TRANSLATION

Distribution and Density of Marine Debris in the North Pacific Based on Sighting Surveys in 1990

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THIS PAPER MAY BE CITED IN THE FOLLOWING MANNER:
Sighting surveys for marine debris were conducted by 40 vessels, and 26,936 pieces of marine debris were found in the total survey distance (effort) of 172,278.5 nautical miles. Generally, no annual change was observed in the percentage composition of debris by type (fishing nets 0.5%, fishing gear other than fishing nets 9.4%, styrofoam 24.2%, petrochemical products (other plastics) 21.2%, floating logs 12.2%, floating seaweed 24.2% and others 8.3%).

Regarding distribution of density, relatively high density of fishing nets, other fishing gear, styrofoam, and other petrochemical products was found in the mid-latitudinal area of eastern Pacific and in the area near Japan, as in previous years. However, the values in 1990 are substantially lower than in 1988 and 1989. It is assumed that the gyre in this area which forms an area of concentration was somewhat different from the past.

For floating logs, relatively high density north of Hawaii and high density along the continent and island were found as usual. In addition, and as usual high density of floating seaweed was found near land.
1. Introduction

Marine debris sighting surveys have been conducted continuously since 1986 in cooperation with research vessels and patrol vessels of the Fisheries Agency of Japan, and training vessels of fisheries high schools and Universities to determine the distribution and the actual volume of marine debris floating on the sea and to observe the annual changes and trends. The main area surveyed was the North Pacific, but also included the South Pacific, Sea of Japan, Yellow Sea, Bering Sea, Okhotsk Sea and its inner part, South China Sea, Indian Ocean, Gulf of Mexico and further to the Antarctic Ocean.

In this study, using data collected by sighting surveys conducted by the above mentioned vessels, the distribution of marine debris was examined. Further, the density of marine debris was estimated by theoretical equations.

2. Method of Survey

1) Vessels Used and Researchers

In order to conduct sighting surveys efficiently and to extend the area covered by the survey, we requested the survey be conducted by a total of 40 vessels including vessels owned by the Fisheries Agency of Japan, training vessels of fisheries high schools and universities, fishing vessels and cargo vessels (Table 1). Researchers were principally officers on duty on the Fisheries Agency's vessels and dedicated researchers were dispatched principally to other vessels.

2) Targets of Sighting

All floating objects on the sea surface were targeted, but objects that were under 5 cm in maximum length were excluded.

3) Sighting from the Vessel

The survey was conducted principally from the bridge.

4) Conduct of Sighting Survey

The survey was conducted principally from sunrise to sunset but the duration was not limited if visibility permitted.

Principally, the survey targeted the sea surface in a range of 180°, i.e. the range of right angles from the course of the vessel. However, in the case of vessels larger than 10,000 GT where only one researcher was on board, the survey was conducted only on one side (at right angles to either the right or left of the course of the vessel).
5) Records

When marine debris was sighted, the angle from the course of the vessel and the estimated distance from the researcher were recorded. The debris sighted were categorized as follows and the number and size of the debris were recorded.

**Type**

**Artificial objects**
- Fishing gear
  - Net (type unknown, trawl net and gillnet)
  - Fishing gear other than fishing nets (including plastic and styrofoam products such as floats and flag buoys)
- Other than fishing gear
  - Pieces of wood (boxes, boards, etc.)
  - Petrochemical products (including products made of plastic, vinyl and polyester)
  - Styrofoam (excluding fishing gear)
  - Glass products and metal products (cans, etc.)

**Natural objects**
- Floating seaweed
- Floating logs

**Others**
- Unknown

In addition, when a number of objects of the same type were found at the same sighting station, the number of objects sighted was recorded by actual number up to two figures and when more than three figures, 99 was recorded. As to the length, the maximum length was measured by eye (e.g. if the size was 20 cm x 30 cm x 40 cm (box shape), then it was recorded as 40 cm) and recorded as S, M or L according to the following size category:

- Less than 50 cm --- S
- 50 cm - 200 cm ---- M
- More than 200 cm -- L

In addition to these data, information on time, location, number of researchers, visibility, wind force (Beaufort scale) and surface temperature when the object was found were also recorded.

Moreover, location, number of researchers, visibility, surface temperature and wind force were recorded every hour even when marine debris were not found. Furthermore, when special oceanographic phenomenon was observed such as current rip, the information was recorded. The height of the eye level of the researcher from the sea surface was also recorded.
3. Results

1) Outline of Results

The area surveyed by the vessels listed in Table 1 is shown in Fig. 1, and sighting effort by block (5° latitude x 10° longitude) is shown in Fig. 2.

The total distance of sighting surveys was 172,279 nautical miles, and the number of pieces of marine debris sighted during the cruises was 26,936. Effort by month, which is shown in Table 2, shows that effort from June to August was 46.5% of the total and effort during the winter from December to February was only 9.7% of the total.

As to the percentage of debris items sighted by type, the number of fishing nets was 137 and the proportion to the total items sighted was 0.5%. By fishing net, drift net was 0.17%, trawl net was 0.03% and unknown type was 0.3%. The amount of fishing gear other than fishing nets that included plastic and styrofoam products such as floats and flag buoys, etc. accounted for 9.4% of the total debris sighted.

As to the number of debris items sighted by type, the amount of floating seaweed sighted was the greatest (6,516) and accounted for 24.2% of the total amount of debris sighted. The number of styrofoam (excluding fishing gear) sightings which was most abundant in 1988 and 1989 was 6,513 and accounted for 24.2% of the total. The number of petrochemical products sighted including those made of plastic, vinyl and polyester was 5,726 and accounted for 21.2% of the total. These plastic products (excluding fishing gear) were 12,239 and accounted for 45.4% or almost a half of the total amount of debris sighted.

The amount of glass and metal sighted was comparatively small and accounted for 2.1% and 1.7% of the total, respectively, however they were greater than the number of fishing nets sighted. Of the biodegradable debris, the total number of pieces of wood and floating logs sighted was 3,284 and accounted for 12.2% of the total.

2) Amount of Marine Debris Sighted by Perpendicular Distance

In this survey, the distance between a researcher and debris sighted and the angle of debris from the bow were recorded when the researcher sighted marine debris. Using these data, the distance of debris from the side of the vessel (hereafter referred to as "the perpendicular distance") was calculated by type of debris and shown in Fig. 3.

The amount of debris sighted by perpendicular distance was maximum for each type of debris when the distance from the vessel was between 10-20 m, and the proportion of them to the total number sighted was 24.3%. Furthermore, the data indicates that 68.8% of debris was sighted at a distance within 40 m and 90.5% at a distance within 100 m.
amount of debris sighted and the perpendicular distance was shown basically as a convex curve. A similar tendency was obtained between the sighting distance and the number of whales sighted in the results of the whale sighting surveys (Nasu and Shimadzu 1969). The number of debris sighted at a distance sharply declined at a perpendicular distance of 50 m and farther.

In general, the reason why the maximum value of the amount of debris sighted was obtained at a distance between 10-20 m is attributed to the fact that the sighting probabilities within 10 m and 10-20 m are regarded to be completely identical, as pointed out by Nasu and Hiramatsu (1989). In addition, the reasons that the amount of debris sighted within 10 m was less than that between 10 m and 20 m were the short time in which marine debris sighted within 10 m remains in the researcher's visual field and that researchers can not observe the sea surface hidden by the hull, etc. (Mio and Takehama 1988).

As a reference, Table 3 shows in 5° latitude x 10° longitude blocks by the type and occurrences of pieces of debris sighted and Table 4 shows the number and percentage of debris sighted by type and by size.

3) Estimation of Density of Marine Debris by Type and by Block

The line transect method was used to estimate the distribution density of marine debris based on the number of debris sighted.

(1) Outline of the Method

Using the line transect method, the number of marine debris per unit area (density) \( N \) is calculated by the following equation (Seber 1982):

\[
N = \frac{n}{2(w/1,852)L}
\]

(1)

Where, \( n \): number of debris sighted
\( L \): cruise distance
\( w \): effective perpendicular distance (\( w \) was divided by 1,852 to obtain \( \text{nm} \) because the unit used in this study was m)

The effective perpendicular distance is calculated by the following equation using the sighting probability by perpendicular distance \( g(y) \) which is estimated from the number of debris sighted by perpendicular distance (Fig. 4):

\[
w = \int_{0}^{C} g(y) \, dy
\]

(2)

where, \( C \) is a width of the observation
(2) Results

For calculating a sighting probability by perpendicular distance, we used the following hazard rate model which is used also in the whale sighting surveys (Kishino et al. 1989) and fit this curve to each type of debris:

\[ g(y) = 1 - \exp\left(-\frac{y}{A}^{(1-B)}\right) \]  

--------- (3)

In addition, the effective perpendicular distance \( w \) was calculated from equation (2) as \( C = 100 \), and the results of the calculation are shown in Table 5 (although the actual observation covered up to 200 m, only the distance up to 100 m was used for the calculation).

Using \( w \) obtained from Table 5, the density of debris was calculated by equation (1). In the case of observation from only one side, the right side of equation (1) that was doubled was used for the calculation.

\[ (N = \frac{n}{(w/1852)L} \text{ or } n \text{ should be doubled before the calculation}) \]

The estimated density distribution of debris obtained by type and by block is shown in Fig. 5.

4). Distribution of Effort

Surveyed cruising distance (effort) by block is shown in Fig. 2. The effort is, as a matter of fact, larger in waters near Japan, and the number of blocks where the cruise distance for surveys was 10,000 nm and more, were 2 in total from off Hokkaido to Kanto area in total. The number of blocks of this category had a tendency to decrease in recent years. Namely, it was 4 in 1988 and 3 in 1989. We examined blocks where the cruise distance for the survey was 5,000-10,000 nm as the blocks which have the second highest effort next to the blocks of the category above. The number of blocks in this category was 5 which was same as in 1988 and 1989. The distribution of these blocks in waters near Japan was observed in the area southeast of Boso Peninsula, Japan Sea, and East China Sea. These blocks were also observed around the Polar front from 150° to 160°E and in the area of 45° to 50°N, 160° to 170°E. This front is the boundary between subarctic water and subtropical water in general. In this paper, this front is formed off the Sanriku area by the Oyashio and Kuroshio currents and extends to the west coast of the U.S. along 40°N. The north side of the front is good fishing grounds for salmon, squid, and etc.). This effort was due to fishery research activities which were conducted intensively from the Polar front area to the North Pacific area.

The number of blocks with effort of 2,000 to 5,000 nm decreased especially in the North Pacific. This was due to the decrease of salmon research activities in these areas. Some blocks with an effort of this magnitude were distributed in the area southwest of Hawaii and the offshore area of Minami Tori island (near 24°N, 154°E). The surveys conducted by training vessels of fisheries high schools contributed most of this effort.
In contrast, low effort blocks were observed south of 10°N and north of 50°N. However generally, no annual change was observed in the distribution pattern of effort in the North Pacific.

5) Density of Marine Debris by Type

a) Fishing nets

The density of fishing nets (Fig.5-1) was generally large in the mid-latitudinal area of 30° to 40°N, 150° to 130°W and 180° to 170°W of the eastern Pacific. This tendency was almost identical with the results obtained in previous years. In addition, the density in waters on the Pacific side of Japan between 30° to 40°N was extremely high. From this area to the mid-latitudinal area of eastern Pacific stated above was consistent with the subarctic boundary. The high density area was observed in northeastern Hawaii as in previous years.

Although the density in the Japan Sea showed a low value in the past (0.7 x 10^{-2}/n.m² (hereafter x 10^{-2}/n.m² is omitted) and 1.2 in 1988 and 0.0 and 1.1 in 1989), it was high at 5.0 and 3.4 in 1990. In addition, it is pointed out as a feature in 1990 that the percentage off Sanriku was extremely high at 18.7% compared to the density of 1.7% in 1988 and 0.8% in 1989. It is necessary to collect more information and conduct analyses to determine the reason why the high percentage of fishing net debris was recorded in these areas.

It is also a feature in 1990 that no fishing net debris was observed in the Okhotsk sea compared with the density of 5.1 in 1989. It is assumed that this is due to a decrease of fishing vessels operating in this area or fishermen becoming more concerned about marine pollution. It is necessary to analyze this phenomenon and take steps to cope with the marine debris problem.

b) Fishing Gear Other Than Fishing Nets

The range of distribution of other fishing gear sighted (Fig.5-2) was wider than that of fishing nets. That is, the number of blocks where fishing nets and other fishing gears were sighted accounted for 31.5% and 73.4% of the total number of blocks, respectively. The percentage for other fishing gear is over twice the percentage for fishing nets. The major part of the fishing nets was under water. In contrast, other fishing gear has a higher portion on the sea surface because its material is mainly styrofoam and polyethylene. Therefore, floats which are a main portion of the category of other fishing gear receive much effect from wind and have less resistance against sea water, and were distributed over a wider range compared to fishing nets. The pattern of distribution of fishing nets and other fishing gear had similar tendencies to those in previous years (1987: fishing net 36.0% and other fishing gear 71.0%, 1988: 39.2% and 21.0%, 1989: 48.8% and 75.2%). In addition, a high density area was observed north of Hawaii as in previous years.
c) Styrofoam

The number of blocks where styrofoam was distributed accounted for 77% of the total number of blocks (Fig. 5-3). High density was found in the area north to northeast of Hawaii as in previous years. Although high density was found in the Japan Sea as in previous years, the density in the East China Sea was extremely high compared to that in 1988 and 1989. That is, in the East China Sea at 25° to 35°N the average values are 15.3 x 10^{-1}/n.m² (hereafter x 10^{-1}/n.m² is omitted) in 1988, 17.6 in 1989, and 57.3 in 1990, respectively. In addition, the average values in the South China Sea are (no survey in 1988), 16.7 in 1989, and 45.3 in 1990, respectively. Although the cause of these phenomena is unknown, it should be pointed out as a feature in 1990.

d) Other Petrochemical Products

The density of petrochemical products (other plastics) is shown in Fig 5-4. The distribution of this item was widest and the number of blocks where this item was distributed accounted for 84% of the total number of blocks. Although the pattern of distribution of this item was similar to that of styrofoam in previous years, the density in the area of north to northeast of Hawaii was substantially lower than in previous years.

In the Bering Sea, the density was especially high east of the Kamchatka peninsula, and the value in 1990 was one order greater than those in 1988 and 1989.

e) Floating logs

The density of floating logs (Fig 5-5) was relatively high in the area north of Hawaii, which was similar to that of other items. This tendency is similar to that of previous years. The density at the subarctic boundary was not especially high, and this tendency is also similar to that of previous years. By area, high density was observed in the area southeast of the Philippines (0° to 5°N, 130°E to 140°E) and the inner part of Okhotsk Sea where the survey had not been conducted before. The high density in the area along the continent is due to logs lost from land, as already reported by Nasu and Hiramatsu (1989 and 1990).

f) Floating seaweed

The range of distribution of seaweed (Fig 5-6) was the second smallest next to fishing nets as in previous years, and accounted for 46.8% of the total number of blocks. In addition, it had a tendency to be more dense area near land. The highest density were observed in the areas east of Taiwan, and along the Aleutian islands. In addition, a relatively high density was observed near Japan. Relatively high density also was observed in the area north to northeast of the Hawaiian Islands (35°N to 40°N, 170°W to 140°W), however it was still lower than that of the area near the continent.
The phenomenon that high density areas of floating seaweed were observed near the continent was substantial is similar to that of floating logs which belong to same natural floating objects.

g) All Floating Objects

The total density of the above types of debris is shown in Fig 5-8. The phenomenon that high density was formed in the nearshore area is due to the concentration in this area of floating logs and seaweed which occupy almost half the debris sighted, and in contrast artificial objects were distributed over a wide range.

According to survey results obtained in the past, the tendency to have a high density area north to northeast of the Hawaiian Islands for artificial objects has been pointed out (Mio and Takehama 1988, Nasu and Hiramatsu 1990). Moreover, based on the result of observations using an Argos buoy (Kubota 1990) and on the result of simulation using drifting data of vessels in the past (Institute of Ocean Research and Development, Tokai University 1988), we were able to determine that the gyre contributed to the formation of concentration.

4. Consideration

It is pointed out as a feature of 1990 that density in the subarctic boundary area (30°N to 40°N, 180° to 130°W) where high density was observed in the past was extremely low (Table 6). In the whole survey area, the density of debris sighted was 47.92 compared to 43.50 in 1988 and 58.83 in 1989, and substantial annual change was not observed. However, the density of all debris items was lower than 1988 and 1989 in the subarctic boundary area, and total density in this area in 1990 (29.05) was only 38% of that in 1988 and 20% of that in 1989.

There were no special changes in effort during the period of 1988 to 1990. The density in 1990 is not considered to be reflected in the volume of debris lost in 1990 because the density in 1990 includes debris lost before 1990 as well as that lost in 1990. Therefore, since the density of all items show a decline in the area of 30°N to 40°N and 180° to 130°W where high density was observed in the past, it is assumed that the phenomenon of the gyre which has been pointed out as a major cause contributing to the formation of concentration was somewhat different in 1990. We are planning to analyze this in the future because at this stage, more information is needed in order to review this marine environment.

Reference


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KUBOTA, M. 1990. Plan of the investigation research on the accumulation mechanism. Oral statement at the planning meeting of the investigation research on the accumulation mechanism. (In Japanese).


Table 1 to 6 and Figs. 1 to 6 are in English in the Japanese document.