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Entanglement Studies, St. Paul Island, 1991 Juvenile Male Northern Fur Seals

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ENTANGLEMENT STUDIES, ST. PAUL ISLAND, 1991

JUVENILE MALE NORTHERN FUR SEALS

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ABSTRACT

During July and early August of 1991, studies of the entanglement of juvenile male northern fur seals (Callorhinus ursinus) in marine debris were conducted on St. Paul Island, Alaska, in the Bering Sea. Seals from 101 roundups were sources of data for providing estimates of entanglement-caused mortality and incidence of entanglement. Other data were collected on the kinds and sizes of debris.

The observed proportion of seals entangled in 1991 was less than that observed during the last several years and lower than that recorded during the commercial harvest and roundups from 1967 to 1986. The proportion of juvenile males observed entangled in 1991 was 0.21%. This rate reflects the continued reduction in the numbers of animals entangled in fragments of trawl webbing. The frequency of occurrence of trawl webbing among the entangling debris in 1991 was about half that observed for 1990 and the levels for 1990 were about half those of earlier levels. In contrast, the proportion of seals entangled in other types of debris did not change.

These studies confirm earlier estimates indicating that after 1 year, seals entangled in small debris (light enough to permit the animals to return to land) are reduced to about half the number expected had they not been entangled.

There is continuing evidence from the 1991 studies that the rate of return (survival) of tagged seals from which debris is removed is significantly higher than for tagged seals on which entangling debris was left.

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INTRODUCTION

Entanglement in marine debris, specifically in plastics associated with the commercial fishing industry, has been implicated as a significant factor in population trends observed for northern fur seals (Callorhinus ursinus) on the Pribilof Islands, Alaska (Fowler 1982, 1987, 1988; Fowler et al. 1990b). The effects of entanglement in such debris on northern fur seals have been examined at the population level (Fowler 1982, 1985, 1987) and at the level of the individual (Fowler 1988). Studies of entanglement and mortality among fur seals have been conducted by the National Marine Mammal Laboratory, in cooperation with the National Research Institute of Far Seas Fisheries of Japan (Fowler and Baba 1991).

The objectives of this work are 1) continued monitoring of the proportion of the seal population entangled, 2) determination of the nature of entangling debris, and 3) determination of the mortality caused by trawl webbing, especially as related to effects at the population level.

This report presents the results of field research conducted during 1991 in the study of entanglement and its impact on juvenile male northern fur seals. Results of this work, and that of previous work with which it is compared, focus on juvenile males (aged 2 to 5 years) from St. Paul Island, Alaska (in the eastern Bering Sea, west of mainland Alaska), as the component of the population most readily studied. The data, analyses, and results of studies in 1991 presented below are organized to

indicate the level of effort and sample sizes, to examine the incidence of entanglement and its effects on survival, to characterize the entangling debris found on the seals, and to compare the frequency of repeated sightings for entangled and nonentangled seals.

METHODS

Entanglement among juvenile male northern fur seals is studied during roundups, as described in Fowler et al. (1990a), Fowler and Ragen (1990) and Fowler and Baba (1991). During roundups, seals are herded into a group and allowed to pass between observers who watch for animals with tags or entangling debris. When such seals are seen, the flow of seals is stopped while each tagged or entangled seal is captured and the relevant information (e.g., tag number, tag type, degree of wound, and type of debris) is recorded. Entangled seals and control animals are tagged. All work is conducted during the breeding season while animals congregate at, or near, breeding rookeries along the shoreline of the island.

As in previous years, the seals on which entanglement research is focused are those judged to be of the size historically taken in the commercial harvest (approximately 105-125 cm in total length). Unless indicated otherwise, data in this report apply to juvenile (subadult) male seals of this size. The total count and the count of entangled animals are used to

estimate the incidence of entanglement for comparison with that observed in the commercial harvest prior to 1985.

In 1991, the total count of juvenile males for one roundup on one area (Zoltoi Sands on 31 July) was not recorded. In calculating the incidence of entanglement, we substituted the mean number counted for the other roundups in that area for the missing count.

In 1991, as in 1989 and 1990, entangled seals were caught and tagged, the nature of each entanglement was recorded, tags were applied to previously untagged seals, and debris was removed from each entangled seal. This is in contrast to roundup procedures in years prior to 1989 during which entangling debris was left on the animals. In addition to entanglement and tag data, characteristics of the entangling debris were also recorded, including the color, weight, and type of debris. The mesh and twine size were determined for net fragments and the length of materials such as packing bands and ropes was recorded. Samples were retained for future analysis. As in previous years of this study, two control seals about the same size as the entangled animal were also tagged to compare rates of return in succeeding years.

In comparing results from studies conducted before and after 1989, the removal of debris was taken into account. This was particularly important in calculating the proportion of seals entangled. Under circumstances prior to 1989, some of the resighted seals, having originally been entangled, would have

died and not been observed. For entangled seals seen in 1989 and after, the debris was removed and the increased survival resulted in more being resighted. To account for this, and to make the data comparable, we used the estimated survival of seals entangled in small debris (0.5 from past studies: Fowler 1984, 1985, 1987; Fowler et al. 1989, 1990a,b; Fowler and Ragen 1990). The number of seals resighted after having had their debris removed in 1989 and 1990 was multiplied by this value. Half of the resighted seals from which debris had been removed in 1990, for example, were assumed to have been seals that would have been resighted as entangled seals in 1991 and would thus contribute to the observed proportion entangled.

The growth of seals was also taken into account, as some of the surviving tagged seals were too large to meet the size criteria above. Estimates of the incidence of entanglement from 1990 presented in Fowler and Baba (1991) were biased slightly upwards from the lack of data to adjust for this factor including the tagged seals that had been entangled at the time of tagging. In 1991, the size of a sample of the resighted seals tagged in 1990 and 1989 was recorded and used to estimate the portion of tagged seals that meet the size criteria 1 and 2 years after being tagged. Thus, in estimating the incidence of entanglement for this report, only that portion of tagged seals within the designated size criteria were included in the count of entangled seals.

Because some animals are rounded up more than once, the sampling scheme for both control and entangled seals is one of sampling with replacement. This is to be compared to the methods used in estimating the incidence of entanglement from the commercial harvest (prior to 1985) in which both entangled and nonentangled seals were killed.

Analytical methods used in the analyses of resight data to estimate the survival rate of entangled seals are presented in the Appendix of Fowler and Baba (1991) as modifications of those used by Fowler and Ragen (1990) and Fowler et al. (1990b).

RESULTS

Roundups

One hundred and one roundups of subadult male northern fur seals were completed on St. Paul Island during July and early August of 1991 (Table 1). During these roundups, 22,524 male seals judged to be of the size historically taken in the commercial harvest were counted. This total includes an estimated 251 (± 109, 0.05 confidence interval) for Zoltoi Sands on 31 July.

As in previous years (Fowler and Baba 1991), about 25-30% of each of the total counts were repeat sightings, based on counts of tagged seals. In all, 33 entangled subadult male seals judged to meet the size criteria were captured and double-tagged with

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1Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Table 1.--Summary of roundups of juvenile (subadult) northern fur seal males conducted on St. Paul Island, Alaska, during July and August of 1991, including the number of both the control and entangled seals in the total tagged.

Date	Location	Total[a] in roundup	Tagged seals[b] resighted	Total seals tagged
7/5	Zoltoi Sands	254	7	0
7/5	Tolstoi	111	2	0
7/3	Zapadni Reef Sands	171	4	0
7/3	Zapadni Reef Sands	89	0	0
7/3	Tolstoi	45	1	0
7/7	Zapadni Sands	923	32	6
7/8	Polovina	379	9	0
7/8	Polovina	38	1	0
7/8	Polovina	31	1	0
7/8	Lukanin	155	9	0
7/8	Kitovi	150	9	0
7/9	Vostochni	263	12	0
7/9	Vostochni	25	0	0
7/9	Vostochni	245	11	0
7/9	Morjovi	230	4	0
7/9	Morjovi	119	6	0
7/9	Morjovi	158	5	0
7/10	Reef	134	4	0
7/10	Gorbatch	248	10	0
7/10	Reef	19	0	0
7/10	Zoltoi Sands	297	8	0
7/11	Zapadni Reef Sands	561	25	0
7/11	Tolstoi	209	13	3
7/12	Zapadni Sands	229	9	0
7/12	Zapadni	134	6	0
7/12	Zapadni	192	7	0
7/12	Zapadni	45	4	0
7/13	Polovina	434	13	0
7/13	Polovina	31	1	0
7/13	Lukanin	292	13	3
7/13	Kitovi	51	5	0
7/15	Vostochni	198	11	0
7/15	Vostochni	129	5	2
7/15	Vostochni	264	15	0
7/15	Vostochni	114	2	0
7/15	Morjovi	266	7	0
7/15	Morjovi	234	8	0
7/15	Morjovi	118	5	0
7/16	Reef	221	2	0
7/16	Gorbatch	683	22	1
7/16	Zapadni Reef Sands	89	6	0
7/17	Tolstoi	239	12	0

Table 1.--Continued.

Date	Location	Total[a] in roundup	Tagged seals[b] resighted	Total seals tagged
7/17	Zapadni Sands	659	22	0
7/17	Zapadni	417	18	3
7/18	Little Polovina	152	11	0
7/18	Little Polovina	135	7	0
7/18	Polovina	353	17	0
7/18	Polovina	308	18	3
7/19	Zoltoi Sands	153	9	2
7/19	Kitovi	114	13	0
7/19	Little Zapadni	45	3	0
7/19	Zapadni Reef	94	7	0
7/20	Vostochni Sands	40	2	0
7/20	Vostochni	127	2	3
7/20	Vostochni	21	0	0
7/20	Vostochni	205	9	3
7/20	Vostochni	222	5	0
7/20	Morjovi	213	10	0
7/20	Morjovi	397	21	0
7/21	Lukanin	560	23	4
7/21	Zapadni Reef Sands	139	3	7
7/22	Reef	85	5	6
7/23	Gorbatch	1,014	32	0
7/23	Tolstoi	147	9	0
9/24	Zapadni	122	7	0
9/24	Zapadni	626	15	3
7/25	Zoltoi Sands	299	16	0
7/25	Little Polovina	119	2	0
7/25	Little Zapadni	185	11	0
7/25	Zapadni Reef	301	13	0
7/26	Vostochni Sands	91	3	0
7/26	Vostochni	79	3	0
7/26	Vostochni	171	3	6
7/26	Vostochni	223	13	3
7/26	Vostochni	36	1	0
7/26	Morjovi	140	2	0
7/26	Morjovi	241	10	1
7/27	Zapadni Reef Sands	46	2	5
7/27	Polovina	190	8	3
7/27	Polovina	234	14	3
7/28	Lukanin	195	12	0
7/28	Kitovi	91	12	3
7/29	Reef	138	3	0
7/29	Gorbatch	586	25	3
7/29	Tolstoi	146	9	3
7/30	Zapadni	272	13	4
7/31	Zoltoi Sands[c]	251	8	0

Table 1.--Continued.

Date	Location	Total[a] in roundup	Tagged seals[b] resighted	Total seals tagged
7/31	Little Zapadni	97	5	0
7/31	Zapadni Reef	130	6	0
7/31	Little Polovina	282	14	3
8/1	Morjovi	420	15	4
8/1	Morjovi	216	14	1
8/1	Vostochni	187	5	0
8/2	Polovina	526	19	3
8/2	Lukanin	363	16	0
8/2	Kitovi	68	7	0
8/2	Zapadni Reef Sands	120	5	3
8/3	Reef	151	7	0
8/3	Gorbatch	248	13	0
8/3	Gorbatch	463	16	3
8/3	Tolstoi	54	1	1
	Totals	22,524	920	101

[a]Seals that are judged to be of the size that were taken in the commercial harvest prior to 1985.

[b]Seals which had any kind of tag (including monel tags applied to pups in 1987, 1988, or 1989) in either fore-flipper and that were successfully restrained to read the tag. Includes any that were resighted more than once this year.

[c]The total count for this roundup is the mean for the counts from the other roundups conducted in the same location for 1991.

numbered green Allflex[1] tags bearing the address of the National Marine Mammal Laboratory (Table 2). One entangled seal tagged with narrow white Allflex tags numbered 5524 was also captured and the debris removed. A total of 68 similarly sized control seals with no entangling debris were tagged (Table 2).

Tagged Seals from Previous Years

Ninety-nine seals which had been tagged during entanglement research in previous years were resighted in 1991 (Table 3). Of these, 21 had Allflex tags applied in 1985, 1986, and 1988. Twenty of the 21 resighted seals were tagged in previous years as controls. One had been entangled when tagged and had lost its entangling debris. The debris that was lost had been noted as being medium in size (150-500 g in estimated weight) at the first sighting of the seal.

Sixty individual seals were resighted with tags applied in 1990, the second year during which debris was removed from entangled juvenile male seals. Of these, 39 had been tagged as controls and 21 had been tagged after being disentangled. Eighteen were resighted with tags applied in 1989, the first year during which debris was removed. Of these, 14 had been tagged as controls and 4 had been tagged after being disentangled.

Table 2.--List of green broad-banded Allflex tags applied to northern fur seals during roundups conducted on St. Paul Island, Alaska, 1991. The first tag number was applied to the left flipper, the second to the right. Entangling debris was removed from entangled seals prior to their being released.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
001	7/6	F	Zapadni Reef	-[a]
002	7/6	F	Zapadni Reef	-[a]
003-004	7/7	M	Zapadni Sands	e
005-006	7/7	M	Zapadni Sands	e
007-008	7/7	M	Zapadni Sands	c
009-010	7/7	M	Zapadni Sands	c
011-012	7/7	M	Zapadni Sands	c
013-014	7/7	M	Zapadni Sands	c
015-016	7/11	M	Tolstoi	e
017-018	7/11	M	Tolstoi	c
019-020	7/11	M	Tolstoi	c
021-022	7/13	M	Lukanin	e
023-024	7/13	M	Lukanin	c
025-026	7/13	M	Lukanin	c
027-028	7/15	M	Vostochni	c
029-030	7/15	M	Vostochni	c
031-032	7/16	M	Gorbatch	e
033-034	7/17	M	Zapadni	e
035-036	7/17	M	Zapadni	c
037-038	7/17	M	Zapadni	c
039-040	7/18	M	Polovina	e
041-042	7/18	M	Polovina	c
043-044	7/18	M	Polovina	c
045-046	7/18	M	Polovina	e
051-052	7/19	M	Zapadni Reef	e
053-054	7/19	M	Zapadni Reef	c
055-056	7/19	M	Zapadni Reef	c
047-048	7/19	M	Zoltoi Sands	c
049-050	7/19	M	Zoltoi Sands	c
057-058	7/20	M	Vostochni	e
059-060	7/20	M	Vostochni	c
061-062	7/20	M	Vostochni	c
063-064	7/20	M	Vostochni	e
065-066	7/20	M	Vostochni	c
067-068	7/20	M	Vostochni	e
069-070	7/20	M	Vostochni	e
071-072	7/21	M	Lukanin	c
073-074	7/21	M	Lukanin	c
075-076	7/21	M	Lukanin	c

Table 2.--Continued.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
077-078	7/21	M	Lukanin	e
079-080	7/21	M	Zapadni Reef Sands	c
081-082	7/21	M	Zapadni Reef Sands	c
083-084	7/21	M	Zapadni Reef Sands	c
085-086	7/21	M	Zapadni Reef Sands	c
087-088	7/21	M	Zapadni Reef Sands	e
089-090	7/21	M	Zapadni Reef Sands	c
091-092	7/21	M	Zapadni Reef Sands	c
093-094	7/22	M	Reef	e
095-096	7/22	M	Reef	c
097-098	7/22	M	Reef	c
099-100	7/22	M	Reef	c
101-102	7/22	M	Reef	c
103-104	7/24	M	Zapadni	c
105-106	7/24	M	Zapadni	e
107-108	7/24	M	Zapadni	c
127-128	7/26	M	Morjovi	e
109-110	7/26	M	Vostochni	e
111-112	7/26	M	Vostochni	e
113-114	7/26	M	Vostochni	c
115-116	7/26	M	Vostochni	c
117-118	7/26	M	Vostochni	c
119-120	7/26	M	Vostochni	c
121-122	7/26	M	Vostochni	e
124-123	7/26	M	Vostochni	c[b]
125-126	7/26	M	Vostochni	c
139-140	7/27	M	Polovina	e
141-142	7/27	M	Polovina	c
143-144	7/27	M	Polovina	c
145-146	7/27	M	Polovina	e
147-148	7/27	M	Polovina	c
149-150	7/27	M	Polovina	c
129-130	7/27	M	Zapadni Reef Sands	e
131-132	7/27	M	Zapadni Reef Sands	c
133-134	7/27	M	Zapadni Reef Sands	c
135-136	7/27	M	Zapadni Reef Sands	c
137-138	7/27	M	Zapadni Reef Sands	c
151-152	7/28	M	Kitovi	e
153-154	7/28	M	Kitovi	c
155-156	7/28	M	Kitovi	c
157-158	7/29	M	Gorbatch	e
159-160	7/29	M	Gorbatch	c
161-162	7/29	M	Gorbatch	c
163-164	7/29	M	Tolstoi	e

Table 2.--Continued.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
165-166	7/29	M	Tolstoi	c
167-168	7/29	M	Tolstoi	c
169-170	7/30	M	Zapadni Sands	e[c]
171-172	7/30	M	Zapadni Sands	e
173-174	7/30	M	Zapadni Sands	c
175-176	7/30	M	Zapadni Sands	c
177-178	7/31	M	Little Polovina	e
179-180	7/31	M	Little Polovina	c
181-182	7/31	M	Little Polovina	c
183-184	8/1	M	Morjovi	e[c]
185-186	8/1	M	Morjovi	e
187-188	8/1	M	Morjovi	c
189-190	8/1	M	Morjovi	c
191-192	8/1	M	Morjovi	e[c]
193-194	8/2	M	Polovina	e
195-196	8/2	M	Polovina	c
197-198	8/2	M	Polovina	c
199-200	8/2	M	Zapadni Reef Sands	e
201-202	8/2	M	Zapadni Reef Sands	c
203-204	8/2	M	Zapadni Reef Sands	c
205-206	8/3	M	Gorbatch	e
207-208	8/3	M	Gorbatch	c
209-210	8/3	M	Gorbatch	c
211-212	8/3	M	Tolstoi	e[d]

[a]Female seal tagged with radio transmitters for behavioral or feeding studies by Japanese biologists. Only one tag applied (to the left flipper).
[b]Tags reversed in numerical order on the flippers of this seal.
[c]This seal was judged to be too large to meet the size criteria.
[d]This seal died immediately after being freed of its debris. No control seals were tagged.

Table 3.--List of tagged northern fur seals seen during July juvenile male roundup activities on St. Paul Island, 1991. Tags were seen on both foreflippers unless noted otherwise. Debris was removed from entangled seals.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/3	Tolstoi	6	Allflex	blue	c	Tagged July 16, 1988, on Zapadni.
7/3	Zapadni Reef Sands	132	Allflex	blue	c	Tagged July 29, 1988 on Vostochni.
7/3	Zapadni Reef Sands	1167	Allflex	orange	c	Tagged July 15, 1989, on Zapadni Reef Sands.
7/5	Tolstoi	1180	Allflex	orange	c	Tagged July 15, 1989 on Reef.
7/5	Zoltoi Sands	0703	Allflex	orange	c	Tagged Aug. 24, 1989 on Reef.
7/5	Zoltoi Sands	1182	Allflex	orange	c	Tagged July 15, 1989 on Reef.
7/7	Zapadni Sands	0734	Allflex	orange	c	Tagged August 24, 1986 on Vostochni.
7/7	Zapadni Sands	1213	Allflex	orange	c	Tagged July 18, 1990 on Vostochni.
7/7	Zapadni Sands	1250	Allflex	orange	c	Tagged July 23, 1989 on Polovina.
7/7	Zapadni Sands	1317	Allflex	white	e'	Tagged July 11, 1990 on Zapadni Sands.
7/7	Zapadni Sands	1362	Allflex	white	c	Tagged July 17, 1990 on Zapadni Reef Sands.
7/7	Zapadni Sands	1444	Allflex	white	c	Tagged July 26, 1990 on Zapadni Sands.
7/7	Zapadni Sands	1460	Allflex	white	c	Tagged July 27, 1990 on Reef.
7/8	Kitovi	0094	Allflex	orange	c	Tagged July 24, 1985 on Morjovi.
7/8	Kitovi	1182	Allflex	orange	c	Tagged July 15, 1989 on Reef.
7/8	Kitovi	1298	Allflex	orange		Adult male. From study in progress on Kitovi; only rear flippers tagged.
7/8	Kitovi	1417	Allflex	white	c	Tagged July 6, 1990 on Lukanin.
7/8	Kitovi	MK2808	Monel			Soviet tag. Missing tag on right.
7/8	Lukanin	1341	Allflex	white	c	Tagged July 16, 1990 on Gorbatch.
7/8	Polovina	1416	Allflex	white	c	Tagged July 6, 1990 on Lukanin.
7/9	Vostochni	94	Allflex	blue	c	Tagged July 26, 1988 on Morjovi. Missing left tag.
7/9	Vostochni	131	Allflex	blue	c	Tagged July 29, 1988 on Vostochni.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/9	Vostochni	1240	Allflex	orange	c	Tagged July 22, 1989 on Kitovi.
7/9	Vostochni	1383	Allflex	white	e[r]	Tagged July 22, 1990 on Vostochni.
7/9	Vostochni	1388	Allflex	white	c	Tagged July 22, 1990 on Vostochni.
7/9	Vostochni	1468	Allflex	white	c	Tagged July 28, 1990 on Vostochni.
7/9	Vostochni	1476	Allflex	white	e[r]	Tagged July 29, 1990 on Polovina.
7/9	Vostochni	MH391	Monel			Soviet tagged animal. Missing left tag.
7/9	Vostochni	XM7440	Monel			Soviet tagged animal.
7/10	Gorbatch	1456	Allflex	white	c	Tagged July 27, 1990 on Reef.
7/10	Reef	1340	Allflex	white	e[r]	Tagged July 16, 1990 on Gorbatch.
7/10	Reef	1460	Allflex	white	c	Tagged July 27, 1990 on Reef.
7/10	Zoltoi Sands	1174	Allflex	white	c	Tagged July 15, 1990 on Gorbatch.
7/11	Tolstoi	1211	Allflex	orange	e[r]	Tagged July 8, 1989 on Vostochni.
7/11	Tolstoi	1257	Allflex	orange	c	Tagged July 23, 1989 on Zapadni.
7/11	Tolstoi	1435	Allflex	white	c	Tagged July 26, 1991 on Lukanin.
7/11	Zapadni Reef Sands	007	Allflex	green	c	Tagged July 7, 1991 on Zapadni Sands.
7/11	Zapadni Reef Sands	009	Allflex	green	c	Tagged July 9, 1991 on Zapadni Sands.
7/11	Zapadni Reef Sands	1314	Allflex	white	c	Tagged July 9, 1990 on Zapadni Reef Sands.
7/11	Zapadni Reef Sands	1319	Allflex	white	c	Tagged July 19, 1990 on Zapadni Sands.
7/11	Zapadni Reef Sands	1352	Allflex	white	e[r]	Tagged July 17, 1990 on Vostochni.
7/11	Zapadni Reef Sands	1416	Allflex	white	c	Tagged July 6, 1990 on Lukanin.
7/11	Zapadni Reef Sands	1474	Allflex	white	c	Tagged July 29, 1990, on Polovina. Harvestable size.
7/12	Zapadni	007	Allflex	green	c	Tagged July 7, 1991 on Zapadni Sands.
7/12	Zapadni	019	Allflex	green	c	Tagged July 11, 1991 on Tolstoi.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/12	Zapadni	1317	Allflex	white	e'	Tagged July 11, 1990 on Zapadni Sands.
7/12	Zapadni	1319	Allflex	white	e'	Tagged July 11, 1990 on Zapadni Sands.
7/12	Zapadni	1440	Allflex	white	e'	Tagged July 26, 1990 on Zapadni Sands.
7/12	Zapadni Sands	0464	Allflex	orange	c	Tagged July 24, 1986 on Zapadni.
7/12	Zapadni Sands	1472	Allflex	white	c	Tagged July 28, 1990 on Vostochni.
7/13	Lukanin	1417	Allflex	white	c	Tagged July 6, 1990 on Lukanin.
7/13	Polovina	1257	Allflex	orange	c	Tagged July 23, 1989 on Zapadni.
7/15	Morjovi	80	Allflex	blue	c	Tagged July 25, 1988 on Tolstoi.
7/15	Morjovi	1208	Allflex	orange	c	Tagged July 18, 1989 on Polovina.
7/15	Morjovi	1331	Allflex	white	c	Tagged July 13, 1990 on Polovina.
7/15	Morjovi (NEP)	57	Allflex	blue	c	Tagged July 20, 1988 on Vostochni.
7/15	Morjovi (NEP)	0716	Allflex	orange	c	Tagged July 24, 1986 on Vostochni. Missing right tag.
7/15	Vostochni	131	Allflex	blue	c	Tagged July 29, 1988 on Vostochni.
7/15	Vostochni	133	Allflex	blue	c	Tagged July 29, 1988 on Vostochni.
7/15	Vostochni	1386	Allflex	white	c	Tagged July 22, 1990 on Vostochni. Harvestable size.
7/15	Vostochni (Sands)	1392	Allflex	white	c	Tagged July 22, 1990 on Vostochni. Too large to count.
7/15	Vostochni (Sands)	1393	Allflex	white	c	Tagged July 22, 1990 on Vostochni.
7/15	Vostochni (Sands)	1420	Allflex	white	e'	Tagged July 7, 1990 on Vostochni.
7/15	Vostochni (Sands)	1476	Allflex	white	e'	Tagged July 29, 1990 on Polovina. Showed a significant scar.
7/16	Gorbatch	009	Allflex	green	c	Tagged July 9, 1991 on Zapadni Sands.
7/16	Gorbatch	1242	Allflex	orange	c	Tagged July 23, 1989 on Lukanin. Too large to count.
7/16	Gorbatch	1435	Allflex	white	c	Tagged July 26, 1990 on Lukanin.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/16	Zapadni Reef Sands	1364	Allflex	white	e[r]	Tagged July 17, 1990 on Zapadni Reef Sands.
7/17	Tolstoi	MK2808	Monel			Soviet tagged animal. Missing tag on right.
7/17	Zapadni	023	Allflex	green	c	Tagged July 13, 1991 on Lukanin.
7/17	Zapadni	141	Allflex	blue	c	Tagged July 30, 1988 on Zapadni.
7/17	Zapadni	1192	Allflex	orange	c	Tagged July 16, 1989 on Zapadni Sands.
7/17	Zapadni Sands	011	Allflex	green	c	Tagged July 7, 1991, on Zapadni Sands.
7/17	Zapadni Sands	1211	Allflex	orange	e[r]	Tagged July 18, 1989, on Vostochni.
7/17	Zapadni Sands	1264	Allflex	orange	e[r]	Tagged July 24, 1989 on Zapadni.
7/17	Zapadni Sands	1336	Allflex	white	c	Tagged July 15, 1990, on Reef. Too large to count.
7/17	Zapadni Sands	1353	Allflex	white	e[r]	Tagged July 17, 1990, on Morjovi.
7/17	Zapadni Sands	1472	Allflex	white	c	Tagged July 28, 1990, on Vostochni.
7/18	Polovina	1374	Allflex	white	c	Tagged July 21, 1990, on Vostochni.
7/18	Polovina	1399	Allflex	white	e[r]	Tagged July 24, 1990, on Vostochni.
7/18	Polovina	1427	Allflex	white	c	Tagged July 25, 1990, on Tolstoi. Harvestable size.
7/18	Polovina	1457	Allflex	white	c	Tagged July 27, 1990, on Reef. Harvestable size.
7/19	Kitovi	1240	Allflex	orange	c	Tagged July 22, 1990, on Kitovi.
7/19	Zapadni Reef	1361	Allflex	white	c	Tagged July 17, 1990, on Zapadni Reef Sands.
7/19	Zoltoi Sands	120	Allflex	blue	c	Tagged July 29, 1988, on Vostochni.
7/20	Morjovi	027	Allflex	green	c	Tagged July 15, 1991, on Vostochni.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/20	Morjovi	1390	Allflex	white	e[r]	Tagged July 22, 1990, on Vostochni.
7/20	Morjovi	1430	Allflex	white	c	Tagged July 25, 1990, on Tolstoi.
7/20	Morjovi	1466	Allflex	white	c	Tagged July 28, 1990, on Vostochni.
7/20	Morjovi	bK3304	Monel			Soviet tagged seal. Right tag missing.
7/20	Morjovi	MH265	Monel			Soviet tagged seal.
7/20	Vostochni	130	Allflex	blue	c	Tagged July 29, 1988 on Vostochni.
7/20	Vostochni	1360	Allflex	white	c	Tagged July 17, 1990, on Zapadni Reef Sands.
7/20	Vostochni	1367	Allflex	white	c	Tagged July 17, 1990, on Zapadni Reef Sands.
7/20	Vostochni	1393	Allflex	white	e[r]	Tagged July 22, 1990, on Vostochni.
7/20	Vostochni	1476	Allflex	white	e[r]	
7/20	Vostochni	1485	Allflex	white	c	Tagged Aug. 2, 1990, on Vostochni.
7/20	Vostochni Sands	1371	Allflex	white	c	Tagged July 18, 1990, on Tolstoi Sands. Harvestable size.
7/21	Lukanin	1364	Allflex	white	e[r]	Tagged July 17, 1990, on Zapadni Reef Sands.
7/21	Lukanin	bH3487	Monel			Left tag was missing.
7/22	Reef	5524	Allflex	white	e	This seal is not part of the entanglement research collection. Two controls were taken and the animal was disentangled but not retagged with green tags. The original tags were narrow white Allflex. The seal's weight was 67 lbs and it had black vibrissae.
7/23	Gorbatch	0003	Allflex	orange	c	Tagged July 9, 1985, on Gorbatch. Too large to count. Size of a mature bull.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/23	Gorbatch	1338	Allflex	white	c	Tagged July 15, 1990, on Reef. Too large to count.
7/23	Gorbatch	1457	Allflex	white	c	Tagged July 27, 1990, on Reef. Harvestable size.
7/23	Tolstoi	0224	Allflex	orange	c	Tagged Aug. 9, 1985, on Tolstoi.
7/24	Zapadni	083	Allflex	green	c	Tagged July 21, 1990, on Zapadni Reef Sands.
7/24	Zapadni	1252	Allflex	orange	c	Tagged July 23, 1989, on Little Zapadni. Too large to count.
7/24	Zapadni	1387	Allflex	white	c	Tagged July 22, 1990, on Vostochni. Harvestable size.
7/24	Zapadni	1486	Allflex	white	c	Tagged Aug. 3, 1990, on Vostochni. Harvestable size.
7/24	Zapadni	1487	Allflex	white	e'	Tagged Aug. 3, 1990, on Morjovi. Harvestable size.
7/25	Little Polovina	1427	Allflex	white	c	Tagged July 25, 1990, on Tolstoi. Harvestable size.
7/25	Little Zapadni	1250	Allflex	orange	c	Tagged July 23, 1989, on Polovina. Too large to count.
7/25	Little Zapadni	1412	Allflex	white	e'	Tagged July 5, 1990, on Zapadni. Harvestable size.
7/25	Zapadni Reef	0467	Allflex	orange	c	Tagged July 24, 1986, on Zapadni.
7/25	Zapadni Reef	1386	Allflex	white	c	Tagged July 22, 1990, on Vostochni. Harvestable size.
7/25	Zapadni Reef	1474	Allflex	white	c	Tagged July 29, 1990, on Polovina. Harvestable size.
7/25	Zoltoi Sands	1257	Allflex	orange	c	Tagged July 23, 1989, on Zapadni. Too large to count.
7/25	Zoltoi Sands	1447	Allflex	white	c	Tagged July 26, 1990, on Zapadni Sands. Too large to count.
7/26	Vostochni	059	Allflex	green	c	Tagged July 20, 1991, on Vostochni.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/26	Vostochni	065	Allflex	green	c	Tagged July 20, 1990, on Vostochni.
7/26	Vostochni	067	Allflex	green	e[r]	Tagged July 20, 1990, on Vostochni.
7/26	Vostochni	1302	Allflex	white	c	Tagged July 7, 1990, on Vostochni. Too large to count.
7/26	Vostochni	1371	Allflex	white	c	Tagged July 18, 1990, on Tolstoi Sands. Harvestable size.
7/26	Vostochni	1392	Allflex	white	c	Tagged July 22, 1990, on Vostochni. Too large to count.
7/26	Vostochni	1450	Allflex	white	c	Tagged July 26, 1990, on Zapadni. Harvestable size.
7/26	Vostochni Sands	1214	Allflex	orange	e[r]	Tagged July 18, 1989, on Vostochni Sands.
7/27	Polovina	005	Allflex	green	e[r]	Tagged July 7, 1991, on Zapadni Sands.
7/27	Polovina	005	Allflex	green	e[r]	Tagged July 7, 1991, on Zapadni Sands.
7/27	Polovina	1319	Allflex	white	e[r]	Tagged July 11, 1990 on Zapadni Sands.
7/27	Polovina	1427	Allflex	white	c	Tagged July 25, 1990, on Tolstoi. Harvestable size.
7/27	Polovina	1430	Allflex	white	c	Tagged July 25, 1990, on Tolstoi.
7/27	Zapadni Reef Sands	1359	Allflex	white	e[r]	Tagged July 17, 1990, on Zapadni Reef Sands. Too large to count.
7/28	Kitovi	806	Roto	blue		Number of tags and side not noted.
7/28	Lukanin	141	Allflex	green	c	Tagged July 27, 1991, on Polovina.
7/29	Gorbatch	1447	Allflex	white	c	Tagged July 26, 1990, on Zapadni Sands. Too large to count.
7/29	Tolstoi	0736	Allflex	orange	c	Tagged August 24, 1985, on Vostochni. Too large to count.
7/29	Tolstoi	bE1185	Monel			Soviet tagged animal.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/30	Zapadni Sands	129	Allflex	green	e[r]	Tagged July 27, 1991, on Zapadni Reef Sands.
7/31	Little Polovina	1336	Allflex	white	c	Tagged July 15, 1990, on Reef. Too large to count.
7/31	Little Zapadni	1419	Allflex	white	e[r]	Tagged July 7, 1990, on Vostochni Sands. Too large to count.
7/31	Little Zapadni	1470	Allflex	white	c	Tagged July 28, 1990, on Vostochni. Harvestable size. Missing left tag.
7/31	Zapadni Reef	085	Allflex	green	e[r]	Tagged July 21, 1991, on Zapadni Reef Sands.
7/31	Zoltoi	1164	Allflex	orange	c	Tagged July 15, 1989, on Zoltoi Sands. Too large to count.
7/31	Zoltoi	1279	Allflex	orange	c	Tagged July 25, 1989, on Vostochni. Too large to count.
7/31	Zoltoi	1459	Allflex	white	c	Tagged July 27, 1990, on Reef. Too large to count.
8/1	Morjovi	117	Allflex	green	c	Tagged July 26, 1991 at Vostochni.
8/1	Morjovi	143	Allflex	green	c	Tagged July 27, 1991 at Polovina.
8/1	Morjovi	1432	Allflex	white	e[r]	Tagged July 26, 1990, on Lukanin.
8/1	Morjovi	MH391	Monel			Soviet tagged animal. Missing tag on left.
8/1	Vostochni	1378	Allflex	white	c	Tagged July 21, 1990, on Vostochni Sands. Harvestable size.
8/2	Kitovi	31	Allflex	blue	c	Tagged July 18, 1988 on Kitovi.
8/2	Kitovi	151	Allflex	green	e[r]	Tagged July 28, 1991 on Kitovi.
8/2	Kitovi	1257	Allflex	orange	c	Tagged July 23, 1989, on Zapadni. Too large to count.
8/2	Lukanin	1417	Allflex	white	c	Tagged July 6, 1990 on Lukanin.
8/2	Polovina	147	Allflex	green	c	Tagged July 27, 1991 at Polovina.
8/2	Polovina	149	Allflex	green	c	Tagged July 27, 1991 on Polovina.
8/2	Zapadni Reef Sands	1166	Allflex	orange	c	Tagged July 15, 1989, on Zapadni Reef Sands. Too large to count.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
8/3	Gorbatch	1444	Allflex	white	c	Tagged July 26, 1990 on Zapadni Sands.
8/3	Gorbatch	1453	Allflex	white	c	Tagged July 27, 1990 on Reef. Too large to count.
8/3	Gorbatch	007	Allflex	green	c	Tagged July 7, 1991 on Zapadni Sands.
8/3	Gorbatch	141	Allflex	green	c	Tagged July 27, 1991, on Polovina.
8/3	Gorbatch	1242	Allflex	orange	c	Tagged July 23, 1989 on Lukanin. Too large to count.
8/3	Gorbatch	1441	Allflex	white	e^r	Tagged July 26, 1990, on Zapadni Sands. Harvestable size.
8/3	Reef	126	Allflex	blue	e^r	Tagged July 29, 1988 on Vostochni. Too large to count.
8/3	Reef	1369	Allflex	white	e^r	Tagged July 17, 1990, on Zapadni Reef Sands. Too large to count.
8/3	Reef	1470	Allflex	white	c	Tagged July 28, 1990, on Vostochni. Harvestable size. In previous sighting left tag was recorded as the one that was missing.

*c = seals that were controls when tagged, e = seals that were entangled at time of being sighted, e^r = seals from which debris had been removed earlier.

Incidence of Entanglement

We examined 38 entangled juvenile male seals in the 1991 roundups (the 33 seals newly tagged, and one previously tagged, as mentioned above, and 3 that were judged to be larger than historically harvested, and 1 that died) to remove and determine the nature of their entangling debris. The sizes and kinds of entangling debris, the extent of any wounds, and the tightness of the entangling debris on the animal are presented in Table 4. A key to the tags applied during the 1990 field season is provided in Table 2.

Of the 38 entangled seals examined, 12 (31.6%) were entangled in trawl webbing, 14 (36.8%) in plastic packing bands, and 10 (26.3%) in string, small line, cords, or rope. The remaining 2 (5.3%) were entangled in other debris.

The overall incidence of entanglement is estimated by the ratio of all (both initial and subsequent) entanglement sightings to the total number of seals examined (Bengtson et al. 1988, Fowler et al. 1990b). As in 1989 and 1990, the sampling design in 1991 included resightings of animals from which debris was removed during the same season; these animals were counted as entangled. Seals from which debris was removed in 1989 and 1990 were also resighted in 1991. Under the design of previous years a portion of these seals would have died and not been counted had the debris not been removed. To maintain consistency, this must be taken into account using the survival of about 50% per year

Table 4.--List of juvenile male northern fur seals tagged as entangled animals during surveys conducted in July and August of 1991, St. Paul Island, Alaska, showing the nature of the debris on each animal. The entangling debris was removed.

Tag number[1]	Date	Location (Rookery name)	Description of debris: Type	Wt. (g)	Color	Tightness[2]	Wound (deg.)	Mesh size (cm)	Twine size (mm)	Footnote
003	7/7	Zapadni Sands	trawl	76.0	green	t	0	26.5	2	
005	7/7	Zapadni Sands	rope	35.0	yellow	t	0	23.0	13	
015	7/11	Tolstoi	packing band	2.9	blue	vt	360	20.8		
021	7/13	Lukanin	packing band	3.5	clear	m	0	23.5		
031	7/16	Gorbatch	packing band	4.0	yellow	t	0	22.3		
033	7/17	Zapadni	trawl	310.0	grey	vt	90	22.5	3	
039	7/18	Polovina	packing band	3.5	green	t	0	27.4		
045	7/18	Polovina	packing band	2.3	white	t	0	21.9		
051	7/19	Zapadni Reef	trawl	16.0	grey	t	360	31.0	2.5	
057	7/20	Vostochni	packing band	2.0	white	m	0	24.3		
063	7/20	Vostochni	trawl	38.5	grey	vt	30	51.5	2.5	
067	7/20	Vostochni	packing band	2.0	blue	m	0	24.0		
069	7/20	Vostochni	fiber	9.0	white	vt	180	39.0		
077	7/21	Lukanin	trawl	146.5	grey	vt	0	23.0	2	
087	7/21	Zapadni Reef	chord	9.0		t	15	36.5	4	3
093	7/22	Reef	packing band	3.3	blue	m	0	19.1		
105	7/24	Zapadni	chord	41.0	grey	t	0	25.8	8	
109	7/26	Vostochni	trawl	18.5	orange	t	0	23.0	1.5	
111	7/26	Vostochni	packing band	3.0	yellow	t	0	26.5	4.5	
121	7/26	Vostochni	chord	8.2	grey	m	0	26.2	5	
127	7/26	Morjovi	chord	3.4	Black	vt	360	33.5	3	
129	7/27	Zapadni Reef	monofilament	3.0		vt	180	21.8	<1	4
139	7/27	Polovina	trawl	135.0	blue	vt	160	22.5	2	
145	7/27	Polovina	packing band	1.5	green	l	0	26.4		
151	7/28	Kitovi	trawl	44.5	blue	l	0	42.5	2.5	
157	7/29	Gorbatch	trawl	130.5	grey	m	0	21.5	3	
163	7/29	Tolstoi	twine	1.3	green	m	0	24.0	5	

Table 4.--Continued.

Tag number	Date	Location (Rookery name)	Description of debris: Type	Wt. (g)	Color	Tightness[1]	Wound (deg.)	Mesh size (cm)	Twine size (mm)	Footnote
169	7/30	Zapadni Sands	trawl	203.0	white	vt	360	22.5	6	[5]
171	7/30	Zapadni Sands	packing band	1.6	yellow	m	0	21.7		
177	7/31	Little Polov.	trawl	23.3	blue	vm	270	15.5	2.5	
183	8/1	Morjovi	packing band	3.0	black	l	0	26.0		[5]
185	8/1	Morjovi	twine	3.5	brown	t	300	23.5	2	
191	8/1	Morjovi	twine	5.0	white	vt	340	31.5	1	[5]
193	8/2	Polovina	twine	5.8	white	vt	350	23.7	2	
199	8/2	Zapadni Reef	packing band	2.8	white	m	0	22.7		
205	8/3	Gorbatch	packing band	2.0	blue	m	180	23.0		
211	8/3	Tolstoi	monofilament	1.8	clear	vt	360	8.0	<1	[6]
5524	7/22	Reef	trawl		grey	vt	360			[7]

[1]Tag number is that placed on the left flipper (See Table 2).
[2]l = loose, m = moderately tight, t = tight, vt = very tight.
[3]Debris was a combination of black and white.
[4]Wound had healed over the debris.
[5]Seals tagged with numbers 169, 183 and 191 were larger than harvestable size and not counted in the calculation of the incidence of entanglement.
[6]Debris on this seal had cut through flesh and into trachea so that the seal breathed through the hole. Animal was released after removing the debris but died very shortly thereafter.
[7]This seal was tagged previously but apparently not during entanglement research. Two controls were taken and the animal was disentangled but not retagged with green tags. The original tags were narrow white Allflex. The seal's weight was 67 lbs and it had black vibrissae. The right tag number was 5533.

that characterizes the portion of the seal population entangled in small debris (Fowler et al. 1990b). Thus, in calculating the incidence of entanglement for 1991, half of the harvestable sized seals resighted in 1991 as seals from which debris had been removed in 1990 were counted as entangled in 1991. All seals from 1989 were considered too large to be included in the calculations. In all, there were 47.25 sightings that qualified for calculating the incidence of entanglement. These included 1) seals of harvestable size observed entangled (n=35), 2) the repeated sightings of animals from which debris had been removed in 1991 (n=6), and 3) one fourth of the seals resighted from 1990 after having had debris removed (n=6.25). This latter number was obtained as follows: first we observed 25 seals tagged in 1990 as seals from which debris had been removed (the 21 mentioned earlier plus their repeated sightings). Half (n=12.5) of these met the size criteria (based on 9 of 18 seals evaluated meeting the criteria). Of these 12.5 seals, if they had remained entangled, half would have survived to be seen as entangled seals in 1991 for a total of 6.25 seals.

The incidence of entanglement for 1991 was thus 0.209% (47.25/22,524), an estimate that is subject to slight upward bias as it assumes that these seals would not have lost their debris. Even so, the 1991 incidence of entanglement is less than the observed incidence of 0.32% in 1990 (Table 5; Fig. 1, noting the revision of the value for 1990 from 0.33 to account for growth and survival of seals from which debris had been removed as

Table 5.--The percent of juvenile male northern fur seals from St. Paul Island, Alaska, entangled in marine debris as recorded from 1967 to 1984 during the commercial harvest (data from Kozloff et al. 1986) and from 1985 to 1991 during roundups (data from Fowler and Baba 1991). The values for 1989 and 1990 have been corrected to account for survival and growth of seals from which debris was removed the year before and, therefore, differ slightly from previously reported values.

Year	Percent entangled
1967	0.15
1968	0.16
1969	0.20
1970	0.28
1971	0.41
1972	0.43
1973	0.48
1974	0.58
1975	0.71
1976	0.42
1977	0.35
1978	0.46
1979	0.40
1980	0.49
1981	0.43
1982	0.41
1983	0.43
1984	0.39
1985	0.51
1986	0.42
1987	--
1988	0.28
1989	0.29
1990	0.32
1991	0.21

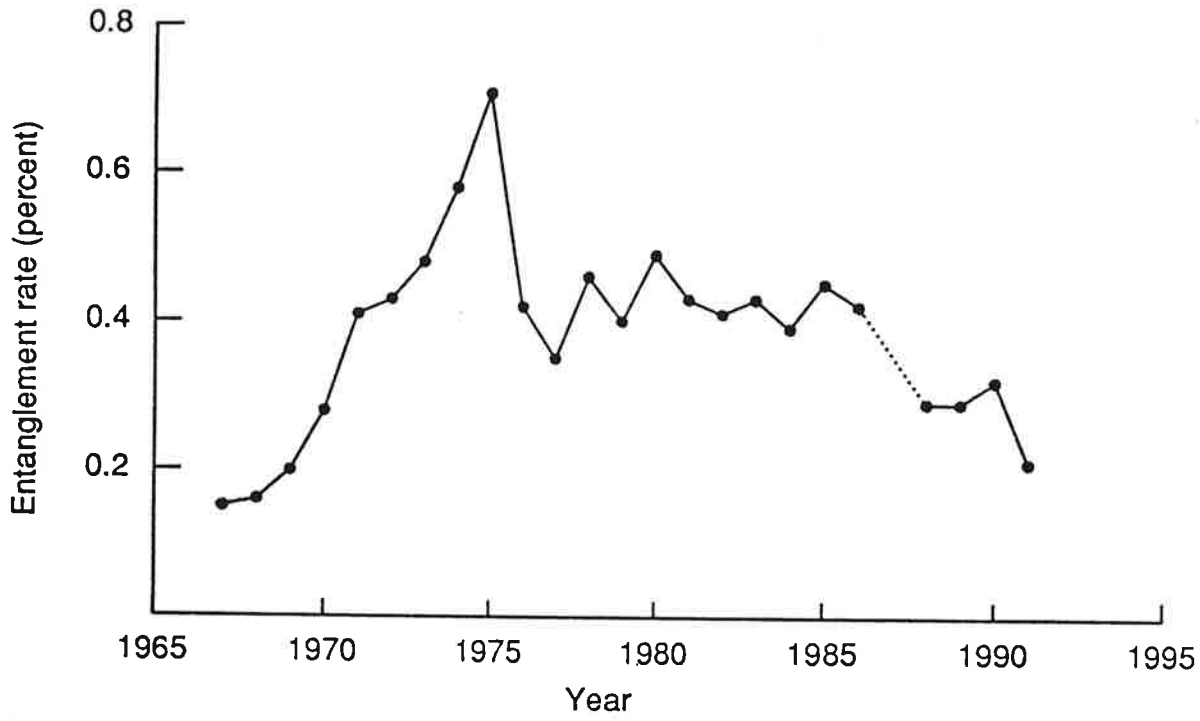

Figure 1. The percentage of juvenile male northern fur seals found entangled in the commercial harvest from 1967 to 1984 and in research roundups from 1985 to 1991 on St. Paul Island, Alaska (updated from Fowler and Baba 1991).

explained above). This reduction is continuing evidence of decline in the observed incidence of entanglement from the 0.4% observed between 1976 and 1985 (Fig. 1, Fowler et al. 1990b, Table 5).

Compared to the entanglement of 1976-86, the relatively smaller proportion of entangled juvenile male seals continues to be attributed to a reduction in the fraction entangled in trawl webbing (Table 6). For the period 1982-86, the mean percent of seals entangled in trawl webbing was 0.27% (Fowler et al. 1990b). In 1988, the percent entangled in trawl webbing dropped to 0.15%; a reduction to 56% of earlier levels (Fowler et al. 1990b). This proportion remained low in 1989 (Fowler and Ragen 1990) and 1990 (Fowler and Baba 1991), and even lower in 1991 at about 0.06% (Table 6). Thus, the 1991 rate of entanglement in trawl webbing is about 50% of the levels of incidence observed for this category of debris between 1988 and 1990 and about 20% of the levels between 1981 and 1985.

Within-Season Incidence of Entanglement

Little attention has been paid to the possibility that the incidence of entanglement among northern fur seals might change over the course of the season. Lead by the subjective impression that more entangled juvenile male seals were seen in the last few roundups of the 1991 season, this question was addressed with an analysis of the data for 1989 to 1991. The season was broken into five periods corresponding to the 5 weeks beginning with 1 July each year. The incidence of entanglement for each period

Table 6.--Debris found on juvenile male northern fur seals from St. Paul Island, 1981-91, expressed as the incidence of entanglement (observed percent) among juvenile males entangled by debris category (data for 1981-89 from Fowler and Ragen 1990 and for 1990 from Fowler and Baba 1991) supplemented with data from the 1991 field study.

Year	Trawl net fragments	Packing bands	Chord, rope, and string	Monofilament net fragments	Misc. items	Sample size*
1981	0.29	0.08	0.04	0.00	0.03	102
1982	0.24	0.10	0.04	0.01	0.01	102
1983	0.30	0.07	0.02	0.01	0.03	112
1984	0.22	0.09	0.05	0.02	0.01	87
1985	0.36	0.05	0.08	0.01	0.01	76
1986	0.27	0.06	0.07	0.01	0.01	70
1988	0.15	0.07	0.05	0.00	0.01	53
1989	0.12	0.10	0.06	0.02	0.01	47
1990	0.11	0.11	0.07	0.01	0.03	71
1991	0.06	0.08	0.06	0.01	0.00	38

*Sample sizes occasionally include debris from seals larger than would be counted for determining the proportion of the juvenile males that are entangled.

was calculated as explained above for 1990 and 1991 (i.e., accounting for resighted seals, mortality, debris removal, and sampling with replacement). For 1989, corrections for growth and survival of seals from which debris was removed were not applied as debris was left on entangled seals in 1988. The data used in these calculations and the results are shown in Table 7. Figure 2 shows a comparison of the results over time for both season and year. As can be seen, there is a tendency for the data in 1991 to show an increase in the incidence of entanglement for the first 4 weeks. This trend, however, is not seen in the other years, especially in 1989 when any trend would be seen as the reverse of that for 1991. In view of the variability between years, these data do not support the conclusion of a consistent trend within season. Further analysis is possible with the data from earlier years and can be conducted provided there is justification for doing so.

Resightings and Survival

An annual summary of the number of tags initially applied to juvenile males and the number resighted in each subsequent year is shown in Table 8 for each year since 1985. No roundups were conducted in 1987. A total of 171 seals judged to be of harvestable size were tagged and released in 1990. Of these, 114 were controls and 57 were entangled when captured. In 1991, 39 of these controls (34.2%) were resighted. Twenty-one (36.8% of the original group of 57) of the seals tagged after removing their debris in 1990 were resighted in 1991. This implies that

Table 7.--Resightings of entangled seals and calculated estimates of juvenile male northern fur seal entanglement on St. Paul Island, Alaska, 1989-1991. Data has been broken into weekly periods with corresponding sample sizes. The incidence of entanglement is estimated by dividing the number of entangled seals by the sample size.

Year	Week[1]	First-year sightings	Second-year sightings	Entangled seals	Sample size	Incidence of entanglement
1989[2]						
	1	-	-	-	-	-
	2	3	2	5.00	1141	0.0044
	3	24	6	30.00	9126	0.0033
	4	18	0	18.00	8318	0.0022
	5	-	-	-	-	-
1990[2]						
	1	10	4	11.00	4787	0.0023
	2	10	4	11.00	4333	0.0025
	3	22	3	22.75	5462	0.0042
	4	26	2	26.50	7088	0.0037
	5	11	1	11.25	4159	0.0027
1991[2]						
	1	2	1	2.25	1593	0.0014
	2	2	7	3.75	4669	0.0008
	3	11	9	13.25	6909	0.0019
	4	13	5	14.25	3887	0.0037
	5	12	4	13.00	5466	0.0024

[1]Week 1 is 1-7 July, week 2 is 8-14 July, week 3 is 15-21 July, week 4 is 22-28 July and week 5 is 29 July- 4 Aug.
[2]No correction is applied to the data for 1989 because debris was not removed in 1988. The number of entangled seals estimated to have been seen for 1990 and 1991 is based on first-year sightings plus one fourth of the second year sightings to account for survival and growth of seals from which debris was removed in the year before.

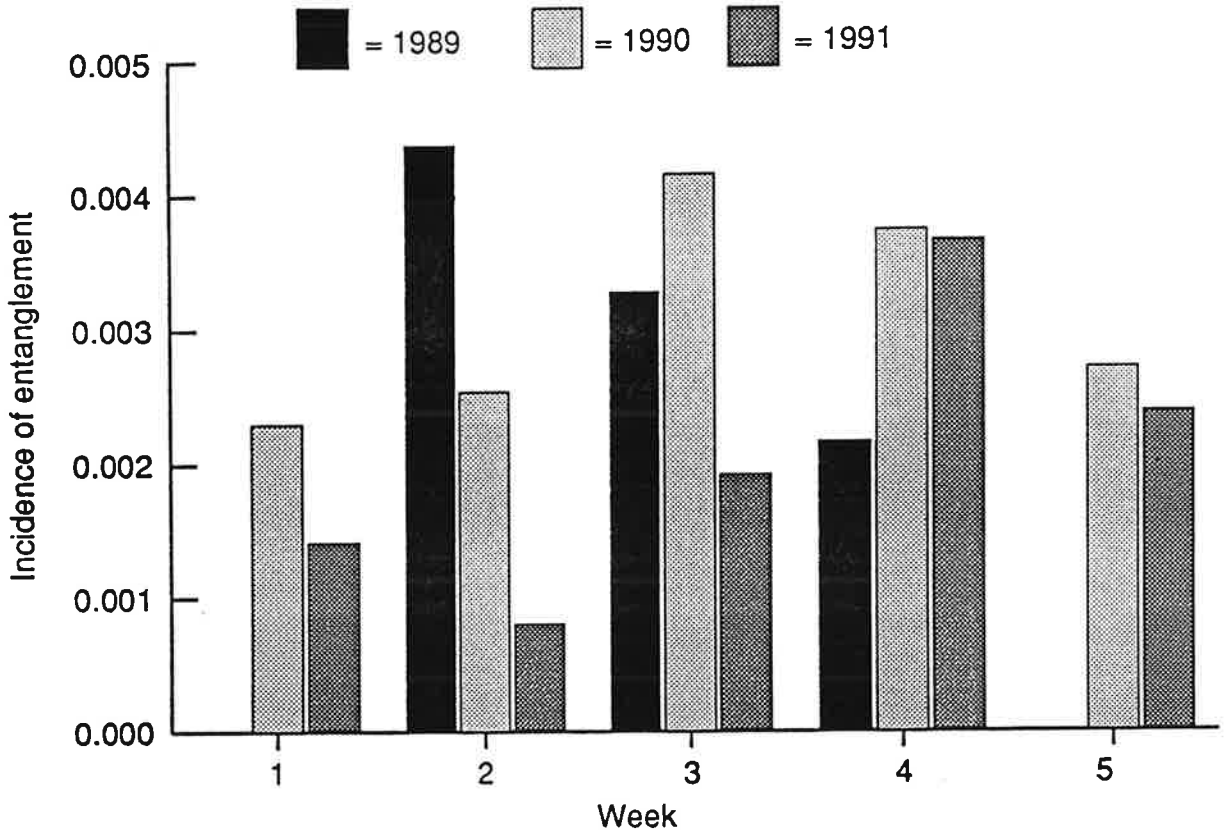

Figure 2. Weekly incidence of entanglement for juvenile male northern fur seals seen in roundups on St. Paul Island, Alaska, as based on data in Table 7 for 1989-91.

Table 8.--Comparison of numbers of tags applied (in parentheses) and resighted (percent resighted shown in brackets below the numbers resighted) by year for entangled and nonentangled male northern fur seals from 1985 through 1991 (none tagged in 1987). Each row corresponds to the tags released in the first year for that row*.

Controls (nonentangled)	Year					
	1985	1986	1988	1989	1990	1991
	(172)	37 [21.5]	13 [7.6]	8 [4.7]	7 [4.1]	4 [2.3]
		(279)	40 [14.3]	32 [11.5]	25 [9.0]	5 [1.8]
			(104)	20 [19.2]	11 [10.6]	11 [10.6]
				(86)	26 [30.2]	14 [16.3]
					(114)	39 [34.2]
						(68)

Entangled	Year					
	1985	1986	1988	1989	1990	1991
	(85)	12 [14.1]	1 [1.2]	0 [0]	0 [0]	0 [0]
		(128)	6 [4.7]	4 [3.1]	1 [0.8]	0 [0]
			(52)	5 [9.6]	2 [3.8]	1 [1.3]
				(43)	11 [25.6]	4 [9.3]
					(57)	21 [36.8]
						(34)

*Updated from Fowler and Baba (1991).

the resighting rate for disentangled seals after 1 year was 107.6% of that for the controls (36.8/34.2 = 1.076). This is not significantly different from a ratio of 1.0 (Chi-square test, $P > 0.05$). The resighting rate of disentangled seals relative to controls is significantly higher than that of entangled seals from previous years (Chi-square test, $P < 0.05$).

In 1991, 5 of 279 seals (or 1.8%) tagged as controls in 1986 were resighted whereas none of the group of 128 animals tagged as entangled in 1986 were resighted. No animals tagged as entangled in 1985 were resighted in 1990; however, four controls from 1985 were resighted. These sample sizes are too small to test for a significant change from the original ratio of tagged entangled seals to controls for that year (Table 8).

Data for relative rates of resighting entangled to control seals tagged between 1985 and 1990 and those seen in 1991, are shown in Figure 3 along with data from previous work (updated from Fowler and Baba 1991). The data from 1991 for seals resighted from tagging from 1985 through 1988 (Fig. 3) are consistent with the results of earlier work (Fowler et al. 1990b), showing an entanglement related survival rate of about 50%. The increase in the survival rate attributable to the removal of debris is shown in data plotted for seals tagged in 1989 and 1990 (as stars in Fig. 3). In spite of the higher survival for 1990-91 data, the combined data for the three points shown by stars in Figure 3 indicate that the seals freed of their debris may fail to experience survival as high as the controls.

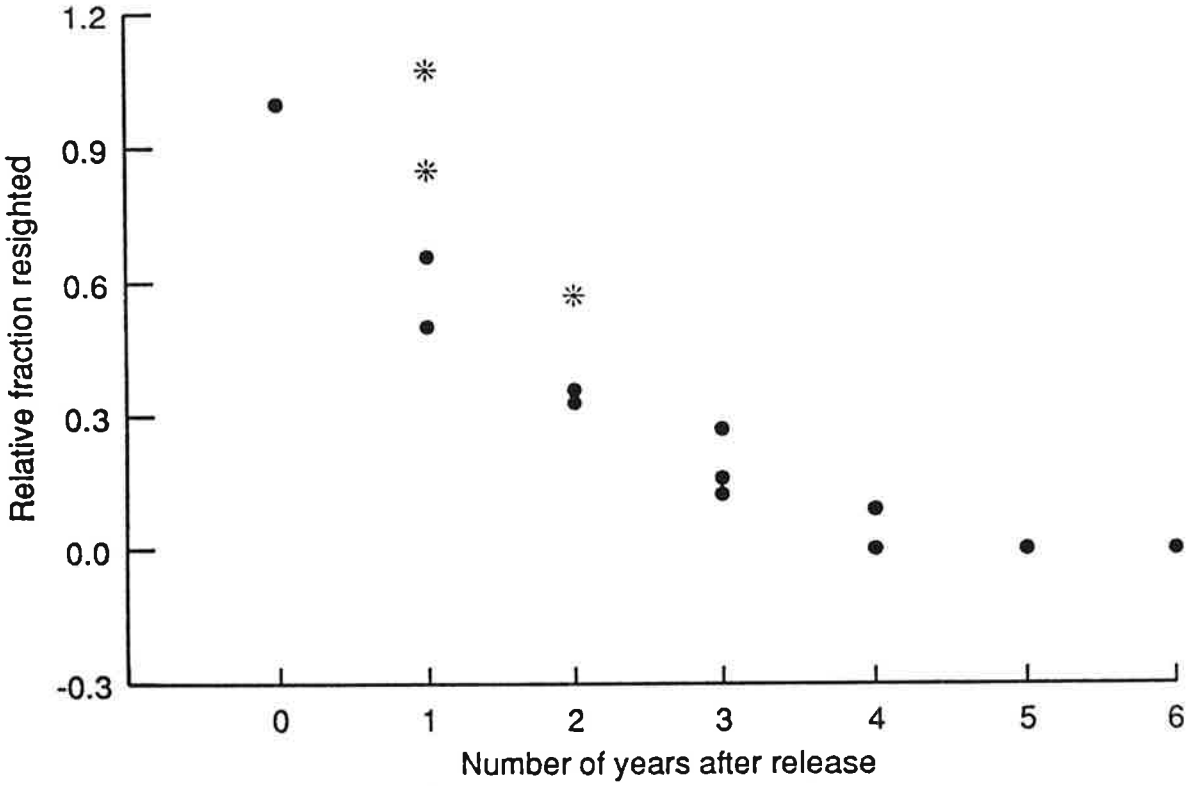

Figure 3. Relative rates of return for entangled juvenile male northern fur seals compared to controls (nonentangled tagged seals) for varying time intervals (Updated from Fowler and Baba 1991, with the data from this report). Each data point represents the fraction of entangled seals resighted divided by the fraction of controls resighted (both from Table 7) for the corresponding time interval (for example, there are 2 data points for 3 years corresponding to the 1985-88 and 1986-89 intervals). The stars correspond to the relative return rate for seals with debris removed.

Using the second approach of Fowler and Baba (1991) for estimating survival (assuming that the probability of resighting is the same for both categories of seals) the percent of the entangled seals resighted is divided by the percent of the controls resighted. This ratio is then raised to the power of 1/n where n is the number of years since the tagged seals were released. This is the estimated annual survival from, or the probability of surviving the hazard of, entanglement--assuming survival from entanglement in small debris is the same from year to year. Such calculations were carried out for the returns for seals tagged in 1988 (Table 8). The results indicated an annual survival of 0.57. This is to be compared with the weighted mean of 0.55 from Fowler and Baba (1991) for previous years using the total sample of resighted seals from the corresponding year as weights (e.g., 14 seals from 1988 resighted in 1988).

Thus, the cumulative data, as presented in Table 8 and Figure 3, continue to show an estimated annual probability of surviving entanglement of about 0.5 for seals entangled in small debris.

Characteristics of Entangling Debris

Because the debris was again removed from the entangled seals in 1991, it was possible to directly determine weights of the debris. Specific weights and mesh sizes are listed in Table 4. These distributions are very similar to those seen in previous studies (Fowler and Baba 1991). For the combined data since 1983, about 74% of the debris found on seals weighed

between 0 and 150 g, about 18% of the debris weighed between 150 and 500 g, and about 8% of the debris weighed over 500 g (Table 9).

Within-Season Resighting Rate

Although the data for 1990 indicated a higher resighting rate for controls than for disentangled seals (Table 10), the data for 1991 are again consistent with historic data. The more general picture from the collective results of 6 years shows that the fraction of seals tagged as entangled seals and resighted in the same field season are about the same as for controls, as seen in previous work (Fowler et al. 1990b). This resighted fraction has been close to 25% in both groups.

DISCUSSION

Entanglement-related field studies of juvenile male northern fur seals from 1989 through 1991 were different from those of earlier years in that debris was removed from entangled animals. Accounting for this difference, the incidence of entanglement continues to be lower than in years prior to 1987. The estimate from 1991 is the lowest of the last 4 years and provides further evidence that a change has occurred in the incidence of entanglement. The reduction for each year is attributable to less entanglement in trawl webbing, with that for 1991 being the lowest observed since 1982 (when data are available for comparison). An explanation for such a change can not be conclusively established at this time. However, the differences

Table 9.--Annual percentage frequency distribution of the size of measured debris from entangled male northern fur seals that were tagged and released (data for 1983 to 1989 from Fowler and Ragen 1990).

Year	n	<150 g (%)	150-500 g (%)	>500 g (%)
1983	84	53(63)	19(23)	12(14)
1984	57	46(81)	7(12)	4(7)
1985	78	56(72)	16(20)	6(8)
1986	128	92(72)	27(21)	9(7)
1988	53	38(72)	8(15)	7(13)
1989	43	34(79)	7(16)	2(5)
1990	71	59(83)	10(14)	2(3)
1991	11	9(82)	2(18)	0(0)
Total	525	387(74)	96(18)	42(8)

Table 10.--Comparison of numbers of tags applied to entangled and control juvenile male northern fur seals in 1985, 1986, 1988, 1989, and 1990 with the numbers in each category resighted the same season. The numbers in parentheses are the percent of the tags applied that were resighted.

	Number of tags			
	Controls		Entangled	
Year	Applied	Resighted	Applied	Resighted
1985	170	35(20.6)	76	21(27.6)
1986	165	54(32.7)	70	19(27.1)
1988	104	21(20.2)	52	15(28.8)
1989	86	20(23.5)	43	8(18.6)
1990	114	56(49.1)	57	18(31.6)
1991	68	18(26.5)	34	6(17.7)
Total	707	204(28.9)	332	87(26.2)

between the 1988-91 incidence of entanglement and those of previous years may be a result of changes in the rate of loss and discard of net fragments from fishing vessels. Consistent with the data for debris on northern fur seals, the abundance of trawl webbing debris observed on sampled beaches of several Alaskan islands has also declined in recent years (Johnson, S. 1990, personal communication). Various educational programs at national and international levels have been in place for several years, and international regulations prohibit the discard of such debris. Other studies are necessary to determine if less debris is actually entering the marine environment.

Results of the 1991 studies are consistent with those of earlier work in showing that some animals escape from their entangling debris. However, as documented in Fowler et al. (1990b), the animals that lose their debris are predominantly seals entangled in small debris (less than 150 g). Such loss is one factor contributing to survival from entanglement. The results of the 1991 studies are consistent with this conclusion with the demonstration of increased survival of tagged seals from which debris was removed during the 1989 and 1990 field studies.

SUMMARY

Entanglement research on juvenile males in 1991 demonstrated:

1) A continued reduction of the overall incidence of entanglement from about 0.4% (1975-86) to less than

0.34% in 1988 through 1990, and down to 0.21% in 1991;

2) Entanglement in trawl webbing in 1991 was less than half of entanglement levels observed for this kind of debris in 1990 which itself was about half of that in previous years (1981-86) and very similar to that observed in 1988 and 1989;

3) Data for relative return rates of entangled seals for years in which debris was not removed continued to produce an estimated rate of mortality due to the hazard of entanglement alone (i.e., independent of natural causes of mortality) of about 0.5 per year; and

4) There is continuing evidence from the 1991 studies that the rate of return of tagged seals from which debris is removed is significantly higher than for tagged, entangled seals but not as high as for controls.

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