TRAWL STUDIES BASED ON BOTTOM CURRENT MEASUREMENTS

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Experiments were designed to test whether the yields of certain important bottom organisms by bottom trawling could be affected by the direction of the tow in relation to prevailing bottom currents. Specifically, the trawl was towed with, against, and across the direction of the prevailing bottom currents, which were measured shortly before the tows were made. It was found that significant improvements in the yields of flatfish species were achieved with tows made against the bottom currents or across the currents in contrast to those made in the direction of the bottom current under otherwise similar conditions. Lobster yields were also significantly improved by orienting the trawl against the bottom current. Some evidence was also obtained to suggest that the yield of crabs and pelagic fishes might also be improved by orienting the gear against prevailing currents in its vicinity. However, further work with these species needs to be done in order to provide conclusive information.

Although it has been known for some time that bottom and surface currents in many areas may be quite different, relatively little trawl gear research has been done with an adequate knowledge of bottom currents. This lack of information may cast doubt on the reliability of some instrumented gear results. In addition, Carruthers (1964) noted that knowledge of bottom currents might be useful in improving the catching efficiency of trawl gear by permitting determination of an optimum attack angle of the gear relative to the orientation of given fish species to the current.

Laevastu (1965) and Laevastu and Hela (1970) have reviewed much of the literature concerning the effects of currents on the swimming behavior and orientation of fishes. Their conclusions indicate passive movements with the current and normal swimming movements against it, depending upon the species and the environmental conditions. For many demersal species, available information to data suggests that normal orientation is against the current with an effective loss of actual swimming speed. An article quoted by Carruthers (1955) regarding some Norwegian work pointed out that the current at fishing depth often runs in a different direction from that at the surface. Furthermore, this factor seemed more pronounced at depths of 50-60 fathoms than at depths of 27-33 fathoms. At that time, Norwegian cod fishermen urged that means be made available to them to know how the water moved at fishing depth in order to improve their catches.

Some evidence is also available to indicate that the geometry of the trawl net is affected by the direction of the tow. Ketchen (1957) found that the opening of the trawl was smaller when the vessel was running with the tide than when it was running against the tide. Saila and Flowers (1969) have shown from theoretical studies of fishing tactics that a knowledge of both the behavior of fishes and of gear performance in relation to current speed and direction is requisite to obtaining optimum performance from towed fishing gear.

This report describes the results of an experiment designed to test whether the catch of marine organisms by trawling could be affected by the direction of the tow based on knowledge of the direction and velocity of bottom currents near the fishing ground.

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MATERIALS and METHODS

The directional towing experiment was conducted in an area of approximately one mile in radius centered at 41°-17 N, 71°31 W in Rhode Island Sound during July-September 1972. The depth at this location ranged from 100-150 feet with a depth of 138 feet at the center. Bottom sediments were fairly uniform and consisted primarily of compacted muds.

Currents were measured with a type 110/119 Remote Reading Current Meter with Temperature and Depth. This instrument is manufactured by Environmental Devices Corp., Marion, Massachusetts. The remote reading deck read-out unit was equipped with 200 feet of connecting cable to the axial flow, ducted impeler current meter. The meter was lowered to depth on a one-half-inch diameter polypropylene rope, which had a lead weight attached one fathom below the meter. The deck read-out unit permitted sequential measurements of water temperature, depth, current speed, and current direction.

The ducted fan sensor on this instrument has a speed range from 0-2.5 knots. According to the manufacturer, the resolution is ±0.05 knot and the accuracy is ± 3 percent of full scale deplection. Magnetic current direction reads from 0-360° with a sensitivity of ± 5° at 0.05 knot, a resolution of ± 1° and an accuracy of ± 1 percent above 0.05 knot.

Current measurements were made during each day of the experiment while anchored at the center of the experimental area. Measurements of direction and velocity were taken at the surface (approx. 1 fathom), mid-depth, and at the bottom (approx. 1 fathom from the sediment-water interface). After three experimental tows, the current measurements were repeated while anchored, and from these data the directions for the next three tows were determined. On some occasions when conditions were unusual, additional current measurements were made at the end of the sixth tow. Carruthers (1955) has described a simple fishermen's current cone consisting of a conical casing which can vary its attitude according to the speed and direction of water flow. He has developed a simple mechanism for recording these factors. Later, Carruthers (1964) described a Pisa Current Indicator consisting of a bottle partly filled with jelly and a circular compass in the bottle which permitted crude estimates of current speed and direction as the jelly set. Neither of these devices was considered suitable for the purposes at hand due to their limitations in operational accuracy.

The trawling experiment was conducted with a standard 71-91 Yankee trawl operated from a 57-foot LOA western rigged stern trawler powered by a 671 GM diesel. The same trawl was used during the entire experiment and no changes were made in any of the rigging. All tows were made at a constant 1450 r.p.m. engine speed.

The entire experiment was planned prior to execution, and it consisted of two replicates of three tow directions during each day of operations. It was designed to compare the relative effectiveness of trawling against the direction of the prevailing bottom current (A), with the direction of the prevailing bottom (W) and crossing at 90° to the direction of the prevailing bottom current (C).

The duration of each experimental tow was 15 minutes from the time the wire was out to the time hauling back was initiated. At the end of each tow, all organisms captured were placed in containers and labeled with the date, treatment, and replicate number. All counts and weights were recorded for individual species upon return to the field laboratory.

The experimental design used for this study consisted of a two-factor analysis of variance model with replication. The set of treatments which consisted of tows against, with, and across the bottom current was replicated two times each day under similar conditions.

The number of replications within days and the number of days for the duration of the experiment were determined by economic and logistic constraints. For example, it was found that six experimental tows could be made within a day and still permit time for processing the fish and crustaceans upon return to the laboratory. Conditions on the experimental site change with time, and extension beyond the period considered would not have increased experimental precision appreciably.

RESULTS

Table 1 lists some of the current measurements and temperatures obtained during the experiment. Although some midwater observations were made, these were not directly utilized in the experiment and are omitted from this table. Graphical representation of these limited data as vectors suggested that the circulation is dominated by the east-west semidiurnal tide, and that there may be a small net nontidal transport in a southwesterly direction. These results are roughly in correspondence with more extensive current measurements made in nearby areas by Polgar (1972) and Shonting (1969).

There was relatively little regularity in the observed differences between surface and bottom current directions, and this justified empirical observations immediately prior to fishing operations. The speed of bottom currents in the experimental area was found to be greater than surface values in only seven of the 19 sets of data. These observations are in contrast to those reported for deeper Scottish waters by Carruthers (1955); there, near-bottom currents of 92 fathoms in the Firth of Clyde were faster than those near the surface. In general, the speed of the bottom currents in this study had a smaller range (0.13-0.50 knot) than the surface values (0.15-1.00 knot) and a lower average value, which was on the order of 0.30 knot.

Because all organisms captured were separately handled by species, it was possible to assess the response of individual species or ecologically similar groups of

TABLE 1 SELECTED HYDROGRAPHIC DATA OBTAINED DURING THE TRAWL TOW DIRECTION EXPERIMENT IN RHODE ISLAND SOUND. 1972.

			SURFACE DATA			BOTTOM DATA		
DATE	TIME	WATER DEPTH (ft)	SPEED (knots)	DIRECTION (Magnetic)	TEMP. (°C)	SPEED (knots)	DIRECTION (Magnetic)	TEMP. (°C)
7/21/72	09:05	134	0.20	290	20.0	0.27	120	11.5
7/21/72	13:10	105	0.50	100	21.0	0.35	250	-
7/26/72	09:50	125	0.30	225	19.3	0.40	300	10.5
7/26/72	12:30	145	0.30	180	19.7	0.13	200	10.5
7/26/72	15:10	145	0.70	120	19.2	0.15	200	10.5
7/27/72	10:05	140	1.00	270	19.0	0.35	290	11.2
7/27/72	13:00	138	0.15	270	19.0	0.20	170	11.5
7/28/72	10:10	140	0.45	290	19.1	0.32	270	11.4
7/28/72	13:45	145	0.35	175	19.0	0.15	225	11.5
8/4/72	10:10	138	0.30	90	19.5	0.30	150	11.5
8/4/72	13:05	148	0.25	150	20.1	0.35	270	12.6
8/16/72	10:30	140	0.20	270	18.0	0.35	300	12.4
8/16/72	12:40	145	0.50	285	18.2	0.40	300	11.6
8/31/72	09:30	135	0.45	10	18.0	0.15	355	14.1
8/31/72	12:10	140	0.50	90	18.0	0.25	5	13.2
9/6/72	09:55	140	0.50	295	18.6	0.15	260	14.2
9/6/72	12:40	145	0.40	70	18.6	0.50	135	14.2
9/7/72	09:45	135	0.85	285	18.6	0.25	315	14.1
9/7/72	12:10	140	0.25	235	18.1	0.30	225	13.9

organisms. Of special significance to New England fishery operations are some species of flatfishes, especially yellowtail and winter flounder. Thus, the results of this experiment using all species of flatfishes captured (window-pane--Scopthalmus aquosus, winter flounder--Pseudopleuronectes americanus, fourspot flounder--Paralichthys oblongus, summer flounder--Paralichthys dentatus, and yellowtail flounder Limanda ferruginea) are considered first.

Examination of the treatment means clearly showed that 15-minute tows made in the direction of prevailing current (W) produced about 29 pounds less than tows across the current (C) and about 18 pounds less than similar-duration tows against the current (A). It is clear also from examination of these data that the yield from the experimental area improved considerably toward the end of the study, and that there is considerable variation in the day-to-day and treatment results. The data of Table 2 were therefore subjected to statistical analysis. The results, shown in Table 3, indicated that the differences observed were of a causal nature and cannot be attributed to chance alone. The interaction term which relates to the interplay of the factors at work was not statistically significant in the abovementioned data.

produced a still lower value than towing with the current, but these values are not very different. The results of an analysis of variance for these data are shown in Table 5. From the table it was evident that the interaction term is negligible, but the differences among treatments (tow directions) were highly significant. The observed improvement in trawling efficiency induced by towing against the current was not a chance phenomenon with respect to the lobster data.

Jonah crabs (Cancer borealis) were also taken consistently during the trawling experiment. The crab data resulting from seven days of trawling are shown in Table 6. Data for only seven days were used because environmental conditions and crab abundance changed dramatically during the last two days. Again, it appeared from a visual comparison of treatment means that more crabs were taken by towing across or against the current then by towing in the direction of the prevailing bottom current. It was also evident that the total yields by day and by individual treatments were quite variable. This variability is further substantiated by the results of the analysis of variance shown in Table 7. The treatment effects (tow directions) were not statistically significant at the conventional 0.05 probability level. However, they were significant at the approximately 0.15 probability level. Interaction effects were not significant in this instance either.

Table 3 - Two-Way Classification Trawl Tow Direction Experiment, 1972 (Weight of all Flatfish species per 15 minute tow in pounds)

Source of variation	Degrees of freedom	Mean square	F
Tow direction	2	3747.05	2.995*
Day	8	38324.44	
Interaction	16	2792.50	2.232
Error	27	1250.88	
Total	53		

*Significant at $\alpha = 0.05$

Since the lobster (Homarus americanus) is a very valuable organism, the tow direction experiment was also analyzed to assess lobster response. Table 4 illustrates the tow data with the number of lobsters taken per 15-minute tow as the response variable. The last row of this table showed that almost twice as many lobsters (25 versus 13) were taken by towing against the current than with the current. Towing across the current

Similar analyses were performed for total benthic fishes (which included 13 species) but excluded the pelagic forms such as shad, bluefish, hake species, and herrings. These data did not reveal any significant differences in the total yield as related to current direction. A tentative explanation for this is

TABLE 2 Data for Trawl Tow Direction Experiment - 1972. The Response Variable is Pounds of Flatfish Species Caught per 15 Minute Tow. W, C, and A refer to tows made with, across and against the bottom current direction, respectively.

DAY	TREATMENT			TOTAL	MEAN
	W	C	A		
7/21	63.0	102.0	53.5		
	23.0	14.5	19.5		
	86.0	116.5	73.0	275.5	45.9
7/26	16.0	15.5	50.0		
	17.0	55.5	31.5		
	33.0	71.0	81.5	185.5	30.9
7/27	29.5	125.5	27.5		
	23.0	174.0	22.0		
	52.5	299.5	49.5	352.0	58.7
7/28	18.5	43.0	11.5		
	44.5	83.0	18.5		
	63.0	126.0	30.0	219.0	36.5
8/14	116.0	104.5	137.5		
	65.0	94.0	83.0		
	181.0	198.5	220.5	600.0	100.0
8/16	90.0	46.0	137.0		
	57.0	56.0	81.0		
	147.0	102.0	218.0	467.0	77.8
8/31	46.5	153.0	154.0		
	75.0	129.5	192.0		
	121.5	282.5	346.0	750.0	125.0
9/6	234.0	264.5	296.5		
	313.0	328.0	142.5		
	547.0	592.5	439.0	1578.5	263.1
9/7	179.0	156.5	231.5		
	209.0	197.0	254.0		
	388.0	353.5	485.5	1227.0	204.5
	=	=	=	=	=
TOTAL	1619.0	2142.0	1943.0	5654.5	670.4
MEAN	89.9	119.0	107.9	314.1	74.5

Table 4 Data for Trawl Tow Direction Experiment - 1972. The Response Variable is the Number of Lobsters Caught per 15 Minute Tow. W, C and A refer to tows made with, across and against the prevailing bottom current direction respectively.

DAY	TREATMENT			TOTAL	MEAN
	W	C	A		
7/21	0.0	0.0	4.0		
	1.0	1.0	38.0		
	1.0	1.0	42.0	44.0	7.3
7/26	4.0	6.0	25.0		
	10.0	2.0	17.0		
	14.0	8.0	42.0	64.0	10.7
7/27	21.0	9.0	56.0		
	11.0	6.0	40.0		
	32.0	15.0	96.0	143.0	23.8
7/28	11.0	10.0	21.0		
	32.0	8.0	35.0		
	43.0	18.0	56.0	117.0	19.5
8/4	9.0	22.0	25.0		
	25.0	12.0	17.0		
	34.0	34.0	42.0	110.0	18.3
8/16	28.0	15.0	32.0		
	13.0	12.0	42.0		
	41.0	27.0	74.0	142.0	23.7
8/31	7.0	29.0	18.0		
	4.0	10.0	23.0		
	11.0	39.0	41.0	91.0	15.2
9/6	23.0	6.0	19.0		
	22.0	15.0	18.0		
	45.0	21.0	37.0	103.0	17.2
9/7	8.0	4.0	11.0		
	6.0	4.0	3.0		
	14.0	8.0	14.0	36.0	6.0
	=	=	=	=	=
TOTAL	235.0	171.0	444.0	850.0	141.7
MEAN	13.1	9.5	24.7	47.2	15.7

Table 5 - Two-Way Classification Trawl Tow Direction Experiment, 1972
(Number of lobsters per 15-minute tow transformed by $\sqrt{X + 0.5}$.)

Source of variation	Degrees of freedom	Mean square	F
Tow direction	2	18.31573	18.31573**
Day	8	6.00725	
Interaction	16	1.65897	1.65897
Error	27	0.92701	
Total	53		

Significant at α = 0.01

Table 6 Data for Trawl Tow Direction Experiment - 1972. The Response Variable is Pounds of Crabs caught per 15 Minute Tow. W, C, and A refer to tows made with, across, and against the bottom current direction, respectively.

DAY	TREATMENT W	TREATMENT C	TREATMENT A	TOTAL	MEAN
7/21	18.0	4.5	14.0		
	16.0	40.0	36.0		
	34.0	44.5	50.0	128.5	21.4
7/26	27.0	19.0	33.0		
	27.5	17.0	44.0		
	54.5	36.0	77.0	167.5	27.9
7/27	17.0	27.5	30.5		
	23.5	67.0	35.0		
	40.5	94.5	65.5	200.5	33.4
7/28	37.0	50.0	25.0		
	44.5	41.0	25.0		
	81.5	91.0	50.0	222.5	37.1
8/4	10.0	45.0	34.0		
	43.0	29.0	44.0		
	53.0	74.0	78.0	205.0	34.2
8/16	23.0	43.0	24.0		
	14.0	19.0	12.0		
	37.0	62.0	36.0	135.0	22.5
8/31	18.0	27.0	48.0		
	6.0	22.0	26.0		
	24.0	49.0	74.0	147.0	24.5
	=	=	=	=	=
TOTAL	324.5	451.0	430.5	1200.0	201.0
MEAN	23.2	32.2	30.8	85.7	28.7

Table 7 - Two-Way Classification Trawl Tow Direction Experiment, 1972
(Weight of all Crab species per 15-minute tow)

Source of variation	Degrees of freedom	Mean square	F
Tow direction	2	329.268	2.046
Day	6	232.151	
Interaction	12	170.198	1.094
Error	21	155.536	
Total	41		

that such a diversity of species has a variety of responses to currents which average out significant differences in the yield for a particular tow direction.

Although the gear fished was bottom trawl gear and not midwater gear, a preliminary analysis of the response of pelagic fishes to tow direction was also made. The response variable was the pounds of all hake species, shad, and herring per 15-minute tow. The results of the experiment showed an increase in the catch of pelagic fish when the net was towed against the prevailing bottom current as contrasted with tows made in the direction of the current. The results of the statistical analysis of these data were inconclusive, primarily because the gear used was not designed for catching these species, and there was considerable variation in the yield per tow.

CONCLUSIONS

The results of these experiments with directional trawling demonstrated that significant increases in the yields of flatfishes and lobsters were achieved under the conditions of the experiment. These amounted to an approximately 27 percent increase in the yield of flatfishes when tows were made against or across the bottom current versus tows made in the direction of the bottom flow. In the case of lobsters, almost a doubling of yield was obtained when tows were made against the bottom current versus the other directions of tows. The explanation for these improvements is tentatively suggested as being related to the net fishing harder by digging into the sediments and therefore fishing more efficiently for these bottom forms. The tension on the tow warps as measured by warp tension meters was higher during tows made against bottom currents than during tows made in the direction of bottom currents. The significance of this work relates to increased trawling efficiency based on knowledge of bottom currents. The limitations of this work include the fact that no tests were made with midwater trawls, which would have provided more objective tests regarding pelagic fishes. The instrumentation used in this study was relatively expensive, and it remains for someone to develop relatively cheap and efficient means for measuring current direction on the bottom suitable for fishermen to use. In addition, an examination of the current and yield data demonstrated that it would have been desirable to have had more frequent measurements of bottom current directions in order to further reduce the unaccountable variation observed.

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