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On the survival of plaice and sole discards in the otter trawl and beam trawl fisheries in the North Sea.

by

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ABSTRACT.

This paper summarizes the results of survival experiments with plaice and sole discards caught by commercial beam trawl vessels and a research vessel fishing with an otter trawl, and with soles that escaped through the meshes in covered cod-end experiments. In the commercial beam trawl fishery the survival of both plaice and sole discards is estimated to be less than 10%. The survival of soles that escape through the meshes is estimated at 60%. The survival of discards is negatively affected by the catching process. During the catching process mortality is caused through the action of the tickler chains and the injuries imposed during the stay in the net. Under present day commercial practice the processing of the catch on deck hardly reduce the survival of discards.

INTRODUCTION.

Trawl fisheries for flatfish are generally mixed fisheries with a variety of target species. In the North Sea the fishery for flatfish is mainly carried out with beam trawl. This gear contributes to more than 75% of the total international landings of sole, plaice, turbot and brill. The catches in this fishery are characterized by a substantial bycatch of various species of fish and evertebrates and a considerable catch of dead material such as stones, fossil shells, sand, wood, garbage etc. A decreasing part of the total international catch is taken by otter trawls. Both gears use tickler chains in front of the ground rope, to stimulate the fish to leave the sea bottom, so that it can be caught by the net.

Most beam trawl vessels in the southern North Sea fish for sole with the legal minimum mesh size of 80 mm. At this mesh size the 50% retention length of sole is 26 cm (Rijnsdorp et al., 1981; van Beek et al., 1982) and a substantial part of the undersized soles (<24 cm)

can escape through the meshes. In other commercial flatfish species, such as plaice, turbot and brill, which have a much lower retention length than sole, the numbers escaping through the meshes are negligible. Consequently discard rates in plaice are much higher than in sole (den Veen and Rodenburg, 1971; de Veen et al., 1975). Also dab, which is commercially less attractive, is discarded in great quantities, but turbot and brill are discarded in low quantities as these species do not recruit to the fishing grounds before reaching the minimum landing size (de Veen et al., 1975).

In order to assess the possible effects of technical management measures as mesh size regulations, closed areas etc, to improve the exploitation of plaice and sole, knowledge on the survival of plaice and sole discards is paramount. As only in sole substantial numbers escape through the meshes also the survival of these soles is important to evaluate the effect of an increase in mesh size. Research on the survival of discards focussed on plaice (Garstang, 1905; Borley, 1909; de Veen et al, 1975; Kelle, 1976). Information on the survival of soles escaping through the meshes is lacking.

Garstang (1905) concluded that the viability of plaice discards was good directly after catching, but that high mortality occurred during their stay on deck. Borley (1909) showed experimentally that the survival of plaice discards was mainly affected by the haul duration, the presence of Medusae and the conditions on deck. Hot sunshine especially caused a substantial mortality. The survival of plaice discards in the otter trawl fishery was estimated to be below 10% in most cases. In the beam trawl fishery the condition of plaice discards was better and in short hauls under favorable conditions half or even three-quarters of the catch survived (Borley, 1909). The survival of plaice and sole discards in the shrimp fishery, employing a light beam trawl, was estimated at about 50-60%, but was reduced by 20-30% when shaking sieves were used to sort the catch (Kelle, 1976). The survival of discards in the present flatfish fishery is expected to have changed with the introduction heavy beam trawlers in the early 1960's. In comparison with the otter trawl fishery in the beginning of the century the fishing speed increased to about 5 knots in the late 1970's and to about 7 knots at present, and the weight of the gear, including a high number of tickler chains, increased to about 10 ton at present. Also the time that discards are exposed on deck was reduced by the introduction of conveyer belts in the early 1980's to improve the working conditions for the crew.

The present paper summarizes the results of the survival experiments with plaice and sole discards carried out between 1972 and 1982 on board of commercial beam trawl vessels and a research vessel in the North Sea. Additional experiments were carried out to estimate the survival of soles that escaped through the meshes.

METHODS.

Survival experiments with plaice and sole discards were carried out on board of commercial beam trawl vessels operating under normal commercial conditions. Additional experiments were carried out with plaice caught with an otter trawl on 'RV' Tridens. Discards were sorted from the catch and their condition was classified according the scale given in Table.1. From each condition class a random sample was taken and placed in a plastic holding tank of 40 - 60 cm and 12 cm height with a maximum of 15 fish per tank. Stacks of holding tanks were placed in a wooden frame and supplied with continuous flow of fresh sea water (Fig.1). On board of 'RV' Tridens the stacks of holding tanks were placed in a large basin of sea water, which was continuously refreshed. If conditions permitted, the experiments were checked every 12 hours and the dead fish were recorded and removed. The experiment was terminated when all fish died or at the end of the cruise. In a number of cases the experiment had to be stopped prematurely due to the weather conditions.

Survival experiments were initiated with discards from catches that varied according the gear used (otter or beam trawl), the number of chains in front of the net, haul duration (between 15 min and 120 min), fishing speed, total catch and the HP of the vessel. The technical information of the experiments is summarized in Table 2. The length range of the discards used in the survival experiments was 20-30 cm in plaice and 20-28 cm in sole.

In addition the effect of the increasing processing speed on the survival of plaice discards was examined by comparing discard mortality of plaice processed by the traditional method and of plaice discards processed using a sorting device. With this method the catch is dumped in a container, which after being filled with water, supplies a conveyer belt along which the catch is sorted and processed. Discards and other unwanted material stays on the conveyer belt and is transported back to sea immediately. In the sorting device used in the presents experiments the catch was kept wet throughout their stay on the conveyer belt.

The overall survival of the discards (S_i) at experimental time i was calculated from the proportion (P_j) of each class (j = 1 .. 4) in the total discard catch and the measured survival (S_i) according to

$$S_i = \Sigma P_j \times S_i$$

The survival of soles was estimated in conjunction with mesh selection experiments on commercial beam trawlers using the covered cod-end technique (Rijnsdorp et al., 1981; van Beek et al., 1982). The survival experiments were set up in pairs; experiment A with soles from the cod-end and experiment B with soles hat escaped through the meshes of the cod-end and retained in the cod-end cover. The length range was 18-25 cm. Further experimental procedures were identical to plaice discards.

RESULTS

Discards.

The condition of discards was classified according to the damage in four classes A to D. The frequency of occurrence is shown in Figure 2. The condition of plaice discards is poorer in the beam trawl experiments as compared to the otter trawl. In both plaice and sole the condition decreases with increasing haul duration. Figure 3 shows that the survival curves of the four condition classes correspond to the subjective classification of condition, but the survival curves of the same condition class differ between otter and beam trawl and between different haul durations. Obviously not all injuries which may cause mortality are visible.

In each experiment the discard survival was estimated from the mortality rate in each condition class and the proportion of this condition class in the total catch. The results, given in Table 3 and 4, show that in general the mortality rate was highest in the first 24 or 48 hours and levelled off afterwards. However, in some experiments substantial mortality started only after 24 hours.

The overall survival was estimated as the survival after an experimental time of 84 h. After this time mortality apparently ceased or was very low (Table 3 and 4). In the few experiments stopped prematurely after 60 or 72 hours, the percentage surviving discards was extrapolated assuming a similar mortality rate between 60 - 72 hours and 72 - 84 hours as in the other experiments. In Table 3 and 4 the extrapolated values are indicated in bold characters. Overall discard survival was estimated between 0% and 50% in plaice and 4% and 40% in sole. In plaice the survival was lower in beam trawl discards compared to otter trawl discards (Mann-Whitney, $P<0.01$). In beam trawl discards the survival was higher in hauls of 60 minutes compared to hauls of 120 minutes, the relation being only significant in sole ($R_s = -0.829$, n= 11, $P<0.05$) and marginally significant in plaice ($R_s = -0.438$, n= 19,

0.05<P<0.10). In otter trawl discards of plaice the opposite was observed, but the number of discards of 60 min hauls was rather small.The method of processing the catch on board did not significantly the survival of discards both in 60 minutes hauls and 120 minutes hauls (Mann-Whitney).

Soles that escaped through the meshes.

A number of experiments was carried out to estimate the survival of soles that escaped through the meshes and were collected in the cod-end cover. The survival of soles originating from the cover is slightly higher compared to those from the cod-end. The higher survival in the cover is however consistent in all experiments, except in experiment 81. The results, given in Table 5 and Fig. 6, show that survival decreased with increasing haul duration and that substantial survival occurred at short hauls of 15 minutes. As the decreased survival at higher haul durations may be caused by the prolonged stay of the escaped soles in the cod-end cover, the extrapolated survival at a haul duration of 0 minutes is about 60% and gives credible estimate of the survival of soles that escape through the meshes.

DISCUSSION.

Several factors may contribute to the mortality of discards, which occur during the process of catching and the sorting process of the catch on board. The experiments presented in this paper allow a first evaluation of the main factors influencing the discard mortality in the modern beam trawl fishery.

With regard to the catching process itself, the survival experiments were initiated with discards, which differed with respect to the number of tickler chains, total catch and haul duration. Because the number of experiments was relatively small only a qualitative evaluation is possible. In both sole and plaice discards the survival was negatively correlated with haul duration, indicating that mortality agents working in the cod-end dominate over the effects of the tickler chains. The tickler chains will affect the survival of discards irrespective the haul duration. A maximum estimate of the contribution of the tickler chains to the discard mortality of sole is given by the extrapolated survival of the discards and of soles which escaped through the meshes at 0 minutes, respectively about 50% and 60%. When compared to the survival of about 25% in 60 minutes hauls and 10% in 120 minutes hauls, it can be concluded that besides the possible effect of the tickler chains also duration of the stay in the cod-end substantially contribute to the mortality. In the present experiments haul duration and the total weight of the catch are correlated and therefore it is not possible to disentangle the contribution of haul duration and total catch weight.

The main injuries of discards, which can be observed macroscopically, are the loss of scales and mucus, and haemorrhages. The latter only appear as dark patches on the blind side of the body several days after catching. It is thought that these injuries are mainly caused by the scraping and pressing of the various objects in the cod-end such as starfish, stones, shells, sand and pieces of wood.

The higher survival of plaice discards in the otter trawl experiments and the reported high vitality of plaice in the historic investigations (Garstang, 1905), might indicate that fishing speed is probably an important factor which amplifies the mechanical damage inflicted during during the stay in the cod-end. Other factors that may contribute to the mortality of discards are depressurization (Feathers and Knable, 1983) and muscular fatigue (Parker et al. 1959, Beamish, 1966). The range of water depth of the main fishing grounds in the southern North Sea are 10 - 50 m, so discards will experience a fall in hydrostatic pressure of about 1 - 5 atmosphere. As plaice and sole do not have a swim bladder the effect of depressurization will be relatively small in comparison with e.g. gadoids. As these factors generally will cause a

quick death (Parker et al. 1959, Beamish, 1966; Feathers and Knable, 1983) their effect will be included in the mortality estimates from our experiments.

Once on deck the discards are subjected to mechanical damage from sorting of the catch, and to temperature differences, sunshine and desiccation (see also Borley, 1909, Kelle, 1976). In a number of plaice experiments the catch was not dumped on deck and sorted by hand, but was processed more quickly by using a conveyer belt on which the catch was kept wet continuously. Nowadays, the majority of the modern beam trawl fleet is equipped with such a device. Comparison of the survival of plaice discards processed by hand and with the conveyer belt showed a higher survival in the latter at haul durations of 60 minutes. Other things being equal, this indicates that the processing on deck actually can affect the mortality of discards and that the quick processing under continuous supply of water gives a slightly better survival. The negative effect on the survival of discards of a long handling time on board was also observed by Garstang (1905), Borley (1909) and Neilson et al. (1989). However, in the present day beam trawl fishery, employing haul durations of 120 min, the processing of the catch on deck did not measurable affected the survival of plaice discards as the condition of plaice discards was already badly reduced during the catching process itself. In contrast to the shrimp fishery, where the survival rate of about 50% in plaice and sole discards was substantially reduced when the catch was processed using a shaking sieve (Kelle, 1976). Rotating sieves and specially designed shaking sieves were shown to improve the survival rate of plaice discards (Boddeke, 1989).

The survival of discards that were classified as either condition A or B (not or only slightly damaged fish) showed a wide variability. This variability is certainly related to the fact that the condition classification is subjective, but also various experimental conditions, in particular temperature and direct sunlight are thought to play an important role as well (see Kelle, 1976). The present experiments however do not allow a further analysis of these factors.

In practice the haul duration of commercial beam trawlers is in the order of 120 minutes unless the ground is very rough and a high amount of bycatch necessitate a reduction in haul duration (de Veen et al., 1975). Therefore, the survival of both plaice and sole discards can be estimated at 10%. This percentage is a maximum estimate, because it is likely that in the survival experiments not all fish died within the experimental period of 84 hours on which the above survival estimate is based. The survivors are possibly those fish captured in the last minutes of the haul.

To estimate the survival of soles that escaped through the meshes, experiments were initiated with fish collected from the cod-end cover. Survival rate decreased with increasing haul duration and the extrapolated survival at a haul duration of 0 min. was estimated at about 60%. The mortality of soles escaping through the net may be caused by the injures inflicted by the catching process (tickler chains, duration of stay in the net) and during their escape through the meshes. Sole can escape through relatively narrow meshes by bending in the dorso-ventral axis and crawling through the mesh. When hauling in the net many sole half way in crawling through the meshes are visible ("stekers"). Visual inspection of these "stekers" show some loss of scales. Inspection of the experimental soles that died also showed the loss of scales and haemorrhages as well. The estimated survival of about 60% therefore seems a reasonable estimate. This implies that the gain of an increase in mesh size will be lower than generally calculated assuming that all soles that escaped through the meshes survived.

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Table 1 Classification of the condition of flatfish according to the damage.

A:	Fish lively, no visible signs of loss of scales or mucus.
B:	Fish less lively, some scratches and some scales missing, mucus layer affected up to 20%, some small red spots on the blind side.
C:	Fish lethargic, several scratches and some areas without scales, mucus layer affected up to 50%, several red spots on the blind side.
D:	Fish lethargic, head reddish, many scratches and areas without scales, mucus layer affected for more than 50%, blind side with many red spots and haemorrhages.

Table 2. Technical information on the survival experiments.

Exp Num	HP	Haul Duration	Total Catch cod-end	x 40 kg cover	Number chains	Depth (m)	Date
Plaice: Otter trawl (fishing speed = 3.5 knots)							
1A	600	20	5.0	-	6	25-30	Nov 1972
2A	600	60	5.5	-	6	25-30	
2B	600	60	5.5	-	6	25-30	
2C	600	60	5.8	-	6	25-30	
3A	600	100	5.8	-	6	25-30	
3B	600	100	8.8	-	6	25-30	
5	600	105	8.0	-	6	20-30	Feb 1975
6	600	105	8.0	-	6	20-30	
Plaice: Beam trawl (fishing speed = 5.0-5.5 knots)							
19	1200	60	5	-	8	20-30	Nov-Dec 1979
21	1200	60	5	-	15	30-50	
27	1200	120	10	-	24	20-30	
31	1200	120	17	-	24	30-50	
36	1015	110	4	-	24	20-25	May-Jun 1981
38	1015	60	1	-	8	20-25	
41	1235	120	22	-	24	20-30	Sep 1982
42	1235	120	22	-	24	20-30	
47	1235	60	11	-	15	30-40	Dec 1982
49	1235	120	23	-	24	30-40	
Plaice: Beam trawl, deck-processing with conveyer belt (fishing speed = 5.0-5.5 knots)							
20	1200	60	5	-	15	20-30	Nov-Dec 1979
22	1200	60	5	-	15	30-50	
28	1200	120	10	-	15	20-30	
32	1200	120	17	-	15	30-50	
43	1235	60	12	-	15	20-30	Oct 1982
44	1235	120	22	-	24	20-30	
45	1235	120	22	-	15	20-30	
46	1235	60	11	-	24	30-40	
48	1235	120	23	-	15	30-40	Dec 1982
Sole: Beam trawl (fishing speed = 5.0-5.5 knots)							
56)[1]	1015	120	7.5	5.5	13	~30	Aug 1981
58)[1]	1015	120	7.5	5.5	13	~30	
61	1015	15	2.0	0.5	12	15-20	
63	1015	60	4.0	1.0	12	15-20	
65	1015	120	7.0	4.0	12	15-20	Aug-Sep 1981
73	1310	30	3.0	0.5	16	20-30	
75	1310	60	4.0	1.5	16	20-30	
77	1310	90	6.0	2.5	16	20-30	
79	1310	60	3.5	3.5	16	20-30	
81	1310	120	7.0	7.0	16	20-30	
83	1310	15	0.5	0.5	16	20-30	

)[1] Irish Sea

Table 3. Plaice: survival in percentage of discards (18-27 cm) and the number of fish at the start of each experiment (N). The **bold** figures are extrapolated values estimated under the assumption that the mortality between 60 and 72 and between 72 and 84 hours was equal to the average mortality at this time in the other experiments. The figures in *italic* are interpolations by eye between the last observation at 36 h and the final at 96 h. The experiment number corresponds to the information given in Table 1.

Exp. Num.	N	Time interval (hours) after start of experiment								
		0	12	24	36	48	60	72	84	96
Otter trawl: 20 min										
1A	40	100.0	100.0	87.8	62.6	35.2	32.5	22.8	22.8	-
Otter trawl: 60 min										
2A	46	100.0	81.6	64.2	50.2	47.6	44.4	40.7	31.6	-
2B	17	100.0	20.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2C	15	100.0	95.3	64.2	8.8	0.0	0.0	0.0	0.0	0.0
Otter trawl: >=100 min										
3A	30	100.0	71.6	66.9	52.3	37.4	31.8	16.9	15.7	-
3B	28	100.0	82.2	64.4	53.5	45.4	41.2	**35.0**	**32.2**	-
5	63	100.0	100.0	96.6	90.3	86.9	79.0	67.7	54.1	-
6	41	100.0	82.5	74.9	57.6	47.2	35.1	33.0	30.8	-
Beam trawl: 60 min										
19	45	100.0	75.6	56.7	37.8	31.1	22.2	17.8	**14.3**	-
21	79	100.0	93.7	87.3	68.4	49.4	36.7	**29.9**	**24.0**	-
38	112	100.0	54.4	45.6	36.5	21.5	16.2	11.6	5.7	5.7
47	44	100.0	100.0	93.2	56.8	*38.0*	*28.0*	*20.0*	*15.0*	11.4
Beam trawl: 120 min										
27	48	100.0	85.4	74.0	62.5	43.8	31.3	27.1	**21.8**	-
31	73	100.0	65.8	31.5	17.8	11.0	6.8	5.5	**4.4**	-
36	111	100.0	59.1	44.0	21.5	4.8	3.4	2.9	2.1	-
41	131	100.0	21.3	13.0	7.0	5.4	4.6	4.6	4.6	-
42	135	100.0	25.9	20.0	16.3	14.9	12.6	9.6	9.6	-
49	88	100.0	87.5	65.9	52.3	*40.0*	*32.0*	*25.0*	*21.0*	19.3
Beam trawl: 60 min and deck-processing with a conveyer belt										
20	49	100.0	98.0	91.9	85.7	77.6	57.1	46.9	**37.7**	-
22	67	100.0	99.3	98.5	83.6	76.1	73.1	**59.6**	**47.9**	-
43	270	100.0	45.0	16.6	11.5	8.5	8.0	6.1	**4.9**	-
46	43	100.0	100.0	90.7	58.1	*40.0*	*25.0*	*19.0*	*14.0*	11.6
Beam trawl: 120 min and deck-processing with a conveyer belt										
28	50	100.0	78.0	61.0	44.0	38.0	30.0	26.0	**20.9**	-
32	72	100.0	70.9	41.7	27.8	16.7	15.3	**12.5**	**10.0**	-
44	270	100.0	24.6	12.1	8.5	6.1	5.8	4.4	**3.5**	-
45	270	100.0	24.0	11.1	7.7	5.3	5.0	3.8	**3.0**	-
48	94	100.0	89.4	55.3	35.1	*26.0*	*20.0*	*16.0*	*14.0*	12.8

Table 4. Sole: survival in percentage of discards (20-28 cm) and the number of soles at the start of each experiment (N). The **bold** figures are extrapolated values estimated under the assumption that the mortality between 72 and 84 hours was equal to the average mortality at this time in the other experiments. The experiment number corresponds to the information given in Table 1.

Exp. Num.	N	Time interval (hours) after start of experiment								
		0	12	24	36	48	60	72	84	96
Beam trawl: 15-30 min										
61	43	100.0	69.9	60.0	42.1	35.9	22.2	19.4	19.4	-
73	109	100.0	89.9	69.6	54.3	48.3	40.2	39.4	36.9	-
83	45	100.0	95.6	82.2	75.6	73.3	66.7	66.7	**66.7**	-
Beam trawl: 60-90 min										
63	43	100.0	60.6	50.1	31.5	27.8	16.1	15.1	15.1	-
75	109	100.0	86.7	60.9	42.3	38.7	33.3	32.3	29.3	-
77	109	100.0	85.4	54.7	35.7	32.5	28.6	27.7	25.3	-
79	90	100.0	62.7	27.2	24.5	18.9	18.4	18.0	15.2	15.2
Beam trawl: 120 min										
56	72	100.0	8.4	6.7	5.8	5.3	5.3	5.2	4.3	3.0
58	25	100.0	34.5	28.2	18.2	8.2	5.8	5.8	**4.9**	-
65	43	100.0	53.8	43.6	24.0	22.5	12.0	11.6	11.6	-
81	90	100.0	55.7	17.3	14.6	9.4	9.2	9.2	6.5	6.5

Table 5. Sole: survival of soles that escaped through the meshes and were collected in the cod-end cover.

Exp. Num.	N	Time interval (hours) after start of experiment								
		0	12	24	36	48	60	72	84	96
Beam trawl: 15-30 min										
61	72	100.0	87.0	67.8	56.4	50.8	40.2	40.2	40.2	-
73	95	100.0	73.5	58.8	49.3	46.0	43.0	43.0	40.7	-
83	75	100.0	92.0	82.7	78.7	77.3	76.0	73.3	73.3	-
Beam trawl: 60-90 min										
63	72	100.0	82.6	63.0	51.0	44.6	30.6	30.6	30.6	-
75	95	100.0	67.9	50.8	41.4	38.3	35.2	35.2	33.5	-
77	95	100.0	63.4	44.5	34.9	32.7	29.3	29.3	28.5	-
79	90	100.0	66.5	33.0	30.4	25.0	24.0	23.4	20.9	20.9
Beam trawl: 120 min										
56	104	100.0	19.6	15.9	15.0	12.6	12.1	12.1	9.7	9.7
58	69	100.0	43.1	36.9	27.8	18.7	16.2	8.2	**6.7**	-
65	72	100.0	76.4	56.0	41.5	32.2	13.0	13.0	13.0	-
81	90	100.0	54.5	15.8	13.0	7.8	7.7	7.7	5.0	5.0

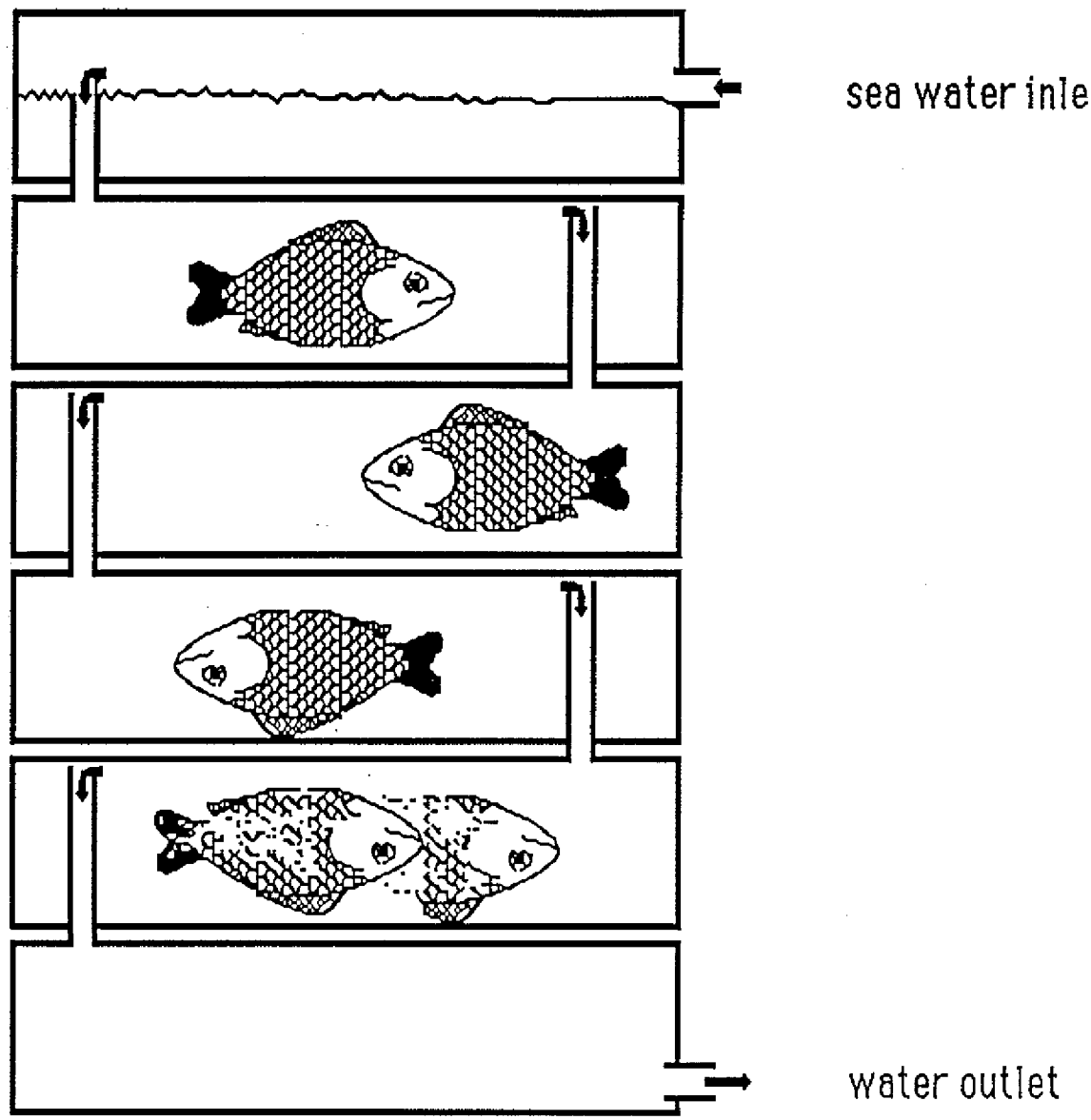

Fig. 1 Experimental set up to estimate the survival of flatfish discards. In each tank upto 15 flatfish were placed depending on the fish size. A continuous flow of water was pumped through the tanks.

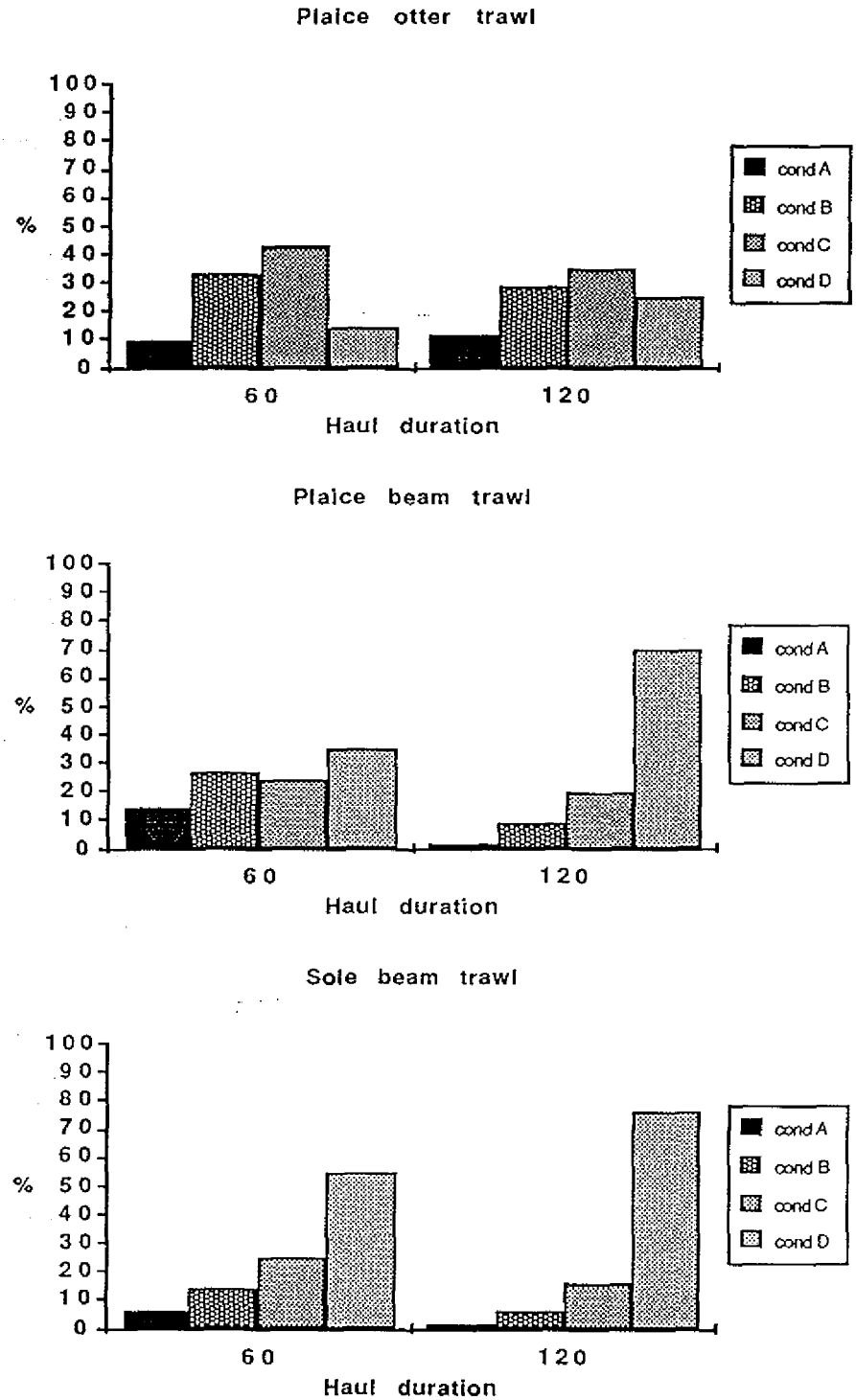

Fig. 2 Frequency distribution of the condition of plaice discards in otter and beam trawl catches and of of sole discards in beam trawl catches for haul durations of 60 and 120 minutes separately. Damage increases from condition A to D.

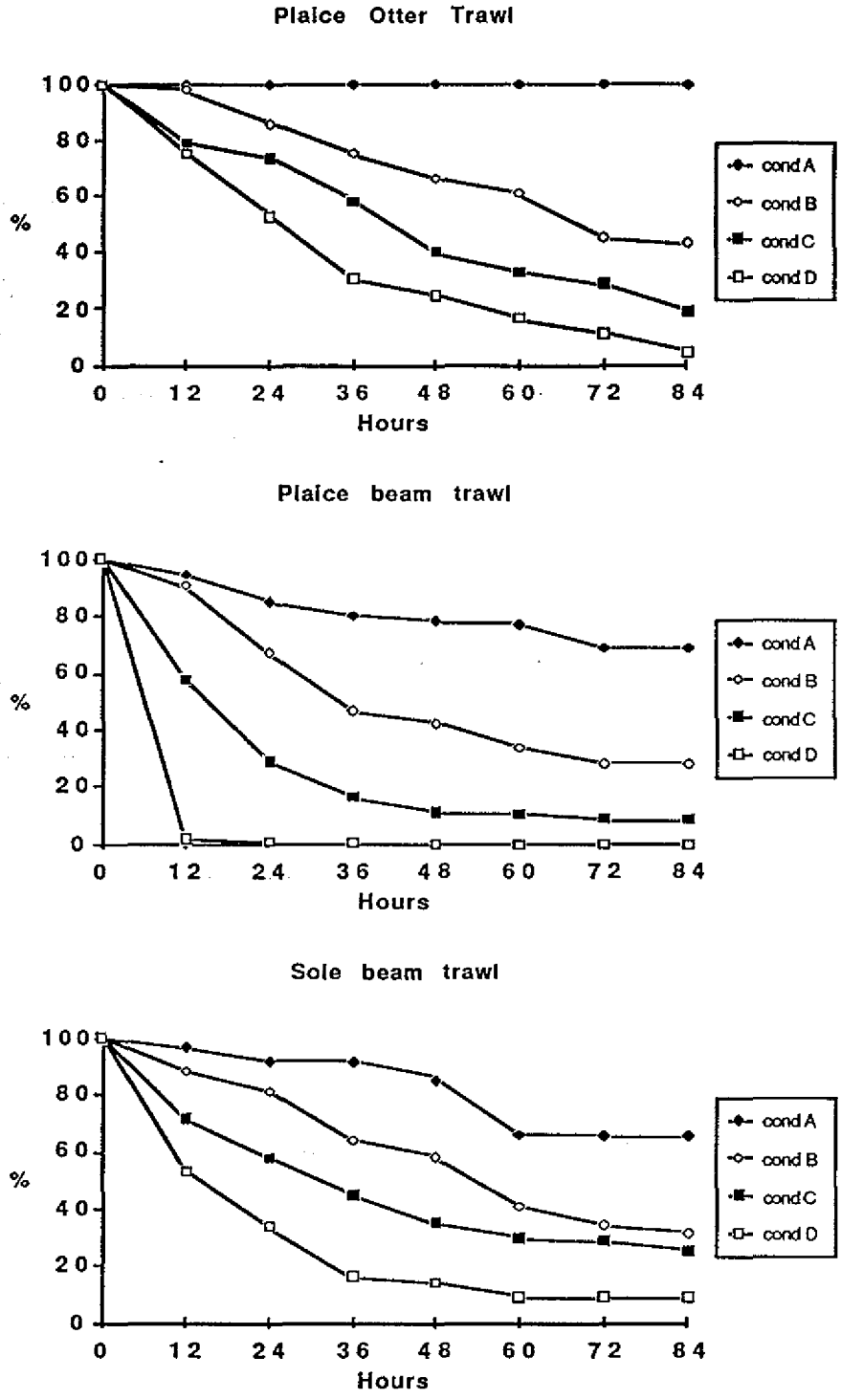

Fig. 3 Survival in relation with experimental time of discards condition classes A - D. The results are given for plaice discards from otter and beam trawl catches and for sole discards from beam trawl catches.

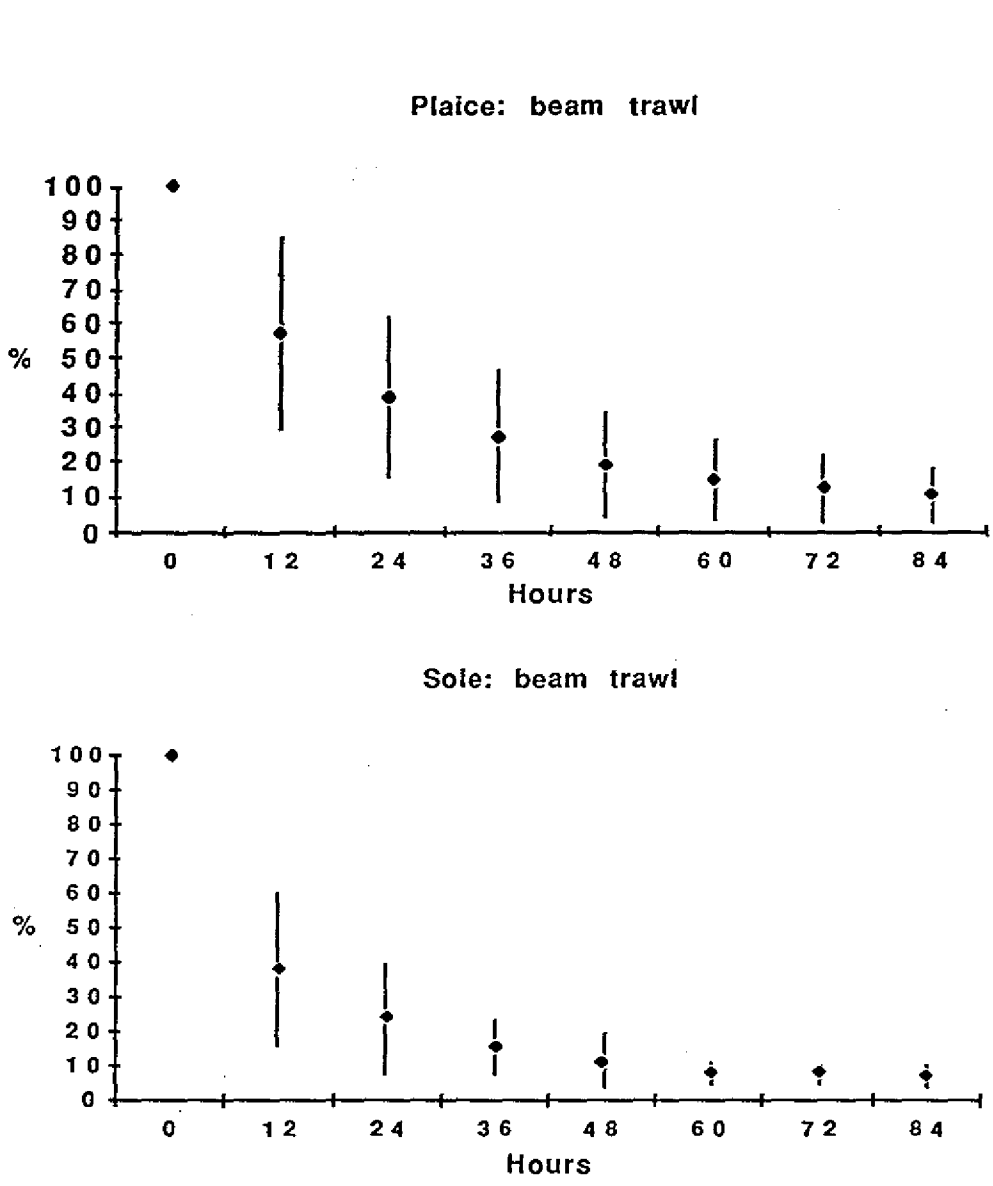

Fig. 4 Survival of plaice and sole discards in relation with the experimental time. The vertical bars show the standard deviations around the mean. The mortality mainly occurs in the first 48 hours.

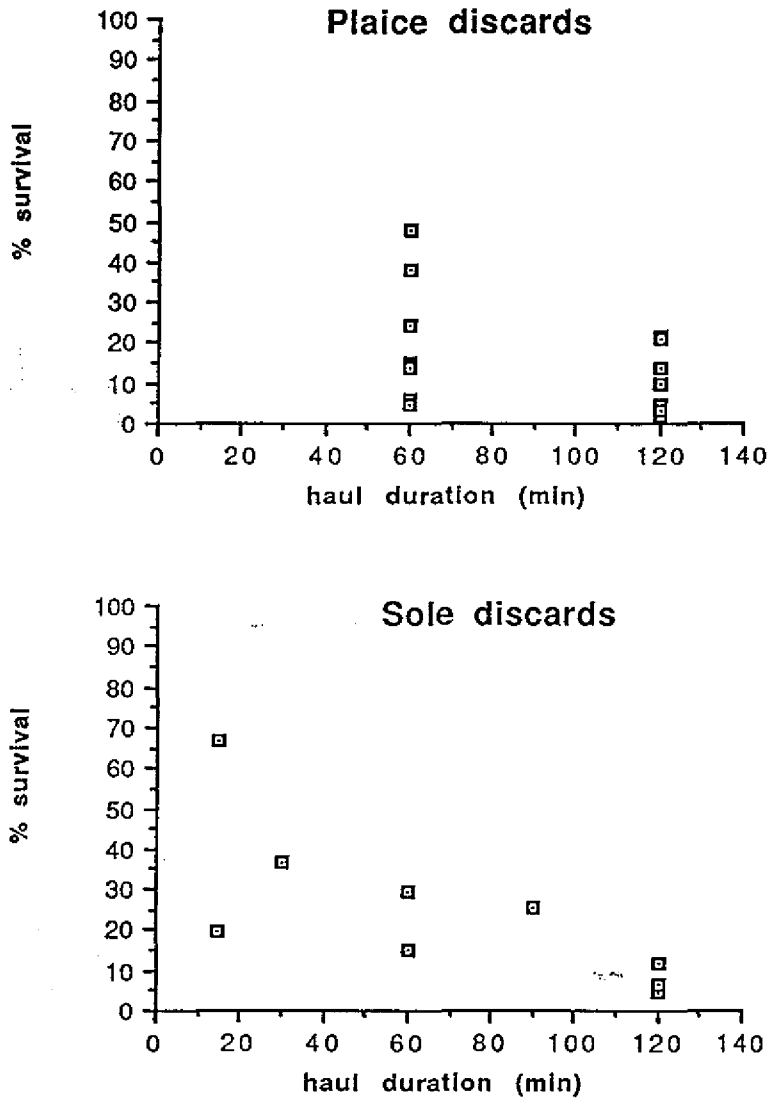

Fig. 5 Survival after 84 h in experimental tanks in relation with haul duration in plaice and sole discards.

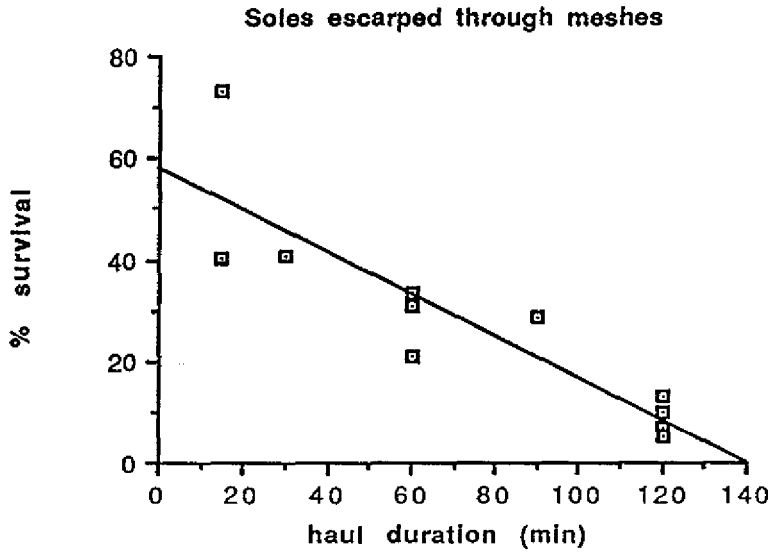

Fig. 6 Survival of sole that escaped through the meshes and were collected in a cod-end cover in relation to haul duration. The survival at haul duration of 0 min is estimated at 60%.