THE RELATIVE SAMPLING PERFORMANCE OF 6- AND 10-FOOT ISAACS-KIDD MIDWATER TRAWLS

WILLIAM A. FRIEDL[1]

ABSTRACT

The relative abilities of 6- and 10-ft Isaacs-Kidd midwater trawls (IKMT) to sample macroplankton and fishes were assessed from comparable hauls taken with graded mesh nets during January and February 1967, in central Puget Sound. The plankton catch, mostly individuals 2 to 2.5 cm long, was dominated by the mysid, *Neomysis kadiakensis*. To quantify zooplankton data from the larger trawl, its cross-sectional area effective in filtering macroplankton was estimated for each month. The mean effective cross-sectional area of the 10-ft IKMT is 1.75 m^2. This implies a significant funneling of macroplankton by the forward section of the trawl.

The fishes taken were dominated numerically by Pacific herring, *Clupea harengus pallasi;* bay gobies, *Lepidogobius lepidus;* and plainfin midshipmen, *Porichthys notatus.* Herring was not taken by the 6-ft trawl; there was little apparent difference in the ability of the two trawls to capture midshipmen and gobies. Overall, the 10-ft IKMT caught more fish, more active fish, and larger fish than the 6-ft trawl. Though the 6-ft IKMT is probably adequate for studies with an emphasis on macroplankton, use of the 10-ft IKMT to sample fishes in inshore waters is preferable.

Interpretation of net haul data depends upon the capabilities and limitations of the sampling gear employed. With the plethora of equipment presently available for sampling the larger plankton and smaller nekton, comparative information on the relative sampling abilities of different gear is needed to equate results obtained with different nets.

This report deals with the relative sampling abilities of two sizes of Isaacs-Kidd midwater trawl (IKMT), a type of net widely employed in marine and freshwater investigations. The results apply to IKMT in general; the assessment elucidates the degree to which data obtained with different trawls are comparable.

METHODS AND MATERIALS

Samples were taken from the University of Washington 65-ft research vessel *Hoh* at night along a N-S track in Port Orchard, a narrow channel west of Bainbridge Island in central Puget Sound with a maximum depth of slightly over 40 m. Comparable IKMT hauls were made on two cruises in January and February 1967. Length frequency data are from five cruises made each month from November 1966 through March 1967.

Two sizes of IKMT with graded mesh nets were compared. The mouth area of the 10-ft IKMT (Figure 1) is 7.68 m^2 and that of the 6-ft IKMT (Aron, 1959) is 2.94 m^2. Mesh sizes for the various sections of the trawls and other

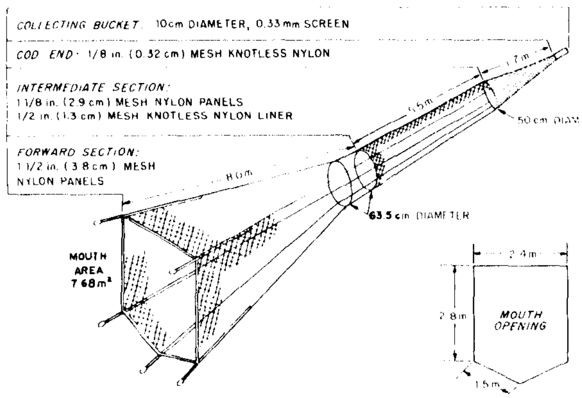

FIGURE 1.—Dimensions and construction details of the 10-ft Isaacs-Kidd midwater trawl used in this study (after Cooney, 1967).

[1] Marine Biology Branch Code 5042, Naval Undersea Research and Development Center, San Diego, Calif. 92132.

Manuscript received January 1971.

TABLE 1.—Dimensions and material specifications of the Isaacs-Kidd midwater trawls compared in this study.

Item	6-ft IKMT	10-ft IKMT
Mesh size		
Forward section	7.6 cm	3.8 cm
Intermediate section	1.3 cm	1.3 cm
Cod end	3.2 mm	3.2 mm
Cross-section area		
Mouth	2.94 m^2	7.68 m^2
Liner	1.26 m^2	0.32 m^2
Cod end	0.20 m^2	0.20 m^2
Filtering area		
Forward section	14.85 m^2	51.96 m^2
Intermediate section	7.02 m^2	9.81 m^2
Cod end	1.61 m^2	1.61 m^2

dimensional data are presented in Table 1. During each haul, speeds were measured at the surface with a Tsurami-Seiki-Koshakusho Co. flowmeter[2] while trawls were at depth. The same engine speed was used for all hauls. Generally, trawls were at depth 10 min and in the water less than 15 min total. In January, several 10-ft IKMT hauls were at depth 15 min. Net depth was monitored on deck from signals transmitted through the towing cable by a pressure-activated sensing unit (designed and built by the Department of Oceanography, University of Washington) mounted above the trawl. A Marine Advisers bathykymograph attached to the trawl bridle was read after each haul to check sampling depth.

The sampling distance was calculated from the speed and duration of each haul. This distance was multiplied by the appropriate trawl mouth area (Table 1) to determine the maximum volume of water filtered during each haul; the volumes so determined were used to calculate the monthly fish concentrations. For determinations of zooplankton concentrations, however, use of filtered volumes based on trawl mouth areas would result in concentrations inordinately low (Banse and Semon, 1963). Instead, volumes filtered should be based on the trawl cross-sectional area effective in sampling zooplankton of the size considered. The effective cross-sectional area, as used here, may be defined as that area which yields the correct zooplankton concentration, as measured independently, when divided into the zooplankton catch per unit distance of tow. Thus, if the length of tow is known, the number of animals caught per unit distance towed can be converted to concentration if the effective cross-sectional area is known. Banse and Semon (1963) compared euphausiid catches from a quantitative high speed catcher with those of the 6-ft IKMT and determined the effective cross-sectional area of the trawl to be not significantly different from the area of the opening of the middle (1.3-cm mesh liner) section of the trawl, namely 1.26 m^2 (Table 1). This effective area, multiplied by the sampling distance for 6-ft IKMT hauls, produced the effective volume of water filtered by the smaller trawl. Macroplankton concentrations were calculated for January and February from total 6-ft IKMT catch and total effective volumes filtered each month. Total 10-ft IKMT macroplankton catch was divided by the total sampling distance to determine the monthly macroplankton catch per kilometer by the larger trawl.

RESULTS AND DISCUSSION

Macroplankton samples from each trawl were compared to determine the effective cross-sectional area of the 10-ft IKMT. The mysid, *Neomysis kadiakensis*, represented 80% of the total catch; the mysid (*Acanthomysis macropsis*), the euphausiids (*Euphausia pacifica* and *Thysanoessa raschii*), and decapods of the genus *Crago* made up most of the rest. Most of the individuals were between 2 and 2.5 cm long. Plankton concentrations were considerably reduced in February (Table 2) and separate estimates of the 10-ft IKMT effective cross-sectional area were made for each month. Using the method of Banse and Semon (1963), division of the 10-ft IKMT catch per kilometer by the catch per 1000 m^3 filtered by the effective cross-sectional area of the smaller trawl yielded an estimate of the 10-ft IKMT effective cross-sectional area for each month (Table 2). The mean effective area, weighted according to the number of 10-ft IKMT hauls made each month, is 1.75 m^2 (Table 2). This is considerably larger than the area of the intermediate section open-

[2] The use of trade names is merely to facilitate descriptions; no endorsement is implied.

TABLE 2.—Summary of macroplankton catch data used to compute the 10-ft IKMT cross-sectional area effective in sampling macroplankton. Separate estimates were made for each month. The mean 10-ft IKMT effective area is computed from the monthly estimates and is weighed according to the number of hauls made with the larger trawl each month (see text).

Month	6-ft IKMT				10-ft IKMT				
	Hauls (no.)	Catch (no.)	Volume (10^3 m^3)	Concentration (catch/10^3 m^3)	Hauls (no.)	Catch (no.)	Distance (km)	Catch/km	Effective area (m^2)
Jan.	8	588	16.16	36.38	6	774	12.95	59.77	1.643
Feb.	8	128	17.41	7.35	12	221	16.62	13.30	1.810

Weighted mean effective area: $\frac{(1.643 \times 6) + (1.810 \times 12)}{18} = 1.754\ m^2$

ing (0.32 m^2; Table 1) and indicative of a significant funneling by the forward section of the trawl.

The effective macroplankton sampling area of the 6-ft IKMT corresponds to the area of the opening of the intermediate section (1.3-cm mesh liner); effects of funneling by the forward section (7.6-cm mesh) of the trawl are not obvious (Banse and Semon, 1963). My results indicate that the forward section of the 10-ft IKMT, with 3.8-cm mesh, is relatively more important a factor in the ability of the net to sample macroplankton than the corresponding section of the smaller trawl. Given forward sections of the same mesh for both trawls, however, the effective macroplankton sampling area of the 6-ft IKMT would probably equal or exceed that of the 10-ft IKMT, for organisms of the size considered here. The ratio of the effective cross-sectional area to total trawl mouth area is 0.43 for the 6-ft IKMT and 0.23 for the 10-ft trawl. Thus, a larger percentage of the water entering the mouth of the smaller trawl is filtered for macroplankton. For this reason, and because the 6-ft IKMT is generally easier to handle and deploy, the smaller trawl would be preferred for studies with primary emphasis on macroplankton or small fishes.

The relative ability to each trawl to sample fishes was also assessed. Total catch figures are presented in Table 3. Numerically, Pacific herring, *Clupea harengus pallasi;* bay gobies, *Lepidogobius lepidus;* and plainfin midshipmen, *Porichthys notatus*, dominated the overall catch. Herring and gobies were common in hauls above 23 m while midshipmen were most abundant in deeper tows. A few shiner perch, *Cymatogaster aggregata*, Pacific cod, *Gadus macrocephalus*, spiny dogfish, *Squalus acanthias*, and miscellaneous flatfishes were also taken and are included in the category "Others" in Table 3. Though the total catch of the 10-ft IKMT exceeds that of the 6-ft IKMT for each category of fishes, the data are not directly comparable because the larger trawl filtered more water in each stratum. To equate catch data between trawls on the basis of equal volumes filtered, the 10-ft IKMT catch for each category of fish was multiplied by the ratio of 6-ft to 10-ft IKMT volumes filtered for each stratum (0.31 for hauls above 23 m; 0.47 for deeper hauls. Exact volumes given in Table 3). The product, expressed

TABLE 3.—Summary of fish catch data, by trawls, from hauls made in January and February 1967. Total catch figures are in whole numbers and concentrations of fishes (Individuals/1000 m^3 of water filtered) are in parentheses. Estimated 10-ft IKMT catch for volumes filtered equal to those of the 6-ft IKMT within each stratum is entered as "Equivalent 10-ft catch" and is directly comparable to the 6-ft IKMT catch data (see text).

Trawl	10 to 22 m						23 to 31 m					
	Hauls (no.)	Volume (10^3 m^3)	Herring	Bay gobies	Midshipmen	Others	Hauls (no.)	Volume (10^3 m^3)	Herring	Bay gobies	Midshipmen	Others
10-ft	14		27	24	4	8	4		1	10	48	11
		171.4	(.16)	(.14)	(.02)	(.05)		53.7	(.02)	(.19)	(.89)	(.20)
6-ft	11		0	2	0	1	5		0	2	22	1
		53.4	--	(.04)	--	(.02)		25.1	--	(.08)	(.88)	(.04)
Equivalent 10-ft catch			8	8	1	3			1	5	22	5

to the nearest whole number, is entered as "Equivalent 10-ft catch" in Table 3 and is directly comparable to the catch figures for the 6-ft IKMT in the row above it. Figures for the overall fish concentrations, from data on total catch and total volume filtered, are also given in Table 3.

When the catch data are compared on an equal volume filtered basis, the superior sampling ability of the 10-ft IKMT is evident. With the exception of *Porichthys* in the lower stratum, the 10-ft IKMT caught more fish of each category than did the 6-ft trawl and the resulting overall concentrations estimated by the 10-ft IKMT are likewise higher (Table 3). Pacific herring, a major component of the mid-depth sonic scattering layer in Port Orchard (Cooney, 1967; Friedl, 1970), were not taken by the 6-ft IKMT and apparently were capable of actively avoiding the smaller trawl. The less active, *Porichthys*, however, was sampled equally by the trawls in the lower stratum. Though the catch and concentrations of *Lepidogobius* appear much lower for the 6-ft IKMT in Table 3, the discrepancy may reflect gear selection and loss through the 7.6-cm mesh of the 6-ft IKMT forward section more than active avoidance of the trawl by the fish. The *Lepidogobius* captured were small, 35 to 50 mm SL, and probably were filtered only by the 1.3-cm mesh liner of the 6-ft IKMT intermediate section. Assuming all gobies taken by the 6-ft IKMT were filtered by the intermediate section only, the concentrations above and below 23 m would be 0.12 and 0.11 fish per 1000 m^3, respectively, and would more nearly approximate those of the larger trawl (Table 3). Thus, as with the macroplankton, the finer mesh of the forward section of the 10-ft IKMT enhanced the ability of the trawl to sample small organisms.

The 10-ft IKMT caught more fish and sampled active fish better than the 6-ft IKMT despite the fact it was generally towed at lower speeds (Table 4). The towing speed of the smaller trawl, though only slightly greater than that of the 10-ft IKMT, could have increased pressure waves and vibrations associated with the trawl and evoked greater avoidance responses in active fishes such as herring (Chapman, 1964; Harrisson, 1967). At present, knowledge of the pressure and vibration characteristics of IKMT underway is lacking and further conclusions regarding the influence of such characteristics on the sampling abilities of trawls would be speculative and beyond the scope of this paper.

TABLE 4.—Net speed data for 6- and 10-foot IKMT hauls in January and February 1967. Speeds measured at the surface while the trawls were at depth. Average speeds are significantly different at the 99% level when compared with Student's *t* distribution (Simpson, Roe, and Lewontin, 1960).

Trawl	Hauls (no.)	Trawling speed (m/sec)		
		Range	Average	Confidence interval (95%)
10-ft	18	1.64 to 2.13	1.84	1.78 to 1.90
6-ft	16	1.99 to 2.25	2.14	2.09 to 2.19

Comparison of the length frequencies of *Porichthys* taken in deeper tows during the entire winter period (November - March) indicates a selection for larger fish by the larger trawl, despite its slower towing speeds and finer mesh (Figure 2). Nearly 70% of the *Porichthys* taken between 20 and 35 m by the 6-ft IKMT in the winter were less than 150 mm long (SL), while half the *Porichthys* taken by the 10-ft IKMT between 25 and 35 m in the same period exceeded 180 mm SL (Figure 2).

My results indicate the 10-ft IKMT catches more fish, more active fish, and larger fish than the 6-ft IKMT used in the study; similar conclusions, with respect to the ability of small and large trawls to sample mesopelagic fishes, were reached by Harrisson (1967). Aron and Collard (1969) studied the influence of net speed on catch for a 6-ft IKMT fully lined with 1.2-cm mesh netting and found that faster tows took larger fish of certain types off the California coast. My data, for inshore fishes, indicate mouth size, towing speed, net mesh size, and, perhaps, the dynamic characteristics of trawls combined with the behavioral aspects of the organisms sampled are all interrelated in a complex way to ultimately determine the sampling ability of a given trawl.

Standardization of gear and techniques used to sample midwater organisms would provide

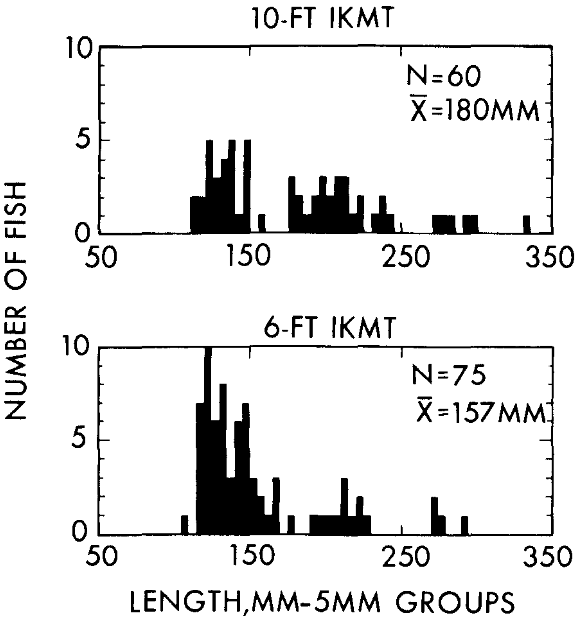

FIGURE 2.—*Porichthys notatus* length frequencies (SL) from hauls made on monthly cruises from November 1966 through March 1967. Ten-ft IKMT catch from five hauls between 25 and 35 m; volume filtered 57,400 m^3. Six-ft IKMT catch from 12 hauls between 20 and 35 m; volume filtered 58,000 m^3. Total catch (N) and mean length ($\bar{X}$) given on graphs for each trawl.

a more valid basis for comparison of different samples, but limitations of resources and equipment often determine the manner and means by which samples are taken. In this study, for instance, the strain of towing the 10-ft IKMT severely taxed the running rigging of the research vessel and prevented the use of the larger trawl on some cruises. At best, results of studies, such as this and that of Aron and Collard (1969), illuminate the limitations and capabilities of sampling gear, characteristics which must be recognized even with widely employed equipment such as the 6-ft IKMT. That trawls may sample only a limited portion of the fauna present is obvious and must be recognized. For instance, recent work in Puget Sound with large trawls indicates concentrations of herring, determined by IKMT hauls in winter sonic scattering layers, may be at least two orders of magnitude low (T. S. English, unpublished data). Thus, discussion of the biological "universe" defined by samples from a given trawl must acknowledge the limitations of the gear employed and avoid conclusions beyond the scope of the data available from the sampler.

In general, my results indicate the 10-ft IKMT to be preferable to the 6-ft IKMT for biological surveys emphasizing fishes in inshore waters, provided the vessel employed is capable of handling the large trawl on a regular basis. For surveys of macroplankton, however, the 6-ft IKMT is adequate and generally easier to deploy. The larger mouth opening and overall finer mesh of the forward section apparently enable the 10-ft IKMT to sample more fish, larger fish, and more active fish better than the 6-ft trawl. Fully lining the trawls with fine-mesh netting (UNESCO, 1968) would help simplify analysis of results by eliminating the need for estimating effective sampling cross-sectional areas when calculating concentrations of small fishes and macroplankton. Such lining would probably also increase the trawls' ability to sample smaller fishes (Backus et al., 1970), but the overall capabilities of the trawls to sample large or active forms would likely change little and utilization of the 10-ft IKMT would still be recommended.

ACKNOWLEDGMENTS

This project was conducted in partial fulfillment of the requirements for a degree of Master of Science in the Department of Oceanography, University of Washington, Seattle, Wash., with the guidance of Dr. T. Saunders English. The efforts of the crew of R/V *Hoh* are gratefully acknowledged as is the critical review of the manuscript by Dr. Eric G. Barham, Naval Undersea Research and Development Center, San Diego, Calif. Final preparation supported by the U.S. Naval Ship Systems Command under SR 104 03 01 Task No. 0588.

LITERATURE CITED

ARON, W.
1959. Midwater trawling studies in the North Pacific. Limnol. Oceanogr. 4: 409-418.

ARON, W., AND S. COLLARD.
1969. A study of the influence of net speed on catch. Limnol. Oceanogr. 14: 242-249.

BACKUS, R. H., J. E. CRADDOCK, R. L. HAEDRICH, AND D. L. SHORES.
1970. The distribution of mesopelagic fishes in the equatorial and western North Atlantic Ocean. J. Mar. Res. 28: 179-201.

BANSE, K., AND D. SEMON.
1963. On the effective cross-section of the Isaacs-Kidd midwater trawl. Univ. Wash. Dep. Oceanogr. Tech. Rep. 88, 9 p.

CHAPMAN, C. J.
1964. Importance of mechanical stimuli in fish behaviour, especially to trawls. *In* Modern fishing gear of the world 2: 537-540. Fishing News (Books) Ltd., London.

COONEY, R. T.
1967. Diel differences in trawl catches of some demersal fishes. M. S. Thesis, Univ. Wash., Seattle, 96 p.

FRIEDL, W. A.
1970. Sonic scattering and its probable causes in two areas of Puget Sound. *In* G. B. Farquhar (editor), Proceedings of an international symposium on biological sound scattering in the ocean, March 31-April 2, 1970, p. 527-550. Maury Center Ocean Sci. Rep. 005.

HARRISSON, C. M. H.
1967. On methods for sampling mesopelagic fishes. *In* N. B. Marshall (editor), Aspects of marine zoology, p. 71-126. Symp. Zool. Soc. London 19.

SIMPSON, G. G., A. ROE, AND R. C. LEWONTIN.
1960. Quantitative zoology. Revised ed. Harcourt, New York, 440 p.

UNESCO.
1968. Zooplankton sampling. UNESCO (U.N. Educ. Sci. Cult. Organ.) Monogr. Oceanogr. Method. 2, 174 p.