

**ESTIMATING THE DENSITY OF FLOATING MARINE
DEBRIS: DESIGN CONSIDERATIONS**

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ABSTRACT

We calculated sample sizes needed to estimate the density of surface marine debris potentially injurious to marine mammal and bird populations in the Gulf of Alaska and the Bering Sea as well as sample sizes needed to specifically estimate floating nets. Using published estimates of debris density, we developed alternative sample size requirements that depended on the accuracy required based on the coefficient of variation of the density. The survey technique used was visual sighting of debris using strip transect methodology. In general, large numbers of transects are needed in order to get estimates even with large coefficients of variation. Sparsity of data and nonstandard definition of transects contribute to the problems in estimating required sample sizes.

INTRODUCTION

The problems of marine debris and its impacts on marine mammals and on human activity in the oceans have been reviewed and discussed extensively by Shomura and Yoshida (1985). There has been interest in estimating the amount of floating marine debris using visual assessment. This technique has been used by many researchers (Venrick et al. 1973; Suzuoki and Shirakawa 1979; Dahlberg and Day 1985; Jones and Ferrero 1985; Yoshida and Baba 1985a, 1985b, 1988; Baba et al. 1986; Ignell and Dahlberg 1986; Day and Shaw 1987; McCoy 1988; Mio and Takehama 1988; Yagi and Nomura 1988). The purpose of this paper is to investigate survey design to estimate the density of surface marine debris in the Gulf of Alaska and Bering Sea.

We considered the design of two surveys. The first was to estimate density for all potentially harmful floating debris that could be visually assessed (specifically nets, fragmented plastic pieces, and strapping bands). Each type of debris was assumed to be equally important. The second design was for estimating the density of floating nets only.

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METHODS

The strip transect was the method used for visually assessing the density of floating objects. This method was chosen because of its widespread use (references cited above). The transects have a fixed width and the assumption is that all objects within that width are seen. The method of Burnham et al. (1980) was used to estimate sample size. This method is nonparametric because it does not make an assumption about the distribution of the debris. Estimation of sample size is based on achieving a certain coefficient of variation for the density of objects.

We used the conservative estimate for total transect length:

$$L = (3 \cdot L1) / (cv(D)^2 \cdot n1)$$

where L1 (total length of transects) and n1 (total number of objects seen) come from a pilot study, and cv(D) is the coefficient of variation (Burnham et al. 1980).

We used previously published papers on the Gulf of Alaska and the Bering Sea for estimates of L1 and n1 for total floating debris and floating nets. In addition, the data for the 1984 marine mammal observer program were made available to us (L. Jones, National Marine Mammal Laboratory, Seattle, WA, pers. commun.).

RESULTS

Total Floating Debris

From Dahlberg and Day (1985), an estimate of all debris was based on a strip transect with a width of 50 m. They do not state the length of their transects but state that an average of 5.5 h/day were spent watching for debris and that 1,516 nmi were sampled from Alaska to Hawaii (Dahlberg and Day 1985). This gives an average transect length of 47 nmi covered per 5.5 h. So the sampling unit will be defined here as a transect 47 nmi long by 50 m wide. Twelve objects were seen in the Gulf of Alaska (n1) and we estimate 670 nmi (Dahlberg and Day 1985, fig. 3) was surveyed (L1). Dahlberg and Day (1985) gave a density estimate for all floating marine debris as 0.28 pieces/km², but they did not publish a variance estimate. Day and Shaw (1987) give density and variance estimates for large floating plastic for the subarctic North Pacific (Gulf of Alaska) and, separately, for the Bering Sea.

Estimates of required sample sizes (number of transects) for estimating total floating debris are presented in Table 1. In general, in order to estimate density to any degree of precision (low cv(D)), 2 months or more of daily transects (5.5 h of observation for a 47-nmi-long by 50-m-wide transect) would be needed. Dahlberg and Day (1985) carried out about 14 transects, which would put their estimate in the 0.50 cv(D) category (not a small coefficient of variation).

Table 1.--Sample size estimation for all floating marine debris using a strip transect of 47 nmi long by 50 m wide for the Gulf of Alaska and the Bering Sea for different coefficients of variation for the density. (L = total transect length and n = number of transects needed to cover that length.)

cv(D)	L (nmi)	n
0.10	16,750	994
0.25	2,680	57
0.50	670	15
0.80	262	6
1.0	167	4
1.2	117	3

Nets

From Jones and Ferrero (1985), 8,759 nmi (L1) were surveyed in 1984 with 12 pieces of net seen (n1). A density estimate of floating nets would be 0.0074 nets/km². A transect for this study was 2 nmi in length and 100 m in width. A total of 1,410 transects were made.

Estimates of total sample size (number of transects) for estimating floating nets are presented in Table 2. In all cases, a large number of transects (2 nmi length by 100 m width) would need to be made to get even an inaccurate estimate of the density of nets. There were 1,410 transects made in 1984, which would put the net density estimate in the 0.80 cv(D) category, a large coefficient of variation.

DISCUSSION

The number of transects needed to produce a reasonable estimate for floating marine debris and especially for nets is extremely large. This demonstrates that targeting for a specific type of debris that is relatively rare, like floating nets, will take a large commitment of resources. These sample size estimates, however, depend on a large number of factors.

First, the approach we used is a nonparametric approach that is extremely general and requires sighting 25 or more objects to produce estimates of means and variances with any degree of accuracy (Burnham et al. 1980). Sample sizes for estimating rare objects like floating nets will be extremely large. A parametric approach such as using a binomial distribution may lead to smaller sample sizes but then the underlying model will have to be verified (Ribic and Bledsoe 1986).

Second, there was little information on which to base preliminary estimates of density and variation. Some of this had to do with the way

Table 2.--Sample size estimation for floating nets using a strip transect of 2 nmi long by 100 m wide for the Gulf of Alaska and the Bering Sea for different coefficients of variation for the density. (L = total transect length and n = number of transects needed to cover that length.)

cv(D)	L (nmi)	n
0.10	218,975	109,488
0.25	35,036	17,518
0.50	8,760	4,380
0.80	3,422	1,711
1.0	2,190	1,095
1.2	1,521	761

the data were reported. For example, in some cases we could not determine the length of a transect so we could not use the reported data. But more importantly, there is little published information on which to base preliminary estimates. Dahlberg and Day (1985) worked along long. 155°W. Jones and Ferrero (1985) worked in the middle of the gillnet fishery. Whether these studies are representative of the rest of the unsampled area is not known.

Third, transect length and width are not standardized, so sample size estimates in this paper depend on a specifically defined transect. Density estimates depend on the dimensions of the strip transect. Therefore, generalizations are difficult, since most researchers use different transect widths and lengths for their transects (e.g., Mio and Takehama (1988) used a width of 10 m).

Fourth, due to lack of information on variation for the Gulf of Alaska and the Bering Sea, we did not consider stratification (Cochran 1977), which could be potentially very useful in determining sample allocation and the placement of transect lines. Dahlberg and Day (1985) and Ignell and Dahlberg (1986) noted the concentration of debris in downwelling areas and frontal zones. A large-scale survey such as that of Mio and Takehama (1988) for the Gulf of Alaska and the Bering Sea would greatly improve our knowledge of the distribution of marine debris and improve survey design immensely.

Further refinement of the survey objective would be helpful when we consider placement of the transect lines. If a study is a one-time occurrence, the transects can be considered temporary and location will be decided by where the ship goes. However, if the study is to be a long-term study, thought should be given to permanent transects. For example, Day and Shaw (1987) compared the density of debris along long. 155°W previously sampled by Dahlberg and Day (1985). The long. 155°W line would be an

example of a permanent transect that could be surveyed over time. Another example is the study of Yagi and Nomura (1988), where the long. 137°E line was surveyed between lat. 0° and 34°N each summer and winter for 9 years; however, they commented that their limited coverage of the area did not allow them to make conclusions about changes in marine debris distribution over time.

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REFERENCES

- Baba, N., K. Yoshida, M. Onoda, N. Nagai, and S. Toishi.
1986. Research on ocean current and drifting stray fishing gear and net fragments in the area to the southwest of the Pribilof Islands and the southern coast of the Aleutian Islands, July-August, 1985. Document submitted to the Standing Scientific Committee of the North Pacific Fur Seal Commission.
- Burnham, K. P., D. R. Anderson, and J. L. Laake.
1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr.* 72.
- Cochran, W. G.
1977. *Sampling techniques*. Third edition. Wiley, N.Y.
- Dahlberg, M. L., and R. H. Day.
1985. Observations of man-made objects on the surface of the North Pacific Ocean. 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. 198-212. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.
- Day, R. H., and D. G. Shaw.
1987. Patterns in the abundance of pelagic plastic and tar in the North Pacific Ocean, 1976-1985. *Mar. Pollut. Bull.* 18:311-316.
- Ignell, S. E., and M. L. Dahlberg.
1986. Results of cooperative research on the distribution of marine debris in the North Pacific Ocean. Document submitted to the International North Pacific Fisheries Commission, Anchorage, AK, November 1986. Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Auke Bay Laboratory, P.O. Box 210155, Auke Bay, AK 99821, 15 p.

Jones, L. L., and R. C. Ferrero.

1985. Observations of net debris and associated entanglements in the North Pacific Ocean and Bering Sea, 1978-84. 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. 183-196. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54.

McCoy, F. W.

1988. Floating megalitter in the eastern Mediterranean. Mar. Pollut. Bull. 19:25-28.

Mio, S., and S. Takehama.

1988. Estimation of distribution of marine debris based on the 1986 sighting survey. In D. L. Alverson and J. A. June (editors), Proceedings of the North Pacific Rim Fisherman's Conference on Marine Debris, Kailua-Kona, Hawaii, October 13-16, 1987, p. 64-94. Unpublished report by Natural Resources Consultants, 4055 21st Avenue W., Seattle, WA 98199.

Ribic, C. A., and L. J. Bledsoe.

1986. Design of surveys for density of surface marine debris in the North Pacific. Northwest Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA. NWAFC Processed Rep. 267, 69 p.

Shomura, R. S., and H. O. Yoshida (editors).

1985. Proceedings of the Workshop on the Fate and Impact of Marine Debris, 26-29 November 1984, Honolulu, Hawaii. U.S. Dep. Commer., NOAA Tech. Memo. NMFS, NOAA-TM-NMFS-SWFC-54, 580 p.

Suzuoki, T., and K. Shirakawa.

1979. Visual observation of floating pollutants in open ocean. Oceanogr. Mag./Kisho-Cho Obun Kaiyoho 30(1-2):55-60.

Venrick, E. L., T. W. Backman, W. C. Bartram, C. J. Platt, M. S. Thornhill, and R. E. Yates.

1973. Man-made objects on the surface of the central North Pacific Ocean. Nature 241:271.

Yagi, N., and M. Nomura.

1988. Sighting survey on marine debris in the midwestern Pacific from 1977 through 1986. In D. L. Alverson and J. A. June (editors), Proceedings of the North Pacific Rim Fisherman's Conference on Marine Debris, Kailua-Kona, Hawaii, October 13-16, 1987, p. 130-142. Unpublished report by Natural Resources Consultants, 4055 21st Avenue W., Seattle, WA 98199.

Yoshida, K., and N. Baba.

1985a. Results of the survey on drifting fishing gear or fish net pieces in the Bering Sea. Document submitted to the 28th Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission, Tokyo, 4-12 April 1985, 13 p.

- 1985b. A survey of drifting stray fishing net fragments in the northern Sea of Japan (western Pacific Ocean). Document submitted to the 28th Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission, Tokyo, 4-12 April 1985, 13 p.
1988. Results of research on the effects of marine debris on fur seal stocks and future research programs. In D. L. Alverson and J. A. June (editors), Proceedings of the North Pacific Rim Fisherman's Conference on Marine Debris, Kailua-Kona, Hawaii, October 13-16, 1987, p. 95-129. Unpublished report by Natural Resources Consultants, 4055 21st Avenue W., Seattle, WA 98199.