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Effect of Tow Duration on Gear Selectivity

by

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Introduction

Annual bottom trawl surveys on Canada's east coast are conducted to estimate abundance of commercial species based on stratified-random design. Within each strata, the sampling unit - i.e., the trawl station - is determined by dividing the total study area by the area of the standard trawl width. The limiting factor to the number of trawl stations is usually time available, hence cost is fixed. A proportion rule based on the number of hauls to strata area is used (longer strata received more hauls) to allocate stations with a minimium of two stations being allocated per strata (see Doubleday 1981 for details). A standard towing time of 30 minutes is used at each selected station with an average speed of 3.5 knots (1.8 m s^{-1}).

Increasing the number of hauls should produce a more precise density estimate. Since time (and cost) is the constraining factor, a reduction in the towing duration followed by increasing the appropriate number of hauls (stations) should increase the precision of survey abundance estimates (Jones 1956, Pennington and Volstad 1989) and size composition (Godø et al. 1990). One would expect a relative decrease in catch rates of large fish, especially powerful swimmers such as large cod, with decreasing tow duration. Godø et al. (1990) found no significant change in catch rates of different size groups and mean length of fish with varying tow duration (5 min. to 2 h) studied in the Barents Sea and Georges Bank. The species studied were cod (Gadus morhua), haddock (Melanogrammus aeglefinus L.) and long rough dab (Hippoglossoides platessoides).

In this paper, I will investigate the Godø et al. (1990) hypothesis that catch per minute is constant as tow duration varies for different size groups of cod, American plaice (long rough dab), yellowtail flounder (Limanda ferruginea), and thorny skate (Raja radiata). The study is based on trawl experiments conducted on the southern Grand Bank using tow durations of 5 minutes, 15 minutes, and 30 minutes.

Materials and Methods

The experiment was carried out in March of 1990 on the southern Grand Bank, Northwest Atlantic Fisheries Organization (NAFO) Div. 3N and 3Ø, off the coast of Newfoundland, aboard the 50-m stern trawler R.V. WILFRED TEMPLEMAN (Fig. 1). At 22 (out of 24) stations, 11 day and 11 night stations were preselected to investigate differences in catch size and length composition from trawl hauls of 5-, 15- and 30-minute duration. The standard 3-bridle Engel High Rise bottom survey trawl was used (Walsh 1989). Trawl geometry and performance was monitored constantly with SCANMAR acoustic instrumentation during all hauls. Average wing spread (upper), door spread, and trawl opening were measured as 19 m, 62 m and 5.6 m repsectively. Tow durations were defined as the period between when SCANMAR height sensor indicated bottom contact and start of pull back. Towing speed was 3.5 knots (1.8 m s^{-1}) as measured by Doppler speed log, and the towing direction for each of the three sets of hauls at the same station was the same. All hauls were made in a depth range of 57-83 m at an average temperature (as determined by CTD system) of -0.5°C.

Experimental design

The design and subsequent analyses paralleled the work of Godø et al. (1990). A randomized block design was chosen with the 22 stations as the blocking effect. At each station, 3 hauls of 5-, 15- and 30-minute duration were made, the order being randomly selected. A total of 70 hauls were completed, of which 66 hauls (22 stations) were used in the analyses. Half of the 22 stations were fished at night and half during the day to examine diel changes in catch size and length composition.

Statistical methods

The effect of tow duration on catch per unit effort (CPUE) in terms of catch size and length composition was analyzed using a randomized block design analysis of variance (ANOVA). CPUE is expected to be proportional to tow duration or linear on the log scale. The model used was:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}$$

where y is the log of CPUE for each tow, μ is the overall mean, α_i is the tow duration effect, β_j is the block or station effect, and ε the error term. The errors are assumed to be independent and normally distributed. Station is used in this model as a blocking effect to reduce spatial and temporal effects in catch rates and increase the sensitivity of detecting changes directly related to tow durations.

I divided the length data of cod, American plaice, and thorny skate into small (<30 cm), medium (30-49 cm), and large fish (≥50 cm). Yellowtail flounder which has a maximum length of 52-54 cm in the Grand Bank population was divided into small (<20 cm), medium (20-39 cm), and large (≥40 cm). I applied the ANOVA to: (1) total catch of all species, not only the 4 species of concern; (2) the individual 4 species, and (3) catch of a species within the three length categories. The ANOVA design was balanced by the addition of zero catches to hauls that didn't contain a particular species in the catch size analyses of #1 and #2 above. CPUE was also examined for day and night effect separately. The log of CPUE was derived by taking the log of the expression of catch/duration. In the case of zero catches, a value of 1 was added to enable the calculation of CPUE based on 22 hauls. All three applications of ANOVA are independent, and for each application there are three independent tests (5, 15 and 30 min.) of the effect of tow duration.

The population mean length was estimated for each species, and each tow duration based on a weighted mean length as calculated by the model:

$$\mu = \Sigma_i w_i \bar{x}_i / \Sigma_i w_i \ , \ \sigma_w^2 = \Sigma w_i \ (\bar{x}_i - \bar{\bar{x}}_w)^2 / \Sigma w_i$$

where w_i = number of fish in a trawl, $\bar{x}_i$ = mean length per tow and $\bar{\bar{x}}_w$ = weighted mean length.

All statisical analyses were performed using SAS (SAS Institute Inc. 1985).

Results

Catch size

The CUPE, measured as mean catch per minute, for the varying tow duration was significantly different for the analyses of the 22 stations (Table 1), the analysis of day sets only (Table 2), and the analysis of night sets only (Table 3). With the exception of yellowtail flounder, the higher catch per minute was found for the 5-minute tow duration for both the total catch and the other individual species in both the combined 22 station analysis and the day and night analyses (Table 4-6).

For the total species analyses, all tows were significantly different from each other. With the exceptions of yellowtail flounder during the combined analysis or the day only analysis (but not the night analysis), there was no significant difference ($P < .05$) in catch size of individual species in a comparison of 15-minute tows with 30-minute tows (Tables 4-6).

Length distribution

The 5-minute tow had a higher CPUE for cod, plaice, yellowtail flounder, and thorny skate than CPUE's for the 15-minute and 30-minute tows regardless of length class (Fig. 2-5). The CPUE for the 15-minute and 30-minute tows were generally comparable for all species' length distributions.

The analyses of mean catch per minute for the different size categories of all species showed that shorter tows of 5 minutes were significantly higher than longer tows ($P < .05$) (Table 7). There was a decline in mean catch per minute in each category as towing time increased; however, with the exception of medium-size cod, and medium- and large-size yellowtail flounder, all mean catch per minute for the varying tow durations were significantly different from each other ($P < .05$) (Table 7). There was insufficient catches of small cod for analysis. The mean catch per minute for the 15-minute and 30-minute tows for medium- and large-size yellowtail founder and medium-size cod, were not significantly different ($P < .05$).

The estimated population mean lengths of yellowtail flounder, plaice, and skate for the varying tows indicated little difference regardless of tow duration. As well, the 15-minute and 30-minute tows of cod produced little variation in mean lengths of these species. The mean length of cod in the 5-minute tows was larger than the 15-minute and 30-minute tows, although this is probably more related to sample size differences.

Discussion and Conclusions

The results presented here indicate that shorter (5-min.) tows appear to be more efficient at catching all sizes of cod, plaice, yellowtail flounder, and skate similar to findings of Godø et al. (1990) for cod, plaice, and haddock. More specificially, and most importantly, the mean length analyses of each species, showed no indication that average length decreased as tow duration was reduced in agreement with the Barents Sea--Georges Bank study (Godø et al. 1990). As well, although some significant difference were generally seen in CPUE of the varying tow durations, usually generated by higher mean catch rates in the 5-minute tows, there was little difference in CPUE of 15-minute and 30-minute tows; and this was also evident in the analyses of day and night sets. Low numbers of small fish is related not to shorter tows but to the inefficiency of this survey trawl to sample small fish (Walsh 1989).

It is obvious that no researcher would reduce his/her tow duration from 30 minutes to 5 minutes; however, a reduction to 15 minutes, given no underestimation of catch rates and the proportion of larger fish in a population, would be more plausible. By using 15-minute tows, less subsampling and associated errors should be required, less probability of tear ups, and more stations could be sampled (Pennington and Volstad 1989). Although more fish are measured in a 30-minute tow than in a 15-minute tow, no apparent gain in precision was obtained from the population mean length estimates. Similar findings were found in the Barents Sea--Georges Bank study (Godø et al. 1990). However, a complete reduction of all tow durations to half may not accomplish all goals of a survey. In areas where the known population of a species is concentrated, the users of a stratified-random design could reduce the tow duration to 15 minutes in strata where concentrations are known (based on past surveys) allowing for an increase in the number of stations in those areas. On the other hand, in strata where the outer fringes of the population are located, it may be wise to continue with 30-minute tows in order to better define distribution while also using the increased available time to add extra stations. As well, in areas with known rough bottom where trawling is precarious, 15-minute tows could offer an advantage over 30-minute tows by allowing stations that otherwise would not be fished to be sampled by decreasing the probability of tear-ups.

Godø et al. (1990) proposed an alternative hypothesis to "catching by exhaustion" (i.e., accepted hypothesis) to explain lack of size selection with varying tow duration. Their "catch by surprise" hypothesis suggested that higher efficiency of the trawl during short tows was related to a lack of schooling of fish during the first few minutes of the tow with no link between size and the surprise effect. This hypothesis may well fit schooling species like cod and haddock (i.e., schooling in the sense of herding) but not the "flatfish" species like American plaice, yellowtail flounder, and thorny skate. Photographic observations of these species in the path of the trawl show that most of these benthic species do not swim but, rather, remain on the bottom; and for those that swam, there was no evidence of herding in the direction of the tow (Beamish 1969). Thus the "catch by surprise" hypothesis based on lack of school formations within the first few minutes does not explain the lack of size selection with varying tow duration in these species. The low temperature (~-0.5°C) does not seem to produce varying size selection related to swimming capabilities. Further research is required to examine the catching process and selectivity of survey trawls.

Acknowledgments

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References

Beamish, F. W. H. 1969. Photographic observations on reactions of fish ahead of otter trawls. In. Ben-Tuvia and W. Dickson [ed.]. Proceedings of the FAO Conference on Fish Behaviour in Relation to Fishing Techniques and Tactics. FAO Fish. Rep. 3: 511-522.

Doubleday, W. G. [ed.] 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Scientific Council Studies No. 2. 53 p.

Godø, O. R., M. Pennington, and J. V. Vølstad. 1990. Effect of tow duration on length composition of trawl catches. Fisheries Research 9: 165-179.

Jones, R. 1956. A discussion of some limitations of the trawl as a sampling instrument. Rapp. P-v. Réun. Cons. Int. Explor. Mer. 166: 44-47.

Pennington, M., and J. H. Vølstad. 1989. Optimum size of sampling unit for estimating the density of marine populations. ICES C.M.1989/D:22. 19 p.

SAS Institute Inc. 1985. SAS User's Guide: Statistics Version 5 edition. N.C. SAS Institute Inc. 956 p.

Walsh, S. J. 1989. Escapement of fish underneath the footgear of a groundfish survey trawl. ICES C.M.1989/B:21. 22 p.

Table 1. Radomized block-analysis of variance with stations as the blocking effect and log catch per unit effort (CPUE in minutes) as the dependent variable.

Source	d.f.	Sum of squares	Mean square	F value	Significance level
Model	23	363.53	15.81	13.64	<.0001
Error	985	1141.04	1.1		
		Type 1 SS			
Station	21	39.42		1.62	0.0383
Tow duration	2	324.12		139.90	<.0001

Table 2. Randomized block - analysis of variance with stations as blocking effect and log CPUE as dependent variable: day sets only.

Source	d.f.	Sum of squares	Mean square	F value	Significance level
Model	12	190.14	15.85	24.16	<.0001
Error	489	320.67	0.67		
		Type 1 SS			
Station	10	5.91		0.90	0.5325
Tow duration	2	184.24		190.47	<.0001

Table 3. Randomized block - analysis of variance with stations as blocking effect and log CPUE as dependent variable: night sets only.

Source	d.f.	Sum of squares	Mean square	F value	Significance level
Model	12	147.44	12.29	7.41	<.0001
Error	494	818.79	1.66		
		Type 1 SS			
Station	10	5.98		0.36	0.9627
Tow duration	2	141.46		42.67	<.0001

Table 4. Mean for catch per minute of total species and individual species: significance level refers to Ho: CPUE is equal for varying tow duration.

Species	Tow duration (min) 5	15	30	Significance level	No significant difference	Significant difference
Total	0.37	0.32	0.30	<0.0001	0	5/15/30
Cod	0.27	0.09	0.18	0.0001	15,30	5/15,30
A. plaice	1.05	0.88	0.80	0.1804	5,15,30	0
Yellowtail flounder	3.42	3.46	2.94	0.0739	5,15/15,30	5/30
Thorny skate	0.38	0.26	0.31	0.0001	15,30	5,/15,30

Table 5. Mean for catch per minute of total species and individual species: significance level refers to Ho: CPUE is equal for varying tow duration-day sets.

Species	Tow duration (min) 5	15	30	Significance level	No significant difference	Significant difference
Total	0.37	0.15	0.15	<0.0001	0	5/15/30
Cod	0.40	0.16	0.14	0.0010	15,30	5/15,30
A. plaice	0.64	0.44	0.37	0.2852	5,15,30	0
Yellowtail flounder	1.17	0.71	0.99	0.0221	5,15/15,30	5/30
Thorny skate	0.42	0.18	0.18	0.0013	15,30	5,/15,30

Table 6 Mean for catch per minute of total species and individual species: significance level refers to Ho: CPUE is equal for varying tow duration-night sets

Species	Tow duration (min) 5	15	30	Significance level	No significant difference	Significant difference
Total	0.78	0.62	0.51	0.0001	0	5/15/30
Cod	0.53	0.15	0.30	0.0193	15,30	5/15,30
A. plaice	1.86	1.46	1.29	0.7039	5,15,30	0
Yellowtail flounder	6.07	6.35	4.96	0.2250	5,15/15,30	0
Thorny skate	0.75	0.46	0.51	0.0064	15,30	5,/15,30

Table 7. Mean for catch per minute of different size groups: significance level refers to Ho: CPUE is equal for varying tow duration (I.D. = insufficient data).

Species	Category	Tow duration (min) 5	15	30	Significance level	No significant difference	Significant difference
Cod	small (<30 cm)	0.40	0.13	0.07	I.D.	I.D.	I.D.
	medium (30-49 cm)	0.48	0.14	0.08	0.0001	15,30	5/15,30
	large (>50 cm)	0.41	0.13	0.07	<0.0001	0	5/15/30
A. plaice	small (<30 cm)	0.43	0.14	0.07	0.0001	0	5/15/30
	medium (30-49 cm)	0.46	0.18	0.10	<0.0001	0	5/15/30
	large (>50 cm)	0.46	0.17	0.09	<0.0001	0	5/15/30
Yellowtail flounder	small (<30 cm)	0.43	0.15	0.07	0.0001	0	5/15/30
	medium (30-49 cm)	0.77	0.34	0.22	<0.0001	15,30	5/15,30
	large (>50 cm)	0.94	0.31	0.30	0.0001	15,30	5/15,30
Thorny skate	small (<30 cm)	0.40	0.14	0.08	0.0001	0	5/15/30
	medium (30-49 cm)	0.42	0.14	0.07	<0.0001	0	5/15/30
	large (>50 cm)	0.40	0.13	0.07	<0.0001	0	5/15/30

Table 8. Estimated population mean length with standard error (in parenthesis) for cod, plaice, yellowtail flounder and thorny skate.

Species	Tow duration (min.) 5	15	30
Cod	80.00 (6.63)	60.11 (7.06)	59.23 (4.87)
A. plaice	46.44 (1.45)	46.71 (1.07)	45.89 (0.94)
Yellowtail flounder	35.30 (0.49)	35.51 (0.51)	34.40 (0.42)
Thorny skate	50.93 (2.62)	47.41 (3.31)	45.23 (2.63)

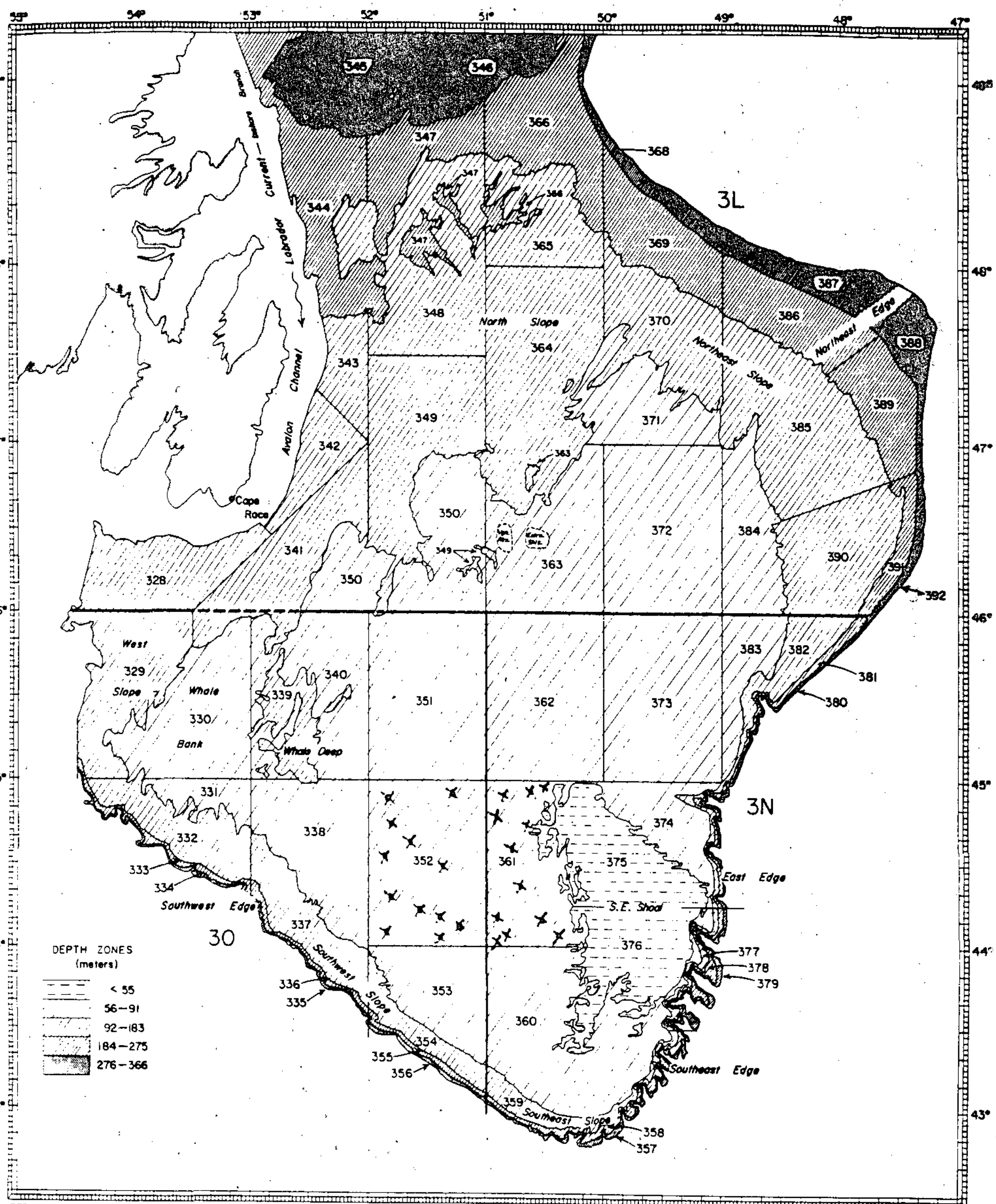

Fig. I. Stratification chart of the Grand Bank, NAFO Divs. 3L, 3N, 30. Experimental stations indicated by an X.

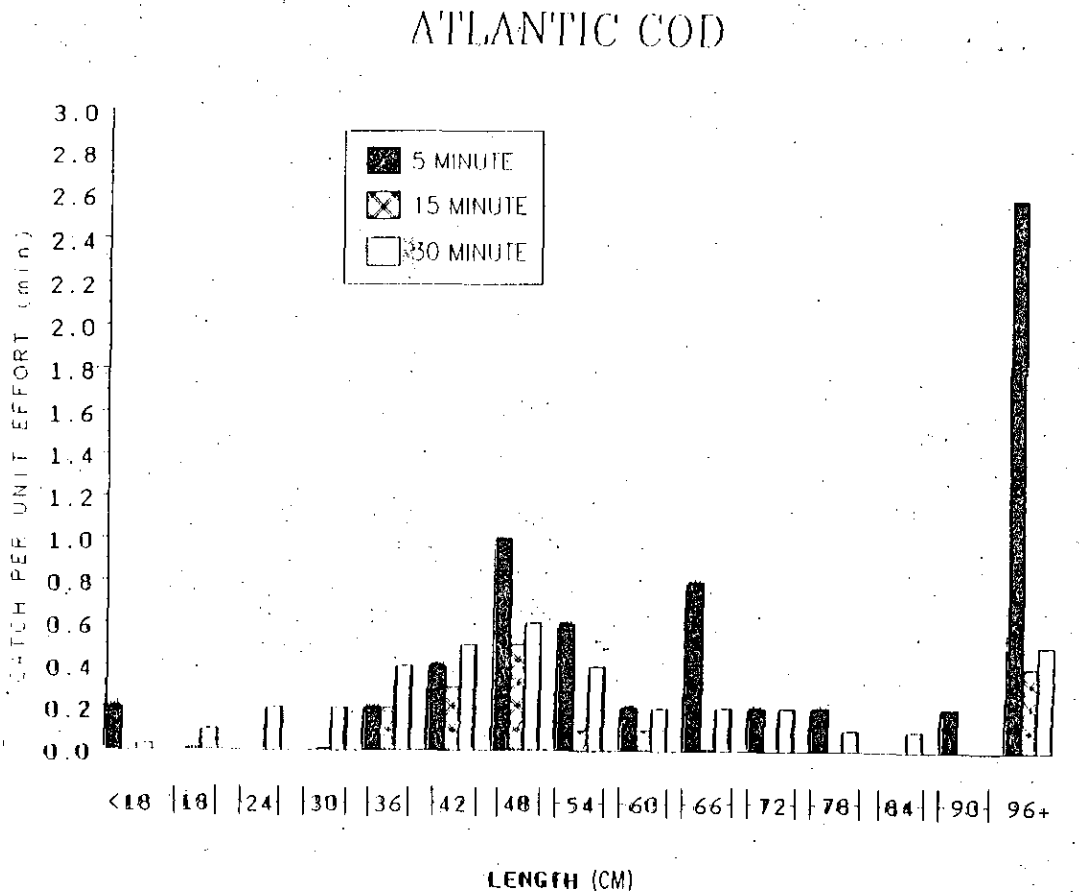

Fig. 2. Mean catch per minute of cod from the 22 stations

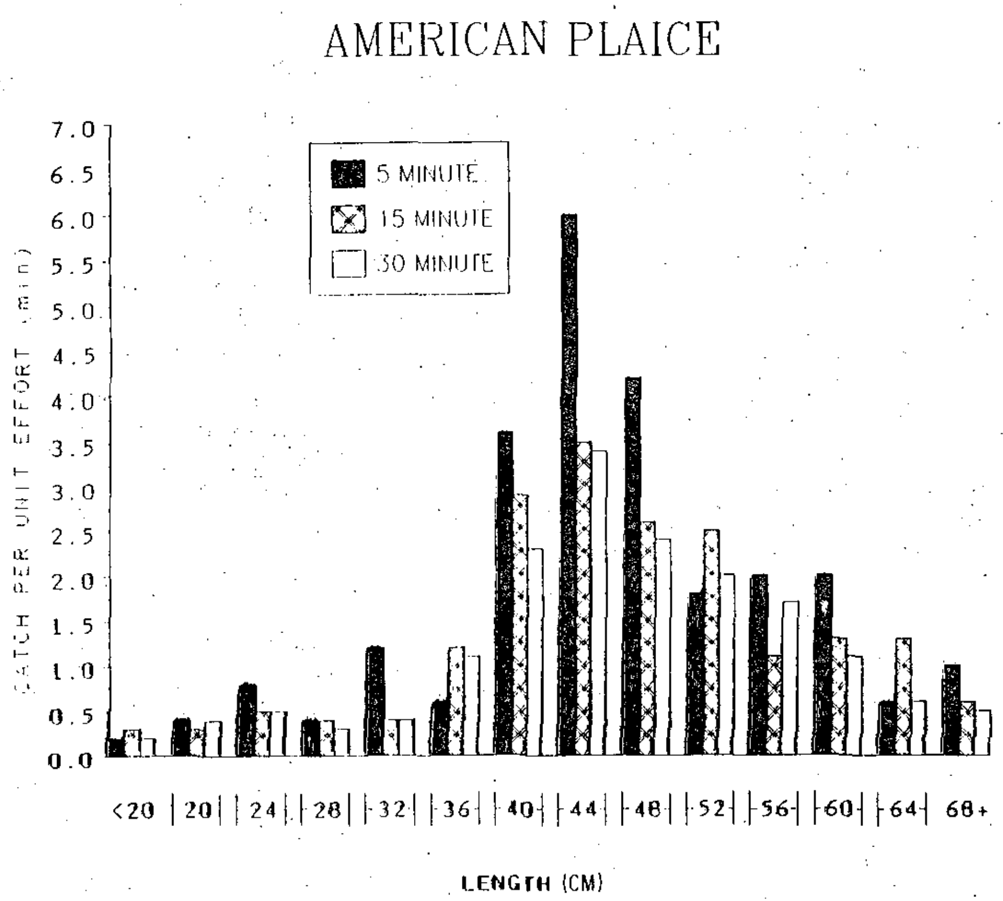

Fig. 3 Mean catch per minute of plaice from the 22 stations

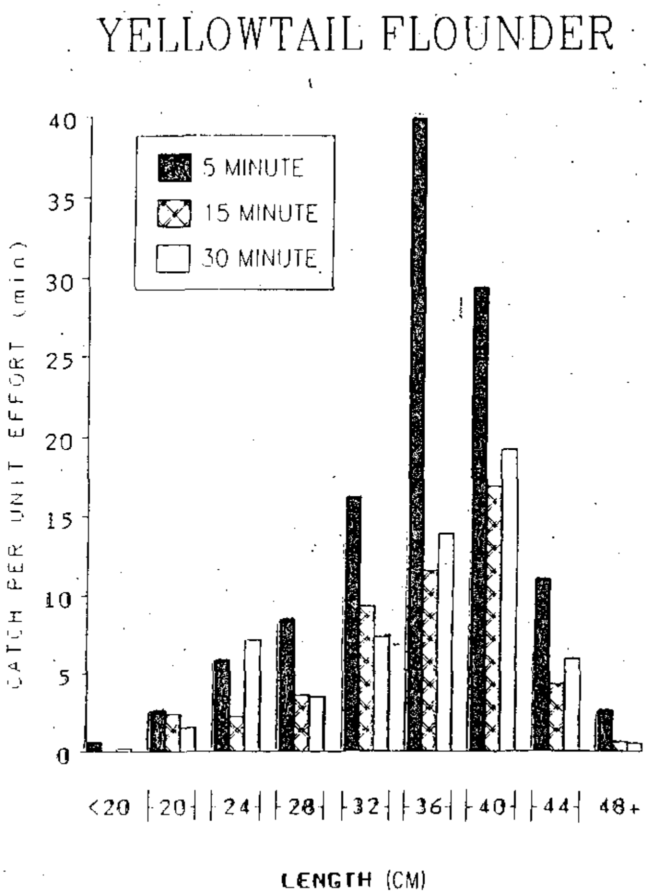

Fig. 4. Mean catch per minute of yellowtail flounder from 22 stations.

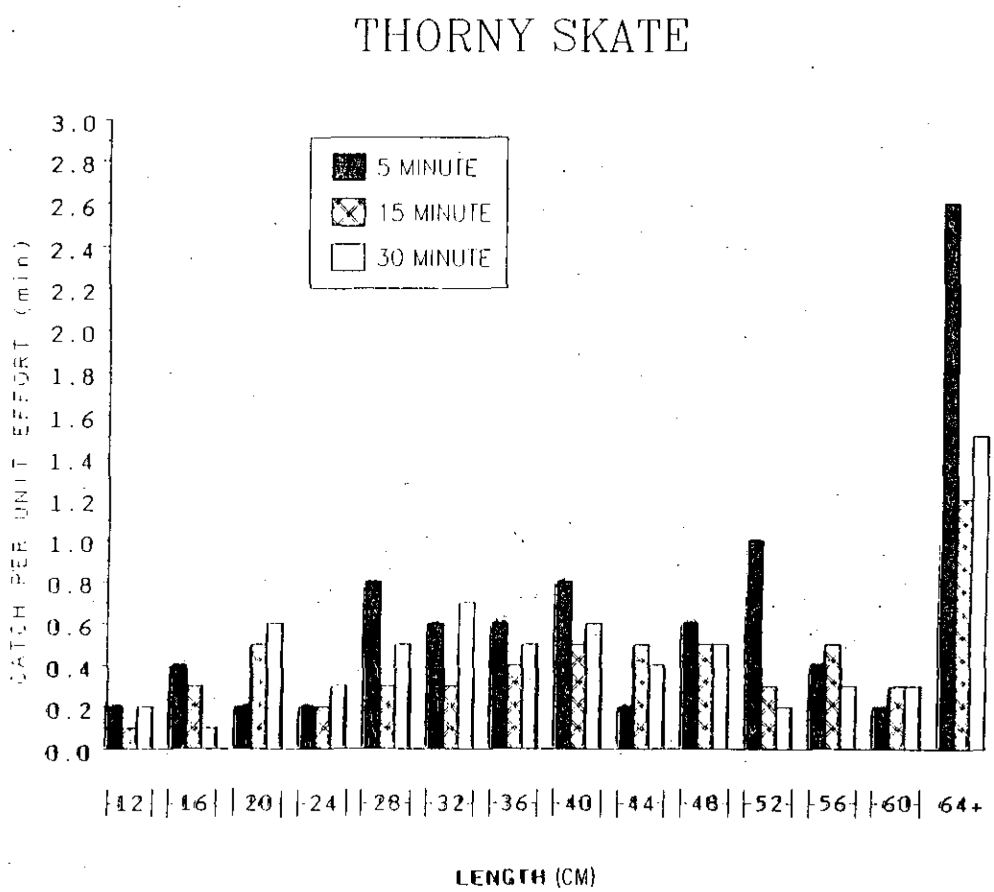

Fig. 5. Mean catch per minute of thorny skate from 22 stations.