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SURVIVAL OF BALTIC HERRING (*Clupea harengus* L.) ESCAPING FROM A TRAWL CODEND AND THROUGH A RIGID SORTING GRID

by

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ABSTRACT

The survival of Baltic herring escaping from a 36 mm diamond mesh codend and through a rigid sorting grid (12 mm bar spacing) was studied in May-June 1993 in the northern Baltic Sea proper. Escapees were captured into a small-meshed netting cage which was released from the trawl and then transferred into a holding cage where the fish were withheld for two weeks. Most deaths occured 3-8 days after escape and the mortality was negligible after 10-12 days. The survival rate of codend escapees (length 8-17 cm) after two weeks caging was around 10-15%, and that of fish escaped through the sorting grid 15-25%. In grid selected herring there was an average of a slightly higher survival in the larger fish groups, but in the codend selected herring no size-dependent long-term mortality was observed. However, the mortality rate among the smallest individuals was higher during the first days after escape. Control fish caught by handline suffered little mortality during a three weeks caging period. It is assumed that the main part of the mortality found in escaping herring can be attributed to the contacts with the trawl. The implications of the results for management purposes are discussed.

1. INTRODUCTION

Minimum mesh size regulations has been imposed in Baltic herring trawl fisheries to enable small fish to escape from nets and grow to larger size. However, few studies assessing the survival rates of herring escaping from a trawl have been conducted so far. Treschev et al. (1975) and Efanov (1981) studied the survival of Baltic herring (*Clupea harengus* L.) escaping from codends of different mesh sizes. According to their experiments, depending on the mesh size, 3-30 % of these fish will die in the following days, the mortality of the smallest "fingerlings" being even higher. On the basis of these results, Efanov (1981) concludes that herring fishery management by mesh size regulation is justified from the point of view of preservation of juveniles.

Recent underwater observations of trawl codends show that herring often strike the netting and collide with each other in a way that obviously will cause skin injury (Suuronen and Millar 1992, Suuronen et al. 1993). Moreover, observations show that already in the rear belly of the trawls especially the smallest herring often hit the meshes and loose scales. These observations and the preliminary survival trials (Suuronen 1991, Suuronen et al. 1992) suggest that under commercial trawling conditions, the survival probability of herring escaping from a codend might not be as high as presented earlier.

A new concept of using rigid grids for sorting undersized fish out of trawls has recently been developed in Norway (e.g. Isaksen et al. 1992). In the survival experiments, the scale loss of mesh selected small haddock was significantly higher than that of the grid sorted fish (Soldal et al. 1991). For selecting an easily injured fish, like herring, out of the trawl, a sorting grid is a potential alternative to the conventional mesh selection. However, knowledge of the survival rates is needed to justify this kind of new technical measures intended to improve selectivity.

This paper describes the techniques used and the results of the survival experiments carried out in 1993 for Baltic herring escaping from a diamond mesh codend and through a rigid sorting grid in a pelagic herring trawl.

2. MATERIAL AND METHODS

2.1 Survey area and fishing trials

Experiments were conducted in May-June 1993 in the Archipelago Sea in the northern Baltic Sea proper (ICES Subdivision 29N), in 35-60 m waters around Gullkronafjärd by using a standard herring midwater trawl (164 meshes x 1600 mm) towed by a stern trawler "Harengus" (300 hp). The headline height of the trawl during towing was 18-20 m. Fishing was conducted at an average towing speed of 3.0 knots (variation 2.8-3.3 knots). The tows were made in the evening and at night at the upper layer of maximum fish concentration (usually at 10-30 m). Due to the short towing times (10 minutes), the catches during the hauls were low (around 50 kg). The catches consisted almost solely of herring.

The experimental 36 mm diamond mesh codend (mesh opening 33-34 mm, twine PA 210/30) had 250 meshes in circumference. The rigid sorting grid was constructed of three rectangular pieces (each 50x80 cm) made of eloxisized aluminium bars (diameter 12 mm). The bar distance was 12 mm. The grid was installed in the front upper panel of the extension piece parallel to the netting (Fig 1).

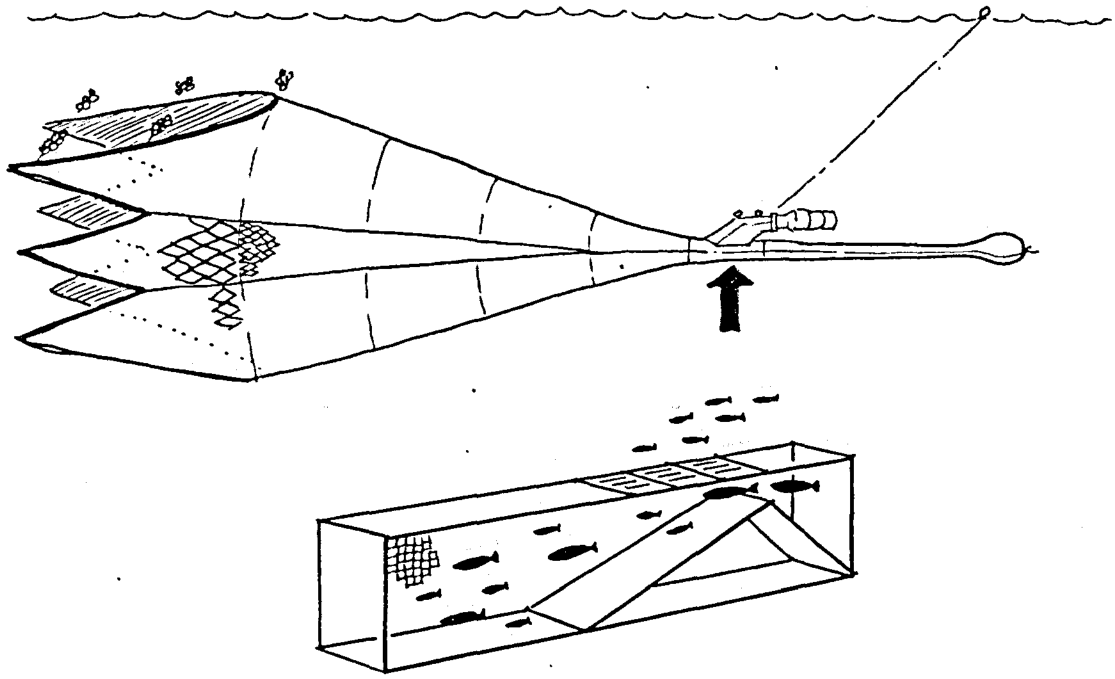

Figure 1. a) The general design of a herring midwater trawl and the position of the rigid sorting grid and the collection bag in the trawl. b) The sorting grid mounted at the front upper panel of the codend extension.

2.2 Survival experiments

The survival of herring escaping from the codend and through the rigid sorting grid was compared. A hooped netting cage (diameter 2 m, length 7 m, volume 20 m^3) was attached to the cover fitted over the codend or the sorting grid (Fig 2A). Fish which escaped from the codend or the sorting grid were guided by the cover aft to the cage. The cover and the cage were made of knotless, square mesh (14 mm stretched) nylon netting except the rearmost panel of the cage which was made of 6 mm stretched netting in order to reduce the water flow through it. During towing, the cover was held off the codend meshes by means of three hoops (diameter 2 m) giving the cover a cylindrical form.

After 10 minutes towing, the cage was remotely released from the trawl and closed (Fig. 2B), and then slowly transported at ½ knot speed in about 5-10 m depth into the large holding cages (Fig. 2C). Transporting time varied from 15 min to 35 min. Underwater observations of the escapees held within the towing cage during transportation revealed that most of these fish swam calmly against the weak flow induced by the cage movement. However, these observations were made at night by using artificial light which may have had affected fish behaviour.

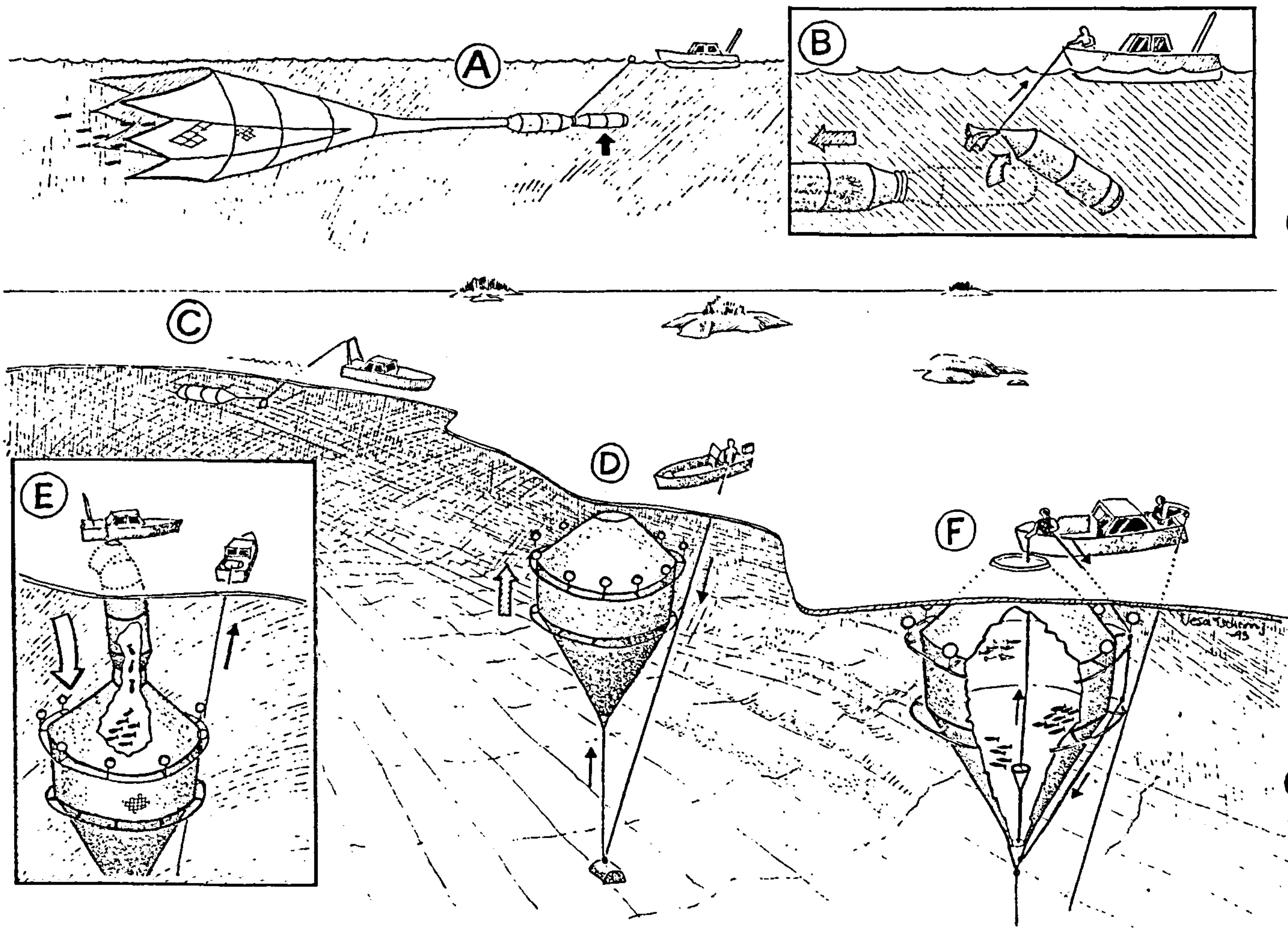

Figure 2. A shematic presentation of the experimental procedures used during towing (A), releasing (B), transporting (C), transferring (D-E) and emptying (F). For further details, see the text.

The 85 m^3 underwater holding cages were made of unimpregnated 14 mm (stretched) knotless nylon square mesh netting, had a diameter of four metres and a total height of 10 metres. The basic design of cage is presented in Figure 2D. Figure 2E shows the technique used when transferring the fish from the towing cage to the large holding cage. The mouths of the cages were connected together by zippers and the whole system was carefully pulled down so that the fish could freely swim from the upper towing cage to the lower holding cage. Then the system was lifted upwards and the upper cage was detached from the large cage which was closed and lowered to the chosen depth. Particular care was taken to avoid additional damage or trauma to the fish during the transferring. Visual observations made from the surface revealed that the fish generally showed no serious panic or attempted escape behaviour during transfer. Occasionally, however, some fish were seen to be caught by the netting folds of the upper cage, but later they swam into the lower cage.

In total, seven cagings were made for fish which had escaped from the trawl, three for the fish escaped from the trawl codend and four for the fish escaped through the sorting grid (Table 1). Usually, two successive hauls were transferred into a holding cage to get enough fish in all size classes and to decrease the variation caused by each single haul. Except one (Grid 1) the duration of the caging period was around two weeks. The depth of the cages was chosen so that the mid-section of the cage was in water of 10°C (±1°C) temperature, which generally was at a depth about 8-12 metres.

Table 1. The date of beginning, the duration and the numbers of herring in the cagings made during the herring survival experiments in May-June 1993. Except for Grid 1, all cagings consisted of two successive trawl hauls.

Cage code	Date	Duration	Numbers of herring
Codend 1	May 19	12 days	761
Codend 2	June 1	15 days	260
Codend 3	June 10	14 days	372
Grid 1	May 18	7 days	165
Grid 2	May 25	15 days	136
Grid 3	May 27	14 days	1094
Grid 4	June 9	14 days	140

Dead fish were removed from the cages 4-8 times during the caging period. Due to occassional bad weather conditions and technical problems, the cages were not visited as regularly as was initially planned. A netting cone mounted down in the cage collected the dead and moribund fish which could then be lifted up to the surface after the cage was first slowly taken up to the surface (Fig. 2F). Underwater observations demonstrated that the cone really did collect all the dead and moribund fish lying on the bottom of the cage without causing any observable harm to the alive. The total body length of the fish was measured to the nearest half centimeter and a rough visual inspection of possible superficial injuries on fish was made. On completion of each survival experiment, the whole cage was lifted to the surface and all dead and alive fish were measured and injuries inspected. The behaviour of fish in the cages were occasionally monitored by the underwater camera.

2.3 Control samples taken by handline

In order to assess the reliability of the caging method, the survival rates of non-trawled herring held in a similar cage were studied. Fish were caught (about 10 m depth) on handlines fitted with barbless hooks. Fish which were hooked cleanly on the lips and showed no signs of physical damage were immediately released into the towing cage lying along the boat. Fish were not touched by hand. In total, 302 fish were caught on June 7-8 by hook and immediately transferred into the large holding cage in the same manner as described in section 2.2., and caged for 3 weeks at a depth of 6-15 m. The fish did not experience the actual transport.

2.4 Towing trials with control fish

In order to test the effects of towing on the escaped herring swimming (and lying) in the towing cage, altogether 782 herring were caught by handline and put into five 20 m^3 towing cages. One of the cages was towed by the trawler at a speed of three knots for 10 minutes and the other for 30 minutes. These, as well as the three non-towed cages, were anchored at a depth of 7-15 metres for 8 to 15 days.

3. RESULTS

3.1 Fish size distribution

The combined length distributions of escaped herring in the caging experiments show that the codend escapees consisted of two size groups, the smaller one-year-old group (7-12 cm) having a mode at 9.5-10 cm length, and the larger size group having a mode at 15 cm (Fig. 3a). In the grid selected group there is no clear peak in the smaller size group and the mode of the larger group is at 14 cm (Fig. 3b). The size distribution of the herring caught by handline is substantially different from that of the escapees, the mean length being around 16-17 cm and the smallest size groups (fish <12 cm) being almost totally absent (Fig. 3c).

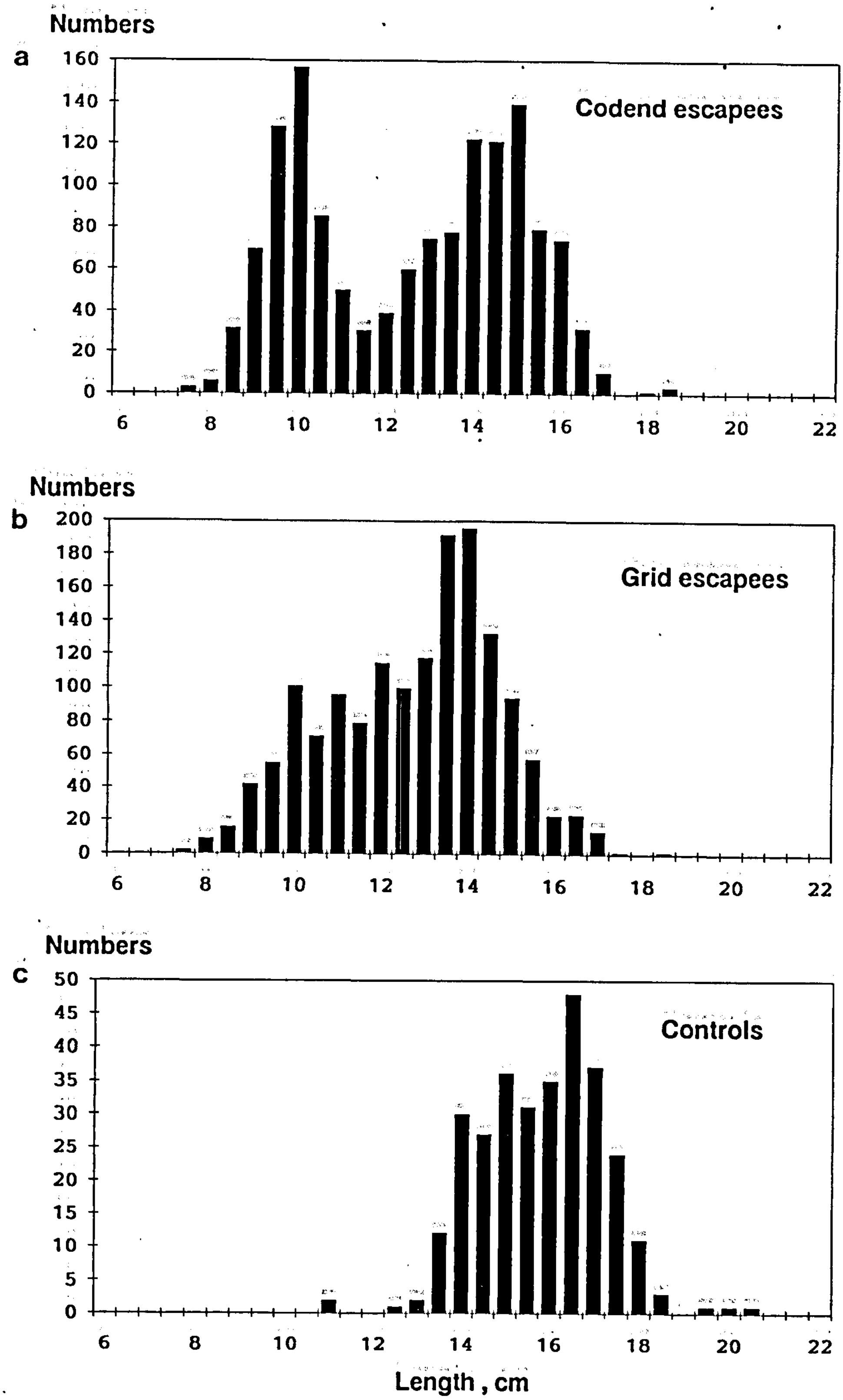

Figure 3. Combined length frequency distributions of herring in the survival experiments. a) codend escapees, b) grid sorted fish and c) control fish caught by the handline (only fish kept in the large holding cage are included).

3.2 Survival rates

Figure 4 shows the mean survival rates of codend and grid selected herring in each single caging. Most of the herring were alive after the first two-three days of caging, the mean survival rates of fish in both selection categories being about 90%. After three or four days, the survival rates substantially dropped. However, when the caging duration exceeded 8-10 days, the survival rates stabilized and almost no mortality was observed after 10-12 days. In all cagings, the survival rate followed a similar pattern. The average survival rate of the codend selected fish after the two weeks caging period was 10-15 % and that of the grid sorted fish 15-25 %. The highest survival rates were encountered in the Grid 3 caging, where the numbers of herring was highest (1094 individuals).

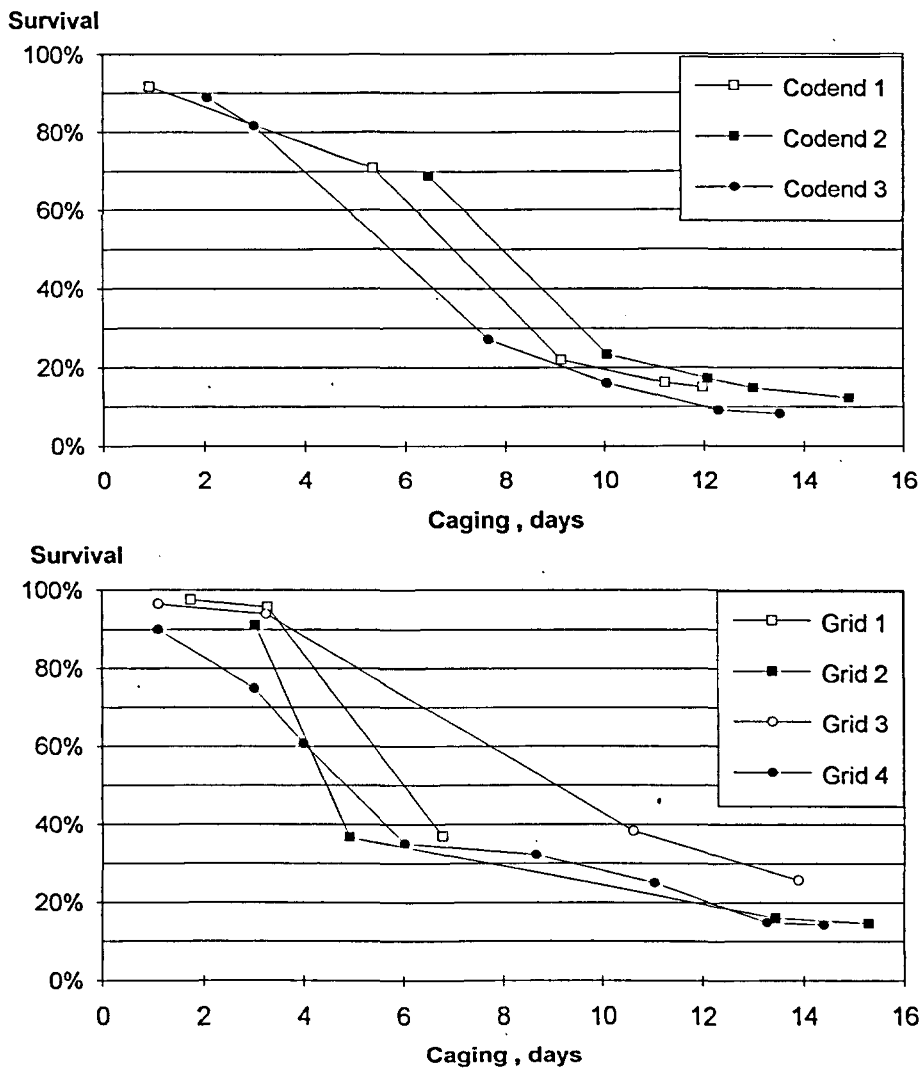

Figure 4. Mean survival rates of herring escaped from the 36 mm diamond mesh codend (upper) and through a sorting grid (lower) in each single caging during the two weeks observation period. Note that the duration of one grid experiment was only seven days.

The survival rate of control fish during the 3 weeks caging period is presented for two size groups (Fig. 5). The average survival rate of herring after two weeks caging was around 90 % and stayed at that level also during the third week. The survival rates of the control fish are clearly at a much higher level than that of codend and grid selected herring. These results suggest that the high mortality rates encountered in codend and grid selected herring is mainly not caused by the caging induced effects (at least in size-groups 13-17 cm).

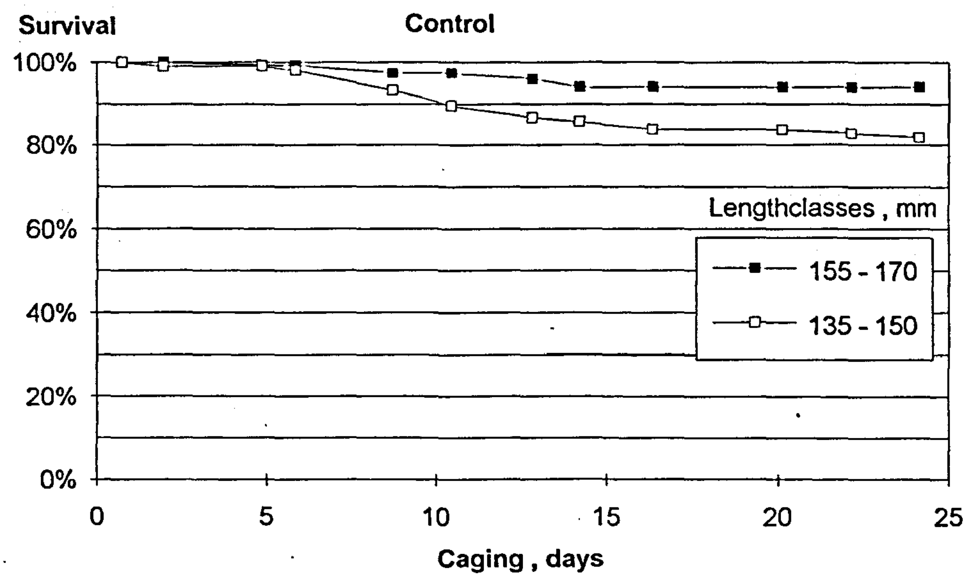

Figure 5. Mean survival rates on handline caught (control) herring in two size groups during the three weeks caging period.

3.3 Effects of fish size on survival

During the first week in cage, the smallest length groups showed a higher mortality rate than the larger herring (Appendixes 1 and 2). However, after two weeks caging, there is generally only a slight evidence of better survival of larger fish. In order to study the relationship between fish size and survival further, the combined mean survival rates in different length groups after two weeks caging were plotted against the fish length (Fig. 6). In the codend escapees there is no clear indication of size dependent mortality. However, in grid selected herring there is a slightly increasing trend in survival rates towards the larger fish groups. For handline caught herring the results show a slightly lower survival rate for the smaller length groups, however, for herring smaller than 13 cm there is a lack of reliable data. On the other hand, the results show no evidence of increased mortality rates in those length classes (14-17 cm) where the fish should have greatest difficulties to swim or wriggle through the codend mesh or the sorting grid.

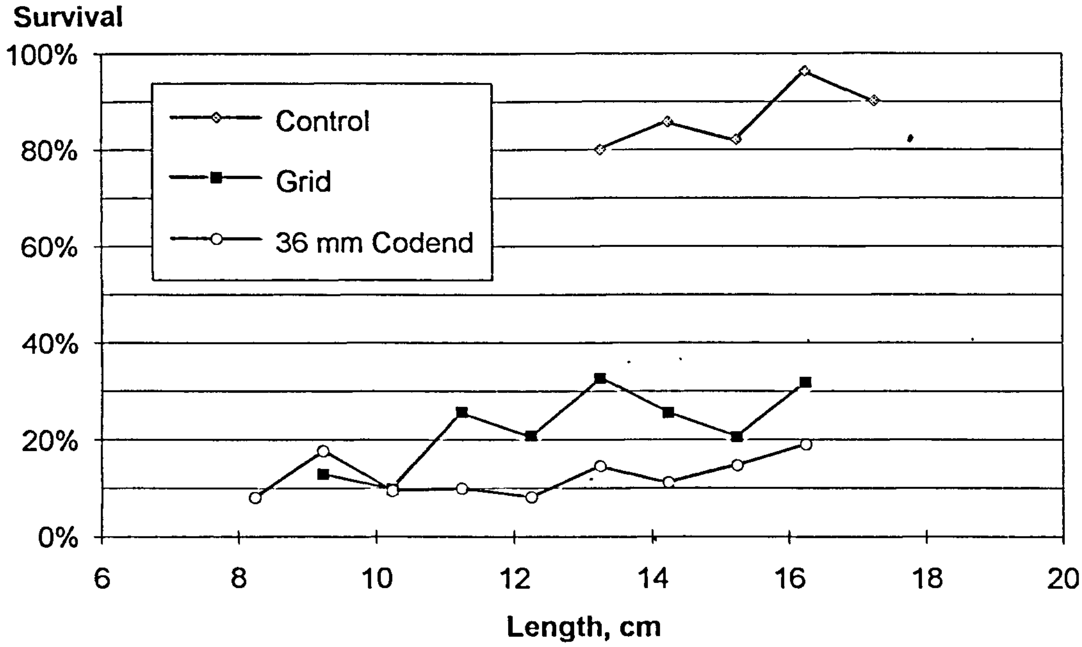

Figure 6. The combined mean survival rates of herring in different length groups in the codend, grid and control groups (after two weeks caging).

3.4 Effect of towing on fish survival

Underwater observations showed that during the survival tows, the escapees swam into the small meshed netting cage and usually soon drifted into rear part of the cage. There the fish, apparently pressed by the water flow, were usually seen lying against the rearmost netting wall (Fig. 7), showing occasionally some restless behaviour. Moreover, when the number of fish in the cage was high, the fish were often lying agaist each other.

Experiments were made to estimate the effects of three knots towing speed on the escaped fish. The survival rate of handline caught herring (length range 13-18 cm) in the three cages which were not towed was 94 %, 98 % and 100 % respectively. In the cage which was towed for 10 minutes, the survival rate was 93 %. Those herring which were towed 30 minutes, suffered a slightly higher mortality, survival rate being 80 %. These preliminary experiments suggest that the towing of herring in the cage during the trawling may have increased the later mortality rates of escaped fish. However, the 10 minutes towing time used in these experiment obviously was not a crucial factor in determining the mortality.

Figure 7. Escaped herring being pressed against the rearest small-meshed netting wall of the towing cage during the trawl tow.

3.5 Fish behaviour and condition during caging

During caging, escapees generally swam calmly around the cage in loose shoals. Some fish were seen swimming lethargically around, often in a head raised attitude and well away from the main shoal, but more often moribund fish were found at the bottom of the cage. White body mucus (fungus?) became evident on many fish on third or fourth day in captivity. Visual examination of the fish removed from the cages showed varying degrees of external injury and decomposition (Fig. 8). The skin of many fish was swollen and had begun to peel away from the underlying tissue, revealing the muscle tissue. These skin damages tended to increase progressively towards the tail. Many fish had sustained tail damages, some of them with the eventual complete loss of the tail. Also, some of the live fish had small, local skin infections, sometimes even red sores on their flanks, especially during the longer caging time. On the contrary to the trawl-caught herring, fish caught by the handline and kept three weeks in captivity without access to surface, were in good condition after the period.

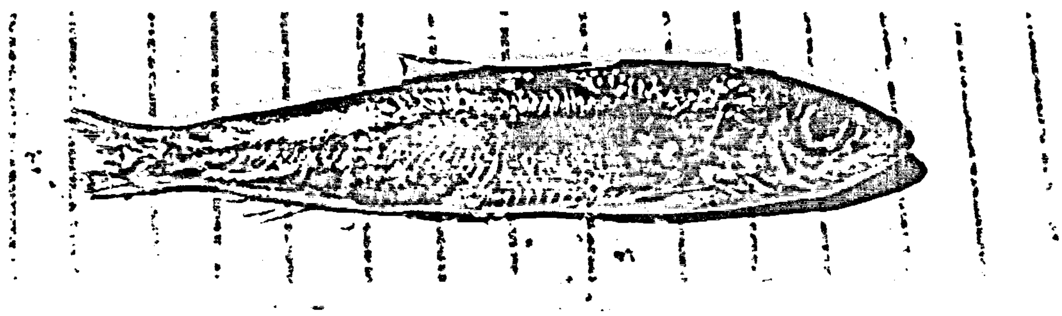

Figure 8. Escapees removed from the cages showed skin injuries and tail damages.

4. DISCUSSION

The results of our study suggest that herring escaping from a pelagic trawl may suffer high long-term mortality. Our results are not consistent with the results obtained by Treschev et al. (1975) and Efanov (1981) who found an average survival rate of 90% for herring escaping from a 32 mm diamond mesh codend. However, caution is needed when comparing the results of fish survival experiments using underwater cages. As pointed out by Main and Sangster (1990, 1991) and Soldal et al. (1993), the results of fish caging experiments may actually indicate mortality rates caused by a set of factors including the capture, escape and the experimental procedure. If the experiment is not carefully planned, it is difficult to draw any clear conclusion of the causes of death. In the earlier survival trials, all the factors likely causing mortality were not studied carefully enough. The present experimental methodology is designed to minimise the uncertainties caused by the method. Nevertheless, it can be estimated that at least 10-20 % of the observed mortality must be ascribed to the experimental procedure.

Moreover, there might be also some unidentified factors which could have biased the survival results of escapees. Being held in cages with other damaged fish may contribute to mortality, possibly through cross-infection. It might also be argued that the recovery of an injured fish is hindered by captivity. The numbers of fish in the cage can be an important factor in determining the mortality, particularly for pelagic fish having a shoaling behaviour habit. To eliminate any variables in environmental conditions and experimental procedure in the further tests, the control fish should be handled equally with the experimental fish. This would provide a more solid basis for intepreting mortalities.

Nevertheless, it can be assumed that the main part of the mortality found in this study is caused by the trawl induced effects, likely by the loss of mucus and scales due to contacts with the trawl netting and subsequent skin infections. Heavy skin abrasion of herring would certainly result from frequent and vigorous contacts with the netting walls of the trawl as has been seen during the numerous underwater observations (Suuronen & Millar 1992, Suuronen et al. 1993). Also the muscular exhaustion caused by the herding of the trawl may play a role in mortality, in particular within the smallest size groups (Treschev et al. 1975, Efanov 1981, Borisov & Efanov 1981). Skin injuries and scale losses have been shown to cause high mortality of the Norwegian spring spawning herring as well as of mackerel when they have been in close contact with netting (Misund & Beltestad 1992, Lockwood et al. 1983). Skin damage obviously facilitates invasion of infective agents and makes fish more susceptible to disease, which may increase mortality. Damage to skin may also be expected to cause disturbance to the normal osmotic balance. On the other hand, in a scale-loss tests, Hay et al.. (1986) found that even a severe loss of scales is not necessarily lethal for a Pacific herring.

The present survival trials were made with very short trawl tows and at low catch rates. Previous underwater observations have shown that in a codend with higher catch, the blocking of the meshes by the fish bulk may prevent the eventual escape and prolong the time fish spend in the codend, and increase the likelihood of superficial damage by abrasion. Consequently, it is likely, that under commercial catch rates, the survival possibilities of herring escaping from a trawl codend will be lower than during our survival trials. In the future tests, the conditions under experiments should be comparable to those situations experienced by the fish during commercial trawling practice. This requires a development of a more advanced methodology.

Previous underwater observations have clearly demonstrated that the passage of herring is easier through a sorting grid than through an open codend mesh (Suuronen 1991, Suuronen et al. 1993). Observations revealed no indications of scale loss on herring when escaping through a sorting grid. Therefore, higher survival rates were expected for fish which have escaped through the grid than through the codend meshes. As a matter of fact, the results obtained indicate a slightly higher survival in grid-selected fish. However, the absolute survival level of grid sorted fish was still low, even if we take in the account the likely extra mortality caused the experimental procedure. This suggest that other factors than the escape process itself may play an important role in determining the survival. Underwater observations have shown that especially the smallest herring are forced to swim far over the limits of their stamina and they are often scraping along and striking the meshes inside the trawl (Suuronen and Millar 1992, Suuronen et al. 1993). It is obvious that these fish actually are driven by the water flow. It might be expected that especially the smallest herring suffer serious injuries before they reach the codend and eventually escape. Therefore, survival rates should increase if the fish could escape before they swim into the codend. Consequently, selection should take place as front in the trawl as possible, likely in the rear belly of the trawl. A rigid sorting device mounted in the rear belly of a pelagic trawl might be one solution. However, on the basis of the trials made so far (Suuronen et al. 1993), a practical and effective sorting device, performing well also under commercial fishing conditions, might be very difficult to find.

The preliminary survival experiments conducted in 1991 and 1992 suggested that the survival of herring escaping from a trawl is strongly related to fish size, the highest mortality occurring in the smallest size classes (Suuronen 1991, Suuronen et al. 1992). Similar observations were also made by Treschev et al. (1975), Borisov and Efanov (1981) and Efanov (1981). The results of the present study, however, indicate that the survival of herring is not as size-dependent as suggested earlier. The obvious reason for the different results of our previous experiments might be the fact that in the earlier trials we restricted caging duration to 5-8 days generally and we could not remove the dead fish from the cage during the experiment. According to the present trials, a period of at least 10-12 days is required to test the long-term survival of escaped herring.

5. CONCLUSIONS

Fishery management by mesh size regulation is based on the assumption that majority of escaping fish survive and become part of the future spawning and exploitable biomass. Our experiments on herring do not support this assumption. The escaping herring seem to suffer high mortality. Consequently, the background and justification of using the minimum mesh size regulations in herring trawl fishery in order to protect small herring should be reviewed. Moreover, the high mortality of escaping herring represents an unaccounted element of fishing mortality which will also reduce the accuracy of stock assessments dependent upon commercial catch statistics.

Acknowledgements

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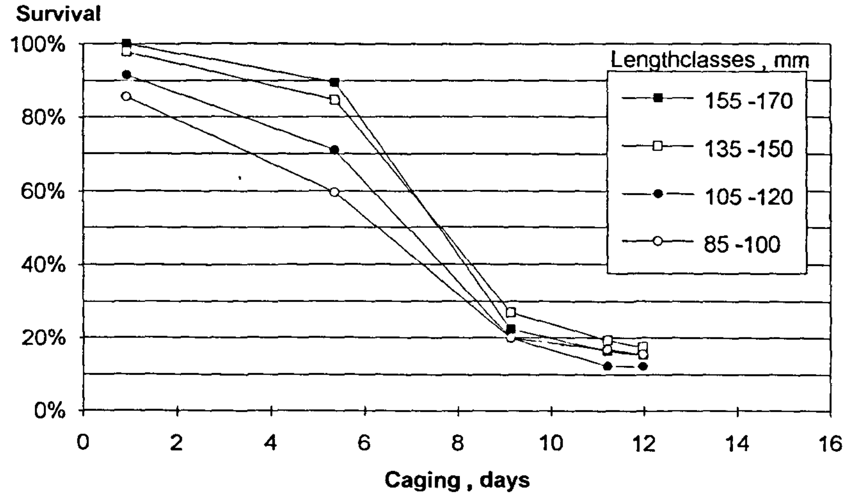
Appendix 1. The survival rate of codend escapees in four different length classes in each individual cagings.



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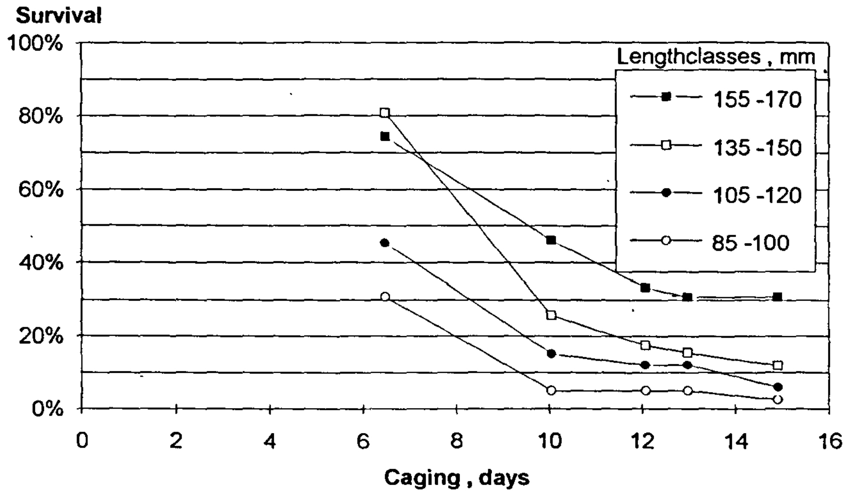

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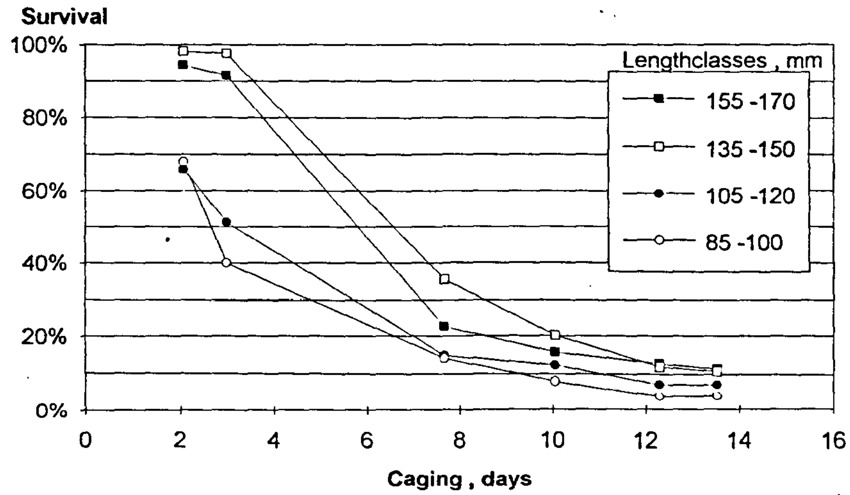
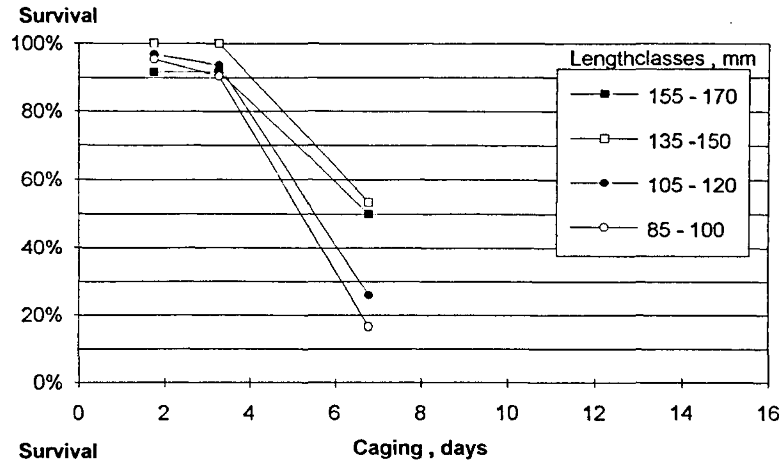


Codend 3

Appendix 2. The survival rate of grid sorted herring in four different length classes in each individual cagings.



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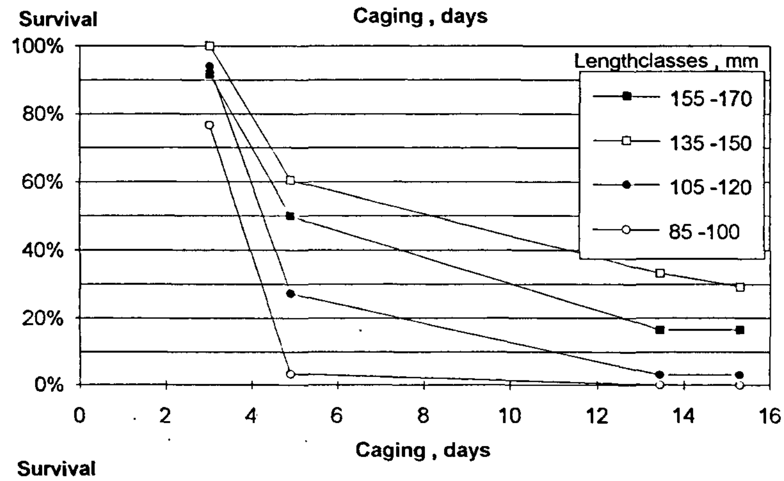

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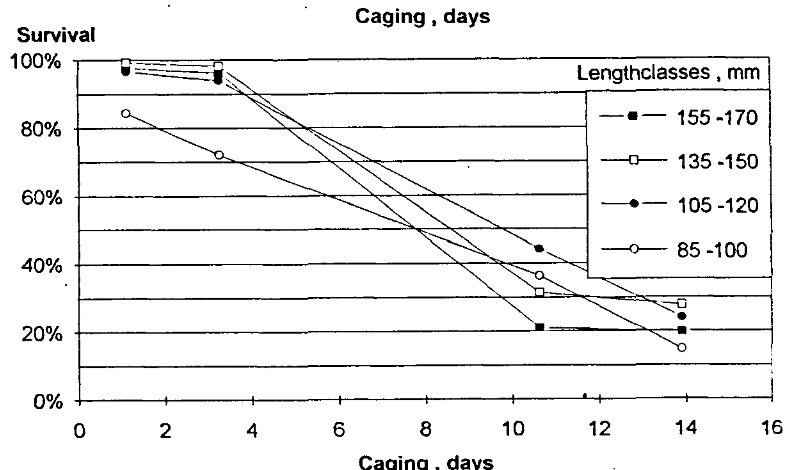

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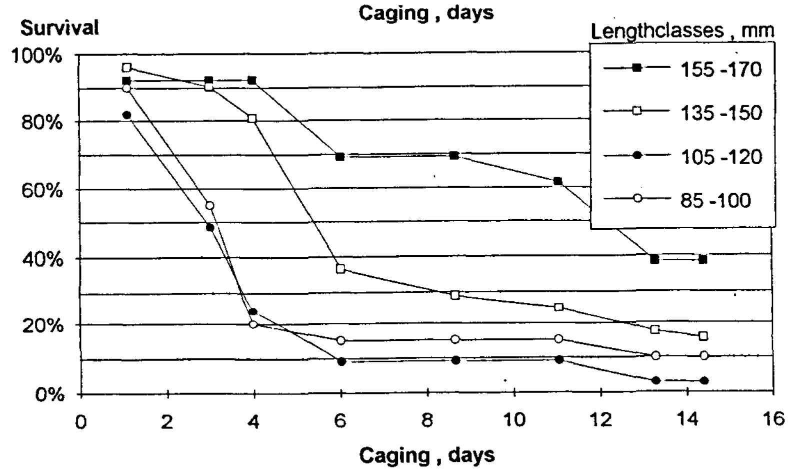

Grid 4