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ENTANGLEMENT STUDIES, ST. PAUL ISLAND, 1990

JUVENILE MALE NORTHERN FUR SEALS

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ABSTRACT

During July and early August of 1990, 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 122 roundups were sources of data for providing estimates of entanglement-caused mortality and entanglement rates. Other data were collected on the growth of wounds, and the kinds and sizes of debris.

The observed proportion of seals entangled in 1990 was similar to that observed during the last 2 years, continuing at a rate that is lower than the rate recorded for the last few years of the commercial harvest and roundups through 1986. The proportion of juvenile males observed entangled in 1990 was 0.33%. 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 remains about half that of the former levels, whereas 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 in numbers to about half the comparable numbers for nonentangled seals. Rates at which entangled animals are resighted indicate that mortality of entangled seals increases with the size (weight) of debris. Data collected on the extent of wounds caused by debris show that wounds

tend to grow -- some encompassing the entire neck within a year's time -- and contribute to the sources of mortality for seals entangled in small debris.

There is evidence from the 1990 studies that the rate of return of tagged seals from which debris is removed is significantly higher than for tagged seals on which entangling debris was left.

INTRODUCTION

Entanglement in marine debris, specifically in plastics associated with the commercial fishing industry, has been documented for a number of species of seals and sea lions (Fowler 1988). The effects of entanglement in such debris have been the subject of a number of studies, especially as related to the impact on northern fur seals (Callorhinus ursinus). Many of these studies have examined effects at the population level (Fowler 1982, 1985, 1987). Others have focused more on the effects at the level of the individual (see Fowler 1988).

Northern fur seals become entangled in plastic debris and scraps of fishing nets as they forage in the open ocean. Such entanglement, especially in scraps of net (owing to their frequency and a structure that enables entanglement), is a source of mortality for this species and has been the focus of research examining recent declines in the northern fur seal population on the Pribilof Islands (Fowler 1987). Recent studies of fur seal entanglement have been conducted by the National Marine Mammal Laboratory, many in cooperative international efforts with the Far Seas Fisheries Research Laboratory of Japan. Some of these studies have focused on the effects of entanglement (Bengtson et al. 1988; Fowler 1984, 1985, 1987; Fowler et al. 1989, 1990; in press, Fowler and Ragen 1990).

Juvenile males (aged 2 to 5 years) from St. Paul Island, Alaska (in the eastern Bering Sea, west of mainland Alaska) are the component of the population most readily studied. Entanglement among these males is studied during roundups, a procedure as described below, in which seals are herded into a group and allowed to pass between observers who watch for, and capture, animals with tags or entangling debris. This report presents the results of the 1990 field research conducted by the National Marine Mammal Laboratory, in cooperation with the National Research Institute of Far Seas Fisheries of the Fisheries Agency of Japan, to examine entanglement and its impact on juvenile male northern fur seals.

The objectives of this work are 1) continued monitoring of the proportion of seals entangled, 2) determination of the nature of entangling debris, 3) determination of the mortality caused by trawl webbing, especially as related to effects at the population level, and 4) assessment of the relative rates at which entangled and control animals are resighted. Part of the study of relative rates of resighting addresses the question of whether an animal's chances of being seen again are altered by being, or having been, entangled.

METHODS

The studies reported here involved roundups, a procedure conducted near the breeding colonies of northern fur seals on St. Paul Island, Alaska. 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 determined and recorded. The general nature of the procedure is described in greater detail in Fowler and Ragen (1990), and Fowler et al. (in press). Specific methods of importance to this study are explained below. All work was conducted during the breeding season while animals congregated at, or near, breeding rookeries along the shoreline of the island.

As in previous years, the seals on which entanglement research is primarily focused are those judged to be of the size historically taken in the commercial harvest (approximately 105 to 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 entanglement rate for comparison with rates observed in the commercial harvest prior to 1985.

As in 1989, 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. As in previous years, data recorded at the time of tagging included the tag number and the extent of the wound caused by the debris. The color, weight, type of debris, and mesh and twine size if it was a net fragment were determined for each piece of debris. Samples

were retained for any future analysis deemed necessary. Also, 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.

The removal of debris must be taken into account in calculating the proportion of seals entangled because, under circumstances of previous work, some of the resighted seals would have died and not been observed. This was done by applying the estimated survival of seals entangled in small debris (0.5 from past studies: Fowler 1984, 1985, 1987; Fowler et al. 1989, 1990, in press; Fowler and Ragen 1990) to the number of seals resighted after having had their debris removed in 1989. Thus, half of the resighted seals from which debris had been removed last year were assumed to have been seals that would have been resighted as entangled seals this year to contribute to the observed proportion entangled.

Some of the surviving seals from which the debris was removed last year had grown to be larger than those taken in the commercial harvests. To account for this in calculating the entanglement rate necessitates differentiating between those that are too large and those that should be counted for estimating entanglement rates. Since information regarding the size of resighted seals from the tagging in 1990 was not recorded, all tagged seals were included. This will result in a slightly inflated estimate of the entanglement rate.

Because some animals are rounded up more than once, the resulting sampling scheme is one of sampling with replacement and the data for both the control animals and the entangled animals are treated accordingly. This is particularly important in estimating the proportion of seals entangled for comparison to historical data.

Analytical methods to estimate the survival rate of entangled seals are presented in the Appendix as modifications of those used by Fowler and Ragen (1990), and Fowler et al. (in press). The differences between these methods and those of the original approach, also used here, are explained in the Appendix.

RESULTS

Roundups

One hundred twenty-two roundups of subdult male northern fur seals were completed on St. Paul Island during July and early August of 1990 (Table 1). During these roundups, 25,829 male seals judged to be of the size historically taken in the commercial harvest were counted. As explained below, about 25-30% of each of the total counts (unentangled and entangled) were repeat sightings. In all, 57 entangled subadult male seals judged to be of harvestable size were captured and double tagged with numbered white Allflex[1] tags bearing the address of the National Marine

[1]Reference 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 1990.

Date	Location	Total[a] in roundup	Tagged seals[b] resighted	Total seals tagged
7/1	Zapadni Reef	6	0	0
7/1	Tolstoi Sands	59	0	1
7/1	Tolstoi Sands	73	2	2
7/1	Tolstoi Sands	138	3	3
7/2	Zoltoi Sands	732	9	1
7/3	Zapadni Reef Sands	361	10	1
7/5	Zapadni	65	0	0
7/5	Little Zapadni	85	1	0
7/5	Zapadni Sands	93	0	0
7/5	Zapadni	100	1	0
7/5	Zapadni	200	1	0
7/5	Kitovi	209	2	0
7/5	Zapadni Sands	233	3	0
7/5	Zapadni Sands	288	1	3
7/5	Zapadni	359	2	3
7/6	Polovina	34	1	0
7/6	Polovina	132	0	0
7/6	Polovina	211	3	0
7/6	Morjovi	248	5	0
7/6	Lukanin	259	9	3
7/7	Vostochni	35	1	1
7/7	Vostochni	75	1	0
7/7	Vostochni	152	5	0
7/7	North East Point	182	0	0
7/7	Vostochni Sands	209	6	11
7/7	Vostochni	249	2	0
7/8	Reef	16	0	0
7/8	Reef	20	0	0
7/8	Reef	147	1	0
7/8	Reef	447	9	0
7/9	Reef	65	1	0
7/9	Reef	146	2	0
7/9	Reef	153	0	0
7/9	Gorbatch	338	6	0
7/10	Zapadni Reef Sands	83	4	0
7/10	Zapadni Reef Sands	252	8	2
7/10	Zoltoi Sands	263	4	0
7/11	Zapadni Sands	22	0	0
7/11	Zapadni	68	2	0
7/11	Zapadni	108	0	0
7/11	Zapadni	112	4	3
7/11	Zapadni Sands	176	2	0
7/11	Zapadni Sands	406	5	3

Table 1.--Continued.

Date	Location	Total[a] in roundup	Tagged seals[b] resighted	Total seals tagged
7/12	Tolstoi Sands	35	0	0
7/12	Tolstoi Sands	55	1	3
7/12	Lukanin	378	15	2
7/12	Tolstoi Sands	525	10	3
7/13	Polovina	20	1	0
7/13	Polovina	136	7	0
7/13	Kitovi	160	3	0
7/13	Polovina	202	2	0
7/15	Reef	38	0	0
7/15	Reef	54	0	0
7/15	Reef	136	0	0
7/15	Reef	229	3	3
7/16	Little Zapadni	72	1	0
7/16	Vostochni Sands	325	8	8
7/16	Gorbatch	568	20	3
7/17	Vostochni	59	0	0
7/17	Vostochni	59	2	0
7/17	Vostochni	61	0	1
7/17	Vostochni	75	1	1
7/17	Zapadni Reef Sands	182	4	14
7/17	Vostochni	485	15	0
7/17	Morjovi	740	15	3
7/18	Tolstoi Sands	115	0	0
7/18	Tolstoi Sands	178	7	3
7/18	Zoltoi Sands	349	6	0
7/19	Kitovi	101	5	1
7/19	Polovina	148	5	0
7/19	Lukanin	155	11	0
7/19	Polovina	228	11	0
7/20	Zapadni	524	20	0
7/21	Vostochni Sands	581	30	8
7/22	Vostochni	191	8	8
7/22	Vostochni	603	15	3
7/22	Vostochni	713	29	12
7/24	Vostochni	38	2	0
7/24	Vostochni	55	3	0
7/24	Vostochni	75	1	3
7/24	Morjovi	225	10	03
7/24	Zapadni Reef Sands	363	11	0
7/25	Zoltoi Sands	323	9	0
7/25	Tolstoi	443	16	9
7/26	Kitovi	98	3	3
7/26	Lukanin	161	8	4
7/26	Zapadni	274	5	0
7/26	Zapadni	449	8	3

Table 1.--Continued.

Date	Location	Total[a] in roundup	Tagged seals[b] resighted	Total seals tagged
7/26	Zapadni Sands	513	13	9
7/27	Reef	105	0	0
7/27	Reef	110	0	0
7/27	Reef	223	1	3
7/27	Reef	266	11	3
7/27	Reef	298	7	3
7/27	Gorbatch	592	23	1
7/28	Vostochni Sands	76	2	0
7/28	Vostochni	108	4	0
7/28	Vostochni	376	17	12
7/28	Vostochni	410	14	0
7/29	Polovina	125	5	3
7/29	Morjovi	349	10	0
7/29	Polovina	498	14	4
7/30	Tolstoi Sands	120	2	0
7/30	Tolstoi Sands	147	7	0
7/30	Little Zapadni	152	4	0
7/30	Zapadni Reef Sands	170	7	0
7/30	Zoltoi Sands	198	5	0
7/31	Zapadni	148	2	0
7/31	Zapadni	234	4	0
7/31	Zapadni	241	7	0
7/31	Zapadni	285	7	0
8/1	Reef	106	3	0
8/1	Kitovi	132	11	0
8/1	Reef	145	8	0
8/1	Lukanin	163	8	1
8/1	Reef	178	8	0
8/2	Vostochni	63	2	0
8/2	Vostochni Sands	111	5	3
8/2	Vostochni	115	4	0
8/2	Vostochni	151	8	3
8/3	Morjovi	110	2	3
8/3	Polovina	218	8	0
	Totals	25,829	680	186

[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 or 1988) in either fore-flipper and that were successfully restrained to read the tag. Includes any that were resighted more than once this year.

Mammal Laboratory (Table 2). A total of 114 similarly sized control seals with no entangling debris were tagged (Table 2).

Tagged Seals from Previous Years

Seals tagged in previous years were resighted (Table 3) along with seals tagged during the 1990 season. Of these resighted seals from previous years for which tags were read, 46 had Allflex tags from 1985, 1986, and 1988 applied during earlier phases of research to evaluate the mortality of young male seals entangled in debris. Forty-three of the 46 resighted seals were tagged in previous years as controls. Three had been entangled when tagged. Of the three seals resighted after having been tagged as entangled, all had lost their entangling debris (keeping in mind that debris was not removed from entangled seals during tagging in years prior to 1989). Two pieces of debris that were lost had been noted at their first sighting as being small (0-150 g in estimated weight) and one was large (over 500 g).

Thirty-seven seals were resighted with tags applied in 1989, the first year during which debris was removed from entangled juvenile male seals. Of these 26 had been tagged as controls, and 11 had been tagged after being disentangled.

Entanglement Rate

We examined 71 entangled juvenile male seals in the 1990 roundups (the 57 seals mentioned above, 12 that were judged to be larger than historically harvested, and 2 that died) to remove and

Table 2.--List of white broad banded Allflex tags applied to subadult male northern fur seals during roundups conducted on St. Paul Island, Alaska, 1990. Entangling debris was removed from entangled seals prior to their being released.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
1301	7/7	m	Vostochni	c
1302	7/7	m	Vostochni	c
1303	7/7	m	Vostochni	c
1304	7/7	m	Vostochni	c
1305	7/7	m	Vostochni	c
1306	7/7	m	Vostochni	c
1307	7/7	m	Vostochni	c
1308	7/7	m	Vostochni	c
1309	7/7	m	Vostochni	e
1310	7/8	f	Zapadni Reef	-[a]
1311	7/8	f	Zapadni Reef	-
1312	7/8	f	Zapadni Reef	-
1313	7/10	m	Zapadni Reef Sands	c
1314	7/10	m	Zapadni Reef Sands	c
1315	7/10	f	Zapadni Reef	-
1316	7/10	f	Zapadni Reef	-
1317	7/11	m	Zapadni Sands	e
1318	7/11	m	Zapadni Sands	c
1319	7/11	m	Zapadni Sands	c
1320	7/11	m	Zapadni	e
1321	7/11	m	Zapadni	c
1322	7/11	m	Zapadni	c
1323	7/11	m	Tolstoi Sands	e
1324	7/12	m	Tolstoi Sands	c
1325	7/12	m	Tolstoi Sands	c
1326	7/11	m	Tolstoi Sands	e
1327	7/12	m	Tolstoi Sands	c
1328	7/12	m	Tolstoi Sands	c
1329	7/12	m	Lukanin	e
1330	7/12	m	Lukanin	c
1331	7/13	m	Polovina	c
1332	7/13	m	Polovina	e
1333	7/13	m	Polovina	c
1334	7/15	m	Reef	e
1335	7/15	m	Reef	c
1336	7/15	m	Reef	c
1337	7/15	m	Reef	c
1338	7/15	m	Reef	c
1339	7/15	m	Reef	e
1340	7/16	m	Gorbatch	e

Table 2.--Continued.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
1341	7/16	m	Gorbatch	c
1342	7/16	m	Gorbatch	c
1343	7/16	m	Vostochni Sands	e
1344	7/16	m	Vostochni Sands	c
1345	7/16	m	Vostochni Sands	c
1346	7/16	m	Vostochni Sands	c
1347	7/16	m	Vostochni Sands	e
1348	7/16	m	Vostochni Sands	e
1349	7/16	m	Vostochni Sands	c
1350	7/16	m	Vostochni Sands	c
1351	7/17	m	Vostochni	e
1352	7/17	m	Vostochni	e
1353	7/17	m	Morjovi	e
1354	7/17	m	Morjovi	c
1355	7/17	m	Morjovi	c
1356	7/17	m	Zapadni Reef Sands	e
1357	7/17	m	Zapadni Reef Sands	e
1358	7/17	m	Zapadni Reef Sands	e
1359	7/17	m	Zapadni Reef Sands	e
1360	7/17	m	Zapadni Reef Sands	c
1361	7/17	m	Zapadni Reef Sands	c
1362	7/17	m	Zapadni Reef Sands	c
1363	7/17	m	Zapadni Reef Sands	c
1364	7/17	m	Zapadni Reef Sands	e
1365	7/17	m	Zapadni Reef Sands	c
1366	7/17	m	Zapadni Reef Sands	c
1367	7/17	m	Zapadni Reef Sands	c
1368	7/17	m	Zapadni Reef Sands	c
1369	7/17	m	Zapadni Reef Sands	e
1370	7/18	m	Tolstoi Sands	c
1371	7/18	m	Tolstoi Sands	c
1372	7/18	m	Tolstoi Sands	e
1373	7/19	m	Kitovi	e
1374	7/21	m	Vostochni Sands	e
1374	7/21	m	Vostochni Sands	c
1376	7/21	m	Vostochni Sands	e
1377	7/21	m	Vostochni Sands	e
1378	7/21	m	Vostochni Sands	c
1379	7/21	m	Vostochni Sands	c
1380	7/21	m	Vostochni Sands	c
1381	7/21	m	Vostochni Sands	c
1382	7/22	m	Vostochni	e
1383	7/22	m	Vostochni	e
1384	7/22	m	Vostochni	e

Table 2.--Continued.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
1385	7/22	m	Vostochni	e
1386	7/22	m	Vostochni	c
1387	7/22	m	Vostochni	c
1388	7/22	m	Vostochni	c
1389	7/22	m	Vostochni	c
1390	7/22	m	Vostochni	e
1391	7/22	m	Vostochni	c
1392	7/22	m	Vostochni	c
1393	7/22	m	Vostochni	c
1394	7/22	m	Vostochni	c
1395	7/22	m	Vostochni	e
1396	7/22	m	Vostochni	e
1397	7/22	m	Vostochni	c
1398	7/22	m	Vostochni	c
1399	7/24	m	Vostochni	e
1400	7/24	m	Vostochni	c
1401	7/1	m	Tolstoi Sands	e
1402	7/1	m	Tolstoi Sands	c
1403	7/1	m	Tolstoi Sands	c
1404	7/1	m	Tolstoi Sands	e
1405	7/1	m	Tolstoi Sands	c
1406	7/1	m	Tolstoi Sands	c
1407	7/2	m	Zoltoi Sands	e
1408	7/3	m	Zapadni Reef Sands	e
1409	7/5	m	Zapadni Sands	e
1410	7/5	m	Zapadni Sands	c
1411	7/5	m	Zapadni Sands	c
1412	7/5	m	Zapadni	e
1413	7/5	m	Zapadni	c
1414	7/5	m	Zapadni	c
1415	7/6	m	Lukanin	e
1416	7/6	m	Lukanin	c
1417	7/6	m	Lukanin	c
1418	7/7	m	Vostochni	e
1419	7/7	m	Vostochni Sands	e
1420	7/7	m	Vostochni	e
1421	7/24	m	Vostochni	c
1422	7/25	m	Tolstoi Sands	e
1423	7/25	m	Tolstoi Sands	e
1424	7/25	m	Tolstoi Sands	e
1425	7/25	m	Tolstoi Sands	c
1426	7/25	m	Tolstoi Sands	c
1427	7/25	m	Tolstoi Sands	c
1428	7/25	m	Tolstoi Sands	c

Table 2.--Continued.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
1429	7/25	m	Tolstoi Sands	c
1430	7/25	m	Tolstoi Sands	c
1431	7/25	m	Zoltoi Sands	e
1432	7/26	m	Lukanin	e
1433	7/26	m	Lukanin	c
1434	7/26	m	Lukanin	c
1435	7/26	m	Lukanin	c
1436	7/26	m	Kitovi	e
1437	7/26	m	Kitovi	c
1438	7/26	m	Kitovi	c
1439	7/26	m	Zapadni Sands	e
1440	7/26	m	Zapadni Sands	c
1441	7/26	m	Zapadni Sands	c
1442	7/26	m	Zapadni Sands	e
1443	7/26	m	Zapadni Sands	c
1444	7/26	m	Zapadni Sands	c
1445	7/26	m	Zapadni Sands	c
1446	7/26	m	Zapadni Sands	e
1447	7/26	m	Zapadni Sands	c
1448	7/26	m	Zapadni	e
1449	7/26	m	Zapadni	c
1450	7/26	m	Zapadni	c
1451	7/27	m	Gorbatch	e
1452	7/27	m	Reef	e
1453	7/27	m	Reef	c
1454	7/27	m	Reef	c
1455	7/27	m	Reef	e
1456	7/27	m	Reef	c
1457	7/27	m	Reef	c
1458	7/27	m	Reef	e
1459	7/27	m	Reef	c
1460	7/27	m	Reef	c
1461	7/28	m	Vostochni	e
1462	7/28	m	Vostochni	e
1463	7/28	m	Vostochni	e
1464	7/28	m	Vostochni	e
1465	7/28	m	Vostochni	c
1466	7/28	m	Vostochni	c
1467	7/28	m	Vostochni	c
1468	7/28	m	Vostochni	c
1469	7/28	m	Vostochni	c
1470	7/28	m	Vostochni	c
1471	7/28	m	Vostochni	c
1472	7/28	m	Vostochni	c

Table 2.--Continued.

Tag number	Date	Sex	Location	Entangled (e) Control (c)
1473	7/29	m	Polovina	c
1474	7/29	m	Polovina	c
1475	7/29	m	Polovina	e
1476	7/29	m	Polovina	e
1477	7/29	m	Polovina	c
1478	7/29	m	Polovina	c
1479	7/29	m	Polovina	e
1480	8/1	m	Reef	e
1481	8/2	m	Vostochni Sands	e
1482	8/2	m	Vostochni Sands	c
1483	8/2	m	Vostochni Sands	c
1484	8/2	m	Vostochni	e
1485	8/2	m	Vostochni	c
1486	8/2	m	Vostochni	c
1487	8/3	m	Morjovi	e
1488	8/3	m	Morjovi	c
1489	8/3	m	Morjovi	c

[a]Female seal tagged with radio transmitters for behavioral or feeding studies by Japanese biologists.

Table 3.--List of tagged northern fur seals seen during July juvenile male roundup activities on St. Paul Island, 1990. Tags were seen on both fore-flippers unless noted otherwise. Debris was removed from entangled seals.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/1	Tolstoi Sands	1157	Allflex	orange	e[r]	Tagged 15 July 1989, on Zoltoi Sands.
7/1	Tolstoi Sands	5112	Allflex	white	c	Tagged 15 Oct. 1986, on Little Zapadni.
7/2	Zoltoi Sands	102	Allflex	blue	c	Tagged 26 July 1988, on Reef.
7/2	Zoltoi Sands	0330	Allflex	orange	c	Tagged 19 July 1986, on Reef.
7/2	Zoltoi Sands	0579	Allflex	orange	c	Tagged 5 Aug. 1986, on Reef.
7/2	Zoltoi Sands	0909	Allflex	orange	c	Tagged 6 Oct. 1986, on Tolstoi.
7/2	Zoltoi Sands	1163	Allflex	orange	c	Tagged 15 July 1989, on Zoltoi Sands.
7/2	Zoltoi Sands	1166	Allflex	orange	c	Tagged 15 July 1989, on Zapadni Reef Sands.
7/2	Zoltoi Sands	1183	Allflex	orange	c	Tagged 15 July 1989, on Reef.
7/2	Zoltoi Sands	1240	Allflex	orange	c	Tagged 22 July 1989, on Kitovi.
7/2	Zoltoi Sands	1257	Allflex	orange	c	Tagged 23 July 1989, on Zapadni.
7/3	Zapadni Reef Sands	1172	Allflex	orange	c	Tagged 15 July 1989, on Zapadni Reef Sands. Right tag only.
7/5	Kitovi	1240	Allflex	orange	c	Tagged 22 July 1989, on Kitovi.
7/5	Zapadni	0245	Allflex	orange	c	Tagged 10 Aug. 1985, on Vostochni. Tags looked a lot like orange instead of white Allflex.
7/5	Zapadni	5144	Allflex	white	c	Tagged 1 Aug. 1986, on Zapadni. Tags looked a lot like orange instead of white Allflex.
7/5	Zapadni Sands	0903	Allflex	orange	c	Tagged 6 Oct. 1986, on Tolstoi.
7/5	Zapadni Sands	1401	Allflex	white	c	Tagged 1 July 1990, on Tolstoi Sands.
7/6	Lukanin	0957	Allflex	orange	c	Tagged 8 Oct. 1986, on Tolstoi Sands.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/6	Morjovi	79	Allflex	blue	e[r]	Tagged 25 July 1988, on Tolstoi.
7/6	Morjovi	1222	Allflex	orange	e[r]	Tagged 19 July 1989, on Vostochni.
7/6	Polovina	1246	Allflex	orange	e[r]	Tagged 23 July 1989, on Polovina.
7/7	Vostochni	1200	Allflex	orange	c	Tagged 18 July 1989, on Morjovi. No note of tag on left.
7/7	Vostochni	5180	Allflex	white	c	Tagged 3 Aug. 1986, on Tolstoi. Tag on right only.
7/7	Vostochni	0444	Allflex	orange	c	Tagged 31 July 1986, on Vostochni.
7/7	Vostochni	0499	Allflex	orange	c	Tagged 25 Aug. 1986, on Polovina. Tag seen on right side but number not verified.
7/7	Vostochni	1155	Allflex	orange	e[r]	Tagged 14 July 1989, on Zapadni Reef Sands.
7/7	Vostochni	1272	Allflex	orange	c	Tagged 25 July 1989, on Morjovi.
7/7	Vostochni	bB2253		monel		
7/7	Vostochni	ME3307		monel		
7/7	Vostochni Sands	133	Allflex	blue	c	Tagged 29 July 1988, on Vostochni. Tag seen on right side but number not verified.
7/8	Reef	1152	Allflex	orange	c	Tagged 15 July 1989, on Tolstoi Sands.
7/8	Reef	1176	Allflex	orange	e[r]	Tagged 15 July 1989, on Reef.
7/8	Reef	1233	Allflex	orange	e[r]	Tagged 21 July 1989, on Reef.
7/8	Reef	1242	Allflex	orange	c	Tagged 23 July 1989, on Lukanin.
7/8	Reef	MK1861		monel		Soviet tagged seal.
7/9	Gorbatch	1242	Allflex	orange	c	Tagged 23 July 1989, on Lukanin.
7/9	Gorbatch	1415	Allflex	white	e[r]	Tagged 6 July 1990, on Lukanin.
7/9	Reef	55	Allflex	blue	c	Tagged 20 July 1988, on Vostochni.
7/9	Reef	0587	Allflex	orange	c	Tagged 5 July 1986, on Reef. Left tag not read but present.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/9	Reef	1179	Allflex	orange	e	Tagged as a control 15 July 1989, on Reef; became entangled since being tagged.
7/10	Zapadni Reef Sands	1176	Allflex	orange	e[r]	Tagged 15 July 1989, on Gorbatch.
7/10	Zapadni Reef Sands	1257	Allflex	orange	c	Tagged 23 July 1989, on Zapadni.
7/10	Zapadni Reef Sands	1285	Allflex	orange	c	Tagged 25 July 1989, on Vostochni.
7/10	Zapadni Reef Sands	1307	Allflex	white	c	Tagged 7 July 1990, on Vostochni.
7/10	Zoltoi Sands	0346	Allflex	orange	c	Tagged 22 July 1986, on Polovina.
7/11	Zapadni Sands	1180	Allflex	orange	c	Tagged 15 July 1989, on Reef.
7/11	Zapadni Sands	1188	Allflex	orange	e[r]	Tagged 16 July 1989, on Little Zapadni.
7/12	Kitovi	0082	Allflex	orange	c	Tagged 23 July 1985, on Tolstoi.
7/12	Lukanin	1402	Allflex	white	e[r]	Tagged 1 July 1990, on Tolstoi Sands.
7/12	Polovina	1247	Allflex	orange	c	Tagged 23 July 1989, on Polovina.
7/12	Tolstoi Sands	5117	Allflex	white	c	Tagged 16 Oct. 1986, on Reef. Left tag not noted.
7/12	Tolstoi Sands	0239	Allflex	orange	c	Tagged 10 Oct. 1985, on Vostochni.
7/12	Tolstoi Sands	0423	Allflex	orange	e[r]	Tagged 27 July 1986, on Tolstoi.
7/12	Tolstoi Sands	0916	Allflex	orange	c	Tagged 6 Oct. 1986, on Tolstoi.
7/12	Tolstoi Sands	1285	Allflex	orange	c	Tagged 25 July 1989, on Vostochni.
7/12	Tolstoi Sands	1320	Allflex	white	e[r]	Tagged 11 July 1990, on Zapadni.
7/13	Polovina	1419	Allflex	white	e[r]	Tagged 7 July 1990, on Vostochni.
7/15	Reef	1244	Allflex	orange	c	Tagged 23 July 1989, on Polovina.
7/16	Gorbatch	158	Allflex	blue	c	Tagged 31 July 1988, on Kitovi.
7/16	Gorbatch	1243	Allflex	orange	c	Tagged 23 July 1989, on Lukanin.
7/16	Gorbatch	1326	Allflex	white	e[r]	Tagged 12 July 1990, on Tolstoi Sands.
7/16	Gorbatch	1336	Allflex	white	c	Tagged 13 July 1990, on Reef.
7/16	Gorbatch	1338	Allflex	white	c	Tagged 15 July 1990, on Reef.
7/16	Gorbatch	1339	Allflex	white	e[r]	Tagged 15 July 1990, on Reef.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/16	Reef	1158	Allflex	orange	e^r	Tagged 15 July 1989, on Zoltoi Sands.
7/16	Vostochni Sands	1277	Allflex	orange	c	Tagged 25 July 1989, on Morjovi.
7/16	Vostochni Sands	1286	Allflex	orange	e^r	Tagged 25 July 1989, on Vostochni.
7/16	Vostochni Sands	bH3487		monel		
7/17	Morjovi	bA657	monel			Soviet tagged seal with tag on one side only; not noted which side.
7/17	Morjovi	1344	Allflex	white	c	Tagged 16 July 1990, on Vostochni Sands.
7/17	Vostochni	1285	Allflex	orange	c	Tagged 25 July 1989, on Vostochni. No note of tag on left.
7/17	Vostochni	0494	Allflex	orange	c	Tagged 25 Aug. 1986, on Morjovi. No tag on right.
7/17	Vostochni	0959	Allflex	orange	c	Tagged 8 Oct. 1986, on Morjovi.
7/17	Vostochni	1271	Allflex	orange	c	Tagged 25 July 1989, on Morjovi.
7/17	Vostochni	1305	Allflex	white	c	Tagged 7 July 1990, on Vostochni.
7/17	Vostochni	1345	Allflex	white	c	Tagged 16 July 1990, on Vostochni Sands.
7/17	Vostochni	1348	Allflex	white	e^r	Tagged 16 July 1990, on Vostochni Sands.
7/17	Vostochni	1350	Allflex	white	c	Tagged 16 July 1990, on Vostochni Sands.
7/18	Tolstoi Sands	1361	Allflex	white	c	Tagged 17 July 1990, on Zapadni Reef Sands.
7/18	Tolstoi Sands	1365	Allflex	white	c	Tagged 17 July 1990, on Zapadni Reef Sands.
7/18	Zoltoi Sands	58	Allflex	blue	c	Tagged 20 July 1988, on Vostochni.
7/18	Zoltoi Sands	0383	Allflex	orange	c	Tagged 23 July 1986, on Gorbatch.
7/18	Zoltoi Sands	bE1185		monel		Soviet tagged seal.
7/19	Kitovi	0229	Allflex	orange	c	Tagged 9 Aug. 1985, on Kitovi.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/19	Polovina	0123	Allflex	orange	c	Tagged 29 July 1985, on Polovina.
7/19	Polovina	159	Allflex	blue	c	Tagged 31 July 1988, on Kitovi.
7/19	Polovina	0421	Allflex	orange	c	Tagged 27 July 1986, on Zapadni Reef.
7/19	Polovina	1250	Allflex	orange	c	Tagged 23 July 1989, on Polovina.
7/20	Vostochni	1309	Allflex	white	e[r]	Tagged 7 July 1990, on Vostochni.
7/20	Zapadni	24	Allflex	blue	c	Tagged 17 July 1988, on Reef.
7/20	Zapadni	1365	Allflex	white	c	Tagged 17 July 1990, on Zapadni Reef Sands.
7/20	Zapadni	1366	Allflex	white	c	Tagged 17 July 1990, on Zapadni Reef Sands.
7/20	Zapadni	1371	Allflex	white	c	Tagged 18 July 1990, on Tolstoi Sands.
7/21	Vostochni Sands	0420	Allflex	orange	c	Tagged 27 July 1986, on Vostochni Sands.
7/21	Vostochni Sands	1214	Allflex	orange	e[r]	Tagged 18 July 1989, on Vostochni Sands.
7/21	Vostochni Sands	1225	Allflex	orange	c	Tagged 19 July 1989, on Vostochni.
7/21	Vostochni Sands	1280	Allflex	orange	c	Tagged 25 July 1989, on Vostochni.
7/21	Vostochni Sands	1343	Allflex	white	e[r]	Tagged 16 July 1990, on Vostochni Sands.
7/21	Vostochni Sands	1348	Allflex	white	e[r]	Tagged 16 July 1990, on Vostochni Sands.
7/21	Vostochni Sands	1349	Allflex	white	c	Tagged 16 July 1990, on Vostochni Sands.
7/21	Vostochni Sands	1350	Allflex	white	c	Tagged 16 July 1990, on Vostochni Sands.
7/21	Vostochni Sands	1409	Allflex	white	e[r]	Tagged July 5 1990, on Zapadni Sands.
7/21	Vostochni Sands	bH3487		monel		Soviet tagged seal.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/22	Vostochni	59	Allflex	blue	c	Tagged 20 July 1988, on Vostochni. Fit with a radio tag at that time.
7/22	Vostochni	59	Allflex	blue	c	Tagged 20 July 1988, on Vostochni. Fit with a radio tag on that time.
7/22	Vostochni	94	Allflex	blue	c	Tagged 26 July 1988, on Vostochni.
7/22	Vostochni	0497	Allflex	orange	c	Tagged 25 July 1986, Morjovi.
7/22	Vostochni	0499	Allflex	orange	c	Tagged 25 Aug. 1986, Polovina.
7/22	Vostochni	1210	Allflex	orange	e[r]	Tagged 18 July 1989, Vostochni. Too big to count in 1989.
7/22	Vostochni	1343	Allflex	white	e[r]	Tagged 16 July 1990, Vostochni Sands.
7/22	Vostochni	1346	Allflex	white	c	Tagged 16 July 1990, Vostochni Sands.
7/22	Vostochni	1346	Allflex	white	c	Tagged 16 July 1990, Vostochni Sands.
7/22	Vostochni	1348	Allflex	white	c	Tagged 16 July 1990, Vostochni Sands.
7/22	Vostochni	1349	Allflex	white	c	Tagged 21 July 1990, Vostochni Sands.
7/22	Vostochni	1379	Allflex	white	c	Tagged 16 July 1990, Vostochni Sands.
7/22	Vostochni	1388	Allflex	white	c	Tagged 22 July 1990, Vostochni.
7/22	Vostochni	1420	Allflex	white	e[r]	Tagged 7 July 1990, Vostochni.
7/22	Vostochni	bH3487		monel		Soviet tagged seal. Weighed 45.5 lbs.
7/24	Morjovi	1392	Allflex	white	c	Tagged 22 July 1990, on Vostochni.
7/24	Morjovi	1417	Allflex	white	c	Tagged 6 July 1990, on Lukanin.
7/24	Zapadni Reef Sands	1366	Allflex	white	c	Tagged 17 July 1990, on Zapadni Reef Sands.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/25	Tolstoi Sands	1165	Allflex	orange	c	Tagged 15 July 1989, on Zapadni Reef Sands.
7/26	Kitovi	0094	Allflex	orange	c	Tagged 24 July 1985, on Morjovi.
7/26	Kitovi	0163	Allflex	orange	c	Tagged 5 Aug. 1985, on Zapadni.
7/26	Lukanin	1285	Allflex	orange	c	Tagged 25 July 1989, on Vostochni. No note of tag on left.
7/26	Lukanin	1417	Allflex	white	c	Tagged 6 July 1990, on Lukanin.
7/26	Zapadni	1198	Allflex	orange	e[r]	Tagged 18 July 1989, on Morjovi.
7/26	Zapadni	1265	Allflex	orange	c	Tagged 24 July 1989, on Zapadni Reef Sands.
7/26	Zapadni	1427	Allflex	white	c	Tagged 25 July 1990, on Tolstoi Sands.
7/26	Zapadni	1430	Allflex	white	c	Tagged 7 July 1990, on Tolstoi Sands.
7/26	Zapadni	1444	Allflex	white	c	Tagged earlier in the day on Zapadni Sands.
7/26	Zapadni	bK1526		monel		Soviet tagged seal. No tag on the right.
7/26	Zapadni Sands	1165	Allflex	orange	c	Tagged 15 July 1989 on Zapadni Reef Sands.
7/26	Zapadni Sands	1371	Allflex	white	c	Tagged 18 July 1990, on Tolstoi Sands.
7/26	Zapadni Sands	XM6525		monel		Soviet tagged seal. No tag on the right.
7/27	Gorbatch	24	Allflex	blue	c	Tagged 17 July 1988, on Reef.
7/27	Gorbatch	136	Allflex	blue	e[r]	Tagged 29 July 1988, on Vostochni.
7/27	Gorbatch	158	Allflex	blue	c	Tagged 31 July 1988, on Kitovi.
7/27	Gorbatch	1159	Allflex	orange	c	Tagged 15 July 1989, on Zoltoi Sands.
7/27	Gorbatch	1170	Allflex	orange	c	Tagged 15 July 1989, on Zapadni Reef Sands.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/27	Gorbatch	1257	Allflex	orange	c	Tagged 23 July 1989, on Zapadni.
7/27	Reef	69	Allflex	blue	c	Tagged 22 July 1988, on Polovina.
7/27	Reef	105	Allflex	blue	c	Tagged 16 July 1988, on Reef.
7/27	Reef	120	Allflex	blue	c	Tagged 29 July 1988, on Vostochni.
7/27	Reef	1244	Allflex	orange	c	Tagged 23 July 1989, on Polovina.
7/27	Reef	1434	Allflex	white	c	Tagged 26 July 1990, on Lukanin.
7/27	Reef	1435	Allflex	white	c	Tagged 26 July 1990, on Lukanin.
7/28	Vostochni	0449	Allflex	orange	c	Tagged 31 July 1986, on Vostochni.
7/28	Vostochni	1219	Allflex	orange	c	Tagged 19 July 1989, on Vostochni.
7/28	Vostochni	1286	Allflex	orange	e[r]	Tagged 25 July 1989, on Vostochni.
7/28	Vostochni	1378	Allflex	white	c	Tagged 21 July 1990, on Vostochni Sands.
7/28	Vostochni	1385	Allflex	white	e[r]	Tagged 22 July 1990, on Vostochni.
7/28	Vostochni	1386	Allflex	white	c	Tagged 22 July 1990, on Vostochni.
7/28	Vostochni	1388	Allflex	white	c	Tagged 22 July 1990, on Vostochni.
7/28	Vostochni	1390	Allflex	white	e[r]	Tagged 22 July 1990, on Vostochni.
7/28	Vostochni	1396	Allflex	white	e[r]	Tagged 22 July 1990, on Vostochni.
7/28	Vostochni	1398	Allflex	white	c	Tagged 22 July 1990, on Vostochni.
7/28	Vostochni	bK3965		monel		Soviet tagged seal.
7/28	Vostochni Sands	1280	Allflex	orange	c	Tagged 25 July 1989, on Vostochni.
7/28	Vostochni Sands	1393	Allflex	white	c	Tagged 22 July 1990, on Vostochni.
7/29	Morjovi	1462	Allflex	white	e[r]	Tagged 28 July 1990, on Vostochni.
7/29	Morjovi	1469	Allflex	white	c	Tagged 28 July 1990, on Vostochni.
7/29	Polovina	1374	Allflex	white	c	Tagged 21 July 1990, on Vostochni Sands.
7/30	Tolstoi Sands	1429	Allflex	white	c	Tagged 25 July 1990, on Tolstoi Sands.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
7/30	Zapadni Reef Sands	0377	Allflex	orange	c	Tagged 23 July 1986, on Gorbatch.
7/30	Zapadni Reef Sands	1426	Allflex	white	c	Tagged 25 July 1990, on Tolstoi Sands.
7/30	Zoltoi Sands	1243	Allflex	orange	c	Tagged 23 July 1989, on Lukanin.
7/30	Zoltoi Sands	1407	Allflex	white	e[r]	Tagged 2 July 1990, on Zoltoi Sands.
7/30	Zoltoi Sands	1444	Allflex	white	c	Tagged 26 July 1990, on Zapadni Sands.
7/31	Zapadni	1439	Allflex	white	e[r]	Tagged 26 July 1990, on Zapadni Sands.
7/31	Zapadni	1441	Allflex	white	c	Tagged 26 July 1990, on Zapadni Sands.
7/31	Zapadni	1446	Allflex	white	e[r]	Tagged 26 July 1990, on Zapadni Sands.
8/1	Kitovi	0745	Allflex	orange	c	Tagged 24 Aug. 1986, on Kitovi.
8/1	Kitovi	1373	Allflex	white	e[r]	Tagged 19 July 1990, on Kitovi. Too large to count.
8/1	Lukanin	1432	Allflex	white	e[r]	Tagged 26 July 1990, on Lukanin.
8/1	Reef	69	Allflex	blue	c	Tagged 22 July 1988, on Polovina. No note of tag on left.
8/1	Reef	78	Allflex	blue	c	Tagged 24 July 1988, on Reef. Also fitted with a radio transmitter at that time.
8/1	Reef	0583	Allflex	orange	c	Tagged 5 Aug. 1986, on Reef.
8/1	Reef	1198	Allflex	orange	e[r]	Tagged 18 July 1989, on Morjovi.
8/1	Reef	1225	Allflex	orange	c	Tagged 19 July 1989, on Vostochni.
8/1	Reef	1240	Allflex	orange	c	Tagged 22 July 1989, on Kitovi.
8/2	Vostochni	1309	Allflex	white	e[r]	Tagged 7 July 1990, on Vostochni.

Table 3.--Continued.

Date	Location	Tag number	Tag type	Tag color	Entanglement status*	Notes
8/2	Vostochni	1465	Allflex	white	c	Tagged 28 July 1990, on Vostochni.
8/2	Vostochni	1470	Allflex	white	c	Tagged 18 July 1990, on Vostochni.
8/2	Vostochni	1472	Allflex	white	c	Tagged 28 July 1990, on Vostochni.
8/2	Vostochni	bK3965		monel		Soviet tagged seal; second sighting. Weight 61 lbs.
8/2	Vostochni	MK2228		monel		Soviet tagged seal. Weighed 50.5 lbs.
8/2	Vostochni Sands	0716	Allflex	orange	c	Tagged 24 Aug. 1986, on Vostochni.
8/2	Vostochni Sands	1376	Allflex	white	e^r	Tagged 21 July 1990 on Vostochni Sands. Too large to count.
8/2	Vostochni Sands	1398	Allflex	white	c	Tagged 22 July 1990, on Vostochni.

*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.

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 71 entangled seals examined, 23 (32.4%) were entangled in trawl webbing, 23 (32.4%) in plastic packing bands, and 16 (22.5%) in string, small line or cords. The remainder (9 or 12.7%) were entangled in other debris. The overall entanglement rate is estimated by the ratio of all (both initial and all subsequent) entanglement sightings to the total number of seals examined (Bengtson et al. 1988, Fowler et al. in press). As in 1989, the 1990 sampling design included resightings of animals from which debris was removed during the same season; these animals were counted as entangled. Seals from which debris were removed in 1989 were also resighted. To account for the survival of about 50% per year that characterizes the portion of the seal population entangled in small debris (Fowler et al. in press) in calculating the entanglement rate for 1990, half of the seals resighted in 1990 from which debris had been removed in 1989 were counted as entangled in 1990. In all, there were 85 sightings that qualified for calculating the entanglement rate. These included: 1) seals of harvestable size observed entangled, 2) the repeated sightings of animals from which debris had been removed in 1990, and 3) half of the seals resighted from 1989 after having had debris removed. The entanglement rate for 1990 was thus 0.33% (85/25,829), an estimate

Table 4.--List of juvenile male northern fur seals tagged as entangled animals during surveys conducted in July and August of 1990, St. Paul Island, Alaska, showing the nature of the debris on each animal.

Tag number	Date	Location (Rookery name)	Description of Debris: Type	Wt. (g)	Color	Tightness[1]	Wound (deg.)	Mesh size (cm)	Twine size (mm)	Footnote
1179	7/9	Reef	packing band	1.6	white	t	0	24.1		2
1309	7/7	Vostochni	trawl	202.6	white	t	360	22.8	3.0	
1317	7/11	Zapadni	trawl	27.4	orange	t	0	22.6	4.5	
1320	7/11	Zapadni	packing band	6.7	green	vt	360	25.2		
1323	7/11	Tolstoi	packing band	1.8	yellow	t	0	22.9		
1326	7/11	Tolstoi	packing band	4.5	black	t	360	24.7		
1329	7/12	Lukanin	trawl	70.6	green	m	0	17.1	5.0	
1332	7/13	Polovina	packing band	1.9	white	t	0	19.7		
1334	7/15	Reef	seine webbing	214.1	green	vt	360	15.1	1.5	
1339	7/15	Reef	trawl	219.6	green	t	0	23.5	3.0	
1340	7/16	Gorbatch	packing band	1.5	yellow	t	0	19.1		
1343	7/16	Vostochni	packing band	2.2	yellow	t	0	23.1		
1347	7/16	Vostochni	trawl	101.4	green	m	0	21.9	3.0	
1348	7/16	Vostochni	trawl	17.7	green	t	0	22.3	2.5	
1351	7/17	Vostochni	twine	1.2	white	t	360	33.0		3
1352	7/17	Vostochni	packing band	1.8	white	t	360			3
1353	7/17	Morjovi	packing band	1.3	blue	t	0	22.1		
1356	7/17	Zapadni Reef	twine	19.8	green	t	220	17.6		
1357	7/17	Zapadni Reef	trawl	25.1	green	t	360	26.4	3.0	4
1358	7/17	Zapadni Reef	trawl	196.2	gray	t	0	29.0	4.0	3
1359	7/17	Zapadni Reef	packing band	7	white	t	360	21.5		
1364	7/17	Zapadni Reef	twine	8.1	white	t	360	31.1		
1369	7/17	Zapadni Reef	trawl	800.6	grey	t	-	23.5	3.0	
1372	7/18	Tolstoi	packing band	2.1	yellow	t	360	20.8		
1373	7/19	Kitovi	trawl	14.5	blue	t	360	3.5		3
1374	7/21	Vostochni	rope	29.1	orange	t	0	20.6	12.0	

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
1376	7/21	Vostochni	trawl	518.90	grey	t	0	23.3	3.5	3
1377	7/21	Vostochni	twine	9.1	yellow	l	0	32.6		
1382	7/22	Vostochni	packing band	1.8	white	m	0	28.0		3
1383	7/22	Vostochni	seine	105.7	grey	t	330	8.4	2.0	
1384	7/22	Vostochni	see note	16.1		t	200			
1385	7/22	Vostochni	trawl	14	white	t	300	21.9	2.0	
1390	7/22	Vostochni	packing band	4.8	yellow	t	360	20.5		
1395	7/22	Vostochni	string	7.6	blue	vt	360	34.3		3
1396	7/22	Vostochni	packing band	1.7	blue	vt	0	21.9		
1399	7/24	Vostochni	packing band	2.8	yellow	m	0	25.7		
1401	7/1	Tolstoi	twine	13.6	blue	t	200	63.9		
1404	7/1	Tolstoi	trawl	142.1	green	t	220	21.5	2.6	
1407	7/2	Zoltoi Sands	twine	2.2	blue	vt	360	22.2		3
1408	7/3	Zapadni Reef	trawl	357.1	green	vt	o	21.8	2.5	
1409	7/5	Zapadni	chord	12.6	white	t	0	26.4		
1412	7/5	Zapadni	packing band	3.5	yellow	-	-	25.1		
1415	7/6	Lukanin	packing band	2.0	white	m	0	23.2		
1418	7/7	Vostochni	trawl net	32.6	green	t	360	21.8	3.0	
1419	7/7	Vostochni	packing band	1.9	white	t	0	24.0		
1420	7/7	Vostochni	chord	6.6	white	t	180			
1422	7/25	Tolstoi	trawl	244.8	*	t	0	19.5	6.0	5
1423	7/25	Tolstoi	chord	26.6	white	l	0	26.8	5.5	
1424	7/25	Tolstoi	chord	129.1	grey	t	360	26.7	5	
1431	7/25	Zoltoi Sands	chord	239.5	grey	t	150	24.5	5	3
1432	7/26	Lukanin	twine	3.9	green	t	360	22.8		
1436	7/26	Kitovi	monofilament	0.1	clear	t	note	19.0		6
1439	7/26	Zapadni	trawl	345.1	green	t	0	23.5	3.0	
1442	7/26	Zapadni	trawl	148.2	green	t	360	22.2	2.5	

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
1446	7/26	Zapadni	packing band	0.7	green	t	0	23.8		
1448	7/26	Zapadni	rubber ring	3.1	brown	m	0	19.2		
1451	7/27	Gorbatch	trawl	97.6	*		0	36.8	3.0	3,7
1452	7/27	Reef	trawl	398.6	*	t		*	3.0	2,3
1455	7/27	Reef	syn. filament	0.1	white	t	360	18.0		
1458	7/27	Reef	twine	0.1	white	t	360	31.8		
1461	7/28	Vostochni	packing band	3.8	white	t	360	-		
1462	7/28	Vostochni	packing band	2.5	yellow	m	0	23.0		
1463	7/28	Vostochni	chord	2.6	white	t	0	25.2		
1464	7/28	Vostochni	seine	35.0	green	t	0	22.1	1.5	
1475	7/29	Polovina	trawl	65.6	grey	t	0	23.5	2.5	
1476	7/29	Polovina	chord	2.5	black	m	320	24.7		
1479	7/29	Polovina	trawl	78.9	*	t	0	23.1	3.0	9
1480	8/1	Reef	packing band	1.2	green	vt	360	25.0		3
1481	8/2	Vostochni	twine	6.7	blue	t	360	34.4		
1484	8/2	Vostochni	trawl	311.6	green	t	0	22.5	2.5	
1487	8/3	Morjovi	packing band	1.0	blue	t	20	20.3		

(see footnotes on page 29)

Table 4.--Continued (footnotes).

[1]l = loose, m = moderately tight, t = tight, vt = very tight.
[2]This seal was tagged as a control July 15, 1989, at Reef; it became entangled since being tagged.
[3]Seals tagged with numbers 1351, 1352, 1358, 1373, 1376, 1382, 1395, 1407, 1431, 1451, 1452, and 1480 were larger than harvestable size and not counted in the calculation of the entanglement rate.
[4]Animal died during restraint to remove debris. Later examination showed that the debris had worn into the left humerus and bone tissue had grown over that part of the wound.
[5]This debris was a grey/white color.
[6]This seal was entangled in debris located around the ears and back of the head in several places making it difficult to estimate the extent of the wound. This animal was found dead on 1 Aug. 1990 on the Kitovi haulout. Necropsy showed that the debris had cut through the skull into the brain.
[7]The color of this webbing was a red-orange.
[8]This webbing was a combination of green and grey with mesh sizes of 23.5 and 22.2 cm. This seal had become entangled twice since there were two separate pieces of webbing.
[9]This debris was a combination of faded green and orange. This animal was later killed in the subsistence harvest on Zapadni, 2 Aug. 1990. Barnacles were noted on the debris.

that is subject to slight upward bias owing to the inclusion of tagged seals that may have grown to be too large to count. Even so, the 1990 rate of entanglement continues to be less than the observed rate of about 0.4% between 1976 and 1985 (Fig. 1, Fowler et al. 1990) but is slightly higher than the rates observed for 1988-89 (Table 5).

Compared to the 1976-86 rates, the relatively smaller proportion of entangled juvenile male seals continues to be attributed to a reduction in the fraction entangled in trawl webbing (Table 5). For the period 1982-86, the mean percent of seals entangled in trawl webbing was 0.27% (Fowler et al. 1990). In 1988, the percent entangled in trawl webbing dropped to 0.15%; a reduction to 56% of earlier levels (Fowler et al. 1990). This proportion remained low in 1989 (Fowler and Ragen 1990) and 1990 at about 0.12% (Table 5).

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 6 for each year since 1985. No roundups were conducted in 1987. A total of 129 tagged seals judged to be of harvestable size were tagged and released in 1989. Of these, 86 were controls and 43 were entangled when captured. In 1990, 26 of these controls (30.2%) were resighted. Eleven (25.6% of the original group of 43) of the seals tagged after removing their debris in 1989 were resighted in 1990. This implies an 85% resighting rate for disentangled seals after 1 year as compared to

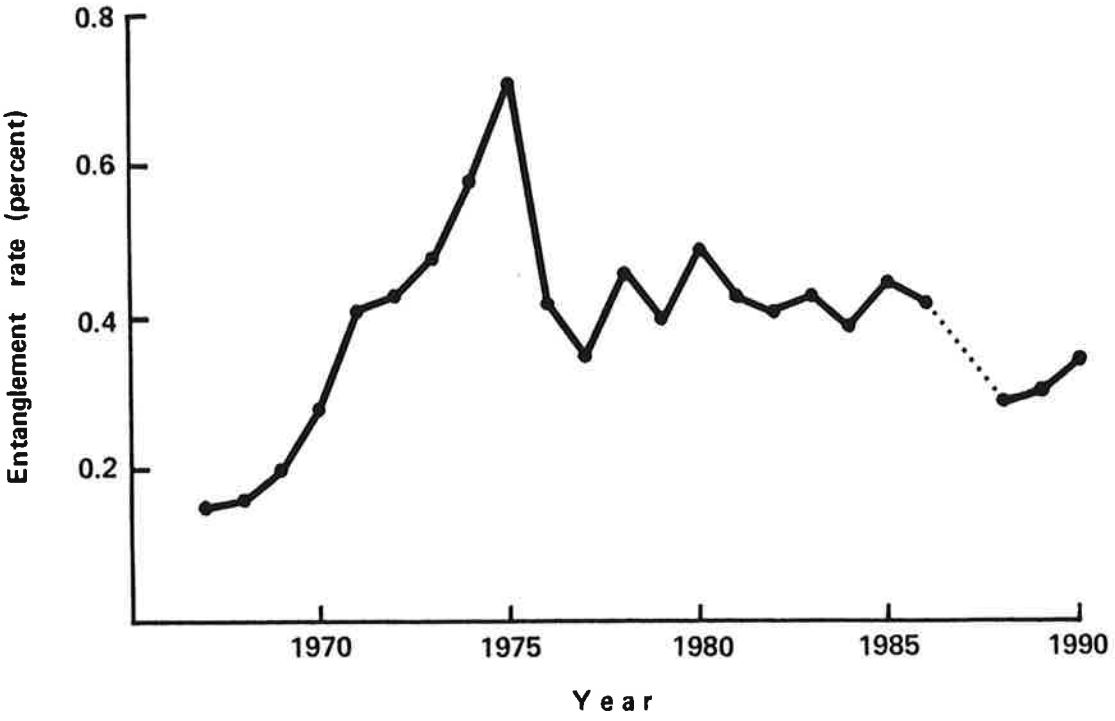

Figure 1. The percentage of juvenile male northern fur seals found entangled in the commercial harvest from 1967 to 1984 and in research roundups from 1985 to 1990, on St. Paul Island, Alaska (updated from Fowler and Ragen 1990).

Table 5.--Debris found on juvenile male northern fur seals in 1990, compared to seven earlier years, expressed as the observed percent of juvenile males entangled by debris category (data for 1982-89 from Fowler and Ragen, 1990)

Type of debris	Entanglement (%) 1982	1983	1984	1985	1986	1988	1989	1990
Trawl net fragments	0.24	0.30	0.22	0.36	0.27	0.15	0.12	0.11
Monofilament net fragments	0.01	0.01	0.02	0.01	0.01	0.00	0.02	0.01
Plastic packing bands	0.10	0.07	0.09	0.05	0.06	0.07	0.10	0.11
Chord, rope, string	0.04	0.02	0.05	0.08	0.07	0.05	0.06	0.07
Miscellaneous items	0.01	0.03	0.01	0.01	0.01	0.01	0.01	0.03
Total	0.41	0.43	0.39	0.51	0.42	0.28	0.30	0.33
Sample size*	102	112	87	76	70	53	47	71

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

Table 6.--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 1990, each row corresponding to the tags released in the first year for that row.*

Controls (Nonentangled)	Year 1985	1986	1987	1988	1989	1990
	(172)	37	-	13	8	7
		[21.5]	-	[7.6]	[4.7]	[4.1]
		(279)	-	40	32	25
			-	[14.3]	[11.5]	[9.0]
			-	-	-	-
			-	-	-	-
				(104)	20	11
					[19.2]	[10.6]
					(86)	26
						[30.2]
						(114)

Entangled	Year 1985	1986	1987	1988	1989	1990
	(85)	12	-	1	0	0
		[14.1]	-	[1.2]	[0]	[0]
		(128)	-	6	4	1
			-	[4.7]	[3.1]	[0.8]
			-	-	-	-
			-	-	-	-
				(52)	5	2
					[9.6]	[3.8]
					(43)	11
						[25.6]
						(57)

*Updated from Fowler et al. (1989).

the controls (25.6/30.2 = 0.85). 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 1990, 25 of 279 seals (or 9.0%) tagged as controls in 1986 were resighted. One seal (also observed in 1989 without its debris) was resighted out of a group of 128 animals tagged as entangled in 1986. The corresponding resighting rate is 0.8%, which is significantly different from the rate for controls (Chi-square test, $P < 0.05$).

No animals tagged as entangled in 1985 were resighted in 1990; however, seven controls from 1985 were resighted. This sample size is too small to test for a significant change from the original ratio of tagged entangled seals to controls for that year (Table 6).

Data for relative resighting rates of seals tagged in 1985, 1986, 1988, and 1989, and those seen in 1990, are shown in Figure 2 along with data from previous work (Fowler et al. in press, Fowler and Ragen 1990). The 1990 data for seals resighted from tagging in years up through 1988 (Fig. 2) are consistent with the results of earlier work (Fowler et al. in press).

Using methods developed in Fowler et al. (in press) and the data from Table 6 and Table 7 it is possible to estimate the effect on survival of entanglement in small debris (light enough for seals to return to the breeding islands). The estimated parameters are

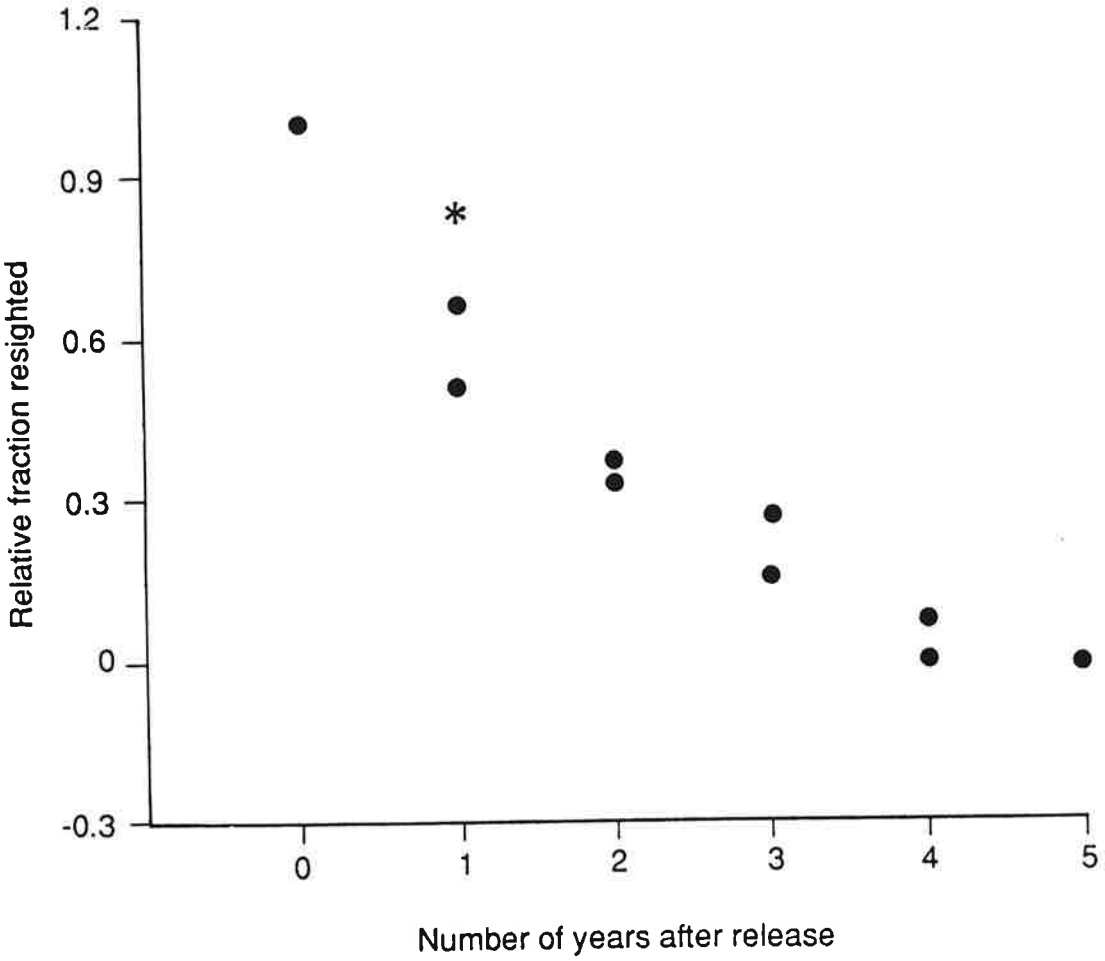

Figure 2. Relative rates of return for entangled juvenile male northern fur seals compared to controls (nonentangled tagged seals) for varying time intervals (Updated from Fowler and Ragen 1990, with the data from this report). Each data point represents the fraction of entangled seals resighted divided by the fraction of controls resighted (both from Table 6) 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 star corresponding to 1 year is the relative return rate for seals with debris removed in 1989 as observed in 1990.

Table 7.--List of data extracted from Table 6 for regression analysis to estimate entanglement related survival; for a linear model of y = a + bx. See Fowler et al. (in press) for details.

A Yr i	B Yr k	C[a] $N_{c,i}/N_{e,i}$	D ln(C)	E[b] $N_{e,ik}/N_{c,ik}$	F ln(E)	y D+F	x B-A
1985	1986	172/85	0.7048	12/37	-1.1260	-0.42	1
1985	1988	172/85	0.7048	1/13	-2.5649	-1.86	3
1985	1989	172/85	0.7048	0/8	-	-	4
1985	1990	172/85	0.7048	0/7	-	-	5
1986	1988	279/128	0.7792	6/40	-1.8971	-1.12	2
1986	1989	279/128	0.7792	4/32	-2.0794	-1.30	3
1986	1990	279/128	0.7792	1/25	-3.2189	-2.44	4
1988	1989	114/52	0.7849	5/20	-1.3863	-0.60	1
1988	1990	114/52	0.7849	2/11	-1.7047	-0.92	2

[a] $N_{c,i}$ = the number of seals tagged as controls in year i;
$N_{e,i}$ = the number of seals tagged as entangled animals in year i.
[b] $N_{e,ik}$ = the number of seals tagged in year i as entangled animals and resighted in year k (regardless of whether or not they were entangled when resighted), k > i;
$N_{c,ik}$ = the number of control seals tagged in year i and resighted in year k, k > i.

determined from regression analysis wherein the regression coefficient is the natural log of the survival (s_e) attributable to entanglement. For the data in Table 6 (excluding cases with no sightings for seals tagged as entangled; e.g., 1985 seals resighted in 1990), $\ln(s_e) = -0.6119$ ($R^2 = 0.919$, $P = 0.001$). The estimated survival of entangled animals from the effects of entanglement (i.e., the conditional probability of survival given survival from other natural effects) is thus 0.54 (calculated as $e^{-0.6119}$ with 95% confidence limits of 0.44 to 0.66).

A second approach to estimating survival simply involves making the assumption that the probability of resighting is the same for both categories of seals. This assumption is based on evidence presented in Fowler et al. (in press) and below, which indicates that seals entangled in debris small enough to allow their return to the island are sighted with probabilities that are statistically not significantly different from the probability of seeing a control. In this approach (explained in detail in Appendix I), the percent of the entangled seals resighted is divided by the percent of the controls resighted, and the ratio is raised to the power of 1/n where n is the number of years since the tagged seals were released. For example, the 1988 resightings involved 1 entangled seal and 13 controls from seals released in 1985. This is 1.2% of the 85 entangled and 7.6% of the controls (Table 6). The ratio of these percentages raised to the 1/3 power (to account for the 3 years between 1985 and 1988) is 0.54. 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 all the returns shown in Table 6 and a weighted mean found using the total sample of resighted seals from the corresponding year as weights (e.g., 14 seals from 1988 resighted in 1988). The weighted mean is 0.55 excluding the resightings of seals disentangled in 1989.

Thus, the cumulative data as presented in Table 6 and Figure 2, continue to show estimated annual probability of surviving entanglement of about 0.5 for seals entangled in small debris.

Characteristics of Entangling Debris

Because the debris was removed from the entangled seals in 1990 (as in 1989, but not in previous years of roundup studies), it was possible to directly determine weights of the debris. The size frequency distribution of the fragments of trawl webbing on seals is shown in Figure 3 for debris weights and in Figure 4 for mesh size. Specific weights and mesh sizes are listed in Table 4. These distributions are very similar to those seen in previous studies (Fowler 1987, and Fowler and Ragen 1990). 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 8).

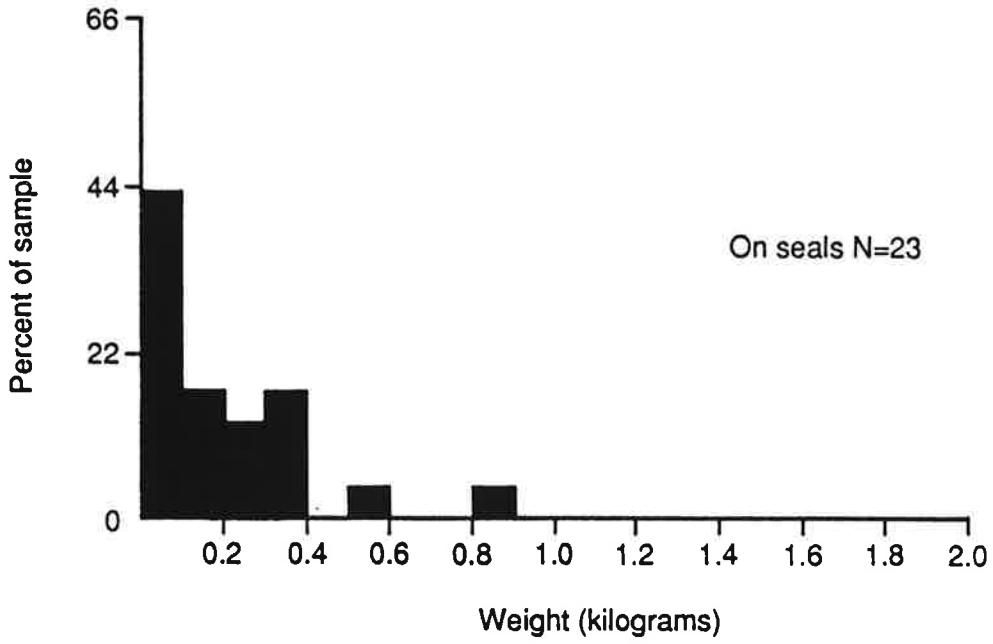

Figure 3. Size frequency distribution of trawl net debris found on entangled juvenile male northern fur seals, July and August 1990, St. Paul Island, Alaska (size measured in kilograms).

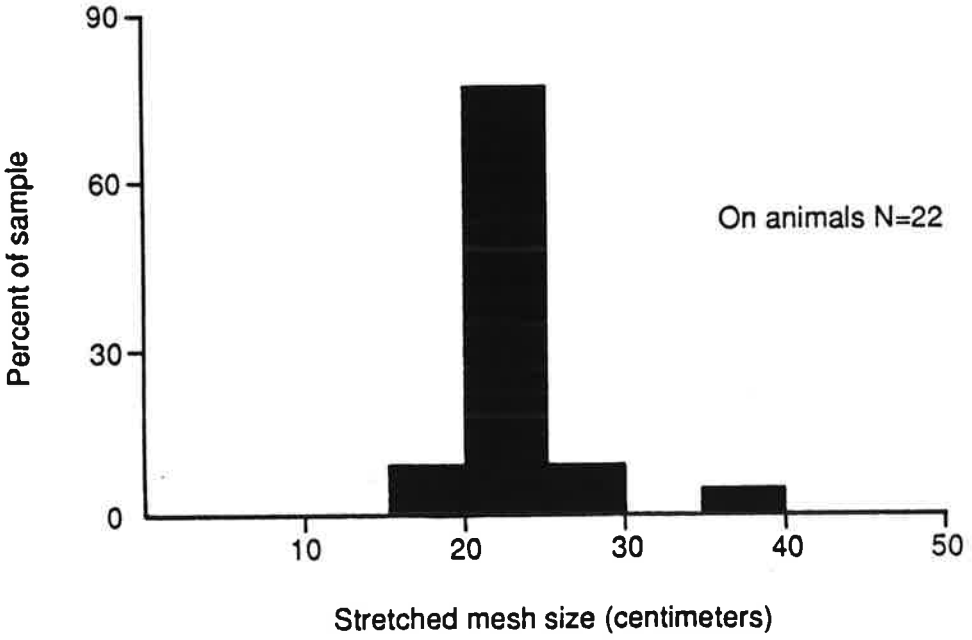

Figure 4. Size frequency distribution of trawl net debris found on entangled juvenile male northern fur seals, July and August 1990, St. Paul Island, Alaska (size measured as length of stretched mesh of trawl net fragments).

Table 8.--Annual percentage frequency distribution of the size of debris on 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)
Total	514	378(74)	94(18)	42(8)

Within Season Resighting Rate

Although the data for 1990 indicate a higher resighting rate for controls than for disentangled seals (Table 9), the more general picture from the collective results of 5 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. 1990). This resighted fraction has been close to 25% for previous years. With increased effort (sample size of 25,829 seals in 122 roundups) in 1990, the resighted fraction is larger for both groups. There is no statistically significant difference in the rates of resighting between the two groups (Chi-square test, $P = 0.543$).

Using the methods presented in Fowler et al. (in press) it is possible to estimate the relative rate of resighting with the data from Table 7. This approach is based on regression analysis wherein the intercept of the regression equation is the natural logarithm of the relative rates of resighting between entangled animals and controls. For the data in Table 7 (excluding cases wherein there are no resighted seals tagged as entangled; e.g., the entangled seals tagged in 1985 none of which were resighted in 1990) the intercept is estimated as 0.1615 ($R^2 = 0.919$, $P = 0.46$). These results imply that the ratio of the probabilities of being resighted is about 1.17 (calculated as $e^{0.1615}$, with 95% confidence limits of 0.70 to 1.99). The chances of being resighted after being tagged as an entangled animal, given that the animal has survived, are estimated to be about 1.17 times that of being

Table 9.--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)
Total	639	186(29.1)	298	81(27.2)

resighted as a control, but this does not differ significantly from 1.0 (i.e., equal probability of sighting controls or previously entangled seals, given their presence in the population).

Analysis of Wounds, Wound Growth and Related Survival

For most years since 1983, data have been collected on the size of wounds of entangled fur seals. These data have been documented in the reports presenting each year's results, but they have not been summarized. Table 10 is a compilation of data on wound development for entangled juvenile male seals. Eight of the 29 seals listed were first sighted with 360-degree wounds (i.e., the point of entanglement -- usually the neck -- was encircled). These wounds could encircle no more of the neck, of course, and could only get deeper if they grew. In one case, a wound may have partially healed over the debris (seal number 480 tagged in 1983). Such healing is occasionally observed on seals entangled with small pieces of monofilament. Of the remaining 21, only 3 did not develop wounds. The other 18 either developed wounds or had wounds that increased in size. Eight developed 360-degree wounds in 1 year's time after being first seen with no wound.

Table 11 presents the frequency of occurrence of wound size on entangled juvenile male northern fur seals seen from 1983 to 1990. Note that most seals either had no wounds (most of the category 0-90 were observed without wounds) or 360-degree wounds. Like the rapid development of wounds presented in Table 10, these results indicate that wounds develop rapidly once the skin has been broken.

Table 10.--List of juvenile male northern fur seals by tag number and wound size (in degrees), both at the time of tagging and at subsequent resightings, St. Paul Island, Alaska.

Year Tagged	Tag number	Degree of Wound at			
		tagging	1 year	2 years	3 years
1983	404	360		360	
1983	411	0	0		
1983	423	360	360		
1983	424	360		360	
1983	436	0	cut	360	
1983	442	270	360		
1983	444	0	360		
1983	464	270	360		
1983	468	0	360		
1983	471	0	0		
1983	472	0	360		
1983	480	360	180		
1983	487	0	360		
1983	497	360	bad cut		
1984	555	0	360		
1984	560	0	360		
1984	581	0	360		
1985	0019	180	360		
1985	0047	360	360		
1985	0065	360	360		
1985	0202	180	200		
1986	0352	220		360	
1986	5193	30		360	
1986	5137	360			360
1988	14	300	360		
1988	18	0	360		
1988	66	0	0		
1988	88	180	360		
1988	123	100	360		

Updated from Bengtson et al. (1988) and Stewart et al. (1989), using data from Scordino et al. (1988), Fowler et al. (1990), Fowler and Ragen (1990), and corresponding data files at the National Marine Mammal Laboratory.

Table 11.--Frequency of occurrence (with percentages in parentheses) of wounds in various size categories (from 0 to 360 degrees) for juvenile male northern fur seals seen in the commercial harvest (1983) and roundups (1985-90) for seals found entangled in marine debris.*

Size	1983	1984	1985	1986	1988	1989	1990	Total
0-90	69(72.6)	59(67.0)	50(65.8)	88(69.3)	29(53.7)	25(59.5)	35(50.0)	355(64.3)
91-180	4(4.2)	8(9.1)	5(6.6)	12(9.4)	3(5.6)	2(4.7)	2(2.9)	36(6.5)
181-270	3(3.2)	4(4.5)	2(2.6)	4(3.1)	3(5.6)	0(0.0)	4(5.7)	20(3.6)
271-360	19(20.0)	17(19.3)	19(25.0)	23(18.1)	19(35.2)	15(35.7)	29(41.4)	141(25.5)
Total	95	88	76	127	54	42	70	552

*Data for 1983 from Scordino et al. (1984), for 1984 from Scordino et al. (1988), for 1985 from Bengtson et al. (1988), for 1986 from Stewart et al. (1989), for 1988 from Fowler et al. (1990), for 1989 from Fowler and Ragen (1990), and for 1990 from this study.

Table 12 contains counts of seals listed in Table 11 that were seen again 1 year later. Each count is also presented as a percent of the total for the corresponding wound size category from the previous year (e.g. 16 of the 69 seals -- 23.2% -- in the 0-90 degree category for 1983 were seen in again 1984). There is not much change in the percent of survivors seen across wound-size categories when presented in this fashion, although a smaller fraction of seals with large wounds (271-360 degrees) were resighted than for the other categories. This is consistent with the view that seals with larger wounds tend to suffer higher mortality. The lower resight rate for the seals with no wounds is confounded by the fact that many are caught in large debris and most likely die from exhaustion before being seen again.

Miscellaneous Observations

Each year there are individual seals, items of debris, or circumstances of entanglement that are noted during the entanglement roundups. We report here a few that are particularly striking.

On two occasions animals tagged as controls in earlier years have been resighted as entangled later, however, none within the same season. The first of these occurrences was noted in 1989 when a seal tagged in 1986 (tag no. 360, tagged on 22 July at Kitovi) was seen again on 25 July 1988 at Morjovi as an animal entangled in 19.5 g of gray trawl webbing with a 360-degree wound. Since there was only one tag (worn) left from the 1986 tagging, this seal was retagged with a broad orange Allflex tag numbered 1270. The second

Table 12.--Numbers of seals listed in Table 11 that were resighted in the year subsequent to being tagged with the corresponding percentages (in parentheses) resighted.[a]

Size	1983	1984	1985	1986	1988	Total[b]
0-90	16(23.2)	12(20.3)	7(14.0)	5(5.7)	2(6.9)	42(14.2)
91-180	0(0.0)	2(12.5)	2(40.0)	0(0.0)	2(66.7)	6(18.7)
181-270	2(66.7)	0(0.0)	0(0.0)	1(25.0)	0(0.0)	3(18.8)
271-360	5(26.3)	2(11.8)	3(15.7)	0(0.0)	1(5.3)	11(11.3)

[a]Data for 1983 from Scordino et al. (1984), for 1984 from Scordino et al. (1988), for 1985 from Bengtson et al. (1988), for 1986 from Stewart et al. (1989), for 1988 from Fowler et al. (1990), for 1989 from Fowler and Ragen (1990), and for 1990 from this study.
[b]The total for each wound size from only 1983-88 were used to calculate the percent for the total since debris was removed from entangled seals in 1989 and 1990.

control seal to become entangled was tagged in 1989 (tag no. 1179, tagged on 15 July 1989 at Reef) and was resighted in 1990 on Reef, entangled in a white packing band. Of the 641 seals tagged as controls prior to 1990 (Table 6), these two seals represent 0.31%.

Entangled seals occasionally exhibit behavioral and physical features (e.g., pelt color, mane, or shape of head) of animals much older than would be consistent with their size. This was noted in 1990 for a seal entangled in a green packing band: tag no. 1320, tagged on 11 July 1990 on Zapadni. The same was noted for a seal seen on 22 July 1990 on Vostochni entangled in a combination of three kinds of debris (monofilament, twine, float line) with a wound that had partially healed over the debris. Scars had shown that the seal earlier had a 360-degree wound such that the seal may have been in the debris for longer than most seals under similar circumstances.

There is evidence that a few seals become entangled more than once. In 1990, this was seen for a seal found on a hauling ground at Reef on 27 July entangled in two pieces of trawl net. The debris were separate pieces: one green and the other gray with no connection to each other. Other animals show more than one scar or two or more wounds as was noted for three seals in 1990 (tag no. 1334, seen on 15 July at Reef; tag no. 1359 seen on 17 July at Zapadni Reef Sands; and tag no. 1372 seen on July 7 at Tolstoi Sands). In all such cases, it is possible that the second wound could have been formed by one piece of debris moving from one wound

to another. Such an explanation seems unlikely because debris in such deep wounds would have to pass over a part of the neck larger than the diameter of the debris.

Two seals encountered in 1990 had debris that had worn into bone tissue. A seal tagged with tag number 1357 on 17 July at Zapadni Reef Sands (in a 25.1 g piece of green trawl webbing) showed a 360-degree wound low on its neck. The animal died during restraint to remove the debris. Later examination showed that the debris had worn into bone near the shoulder joint and had partially healed over with new bone tissue. A second seal (tag no. 1436 disentangled and released on 7 July at Kitovi) was entangled in 0.1 g of monofilament webbing around the ears and back of the head in several places. This animal was found again, dead, 1 August also on Kitovi. Necropsy showed that the debris had cut through the skull into the brain leaving a notch in the skull about 5 cm in length, probably extending into brain tissue about 1 cm. Further details concerning these two cases will be developed in a separate publication.

A final observation concerns a seal seen on Northwest Point of Bering Island in the Commander Islands on 17 August 1989. This seal had been tagged on Morjovi (St. Paul) on 29 July 1988. At that time it had been entangled in a small piece of green trawl webbing and had a 360-degree wound. This seal was entangled when resighted and the debris (presumably the same seen in 1988) was removed.

DISCUSSION

Entanglement related field studies of juvenile male northern fur seals in 1989 and 1990 were different from those of earlier years in that debris was removed from entangled animals. Accounting for this difference, which is reflected in the resighting of disentangled animals, the entanglement rate continues to be lower than in years prior to 1987, but not quite as low as those observed in 1988 or 1989. The third year (1990) has provided convincing evidence that a change has occurred in the entanglement rate. These data are especially convincing since the reduction for each year is attributable to less entanglement in trawl webbing. An explanation for such a change can not be conclusively established at this time. However, the differences between the 1988-90 rates 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. Various education 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 1990 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. (in press), the animals that lose their debris are predominantly seals entangled in small debris (less than 150 g). This is one mechanism contributing to survival from entanglement. The results of the

1990 studies are consistent with this conclusion through the demonstration of increased survival of tagged seals from which debris was removed during the 1989 field studies.

SUMMARY

Entanglement research on juvenile males in 1990 demonstrated:

1) A continued reduction of the overall entanglement rate from about 0.4% (1975-86) to less than 0.34% in 1988 through 1990;
2) Entanglement in trawl webbing in 1990 was less than half of entanglement levels observed for this kind of debris in previous years (1981 to 1986) and very similar to that observed in 1988 and 1989;
3) The rate of resighting for animals tagged in 1986 showed that entangled animals tagged that year were seen at a rate that was significantly less than that for controls;
4) 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
5) There is evidence from the 1990 studies that the rate of return of tagged seals from which debris is removed is significantly higher than for tagged entangled seals.

A summary of accumulated data (i.e, including data beyond that collected in 1990) indicates that wounds tend to increase in size,

presumably contributing to the reduced survival that entangled seals experience. Sometimes these wounds increase to encompass 360-degrees in 1 year.

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APPENDIX

Estimation of Entanglement Related Survival

To make use of the data on the returns of juvenile male northern fur seals (i.e., those resighted) as shown in Table 6, we make a set of assumptions and define the following terms, as in Fowler et al. (in press). Let

$N_{c,ik}$ = the number of control seals tagged in year i and resighted in year k, where k > i (i = 1985, 1986, 1988; k = 1986, 1988, 1989, 1990);

$N_{e,ik}$ = the number of seals tagged in year i as entangled animals and resighted in year k (regardless of whether or not they were entangled when resighted), where k > i (i = 1985, 1986, 1988; k = 1986, 1988, 1989, 1990);

$p_{i,k} = N_{e,ik}/N_{c,ik}$, or the ratio of numbers of seals resighted in year k that were entangled when first tagged in year i to the numbers of nonentangled (control) seals tagged in year i and resighted in year k;

$s_{c,j}$ = the annual survival of control animals, or the animals tagged without debris in year j, for j from i to k (i.e., $s_{c,j}$ = survival from j to (j+1). This is the probability of avoiding natural causes of mortality during one year;

s_e = the conditional probability of surviving entanglement in small debris over 1 year's time given that an animal has survived natural causes of mortality. It is assumed to be independent of $s_{c,j}$ (so their total annual survival is $s_{c,j}s_e$) and to be constant from year to year;

$N_{e,i}$ = the number of seals tagged as entangled animals in year i (i = 1985, 1986, 1988); and

$N_{c,i}$ = the number of seals tagged as controls in year i (i = 1985, 1986, 1988).

In contrast to Fowler et al. (in press), we assume here that the same proportion of surviving entangled seals return to the islands to be seen when compared to surviving controls. For the purposes of developing the estimation procedure, this assumption will be implemented below; for now the proportions will be represented by separate variables. Thus, we define

f_{ek} = the probability of resighting a seal in year k given that it was entangled when tagged and that it is alive. This

probability is expressed on the basis of a unit of searching effort that is the same as applied in looking for control animals. It is assumed to vary from year to year, but not in relation to f_{ck} (below); and

f_{ck} = the probability of resighting a control animal in year k given that it is alive in the population, again as based on the unit of effort spent in searching for both control and entangled seals. This is also assumed to vary from year to year but not in relation to f_{ek} (f_{ek}/f_{ck} is assumed constant).

With these terms, the expected number of seals that were entangled when tagged and sighted in year k after being tagged in year i for one unit of effort is

$$E(N_{e,ik}|N_{e,i}) = f_{ek}\beta_k s_e^{(k-i)}N_{e,i}$$

(β_k is the product of $s_{c,j}$ for j from i to k),

and the expected number of controls for the same circumstances is

$$E(N_{c,ik}|N_{c,i}) = f_{ck}\beta_k N_{c,i}$$

(β_k is the product of $s_{c,j}$ for j from i to k).

Substituting the observed for the expected values we have the following moment estimators:

$$N_{e,ik} = f_{ek}\beta_k s_e^{(k-i)} N_{e,i}$$

and

$$N_{c,ik} = f_{ck}\beta_k N_{c,i}.$$

The ratio of these two equations, then, is

$$N_{e,ik}/N_{c,ik} = p_{i,k} = (f_{ek}/f_{ck})(N_{e,i}/N_{c,i}) s_e^{(k-i)}$$

which can be used to estimate f_{ek}/f_{ck} and s_e.

We note that variability in natural survival (i.e., the survival of the controls and that part of the survival of entangled animals from natural effects) can occur over time and not affect the calculation since these terms cancel in the formulation of the equation above. We also note that the probability of resighting animals from each of the two groups can vary from year to year as long as their ratio remains the same, as assumed above. Effort spent in resighting entangled and control seals is the same (the same roundups) but the number of roundups can vary each year. This is because effort for each of the two groups influences the above relationships only as a ratio in f_{ek}/f_{ck} (i.e., it cancels and need not be defined). By rearranging terms we have

$$p_{i,k}(N_{c,i}/N_{e,i}) = (f_{ek}/f_{ck})s_e^{(k-i)}.$$

At this point, the assumption of equal probability of being resighted is implemented, i.e., we assume that $(f_{ek}/f_{ck}) = 1.0$. The probabilities may vary from year to year, but are assumed to be the same within any year for each group. With this assumption, the above equation can be solved for s_e:

$$s_e = p_{i,k}(N_{c,i}/N_{e,i})^{1/(k-i)}.$$

This calculation can be carried out for each year (year k) with seals resighted from an earlier year (year i).