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EFFECTS OF FISHING STRATEGY ON RELATIVE SELECTIVITY IN TRAWLS, LONGLINE AND GILLNETS

by

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ABSTRACT

Exploitation of fish stocks is dependent on effort, catchability, the selectivity of the gear used, and the fishermen's choice of time and place. A full-scale fishing experiment was conducted in February 1996 at the coast of Finnmark, Norway; involving a trawler, a longliner and a gillnetter. The objective was to investigate how the length distributions of the catches were influenced by the gear type and the fishermen's strategy in fishing operations. The target species was North-East Arctic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*).

The study analyses relative selectivity of the gears during a week when the boats fished in a predestined area, and during a week when the skippers were allowed to fish as close to commercial operation as possible with regard to choice of fishing grounds and depths. Gillnet catches consisted almost solely of large cod. Trawl and longline fished similar length distributions of cod although the L_{50} for cod was higher in long line than in trawl. The fishing strategy of the longliner increased the mean length of haddock in the second part of the experiment. Other length and species distributions were almost unaffected.

INTRODUCTION

Choice of fishing gear and catching strategy should be taken into consideration in the management of fish stocks. Knowledge on fishing gear selectivity is therefore fundamental for making recommendations for harvesting strategies. As stock abundance estimates often are based partly on catch data obtained from commercial fishing gears, such information is also of importance for proper fish stock assessment.

Studies concerning selectivity in fishing gear have mostly focused on how different gear characteristics affect size selection in trawl and gillnet. Few investigations for comparing the size selectivity of different gears have been conducted, although fixed gears such as longline and gillnet are regarded as more size-selective than towed gears. With a few exceptions (Engås *et al.* 1996; Nedreaas *et al.* 1996), this conclusion is based on comparisons of catches taken from different fishing grounds, at different times, or with gears that do not fulfill current regulation (McCracken 1963; Sætersdal 1963; Klein 1986; Hovgård and Riget 1992).

Size composition of commercial catches is affected both by gear characteristics (e.g. mesh size, bait size) and fishing strategy (e.g. choice of fishing ground and depth). Choice of fishing strategy is based on the skipper's experience on how and where to operate the fishing gear to obtain more profitable catches of desired species and size composition. We conducted a fishing experiment where cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) were fished simultaneously with trawl, gillnet and longline. In the first period of the experiment the gears were operated on the same fishing ground, whereas in the second period the skippers of the three fishing vessels were allowed to choose fishing ground to obtain data on how their decisions affected size and species composition of commercial catches.

MATERIALS AND METHODS

Three commercial fishing vessels were hired to conduct regular fishing operations. The gillnetter (29 m, 500 HP) used fleets that consisted of 40 nets with nominal mesh size of 180 mm stretched mesh (measured to 186 mm) and a hanging ratio of 50%. Each fleet is treated as one station. The rigging of the nets was as under commercial fishing. The nets were soaked from 8 to 16 h. A total of 52 fleets were set during the experiment, of which 37 were used in further analysis. The stations not analysed were fished with different mesh sizes or in a different area, and with the exception of the total catch in kg, these data are excluded from further analysis. The gillnet fleets were bottom-set and anchored at both ends.

The longliner (38 m, 1100 HP) was equipped with a Mustad Autoline System. The longline used was a 7 mm swivel line rigged with Mustad EZ-baiter hooks no 12/0 at a hook spacing of 1.4 m. The lines were baited with 2/3 squid and 1/3 mackerel cut at a bait width of 3 cm. Each longline fleet had 6300 or 8230 hooks. A longline fleet is called a station in the experiment. A total of 59 longline stations were set during the experiment, of which 5 are excluded from the analysis except for total catch in kg. The exclusion was done because the stations were fished in an alternative area, before the experimental area was properly set.

The trawler used was a freezer trawler (50.7 m, 2400 HP) fishing with a standard fishing trawl, Euronete/Alfredo no. 3 with a twin cod-end and rockhopper gear, using W11 doors of 7.8 m^2 and 2275 kg. The mean mesh size of the twin bags were measured to 140.2 mm stretched mesh (range: 135 - 148 mm.). The sweep length was 144 m, and the doorspread 135 to 146 m. The vertical opening of the trawl was 3.6 to 4.6 m. The towing duration was 3-4 hours at a speed of 2.1 m/s, as is common in commercial fishing operations. A total of 34 hauls were made.

Selectivity experiments were conducted by the trawler, using the trouser trawl method, with a vertical panel mounted from the middle of the belly to the codend. During the selectivity hauls one of the 140 mm twin bags were covered with a innernet of 60 mm mesh size. The duration of the selectivity hauls were 0.5 h, and a total of 10 hauls were conducted.

During the first six days of the experiment (Period 1), the three vessels fished at similar depths (mean values: trawl 293 m, longline 289 m, and gillnet 290 m) and as close as possible in a predestined area (Fig. 1). The differences between the mean fishing depths of the gears were not significant. Due to high fishing activity in the area, with large areas occupied by stationary gears, the chartered vessels were fairly limited in where to operate their gears. The last six days of the experiment (Period 2), the skippers of each vessel were allowed to choose their fishing grounds and fishing strategy within wider borders (Fig. 2). The skippers chose shallower depths in Period 2, but there were no significant difference between the boats (mean values: trawl 245 m, longline 259 m, and gillnet 227 m).

From the total catches of cod and haddock, a subsample of 250 to 350 individuals were length measured at each station. On each vessel individual biological data were collected from three cods in each 5-cm length group at every second station. The individual data sampled were length, weigth, otoliths, sex and maturity stage. Otoliths and biological data were not sampled for haddock.

The SELECT (Share Each LEngth's Catch Total) described by Millar (1991, 1992, 1993, Millar and Walsh 1992) was used to establish a selection curve for cod taken by the Euronete/Alfredo no. 3 trawl and to determine the selection parameters (25%, 50% and 70% retention length (L_{25}, L_{50}, L_{75}), and selection range) with confidence limits. This method was also used to fit a selection curve for cod from the longline data. The depth at the longline stations differed no more than 50 m from the towing depth of the trawl-stations used for selectivity hauls, and the longlines were set within a distance of 50 nautical miles from the trawl grounds. The length distribution calculated from the sampling trawl catches was used as the true size distribution of the fish population at the longline grounds, and used for estimating the longline selectivity parameters.

RESULTS

A total of 320 metric ton cod and 113 metric ton haddock (Table 1) were caught during the experiment. The number of bycatch per metric ton of commercial landings (cod and haddock) was 8 for gillnets, 41 for trawl and 133 for longline. The dominant bycatch in trawl was saithe (*Pollachius virens*) with 26 individuals per metric ton of cod and haddock, in longline there were 90 individuals of skates (*Raja* sp.) per metric ton.

Haddock

Because of the large mesh size used, the gillnetter caught only a total of 153 haddock during Period 1 and 2. This number was too low for analyses of size selection. Of the total catch taken by the longliner and the trawler, more than 23,000 haddock were length measured.

In Period 1, when the vessels fished within the same area, the longliner caught more small haddock than the trawler (Fig. 3). In Period 2, the longliner and trawler moved to different areas. The length distribution of haddock taken in this period showed that the longliner caught significantly larger haddock than the trawler (Table 2, Fig. 4). The size distribution of haddock in the trawl catches did not change between the periods, whereas the mean length of haddock caught by longline increased by 3 cm (Table 2). The range between 25% and 75% percentiles of the length distributions from the trawl catches did not change between the time periods (Table 2). The size range in the longline catches became wider and increased with 1 cm from Period 1 to 2.

Cod

A total of 35,000 cod were length measured, and out of these more than 2000 individuals were weighted and aged. The length distributions (Figs. 5 and 6) were quite similar for cod caught by trawl and longline, but longline caught cod over a wider size range. The length distribution of cod caught by gillnet was skewed approximately 20 cm to the right compared to the trawl and longline catches.

The mean length of cod caught by gillnets was significantly larger than those of trawl and longline, both in Period 1 and 2. The mean length of cod taken by longline was slightly, but significantly, larger than that taken by trawl (Table 3). The range of the length distribution of cod decreased for longline and gillnet from Period 1 to Period 2.

The gillnetter stayed in the same area both in Period 1 and 2. There was a small (approximately 1.2 cm) but significant decrease in the mean length of cod taken by gillnet. There was no significant change from Period 1 to 2 for cod caught by trawl or longline.

The size selectivity curve for the Alfredo no 3 trawl and the longline based on the SELECT methodology with a logistic relationship is shown in Figures 7 and 8. The 50% retention length (L_{50}) for longline was estimated to be 62.7 cm, or 7.7 cm above the L_{50} estimated for the trawl (55 cm) (Tables 4 and 5). Also the selection range was found to be 2 cm narrower for longline than for trawl.

The age-length tables (not shown) showed a tendency that cod caught by longline had poorer growth than cod caught by trawl. To analyse this more closely a von Bertalanffy function of growth was adjusted to the age and length data for fish of length 45-95 cm. The equation is $L_{(t)} = L_{\infty} (1- e^{k(t-to)})$, where the factor k is the growth rate of the fish. The estimated k from the model converged at almost the same value for trawl and longline data, but with a pronounced difference between the gillnet data and the two other gears (Table 6).

A test of the condition factor K=(100*length)/(weigth**3) calculated directly from weight and length data for each age, showed that the condition factor was lowest for the longline caught fish (Table 7). Also the mean length per age was lower for longline caught fish (Table 8).

The catches consisted of both Norwegian coastal cod and North-East Arctic cod. A difference in the frequency of coastal cod between the gears, could influence the distributions of length, age, and condition factor. Characteristics in the shape of the otoliths used for age determination (sacculus) was used to classify the fish. Table 9 shows that there was no difference in the proportions of North-East Arctic and coastal cod between the gears.

DISCUSSION

Fishing gears based on different catching principles are likely to harvest differently on fishing grounds with a mixed species and size composition. The catching processes of bottom trawl, longline and gillnets are different. The trawl is an active gear which sweeps along the bottom and catches fish in its path. Longline and gillnets are stationary gears; the former attracting fish by scent released from the bait, while the latter takes advantage of the swimming activity of the fish. The present study demonstrates significant differences in both species and size composition of catches taken by these gears.

The selective properties of longline gear depend on several factors such as feeding motivation, hooking probability in different groups of fish, and competition between species and size groups for the available baits (Fernø *et al.* 1986; Bertrand 1988; Løkkeborg and Bjordal 1992). In principle, the trawl harvests all fish in the trawl path if they are large enough to be held by the meshes in the cod-end. However, avoidance reactions to the approaching gear and fish escapement below the ground gear and above the headline, which may differ between age groups, are known to bias the length and species composition also in trawl catches (Engås and Godø 1989; Ona and Godø 1990, Michalsen *et al.* 1996).

In the present experiment the mean size of the cod caught by longline was slightly but significantly larger than that of cod caught by trawl when the gears fished within the same area. This finding is in accordance with earlier investigations (Engås *et al.* 1996). The selectivity parameters calculated from the catch data in Period 1 showed a larger L_{50} for longline (62.7 cm) than for trawl (55.0), which also indicates that longline has better selectivity for cod than trawl. Both the trawl and longline data were fitted to a sigmoid-shaped selection curve (Figures 7 and 8). However, the right part of the plot for longline may indicate that the selectivity is decreasing for the larger size groups of cod, and that a bell-shaped curve might give a better fit.

The longline caught more small haddock than the trawl when the gears fished in the same area. A similar difference was also demonstrated by Engås *et al.* (1996), who explained the differences by the fact that a large proportion of the haddock population was smaller than L_{50} for the Alfredo trawl (L_{50} for haddock: 43 cm (Isaksen *et al.* 1990)), and thus they can escape out of the trawl through the mesh openings.

The present findings shows that the trawl caught fish of a narrower length range (75% - 25%) than both gillnet and longline, suggesting that also the trawl selectivity should be fitted to a bell-shaped curve. Avoidance from the path of the vessel has been shown (Ona and Godø, 1990), and also that large fish can swim in the mouth area of the trawl for a longer period and swim out again after first having entered the trawl (Wardle 1983, 1986). The slope of the length distributions shows that the catches from longline and trawl data are almost identical from 90 cm and up, while the catches in the gillnet decreases more slowly. This may indicate that a bell-shaped curve could be as good a fit to the trawl catch data as for the longline data.

The present investigation, beyond revealing significant differences in gear selectivity per ce when the vessels fished in overlapping areas, also clearly demonstrated the differences in total selection of the three fishing methods, i.e. the gear selection combined with the fishing strategy of the skipper. This strategy is how the skipper operates the gear to achieve the maximum catch rates, the largest fish or the best bottom ground, or rather the combination of these factors. In the last period of the investigation, the skippers were allowed to choose their fishing strategies within wide borders. The mean length of haddock caught by longline, which in Period 1 was significantly smaller than that of trawl, increased by 3.1 cm in Period 2 and became larger than that of trawl-caught haddock. The total selectivity of the longline gear was thus improved by the skipper's choice of fishing strategy. A similar effect has been demonstrated in the Norwegian fisheries for Greenland halibut (Nedreaas *et al.* 1996). The total selectivity of the trawl seems to be more robust to changes in fishing strategy than longline. It has ealier been stated (Engås *et al.* 1996) that the trawl catches reflects the true size and species distributions in an area better than longline, and that the selection process in longline is affected by fish density and species composition.

The selective properties of gillnets are well documented (e.g. Olsen 1959; Hamley 1975; Hylen og Jacobsen 1979; Kirkwood and Walker 1986; Aldebert *et al.* 1993). The mean length of cod caught by gillnets was approximately 17 cm larger than those caught by longline and trawl. In addition, almost no haddock was caught by gillnets, because the mesh size was too large. Gillnet selection is supposed to remain fairly constant regardless of the size composition of the fish in the area. In this study we found a small decrease in the mean length of cod from Period 1 to Period 2, although the gillnet vessel remained on the same fishing ground in both periods. This can be explained by the spawning migration of cod. Spawning cod migrate westwards through the experimental area in February, and it is shown that the biggest cod are the first to migrate to the spawning grounds (Sund 1938). The proportion of big cod may therefore have decreased from Period 1 to Period 2.

The observed differences in condition factor between trawl, longline and gillnet may be explained by the catching process of these gears and fish behaviour. Fish caught by gillnet are mainly gilled by the meshes, and this gear therefore catch fish only within a narrow size range. However, for fish that have a wedge-shape, a wider size range may be caught by gillnet. Fish with higher condition factor are more wedge-shaped than skinny fish, and this may explain the high condition factor of the gillnet-caught fish. Fish with low condition factor, i.e. skinny fish, probably have a higher demand for food and thus higher feeding motivation. It is likely that these fish are caught in higher proportion by longlines that take advantage of the feeding behaviour of the target fish. Trawl, that caught the fish of intermediate condition factor in this experiment, catch the fish in its path, and trawl catches are therefore more likely to give a more representative sample of the fish in the area fished, at least with regard to condition factor.

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Table 1. Catch mean per station and standard error (in parenthesis), with grand total catch in the lower part of the table. Cod and haddock in kg, bycatch (including saithe) in numbers.

Period	Species	Trawl		Longline		Gillnet	
1	Cod	3237	(410)	1532	(114)	1117	(125)
	Haddock	1973	(236)	538	(48)	*	*
	Bycatch	68	(11)	34	(6)	4	(0.3)
2	Cod	1981	(856)	1849	(132)	3390	(398)
	Haddock	597	(208)	1181	(117)	*	*
	Bycatch	36	(15)	102	(15)	5	(1)
Total	Cod	142 tons		97 tons		81 tons	
	Haddock	67 tons		46 tons		0.3 tons	
	Bycatch	8652		19007		668	

Table 2. Mean bodylength (cm) in catches of haddock by gear and time period. P-levels from Kruskal-Wallis test for differences. Quantiles of 25% and 75% of the length distribution in parenthesis.

	Trawl	Longline	Probability
Period 1	53.0 (50-56)	51.4 (48-55)	0.0001
Period 2	53.1 (50-56)	54.5 (50-58)	0.0001
Probability	NS	0.0001	

Table 3. Mean length in catches of cod by gear and time period. P-levels from Kruskal-Wallis Test for differences between gears (column 4) and between time periods (last row). Quantiles of 25% and 75% of the length distribution in parenthesis.

	Trawl	Longline	Probab.	Gillnet
Period 1	67.2 (61-72)	67.9 (61-75)	0.0001	84.4 (80-94)
Period 2	67.6 (62-74)	68.2 (60-73)	0.0001	83.2 (77-88)
Probab.	NS	NS		0.0001

Table 4. Parameter estimates (cm) with asymptotic standard errors for the Alfredo no. 3 trawl from the selection experiment.

Parameter	Estimated value	Asymptotic standard error
25% retention length	47.8	1.21
50% retention length	55.0	1.80
75% retention length	62.2	2.60
Selection range	14.4	

Table 5. Parameter estimates (cm) with asymptotic errors from comparing catches from longlining with the catch in the control codend (60 mm meshsize).

Parameter	Estimated value	Asymptotic standard error
25% retention length	56.8	0.87
50% retention length	62.7	1.53
75% retention length	69.2	2.65
Selection range	12.4	

Table 6. Growth rate, k, for cod. Based on catches from longline, trawl and gillnet. The value is estimated by nonlinear regression to the von Bertalanffy's equation. The method used is least square by Marquardt. There is significant difference between the value obtained from gillnet catches, compared to trawl and longline.

	k	Lower 95 % conf. lim.	Upper 95 % conf. lim.
Longline	0.0192	0.003	0.035
Trawl	0.0194	0.0002	0.039
Gillnet	0.1052	0.085	0.126

Table 7. Mean condition factor (K=(100*weight)/(length**3)) by gear and age. P-levels from Kruskall-Wallis test for differences between pairs of gears.

Age:	4	5	6	7
Longline	0.831	0.831	0.842	0.852
Gillnet	0.880	0.993	1.065	1.112
Probability	NS	0.0062	0.0001	0.0001
Longline	0.831	0.831	0.842	0.852
Trawl	0.858	0.864	0.865	0.880
Probability	NS	0.0006	0.002	0.0137

Table 8. Mean length by age in different catches. P-levels from Kruskall-Wallis test for differences between pairs of gear.

Age:	4	5	6	7
Longline	44.6	52.7	63.7	78.0
Gillnet	44.5	53.1	67.0	81.4
Probability	NS	NS	0.0003	0.0022
Longline	44.6	52.7	63.7	78.0
Trawl	45.5	53.0	66.0	82.1
Probability	NS	NS	0.0011	0.0001

Table 9. Frequency table for distribution of Norwegian coastal cod and north east Arctic cod. Numbers are percentage by each gear.

	Norwegian coastal cod	Northeast Arctic cod
Trawl	5.46	94.54
Longline	5.49	94.51
Gillnet	5.40	94.60

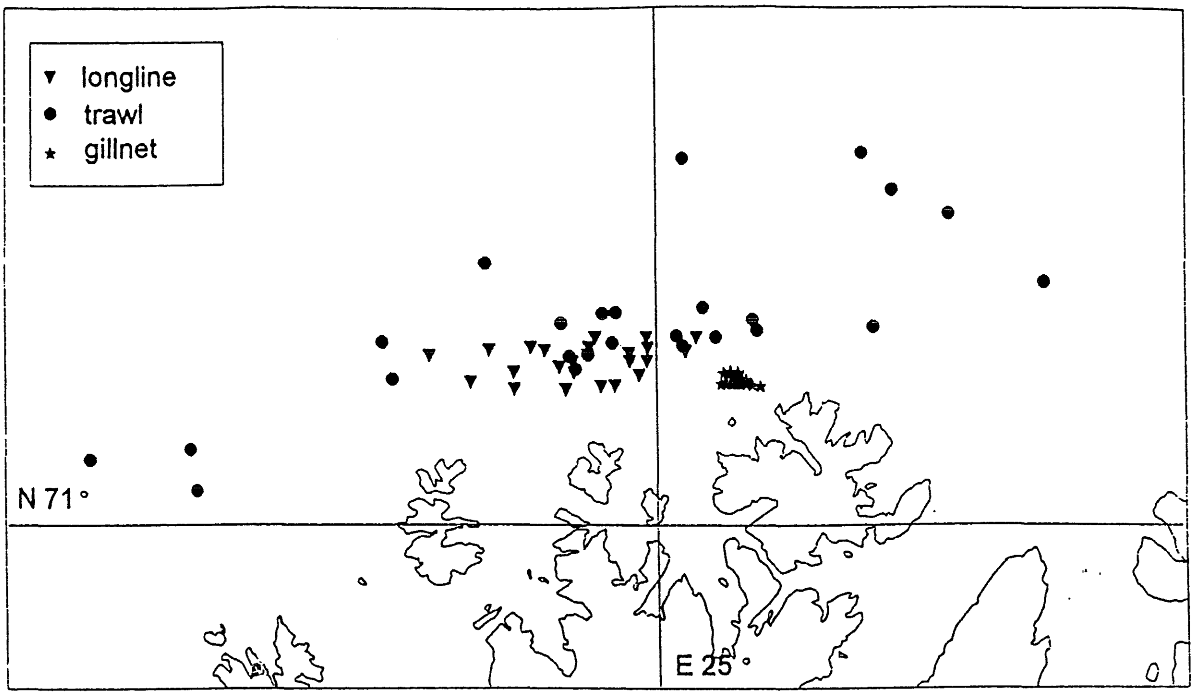

Figure 1. Stations fished in Period 1 of the experiment.

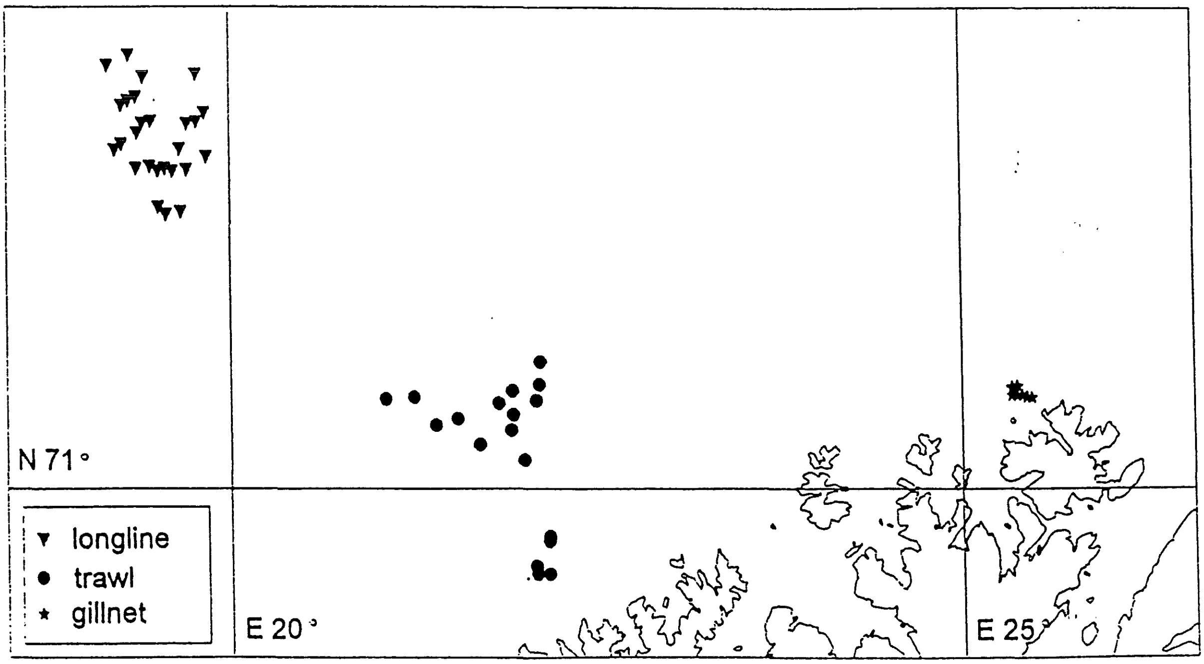

Figure 2. Stations fished in Period 2 of the experiment.

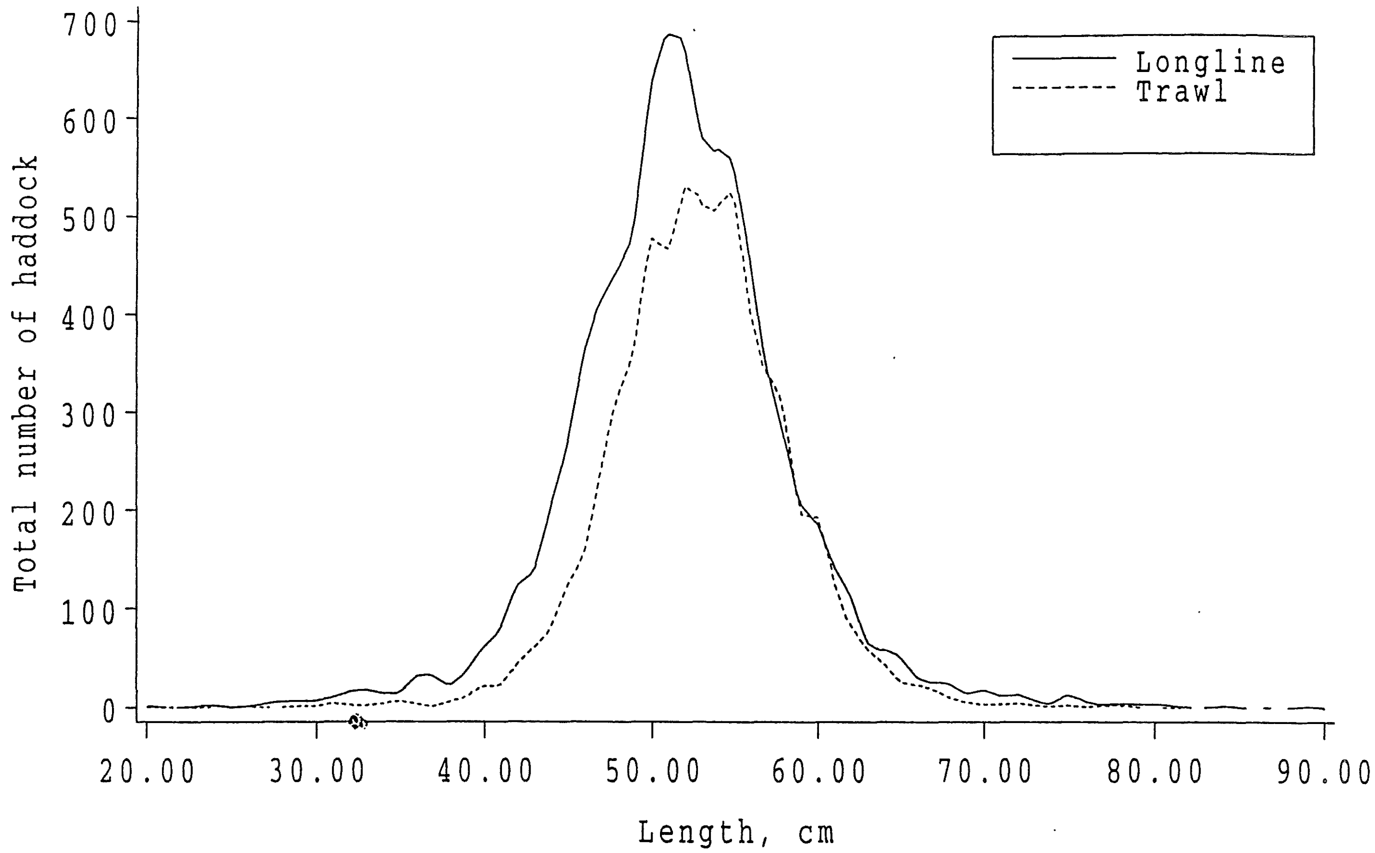

Figure 3. Length distribution of haddock, caugth in Period 1 of the experiment.

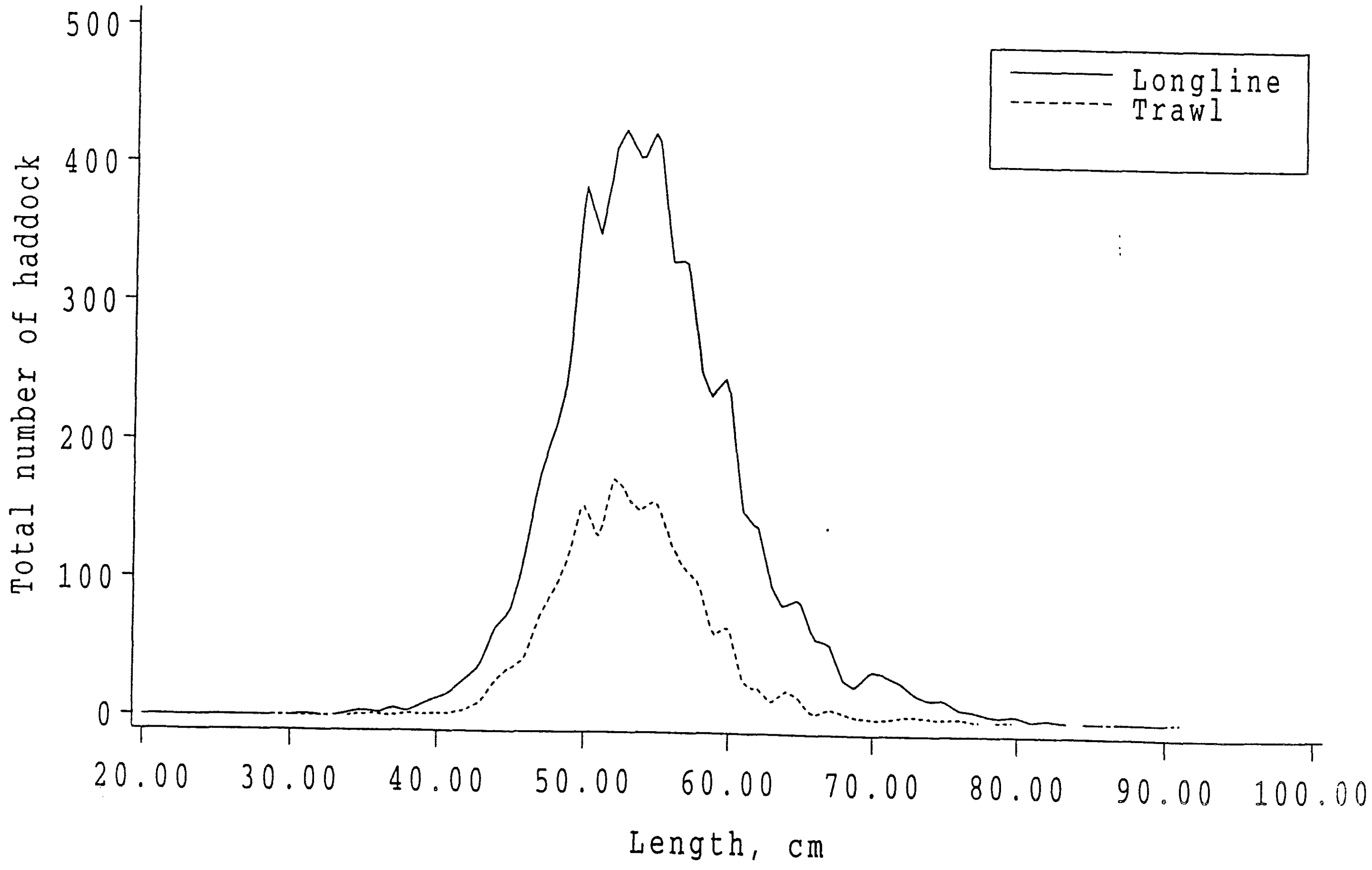

Figure 4. Length distribution of haddock, caugth in Period 2 of the experiment.

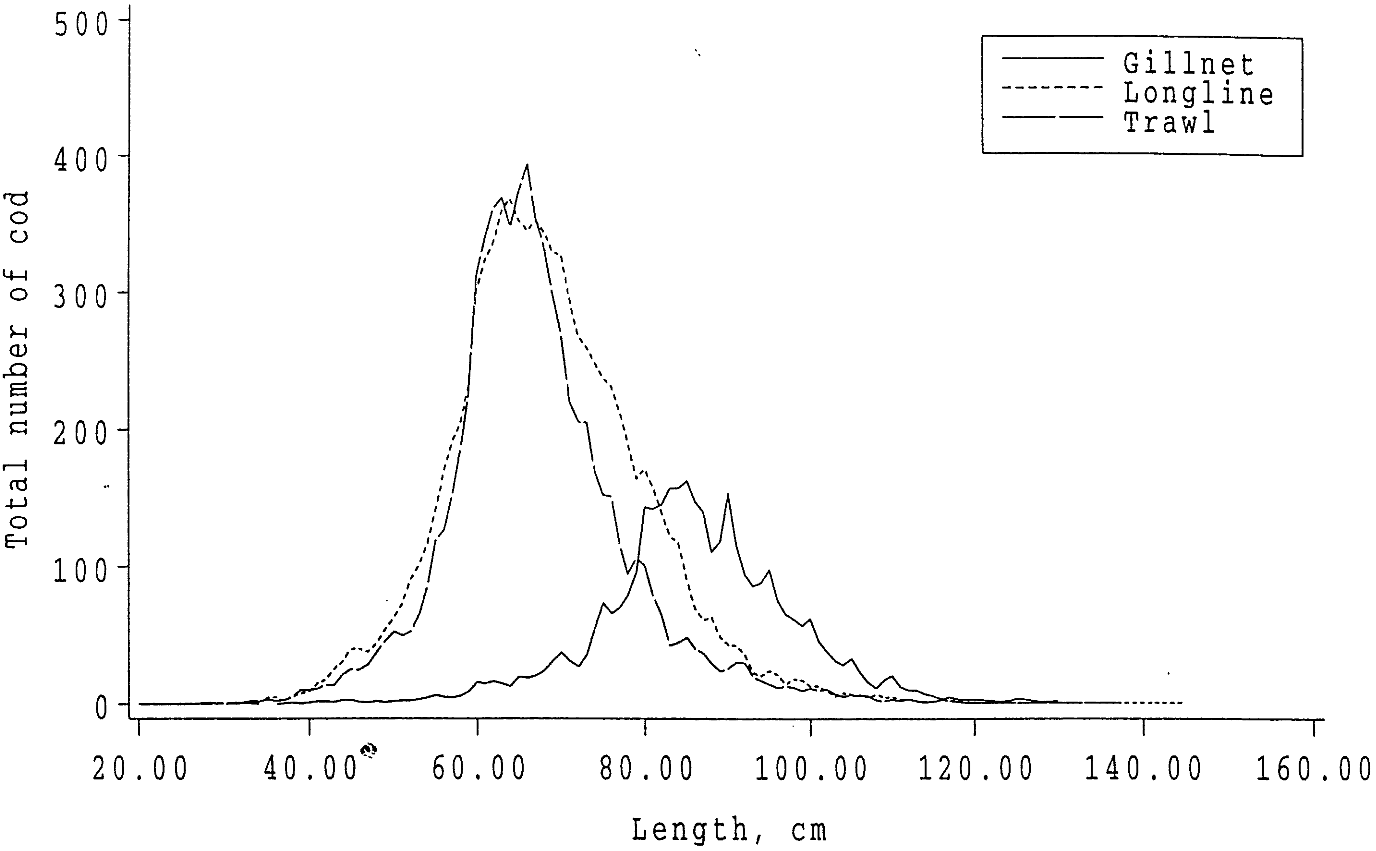

Figure 5. Length distribution of cod, caugth in Period 1 of the experiment.

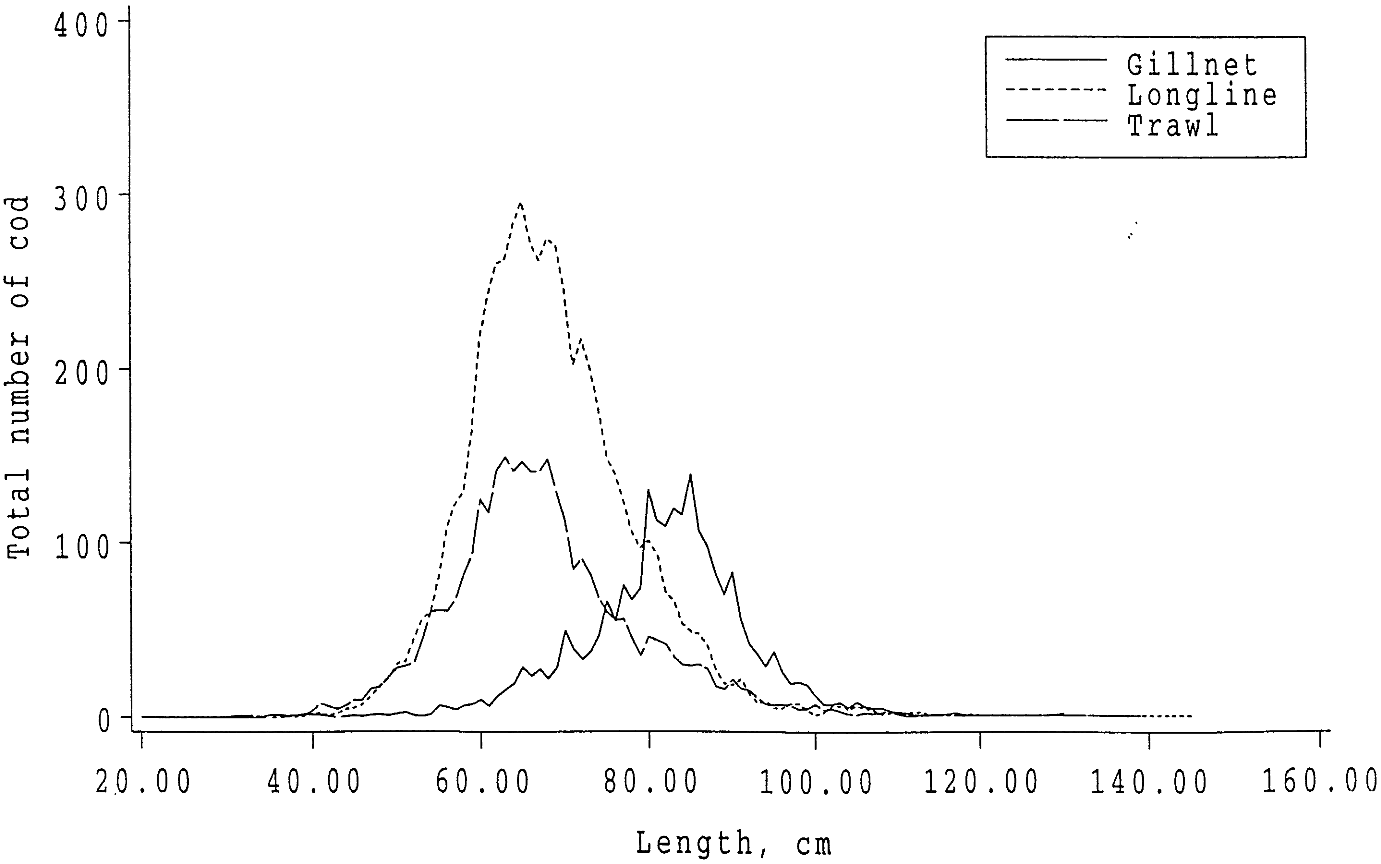

Figure 6. Length distribution of cod, caugth in Period 2 of the experiment.

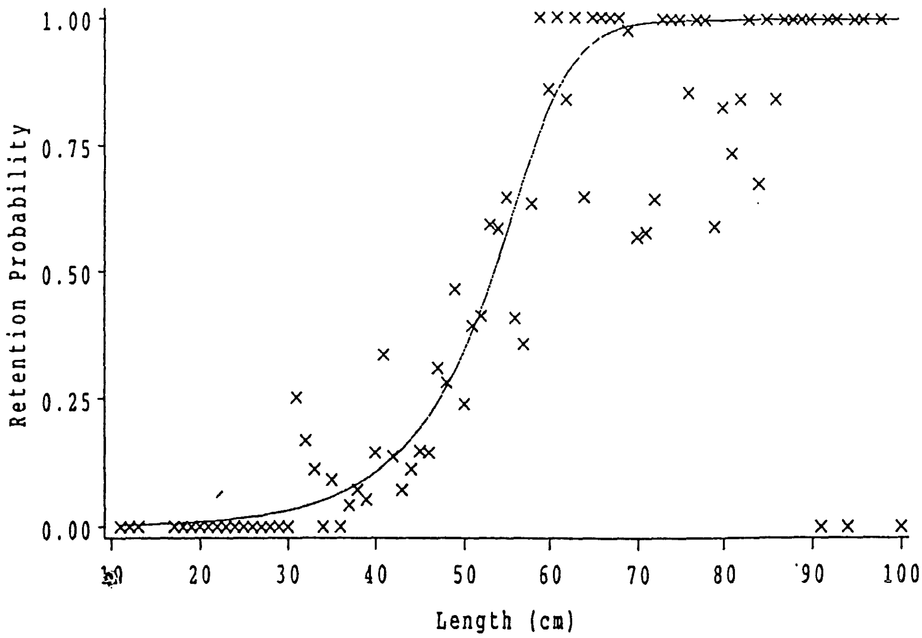

Figure 7. Selectivity curve for cod in the 140 mm mesh trawl.

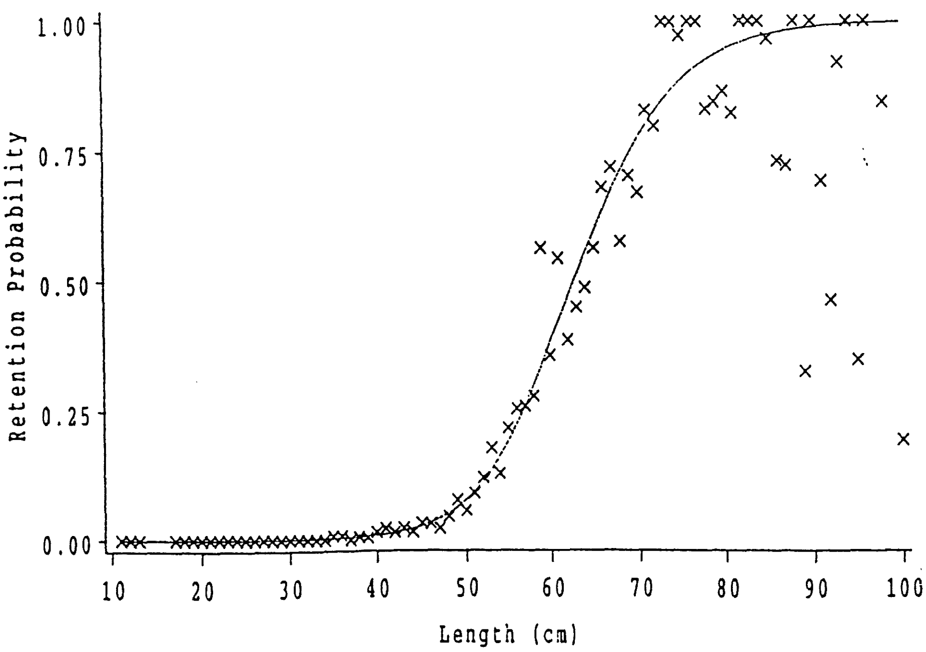

Figure 8. Selectivity curve for cod caught on longline.