Postrelease Monitoring of Radio-instrumented Sea Otters in Prince William Sound

by

C. Monnett

Prince William Sound Science Center
P. O. Box 705
Cordova, Alaska 99574

L. M. Rotterman

University of Minnesota
Department of Ecology and Behavioral Biology
318 Church St. S.E.
Minneapolis, Minnesota 55455

C. Stack

Prince William Sound Science Center
P.O. Box 705
Cordova, Alaska 99574

and

D. Monson

U.S. Fish and Wildlife Service
Alaska Fish and Wildlife Research Center
1011 E. Tudor Road
Anchorage, Alaska 99503

ABSTRACT.—Sea otters (*Enhydra lutris*) that were captured in western Prince William Sound (PWS) or the Gulf of Alaska, treated, and held in captivity at the temporary rehabilitation centers established in response to the T/V *Exxon Valdez* oil spill were instrumented with radio transmitters, released into eastern PWS, and monitored by radiotelemetry. We undertook the present study to gain information for guiding the release of the remaining captive otters and evaluating the efficacy of sea otter rehabilitation after exposure to crude oil. Radio transmitters were attached to the flippers of seven sea otters released in May 1989 and monitored for periods of a few hours to more than 60 days. However, little was learned about the fate of these animals because the radio transmitters used proved unreliable. Forty-five additional sea otters from the

rehabilitation centers were implanted with radio transmitters, released into northeastern PWS and monitored for 8 months. During the first 20 days after the first release of these implanted otters (n = 21), they were more mobile than wild-caught and released sea otters studied in PWS, from 1984 through 1990. All were alive and vigorous at the end of the 20-day period. Tracking of all 45 implanted sea otters during the 8-month period showed that the otters remained highly mobile. Many (46.6%) crossed into western PWS. However, by the end of the 8 months, 12 of the instrumented otters were dead and 9 were missing. One radio failed. These mortality and missing rates are much higher than those normally observed for adult sea otters in PWS. The death rate was highest in winter. These data suggest that, despite the tremendous amount of money and energy directed toward the treatment and care of these animals, the sea otters released from the centers were not completely rehabilitated, that is, not returned to a normal state. We recommend that future policies focus on preventing otters from becoming oiled, rather than attempting to treat them after oiling has occurred. This focus is especially recommended because of stress and disease risks associated with bringing wild animals into captivity.

The vulnerability of the sea otter (*Enhydra lutris*) to oil contamination was well established (Geraci 1988) before the oil spill resulting from the grounding of the T/V *Exxon Valdez*. Thus, in response to the spill, a large number of otters were captured in or adjacent to oiled areas and brought into centers that were hastily established for their temporary treatment and care.

Our major short-term goal was to provide information necessary to make decisions about whether sea otters should be released back into the wild, and if so, where such releases should occur. Thus, the short-term concerns were whether sea otters held for long periods in captivity and released into clean areas would resume basic activities necessary to survive in the wild, and whether they would immediately return to the areas where they were captured, and thus potentially come into contact with oil.

Our primary long-term goal was to gain insights into the efficacy of the rehabilitation strategy by providing data on survival, reproduction, and behavior of these sea otters.

We offer preliminary results on the behavior and survival of otters that were taken from the otter centers and released into northeastern Prince William Sound (PWS), and comparable data from two other studies of sea otters in PWS.

Methods

On 15 May 1989, seven sea otters (four males and three females) from the Valdez Otter Rehabilitation Center were equipped with small radio transmitters. The transmitters were affixed with epoxy to nylon cattle ear tags and attached through the interdigital webbing of their hind flippers by a procedure similar to that of Garshelis and Siniff (1983). The seven otters were transported by helicopter and released in Simpson Bay near Cordova, Alaska.

Forty-five sea otters (18 males and 27 females) were selected from otter centers during July and August 1989 and instrumented with surgically implanted radio transmitters (Garshelis and Siniff 1983; Monnett 1988; Monnett and Rotterman 1988). These otters were held for observation for at least 1 week after surgery. They were transported by helicopter in individual kennels and released in Sheep Bay (females) or Nelson Bay (males) in eastern PWS. Twenty-one otters were released on 27–28 July. Data from these individuals provided the basis for the release of the rest of the otters in mid-August. Otters were released 100–400 km from the site of capture into what was presumed to be unfamiliar and unoiled habitat. Figure 1 shows the capture sites of the otters selected for this study, which we refer to as treated otters.

Unpublished data from two other ongoing radiotelemetry studies of untreated sea otters are given for comparison. Fifty-eight sea otters (44 females and 14 males) were captured in eastern PWS from July to October 1987. Additionally, 30 females were captured in various parts of PWS in October and November 1989. Otters in both studies were placed in kennels and transported 1–10 km by boat to holding facilities. Because otters were captured at night, they were usually held in a floating pen until the following day. They were instrumented according to the same surgical protocol and with the same type of radio transmitters as those implanted in the otters from the rehabilitation centers. Otters were held for less than 24 h and were generally released within 1 km of the place at which they were captured.

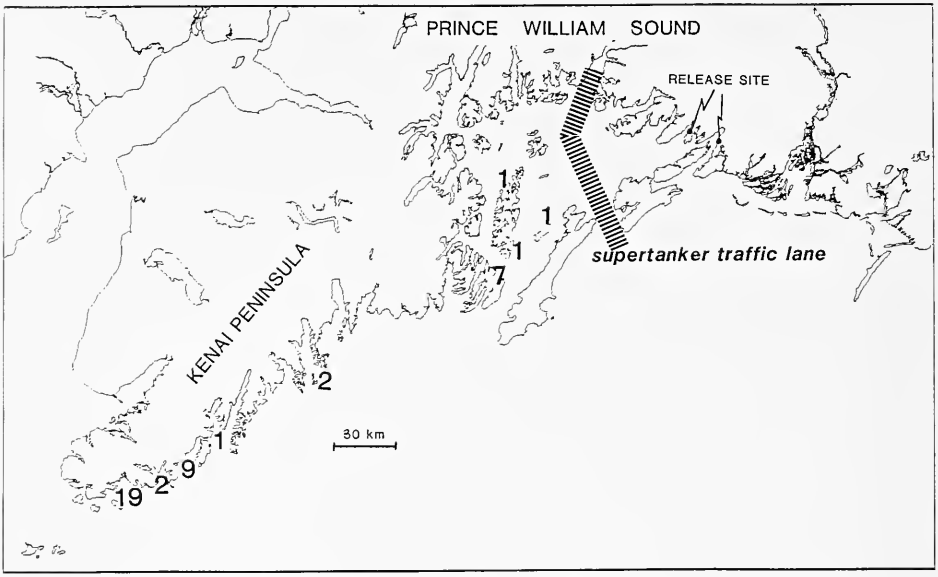

Fig. 1. Capture locations of sea otters (*Enhydra lutris*) treated in otter rehabilitation centers, implanted with radio transmitters, and released in eastern PWS for followup studies. Two otters that were captured in the Kodiak Archipelago are not shown on the figure.

In all studies, monitoring of radio-instrumented individuals was conducted from small skiffs and fixed-wing aircraft as described by Monnett (1988). Since the release of the first otters in May 1989, fixed-wing aircraft have been used about 1,000 h for radiotracking instrumented sea otters. Small boats have been used for an additional 1,500–2,000 h. The search area included PWS, the coastline of the Gulf of Alaska between Kachemak Bay and Sitka, the Barren Islands, and some other areas of the Kodiak Archipelago. An attempt was made to locate and visually examine each otter every 7–14 days after instrumentation.

Results

Observations on Otters With Flipper-tag Transmitters

Seven otters with externally attached flipper radio transmitters were monitored over periods of a few hours to more than 60 days. One large male was seen only once after his release, a few kilometers from the release site. The radio transmitters of three otters failed prematurely (8 days of life or less) and when last heard, after 21 days, the strength of a fourth transmitter was substantially reduced. Thus, it is likely that at least four, and possibly five, radio transmitters either malfunctioned or were damaged by otters.

No mortalities were observed during the observation period. However, several females seemed to be relatively inactive, especially when compared with the treated otters that were instrumented and released in July. One female was hauled out during observations in a 2-day period. She was reluctant to enter the water when approached by observers in a skiff. Unfortunately, when she was last observed her radio transmitter was failing, and her fate was uncertain.

No otters were observed west of the supertanker traffic lanes (Fig. 1). Two males swam to Orca Inlet, 30–40 km from the release site, and entered male groups. A third male was last observed 12 days after release within 10 km of the release site. The maximum distances known to have been traveled from the site of release by three females were 2, 10, and 16 km.

Early Observations of Radio-implanted Otters

About 400 radiolocations were taken on 21 radio-implanted sea otters during the 20-day observation period prescribed under the U.S. Fish and Wildlife Service's release plan. Most radiolocations were accompanied by a brief visual observation, sufficient to establish the status and behavior of the sea otter. No days were lost because of bad weather. Sighting locations for each of the 21 otters studied during the first 20 days after release are presented in the Appendix.

All 21 otters were alive at the end of the 20-day observation period. None exhibited prolonged periods of inactivity. However, during the first week or longer, many otters were swimming rapidly when observed, alternating short periods of swimming on the surface with longer periods of swimming underwater. Initially upon release, some of the otters swam continuously away from the release site for many hours. During the first week after release, travel rates of 20–40 km/day were not unusual. During the first 20 days, the median total distance traveled by males was 45 km (range, 10–280 km), whereas that of females was 160 km (range 5–300 km). Six of nine females traveled more than 150 km, but only 3 of 12 males did so.

Two of 21 otters traveled into areas officially classified as being within the coverage of the T/V *Exxon Valdez* oil spill. However, only a single otter (ID no. 4098) remained within the oil spill area for more than a few days. Both otters were seen in the vicinity of beaches that were being subjected to Exxon's cleaning protocols. On the 14th day of observation, one of the females (ID no. 4098) was seen hauled out near Eleanor Island on oil-contaminated rocks that were surrounded by oil sheen. However, both otters appeared vigorous during the entire 20 days of the study, and both swam in excess of 100 km after encountering oiled habitat.

Later Observations of Radio-implanted Otters

During the first 8 months after release from the otter rehabilitation centers, 21 of 45 instrumented otters were known to have traveled from their release sites into areas of western PWS affected by the oil spill. Six otters returned to waters adjacent to the Kenai Peninsula. One otter traveled about 90 km to Controller Bay, which is southeast of PWS. Several otters took up at least a temporary residence in the Gulf of Alaska, along the southern coast of Hinchinbrook Island or Montague Island. The maximum known distance traveled from the site of release was by a female that swam to English Bay on the Kenai Peninsula, a distance of about 400 km.

As of 19 April 1990, 23 of 45 (54.5%) radio-instrumented sea otters released from the otter centers were known to be alive (Table 1). Another otter experienced a radio transmitter malfunction, and its radio was no longer broadcasting. Twenty-one otters were either dead (12) or classified as missing (9). Not counting the otter with the malfunctioning radio transmitter or those that were missing, 65.7% of the radio-instrumented otters survived the first 8 months after release. Mortality increased strikingly during the winter season (January–April; Table 1). The proportion of otters known dead versus those classified as missing was higher after 1 January than in previous months (Table 1; August–December, 1 dead vs. 6 missing; January–April, 11 dead vs. 3 missing; $\chi^2 = 7.9$, 1 df, $P < 0.01$).

The proportion of the radio-instrumented otters released that survived was less than that of the two groups of untreated otters (Fig. 2). Fifty-eight sea otters were radio-instrumented in 1987. After 8 months of monitoring, all 58 otters were alive (if individuals from otter centers classified as missing are excluded; $\chi^2 = 22.2$, 1 df, $P < 0.001$). A single radio transmitter malfunctioned during the 1987 study. The otter, a female, was observed during the following summer, when she was identified by her flipper tag colors while swimming near a skiff on which her pup was being tagged. Moreover, proportionately more of the otters from the treatment centers were classified as missing (Table 2; $\chi^2 = 12.9$, 1 df, $P < 0.01$).

A second group of untreated sea otters was radio-instrumented during October-November

Table 1. *Fates of sea otters (*Enhydra lutris*) implanted with radio transmitters and released from otter centers, summarized by season.*

Status	Aug.–Sept.	Oct.–Dec.	Jan.–April	Total
Alive	40	37	23	23
Dead	1	0	11	12
Missing	3	3	3	9
Transmitter failure	1	0	0	1

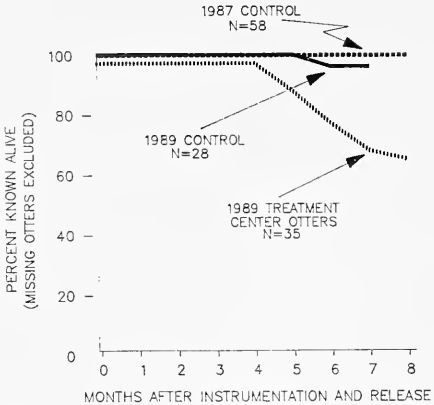

Fig. 2. Survival rates of sea otters (*Enhydra lutris*) implanted with radio transmitters in three studies during the first 8 months of observation. Otters classified as missing were not included in this analysis, as reflected in sample sizes given.

1989 and monitored, as of 3 June 1990, for 7–8 months. During this period, one individual died, and two were classified as missing. When compared to the otters released from the otter centers, proportionately fewer of the untreated otters were dead (individuals classified as missing excluded; $\chi^2 = 9.0$, 1 df, $P < 0.01$). However, the proportion of individuals classified as missing in the two studies was not significantly different ($\chi^2 = 2.7$, 1 df, $P > 0.05$).

The likelihood that an individual survived during the study period did not seem to be related to whether it reentered waters in the vicinity of the spilled oil trajectory. The proportion of dead or missing animals was similar between those that, at some point after release, crossed the supertanker traffic lanes into the western PWS and those that remained in the east. Eleven of the 21 otters that were known to have traveled into western PWS were missing or dead as of 1 April. A comparable proportion (10 missing or dead otters of 23) was observed for otters that remained in habitat east of the tanker lanes. Moreover, the vast majority of the dead or missing otters were, when last observed alive, in habitat located east of the tanker lanes (Table 2).

Whether an individual was dead or missing was apparently not related to whether the individual was captured in PWS versus along the Kenai Peninsula (Table 3; $\chi^2 = 0.16$, 2 df, not significant).

Table 2. *Last known location of dead or missing sea otters (*Enhydra lutris*). Habitat east of the supertanker lanes was generally not oiled by the T/V* Exxon Valdez *oil spill. Otters entering habitat west of the supertanker lanes would probably traverse oiled habitat.*

Status	East of the supertanker lanes	West of the supertanker lanes
Dead	10	2
Missing	7	2

Discussion

The sea otters that were captured, underwent treatment, and were selected for inclusion in this study seemed to be healthy and in good condition at the time of release into eastern PWS (Haebler 1990). Most of these animals seemed to remain vigorous in the first 20 days after release. More important, however, during the first 8 months after release the survival rates of the otters released from the rehabilitation centers seemed to have been relatively low. These findings are particularly sobering when one considers that by the time the seven individuals were selected for the first phase of this study (15 May 1989), 40.1% of the otters that had been admitted alive to the rehabilitation centers had already died (Williams et al., 1990; Appendix). Thus, all of the otters that were even considered for inclusion in this study were the "survivors" of the capture and treatment process, and as such, were a subset of those that entered the rehabilitation centers. Moreover, the sea otters included in this study (those that were selected for instrumentation) were among the healthiest of these survivors.

Table 3. *Fates of sea otters (*Enhydra lutris*) captured and taken to otter centers and location of capture. Both otters captured within the Kodiak Archipelago are classified as missing.*

Status	Prince William Sound	Kenai Peninsula
Alive	6	17
Dead	3	9
Missing	1	6

Our results emphasize the value and the necessity of long-term monitoring with reliable radio transmitters to assess the long-term fates of these animals. If only the flipper radio transmitter data were available, there would be insufficient information to reach any conclusion about the fates of these animals. If data for only the first 20 days after release were available (as was true when decisions about the release of the remaining captive otters had to be made), very different fates would be assumed for these animals than those that we now know or suspect occurred.

Study of Otters With Flipper Radio Transmitters Not Informative

The goals of the flipper radio transmitter study were to provide short-term information necessary for formulating policy about whether to release sea otters held in the centers back to the wild, and if so, where they should be released. Those who designed the study hoped that it would provide sufficient data to indicate whether animals initially captured in western PWS would remain in the clean northeastern PWS where they were released, and whether they would be able to survive in the wild after their experiences with oil, treatment, and captivity. However, because of the intrinsic limitations of flipper radio transmitters (e.g., if an animal dies in the water, its flippers are mostly underwater and the radio signal cannot be detected) and the poor performance of the transmitters in this study, little insight into these issues was gained.

Insight From Study of Otters With Implanted Radios

It is insightful to compare the findings obtained after the first 20 days of tracking the radio-implanted otters with those available after 8 months. The data on relative mobility tended to be similar over the two periods, whereas the data on fate of the otters were not.

As noted, otters released from the centers tended to be more mobile than normal sea otters in eastern PWS, both over the first 20-day period and over the first 8 months of monitoring. Some otters could be termed hyperactive, swimming almost constantly. During the 8-month period, 46.6% of the instrumented otters from the centers entered western PWS one or more times. Conversely, of 75 normal adult females captured since 1984 in eastern PWS and studied using transmitters such as those in this study, only one old, morphologically aberrant female has ever been known to cross into western PWS. That sea otters are capable of making a movement of this magnitude is well documented (e.g., during the recolonization of the Aleutian Islands [Lensink 1962; Kenyon 1969]). However, Lensink (1962) noted that natural features, such as deep, wide bodies of water, can act as barriers or discouragements to sea otter movement unless otters are sufficiently motivated, such as by depletion of food resources.

The motivations underlying the movements of the otters released from the treatment centers are not readily apparent. However, the process of releasing animals caught in western PWS, or even farther west, into eastern PWS was essentially a translocation of those individuals. All information available from previous translocations (e.g., the translocations to Oregon, or the recent translocation of otters to San Nicolas Island) suggests that sea otters are unlikely to remain at the release site. However, the translocation made here differs from those attempted before in at least four important ways: animals were held for long periods in captivity between capture and translocation; the habitat from which they were captured, was, at least in some cases, one in which their recent experiences were likely to have been unpleasant; the habitat into which they were released contained large numbers of otters; and the release location was not isolated from other suitable habitat by many miles of open ocean, as was true in the recent San Nicolas Island translocation. Because of these differences, the behavior of the animals after release could not be predicted with any certainty.

Regarding the prognosis for future survival of the otters released from the centers, the short-term results of this study were optimistic, as compared with those available after 8 months. At the end of the first 20 days of monitoring the first 21 animals in the long-term study, all appeared healthy and were obviously competent to care for themselves in the wild. However, mortality increased sharply as winter weather patterns developed. The mortality observed over the first 8 months of observation of these animals was much higher than that observed in the control groups.

On the basis of directly comparable data from previous studies in which adult sea otters from PWS were surgically implanted with radio transmitters, it is clear that survival rates of adult sea otters in normal, healthy populations tend to be high. For example, 8 months after instrumentation (the interval examined in this paper) all of the

58 adult females implanted in 1987 in PWS were known to be alive (Fig. 2).

The number of treatment center animals that are categorized as missing is also high. While this study is ongoing, and hence, results are preliminary, it is likely that many or all of the sea otters now in the missing category are dead. Alternatively, they could be alive with functioning radios, but remain undetected, or their radios could have failed. Since a large area, including the entire PWS, the Kenai Peninsula, and the Gulf of Alaska to Controller Bay has been searched many times, we are confident that few or no "missing" animals with functional radios are alive within that area. Additionally, an even larger area, from PWS to the Barren Islands, and the nearshore areas of the Gulf of Alaska south to Sitka, has also been searched at least once. Some of the missing animals could be alive, with functional radios, if they traveled great distances (i.e., south of Sitka, west of the Barren Islands, or into Cook Inlet) or were living far offshore. While such distant travel is possible, we think it is unlikely to account for any significant portion of the missing animals, especially because many of the animals that became missing should have been detected at least once while en route to such locations. Regarding the possibility of radio failure, there is no reason to think that the performance of the radio transmitters would be different in the sea otters from the treatment centers than in any of the other otters that have undergone this type of instrumentation, either as controls for this study or in the past. Hence, radio failure is unsatisfactory as an explanation for the increased rate of missing animals in the group from the treatment centers versus otters in the control groups or in previous studies.

Radiotelemetry has become an effective and reliable tool for studies of sea otter natural history in recent years. Individuals are usually easily relocated and seldom remain undetected if living in an area that is overflown by a tracking flight more than one time. However, we suggest that it should not be expected that all dead sea otters would have been recovered during this study, for several reasons. The search area is bounded by thousands of miles of ocean. Certainly, some carcasses would be likely to drift out to sea. We have observed that, in PWS, otter carcasses are often scavenged within a few days. Once released from a carcass a radio may become submerged and go undetected indefinitely. Carcasses have been known to freeze into ice sheets that form in the backs of bays, where they may become submerged or destroyed, or they may drift away in ice floes. Radios may even be carried off by other wildlife and go undetected. For example, sea otter radios have been found in raptor nests and bear caches. In the case of raptors, we doubt that the radios were transported while still in the carcasses. The radios must have been selected and carried independently. Last, some carcasses may sink and remain undetected.

At this time, information and analyses are incomplete and insufficient to allow us to reach conclusions about the causes of the deaths of the sea otters studied. As noted, most of the mortality of the instrumented animals from the treatment centers occurred during the winter. Apparently, the animals that died could not tolerate the winter weather conditions. Potential causes of the reduced survival rate of the animals that went through the capture and rehabilitation process include the following: chronic damage (e.g., organ or immune system damage) from initial exposure to oil or from stress of captivity, disease, translocation, and damage from chronic exposure to oil or contaminated prey following release.

These factors may be interactive. For example, a hypothetical sea otter with a damaged immune system due to exposure to toxic components of crude oil would be more susceptible to disease and stress associated with translocation and captivity. Geraci and Smith (1976) concluded that captivity-related stress was probably the primary cause of death in seals experimentally contaminated with crude oil, and that the oil served as a trigger for the stress. St. Aubin (1988) suggested that the proximate cause of death in these seals may have been cardiac fibrillation resulting from high levels of epinephrine (due to stress) and hydrocarbons. Many or all of the sea otters examined in this study may have ingested, had their fur contaminated with, or inhaled components of Prudhoe Bay crude oil. Certain components and metabolites of crude oil are known to have pathogenic effects in mammals, including mutagenic, carcinogenic (Bingham et al. 1980), and embryopathic effects (Currie et al. 1970; Bui et al. 1986).

The case of the lesions at the Seward Center is a good model of the potential for disease transmission at an otter center and thus the risks inherent in captivity. Harris et al. (1990) pointed out that well-defined oral lesions, assumed to have been caused by a herpes-like virus, were common to otters housed at the Seward center. The presence of the viral-induced lesions, assumed to be benign (Harris et al. 1990), was correlated with the otters being held captive at the Seward Center. Similar,

well-defined lesions were not observed at the Valdez Center or in wild sea otters in PWS. Presumably, if an ostensibly harmless virus can be transmitted so thoroughly through a captive population, so could a more harmful virus.

Further analyses, including evaluation of data from necropsy and histopathology studies, may permit better definition of the cause of death in these animals.

Several potential explanations for the increase in mortality are not supported by the data analyzed to date. There is no indication from necropsy results (R. Moeller, Armed Forces Institute of Pathology, Washington, D.C., and J. Blake, University of Alaska, Fairbanks, personal communication) or from previous or current studies of otters that were captured in the wild, instrumented, and immediately released that the radio implants were in any way related to the increased mortality of the sea otters released from the treatment centers. As noted previously, the untreated individuals are also carrying the same type of implanted radios. At present, the increased mortality observed in the otters from the centers does not seem to be directly related to the location inhabited postrelease. Thus, preliminary analyses indicate that otters that crossed into western PWS, at any point after release, were no more likely to die than those that did not make the crossing. The instrumented animals from the centers were not present in large numbers in western PWS during the periods of winter storms, when oil was coming off the beaches and recirculating, and when large slicks were observed. However, more detailed analyses are required to determine the relation (if any) between probability of death and time spent in the oil spill area after release.

Failure to Rehabilitate Suggests Broadened Perspective

The term rehabilitate means to restore to customary activity or to a former state. The findings presented and discussed in the present paper suggest that the combination of measures undertaken in an attempt to aid sea otters after the T/V *Exxon Valdez* oil spill did not result in the true rehabilitation of the surviving otters. This combination included capture (often by inexperienced personnel); treatment, which often involved frequent sedation; holding in a highly artificial situation with extensive exposure to humans and, in some instances, domesticated animals; and release in unfamiliar, but rich, habitat. It is not our purpose to attempt to determine why this combination of measures failed. However, the data presented here indicate that it failed to result in the rehabilitation of captured sea otters. Thus, because there are no data available that indicate that rehabilitation can be accomplished, we suggest that in future discussions the centers that were established be referred to as treatment centers rather than rehabilitation centers, and the released otters be referred to as treated otters, not rehabilitated otters. This distinction is not simply semantic; it is critical. The implication from the word rehabilitate is that if the otters in the rehabilitation centers were damaged, for whatever reason, the damage could be, and was, fixed. To imply such an ability, if no such ability exists, tends to mollify the public's and policymakers' concerns by providing a false sense of security about our ability to mend what we break.

We recommend that the entire strategy of focusing on oiled animals undergo careful reconsideration. Alternative strategies that are more likely to result in the long-term health and viability of sea otter populations include the following, listed in order of priority: (1) prevention of oil spills; (2) protection of critical habitats and areas of high population density, in the event of a spill, with concurrent minimization of disturbance in such areas; (3) preemptive capture of individuals in the path of a spill, with removal of the unoiled animals to natural, barricaded, remote habitats where natural food items are supplemented and in which human contact is minimal. All of these strategies emphasize preventing otters from becoming oiled, rather than trying to treat animals after oiling. All are feasible in certain situations. For example, it is clear from the success enjoyed by those involved in commercial fisheries in Cordova, Alaska, in their attempts to protect hatcheries and fish streams, that many of the critical sea otter habitat areas in western PWS could have been effectively protected with booms during the T/V *Exxon Valdez* spill. Additionally, these strategies keep sea otters out of highly captive situations and away from people.

Our viewpoint is that captivity, in and of itself, poses serious dangers to the specific otters brought in, to the population exposed to capture procedures during an oil spill, and to the population into which the otters are released. Factors contributing to captivity risk are (1) stress—during capture (particularly by inexperienced personnel, some of whom chased sea otters during "rescue efforts" for periods in excess of 1 h, [M. DeVille, Cordova,

Alaska, personal communication]), during captivity (e.g., Geraci and Smith [1976] documented a dramatic difference in the survival of oiled seals held indoors versus those in pens in a natural situation), and during translocation; (2) disease—contracted from humans or domesticated animals, which risks the captive population and eventually, through release, the wild population (Spraker 1990); (3) separation of mother–pup pairs (Ames 1990); and (4) disruption of the natural learning processes of young animals.

Holding otters captive, then releasing them back into the wild, should be viewed as an option that may result in the death of many captive and wild individuals. Hence, such an action is a measure of last resort and should be taken only with extreme caution. Unless it can be demonstrated that treatment will be effective and that the risk of spreading disease to the wild population will be eliminated, capture and housing policies such as those after the T/V *Exxon Valdez* oil spill should not be repeated. Avoiding oiling and captivity are more promising strategies.

In conclusion, despite the tremendous amount of resources invested in the attempted rehabilitation of sea otters after the T/V *Exxon Valdez* oil spill, indications are that survival was reduced and behavior was, at least temporarily, abnormal—hence, rehabilitation did not occur.

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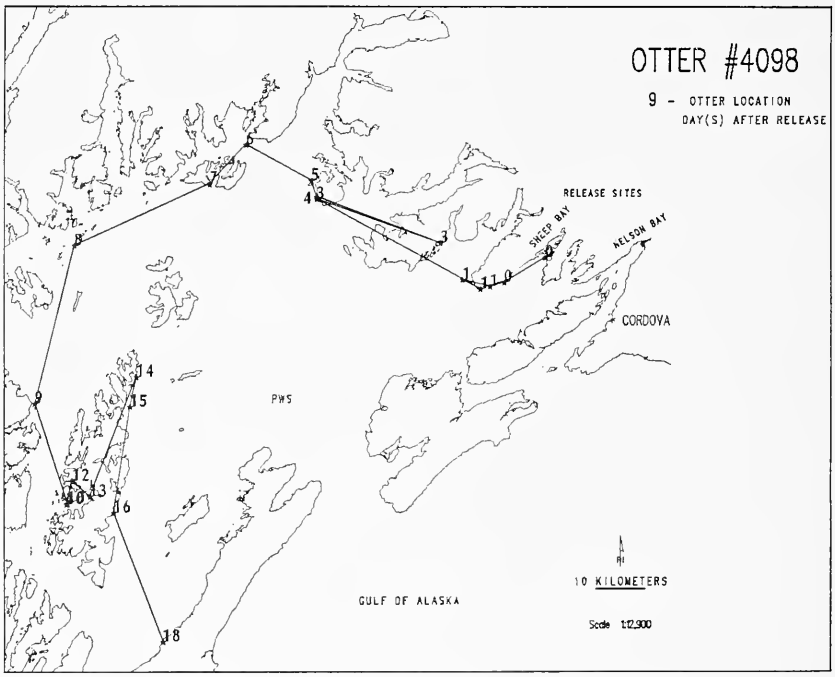
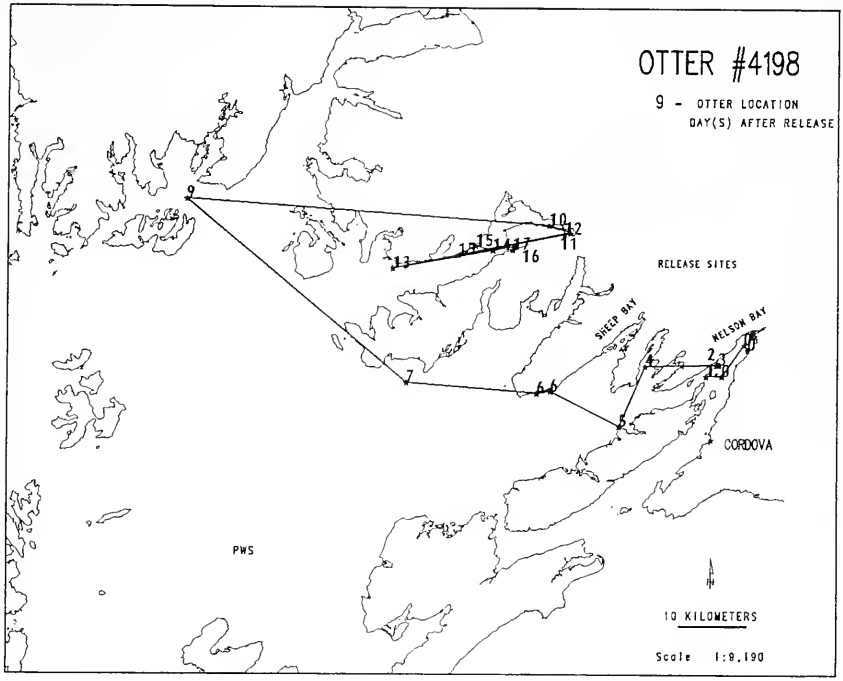
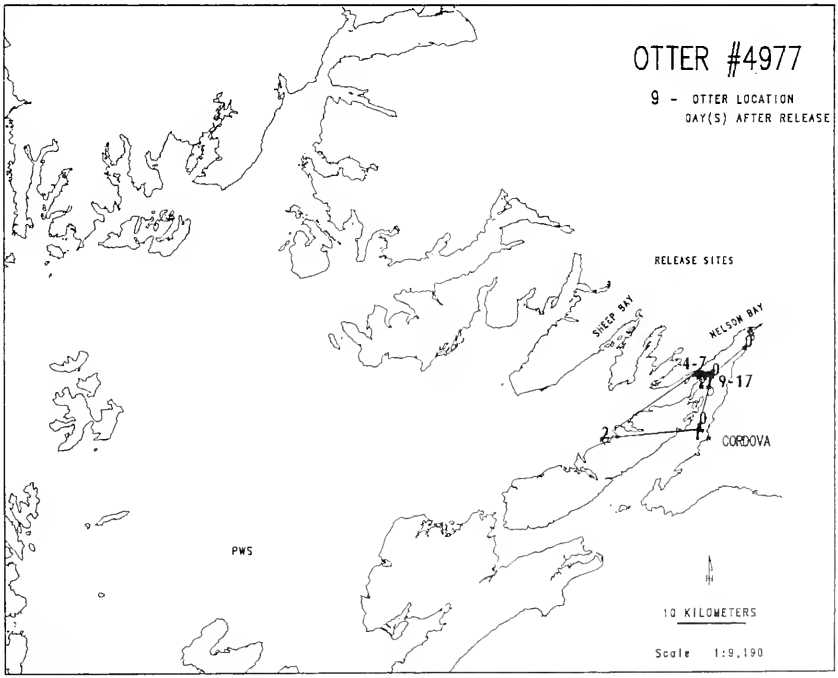
Appendix. Locations of radio fixes taken over the first 20 days of observation on instrumented sea otters (*Enhydra lutris*) released into eastern Prince William Sound. Otters were captured, transported to, treated in, and held in treatment centers established in response to the 24 March 1989 T/V *Exxon Valdez* oil spill. Numerals on each map indicate the day the radiolocation was obtained after the day of release.




OTTER #4198
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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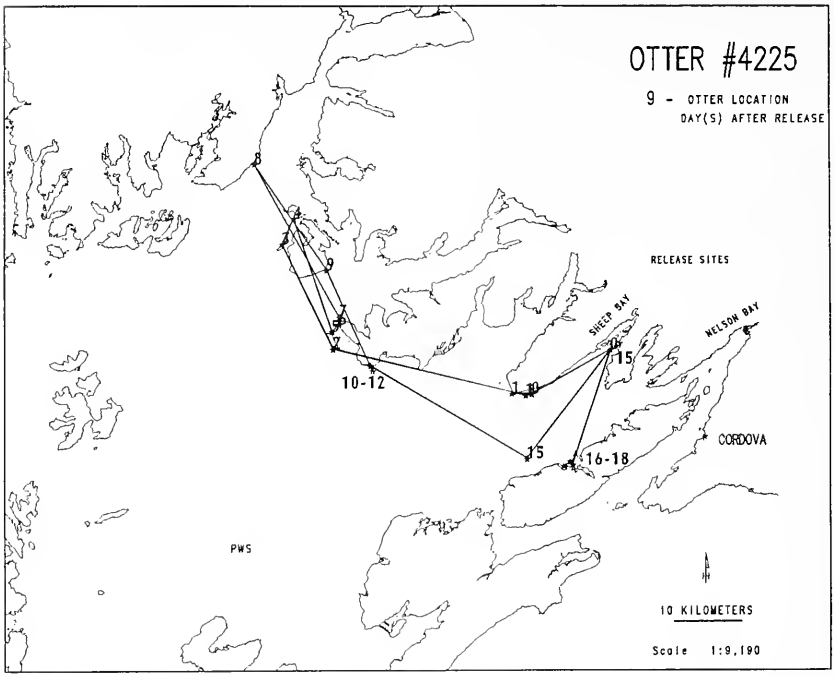
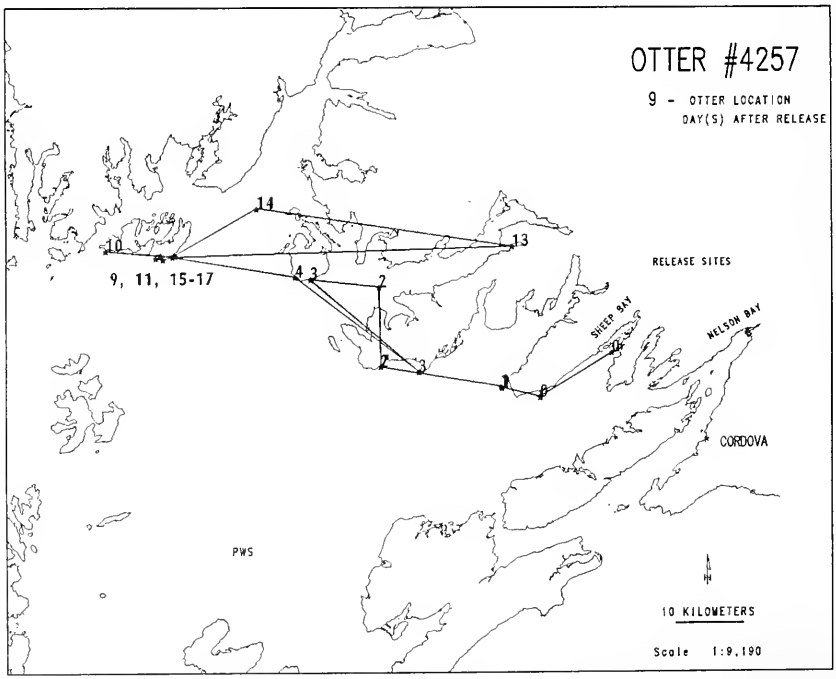
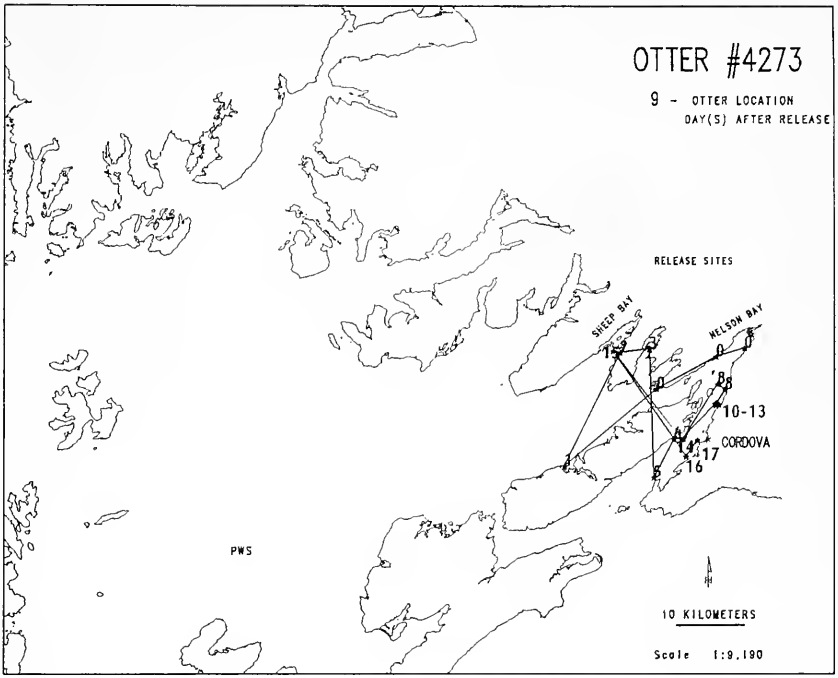
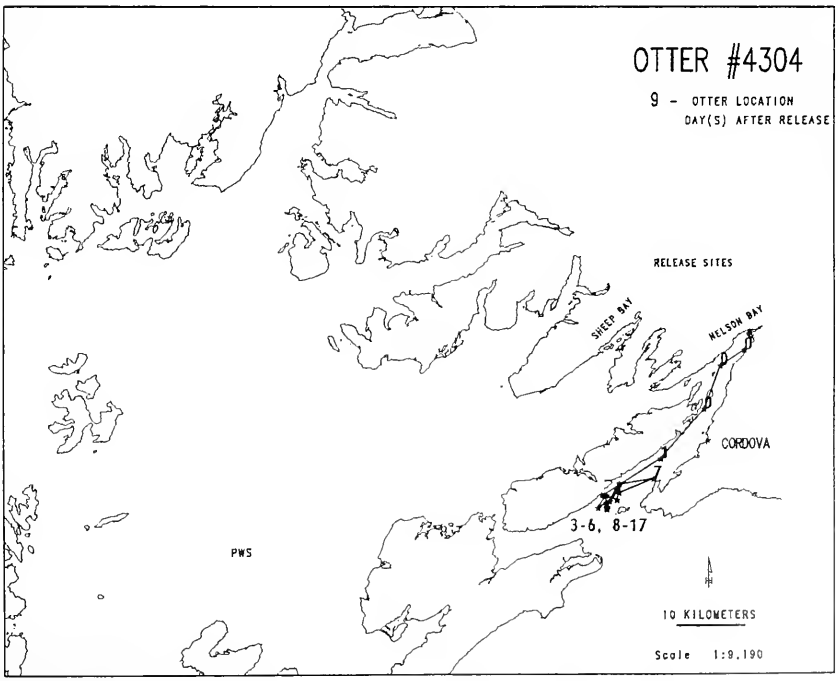
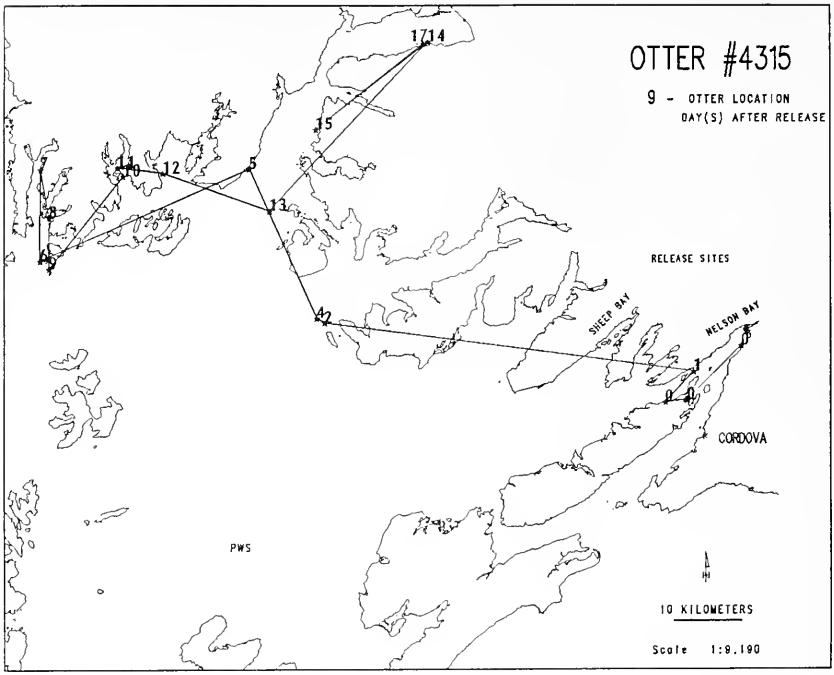
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190


OTTER #4225
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10-12
15
16-18
10 KILOMETERS
Scale 1:9,190


OTTER #4257
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
14
13
10
9, 11, 15-17
4 3
2
10 KILOMETERS
Scale 1:9,190


OTTER #4273
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
10-13
CORDOVA
17
16
PWS
10 KILOMETERS
Scale 1:9,190


OTTER #4304
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
3-6, 8-17
PWS
10 KILOMETERS
Scale 1:9,190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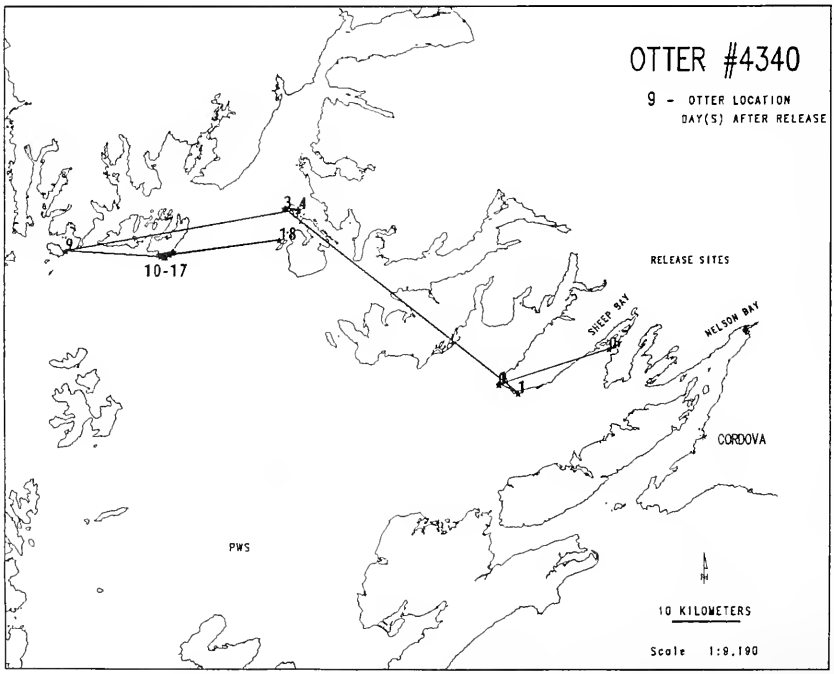
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:8,190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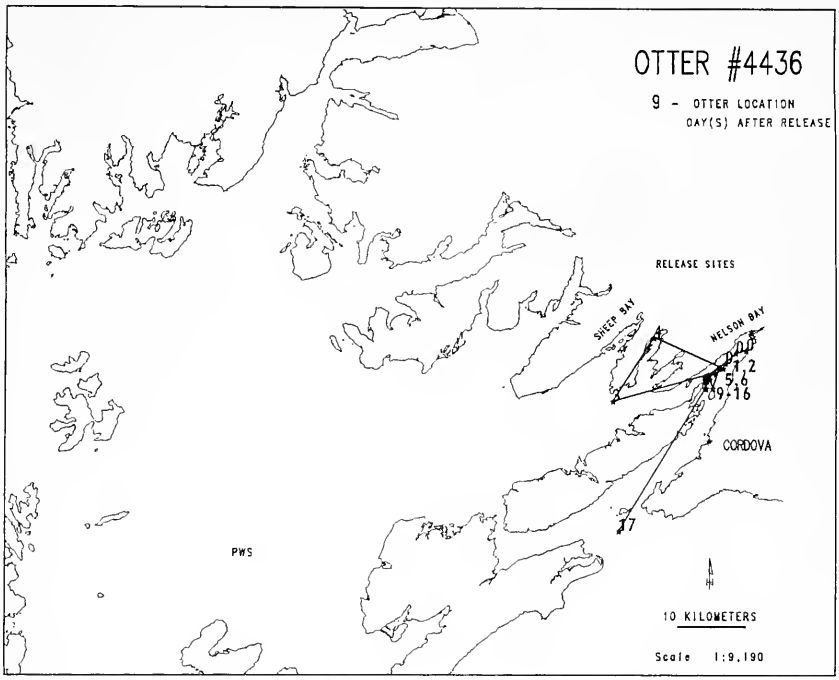
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10-17
10 KILOMETERS
Scale 1:8,190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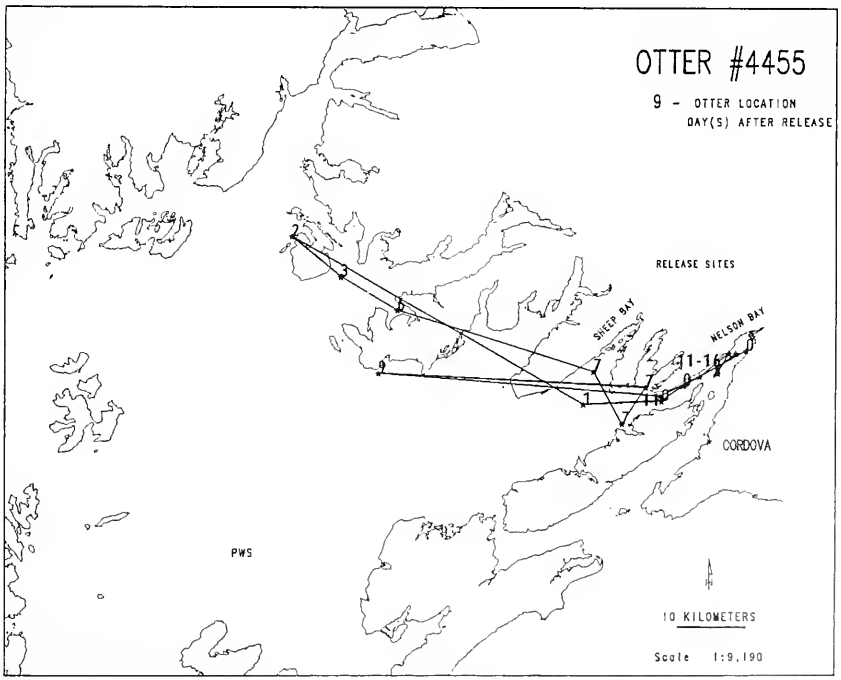
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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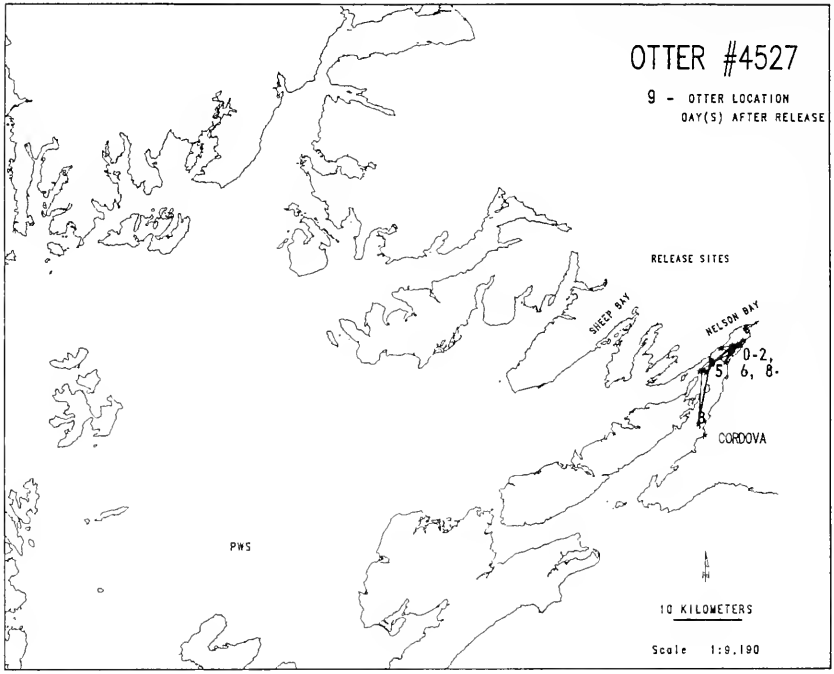
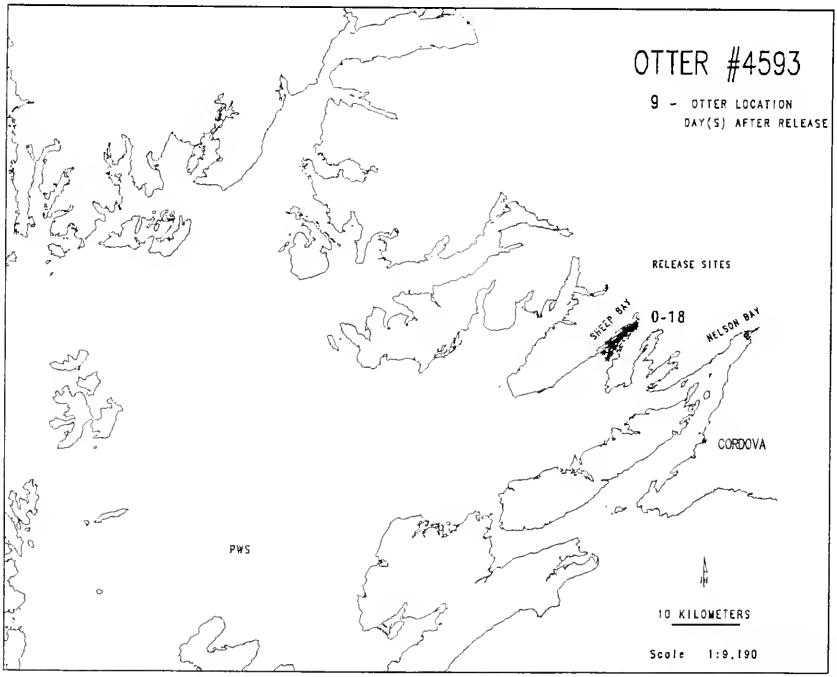
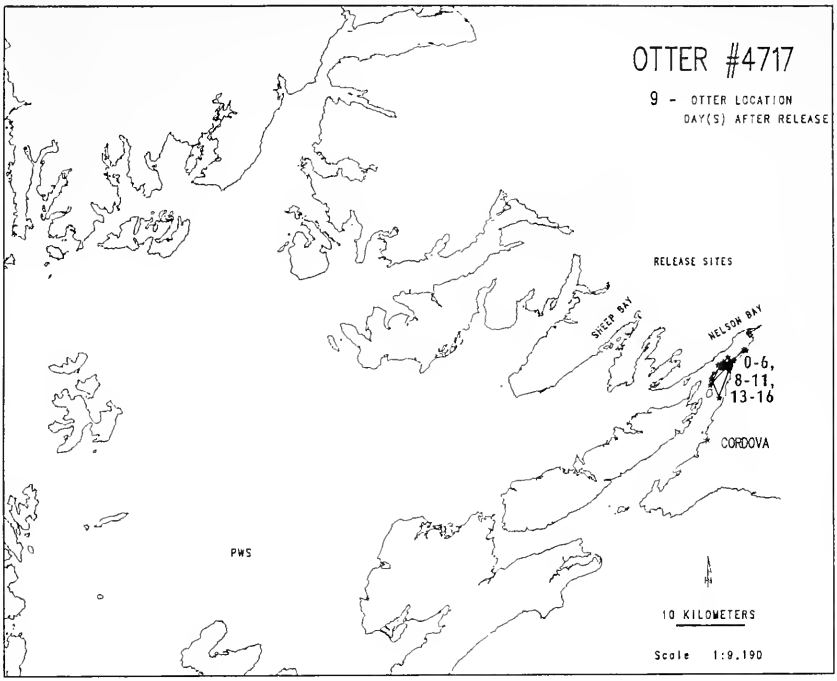
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190


OTTER #4527
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
0-2,
5, 6, 8-
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190


OTTER #4593
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
0-18
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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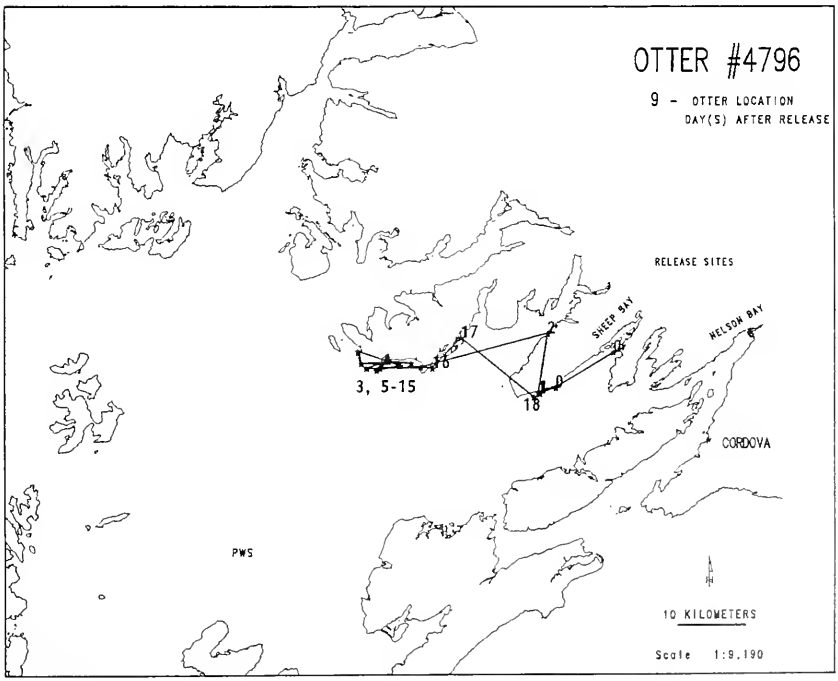
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
0-6,
8-11,
13-16
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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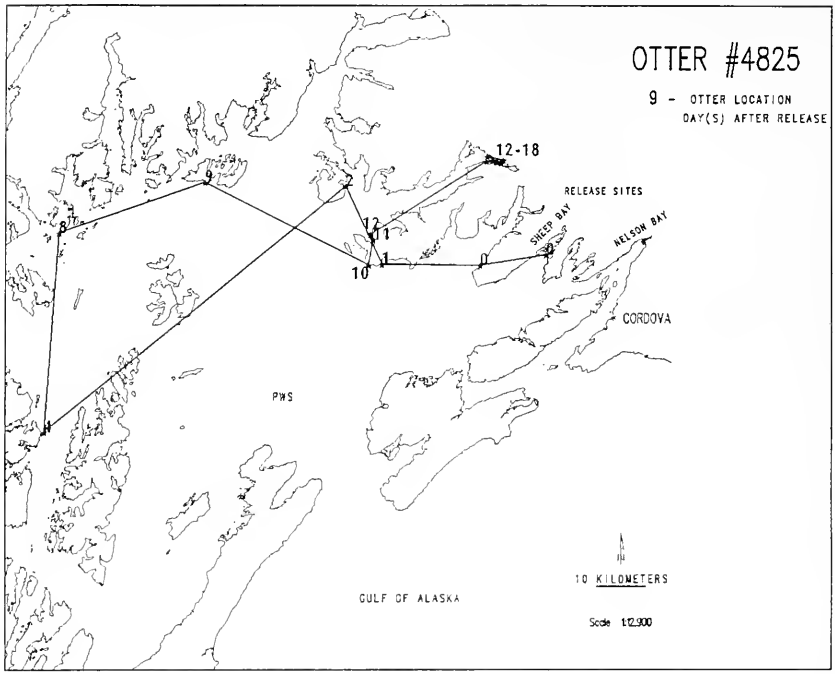
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
17
16
3, 5-15
0
18
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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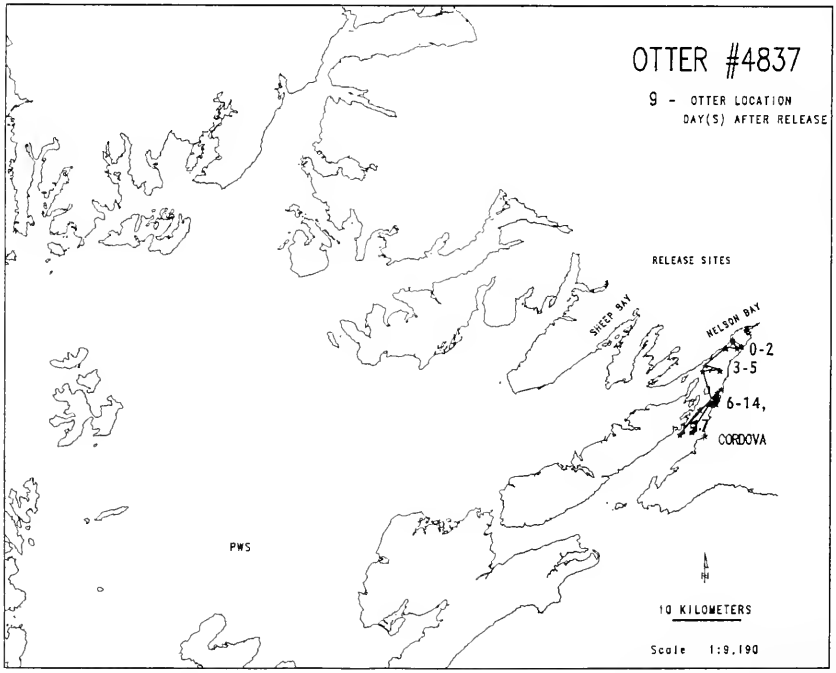
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
12-18
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
GULF OF ALASKA
10 KILOMETERS
Scale 1:2,900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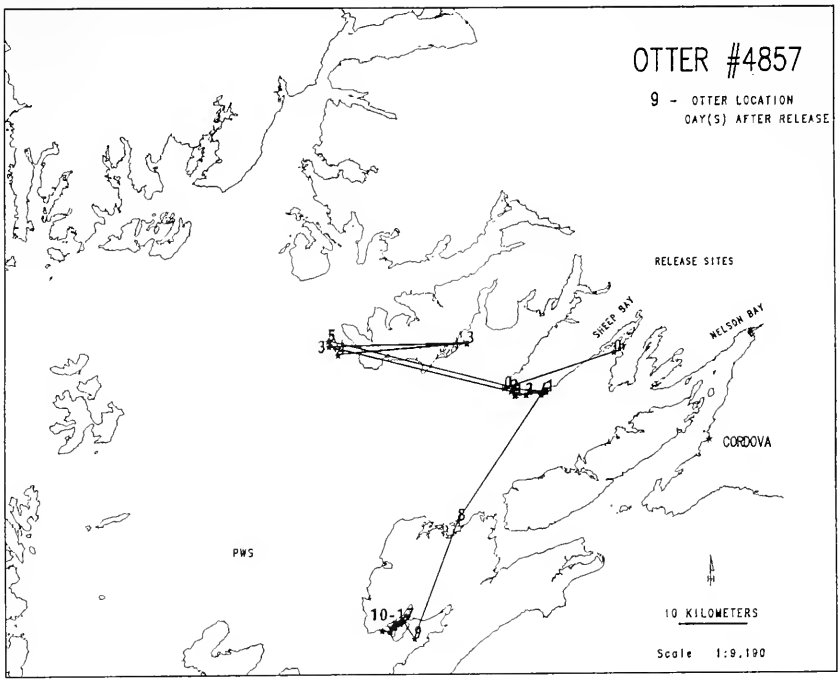
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
0-2
3-5
6-14,
17
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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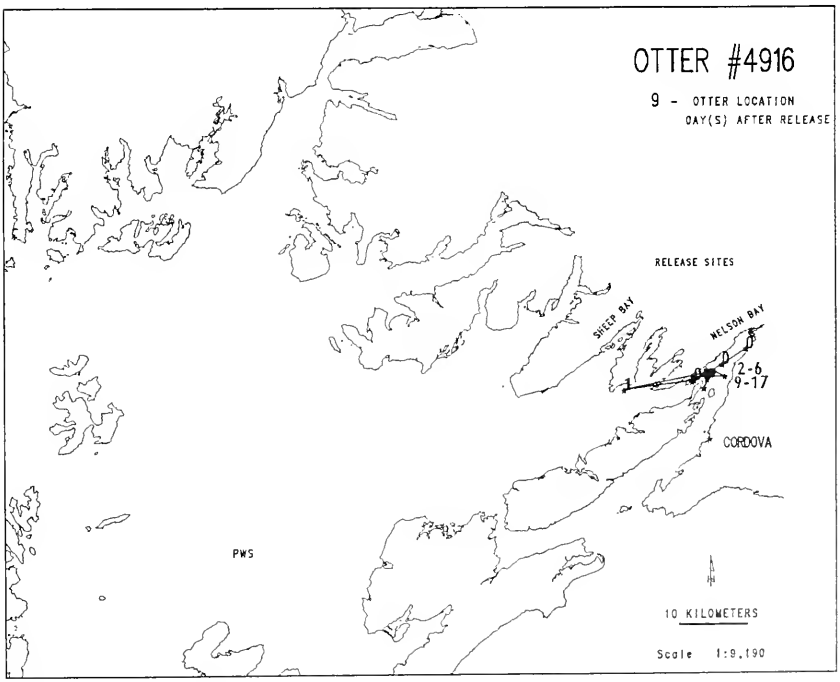
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10-17
10 KILOMETERS
Scale 1:9,190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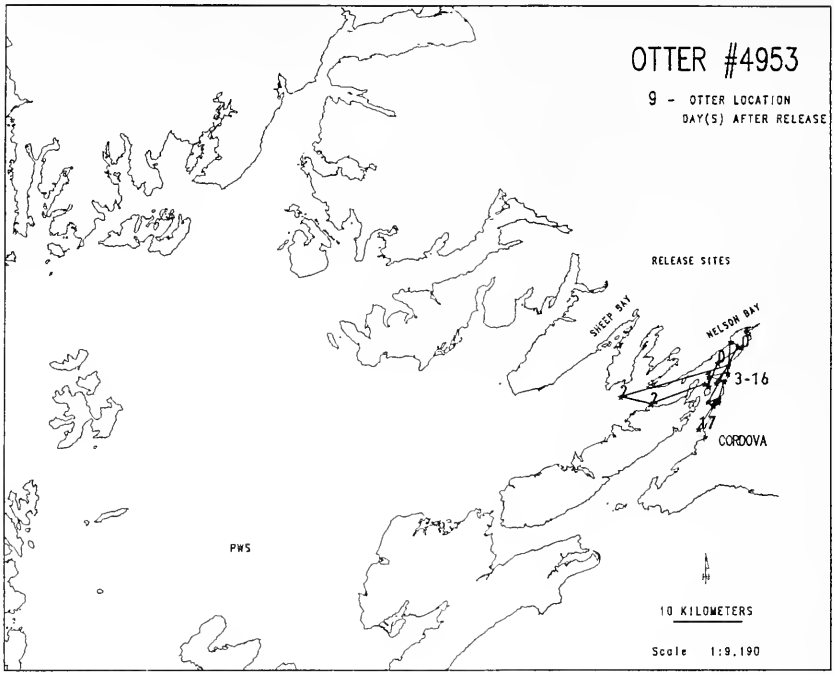
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
2-6
9-17
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
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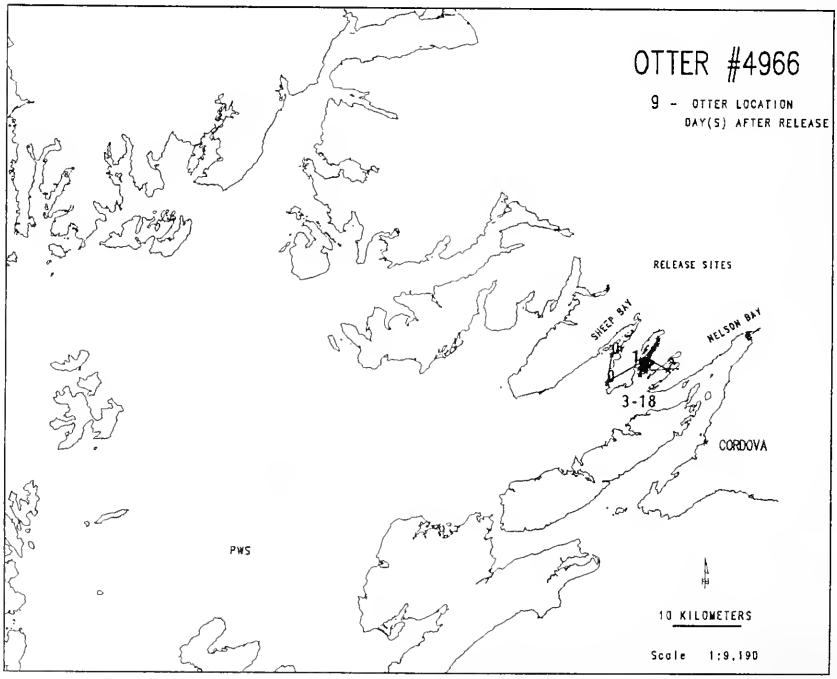
NELSON BAY
3-16
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
3-18
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190