STUDIES OF THE EFFECTS OF NET FRAGMENT ENTANGLEMENT ON NORTHERN FUR SEALS PART 2: SWIMMING BEHAVIOR OF ENTANGLED AND NONENTANGLED FUR SEALS

Kazumoto Yoshida
Seikai National Fisheries Research Institute
Nagasaki, 850 Japan

Norihisa Baba, Masashi Kiyota
National Research Institute of Far Seas Fisheries
Fisheries Agency, the Government of Japan
Shimizu-shi, Shizuoka, 424 Japan

Masayuki Nakajima, Yasutoshi Fujimaki, and Akira Furuta
Izu-Mito Sea Paradise
Numazu, Shizuoka, 410-02 Japan

ABSTRACT

The effects of net fragment entanglement on the swimming behavior of fur seals were observed. Net fragments of six different weights (0.5 to 3 kg) were attached to the necks of eight fur seals, two males and six females, 4 to 9 years old. They were released in an aquarium pool with fish, and their swimming speed and time required to capture a fish were recorded. Of the eight individuals examined, three showed active feeding behavior. As the amount of attached net was increased, swimming speed decreased and more time was required for an entangled seal to catch a fish. Decrease in swimming speed was proportional to the relative load of net fragments (net weight/body weight).

INTRODUCTION

Marine debris is known to cause problems for various animals such as fish (High 1985), marine mammals (Calkins 1985; Henderson 1985), seabirds (Tull et al. 1972), and turtles (Balazs 1985; Cawthorn 1985). Many fur seals have been found on the breeding islands entangled in fishing net fragments and packing bands (Waldichuk 1978; Scordino 1985). Fowler (1982) noticed that entanglement probably was a cause of recent decline in the Pribilof population of the northern fur seal, *Callorhinus ursinus*. In order to understand the mechanism and impact of net entanglement on northern fur seals, the National Research Institute of Far Seas Fisheries has conducted various experiments at the Izu-Mito Sea Paradise, an aquarium, since 1983. The mechanism of entangling and influence of entanglement on activity patterns of fur seals were surveyed before (Yoshida et al. 1985,

In R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. 1990.

1990). In this study, experiments were conducted to understand the effect of net entanglement on swimming behavior of fur seals.

MATERIALS AND METHODS

Swimming speed and feeding behavior of net-entangled fur seals were observed in a pool of the Izu-Mito Sea Paradise in Numazu, Japan, from 27 January to 19 February 1986. The pool was 22 m wide, 10 m long, and 4 m deep (Fig. 1). The front of the pool was made of transparent plexiglass through which underwater movements of fur seals were observed. Trawl net fragments of six different weights were attached to the necks of eight fur seals, two males, and six females, estimated to be from 4 to 9 years old (Table 1). The nets used were gray trawl nets made of polyethylene, with a twine size of 3.4 mm and a mesh size of 24 cm. Specific gravity of the net was 0.77, which meant that a net fragment weighing 1 kg of air had a buoyancy of 340 g in seawater with a specific gravity of 1.03. Weights of the six fragments were 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 kg. As a control, free-swimming animals were also observed.

Experiments were conducted between 1600 and 1730 every day. Fur seals had not been fed since the previous day so that they would respond readily to food. Measurement of swimming speed was conducted in the following manner. One seal was released into the pool and lured to one corner by a display of food. Then a man showed a fish and threw it 8-10 m from the seal. When the seal started swimming after the fish, one observer recorded the time taken by the seal to swim a distance of 6 m. The distance was measured using the interval of frames supporting the glass wall. Each individual was tested using nets of two different weights per day. For each weight of net, an individual was obliged to swim eight times. One seal could make up to 16 swims in a day. If a seal would not chase a fish, it was removed from the pool and another individual was introduced.

Time to capture a fish was measured for the three seals which readily swam for a fish (M1, M2, and F1 in Table 1). Basic design of the experiment was the same as that for swimming speed measurement. Live sardine, *Sardinops melanostictus*, 12.5 to 15.0 cm in length and 15-29 g in weight, was used as bait and was thrown 8-10 m ahead of the seal. The time it took the seal to catch the fish was measured. Eight trials were made for each net weight, although the number was reduced when an animal with heavy entanglement looked tired.

To evaluate the effect of net entanglement on the basis of body weight, relative load of attached net was calculated:

$$\text{relative load} = \frac{\text{weight of attached net}}{\text{body weight of fur seal}} \times 100\ (\%)$$

During the experiment period, average air temperature was 7.1°C (1.1°-11.0°C), average water temperature was 12.7°C (12°-13.4°C), and average humidity was 57.4% (36-83%).

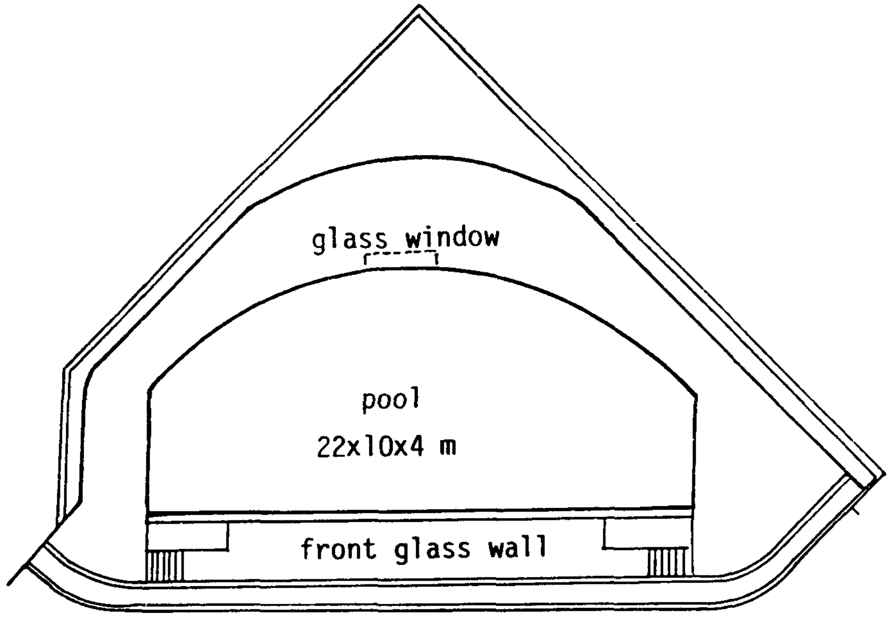

Figure 1.--The pool used in this study. Underwater movements of fur seals were observed through the glass wall.

RESULTS

Individuals Used in the Experiment

Of the six female fur seals used, only one individual (Fl) swam actively for fish. She chased fish a total of 32 times for swimming speed measurement, whether she was free-swimming or entangled in 0.5 to 1.5 kg of nets. Two other females (F3 and F5) swam only once or twice, even when they were free from nets. The remaining three made no attempt to swim after a fish. Two males (Ml and M2) tried to catch a fish in every case, whether free-swimming or entangled in up to 3.0-kg nets.

General Behavior

Fur seals often swam on their backs when they were free from entanglement, but entangled seals did not exhibit this type of swimming. All the seals tested were able to swim down to the bottom of the pool (4 m deep) in every degree of entanglement. When they chased a fish, they swam in the upper layer within 1 m of the surface. When entangled seals swam, their bodies twisted up and down. The body undulation was intensified as the amount of attached net was increased.

Swimming Speed

Swimming speed of the three fur seals (Ml, M2, and Fl), calculated from the amount of time it took them to pass the 6-m mark, decreased as the weight of attached nets increased (Table 2, Fig. 2). The average swimming speed of Ml without entanglement was 2.98 m/sec, but fell to 1.05 m/sec

Table 1.--Information on the fur seals used in the experiment.

		Capture			Age and size at experiment		
			Location				
Seal	Sex	Date	(Lat.)	(Long.)	Age (year)	Body length (cm)	Body weight (kg)
M1	M	July 1981	Robben Island		4	137	58.0
M2	M	4 Mar. 1982	36°34'N	141°14'E	4	132	54.0
F1	F	July 1981	Robben Island		4	120	23.0
F2	F	10 May 1980	37°57'N	142°14'E	6[a]	120	35.5
F3	F	8 Mar. 1982	36°26'N	141°06'E	6[a]	121	30.5
F4	F	4 Mar. 1982	36°42'N	141°15'E	9[a]	125	36.0
F5	F	8 Mar. 1982	36°27'N	141°10'E	8[a]	124	38.0
F6	F	9 Mar. 1982	36°30'N	141°16'E	7[a]	122	32.5

[a]Estimated age.

when 3-kg nets were attached. That of M2 decreased from 3.04 to 0.96 m/sec when 3-kg nets were loaded. For both M1 and M2, the speed was about one-third of that in a nonentangled state. The average swimming speed of F1 free from entanglement was 2.51 m/sec, but it fell to 0.73 m/sec when 1.5 kg nets were attached.

Figure 3 shows the relation between average swimming speed and relative load of net fragments. The relationship was similar for the three individuals. Swimming speed decreased in proportion to the relative load of attached nets. Linear regression of the relationship between relative load and swimming speed was

$$\text{swimming speed (m/sec)} = 2.26 - 0.25 \times \text{relative load (\%)} \qquad (r = -0.97)$$

Swimming speed of free-swimming animals was excluded from the regression.

Time Required to Capture a Fish

Table 3 shows the time it took for three seals, M1, M2, and F1, to capture a fish. F1 was not tested with net fragments heavier than 1.5 kg because that much weight seemed too heavy for her. The relationship between weight of nets and time required to capture a fish is shown in Figure 4. Although there was a considerable range, all three seals required more time to catch a fish as the amount of attached net was increased. For the three weights of nets examined, average capture time was the longest for F1. It was observed that when fur seals tried to catch a live fish, they approached the fish and turned their heads quickly to snap at it. Entangled seals had difficulty with the dash and snap.

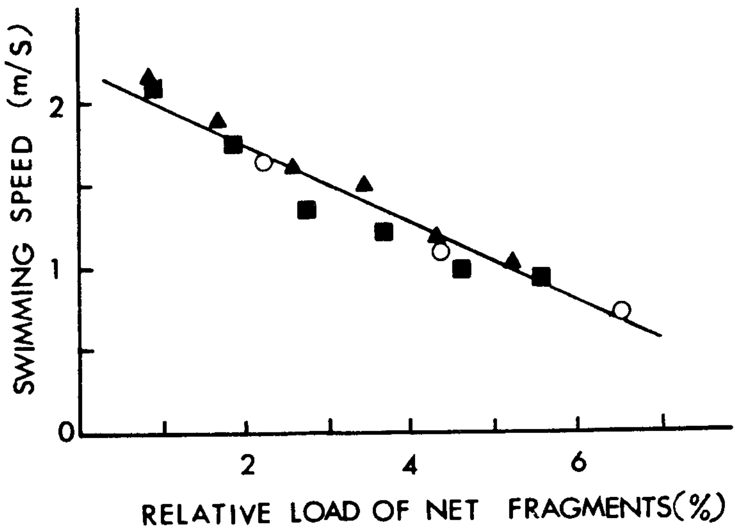

Figure 2.--Changes in swimming speed of three fur seals due to net entanglement. M1: ▲ M2: ■ F1: ○ .

Table 2.--Changes in swimming speeds (m/sec) of three fur seals due to amount of net entanglement. Speeds were calculated using the time it took the seals to swim a distance of 6 m.

	Weight of net (kg)						
Seal	0.0	0.5	1.0	1.5	2.0	2.5	3.0
				Swimming speed			
M1							
Mean	2.98	2.16	1.92	1.63	1.50	1.20	1.05
Minimum	2.72	2.06	1.71	1.50	1.39	1.11	0.95
Maximum	3.15	2.40	2.06	1.76	1.66	1.27	1.20
Standard error	0.14	0.11	0.13	0.10	0.08	0.06	0.08
Sample number	8	8	8	8	8	8	8
M2							
Mean	3.04	2.09	1.77	1.37	1.23	1.01	0.96
Minimum	2.60	1.87	1.66	1.25	1.13	0.93	0.82
Maximum	3.33	2.30	1.87	1.57	1.33	1.17	1.09
Standard error	0.29	0.15	0.07	0.10	0.07	0.07	0.11
Sample number	8	8	8	8	8	8	8
F1							
Mean	2.51	1.66	1.09	0.73	--	--	--
Minimum	2.30	1.50	0.90	0.58	--	--	--
Maximum	2.85	1.93	1.25	0.89	--	--	--
Standard error	0.23	0.16	0.15	0.12	--	--	--
Sample number	6	6	6	6	0	0	0

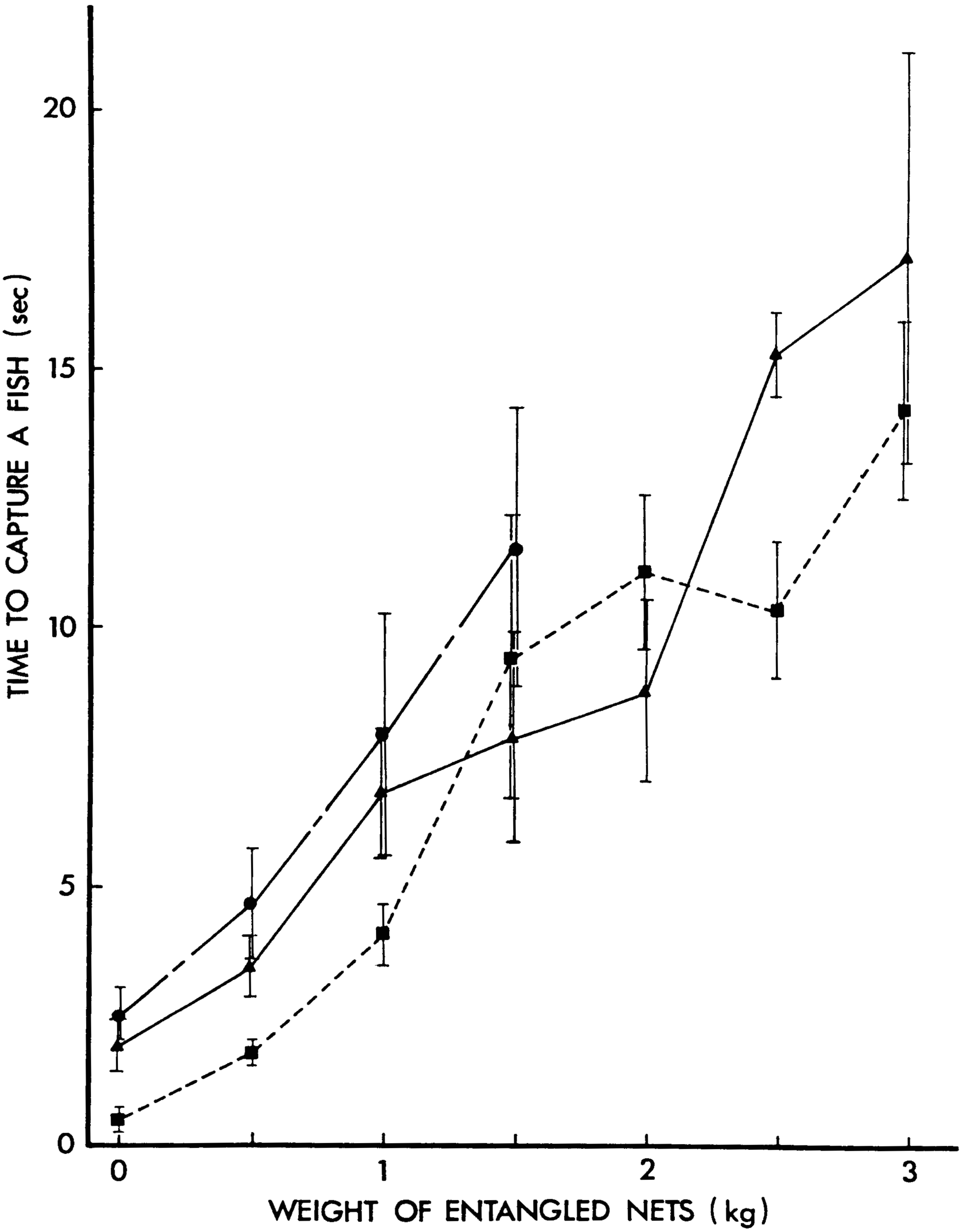

Figure 3.--Relationship between average swimming speed and relative load of attached net. M1: ▲——▲ M2: ■---■ F1: ●--●

Table 3.--Time to capture a live fish, *Sardinops melanostictus*, required by the three seals carrying different weights of nets.

	Weight of net (kg)						
Seal	0.0	0.5	1.0	1.5	2.0	2.5	3.0
				Capture time (seconds)			
M1							
Mean	18.1	34.1	68.1	78.8	87.8	152.8	171.6
Range	4-47	11-62	9-115	15-200	30-178	135-191	35-346
Standard error	5.2	5.9	12.1	21.0	17.3	8.0	39.4
Sample number	8	8	8	8	8	8	6
M2							
Mean	4.4	17.6	40.6	94.3	110.9	103.6	142.2
Range	3-5	9-30	15-71	12-247	58-180	67-150	76-210
Standard error	0.3	2.5	5.9	27.4	14.9	13.0	17.0
Sample number	8	8	8	8	8	6	6
F1							
Mean	25.1	46.3	79.0	115.3	--	--	--
Range	14-59	16-97	17-218	30-264	--	--	--
Standard error	5.3	10.7	23.7	27.0	--	--	--
Sample number	8	8	8	8	0	0	0

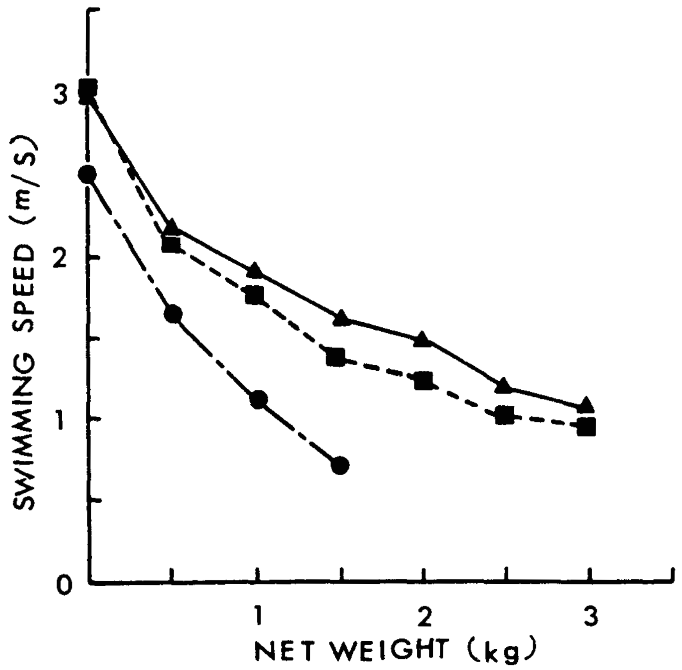

Figure 4.--Relationship between weight of nets and time required to capture a fish. Vertical lines indicate standard error. M1:▲——▲ M2:■---■ F1:●-·-● .

DISCUSSION

Of the eight animals used in these experiments, only three 4-year-olds, one female and two males, tried to capture a thrown fish. M1 and F1 were brought from Robben Island in 1981 as pups and were fed milk by men. All the other seals were caught pelagically. Difference in tractability of the seals might be derived from individual history as well as age, sex, hunger, and disposition.

Swimming speed of the entangled seals decreased as the weight of nets increased. Negative linear relation was observed between swimming speed and relative net load. Decrease in swimming speed might result from two physical forces of net fragments: buoyancy and drag. Buoyancy lifted the body at the neck and shifted the center of gravity. Buoyancy of nets is likely to hinder the dives of entangled seals although all the seals could dive to the bottom of the pool. Body undulation of entangled seals, which was observed when they swan, might be brought about by lifting of the neck caused by buoyancy. At the same time, swimming efficiency was reduced by the drag of the attached nets. These two forces would interfere with diving and swimming and would increase the energy expenditure of entangled seals.

Entangled seals took longer to capture a live fish as the weight of attached nets increased (Fig. 4). The increase in the capture time was derived from a decrease in swimming speed and hindrance of quick body motion. This result indicates that foraging efficiency of entangled seals will be lower than that of free-swimming seals. Heavily entangled seals should suffer from a large expenditure and a small intake of energy. Such an energy problem may be a cause of mortality of entangled seals as well as traumatic damage.

ACKNOWLEDGMENTS

We are grateful to the breeding technicians of the Izu-Mito Sea Paradise, who collaborated in the research, and to officials of the Fishing Ground Environment Conservation Division of the Fisheries Agency, the Government of Japan, who provided us with the opportunity to conduct this study.

REFERENCES

Balazs, G. H.
1985. Impact of ocean debris on marine turtles: Entanglement and ingestion. *In* R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii, p. 387-429. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Calkins, D. G.
1985. Steller sea lion entanglement in marine debris. *In* R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii, p. 308-314. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Cawthorn, M. W.
1985. Entanglement in, and ingestion of, plastic litter by marine mammals, sharks, and turtles in New Zealand waters. *In* R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii, p. 336-343. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Fowler, C. W.
1982. Interactions of northern fur seals and commercial fisheries. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:278-292.

Henderson, J. R.
1985. A review of Hawaiian monk seal entanglements in marine debris. *In* R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii, p. 326-335. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

High, W. L.
1985. Some consequences of lost fishing gear. *In* R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii, p. 430-437. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Scordino, J.
1985. Studies in fur seal entanglement, 1981-84, St. Paul Island, Alaska. *In* R. S. Shomura and H. O. Yoshida (editors), Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii, p. 278-290. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

Tull, C. E., P. Germain, and A. W. May.
1972. Mortality of thick-billed murres in the West Greenland salmon fishery. Nature (Lond.) 237:42-44.

Waldichuk, M.
1978. Plastics and seals. Mar. Pollut. Bull. 9:197.

Yoshida, K., N. Baba, M. Kiyota, M. Nakajima, Y. Fujimaki, and A. Furuta.
1990. Studies of the effects of net fragment entanglement on northern fur seal. Part 1: Daily activity patterns of entangled and nonentangled fur seals. *In* R. S. Shomura and M. L. Godfrey (editors), Proceedings of the Second International Conference on Marine Debris, 2-7 April 1989, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFSC-154. [See this document.]

Yoshida, K., N. Baba, M. Nakajima, Y. Fujimaki, A. Furuta, S. Nomura, and K. Takahashi.
1985. Fur seal entanglement survey report: Test study at a breeding facility, 1983. Background paper submitted to the 28th meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. National Research Institute of Far Seas Fisheries, Shimizu, Japan, 21 p.