INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA

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EC-PROJECT TE-2-554 "IMPROVED SELECTIVITY OF FISHING GEARS IN THE NORTH SEA FISHERY - BEAM TRAWLING"

by

B. van Marlen*, R. Fonteyne, H. Polet** & K. Arkley***

* Netherlands Institute for Fisheries Research
P.O. Box 68, 1970 AB IJmuiden, The Netherlands

** Rijksstation voor Zeevisserij
Ankerstraat 1, B-8400 Ostend Belgium

*** Sea Fish Industry Authority - Sea Fish Technology
Sea Fish House, St. Andrew's Dock
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SUMMARY

EEC-Project TE-2-554 "Improved Selectivity of Fishing Gears in the North Sea Fishery - Beam Trawling" aimed at reducing the by-catch of round fish in beam trawls, whilst maintaining the catches of flatfish species. The project was set up in four phases. Phase 1 consisted of a literature search to identify the present state of knowledge in this field, and inventories of the various beam trawl fleets to determine the most representative gear types and sizes. Model experiments were done in Phase 2 in the SEAFISH flume tank at Hull, UK. A selection has been made among the most promising technical solutions for further study at full-scale. A large diamond mesh and a hexagonal rope-mesh top panel in a 12m V-net were observed in March 1992, and a square mesh top panel, a cut-away or reduced top panel and a combination of this panel with a square mesh window were observed in a "round" net (R-net) on a commercial Belgian trawler in cooperation with RV "Isis". A first series of catch comparisons was also made during the last mentioned observation trip (Phase 3). Further comparative fishing experiments at sea were carried out in April 1992 on RV "Tridens" by RIVO-DLO, in September-October 1992 on a commercial vessel by RVZ, and in December 1992 by SEAFISH, also on a commercial vessel (Phase 4). The research showed potential for improving the species selectivity of beam trawls, particularly for whiting and haddock, without affecting the flatfish catches to a great extent. The results for cod were somewhat less consistent in different periods of the year. Constructions that seem effective are large mesh top panels in the 12m V-nets, and a reduced top panel with a square mesh window in a 9-10m round net. A follow-up project has been proposed as it was felt that more data are needed for definite conclusions and the gear modifications are still to be optimized.

1. INTRODUCTION

The objective of this project was to develop a species selective beam trawl with special emphasis on a substantial decrease of the discards of young round fish while maintaining the level of flatfish catches, and hence the level of income for beam trawl fishermen. Beam trawls are very efficient fishing gears for catching flatfish species and are particularly used in the Netherlands, Belgium and the United Kingdom. The Dutch fleet consists of some 500 beam trawlers, the Belgian fleet of some 170 vessels and the fleet of the United Kingdom of approximately 100 vessels. Both tickler chains and chain mats are used to scare the flatfish off the seabed. Although flatfish are the target species of beam trawlers a considerable amount of demersal round fish is also caught by this category of fishing vessels. In view of the poor condition of the round fish stocks, and consequently the low round fish quota, this means a serious competition to the otter trawl fleet which depends largely on round fish. In 1988-1989 the various Ministries of Agriculture imposed important limitations (quantity and minimum landing size) on round fish landings by beam trawlers, especially for cod. However, these measures initiated a serious discard problem. Experiments with otter trawls and seine nets using square mesh codends have shown improved selectivity for round fish compared to the traditional diamond shaped meshes (Robertson and Stewart, 1988). Belgian experiments conducted in 1988 with square mesh codends in the coastal beam trawl fishery showed no changes in the selective properties of the codend for sole (Fonteyne and M'Rabet, 1992). A Canadian study on American plaice and flounder showed that square meshes were less selective than diamond meshes (Walsh *et al.*, 1992). New codend configurations for beam trawls based on the application of square meshes or a combination of square and diamond meshes were believed to improve the chances of escapement for young round fish without affecting the catches of the target flatfish species. Changes to the dimensions of the codends could result in meshes opened better, and hence lead to improved escape opportunities of small round fish. The project described in this paper was carried out as a cooperation between the Netherlands Institute for Fisheries Research (abbreviated RIVO-DLO), the Sea Fish Industry Authority (SEAFISH) of Hull, UK and the Fisheries Research Station (RVZ) of Ostend, Belgium.

2. MATERIALS AND METHODS

2.1 Project outline

The project was set up in four phases, starting from problem orientation and generating possible technical solutions to working out the most feasible solutions through a selection from model tests and direct observation at sea. Comparative fishing trials were done on the most promising options. The sequence of events was carefully chosen to maximize the chances for success. It was decided at an early stage that RIVO-DLO would investigate a 12m V-net rigged with tickler chains, and both RVZ and SEAFISH a 9m-10m beam trawl rigged with a chain mat. These types were found to be most representative for the beam trawl fleets in the various countries. Table 3 gives a timing of the main activities for the four phases.

2.2 Gears tested

Figures 1-8 depict all the gear configurations tested in the project by the three institutes. Table 2 summarises the configurations tested at model scale, and Tables 3, 4, 5, and 6 all the configurations tested at full-scale at sea. A few options originated during the work at sea and were not studied at model scale before. All modifications tried at sea were relatively simple in construction.

2.3 Model tests

Model tests at scale 1:5 revealed valuable insights in the shape and performance of several designs of more selective gears. The tests were done in October and November 1991 in the SEAFISH flume tank at Hull. A total of 40 different variations were studied of the configurations listed in Table 2. The final choice of options tested at sea is given in Tables 3-6 for all three institutes with the number of hauls carried out in comparative fishing experiments. Some of the options were not studied at model scale but originated during the sea-trials, such as the square mesh windows in the round nets. This gives a good indication of the flexibility maintained and the creativity of the research workers, which is an essential ingredient in research.

The model studies showed, that all configurations were feasible from a technical point of view. In some cases the design could be improved after observing the shape of the model. In the case of square mesh top panels, it was found that a better net shape could be obtained by taking less bars in depth than based on the calculated length of the original diamond mesh panel. The reason for this is that the opening of the mesh in diamond mesh net panels varies from the front to the rear part of the net and that in square mesh netting the elongation is longer as the load is taken only by half of the mesh bars. A square mesh window in the lower panel did not seem adequate for the V-net, as this gear has a good deal of slack netting in the lower panel just behind the footrope. For this reason this option was not investigated at model scale. The round nets have less slack netting and a more gradual tapered shape. A square mesh window in the lower panel opens meshes further in this part, but problems may arise just behind the footrope, where a bulbous shape easily emerges.

Good net shapes can result from adding a large mesh top panel or a hexagonal rope-mesh panel. For the oblique separator panel the correct height of the panel headline in relation to the top panel of the net may be critical to obtain good results. When the separator panel takes most tension, the top panel can be relatively slack, ensuring maximum escape openings at the junction.

The effect on the gear drag of the various configurations was generally not very profound. The biggest differences were found when the headline attachment was lowered in the V-net, although it should be realised, that the drag measurements in the tank may deviate substantially from reality, as bottom friction forces are not modelled correctly. For this gear inserting large mesh panels in the top also had a clear effect on the drag of the model. At full-scale the differences turned out to be smaller. The drag of a separator panel did not seem excessively large.

2.4 Direct observations

Direct observations were planned before the actual comparative fishing trials in order to check the geometry and catchability of the standard and experimental gears. Initial checks on the gear shape were done during the model studies, that revealed ways to improve the first designs. It was decided to split the observations into two periods, aimed at the two different types of gear i.e. the V-net and the round-net. The 12m V-nets were operated from RV "Tridens" in March 1992, the Belgian 10m beam trawls from a commercial vessel in cooperation with RV "Isis" in May 1992 (See Table 1). The big diamond mesh and hexagonal mesh top panels were filmed using the Remotely Operated Vehicle (ROV) on several hauls and slight modifications were introduced and checked later. For instance the lengths of the hexagonal mesh bars were corrected after the first observation. It was difficult to view a large part of the gear due to the sand clouds generated by the beam shoes and tickler chains. The tunnel and codend could not be observed at all. In spite of limitations resulting from bad weather and poor visibility, the impression was that all modifications observed were ready for the actual selectivity experiments. In addition a net with a square mesh top panel and the standard net were observed.

The beam trawler Z-50 "Tijl" from Zeebrugge was chartered in May 1992 for the observations on 9m beam trawls. The vessel has an engine power of 900hp, a length over all of 30.0m and a gross tonnage of 181.93gt. The underwater observations were made with RIVO's towed underwater vehicle operated from the Dutch RV "Isis". Fishing took place in the North Sea, mainly on grounds south to west of the Dogger Bank (ICES area IV_b). The bottom consisted of hard sand with stones and boulders. The depth varied from 25 to 60m. The average tow duration was 2.5 hours, fishing speed was 4.5 to 5 knots. The experimental gears were fished from the port side, and the vessel's standard control gear at the starboard side. Two mesh sizes were used in the standard net: 17cm in the front part and 12cm in the rear part. All gears were rigged with identical chain mats, flip-up ropes, bobbin gears and 90mm codends. As fishermen have often reported a decrease in round fish catches when the headline of the beam trawl is lowered, a number of hauls were made with the headline attached about halfway up the trawl shoe height (35cm above the sole plate instead of 60cm). Few fish reactions were observed with the standard gear. A square mesh panel did have a good shape when the headline was fixed to the beam. When detached more mesh distortion occurred. Bottom contact deteriorated when lowering the headline to a point closer to the shoe plate. The first design of a reduced panel did not seem to be effective as fish was taken over by the net after being hit by the chain mat before any reaction could take place. A second design cut deeper and wider proved to be more effective on haddock although no fish reactions were filmed. The general observation that fish is overtaken by the trawl before they can react led to the design of a square mesh window in the aft part of the net. The shape could be observed and was found adequate. Also some fish were seen to escape through the window.

2.5 Comparative fishing trials

The comparative fishing trials were both done on a research vessel and on chartered commercial vessels depending on availability and circumstances. All experimental gears were tested against standard non-modified control nets. Sets of paired data were obtained in this manner. Both nets were checked in fishing performance regularly to avoid bias.

Catches were compared during the first series of trials on the 9m beam trawls on the Belgian charter Z-50 "Tijl" in cooperation with RV "Isis". The square mesh top panel (mesh size 15 cm) released up to 75% whiting and 29% haddock. Cutting a large escape opening in the top panel behind the beam slightly affected the haddock catches (-15%), but the results were better for day-time hauls (-46%). The cod catches could be reduced by inserting a square mesh window (13cm bar length) in front of the codend. The number of cod caught dropped by 23%. The square mesh window seemed to be more effective at night with a cod catch decrease of 41%. This device was also effective for whiting. Their number decreased by 60%. With the current designs marketable fish as well as undersized fish were affected. It should be noted that these successful reductions were only partly duplicated in the second series of experiments in September-October 1992 (Table 10 and Table 11).

The selectivity trials with 12m, V-type beam trawls were conducted on RV "Tridens" in April 1992 on fishing grounds in the North Sea. Three experimental beam trawl configurations were tested on parallel tows against a standard net. All fishing was done at nighttime between 16.00 pm and 10.30 am in order to increase the chance of catching cod and whiting. The tow duration was approximately 2.5 hours at speeds of 6-7 knots. In case of large catches a sample of one basket was taken from the conveyor belt, and all fish herein counted and multiplied by the total number of baskets in the catch for port and starboard. The length of each fish in a sample was measured by hand and length-frequency distributions determined. The catch weight of sole was estimated from the contents of each basket (full = 40 kg, Table 8). The numbers of fish caught for each experimental gear and for the standard gear are given in the Table 9 with calculated percentages difference, and mean lengths and standard deviation of length.

Fewer cod and whiting are caught in the trawls with large meshes or hexagonal meshes in the top panel. Catches of whiting can be reduced to about 50% in numbers by using these large meshes. During the nighttime hauls of the last week a reduction of some 50% in cod was found for the experimental net with the very large diamond meshes compared to the standard net. The data for both species are accurate, as no sub-samples were taken and all fish countend and measured.

Plaice and sole catches were hardly affected by the larger openings in the top panel if compared by weight, both for the hexagonal mesh and big diamond mesh top panels. In numbers more variety was found. Sometimes more fish were caught, sometimes fewer in the experimental gears. No significant effect was found on the mean length of flatfish caught. In other words size selectivity has not been not improved. More research is recommended, although flatfish catches seemed more or less maintained to existing levels. Sole data were fairly accurate. In most cases no sub-samples were taken, while when this was the case the samples were large (*i.e.* a split in two halves). Plaice data are subject to small samples due to large catches with inaccuracies in multiplication. The experimental large mesh panels did not provide any difficulties in gear handling. A noticeable decrease in drag for these gears as might be expected was not found. Material savings are to be expected using such large mesh top panels.

Based on the conclusions of the first set of trials six experimental configurations for a species selective beam trawl were tested during two seatrips on the commercial vessel Z-50 "Tijl" in September and October 1992. The catch comparisons from the first series of trials showed that a square mesh top panel, a reduced top panel and a square mesh window were promising devices to improve round fish selectivity. The six configurations have been applied to a 9m beam trawl equipped with a chain mat. Configurations 1 and 2 were already tested in May 1992.

The beam trawler Z-50 "Tijl" from Zeebrugge was chartered again for two sea trips in September and October 1992. The fishing experiments were carried out in the North Sea, on grounds south to west of the Indefatigable bank, on Flamborough Head and Markham's Hole. Various bottom types were fished, ranging from soft sand to rough stony grounds. The depth varied from 20m to 65m. The average tow duration was 2.5 hours and fishing speed was 4 to 5 knots. All gears were rigged with identical chain mats, flip-up ropes, bobbin gears and 80mm codends. The catch consisted mainly of plaice and cod. Lemon sole, sole, haddock and whiting were caught in smaller quantities and not in every haul. For each configuration in Table 1 the length distribution of each species was determined. Fish lengths were measured to the cm below. The results of the experiments are given in Tables 10 and 11. The latter shows some low numbers of fish, that cast doubt on any conclusions. For these, percentages difference have been omitted.

Good results were obtained with the reduced top panel with square mesh window (13cm bar length) for haddock with a catch reduction of 41%. Day-time hauls show an even better selection with 57% of the fish escaping. However, the good results obtained with this configuration for cod in May 1992 were not confirmed. This time the experimental net caught 3% more cod, instead of substantially less. Splitting-up day and night hauls showed that the experimental gear caught 25% more cod during day-time and 7% less cod during night-time. The experimental net also caught 5% more flatfish than the standard gear. This may have been caused by a somewhat higher fishing efficiency of the port side of the vessel.

Catches of cod were only 6% lower with the square mesh top panel. Contrary to the square mesh windows fixed in the rear part of the net there was no difference in escape rate between day- and night-hauls. No haddock were caught but for whiting the catch in the experimental gear was reduced by 30%, with a much better selection during day-time (-59%). The plaice catches were the same for both nets. For sole, 5% of the fish, mainly undersized, escaped from the experimental gear.

The reduced square mesh top panel was the most effective in releasing haddock and whiting, although one should bear in mind that the numbers caught were rather low. The catches were reduced by respectively 57% and 48%, showing again the effectiveness of an escape opening in the top panel for these species. However, in spite of the enlarged escape route, this configuration caught 3% more cod than the standard gear. Again there was only very little difference between day- and night-hauls. Plaice was only caught in small quantities with no differences between the two gears.

The square mesh window with 13cm bar length caught 18% fewer cod than the standard net. The selection seems to be higher at night (-27%). No haddock or whiting were caught. As for configuration 1, 6% more flatfish were caught by the experimental net.

Compared a bar length of 13cm the number of cod that escaped from the square mesh window with 10cm bar length decreased from 18 to 12%. Contrary to the other configurations with a square mesh window, more cod escaped during day-time hauls. The numbers of haddock caught decreased by 22%. The release was again more effective at day-time (-44%). The experimental gear showed a 20% higher plaice catch.

The number of round fish caught during the hauls with the combined square mesh window with 10 and 13 cm bar length was low, which makes it difficult to draw firm conclusions. The reduction in cod catches was 6%. As in the reduced top panel the day-time hauls show the unreasonable result of 21% higher cod catches in the experimental net. At night 22% of the cod catch was released by the experimental net. 39% of the haddock were released through the window. The number of plaice caught by the experimental gear was 9% higher.

In December 1992 the Brixham registered Beam trawler, MFV "Zuiderkruis" (BM-246) was chartered by SEAFISH to carry out comparative fishing trials. MFV "Zuiderkruis" is an ex-Dutch vessel of traditional design (26.34m in length) currently operating out of Aberdeen on the North East coast of Scotland. The main target species in this fishery were: plaice *(Pleuronectes platessa)*, monkfish *(Lophius piscatorius)*, and lemon sole *(Microstomus kitt)*.

One of the two otherwise identical beam gears was modified by inserting a square mesh panel in the top sheet of the net just ahead of the codend section of the gear. The panel was positioned in the top panel of the net ahead of the codend, seven meshes up from the codend joining round, and one mesh in from the selvedge at the bottom edge. It was set in to the back net of the trawl at a horizontal joining rate of two diamond meshes to one square mesh bar on the panel and longitudinally at a rate of one diamond mesh to one bar on the panel. During the following six days 40 paired hauls were carried out in which the catches from the standard gear were compared with those from the modified, square mesh panel gear. The catches of plaice, lemon sole, cod and haddock were all quantified haul by haul and fish length data collected for each species for later analysis. Of the 40 hauls completed 20 pairs were conducted with the panel in the starboard net and 20 with the panel swapped over to the port net. By changing the panel from side to side, any variations in the fishing performance of the two sides of the gears could be allowed for.

The results obtained during the recent sea trials onboard MFV "Zuiderkruis" are summarised in Table 12. For plaice the starboard gear caught more fish compared to the net fitted with the square mesh panel. The difference in numbers was relatively small (214). After breaking the catch down into marketable and discarded fish, the results showed an increase in discard levels of 13% (57 fish) by the square mesh panel net and also a marketable loss of 9% (271) fish compared to the standard net. For lemon sole the standard gear caught more fish but in comparison with the square mesh panel it caught more undersized soles, *i.e.* the square mesh panel side reduced discards by 17% (12 fish) but this difference was represented by very few fish.

This side also showed a loss of marketable fish of 8% (62 fish). For the round fish species of cod and haddock, again the standard gear caught more than the experimental side. However, in the case of cod this was a difference of only one fish. For haddock the difference was 81 fish. For cod there was an increase in discards by the panel net of 8%, but the numbers were very low (12 fish). For haddock a 7% reduction in discards was achieved but again the numbers were very low (7 fish). There was a loss of marketable fish from the panel net for both cod and haddock species of 4% (13 fish) and 12% (74 fish) respectively. Here again the low numbers involved mean that these figures would not be statistically significant.

3. ECONOMIC ASSESSMENT

The data gathered during the selectivity experiments were used to appraise the effects of catch differences on the economics of fishing. Fish is sorted in length groups or grades in various countries, for which prices per unit of weight are recorded. As fish was recorded by length a conversion from length to weight is required. Coull *et. al.*, 1989 gave such relationships for 88 species of fish in the North Atlantic. By comparing the numbers of fish caught in each grade and multiplying this number with an average price per grade, income differences between the experimental and the standard gear can be determined.

The data of the three sets for hauls 1-21, hauls 22-43 and hauls 44-57 for the 12m V-nets were tabulated in several grades used for the four species: sole, plaice, whiting and cod in The Netherlands. The cumulative totals for the experimental net (port) and the standard net (starboard) were taken within the length limits of each grade. Fish numbers on the bounderies were equally split between the lower and the higher grade. This split was done so that decimal fractions were avoided in case of odd numbers, by rounding to the lower natural number for the lower grade, and to the higher natural number for the higher grade. The exact duration of tow for each species was calculated. The total numbers of fish, converted weights, and values were then calculated in a spreadsheet, and these numbers converted to income per trawling hour. Also the difference between both gears was calculated. A similar procedure was followed for the Belgian data. These intermediate results are not given here.

The amounts were used to appraise the effect for an average Dutch 2000hp and a Belgian 900hp beam trawler over a whole year. The assumptions are given in Table 13 with some derived quantities. Based on the figures obtained in the selectivity experiments the total losses, an estimate of the total income, and percentages loss in income over a year were calculated for the experimental nets. The results are given in Table 14. The percentage loss ranges from 3 - 16% for the 2000hp trawler, which gives an indication of the overall effect. Fishermen will not accept losses of such magnitude without trying to find ways to compensate for it. The important message is that the effect on particularly flatfish catches should be investigated in more detail, and it is recommended to obtain more data to be certain of the effect before defining any legislation on new gear designs.

The conclusion for the Belgian data is that the introduction of these prototypes of selectivity improving devices in the beam trawl fishery will not have a strong impact on the returns. The reasons are :

- Haddock and whiting show the best escape in the selective beam trawls. Since their part in the total catch and their market prices are not so high, they do not have a strong influence on the annual returns of beam trawlers.

- Cod represents a higher portion in the total catch and has higher market prices. However, this species was not released to the same level as haddock and whiting, which reduced its impact on the returns.

- The small increases in flatfish catches, which often occured, have a strong impact on the returns because these are the main target species with the higher market prices.

Since the influence of the loss of roundfish on the returns for the experimental gears was obscured by higher flatfish catches in most of the Belgian configurations, a calculation assuming equal flatfish catches in the experimental and the control gear was also made. However, even with the assumption of equal flatfish catches, the financial loss is never higher than 10%. For the reduced top panel + square mesh window, with 41% haddock escaping, the financial losses were very low (between -3% and zero). For the other options the results showed more important fluctuations (between -10% and +11%), depending on the calculation set and on the assumption of flatfish catches being equal.

4. SUMMARY OF CONCLUSIONS

The results of all three series of selectivity trials showed that for all selection devices tested the plaice and sole catches were hardly affected.

Large diamond and hexagonal mesh top panels were found to be effective in releasing whiting from 12m Dutch type V-nets. For round nets the best results were obtained with a square mesh top panel, and to a lesser extent with a reduced top panel. Not enough data were obtained to draw conclusions for the square mesh windows.

For haddock no data was found with the V-nets. All reduced top panels gave good results in 9m round nets and all square mesh windows showed more release than the standard net, but not as much as with the reduced top panels. A square mesh window was shown to release haddock in the SEAFISH experiments.

Good escapement was found for cod in the V-net with the very large diamond mesh top panel during a number of hauls where juvenile fish were encountered. The picture for marketable fish was not so clear, due to the relatively small numbers caught in a haul. There was a slight tendency of release for the other two experimental nets. RVZ found some effectiveness of a square mesh window, but the SEAFISH trials did not give a firm back-up of this result. The behaviour of cod did not seem to be very consistent over the range of trials.

The best possible option for the V-net seems to be the very large diamond mesh top panel, although the evidence of superiority was not very strong. For the round nets the combination of a reduced top panel with a square mesh window seems most effective. Some practicalities should be noted. If available the use of knotless netting is to be recommended in order to avoid mesh distortion after some time of commercial use.

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Table 1: Timing of the project

Phase	Project Activities	Dates
1	Planning and administrative meeting 1	10-12 Dec '90
1	Literature search	Jan-Apr '90
1	Meeting 2 of experts	26 Apr '91
1	Periodic report No 1	20 Dec '91
2	Design of net models	Oct '92
2	Model experiments 1 in a flume tank	8-11 Oct '91
2	Meeting 3 of experts	10 Oct '91
2	Model experiments 2 in a flume tank	13-14 Nov '91
2	Meeting 4 of experts	25-26 Nov '91
3	Design of full-scale selective configurations	Jan '92
3	Construction of selective configurations	Feb '92
3	RIVO-DLO direct observation on RV "Tridens"	9-20 Mar '92
3	Video tape editing	Mar '92
3	Meeting 5 of experts	13 Feb '92
3	RIVO-DLO+RVZ direct observations+ selectivity trials, series 1	18-27 May '92
3	Periodic report No 2	22 Jul '92
4	RIVO-DLO selectivity trials	6-28 Apr '92
4	Data analysis	May '92
4	Meeting 6 of experts	2 Jul '92
4	RVZ selectivity trials, series 2	17-29 Sep, 1-12 Oct '92
4	Data analysis	Nov '92
4	SEAFISH selectivity trials	7-13 Dec '92
4	Data analysis	Dec '92
4	Meeting 7 of experts	21-22 Dec '92
4	Periodic report No 3	Dec '92
4	Final report	Feb '92

Table 2: Configurations tested at model scale in the flume tank.

Configuration/Institute	RIVO-DLO	RVZ	SEAFISH
Standard net	X	X	X
Lower headline attachment	X	X	X
Square mesh top panel	X	X	X
Oblique separator panel	X	-	-
Shortened lastridge ropes	X	X	X
Large diamond meshes in top panel	X	-	-
Hexagonal meshes in top panel	X	-	-
Square mesh window in lower belly	-	X	-
Reduced top panel (27 meshes deep)	-	X	-
Square meshed top half of codend	-	X	-

Table 3: Configurations tested in selectivity experiments of RIVO-DLO .

Port side	Starboard side	No of hauls (valid)
Hexagonal mesh top panel	Standard gear	21
Large diamond mesh top panel (2m mesh)	Standard gear	22 (18)
Very large diamond mesh top panel (2-4.80m mesh)	Standard gear	14 (13)

Table 4: Configurations tested in first series of selectivity experiments of RVZ.

Port side	Starboard side	No of hauls
Square mesh top panel	Standard gear	7
Square mesh top panel	Standard gear, headline lowered	2
Square mesh top panel, headline lowered	Standard gear, headline lowered	3
Reduced top panel (27 meshes deep)	Standard gear	5
Reduced top panel (27)	Standard gear, headline lowered	4
Reduced top panel (27), headline lowered	Standard gear	6
Reduced top panel (34 meshes deep)	Standard gear	13
Reduced top panel (34) + square mesh window 13 cm	Standard gear	10

Table 5: Configurations tested in second series of selectivity experiments of RVZ.

Port side	Starboard side	No of hauls
Reduced top panel (34 meshes deep) + square mesh window 13 cm	Standard gear	37
Square mesh top panel	Standard gear	33
Reduced (34) square mesh top panel	Standard gear	12
Square mesh window 13 cm	Standard gear	20
Square mesh window 10 cm	Standard gear	20
Square mesh window 13 cm + 10 cm	Standard gear	12

Table 6: Configurations tested in selectivity experiments of SEAFISH.

Port side	Starboard side	No of hauls
Square mesh window 14.25 cm	Standard gear	40

Table 7: Catch results of the selectivity experiments of RIVO-DLO

Gear	Hexagonal mesh top panel (P) Hauls 1-21				Standard beam trawl (S) Hauls 1-21		
Species:	No of fish	% diff	mean L	stdev	No of fish	mean L	stdev
Plaice	13 898	- 7.6	25.41	4.03	15 043	25.48	3.95
Sole	4 492	+4.8	28.78	3.75	4 288	29.06	3.83
Whiting	558	**-14.4**	25.47	3.77	652	26.14	3.70
Cod	8	**-60.0**	49.75	30.48	20	57.00	22.88
Gear	Large (2 m) mesh top panel (P) Hauls 22-43				Standard beam trawl (S) Hauls 22-43		
Species:	No of fish	% diff	mean L	stdev	No of fish	mean L	stdev
Plaice	4 859	-27.6	27.15	4.41	6 708	26.69	4.09
Sole	2 052	-11.4	29.75	3.87	2 317	29.80	3.74
Whiting	698	**-49.6**	26.58	3.82	1 385	27.19	3.91
Cod	14	**-12.5**	57.71	23.46	16	48.31	29.88
Gear	Very large mesh (2-4.8 m) top panel (P) Hauls 44-57				Standard beam trawl (S) Hauls 44-57		
Species:	No of fish	% diff	mean L	stdev	No of fish	mean L	stdev
Plaice	3 562	+8.6	25.59	3.47	3 281	24.84	3.60
Sole	2 157	-13.5	29.64	3.61	2 493	29.28	3.70
Whiting	356	**-55.5**	28.04	3.52	800	27.39	3.15
Cod	156	**-51.9**	28.13	4.08	324	27.78	3.43

Table 8: Catch results of the selectivity experiments of RIVO-DLO in estimated weight.

Gear	Experimental beam trawl (P)					Standard beam trawl (S)		
Sole	total kg	% diff	mean kg	stdev	Code	total kg	mean kg	stdev
Hauls 1-21	895	**-0.11**	42.62	10.49	hmt	896	42.67	11.77
Hauls 22-43	492	**-10.05**	27.33	13.35	dmt2	547	30.39	13.29
26 omitted	477	**-4.02**	28.06	13.39	dmt2	497	29.24	12.74
Hauls 44-57	444	**-1.11**	34.15	7.60	dmt2-4.8	449	34.54	8.96

Table 9: *Catch results of the selectivity experiments of RVZ, all fish, first series d = daytime fishing; n = nighttime fishing*

Gear	Reduced top panel with square mesh window 13 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	978	-	-	819	-	-
% diff.	+19					
Cod	219	102	117	283	84	199
% diff.	-23	+21	-41			
Whiting	49	-	-	121	-	-
% diff.	-60					
Gear	Square mesh top panel (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	348	-	-	316	-	-
% diff.	+10					
Lemon sole	102	-	-	91	-	-
% diff.	+12					
Cod	190	-	-	194	-	-
% diff.	-2					
Haddock	280	-	-	394	-	-
% diff.	-29					
Whiting	69	-	-	277	-	-
% diff.	-75					
Gear	Reduced top panel (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	429	-	-	369	-	-
% diff.	+16					
Lemon sole	558	-	-	567	-	-
% diff.	-2					
Cod	210	-	-	198	-	-
% diff.	+6					
Haddock	502	104	398	589	194	395
% diff.	-15	-46	+1			
Whiting	123	-	-	95	-	-
% diff.	+29					

Table 10: Catch results of the selectivity experiments of RVZ, all fish, second series d = daytime fishing; n = nighttime fishing

Gear	Reduced top panel with square mesh window 13cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	3101	-	-	2931	-	-
% diff.	+6					
Sole	331	-	-	296	-	-
% diff.	+12					
Lemon sole	722	-	-	706	-	-
% diff.	+2					
Cod	1174	450	724	1138	361	777
% diff.	3	25	-7			
Haddock	926	199	727	1570	462	1108
% diff.	-41	-57	-34			
Whiting	27			37		
% diff.	-27					
Gear	Square mesh top panel (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	2991	-	-	2989	-	-
% diff.	0					
Sole	1432	-	-	1514	-	-
% diff.	-5					
Cod	1807	583	1224	1924	619	1305
% diff.	-6	-6	-6			
Whiting	89	30	59	128	73	55
% diff.	-30	-59	+7			
Gear	Reduced square mesh top panel (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	385	-	-	376	-	-
% diff.	+2					
Cod	420	175	245	406	167	239
% diff.	+3	+5	+3			
Haddock	143	61	82	332	160	172
% diff.	-57	-62	-52			
Whiting	99	23	76	189	41	148
% diff.	-48	-44	-49			

Table 10: (cont.) *Catch results of the selectivity experiments of RVZ, all fish, second series d = daytime fishing; n = nighttime fishing*

Gear	Square mesh window 13 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	1274	-	-	1227	-	-
% diff.	+4					
Sole	354	-	-	302	-	-
% diff.	+17					
Cod	949	372	577	1160	368	792
% diff.	-18	+1	-27			
Gear	Square mesh window 10 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	470	-	-	392	-	-
% diff.	20					
Lemon sole	545	-	-	549	-	-
% diff.	-1					
Cod	666	198	468	761	255	506
% diff.	-12	-22	-8			
Haddock	222	25	197	284	45	239
% diff.	-22	-44	-18			
Gear	Square mesh window 10 and 13 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Plaice	740	-	-	676	-	-
% diff.	+9					
Cod	212	104	108	225	86	139
% diff.	-6	+21	-22			
Haddock	122	41	81	200	62	138
% diff.	-39	-34	-41			

Table 11: Catch results of select. experiments of RVZ, undersized fish, second series

Gear	Reduced top panel with square mesh window 13 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Cod	711	263	448	662	206	456
% diff.	+7	+28	-2			
Haddock	361	73	288	500	132	368
% diff.	-28	-45	-22			
Gear	Square mesh top panel (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Cod	737	215	522	717	228	489
% diff.	+3	-6	+7			
Whiting	5	1	5	2	2	1
% diff.	-	-	-			
Gear	Reduced square mesh top panel (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Cod	239	104	135	247	101	146
% diff.	-3	-6	7			
Haddock	35	16	19	200	116	84
% diff.	-83	-86	-77			
Whiting	99	23	76	189	41	148
% diff.	-48	-44	-49			
Gear	Square mesh window 13 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Cod	265	79	186	279	78	201
% diff.	-5	+1	-7			
Gear	Square mesh window 10 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Cod	306	82	224	352	116	236
% diff.	-13	-29	-5			
Haddock	43	2	41	44	6	38
% diff.	-2	-	+8			
Gear	Square mesh window 10 and 13 cm (P)			Standard beam trawl (S)		
Species:	No fish all	No fish d	No fish n	No fish all	No fish d	No fish n
Cod	97	38	59	96	29	67
% diff.	+1	+31	-12			
Haddock	33	19	14	52	16	36
% diff.	-37	+19	-61			

Table12: Catch results of selectivity experiments of SEAFISH

Net		Plaice		Lemons		Cod		Haddock	
		No	%	No	%	No	%	No	%
Control	Total:	3274		854		451		734	
	Discards:	445	14%	72	8%	143	32%	103	14%
	Marketable:	2829	86%	782	92%	308	68%	631	86%
Square	Total:	3060		780		450		653	
	Discards:	502	16%	60	8%	155	34%	96	15%
	Marketable:	2558	84%	720	92%	295	66%	557	85%
Differences (Con-Squ)	Total:	214		74		1		81	
	Discards:	-57	-13%	12	17%	-12	-8%	7	7%
	Marketable:	271	9%	62	8%	13	4%	74	12%

Table 13: Assumptions in economic calculation of selective beam trawls of RIVO-DLO and RVZ

Quantity	Value	Unit	Value	Unit
Engine power	2000	hp	900	hp
Number of days at sea	168	days/year	220	days/year
Number of sea weeks/trips	42	weeks/year	20	trips/year
Number of sea hours	96	hrs/week	264	hrs/trip
Steaming time	12	hrs/week	48	hrs/trip
Number of hauls per day	12	hauls/24hrs	8	hauls/24hrs
Number of hauls per week/trip	42	hauls/week	72	hauls/trip
Haul duration	1h45'	hrs.min	2h30'	hrs.min
Total number of hauls	1764	hauls/year	1440	hauls/year
Fishing time (incl. shooting and heaving)	84	hrs/week	216	hrs/trip
Fishing time (excl. shooting and heaving)	73.5	hrs/week	180	hrs/trip
Fishing time factor	0.765625	=73.5/84	0.681818	=180/264
Total fishing time	3 087	hrs/year	3 600	hrs/year
Investment in gear alterations	5 000	HFL	60 000	BFR
Income	3 000 000	HFL/year	20 581 104	BFR/year
Fuel consumption	1 250 000	ltr/year	-	ltr/year
Fuel price	0.31	HFL/ltr	-	BFR/ltr
Fuel costs	387 500	HFL/year	-	BFR/year
Reduction in gear drag	0	%	0	%
Percentage reduction in fuel consumption	0	%	0	%
Fuel costs reduction per year	0	HFL/year	0	BFR/year
Capital Recovery Factor CRF(18,5)	0.323	-	-	-

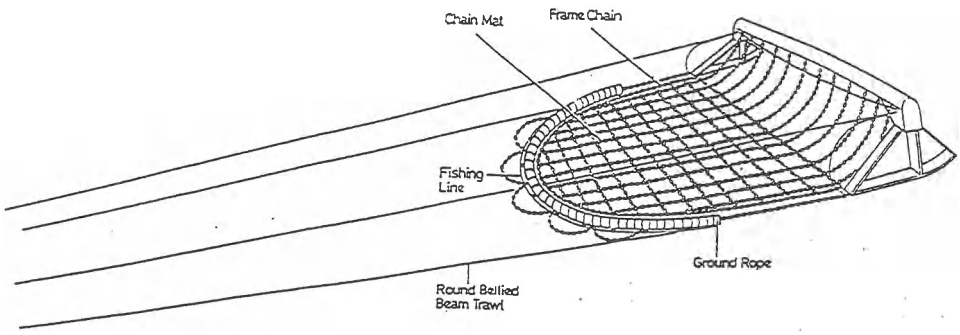
Table 14: Predicted economic effects on a 2000hp beam trawler.

Experimental gear vs Standard gear	% losses in yearly earnings
Hexagonal mesh top panel	**3**
Large diamond mesh top panel (2m mesh)	**16**
Very large diamond mesh top panel (2-4.80m mesh)	**8**

Table 15: Predicted economic effects on a 900hp beam trawler, based on existing flatfish catches.

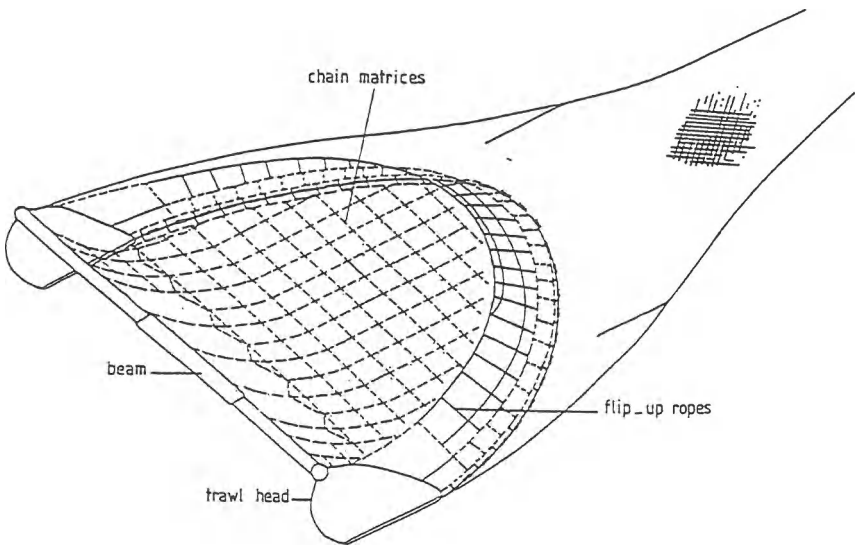
Experimental gear vs Standard gear	% losses in yearly earnings
Reduced top panel (34 meshes deep) + square mesh window 13 cm	**0.04**
Square mesh top panel	**4.60**
Reduced square mesh top panel (34 meshes deep)	**0.14**
Square mesh windows	**-6.12**

Figure 1a



Beam Trawl Rigged with Chain Mat

Figure 1b



Beam trawl equipped with chain matrices and flip_up ropes.

Figure 2

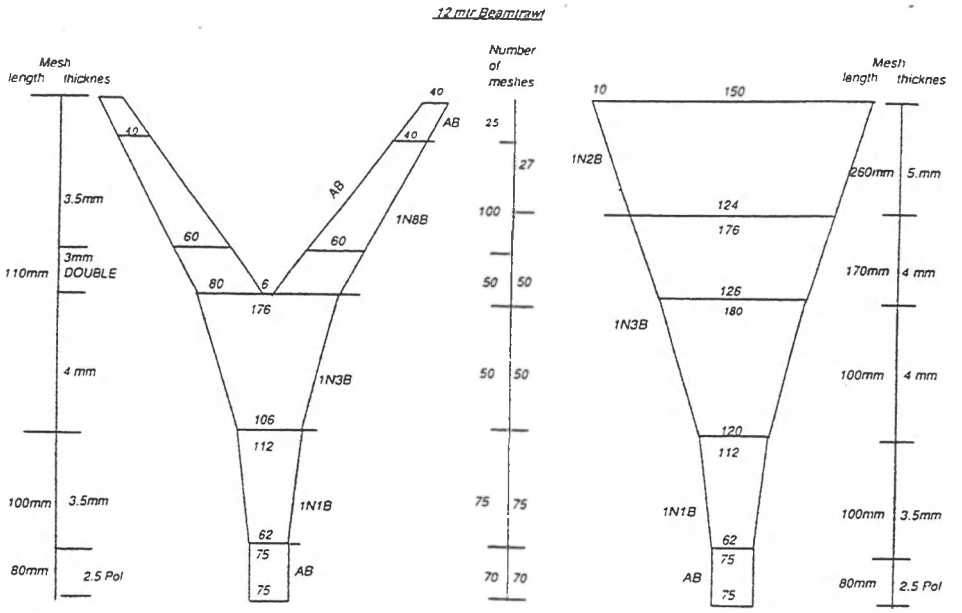
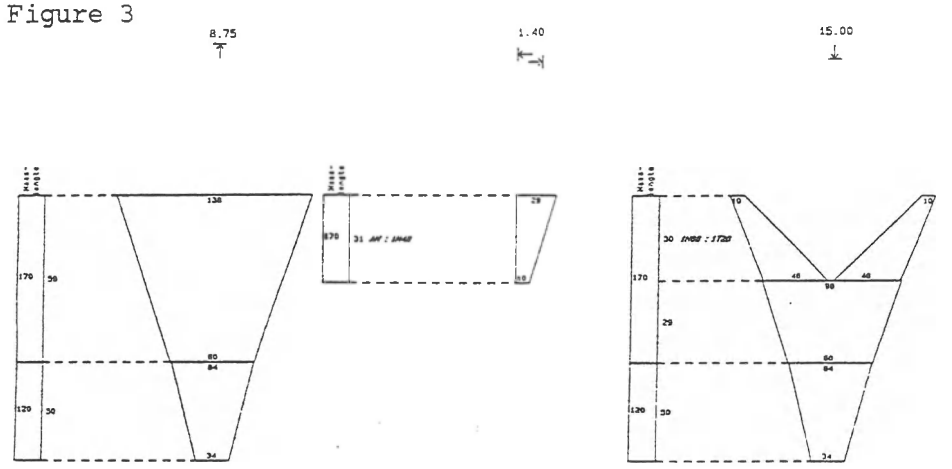
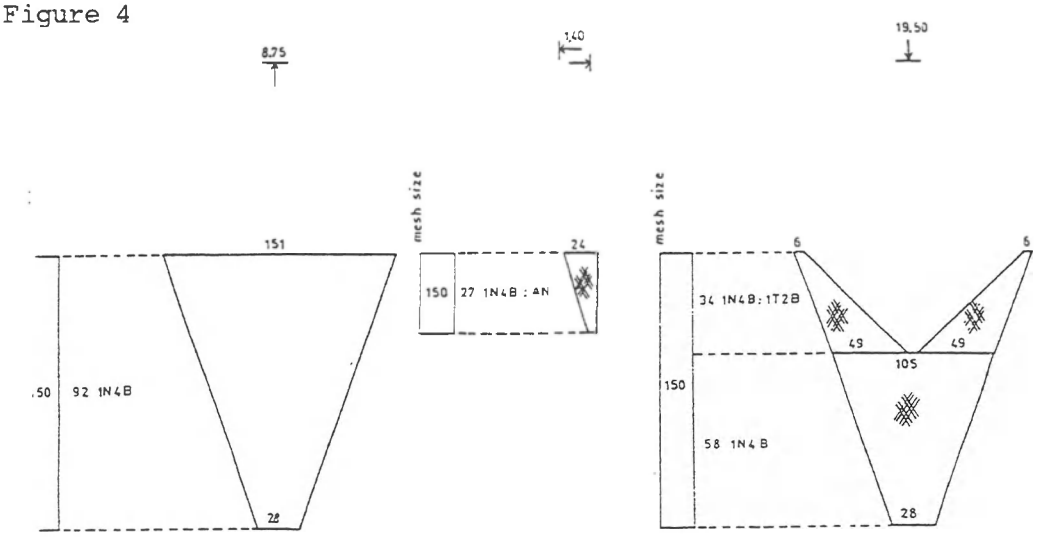


Figure 3



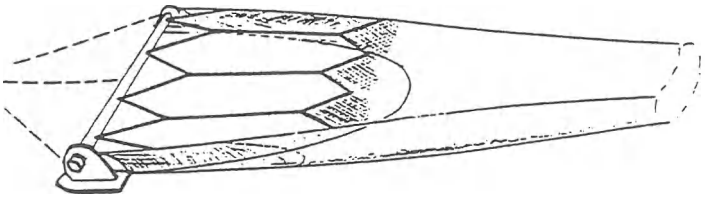
Standard net, first series RVZ

Figure 4

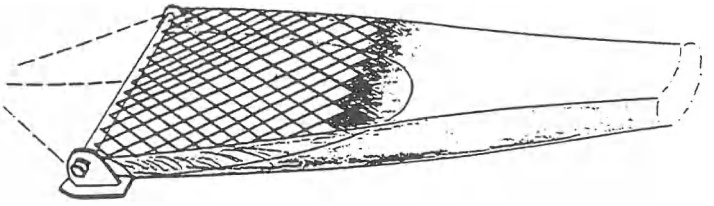


Standard net, second series RVZ

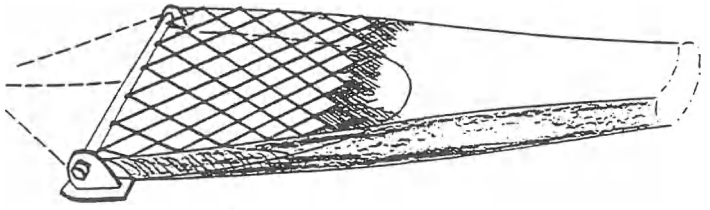
Figure 5a



Hexagonal mesh top panel



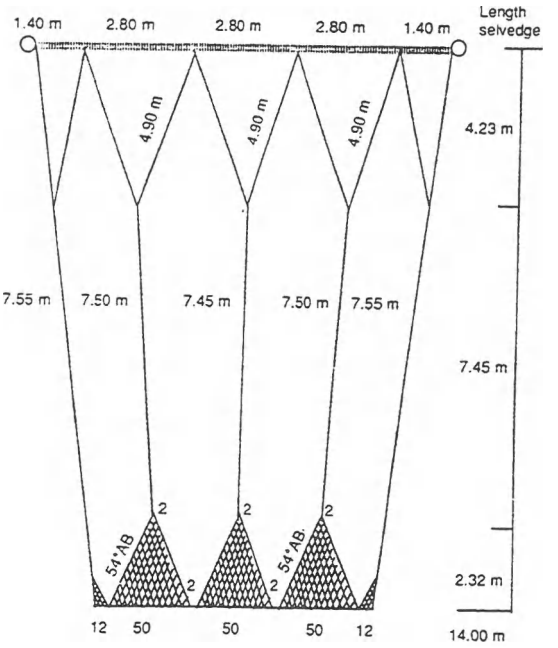
Large diamond mesh top panel
mesh size 2 m



Very large diamond mesh top panel
mesh size varying from 4.8 to 2 m

Figure 5b

Hexagonal mesh top panel, 12m beam trawl



174 meshes of 120 mm
joined to 180 meshes of
100 mm mesh size

Figure 5c

Large diamond mesh top panel
12 m V-net, mesh size : 2 m.

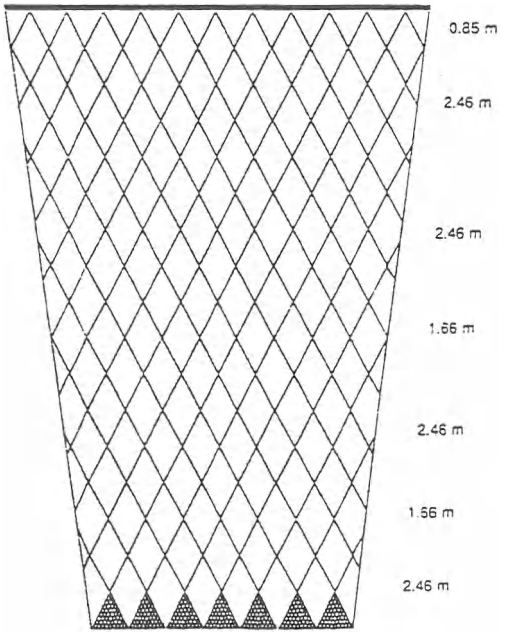


Figure 5d

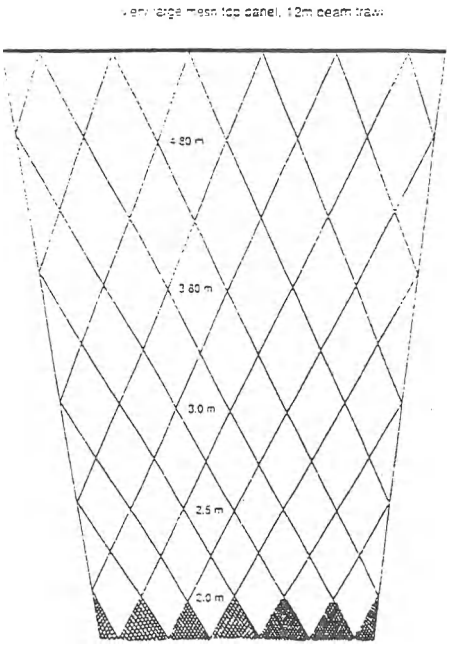
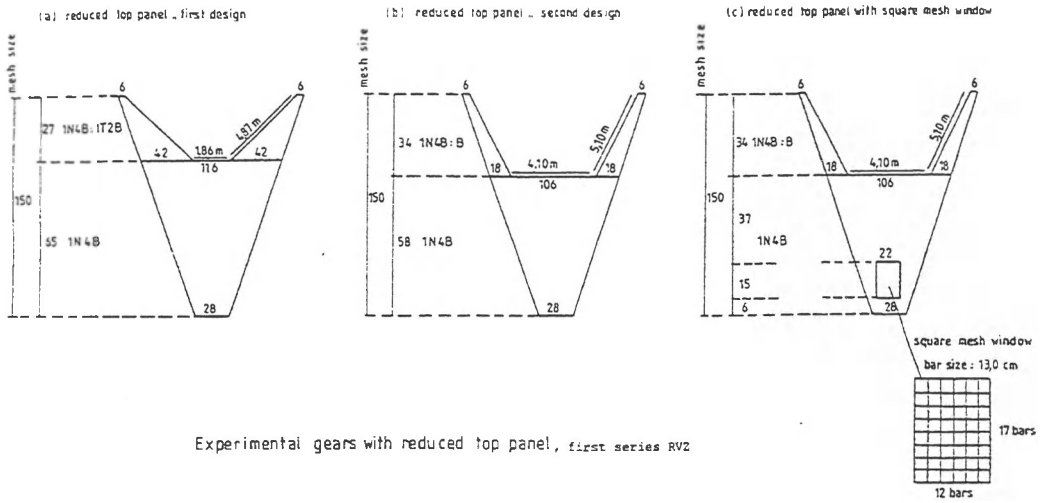
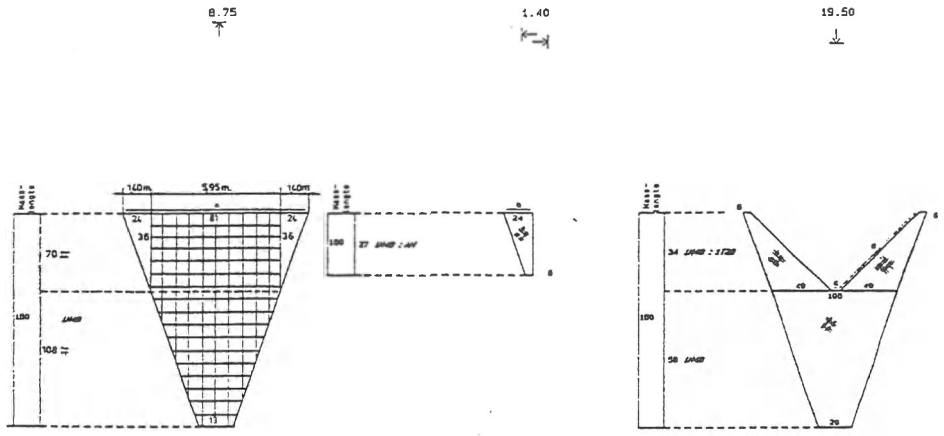


Figure 6



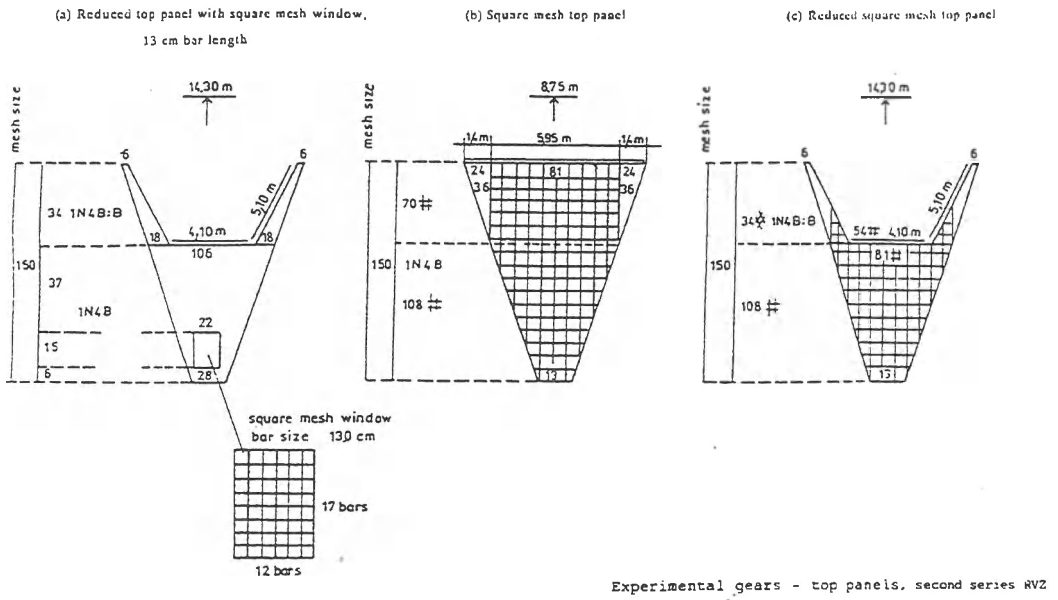
Experimental gears with reduced top panel, first series RV2

Figure 6d

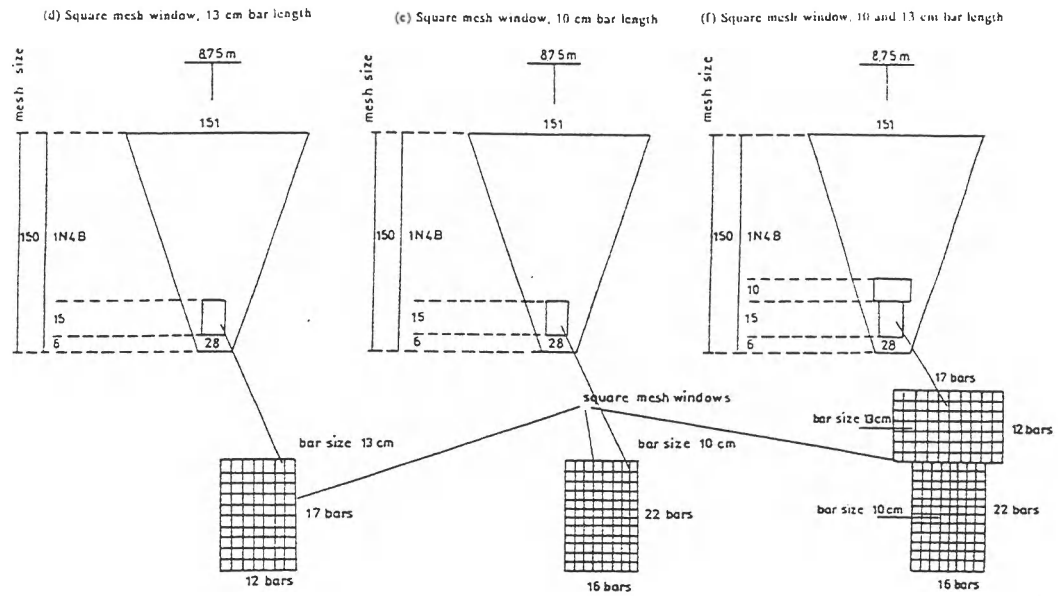


Net with square mesh top panel, first series RV2

Figure 7



Experimental gears - top panels, second series RVZ

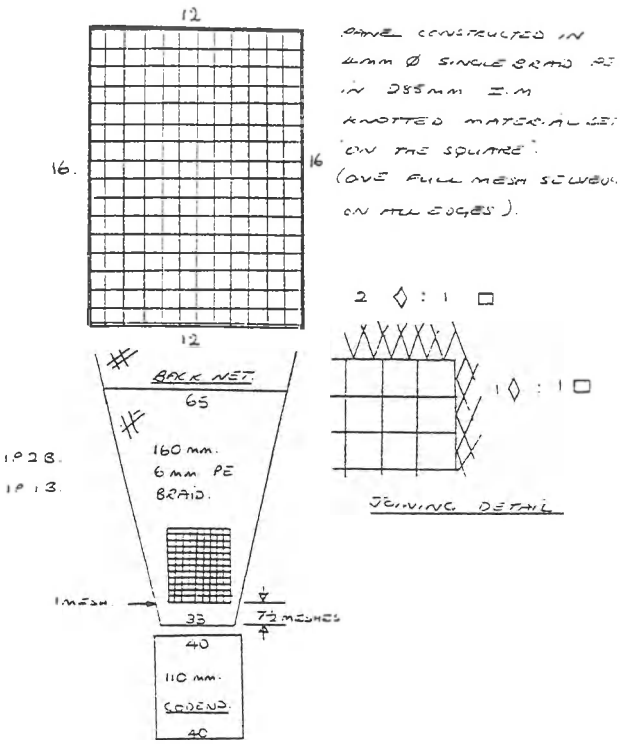


Experimental gears - top panels, second series RVZ

Figure 8

SQUARE MESH PANEL DETAILS

MFV "ZUIDERKRUIS" (SM 246)



POSITION OF PANEL IN 70.° PANEL OF TRAWL