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

Technical Report: Marine Mammals Study Number 6

Mortality and Reproduction of Sea Otters Oiled and Treated as a Result of the *Exxon Valdez* Oil Spill

Marine Mammal Study 6-14
Final Report

Charles Monnett[1]

Lisa Mignon Rotterman[1]

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

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[1] Current address: P.O. Box 3448, Homer, Alaska 99603

Technical Report: Marine Mammal Study Number 7

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Charles Monnett and Lisa Mignon Rotterman

P.O. Box 1846

Cordova, Alaska 99574

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Study History: Marine Mammal Study 7 (MM7), titled *Mortality and Reproduction of Sea Otters Oiled and Treated as a Result of the Exxon Valdez Oil Spill* was initiated in 1989 as part of the Natural Resource Damage Assessment (NRDA). In 1991, MM7 was incorporated into NRDA Marine Mammal Study 6 (MM6), *Assessment of the Magnitude, Extent and Duration of Oil Spill Impacts on Sea Otter Populations in Alaska*. Final results of MM6 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. 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 reported in a December 1990 Draft Report on MM7, *Assessment of the Fate of Sea Otters Oiled and Treated as a Result of the Exxon Valdez Oil Spill*, submitted by Drs. Monnett and Rotterman, and as a paper (*C.W. Monnett, L.M. Rotterman, C. Stack, and D. Monson. 1990. Postrelease Monitoring of Radio-instrumented Sea Otters in Prince William Sound* in Bayha, Keith, and J. Kormendy, Technical Coordinators. Sea Otter Symposium: Proceedings of a symposium to evaluate the response effort on behalf of sea otters after the T/V *Exxon Valdez* oil spill into Prince William Sound, Anchorage, Alaska, 17-19 April 1990. U.S. Fish Wildl. Serv., Biol. Rep. 90(12).).

Summary: Radio-instrumented sea otters (N = 45) that were released into eastern Prince William Sound during summer, 1989, following efforts to rehabilitate them at otter treatment centers, have been monitored regularly for approximately 2 years. Respective survival rates of male and female sea otters released from the treatment centers were: Year 1: males P = 0.401, females P = 0.445; Year 2: males P = 0.714, females P = 0.692. Only 2 of 11 (18%) mature females pupped during 1990. Sea otters released from treatment centers had lower survivorship and pupping rates than sea otters in other study populations.

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

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SUMMARY

Radio-instrumented sea otters (N = 45) that were released into eastern Prince William Sound during summer, 1989, following efforts to rehabilitate them at otter treatment centers, have been monitored regularly for approximately 2 years. Respective survival rates of male and female sea otters released from the treatment centers were: Year 1: males $P = 0.401$, females $P = 0.445$; Year 2: males $P = 0.714$, females $P = 0.692$. Only 2 of 11 (18%) mature females pupped during 1990. Sea otters released from treatment centers had lower survivorship and pupping rates than sea otters in other study populations.

INTRODUCTION

In response to the massive oil spill caused by the wreck of the T/V *Exxon Valdez*, several hundred sea otters (*Enhydra lutris*) were captured and brought into centers that were established in order to wash them, and to provide them with medical and other supportive treatment (e.g., see Williams et al. 1990). Many of the sea otters that survived such treatment were eventually released into wild populations in Prince William Sound and along the Kenai Peninsula. Of these survivors, forty-five were equipped with radio-transmitters, released in Prince William Sound and monitored during subsequent months. The goal of the study reported herein was to provide data on the survival and reproduction of the radio-instrumented sea otters, and by doing so, to gain insights into both the damage done to the Prince William Sound sea otter population by that spill and into the efficacy of the "rehabilitation" strategy.

OBJECTIVES

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

1. To test the hypothesis that survival of sea otters that underwent oiling, cleaning, treatment and release is not different from that of sea otters that were not affected by the oil spill.

2. To test the hypothesis that the reproductive rate of female sea otters that underwent oiling, cleaning and treatment does not differ significantly from that of female sea otters that were not affected by the oil spill.

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 cannot 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

Data from the treatment center otters were compared with concurrent data from otters that were captured in Prince William Sound.

Forty-five adult sea otters (28 females (TC FEMALES) and 17 males (TC MALES)) were selected as candidates for radio-instrumentation from individuals being held at the three treatment centers (see Haebler et al. 1990). Of these, 9 were captured in Prince William Sound, 34 along the Kenai Peninsula and 2 in the Kodiak Archipelago (Table 1). Capture/admission dates for this group were distributed: April = 17 otters; May = 21 otters; June = 5 otters; July = 2 otters.

The eastern Prince William Sound female grouping (EPWS FEMALES) consisted of 40 females that were instrumented during 1987, 22 females that were instrumented during 1989, and 22 females that were instrumented during 1990. The western Prince William Sound female grouping (WPWS FEMALES) consisted of 8 females instrumented during 1989 and 39 females instrumented during 1990. The EPWS FEMALES and WPWS FEMALES groupings were combined into the ALL FEMALES grouping. The eastern Prince William Sound male grouping (EPWS MALES) consisted of 12 males that were instrumented during 1987. The western Prince William Sound male grouping (WPWS MALES) consisted of 2 males instrumented during 1989 and one male instrumented during 1990.

Data on survival were separated temporally into two groupings relative to the release of the otters from the treatment centers: year one (August 1989 - July 1990) and year two (August 1990 - July 1991). Survival analysis was completed on both temporal groupings. Data on reproduction is given for 1990 and 1991. However, analysis of pupping rates was completed on only the 1990 data set because too few females survived through the 1991 pupping season to warrant analysis.

Three females that were resident near the western end of the Kenai Peninsula were not included in the analysis of pupping rates because monitoring was infrequent and unreliable during the summer of 1990 (see Appendix I).

Instrumentation and Monitoring

Sea otters in this study were anesthetized and radio-transmitters were surgically implanted in their peritoneal cavities (Garshelis and Siniff 1983; DeGange and Williams 1990). After a recovery period, individuals from the treatment centers were released in eastern Prince William Sound during July and August, 1989. Sea otters in the EPWS FEMALE and WPWS FEMALE study groupings were released at the location of capture immediately after recovering from their anesthesia. An attempt was made to locate each individual at least once each week, using aircraft or boats equipped with Yagi antennas. Additional methodological details are provided in Monnett et al. (1990).

Analyses

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 pupping rates between study groupings.

RESULTS AND DISCUSSION

Results of this study through spring 1990 have been previously reported (see Appendix II).

Survival rates

Of the 45 sea otters from the treatment centers that were instrumented and released, as of July 31, 1991, 14 were known dead, 15 were missing and presumed to have died, and one radio-transmitter had malfunctioned prematurely (Table 1). Fifteen individuals were alive and being monitored. Locations of the last radio-locations of dead and missing sea otters from the treatment centers are shown in Figure 1. Last locations of live sea otters from the treatment centers are shown in Figure 2. Data on the fates of sea otters by groupings used in the following analyses are summarized in Table 2 and Table 3.

No differences were found between the survival rates of male and female sea otters from the treatment centers for either year of the study; Year 1 probability survival: males $P = 0.401$, females $P = 0.445$, $\chi^2 = 0.02$, 1 *DF*, N.S.; Year 2 probability survival: males $P = 0.714$, females $P = 0.692$, $\chi^2 = 0.003$, 1 *DF*, N.S. (Table 4).

Male treatment center otters were not included in further survival analysis due to lack of sufficient sample sizes and lack of biologically appropriate groups for comparison.

For year-one, female sea otters from the treatment centers exhibited lower survival rates than female sea otters from groupings EPWS FEMALES (missing individuals were assumed to be dead: $\chi^2 = 13.82$, 1 *DF*, $P < 0.001$; missing individuals were excluded: $\chi^2 = 8.36$, 1 *DF*, $P < 0.01$) and ALL FEMALES (missing individuals were assumed to be dead: $\chi^2 = 12.97$, 1 *DF*, $P < 0.001$; missing individuals were excluded: $\chi^2 = 6.88$, 1 *DF*, $P <$ O.02; Table 4). Insufficient females were available in the WPWS FEMALES grouping to warrant separate analysis for year-one.

For year-two, probability of survival was not significantly different between female sea otters from the treatment centers and female sea otters in the EPWS FEMALES and ALL FEMALES groupings. However, the females in the WPWS FEMALES did exhibit a higher survival rate than females released from the treatment center during year-two when missing individuals were assumed to have died (missing individuals were assumed to be dead:

$\chi^2 = 5.93$, 1 *DF*, $P < 0.02$; missing individuals were excluded: $\chi^2 = 1.03$, 1 *DF*, $P > 0.30$) (Table 4).

We suggest that the lack of difference in survival rates between the TC FEMALES grouping and the EPWS FEMALES grouping (probability of survival, missing individuals assumed to be dead: TC FEMALES $P = 0.692$ cf., EPWS FEMALES $P = 0.648$) should not be construed to indicate that treatment center females are exhibiting a "normal" rate of survival. Either value is abnormally low for prime-aged sea otter females (cf. probability survival year-two, WPWS FEMALES $P = 0.934$, missing individuals assumed to be dead; and year-one values Table 4). The question of the unusually low survival rates for females in eastern Prince William Sound will be treated in a future technical report on the survival of non-treatment center sea otters.

Summaries of survival data, rates and confidence intervals for various groupings are given in tabular form in Appendix III.

Pupping

None of the 28 females released from the treatment centers pupped following release during the summer or fall, 1989. Fourteen of the 28 females survived through the summer of 1990; 11 were monitored adequately for data to be included in analysis (Kenai otters excluded as explained above). Based upon body size, all 11 were mature individuals and should have been capable of pupping during 1990. However, only 2 of the females pupped. The proportion of females released from the treatment centers that pupped was lower than the proportions of females pupping during 1990 in both the EPWS FEMALES grouping ($\chi^2 = 3.29$, 1 *DF*, $P < 0.08$) and the WPWS FEMALES grouping ($\chi^2 = 6.19$, 1 *DF*, $P < 0.02$; Table 5). Reproduction by instrumented females released from the treatment centers is summarized in Table 6.

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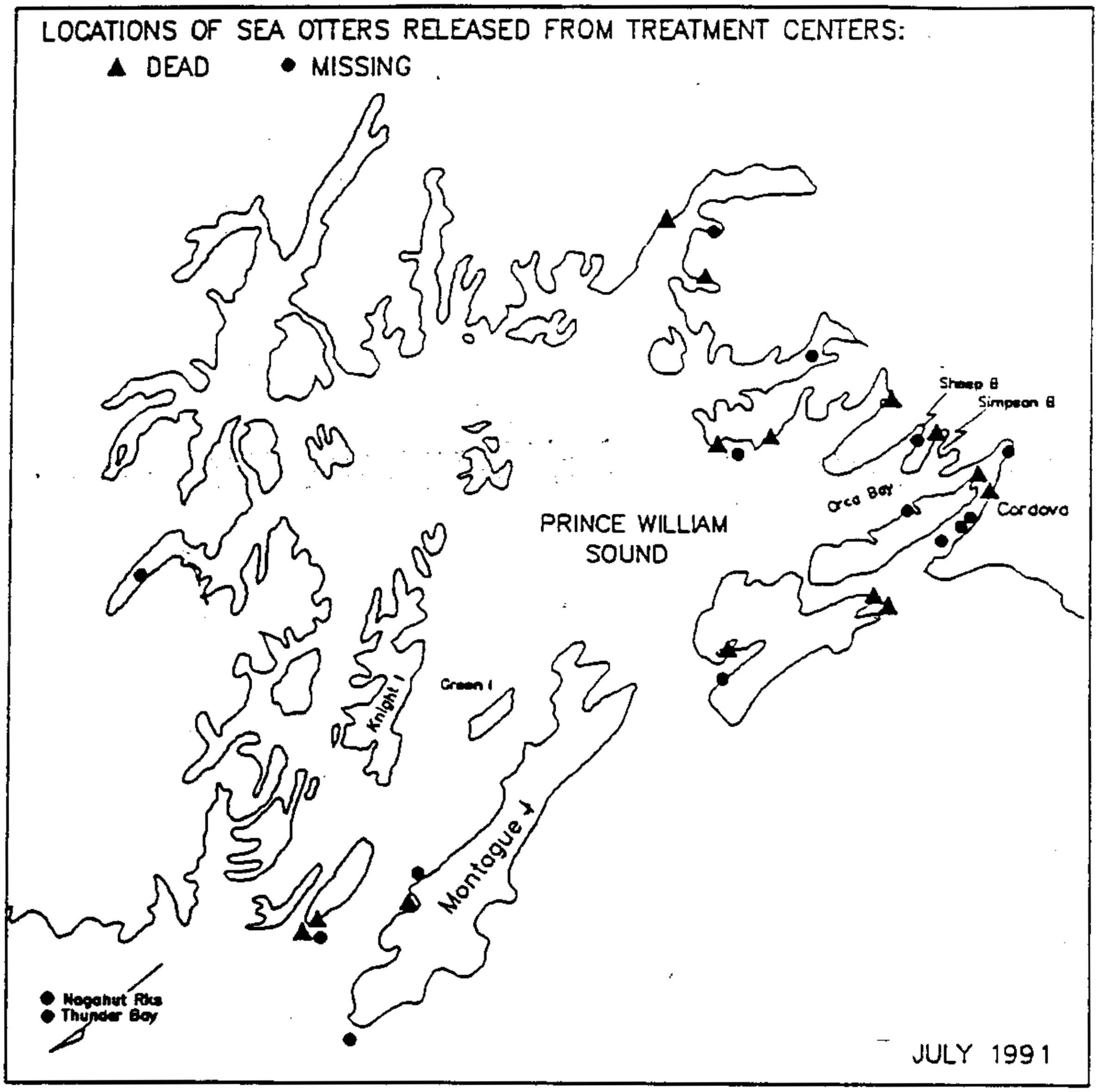

Figure 1. Locations of last radio-telemetry fixes of dead and missing instrumented sea otters released from otter treatment centers during summer, 1989.

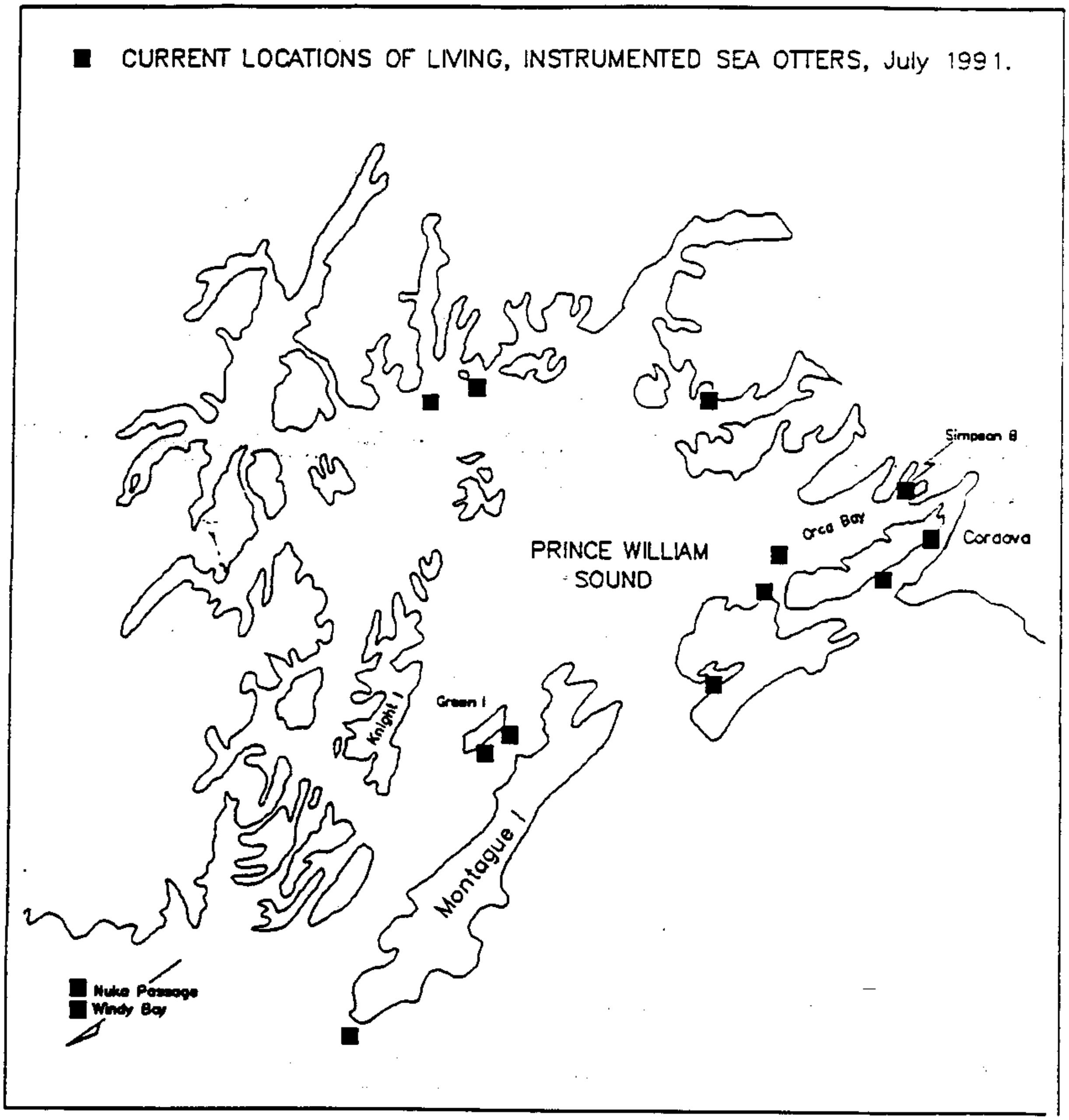

Figure 2. Summary of recent locations of sea otters released from otter treatment centers during 1989.

Table 1. Identification and status information of sea otters from EVOS treatment centers.

Treatment center ID	Sex	Capture location	Treatment center	Date released	Status	Days observed
S-002	F	Tonsina B.	Hom-VORC	7/27/89	alive	617
S-124	F	Rocky B./KP	SORC	8/16/89	missing	283
S-069	F	Rocky B./KP	SORC-JPRF	8/22/89	alive	704
S-162	F	Tonsina B.	SORC	8/16/89	missing	37
V-123	M	Natoa Is.	Sew-VORC	7/28/89	dead	246
S-015	F	Bootleg B.	SORC-VORC	7/27/89	missing	82
S-157	F	Rocky B./KP	SORC	8/16/89	missing	49
S-068	F	Rocky B./KP	SORC-VORC	7/27/89	tx fail.	36
V-048	M	Flemming Is.	VORC	7/28/89	dead	288
V-139	M	Crab B.	VORC	7/28/89	alive	728
V-104	M	Iktua B.	VORC	7/28/89	dead	263
S-045	F	Picnic Hbr.	SORC-VORC	7/27/89	alive	617
S-060	F	Windy B.	SORC-JPRF	8/22/89	dead	194
S-152	M	Rocky B./KP	SORC-JPRF	8/22/89	missing	27
S-161	F	Tonsina B.	SORC	8/16/89	alive	710
S-038	M	Windy B./KP	SORC-JPRF	8/22/89	dead	157
V-130	M	Natoa Is.	Sew-VORC	7/28/89	missing	309
S-003	F	Tonsina B.	Hom-SORC-JPRF	8/22/89	dead	184
V-138	M	Crab B.	VORC	7/28/89	missing	190
S-080	F	Rocky B./KP	SORC-JPRF	8/22/89	dead	172
S-054	F	Windy B./KP	SORC-JPRF	8/22/89	dead	151
V-029	M	Green Is.	VORC	7/28/89	alive	725
S-006	F	Tonsina B.	Hom-SORC-JPRF	8/22/89	missing	342
S-122	M	Kupreanof/KI	SORC-JPRF	8/22/89	missing	0
V-145	F	Tonsina B.	Hom-VORC	7/27/89	missing	443
S-114	F	Uyak B./KI	Kod-SORC-JPRF	8/22/89	missing	135

Treatment center ID	Sex	Capture location	Treatment center	Date released	Status	Days observed
S-044	M	Taylor B.	SORC-JPRF	8/22/89	dead	184
S-057	F	Natoa Is.	SORC-JPRF	8/22/89	missing	116
S-043	F	Taylor B.	SORC-JPRF	8/22/89	dead	238
V-152	M	Berger B.	Hom-VORC	7/28/89	dead	388
S-007	F	Tonsina B.	Hom-SORC-JPRF	8/22/89	missing	555
S-053	F	Windy B./KP	SORC-JPRF	8/22/89	missing	165
S-155	F	Rocky B./KP	SORC	8/16/89	missing	701
S-017	F	Bootleg B.	SORC-VORC	7/27/89	alive	741
S-146	F	Windy B./KP	SORC	8/16/89	alive	709
S-059	F	Windy B./KP	SORC	7/27/89	alive	739
V-062	M	Hogan B.	VORC	7/28/89	alive	737
S-035	F	Windy B./KP	SORC-VORC	7/27/89	dead	654
V-137	M	Crab B.	VORC	7/28/89	dead	187
S-128	F	Rocky B./KP	SORC	8/16/89	dead	10
V-150	F	Tonsina B.	SORC-VORC	8/16/89	alive	722
V-146	M	Nuka B.	Hom-VORC	7/28/89	alive	735
V-068	F	Herring B.	VORC	7/27/89	alive	730
V-140	M	Crab B.	VORC	7/28/89	alive	742
V-148	M	Bainbridge P.	VORC	8/16/89	missing	467

Table 2a. Summary of the fates of female sea otters radio instrumented and released from the sea otter treatment centers.

Month	# at Risk	# Dead	# Missing	Tx Expired	# Added
Jul 89	0	0	0	0	9
Aug 89	9	1	0	0	19
Sep 89	27	0	1	1	0
Oct 89	25	0	2	0	0
Nov 89	23	0	0	0	0
Dec 89	23	0	1	0	0
Jan 90	22	1	1	0	0
Feb 90	20	2	1	0	0
Mar 90	17	1	0	0	0
Apr 90	16	1	0	0	0
May 90	15	0	1	0	0
Jun 90	14	0	0	0	0
Jul 90	14	0	1	0	0
Aug 90	13	0	0	0	0
Sep 90	13	0	0	0	0
Oct 90	13	0	0	0	0
Nov 90	13	0	1	0	0
Dec 90	12	0	0	0	0
Jan 91	12	0	0	0	0
Feb 91	12	0	1	0	0
Mar 91	11	0	0	0	0
Apr 91	11	0	0	0	0
May 91	11	1	0	0	0
Jun 91	10	0	0	0	0
Jul 91	10	0	0	0	0

Table 2b. Summary of the fates of male sea otters radio instrumented and released from the sea otter treatment centers.

Month	# at Risk	# Dead	# Missing	Tx Expired	# Added
Jul 89	0	0	0	0	12
Aug 89	12	0	1	0	5
Sep 89	16	0	1	0	0
Oct 89	15	0	0	0	0
Nov 89	15	0	0	0	0
Dec 89	15	0	0	0	0
Jan 90	15	2	0	0	0
Feb 90	13	1	1	0	0
Mar 90	11	1	0	0	0
Apr 90	10	1	0	0	0
May 90	9	1	0	0	0
Jun 90	8	0	1	0	0
Jul 90	7	0	0	0	0
Aug 90	7	1	0	0	0
Sep 90	6	0	0	0	0
Oct 90	6	0	0	0	0
Nov 90	6	0	0	0	0
Dec 90	6	0	1	0	0
Jan 91	5	0	0	0	0
Feb 91	5	0	0	0	0
Mar 91	5	0	0	0	0
Apr 91	5	0	0	0	0
May 91	5	0	0	0	0
Jun 91	5	0	0	0	0
Jul 91	5	0	0	0	0

Table 3. Summary of the fates of radio-instrumented sea otters in study groupings used in survival analysis for comparison with sea otters released from sea otter treatment centers.

	1987 Study EPWS Females					1987 Study EPWS Males					1989-90 EPWS Females					1989-90 WPWS Females					1989-90 WPWS Males				
Month	R[1]	D	M	E	A	R	D	M	E	A	R	D	M	E	A	R	D	M	E	A	R	D	M	E	A
Jul 89	39	1	0	0	0	12	0	0	0	0															
Aug 89	38	1	1	0	0	12	3	0	0	0															
Sep 89	36	0	0	0	0	9	0	1	0	0															
Oct 89	36	0	0	0	0	8	0	0	0	0					22										
Nov 89	36	1	0	1	0	8	0	0	0	0	22	0	0	0	0					8					2
Dec 89	34	0	1	1	0	8	0	1	0	0	22	0	2	0	0	8	0	0	0	0	2	0	0	0	0
Jan 90	32	0	1	0	0	7	1	0	0	0	20	0	0	0	0	8	0	0	0	0	2	0	0	0	0
Feb 90	31	0	0	2	0	6	1	1	0	0	20	0	0	0	0	8	0	0	0	0	2	0	0	0	0
Mar 90	29	0	0	1	0	4	1	0	0	0	20	1	0	0	14	8	0	0	0	0	2	0	0	0	0
Apr 90	28	0	0	0	0	3	0	0	0	0	33	0	0	0	4	8	0	0	0	39	2	0	0	0	1
May 90	28	0	0	1	0	3	0	0	0	0	37	1	0	0	0	47	0	0	0	0	3	0	0	0	0
Jun 90	27	0	0	4	0	3	0	0	1	0	36	0	0	0	0	47	0	0	0	0	3	0	0	0	0
Jul 90	23	0	0	2	0	2	0	0	0	0	36	0	0	0	0	47	0	0	0	0	3	0	0	0	0
Aug 90	21	0	0	3	0	2	0	0	0	0	36	0	0	0	0	47	0	0	0	0	3	0	0	0	0
Sep 90	18	0	0	5	0	2	0	0	0	0	36	0	1	0	2	47	1	0	0	0	3	0	0	0	0
Oct 90	13	0	0	0	0	2	0	0	2	0	37	1	1	0	2	46	0	0	0	0	3	0	0	0	0
Nov 90	13	0	0	5	0	0					37	0	1	0	0	46	0	0	0	0	3	0	0	0	0
Dec 90	8	0	0	8	0						36	1	1	0	0	46	0	0	0	0	3	0	0	0	0
Jan 91	0										34	0	0	0	0	46	0	0	0	0	3	0	1	0	0
Feb 91											34	0	0	0	0	44	0	0	0	0	2	0	0	0	0
Mar 91											34	1	0	0	0	44	0	0	0	0	2	0	0	0	0
Apr 91											33	0	1	0	0	44	0	0	0	0	2	0	0	0	0
May 91											32	0	0	0	0	44	0	0	0	0	2	0	0	0	0
Jun 91											32	0	4	0	0	44	0	2	0	0	2	0	0	0	0
Jul 91											28	0	3	0	0	42	0	0	0	0	2	0	0	0	0
Aug 92											25					42					2				

[1] KEY

R Number of sea otters at risk during month

D Number of sea otters that died during month

M Number of sea otters classified missing during month

E Number of sea otters having transmitters expire during month

A Number of sea otters added to study during month

Table 4. Summary of statistics on survival of sea otters radio-instrumented and released in Prince William Sound. Study groupings include individuals released from otter treatment centers (T.C.), individuals from eastern Prince William Sound (EPWS) and individuals from western Prince William Sound (WPWS).

Years	Study grouping	p Survival	C.I.	χ^2	D.F.	p
Missing Assumed Dead						
1989-90	T.C. Females	0.445	(0.223-0.667)	0.02	1	N.S.
	T.C. Males	0.401	(0.133-0.670)			
1990-91	T.C. Females	0.692	(0.421-0.964)	0.003	1	N.S.
	T.C. Males	0.714	(0.314-1.115)			
1989-90						
Missing Assumed Dead						
	All Females	0.85	(0.757-0.943)	13.82	1	0.001
	T.C. Females	0.445	(0.223-0.667)			
	EPWS Females	0.834	(0.733-0.934)	12.97	1	0.001
	T.C. Females	0.445	(0.223-0.667)			
Missing Eliminated						
	All Females	0.932	(0.862-1.001)	8.36	1	0.01
	T.C. Females	0.674	(0.412-0.935)			
	EPWS Females	0.923	(0.847-0.999)	6.88	1	0.02
	T.C. Females	0.674	(0.412-0.935)			
1990-91						
Missing Assumed Dead						
	All Females	0.798	(0.716-0.880)	0.79	1	N.S.
	T.C. Females	0.692	(0.421-0.964)			
	EPWS Females	0.648	(0.506-0.790)	0.19	1	N.S.
	T.C. Females	0.692	(0.421-0.964)			
	WPWS Females	0.934	(0.862-1.006)	5.93	1	0.02
	T.C. Females	0.692	(0.421-0.964)			
Missing Eliminated						
	All Females	0.956	(0.915-0.998)	0.3	1	N.S.
	T.C. Females	0.909	(0.713-1.105)			
	EPWS Females	0.930	(0.848-1.011)	0.19	1	N.S.
	T.C. Females	0.909	(0.713-1.105)			
	WPWS Females	0.979	(0.936-1.021)	1.03	1	N.S.
	T.C. Females	0.909	(0.713-1.105)			

Table 5. Summary of reproduction by females from treatment centers vs. wild captured females in Prince William Sound, 1990.

	Females Pupping	Females Not Pupping	
Treatment Center Females	2	9	$\chi^2 = 3.29$, 1 D.F., $p < 0.08$
1989-90 East PWS Females	14	14	

	Females Pupping	Females Not Pupping	
Treatment Center Females	2	9	$\chi^2 = 6.19$, 1 D.F., $p < 0.02$
1989-90 West PWS Females	22	14	

	Females Pupping	Females Not Pupping	
Treatment Center Females	2	9	$\chi^2 = 5.52$, 1 D.F., $p < 0.02$
1989-90 All PWS Females	36	28	

Table 6. Summary of reproduction by individual instrumented female sea otters following release from sea otter treatment centers.

TX	Otter ID	Jul 90 status	Date last seen	Est. date pupped	Fate of pup	Jul 91 status	Date last seen	Est. date pupped	Fate of pup
4098	S-002	alive		didn't pup		alive	05 Apr 91	didn't pup	
4135	S-124	missing	26 May 90	didn't pup					
4148	S-069	alive		19 Oct 90	weaned	alive	27 Jul 91	didn't pup	
4176	S-162	missing	22 Sep 89	didn't pup					
4225	S-015	missing	17 Oct 89	didn't pup					
4238	S-157	missing	04 Oct 89	didn't pup					
4257	S-068	TX failure	01 Sep 89	didn't pup					
4340	S-045	alive		06 Apr 90	unknown	alive	05 Apr 91	didn't pup	
4355	S-060	dead	04 Mar 90	didn't pup					
4398	S-161	alive		didn't pup		alive	27 Jul 91	didn't pup	
4447	S-003	dead	22 Feb 90	didn't pup					
4478	S-080	dead	10 Feb 90	didn't pup					
4498	S-054	dead	20 Jan 90	didn't pup					
4547	S-006	alive		didn't pup		missing	30 Jul 90	didn't pup	
4593	V-145	alive		didn't pup		missing	13 Oct 90	didn't pup	
4608	S-114	missing	04 Jan 90	didn't pup					
4649	S-057	missing	16 Dec 89	didn't pup					
4696	S-043	dead	17 Apr 90	didn't pup					
4728	S-007	alive		didn't pup		missing	28 Feb 91	didn't pup	
4755	S-053	missing	03 Feb 90	didn't pup					
4789	S-155	alive		didn't pup		missing	18 Jul 91	didn't pup	
4796	S-017	alive		31 Dec 89	weaned	alive/pup	07 Aug 91	07 Feb 91	w/mother
4815	S-146	alive		didn't pup		alive/pup	26 Jul 91	16 May 91	w/mother
4825	S-059	alive		didn't pup		alive	05 Aug 91	didn't pup	
4857	S-035	alive		didn't pup		dead	12 May 91	didn't pup	
4928	S-128	dead	26 Aug 89	didn't pup					
4935	V-150	alive		didn't pup		alive	08 Aug 91	didn't pup	
4966	V-068	alive		didn't pup		alive	27 Jul 91	didn't pup	

Appendix I. Correspondence regarding three female sea otters, resident among Kenai Penninsula. Females were eliminated from consideration for reproductive study given erratic monitoring and unreconcilable errors in data.

13 June 1990

Larry Pank
Chief, Mammals Section
Alaska Fish and Wildlife Research Center
U. S. Fish and Wildlife Service
1011 E. Tudor Rd.
Anchorage, AK 99503

Dear Larry,

I have been reviewing telemetry data collected last summer by your staff on treatment center sea otters located along the Kenai Peninsula. I note that five of the 8 radio-fixes were taken near Rocky Bay. However, latitude-longitude coordinates indicate that your staff observed these otters near Rocky Bay on the NE end of Montague Island. This is clearly nonsense for two reasons. First, all of our observations on these individuals indicate that they were located near Rocky Bay on the Kenai Peninsula. Moreover, on 10/2 your data indicates that your aircraft was at Tonsina Bay only 20 minutes before the sightings at Rocky Bay. This would not have been possible if the observations had actually been taken near Montague Island. It seems obvious that whoever recorded the data did not know which Rocky Bay was being surveyed. It would be difficult to confuse these bays if the recorder had been on site when the data were taken. This in turn, leads me to speculate that some individual generated this radio-fix data by going to a chart in your office and guessing at the location. The location type is classified as "VG" for one of the 10/2 fixes, thus the observer should have had confidence in the location to within a few hundred meters.

I include a copy of the data set for your perusal. Would you please ask your staff to clarify this situation.

Thank you for your attention to this matter.

Sincerely,

Charles Monnett, Ph.D.
Princple Investigator
Prince William Sound Science Center

Frequency	Date	Time	General Location	Lat.	Long	Location Type	Reproductive Status	Group Size (Pups)	Weather/ Beaufort	obs.	Reciever #
4098	9-7-90	2:30 PM	Tonjina Bay	59°18'	150° 54'	VG	N Pup		Clear water 5	cl	4101
4340	9-7-90	3:15	Rocky Bay	60°21'30"	147° 03'	RI		40 +	clear water 5	cl	4343
4728	9-24 90	12:15	Rocky Bay	"	"	RI		30	[illegible] wind 210 @ 35K	cl	4731
4340	9-24-90	12:30	Rocky Bay	"	"	RI		P	" "	cl	4343
4098	9-24 90		Tonjina Bay	59°18'	150° 54	RI		P	[illegible] wind 210 @ 35K	cl	4101
4098	10-2	1:50 PM	Tonjina Bay	59°18'	150° 54	RI			wind NW 15K	cl	4101
4728	10-2	2:10	Rocky Bay	60°21'30"	147° 03'	VG	N Pup		NW 15	cl	9731
4340	10 2	2:25	Rocky Bay	" "	" "	RI			NW 25	cl	4343
4098	14 Dec 90	1350	Tonjina Bay			RA			W ~15	cl/sub	4101
4343	" "	1405	Rocky Bay			RA			" "	cl/sub	4343
4748	" "	1413	Windy Bay			RA			"	cl/sub	4343

Locations were recieved @ 2500' ∴ No coordinates were assigned

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Appendix II. Proceedings of presentation by Lisa Rotterman at Sea Otter Symposium sponsored by U.S. Fish and Wildlife Service in Anchorage, April 1990.

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.

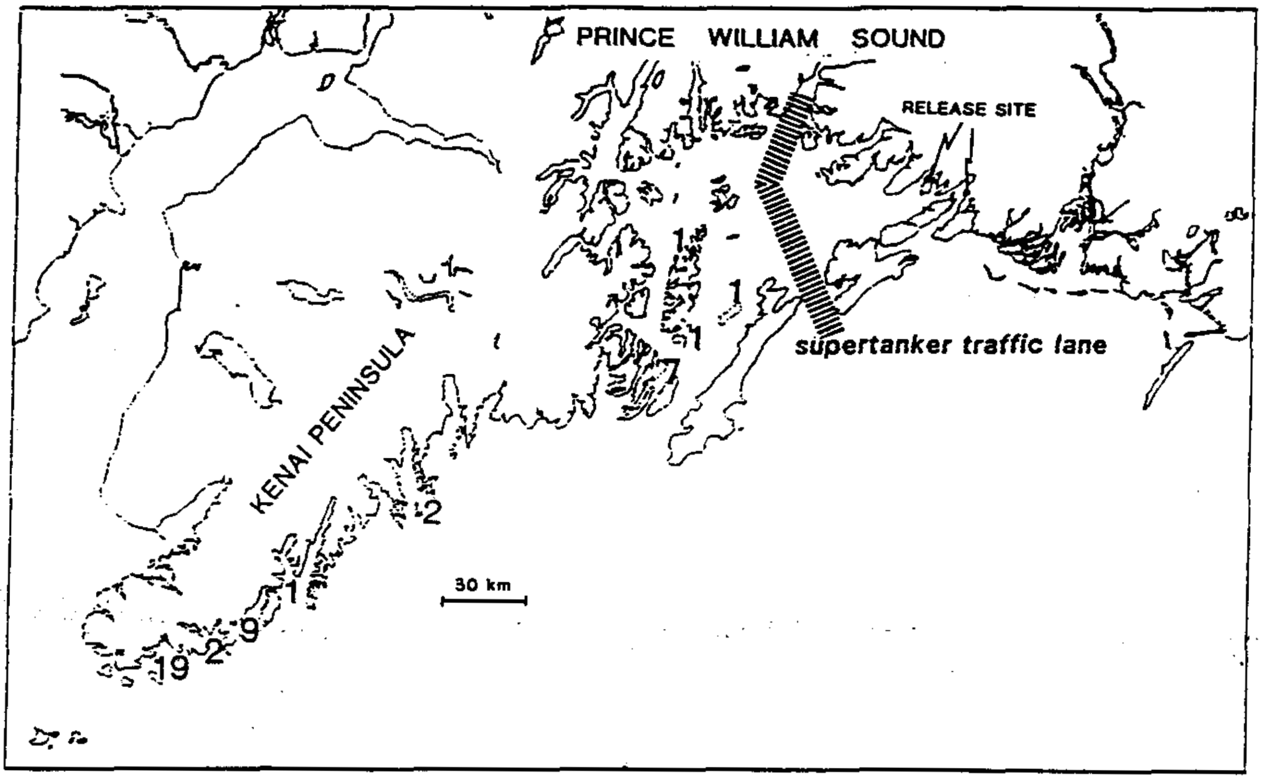

Fig. 1. Capture locations of sea otters (*Enhydra lutris*) treated in otter rehabilitation centers, implanted with radio transmitters, and released in eastern PWS for followup studies. Two otters that were captured in the Kodiak Archipelago are not shown on the figure.

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

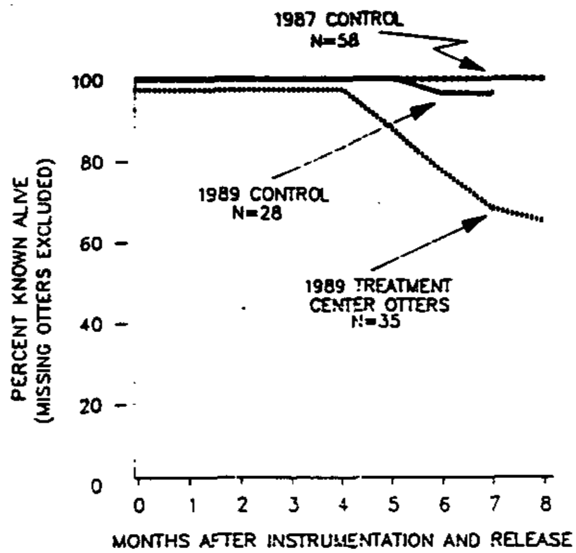

Fig. 2. Survival rates of sea otters (*Enhydra lutris*) implanted with radio transmitters in three studies during the first 8 months of observation. Otters classified as missing were not included in this analysis, as reflected in sample sizes given.

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.

Acknowledgments

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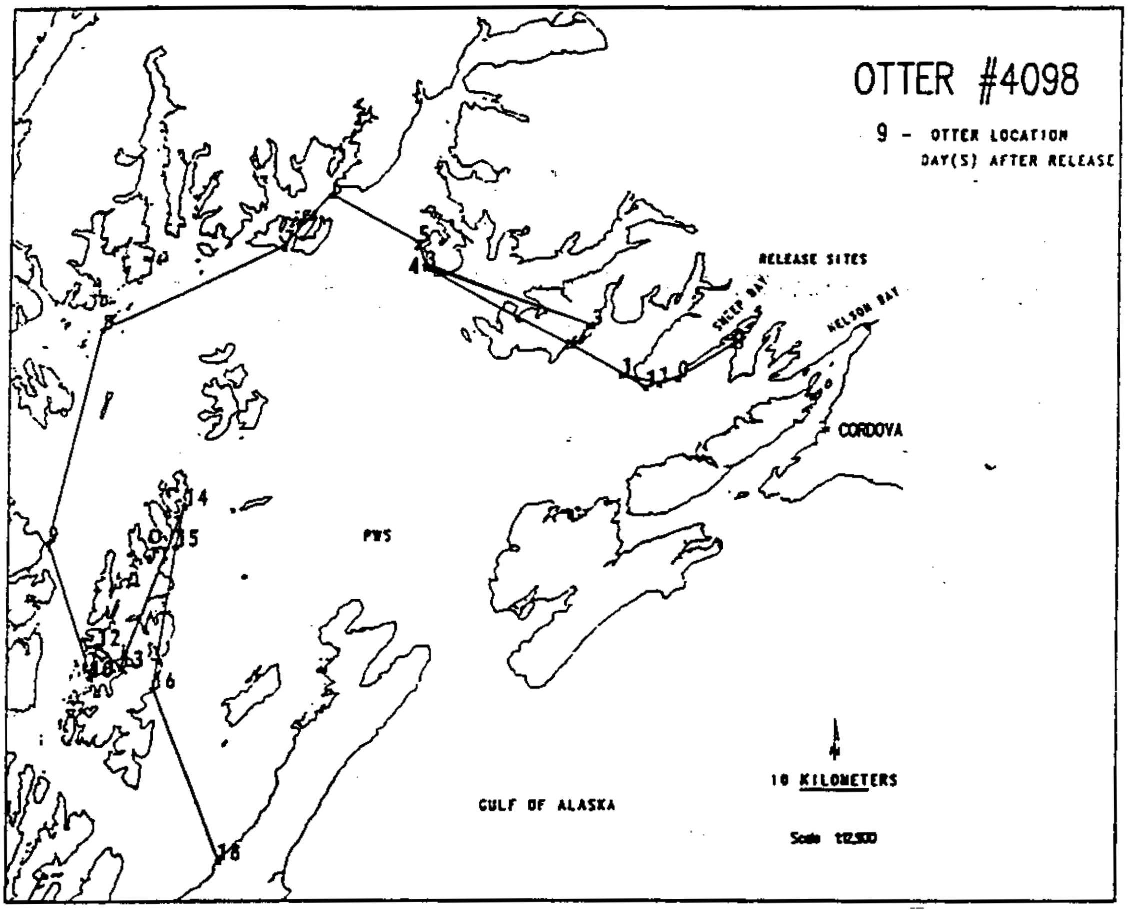
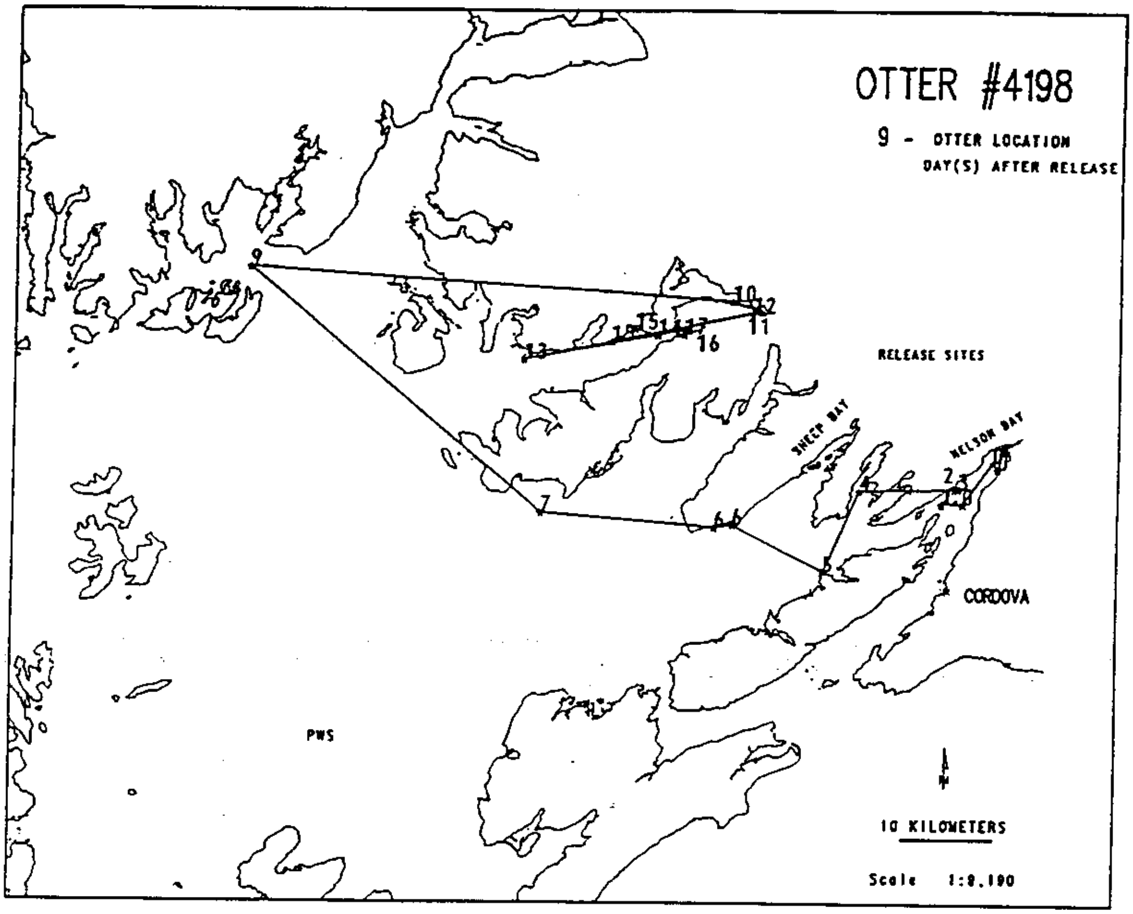
Appendix. Locations of radio fixes taken over the first 20 days of observation on instrumented sea otters (*Enhydra lutris*) released into eastern Prince William Sound. Otters were captured, transported to, treated in, and held in treatment centers established in response to the 24 March 1989 T/V *Exxon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

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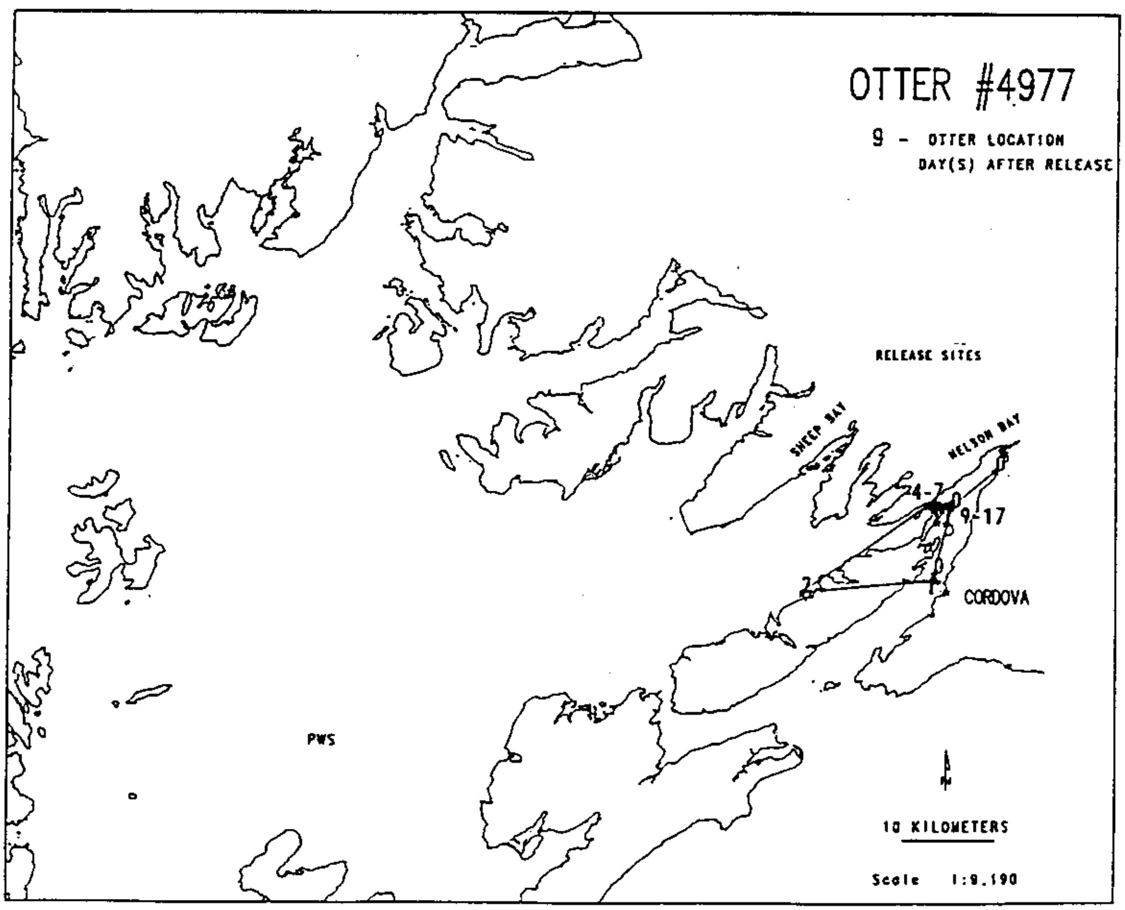
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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NELSON BAY
CORDOVA
PWS
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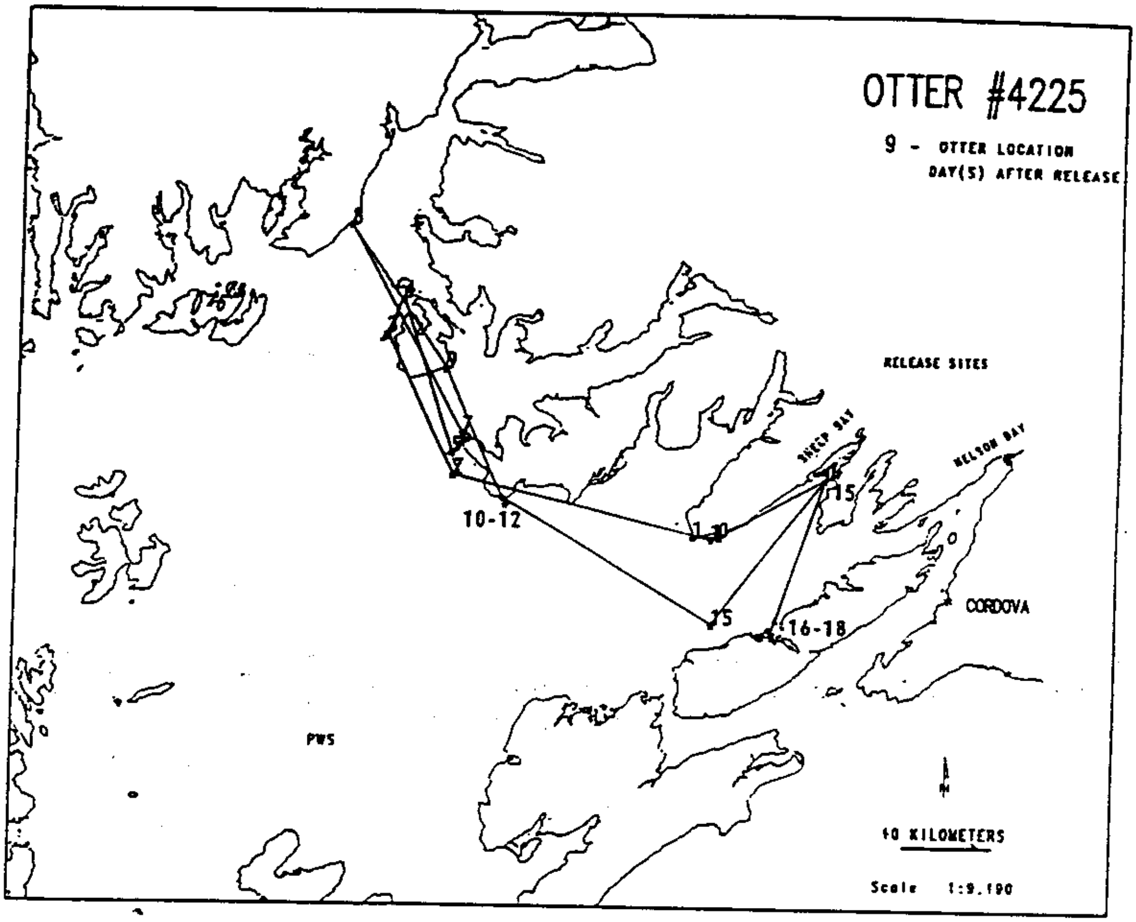
Scale 1:9,190


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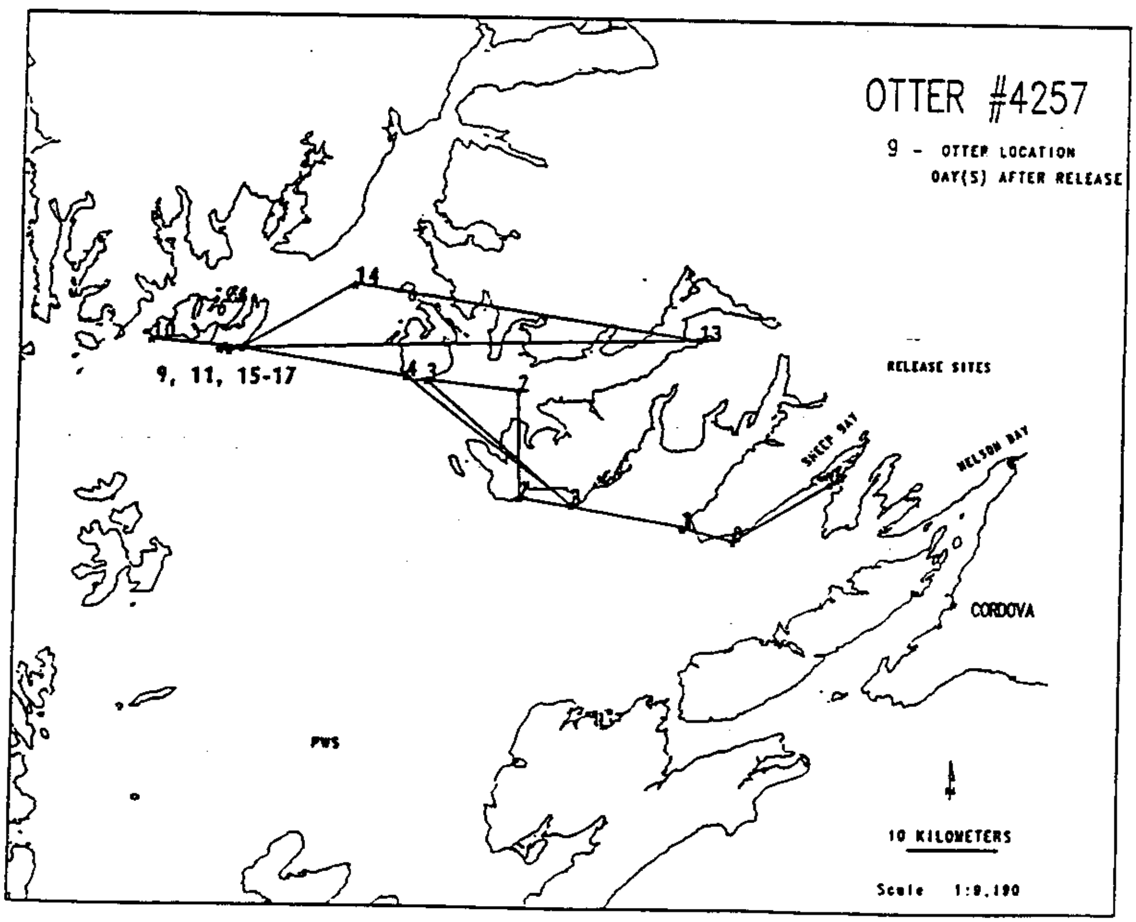
NELSON BAY
10-12
15
16-18
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190


OTTER #4257
9 - OTTER LOCATION
DAY(S) AFTER RELEASE
14
13
10
9, 11, 15-17
4 3
RELEASE SITES
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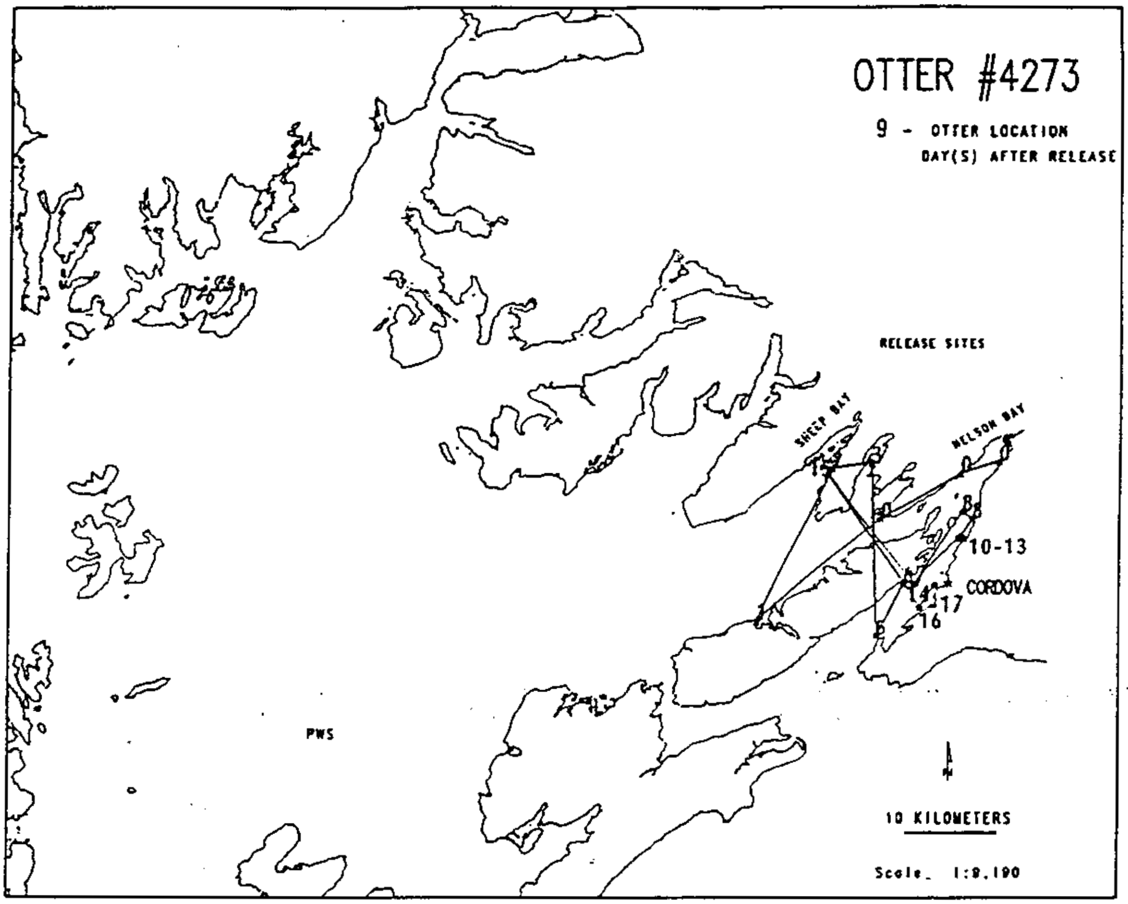
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
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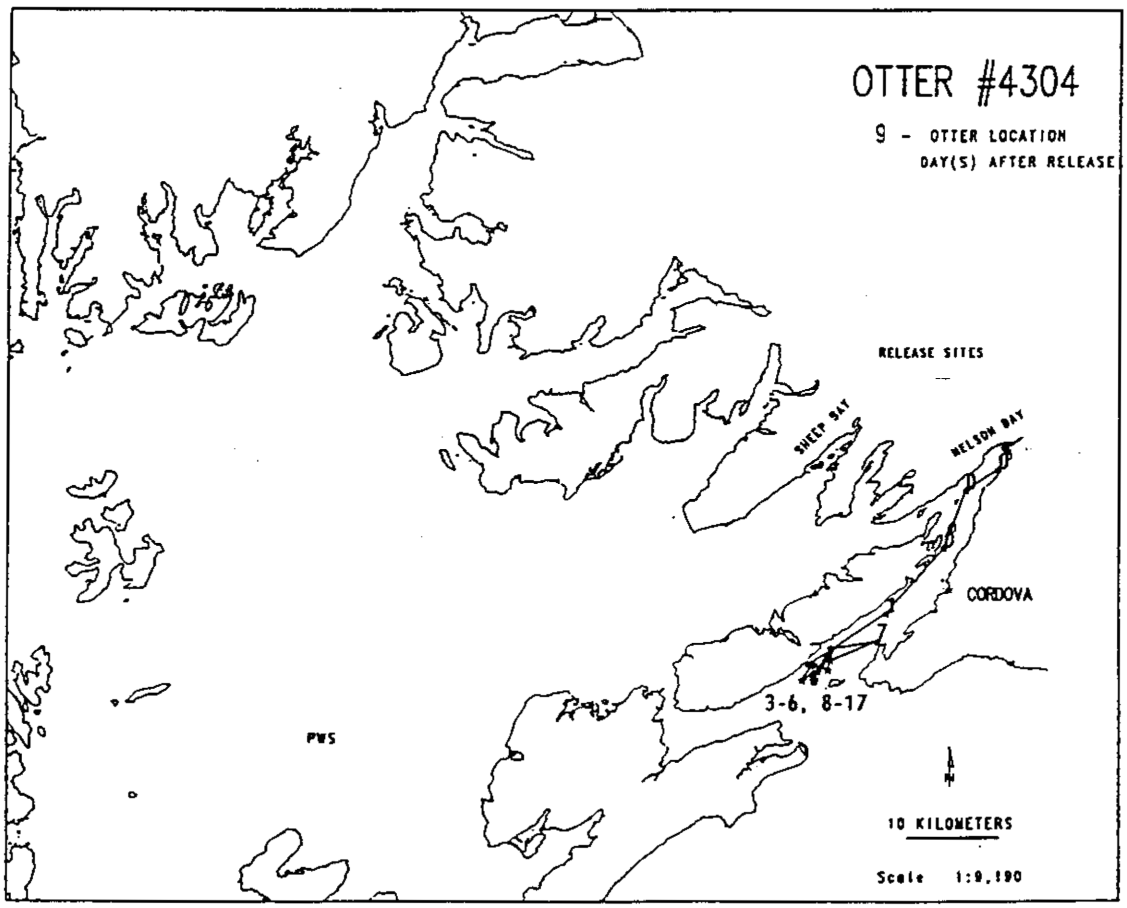
NELSON BAY
10-13
CORDOVA
17
16
PWS
10 KILOMETERS
Scale 1:9,190


OTTER #4304
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DAY(S) AFTER RELEASE
RELEASE SITES
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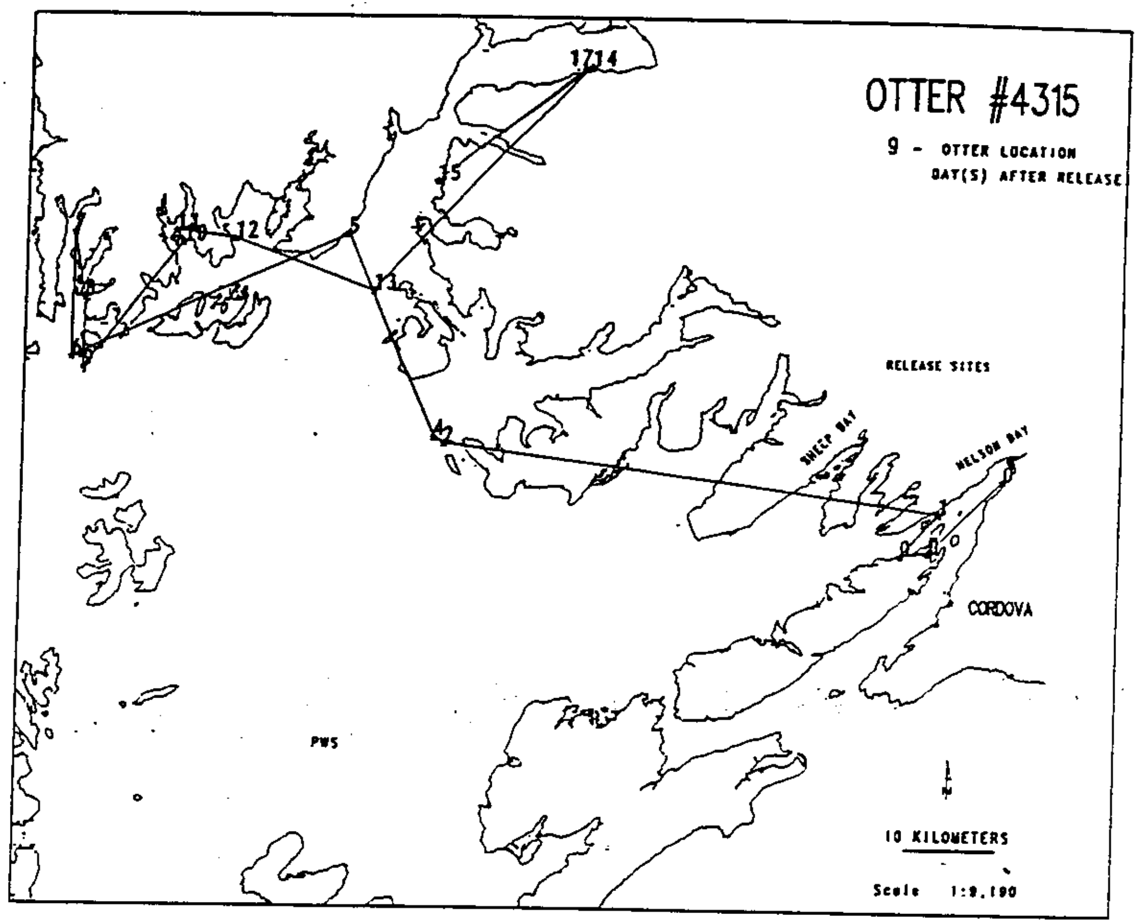
NELSON BAY
CORDOVA
3-6, 8-17
PWS
10 KILOMETERS
Scale 1:9,190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NELSON BAY
CORDOVA
PWS
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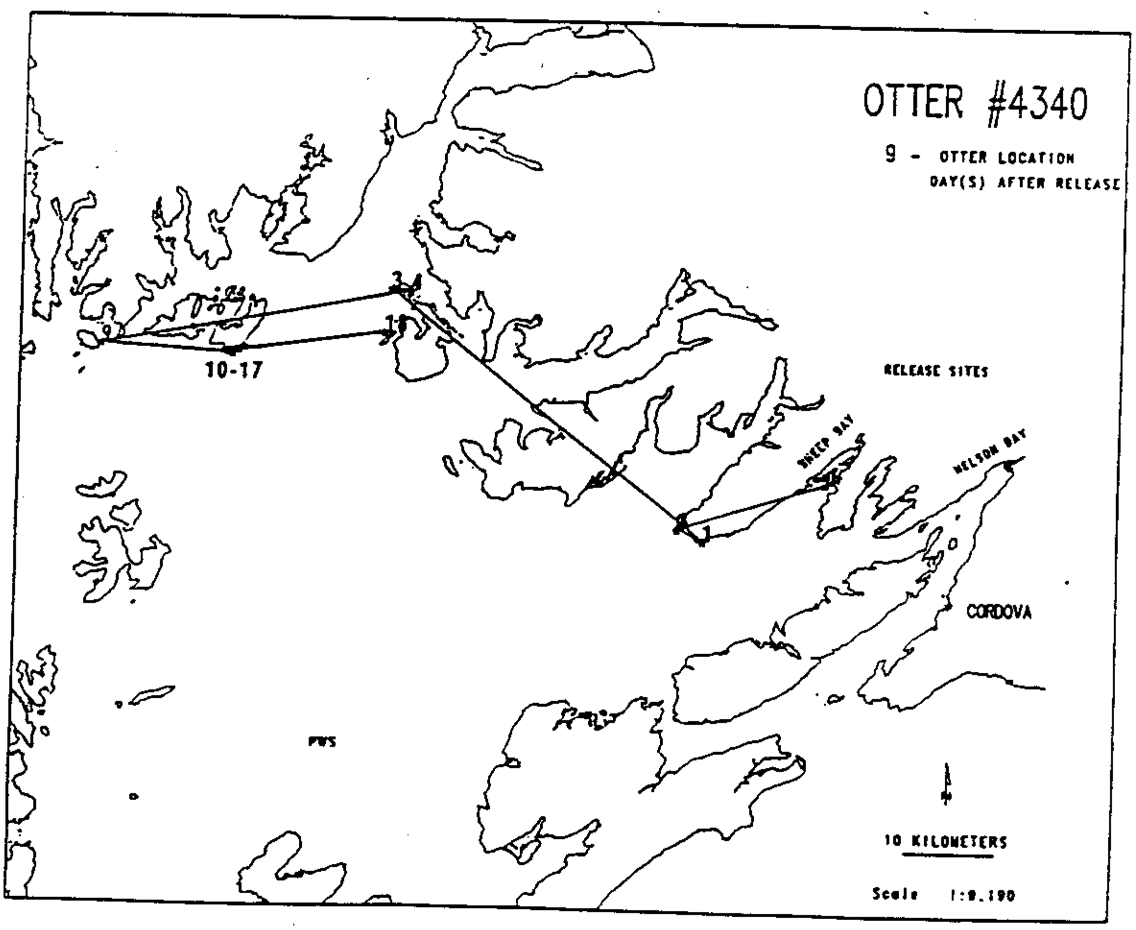
Scale 1:9,190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DAY(S) AFTER RELEASE
10-17
RELEASE SITES
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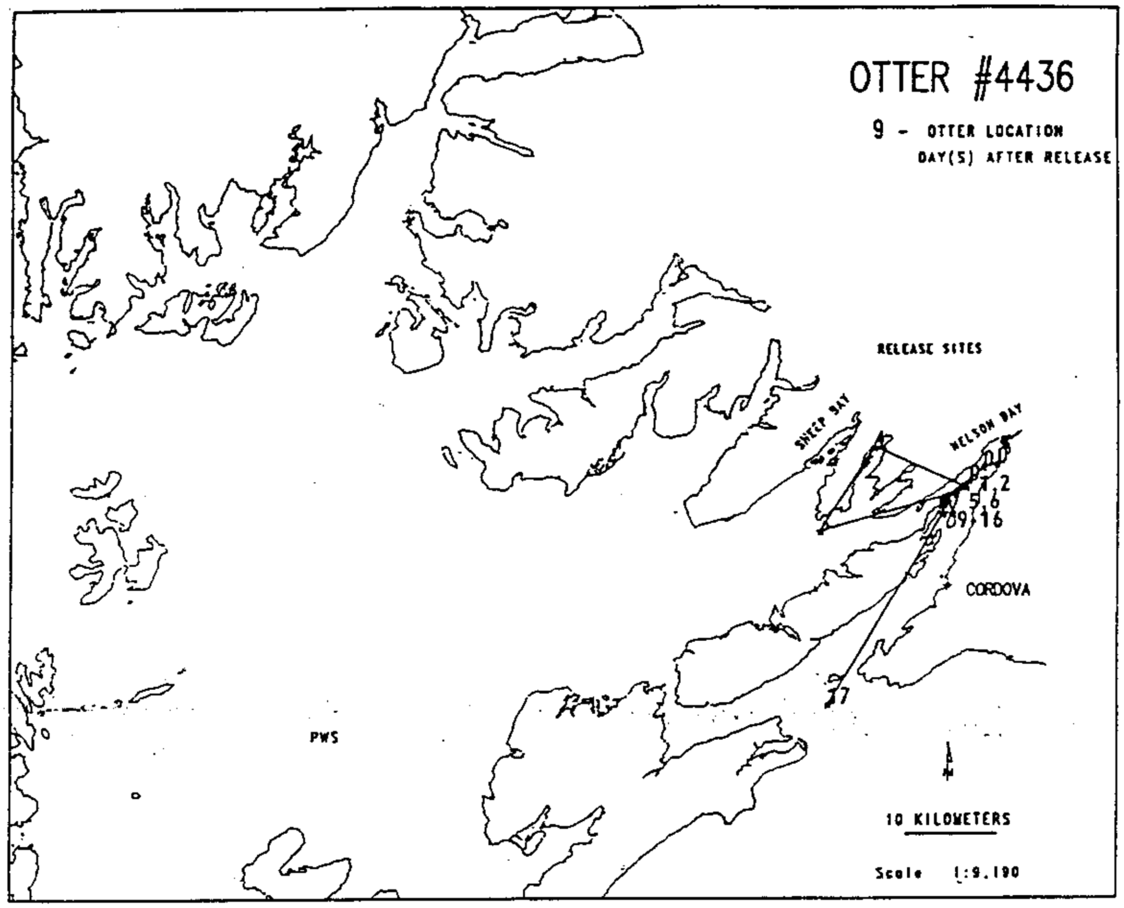
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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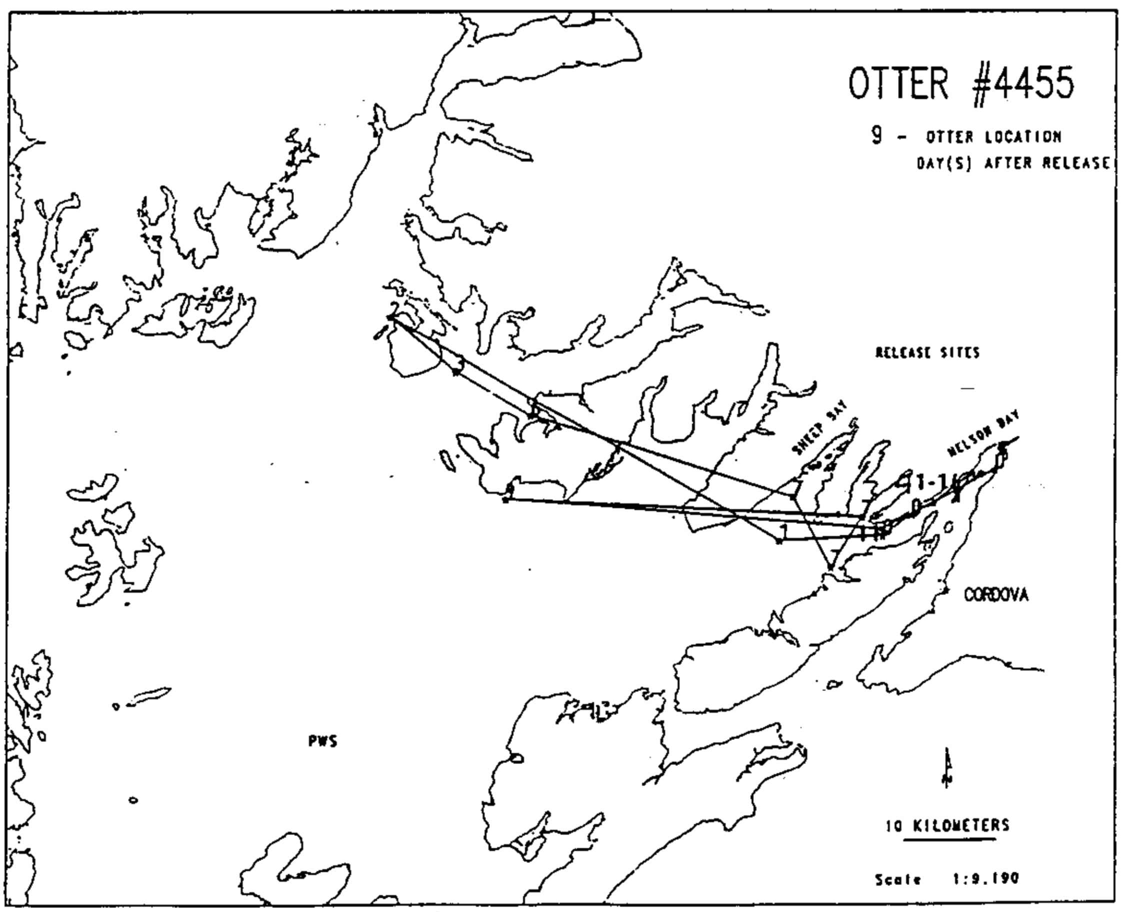
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
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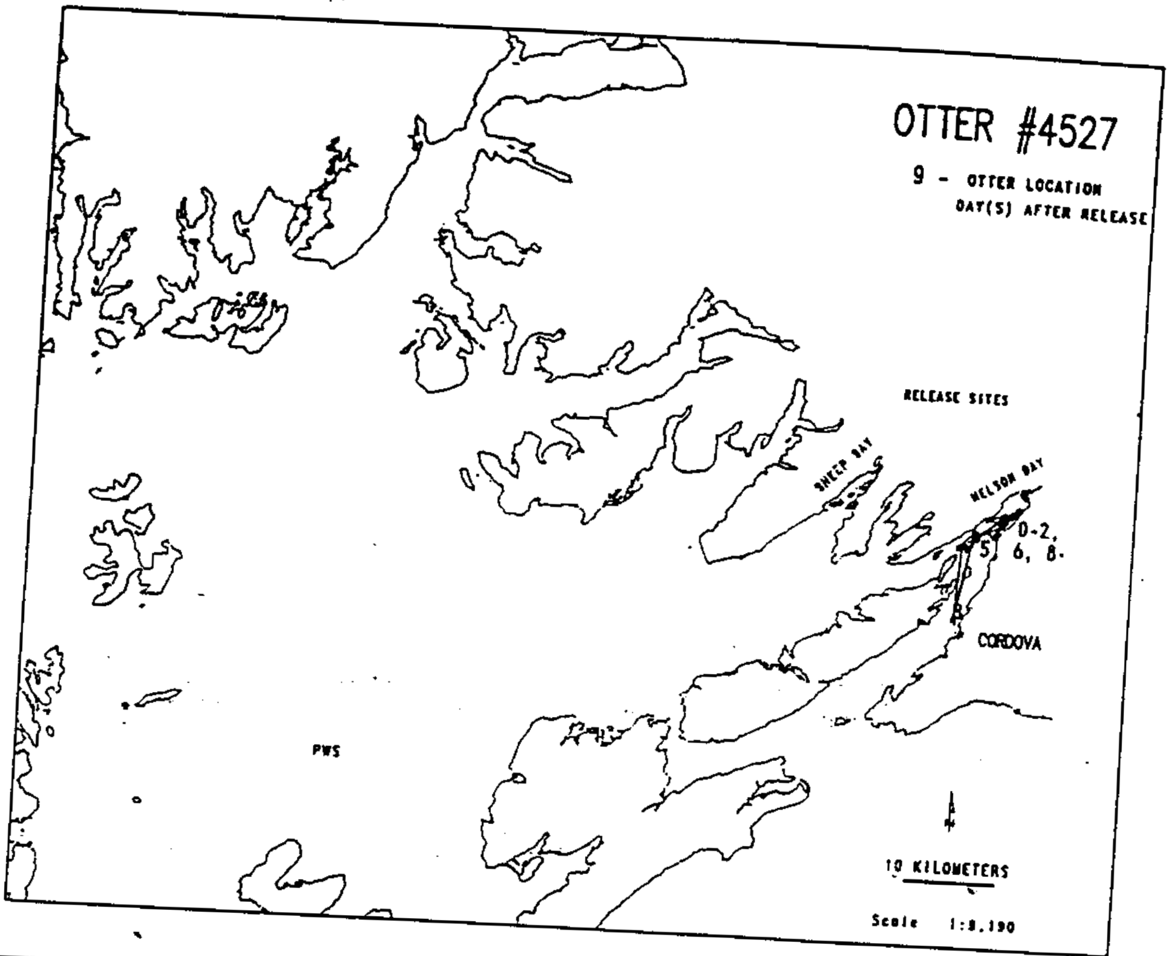
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
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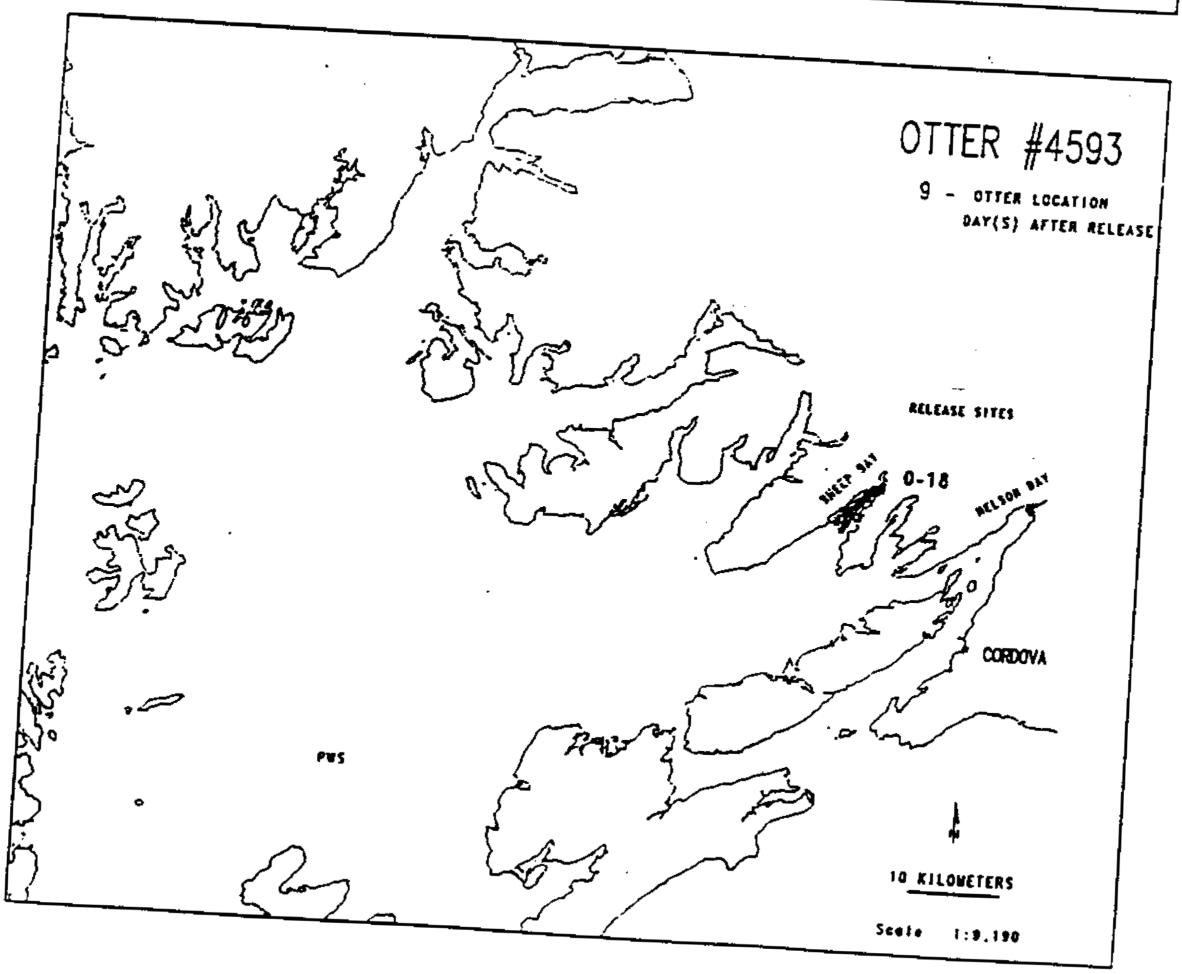
NELSON BAY
0-2,
5, 6, 8.
CORDOVA
PWS
10 KILOMETERS
Scale 1:8,190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DAY(S) AFTER RELEASE
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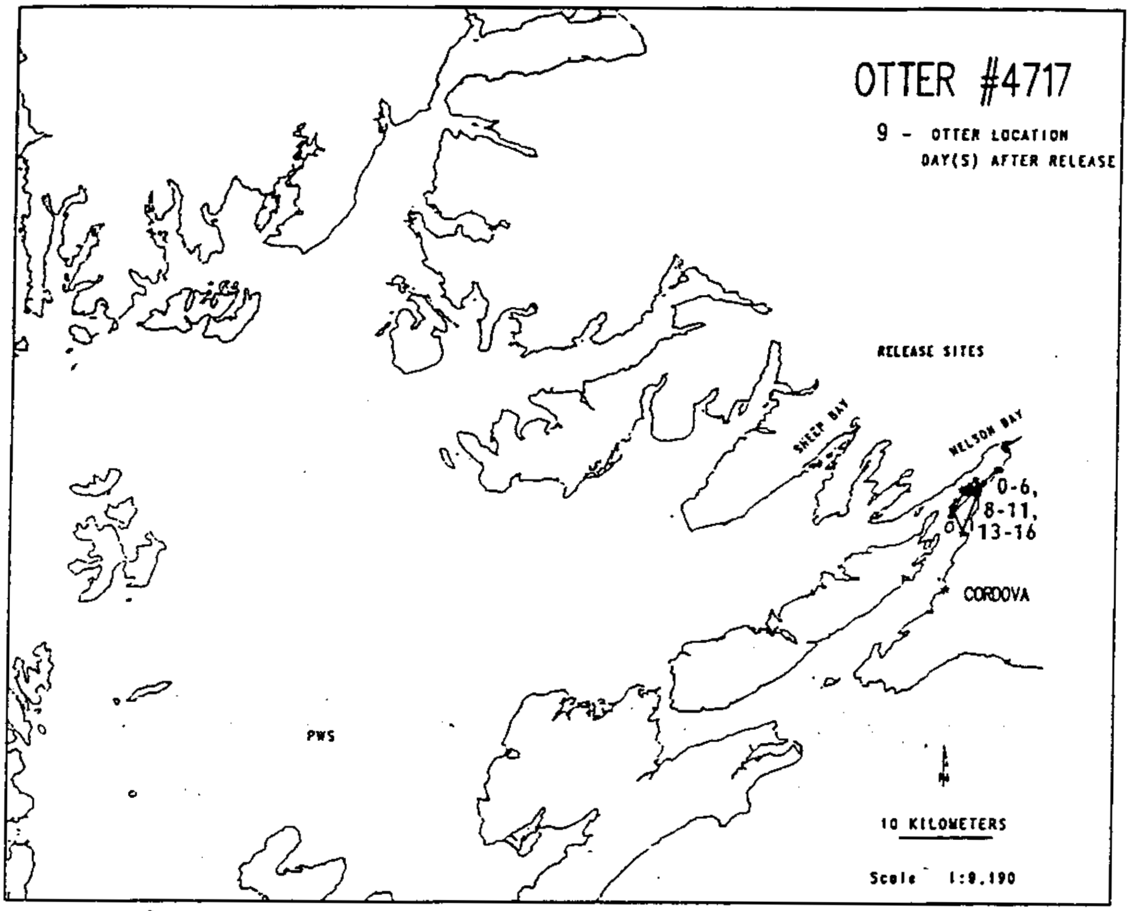
0-18
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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9 - OTTER LOCATION
DAY(S) AFTER RELEASE
RELEASE SITES
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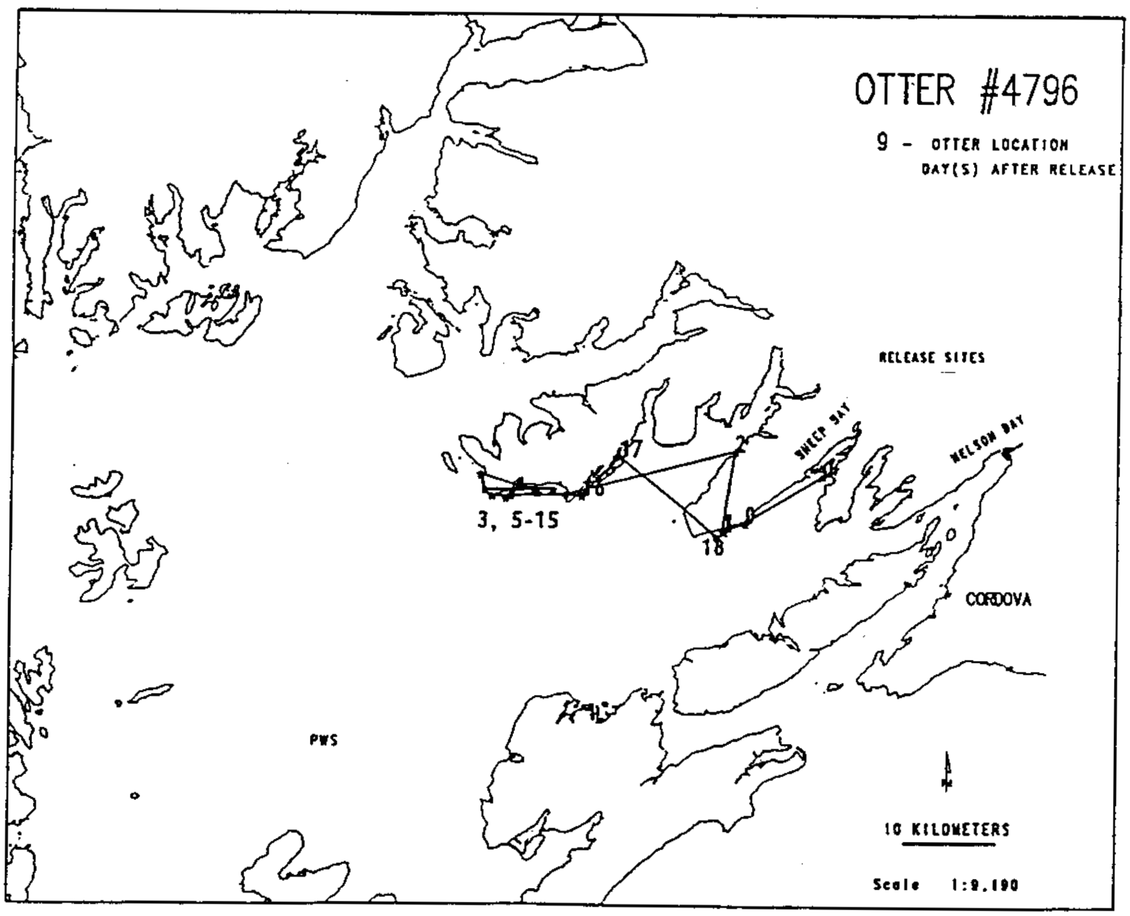
NELSON BAY
0-6,
8-11,
13-16
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
RELEASE SITES
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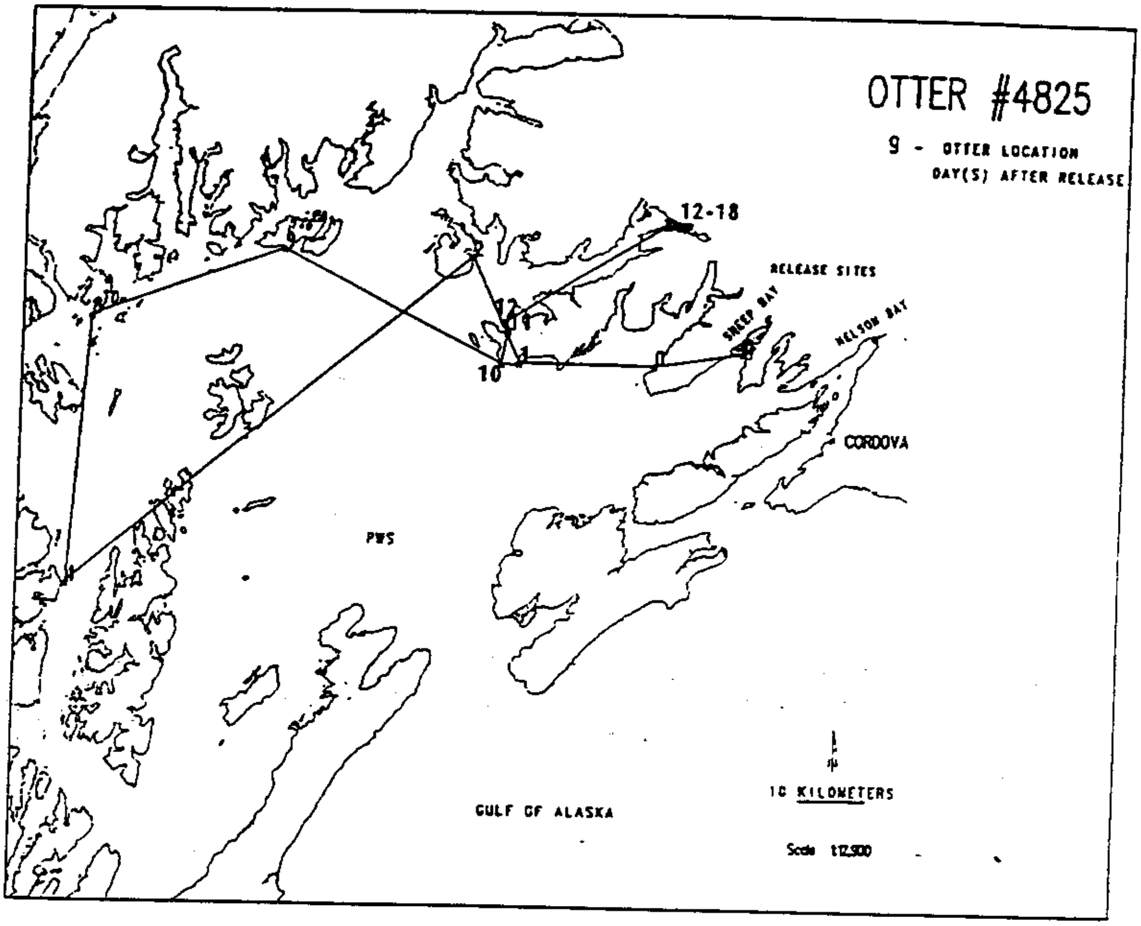
NELSON BAY
17
16
3, 5-15
18
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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9 - OTTER LOCATION
DAY(S) AFTER RELEASE
12-18
RELEASE SITES
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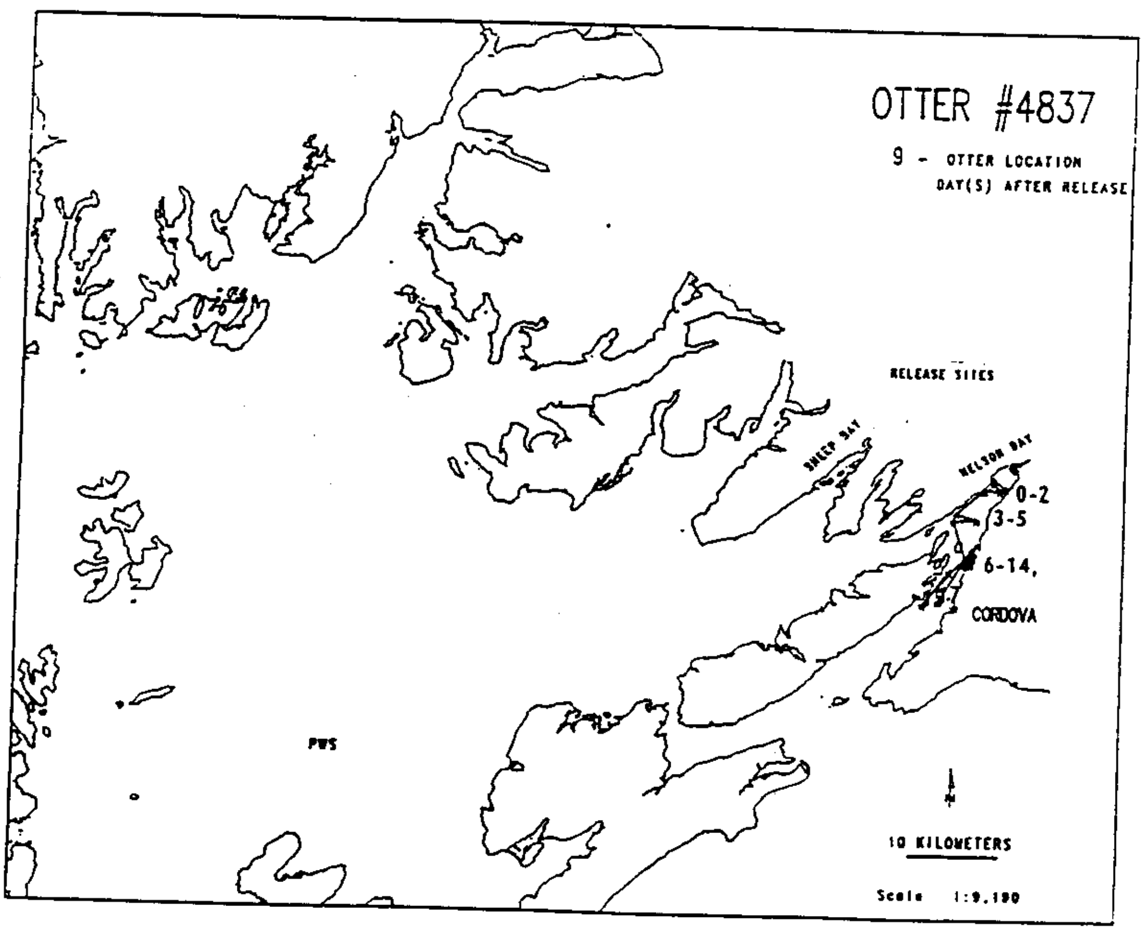
NELSON BAY
10
CORDOVA
PWS
10 KILOMETERS
GULF OF ALASKA
Scale 1:12,900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DAY(S) AFTER RELEASE
RELEASE SITES
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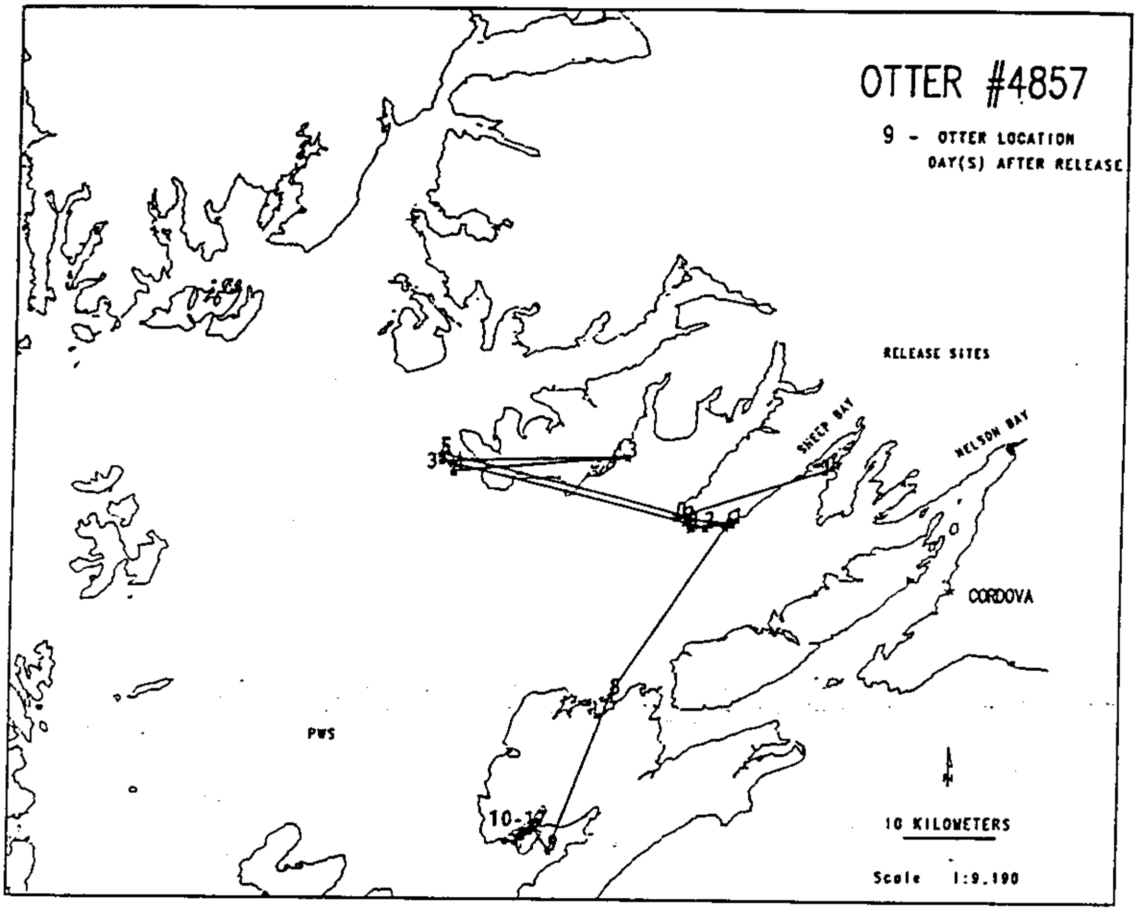
NELSON BAY
0-2
3-5
6-14,
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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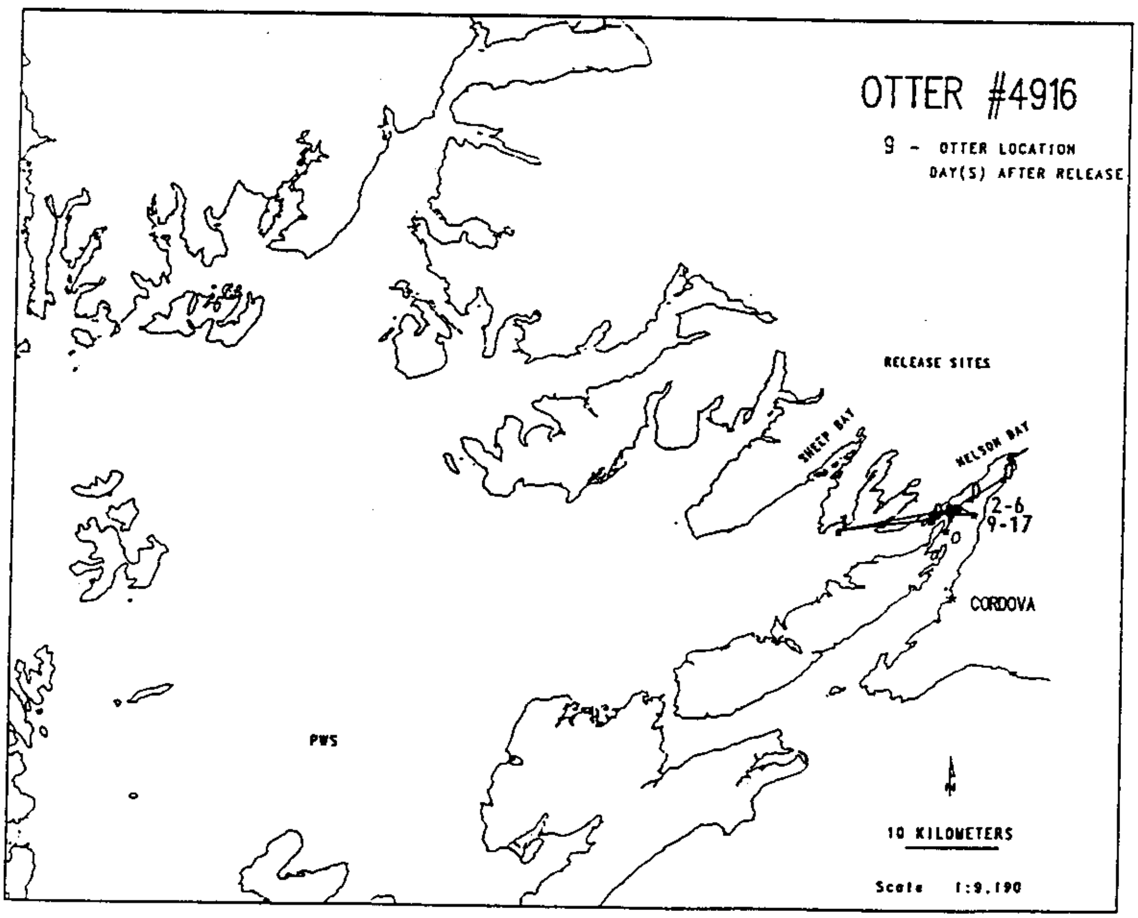
NELSON BAY
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
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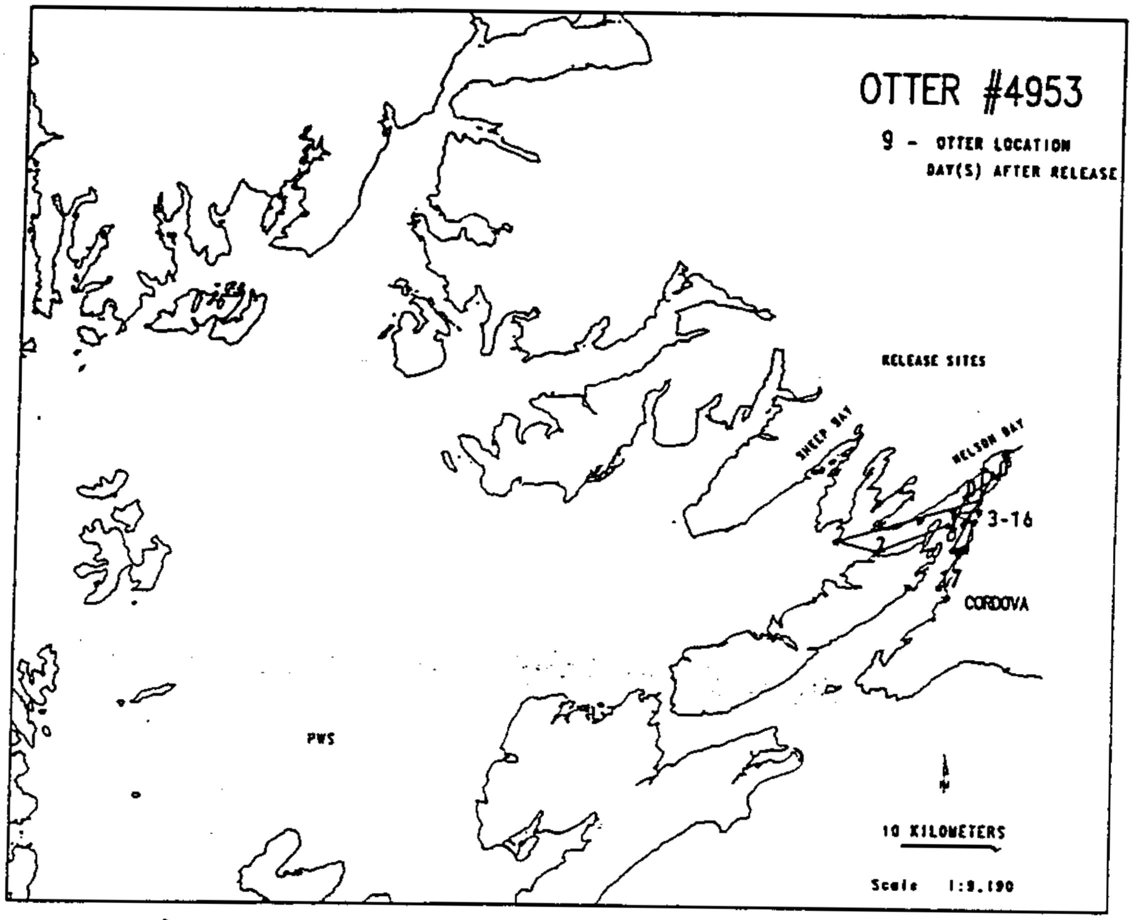
NELSON BAY
2-6
9-17
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
RELEASE SITES
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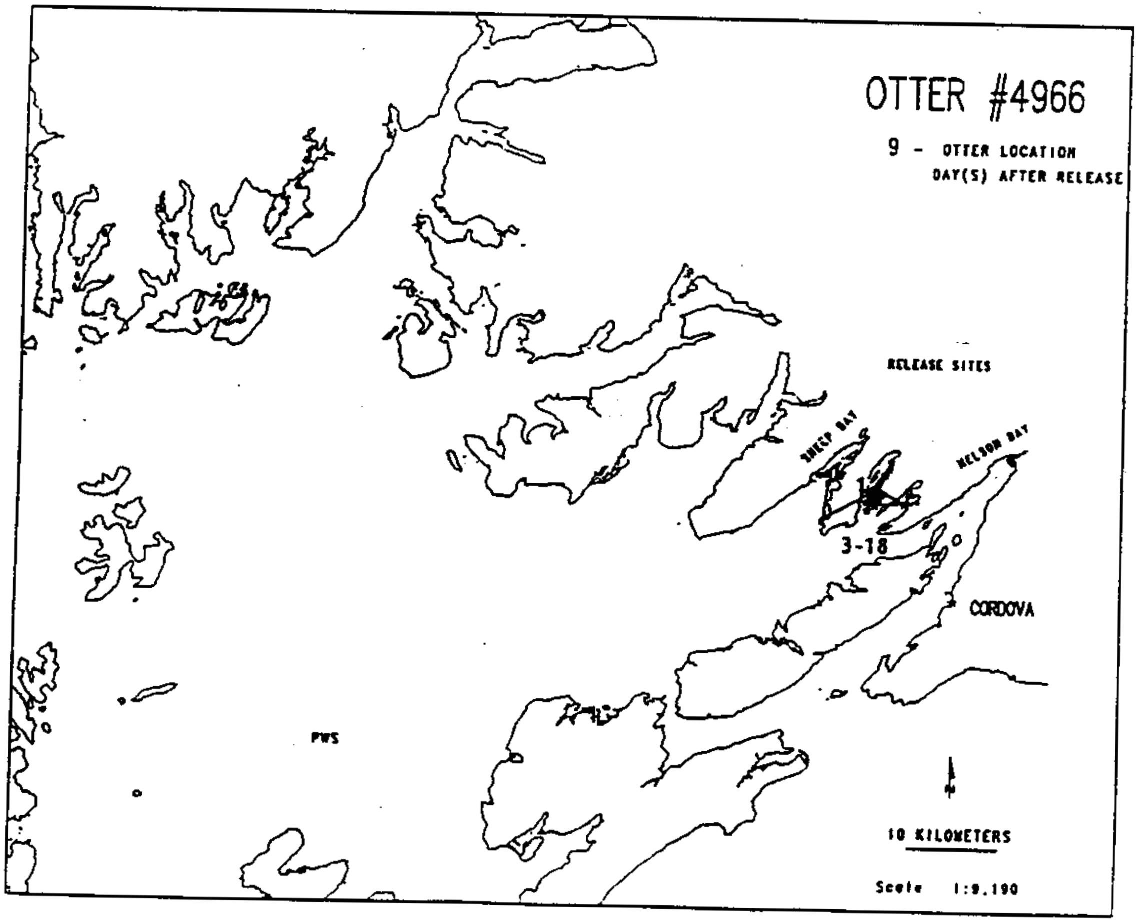
NELSON BAY
3-16
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190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DAY(S) AFTER RELEASE
RELEASE SITES
SHEEP BAY
NELSON BAY
3-18
CORDOVA
PWS
10 KILOMETERS
Scale 1:9,190

Appendix III. Summaries of survival data, rates and confidence intervals for study groupings used for comparison with sea otters radio-instrumented and released from sea otter treatment centers.

Appendix IIIa. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: ALL FEMALES study grouping, missing individuals are assumed to be dead.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					0		1.000	1.000	1.000	
Aug 89	38	1	1	0	0	0.947	0.947	0.876	1.019	2.03
Sep 89	36	0	0	0	0	1.000	0.947	0.876	1.019	2.03
Oct 89	36	0	0	0	22	1.000	0.947	0.876	1.019	2.03
Nov 89	58	1	0	1	8	0.983	0.931	0.854	1.008	2.00
Dec 89	64	0	3	1	0	0.953	0.887	0.801	0.974	2.00
Jan 90	60	0	1	0	0	0.983	0.873	0.783	0.963	2.00
Feb 90	59	0	0	2	0	1.000	0.873	0.782	0.963	2.00
Mar 90	57	1	0	1	14	0.982	0.857	0.764	0.951	2.00
Apr 90	69	0	0	0	43	1.000	0.857	0.764	0.951	2.00
May 90	112	1	0	1	0	0.991	0.850	0.757	0.943	1.98
Jun 90	110	0	0	4	0	1.000	0.850	0.757	0.943	1.98
Jul 90	106	0	0	2	0	1.000	0.850	0.757	0.943	1.98

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	104	0	0	3	0	1.000	1.000	1.000	1.000	1.98
Sep 90	101	1	1	5	2	0.980	0.980	0.953	1.007	1.98
Oct 90	96	1	1	0	2	0.979	0.960	0.921	0.999	2.00
Nov 90	96	0	1	5	0	0.990	0.950	0.906	0.993	2.00
Dec 90	90	1	1	8	0	0.978	0.929	0.877	0.980	2.00
Jan 91	80	0	0	0	0	1.000	0.929	0.877	0.980	2.00
Feb 91	78	0	0	0	0	1.000	0.929	0.877	0.980	2.00
Mar 91	78	1	0	0	0	0.987	0.917	0.861	0.973	2.00
Apr 91	77	0	1	0	0	0.987	0.905	0.845	0.965	2.00
May 91	76	0	0	0	0	1.000	0.905	0.845	0.965	2.00
Jun 91	76	0	6	0	0	0.921	0.833	0.758	0.909	2.00
Jul 91	70	0	3	0	0	0.957	0.798	0.716	0.880	2.00
Aug 91	67	0	0	0	0	1.000	0.798	0.716	0.880	2.00

Appendix IIIb. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: KPWS FEMALES study grouping, missing individuals are assumed to be dead.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					0		1.000	1.000	1.000	
Aug 89	38	1	1	0	0	0.947	0.947	0.876	1.019	2.03
Sep 89	36	0	0	0	0	1.000	0.947	0.876	1.019	2.03
Oct 89	36	0	0	0	22	1.000	0.947	0.876	1.019	2.03
Nov 89	58	1	0	1	8	0.983	0.931	0.854	1.008	2.00
Dec 89	56	0	3	1	0	0.946	0.881	0.791	0.971	2.00
Jan 90	52	0	1	0	0	0.981	0.864	0.770	0.959	2.01
Feb 90	51	0	0	2	0	1.000	0.864	0.770	0.959	2.01
Mar 90	49	1	0	1	14	0.980	0.847	0.747	0.946	2.01
Apr 90	61	0	0	0	4	1.000	0.847	0.748	0.945	2.00
May 90	65	1	0	1	0	0.985	0.834	0.733	0.934	2.00
Jun 90	63	0	0	4	0	1.000	0.834	0.733	0.934	2.00
Jul 90	59	0	0	2	0	1.000	0.834	0.733	0.934	2.00

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	57	0	0	3	0	1.000	1.000	1.000	1.000	2.00
Sep 90	54	0	1	5	2	0.981	0.981	0.945	1.018	2.01
Oct 90	50	1	1	0	2	0.960	0.942	0.878	1.006	2.01
Nov 90	50	0	1	5	0	0.980	0.923	0.851	0.996	2.01
Dec 90	44	1	1	8	0	0.955	0.881	0.791	0.972	2.02
Jan 91	34	0	0	0	0	1.000	0.881	0.790	0.973	2.04
Feb 91	34	0	0	0	0	1.000	0.881	0.790	0.973	2.04
Mar 91	34	1	0	0	0	0.971	0.855	0.753	0.958	2.04
Apr 91	33	0	1	0	0	0.970	0.830	0.718	0.941	2.04
May 91	32	0	0	0	0	1.000	0.830	0.718	0.941	2.04
Jun 91	32	0	4	0	0	0.875	0.726	0.595	0.857	2.04
Jul 91	28	0	3	0	0	0.893	0.648	0.507	0.789	2.05
Aug 91	25	0	0	0	0	1.000	0.648	0.506	0.790	2.06

Appendix IIIc. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: **TREATMENT CENTER FEMALES** study grouping, missing individuals are assumed to be dead.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					9		1.000	1.000	1.000	
Aug 89	9	1	0	0	19	0.889	0.889	0.652	1.126	2.26
Sep 89	27	0	1	1	0	0.963	0.856	0.639	1.073	2.05
Oct 89	25	0	2	0	0	0.920	0.787	0.569	1.006	2.06
Nov 89	23	0	0	0	0	1.000	0.787	0.568	1.007	2.07
Dec 89	23	0	1	0	0	0.957	0.753	0.533	0.974	2.07
Jan 90	22	1	1	0	0	0.909	0.685	0.464	0.905	2.07
Feb 90	20	2	1	0	0	0.850	0.582	0.365	0.799	2.09
Mar 90	17	1	0	0	0	0.941	0.548	0.328	0.767	2.12
Apr 90	16	1	0	0	0	0.938	0.514	0.296	0.731	2.12
May 90	15	0	1	0	0	0.933	0.479	0.265	0.694	2.13
Jun 90	14	0	0	0	0	1.000	0.479	0.252	0.707	2.26
Jul 90	14	0	1	0	0	0.929	0.445	0.223	0.667	2.26

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Sep 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Oct 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Nov 90	13	0	1	0	0	0.923	0.923	0.768	1.078	2.26
Dec 90	12	0	0	0	0	1.000	0.923	0.768	1.078	2.26
Jan 91	12	0	0	0	0	1.000	0.923	0.768	1.078	2.26
Feb 91	12	0	1	0	0	0.917	0.846	0.637	1.055	2.26
Mar 91	11	0	0	0	0	1.000	0.846	0.637	1.055	2.26
Apr 91	11	0	0	0	0	1.000	0.846	0.637	1.055	2.26
May 91	11	1	0	0	0	0.909	0.769	0.517	1.021	2.26
Jun 91	10	0	0	0	0	1.000	0.769	0.517	1.021	2.26
Jul 91	10	0	1	0	0	0.900	0.692	0.421	0.964	2.26

Appendix IIId. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: **TREATMENT CENTER MALES** study grouping, missing individuals are assumed to be dead.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					12		1.000	1.000	1.000	
Aug 89	12	0	1	0	5	0.917	0.917	0.751	1.083	2.26
Sep 89	16	0	1	0	0	0.938	0.859	0.676	1.042	2.12
Oct 89	15	0	0	0	0	1.000	0.859	0.675	1.043	2.13
Nov 89	15	0	0	0	0	1.000	0.859	0.675	1.043	2.13
Dec 89	15	0	0	0	0	1.000	0.859	0.675	1.043	2.13
Jan 90	15	2	0	0	0	0.867	0.745	0.518	0.971	2.13
Feb 90	13	1	1	0	0	0.846	0.630	0.374	0.886	2.26
Mar 90	11	1	0	0	0	0.909	0.573	0.310	0.836	2.26
Apr 90	10	1	0	0	0	0.900	0.516	0.249	0.783	2.26
May 90	9	1	0	0	0	0.889	0.458	0.191	0.725	2.26
Jun 90	8	0	1	0	0	0.875	0.401	0.139	0.663	2.31
Jul 90	7	0	0	0	0	1.000	0.401	0.133	0.670	2.37

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
								1.000	1.000	
Jul 90					0		1.000	1.000	1.000	
Aug 90	7	1	0	0	0	0.857	0.857	0.544	1.170	2.37
Sep 90	6	0	0	0	0	1.000	0.857	0.534	1.181	2.45
Oct 90	6	0	0	0	0	1.000	0.857	0.534	1.181	2.45
Nov 90	6	0	0	0	0	1.000	0.857	0.534	1.181	2.45
Dec 90	6	0	1	0	0	0.833	0.714	0.333	1.096	2.45
Jan 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
Feb 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
Mar 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
Apr 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
May 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
Jun 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
Jul 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57
Aug 91	5	0	0	0	0	1.000	0.714	0.314	1.115	2.57

Appendix IIIe. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: WPWS FEMALES study grouping, missing individuals are assumed to be dead.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89	1	0	0	0	1	1.000	1.000	1.000	1.000	
Aug 89	1	0	0	0	1	1.000	1.000	1.000	1.000	*****
Sep 89	1	0	0	0	1	1.000	1.000	1.000	1.000	*****
Oct 89	1	0	0	0	1	1.000	1.000	1.000	1.000	*****
Nov 89	1	0	0	0	8	1.000	1.000	1.000	1.000	*****
Dec 89	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Jan 90	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Feb 90	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Mar 90	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Apr 90	8	0	0	0	39	1.000	1.000	1.000	1.000	2.31
May 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01
Jun 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01
Jul 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01
Sep 90	47	1	0	0	0	0.979	0.979	0.936	1.021	2.01
Oct 90	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Nov 90	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Dec 90	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Jan 91	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Feb 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Mar 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Apr 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
May 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Jun 91	44	0	2	0	0	0.955	0.934	0.862	1.006	2.02
Jul 91	42	0	0	0	0	1.000	0.934	0.862	1.006	2.02
Aug 91	42	0	0	0	0	1.000	0.934	0.862	1.006	2.02

Appendix IIIf. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: ALL FEMALES study grouping, missing individuals are eliminated.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					0		1.000	1.000	1.000	
Aug 89	38	1	0	0	0	0.974	0.974	0.921	1.026	2.03
Sep 89	36	0	0	0	0	1.000	0.974	0.921	1.026	2.03
Oct 89	36	0	0	0	22	1.000	0.974	0.921	1.026	2.03
Nov 89	58	1	0	1	8	0.983	0.957	0.896	1.018	2.00
Dec 89	64	0	0	1	0	1.000	0.957	0.897	1.017	1.96
Jan 90	60	0	0	0	0	1.000	0.957	0.896	1.018	2.00
Feb 90	59	0	0	2	0	1.000	0.957	0.896	1.018	2.00
Mar 90	57	1	0	1	14	0.982	0.940	0.871	1.009	2.00
Apr 90	69	0	0	0	43	1.000	0.940	0.873	1.007	1.96
May 90	112	1	0	1	0	0.991	0.932	0.863	1.000	1.96
Jun 90	110	0	0	4	0	1.000	0.932	0.863	1.000	1.96
Jul 90	106	0	0	2	0	1.000	0.932	0.863	1.000	1.96

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	104	0	0	3	0	1.000	1.000	1.000	1.000	1.96
Sep 90	101	1	0	5	2	0.990	0.990	0.971	1.009	1.96
Oct 90	96	1	0	0	2	0.990	0.980	0.952	1.008	1.96
Nov 90	96	0	0	5	0	1.000	0.980	0.952	1.008	1.96
Dec 90	90	1	0	8	0	0.989	0.969	0.934	1.004	1.96
Jan 91	80	0	0	0	0	1.000	0.969	0.934	1.004	1.96
Feb 91	78	0	0	0	0	1.000	0.969	0.934	1.004	1.96
Mar 91	78	1	0	0	0	0.987	0.956	0.915	0.998	1.96
Apr 91	77	0	0	0	0	1.000	0.956	0.915	0.998	1.96
May 91	76	0	0	0	0	1.000	0.956	0.915	0.998	1.96
Jun 91	76	0	0	0	0	1.000	0.956	0.915	0.998	1.96
Jul 91	70	0	0	0	0	1.000	0.956	0.915	0.998	1.96
Aug 91	67	0	0	0	0	1.000	0.956	0.915	0.998	1.96

Appendix IIIg. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: EPWS FEMALES study grouping, missing individuals are eliminated.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					0		1.000	1.000	1.000	
Aug 89	38	1	0	0	0	0.974	0.974	0.921	1.026	2.03
Sep 89	36	0	0	0	0	1.000	0.974	0.921	1.026	2.03
Oct 89	36	0	0	0	22	1.000	0.974	0.921	1.026	2.03
Nov 89	58	1	0	1	8	0.983	0.957	0.896	1.018	2.00
Dec 89	56	0	0	1	0	1.000	0.957	0.896	1.018	2.00
Jan 90	52	0	0	0	0	1.000	0.957	0.896	1.018	2.01
Feb 90	51	0	0	2	0	1.000	0.957	0.896	1.018	2.01
Mar 90	49	1	0	1	14	0.980	0.937	0.866	1.009	2.01
Apr 90	61	0	0	0	4	1.000	0.937	0.866	1.008	2.00
May 90	65	1	0	1	0	0.985	0.923	0.847	0.999	2.00
Jun 90	63	0	0	4	0	1.000	0.923	0.847	0.999	2.00
Jul 90	59	0	0	2	0	1.000	0.923	0.847	0.999	2.00

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	57	0	0	3	0	1.000	1.000	1.000	1.000	2.00
Sep 90	54	0	0	5	2	1.000	1.000	1.000	1.000	2.01
Oct 90	50	1	0	0	2	0.980	0.980	0.940	1.020	2.01
Nov 90	50	0	0	5	0	1.000	0.980	0.940	1.020	2.01
Dec 90	44	1	0	8	0	0.977	0.958	0.898	1.017	2.02
Jan 91	34	0	0	0	0	1.000	0.958	0.898	1.018	2.04
Feb 91	34	0	0	0	0	1.000	0.958	0.898	1.018	2.04
Mar 91	34	1	0	0	0	0.971	0.930	0.848	1.011	2.04
Apr 91	33	0	0	0	0	1.000	0.930	0.848	1.011	2.04
May 91	32	0	0	0	0	1.000	0.930	0.848	1.011	2.04
Jun 91	32	0	0	0	0	1.000	0.930	0.848	1.011	2.04
Jul 91	28	0	0	0	0	1.000	0.930	0.848	1.011	2.05
Aug 91	25	0	0	0	0	1.000	0.930	0.848	1.011	2.06

Appendix IIIh. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: WPWS FEMALES study grouping, missing individuals are eliminated.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					1		1.000	1.000	1.000	
Aug 89	1	0	0	0	1	1.000	1.000	1.000	1.000	*****
Sep 89	1	0	0	0	1	1.000	1.000	1.000	1.000	*****
Oct 89	1	0	0	0	1	1.000	1.000	1.000	1.000	*****
Nov 89	1	0	0	0	8	1.000	1.000	1.000	1.000	*****
Dec 89	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Jan 90	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Feb 90	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Mar 90	8	0	0	0	0	1.000	1.000	1.000	1.000	2.31
Apr 90	8	0	0	0	39	1.000	1.000	1.000	1.000	2.31
May 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01
Jun 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01
Jul 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90	1				1 0		1.000	1.000	1.000	
Aug 90	47	0	0	0	0	1.000	1.000	1.000	1.000	2.01
Sep 90	47	1	0	0	0	0.979	0.979	0.936	1.021	2.01
Oct 90	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Nov 90	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Dec 90	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Jan 91	46	0	0	0	0	1.000	0.979	0.936	1.021	2.01
Feb 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Mar 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Apr 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
May 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Jun 91	44	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Jul 91	42	0	0	0	0	1.000	0.979	0.936	1.021	2.02
Aug 91	42	0	0	0	0	1.000	0.979	0.936	1.021	2.02

Appendix IIIi. Summary of fates, survival probabilities and confidence intervals for radio-instrumented female sea otters: TREATMENT CENTER FEMALES study grouping, missing individuals are eliminated.

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 89					9		1.000	1.000	1.000	
Aug 89	9	1	0	0	19	0.889	0.889	0.652	1.126	2.26
Sep 89	27	0	0	1	0	1.000	0.889	0.674	1.104	2.05
Oct 89	25	0	0	0	0	1.000	0.889	0.673	1.105	2.06
Nov 89	23	0	0	0	0	1.000	0.889	0.672	1.106	2.07
Dec 89	23	0	0	0	0	1.000	0.889	0.672	1.106	2.07
Jan 90	22	1	0	0	0	0.955	0.848	0.626	1.071	2.07
Feb 90	20	2	0	0	0	0.900	0.764	0.529	0.998	2.09
Mar 90	17	1	0	0	0	0.941	0.719	0.476	0.961	2.12
Apr 90	16	1	0	0	0	0.938	0.674	0.429	0.919	2.12
May 90	15	0	0	0	0	1.000	0.674	0.427	0.920	2.13
Jun 90	14	0	0	0	0	1.000	0.674	0.412	0.935	2.26
Jul 90	14	0	0	0	0	1.000	0.674	0.412	0.935	2.26

Month	# at risk	# D	# M	# C	# add	surv mo	S hat	lower CI	upper CI	t=
Jul 90					0		1.000	1.000	1.000	
Aug 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Sep 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Oct 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Nov 90	13	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Dec 90	12	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Jan 91	12	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Feb 91	12	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Mar 91	11	0	0	0	0	1.000	1.000	1.000	1.000	2.26
Apr 91	11	0	0	0	0	1.000	1.000	1.000	1.000	2.26
May 91	11	1	0	0	0	0.909	0.909	0.713	1.105	2.26
Jun 91	10	0	0	0	0	1.000	0.909	0.713	1.105	2.26
Jul 91	10	0	0	0	0	1.000	0.909	0.713	1.105	2.26
Aug 91	9	0	0	0	0	1.000	0.909	0.713	1.105	2.26