters in PWS and is typical of hypothermic birds. We observed a post-operative white-wing scoter alone at the head of St. Matthew's Bay. This was unusual because the bird was isolated from the flock and in an area not used by scoters. Breeding ground implant studies have the advantage of warmer weather, warmer water, and fewer predators or better escape cover which potentially will improve survival. In eastern Canada few eagles occur near the capture sites (Michel Robert, CWS. pers. comm.)

We regret the death of our study birds, however, the valuable information gained by this study can not be acquired by other means. We were able to recover 9 transmitters from birds that died soon after release. However, the lack of an intact carcass prevented us from assessing the cause of mortality. In 2000, we plan to hold birds in captivity at the Alaska Sea Life Center in hopes of increasing survival and possibly identifying potential causes of mortality.

Satellite telemetry has allowed us to define the extensive range of these species and the importance of PWS as a winter and staging area. Our results have several applications for conservation. Most importantly we have begun to define affiliations between wintering, breeding, and molting populations and the migration routes between these areas. This, along with the information we obtained on the timing of movements will help managers interpret population surveys and identify the causes of population change. Information gained from this study will allow managers to link seasonal harvest data to specific scoter populations. This will help manage both sport and subsistence hunting.

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Table 1. Programmed transmission cycles (duty cycles) for 2 models of implantable satellite transmitters used to monitor movements of surf and white-winged scoters captured and released in Prince William Sound, Alaska during the spring (April, May) in 1999.

Duty cycle[a]	hours on	hours off	number of cycles
1	6	48	31
2	6	96	9
3	6	72	31
4[b]	6	96	until battery failure
4[c]	6	120	17
5[c]	6	96	until battery failure

[a] Both models programmed for duty cycles 1,2, and 3.
[b] lighter transmitter only(approximately 36 grams). 500 transmission hours expected.
[c] heavier transmitter only(approximately 52 grams). >500 transmission hours expected.

Table 2. Number and composition of sea ducks captured[a] with floating mist nets during early spring near St. Matthew's Bay in Prince William Sound, Alaska.

Species	Male	Female	Total
Surf scoter *(Melanitta perspicillata)*	75	15	90
White-winged scoter *(Melanitta fusca)*	49	28	77
Black scoter *(Melanitta nigra)*	10	11	21
Harlequin duck *(Histrionicus histrionicus)*	12	6	18
Oldsquaw (*Clangula hyemalis*)	5	4	9
Total	151	64	215

[a] Birds were captured in seven days of trapping from 26 April to 5 May 1999.

Table 3. Status of surf (SUSC) and white-winged (WWSC) scoters captured in Prince William Sound, Alaska from 26 April to 5 May 1999 and surgically implanted with satellite transmitters.

PTT[a]	Species	Sex	Status	Date of last location data[b]	Date of last sensor data
12752	SUSC	female	off air	1 July 1999	30 Jan. 2000
12753	SUSC	female	off air	26 Dec. 1999	30 Dec. 1999
12754	SUSC	female	off air	5 July 1999	22 July 1999
12772	SUSC	female	off air	16 July 1999	27 Jan. 2000
12773	SUSC	female	died		
12774	SUSC	female	off air	3 May 1999	3 May 1999
12943	SUSC	female	off air	5 July 1999	7 Feb. 2000
12944	SUSC	female	died		
12945	SUSC	female	died		
12990	SUSC	female	died		
12991	SUSC	male	died (transmitter recovered)		
12992	SUSC	male	died (transmitter recovered)		
14019	SUSC	male	off air	24 Aug. 1999	21 Sep. 1999
14020	SUSC	male	died		
20376	SUSC	male	died (transmitter recovered)		
23888	SUSC	male	died (shot by hunter 14 Dec.)	10 Aug. 1999	10 Aug. 1999
23891	SUSC	male	died (transmitter recovered)		
23893	SUSC	male	off air	12 Jan. 2000	12 Jan. 2000
14021	WWSC	female	died		
20375	WWSC	female	off air	8 Aug. 1999	28 Aug. 1999
20377	WWSC	male	died (transmitter recovered)		
23887	WWSC	female	died (transmitter recovered)		
23889	WWSC	female	died (transmitter recovered)		
23890	WWSC	female	off air	15 Jan. 2000	25 Jan. 2000
23894	WWSC	male	died (transmitter recovered)		
24124	WWSC	male	off air	23 Nov. 1999	23 Nov.1999
24125	WWSC	male	died (transmitter recovered)		
24126	WWSC	female	died		
20376*	WWSC	male	off air	22 Dec. 1999	22 Dec. 1999
23887*	WWSC	female	off air	28 Nov. 1999	28 Nov. 1999
23894*	WWSC	female	off air	24 July 1999	4 Sep. 1999

[a] Satellite transmitter (platform transmitter terminal) identification number.
[b] For birds that died refer to Table 4.
* Satellite transmitter recovered from a dead bird and re-implanted in this bird.

Table. 4. Summary data for scoters known or believed to have died after being surgically implanted with a satellite radio transmitter.

PTT[a]	Species	Sex	Date deployed	Last date known alive[b]	Fate	Date fate determined[b]	Cause of fate	Min./max. days alive post surgery
12773	Surf scoter	female	26 April	29 April	died	15 July	unknown	4-80
12774	Surf scoter	female	28 April	3 May	off air	3 May	unknown	6-?
12944	Surf scoter	female	26 April	1 May	died	5 May	unknown	6-9
12945	Surf scoter	female	28 April	3 May	died	6 May	unknown	6-8
12990	Surf scoter	female	26 April	26 April	died	4 May	unknown	1-8
12991	Surf scoter	male	27 April	16 May	died	18 May	unknown	20-21
12992	Surf scoter	male	26 April	1 May	died	4 May	unknown	6-8
14020	Surf scoter	male	27 April	27 April	died	29 April	unknown	1-2
20376	Surf scoter	male	28 April	3 May	died	4 May	unknown	6
23888	Surf scoter	male	29 April	10 Aug	died	14 Dec	shot by hunter	229
23891	Surf scoter	male	29 April	2 May	died	4 May	unknown	4-5
14021	White-winged scoter	female	26 April	28 May	died	31 May	possibly shot	33-35
20377	White-winged scoter	male	26 April	1 May	died	3 May	unknown	6-7
23887	White-winged scoter	female	28 April	28 April	died	30 April	unknown	1-2
23889	White-winged scoter	female	28 April	7 May	died	8 May	unknown	10
23894	White-winged scoter	male	27 April	30 April	died	2 May	unknown	4-5
24125	White-winged scoter	male	26 April	12 May	died	16 May	unknown	17-19
24126	White-winged scoter	female	26 April	26 April	died	28 April	unknown	1-2

[a] Satellite transmitter (platform transmitter terminal) identification number. Programmed to transmit for 6 hours every 54 hours for first 31 cycles.

[b] Temperature sensor data indicated the status (alive or dead) of the bird.

Table 5. Performance ratings for satellite transmitters surgically implanted in scoters.[a]

	Satellite transmitter quality categories and ratings					Longevity		
PTT[b]	Transmission consistency	Location accuracy	Location deficiency	Abundance of accurate locations	Overall quality rank[c]	days active	hours on	rank
23893	1.00 (1)[1]	0.99 (1)[1]	0.00 (1)[1]	6.3 (1)	(1)	258	504	(3)
23887	1.00 (1)[1]	0.99 (1)[1]	0.00 (1)[1]	5.5 (2)	(2)	214	438	(6)
23888	1.00 (1)[1]	0.97 (2)	0.03 (2)[2]	4.6 (3)	(3)	103	234	(11)
24124	1.00 (1)[1]	0.83 (4)	0.00 (1)[1]	3.5 (5)	(4)	209	432	(7)
14021*	1.00 (1)[1]	0.93 (3)	0.07 (4)	4.4 (4)	(5)	32	90	(13)
23890	1.00 (1)[1]	0.73 (6)[6]	0.03 (2)[2]	2.8 (8)	(6)	272	516	(2)[2]
14019	0.94 (2)	0.80 (5)	0.12 (5)	3.0 (7)	(7)[7]	147	312	(8)
20376	1.00 (1)[1]	0.73 (6)[6]	0.05 (3)	2.4 (9)	(7)[7]	231	444	(5)
12753[+]	0.43 (7)	0.56 (7)	0.21 (6)	3.2 (6)	(8)	246	474	(4)
12772[+]	0.49 (6)	0.36 (8)	0.29 (8)	1.8 (11)	(9)	274	516	(2)[2]
12754[+]	0.73 (4)[4]	0.24 (11)[11]	0.24 (7)	1.3 (13)	(10)	82	204	(12)
20375	0.86 (3)	0.30 (10)	0.46 (11)	1.6 (12)	(11)[11]	122	258	(10)
12752[+]	0.56 (5)	0.33 (9)	0.56 (12)	2.2 (10)[10]	(11)[11]	278	516	(2)[2]
12943[+]	0.42 (8)	0.24 (11)[11]	0.38 (9)	2.2 (10)[10]	(12)	284	528	(1)
23894	0.73 (4)[4]	0.13 (12)	0.44 (10)	1.0 (14)	(13)	124	264	(9)

[a] Ranked from best (1) to worst within each category except for Location deficiency where a score of 0 is the best. Numeric superscripts identify ties in rank within categories. See methods section for definitions of transmitter quality categories and longevity.

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

[c] Average sum of ranks.

* Known to have died before transmitter failure.

[+] 36 gram (lighter) satellite transmitter.

Table 6. Last locations for scoters obtained with satellite telemetry prior to departing Prince William Sound, Alaska during spring in 1999.

PTT[a]	Species	Sex	Date	Last location
12752	Surf scoter	female	4 June	Orca Inlet
12753	Surf scoter	female	18 May	Nelson Bay
12754	Surf scoter	female	28 May	College Fjord
12772	Surf scoter	female	12 May	Makarka Point
12943	Surf scoter	female	2 June	Passage Canal
14019	Surf scoter	male	2 June	Orca Inlet
14021	White-winged scoter	female	26 May	Orca Inlet
20375	White-winged scoter	female	31 May	Orca Inlet
20376	White-winged scoter	male	29 May	Orca Inlet
23887	White-winged scoter	female	1 June	Orca Inlet
23888	Surf scoter	male	13 May	Orca Inlet
23890	White-winged scoter	female	27 May	Orca Inlet
23893	Surf scoter	male	18 May	College Fjord
23894	White-winged scoter	female	29 May	Orca Inlet
24124	White-winged scoter	male	1 June	Ewan Bay

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

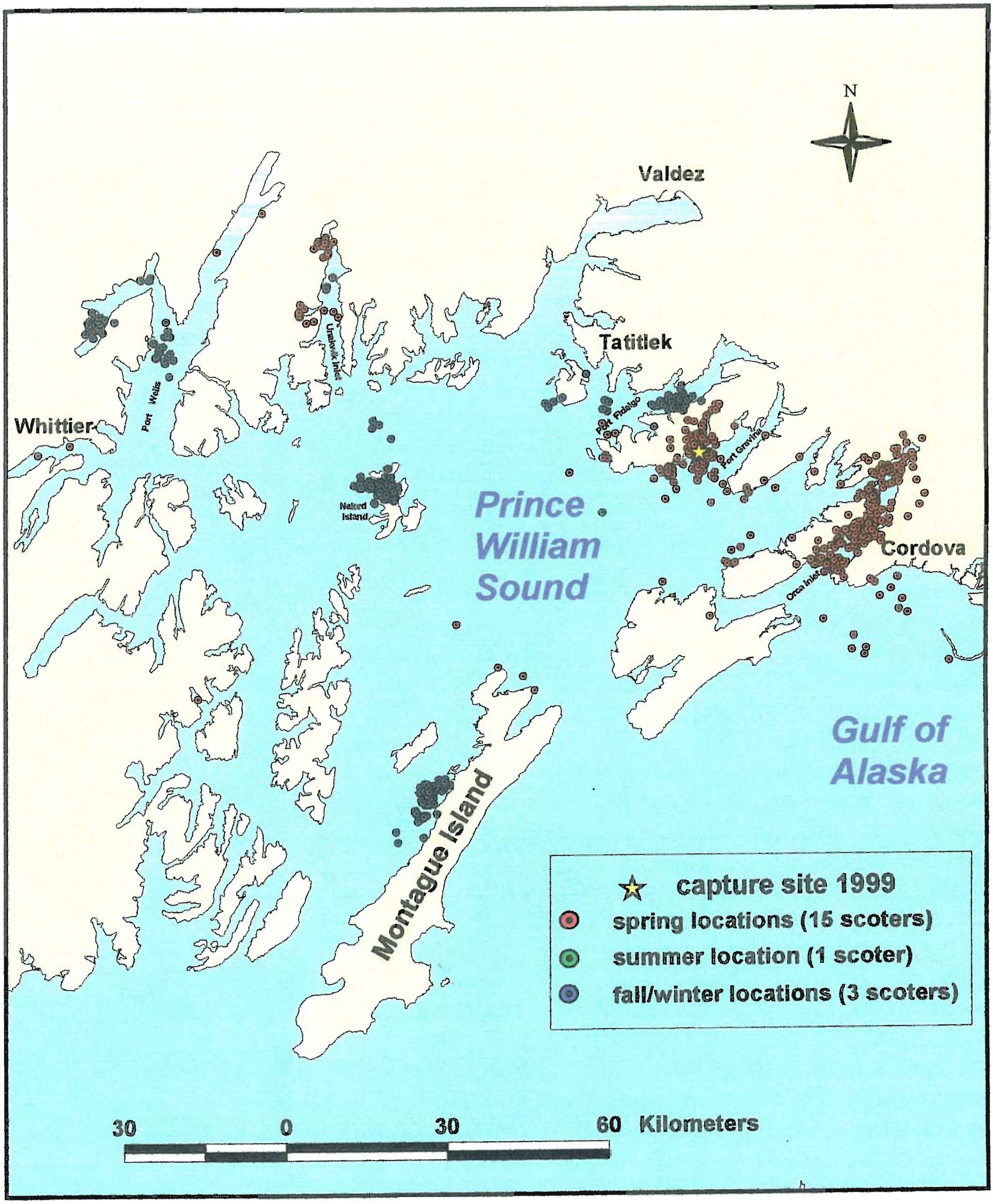

Fig. 1. Locations obtained with satellite telemetry during the spring, summer and fall/winter for surf and white-winged scoters captured near the mouth of St. Mathew's Bay, Prince William Sound, Alaska in 1999.

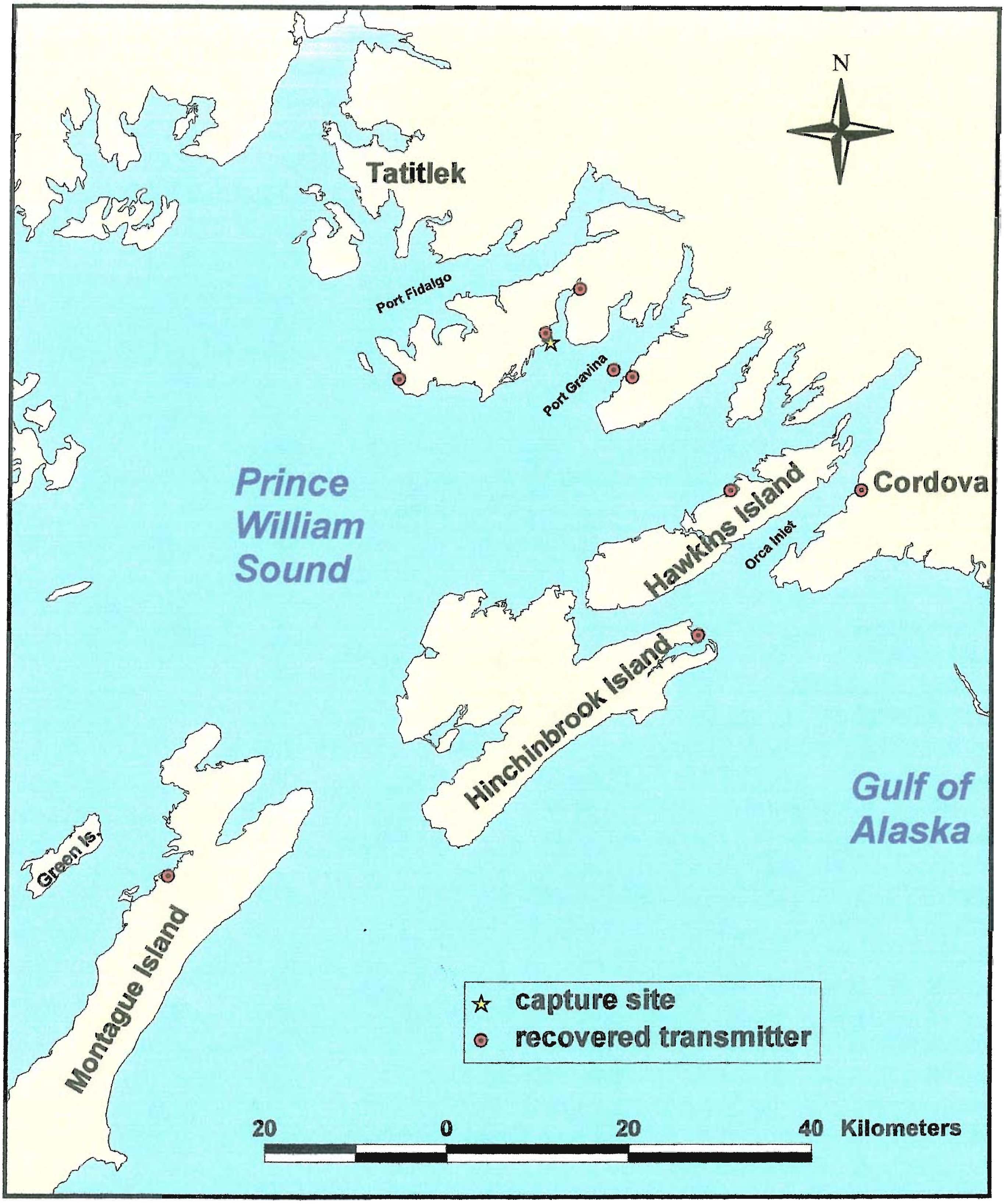

Fig. 2 Locations of satellite transmitters recovered from scoters (n=9) that died during the spring in Prince William Sound, Alaska soon after surgery and release in 1999.

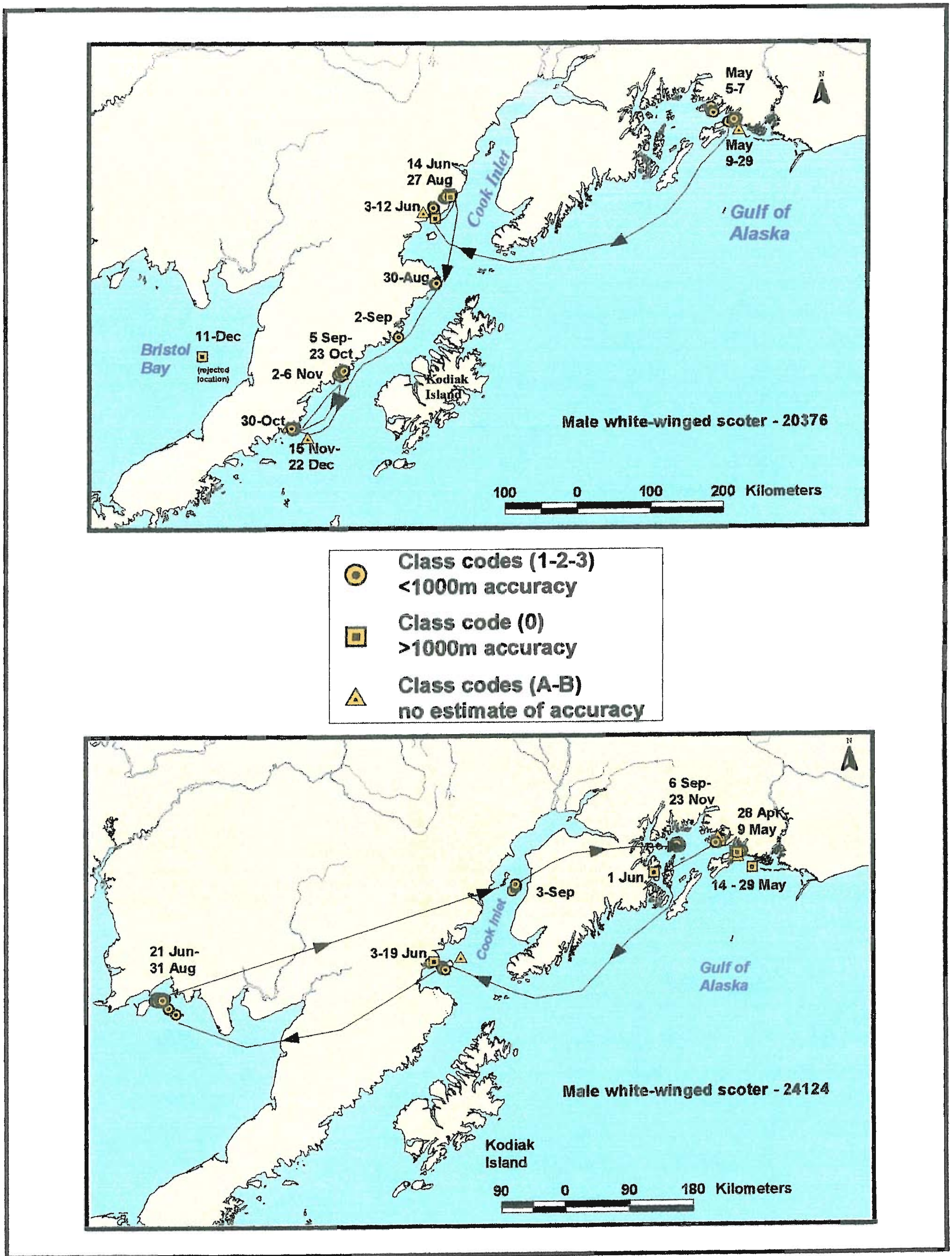

Fig. 3. Locations obtained with satellite telemetry for male white-winged scoters captured in Prince William Sound, Alaska during the spring in 1999. Arrows indicate general direction of travel, not actual route.

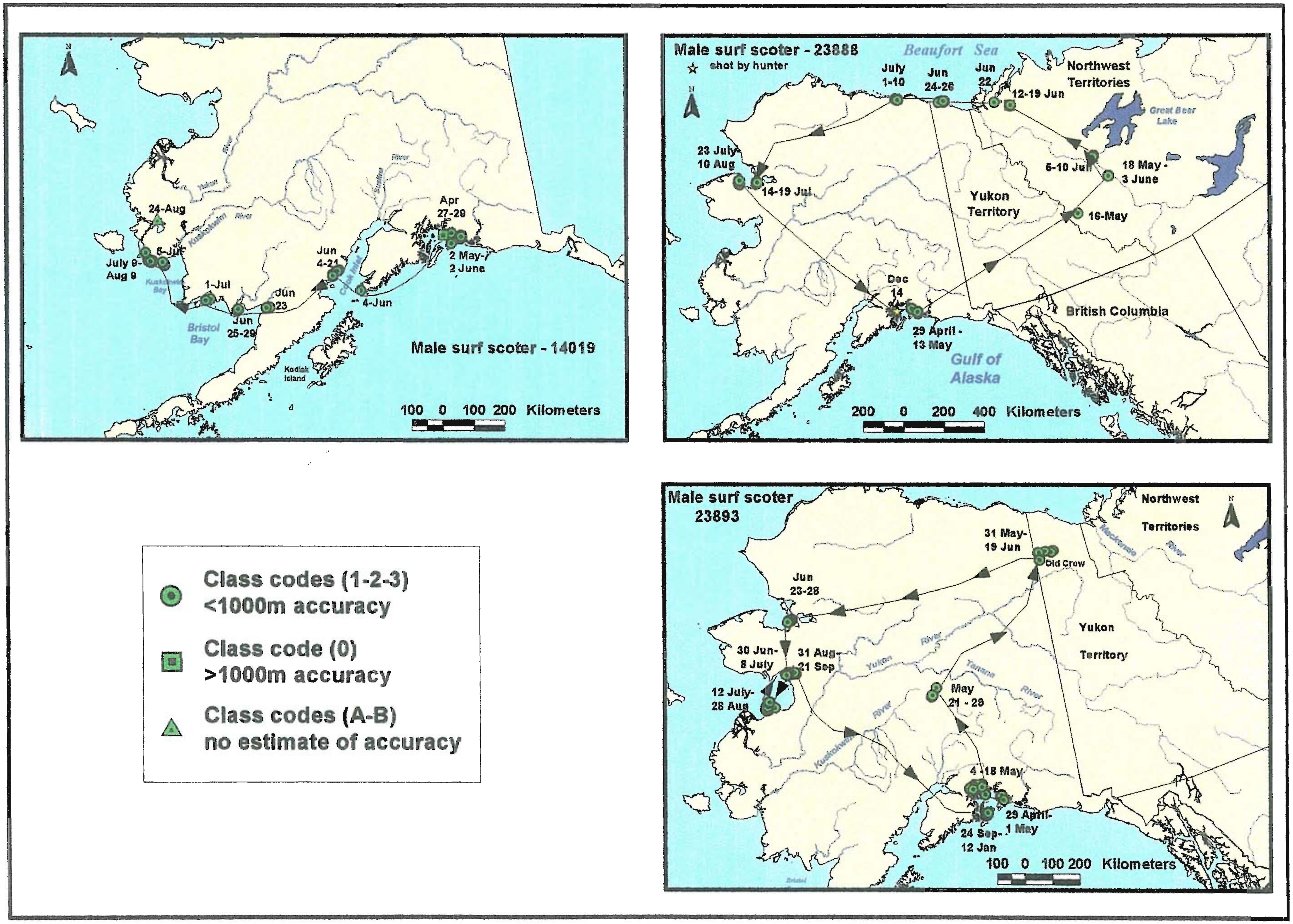

Fig. 4. Locations obtained with satellite telemetry for male surf scoters captured in Prince William Sound, Alaska during the spring in 1999. Arrows indicate general direction of travel, not actual route.

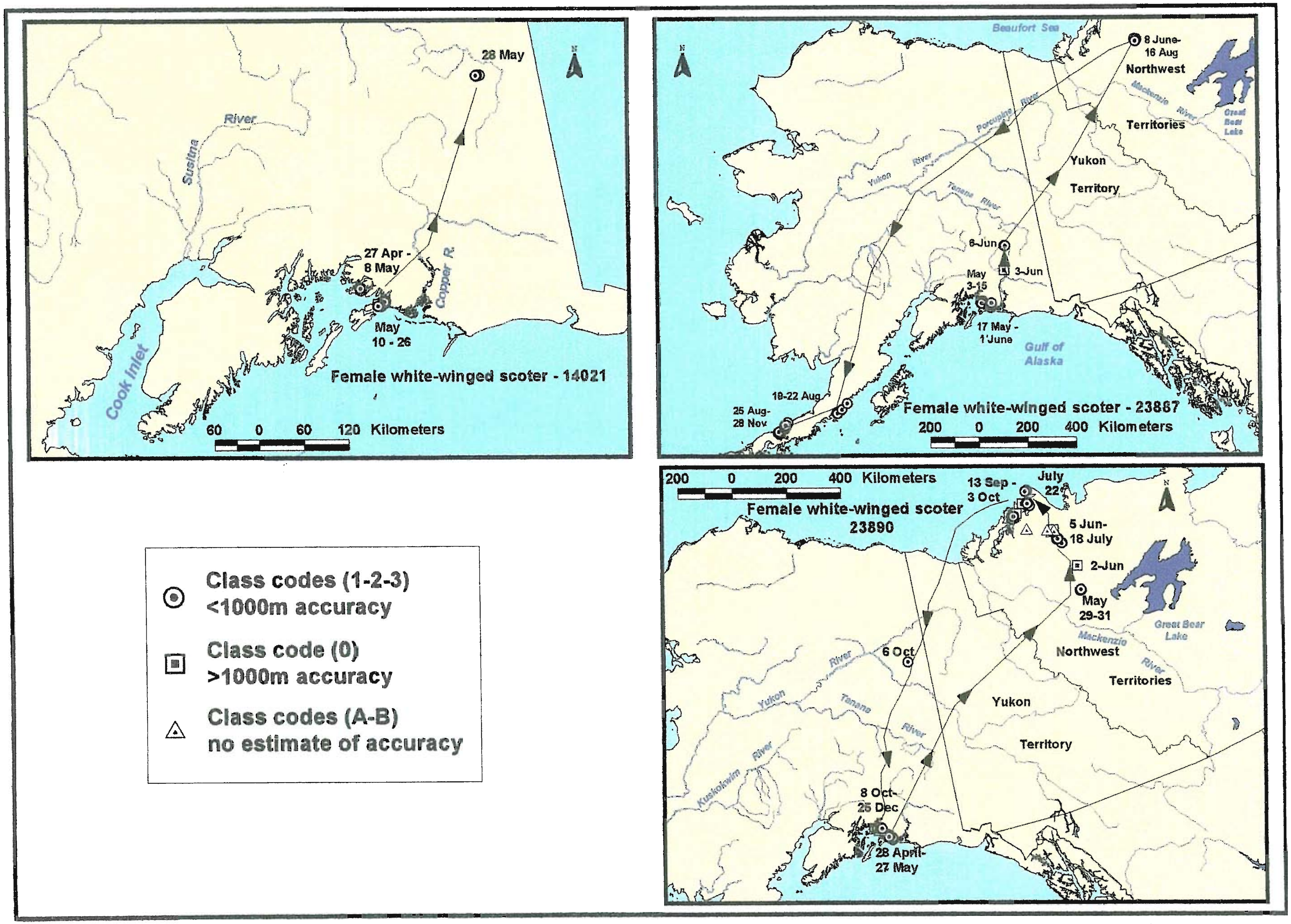

Fig. 5. Locations obtained with satellite telemetry for female white-winged scoters captured in Prince William Sound, Alaska during the spring in 1999. Arrows indicate general direction of travel, not actual route.

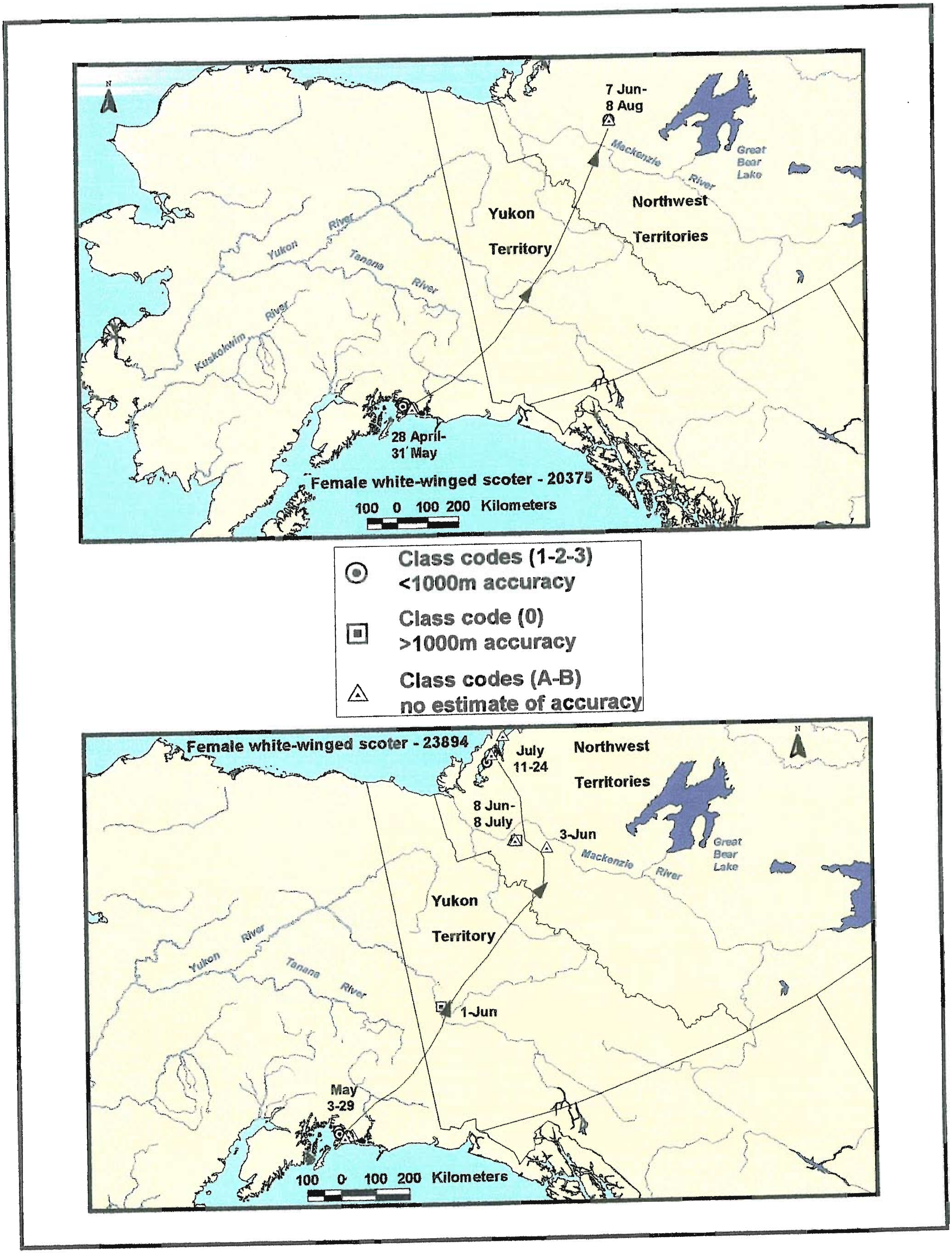

Fig. 5 (continued)

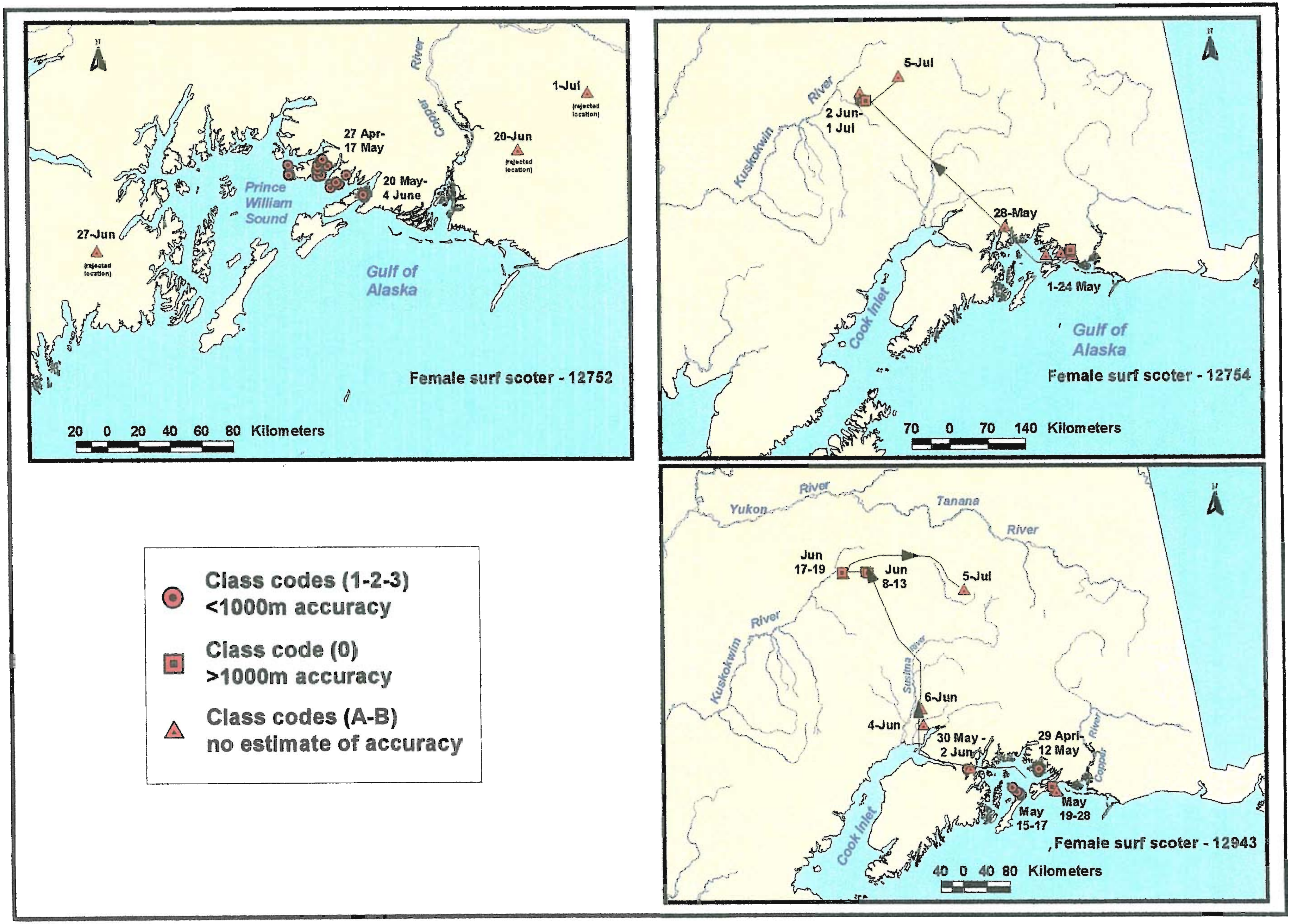

Fig. 6. Locations obtained with satellite telemetry for female surf scoters captured in Prince William Sound, Alaska during the spring in 1999. Arrows indicate general direction of travel, not acutal route.

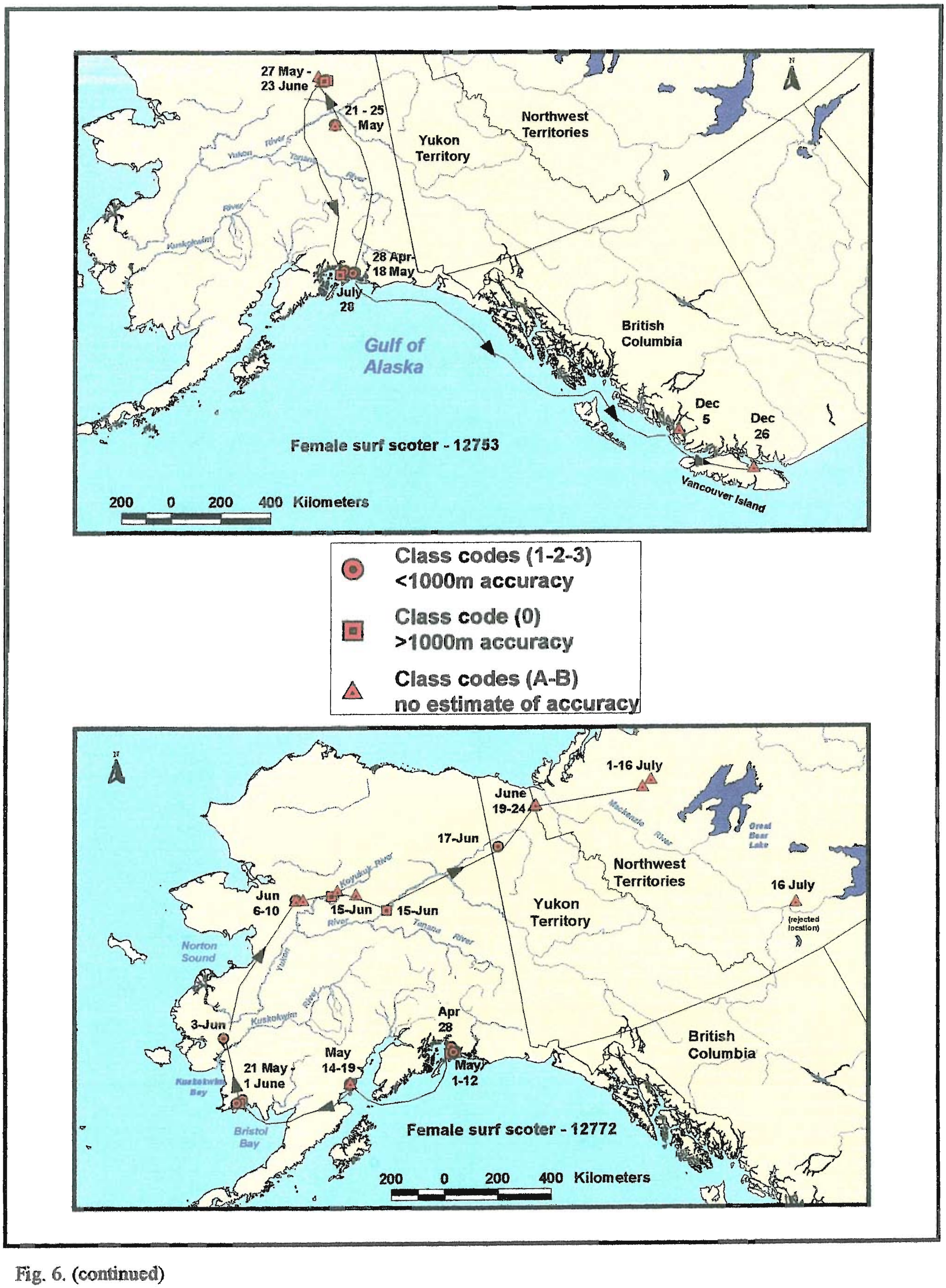

Fig. 6. (continued)