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SELECTION AND MORTALITY IN PELAGIC LONGLINE FISHERIES FOR HADDOCK

by

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Abstract

The bycatch of haddock *(Melanogrammus aeglefinus)* below legal size in the pelagic longline fisheries for haddock off the coast of Finnmark, northern Norway, is often high. This project was aimed at reducing the bycatch of undersized haddock through alterations in gear technology and fishing strategy.

Fishing experiments with commercial longline vessels were carried out in June/July 1995 and 1996. The following modifications of fishing gear and fishing technology were tested: longlines with increased sinking speed; hooks with an inedible plastic body attached to the shank; hooks with nylon bristles attached to the shank; restructured bait based on mackerel (*Scomber scombrus*) and sandeel (*Ammodytes lancea*); mackerel bait of twice the normal size; restructured mackerel bait of twice the normal size.

None of the methods tested gave the desired improvements in the size distribution of the haddock catches. Traditional mackerel bait of twice the normal size about 40% reduction in undersized fish, but an increase in bait costs due to larger bait size, will not be accepted by commercial fishermen.

In the survival experiments, where 18 haddock were torn off the longline hooks at the sea surface and kept in sea water tanks for five days, no mortality was found. One of the fishes was in bad condition at day five, and would probably not have survived if it was released to the sea. Additional experiments have to be carried out to confirm these results.

Introduction

Even though haddock (*Melanogrammus aeglefinus*) usually is considered as a typical bottom dwelling species, it occasionally occurs pelagic (see e.g. Bergstad *et al.* 1987). The seasonal fishery for haddock with pelagic longlines off the coast of Finnmark, northern Norway, is founded on the existence of pelagic haddock. The bycatch of haddock below legal size (44 cm) in this fishery is often severe. The small fish are not taken onboard the vessel, but are torn off the hook at the vessel side and returned to the sea. It is generally thought that most of the discarded haddock die. To improve the size selectivity of the pelagic longlines, as well as to quantify the mortality of haddock discarded at the vessel side, a two-year project was carried out.

Longline fishing is often regarded as a size-selective fishing method that causes low exploitation of the younger year classes of fish (Løkkeborg & Bjordal 1992), particularly compared to demersal trawl. Most investigations where the selectivity of longlines is compared to other fishing gears are, however, done with cod (*Gadus morhua*) as the main target species. In two experiments, where longline and trawl fished simultaneously within the same area (Engås *et al.* 1994; Huse *et al.* 1996), it was found that longline was less size selective than trawl when fishing for haddock.

There are several factors influencing the species- and size distribution in the catches taken by longline:

a) Gear technological factors like bait type, bait size, hook design, hook size and hook spacing.
b) Catching strategy: i.e. how the fishermen use their gear relative to the vertical and horizontal distribution of fish.

In this project means from both groups were used with the aim of improving the selectivity of the pelagic longline fisheries.

Materials and methods

Fishing experiments

The experiments were carried out in July 1995 and June/July 1996, with two hired commercial coastal longliners (Vessel I: 14.99 m, 321 hp; Vessel II: 14.12 m, 246 hp). The areas where the vessels operated (area I and II, respectively) are shown in Figure 1.

In 1995, the fishing experiments were carried out with the mainline made of 2 mm polyamide monofilament, snoods of 0.8 mm monofilament, and Mustad Wide Gap hooks no. 5. The rigging of the lines is shown in Figure 2. Vessel I used 30 fathoms (55 m) setting depth, while vessel II used 40 fathoms (73 m). The distance between the floats varied, but this did not influence the catch composition significantly. Vessel I used longline fleets of 400 hooks, divided into 8 cells of 50 hooks, while vessel II used fleets of 300 hooks divided into 6 cells of 50 hooks. The hooks were baited with mackerel cut in 2 cm broad slices.

Two means of improving the size composition of the catches were tested in 1995:

a) Longlines with increased sinking speed. The lead weight on the line was doubled in order to make the gear sink rapidly through the upper water layers where the smallest haddock often are supposed to be located.
b) Hooks with inedible plastic bodies attached to the shank (Fig. 3). The intention was to make the hook appear visually as a large bait without increasing the bait costs. The hooks were baited with mackerel baits of the same size as the control hooks.

In 1966, the mainline consisted of 1.8 mm polyamide monofilament, 60 cm snoods of 0.8 mm monofilament, and Eagle Claw 1607 hooks. The hook spacing was 1.67 m. Each longline fleet consisted of 400 hooks divided into 8 cells of 50 hooks. The setting depth was 30 fathoms (55 m) The lines of both vessels were rigged as type II in Figure 2, but with 100 hooks between floats.

The experiments with increased sinking speed was continued the second summer. In addition several hook and bait types were tested:
a) Hooks with nylon bristles attached to the shank
b) Restructured bait based on mackerel (Løkkeborg 1996)
c) Restructured bait based on sandeel
d) Mackerel bait of twice the normal size
e) Restructured mackerel bait of twice the normal size

It has been claimed (Løkkeborg and Bjordal 1995) that visual stimuli are more important in attracting fish in pelagic than in demersal fisheries because the baits are more easily seen in free water than at the bottom. To investigate the importance of visual stimuli in pelagic longline fisheries, hooks without bait, but with red and white nylon bristles attached to the shank, were tested (Fig. 4). As it was not baited, it would attract fish only through visual stimuli.

In the tests with increased sinking speed, where the lead weight was doubled, fleets of experiment lines were set alternately with control fleets. Hook and bait experiments were carried out by setting fleets where cells of 50 hooks with experiment hook/bait were alternating with cells of 50 control hooks (normal hooks with mackerel bait).

Strong winds halted the experiments in 1995. Vessel I only achieved three full fishing days, while vessel II achieved six. In 1996 the weather was nearly ideal for fishing experiments throughout the charter period.

Acoustic investigations

Acoustic investigations of horizontal and vertical size distribution of pelagic haddock were carried out from a small research vessel (49 feet) equipped with a 38 kHz split-beam transducer and a portable Simrad EK500 echo sounder. These instruments made it possible to trace target strength (TS) of single fish located in the transducer beam. The acoustic equipment were calibrated prior to the start of the experiment according to standard practice (Foote *et al.* 1987). The raw data from the echo sounder were stored on an optical disk (Sierra, Pinnacle Micro) for later analyses. Acoustic data from the relevant depth layers were transferred to ASCII files and analysed with the statistical programme SAS (SAS Institute Inc., NC, USA). The target strength values were used as a relative measure of fish size, but as

they are given on log scale, they were transformed to a linear value, σ (acoustic back scattering cross-section of single fish), for statistical analyses.

(1) $$<\sigma> = 4\pi 10^{(0.1TS)}$$

The pelagic haddock registrations were mainly found at depths between 25 and 100 m. Fishermen claim that the smallest haddock are standing in shallower waters than larger fish. To test possible differences in the vertical distribution of different size groups, the relevant water column was divided in three depth layers: 25-50 m, 50-75 m, and 75-100 m. Differences in average σ-values between the different layers, between geographical areas, and between logging stations, were tested using GLM analyses (General Linear Models, SAS).

Acoustic data were collected in areas where typical pelagic haddock traces were recorded on the echo sounder. Most logging stations were placed close to the hired longliners while they were fishing. While acoustic logging was done, the research vessel was drifting freely with the engine disconnected. Reliable TS-data can only be obtain in calm weather with insignificant vessel movement.

Mortality of discarded haddock

Haddock below legal size are usually not taken onboard the vessel, but are torn off the hook at the vessel side and discarded to the sea. It has earlier been thought that most discarded haddock will die. In 1996, 18 haddock thrown over board from a coastal longliner were collected at the sea surface, transferred to a holding tank onboard a small research vessel, and observed for five days. A similar experiment was planned also in 1995, but was cancelled due to bad weather.

Results

Fishing experiments

The catch rates of haddock were high in both areas investigated both in 1995 and 1996. From 50 to 90 haddock per 100 hooks were caught in 1995 and from 50 to 78 haddock per 100 hooks in 1996.

Longlines with increased sinking speed

Table 1 shows the results from the catching experiments with longlines of increased sinking speed, i.e. doubled lead weight. In 1995, a significant reduction in the proportion of haddock below legal size as well as an increased catch rate (about 30% increase) was found in the eastern area. These results were, however, not confirmed in the western area. In 1996 no differences were found in any of the areas.

Hook designs

Fishing with hooks with an inedible plastic body gave a small reduction in the amount of undersized fish in the catches, but also a significant reduction in catch rate (Table 2). Hooks with nylon bristles gave almost no catch at all (Table 3). Vessel II stopped using these hooks already after one day of fishing because of the low catch rates. Vessel I started to bait them

with mackerel. The catch rates and size distributions were then similar to those of the control hooks baited with mackerel (Table 3).

Bait experiments

No significant differences in catch rate or mean length was found between the restructured mackerel-based bait and the standard mackerel bait (Table 3 and 4). Restructured sandeel-based bait was tested on a smaller scale. Onboard vessel II there was found a decrease in the proportion of undersized haddock and an increase in mean fish length on hooks baited with restructured sandeel bait (Table 4). The same trend was not found on vessel I (Table 3), and no differences was found in catch rates in any area. The number of hooks tested with this bait was, however, low onboard vessel II, only 400 hooks.

Vessel I tested 795 hooks baited with «large» restructured bait and 800 hooks with «large» mackerel, both cut in pieces twice the normal size. The catch rates of these hooks were not significantly different from bait of normal size, but the large mackerel bait caught less fish below legal size than bait of normal size (Table 4). The number of hooks was, however, too small to draw firm conclusions.

Acoustic investigations

In 1995, strong winds made the conditions for making acoustic recordings difficult. The following year, however, the weather conditions were almost ideal.

No significant differences were found (Table 5) among geographic areas, stations within an area, or between depth layers in σ-values used as an expression of the average fish size.

Mortality of discarded haddock

The 18 haddock caught for survival studies survived the observation period of 5 days. One fish was, however, in bad condition when the experiment was terminated and would probably have died if it was released to the sea. The other 17 was apparently in good shape, although most of them was injured in the jaw region to a varying degree. The majority would probably have survived in the sea, although it is difficult to predict to what extent the jaw damage might influence the long term survival. It is, however, known that fish are able to survive for several weeks/months in the temperature conditions that prevails in the Barents Sea without feeding.

The survival rates observed in this experiment was higher than expected. The number of fish in the experiment was, however, low, and the observation time too short to draw firm conclusions. Further investigations should be carried out to study the survival of discarded longline caught fish more thoroughly.

Discussion

The aim of the project was to reduce the mortality of haddock below legal size (44 cm) by 50% in the pelagic longline fisheries off the coast of Finnmark. The catching experiments

with alternative hook and bait types as well as increased sinking speed did not give the desired improvement of the size selectivity of the pelagic longlines.

Earlier catching experiments with longline for cod have shown that large baits catch larger fish than smaller ones (Johannessen 1983; Løkkeborg 1990). For haddock it is shown that bait size has a larger effect on catch rate than on the size distribution of the catch. Small baits catch more haddock of all size groups than larger bait (Johannessen 1983).

In our experiments where we tried to imitate large baits visually by attaching an inedible plastic body to the hook shank, we found about 15% reduction in the amount of fish below legal size in the catches. Hooks with inedible plastic bodies gave in addition an unacceptable decrease in catch rates. A similar hook was tested on a small scale in an earlier experiment (Løkkeborg & Bjordal 1995) with similar results. Mackerel bait of twice the normal size gave an apparently larger effect than plastic bodies on the size distribution, but the number of hooks tested was small. Although it might be possible to improve the size distribution by using larger bait or inedible plastic bodies, a doubling of the bait costs or increased hook expenses combined with reduced catch rates would make these changes in fishing technology unprofitable for the commercial longline fisheries

Løkkeborg and Bjordal (1995) claimed that visual stimuli, like large baits, might have a more profound effect in pelagic fisheries where the bait floats freely in the water column and are more easily seen by the fish, than in fishing close to or at bottom. We tried to test the importance of visual stimuli in pelagic longline fishing by using hooks where nylon bristles replaced the bait. This hook form gave, however, almost no catches. It seems therefore that chemical stimuli are of vital importance also in the pelagic, and that visual stimuli play a minor role in fish attraction.

The experiments with restructured baits did not give any large effects on the size distribution of the catches, although the results were somewhat inconsistent. Even though it was not the aim of the project, it was interesting to observe that restructured baits, based on wastes from the fishing industry, gave as good catches as traditional mackerel bait. The handling and baiting properties of this bait are excellent, and the potential of utilising offal in the production of baits and thus saving species like mackerel and squid for human consumption is challenging.

We also tried to improve the size selectivity of the line by increasing the sinking speed in order to make the longline pass rapidly through the upper water layers where the fishermen claims that the smallest fish are located. The experiments were not successful. This is, however, in accordance with the acoustic observations, where no differences was found in the mean haddock size relative to water depth.

The fate of the fish that are discarded at the sea surface during hauling of the line has not been studied in earlier experiments. It has been assumed that most of these fish die (Michalsen *et al.* 1993). The small survival experiment carried out in this project showed a surprisingly high survival through the five first days after release from the hook. The number of fish in the experiment was, however, low, and the observation time too short to give reliable results. Further studies have to be carried out to verify the survival rate. If these results are confirmed in future experiments, the consequences of discarding haddock below legal size in the pelagic longline fisheries for haddock may be less severe than earlier expected.

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Table 1. Total number of haddock, the proportion of haddock below legal size (44 cm), and mean length in the catches taken by longline with increased sinking speed. DW: Double lead weight; NW: Normal lead weight

Area and year	Gear type	No. of hooks	Catch (no. of haddock)	Catch per 100 hooks (no. of haddock)	Haddock below legal size (%)	Mean length (cm)
Area I	DW	2100	1913	91*	12.9**	49.2
1995	NW	3180	2178	68	16.5	48.7
Area II	DW	600	312	52	25.3	46.1
1995	NW	600	76	46	20.7	46.0
Area I	DW	6152	4315	70	18.3	47.6
1996	NW	15323	11338	74	17.8	47.6
Area II	DW	5170	3102	60	17.1	48.5
1996	N W	7250	4204	58	16.0	48.5

* Catch rate significantly higher than for longline with normal lead weight ($p<0.001$)
** The proportion of haddock below legal size significantly lower than for longline with normal lead weight ($p < 0.001$)

Table 2. Total number of haddock, the proportion of haddock below legal size (44 cm), and mean length in the catches taken by longline with hooks with (W) and without (WO) inedible plastic body.

Area and year	Gear type	No. of hooks	Catch (no. of haddock)	Catch per 100 hooks (no. of haddock)	Haddock below legal size (%)	Mean length (cm)
Area I 1995	W	2945	2021	68*	12.2**	49.5
	WO	3000	2317	77	14.6	49
Area II 1995	W	1900	811	43*	30.8**	46
	WO	2000	1045	52	34.2	45.6

* Catch rate significantly lower than for hooks without plastic body ($p<0.001$)
** The proportion of haddock below legal size significantly lower than for hooks without plastic body ($p<0.001$)

Table 3. Total number of haddock, the proportion of haddock below legal size (44 cm), and mean weight onboard Vessel I in 1996. NMB: Normal mackerel bait; RMB: Restructured mackerel bait; RSB: Restructured sandeel bait; NB: Hooks with nylon bristles; NBM: Hooks with nylon bristles and mackerel bait; NBR: Hooks with nylon bristles and restructured mackerel bait.

Gear type	No. of hooks	Catch (no. of haddock)	Catch per 100 hooks (no. of haddock)	Haddock below legal size** (%)	Mean length** (cm)
NMB	15323	11338	74	17.8	47.6
RMB	4566	3473	76	17.4	47.8
RSB	1563	894	57	18.8	47.2
NB	786	25	3*	8.0	47.4
NBM	1176	702	60	14.5	48.0
NBR	784	541	69	18.1	47.7

* Catch rate significantly lower than the other experiment groups ($p<0.001$)
** No significant differences (hooks with nylon bristles are deleted due to low catch rates)

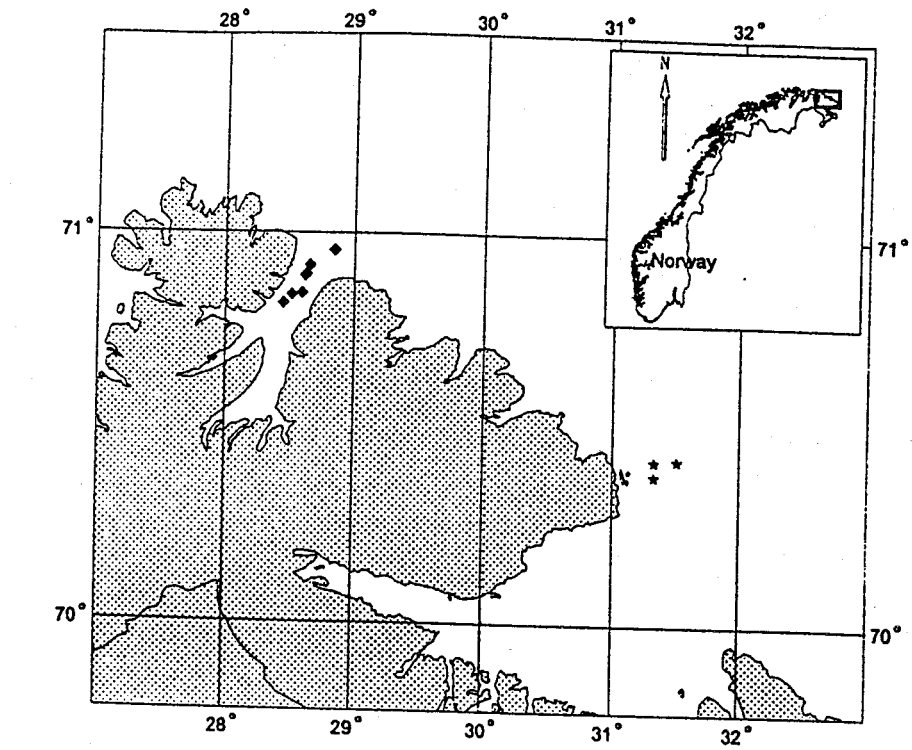
Table 4. Total number of haddock, the proportion of haddock below legal size (44 cm), and mean weight onboard Vessel II in 1996. NMB: Normal mackerel bait; RMB: Restructured mackerel bait; RSB: Restructured sandeel bait; LMB: Large mackerel bait; LRB: Large restructured mackerel bait.

Gear type	No. of hooks	Catch (no. of haddock)	Catch per 100 hooks (no. of haddock)	Haddock below legal size** (%)	Mean length** (cm)
NMB	7250	4204	58	16.0	48.5
RMB	4550	2322	51	16.8	48.2
RSB	400	247	62	5.2**	51.9 **
LMB	800	546	68	9.3**	49.9 **
LRB	795	604	76	14.1	48.4

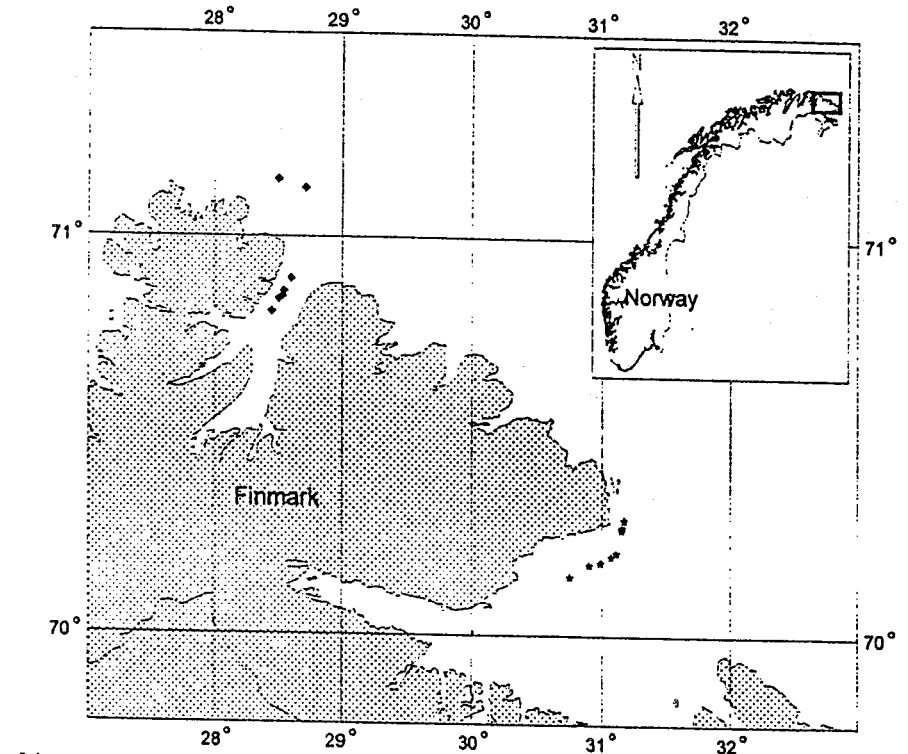
*No significant differences between groups
** Significantly lower proportion of haddock below legal size and higher mean length than the other groups

Table 5. Analysis of variance (GLM) of mean acoustic back scattering cross section at the different logging stations.

	Source	Degree of freedom	Sum of squares	Mean sum of squares	F	p
1995	Main effects					
	Station	10	0.000051	0.000005	1.60	0.205
	Depth	2	0.000008	0.000004	1.27	0.311
	Rest	14	0.000044	0.000003		
	Total	26	0.000104			
1996	Main effects					
	Station	13	0.000510	0.000039	1.14	0.373
	Depth	2	0.000029	0.000014	0.41	0.665
	Rest	25	0.000859	0.000034		
	Total	40	0.001412			



a)



b)

Figure 1. Experimental area in a) 1995 and b) 1996. Symbols indicate the position of each longline fleet set during the experiments. Stars: Vessel I; Squares: Vessel II. The activity area of vessel I is called area I, and that of vessel II, area II.

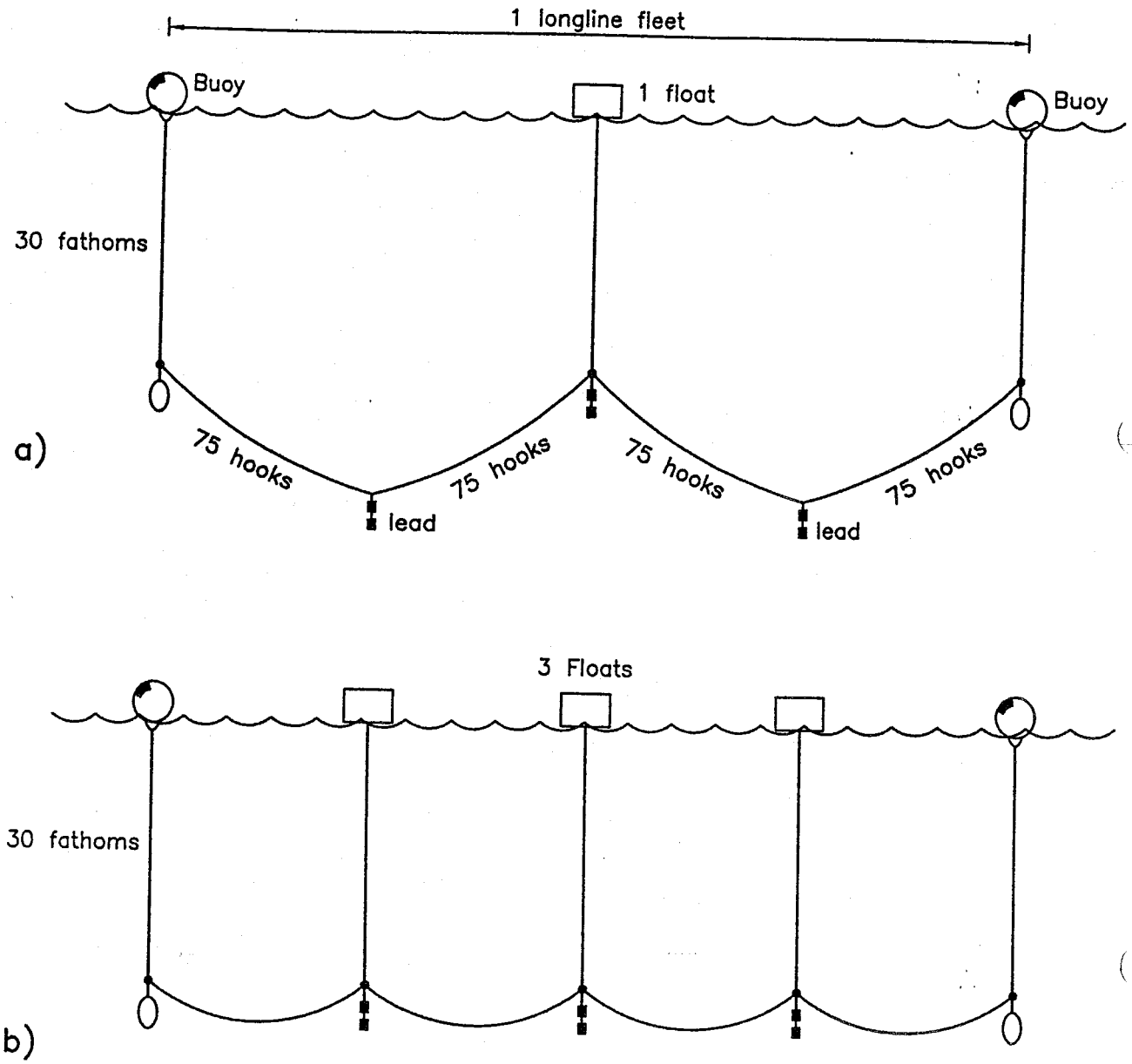


Figure 2. Rigging of the longline fleets. Vessel II used both method a) and b) in 1995, while vessel I rigged as b) with 100 hooks between the floats. In 1996 both vessels used the last method.

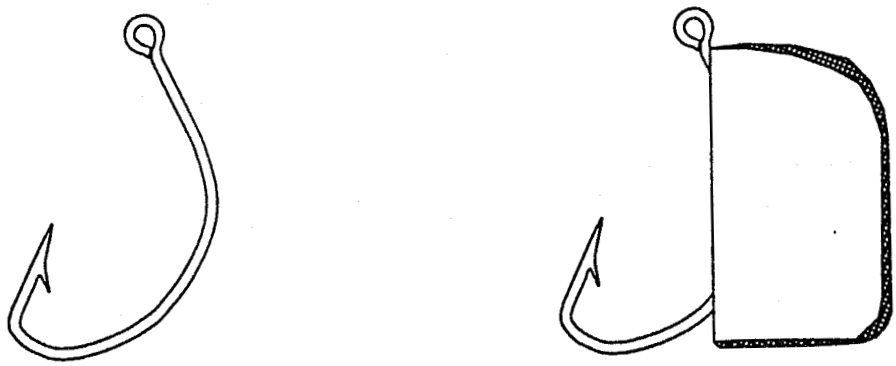


Figure 3. Mustad Wide Gap 5 hooks with and without an inedible plastic body attached to the hook shank.

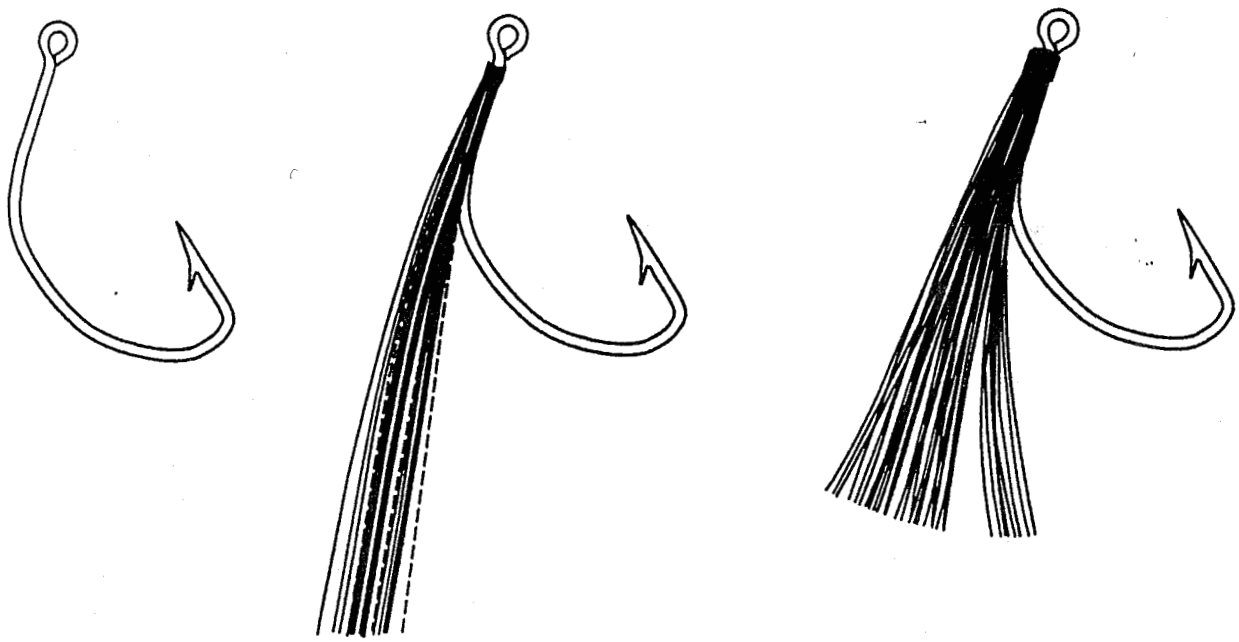


Figure 4. Eagle Claw 1607 hooks without (a), with white (b) and red (c) nylon bristles attached to the hook shank.