DISTRIBUTION OF MARINE DEBRIS AND NORTHERN FUR SEALS IN THE EASTERN BERING SEA

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ABSTRACT

To obtain basic information about entanglement rate and mortality of the northern fur seal, *Callorhinus ursinus*, at sea, we conducted sighting surveys of fur seals and marine debris along eight transect lines in 1984 and four in 1985 and 1988 in summer near the Pribilof Islands in the eastern Bering Sea. These southeast to northwest transects were approximately 300-500 km long. We observed 710 fur seals and 7 debris items of fisheries origin in 1984, 345 seals and 17 debris items in 1985, and 343 seals and 18 debris items in 1988. In 1985, one dead male fur seal was observed entangled in a trawl net fragment weighing 40 kg. Distributions of both marine debris and fur seals were concentrated in the area along the continental slope west of the Pribilof Islands. It is considered that this co-occurrence is a result of the mutual relationship between fish resources, seals' feeding, fishing grounds of trawlers in the area, and northward-flowing current.

INTRODUCTION

Japanese trawlers began operating in the eastern Bering Sea in 1933 and other nations have begun fishing there later the U.S.S.R. in 1959, South Korea in 1968, Taiwan in 1974, Poland in 1979, and West Germany in 1980. The estimated total number of trawl-fishing vessels off Alaska increased from 5 in 1933 to 432 in 1963, and dropped to 317 in 1983 (Low et al. 1985).

At the 10th meeting of the North Pacific Fur Seal Commission (NPFSC), the survival rate of fur seals that were entangled in fishing net fragments was reported (NPFSC 1967). Since then, the United States has been actively collecting data on entanglement of fur seals (Scordino 1985). Japan-United States joint research started in 1983 (Bengtson et al. 1988; Scordino et al. 1988). The fur seal population on the Pribilof Islands has steadily declined since the 1960's, and entanglement of seals has been suggested as a partial cause (Fowler 1982).

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Merrell (1980) estimated that about 1,645 metric tons of plastic material were dumped into the Bering Sea and Aleutian Islands area each year in the 1970's. Dahlberg and Day (1985) encountered 0.356 trawl debris items per 1,000 km in the central North Pacific between Kodiak Island and Hawaii, whereas Jones and Ferrero (1985) found 1.349 pieces of trawl net debris per 1,000 km off the Aleutian Islands in the North Pacific. The common pelagic distribution of fur seals and marine debris has not, however, been studied at all. If the drifting routes and local accumulations of marine debris coincide with migration routes and feeding grounds of fur seals, the probability that seals will become entangled in marine debris will increase. The greater the density of marine debris, the greater will be the number of entangled seals. To properly assess the impact of entanglement on the fur seal population, the common distribution and density of fur seals and marine debris at sea must be known.

In this study, we conducted a sighting survey for fur seals and marine debris in the eastern Bering Sea in 1984, 1985, and 1988, and obtained basic information on the pelagic distribution of fur seals and marine debris.

MATERIALS AND METHODS

We conducted sighting surveys of northern fur seals and marine debris along eight transect lines from 13 July to 8 August 1984, four from 12 to 21 July 1985, and four from 10 to 23 July 1988 in the eastern Bering Sea using RV *Shunyo Maru* (Table 1). These southeast to northwest transects were approximately 300 to 500 km long. The survey areas made up of blocks measuring 30 min of latitude by 1 degree of longitude, were 248,845 km^2 in 1984, 152,937 km^2 in 1985, and 184,066 km^2 in 1988. In 1984, both western and eastern areas of the Pribilof Islands were surveyed, and in 1985 and 1988 only the western area was surveyed (Fig. 1).

Sightings were conducted by one or two people from the pilothouse and four or five people from the flying deck (8 m above sea level) on top of the pilothouse each day from sunrise to sunset. Observers were placed on both sides of the ship and surveyed the area on only one side. Each observer engaged in sightings for 4 h and rested for 1 h. Binoculars (7×50) were used only to confirm the kind and number of objects observed. We recorded the number, the time, and the location of fur seals and marine debris encountered. The speed of the ship during sightings was about 8 kn in 1984 and 1985 and about 10 kn in 1988. The ship's course was not changed except to collect debris of fishing origin such as fishing net fragments, plastic packing bands, floats, and ropes. When visibility dropped to less than about 200 m, the survey was interrupted.

In 1984 and 1985 we concentrated on sighting of fisheries-related debris; however, in 1988 we recorded all floating debris including Styrofoam, nylon bags, wood, and debris of fisheries origin. Because the debris surveys differed among years, we compared only the distributions and densities of fisheries-related debris.

Table 1.--Research period, area east or west of the Pribilof Islands, distance traveled, and number of fur seals and pieces of debris of fisheries origin observed.

Period	Days	Area	Distance traveled (km)	Number of fur seals observed	Number of pieces of debris of fisheries origin observed
13-19 July 1984	7	East	1,133	71	1
25 July-8 Aug. 1984	9	West	1,855	639	6
12-21 July 1985	9	West	1,892	345	17
10-23 July 1988	9	West	2,184	343	18

RESULTS

Distribution and Kinds of Debris of Fisheries Origin

In 1984, seven pieces of debris of fisheries origin were found: two on the continental shelf northwest of the Pribilof Islands, four near the continental slope southeast of the islands, and one to the south of St. George Island (Fig. 2A). In 1985, 17 pieces of debris of fisheries origin were found 2 on the continental shelf, 12 along the continental slope, and 3 northwest of Umnak Island (Fig. 2B). In 1988, 18 pieces of debris of fisheries origin were collected 2 on the continental shelf, 9 along the continental slope, and 7 southwest of the Pribilof Islands (Fig. 2C). Generally, debris items were found along the continental slope during the 3 years.

Debris of fisheries origin collected in 1984, 1985, and 1988 included trawl nets, gillnets, string, rope, floats, and plastic packing bands. Fifteen trawl net pieces collected ranged in weight and mesh size from 15 g, 7 cm to 40 kg, 20.5 cm; two gillnet pieces were similar at 1.75 kg, 11.7 cm and 1.8 kg, 11.5 cm. Three of four packing band pieces collected weighed 6.4 kg or more (Table 2). Trawl net accounted for 71.4% (five pieces) of all debris in 1984, 41.2% (seven pieces) in 1985 and 16.7% (three pieces) in 1988 (Table 3). Trawl net constituted the major part of the collection in 1984, floats in 1988.

Entanglement of Fur Seal

We found a dead male fur seal (110 cm long and weighing 20 kg), which we estimated to be 2 years old, entangled in a net fragment about 30 nmi southwest of St. Paul Island on 19 July 1985. The net fragment was gray trawl net weighing 40 km (mesh size 20.5 cm; twine size 7.6 mm).

Distribution of Fur Seals

The sighting frequency of fur seals (number of fur seals sighted per 1 km) was calculated for each block measuring 30 min of latitude by 1 degree of longitude.

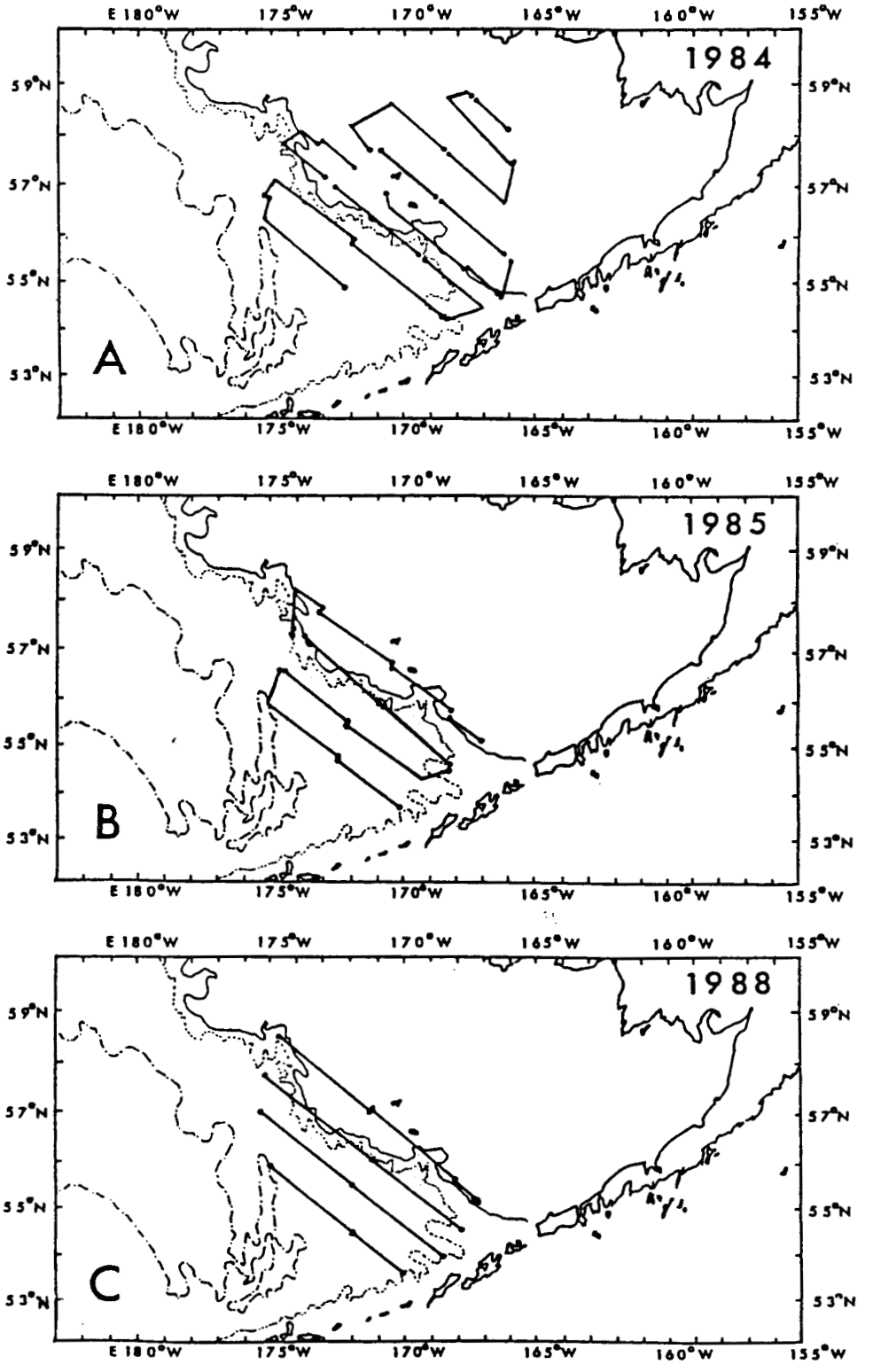

Figure 1.--Transect line surveyed in 1984 (A), 1985 (B), and 1988 (C) (—— = 100 fathoms, --- = 1,000 fathoms, — • — = 2,000 fathoms).

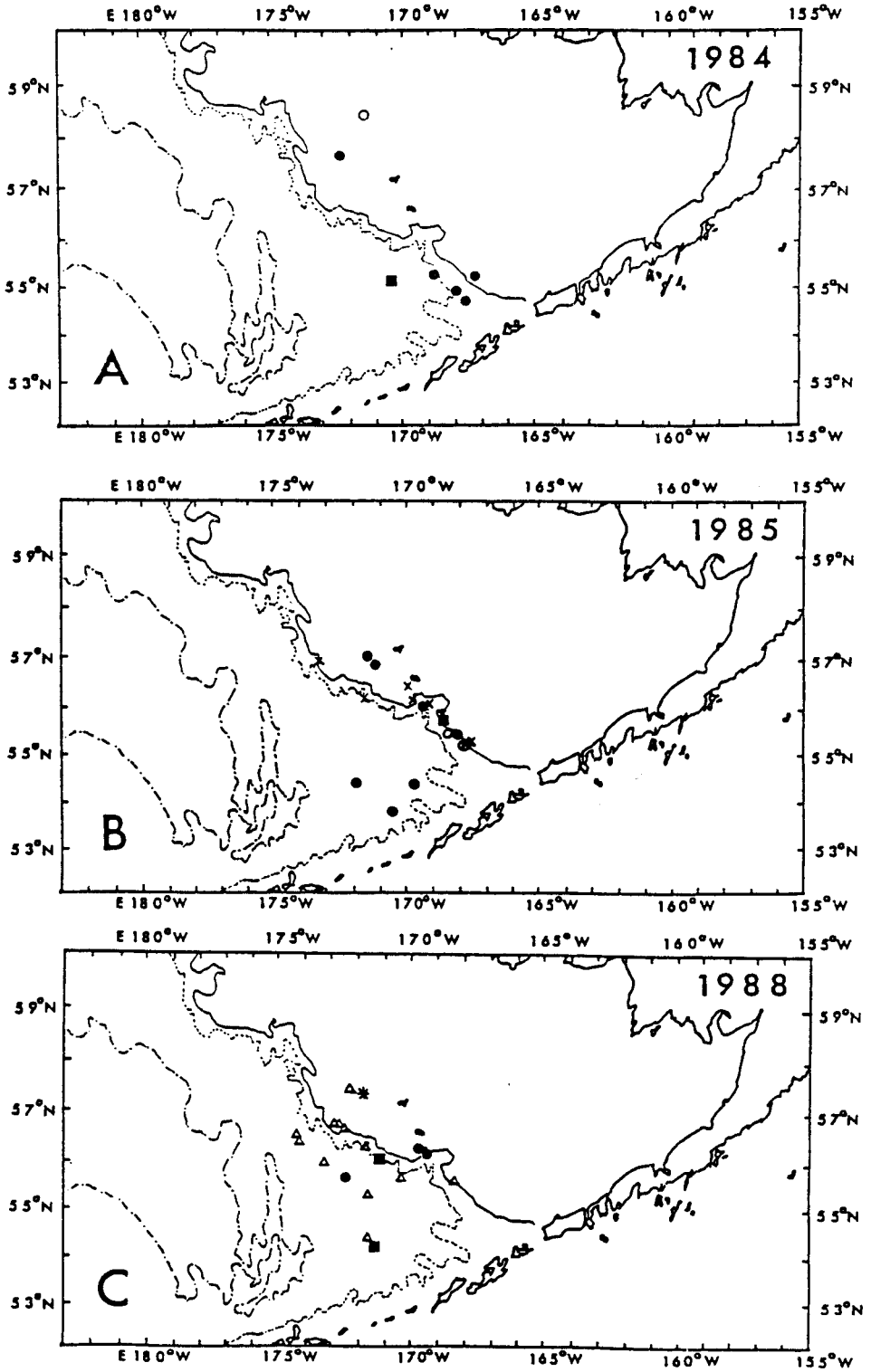

Figure 2.--Location of debris of fisheries origin.
• = trawl net, o = gillnet, ✳ = unidentified net,
⊗ = string, × = rope, Δ = float, ▪ = plastic packing band.

Table 2.--Kinds (PP = plastic packing band), date, location, and characteristics of fisheries-related debris observed on the line transect surveys, 1984, 1985, and 1988, in the eastern Bering Sea.

No.	Kinds	Date	Latitude N	Longitude W	Color	Weight (kg)	Mesh (mm)	Twine (mm)	Length (m)
1	Gillnet	14 July 1984	58°20′	171°26′	Green	1.8	115	0.5	--
2	Trawl net	25 July 1984	55°13′	167°18′	Blue	17.6	140	4.0	--
3	Trawl net	29 July 1984	57°34′	172°20′	Blue	3.0	130	5.0	--
4	Trawl net	5 Aug. 1984	54°40′	167°37′	Green	0.015	70	3.0	--
5	Trawl net	5 Aug. 1984	54°48′	167°55′	Orange	0.35	200	3.5	--
6	Trawl net	5 Aug. 1984	55°10′	168°43′	Green	1.15	135	4.0	--
7	PP band	6 Aug. 1984	55°04′	170°22′	Yellow	9.4	--	--	--
8	Trawl net	12 July 1985	53°43′	170°21′	[a]Green	--	--	--	--
9	Trawl net	12 July 1985	54°20′	171°45′	Green	6.4	155	3.0	--
10	Trawl net	15 July 1985	54°16′	169°31′	Gray	0.52	170	3.0	--
11	Trawl net	19 July 1985	57°02′	171°20′	Orange	2.9	125	6.0×4.5	--
12	Trawl net	19 July 1985	56°57′	171°07′	Gray	40.0	205	7.6	--
							114	3.4	--
13	Trawl net	20 July 1985	56°05′	169°12′	Green	0.07	--	4.2	--
14	Trawl net	21 July 1985	55°25′	168°01′	Orange	0.03	195	2.2×4.6	--
					Black		--	3.4	--
					Green	--	--	2.0×4.4	--
15	Gillnet	21 July 1985	55°25′	168°06′	Green	1.75	117	0.5	--
16	Rope	17 July 1985	56°09′	171°33′	White	0.71	--	18.5	2
17	Rope	17 July 1985	56°59′	173°18′	Yellow	0.2	--	25.0	1.3
18	Rope	20 July 1985	56°18′	169°49′	Yellow	4.8	--	18.0	20
19	Rope	20 July 1985	56°12′	169°31′	White	1.8	--	19.8	6
20	Rope	20 July 1985	56°03′	169°06′	Yellow	8.6	--	18.0	50
21	Rope	20 July 1985	55°50′	168°32′	Yellow	2.0	--	17.4	13
22	Rope	21 July 1985	55°13′	167°27′	Yellow	0.1	--	12.4	1
23	String	21 July 1985	55°16′	167°34′	Orange	0.02	--	3.0×5.0	2
24	PP band	20 July 1985	55°50′	168°32′	White	0.01	--	--	2
25	Net	17 July 1988	57°17′	171°58′	(a)	--	--	--	--
26	Trawl net	12 July 1988	55°32′	172°25′	Gray	--	--	--	--
27	Trawl net	23 July 1988	56°06′	169°19′	Orange	0.82	129	5×3	--
28	Trawl net	23 July 1988	56°13′	169°32′	Orange	0.75	195	5×3	--
29	Float	10 July 1988	54°17′	171°41′	--	--	--	--	--
30	Float	12 July 1988	56°28′	174°18′	--	--	--	--	--
31	Float	12 July 1988	56°29′	174°18′	--	--	--	--	--
32	Float	12 July 1988	55°59′	173°13′	--	--	--	--	--
33	Float	13 July 1988	55°16′	171°40′	--	--	--	--	--
34	Float	15 July 1988	55°39′	170°21′	--	--	--	--	--
35	Float	16 July 1988	56°14′	171°42′	--	--	--	--	--
36	Float	16 July 1988	56°34′	172°28′	--	--	--	--	--
37	Float	16 July 1988	56°44′	172°47′	--	--	--	--	--
38	Float	16 July 1988	56°44′	172°48′	--	--	--	--	--
39	Float	17 July 1988	57°28′	172°21′	--	--	--	--	--
40	Float	23 July 1988	55°37′	168°18′	--	--	--	--	--
41	PP band	10 July 1988	54°09′	171°24′	Yellow	6.4	--	--	[b]Roll
42	PP band	15 July 1988	56°01′	171°11′	Yellow	6.4	--	--	[b]Roll

[a]Not collected.
[b]The roll of plastic packing band was estimated to be >100 m.

Table 3.--Kinds, number, and percent of fisheries-related debris pieces collected during line transect surveys in 1984, 1985, and 1988 in the area west of the Pribilof Islands.

Kind		1984	1985	1988	Total
Trawl net	No.	5	7	3	15
	%	(71.4)	(41.2)	(16.7)	(35.7)
Gillnet	No.	1	1	0	2
	%	(14.3)	(5.9)	(0.0)	(4.8)
Unidentified net	No.	0	0	1	1
	%	(0.0)	(0.0)	(5.6)	(2.4)
Float	No.	0	0	12	12
	%	(0.0)	(0.0)	(66.7)	(28.6)
Rope	No.	0	7	0	7
	%	(0.0)	(41.2)	(0.0)	(16.7)
String	No.	0	1	0	1
	%	(0.0)	(5.9)	(0.0)	(2.4)
Plastic packing band	No.	1	1	2	4
	%	(14.3)	(5.9)	(11.1)	(9.5)
Total	No.	7	17	18	42

In July 1984, we surveyed the area east of a line extending through St. George and St. Paul Islands. Most blocks showed fewer than 0.3 seal/km or showed no seals in this area.

In August 1984 and in July 1985 and 1988, we surveyed the area west of same line. In August 1984, more than 0.3 seal/km were seen in many blocks along the continental slope, and southwest of the islands over 0.9 seal/km were seen. No seals were found to the southeast or over the continental slope (Fig. 3A). Mean frequency of seals in all blocks west of the islands was greater than to the east, differing significantly ($t = 4.7528$, $P < 0.0001$).

In July 1985, we found fur seals mainly on the continental shelf and along the continental slope. Frequencies of over 0.6 seal/km occurred in two blocks to the northwest and southwest of St. Paul Island (Fig. 3B). Mean frequency of seals of this year was less than in August 1984, differing significantly ($t = 2.449$, $P < 0.005$).

In July 1988, we found frequencies greater than 0.3 seal/km only on the continental shelf and along the continental slope within about 200 km of the Pribilof Islands. Frequencies were greater than 0.9 seal/km in two

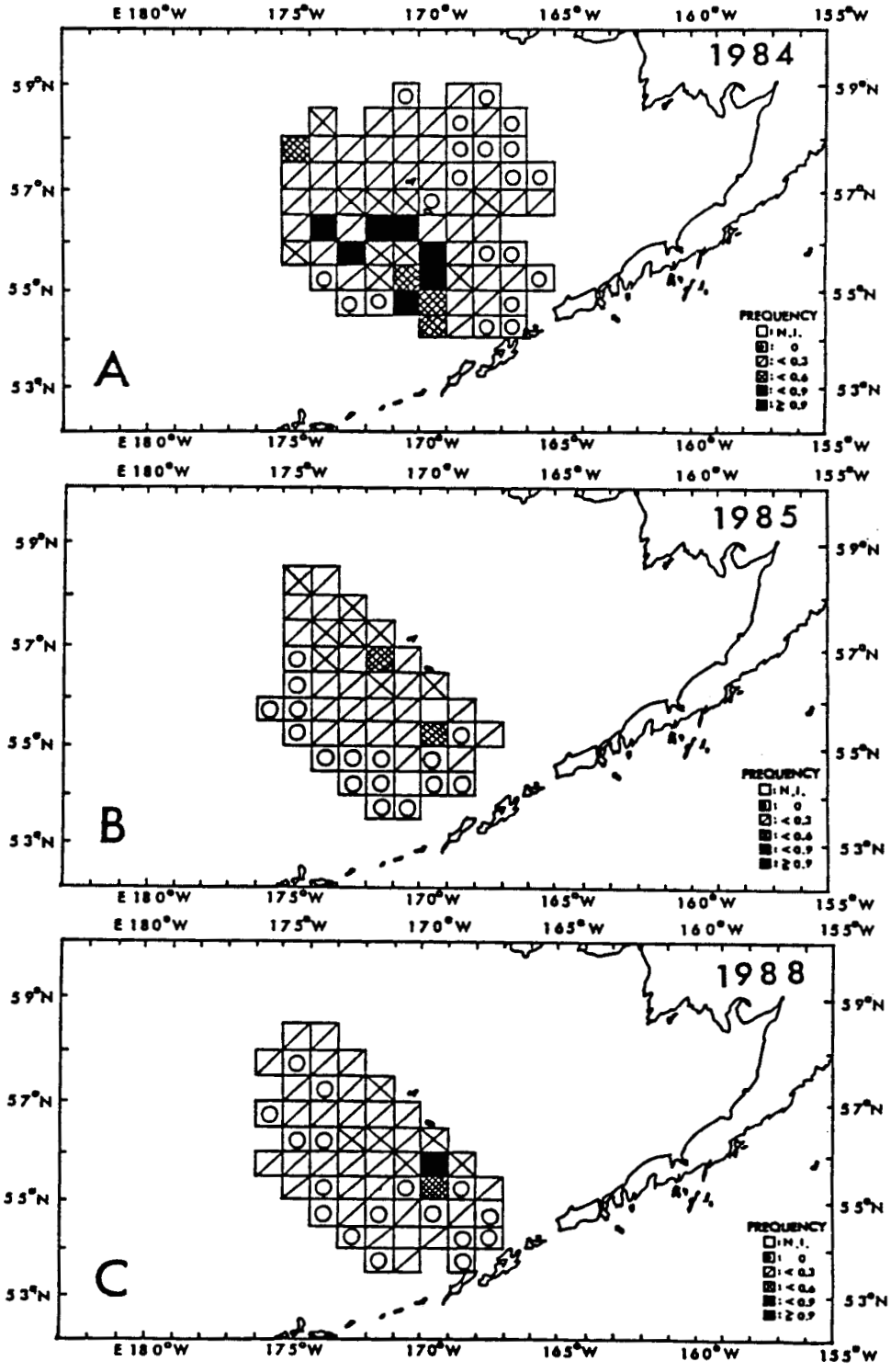

Figure 3.--Sighting frequency of fur seals per block measuring 30 min of latitude by 1 degree of longitude including transect line. Frequency equals the number of fur seals sighted per 1 km of research distance. (NI = not investigated.)

blocks along the continental slope south of St. George Island. Generally we saw no seals near the northwestern and southeastern ends of the continental slope or along the southwestern edges (Fig. 3C). Mean frequency of seals this year was almost the same as in July 1985, not significantly different ($t = 0.6499$, $P > 0.006$).

Coincident Sightings of Fur Seals and Fisheries-Related Debris

The sighting frequencies of fur seals in coincidental areas surveyed in 1984, 1985, and 1988 were 360.4/1,000 km in 1984, 211.0/1,000 km in 1985, and 197.8/1,000 km in 1988, whereas the densities of debris (of fisheries origin only) were 2.561/1,000 km in 1984, 7.975/1,000 km in 1985, and 9.798/1,000 km in 1988 (Table 4).

DISCUSSION

Most female fur seals at St. Paul Island deliver pups in July. After a perinatal fast of 8-10 days, they go to sea to feed for 4- to 10-day periods punctuated by 1-2 days of nursing their pups. Feeding trips lengthen as pups age until they are weaned at about 120 days postpartum (Peterson 1968). York and Kozloff (1987) reported that the number of newborn pups on St. Paul Island did not change greatly between 1981 and 1986. Therefore, we believe that the greater number of fur seals sighted in 1984 was due to the later survey period (late July-early August) and consequent greater proportion of lactating females at sea then, compared with 1985 and 1988 when surveys were in early to mid-July.

In all years, we found most seals near the continental slope in the eastern Bering Sea. Echo soundings of fish biomass, which we conducted simultaneously with transect surveys, indicated that the walleye pollock, *Theragra chalcogramma*, biomass was greatest in that area (Harada et al. 1985). Kajimura (1984) reported that fur seals in the Bering Sea ate mostly capelin, *Mallotus villosus*, and walleye pollock in July and August.

Table 4.--Sighting frequency of fur seals and fisheries-related debris (fishing nets, rope, string, plastic bands, floats) observed on the line transect surveys in 1984, 1985, and 1988 west of the Pribilof Islands.

Period	Research distance (km)	Seals	Debris	Frequency per 1,000 km	
		No.	No.	Seals[a]	Debris[b]
25 July-8 Aug. 1984	1,562	563	4	360.4	2.561
12-21 July 1985	1,630	344	13	211.0	7.975
10-23 July 1988	1,633	323	18	197.8	9.798

[a]Number of seals divided by research distance.
[b]Number of debris items divided by research distance.

Trawl-net fisheries for those species also operate primarily along the continental shelf and the continental slope in the eastern Bering Sea (Mito 1986), also suggesting that the greatest fish biomass is concentrated there. We believe that our observations showing most marine debris and most fur seals concentrated in the area from the continental shelf to the continental slope west of the Pribilof Islands are related to the concentration of prey resources and marine debris (e.g., fishing net, plastic packing bands) in that area and to the northward currents along the continental slope (Favorite et al. 1976) which act to concentrate debris there.

As fur seals migrate in winter from the Pribilof Islands to as far south as Mexico in the eastern Pacific (lat. 32°N) (Kajimura and Loughlin 1988), we feel that it is important to conduct surveys in waters off British Columbia, Washington, Oregon, and California in the future to ascertain the distribution and abundance of marine debris and fur seals there.

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