# TYPE, SOURCE, AND ABUNDANCE OF TRAWL-CAUGHT MARINE DEBRIS OFF OREGON, IN THE EASTERN BERING SEA, AND IN NORTON SOUND IN 1988

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## ABSTRACT

In 1988, National Marine Fisheries Service scientists collected information on type, source, and abundance of marine debris caught during annual bottom trawl surveys off Oregon, in the eastern Bering Sea, and in Norton Sound. Numbers of individual debris items caught were tallied by haul. When possible, the nationality of origin was determined. Animals entangled or associated with debris items were noted. Debris items were categorized by material (e.g., plastic, glass) and use (e.g., galley wastes, fishing equipment). Effort in square kilometers trawled was calculated for each haul from distance fished and average net width measurements. Average catch-per-unit-effort (CPUE) in numbers of items per square kilometer was calculated for individual debris items, major categories, and total debris by area and for combined areas.

Of the 696 hauls surveyed, 70 were off Oregon, 541 in the eastern Bering Sea, and 85 in Norton Sound. Marine debris was most abundant off Oregon, occurring in 70% of the hauls and averaging 149.6 items/km$^2$. In the eastern Bering Sea, 23% of the hauls caught marine debris, for an average of 7.5 items/km$^2$. Norton Sound had the least amount of debris. It occurred in 7% of the hauls and averaged 1.9 items/km$^2$. Galley wastes dominated debris in Oregon (64% of the total CPUE) and in the eastern Bering Sea (40% of the total CPUE), followed by engineering/processing wastes. Fishing equipment debris was abundant in the eastern Bering Sea (1.86 items/km$^2$) and off Oregon (1.69 items/km$^2$), but was not found in Norton Sound. Plastic debris was found in all three areas, but was most abundant in the eastern Bering Sea. Debris of foreign origin accounted for 70% of the total CPUE of all debris found in the eastern Bering Sea; however, domestic debris dominated off Oregon (88% of the total CPUE) and in Norton Sound (100% of the total CPUE).

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*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.

## INTRODUCTION

Marine debris, particularly plastic debris, has been identified as a potential threat to the marine environment world wide (Pruter 1987). To determine the magnitude of the problem, scientists must document the effects and abundance of different types of debris in the marine environment. Educators need to know the probable sources of marine debris in order to direct information campaigns at the proper audiences.

Prior to 1985, the majority of information about marine debris was anecdotal. Few studies presented scientific evidence on the abundance of marine debris or its effects on the marine environment. Recently, studies have reported on the effects of marine debris on marine mammals (Fowler 1988), marine birds (Day et al. 1985), marine turtles (Balazs 1985), and other marine wildlife (Pruter 1987).

While several studies have attempted to estimate the abundance of debris in the marine environment from at-sea disposal rates (Horseman 1982), few studies have addressed the abundance of marine debris using systematic methods. Quantitative surveys of marine debris deposited on beaches in Alaska have been conducted since 1980 (Merrell 1980; Johnson 1988). At-sea surveys have quantified floating debris in the North Pacific since 1977 (Shaw 1977; Dixon and Dixon 1983; Yagi and Nomura 1988). Berger and Armistead (1987) reported the number of pieces of net material caught in trawl nets deployed by foreign fishing vessels in the exclusive economic zone off Alaska between 1982 and 1984.

This study presents baseline information on the type, probable source, and abundance of marine debris caught on the seabed during bottom trawl surveys off Oregon, in the eastern Bering Sea, and in Norton Sound off Alaska during 1988.

## METHODS

### Survey Areas and Sampling Design

Marine debris was sampled by National Marine Fisheries Service (NMFS) scientists from bottom trawl hauls conducted during 1988 off the coast of Oregon in November-December, in the eastern Bering Sea from May to August, and in Norton Sound during August. A total of 696 hauls were completed covering 33.1 $km^2$ over a combined survey area of 907,851 $km^2$ (Table 1).

Seventy hauls were conducted between 45 and 110 km off the coast of Oregon between lat. 44° and 45°30'N and from 100 to 675 m deep (Fig. 1). The survey area off Oregon encompassed 7,230 $km^2$, of which 2.7 $km^2$ was actually covered by bottom trawls (Table 1).

In the eastern Bering Sea, 541 hauls were conducted from the 20 m isobath on the Alaskan coastline out to the 500 m isobath on the continental slope and north from the Alaska Peninsula to Saint Lawrence Island. Stations were sampled at the centers of 37 × 37 km (20 × 20 nmi) grids. The survey area encompassed an area of 858,941 $km^2$, of which 26.2 $km^2$ was

Table 1.--Survey area (square kilometers) and sampling density for marine debris during the NMFS bottom trawl survey off Oregon, in the eastern Bering Sea, and in Norton Sound, 1988.

| Area | Effort | | | | | |
|---|---|---|---|---|---|---|
| | Area encompassed by survey ($km^2$) | Area covered by trawls ($km^2$) | Percent area sampled | Total number of hauls | Number of hauls with debris | Percent hauls with debris |
| Oregon | 7,230 | 2.7 | 0.037% | 70 | 49 | 70% |
| Eastern Bering Sea | 858,941 | 26.2 | 0.003% | 541 | 122 | 23% |
| Norton Sound | 41,680 | 4.2 | 0.010% | 85 | 6 | 7% |
| Total | 907,851 | 33.1 | 0.004% | 696 | 177 | 25% |

actually covered by trawl hauls. Because of differences in sampling density, the eastern Bering Sea survey area was divided into four subareas. The four subareas for analysis were the north-south shelf and slope (Fig. 2).

Eighty-five hauls were conducted in Norton Sound between the 7 and 20 m isobaths (Fig. 2). The Norton Sound survey area encompassed 41,680 $km^2$ and a total of 4.2 $km^2$ was actually surveyed.

Trawls were towed on the bottom for approximately 0.5 h at each station at a towing speed of about 5.6 km/h (3 kn). For each haul, location, depth, and distance fished were recorded. The effective path width of the trawl net on the bottom was estimated using a sonar measuring device on a subset of hauls during each survey.

Catches of 1 metric ton or less were entirely sampled. Larger catches were weighed and subsampled, and numbers of marine debris items extrapolated to the total catch. Marine debris items in the catch or subsample were sorted by type of material: plastics, glass, rubber, metal, wood, paper, cloth, and other. Debris items were also described as accurately as possible, such as "plastic strapping band" or "metal beverage can." The number of each of the items caught was recorded on a tally sheet and the vessel, cruise, and haul number indicated. When possible, the U.S. or foreign original of an item was indicated and the percent of all items from U.S., foreign, and unknown sources indicated on each haul tally sheet. The number of entangled animals was recorded by species and debris item. A complete description of NMFS sampling procedures is provided by Wakabayashi et al. (1985).

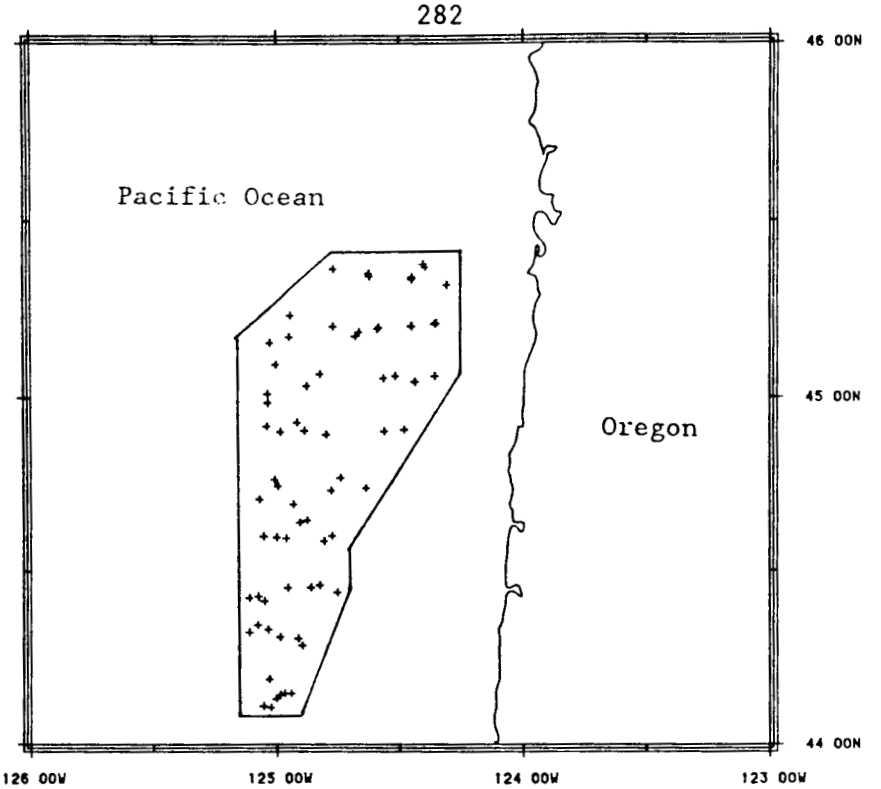


Figure 1.--Area surveyed and station locations sampled for marine debris during the National Marine Fisheries Service bottom trawl survey off Oregon, 1988.

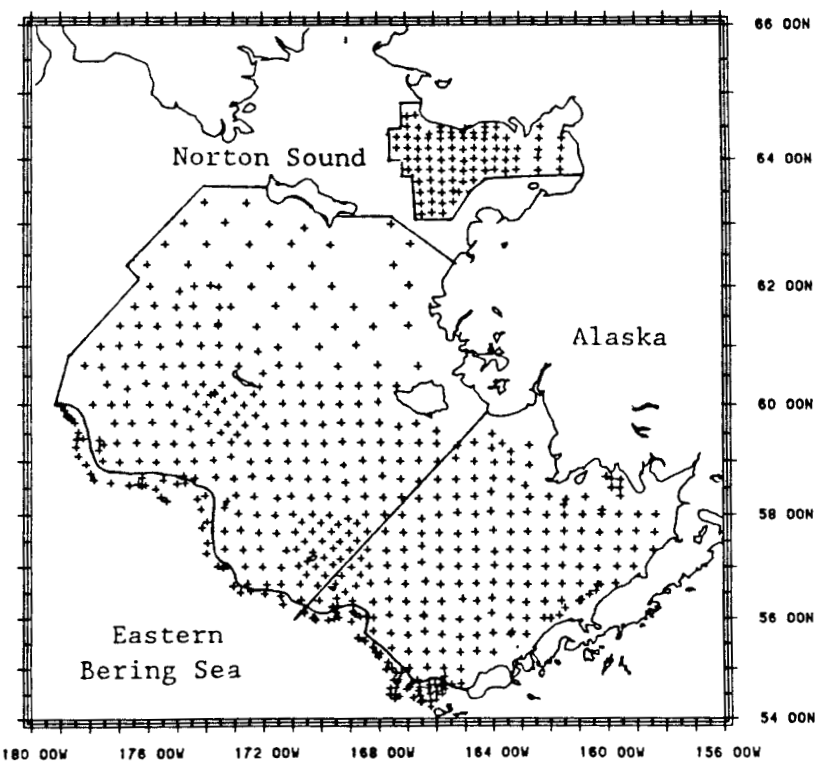


Figure 2.--Area surveyed and station locations sampled for marine debris during the National Marine Fisheries Service bottom trawl survey in the eastern Bering Sea and Norton Sound, 1988.

## Vessels and Fishing Gear

The survey off the coast of Oregon was conducted aboard the 64.6 m NOAA ship *Miller Freeman* using two nets, a modified Nor'eastern trawl and a poly-Nor'eastern trawl. The mean effective path width of the poly-Nor'eastern trawl was estimated to be 14.7 m and the modified Nor'eastern 16.4 m. The eastern Bering Sea survey was conducted using three vessels: the *Miller Freeman*, the 30.5 m RV *Alaska*, and the 37.5 m MV *Morning Star*. Two nets were used during the survey, the eastern trawl, with an estimated mean effective path width of 17.0 m, and the modified Nor'eastern trawl used on the Oregon survey. The *Miller Freeman* conducted the Norton Sound survey with the eastern trawl used in the eastern Bering Sea survey. The eastern trawl had 10.2 cm (4 in) mesh in the wings and body, 8.9 cm (3.5 in) mesh in the cod end, and a 3.2 cm (1.25 in) cod end liner. The modified and poly-Nor'eastern had construction similar to the eastern trawl except for 12.7 cm (5 in) mesh in the wings and body.

## Data Analysis

It was assumed all debris 6.5 $cm^2$ (1 $in^2$) and larger lying on the surface of the bottom and within the mean effective path width of each net was caught with equal efficiency by each net. This assumption may not necessarily be valid for all hauls, since different nets and different towing conditions can affect the ability of the net to catch objects on the bottom. However, since the NMFS has standardized fishing gear and methods used during most of its annual resource assessment surveys, results obtained from the 1988 surveys should be comparable to future surveys using the same gear and techniques. A second assumption was that scientists identified all of the marine debris caught in each haul.

Marine debris items were grouped by use and by material of composition. Use categories included galley waste, personal use waste (e.g., deodorant tubes, gloves, lighters), fishing gear, engineering and fish processing waste, and other unidentified use waste. Material categories included plastic, glass, rubber, metal, wood, paper, and other. Numbers of items caught were summed by use and material categories by haul and by combinations of the two categories, such as plastic galley waste or metal engineering and processing waste.

The effort expended in each haul was calculated in square kilometers by multiplying the distance fished in each haul by the effective path width of the net. The numbers of individual and grouped marine debris items caught in each haul were divided by the effort to give catch-per-unit-effort (CPUE) in numbers of items per square kilometer for each haul. Mean CPUE per haul was calculated for the entire survey area off Oregon and in Norton Sound and for individual subareas in the eastern Bering Sea using the following formulas:

For an individual haul, CPUE = catch in numbers per unit effort in square kilometers.

For the entire survey area,

$$\text{Mean CPUE} = \frac{\Sigma(\text{CPUE})}{N}$$

$$\text{Variance} = \frac{\Sigma((\text{CPUE} - \text{mean CPUE})^2)}{(N * (N-1))}$$

where $\Sigma$ = summation for all hauls in the area,

$N$ = the number of hauls in the area.

In the eastern Bering Sea the mean CPUE and variance for the combined subareas were weighted by the area of each subarea in square kilometers using the formulas:

$$\text{Overall mean CPUE} = \frac{\Sigma(A * \text{mean CPUE})}{\Sigma(A)}$$

$$\text{Variance} = \frac{\Sigma(A^2 * \text{variance (mean CPUE)})}{\Sigma(A)^2}$$

where $\Sigma$ = summation for all subareas,

$A$ = subarea weighting factor.

South shelf = 299,115 km$^2$
North shelf = 520,618 km$^2$
South slope = 17,544 km$^2$
North slope = 21,660 km$^2$

Estimates of CPUE for material and use categories and for total debris items were calculated independently and therefore sums of individual categories do not necessarily equal totals. A more complete description of the standard NMFS methods of calculating CPUE is given in Wakabayashi et al. (1985).

Estimates of the total number of items of debris on the bottom of each area during the 1988 surveys were calculated using an area-swept method (Wakabayashi et al. 1985). Mean CPUE and estimates of numbers of items present in each area are presented as baseline estimates for subsequent comparisons within areas and for all areas combined and were not meant to provide statistically significant comparisons between areas. The percent of debris items by use and material categories is presented for each area and for all areas combined.

## RESULTS

### Oregon

Of the three areas surveyed, the area off Oregon had the highest concentration of marine debris with 149.6 items/km$^2$ (Table 2, Fig. 3). A total of 399 debris items were caught in 49 out of the 70 hauls completed (Table 1). Within use categories, the mean CPUE of galley waste was 89.4 items/km$^2$, accounting for 64% of the CPUE of all debris items caught, followed by engineering and processing waste (27%), personal use waste (6%), other use waste (2%), and fishing equipment (1%). Of material categories, the mean CPUE of metal debris was 54.08 items/km$^2$ and represented 36% of the mean CPUE of all debris caught, followed by plastics (26%) (Fig. 4), glass (19%), rubber (8%), cloth (6%), wood (3%), and paper (1%) (Table 3).

Of the 399 debris items caught off Oregon, 149 or 37% were identified as of either U.S. or foreign origin. Debris of U.S. origin made up 88% of the mean CPUE of debris of identifiable national origin caught off Oregon, 100% of the CPUE for engineering and processing waste and fishing equipment (Table 4). Foreign debris was represented in the CPUE as galley waste (15%) and personal use items (11%). By material category, U.S. debris caught off Oregon dominated all categories except rubber debris, where foreign debris was 54% of the CPUE of identified items (Table 5).

No animals entangled in marine debris were found in the survey off Oregon. Anemones were attached to a glass bottle and starfish were observed on a piece of plastic rope.

### Eastern Bering Sea

The mean CPUE of all debris items caught in the eastern Bering Sea was 7.52 items/km$^2$ (Table 2, Fig. 5). Out of the 541 hauls completed, 122 hauls contained a total of 255 marine debris items (Table 1). Galley waste CPUE was 3.15 items/km$^2$ or 40% of the mean total CPUE, followed by fishing equipment (24%), engineering and processing waste (24%), and personal use waste (12%). By material category, plastic dominated the total mean CPUE with 4.4 items/km$^2$ (51%) (Fig. 6), followed by metal debris (27%), rubber debris (9%), cloth debris (5%), glass debris (4%), and wood debris (1%) (Table 3).

Of the 255 debris items caught in the eastern Bering Sea, U.S. or foreign origin was identified for 60 items. Foreign debris dominated the identified items, accounting for 70% of the mean CPUE (Table 4). Foreign debris was 76% of the CPUE of identified galley waste and 93% of the personal use waste CPUE. Debris of U.S. origin was greatest in fishing equipment waste (67% of CPUE) and engineering and processing waste (64% of CPUE). Foreign debris made up most of the plastic (76% of CPUE), metal (57% of CPUE), rubber (100% of CPUE), and glass debris (84% of CPUE) (Table 5). The U.S. debris accounted for 100% of the CPUE of identified paper and other material debris.

Table 2.--Catch-per-unit-effort (CPUE) (number per square kilometer) by use category and area for marine debris caught during the National Marine Fisheries Service bottom trawl survey, 1988 (CI = confidence interval).

| | Oregon | | Eastern Bering Sea | | Norton Sound | | All areas | |
|---|---|---|---|---|---|---|---|---|
| Use category | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE |
| Galley wastes | 89.40 (57.2-121.6) | 64% | 3.15 (2.1-7.2) | 40% | 0.70 (0.0-1.7) | 36% | 5.12 (2.7-7.6) | 51% |
| Engineering and processing | 37.87 (18.3-57.4) | 27% | 1.84 (1.0-2.6) | 23% | 0.73 (0.0-1.8) | 38% | 2.10 (1.3-2.8) | 21% |
| Fishing equipmment | 1.69 (0.0-3.4) | 1% | 1.86 (1.1-2.6) | 24% | 0.00 -- | 0% | 1.80 (1.1-2.5) | 18% |
| Personal use items | 8.92 (0-18.9) | 6% | 0.91 (0.0-1.9) | 12% | 0.51 (0.0-1.2) | 26% | 0.96 (0.0-1.9) | 10% |
| Other debris | 2.55 (0.0-6.6) | 2% | 0.08 (0.0-0.2) | 1% | 0.00 -- | 0% | 0.05 (0.0-0.1) | <1% |
| Total | 149.60 (97.9-201.3) | 100% | 7.52 (6.7-14.4) | 100% | 1.94 (0.3-3.6) | 100% | 11.26 (7.6-14.9) | 100% |

Note: Individual and total debris categories were calculated separately and thus are not necessarily additive.

Table 3.--Catch-per-unit-effort (CPUE) (number per square kilometer) by debris material category and area for marine debris caught during the National Marine Fisheries Service bottom trawl survey, 1988 (CI = confidence interval).

| Debris category | Oregon | | Eastern Bering Sea | | Norton Sound | | All areas | |
|---|---|---|---|---|---|---|---|---|
| | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE | Number/km$^2$ (95% CI N = 70) | Percent of area total CPUE |
| Plastic | 39.05 (20.7-57.4) | 26% | 4.40 (4.9-7.8) | 51% | 0.24 (0.0-0.7) | 12% | 6.37 (5.0-7.7) | 57% |
| Metal | 54.08 (29.6-78.6) | 36% | 2.33 (0.0-4.8) | 27% | 0.96 (0.0-2.3) | 49% | 2.68 (0.3-5.0) | 24% |
| Rubber | 12.10 (0.3-23.9) | 8% | 0.80 (0.0-1.8) | 9% | 0.26 (0.0-0.8) | 13% | 0.87 (0.0-1.8) | 8% |
| Glass | 28.66 (16.4-40.9) | 19% | 0.38 (0.1-0.6) | 4% | 0.00 -- | 0% | 0.59 (0.3-0.8) | 5% |
| Cloth | 9.61 (3.6-15.6) | 6% | 0.41 (0.1-0.7) | 5% | 0.48 (0.0-1.2) | 25% | 0.49 (0.2-0.8) | 4% |
| Wood | 4.24 (0.0-8.9) | 3% | 0.11 (0.0-0.2) | 1% | 0.00 -- | 0% | 0.14 (0.0-0.3) | 1% |
| Paper | 1.34 (0.0-2.7) | 1% | 0.13 (0.0-0.3) | 2% | 0.00 -- | 0% | 0.13 (0.0-0.3) | 1% |
| Other | 0.54 (0.0-6.4) | <1% | 0.00 -- | 0% | 0.00 -- | 0% | >0.01 (0.0-0.1) | <1% |
| Total | 149.60 (97.9-201.3) | 100% | 7.52 (6.7-14.4) | 100% | 1.94 (0.3-3.6) | 100% | 11.26 (7.6-14.9) | 100% |

Note: Individual and total debris categories were calculated separately and thus are not necessarily additive.

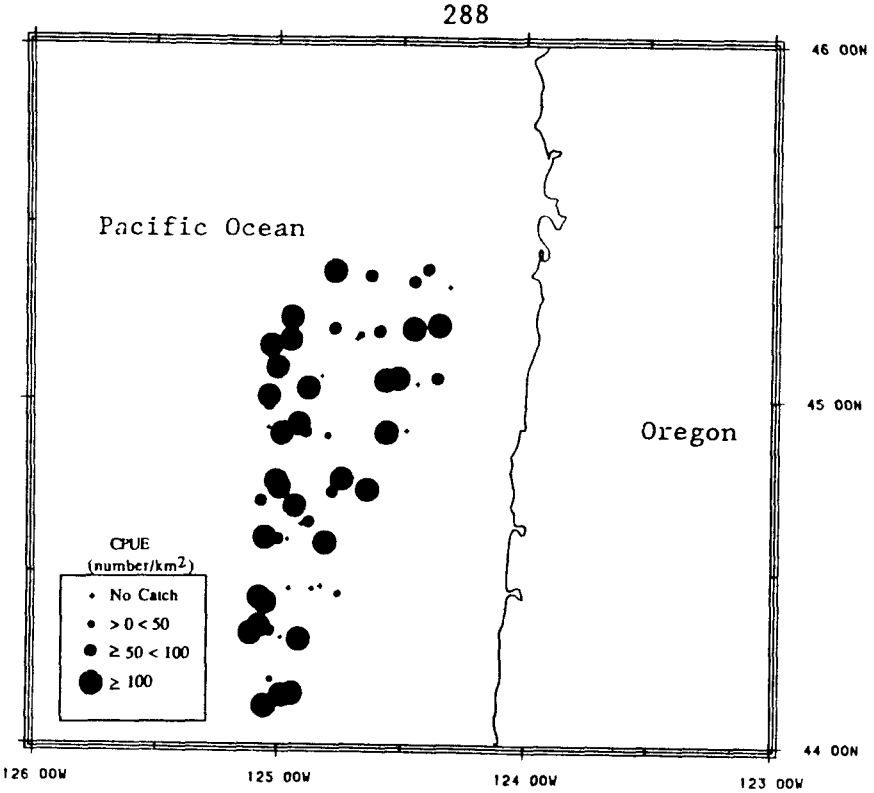


Figure 3.--Relative density (catch-per-unit-effort (CPUE) in number per square kilometer) of all marine debris caught during the National Marine Fisheries Service bottom trawl survey off Oregon, 1988.

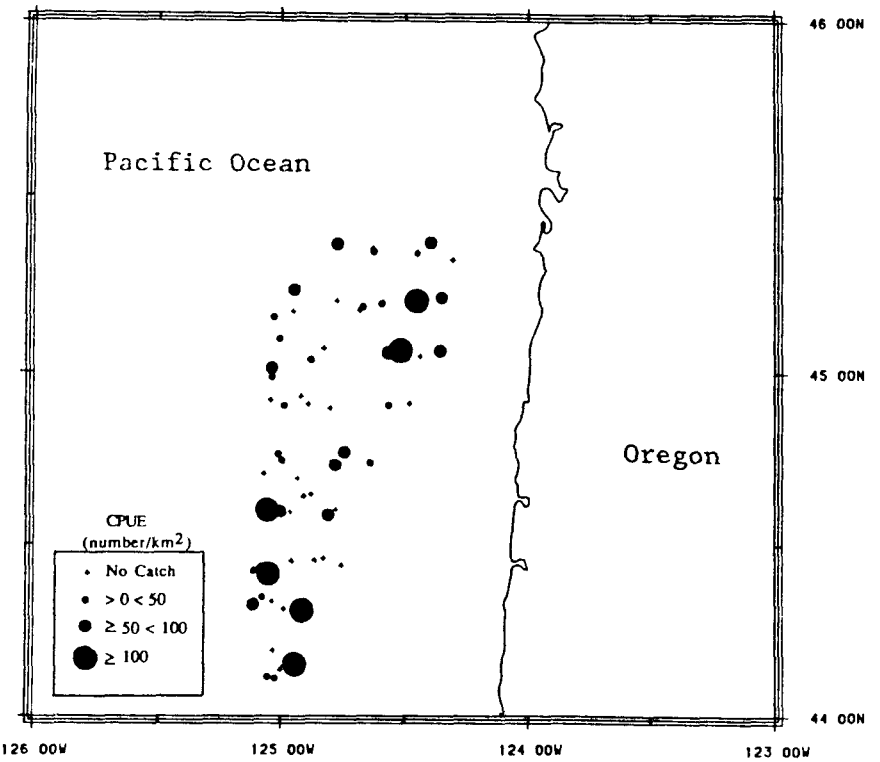


Figure 4.--Relative density (catch-per-unit-effort (CPUE) in number per square kilometer) of plastic marine debris caught during the National Marine Fisheries Service bottom trawl survey off Oregon, 1988.

Table 4.--Percent of catch-per-unit-effort (number per square kilometer) by foreign or domestic (U.S.) origin, use category, and area for marine debris caught during the National Marine Fisheries Service bottom trawl survey, 1988.

| | Oregon | | Eastern Bering Sea | | Norton Sound | | All areas | |
|---|---|---|---|---|---|---|---|---|
| Use category | U.S. | Foreign | U.S. | Foreign | U.S. | Foreign | U.S. | Foreign |
| Galley wastes | 85% | 15% | 24% | 76% | 0% | 0% | 37% | 63% |
| Engineering and processing | 100% | 0% | 64% | 36% | 100% | 0% | 75% | 25% |
| Fishing equipment | 100% | 0% | 67% | 33% | 0% | 0% | 66% | 34% |
| Personal use items | 89% | 11% | 7% | 93% | 0% | 0% | 24% | 76% |
| Other debris | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% |
| Percent by area | 88% | 12% | 30% | 70% | 100% | 0% | 42% | 58% |

Table 5.--Percent of catch-per-unit-effort (number per square kilometer) by foreign or domestic (U.S.) origin, material category, and area for marine debris caught during the National Marine Fisheries Service bottom trawl survey, 1988.

| | Oregon | | Eastern Bering Sea | | Norton Sound | | All areas | |
|---|---|---|---|---|---|---|---|---|
| Debris material | U.S. | Foreign | U.S. | Foreign | U.S. | Foreign | U.S. | Foreign |
| Plastic | 100% | 0% | 24% | 76% | 0% | 0% | 33% | 67% |
| Metal | 85% | 15% | 43% | 57% | 100% | 0% | 55% | 45% |
| Rubber | 46% | 54% | 0% | 100% | 0% | 0% | 4% | 96% |
| Glass | 81% | 19% | 16% | 84% | 0% | 0% | 37% | 63% |
| Cloth | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Wood | 100% | 0% | 0% | 0% | 0% | 0% | 100% | 0% |
| Paper | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% |
| Other | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% |
| Percent by area | 88% | 12% | 30% | 70% | 100% | 0% | 43% | 57% |

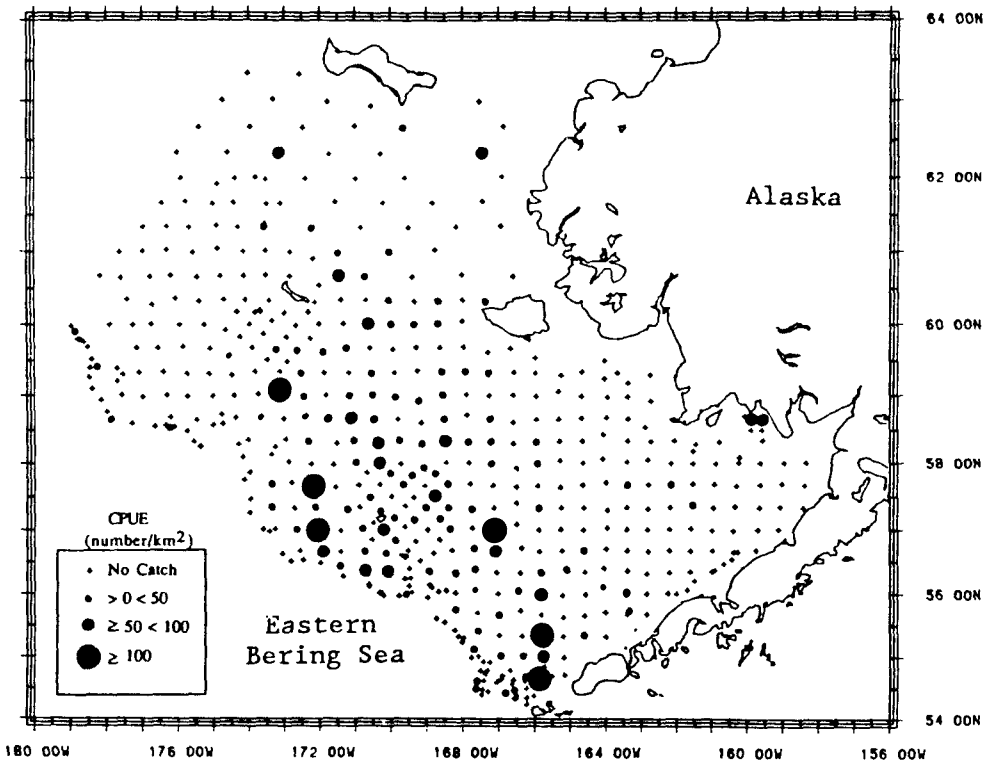


Figure 5.--Relative density (catch-per-unit-effort (CPUE) in number per square kilometer) of all marine debris caught during the National Marine Fisheries Service bottom trawl survey in the eastern Bering Sea, 1988.

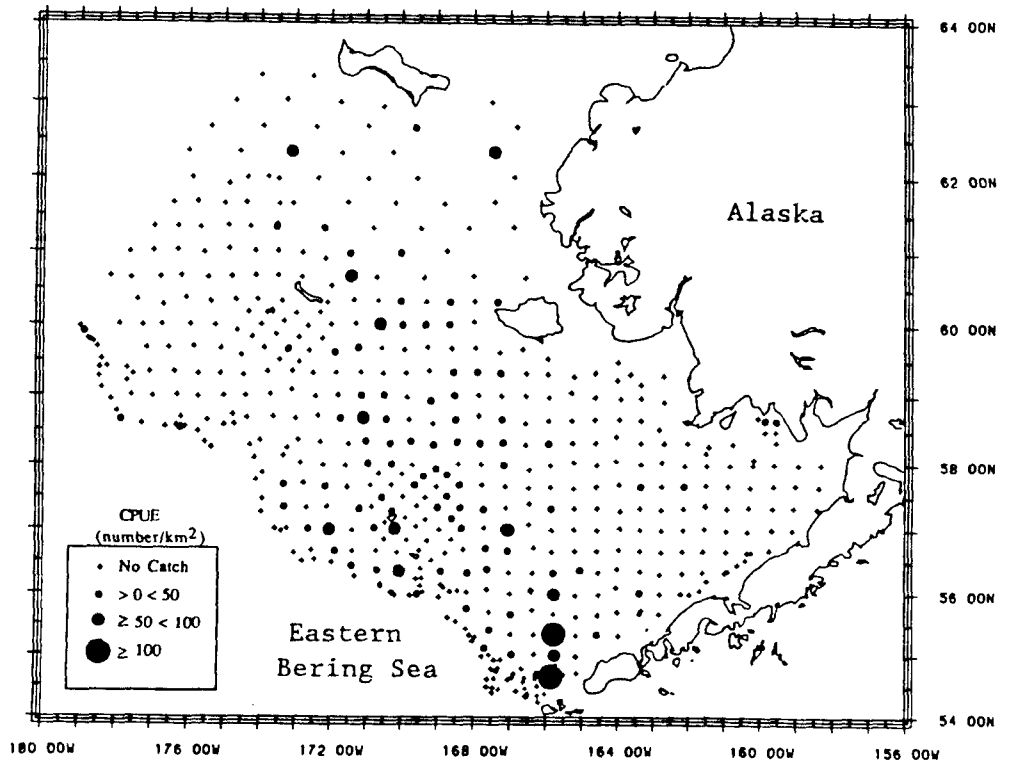


Figure 6.--Relative density (catch-per-unit-effort (CPUE) in number per square kilometer) of plastic marine debris caught during the National Marine Fisheries Service bottom trawl survey in the eastern Bering Sea, 1988.

A Tanner crab, *Chionoecetes opilio*, and an unidentified hermit crab, Paguridae, entangled in separate pieces of plastic trawl web twine, were caught during the eastern Bering Sea survey. Numerous invertebrates including mussels, anemones, octopus, barnacles, unidentified tunicates, and starfish were associated with plastic sheeting, plastic rope, glass bottles, and a rubber shoe. Fish eggs were found attached to plastic sheeting.

### Norton Sound

Of the three areas surveyed, Norton Sound had the lowest concentration of marine debris, with 1.94 items/km$^2$ (Table 2, Fig. 7). Eight items of debris were found in 6 of the 85 hauls completed. Galley waste had a mean CPUE of 0.73 items/km$^2$ or 38% of the total debris mean CPUE followed by engineering and processing waste (36%), and personal use waste (26%). No fishing equipment waste was found in Norton Sound. Metal debris accounted for 49% of the total debris mean CPUE, cloth debris 25%, rubber debris 13%, and plastic debris 12% of the total debris mean CPUE (Fig. 8).

Out of the eight debris items caught in Norton Sound, a single debris item, a metal piece of railroad track, was identified as being of U.S. origin.

No animals were found entangled or associated with marine debris in Norton Sound.

### All Areas Combined

Out of a total of 696 trawl hauls examined for marine debris in the 3 areas, 177 (25%) had a total of 662 marine debris items identified in the catch. For the 3 areas combined, the mean CPUE of all debris items, weighted by surface area, was 11.3 items/km$^2$ (Table 2). Galley waste accounted for 51% of the mean CPUE of all debris items, followed by engineering and processing waste (21%), fishing equipment waste (18%), and personal use waste (10%). Over all areas surveyed, plastic was the most abundant debris material, caught with a mean CPUE of 6.37 items/km$^2$ (57% of the mean total CPUE), followed by metal debris (24%), rubber (8%), glass (5%), cloth (4%), and wood and paper (1% of the mean total CPUE) (Table 3).

Of the 210 debris items identified to national origin in the 3 areas, 58% of the mean total CPUE was foreign (Table 4). Foreign debris dominated galley waste (63%) and personal use waste (76%). The U.S. debris accounted for 75% of the mean CPUE of identified engineering and processing waste and 66% of identified fishing equipment waste mean CPUE. Foreign debris accounted for 67% of the mean CPUE of identified plastic debris, 96% of rubber debris, and 63% of the mean CPUE of identified glass debris (Table 5). The U.S. debris dominated identified debris made of metal (55% of mean CPUE) and accounted for all of the identified wood and paper debris caught in the three areas. Plastic represented the largest percentage of CPUE of galley waste (46%), engineering and processing waste (48%), and fishing equipment waste (92%) (Table 6). Rubber debris made up most of the CPUE of personal use waste (77%). A complete list of the individual marine debris items found during the survey is found in Tables 7 through 9.

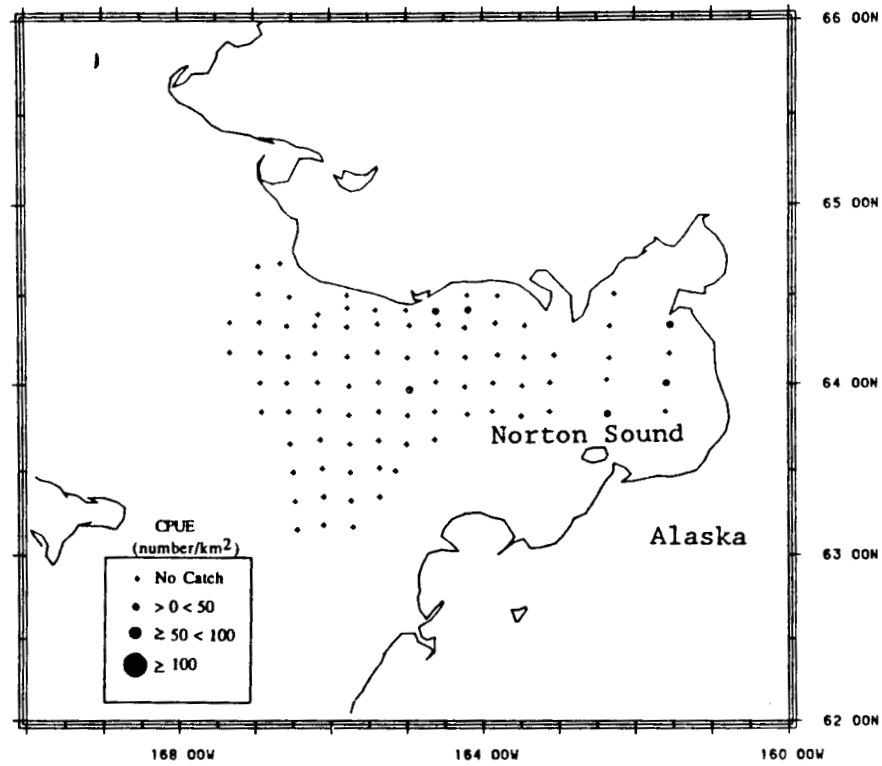


Figure 7.--Relative density (catch-per-unit-effort (CPUE) in number per square kilometer) of plastic marine debris caught during the National Marine Fisheries Service bottom trawl survey in the Norton Sound, 1988.

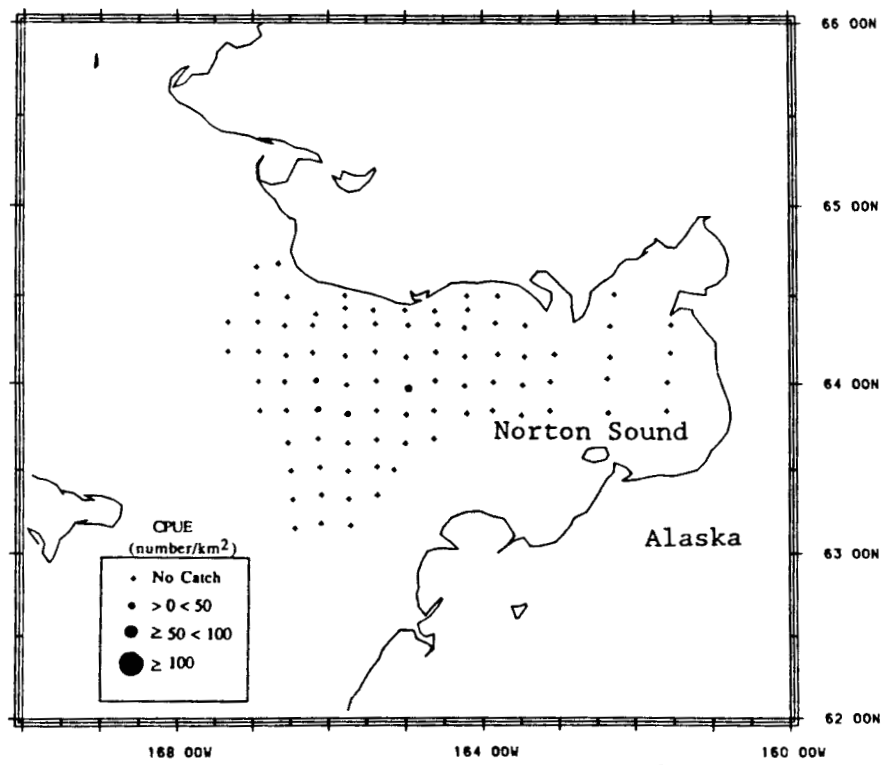


Figure 8.--Relative density (catch-per-unit-effort (CPUE) in number per square kilometer) of all marine debris caught during the National Marine Fisheries Service bottom trawl survey in the Norton Sound, 1988.

Table 6.--Percent of catch-per-unit-effort (number per square kilometer) by debris material and use categories for marine debris caught during the National Marine Fisheries Service bottom trawl survey off Oregon, in the eastern Bering Sea, and in Norton Sound, 1988.

| | Use category | | | | | |
|---|---|---|---|---|---|---|
| Debris | Galley wastes | Engineering and processing | Fishing equipment | Personal use | Other | Percent by material category |
| Plastic | 45.8% | 47.5% | 91.8% | 9.9% | 65.4% | 56.6% |
| Metal | 42.9% | 16.9% | 6.1% | 0.0% | 30.8% | 23.8% |
| Rubber | 0.0% | 6.1% | 0.0% | 77.4% | 3.8% | 7.7% |
| Glass | 10.7% | 0.0% | 2.1% | 0.0% | 0.0% | 5.2% |
| Cloth | 0.0% | 20.3% | 0.0% | 7.0% | 0.0% | 4.3% |
| Wood | 0.0% | 6.5% | 0.0% | 0.0% | 0.0% | 1.2% |
| Paper | 0.5% | 2.5% | 0.0% | 5.6% | 0.0% | 1.2% |
| Other | 0.0% | 0.2% | 0.0% | 0.0% | 0.0% | <1% |
| Percent by use category | 51.3% | 20.8% | 17.8% | 9.6% | 0.5% | 100.0% |

## DISCUSSION

The three areas surveyed provide an interesting comparison of the abundance and type of marine debris found on the bottom in areas with different amounts and types of vessel use. The area off Oregon is used extensively by cargo vessels, U.S. and U.S.-foreign joint venture commercial fishing operations, and recreational boaters and fishermen. In 1985, the latest year for which data are available, approximately 1,740 commercial fishing vessels operated off the coast of Oregon (Korson and Thomson 1987) and the U.S. Coast Guard reported 143,373 commercial and recreational vessels in Oregon with Coast Guard identification numbers (Coast Guard 1986). The area surveyed off Oregon is located on one of the major north-south west coast cargo shipping lanes, with frequent vessel traffic observed during the survey (T. Dark, Alaska Fisheries Science Center, Seattle, Wash., pers. commun. 1989).

In the eastern Bering Sea, some nonfishery tug, barge, and cargo vessel operations exist, but vessel traffic is predominantly associated with the commercial fishing industry. Harvesting vessels, domestic and foreign processing vessels, and a wide variety of support vessels operate in the eastern Bering Sea each year. In 1985, the Alaska Department of Fish and Game (1986) estimated that 1,729 domestic commercial fishing vessels operated in the eastern Bering Sea, and the NMFS estimated that 254 254 foreign vessels fished or processed seafood in the eastern Bering

Table 7.--Description, material and use category, number caught, catch-per-unit-effort (CPUE) (number per square kilometer), and swept-area estimate of the number of debris items in the survey area for marine debris caught off Oregon during the National Marine Fisheries Service bottom trawl survey, 1988 (CI = confidence interval).

| | | Catch | | | Swept-area estimate | |
|---|---|---|---|---|---|---|
| Use category | Item | Number caught | Mean CPUE km$^2$ | CPUE variance | Estimated number | 95% CI |
| | | | **Plastic** | | | |
| Galley waste | Bags | 39 | 14.31 | 11.2468 | 103,277 | 54,946-151,607 |
| | Bottles | 2 | 0.51 | 0.1290 | 3,702 | 0-8,896 |
| | Lids, caps | 4 | 1.71 | 1.4426 | 12,325 | 0-29,634 |
| | Six-pack ring | 1 | 0.25 | 0.0624 | 1,803 | 0-5,405 |
| | Vegetable sack | 1 | 0.90 | 0.8185 | 6,529 | 0-19,567 |
| | Other | 2 | 0.72 | 0.2909 | 5,170 | 0-12,943 |
| Fishing equipment | Fishing line | 2 | 0.88 | 0.4228 | 6,347 | 0-15,718 |
| | Fishing net | 1 | 0.27 | 0.0732 | 1,952 | 0-5,850 |
| | Rope | 21 | 9.45 | 12.9024 | 68,218 | 0-119,983 |
| Personal use | Lighter | 1 | 0.27 | 0.0717 | 1,932 | 0-5,790 |
| | Deodorant tube | 15 | 4.02 | 16.1272 | 28,981 | 0-86,855 |
| Engineering and processing | Sheeting | 8 | 2.36 | 2.8377 | 17,058 | 0-41,339 |
| | Strapping band | 9 | 2.92 | 1.2100 | 21,102 | 0-36,955 |
| | Duct tape | 1 | 0.22 | 0.0494 | 1,605 | 0-4,809 |
| Other | Clay pigeon | 1 | 0.25 | 0.0601 | 1,770 | 0-5,303 |
| | | | Glass | | | |
| Galley waste | Bottle | 65 | 25.92 | 32.4534 | 187,265 | 105,167-269,364 |
| | Pieces | 2 | 0.75 | 0.3088 | 5,447 | 0-13,456 |
| | Fruit jar | 4 | 1.95 | 3.0305 | 14,082 | 0-39,170 |
| | | | **Rubber** | | | |
| Personal use | Gloves | 6 | 2.47 | 0.1049 | 17,798 | 3,035-32,561 |
| | Shoe | 1 | 0.86 | 0.4123 | 6,211 | 0-15,465 |
| Engineering and processing | Tar | 10 | 5.05 | 0.2546 | 36,411 | 0-109,125 |
| | Gasket | 3 | 0.79 | 0.3292 | 5,666 | 0-13,935 |
| | Paint | 4 | 1.80 | 2.4378 | 13,012 | 0-35,513 |
| | Sheeting | 2 | 0.87 | 0.4358 | 6,287 | 0-15,801 |
| Other | Misc. pieces | 1 | 0.27 | 0.0702 | 1,913 | 0-5,732 |

Table 7.--Continued.

| Use category | Item | Catch: Number caught | Catch: Mean CPUE km² | Catch: CPUE variance | Swept-area estimate: Estimated number | Swept-area estimate: 95% CI |
|---|---|---|---|---|---|---|
| | | | Metal | | | |
| Galley waste | Beverage can | 95 | 35.38 | 75.5465 | 255,327 | 130,066-380,587 |
| | Lids, caps | 4 | 1.46 | 0.8108 | 10,537 | 0-23,514 |
| | Container | 5 | 1.96 | 0.8102 | 14,136 | 1,164-27,108 |
| | Pull tab | 7 | 2.50 | 3.1064 | 18,075 | 0-43,475 |
| | Tinfoil | 2 | 0.50 | 0.1231 | 3,581 | 0-8,638 |
| | Cook pot | 2 | 0.54 | 0.1429 | 3,879 | 0-9,326 |
| Fishing equipment | Crab trap | 1 | 0.54 | 0.2867 | 4 | 0-11,581 |
| Engineering and processing | Drum, 208.2 liter (55-gal) | 1 | 0.50 | 0.2546 | 3,641 | 0-10,913 |
| | Pieces | 16 | 5.94 | 7.1185 | 42,849 | 4,398-81,299 |
| | Instruments | 3 | 0.97 | 0.3255 | 6,972 | 0-15,193 |
| | Paint can | 4 | 1.76 | 2.4200 | 12,715 | 0-35,134 |
| Other | Bullet | 4 | 2.04 | 4.1527 | 14,706 | 0-44,074 |
| | | | Paper | | | |
| Personal use | Newspaper | 1 | 0.27 | 0.0717 | 1,932 | 0-5,709 |
| | Pieces | 2 | 0.53 | 0.1371 | 3,807 | 0-9,144 |
| | Book | 1 | 0.25 | 0.0613 | 1,770 | 0-5,303 |
| Engineering and processing | Carton | 1 | 0.30 | 0.0879 | 2,139 | 0-6,412 |
| | | | Wood | | | |
| Engineering an processing | Pieces | 14 | 3.76 | 5.2919 | 26,951 | 0-60,103 |
| | Broom | 1 | 0.29 | 0.0813 | 2,058 | 0-6,168 |
| | Fiberboard | 1 | 0.22 | 0.0494 | 1,605 | 0-4,809 |
| | | | Cloth | | | |
| Engineering and processing | Pieces and rags | 6 | 9.61 | 9.0228 | 69,330 | 26,041-112,619 |
| | | | Other | | | |
| Engineering and processing | Fire brick | 26 | 0.54 | 0.2867 | 3,864 | 0-11,581 |

Table 8.--Description, material and use category, number caught, catch-per-unit-effort (CPUE) (number per square kilometer), and swept-area estimate of the number of debris items in the survey area in the eastern Bering Sea during the National Marine Fisheries Service bottom trawl survey, 1988 (CI = confidence interval).

| | | Catch | | | Swept-area estimate | |
|---|---|---|---|---|---|---|
| Use category | Item | Number caught | Mean CPUE $km^2$ | CPUE variance | Estimated number | 95% CI |
| | | | Plastic | | | |
| Galley waste | Bags | 49 | 1.10 | 0.0653 | 1,629,941 | 1,195,289-2,064,593 |
| | Bottles | 2 | 0.01 | 0.0017 | 11,209 | 0-33,626 |
| | Lids, caps | 3 | 0.11 | 0.0070 | 97,164 | 0-239,880 |
| | Wrappers | 4 | 0.21 | 0.0177 | 177,959 | 0-404,079 |
| | Other | 1 | 0.04 | 0.0016 | 34,424 | 0-102,581 |
| Fishing equipment | Bait jar | 2 | 0.09 | 0.0041 | 74,915 | 0-183,768 |
| | Fishing line | 17 | 0.78 | 0.0546 | 669,889 | 272,412-1,067,367 |
| | Fishing net | 7 | 0.35 | 0.0173 | 299,166 | 75,558-522,774 |
| | Net twine | 8 | 0.33 | 0.0140 | 285,103 | 83,872-486,335 |
| | Floats | 1 | 0.05 | 0.0030 | 46,871 | 0-139,671 |
| | Light stick | 2 | 0.11 | 0.0113 | 91,208 | 0-271,792 |
| | Rope | 28 | 1.32 | 0.0646 | 1,131,965 | 669,668-1,564,263 |
| Personal use | Hard hat | 1 | 0.01 | 0.0001 | 5,894 | 0-17,681 |
| | Toothpaste tube | 2 | 0.05 | 0.0017 | 40,270 | 0-109,798 |
| | Glove liner | 1 | 0.01 | 0.0001 | 9,100 | 0-27,491 |
| Engineering and processing | Sheeting | 15 | 0.72 | 0.0775 | 619,684 | 146,206-1,093,162 |
| | Strapping band | 7 | 0.22 | 0.0094 | 192,401 | 27,813-356,990 |
| | Duct tape | 1 | 0.05 | 0.0026 | 44,114 | 0-131,455 |
| Other | Clay pigeon | 1 | 0.04 | 0.0017 | 35,414 | 0-105,532 |
| | XBT tube[a] | 1 | 0.04 | 0.0013 | 30,766 | 0-91,681 |
| | | | Glass | | | |
| Galley waste | Bottle | 8 | 0.31 | 0.0133 | 263,374 | 67,448-459,299 |
| | Pieces | 1 | 0.03 | 0.0010 | 28,129 | 0-83,823 |
| Fishing equipment | Glass float | 1 | 0.04 | 0.0016 | 34,424 | 0-102,581 |
| | | | Rubber | | | |
| Personal use | Gloves | 14 | 0.67 | 0.2437 | 571,566 | 0-1,411,060 |
| | Shoes | 2 | 0.07 | 0.0028 | 64,347 | 0-154,201 |
| Engineering and processing | Tar | 1 | 0.01 | 0.0001 | 6,433 | 0-19,299 |
| | Sheeting | 1 | 0.05 | 0.0030 | 47,198 | 0-140,648 |

Table 8.--Continued.

| Use category | Item | Catch | | | Swept-area estimate | |
|---|---|---|---|---|---|---|
| | | Number caught | Mean CPUE km² | CPUE variance | Estimated number | 95% CI |
| | | | Metal | | | |
| Galley waste | Beverage can | 33 | 1.55 | 1.4860 | 1,328,689 | 0-3,401,783 |
| | Lids, caps | 1 | 0.05 | 0.0029 | 45,914 | 0-136,821 |
| | Container | 7 | 0.26 | 0.0188 | 223,756 | 0-457,004 |
| | Tinfoil | 1 | 0.05 | 0.0026 | 43,827 | 0-130,601 |
| | Cook pot | 1 | 0.03 | 0.0012 | 29,301 | 0-87,316 |
| Fishing equipment | Crab trap | 3 | 0.11 | 0.0050 | 94,090 | 0-214,290 |
| Engineering and processing | Pieces | 3 | 0.17 | 0.0280 | 143,604 | 0-427,928 |
| | Wire | 9 | 0.10 | 0.0054 | 89,238 | 0-214,176 |
| | | | Paper | | | |
| Galley waste | Bag | 1 | 0.03 | 0.0008 | 24,249 | 0-72,261 |
| Personal use | Piece | 1 | 0.05 | 0.0024 | 41,663 | 0-124,152 |
| Engineering and processing | Carton | 1 | 0.05 | 0.0027 | 44,404 | 0-132,320 |
| | | | Wood | | | |
| Engineering and processing | Pieces | 2 | 0.04 | 0.0014 | 37,988 | 0-101,750 |
| | Paint brush | 1 | 0.03 | 0.0010 | 27,047 | 0-80,599 |
| | Other | 1 | 0.03 | 0.0010 | 27,196 | 0-81,044 |
| | | | Cloth | | | |
| Personal use | Pants | 1 | 0.06 | 0.0034 | 49,995 | 0-148,982 |
| Engineering and processing | Pieces | 6 | 0.25 | 0.0120 | 217,809 | 31,675-403,944 |
| | Tarp | 1 | 0.05 | 0.0026 | 43,544 | 0-129,759 |
| | Bag | 1 | 0.05 | 0.0024 | 41,663 | 0-124,152 |

*XBT = Expendable bathythermograph.

Table 9.--Description, material and use category, number caught, catch-per-unit-effort (CPUE) (number per square kilometer), and swept-area estimate of the number of debris items in the survey area for marine debris caught in Norton Sound during the National Marine Fisheries Service bottom trawl survey, 1988 (CI = confidence interval).

| Category | | | Catch | | | Swept-area estimate | |
|---|---|---|---|---|---|---|---|
| Material | Use | Item | Number caught | Mean CPUE No./km$^2$ | CPUE variance | Estimated number | 95% CI |
| Plastic | Galley waste | Bag | 1 | 0.24 | 0.0559 | 9,857 | 0-29,493 |
| Rubber | Personal use | Shoe | 1 | 0.26 | 0.0664 | 10,741 | 0-32,138 |
| Metal | Galley waste | Beverage can | 2 | 0.46 | 0.2128 | 19,228 | 0-57,530 |
| | Engineering and processing | Railroad track | 2 | 0.50 | 0.2516 | 20,906 | 0-62,557 |
| Cloth | Engineering and processing | Pieces and rags | 1 | 0.23 | 0.0539 | 9,674 | 0-28,947 |
| | Personal use | Dress | 1 | 0.25 | 0.0629 | 10,453 | 0-31,275 |

Sea-Aleutian Islands area (Berger et al. 1988). There are few, if any, recreational boaters operating in the eastern Bering Sea and the major cargo transit routes lie south of the Aleutian Islands.

Norton Sound has the least amount of vessel traffic of the three areas surveyed. Tug and barge traffic to Nome, Alaska, occurs during the spring and summer. A fleet of about a dozen vessels conducts a commercial red king crab fishery in the survey area for approximately 1 week each year (Alaska Department of Fish and Game 1986). During the winter, most of Norton Sound is covered by ice.

The estimated abundance of marine debris in the three areas surveyed differed by nearly two orders of magnitude, from 1.94 items/km$^2$ in Norton Sound to 149.60 items/km$^2$ off Oregon. The higher concentration of marine debris off Oregon is probably related to the extensive vessel operations in this area. Most of the marine debris off Oregon was galley waste, 89.4 items/km$^2$ (64%), and engineering and processing waste, 37.87 items/km$^2$ (27%), which are associated with the operation of most types of vessels. Fishing equipment waste abundance off Oregon, 1.69 items/km$^2$, was quite similar to that found in the eastern Bering Sea, 1.84 items/km$^2$. It is

interesting to note that the numbers of commercial fishing vessels operating off Oregon and in the eastern Bering Sea were also similar, 1,740 and 1,983, respectively. The abundance of galley waste and engineering and processing debris caught in the eastern Bering Sea may represent the average amount resulting from commercial fishing operations and minimal cargo traffic. The higher abundance of galley waste and engineering and processing waste found off Oregon may be due to the added input of cargo vessel and recreational boater debris.

## RECOMMENDATIONS

- Collect marine debris data from all annual NMFS bottom trawl surveys.
- Develop a standardized data collection protocol, data base system, analysis methodology, and reporting format.
- Provide similar marine debris data forms to commercial trawl fishermen.
- Encourage foreign governments to conduct similar bottom trawl marine debris surveys.

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