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

Technical Report: Marine Mammals Study Number 6

Movements of Weanling and Adult Female Sea Otters in Prince William Sound, Alaska, after the T/V *Exxon Valdez* Oil Spill

Marine Mammal Study 6-12
Final Report

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Submitted to EVOS Trustee Council
May 1995

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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). Final results are presented in a series of 19 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. Portions of the material in this report were initially reported in a December 1990 Draft Report on MM6 submitted by Drs. Monnett and Rotterman.

Abstract: Ninety-six adult female sea otters and 64 weanling sea otters were instrumented with implanted radio-transmitters in Prince William Sound during 1989-1990 and monitored until November, 1991. Observations of the movements of adult female and weanling sea otters in Prince William Sound indicated no tendency for individuals to emigrate from, or immigrate to, the area affected by oil spilled from the *Exxon Valdez*. This finding indicates that the study groups of sea otters categorized as "western Prince William Sound oil-spill treatment" otters and "eastern Prince William Sound control" otters are indeed distinct groups of individuals. No tendency was observed for recently weaned sea otters to exhibit a preference for habitat units based on the likelihood that they would encounter spilled oil therein. Finally, data reported herein suggest that the recovery of the sea otter population in the oil spill affected region of Prince William Sound will likely be a direct function of the rates of survival and reproduction of the sea otters in the affected habitat with little or no influence from emigration or immigration.

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

Citation: Monnett, C., and L. M. Rotterman. 1992. Movements of weanling and adult female sea otters in Prince William Sound, Alaska, after the T/V *Exxon Valdez* oil spill, *Exxon Valdez* Oil Spill State/Federal Natural Resource Damage Assessment Final Report (Marine Mammal Study 6-12), U.S. Fish and Wildlife Service, Anchorage, Alaska.

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OBJECTIVE

The objective of this study was defined as follows in the statements of work of U.S. Fish and Wildlife Service cooperative agreement #'s 14-16-0007-90-7717 and 14-16-0007-91-7737 with the Prince William Sound Science Center:

> "To evaluate the movements of weanling and adult female sea otters with respect to areas in Prince William Sound that have been affected by the oil spill."

SUMMARY

Ninety-six adult female sea otters and 64 weanling sea otters were instrumented with implanted radio-transmitters in Prince William Sound during 1989-1990 and monitored until November, 1991.

Observations of the movements of adult female and weanling sea otters in Prince William Sound indicated no tendency for individuals to emigrate from, or immigrate to, the area affected by oil spilled from the T/V *Exxon Valdez*. This finding indicates that the study groups of sea otters categorized as "western Prince William Sound oil-spill treatment" otters and "eastern Prince William Sound control" otters are indeed distinct groups of individuals.

No tendency was observed for recently weaned sea otters to exhibit a preference for habitat units based on the likelihood that they would encounter spilled oil therein.

Finally, data reported herein suggest that the recovery of the sea otter population in the oil spill affected region of Prince William Sound will likely be a direct function of the rates of survival and reproduction of the sea otters in the affected habitat with little or no influence from emigration or immigration.

INTRODUCTION

As a result of the wreck of the *Exxon Valdez*, on March 24, 1989, several thousand sea otters (*Enhydra lutris*) were probably killed in western Prince William Sound, Alaska, R. Garrott and L. Eberhardt (*in litt.*). As a consequence, sea otter densities must have been greatly reduced in all, or portions of, the affected area. However, populations of sea otters in adjacent habitat were not believed to have been seriously affected directly by the spilled oil.

There are several reasons why an understanding of the movements of sea otters in oil affected and adjacent areas is important to achieving a full understanding of the damages to the affected population(s) and the likely course of recovery of that population. First, movement data are crucial for evaluating the basic design of many of the sea otter damage assessment studies and for guiding other analyses. Many of the sea otter damage assessment studies compared attributes of sea otters captured in oiled areas in western Prince William Sound (the treatment group) with their counterparts in eastern Prince William Sound (the control group). Implicit to such a design is the assumption that the location of capture is indicative of the general area of residence and that sea otters from the two groups (treatment and control) do not live in the same habitat at any time. However, given the great potential mobility of sea otters documented in other studies, movement data are needed to test this assumption. Relatedly, in order to understand how to analyze data within the oil spill zone, it is necessary to understand on a finer scale the movements of individuals being studied relative to categorization of habitat with regard to degree of oiling.

A second major reason that movement data are needed is to understand and to be able to make predictions about the recovery of sea otters in the oil spill affected areas. Thus, movement data are needed to evaluate whether there is significant immigration or emigration of sea otters into, or from, the oil spill affected region in general and whether sea otters within the oil spill affected region appear to be preferentially using or avoiding the most heavily oiled areas.

Following the oil spill, the prospects for rapid reestablishment of sea otters to "normal" densities in affected habitat were, and are still, strongly linked to the behavioral responses of individual sea otters living both in the affected area and in the adjacent habitat (as well as to potential chronic oil spill effects on otters in affected areas). Unfortunately, behavioral responses of the otters are difficult to predict. On one hand, individuals experiencing oiled coastlines and waterways and/or finding contaminated or damaged prey might be expected to emigrate outside the oil spill affected area to cleaner and less affected adjacent habitat. If so, recovery of sea otters within the oil spill affected area would be expected to take place even more slowly than one would expect, based on the immediate mortality data only. Conversely, the deaths, and consequent lowered densities, of otters in the affected area might lead to significant increases in prey densities, as well as reduced intraspecific competition for breeding or resting sites. If this were the case, immigration of individuals from adjacent habitat might occur and recovery could be more rapid than expected.

In order to provide movement data necessary to address the issues raised above, we monitored the movements of radio-instrumented weanling and adult female sea otters between October, 1989, and November, 1991. We made observations on individuals inhabiting the area affected by the oil spill in western Prince William Sound (WPWS) and on individuals living in ostensibly unaffected habitat in eastern Prince William Sound (EPWS).

METHODS

Study Area and Methods

This study was carried out in Prince William Sound and along the adjacent coastline of the northern Gulf of Alaska from October 1989 - July 1991.

Adult otters included in this study were captured between October 8, 1989 and October 14, 1990 (Table 1, Table 2). All dependent sea otter pups in this study were captured during the fall of 1990 (Table 1). Sea otters were captured when they became entangled in modified gill nets (Odemar and Wilson 1969) or using handheld dipnets (Monnett 1988, Monnett et al. 1991). Research subjects were immobilized with a combination of fentanyl and azaperone, as described previously (Williams et al. 1981), but the dosages administered were considerably higher (Monnett and Rotterman unpublished data). Individuals were tagged with unique color combinations of nylon cattle taqs throuqh the inter-diqital webbing of each hind flipper (Ames et al. 1983). 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 50 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. Extensive aircraft searches were conducted for missing instrumented adults and weanlings on a regular basis. All coastline within Prince William Sound was searched > 5 times per year. Coastline along the Gulf of Alaska between the Bering River and the native village of English Bay was carefully searched at least 3 times per year.

The study area, research subjects and research protocols have been described more fully by Monnett (1988), Rotterman (1992), Monnett and Rotterman (1992), and Rotterman and Monnett (1991).

Index of Home Range

It was necessary to have a means by which to describe the magnitude of the movements of individuals in order to understand how to analyze the data of individuals (e.g., to determine whether it was possible to determine the exposure of an individual to oil based on the habitat occupied), to determine whether the pattern of movements of individuals within the area affected by the oil spill appeared to be atypical, and to provide insight into whether it was likely that some sea otters not inhabiting the area directly affected by the spill, at the time of the spill, were likely to have been impacted in any way. Garshelis and Garshelis (1984) suggested that an index of home range: "distance between extreme locations" (DBEL) be used for such purposes. The distance between extreme locations is the minimum distance an otter would have to swim along the coastline (because it is assumed that otters do not typically travel overland) to go between its two most widely spaced radiolocations during some time interval. It is approximately equivalent to the maximum dimension of the home range (Garshelis and Garshelis 1984). As Garshelis and Garshelis (1984) pointed out, the annual home range of Prince William Sound sea otters is composed of numerous centers of activity connected by long travel corridors. The area of any portion of the annual home range, or rather, any cluster of fixes, can be estimated by measuring the area of the minimum convex polygon enclosing the fixes (Odum and Kuenzler 1965; Garshelis and Garshelis 1984). In Prince William Sound, sea otter travel corridors often cross, and enclose, deep, broad, and presumably, inhospitable expanses of water. As a consequence, the same procedure, when applied to estimation of annual home ranges, drastically overestimates the areas actually utilized. The large number of fixes required for characterization of such habitat utilization patterns, at least 40 per activity center (Garshelis and Garshelis 1984), makes an accurate measurement of annual, or longer-term, home range impractical. DBEL's were estimated for individuals only if they were monitored for at least 160 days and had 30 or more radiolocations.

Immigration and Emigration

As noted previously, it is important to have an assessment of whether sea otters tend to immigrate to or emigrate from the area affected by the oil spill. Analysis of immigration of otters to the oil spill affected area is based on observations of movements of radio-instrumented adult female and weanling sea otters in EPWS. For immigration to occur individuals would be required to cross Hinchinbrook Entrance and occupy habitat within the oil spill affected area as defined by the Alaska Department of Environmental Conservation Geographical Information System product summarizing beach oiling entitled: Prince William Sound, 5 Months Maximum Impact Map, 3/24/89 - 8/24/89. Emigration would occur if individual sea otters captured and radio-instrumented inside the oil spill affected area, as defined by the aforementioned ADEC product, had occupied and remained in habitat outside the boundaries of the oil spill affected area.

Categorization of Habitat by Risk of Encountering Oil

In order to evaluate whether weanling sea otters were making post weaning movements to or away from the most heavily oiled habitat in western Prince William Sound, movements were analyzed with respect to degree of oiling of coastline. Habitat was classified using an Alaska Department of Environmental Conservation Geographical Information System product entitled: Prince William Sound, 5 Months Maximum Impact Map, 3/24/89 - 8/24/89. Habitat in the oil spill affected area was classified subjectively as High, Moderate, and Low with respect to the likelihood that weanlings would encounter oil on beaches or in recirculation (Figure 1). On Figure 1 the area classified as High was composed of habitat exhibiting regular occurrence of heavily or moderately oiled shoreline. The Moderate classification was composed of shoreline having isolated heavily or moderately oiled coastline surrounded by predominantly light or unoiled habitat. The area classified as Low was composed of the remained of the habitat along which the oil slick traveled following the spill. It was dominated by unoiled or lightly oiled coastline with moderately and heavily oiled segments being rare.

RESULTS

Capture and Instrumentation

During this study 485 sea otters were captured in order to select 164 individuals for radio-instrumentation. Of the 164 sea otters that were instrumented, 95 were adult females (WPWS = 51; EPWS = 44), 4 were adult males (all WPWS) and 64 were dependent pups (WPWS = 40; EPWS = 24). Further breakdowns by capture locations and dates are given in Table 1. Capture locations for dependent pups and adult females are shown on Figure 2 and Figure 3, respectively. Data taken on the 4 radio-instrumented adult males are not discussed in this report.

Adult Females

On average, more observations were made per female in EPWS than in WPWS (EPWS: 77.4, S.D. = 23.2, N = 40 versus WPWS 45.6, S.D. 8.0, N = 45; t = 8.8, 83 D.F., $P < 0.001$). However, most females were observed on 40 or more occasions as recommended by Garshelis and Garshelis (1984) and DBEL were not correlated with the number of observations per female (Figure 4; $R^2 = 0.02$, N = 85, $P > 0.83$). Data are listed for each sea otter in Table 2.

Females in EPWS had larger DBEL than females in WPWS (EPWS: mean = 39.6 km, S.D. = 17.7, N = 40 versus WPWS: mean = 28.3 km, S.D. = 8.4, N = 45; t = 2.6, 83 D.F., $P < 0.01$; Figure 5). The females exhibiting the longest movements in EPWS typically moved > 60 km between Orca Inlet, near Cordova, and Port Fidalgo. Females moving the greatest distances in WPWS tended to be those that traveled from the northern tip of Montague Island to the west side of Knight Island, or in one instance northward to Unakwik. Only 3 females in WPWS moved from habitat located on the east side of Knight Island to habitat on the west side of Knight Island. The movements of the 3 females having the greatest DBEL in EPWS and WPWS are summarized in Figure 6.

There was no evidence of emigration or immigration of adult females relative to the oil spill affected habitat. None of the study females (N = 95) crossed Hinchinbrook Entrance (going eastward or westward), a deep water channel with strong tidal fluxes that divides Prince William Sound and separates Montague Island from Hinchinbrook Island. That tendency suggests that Hinchinbrook Entrance may serve as a fairly effective barrier between intra Prince William Sound populations.

Weanlings

Weanling survival was poor (Rotterman and Monnett 1992). Observational data on only a few pups meets the 160 day-30 radiolocation minimum adopted for home range analysis and thus, data are insufficient to permit any meaningful analysis of differences in home range sizes between weanlings in WPWS and EPWS. A summary of the length of monitoring periods before and after weaning is shown in Table 3.

One of 40 weanlings in WPWS emigrated from the oil spill affected area, crossing Hinchinbrook Entrance to eventually die in Port Gravina. None of the 22 weanlings instrumented in EPWS traveled west of Hinchinbrook Entrance to enter the area affected by the oil spill. The movements of 5 weanlings in WPWS exhibiting the greatest DBEL are summarized in Figure 7.

In order to test the hypothesis that the degree of oil contamination in a weanling's natal (preweaning) home range does not influence whether it leaves its natal home range following weaning, we have created a subjective "probability-of-oiling" categorization of habitat as having Low, Moderate or High probabilities of sea otters encountering oil (Figure 1). Forty-two percent (11 of 26) of the pups raised in habitat classified as "low probability" remained within their natal home ranges following weaning, whereas, 29% (2 of 7) of the pups raised in habitat classified as "moderate probability" or "high probability" did so ($\chi^2 = 0.44$, 1 D.F., $P > 0.51$). Seven weanlings were excluded from the analysis because we were unable to determine either their preweaning or postweaning homeranges due to inadequate movement data.

In order to determine whether weanlings that left their natal home range after weaning had a tendency to settle in habitat in which they were less likely to encounter spilled oil, we compared the probability-of-oiling categories assigned to habitat included in the preweaning and postweaning homeranges of 19 pups that dispersed from their natal home ranges following weaning (Table 4). There was no clear tendency for individuals to move into either more heavily oiled habitat or less heavily oiled habitat (Table 4: weanling moved to habitat classified as same probability = 12 weanlings, moved to higher probability = 5, moved to lower probability = 2).

DISCUSSION

Data presented in this report on sea otter movements indicate that the study groups of sea otters categorized as "western Prince William Sound oil-spill treatment" otters and "eastern Prince William Sound control" otters are indeed distinct groups of individuals. Observations of the movements of adult female and weanling sea otters in Prince William Sound indicated no tendency for adult females to cross Hinchinbrook Entrance. Only one weanling male made such a crossing, traveling from the Green Island area to Port Gravina, but he died shortly thereafter. We were not able to evaluate whether this finding could be extended to adult males, since a comparable study of the movements of adult males was not undertaken. However, there is some indication (Garshelis and Garshelis 1984) that males may move between western and eastern Prince William Sound, at least for the purpose of overwintering, and hence, there are some problems with attempting to categorize adult males as either treatment or controls with regards to the effects of the oil spill.

Within the oil spill zone, the scale of movements of adult females, relative to the gross scale of oiling regimes, indicates that further categorization of adult females with respect to "degree of oiling of habitat" is not likely to be fruitful. However, the overall extent of movements by individuals in both the control and treatment groups was well within the range of normal for sea otters as observed in other longterm telemetry studies for adult females (Monnett 1988, Monnett and Rotterman 1988, Rotterman and Simon-Jackson 1988, Monnett and Rotterman 1989, Ralls et al. 1988) and weanlings (Monnett 1988). Differences in the extent of movements observed between adult females in EPWS and WPWS are probably most easily explained by the constraints of geography. While, females in WPWS exhibited apparently smaller home ranges, they were confronted with more and deeper barriers to everyday movements in the form of islands and channels.

Despite the fact that mass movements of sea otters into uncolonized habitat have previously been observed (Kenyon 1969), it is not surprising that sea otters in the area studied exhibited fidelity to the general region of their capture. The degree of site fidelity exhibited by individuals both within and adjacent to the area affected by the oil spill is consistent with results of other studies. For example, sea otters have shown strong tendencies to return to their home ranges following translocation experiments (e.g., Monnett et al. 1990).

Our finding that neither adult female nor weanling sea otters of either sex tend to move in either direction between eastern and western Prince William Sound, or out of the oil spill affected area in any other direction, is probably most important because of the insight that it provides about the course of recovery of sea otters in the oil spill region. The movement data suggest that the recovery of the sea otter population in the oil spill affected area of Prince William Sound will likely be a direct function of the birth and survival rates of sea otters in the affected habitat with little or no effects due to emigration or immigration.

Moreover, no tendency was observed for recently weaned sea otters within the oil spill affected area to exhibit a preference for habitat units based on the likelihood that they would encounter spilled oil therein. Thus, it is likely that some recolonization of the most severely oiled and heavily impacted areas of Prince William Sound would begin to occur if survival rates of weanlings were sufficient.

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Table 1. Summary of take of sea otters for purposes of radio-instrumentation between October 1, 1989 and October 15, 1990. Take is broadly defined and refers to "take by harrassment" for research purposes under the guidelines of The Marine Mammal Protection Act of 1972. Take includes individuals that were captured but released without further handling. In instances where only one member of a mother-pup pair was captured, both individuals are counted as take even though the second individual was not actually captured.

	Area	Category	Number taken	Number implanted
Fall 1989	EPWS	Adult Male	10	0
		Adult Female (indep)	42	23
		Mother-Pup Pairs	34 (17 prs.)	0
		Unknown	3	0
	WPWS	Adult Male	21	3
		Adult Female (indep)	12	9
		Mother-Pup Pairs	18 (9 prs.)	0
		Unknown	2	0
Spring 1990	EPWS	Adult Male	2	0
		Adult Female (indep)	29	18
		Mother-Pup Pairs	8 (4 prs.)	0
		Unknown	0	0
	WPWS	Adult Male	7	1
		Adult Female (indep)	48	42
		Mother-Pup Pairs	0	0
		Unknown	0	0
Fall 1990	EPWS	Adult Male	8	0
		Adult Female (indep)	37	4
		Mother-Pup Pairs	106 (53 prs.)	24 pups
		Unknown	2	0
	WPWS	Adult Male	2	0
		Adult Female (indep)	1	0
		Mother-Pup Pairs	96 (46 prs.)	40 pups
		Unknown	0	0
Subtotals	EPWS	Adult Male	20	0
		Adult Female (indep)	108	45
		Mother-Pup Pairs	148 (74 prs.)	24
		Unknown	6	0
		Total	282	69
	WPWS	Adult Male	30	4
		Adult Female (indep)	61	51
		Mother-Pup Pairs	110 (55 prs.)	40
		Unknown	2	0
		Total	203	95
Grand Total			485	169

Table 2(1). Summary of observations on radio-instrumented adult female sea otters in EPWS, October 1989 - July 1991. Individuals having superscript 1 following sex were excluded from calculation of statistics on # of fixes (i.e., radiolocations) and DBEL due to insufficient data.

Age	Sex	Location captured	# fixes	DBEL km	Date captured	Date last observed	# of days in study
Adult	Female[1]	EPWS	9		24 Mar 90	12 May 90	49
Adult	Female[1]	EPWS	9		20 Oct 89	26 Dec 89	67
Adult	Female[1]	EPWS	0		20 Oct 89	20 Oct 89	0
Adult	Female[1]	EPWS	3		20 Oct 89	30 Dec 89	71
Adult	Female	EPWS	36	86	22 Mar 90	05 Dec 90	258
Adult	Female	EPWS	39	48	26 Mar 90	04 Nov 90	223
Adult	Female	EPWS	41	15	18 Mar 90	24 Oct 90	220
Adult	Female	EPWS	41	51	12 Oct 89	21 Mar 90	160
Adult	Female	EPWS	41	51	14 Oct 90	09 Apr 91	177
Adult	Female	EPWS	49	11	12 Oct 89	04 Oct 90	357
Adult	Female	EPWS	50	68	22 Oct 89	11 Dec 90	415
Adult	Female	EPWS	52	9	09 Sep 90	11 Jun 91	275
Adult	Female	EPWS	53	15	04 Sep 90	31 Jul 91	330
Adult	Female	EPWS	58	60	11 Oct 90	31 Jul 91	293
Adult	Female	EPWS	59	48	26 Mar 90	16 Mar 91	355
Adult	Female	EPWS	64	18	13 Oct 89	09 Sep 90	331
Adult	Female	EPWS	66	51	26 Mar 90	31 Jul 91	492
Adult	Female	EPWS	70	7	05 Apr 90	31 Jul 91	482
Adult	Female	EPWS	73	31	04 Apr 90	31 Jul 91	483
Adult	Female	EPWS	75	42	26 Mar 90	31 Jul 91	492
Adult	Female	EPWS	77	33	22 Mar 90	31 Jul 91	496
Adult	Female	EPWS	77	37	05 Apr 90	31 Jul 91	482
Adult	Female	EPWS	77	64	16 Mar 90	22 Jun 91	463
Adult	Female	EPWS	77	48	16 Mar 90	31 Jul 91	502
Adult	Female	EPWS	78	44	27 Mar 90	31 Jul 91	491
Adult	Female	EPWS	78	35	16 Mar 90	31 Jul 91	502
Adult	Female	EPWS	79	51	24 Mar 90	31 Jul 91	494

Age	Sex	Location captured	# fixes	DBEL km	Date captured	Date last observed	# of days in study
Adult	Female	EPWS	84	49	12 Oct 89	31 Jul 91	657
Adult	Female	EPWS	85	44	08 Oct 89	31 Jul 91	661
Adult	Female	EPWS	85	42	05 Apr 90	31 Jul 91	482
Adult	Female	EPWS	85	20	08 Oct 89	31 Jul 91	661
Adult	Female	EPWS	86	26	12 Oct 89	31 Jul 91	657
Adult	Female	EPWS	90	24	16 Mar 90	11 Jun 91	452
Adult	Female	EPWS	90	58	13 Oct 89	31 Jul 91	656
Adult	Female	EPWS	91	49	22 Oct 89	31 Jul 91	647
Adult	Female	EPWS	92	27	22 Oct 89	31 Jul 91	647
Adult	Female	EPWS	95	49	13 Oct 89	31 Jul 91	656
Adult	Female	EPWS	99	53	22 Oct 89	05 Aug 90	287
Adult	Female	EPWS	101	62	12 Oct 89	31 Jul 91	657
Adult	Female	EPWS	105	44	22 Oct 89	31 Jul 91	647
Adult	Female	EPWS	106	33	08 Oct 89	12 Jul 91	642
Adult	Female	EPWS	107	22	09 Oct 89	31 Jul 91	660
Adult	Female	EPWS	109	40	12 Oct 89	31 Jul 91	657
Adult	Female	EPWS	114	46	20 Oct 89	10 Jun 91	598
Adult	Female	EPWS	140	11	08 Oct 89	31 Jul 91	661

Table 2(2). Summary of observations on radio-instrumented adult female sea otters in WPWS, October 1989 - July 1991.

Age	Sex	Location captured	# fixes	DBEL km	Date captured	Date last observed	# days in study
Adult	Female[1]	WPWS	2		11 Apr 90	18 Apr 90	7
Adult	Female[1]	WPWS	1		13 Nov 89	15 Nov 89	2
Adult	Female[1]	WPWS	16		09 Apr 90	04 Oct 90	178
Adult	Female[1]	WPWS	19		11 Apr 90	24 Sep 90	166
Adult	Female[1]	WPWS	1		28 Apr 90	31 May 90	33
Adult	Female[1]	WPWS	1		30 Apr 90	14 May 90	14
Adult	Female	WPWS	30	31	23 Apr 90	31 Jul 91	464
Adult	Female	WPWS	32	38	26 Apr 90	22 Jun 91	422
Adult	Female	WPWS	33	62	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	36	22	22 Apr 90	31 Jul 91	465
Adult	Female	WPWS	36	40	27 Apr 90	31 Jul 91	460
Adult	Female	WPWS	37	13	11 Apr 90	14 Jan 91	278
Adult	Female	WPWS	38	31	22 Apr 90	31 Jul 91	465
Adult	Female	WPWS	38	42	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	39	29	24 Apr 90	31 Jul 91	463
Adult	Female	WPWS	39	42	13 Apr 90	22 Jun 91	435
Adult	Female	WPWS	39	24	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	40	22	24 Apr 90	31 Jul 91	463
Adult	Female	WPWS	40	22	22 Apr 90	31 Jul 91	465
Adult	Female	WPWS	40	33	30 Apr 90	31 Jul 91	457
Adult	Female	WPWS	42	31	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	43	60	26 Apr 90	31 Jul 91	461
Adult	Female	WPWS	44	27	24 Apr 90	31 Jul 91	463
Adult	Female	WPWS	45	18	22 Apr 90	31 Jul 91	465
Adult	Female	WPWS	45	16	29 Apr 90	31 Jul 91	458
Adult	Female	WPWS	46	26	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	46	22	29 Apr 90	31 Jul 91	458

Age	Sex	Location captured	# fixes	DBEL km	Date captured	Date last observed	# days in study
Adult	Female	WPWS	46	27	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	46	29	26 Apr 90	31 Jul 91	461
Adult	Female	WPWS	46	11	26 Apr 90	31 Jul 91	461
Adult	Female	WPWS	46	33	30 Apr 90	31 Jul 91	457
Adult	Female	WPWS	46	18	29 Apr 90	31 Jul 91	458
Adult	Female	WPWS	46	9	04 Nov 89	24 Jan 91	446
Adult	Female	WPWS	46	11	11 Apr 90	31 Jul 91	476
Adult	Female	WPWS	47	42	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	47	11	28 Apr 90	31 Jul 91	459
Adult	Female	WPWS	47	18	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	48	26	29 Apr 90	31 Jul 91	458
Adult	Female	WPWS	48	31	11 Apr 90	31 Jul 91	476
Adult	Female	WPWS	48	22	13 Apr 90	31 Jul 91	474
Adult	Female	WPWS	49	15	11 Apr 90	31 Jul 91	476
Adult	Female	WPWS	50	75	13 Nov 89	31 Jul 91	625
Adult	Female	WPWS	52	5	28 Apr 90	31 Jul 91	459
Adult	Female	WPWS	53	15	16 Nov 89	31 Jul 91	622
Adult	Female	WPWS	54	11	11 Apr 90	31 Jul 91	476
Adult	Female	WPWS	55	44	07 Nov 89	31 Jul 91	631
Adult	Female	WPWS	56	11	15 Nov 89	31 Jul 91	623
Adult	Female	WPWS	56	24	06 Nov 89	31 Jul 91	632
Adult	Female	WPWS	60	16	15 Nov 89	31 Jul 91	623
Adult	Female	WPWS	64	104	12 Nov 89	31 Jul 91	626
Adult	Female	WPWS	70	16	13 Apr 90	31 Jul 91	474

Table 3. Summary of length of monitoring periods before and after weaning on radio-instrumented sea otter pups in Prince William Sound, 1990-1991.

Study area	Total N	Total study Mean	Total study S.D.	Total study N	Preweaning Mean	Preweaning S.D.	Preweaning N[2]	Postweaning Mean	Postweaning S.D.	Postweaning N
WPWS	40	137d	70d	40	56d	23d	34	85d	69d	34
EPWS	22[1]	144d	116d	22	22d	20d	19	136d	109d	19

1 Two individuals were excluded because their deaths may have been caused by research related activities.

2 Individuals were excluded if they were not weaned during the reporting period or if a weaning date could not be estimated.

Table 4. Summary of postweaning movements of sea otters between locations at which they were more or less likely to encounter beached or recirculated oil spilled by the T/V *Exxon Valdez*. Although 40 pups were instrumented in WPWS, only 19 could be used in this analysis. One pup was excluded because it remained with its mother over winter 1989-90. Seven pups were excluded because they died before they established postweaning homeranges. Thirteen pups were not used in this analysis because they did not leave their preweaning home range following weaning. In this table, for example, 2 individuals made post weaning movements from habitat in which they had a moderate probability of encountering spilled oil into habitat in which they had a high probability of encountering oil. Habitat classification is subjective and is based on Alaska Department of Environmental Conservation Geographical Information System product entitled: Prince William Sound, 5 Months Maximum Impact Map, 3/24/89 - 8/24/89 (See Figure 3).

		Habitat occupied before weaning		
		Low	Moderate	High
Habitat occupied following weaning	Low	11	1	
	Moderate	1		
	High	1	2	1
	Not oiled	1		1

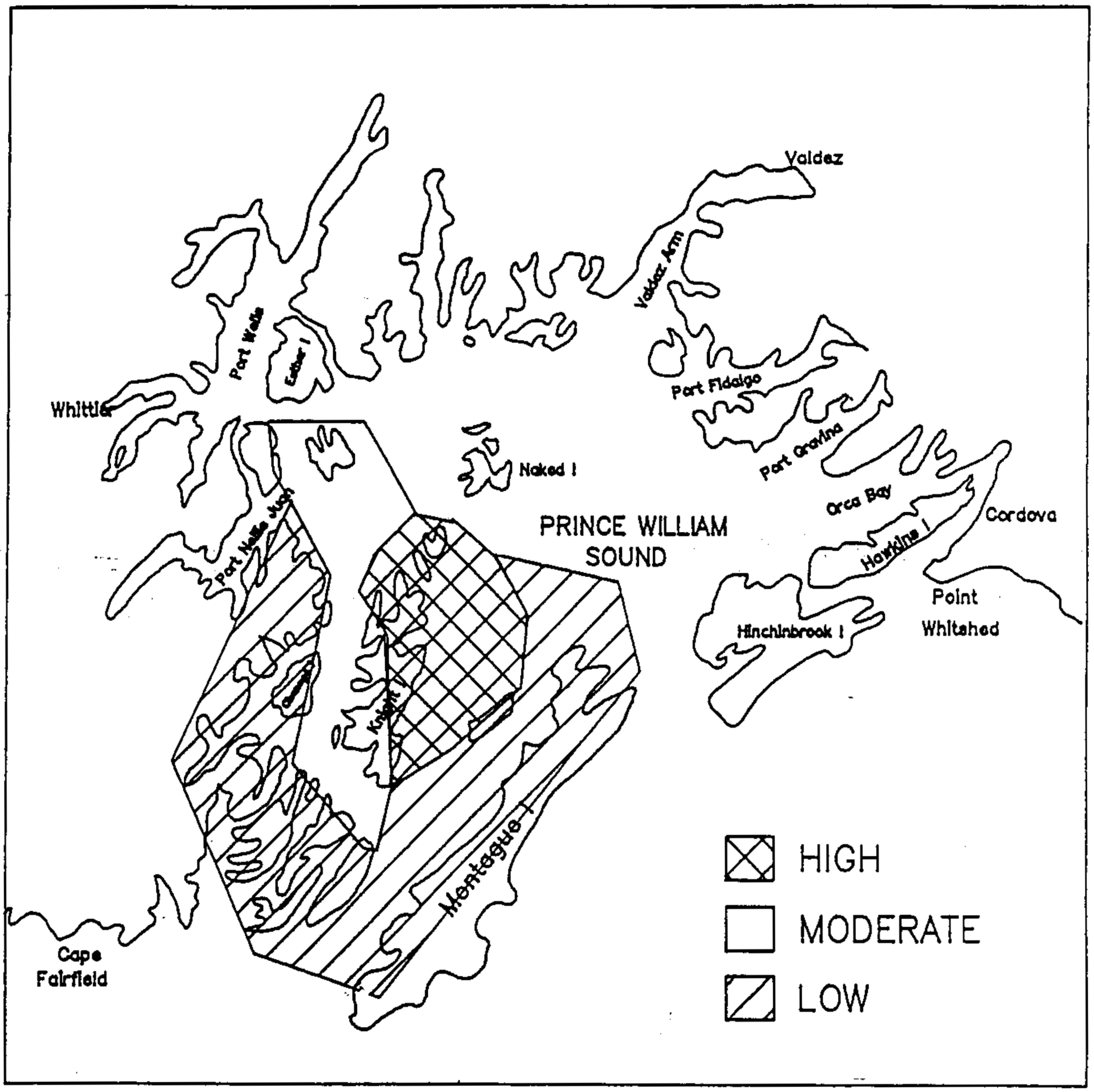

Figure 1. Habitat in western Prince William Sound was classified (see key) using an Alaska Department of Environmental Conservation Geographical Information System product entitled: Prince William Sound, 5 Months Maximum Impact Map, 3/24/89 - 8/24/89. Habitat in the oil spill affected area was classified subjectively as High, Moderate and Low with respect to the likelihood that weanlings would encounter oil on beaches or in recirculation. Only the portion of the area affected by spilled oil that was frequented by instrumented weanlings is classified on the figure.

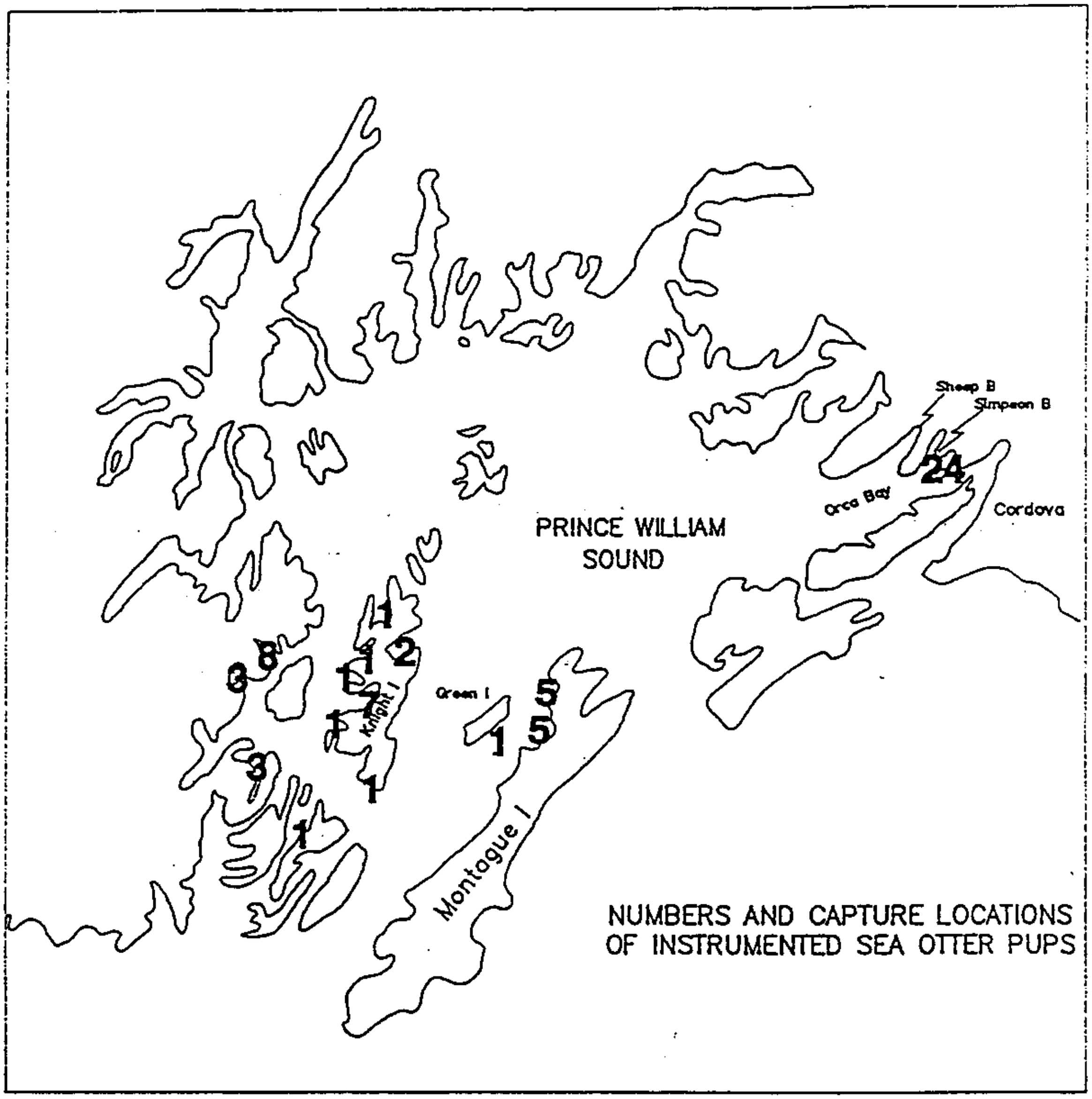

Figure 2. Capture locations of radio-instrumented dependent sea otter pups in Prince William Sound during 1990.

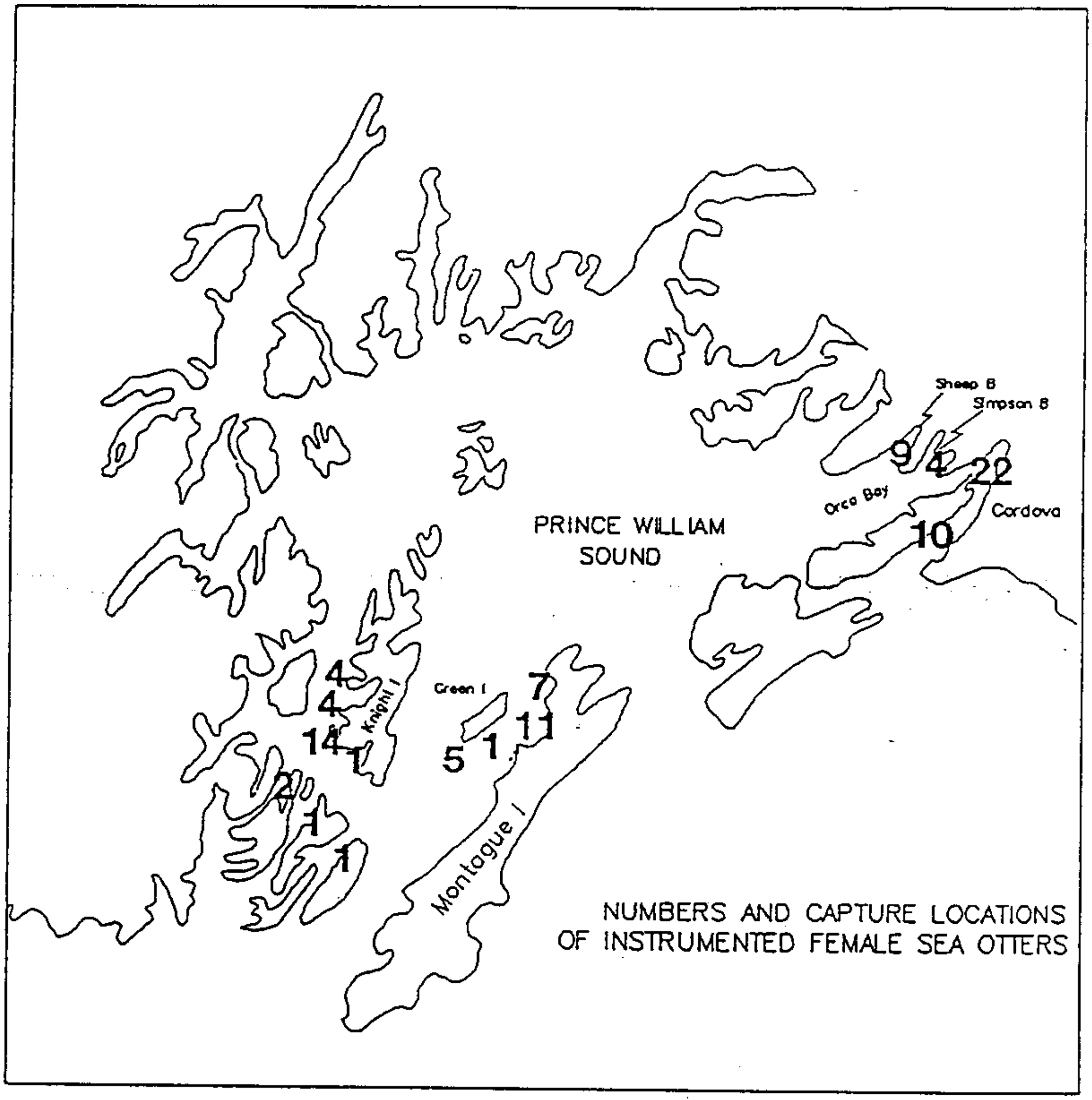

Figure 3. Capture locations of radio-instrumented adult female sea otters in Prince William Sound, 1989-1990.

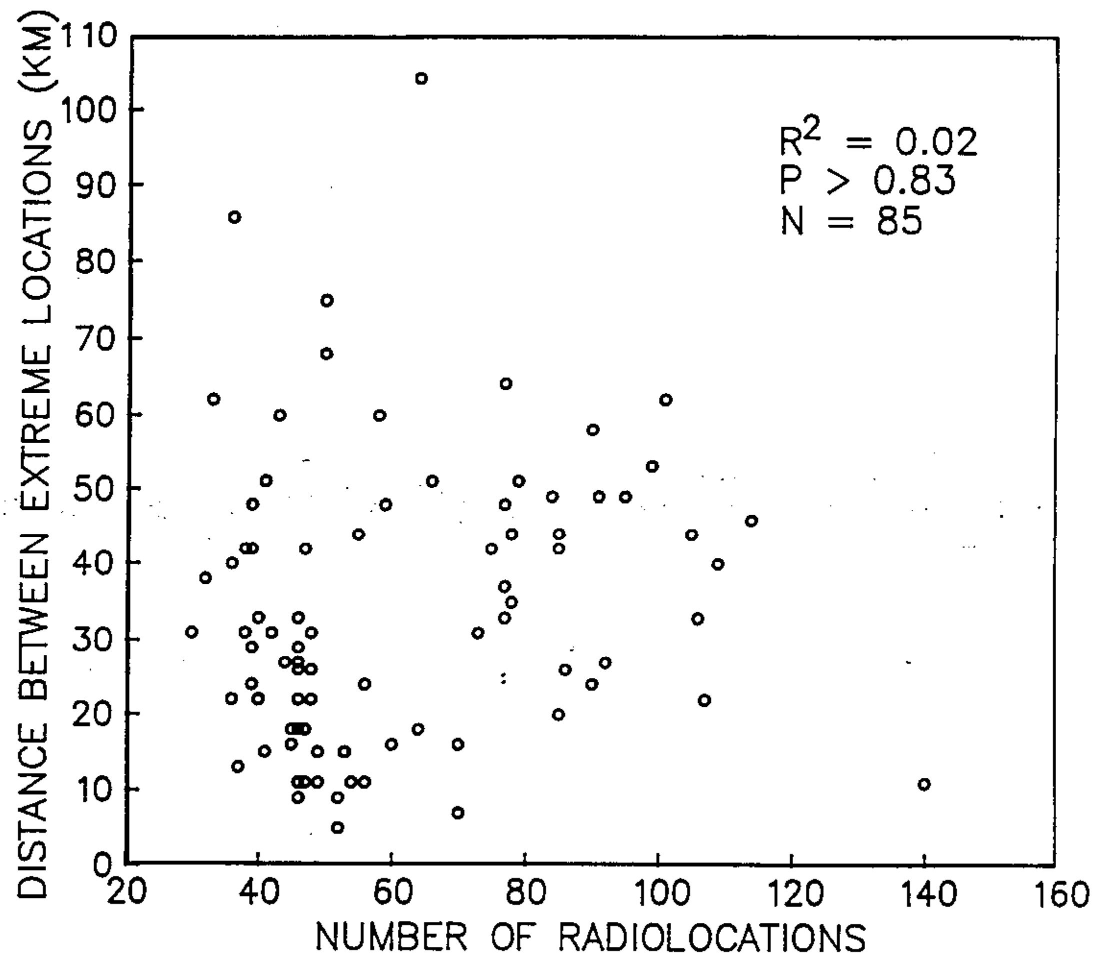

Figure 4. Number of radiolocations versus the distance between extreme locations (DBEL) of sea otters in Prince William Sound, Alaska.

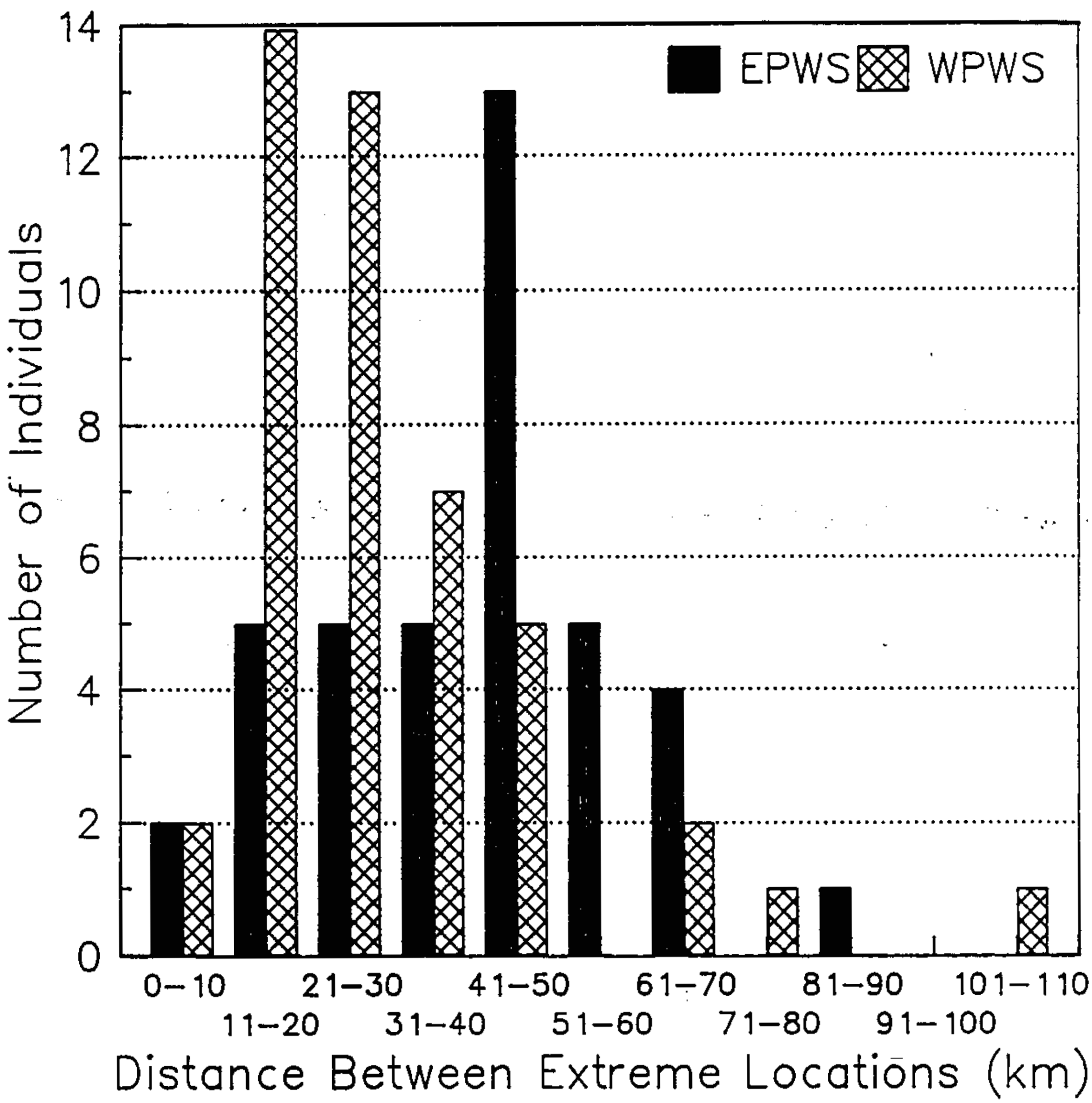

Figure 5. Distances between extreme locations (DBEL) are shown for adult female sea otters in Eastern versus Western Prince William Sound. The distance between extreme locations is the minimum distance an otter would have to swim to go between its two most widely spaced fixes during some time interval. It is approximately equivalent to the maximum dimension of the home range (Garshelis and Garshelis 1984).

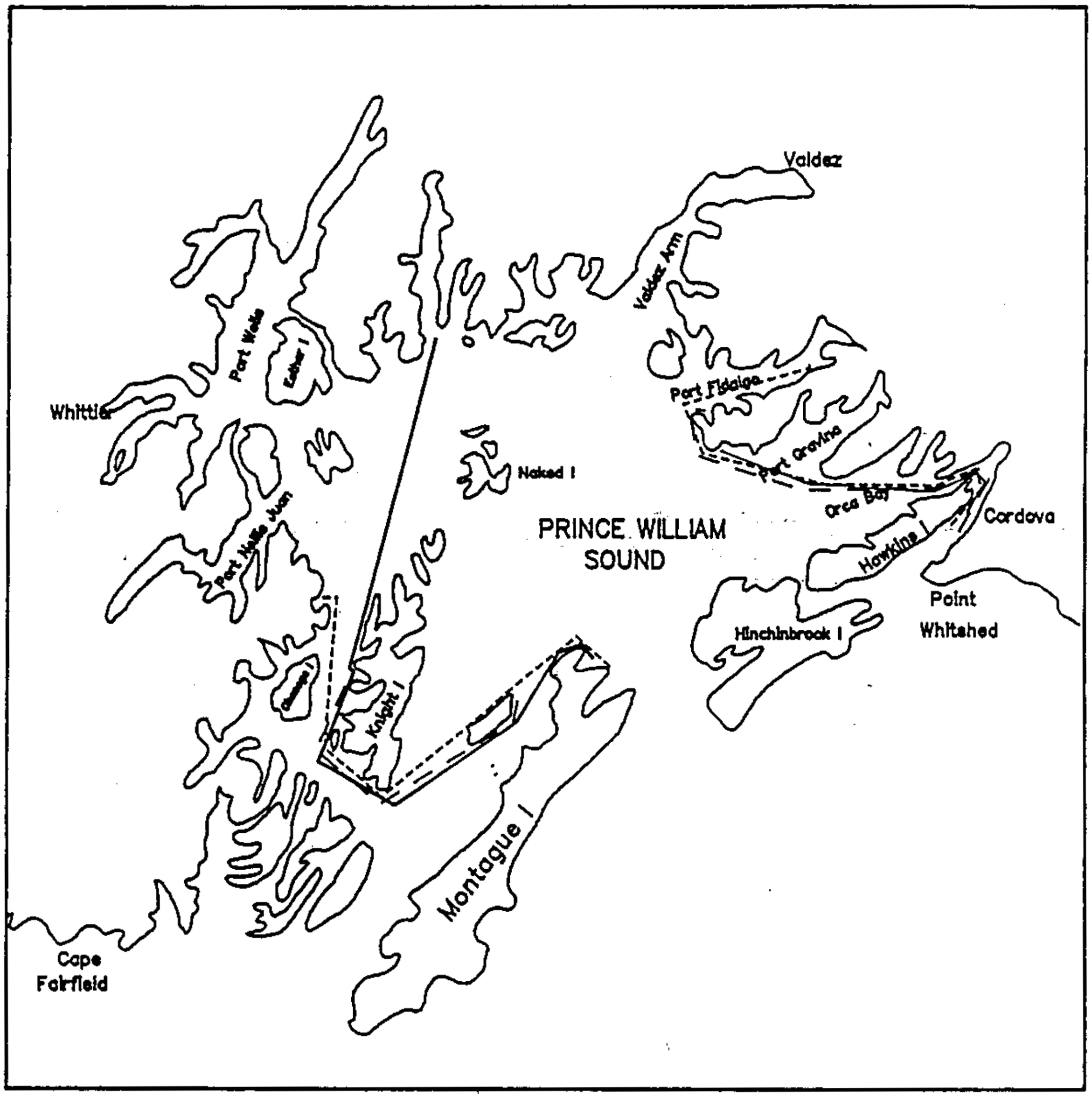

Figure 6. The movements of the females having the greatest DBEL in EPWS and WPWS (3 in each geographic area) are portrayed using different types of lines. Eighty-four females were included in this analysis. None of the 84 females moved between EPWS and WPWS during the course of this study. Also, none of the 84 females left the waters of Prince William Sound and entered the Gulf of Alaska.

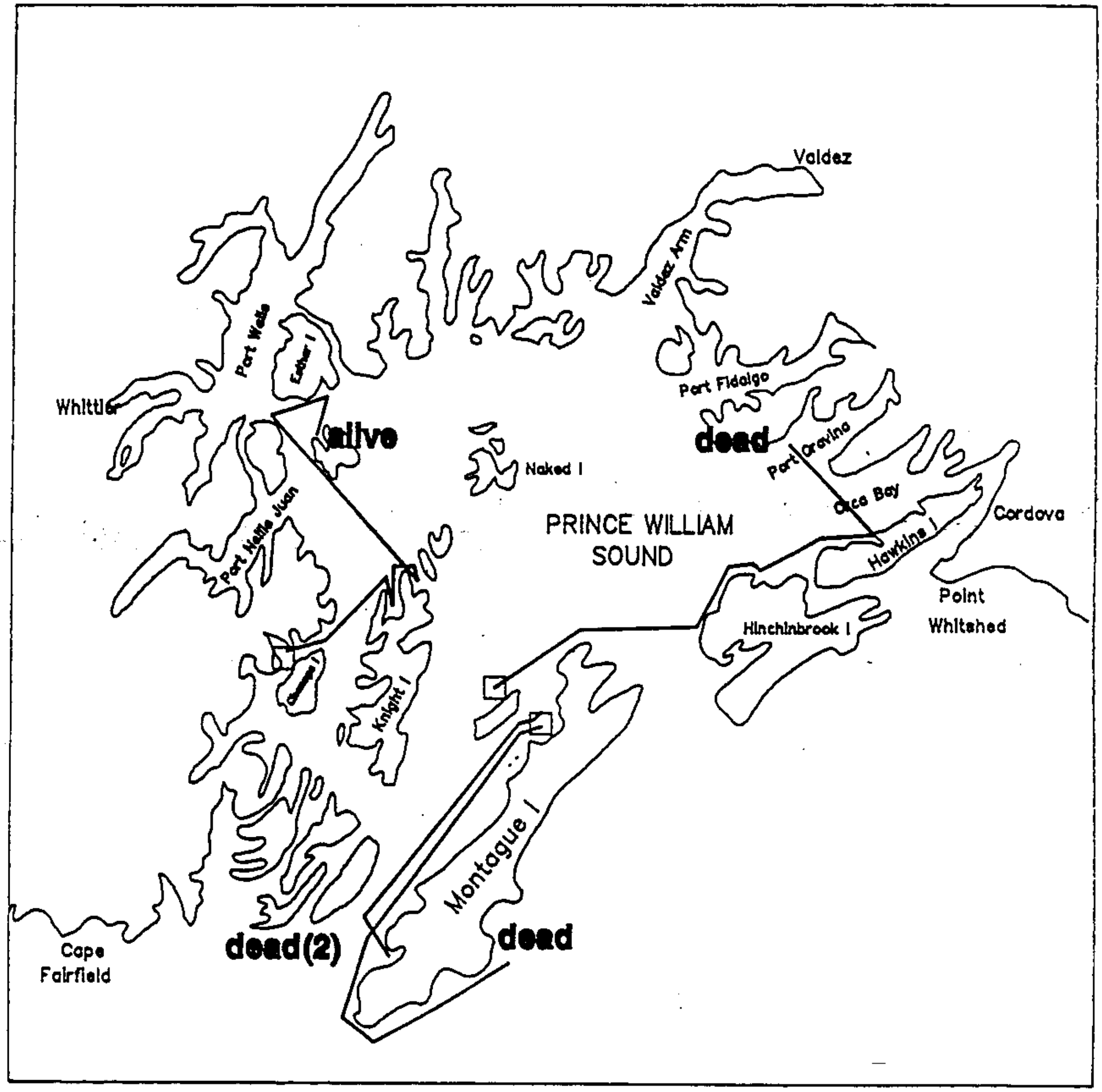

Figure 7. The movements of the 5 weanlings in WPWS exhibiting the greatest DBEL are summarized as solid lines. A single weanling that was weaned near Green Island, crossed between EPWS and WPWS.