Exxon Valdez Oil Spill State/Federal
Natural Resource Damage Assessment
Final Report

Mortality and Reproduction of Female Sea Otters in Prince William Sound, Alaska

Marine Mammal Study 6-13
Final Report

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Submitted to EVOS Trustee Council
May 1995

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Technical Report: Marine Mammal Study Number 6

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Study History: Marine Mammal Study 6 (MM6), titled *Assessment of the Magnitude, Extent, and Duration of Oil Spill Impacts on Sea Otter Populations in Alaska*, was initiated in 1989 as part of the Natural Resource Damage Assessment (NRDA). The study had a broad scope, involving more than 20 scientists over a three year period. Final results are presented in a series of reports that address the various project components. The work reported herein was conducted by Drs. C. Monnett and L.M. Rotterman as part of a Cooperative Agreement between the Prince William Sound Science Center and the U.S. Fish and Wildlife Service. A draft of this report was included in the November 1991 NRDA Draft Preliminary Status Report for MM6; portions of the material in this report were initially reported in a December 1990 Draft Report on MM6 submitted by Drs. Monnett and Rotterman.

Summary: Ninety-six female sea otters were instrumented with implanted radio-transmitters in Prince William Sound, Alaska, during 1989-1990. Females in eastern Prince William Sound exhibited a lower survival rate than those in western Prince William Sound. No differences were observed between rates of pupping or between rates of survival of dependent pups for sea otters in the two areas.

Key Words: *Enhydra lutris*, *Exxon Valdez*, sea otter.

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SUMMARY

Ninety-six female sea otters were instrumented with implanted radio-transmitters in Prince William Sound, Alaska, during 1989-1990. Females in eastern Prince William Sound exhibited a lower survival rate than those in western Prince William Sound. No differences were observed between rates of pupping or between rates of survival of dependent pups for sea otters in the two areas.

INTRODUCTION

On March 24, 1989, over 11 million gallons of crude oil were spilled in Prince William Sound, Alaska, due to the wreck of the T/V *Exxon Valdez*. The research discussed in this report was undertaken as part of Natural Resource Damage Assessment studies aimed at determining if the spill caused damage to the sea otter population(s) in the region, and, if so, the type, magnitude, and significance of the damage(s). The goals of this study were to determine whether the mortality and reproductive rates of adult females were different in areas within or near the areas through which large amounts of crude oil were spilled than in areas in which no crude oil was known to have passed. This information is crucial to understanding the overall extent of damage to the sea otter population(s); to estimating the rate and pattern of recovery; and to formulating restoration and response policies for sea otters throughout their range.

OBJECTIVES

The specific objectives of this study were defined in the corresponding statement of work as follows:

1. To test the hypothesis that survival of adult female sea otters is not different in oiled and unoiled areas.

2. To test the hypothesis that pupping rates of adult female sea otters are not different between oiled and unoiled areas.

3. To test the hypothesis that pup survival pre-weaning is not different between oiled and unoiled areas.

METHODS

Definitions

Status classifications are made based on consideration of data through July 31, 1991. Individuals classified as "dead" are known to be dead because their carcass or other remains were observed and, in some cases, recovered. "Missing" individuals are those whose radio signal could not be detected by boat or aircraft radio searches within Prince William Sound or adjacent areas along the Kenai Peninsula and Copper River Delta. The classification of "alive" is based upon visual observations of the individual. Females were classified as having pupped based upon visual observations that they were accompanied by a pup.

Study Groups

The eastern Prince William Sound grouping (EPWS) consists of 22 females that were instrumented during 1989 and 22 females that were instrumented during 1990. The western

Prince William Sound grouping (WPWS) consisted of 9 females instrumented during 1989 and 42 females instrumented during 1990 (Table 1). Capture locations are summarized in Figure 1.

Methods

Sea otters were captured when they became entangled in modified gill nets (Odemar and Wilson 1969; Garshelis et al. 1984). Research subjects were immobilized with a combination of fentanyl and azaperone as described in Williams et al. (1981).

Individuals were tagged with unique color combinations of nylon cattle tags through the inter-digital webbing of each hind flipper (Ames et al. 1983). Pulsing, 164 mHz radio-transmitters (Cedar Creek Bioelectronics Lab, Bethel, MN 55005), were similar to those described by Garshelis and Siniff (1983) and Ralls et al. (1989) but, measured 85 mm X 5 mm X 25 mm, weighed 150 g and contained 3 MIREL T batteries, rather than 2 such batteries as used by Ralls et al 1989. Radio-transmitters were surgically implanted in the peritoneal cavity of female sea otters by licensed veterinarians following a protocol adapted from that of Williams and Siniff (1983).

Radio-implanted females were monitored year-around from fixed-winged aircraft or boats equipped with Yagi antennas using 2000-channel, programmable scanning receivers (Cedar Creek Bioelectronics Lab). Radio-transmitters had ranges of 1-5 km and 6-10 km when monitored from boats and aircraft, respectively. An attempt was made to observe each individual at least biweekly.

Reproductive status was determined from direct visual observations of females carrying or being accompanied by pups. Radio-transmitters were judged to have expired when cessation of operation was preceded by observations of the radio-transmitter exhibiting a significantly reduced pulse rate (rate halved) and diminished signal strength (detection from only several hundred meters at sea level).

Analysis

Probabilities of survival and 95% confidence intervals (CI's) are calculated using Pollock et al.'s (1989) staggered entry modification to the Kaplan and Meier (1958) product limit procedure. Differences in the probability of survival between study groups are tested using the procedure described by Cox and Oakes (1984); see also Pollock et al. (1989) and White and Garrott (1990). Contingency Chi-squared analyses were used to test for differences in rates between study groupings.

Analysis of survival of dependent pups was confined to pups during the first 60 days following birth. It has been shown that sea otter pups in Prince William Sound may become independent and survive at less than 90 days of age (Monnett 1988).

RESULTS

Monitoring

Intervals between radio-locations were on average: EPWS (1990) = 5.8 days (SD = 1.0), (1991) = 5.9 days (SD = 3.2); WPWS (1990) = 8.7 days (SD = 1.4), (1991) = 11.1 days (SD = 4.7). Intervals between visual observations were on average: EPWS (1990) = 8.6 days (SD = 1.8), (1991) = 7.3 days (SD = 5.3); WPWS (1990) = 10.7 days (SD = 2.6), (1991) = 12.7 days (SD = 5.3).

Survival Rates of Adult Females

If females that were classified as missing are assumed to have died, the survival rate of females in WPWS was higher than that of females in EPWS (Table 2). If females classified as missing are excluded from the analysis, no differences exist (Table 2).

Pupping Rates

No differences were found in pupping rates of adult females between EPWS and WPWS in either 1990 or 1991: (1990) EPWS = 13/28 (46%) females pupped versus WPWS = 21/36 (58%) females pupped ($\chi^2 = 0.92$, 1 DF, $p > 0.50$); (1991) EPWS = 21/30 (70%) females pupped versus WPWS = 29/37 (78%) females pupped ($\chi^2 = 0.61$, 1 DF, $p > 0.50$).

Pup Survival

The survival rates of dependent pups for the first 60 days following birth were compared between EPWS and WPWS. No differences were found between the survival rates of dependent pups in either 1990 or 1991: (1990) EPWS = 9/13 (69%) pups survived versus WPWS = 15/21 (76%) pups survived ($\chi^2 = 0.19$, 1 DF, $p > 0.70$); (1991) EPWS = 17/21 (81%) pups survived versus WPWS = 28/29 (97%) pups survived ($\chi^2 = 3.29$, 1 DF, $p < 0.08$).

DISCUSSION

Based on directly comparable data from previous studies in which adult sea otters from Prince William Sound 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, for the first full year after instrumentation all of the 58 adult sea otters implanted in 1987 in Prince William Sound were known to be alive (Monnett and Rotterman unpublished data). Data collected post-EVOS suggest that sea otters in the western Sound are exhibiting typical survival rates whereas, those in the eastern Sound are surviving at abnormally low rates.

Potential Sources of Error in Estimates

Survival estimates.--We believe that 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 (however, see previous paragraph). 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 very 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, have also been searched at least once. Some of the missing animals could be alive, with functional radios if they traveled very 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 as many of the animals that became missing should have been detected at least once while enroute to such locations. With regards to the possibility of radio failure, there is no reason to think that the performance of the radio-transmitters would be different in the study sea otters than in any of the other otters that have undergone this type of instrumentation in the other studies. Hence, radio failure as an explanation for the increased rate of "missing" animals in the group from the EPWS versus otters in the WPWS, or in previous studies, is unsatisfactory.

Radio-telemetry 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 heen 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. Additionally, some intact carcasses may sink and remain undetected. Carcasses have been known to freeze into ice sheets that form in the backs of bays. Once therein, they may become submerged, destroyed or drift away in ice floes. Radios may even be carried off by other wildlife and go undetected.

Reproduction.--If pups were born and not recorded during this study, the actual probabilities of pupping would be higher than the estimates reported, herein. It is possible that biweekly monitoring may have resulted in a small number of missed births. For a separate study (Monnett and Rotterman in preparation), females were palpated to determine pregnancy before instrumentation. EPWS and WPWS females were monitored at different average rates. When females were visually examined every 10.7 days, 13/14 known pregnant females were eventually observed to have had pups. When observations were made every 8.6 days, 4/5 were seen with pups. It was not clear to what extent the missed births were a result of spontaneous abortions or mortality of very young pups.

Assumptions about minimum period of dependency.--If a proportion of the pups assumed to have been weaned actually died, measures of pup survival and female reproductive success (i.e., the probability of a pup surviving to weaning and the probability that a mature female produced a pup that survived to weaning) are over estimated, herein.

For our analysis we assume that 90 days is the minimum age at which a pup can achieve independence and survive. This age is considerably shorter (cf. ≥ 150 days) than that used Siniff and Ralls (1991) for sea otters in California. However, we believe that our assumption is valid for Prince William Sound for a number of reasons: 1) In 1984-1985, 4 instrumented pups in eastern Prince William had estimated dependency periods of from 76-100 days, had estimated weights at weaning of 9.5 - 12 kg and yet survived for many months after weaning (Monnett 1988). Healthy weanlings ($n = 3$) have been captured (2 were radio-instrumented) in Prince William Sound that weighed 10-12 kg (Monnett and Rotterman unpublished data); 2) In general, pups in Prince William Sound would be fairly large by 90 days of age. Assuming an average birth weight of 2 kg and an average growth rate of 90 grams per day (Monnett 1988, Monnett et al. 1991), the average body mass of pups in EPWS would be expected to be 10.1 kg at 90 days of age (2 kg + 8.1 kg). Pups of < 10 kg body mass are frequently strong divers and capable of evading pursuit by dipnetters in boats (personnel observation); 3) Pups weaned prematurely during research activities in EPWS, having estimated body mass as small as 10 kg showed no indication of post-weaning stress and survived over winter in most instances (Monnett and Rotterman unpublished data); 4) In California pups may be capable of surviving separation from their mothers at much younger ages than 150 days. For example, Payne and Jameson (1984) found that pups swam and dove proficiently at 70-104 days-of-age and ate nearly as rapidly as adults by 84 days-of-age.

Survival of dependent pups.--The probability that a pup survived from birth to weaning during this study was considerably greater than reported in other studies in Alaska ($p = 0.5$, $n = 8$: Garshelis et al. 1984) and California ($p = 0.46 - 0.58$, $n = 26$: Siniff and Ralls 1991). A small amount of the difference can be explained by differences in the age that a pup must reach before it is assumed to have survived to weaning (see above). Otherwise, the Garshelis (1983) data set is troubled by a small sample size. Siniff and Ralls (1991) combine telemetry data with that from tag-resighting data from California Department of Fish and Game. They suggest that the observed difference in the proportion of pups that die shortly after birth between the two studies may be a result of undocumented births in the tag-resighting study. If so, survival may be somewhat lower than that they reported (see above). It is not clear why so many pups die shortly after birth in California. Siniff and Ralls (1991) cite differences in weather patterns, contamination with pesticides or other pollutants, greater energy constraints on females. Another possible explanation is that sea otters in California are inbred and appear to lack genetic diversity which may result in the fixation of deleterious alleles (Rotterman 1992).

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Table 1. Data on instrumentation of female sea otters in Prince William Sound (PWS). Study groupings: EPWS = Eastern Prince William Sound; WPWS = Western Prince WIlliam Sound.

Otter ID	Study Grouping	Date Instrumented	Location Instrumented
89101	EPWS	08-Oct-89	Sheep Bay
89102	EPWS	08-Oct-89	Sheep Bay
89103	EPWS	08-Oct-89	Sheep Bay
89104	EPWS	08-Oct-89	Sheep Bay
89105	EPWS	09-Oct-89	Sheep Bay
89106	EPWS	12-Oct-89	North Island
89107	EPWS	12-Oct-89	North Island
89108	EPWS	12-Oct-89	North Island
89109	EPWS	12-Oct-89	North Island
89110	EPWS	12-Oct-89	North Island
89111	EPWS	12-Oct-89	North Island
89112	EPWS	13-Oct-89	North Island
89113	EPWS	13-Oct-89	North Island
89114	EPWS	13-Oct-89	North Island
89115	EPWS	20-Oct-89	North Island
89116	EPWS	20-Oct-89	North Island
89117	EPWS	20-Oct-89	North Island
89118	EPWS	20-Oct-89	North Island
89121	EPWS	22-Oct-89	North Island
89122	EPWS	22-Oct-89	North Island
89124	EPWS	22-Oct-89	North Island
89125	EPWS	22-Oct-89	North Island
89126	EPWS	22-Oct-89	North Island
89127	WPWS	04-Nov-89	Chicken Island, Latouche P.
89128	WPWS	06-Nov-89	Bainbridge Passage
89131	WPWS	07-Nov-89	Bainbridge Passage
89140	WPWS	12-Nov-89	Port Chalmers
89141	WPWS	13-Nov-89	Port Chalmers
89142	WPWS	13-Nov-89	Channel Island, Green Is.
89150	WPWS	15-Nov-89	Port Chalmers

Otter ID	Study Grouping	Date Instrumented	Location Instrumented
89153	WPWS	15-Nov-89	Port Chalmers
89155	WPWS	16-Nov-89	Port Chalmers
90001	EPWS	16-Mar-90	North Island
90004	EPWS	16-Mar-90	North Island
90005	EPWS	16-Mar-90	North Island
90006	EPWS	16-Mar-90	North Island
90008	EPWS	18-Mar-90	Quarry, Orca Inlet
90013	EPWS	22-Mar-90	Quarry, Orca Inlet
90014	EPWS	22-Mar-90	Quarry, Orca Inlet
90016	EPWS	24-Mar-90	Quarry, Orca Inlet
90017	EPWS	24-Mar-90	Quarry, Orca Inlet
90018	EPWS	26-Mar-90	Quarry, Orca Inlet
90019	EPWS	26-Mar-90	Quarry, Orca Inlet
90020	EPWS	26-Mar-90	Quarry, Orca Inlet
90022	EPWS	26 Mar-90	Quarry, Orca Inlet
90023	EPWS	27-Mar-90	Quarry, Orca Inlet
90024	EPWS	04-Apr-90	Sheep Bay
90027	EPWS	05-Apr-90	Sheep Bay
90028	EPWS	05-Apr-90	Sheep Bay
90029	EPWS	05-Apr-90	Sheep Bay
90031	WPWS	09-Apr-90	Little Green Island
90033	WPWS	11-Apr-90	Port Chalmers
90034	WPWS	11-Apr-90	Port Chalmers
90035	WPWS	11 Apr-90	Port Chalmers
90036	WPWS	11-Apr-90	Port Chalmers
89010	WPWS	11-Apr-90	Port Chalmers
90037	WPWS	11-Apr-90	Little Green Island
90038	WPWS	11-Apr-90	Port Chalmers
90039	WPWS	13-Apr-90	Squire Island, Knight Is.
90040	WPWS	13-Apr-90	Squire Island, Knight Is.
90041	WPWS	13-Apr-90	Squire Island,.Knight Is.
90042	WPWS	13-Apr-90	Squire Island, Knight Is.
90043	WPWS	13-Apr-90	Squire Island, Knight Is.

Otter ID	Study Grouping	Date Instrumented	Location Instrumented
90044	WPWS	13-Apr-90	Squire Island, Knight Is.
90045	WPWS	13-Apr-90	Squire Island, Knight Is.
90046	WPWS	13-Apr-90	Squire Island, Knight Is.
90047	WPWS	13-Apr-90	Squire Island, Knight Is.
90048	WPWS	13-Apr-90	Squire Island, Knight Is.
90049	WPWS	13-Apr-90	Squire Island, Knight Is.
90052	WPWS	22-Apr-90	Mummy Island, Knight Is.
90053	WPWS	22-Apr-90	Mummy Island, Knight Is.
90054	WPWS	22-Apr-90	Mummy Island, Knight Is.
90055	WPWS	22-Apr-90	Mummy Island, Knight Is.
90056	WPWS	23-Apr-90	Iktua Bay, Evans Island
90057	WPWS	24-Apr-90	Squire Island, Knight Is.
90058	WPWS	24-Apr-90	Squire Island, Knight Is.
90059	WPWS	24-Apr-90	Squire Island, Knight Is.
90061	WPWS	26-Apr-90	Squirrel Island, Knight Is.
90062	WPWS	26-Apr-90	Squirrel Island, Knight Is.
90063	WPWS	26-Apr-90	Squirrel Island, Knight Is.
90064	WPWS	26-Apr-90	Squirrel Island, Knight Is.
90065	WPWS	27-Apr-90	Mummy Bay Reef
90066	WPWS	28-Apr-90	Stockdale Harbor
90067	WPWS	28-Apr-90	Stockdale Harbor
90068	WPWS	28-Apr-90	Stockdale Harbor
90070	WPWS	29-Apr-90	Stockdale Harbor
90071	WPWS	29-Apr-90	Stockdale Harbor
90072	WPWS	29-Apr-90	Stockdale Harbor
90073	WPWS	29-Apr-90	Stockdale Harbor
90074	WPWS	30-Apr-90	Little Green Island
90075	WPWS	30-Apr-90	Little Green Island
90077	WPWS	30-Apr-90	Little Green Island
90110	EPWS	04-Sep-90	Simpson Bay, east arm
88208	EPWS	09-Sep-90	Simpson Bay, east arm
90169	EPWS	11-Oct-90	Simpson Bay, east arm
88186	EPWS	14-Oct-90	Simpson Bay, east arm

Table 2. Summary of statistics on survival of sea otters radio-instrumented in Prince William Sound. Study groupings include individuals from eastern Prince William Sound (EPWS) and individuals from western Prince William Sound (WPWS).

		p Survival	C.I.	χ^2	D.F.	p
MISSING ASSUMED DEAD						
Dec.89-Oct.90	WPWS	0.979	(0.987-1.020)	3.435	1	$p<0.07$
	EPWS	0.773	(0.654-0.891)			
Nov.90-Oct.91	WPWS	0.956	(0.895-1.016)	9.347	1	$p<0.01$
	EPWS	0.703	(0.553-0.853)			
Dec.89-Oct.91	WPWS	0.935	(0.864-1.006)	11.29	1	$p<0.001$
	EPWS	0.559	(0.414-0.705)			
MISSING EXCLUDED						
Dec.89-Oct.90	WPWS	0.979	(0.937-1.020)	0.923	1	$p>0.30$
	EPWS	0.899	(0.807-0.991)			
Nov.90-Oct.91	WPWS	1.000	(1.000-1.000)	2.515	1	$p<0.11$
	EPWS	0.944	(0.856-1.032)			
Dec.89-Oct.91	WPWS	0.979	(0.937-1.020)	2.870	1	$p<0.09$
	EPWS	0.8849	(0.719-0.978)			

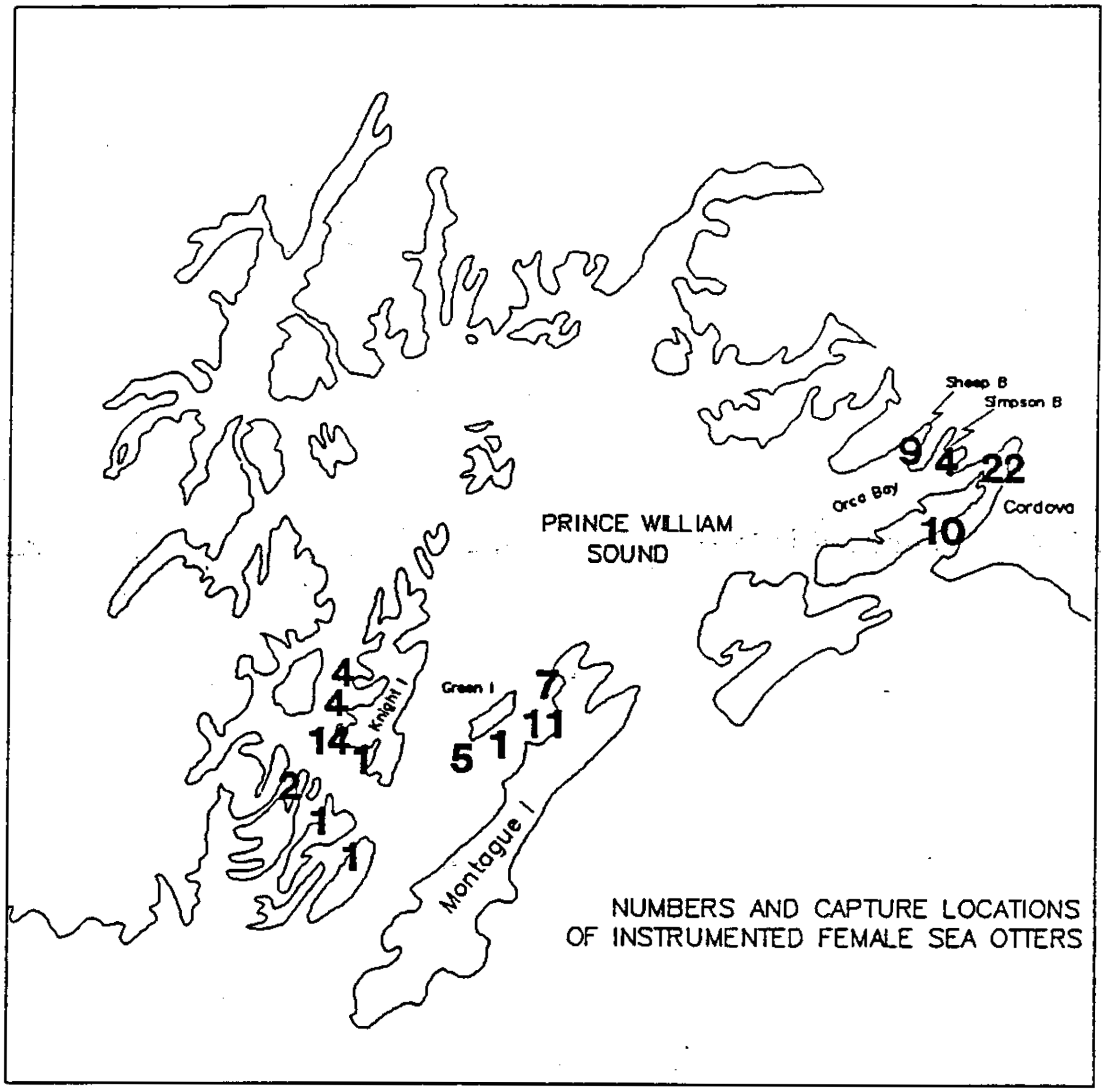

Figure 1. Capture locations of female sea otters in Prince William Sound.