SELECTION AND SURVIVAL IN THE NORWEGIAN SHRIMP TRAWL FISHERIES

by

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ABSTRACT

Shrimp trawling has always been associated with large bycatches. The problems are solely due to the small mesh sizes generally used in shrimp trawl compared to mesh size in trawls used for various groundfish. During the last 25 years, a lot of experiments have been performed to reduce the bycatch in shrimp trawl, but so far one has only partly managed to solve the problem. It still remains to develop devices that effectively separate small fish from shrimp and small shrimp from larger shrimp, that is a combined solution for species and size selection in shrimp trawl.

The survival of one-year-old cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangius*), excluded from a shrimp trawl by a diagonal metal grid placed in front of the codend (the Northmrre grid), was studied during June 1993 and 1994. Fish leaving the gear in front of this grid during trawling were retained by a net covering the fish outlet, and led into a collecting cage. The collecting cages were released from the trawl at the fishing depth and anchored for five to 12 days. The fish in the cages were then observed daily by underwater television, and in the second season also by divers. The escapees from separate trawl hauls were analysed for body damage.

No mortality was found among the young gadoids during the observation period, except for one haddock in the control group. There were almost no visible skin injuries or scale loss in cod, while in whiting and haddock there was a significantly larger occurence of these factors. No correlation was observed between fish size and the amount of scale loss.

INTRODUCTION

Shrimp trawling has always been associated with large bycatches, both nationally and internationally. The problems are solely due to the small mesh sizes generally used in shrimp trawl compared to mesh size in trawls used for various groundfish. The minimum mesh size for ground fish trawls in the Barents Sea is 135 mm, whereas the minimum mesh size in shrimp trawls is only 35 mm. This has involuntarily caused shrimp trawls, depending on the time of the year, to catch large amounts of juveniles and fish below minimum landing size. Some of the fjords in Northern Norway have therefore been closed to shrimp trawl fishing for decades due to this problem. With the introduction of the "Nordmøre grid", the problem with fish in shrimp trawls has been reduced, but there are still difficulties in selecting the smallest fish, that is 0- and 1-group of cod and haddock up to 16-18 cm and redfish up to 12-14 cm.

After the settlement of 0-group fish late in the autumn, it is almost a yearly phenomenon that the intermixture of of juvenile fish is too high in the shrimp catches, resulting in closure of good shrimp grounds in the fjords as well as offshore. The problem will often continue until March-May when the juveniles either disappear from the grounds or grow into the selection range of the Nordmøre grid.

Bycatch in shrimp trawl is, however, not only associated with fish, but also with shrimp smaller than the minimum landing size. If the catches contain more than 10% small shrimp in weigth, the fishing grounds will be closed. The problem with small shrimp will mainly occur in the late summer/early autumn, and before the 0-group fish settle on the bottom. Altogether shrimp grounds can be closed for fishing for several months in coastal areas.

The bycatch of small shrimp is also noticed in the fjords off Svalbard, with partial closure of the fishing grounds when this happens. The Norwegian sterntrawlers fishing for shrimp in waters off Greenland and on Flemish Cap also encounter difficulties with small, low-value shrimp. These boats have been given "vessel"-quotas and want only big shrimp. Observers onboard prevent size sorting on deck, and these vessels are looking for some device to size-sort the shrimp during fishing.

During the last 25 years, a lot of experiments both nationally and internationally have been performed to reduce the bycatch in shrimp trawl, but so far one has only partly managed to do so. It still remains to develop devices that effectively separate small fish from shrimp and small shrimp from big shrimp, in other words a *combined solution* for *species- and size selection in shrimp trawls.*

SELECTION IN SHRIMP TRAWL – A SHORT REVIEW

Size sorting of shrimp and fish by means of meshes/net-panels

Shrimp

Experiments performed in 1974 revealed that it was possible to obtain relatively good size selection by increasing the mesh size. These experiments were, however, performed with relatively low catch-rates, and later experiments, performed in the mid 1980s, indicated that the selectivity for shrimp would decrease with incresaing catch rate (Directorate of Fisheries, unpublished data). Theoretical considerations on the phenomenon are given by Valdemarsen (1989). Recently performed experiments have shown that it may be possible to improve the selectivity in the shrimp trawl codend by removing the outer protection/strengthening net normally used on shrimp trawl codends. With small catches this procedure may be an option to improve the selectivity, but for stern trawlers hauling big catches up the stern ramp, there is definitely a need for a strengthening net.

Karlsen and Larsen (1989) showed that it was possible to improve shrimp size selectivity by using square mesh codends, but also these experiments revealed that the selectivity became poor by increased amounts of catch in the codend. A nordic project performed at Greenland on shrimp selctivity gave similar results; when the catch in the codend increased, the selectivity properties of the codend decreased because the changed mesh configuration gave about the same selectivity as normal codends (Lehmann et al. 1993).

At the east coast of Canada, several experiments with different mesh configurations have been performed; square mesh, meshes stiffened by plastic coating and lastridge ropes. The experiments have not given any better results than normal meshes, and it can be stated that open meshes in the upper/lower and side panels of a shrimp codend have no effect; the shrimp have no directional swimming behaviour and cannot benefit from open meshes like a fish.

Fish

From 1975 to 1978, the so-called HH-panel was developed at the Fish Capture Division, Bergen (Karlsen 1978). This method of excluding fish is based upon an oblique-mounted oval net placed between the extention piece and the codend in the shrimp trawl. The HH-net was used in experimental fishing in the fjords in northern Norway as well as in the offshore fishery in the mid 1980s (Karlsen 1983). It gave acceptable results with regard to shrimp loss and exclusion of fish. However, when the device was used on grounds with a lot of redfish, there were indications that difficulties were caused by meshed redfish. The HH-panel was used for a short period by most of the coastal shrimp trawlers, giving them the possibility to fish on grounds which were closed for traditional gear.

Experiments with side sorting panels were also performed (Isaksen 1994). The method gave similar results as the HH-panel, but was somewhat more difficult to install and enforce.

A third system tested to sort out fish from shrimp was the Radial Escape Section - RES - (Valdemarsen and Isaksen 1986). The system consists of two funnels connected by ropes or big meshes. While fish could swim out between the two funnels, shrimp was led passively from one funnel to the other and back into the codend (Figure 1). Except for the HH-panel, none of the devices made from net panels came into practical use in the 1980s.

Size and species selectivity by means of sorting grid systems

Fish

Upon request from the Mixed Russian-Norwegian Fisheries Commission, a large selectivity progamme on bycatch in shrimp trawls was started early 1989. During spring this year, a solid sorting device was developed, actually based on a device used to exclude jelly-fish developed by some fishermen at Nordmøre (Isaksen et al. 1992). This device, named the Nordmøre grid, very soon proved to be efficient in excluding fish during shrimp trawling. The device has a relatively simple construction, and consists of a guiding funnel in front of a 45^{O} sloped grid, and with a fish outlet in the upper panel just in front of the grid, as illustrated in Figure 2. While shrimp are led passively through the grid, fish are led up along the grid and through the fish outlet. The Nordmøre grid was soon introduced in the fjord shrimp fishery and on the offshore grounds of the Barents Sea during the early 1990s. In addition to Norway and Russia, this device is now in compulsory use in Iceland, Canada, USA and Australia, and several other countries are going to introduce it in near future.

By using a Nordmøre grid with 19 mm inter-bar distance, it is possible to exclude all cod and haddock above 18-20 cm and all redfish above 13-15 cm, at the same time as the shrimp loss is kept below 2-3%. A smaller inter-bar distance would definitely improve the exclusion of fish, but would at the same time result in a higher shrimp loss.

From 1992 and up to 1996, very little was done with respect to the Nordmøre grid. After several requests from fishermen, some experiments were carried out with a large grid with a width of 1.3 m and length of 2.5 m (Larsen et al. 1997). This grid sloping only 30°, gave about the same shrimp loss as earlier, but gave far less clogging of flatfish and rays on the sorting surface. The grid is now allowed used in the Barent Sea.

Although the Nordmøre grid has reduced fish bycatch considerably in deepwater fisheries for *Pandalus borealis*, it still remains to develop a device that effectively exclude the smallest fish.

Shrimp

Inspired by the good results from the use of solid grids in shrimp trawls, several experiments were performed in the early 1990s to size select the shrimp during the fishing operation (Karlsen 1990, Valdemarsen and Mikalsen 1991). Later on, most of the size selectivity work on shrimp was performed as an inter-nordic prosject with several cruises at Greenland. Up to this date, several grid devices have been tested, from plane grids (Karlsen 1990) to more complicated devices like the FASS (Figure 3) (Valdemarsen 1993, Kanneworf and Lehmann 1989, Anon 1996). Most of these experiments have resulted in increased size selectivity, but have encountered a common problem. Clogging of the grid sorting surface has been a dominating difficulty that increases with increasing haul duration as observed by means of UTV-equipment. After for instance 3 hour towing, the whole sorting surface may be blocked, and no further size sorting takes place. During haulback, the shrimp will loosen from the grid, and when heaving the grid device up the stern, everything looks fine.

It has been realized that size sorting of shrimp is strongly dependant on factors like grid angle, bar diameter, smoothness of bar surface, relationship between bar diameter and bar distance as well as profile of bar - round or V-shaped (Mikalsen 1997, Baio 1996).

Behaviour studies of shrimp and fish

Shrimp

Deepwater shrimp (*Pandalus borealis)* have on several occasion been observed by UTV-equipment, either mounted on remote vehicles like "Ocean Rover" or "Fokus 400" (Valdemarsen et al. 1990) or directly on the trawl in front of grids and various places in the belly (Larsen and Isaksen 1994, Isaksen et al. 1995). The observations revealed that the shrimp have no directional swimming ability. When a shrimp gets into contact with the panels in the front part of the trawl, it will flick with the tail. and the direction of swimming is given by the orientation of the shrimp, the shrimp may swim against the net panel or away from the panel, the direction is more or less random. As the shrimp falls back into the trawl, this behaviour ceases, and in front of the codend the shrimp is relative passive, and most probably exhausted. Any kind of selectivity in the codend is therefore mostly due to passive filtration or a kind of "wash out" (Valdemarsen 1989).

Fish

UTV-observations of 0-group cod and haddock less than 15 cm in length recently settled onto bottom have shown that these size groups of juveniles have poor chances to be excluded by the Nordmøre grid (Isaksen 1997). With as low trawling speed as 1.4 knots, the juveniles were observed to swim energetically in the same direction as the trawl, but were quite soon over-run by the grid, without making any attempt to move upwards towards the fish outlet.

Conclusions

Regarding size selectivity of shrimp, most of the devices tested up to date have given imperfect results. However, the grids have given some promising results, and based on the knowledge gained through the different experiments, the following criteria have to be fullfilled to give satisfactory size selection of shrimp:

- all shrimp have to be led towards and have a physical contact with the sorting surface; that is passive filtration.
- all shrimp should be length-oriented along the bar spacings; the shrimp are size selected in a grid due to its width, not its length.
- the bars should have a shape that prevents clogging.
- the grid should have a low angle of attack to prevent clogging.
- the shrimp not being sorted out by the grid should immediately slide away from the grid, that is; the surface of the bars should be very smooth.

The few UTV-observations of small fish in shrimp trawls have shown that juveniles are more or less abandoned the water flow conditions in the codends, for instance behind a Nordmøre grid. Passive filtration through a grid may be one solution, but would lead to a shrimp loss. An efficient solution for excluding small fish has to rely upon the swimming ability that exsists in fishes. A change of flow picture in the extention piece and codend, could give the small juveniles of fish a possiblity to position themselves in low current areas, and subsequently a possibilty to escape.

SURVIVAL

During the past decade there has been concern about the survival of fish escaping from fishing gear. Escapees may die as a direct result of physical damage and stress, or indirectly due to reduced capacity to escape predators or resist disease from infections after being injured (Chopin and Arimoto, 1995). Since 1989 the Institute of Marine Research has been studying the survival of gadoid fish in Norwegian trawl fisheries. Experiments with roundfish trawls showed insignificant levels of mortality of cod and less than 10% of haddock after escape through codend meshes (135 mm mesh size) or after passing through a metal sorting grid (Soldal *et al.*, 1993). In these experiments most of the fish were larger than 30 cm. However, the few smaller fish caught suffered a greater rate of scale loss than larger ones, which in turn might lead to higher mortality rates for small than for large fish (Sangster and Lehmann, 1993). The aim of the experiments reported here was to study the survival of young gadoids sorted out from a shrimp trawl by means of the Nordmrre grid.

Materials and methods

The trawl experiments were carried out in two fjords in northern Norway: Ramfjorden (June 1993) and Ullsfjorden (June 1994), from a coastal shrimp trawler (16 m, 270 HP). Trawling was performed at a depth of 50 m, towing for 30 min at a speed of 0.6 ms^{-1} (1.2 knots). The Nordmrre grid was installed as described by Isaksen *et al.* (1992) in the extension piece of a coastal shrimp trawl frequently used in Norwegian waters. The grid and the rigging of the trawl was as described by Isaksen *et al.* (1992).

During the experimental hauls a cover net made of knotless nylon (20 mm mesh) was mounted over the fish outlet to collect excluded fish (Fig. 4). This net was connected by detachable chain stitches to a 7 m long nylon cage (knotless, 10 mm mesh), held open by three aluminium rings (12 mm) of 1.7 m diameter (Figs. 4 and 5). The end of the cage (1 m) was made of 5 mm knotless nylon to create a bucket effect during towing. For control hauls the collecting cage was connected directly to the extension piece of the trawl (Fig. 6). To prevent large fish predators from entering the cage, a second metal grid was mounted in the cover net (experiment hauls) or trawl extension (control hauls). This grid was made of vertical aluminium bars with a spacing of 30 mm. Escapees for survival studies were collected from three hauls with sorting grid in 1993 and five in 1994, while two control hauls were made in 1993 and three in 1994 (Appendix 1).

After towing, the cages were released from the trawl at the fishing depth by means of an acoustic release, and anchored at 10-15 m depth close to the towing path. The cages were kept for five to six days in 1993 and eight to 12 days in 1994. Daily observations were made by a low-light underwater camera (Osprey SIT) lowered down the buoy rope (Fig. 7). In 1994, dead fish were removed by divers three times during the observation period through a zipper in the cage floor, and brought to the surface for identification and measurements. The fish in the cages were not fed. The sea temperature at the trawl depth was 4°C, while at the anchoring depth it was 6°C.

In four hauls an RS 400 self-recording video unit was mounted inside the grid cover or the cage in order to record (a) the performance of the cover and cage, (b) fish behaviour during trawling and (c) fish behaviour during towing of the cages and anchoring.

In 1994 the catches from three trawl hauls were analysed for scale loss. The trawl procedure and rigging were carried out as described above, but instead of anchoring the cages, they were slowly raised to the surface. The zipper in the bottom of the cage was opened, and the fish were allowed to swim out on to a submerged PVC tarpaulin, from which they were carefully transferred by a plastic coated landing net to a seawater tank onboard the vessel.

The degree of scale loss along the sides of the fish was assessed according to Main and Sangster (1988), where each side was divided into 10 segments and the fraction of scale loss in each of them was visually assessed. For statistical analyses, we used a scale loss index, calculated as the percentage of scale loss of each segment summed for each fish.

Results

Species and length composition of the catches

The target species of this investigation were primarily one-year-old cod, haddock and whiting. Few cod were caught in 1993 (19) and 1994 (16). Whiting made up a significant part of the catches in 1994, but were almost absent in 1993

The length frequency distributions of haddock and whiting in the cages are given in Figure 8. According to established length/age relationships for cod, haddock and whiting (Bergstad *et al.*, 1987), the fish in the cages were predominantly one-year-olds. Fish larger than approximately 32 cm were prevented from entering the cages by means of the aluminium sorting grid in the trawl opening.

Fish mortality

During the 1993 and 1994 observation periods no cod and whiting died in the experimental or the control groups (Table 1). Only one haddock died, and this specimen was from the control group.

Fish injuries

The mean percentage of scale loss of each body fraction for cod, haddock and whiting is shown in Figure 9. For cod, the amount of scale loss was negligible. The amount of scale loss differed significantly from species to species ($p<0.001$, Kruskal-Wallis test). The total scale loss in whiting was higher than that in either haddock or cod ($p=0.001$ and $p<0.001$), while in haddock it was higher than in cod ($p<0.001$). The amount of scale loss was larger above the lateral line organ than below, and in haddock and whiting it increased towards the tail. No significant relationship was observed between fish body length and the amount of scale loss.

Discussion

This study of gadoids excluded from a coastal shrimp trawl with a diagonal deflecting grid showed that both cod, haddock and whiting had 100% survival rate after an observation period of five to 12 days. These results support our earlier investigations, which showed no mortality of cod, and 96% (135 mm diamond meshes) and 92% (diagonal metal sorting grid, 55 mm bar spacing) survival of bottom-trawl escapees of haddock (Soldal *et al.*, 1991; Soldal *et al.*, 1993) and 95% survival of haddock escaping from Danish seines (135 mm diamond meshes (Soldal and Isaksen, 1993)).

High survival rates in cod after escaping from trawls have also been reported by Main and Sangster (1991), DeAlteris and Reifsteck (1993) and Suuronen *et al.* (1995), while Jacobsen *et al.* (1992) found a 97.5% survival rate among saithe (*Pollachius virens*) escapees. Sangster and Lehmann (1993) observed lower survival rates (approximately 70-90%, depending on mesh size) among both haddock and whiting escapees from bottom- trawls. The survival of haddock escapees in a tank experiment (Jonsson, 1994) was, however, found to be low (30-50%).

Fish that encounter a trawl are exposed to several kinds of physical strains, e.g. from swimming in front of the trawl, through hitting the net walls on their way back to the codend, as well as from possible skin injuries suffered while escaping from the codend. Several authors have shown that physical injury incurred during capture may lead to death (see e.g. Hislop and Hemmings 1971). The main difference between the selection method in the shrimp trawl used in this study and those used in the roundfish trawl experiments was the sorting grid. In our shrimp trawl, the fish were prevented from entering the codend by the Nordmrre grid and passed through a fish outlet in the top panel. The fish did not pass through net meshes or between the metal bars of the Nordmrre grid to escape. Underwater observations during trawling showed that when a fish entered the trawl, it stopped and kept swimming in front of the grid for a while. Soon, however, it calmly rose and headed for the fish outlet. Except for an initial touch with the tail, the fish were not observed striking the metal bars. There is reason to believe that the risk of being hurt during escape is significantly less than for ordinary codend escapees, and lower mortality rates are therefore expected. This suggestion is supported by the fact that the scale loss analyses showed that haddock and whiting suffered less injury than codend escapees of these species in earlier experiments (Sangster and Lehmann, 1993; Soldal *et al.*, 1991; Soldal and Isaksen, 1993).

However, the fish taken for survival studies ran a higher risk of being hurt than fish that escape during ordinary trawling. In our experiment an aluminium metal sorting grid was placed in the trawl extension to prevent large fish from entering the cages. Although the spacings between the bars were large enough to ensure that the one-year-old gadoids could easily pass through the openings, the grid may have caused the fish additional injuries. The fish might also have been hurt while swimming inside the cage during towing and anchoring. These additional experimental stresses, however, did not result in mortality in cod and whiting, but may have caused the single haddock death in the control group.

The gadoids in this study were mainly one-year-olds. No 0-group fish were present during the season when the experiments were carried out. Some earlier investigations have shown that there may be a negative correlation between fish size and the amount of skin damage of escapees (Sangster and Lehmann, 1993; Soldal and Isaksen, 1993) and also between fish size and survival (Sangster and Lehmann, 1993), although these results were not supported by this study. A recent study of the survival of 0-group escapees in the shrimp fisheries off Iceland (Thorsteinsson, 1995) suggested a significant mortality rate, but the number of specimens caught was too small to draw any firm conclusions.

REFERENCES

Anon. 1991. Sorteringsrist i reketrål - 1991. Rapport fra Kontoret for fiskeforsrk og Veiledning, Fiskeridirektoratet, Bergen (in Norwegian).

Anon. 1996. Seleksjon i reketrål. Forsrk med ristteknologi og kvadratiske masker for å forbedre strrrelsesseleksjon i trDlfisket. TemaNord 1996 (in Norwegian).

BAIO, A. 1996. By-catch and Selectivity Studies in The Shallow Water Shrimp Fisheries off Freetown, Sierra Leone. M. Phil. Thesis, Department of Fisheries and Marin Biology, University of Bergen, Norway.

BERGSTAD, O.A., JRRGENSEN, T. and **DRAGESUND, O.** 1987. Life history and ecology of the gadoid resources of the Barents Sea. Fisheries Research, 5: 119-161.

CHOPIN, F.S. and **ARIMOTO, T.** 1995. The condition of fish escaping from fishing gears - a review. Fisheries Research, 21: 315-327.

De ALTERIS, J.T. and **REIFSTECK, D.M.** 1993. Escapement and survival of fish from the codend of a demersal trawl. ICES Marine Science Symposia, 196: 128-131.

HISLOP, J.R.G. and **HEMMINGS, C.C.** 1971. Observations by divers on the survival of tagged and untagged haddock Melanogrammus aeglefinus (L.) after capture by trawl or Danish seine net. Journal du Conseil pour l'Exploration de la Mer, 33: 428-437.

ISAKSEN, B. 1984. Experiments with vertical side sorting panels in Norwegian shrimp trawls 1982-1984.Coun Meet Int Coun Explor Sea, 1984 (B:22)

ISAKSEN, B. 1989. Reduksjon av uerbifangst i havreketrål. Bakgrunn og referat fra fra seminar holdt i Bergen 16.februar 1989. FTFI arbeidsnotat (in Norwegian).

ISAKSEN, B. 1997. Atferdsobservasjoner av fiskeyngel i reke i kystreketrål. Arbeidsnotat, Fangstseksjonen, Havforskningsinstituttet. (In prep.)

ISAKSEN, B., SOUSA, L. and **CHRUICKSHANK, O.** 1995. Preliminary report on the selectivity experiments with 54 and 60 mm mesh size in the Mocambiquean shallow water shrimp fisheries and further experiments on grid sorting devices. Notat Havforskningsinstituttet / Instituto de Invest. Pescueira, Maputo, Mosambique

ISAKSEN, B., VALDEMARSEN, J.W., LARSEN, R.B. and **KARLSEN, L.** 1992. Reduction of fish by-catch in shrimp trawls using a rigid separator grid in the aft belly. Fish. Res., 13: 335-352.

JACOBSEN, J.A, THOMSEN, B. and **ISAKSEN, B.** 1992. Survival of saithe (Pollachius virens) escaping through trawl meshes. ICES CM 1992/B:29, 10 pp.

JONSSON, E. 1994. Scale damage and survival of haddock escaping through cod-end meshes (tank experiment). ICES CM 1994/B:16 Ref. G, 8 pp.

KANNEWORF, P. og **LEHMANN, K.** 1989. Endelig rapport til Erhvervsdirektoratet vedrrrende forsrg med sortereapparat i rejetrawl, 1989. Grønlandske Fiskeriundersrkelser, Rejeafdelingen (in Norwegian).

KARLSEN, L. 1978. Forsrk med sorteringsnett i reketrål i tidsrommet 1975 - 1978. Rapport no 1-95, FTFI, Fangstseksjonen, Bergen (in Nowegian).

KARLSEN, L. 1983.Utprrving av sorteringsnett i kystreketrål i Vesterålen, Troms og Finnmark 1982/83 (in Nowegian).

KARLSEN, L. og **LARSEN, R.B.** 1989. Progress in the Selective Shrimp Trawl Development in Norway. In Proceedings World Symposium Fishing Gear and Fishing Vessel Design. 1988. The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St.John's, Newfoundland.

KARLSEN, L. 1989. Toktrapport fra M/S "Remifisk. Forsrk med sorteringsrist i 1800# havreketrål på Mehamnleira 22.-25.05.1989. Institutt for Marin Prosjektering, NTH, Trondheim (in Norwegian).

KARLSEN, L. 1990. Arts- og strrrelsesseleksjon i reketrDl. Sluttrapport - NFFR. Institutt for Marin Prosjektering, NTH, Trondeim (in Norwegian).

LARSEN, R.B. og **ISAKSEN,** B.1994. Atferdsstudier og fiskeforsrk med alternative utforminger av Nordmrrsrist. Rapport fra Norges Fiskerihrgskole, Universitetet i Tromsø (in Norwegian).

LARSEN, R., GAMST, K., LANGEDAL, G. and **JENSVOLL, T.** 1997. Selectivity experiments and comparison of two types of Nordmøre grid. Report from the Directorate of Fisheries, Bergen (in Norwegian).

LEHMANN,K., VALDEMARSEN, J.W., AND RIGET, F. 1993. Selectivity in shrimp codends tested in a fishery in Greenland. ICES mar. Sci. Symp., 196: 80 - 85.

MAIN, J. and **SANGSTER, G.** 1991. Do fish escaping from cod-ends survive? Scottish Fisheries Working Paper no. 18/91, 15 pp.

MAIN, J. and **SANGSTER, G.** 1988. A progress report on an investigation to assess the scale damage and survival of young gadoid fish escaping from the cod-end of a demersal trawl. Scottish Fisheries Working Paper no. 3/88, 12 pp.

MIKALSEN, L., 1997. Size Selection of Nothern Shrimp (Pandalus borealis) by Metal Sorting Grids in Shrimp Trawls. Cand. Scient thesis in Fishery Biology. Department of Fisheries and Marine Biology. University of Bergen, Norway.

SANGSTER, G.I. and **LEHMANN, K.** 1993. Assessment of the survival of fish escaping from commercial fishing gears. ICES CM 1993/B:2, 10 pp.

SOLDAL, A.V., ENGÅS, A. AND ISAKSEN, B. 1993. Survival of gadoids that escape from a demersal trawl. ICES Marine Science Symposia, 196: 122-127.

SOLDAL, A.V. and **ISAKSEN, B.** 1993. Survival of cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) escaping from a Danish seine at the sea surface. ICES Fish Capture Committee, FTFB Working Group Meeting, Gothenburg 19.-20. April, 1993, 8 pp.

SOLDAL, A.V., ISAKSEN, A.V., MARTEINSSON, J.E. AND ENGÅS, A. 1991. Scale damage and survival of cod and haddock escaping from a demersal trawl. ICES CM 1991/B:44, 12 pp.

SUURONEN, P., LEHTONEN, E., TSCHERNIJ, V. and **LARSSON, P.-O.** 1995. Skin injury and mortality of Baltic cod escaping from trawl codends equipped with exit windows. ICES CM 1995/B:8, 13 pp.

THOMASSEN og **ULLTANG, Q.** 1977. Report from mesh selection experiments on Pandalus borealis in Norwegian waters. ICES CM 1980/B:7. 11pp.

THORSTEINSSON, G. 1995. Survival of shrimp and small fish in the inshore shrimp fishery at Island. ICES Study Group on Unaccounted Fishing Mortality in Fisheries Aberdeen, 17.-18. April, 1995, 13 pp.

VALDEMARSEN, J.W. 1989. Size selectivity in shrimp trawls. In Proceedings World Symposium on Fishing Gear and Fishing Vessel Design. 1988. The Newfoundland and Labrador Institute of Fisheries and Marine Technology, St.John's, Newfoundland.

VALDEMARSEN, J. 1997 Strørelses- og artsseleksjon i reketrDl. Forsrk med kombirist og maskevidde i nykonstruert siamesisk tvillingtrDl i Nordsjren med F/F "Michael Sars" i juni 1996. Fisken og Havet, 1997 (in Norwegian).

VALDEMARSEN, J.W. 1993. Seleksjon i rekefisket. Rapport fra Senter for marine ressurser, nr 13-1993. (Sluttrapport NFFR-prosjekt nr 4001-701.248.) (in Norwegian).

VALDEMARSEN, J.W. and **ISAKSEN 1986.** Further Experiments with Radial Escape Section (RES) as fish-shrimp seperator in trawl. ICES CM 1986/B:29.

VALDEMARSEN, J.W., ISAKSEN, B. og **LARSEN, R.B.** 1990. Observasjoner av atferd til fisk og reke, og seleksjonsinnretninger i reketrål med M/S "Fjordfangst". Rapport fra Fiskeriteknologisk forskningsinstitutt, Fangstseksjonen, no. 01-90.

VALDEMARSEN, J.W. LEHMANN, K., RIGET,F., and **JESPER, B.** 1993. Grid devices to select shrimp size in trawls. ICES CM. 1993/B:35.

VALDEMARSEN, J.W. AND MIKALSEN, L. 1991. Preliminary tests with a grid arrangement to select sizes of shrimp in trawls. ICES FTFB WG-Meeting, Ancona, 22-24 April 1991.

Table 1. Mean survival of haddock, whiting and cod in 1993 and 1994.

Species	Year	Group	No. of fish	No. of deaths
Haddock	1993	Grid	32	0
		Control	7	1
	1994	Grid	57	0
		Control	2	0
Whiting	1993	Grid	2	0
		Control	1	0
	1994	Grid	80	0
		Control	21	0
Cod	1993	Grid	11	0
		Control	8	0
	1994	Grid	6	0
		Control	10	0

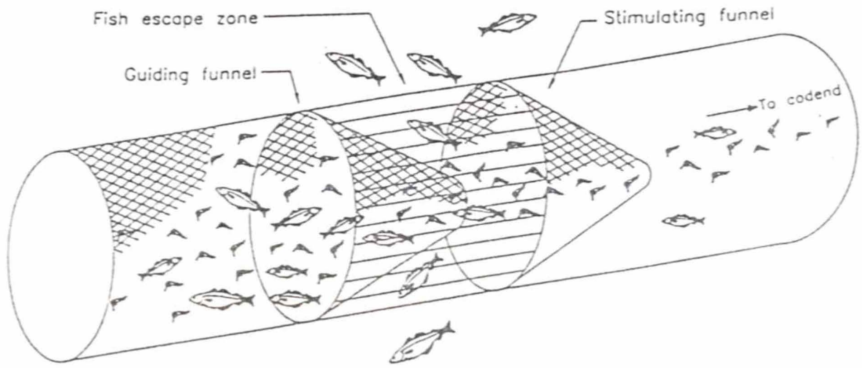


Figure 1. Radial Escape Section - RES.

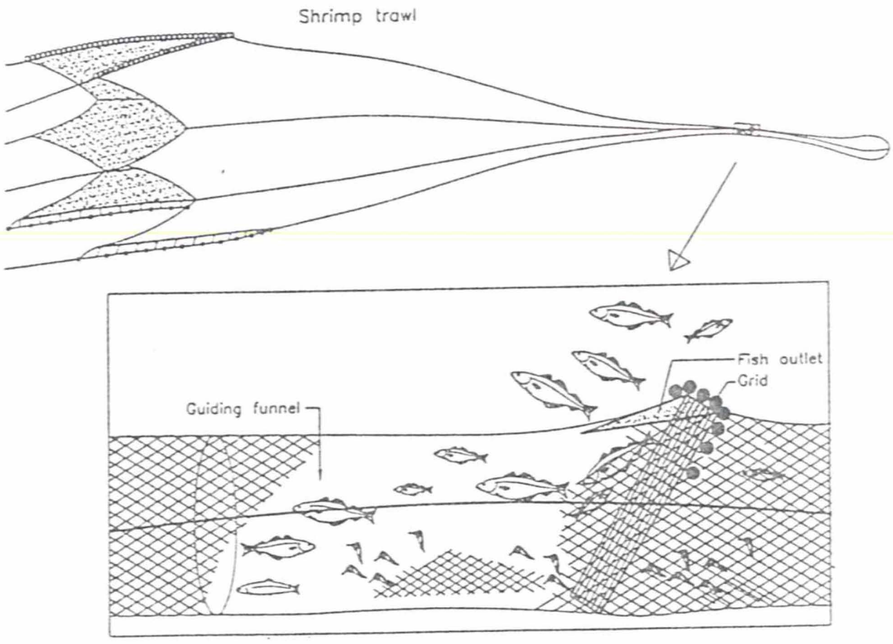


Figure 2. The Nordmøre grid.

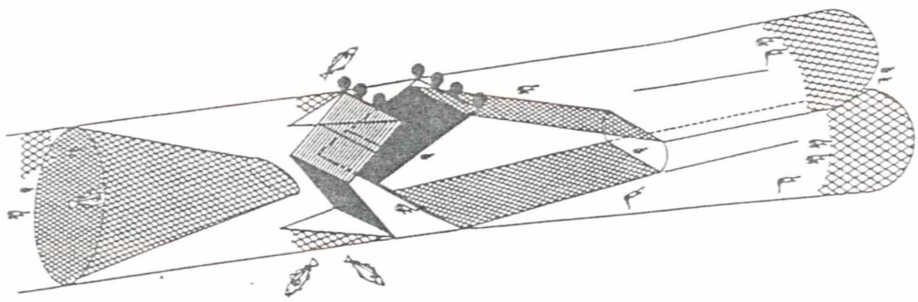


Figure 3. Fish and shrimp size selector in front of the codends (FASS). Horizontal V-shaped mode.

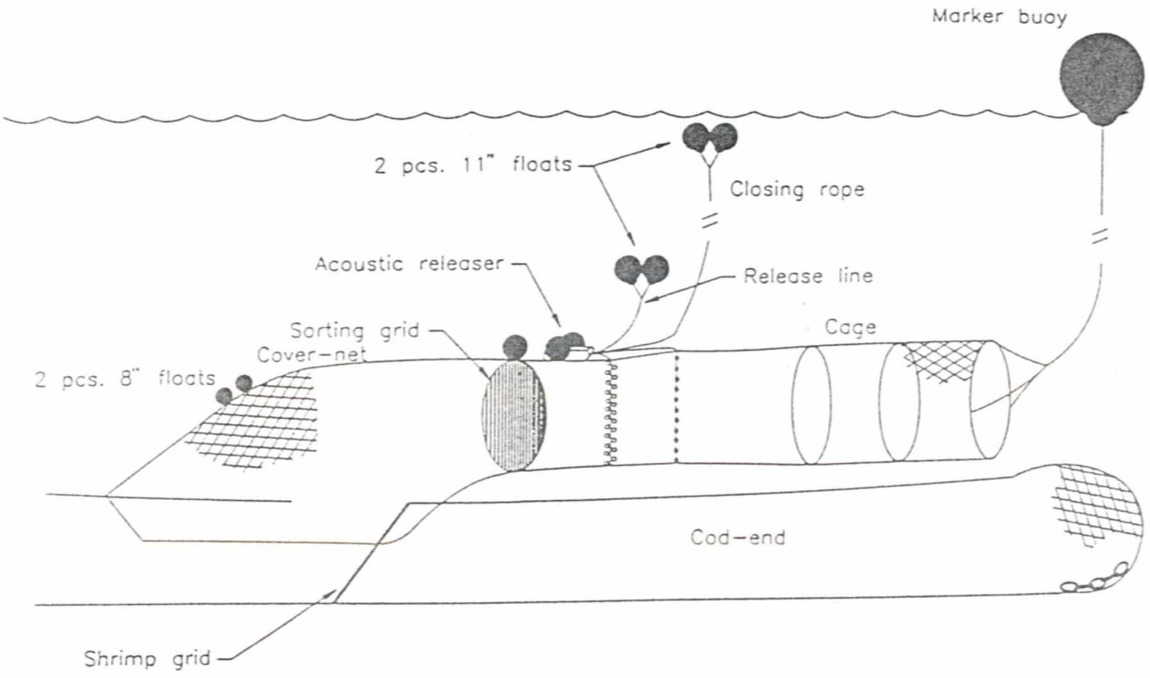


Figure 4 Rigging of the codend cover and cage for catching fish escaping through the exit window in front of the sorting grid.

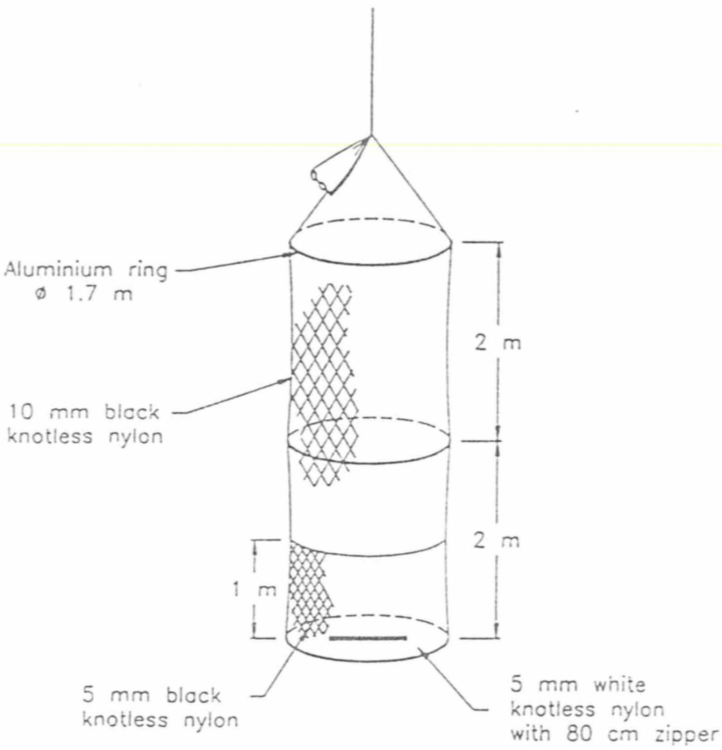


Figure 5. Cage for collecting and observing fish.

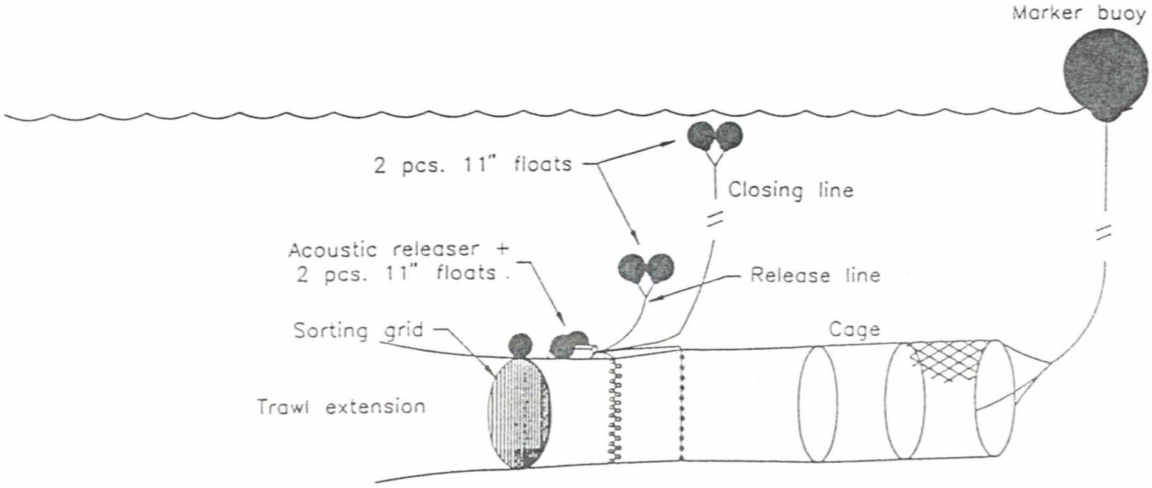


Figure 6. Rigging of trawl gear and cage for control hauls. The cage was mounted directly to the open codend.

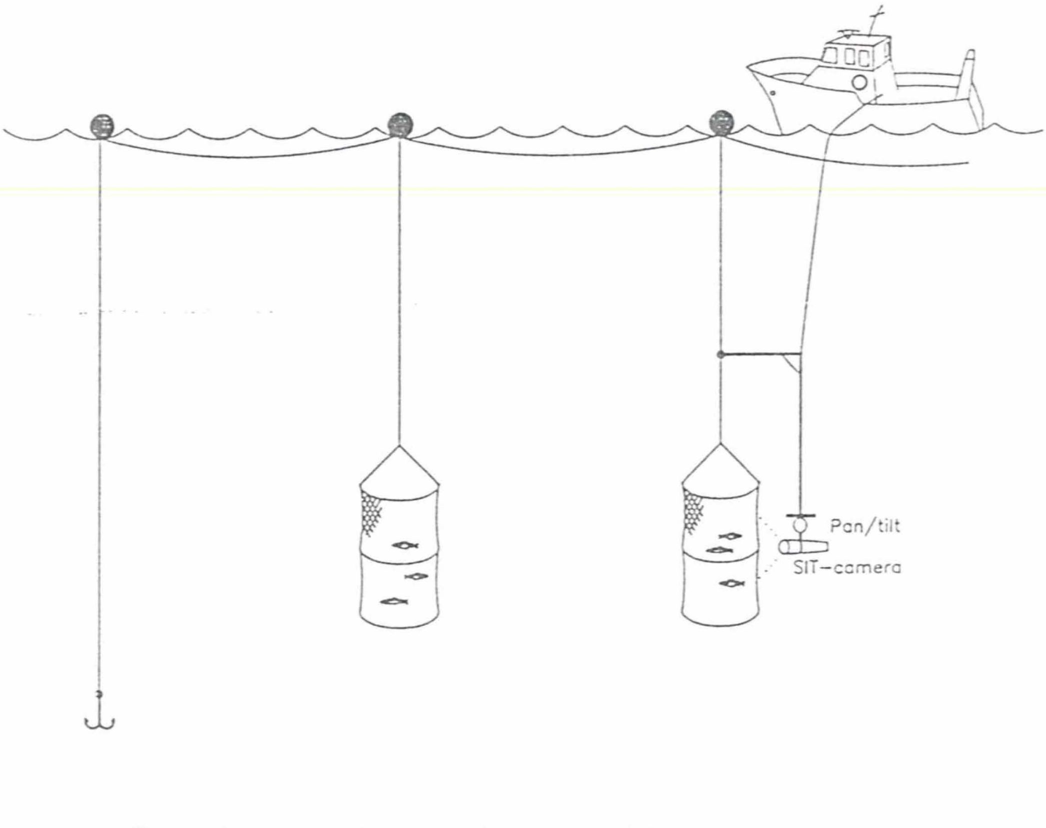
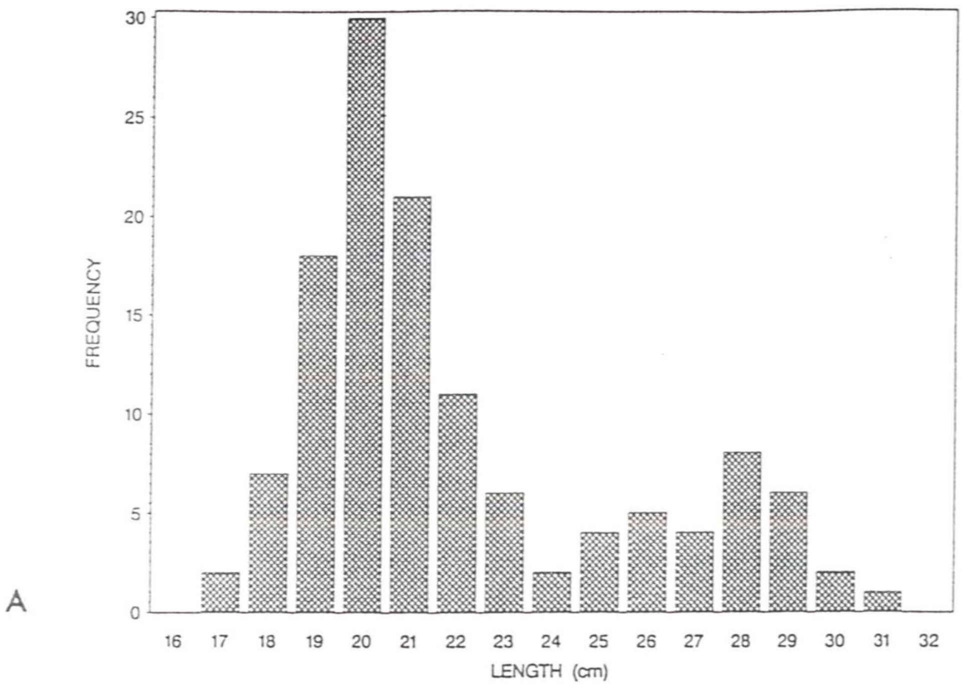


Figure 7. Anchoring and observing of the cages.



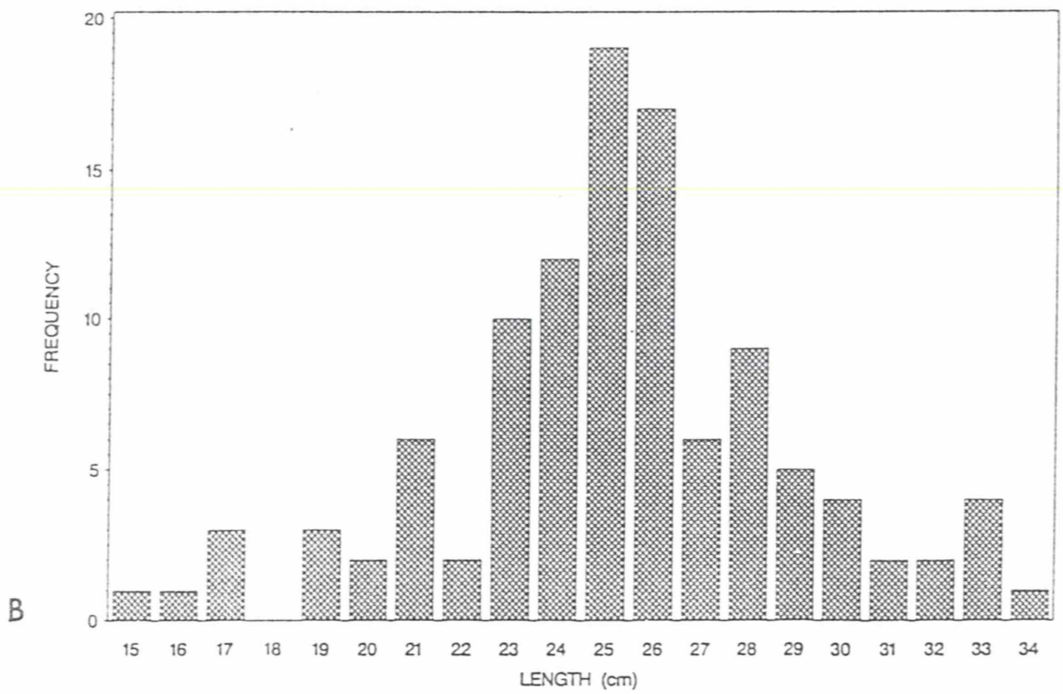


Figure 8. Length frequency distribution of haddock (A) and whiting (B) in the cages.

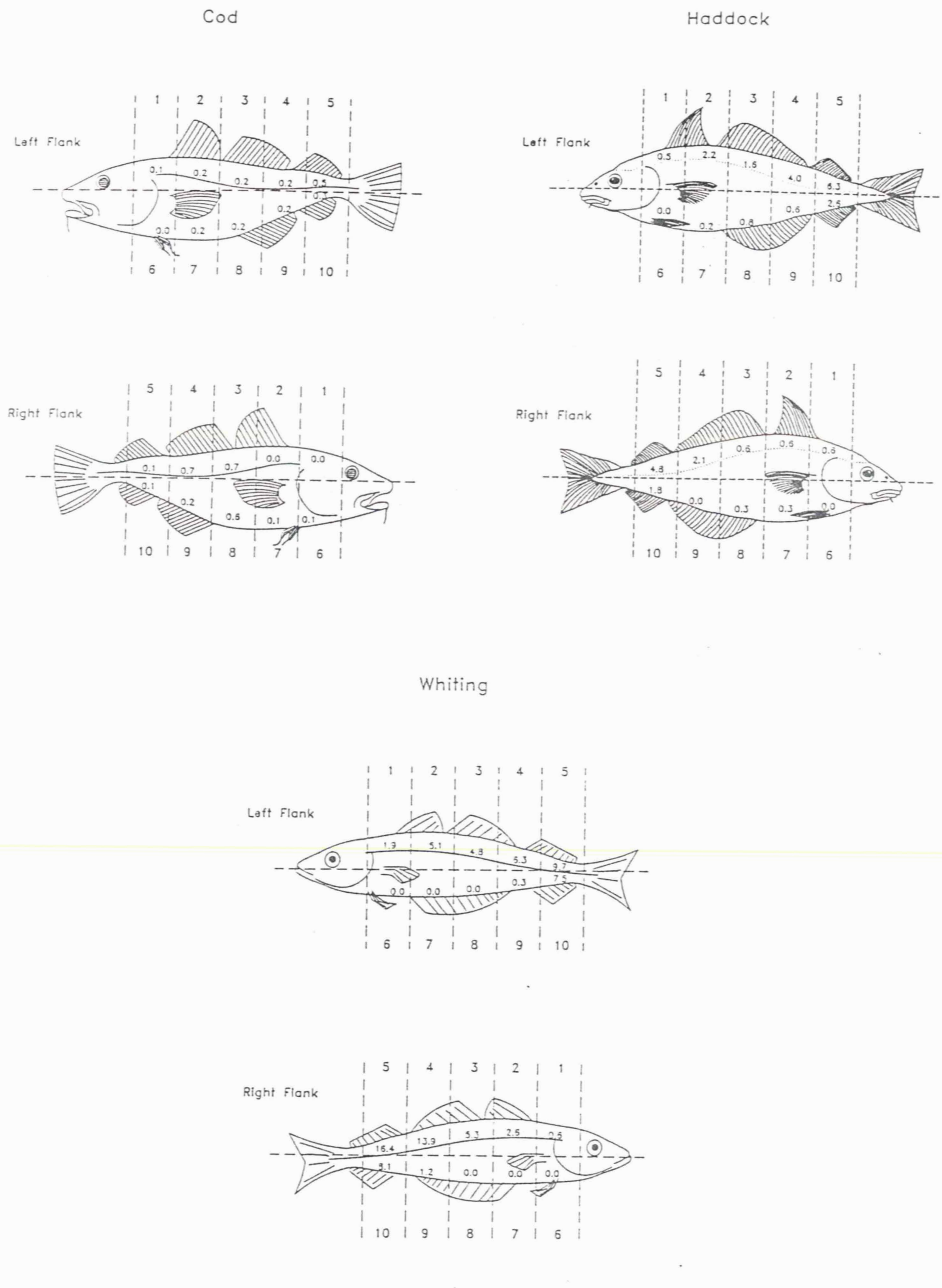


Figure 9. Mean sectional scale loss (%) of cod, haddock and whiting.

Appendix 1b. Species composition, mean length and mortality in the individual cages in 1994.

Cage no	Obs. time (days)	Group	Species	No. of fish	Mean length (cm)	No of deaths	Mortality (%)
1	11	Grid	Haddock	12	24.0	0	0
			Whiting	16	25.9	0	0
			Cod	2	27.0	0	0
			Herring	7	18.0	1	88
			Capelin	52		52	100
			Long rough dab	1	29	1	100
2	12	Grid	Haddock	11	26.0	0	0
			Whiting	13	26.4	0	0
			Cod	1	16	0	0
			Plaice	1	29	1	100
3	12	Grid	Haddock	15	24.6	0	0
			Whiting	11	22.3	0	0
			Capelin	58		58	100
			Witch	1	42	1	100
			Long rough dab	3	32.3	3	100
4	12	Grid	Haddock	15	24.5	0	0
			Whiting	18	25.9	0	0
5	11	Grid	Haddock	4	22.8	0	0
			Whiting	20	25.9	0	0
			Cod	3	22	0	0
			Herring	1	18	1	100
			Capelin	48		48	100
			Long rough dab	1	26	1	100
6	9	Control	Haddock	1	21	0	0
			Whiting	9	24.8	0	0
			Cod	4	18.3	0	0
			Herring	1	12	1	100
			Capelin	169		169	100
			Long rough dab	6	22.2	6	100
7	9	Control	Whiting	8	25.1	0	0
			Cod	2	27.5	0	0
			Herring	1	13	1	100
			Capelin	171		170	99.4
			Witch	1	40	1	100
			Long rough dab	2	25	2	100
8	8	Control	Haddock	1	23	0	0
			Whiting	4	25.5	0	0
			Cod	4	26.5	0	0
			Capelin	40		40	100
			Plaice	1	28	1	100
			Long rough dab	8	24.3	1	87.5