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Comparative Fishing for Cod and Haddock With Commercial Trawl and Longline at Two Different Stock Levels

by

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Abstract

Fishing experiments for cod and haddock were performed simultaneously within the same area with commercial bottom trawl and longline during two periods with different stock levels. Stock level, species and length composition in the experimental area were determined from a combined acoustic and bottom trawl survey. The fishing trials showed that the haddock:cod ratio was higher in longline than in trawl. This result was explained by difference in behaviour between cod and haddock towards the two gears. Longline was found to catch less under-sized cod and more under-sized haddock than trawl. The size selectivity of longline was affected by the fish density and size composition of the area fished. The implications of these results for optimal harvest strategy are discussed.

Introduction

Management of fish stocks are based on recommendations only for total catch quotas, and allocation of quotas between different fishing gears are based mainly on traditional fishing patterns. A more optimal harvest strategy has been sought by improving gear selectivity, and by closing fishing grounds when the proportion of under-sized fish in the catches exceeds the legal proportion. However, proper fisheries management should also take into consideration the choice of fishing gear and catching strategy (Løkkeborg and Bjordal, 1992). This requires knowledge of how size and species composition of catches are affected by the type of gear used.

Such information is also of importance for biologists dealing with interpretation of stock assessment surveys. Most ground fish surveys use trawl sampling methods, although some bottom fish stocks are often found in untrawlable areas. Alternative survey gears, namely longlines and gillnets, must be used for such areas, and size-dependent conversion equations are required to relate the catch rates of these gears to that of the trawl (Hovgård and Riget, 1992).

However, few studies have been conducted to compare size selection between towed and stationary gears, and knowledge of how the species composition in catches from a mixed fishery is affected by fishing method is scarce. A lower proportion of small cod (*Gadus*

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morhua) was found for longline catches compared to trawl catches taken in the same areas and in the same periods (Hovgård and Riget, 1992). In addition, other studies indicate that longlining is a more size-selective fishing method for cod than is trawling (McCracken, 1963; Sætersdal, 1963; Bjordal and Laevastue, 1990), although these data were not obtained from fishing vessels operating in the same area or at the same time.

In this study we compared the size and species selectivity of commercial longlining and trawling by using data from a fishing experiment that primarily was designed to study the effect of seismic exploration with airguns on catching success. As the seismic activity caused a decrease in the fish density and changes in the size and species composition of the area studied, analyzing catch data from before and after seismic shooting gave us a unique chance to compare the selection patterns of trawl and longline at two different stock levels.

Materials and Methods

During a programme to map the effect of geophysical exploration with air guns on the catch availability of fish, fishing trials with bottom trawl and longline were carried out in May 1992 on the North Cape Bank in the Barents Sea (Fig. 1). In the original experiment catch data were collected 7 days before a seismic vessel started air gun shooting within the experimental area, 5 days during shooting and 5 days after shooting ended. In this paper catch data from before (**Period 1**) and after (**Period 2**) shooting are compared, while data collected during shooting are omitted. In addition to the fishing trials, acoustic mapping of fish abundance and distribution were performed within the same area and time period.

The experimental area was 10 x 16 nautical miles (19 x 30 km); with good operating conditions for both bottom trawl and longline, and with relative homogeneous bottom depths of about 250-280 m. The weather conditions were good during the experiment.

<u>Acoustic mapping</u>

A hired stern trawler was equipped with SIMRAD EK500 echo sounding system connected to a split-beam transducer (ES38-29) and the Bergen Echo Integrator (BEI), to perform mapping of fish distribution within the experimental area. A detailed description of equipment, calibration of the system, survey transects within the investigated area and acoustic method for estimating fish abundance, are given in Engås et al. (1993). The vessel was also equipped with the Institute of Marine Research's standard bottom sampling trawl (Campelen 1800; Engås and Godø, 1989). The door spread of the trawl was 54 m, with an average trawl height of 3.8 m. Each trawl haul lasted for 30 min, at a towing speed of 3 knots (1.5 m/s). The number of hauls was 14 in both Period 1 and 2.

<u>Trawl trials</u>

A commercial factory trawler equipped with a standard fishing trawl, Alfredo no. 3, was hired for the trawl trials. She was rigged with 145 m sweeps and V-doors (7.8 m^2, 2200 kg). The mesh sizes in the twin bags were measured with an ICES gauche meter (5 kg loading) to be 146 and 147 mm, respectively (minimum legal mesh size is 135 mm). Each trawl haul lasted for 30 min at a towing speed of 3.5 knots (1.8 m/s). The door spread was measured to be 150 m, and the vertical opening of the trawl was 4.2 m. In each of Periods 1 and 2, 28 hauls were taken. The positions and time of day of the hauls were randomly distributed within the experimental area.

Longline trials

A hired autoliner used her ordinary fishing gear; Mustad Qiuck Snap line (7 mm) rigged with double-twisted gangions no. 14 and Mustad EZ-hook (quality 39975, no. 12/0). Each longline fleet had about 3000 hooks, and the hook spacing was 1.3 m (longline length = 3900 m). The longlines were baited with 50% mackerel and 50% squid. The bait width was 30 mm.

Four longline fleets were hauled each day. The fleets were set in north-south direction at specific distances randomly distributed on the north and the south side of the center of the experimental area. A total of 28 and 20 longline fleets were hauled during the two periods, respectively. The longline fleets were set between 0600 and 1000 hours every day. The soak time varied from 6 to 18 hours.

Results

Acoustic abundance and sampling trawl

Figure 2 shows the total acoustic density of cod and haddock in the experimental area, split in a pelagic and a near-bottom part (the lowest 10 m) and expressed in terms of the average area backscattering coefficient (s_A). The total acoustic density was reduced from an average of 130 m^2/NM^2 in Period 1 to 46 m^2/NM^2 in Period 2, which is a reduction of 64%. The reduction was larger in the pelagic part of the water column than in the bottom channel, 70 and 52%, respectively. Figure 3 shows the acoustic average per day during the two time periods. The population level seemed to have stabilized at a lower abundance level after the seismic activity stopped.

The length-frequency distributions of the two main species, cod and haddock, as reflected by the catches taken by the sampling trawl, are shown in Figure 4 a and b. The largest fraction of cod in the catches was made up of fish between 25 and 55 cm. The number of cod caught was significantly lower in Period 2 than in Period 1 ($p<0.001$, Anova). The reduction in numbers were, however, relatively larger for fish above than below 55 cm. Fish between 15 and 40 cm were most frequent in the haddock catches. For haddock larger than 25 cm, the catch was significantly larger in Period 1 than in Period 2, while there was no difference for smaller fish.

Longline and trawl comparison

The average catch of cod in Period 1 was 544 kg per trawl haul (30 min) and 789 kg per longline fleet (Table 1). The catch of haddock taken by trawl was low, only about 30 kg at average per haul, while the longline caught almost 10 times as much per fleet. The haddock:cod ratio (in numbers) was therefore different for the two gears ($p<0.001$, Wilcoxon 2-sample test); 0.66 for longline and 0.11 for trawl (Fig. 5).

The length-frequency distributions of cod and haddock taken by longline and trawl in Period 1 are shown in Figure 6 a and b. The mean length of cod taken by longline was 68.2 cm, while it was 66.0 cm in the trawl catches (Table 2). For haddock the mean length was 53.4 cm and 53.0 cm, respectively. The longline caught relatively less cod below the legal size (47 cm) than the trawl, 7 and 12%, respectively ($p<0.001$; Fig. 7a). For haddock, the longline caught more under-sized fish (below 44 cm) than the trawl, 25 and 15%, respectively ($p<0.005$; Fig. 7b).

In Period 2, the trawl catches of cod were 57% lower in weight than in Period 1 (Table 1), while the longline catches were reduced only by 13%. The haddock catches in Period 2 were approximately 70 % lower than in Period 1, both for longline and trawl.

Also in Period 2 there was a significant higher proportion of under-sized haddock in the longline than in the trawl catches ($p<0.001$), while the difference in the proportion of under-sized cod was not significant ($p>0.10$). The proportions of cod and haddock below legal size were higher for both gears in Period 2 than in Period 1 ($p<0.001$ for both species in the longline catches; $p<0.05$ and $p<0.01$, respectively, for cod and haddock in the trawl catches), but the increase was larger for longline than for trawl (Fig. 7 a and b). The number of haddock relative to cod was lower both in trawl and longline catches in the last period ($p<0.001$, Fig. 5).

Figure 8 a and b show the length-frequency distributions of cod and haddock in the catches in Period 2. In the trawl catches there was a reduction in number of cod in all length groups compared to Period 1, although there was a relatively larger decrease in the larger size groups. The longline, however, caught more cod smaller than 55 cm in Period 2 than in Period 1, while there was a decrease in larger fish. The number of haddock was significantly lower for both gears, but the reduction was largest for big fish. The relatively larger reduction in numbers of large than of small fish resulted in a drop in mean length of both species in the catches from both gears (Table 2).

Discussion

Fishing gears based on different catching principles are likely to harvest differently on fishing grounds with a mixed composition of species and sizes of fish. The catching processes of bottom trawl and longline are completely different, the former is an active gear which sweeps along the bottom and catches the fish in its path and the latter, a stationary gear to which fish are attracted by scent released from the baits. Both longline and trawl were found to be highly size selective compared to the true stock composition in the area as reflected by the sampling trawl. However, the present results demonstrate significant differences in both species and size compositions of catches taken by commercial trawl and longline.

Our results are based on catches taken by vessels using gears and operating as is common in commercial fishing. The only exception was the low trawl catches. In commercial trawling, the hauls would have been much longer to obtain higher catches. When the catch increased from <500 kg to 500-1000 kg, the 50% retention lengths for cod and haddock were shown to decrease by 5 and 3 cm, respectively (Isaksen et al., 1990). The trawl catches in the present study had an average of 544 and 232 kg, respectively, for the two fish densities. The results obtained may therefore indicate better size selection for trawl than in commercial fishing where higher catches are normally obtained.

The proportion of haddock in the longline catches was higher than that of the trawl catches, indicating that longlines are more effective in catching haddock and/or that trawl is more effective in catching cod. The high haddock:cod ratio in the longline catches may be explained by differences in the behaviour of cod and haddock towards baited hooks. Behaviour studies have shown that haddock more frequently responded to and bit a baited hook than did cod (Løkkeborg et al., 1989). The low haddock:cod ratio in the trawl catches may be due to haddock being smaller than cod and therefore escaping through the meshes in a higher proportion. Furthermore, haddock but not cod have been observed to escape over the headline of the trawl when the rate of turnover in the net mouth area is low or when high densities of haddock arrive at the net mouth area within a short time interval (Engås, 1991). However, more cod than haddock have been documented to escape by diving under the fishing line of the trawl (Engås and Godø 1989). It is therefore not known if more haddock than cod escape in the front of the trawl. Thus, longlines may catch haddock more efficiently than cod due to behavioural differences, whereas trawl may catch cod more efficiently because more haddock escape through the meshes and perhaps also in the front of the trawl.

The proportion of under-sized cod was higher for trawl than for longline. Longlining is regarded to be a more size selective fishing method than trawling (Løkkeborg and Bjordal, 1992), and differences in size composition between trawl and longline catches have been reported by others (Sætersdal, 1963; Hovgård and Riget, 1992). Fish are attracted to longlines by scent released from the baits, and the behaviour of fish responding to baited hooks is similar to that of foraging fish (Atema, 1980; Løkkeborg, 1989). Larger fish have larger foraging area (Hart, 1986), and constraints on feeding activity are less pronounced in larger fish (Milinski, 1986). Thus, before the fish come into contact with baited gears, there is a selection process that exposes a relatively high proportion of large individuals to the gear (Løkkeborg and Bjordal, 1992). This process is unique for baited gears and will not affect the size composition of trawl catches.

More under-sized haddock were, however, caught by longline than by trawl, indicating that longlines are less size selective for haddock than for cod. Bait size is regarded to be the most important factor affecting size selectivity of longlining (Løkkeborg and Bjordal, 1992), and baits of certain sizes have been shown to be ineffective in catching smaller cod (McCracken, 1963; Johannessen, 1983). However, bait size had little effect on the size of haddock caught by baited hooks (Johannessen, 1983). Lower proportion of under-sized haddock in the trawl catches than in the longline catches may also be due to effective size selection by the trawl. The 50% retention length of the mesh size used has been reported to be 48.6 cm for haddock (Isaksen et al., 1990), and a high proportion of fish below 44 cm should therefore escape through the meshes. However, effective size selection in the present trawl catches may, as discussed above, be due to the low catches. The observed difference in proportion of under-sized haddock between trawl and longline may therefore not apply to higher trawl catches.

Our results also showed that fish density affected the selection process of longline. The acoustic mapping and catching trials with the sampling trawl showed that the fish density was reduced by 64% from Period 1 to 2, and that there was a relatively larger reduction of larger than smaller fish. This change can explain that the increase of under-sized fish from Period 1 to 2 was more pronounced in the longline catches than in the trawl catches. Length-frequency distributions of angling and handline catches indicated the existence of competition for available baits among fish of different sizes (Allen, 1963; Bertrand, 1988), and behavioural studies have shown that large fish frighten smaller fish away from baited hooks (Løkkeborg and Bjordal, 1992). With lower fish density and lower proportion of larger fish there will be less competition for the baits and the small individuals may therefore be more successful in taking the available baits.

As pointed out earlier the choice of fishing gear and catching strategy should be taken into consideration for proper management of fish stocks. Very few fisheries are based solely on a single species. The choice of fishing gear to obtain a more optimal harvest strategy will depend on the state of the different stocks, as longline and trawl have highly different species selectivity. Also, the size selectivity of the gears are different, but depends on the fish density and size composition in the area fished. As an example, in situations with high density, longline will protect the younger year classes of cod more than trawl gear, but also give a higher exploitation rate of haddock, which is desirable or not depending on the state of the haddock stock.

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Table 1. Average catch per fleet/haul (kg) taken by longline and trawl during the two experiment periods.

Gear	Period	Cod Mean catch (kg)	Cod Standard error	Haddock Mean catch (kg)	Haddock Standard error
Longline	1	789	29	277	32
	2	691	40	90	7
Trawl	1	544	48	29.6	3.7
	2	232	23	8.7	1.0

Table 2. Mean length (cm) of individual cod and haddock in longline and trawl catches during the two experiment periods.

Gear	Period	Cod Mean length (cm)	Cod Standard error	Haddock Mean length (cm)	Haddock Standard error
Longline	1	68.2	0.2	53.4	0.2
	2	62.8	0.2	47.2	0.3
Trawl	1	66.0	0.2	53.0	0.4
	2	61.5	0.3	50.4	0.8

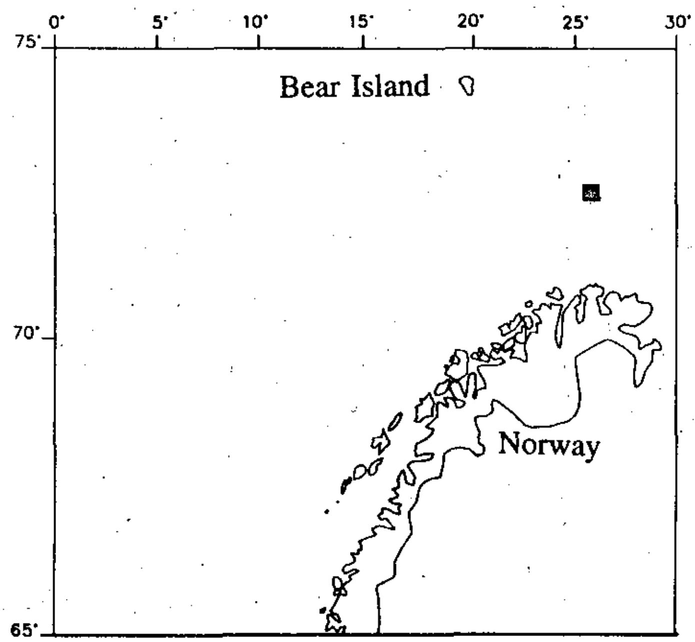


Figure 1. Position of the experimental area.

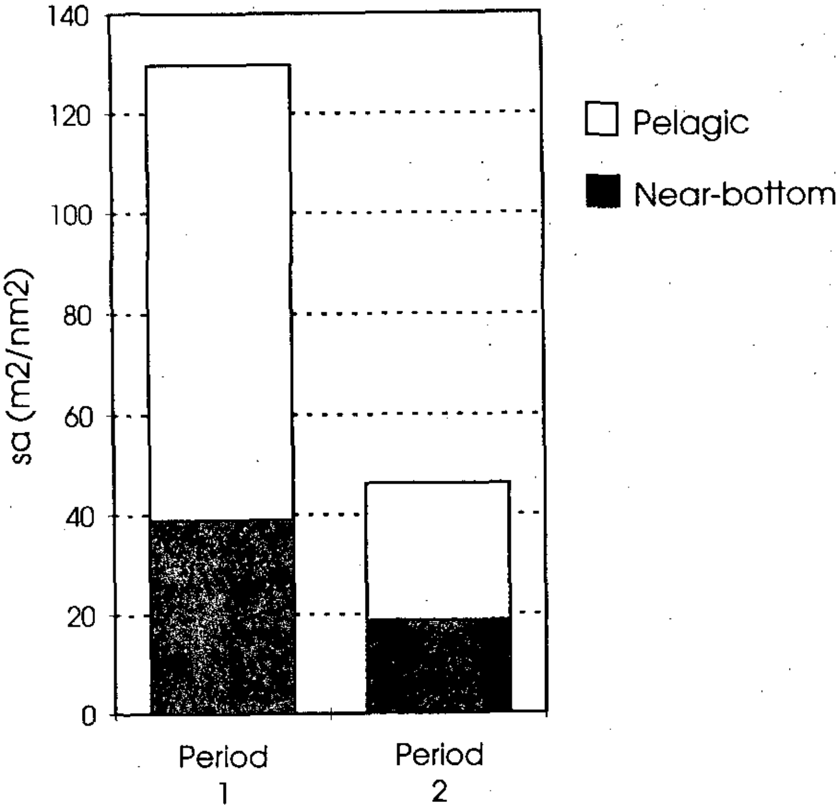


Figure 2. Total acoustic density of cod and haddock in the experimental area split in a pelagic and a near-bottom part (10 m).

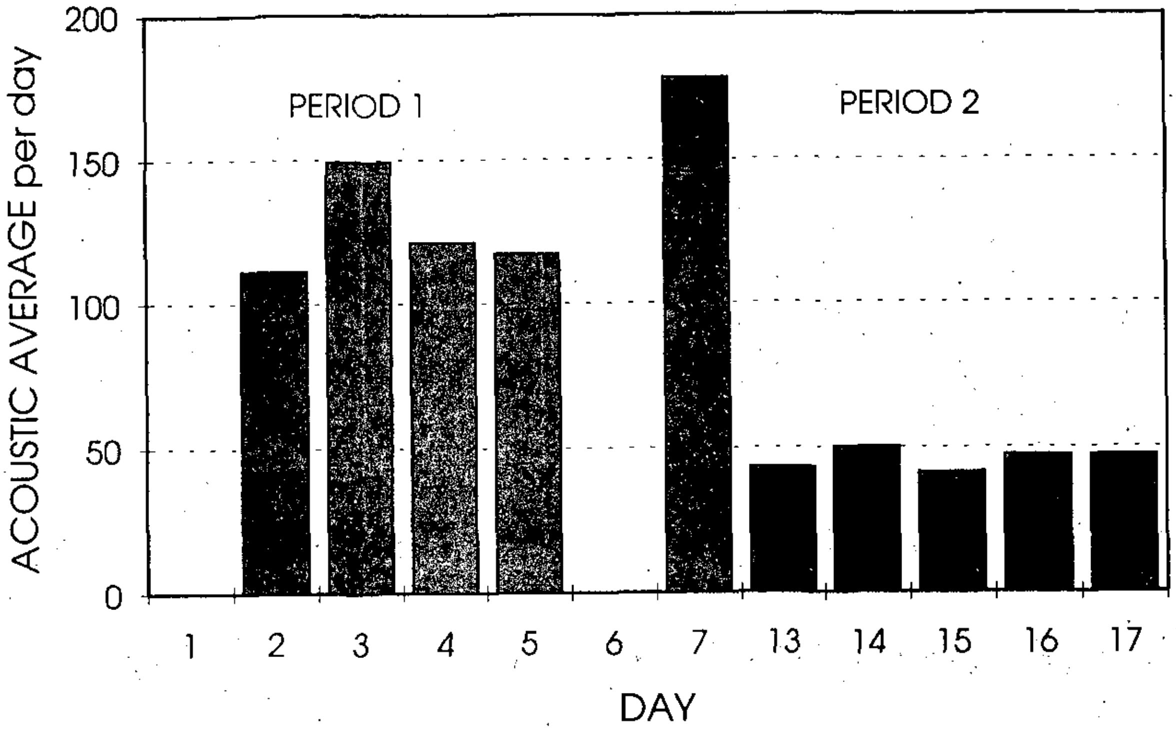
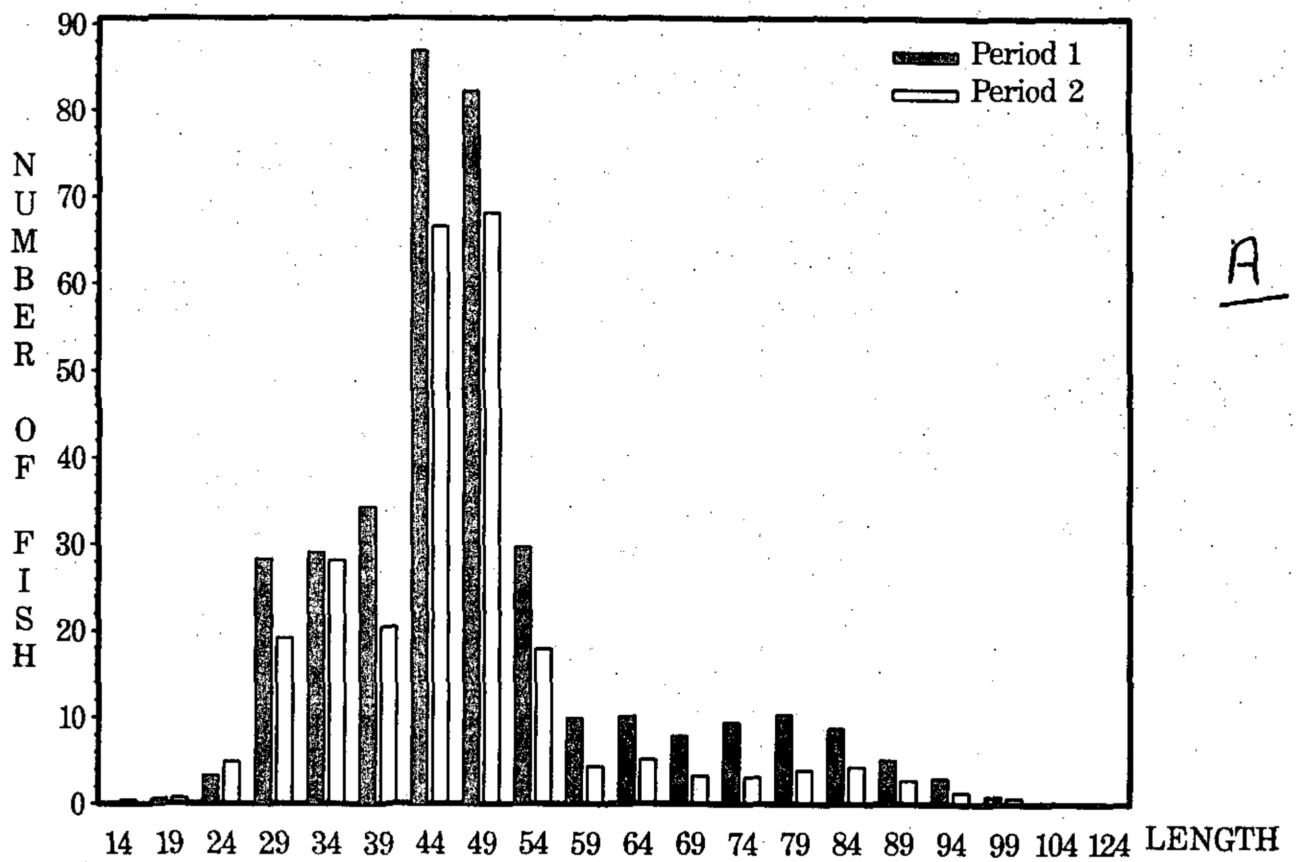


Figure 3. Average daily acoustic density during Period 1 (day 1-7) and Period 2 (day 13-17). Acoustic data were not sampled at day 1 and 6.



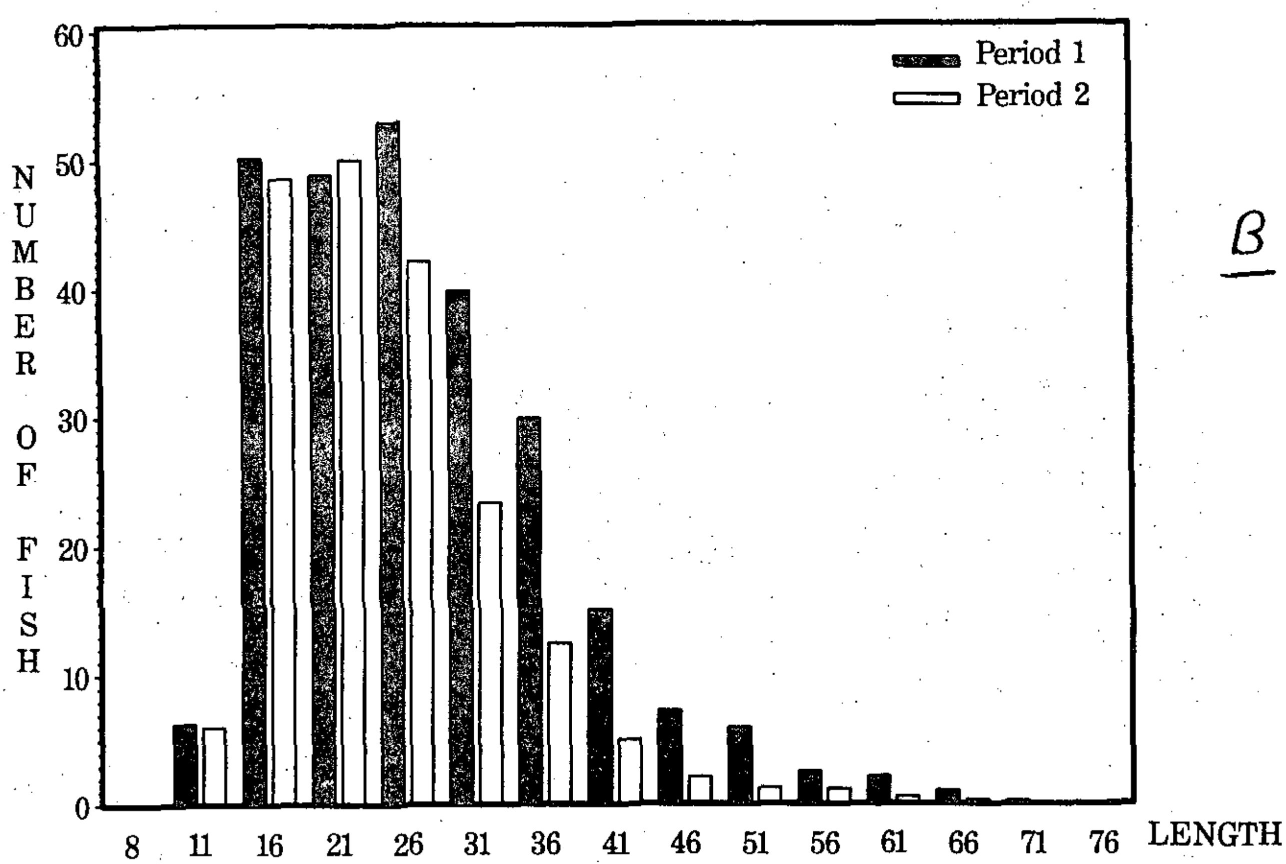


Figure 4. Length-frequency distributions of cod (a) and haddock (b) in the sampling trawl catches.

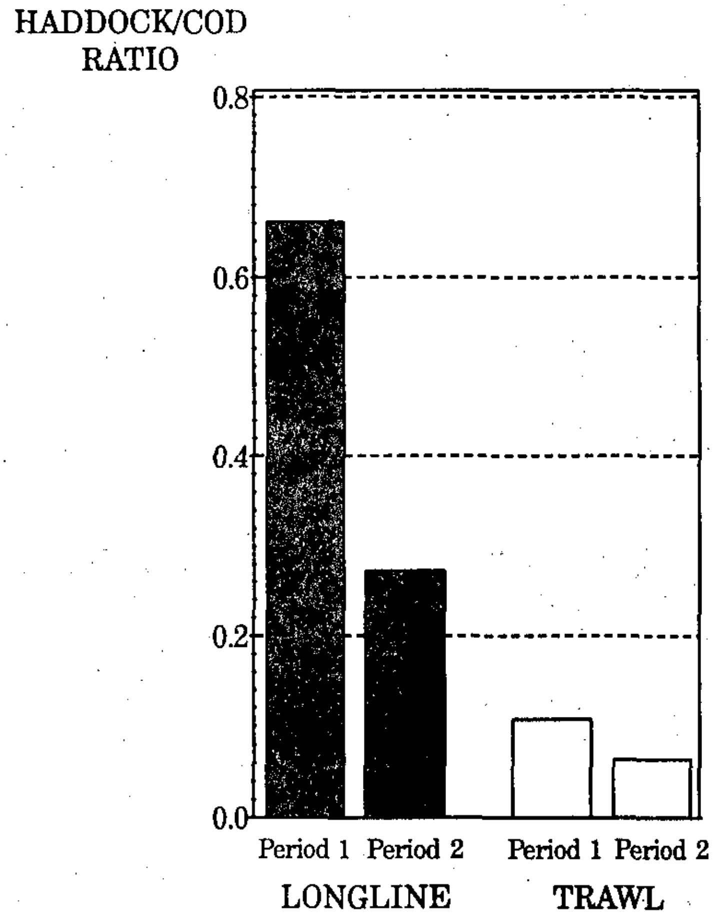
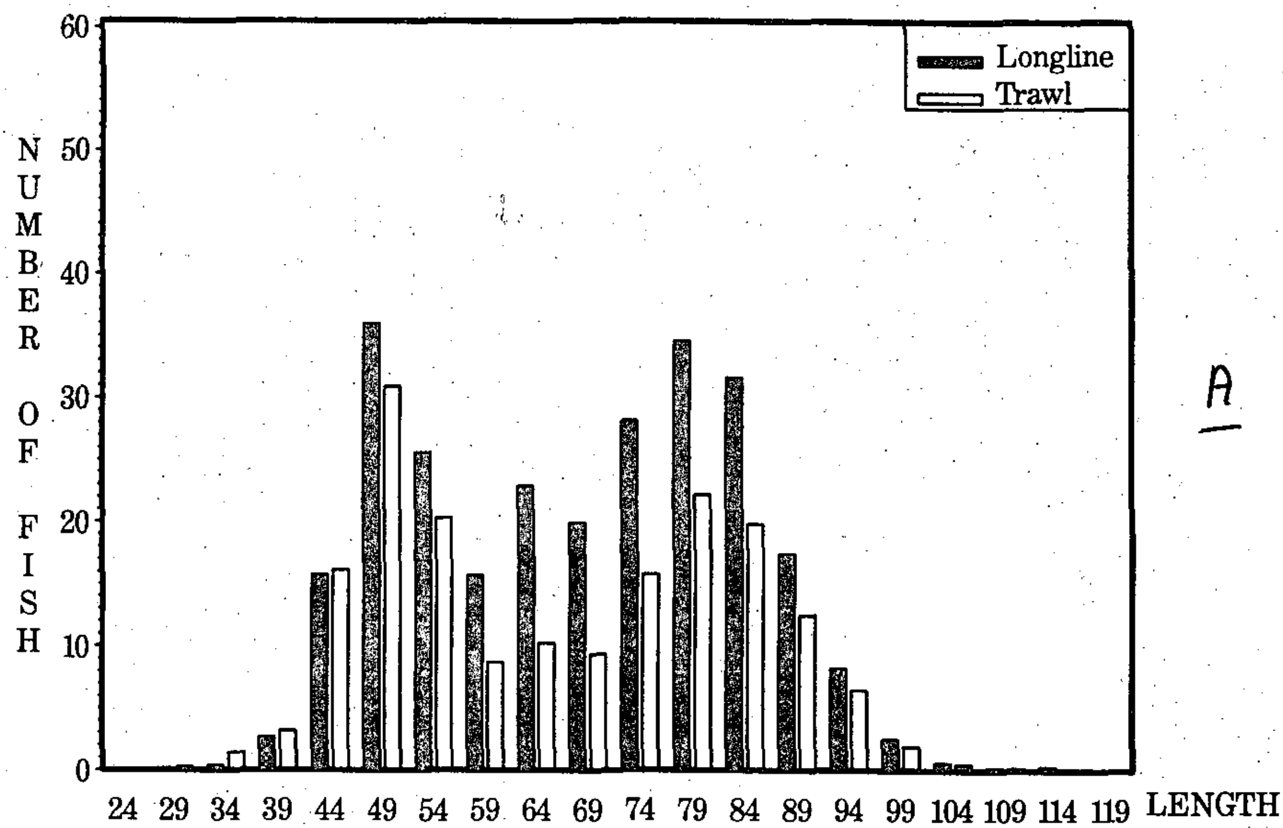


Figure 5. Haddock:cod ratio (in numbers) in the longline and trawl catches in the two periods.



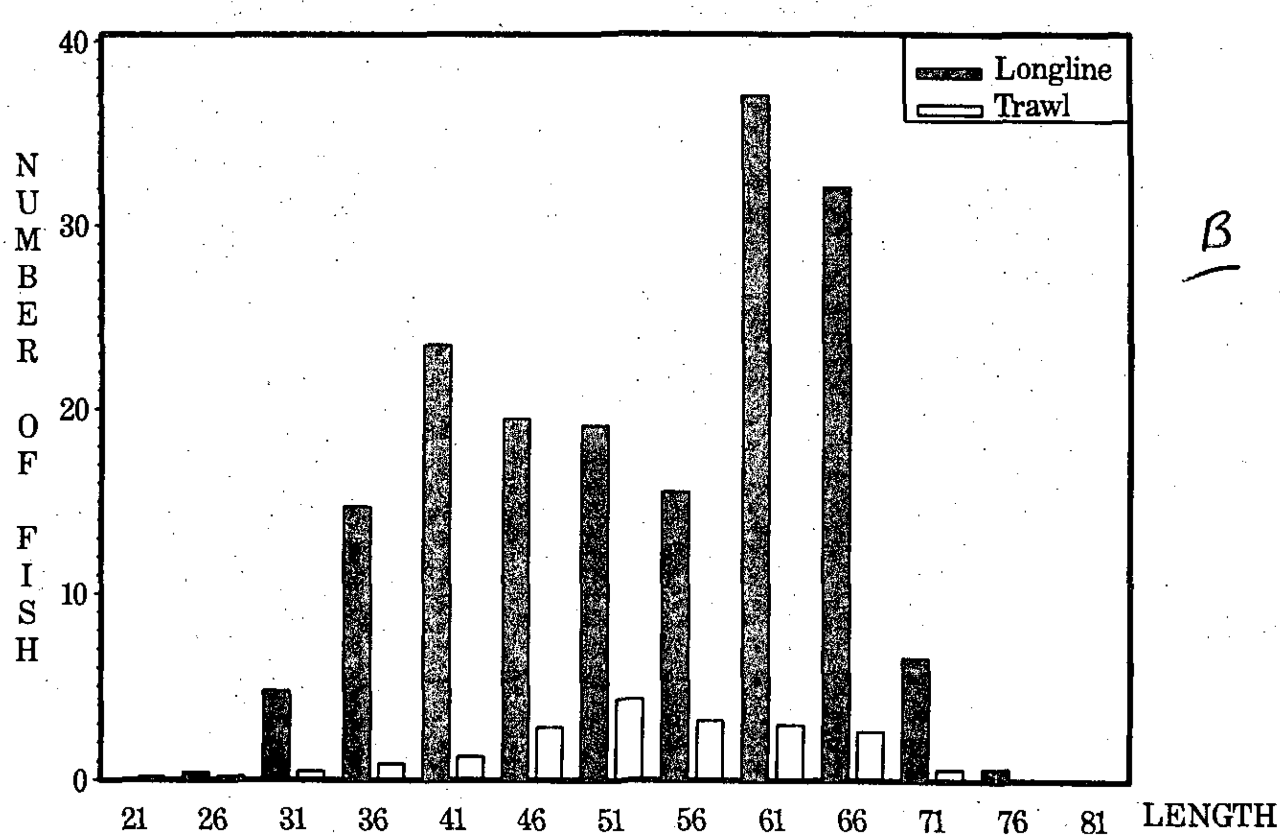
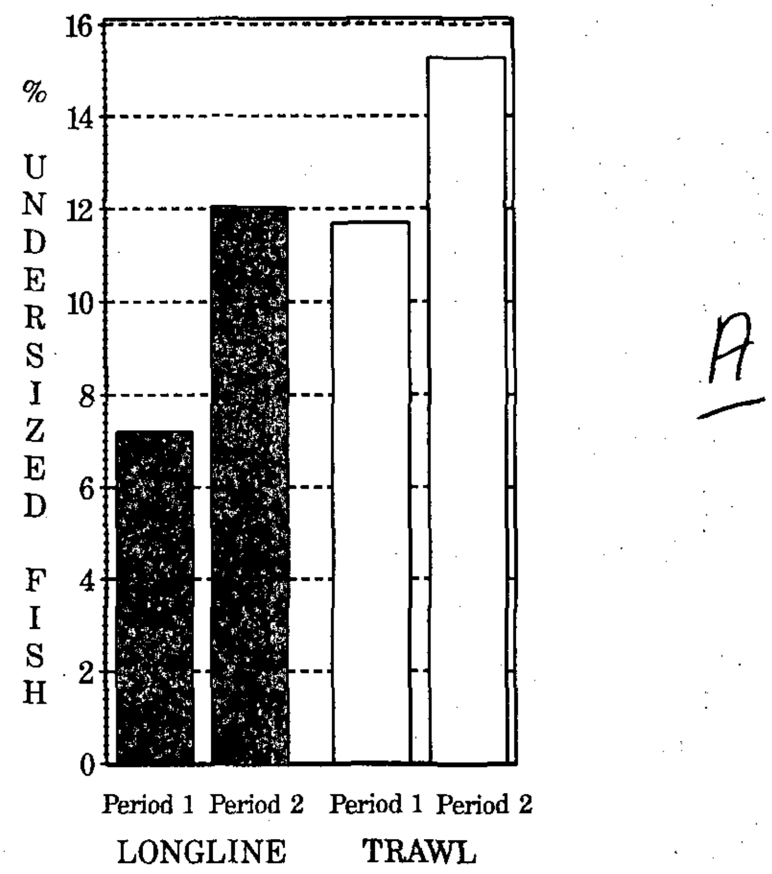


Figure 6. Length-frequency distributions of cod (a) and haddock (b) in the longline and trawl catches in Period 1. Average numbers per trawl haul and longline fleet.



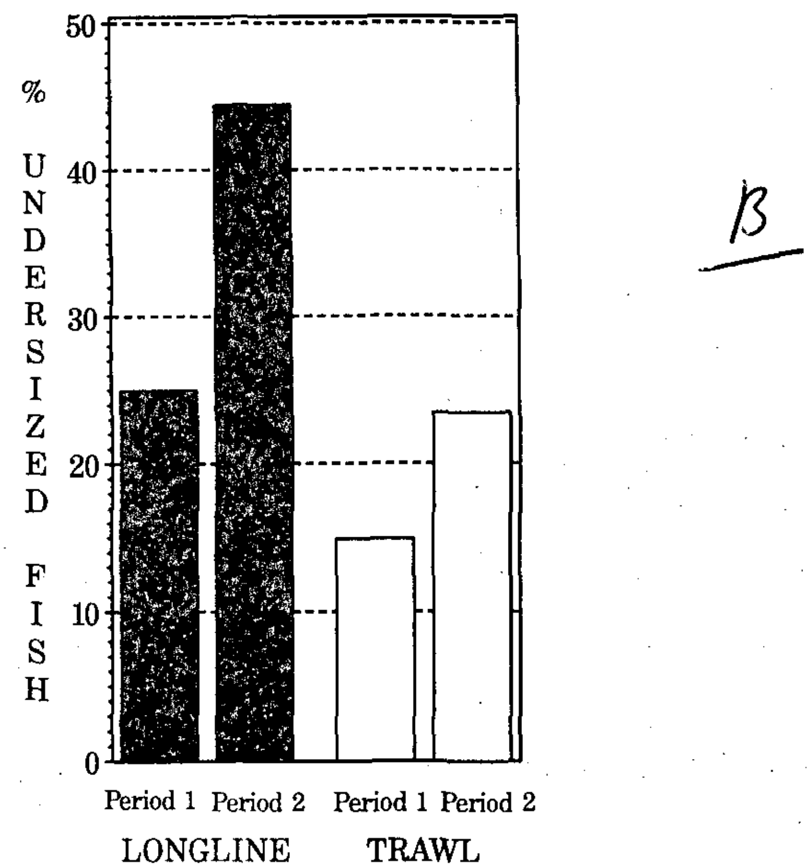
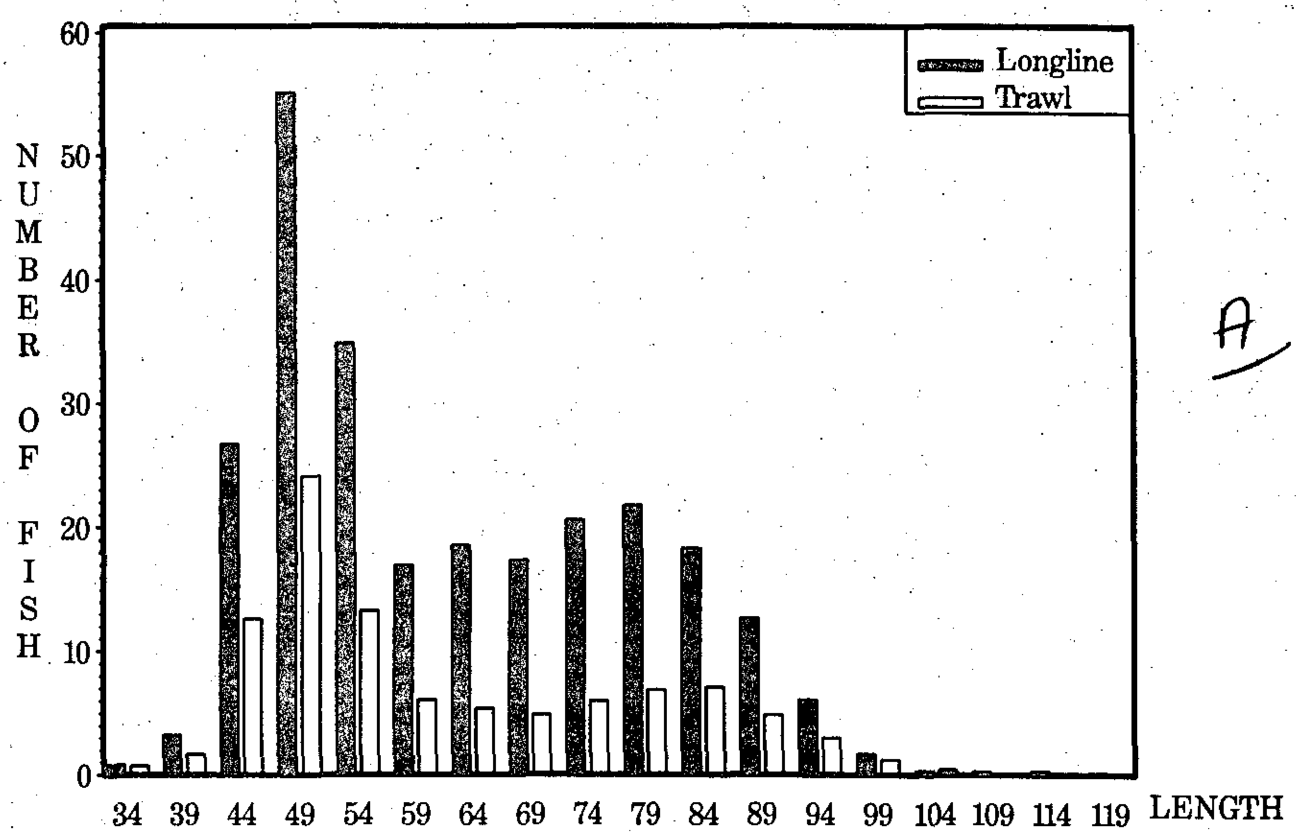


Figure 7. Proportion of under-sized cod (a) and haddock (b) in the trawl and longline catches in Period 1 and 2.



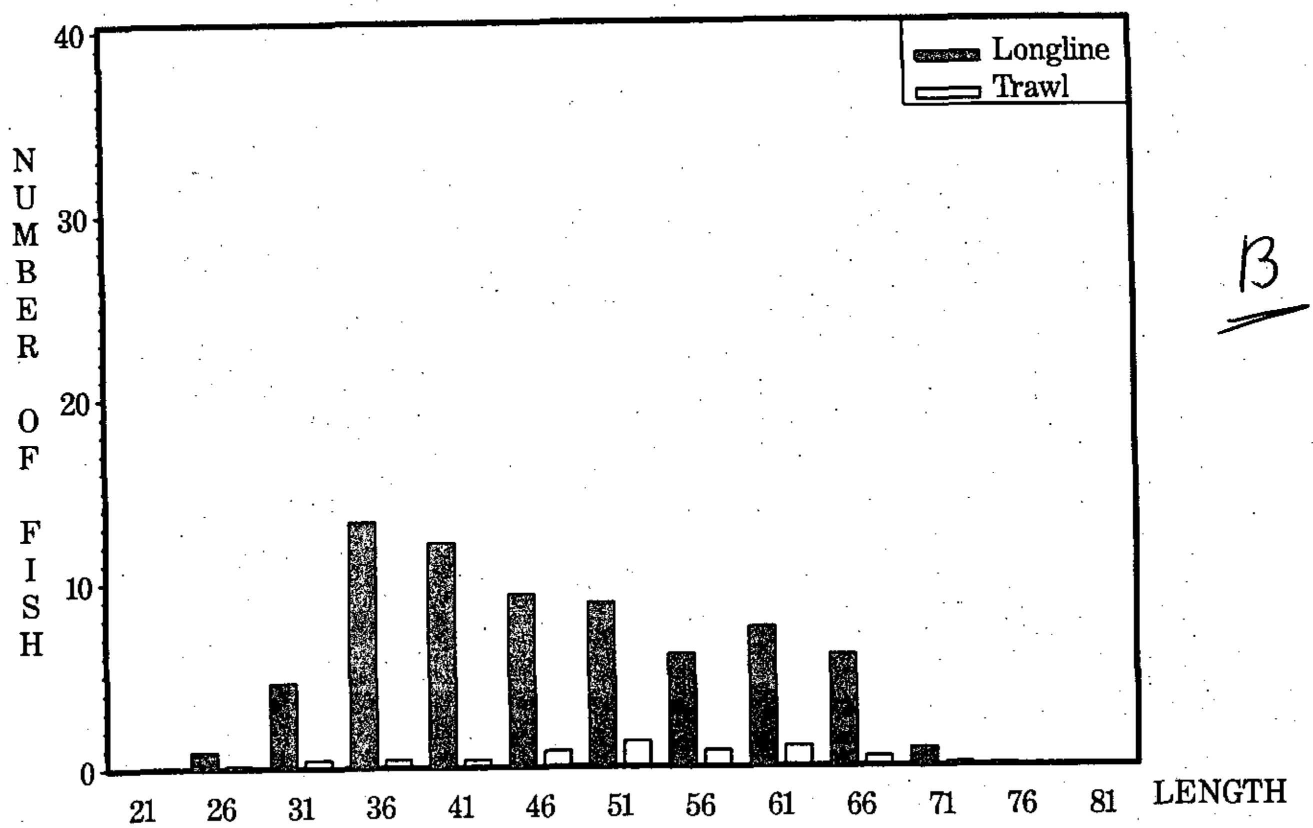


Figure 8. Length-frequency distributions of cod (a) and haddock (b) in the longline and trawl catches in Period 2. Average numbers per trawl haul and longline fleet.