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# Comparative Fishing Trials for Cod and Haddock Using Commercial Trawl and Longline at Two Different Stock Levels

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## Abstract

Fishing trials were performed simultaneously using commercial bottom trawl and longline in an investigation that was primarily designed to explore the effects of seismic airgun shooting on catch rates of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Fish density, species and length composition in the experimental area were determined from a combined acoustic and bottom trawl survey. The seismic shooting led to lower fish density and changes in size and species composition, and analyzing catch data obtained before and after shooting made it possible to compare the species and length compositions of trawl and longline catches at two different stock levels. The fishing trials showed that both the species and size compositions obtained by the two gears were significantly different. Relatively more haddock were caught by longline than by trawl, and longline fishing was found to catch less undersized cod and more undersized haddock than trawling. It appeared that the size compositions of the longline catches were affected by the fish density and size composition in the area. The implications of these results for optimal harvest strategy are discussed.

*Key words*: Cod, gear selectivity, haddock, longline, size composition, species composition, trawl

## Introduction

The management of fish stocks in the Barents Sea is based on recommendations for total allowable catches (TACs) only, and the allocation of TACs between different types of fishing gear is based mainly on traditional fishing patterns. A better harvest strategy has been sought by improving gear selectivity, and by closing fishing grounds when by-catch of non-target species or the proportion of undersized fish in the catches exceeds the legal proportion. However, proper fisheries management should also take into consideration the operator's choice of fishing gear and catching strategy (Løkkeborg and Bjordal, 1992). This requires knowledge of how the size and species composition of catches are affected by the type of gear used.

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

However, only a few studies designed to compare size selection between towed and stationary gears have been conducted, and our knowledge of how the species composition in catches from a mixed fishery is affected by the fishing method is scarce. A lower proportion of small cod (*Gadus morhua*) was found in longline catches compared with trawl catches taken in the same areas and in the same periods (Hovgård and Riget, 1992). Other studies indicate that longlining is a more size-selective fishing method for cod than trawling (McCracken, 1963; Sætersdal, 1963; Bjordal and Laevastu, MS 1990), although these data were not obtained from fishing vessels operating in the same area or at the same time.

In this study we compare the size and species compositions obtained in commercial longlining and trawling by using data from a fishing experiment that was primarily designed to study the effect of seismic surveys with airguns on catching success of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). As the seismic activity caused a decrease in the fish density and changes in the size and species composition of catches from the area studied, analyzing catch data from before and after seismic shooting gave us a unique chance to compare the compositions of catches taken by trawl and longline at two different stock levels. The stock levels were determined from a combined acoustic and bottom trawl survey.

## Materials and Methods

### Experimental area

During a program to map the effect of geophysical exploration with airguns on the catch availability of fish, fishing trials with bottom trawl and longline were performed in May 1992 on the North Cape Bank in the Barents Sea (Fig. 1). Catch data for cod and haddock were collected for seven days before a seismic vessel started airgun shooting within the experimental area, for five days during shooting and for five days after shooting ended. In this paper catch data from before (Period 1) and after (Period 2) airgun 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 periods. The experimental area was 26 × 37 km (14 × 20 naut. miles), with good operating conditions for both bottom trawl and longline, and with relative homogeneous bottom depths of 250–280 m.

### Acoustic mapping

A stern trawler ("Stallo") was equipped with a 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 the equipment, calibration of the system, survey transects within the area investigated and the acoustic method of 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 with a codend mesh size of 40 mm (Campelen 1800) (Engås and Godø, 1989). The door spread of the trawl was 54 m, with an average headline height of 3.8 m. Each haul lasted for 30 min at a towing speed of 1.5 m/s (3 knots). The positions of the hauls within the experimental area are shown in Fig. 2.

### Trawl trials

The commercial trawler ("Anny Kræmer") was equipped with a standard fishing trawl, Alfredo no. 3, rigged with 145 m sweeps and V-doors (7.8 $m^2$, 2 200 kg). The mesh sizes in the twin bags were measured with an ICES gauge set at 5 kg tension to be 139 and 140 mm, respectively (minimum legal mesh size is 135 mm). Each trawl haul lasted for 30 min at a towing speed of 1.8 m/s (3.5 knots). The door spread was measured at 150 m, and the vertical opening of the trawl was 4.2 m. In each of Periods 1 and 2, 28 hauls were made. The positions and time of day of the hauls were randomly distributed within the experimental area (Fig. 2).

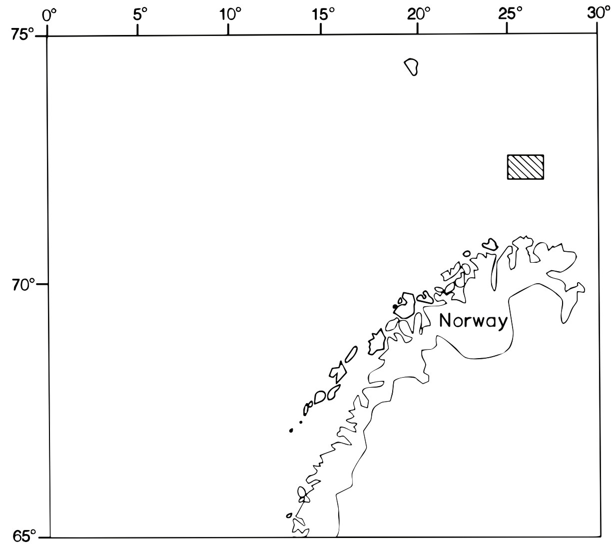


Fig. 1. Location of the experimental area in the Barents Sea.

### Longline trials

The longline vessel was equipped with the Mustad Autoline system. Mustad Quick Snap line (7 mm) rigged with double-twisted gangions no. 14 and Mustad EZ-hook (quality 39975, no. 12/0) were used. Each longline fleet had about 3 000 hooks, and the hook spacing was 1.3 m (fleet length = 3 900 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 a north-south direction at specific distances randomly distributed on the north and the south side of the centre of the experimental area. A total of 28 and 18 longline fleets were hauled during Periods 1 and 2, respectively (Fig. 2). 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

The acoustic abundance of cod and haddock in the experimental area, expressed in terms of the average area backscattering coefficient ($S_A$), showed that the acoustic density in the near-bottom zone (the lowest 10 m) was reduced from an average of 38.0 $m^2$/(naut. mile)$^2$ in Period 1 to 19.6 $m^2$/(naut. mile)$^2$ in Period 2, which is a reduction of 48%. The mean acoustic level per day during the two periods indicated that the population density

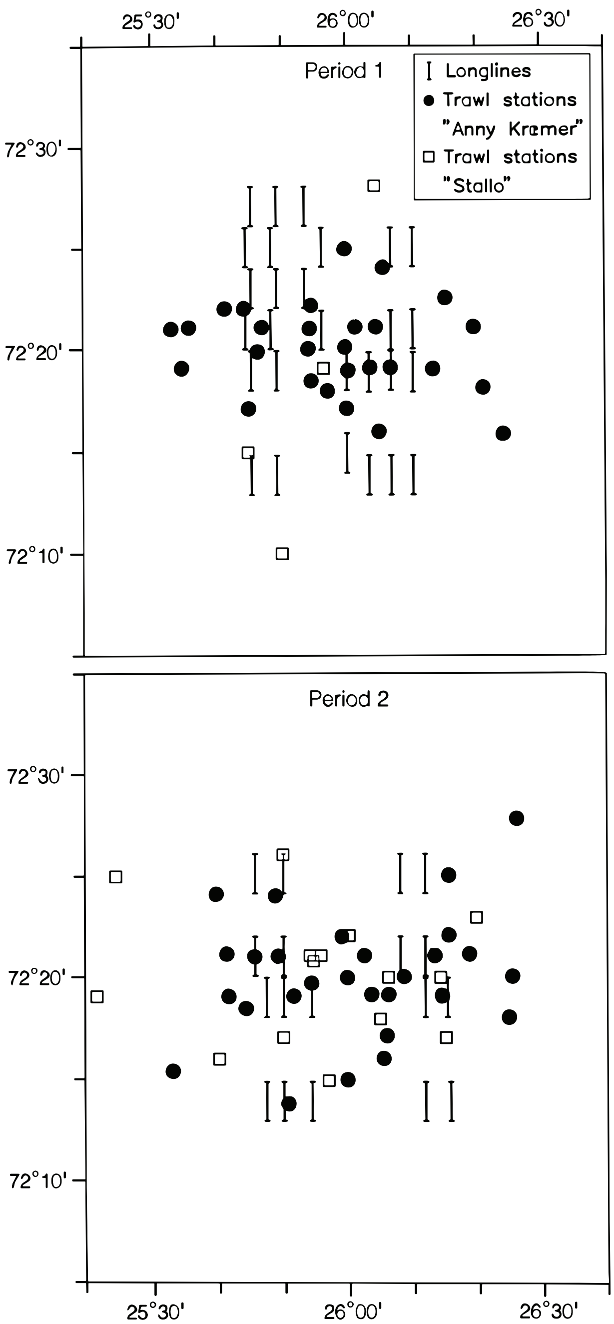


Fig. 2. Distribution of trawl hauls and longline fleets in the trial area in Periods 1 and 2.

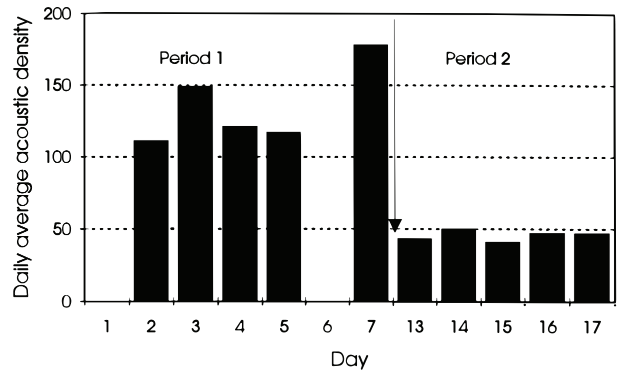


Fig. 3. Average daily acoustic density during Period 1 (days 1–7) and Period 2 (days 13–17). Acoustic data were not sampled on days 1 and 6.

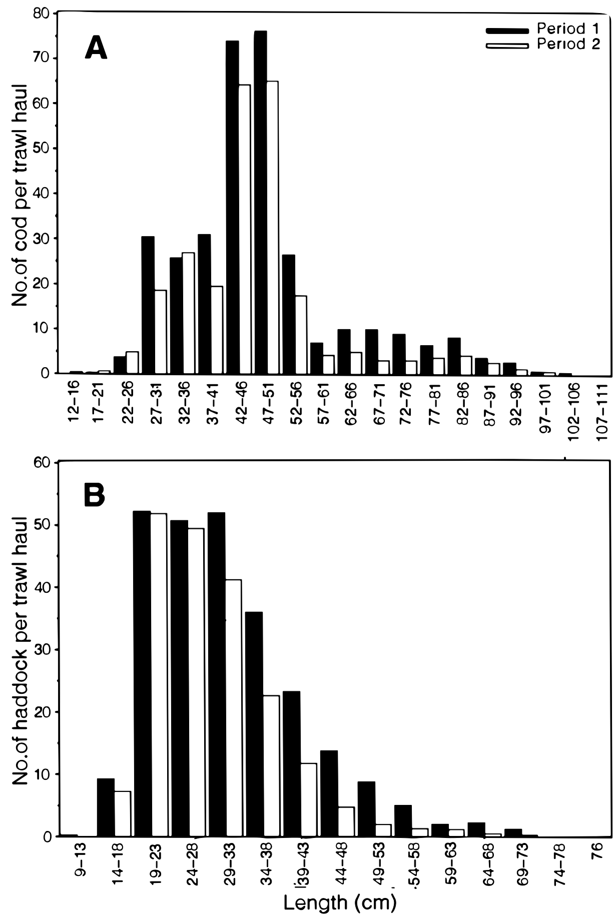


Fig. 4. Length-frequency distributions of cod (**A**) and haddock (**B**) in the sampling trawl catches during Periods 1 and 2.

stabilized at a much lower level after the seismic activity stopped (Fig. 3).

The length-frequency distribution of cod, as reflected by the catches taken by the sampling trawl, indicated that the largest fraction of cod in the catches was made up of fish between 27 and 56 cm (Fig. 4a). The number of cod caught was lower in Period 2 than in Period 1. The reduction in numbers was relatively larger for fish above than below 56 cm. Fish between 19 and 43 cm were most frequent in the haddock catches (Fig. 4b). For haddock larger than 29 cm, the catch was lower in Period 2 than in Period 1, while there was no difference for smaller fish.

**Longline and trawl**

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 in Period 1, only about 30 kg per haul on average, while the longline caught almost 10 times as much per fleet. In Period 2, the trawl catches of cod were 57% lower in weight than in Period 1, while the longline catches were reduced by only 13%. The haddock catches were approximately 70% lower in Period 2 than in Period 1, for both longline and trawl.

The haddock:cod ratio (in numbers) was higher for longline than for trawl in both periods ($p<0.001$, Wilcoxon 2-sample test) (Fig. 5). There was a decrease in this ratio from the first to the last period for both gears ($p<0.001$). In Period 1 the haddock:cod ratio was 0.66 for longline and 0.11 for trawl, while in Period 2 it was 0.27 and 0.06, respectively.

The length-frequency distributions for cod and haddock taken by longline and trawl are shown in Fig. 6 (Period 1) and Fig. 7 (Period 2). In the trawl catches the numbers of cod were lower in Period 2 than in Period 1 ($p<0.001$, ANOVA), and the decrease was relatively larger in the larger size groups. The longline, however, caught more cod that were smaller than 55 cm in Period 2 than in Period 1, while there was a decrease in the numbers of larger fish. The number of haddock taken was significantly lower for both gears in Period 2 ($p<0.001$), and the length-frequency distributions indicated a more pronounced reduction for big fish. A relatively larger reduction in numbers of big than of small fish were shown by a significant drop in the mean length of both species in the catches from both types of gear ($p<0.01$, t-test; Table 2).

The longline caught relatively fewer cod below legal size (47 cm) than the trawl in Period 1, 7% and 12%, respectively ($p<0.001$, Wilcoxon 2-sample test; Fig. 8a), while for haddock, the longline caught more undersized fish (below 44 cm) than the trawl, 25% and 15%, respectively ($p<0.005$; Fig. 8b). In Period 2, there was also a significantly higher proportion of undersized haddock caught by

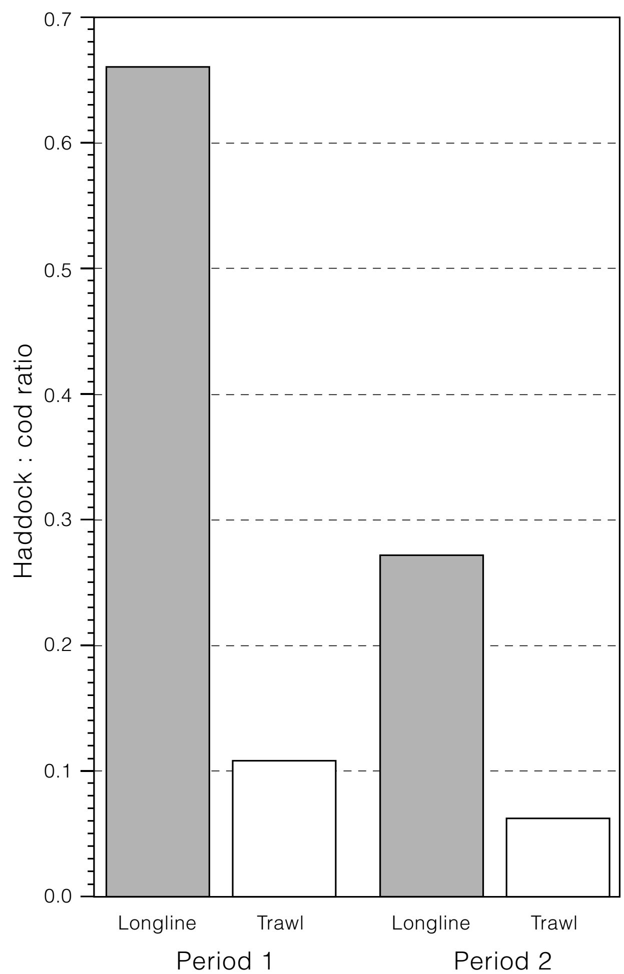


Fig. 5. Haddock:cod ratio (in numbers) in the longline and trawl catches during Periods 1 and 2.

TABLE 1. Mean catch taken by longline (kg/fleet) and trawl (kg/haul) during the two experimental 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 |

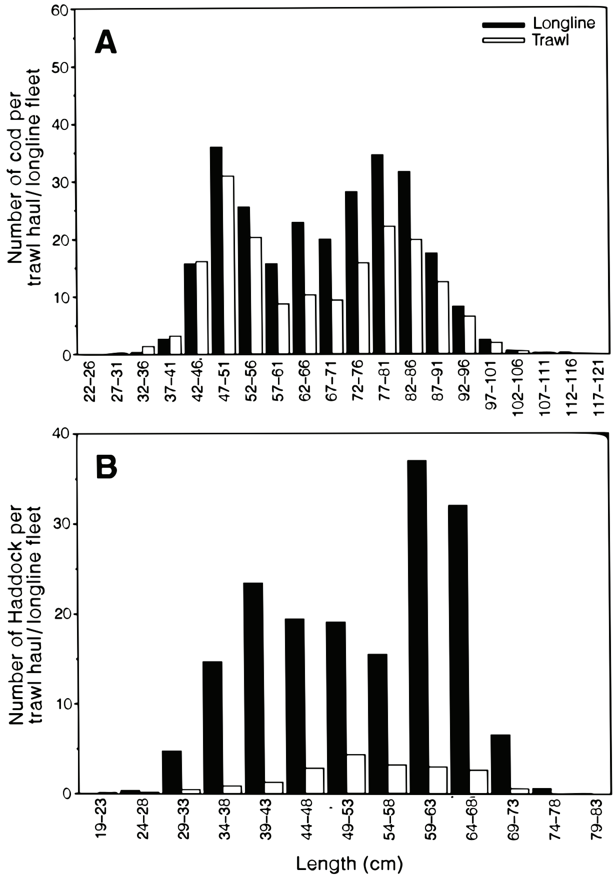


Fig. 6. Length-frequency distributions of cod (**A**) and haddock (**B**) in the longline and trawl catches in Period 1. Average numbers per trawl haul and longline fleet.

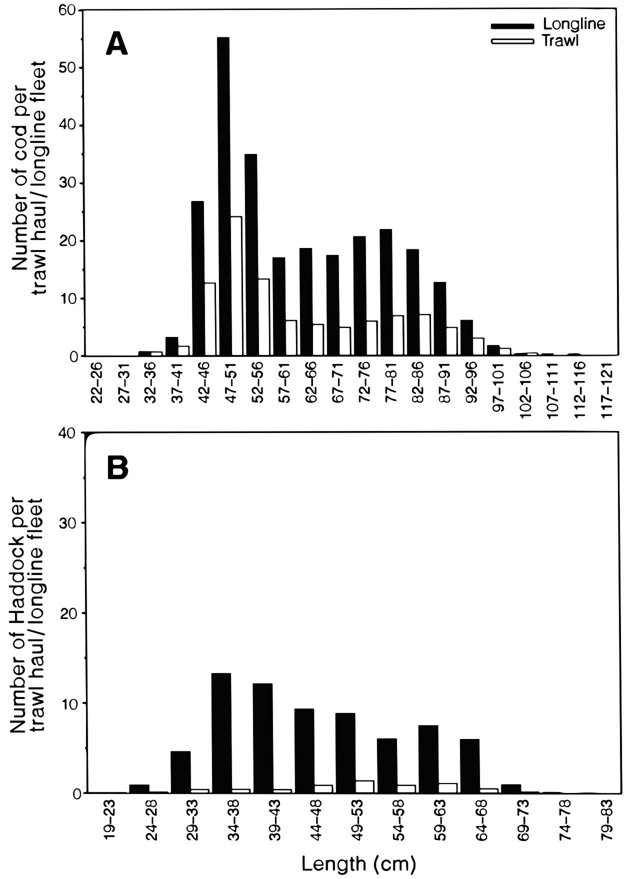


Fig. 7. Length-frequency distributions of cod (**A**) and haddock (**B**) in the longline and trawl catches in Period 2. Average numbers per trawl haul and longline fleet.

TABLE 2. Mean length (cm) of cod and haddock in longline and trawl catches during the two experimental periods.

| | | Cod | | Haddock | |
|---|---|---|---|---|---|
| Gear | Period | Mean length (cm) | Standard error | Mean length (cm) | 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 |

longline than by trawl ($p<0.001$), while the difference in the proportion of undersized cod between gears 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. 8a and b).

## Discussion

Fishing gear based on different catching principles are likely to harvest differently on fishing

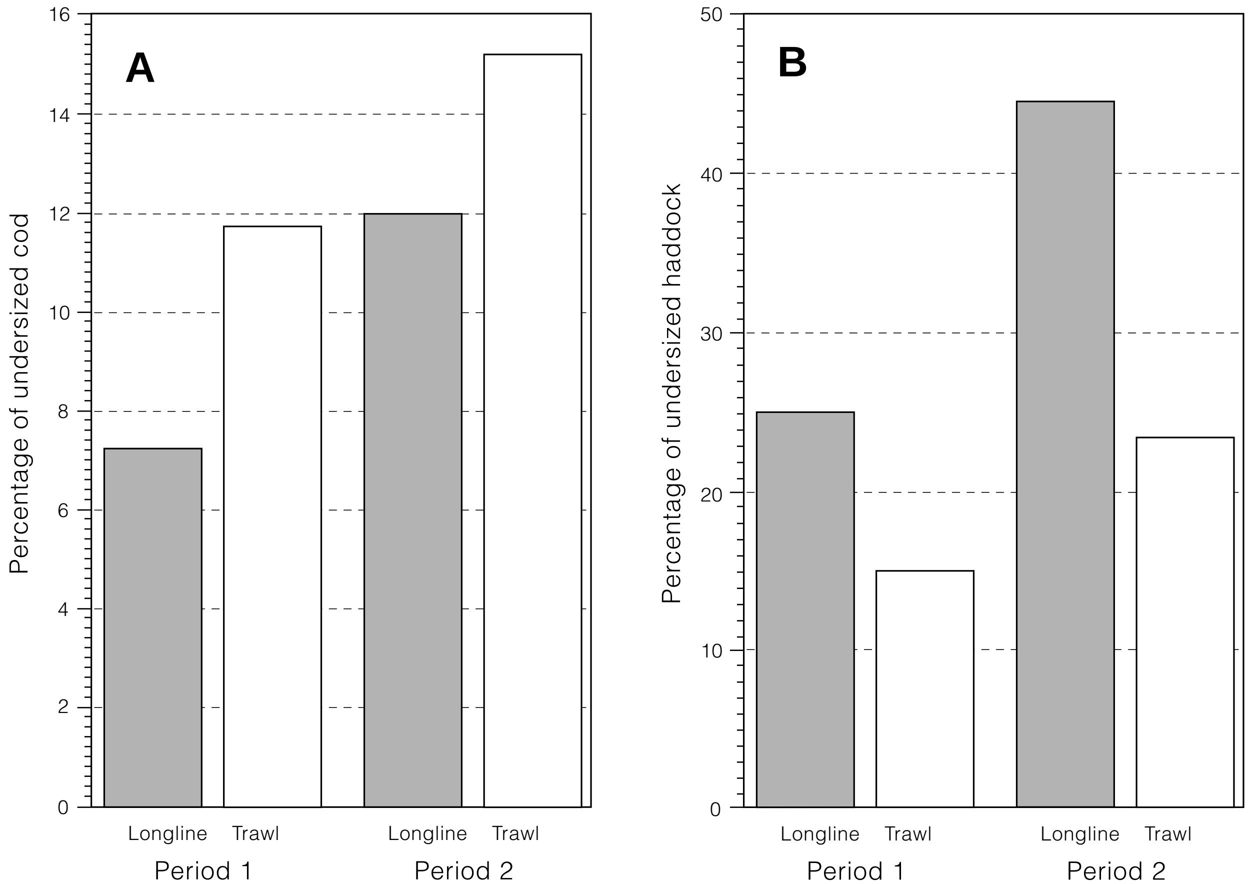


Fig. 8. Proportion of undersized cod (**A**) and haddock (**B**) in the trawl and longline catches in Periods 1 and 2.

grounds with a mixed species and size composition. The catching processes of bottom trawl and longline are completely different; the former is an active gear which sweeps along the bottom and catches fish in its path, while the latter is a stationary gear to which fish are attracted by scent released from the baits. The present results demonstrated significant differences in both the species and size compositions of catches taken by commercial trawl and longline.

Our results are based on catches taken by vessels using gear and operating according to normal commercial fishing conditions, except that, in commercial trawling, the towing time would have been much longer to obtain higher catches. When the catch increased from <500 kg to 500–1 000 kg, the 50% retention lengths for cod and haddock were shown to decrease by 5 and 3 cm, respectively, using an identical trawl (Isaksen *et al.*, MS 1990). The trawl catches in the present study had an average weight of 574 and 241 kg, respectively, for the two fish densities. The results obtained may therefore indicate a 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 the longline is more effective in catching haddock, and/or that trawling is a more effective way of 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. Behaviourial 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 higher proportions. The selection parameter, $L_{50}$, was found to be 47.6 cm for cod and 43.0 cm for haddock with catches between 500–1 500 kg, using an identical trawl with mesh size of 137 mm (Isaksen *et al.*, MS 1990). The sampling trawl catches indicated few haddock above 43.0 cm, whereas there was a significant proportion of cod above 47.0 cm in the area.

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 (Main and Sangster, 1981; Engås, MS 1991). In contrast, more cod than haddock have been shown to escape by diving under the fishing line of the trawl (Engås and Godø, 1989). It is therefore not known whether more haddock than cod escape in the front of the trawl. Thus, longlines may catch haddock more efficiently than cod due to behaviourial differences, whereas trawls may catch cod more efficiently because more haddock escape through the codend meshes and perhaps also ahead of the trawl.

The proportion of undersized cod was higher for trawl than for longline. Longlining is regarded as 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; Klein, 1986; Hovgård and Riget, 1992). Fish are attracted to longlines by scent released from the baits (Atema, 1980; Løkkeborg, MS 1989). Larger fish have larger foraging areas (Hart, 1986), and constraints on feeding activity are less pronounced in larger fish (Milinski, 1986). Thus, a selection process that exposes a relatively high proportion of large individuals to the gear takes place when fish are attracted to longlines (Løkkeborg and Bjordal, 1992). Furthermore, bait size is regarded as the most important factor that affects the 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, MS 1983). However, bait size only slightly affected the size of haddock caught by baited hooks (Johannessen, MS 1983), indicating that longlines are less size selective for haddock than cod. The lower proportion of undersized 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.*, MS 1990), and a high proportion of fish below legal size (44 cm) should therefore escape through the meshes. However, the effective size selection in the present trawl catches may, as suggested above, be due to the low catches. The observed difference in the proportions of undersized haddock taken by the trawl and the longline may therefore not apply to higher trawl catches.

Our results also showed that fish density affected the selection process of longline fishing. The acoustic mapping and catching trials with the sampling trawl showed that the fish density fell by 48% between Period 1 and 2, and that there was a relatively greater fall in the number of larger than smaller fish. We assume here that the true size distribution is more correctly reflected by the catches taken with the sampling trawl than by the commercial trawl, due to reduced mesh selection. Even for larger fish, >60 cm, the sampling trawl has been proven to be as efficient as the commercial trawl when corrections for difference in swept area are accounted for (Godø and Korsbrekke, MS 1990). The observed change in density and size composition may explain why the increase in the proportion of undersized fish between Period 1 and 2 was more pronounced in the longline catches than in the trawl catches. Length-frequency distributions of angling and handline catches indicate the existence of competition for available baits among fish of different sizes (Allen, 1963; Bertrand, 1988), and behaviourial studies have shown that large fish frighten smaller fish away from baited hooks (Løkkeborg and Bjordal, 1992). With lower fish density and a 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 baits available.

As pointed out in the introduction, 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 longline versus trawl to obtain a better harvest strategy will depend on the state of the different stocks, as these two types of gear give different species compositions. The size compositions of the catches by the two types of gear are also different, but depend on the fish density and size composition in the area fished. As an example, in situations with high density, longline fishing will protect the younger year-classes of cod more than trawling, but also result in a higher exploitation rate of haddock, which may or may not be desirable depending on the state of the haddock stock.

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