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Survival of young gadoids excluded from a shrimp trawl by a rigid deflecting grid

Aud Vold Soldal and Arill Engås

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The survival of one-year-old cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*), excluded from a shrimp trawl by a diagonal metal grid placed in front of the codend (the Nordmøre 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 5 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 incidence of these factors. No correlation was observed between fish size and the amount of scale loss.

Key words: Fish mortality, selectivity, sorting grid, shrimp trawl.

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A. V. Soldal and A. Engås: Institute of Marine Research, P.O. Box 1870 Nordnes, N-5024 Bergen, Norway.

Introduction

By-catches of under-sized fish and unwanted species are obvious problems in many fisheries, and much effort has been put into improving the selectivity of fishing gears. Mesh-size regulations have been widely used in trawling to minimize the capture of undersized fish since the early 1950s. More recently, new techniques such as escape outlets combined with guiding panels and sorting grids have been implemented to improve the selectivity of trawling operations (Isaksen and Valdemarsen, 1994). In the Norwegian trawl fisheries for shrimp (*Pandalus borealis*), by-catches and the discarding of small gadoids (0-, 1- and 2-groups) used to be major problems. However, since the deflecting grid ("the Nordmøre grid") was introduced (Isaksen *et al.*, 1992), this by-catch problem has been significantly reduced, except for 0-group fish in the late autumn.

During the past decade there has been some 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 secondary 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).

However, tests have not determined whether small fish that are deflected by the Northmøre grid survive the escapement process. Experiments were therefore undertaken to study the survival of young gadoids sorted out from a shrimp trawl by such a deflecting 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

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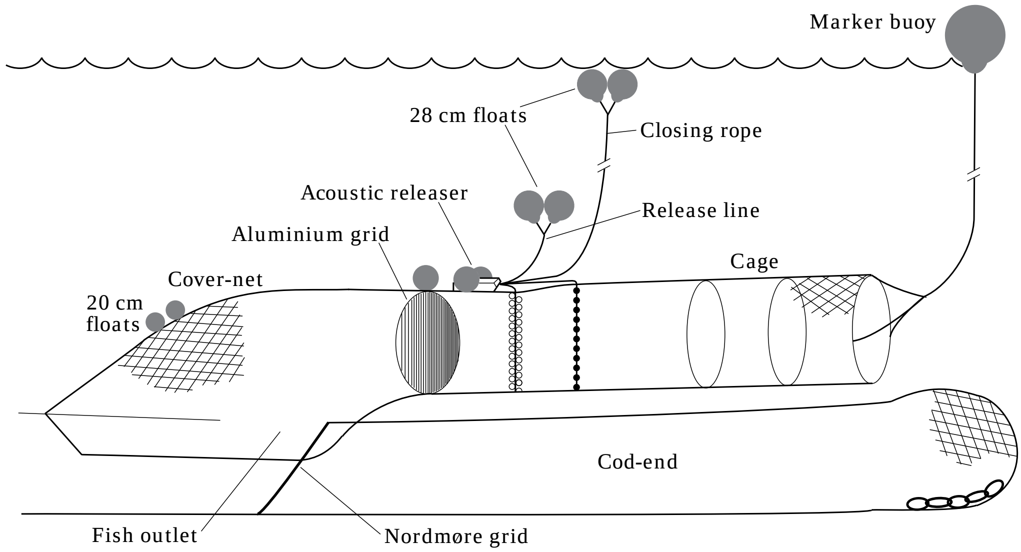

Figure 1. Rigging of the codend cover and cage for catching fish escaping through the exit window in front of the sorting grid.

50 m for 30 min at a speed of 0.6 ms^{-1} (1.2 knots). A deflecting grid ("the Nordmøre grid") was installed as described by Isaksen *et al.* (1992) in the extension piece of a coastal shrimp trawl frequently used in Norwegian waters (Fig. 1). The grid (60 × 130 cm) was built of 12 mm diameter vertical steel tubes with 20 mm bar spacing. The fish outlet and flapper was as described by Isaksen *et al.* (1992).

During the experimental hauls a cover net made of knotless nylon (20 mm mesh size) was mounted over the fish outlet to collect excluded fish (Fig. 1). This net was connected by detachable chain stitches to a 7 m long nylon cage (knotless netting, 10 mm mesh size), held open by three aluminium rings (12 mm) of 1.7 m diameter (Figs 1 and 2). The end of the cage (1 m long) 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. 3). To prevent large fish predators (larger than approximately 32 cm) 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 deflecting grids 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 5 to 6 days in 1993 and 8 to 12 days in 1994. Daily observations were made by a low-light underwater camera (Osprey SIT) lowered down the buoy rope. 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

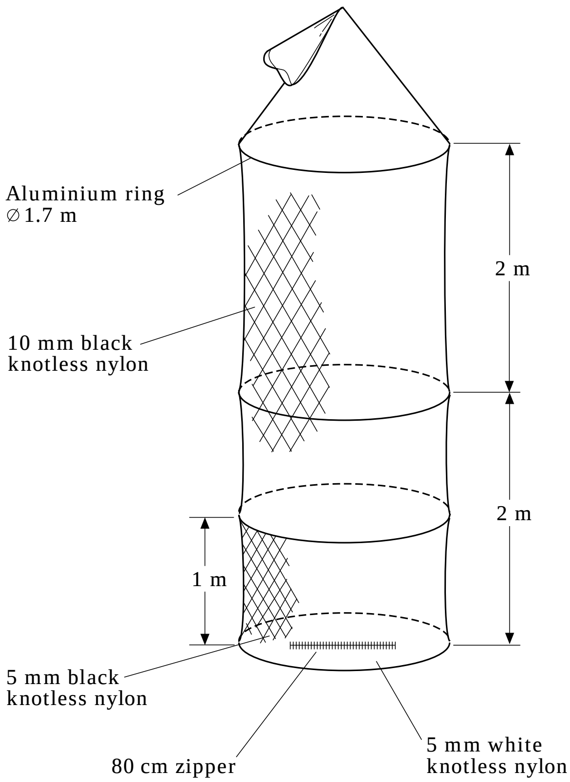

Figure 2. Cage for collecting and observing fish (mm refers to stretched mesh size).

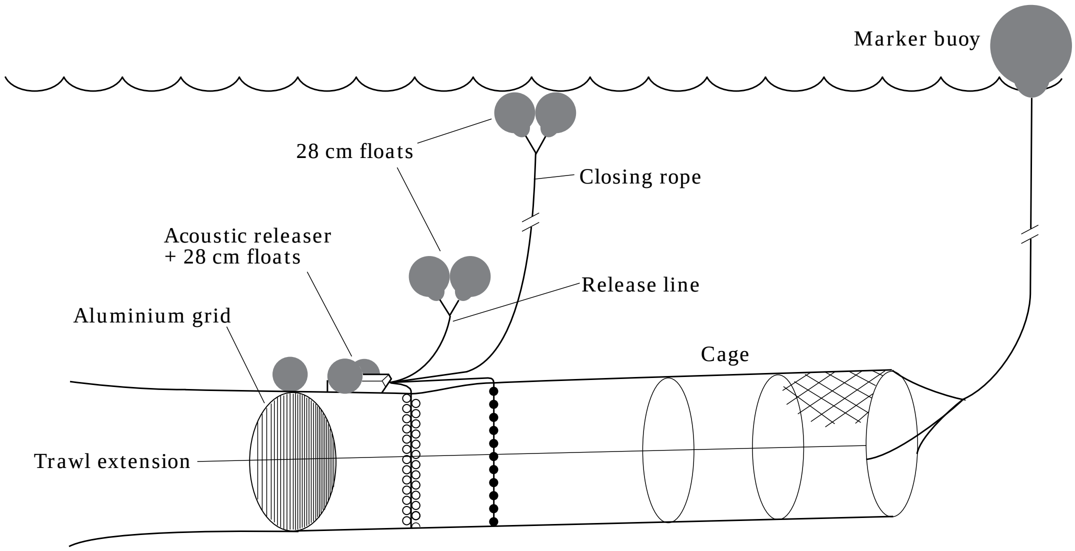

Figure 3. Rigging of trawl gear and cage for control hauls. The cage was mounted directly on the trawl extension.

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 taken for scale loss analysis. 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 on-board 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. The species compositions of the individual cages are given in Appendix 1. 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. Besides the main target species, numbers of herring (*Clupea harengus*), capelin (*Mallotus villosus*), Norway pout (*Trisopterus esmarkii*), long rough dab (*Hippoglossoides platessoides*) and plaice (*Pleuronectes platessa*) were caught.

Re-rigging the trawl from experimental to control hauls was time-consuming. Instead of alternating between the two types of hauls, all hauls from the same group were conducted in succession. However, catch rates declined in the course of the experimental period, which resulted in fewer fish in the control groups than the experimental groups.

The length–frequency distributions of haddock and whiting in the cages are given in Figure 4, and the mean lengths of all species caught are given in Appendix 1. 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 behaviour and gear performance

Video observations of fish in front of the Nordmøre grid, at the entrance of the cage and within the cage during towing showed that gadoid fish swam calmly along inside the trawl or within the cage, head first, apparently with no signs of panic. No fish were seen to strike the trawl netting in the grid area or the cage walls. When they touched the deflecting grid with their tails, the fish would make a rapid burst of speed forwards. After some minutes swimming in front of the grid, the fish calmly rose and escaped through the fish outlet above the grid and into the cage. While the cage was still moving during trawling, the fish usually maintained their positions in the upper half of the cage cross-section. No fish were observed lying against the rear cage wall.

After the cages were anchored at the observation site, the fish were seen circling calmly within the cage.

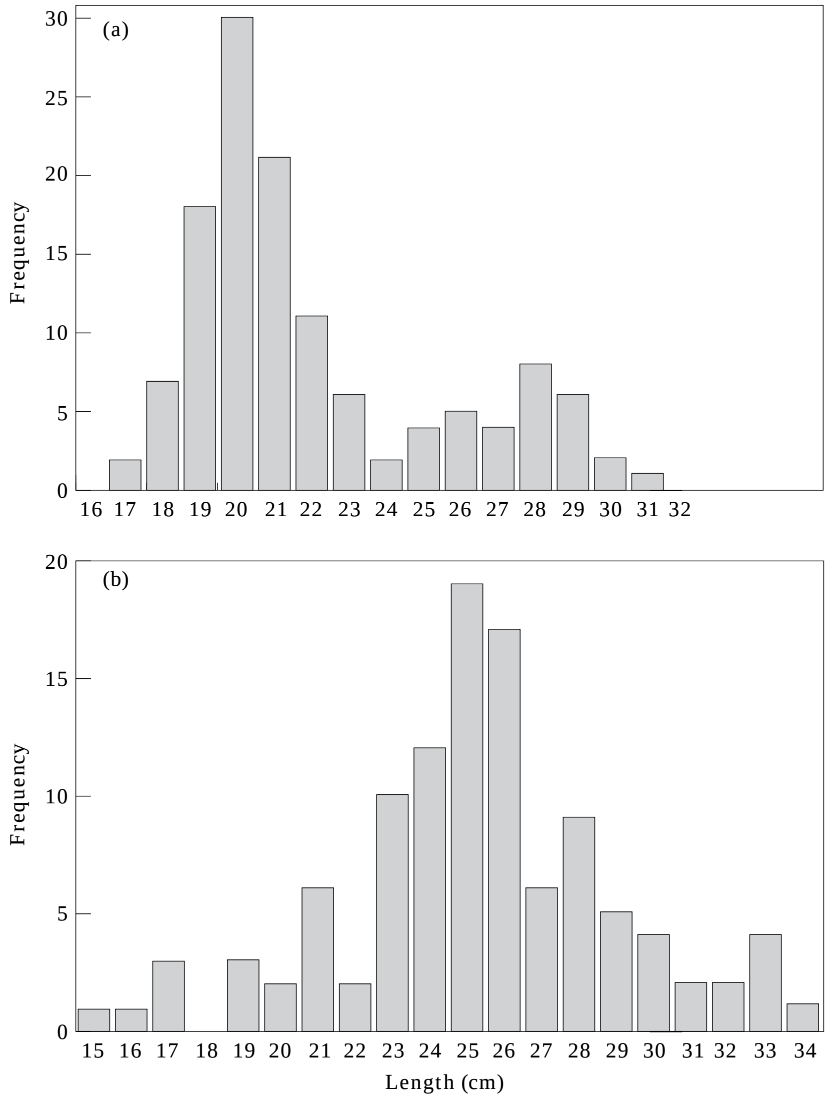

Figure 4. Length frequency distribution of haddock (a) and whiting (b) in the cages.

Herring and capelin schooled in the upper half of the cage, while gadoids (cod, haddock, whiting and Norway pout) swam more loosely about close to the bottom. The flatfish rested on the cage floor.

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. The mortality rates of the other species in the cages were significantly higher (Appendix 1a and b). However, the experimental set up was designed for demersal gadoids, and the survival figures for the other species should therefore not be relied on.

Fish injuries

The mean percentage of scale loss of each body fraction for cod, haddock and whiting is shown in Figure 5. 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 (Fig. 6).

Table 1. 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

Discussion

This study of gadoids excluded from a coastal shrimp trawl with a diagonal deflecting grid showed that cod, haddock and whiting had a 100% survival rate after an observation period of 5 to 12 days. These results support our earlier investigations, which showed no mortality of cod, and 96% (135 mm diamond meshes) and 92% (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 of 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%

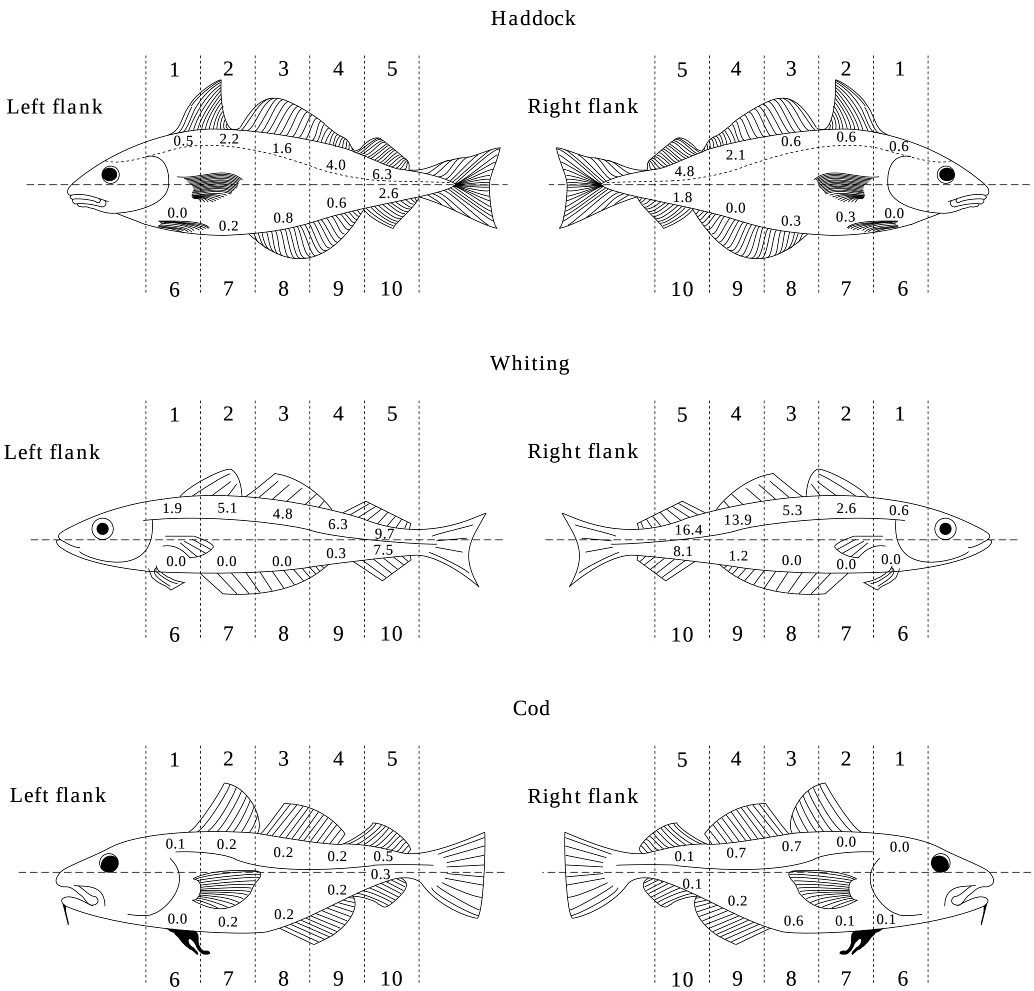

Figure 5. Mean sectional scale loss (%) in 10 areas of the flank (1–10) of haddock, whiting and cod.

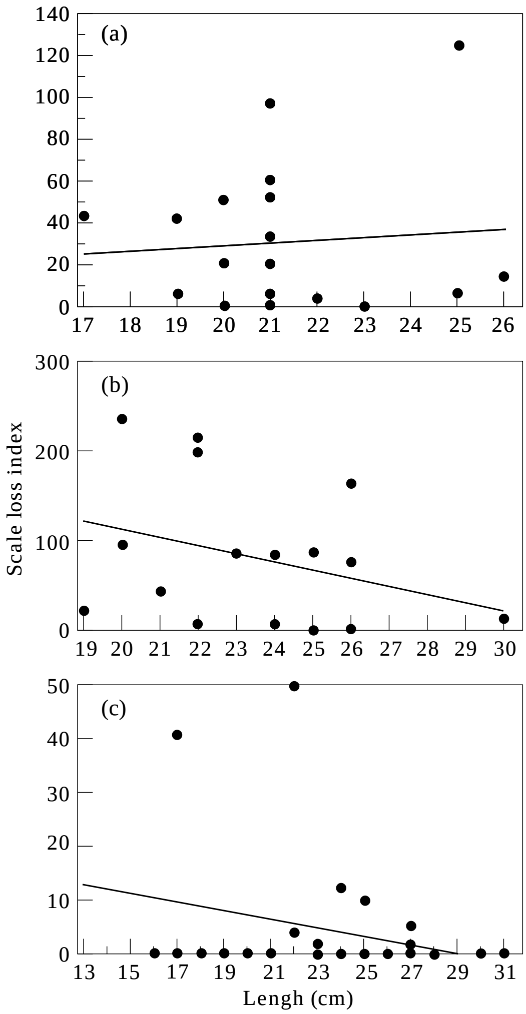

Figure 6. Fish size vs. scale loss index for haddock (a), whiting (b) and cod (c). None of the regression coefficients were significant.

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 deflecting grid. In our shrimp trawl, the fish were prevented from entering the codend by the Nordmøre 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 Nordmøre grid to escape. Underwater observations during trawling showed that when a fish entered the trawl, it stopped and kept swimming in front of the Nordmøre grid for a while. Soon, however, it calmly rose and moved towards 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 in earlier experiments (Sangster and Lehmann, 1993; Soldal *et al.*, 1991; Soldal and Isaksen, 1993).

However, as in other survival studies, the fish 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 may 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 or by Suuronen *et al.* (1995). 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.

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Appendix 1a. Species composition, mean length and mortality in the individual cages in 1993.

Cage no.	Obs. time (days)	Group	Species	No. of fish	Mean length (cm)	No. of deaths	Mortality (%)
1	6	Grid	Haddock	21	19.9	0	0
			Cod	5	25.8	0	0
			Norway pout	2	16.5	0	0
			Herring	2	16.5	2	100
2	6	Grid	Haddock	4	20.5	0	0
			Whiting	2	28	0	0
			Cod	4	17.3	0	0
			Norway pout	21	13.4	12	57.1
3	6	Grid	Haddock	7	19.9	0	0
			Cod	2	22	0	0
			Norway pout	129	13.7	41	31.8
			Herring	36	11.8	22	61.1
4	5	Control	Haddock	1	20	1	100
			Cod	4	20.8	0	0
5	5	Control	Haddock	6	20.3	0	0
			Whiting	1	30	0	0
			Cod	4	21.5	0	0
			Norway pout	1	13	1	100

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	8	18.0	7	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	7	87.5