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COMPARISON OF OTTER TRAWLS USED IN SOUTHERN CALIFORNIA COASTAL SURVEYS

Alan J. Mearns
Harold H. Stubbs

SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT
1500 East Imperial Highway, El Segundo, California 90245

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1500 East Imperial Highway
El Segundo, California 90245
(213) 322-3080

INTRODUCTION AND SUMMARY

Since 1957, small otter trawls (shrimp trawls or trynets) have been used in southern California to sample and monitor bottom fish and invertebrate populations of the coastal shelf. The gear used by public, private, and academic agencies have varied in terms of net size and type, mesh size, size of otter trawl boards (doors), and bridle lengths; towing speed and duration has also varied from agency to agency. For this reason, it has been difficult to make judgments about the relative abundance and health of epibenthic fauna in the different sampling regions (some of the general aspects of this problem are discussed by Allen et al. (1960)).

These considerations have prompted the Coastal Water Research Project to investigate the trawl gear and procedures now in use. Our studies, conducted in cooperation with other private and public agencies, include a detailed review of existing literature on trawling, actual field tests to compare catches taken by various gear, and a program to construct, modify, and generally improve upon the kind of gear most useful for sampling coastal shelf fish and invertebrate communities. We have already reported on the effect of variations in mesh size on catches of small fishes (Chapter 7, Southern California Coastal Water Research Project 1973). This report contains results of direct surface-towing observations of the spread characteristics of the nets of six local agencies.

In general, there was a threefold variation in the spread of the trawl boards on the nets tested. The spread of the boards, which determines the width of the net opening, was not necessarily a function of headrope length: Major differences in spread may be related to major differences in field rigging procedures, door size, and towing speed.

In our initial attempts to relate the gear differences we observed to catch statistics, we found that data from three agencies, two of which trawl off Orange County, should be directly comparable. However, data taken by the two agencies surveying the areas of heaviest wastewater discharge (Santa Monica Bay and Palos Verdes) are not comparable, either to the data from each other or to that of agencies working in other areas. Replicate field tests are required to confirm apparent relationships and provide information on absolute difference in gear efficiency.

METHODS

Otter trawl nets and boards were obtained from the six agencies that have been conducting most of the trawl monitoring in southern California in recent years (Table 1). Our detailed description of each gear type was based on direct measurement (Figure 1) and examination of the specification data available from purchase orders. The features of interest were (1) net dimensions, (2) bag and cod-end mesh size, (3) number of meshes along all joined edges (including wings and square), (4) thread types, (5) length of headrope, footrope, leglines, and bridles, and (6) number of headrope floats. From the nets examined, six net and door assemblies were selected for direct observation of relative spreading efficiency under tow at 1.3 m/sec (2.5 kn) near the surface. Tows were made in relatively calm water at Morro Bay, California, during April 1973. Each net was attached to a standard[1] set of 22-m (72-ft) bridles and towed close astern so that the spread of bridles could be measured. These experiments were similar to those reported by Ketchen (1951) in which he found an inverse relation between vessel speed and distance between otter boards.

Estimates of trawl board and net openings were made by directly measuring the spread (in inches) of the bridles at a distance of 3 ft from their point of attachment to the towing cable (Figure 2). Trawl board spread was estimated by the relationship:

$$\text{Trawl board spread (ft)} = \frac{\text{Bridle length x Spread of Bridles at 3 ft}}{\text{3 ft}}$$

These observations and estimates provide a relative (rather than actual) basis for comparing gear, because the bridle used in our test differed in length from those actually used in the various field surveys.

Finally, field data obtained using some of the gear in question were examined to determine whether or not gear differences might be related to catch differences.

RESULTS

Gear and Gear Use Procedures

Each of the six agencies uses one or more of the nets we examined (Table 1); net headropes vary from 4.9 to 12.2 m (16 to 40 ft). During actual field surveys (Table 2), all agencies except Hyperion tow at speeds between 1.3 and 1.5 m/sec (2.5 to 3.0 kn)--Hyperion

1. As a general rule, bridles should be at least three times as long as the headrope.

Table 1.

Gear types and trawling regions of six agencies monitoring southern California coastal waters.

Agency	Region Sampled	Gear Make	Headrope Length m	Headrope Length ft
Hyperion Treatment Plant, City of Los Angeles	Santa Monica Bay	Wilcox 25-ft semiballoon	7.62	27
County Sanitation Districts of Los Angeles County	Palos Verdes and Catalina Is.	Wilcox 40-ft semiballoon	12.2	40
		Wilcox 25-ft semiballoon	7.62	27
Marine Biological Consultants (MBC), Costa Mesa	Orange, Ventura Counties	Marinovich 25-ft semiballoon	7.62	25
		Marinovich 16-ft semiballoon	4.88	16
Orange County Department of Education, Marine Sciences Program	Dana Point, Orange County	Marinovich 16-ft semiballoon	4.88	16
Occidental College, Los Angeles	San Pedro Bay, Orange County	Marinovich 25-ft semiballoon	7.62	25
	L.A.-L.Bch. Harbor, San Pedro Bay	Marinovich 16-ft semiballoon	4.88	25
Coastal Water Research Project	All areas above	Marinovich 25-ft semiballoon	7.62	25

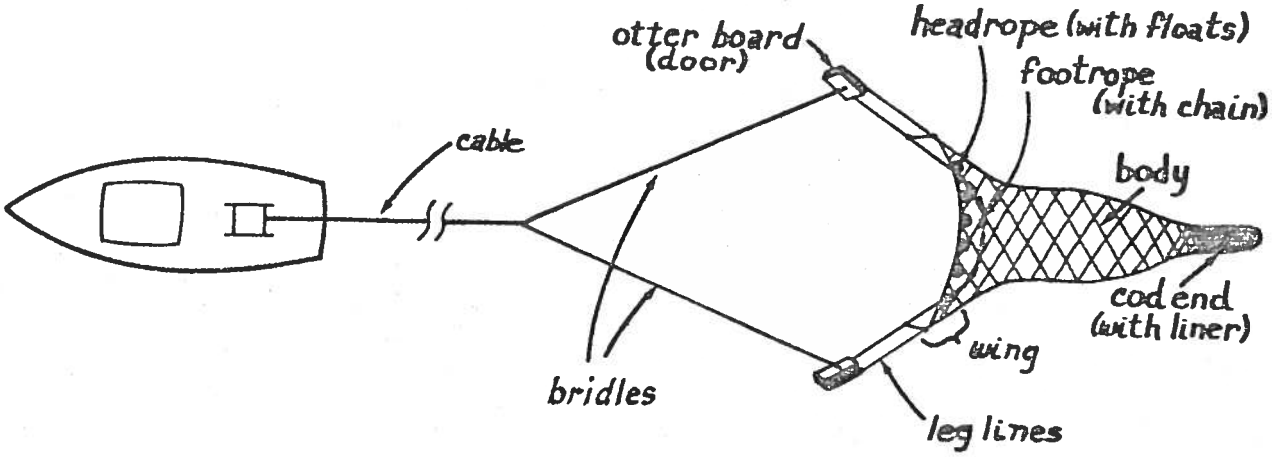

Figure 1. Basic features of the small two- and four-seam otter or shrimp trawls used in southern California bottomfish surveys.

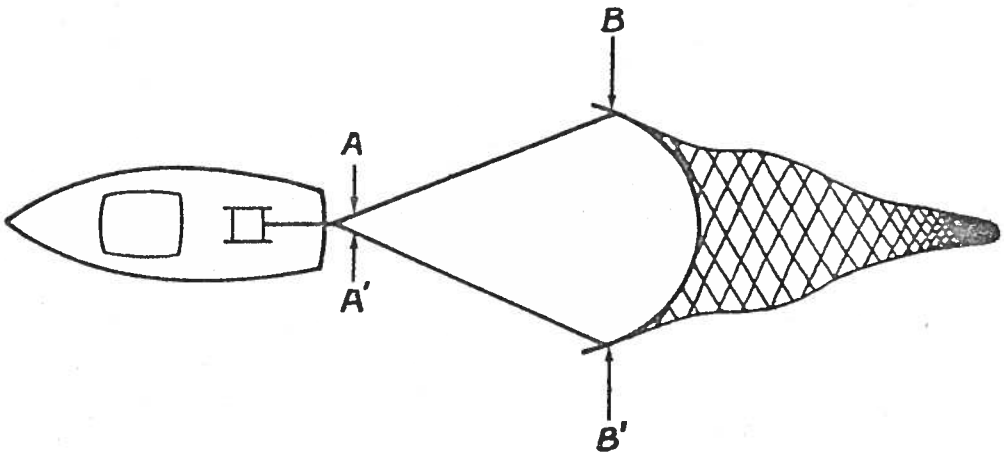

Figure 2. Measurement of trawl net opening. During surface towing, width between bridles (A-A') was measured; distance between trawl boards (B-B') was estimated by calculation.

Table 2.

Operational conditions of six southern California agencies during trawl surveys in the field.

Agency and Area	Net Used[a]	Towing Speed kn	Towing Speed m/sec	Scope Ratio[b]	Time on Bottom (min)	Bridle Length (ft)	Surveys Frequency	Surveys No. of Sta.	Depth Range (m)
Hyperion, Santa Monica Bay	25-ft W	1.5	0.77	3:1	10	28	Biannual	30-35	18-183
Los Angeles Co., Palos Verdes	25- and 40-ft W	2.5-2.7	1.3-1.5	4:1	10	60	Biannual	21	23-183
MBC, Inc., Orange Co.	25-ft M	2.5-2.7	1.3-1.5	5:1	10	100	Quarterly	8	11-141
Occidental College, San Pedro Bay	16- and 25-ft M	2.5-2.7	1.3-1.5	5:1	20 & 10	150	Continuously	50-70/yr	9-366
Orange Co. Educ., So. Orange Co.	16-ft M	2.5-2.7	1.3-1.5	5:1	15	150	Continuously	>100/yr	20-100
Coastal Water Project, all areas above	25-ft M	2.5-2.7	1.3-1.5	5:1	10	75	Periodically		18-183

a. W = Wilcox; M = Marinovich.
b. Towing cable length vs. depth.
c. Hyperion uses a steel bridle; the other agencies use polypropylene bridles.

tows at 0.8 m/sec (1.5 kn). Four of the agencies use a scope ratio (towing cable length vs. depth) of 5 to 1; Los Angeles County uses 4 to 1, and Hyperion, 3 to 1. Bridle lengths vary considerably, from 28 to 105 ft. Otter trawl boards also vary considerably in size (Figure 3 and Table 3).

Four of the agencies use Marinovich 25-ft and 16-ft nets (Table 3). These nets are similar except in bridle lengths, which vary from 50 to 150 ft, and trawl board dimensions.

The two sanitation districts (Hyperion and Los Angeles County) use Wilcox nets. The 25-ft nets used by each agency are identical for all parameters except legline lengths (3.5 ft for Hyperion, 31 ft for Los Angeles County), the use of 1/2 in. cod-end liners (not used by Hyperion), and the dimensions of otter boards (24 x 12 in. for Hyperion, 36 x 19-1/2 in. for Los Angeles County). These agencies used short bridle lengths (Hyperion, 28 ft, steel wire; Los Angeles County, 60 ft, polypropylene).

Los Angeles County was the only agency using a 40-ft net (Wilcox). In addition to size, this net differed from all other nets in that

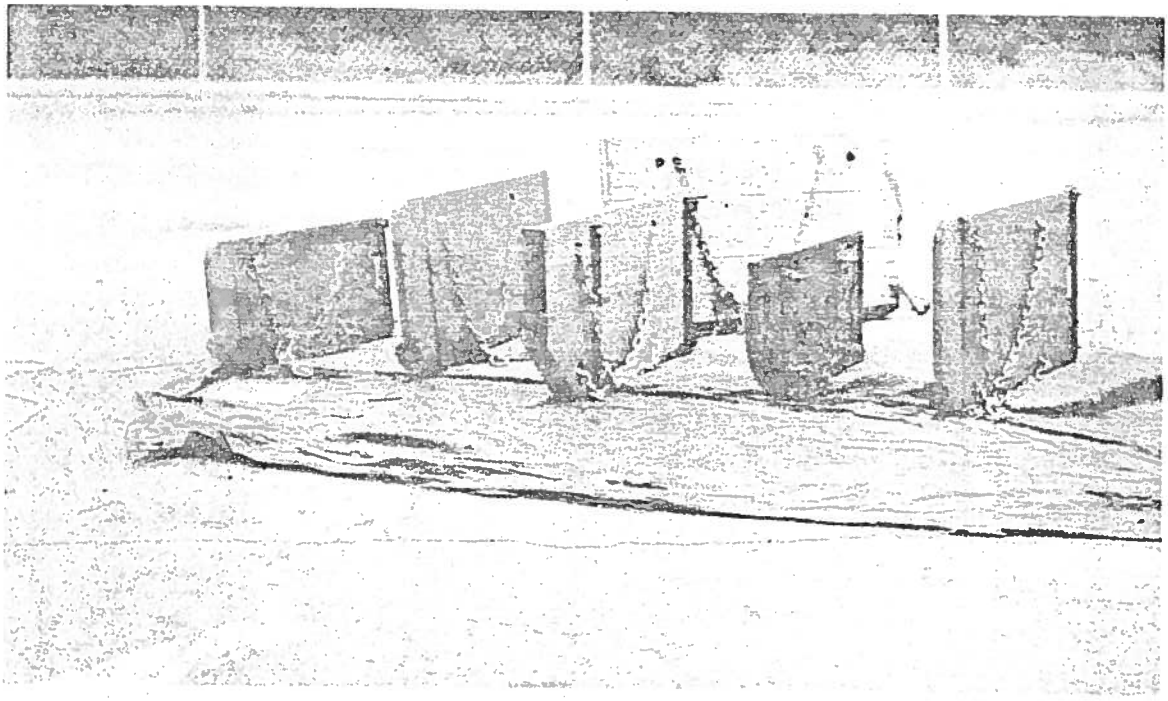

Figure 3. Otter trawl boards used by six agencies in southern California trawling surveys. Front, left to right: 16-ft Marinovich, Marine Biological Consultants; 25-ft Marinovich, Coastal Water Project; 16-ft Marinovich modified for Orange County Department of Education; 25-ft Wilcox, Hyperion; and 25-ft Marinovich, Marine Biological Consultants. Back: 25- and 40-ft Wilcox, Los Angeles County.

Table 3.

Specifications for gear used by six southern California sampling agencies.*

	Wilcox			Marinovich					
	40-ft, Los Angeles Co. San. Dist.	25-ft, Hyperion	25-ft, Los Angeles Co. San. Dist.	25-ft, MBC	25-ft, Occiden-tal College	25-ft, Coastal Water Project	25-ft, MBC	16-ft, Orange Co. Dept. of Educ.	16-ft, Occiden-tal College
Headrope length, ft	40	27	27	25	25	25	16	16	16
Footrope length, ft	Not measured	30	30	31	31	31	19	19	19
Leglines, ft	22	3.5	31	4	4	4	3	3	3
Body and Intermediate Webbing									
Stretch mesh, in.	1-7/8	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2
Thread (all nylon)	#15	#12	#12	#9	#9	#9	#9	#9	#9
Cod-end webbing									
Stretch mesh, in.	1-3/8	1	1	1-1/4	1-1/4	1-1/4	1-1/2	1-1/2	1-1/2
Thread (all nylon)	#21	#21	#21	#15	#15	#15	#15	#15	#15
Cod-end liner									
Mesh, in.	None	None	1/2	1/2	1/2	1/2	1/2	1/2	1/2
Thread (all knotless)	None	None	#63	#63	#63	#63	#63	-	-
Footrope Chain									
Size	3/16 in.	3/16 in.	3/16 in.	2/0	2/0	2/0	1/8 in.	1/8 in.	1/8 in.
Galvanized?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
In mouth?	6 in. of 1/4 in.	6 in. of 1/4 in.	6 in. of 1/4 in.	No	No	No	No	No	No
Floats	6-10	6	6	6 Ark	6 Ark	6 Ark	4 Ark	4 Ark	4 Ark
Trawl Boards									
Length, in.	36	24	36	30	36	34	24	26-1/2	30
Width, in.	19-1/2	12	19-1/2	16	18	15	11	15	15
Surface area, sq in.	702	288	702	480	648	510	264	397-1/2	450
Shoe width, in.	1	1	1	2	2	2	2	2	1-1/2

*Operational specifications (bridle length, legline lengths, and cod-end liner mesh size) are those used in actual field surveys by each agency.

it had the largest mesh size (body and cod end) and long leglines (22 ft). In actual field surveys, 60-ft bridles were used with this gear.

In summary, differences found among Marinovich nets of similar size were not substantial compared to the differences between Marinovich and Wilcox nets and the differences among the three Wilcox nets. Legline length, body and cod-end mesh, use of cod-end liners, bridle lengths, and trawl board dimensions were the prominent gear variables. Towing speed and on-bottom trawl time (and therefore distance trawled) were similar for all agencies except Hyperion (which trawled at 1.5 kn) and Occidental College (which frequently trawled for 20 min).

Towing Observations

Relative board spread of the nets varied threefold (9 to 26 ft, Table 4) during our surface tow observation with 75-ft bridles. Door spread was only generally related to headrope length. The widest spreading net was the 40-ft Wilcox (Los Angeles County: 26 ft) followed by the 25-ft Wilcox (Los Angeles County: 24 ft). All three 25-ft Marinovich nets tested produced similar and narrower spreads (15 to 16 ft), followed by an 11-ft spread for the 16-ft Marinovich. Finally, the 25-ft Wilcox net used by Hyperion spread only 9 ft and therefore deviated substantially from the general relation between net size and board spread.

DISCUSSION

Since these observations do not include comparable tests with catch statistics and since bridle length was standardized, they provide only a relative comparison of differences in the efficiency of the gear. Nevertheless, we found that under similar operational conditions, there was a threefold range of door spread. With double-warp nets, this could account for a similar order of differences in catch per unit effort, perhaps equivalent to the threefold to fivefold variation due to seasonal and annual fluctuations in abundance of demersal fish within a survey region sampled by uniform procedures (for example, see data in Carlisle 1969 and in Southern California Coastal Water Research Project 1973).

A discussion of possible factors affecting opening efficiencies is presented by gear type below. Tables 4, 5, 6, and 7 show recent catch statistics for a parameter of interest to this discussion, median[2] catch per haul per survey.

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2. Catch (number of specimens) per haul in a survey is not normally distributed and requires log transformation or some other method of accounting for skewness, e.g., the median (Taylor 1953; Barnes and Bagenal 1951; Gulland 1956; Roessler 1965).

Table 4.

Spread of 72-ft bridles at 3 ft from cable* and calculated spread of trawl boards for seven nets used in southern California trawl surveys.

Agency	Net Size and Make	Head-rope Length (ft)	Bridle Spread at 3 ft from Cable (in.)	Calculated Board Spread (ft)
Los Angeles Co. San. Dist.	40-ft Wilcox	40	13	26
	25-ft Wilcox	27	12	24
Hyperion	25-ft Wilcox	27	4.5	9
MBC, Inc.	25-ft Marinovich	25	8	16
Occidental College	25-ft Marinovich	25	8	16
Coastal Water Research Project	25-ft Marinovich	25	7.5	15
MBC, Inc.	16-ft Marinovich	16	5.5	11

*Towing speed: 2.5 knots in 2 to 3 meters of water at Morro Bay, California.

Marinovich Nets

Marinovich nets are in wide use in many types of coastal surveys, and their continued use seems certain (Marinovich and Whiteleather 1968).

Three 25-ft and two 16-ft nets were examined (the only net we did not observe under tow was the one used by the Orange County Department of Education). The 25-ft nets used by the Coastal Water Project, Marine Biological Consultants, and Occidental College showed relatively minor differences in trawl board spread under the test conditions. All appeared to open efficiently.

At eight standardized stations off Orange County (February 1971 through November 1973), the Marine Biological Consultants net produced median catches ranging from 216 to 880 fish per haul (Grand Mean = 479 fish/haul/survey, Table 5). At similar sites in September 1973, the 25-ft net used by the Coastal Water Project produced a median of 364 fish/haul, a value well within the seasonal variations observed by Marine Biological Consultants and closely

Table 5.

Comparison of median fish catch per haul for southern California trawl surveys, 1971-73.[a]

Year and Quarter[b]		Santa Monica Bay, Hyperion, 25-ft Wilcox, 1.5 kn	Palos Verdes, Los Angeles County, 40-ft Wilcox, 2.7 kn	Palos Verdes, Los Angeles County, 25-ft Wilcox, 2.7 kn	San Pedro Bay, MBC, Inc., 25-ft Marinovich, 2.5 kn
1971	1	169 (15)	164 (13)	-	373 (8)
	2	108 (6)	-	-	880 (8)
	3	132 (28)	82 (28)	-	598 (8)
	4	-	102 (11)	-	454 (8)
1972	1	-	-	-	470 (8)
	2	98 (31)	214 (25)	-	512 (8)
	3	-	-	-	394 (8)
	4	-	-	494 (26)	414 (8)
1973	1	-	167 (18)	297 (19)	303 (8)
	2	-	-	684 (21)	588 (8)
	3	-	-	-	216 (8)
	4	-	-	NA[c]	549 (8)
$\bar{x}$ of Survey Medians $\pm SE_{\bar{x}}$		127 ±15.8 (4)	146 ±23.9 (5)	492 ±112 (3)	479 ±49 (12)
Median, Coastal Water Project, Sep 73, 25-ft Marinovich		400 (9)	331 (9)		364 (9)

a. Number of samples in parentheses; all surveys within depth range of 18 to 200 m.
b. Quarters: 1 = Feb-Apr; 2 = May-Jul; 3 = Aug-Oct; 4 = Nov-Jan.
c. NA = Not yet analyzed.

approximating a low median of 216 by Marine Biological Consultants during the third quarter of 1973. Although similar data is not presently available for the Occidental College net, all available observations suggest that under somewhat similar towing and rigging conditions, data from the three nets and agencies should be directly comparable. Vessel speed, bridle lengths, on-bottom time, cod-end mesh and trawl board sizes may account for more subtle differences in catches and should be considered in any future comparisons of the data from these agencies. In actual practice, for example, bridle lengths are known to be 50 and 72 ft (Coastal Water Project), 100 ft (Marine Biological Consultants), and 150 ft (Occidental College).

The 16-ft Marinovich net used by Marine Biological Consultants also appeared to open efficiently (11 ft) under test conditions. We presently have no door spread data on the 16-ft nets of Occidental College or Orange County Department of Education with which to compare this observation.

Not reported here are trawl survey data being taken by Marine Biological Consultants for the City of Oxnard, Ventura County. A recent report (Whitt and Mitchell 1974) cites the use of a 25-ft net (Marinovich) towed at 1.0 to 1.5 kn; due to the relatively slow trawl speed, these data are likely not be be comparable to those mentioned in this report.

Wilcox Nets

The three Wilcox nets tested (Hyperion 25-ft and Los Angeles County 25- and 40-ft nets) showed considerable differences in opening that were not proportional to headrope lengths. The Hyperion net spread the smallest amount of all the nets tested during the test trawl (9 ft); as Hyperion also had the slowest trawl speed (1.5 kn), and therefore the shortest distance trawled per unit time, we would expect the lowest catch per unit effort from this agency. In the field, median catch per haul for the 1971 and 1972 Hyperion data (Santa Monica Bay) averaged 127 fish compared to 548 fish per haul off Orange County (Marine Biological Consultants) during the same sampling seasons (Table 6). The recent Coastal Water Project survey (September 1973) using the Marinovich net produced considerably higher catches (400 fish per haul) in Santa Monica Bay, and the catches were similar to those in San Pedro Bay (364 fish per haul; Table 5). These differences may, in part, reflect the lower efficiency of the Hyperion sampling gear and operational procedures. Replicate sampling in the field is required to confirm this conclusion.

The poor opening efficiency of the Hyperion net may be due to several factors including the relatively low trawl speed. The trawl boards used, which were designed by Hyperion, were small (288 sq in.) relative to those used by other agencies using 25-ft gear (480 to 702 sq in.) and were found to be inadequate on even the 16-ft net used by Orange County Department of Education.[3] Moreover,

3. Mark Howe, Orange County Department of Education, Marine Sciences Department, Santa Ana, California, personal communication.

the 25-ft net was observed to open only one-third of its total potential height (maximum footrope-to-headrope distance). This may partially account for the relatively high proportion of benthic invertebrates (starfish, urchins, shrimp) and low abundance of fish in hauls taken by this agency.

The two Wilcox nets used by Los Angeles County present a slightly different picture (Table 5). In 1971-73, this agency used the 40-ft Wilcox net with legline extensions that produced a long distance between the very large doors and net wings (22 ft). Median survey catches averaged 146 fish/haul (5 surveys, 95 samples). In November 1972, the County switched to the 25-ft rig using the same doors and 31-ft leglines. Median survey catches with this gear averaged 492 fish/haul (3 surveys, 66 samples) and were comparable to Marine Biological Consultants' results in San Pedro Bay during the same period (Table 7). In March 1973, both nets were used at the Palos Verdes sampling site. The 40-ft net produced a median of 167 fish/haul (18 samples) compared to 297 fish/haul produced by the 25-ft net.

These observations confirm the possibility of higher catches off Palos Verdes and suggest that the 25-ft net was slightly more efficient than the 40-ft net. As noted in Table 3, these nets did not differ considerably in their estimated door spread (26 ft for the 40-ft net, 24 ft for the 25-ft net). Examination of length frequency data indicated that the smaller mesh of the 25-ft net contributed larger numbers of small fish (data in preparation). In addition, it is possible that the actual net opening may have been greater in the 25-ft net. Considering the use of long leglines (compared to Hyperion) and larger mesh sizes than other nets (Table 2), it is presently difficult to determine the factors that are important in comparing catches from the three variations of the Wilcox nets, but it is quite clear that actual spread between the doors is regulated by factors other than headrope length. Field tests with replicate sampling should be conducted with all the variations on these gear.

CONCLUSIONS

These observations, together with examination of field performance, indicate major differences in the spread characteristics of otter trawl gear now in use by various coastal monitoring agencies. The differences may account for major regional differences in catch statistics, but replicate field tests are required to determine the degree to which previous catches have been influenced.

For 25-ft headrope trawls, differences in spread characteristics appear to be related more to differences in basic operational rigging (bridle lengths, legline lengths, door size). Catch statistics suggest that secondary differences may be due to cod-end mesh size, seasonality of populations, and minor gear and gear use differences. Allowing for some variation for adjustments in the field, standardization of bridle length, legline lengths and door sizes for 25-ft gear are required before regional differences in the abundance of bottom fish populations can be adequately assessed and before the

Table 6.

Comparison of average fish catches per survey for southern California trawl surveys, February 1971 through May 1972.

	Santa Monica Bay, Hyperion, 25-ft Wilcox, 1.5 kn	Palos Verdes, Los Angeles Co. 40-ft Wilcox, 2.7 kn	San Pedro Bay, MBC, Inc., 25-ft Marinovich, 2.5 kn
$\bar{x} \pm SE_{\bar{x}}$	127 ± 15.8	141 ± 30.1	548 ± 72.9
No. of Surveys	4	4	6

Table 7.

Comparison of average fish catches per survey for southern California trawl surveys, November 1972 through May 1973.

	Palos Verdes, Los Angeles Co., 25-ft Wilcox, 2.7 kn	San Pedro Bay, MBC, Inc., 25-ft Marinovich, 2.5 kn
$\bar{x} \pm SE_{\bar{x}}$	492 ± 111.7	435 ± 82.9
No. of Surveys	3	3

effects of other gear differences (e.g., scope ratio, see Pererya 1963) or behavioral patterns (Blaxter and Parrish 1966; Foster 1969; High et al. 1969) can be checked. In any case, it appears that under similar operational procedures, data taken by Marine Biological Consultants (using the Van Tuna), the Coastal Water Project, and Occidental College may be directly comparable, while previous data taken by Hyperion and the County of Los Angeles cannot be compared directly with each other or with the data of other agencies.

The goal of trawl monitoring should not be to catch as many fish as possible, but to take adequate samples (for the purpose of estimating diversity and abundance), to sample frequently (for determining seasonal differences), and to sample in a regionally standardized manner (for determining to what degree local populations reflect large-scale distirbutional patterns). Thus the best gear and sampling procedures may not necessarily be those that are most efficient or catch the most fish, but simply regionally acceptable gear whose efficiency and characteristics are known.

We are presently preparing recommendations for the use and maintenance of gear in coastal monitoring. These will be presented in a future report.

ACKNOWLEDGMENTS

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