IMPROVED SELECTIVITY IN TOWED GEARS

Sea Trials to Evaluate Selectivity of Separator Trawls Used to Catch Mixed White Fish Species

MAFF Commission

Seafish Report No.441

May 1994 (revised April 1995)

MAFF R&D Commission 1993/94

Sea Fish Industry Authority

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Summary

The report describes a set of experiments, funded by MAFF, to investigate selectivity aspects of separator trawls. The main species mix was cod, whiting and flatfish with a few haddock. The work was initiated through cooperative trials with Yorkshire fishermen and their national association. These led to a research programme involving the MAFF's Chief Scientist's Group and their Directorate of Fisheries Research, the SOAFD Marine Laboratory, the National Federation of Fishermen's Organisations and Seafish.

A twin rig trawler, *MFV HEATHER SPRIG,* was chartered for 15 days and towed two separator trawls with a range of three mesh sizes in the four codends. Care had to be taken to ensure that the mesh sizes were varied randomly and that the nets were fishing normally.

Very good data were obtained on separation with the cod consistently being found in the lower codends. Selectivity data were less good because the quantities of fish were a little too low in that respect.

Enough information was obtained to conclude that the concept of separator panels has a very good conservation potential. Quantifying the exact degree of benefit will require better selectivity data derived from greater numbers of fish - particularly cod. An opportunity to achieve that end is identified in the report.

1. Background

The level of North Sea cod stocks has put pressure on the Fisheries Departments and the fishing industry to find ways of improving the situation. Ultimately the solution must lie in a reduction in fishing mortality.

The minimum mesh size regime has not been successful in achieving that result, hence other technical conservation measures have attracted increasing attention recently.

In 1992 the U.K. Government published the Seafish (Conservation) Act, 1992. This aimed to reduce fishing effort, and therefore fishing mortality, to the levels set by the European Multi Annual Guidance Programme, by means of limiting days at sea. In response the National Federation of Fishermen's Organisations produced a set of proposals to satisfy that same MAGP target by a range of technical conservation measures combined with changes to the decommissioning and structural regimes.

The potential benefit of those measures was largely unproven and unquantified hence their case needed to be strengthened by some systematic investigations that would satisfy both the U.K. and European authorities.

One very promising technical measure proposed was the use of horizontal separator panels in demersal whitefish trawls. Seafish, having already assisted in formulating the initial technical proposals, then organised some early evaluation trials, also in conjunction with NFFO. As these appeared to be successful the Fisheries Departments then offered financial support and advice for more sustained fishing and selectivity trials.

The outcome was a 15 day charter funded by MAFF. The trials were conducted by Seafish with the experimental design being a cooperative exercise between Seafish and MAFF's Directorate of Fisheries Research (DFR). SOAFD provided a remote operated vehicle and underwater camera system plus staff support and NFFO arranged a fishing advisor and local liaison on the fishing grounds.

The exercise thus demonstrated the degree of cooperation that can be achieved when sufficient priority is given to resolving a problem area.

This report describes those trials, analyses and interprets the catch data and then recommends a course of action to enable appropriate development of the concepts involved.

2. Introduction

Prior to formulation of the proposals put forward by NFFO as alternatives to the Government's Seafish (Conservation) Act, 1992, a number of U.K. fishermen (in particular from the East coast of England) expressed an interest in using the separator panel principle as a means of possibly improving the selectivity of their trawls for species such as cod and flatfish.

It is accepted that it is extremely difficult to provide technical conservation measures that satisfy multi-species fisheries. Variations in species morphology, behaviour and wide ranging minimum landing sizes (MLS) all combine to make the task of producing a more selective fishing gear more difficult.

It was felt that the separator trawl principle could be used to separate certain components of a mixed species catch in order that they could be treated separately with respect to improving selectivity. In other words, being more species specific with the conservation measure chosen to reduce discard levels of the species in question while at the same time minimising the losses of marketable fish of other species.

The aim was to provide a tool that would be effective but relatively simple and cheap to use. This meant utilising existing trawl designs and avoiding the introduction of complicated gear technology.

Seafish provided technical assistance by designing horizontal separator panels for insertion into a standard design of East Coast demersal white fish trawl to be evaluated by a number of vessels over time.

This initial exercise was designed to evaluate the levels of separation of the different species in question. No additional improved selectivity measures were applied at this stage.

The separator panels used followed the same general configurations as have been used in the past. For example in *Nephrops* separator trawls the different components of the catch were separated by the panel and collected in two separate codends. The objective here was to have cod and flatfish species retained in the lower codend and other species including haddock and whiting retained in the upper codend.

Over a period of a few months the reports obtained from these exercises proved to be very promising. Commonly between 70% and 90% of cod were being retained in the lower codends along with 95-100% of flatfish species. Species like whiting and haddock showed more variation but commonly upwards of 80% of these species were separated into the upper codends *(see Appendix I).*

Encouraged by this industry led initiative and the very promising indications from the fishermen's experiences, Seafish decided the situation warranted further investigation.

Under MAFF Commission (Project Code MF0612) and in collaboration with scientists from the Directorate of Fisheries Research (DFR), Lowestoft, a programme of sea trials to further evaluate the use of separator trawls was initiated.

The aim of the trials was to obtain separator trawl selectivity data required to make scientific assessments of the impact of its adoption with particular reference to cod.

Seafish's main consideration was to establish whether the separator trawl principle could be effectively applied to segregate cod and flatfish species from haddock and whiting.

The selectivity parameters of larger mesh sizes used in conjunction with the separator trawl configuration were the main concern of DFR scientists.

3. Aims

i. To determine, systematically, the levels of separation of cod, haddock, whiting and flatfish *via* use of a separator panel.

ii. To establish the selectivity characteristics of twin codends, for the species in question, using three different mesh sizes.

iii. To determine the commercial practicability of the separator trawl concept in inshore fisheries.

iv. To contribute to the debate as to whether separator trawls could be used as a means of reducing the fishing mortality levels for certain species.

v. To evaluate the suitability of the twin trawl configuration for selectivity trials.

4. Observation and Fishing Trials

A certain amount of experience had already been gained by Seafish with Yorkshire Coast vessels operating a separator trawl. It was decided therefore to continue the investigations in the same area. This decision was backed up by information from MAFF showing these areas to be providing the best cod landings in recent years for the time of year when the exercise was to be carried out *(Fig. 1)*.

Since the separator panel design work had already been done and to a limited degree been shown to be effective, it was decided to continue the work with the same trawl design which was fairly typical for the areas of operation chosen.

The vessel selected for this exercise was the Scottish, Buckie registered *MFV HEATHER SPRIG (BCK 181)*. The vessel is a purpose built multi-rig trawler operated by a skipper and crew very experienced in this type of experimental fishing exercise.

Ideally, a local vessel would have been selected for the work but unfortunately no suitable, established twin rig trawlers were available at the time.

In collaboration with scientists from DFR Lowestoft, a programme of fishing trials was devised in order best to evaluate the separator trawl principle and the codend arrangements under test.

The trials were monitored by two Seafish gear technologists and an observer from DFR Lowestoft. A local fisherman also participated in the fishing trials as and when required. He supplied the necessary information on local fishing grounds and conditions enabling the *HEATHER SPRIG* to operate with the rest of the local fleet.

4.1 Fishing Gear

The twin trawl method was considered to be the most suitable for direct comparison of the gears and codend combinations under test.

Two identical trawls were therefore constructed by a local fishing gear manufacturer to be towed side by side in a three warp, twin trawl arrangement *(Figs. 2 & 3)*.

For the collection of selectivity data in this type of exercise, the use of small mesh codend covers was not considered practical. The next best method was to use small mesh codends *(Fig. 4)*.

Small mesh codends of nominal 60mm mesh were fitted to one of the pair of trawls in order to obtain population samples for comparison with the two large mesh codend combinations to be towed from the other of the pair of trawls. The two mesh sizes chosen for selectivity evaluation for the lower codend (designed to retain cod and flatfish species) were 100mm and 140mm (nominal). These were evaluated in conjunction with an upper codend constructed of 100mm mesh *(Fig. 5)*.

These mesh sizes were selected as the current legal minimum (100mm) and as a mesh size of sufficient increase from the current minimum mesh size (MMS) in order to obtain selectivity data that would allow interpolation for mesh sizes within this range (100-140mm).

The 60mm small mesh size was selected to obtain population samples. This size was chosen as the maximum to retain sufficient fish of the length classes required of the species in question; namely cod and flatfish.

The use of mesh sizes smaller than 60mm was avoided to reduce any potential bias in gear performance between the two halves of the twin rig arrangement. The increased drag imposed by the small mesh codends on one side of the twin trawl arrangement could potentially affect fishing performance of the net. The avoidance of very small mesh sizes also reduced the risk of other practical handling problems.

Mesh sizes were recorded at the start of the trials and checked on completion of the work. Measurements were made using an ICES net gauge set at 4kg *(Appendix IV)*.

The trawl net design chosen for this work was of a standard design typical of that used on this part of the Yorkshire coast selected for the trials *(Fig. 6)*.

The net, of box trawl design, was rigged on heavy rockhopper groundgear consisting of 60ft of 14in rubber discs throughout. This rig allows the gear to be used on rough ground *(Fig. 7)*.

A two bridle arrangement was used consisting of 12.5 fathoms of 10mm wire for the headline leg and 12mm chain for the ground leg. These were then connected to 7.0ft steel Dangren 'V' doors by a further 12.5 fathoms of 18mm steel wire single sweep *(Fig. 8)*.

The requirement for haul-by-haul codend changes for the random evaluation of the different codend mesh size combinations meant that a considerable amount of fishing time would be wasted. In order to try and reduce this down-time wherever possible the codend combinations to be tested were rigged together using an extension incorporating the last tapered section of the separator panel. This meant that codend changes only required the swapping of one unit at a time, involving only one join *(Fig. 9)*.

The use of four sets of codends at one time posed a number of handling problems. The combinations involving the larger mesh sizes were treated as one codend for the purposes of hauling onboard. The small mesh codends were treated separately due to their potential for holding greater volumes of fish.

The heavy rockhopper ground gears also proved to be difficult to handle in the twin trawl format. Combined with the additional work of handling the extra codends, the hauling and shooting process took considerably longer than a normal commercial operation.

Whenever possible the larger mesh codends were hauled and emptied first. In this way the potential for loss of fish through the washing action at the surface was reduced.

During the second half of the fishing trials the gear geometry was checked using SCANMAR instrumentation. Gear parameters such as door spread, headline height, wingend spread and warp tensions were recorded. These results are shown in *Appendix II.*

4.2 Observation Trials

Prior to the commencement of the comparative fishing and selectivity trials, two days were spent setting-up the twin trawl arrangement and optimising fishing gear parameters such as door spread, wingend spread and headline height. This was to ensure that the separator panel was rigged and performing correctly.

The separator panel was set at a height of 1.0m at its leading edge. This was achieved by the use of retaining ropes attached to the quarters of the panel and footrope *(Figs. 10 & 11).*

The trawl gear parameters were checked using SCANMAR acoustic trawl monitoring equipment provided by Seafish and also by direct underwater observations using a Remote Controlled Towed Vehicle (RCTV) carrying underwater video equipment. This was provided and operated by SOAFD's Marine Laboratory, Aberdeen.

The underwater observation and instrumentation trials were carried out off the vessel's home port of Buckie prior to steaming south to the Yorkshire coast fishing grounds.

The instrumentation trials allowed the fine tuning of the twin rig arrangement to ensure both nets were fishing square by correctly adjusting the centre warp length differential and checking by direct observation using RCTV.

The panel setting was found to be correct with a good even tension throughout its leading edge. The panels throughout their full length from the mouth of the trawls to the codends showed good shape with little or no slack netting.

At the end of the separation panel where the double codend arrangements were attached, the codends showed clear open entrances in the form of a figure of eight allowing clear passage of fish into the codends.

The overall panel and trawl configurations were more than satisfactory.

A minor problem with the fishing line and ground gear twisting towards the wingend of one net was observed during the first tow. This was soon corrected after the first haul and observed to be clear during subsequent tows.

The direct observations were invaluable in confirming the correct rigging of the separator panel and general gear arrangements prior to the commencement of the fishing trials.

4.3 Fishing Trials

Following the successful setting-up of the twin rig arrangement using video and instrumentation the trials vessel proceeded south for the Yorkshire coast inshore fishing grounds.

The port of Whitby was used as a base for the duration of the trials.

Information about local fishing grounds and conditions was provided by a local fisherman who also acted as general liaison/contact for the vessel during its stay in Whitby.

Over a period of 10 days fishing at the end of March 1994, a total of 20 valid hauls were recorded from a total of 26 carried out. A number of hauls were invalidated due to net damage caused as a consequence of towing on very rough ground. Details of the trawling operations are provided in *Appendix III.*

The trials were severely hampered by adverse weather and poor fishing conditions. Only limited quantities of fish were located.

Towing times were reduced from the commercial average of 3½-4 hours to allow for sufficient gear and catch handling time in an attempt to achieve a four haul sequence per day. Even with towing times down to 2½ hours, target sequences were not always achieved due to the invalidated hauls on a number of occasions.

Randomisation of codends was organised in blocks of 4 valid hauls. The possible combinations being 60mm upper and 60mm lower codends (60/60) on one side of the trawl with 100mm upper and 100mm lower codends (100/100) on the other side of the trawl and 60/60 on one side and 100/140 on the other side. Each of these combinations was assigned random order to the port and starboard sides of the trawl once over the course of 4 hauls. Thus 5 balanced complete blocks of 4 hauls were completed over the course of 20 valid hauls (*Appendix III* shows the details of the hauls).

The arrangement meant that:

- The side of fishing contributed in a balanced random way to the overall variance but could reasonably be ignored as an experimental factor for each completed block.

- The opportunity existed for removing through statistical analysis the local effects of weather or ground type as a 'block effect', thus reducing experimental error.

Fishing staff were requested to randomise all other variables associated with the hauls such as angle to the tide and wind within the range of possibilities offered by typical commercial practice.

At approximately the half way stage of the fishing trials the two nets were swapped from side to side in order to limit any bias there may have been in the fishing performance of the two halves of the twin trawl arrangement.

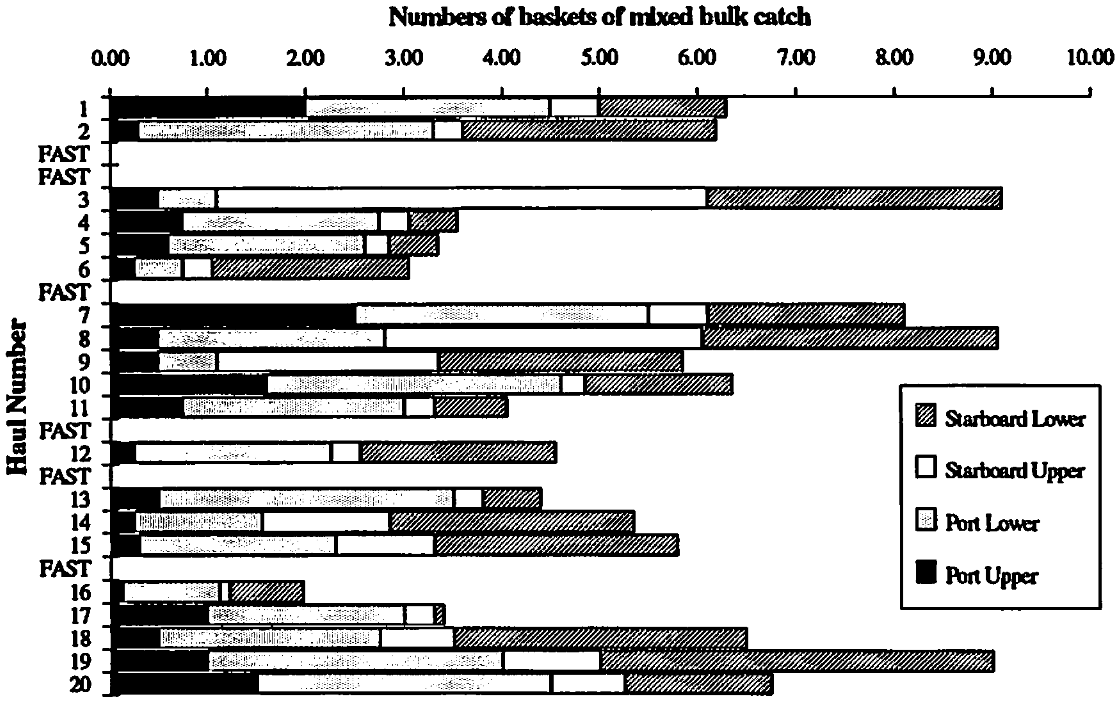
4.3.1 Catch Sampling and Data Collection

Due to the complex nature of the trial, with two pairs of codends to be monitored, each codend was individually coded with a knotted piece of twine in the upper panel for easy identification. In addition, both of the upper codends had two 7" diameter trawl floats attached inside; this made it simple to distinguish an upper codend from a lower codend.

The starboard trawl was always the first to be emptied. This was maintained throughout the trial. The upper codend was always cleared first, followed by the lower codend as soon as the fish hopper had been cleared of the previous batch of fish. The port trawl was emptied in the same manner. The fish hopper was designed so that it could be divided into four separate internal compartments, each of which could be independently emptied. The contents were passed out of the hopper along a conveyor and into baskets with no sorting. This allowed an assessment of the bulk quantity of catch present, including rubbish. Each basket was then given two coloured plastic tags to identify it, as it must be remembered that for any individual haul there were four sets of codend catches to be separately accounted for. A basket of fish from a starboard upper codend would be given a green tag and a yellow tag; fish from the lower codend of the same trawl were given a green tag and a blue tag. The port trawl was treated in the same manner, except that the green tags were replaced with red ones.

All commercially important species present in the catches were measured for total length. Inevitably, there were hauls in which particular species of fish did not feature. The diagram below shows the relatively small quantities of fish taken over the two week trial period; the maximum catch between four codends was 10 baskets (1 basket averaged at 38kg). All fish except two large samples of whiting taken on hauls 3 and 8 were thus able to be measured.

There were 20 valid hauls made in all, and within each haul the catch was divided into the four sections of port/starboard and upper/lower, as described. Each species therefore provided between 0 (if it did not feature) and 4 samples for each haul. Each sample was carefully measured and the number of fish in each 1cm length class from 10cm to 90cm was recorded in length-frequency format. The data were entered into a portable laptop computer using EXCEL whilst at sea; this was to enable a rapid downloading of data to desktop computers for further analysis at the end of the trial.


Numbers of baskets of mixed bulk catch
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Haul Number
1
2
FAST
FAST
3
4
5
6
FAST
7
8
9
10
11
FAST
12
FAST
13
14
15
FAST
16
17
18
19
20
Starboard Lower
Starboard Upper
Port Lower
Port Upper

5. Results

The analysis of these data took into account the following factors:

Blocked factors:
- i. Side (port, starboard)
- ii. Net (A, B)

Treatment factors:
- i. Codend (upper, lower)
- ii. Mesh size (60mm, 100mm, 140mm)

By numerical analysis, estimates for the following quantities were made:

- i. Mean catch per haul.
- ii. Proportionate separation in the upper and lower codends by fish species.
- iii. Selectivity of the 100 and 140mm codends using the catches in the 60mm codends as the control (or reference) population. For each mesh size, selectivity was assessed by comparing the numbers in each centimetre length group with the control mesh (Section 5.2.1) and fitting a logistic curve.
- iv. Cumulative length/frequency curves were of whiting in 60mm and 100mm mesh sizes in the upper and lower codends.

Catch data were collected for cod, whiting and a number of flatfish species. These species were the main components of the catches from the total of 20 valid hauls examined.

Catch levels were generally very low for the duration of the trials and in some hauls insignificant, particularly in the larger mesh sizes examined.

Because of the random selection of codend configurations, more data were collected for some codends than others. For each main species the data were collected as counts for each centimetre group from 10cm up to 90cm for each codend mesh size.

Initial analysis of these data was carried out to examine whether there was any significant differences (by analysis of variance) in mean catch per haul of all species in the port and starboard sides of the trawl or between nets A and B. No significant differences were detected in these blocked factors. In contrast, the treatment factors (mesh size 60/100/140mm and upper and lower codend) did show significant variation in catch per haul as expected. The analysis therefore proceeded without further reference to net A and B and side of trawl.

The species under consideration are known to behave differently and it is this difference that is exploited to obtain the required separation. Cod and whiting had very different distributions between upper and lower codends. Comparisons made are within single species, or grouped on the basis of known similar behaviour as in the case of the flatfish species.

In some instances the analysis required individual species data. In the case of flatfish species the most common species caught was used as representative of the general flatfish category. In this exercise the species selected was plaice.

The three main considerations in this exercise were:-

i. Evaluation of the performance of separator trawls with regard to separating cod and flatfish species from haddock and whiting.

ii. Obtaining selectivity data for 100mm and 140mm codends designed to retain the cod and flatfish components of a mixed species catch.

iii. Evaluation of the suitability of the twin trawl procedure for conducting comparative fishing trials with separator trawls to obtain selectivity data.

5.1 Separation Results

Considering the vertical species separation, initial analysis showed no significant differences between the performance of the two individual nets A and B. Likewise the two halves of the twin rig arrangement showed no differences of any significance.

5.1.1 Cod

Despite the relatively low numbers of cod caught, the separation was very good. Between 88% and 91% of the cod were retained in the lower codends for both the 60mm and 100mm mesh sizes *(Table 1, p14)*. The length/number distributions showed that the size ranges of fish retained in the 60mm and 100mm codends were very similar *(Figs. 18 & 19)*.

5.1.2 Whiting

The numbers of whiting caught in the population samples (60mm mesh) were higher than for cod. However, as expected the numbers retained in the 100mm and 140mm codends were small and provided less significant results.

The separation levels indicated for whiting were more variable between the 60mm and 100mm codends than for other species presumably due to the higher losses of whiting from the larger mesh sizes.

The population samples showed separation of 69% of the whiting into the upper codend. The 100mm codend retained 57% of whitings in the upper half of the net. Since roughly half the population sample were below MLS it is reasonable to assume that the difference in indicated separation is due to the losses of small whiting through the larger 100mm mesh *(Table 1)*.

The whiting length/number distributions for the 60mm population samples show almost identical size characteristics for the upper and lower codends. This suggests no signs of size related difference in behavioural responses to the separator panel for the size range of whitings caught.

5.1.3 Flatfish

The results for flatfish relate to combined catch data for all the principal species caught, i.e. plaice, sole, lemon sole, turbot and brill. This is justified because these species have similar behavioural characteristics in response to the fishing gear - they enter the gear below the level of the separator panel - hence the combining of flatfish species provides a more significant result.

On examination of the length/number distributions it was noted that for cod, whiting and plaice, the catch was split with approximately 50% of fish above and below the respective minimum landing sizes (MLS).

These separator results correspond to the indications received from fishermen that have used this type of gear in the same fishery, as shown in *Appendix I.*

Table 1
Separation Levels Between Upper and Lower Codends for Cod, Whiting, Plaice and All Flatfish Species Combined

Target species	Mesh size		Numbers of fish:			Percent:		Vertical Separation
			Below MLS	Above MLS	Total	Below MLS	Above MLS	
Cod:	60mm	Upper	69	73	142	49%	51%	12%
		Lower	494	517	1011	49%	51%	88%
	100mm	Upper	1	26	27	4%	96%	9%
		Lower	51	221	272	19%	81%	91%
	140mm	Lower	2	34	36	6%	94%	n/a
Whiting:	60mm	Upper	843	1018	1861	45%	55%	69%
		Lower	462	357	819	56%	44%	31%
	100mm	Upper	69	226	295	23%	77%	57%
		Lower	53	166	219	24%	76%	43%
	140mm	Lower	7	11	18	39%	61%	n/a
Plaice:	60mm	Upper	7	3	10	70%	30%	3%
		Lower	144	170	314	46%	54%	97%
	100mm	Upper	5	1	6	83%	17%	6%
		Lower	28	66	94	30%	70%	94%
	140mm	Lower	5	36	41	12%	88%	n/a

Target species	Mesh size		Numbers of fish retained:			Vertical Separation:	
			Port side	St'bd side	Total	Port side	St'bd side
All Flatfish Combined	60mm	Upper	8	17	25	2%	3%
		Lower	483	547	1030	98%	97%
	100mm	Upper	7	11	18	4%	7%
		Lower	148	143	291	96%	93%
	140mm	Lower	n/a	n/a	n/a	n/a	n/a

Flatfish includes Lemon sole, Dover sole, Turbot, Brill and Plaice

NOTE: *These results are consistent with those received from fishermen under commercial conditions and shown in Appendix I.*

5.2 Selectivity Results

The selectivity data are presented in two forms; as plots showing the mean numbers of fish at each centimetre length class for each species and codend configuration and as ogive plots showing the proportion of fish retained at each centimetre length class for each species and for each codend configuration, i.e. upper, lower, 100mm or 140mm codends *(Figs. 12-25).*

The data are summarised in tabular format expressing retention lengths, selection factors and range.

NOTE:-

- *The 50% retention length of a codend for a particular species is the fish length at which 50% of the species entering the codend is retained.*
- *The selection range (SR) is the difference between the 75% retention length and the 25% retention length.*
- *The selection factor of a codend for a particular species is the ratio of the 50% retention length and the mean measured mesh size.*

For each of the species under consideration the data from each haul have been combined and presented as the mean results.

The results have been presented for upper and lower codend configurations separately. Where appropriate they have been combined to present the aggregate view of selectivity for a particular mesh size.

5.2.1 Selectivity curves

Two methods were available to obtain selectivity curves:

i. A modified Millar and Walsh method (Millar, R.B. and Walsh, S.J., 'Analysis of trawl selectivity studies, with an application to trouser trawls', Fish Res. 13, pp205-220, 1992). This method originally designed for single 'trouser' trawls was modified to enable the estimation of the proportion of fish retained in the upper and lower cod ends as well as the selectivity parameters. In this method, the curves can be fitted by an iterative method using the conventional logistic selectivity function (the proportions of retained fish) for data obtained simultaneously from the upper and lower codends of a separator trawl.

ii. Using the same conventional logistic selectivity function as above, but estimating selectivity parameters for upper and lower codends separately.

Results using method (ii) are given in *Figs. 15, 16, 17* for whiting; 21 and 22 for cod; and 25 for plaice.

5.2.2 Whiting

The results for whiting using 100mm mesh showed a difference in the selectivity curves between the upper and lower codends *(Figs. 15, 16 & 17).*

The mean values obtained by method (ii) resulted in L_{50} values ranging from 28cm to 43cm, with an overall mean of L_{50}=35cm.

Whiting in 100mm Upper Codend (see Fig. 15)									
Mesh size	Retention Lengths			Selection		No. in selection range		n	n
mm	50%	25%	75%	Factor	Range	100mm	60mm	100mm	60mm
100	37.69	31.77	43.6	3.77	11.81	122	358	295	1861

Whiting in 100mm Lower Codend (see Fig. 16)									
Mesh size	Retention Lengths			Selection		No. in selection range		n	n
mm	50%	25%	75%	Factor	Range	100mm	60mm	100mm	60mm
100	30.52	26.72	34.33	3.05	7.6	143	343	219	819

Whiting in 100mm Upper and Lower Codend Combined (see Fig. 17)									
Mesh size	Retention Lengths			Selection		No. in selection range		n	n
mm	50%	25%	75%	Factor	Range	100mm	60mm	100mm	60mm
100	35.82	30.17	41.48	3.58	11.3	263	769	514	2680

Whiting was the only species for which there was sufficient fish in both upper and lower 100mm codends to provide selectivity curves for both codends for method (ii). The mean L_{50} values for the upper codend was L_{50}=38cm, with a variation of 24cm to 47cm, compared with L_{50}=31cm for the lower codend and a variation of 28cm to 35cm. Comparison *(Figs. 15 & 16)* of the upper and lower codend selectivity curves suggested that there was a difference in the selectivity of the two codends and this was investigated further.

Since the codends were in other ways identical it would be expected to obtain similar selectivity results for both upper and lower codends of the same specification. The differences in these results may be attributable to the positioning of the codends one above the other.

It was suspected that in this configuration, the upper codend could cause some masking of the upper section of the lower codend. Since most escapes take place from the upper netting of the codend this may be a contributory factor to these noticeable differences.

In order to assess the significance of the difference between the curves in *Figs. 15 and 16* they were examined further by generalised linear regression. The curves were fitted in the same way as in method two (a logistic curve in the aggregated result) but a significance test was carried out on the slope and the intercept. A significant difference (at $p<0.05$) between the slopes of the upper and lower curves was established but no significant difference was obtained for the intercepts.

5.2.3 Cumulative length/frequency curves for whiting

In order to examine the length frequency distributions for whiting *(Figs. 12 & 13)* for differences between upper and lower codends these data were transformed into cumulative length frequency distributions. This was calculated for each length interval by:-

PLx = CLx/CL (the sum of CL 11....90)

where PLx = cumulative proportion of fish at length L
CLx = cumulative count of fish at length L
CL = the sum of counts of all fish from length 11cm to 90cm

The cumulative proportions for each length group was fitted as a binomial proportion of the total (using the Logit link function).

Separate curves were modelled for the upper and lower codends, each in 60mm and 100mm mesh. These are shown in *Fig. 26*. The curves are smoothed representations of the length/frequency distributions. Because they are modelled this enables the significance of differences between distributions to be tested. However, a basic assumption of the fit of binomial models (of which this is one) is that the count in each group (in this case length group) is independent of the adjacent length groups. This may not be so in this case because if there are counts of fish in one length group there are likely to be counts of fish in the adjacent length groups. Thus it is necessary to approach this method with caution and only attach importance to highly significant results.

With this point taken into consideration, significant differences ($p<0.01$) in the cumulative length/frequency distributions for whiting in the upper and lower codends in both 60mm and 100mm mesh sizes were found. In both cases the cumulative curve in the lower codend was shifted to the right. In order to illustrate this effect the percentage discards for whiting as obtained from the model in *Fig. 26* with their estimated standard errors are shown below:-

Predicted percentage discards compared for whiting				
Codend	**Mesh size 60mm**		**Mesh size 100mm**	
	Mean	**SE**	**Mean**	**SE**
Upper	56%	0.25	29%	0.5
Lower	63%	0.4	35%	0.6

In both mesh sizes the modelled proportion of discards in the lower codend is 7% higher than that in the upper codend. It is instructive to compare these results with the actual percentages shown in *Table 1, p14*. Although both mesh sizes in the upper and lower codends contained proportionately more discards than the upper codends in both the modelled and actual results, the differences between the modelled results and actual results is quite large. This reflects the degree of smoothing occuring in obtaining the cumulative curve.

The results suggest that the length frequency distributions of the whiting entering the upper and lower codends were significantly different. This could be due to differences in the vertical distribution of the different size groups of the population; smaller fish making up a higher proportion of the fish in the lower codends.

The implication of these results is that the upper and lower codends are exploiting different sections of the whiting population; a higher proportion of discards being found in the lower codends of both 60mm and 100mm mesh sizes. Thus changes in the geometry of the gear, such as alteration of the height of the panel, are likely to alter the exploitation pattern of the different length groups in the population of whiting. It seems plausible that other fish species may exhibit similar effects. However, there is insufficient data to elucidate these effects.

5.2.4 Cod

Considering the relatively low numbers of cod retained during these trials, particularly in the 140mm mesh codends, it was not expected to obtain very reliable results. This is reflected in the highly variable data as shown.

The results for cod are more reliable for the 100mm lower codend than for the 140mm lower codend. An L_{50} of 32.6cm for all of the hauls combined compares well with individual haul results. However, only two hauls could be analysed separately. The Millar & Walsh method was able to fit more of the individual hauls, but with a higher variation. The mean L_{50} was very similar, at L_{50}=34cm. The 140mm codend fitted by method (ii) would only yield results for all hauls combined - individual hauls could not be analysed separately. The L_{50} for this method was L_{50}=64cm. Results obtained by Millar & Walsh method indicated variability in the L_{50} values from 40cm to 80cm, but the mean L_{50} was very similar to that obtained by method (ii) at L_{50}=67cm. However, as previously mentioned the numbers of fish contributing to this result were very low and therefore the results cannot be considered significant.

Cod in 100mm Lower Codend (see Fig. 21)									
Mesh size	Retention Lengths			Selection		No. in selection range		n	n
mm	50%	25%	75%	Factor	Range	100mm	60mm	100mm	60mm
100	32.62	29.35	35.89	3.26	6.52	33	59	272	490

Cod in 140mm Lower Codend (see Fig. 22)									
Mesh size	Retention Lengths			Selection		No. in selection range		n	n
mm	50%	25%	75%	Factor	Range	140mm	60mm	140mm	60mm
140	64.65	54.88	74.43	4.62	19.53	15	33	36	521

The selectivity curves for cod are shown in *Figs. 21 & 22.*

5.2.5 Flatfish (Plaice)

The flatfish data are shown in *Figs. 23-25* inclusive. By considering only plaice as the representative flatfish species we have greatly reduced the data set resulting in insignificant numbers and therefore unreliable data. Again this is a problem resulting from low catch rates during the trials.

Plaice in 140mm Lower Codend (see Fig. 25)									
Mesh size	Retention Lengths			Selection		No. in selection range		n	n
mm	50%	25%	75%	Factor	Range	140mm	60mm	140mm	60mm
140	34.99	30.98	39.01	2.5	8.02	19	49	41	198

Although data is sparse for plaice in the 140mm lower codend, the fit by method (ii) appears to be good. The L_{50} thus obtained was L_{50}=35cm, and this is consistent with the Millar & Walsh method, for which a mean L_{50} of L_{50}=37cm was obtained. However, examination of the data sets indicated that there was one outlying data set with an L_{50}=47cm, and this has a disproportionate effect on the mean value. Results for 100mm lower codend were obtained by the Millar & Walsh method only, and gave an L_{50}=27cm, with a variation of 23cm-29cm.

Due to the mechanics of the data analysis program and the low numbers of fish obtained, a complete analysis of the plaice data was not possible. The selectivity data for the 100mm codend is therefore limited.

The plaice catches for the corresponding 60mm and 100mm lower codend comparisons showed insignificant differences in numbers of individuals caught (113 and 94 plaice respectively).

5.2.6 General

The catches of the principal species examined contained samples across a wide size range with good proportions of small and large fish.

The decrease in the gradient of the selection curve for whiting in the lower codend suggests that the ability to escape from the upper codend increases with size.

The indication here is that the larger fish appear to be released more readily from the upper codend of the pair. Because of the low numbers involved these results must be viewed with reservations *(Table 2, below)*. However, this does support the other observations regarding the differences in results between upper and lower codends.

Since there was a fairly even split of fish in the population (60mm mesh) above and below MLS for these species *(Figs. 12a-13a)*, this result may possibly suggest that escapes have been restricted from the lower codend by the presence of the upper codend (possibly masking of the meshes) and that this influence affects the larger size classes to a greater degree.

When comparing the 60mm codends with the 140mm codends it can be seen that very few discards or marketable cod and whiting are retained in the 140mm codends. Even the plaice catch shows higher losses of marketable fish.

Table 2

Estimated Mean Catch Per Haul (Denotes % Discards)			
Species	**Mesh Size**	**Upper Codend**	**Lower Codend**
Cod:	60mm 100mm 140mm	7.0 3.0 No observations	50.5 14.0 (32%) 2.0 (9%)
Whiting:	60mm 100mm	193.0 31.0 (29%)	75.0 11.0 (35%)
Plaice:	60mm 100mm 140mm	0.5 0.6 No observations	15.5 5.0 2.0

Table 2 shows the mean numbers of fish per haul for each of the principal species. This clearly shows that the catch rates were very low and that the results, particularly for cod and plaice, can only be considered indicative and not conclusive.

6. Observations and Discussion

6.1 Experimental Technique

The decision to conduct this evaluation exercise using the twin trawl method was made with some reservations. As far as is known, this was the first time that twin rockhopper separator trawls had been used in this way.

Despite some initial handling problems caused by the scale of the ground gears and the use of four sets of codends, the method proved successful at producing valid comparisons between the two halves of the twin rig system enabling evaluation of the performance of the separator panels.

By careful construction of two, as near identical nets as was possible and attention to maintaining a balanced twin rig arrangement, net and side for side variations were limited to acceptable levels.

The use of small mesh codends to obtain population samples was the only method possible for this exercise. The difference in drag imposed by the small mesh codends towed alongside the large mesh combinations did not appear to adversely affect the fishing performance of the gear. Both initial checks with direct underwater observations and gear geometry measurements with SCANMAR instrumentation indicated a symmetrical and balanced twin rig arrangement. However, it was felt that mesh sizes smaller than 60mm could potentially cause problems, particularly when large concentrations of small fish are caught.

Unfortunately, in this exercise adverse weather conditions and a shortage of fish limited the results. The additional gear handling times imposed by the nature of the trial limited the number of hauls possible in the time available.

Despite these limitations, the results demonstrated that the separator panel principle can be applied to a white fish demersal trawl to separate certain components of a mixed species catch. In this instance very good separation levels were achieved for cod and flatfish from whiting. It had been hoped that a similar result could have been observed for haddock but the shortage of this species on the grounds selected precluded this.

6.2 Commercial Considerations

Apart from some additional catch handling time attributable to the double codend arrangement, the insertion of the separator panel into the standard net does not incur any additional handling problems. Panel height adjustments are made at the leading edge by simply adjusting two rope lengths as required.

There has been some concern voiced by fishermen over potential problems with repair of separator trawls. Whilst it can be argued that additional work and time may be incurred in repairing a damaged separator trawl (where the panel itself has sustained damage), it is fair to say that the nature of the repair can be no more complicated than that for a standard trawl. The basic panel design (shape and cutting rates) is identical to the corresponding top sheet sections of the net into which it is inserted. If it is constructed sensibly and mounted onto its own frame rope it can be incorporated into the net as an independent selvedge for ease of repair or removal if necessary.

During the course of the sea trials considerable damage was sustained to the experimental gear on a number of occasions. This included severe damage and netting loss from the belly section of one trawl without sustaining damage to the panel itself.

6.3 Specific Observations

From the initial observations made with the RCTV it was clear that with both upper and lower codends of the same length, the potential for the upper codend to mask the lower codend was considerable.

In order to try and improve the separation distance between upper and lower codends two 7in trawl floats were attached to the inside of the top sheet of the upper codend.

In a commercial application of the separator trawl it would be envisaged that the lower codend would be longer than the upper one so that the main area of release would remain clear of any interference from the upper codend. In this way the selectivity of the lower codend could be improved.

The problem of masking did appear to be an explanation for some of the differences in results between the upper and lower codends.

7. Conclusions

i. Separation levels were determined for cod, whiting and flatfish species. For these species the levels achieved were high enough to enable cod and flatfish then to be subject to a different mesh size regime. Virtually no haddock were caught but they have been observed to respond predictably to separator panels.

ii. Selectivity data were difficult to derive because of the low numbers of fish found. The data for whiting suggest normal selectivity occurred except where it seems the upper codend was masking the lower to some extent. This problem is easily rectifiable.

   The data obtained in the course of these trials can be added to other data from comparable experiments.

iii. The separator trawls performed reliably during this and previous trials. They cost more than standard trawls but construction and repair do not present problems.

iv. Separator trawls offer some potential to be used as a technical means of stock conservation.

v. The trials were very satisfactory in demonstrating the benefits of using twin trawls for comparative fishing experiments.

8. Recommendations

The selectivity aspects of this exercise were less successful than the evaluation of the separation levels as they are more dependant on greater quantities of fish.

The losses from the large mesh size (140mm) indicate the difficulties in obtaining selectivity data for a variety of species in a mixed species fishery when considering mesh sizes above 100mm. It is extremely difficult to locate large enough quantities of fish at the higher length classes to produce significant selectivity data.

If further work is to be conducted into improved selectivity methods for cod then these factors must be considered to be of paramount importance.

If conservation is to be effected by larger mesh sizes then further experimentation must be conducted in areas where both the quantities and the size range of target species are suitable. Unfortunately, due to the current state of cod stocks in U.K. waters the options for such work are becoming more and more limited. However, fisheries like the Yorkshire Coast late summer codling fishery may provide some of these opportunities.

This exercise has demonstrated that separation of cod and flatfish species can be achieved. Further work is now required to come up with a codend configuration for the lower half of the net that will give improved selectivity for cod and flatfish without incurring excessively high losses of marketable fish.

Given the success with flatfish there could be great potential in exploiting the separator trawl idea in fisheries where excessive quantities of juvenile flatfish occur in mixed species catches.

There may also be a requirement to establish if the same levels of separation are attainable for the same species under different environmental conditions, for example species mix, water temperature and clarity, or in different fisheries at different times of the year. Separation of cod and flatfish from other round fish may be achievable at acceptable levels in a fishery in the North Sea but may not be effective in a similar fishery in the English Channel.

Further underwater observation work to assess fish behaviour and reactions in relation to this type of gear would be invaluable in any further development work in this field.

Having established that the separator panel principle can be applied quite simply to the net design chosen for this work, it will be necessary to examine the feasibility of converting a wider range of net designs and perhaps including pair trawls. This would also require some close collaboration with net manufacturers.

9. Acknowledgements

Seafish would like to gratefully acknowledge the following:-

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- Steve Leadley and the staff at Caedmon Nets for supplying the fishing gear and supporting the trials.

- Mr. Arnold Locker for his assistance in making the trials run so smoothly and providing his invaluable local knowledge on the fishing grounds.

- Dr. John Cotter of MAFF, DFR, Lowestoft for provision of the randomised blocks, experimental design, modification, interpretation and development of the software for the Millar and Walsh method.

- Mr Allan Reese of Hull University provided the software for the analysis of the cumulative length/frequency curves and advised on their interpretation.

- Mr. Trevor Boon and Mr. Clive Brown from MAFF, DFR Lowestoft for their collaboration and assistance with the project.

- The NFFO through which Mr. Arnold Locker's services were provided.

FIGURES 1-11

COD LANDINGS tonnes BOTTOM TRAWL MARCH 1993

FOR U.K. VESSELS LANDING IN ENGLAND

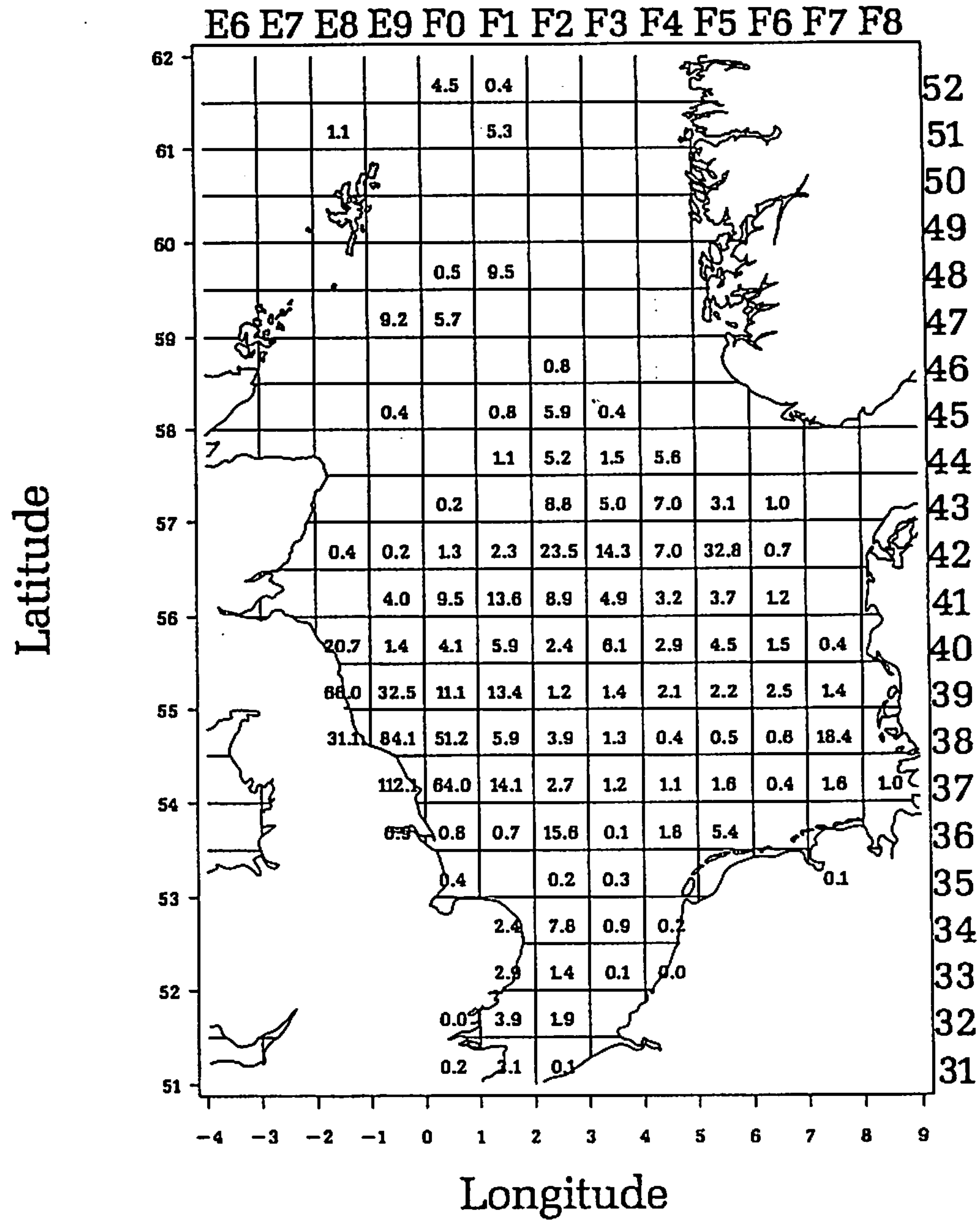


Fig. 1

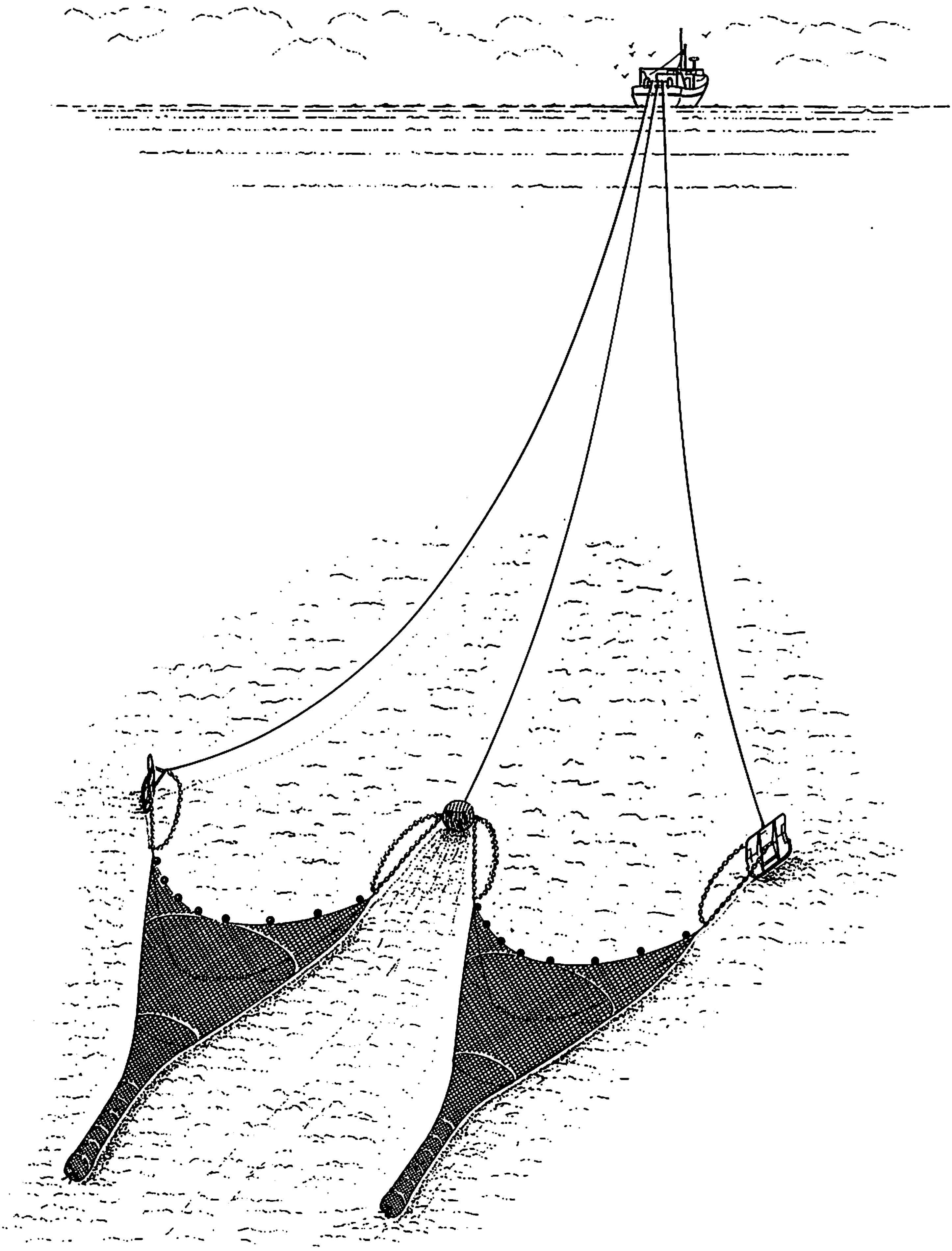
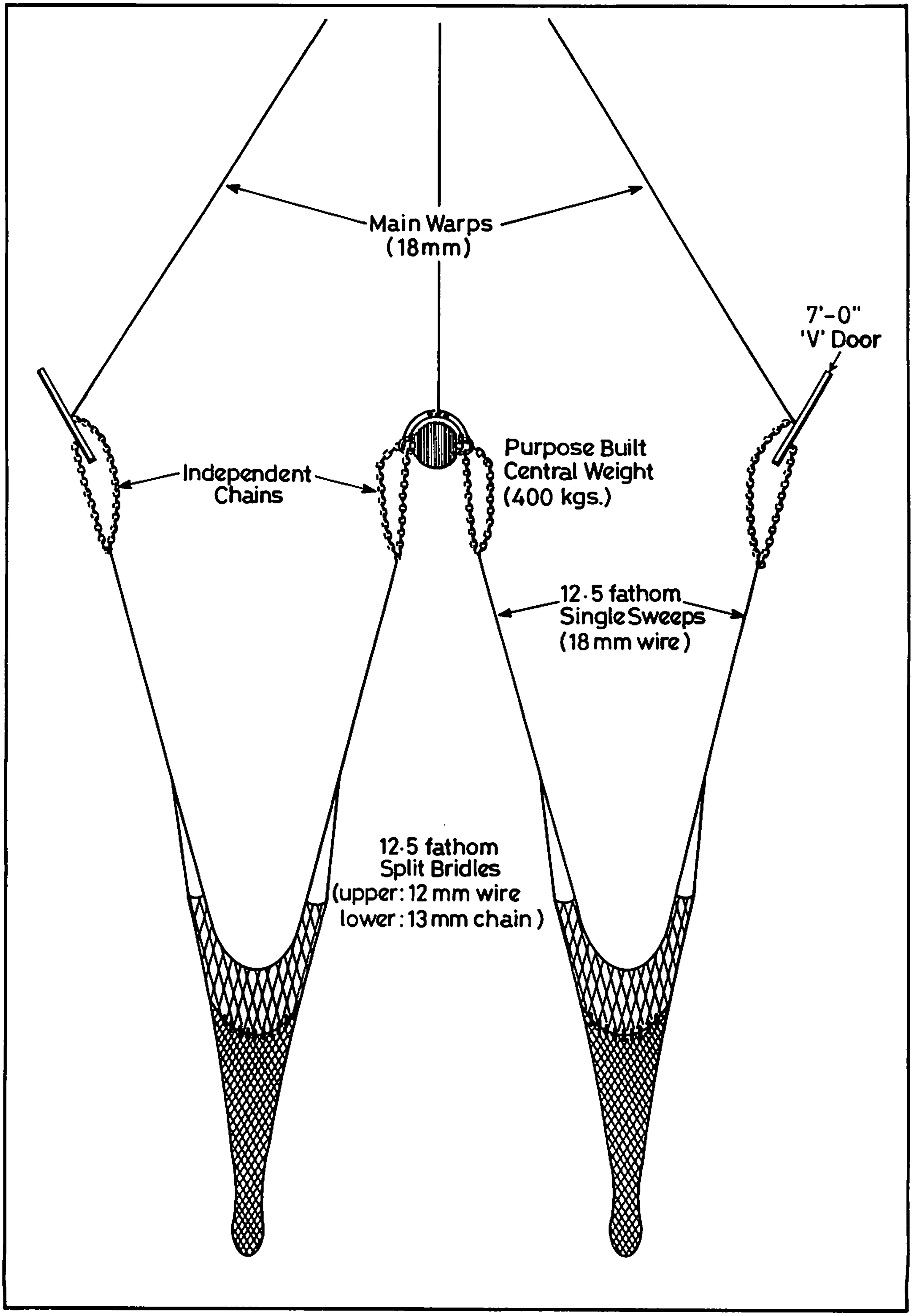
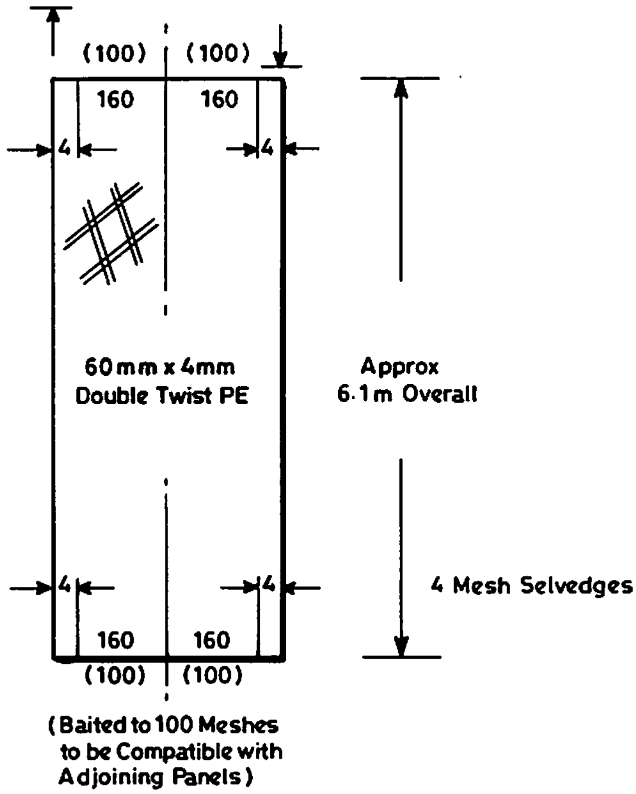


Fig. 2

Three warp twin trawl arrangement

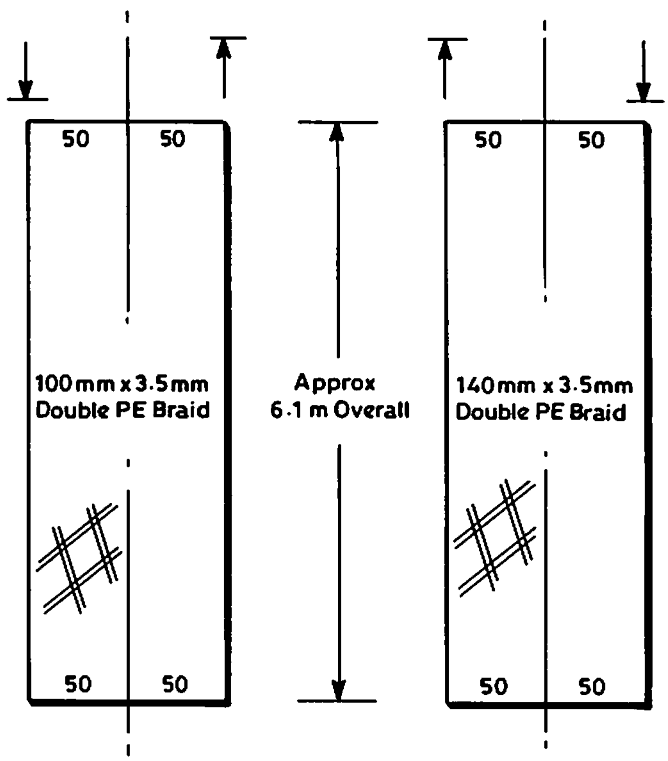


Twin-Rig Arrangement used on 'HEATHER SPRIG' Fig.3



Small Mesh Codend Specification

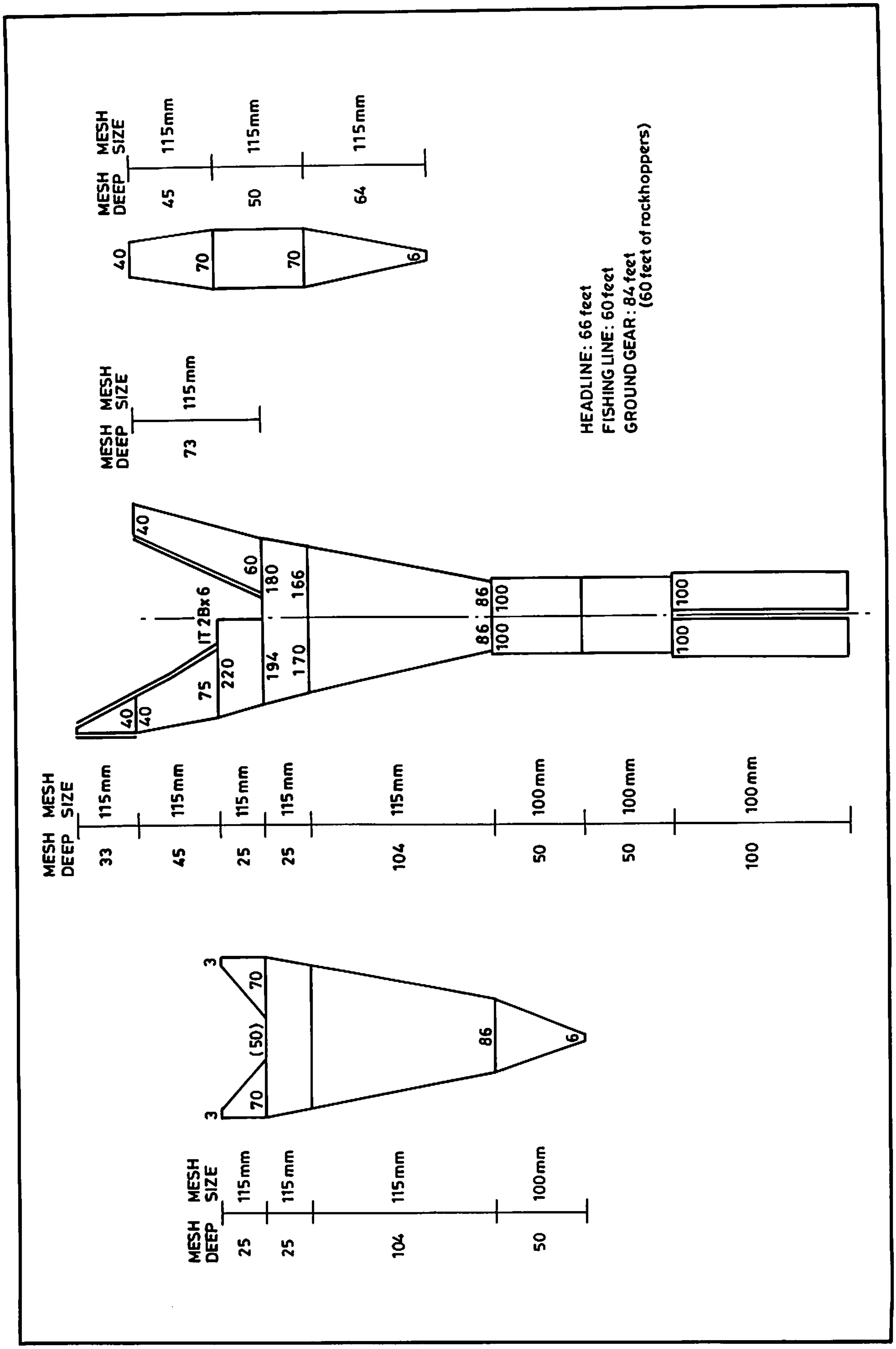
Fig.4



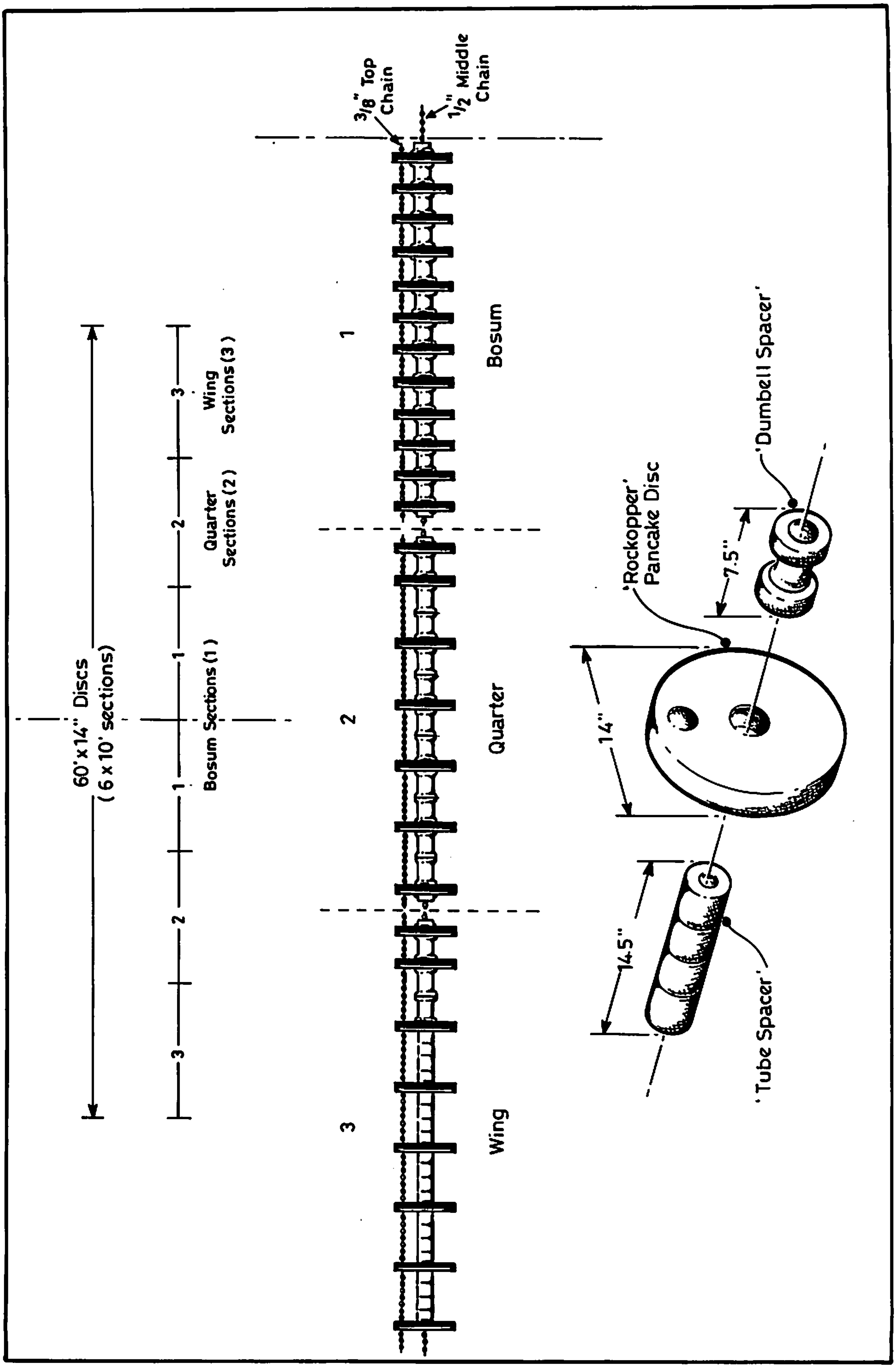
Codend Specifications

Fig.5

Fig.4 & 5.

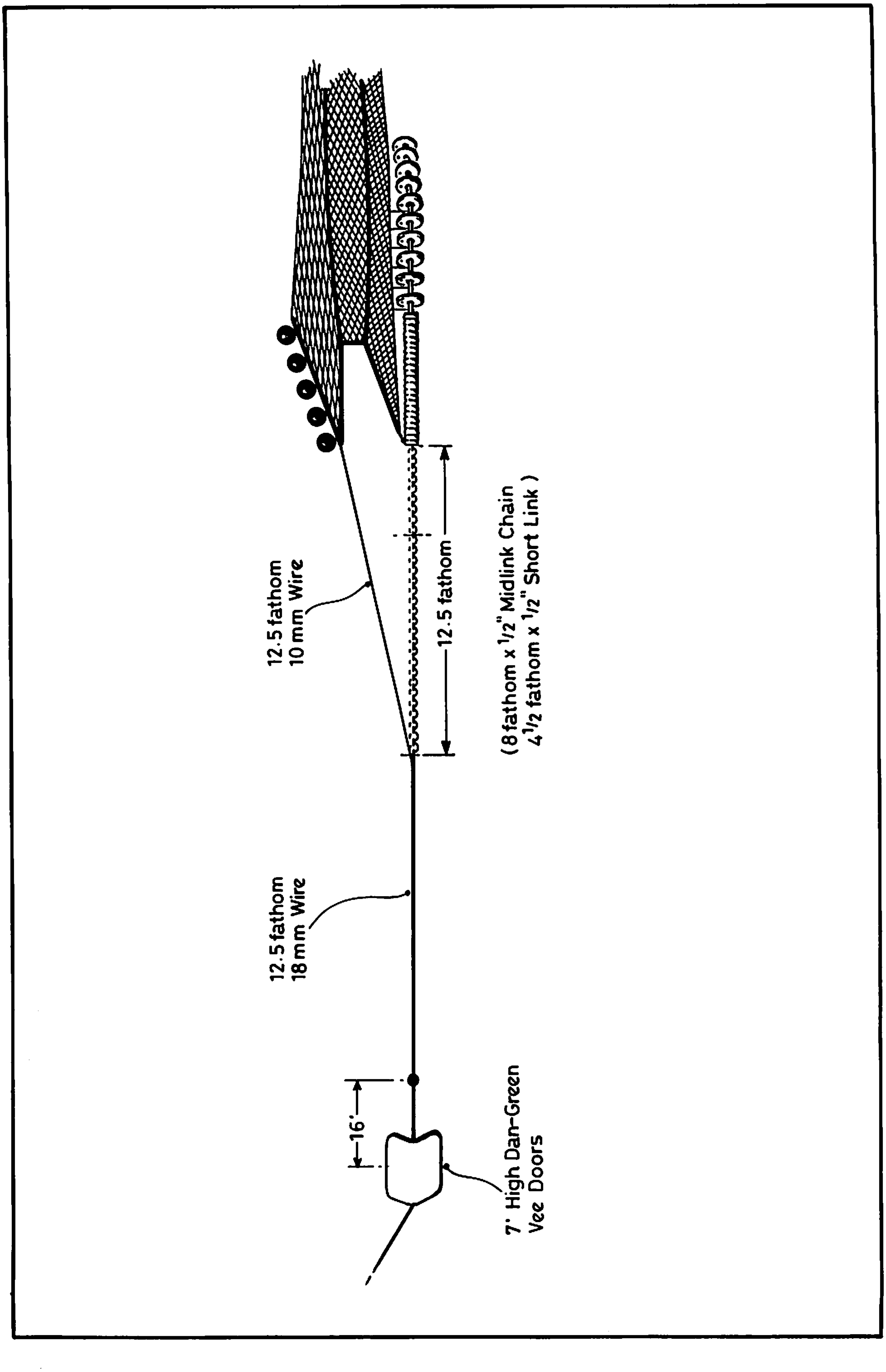


Net Design Modified to Incorporate Separator Panel Fig.6

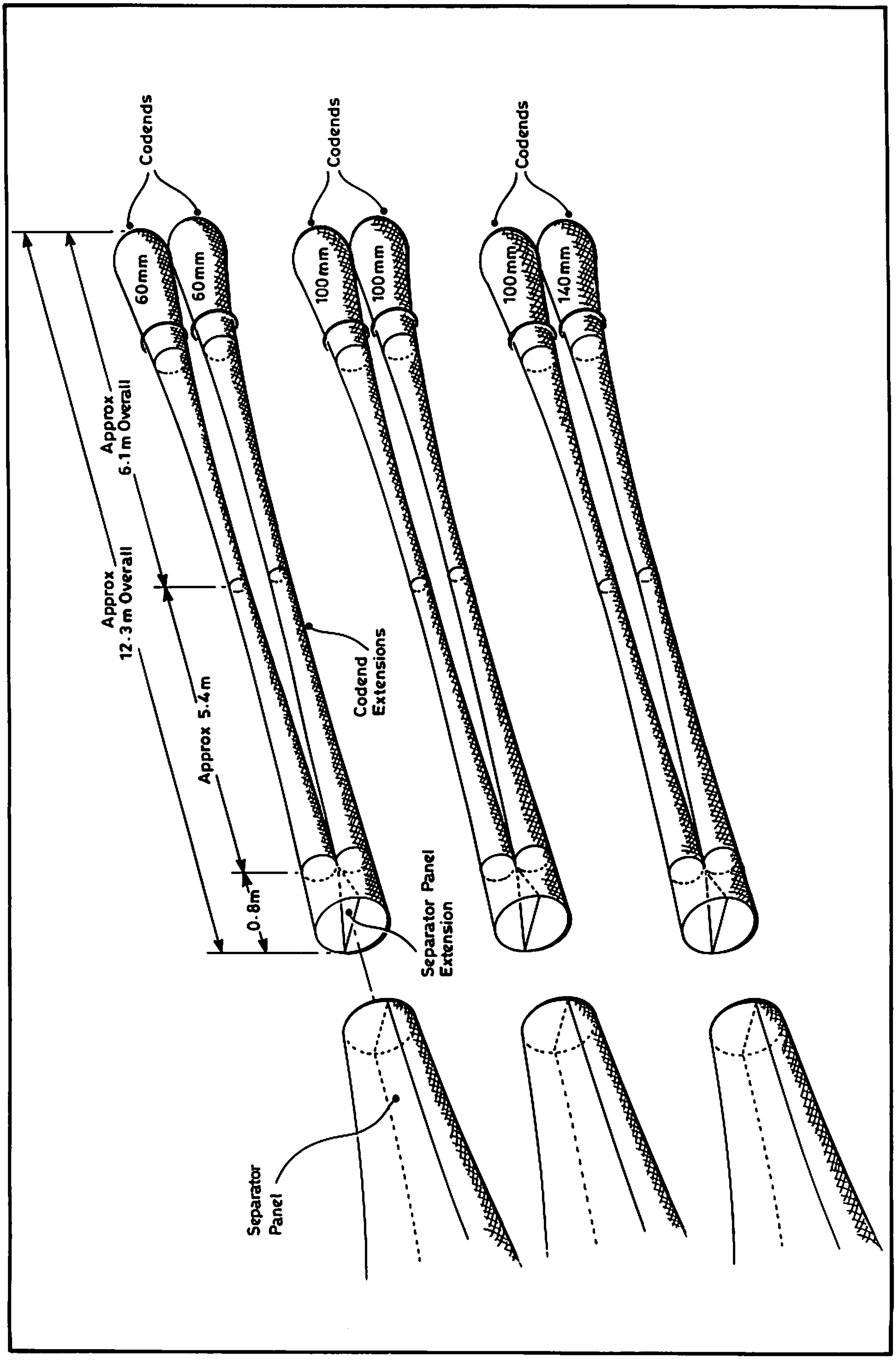


Details of 'Rockhopper' Rig for Separator Trawl

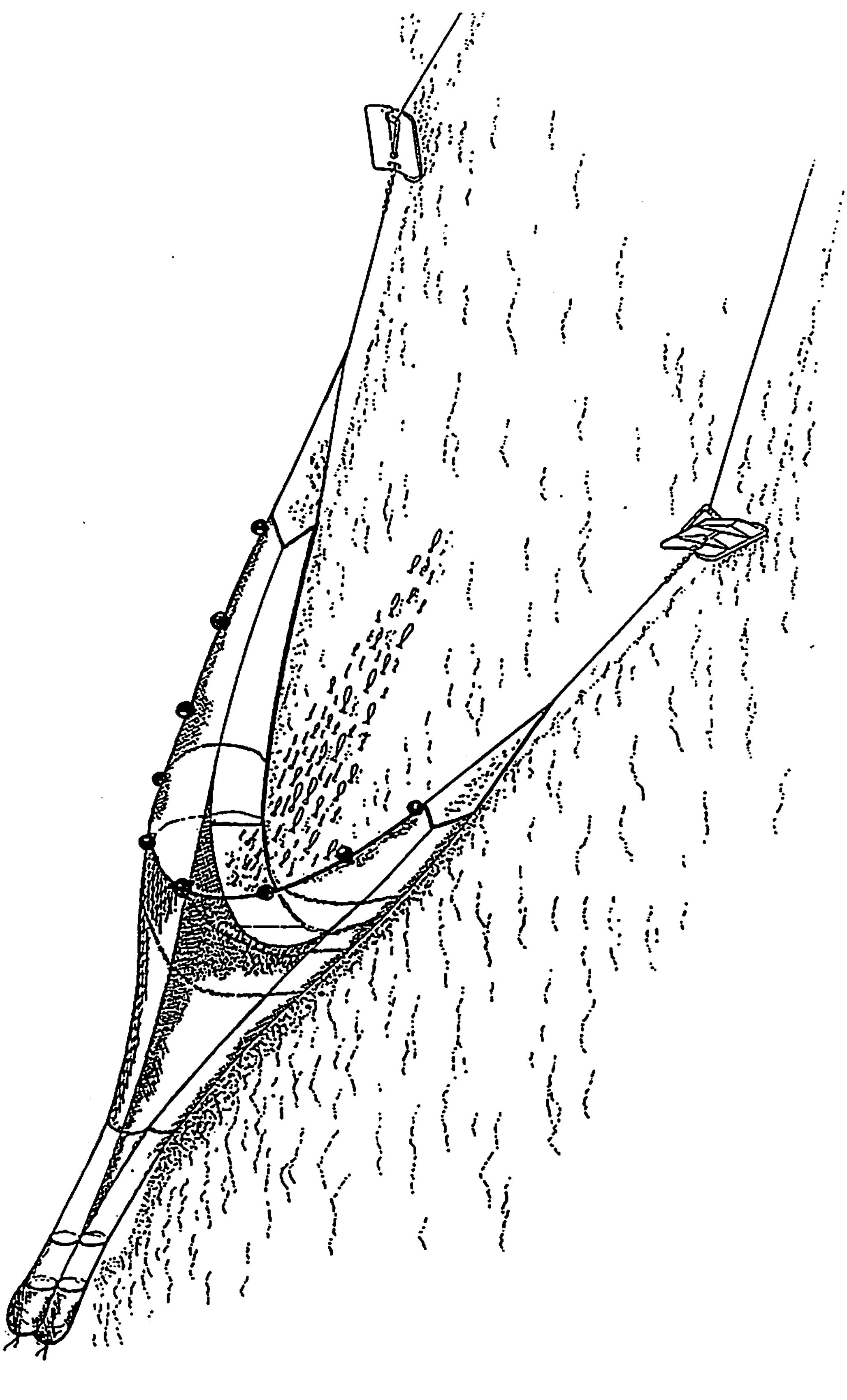
Fig. 7



Sweep / Bridle Arrangements Fig.8

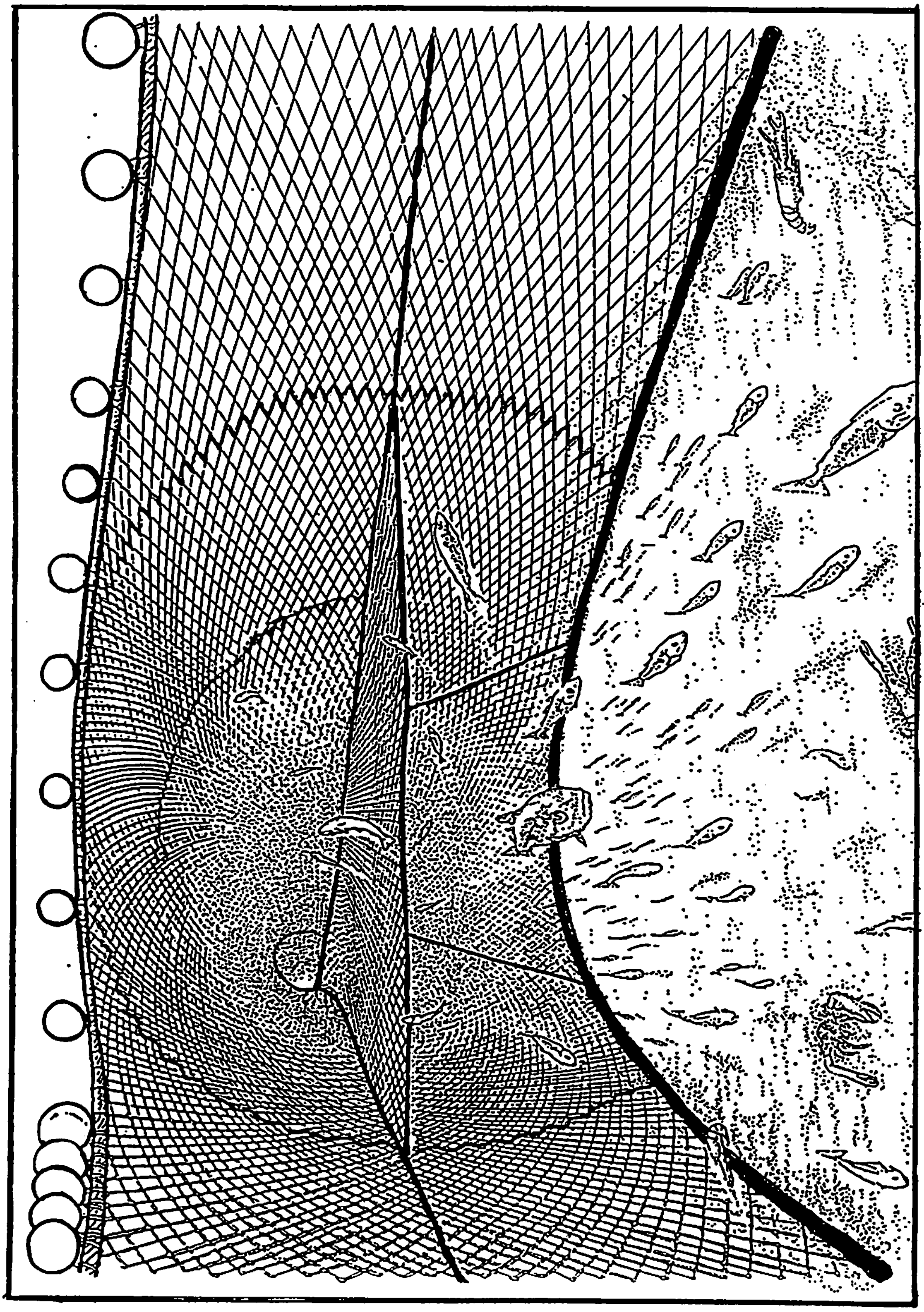


Separator Trawl Trials - Codend Arrangements Fig.9



Sketch of separator trawl showing panel position and twin codend arrangement

Fig. 10



Sketch showing panel position and ropes controlling the panel height inside the mouth of the trawl

Fig. 11

FIGURES 12-25

- **PLOTS SHOWING THE MEAN NUMBERS OF FISH PER HAUL AT EACH CENTIMETRE LENGTH CLASS FOR EACH SPECIES**

- **OGIVE PLOTS SHOWING THE PROPORTION OF FISH RETAINED AT EACH CENTIMETRE LENGTH CLASS FOR EACH SPECIES**

FOR THE FOLLOWING CODEND CONFIGURATIONS:-

- **60mm Upper Codend in Comparison with 100mm Upper Codend**
- **60mm Lower Codend in Comparison with 100mm Lower Codend**
- **60mm Lower Codend in Comparison with 140mm Lower Codend**

NOTE:

1. *Rejected data sets cannot be curve-fitted satisfactorily*
2. *? Denotes range greater than 1.0*
3. *For numbers in SR (selection range), 'LARGE' corresponds to mesh under test, i.e. 100 or 140mm, 'SMALL' corresponds to 60mm control mesh*

Fig 12 (a) Whiting, 60mm upper codend, 10 hauls, none with no fish, mean numbers per haul = 186 fish, total for all hauls = 1861 fish.

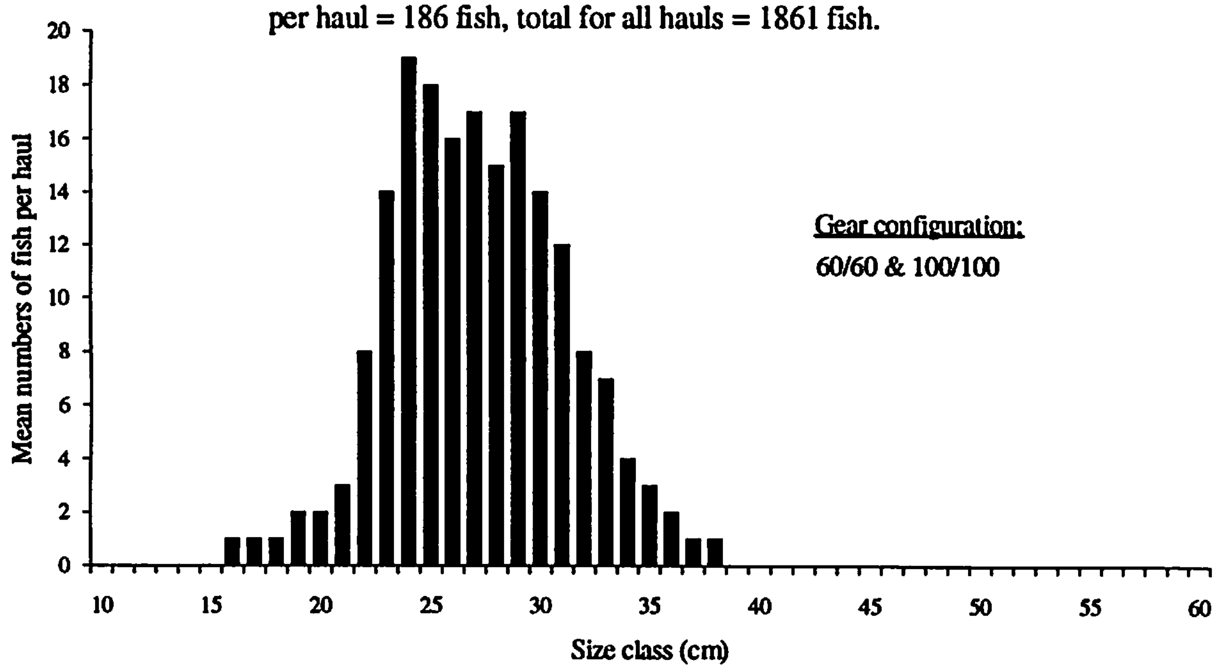


Fig 12 (b) Whiting, 100mm upper codend, 10 hauls, none with no fish, mean numbers per haul = 30 fish, total for all hauls = 295 fish.

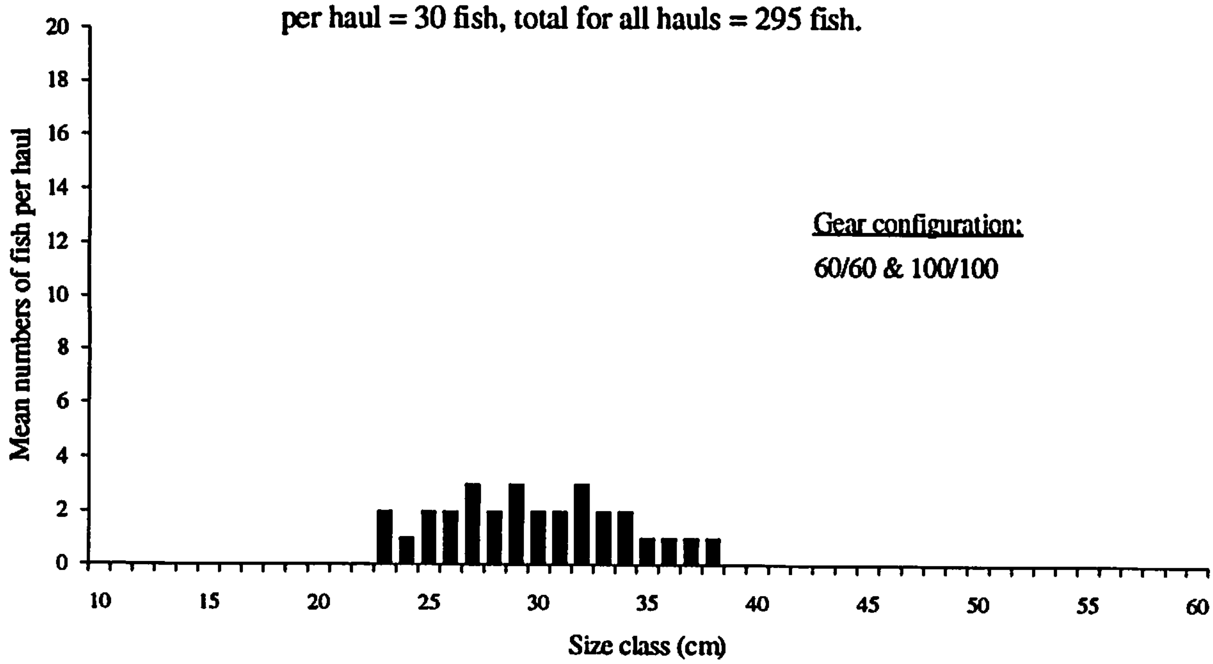


Fig. 12

Fig 13 (a) Whiting, 60mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 82 fish, total for all hauls = 819 fish.

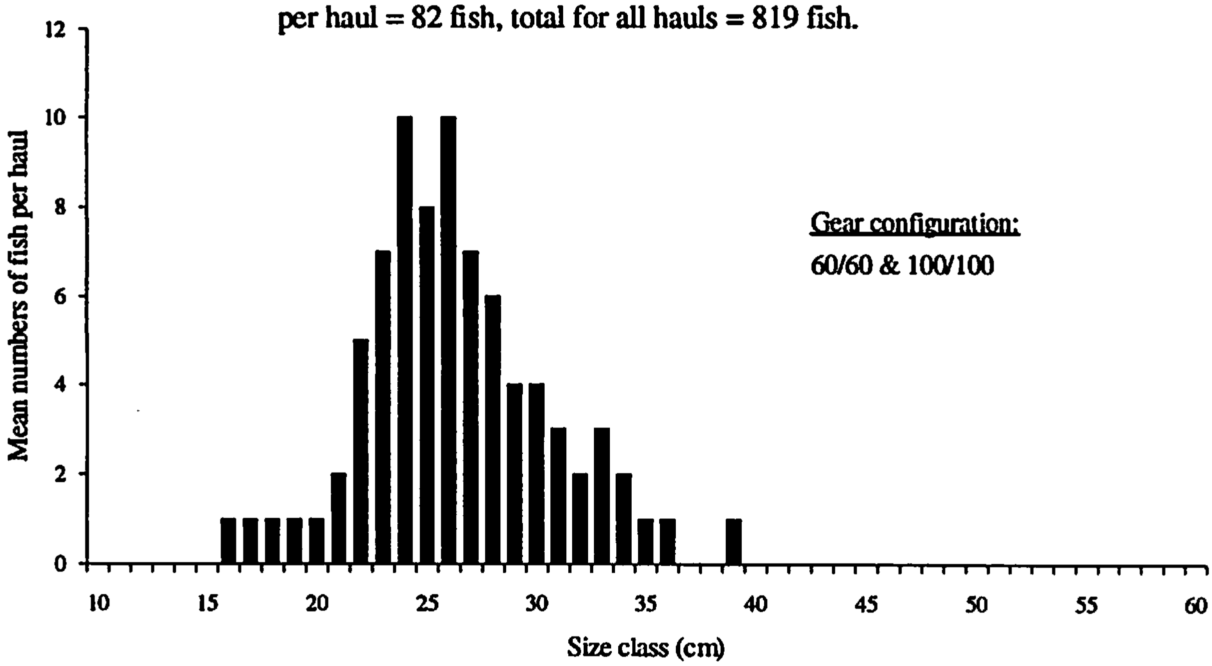


Fig 13 (b) Whiting, 100mm lower codend, 10 hauls, 2 with no fish, mean numbers per haul = 27 fish, total for all hauls = 219 fish.

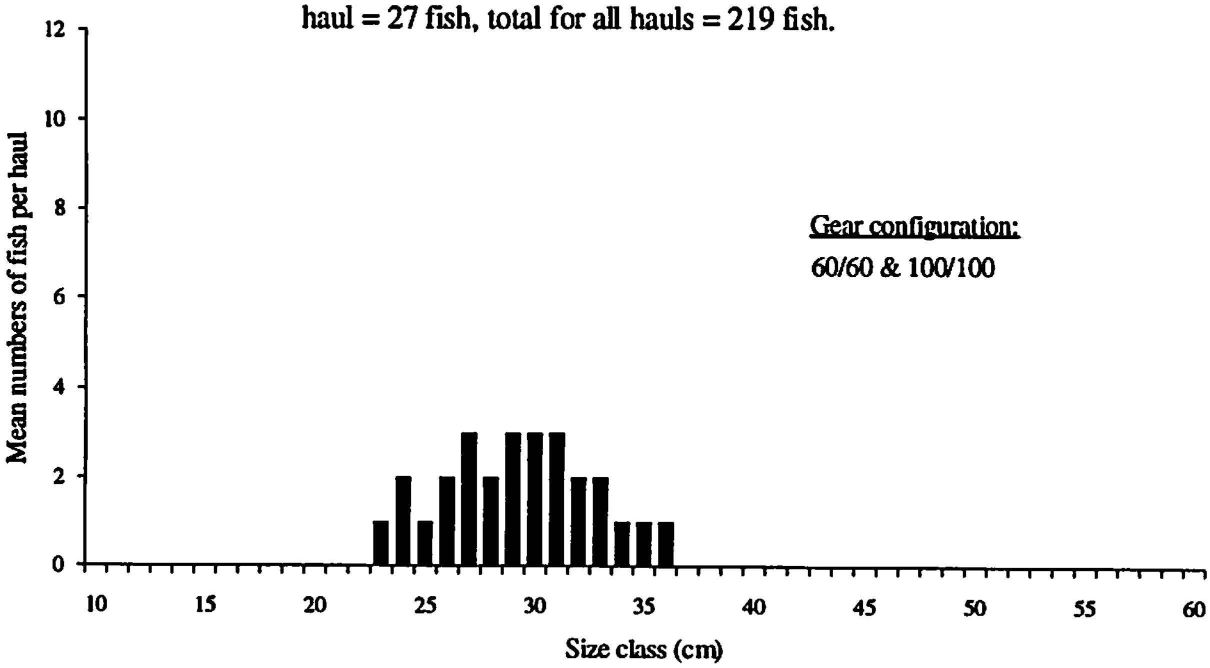


Fig. 13

Fig 14 (a) Whiting, 60mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 69 fish, total for all hauls = 689 fish.

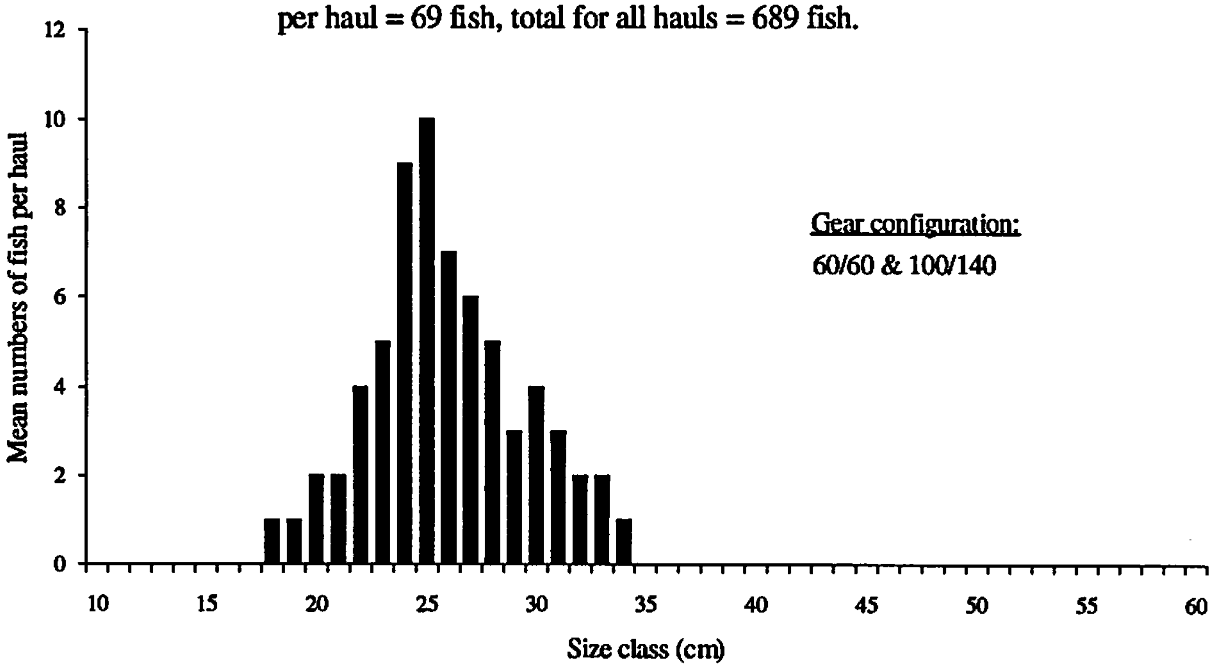


Fig 14 (b) Whiting, 140mm lower codend, 10 hauls, 2 with no fish, mean numbers per haul = 2 fish, total for all hauls = 18 fish.

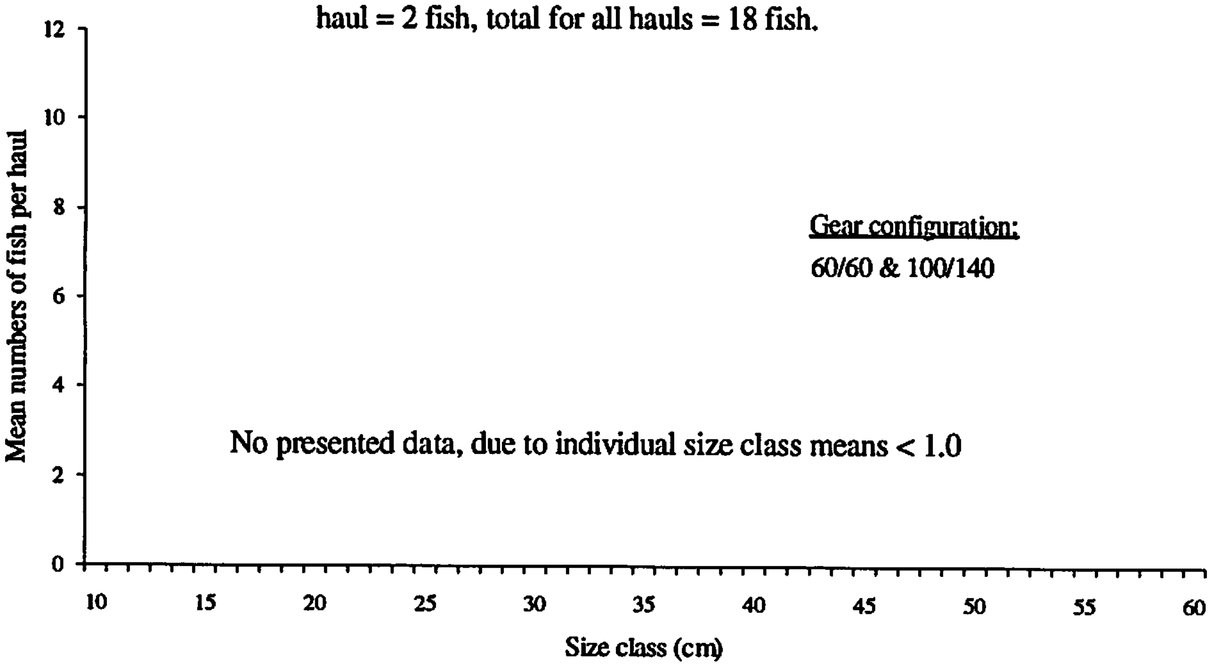
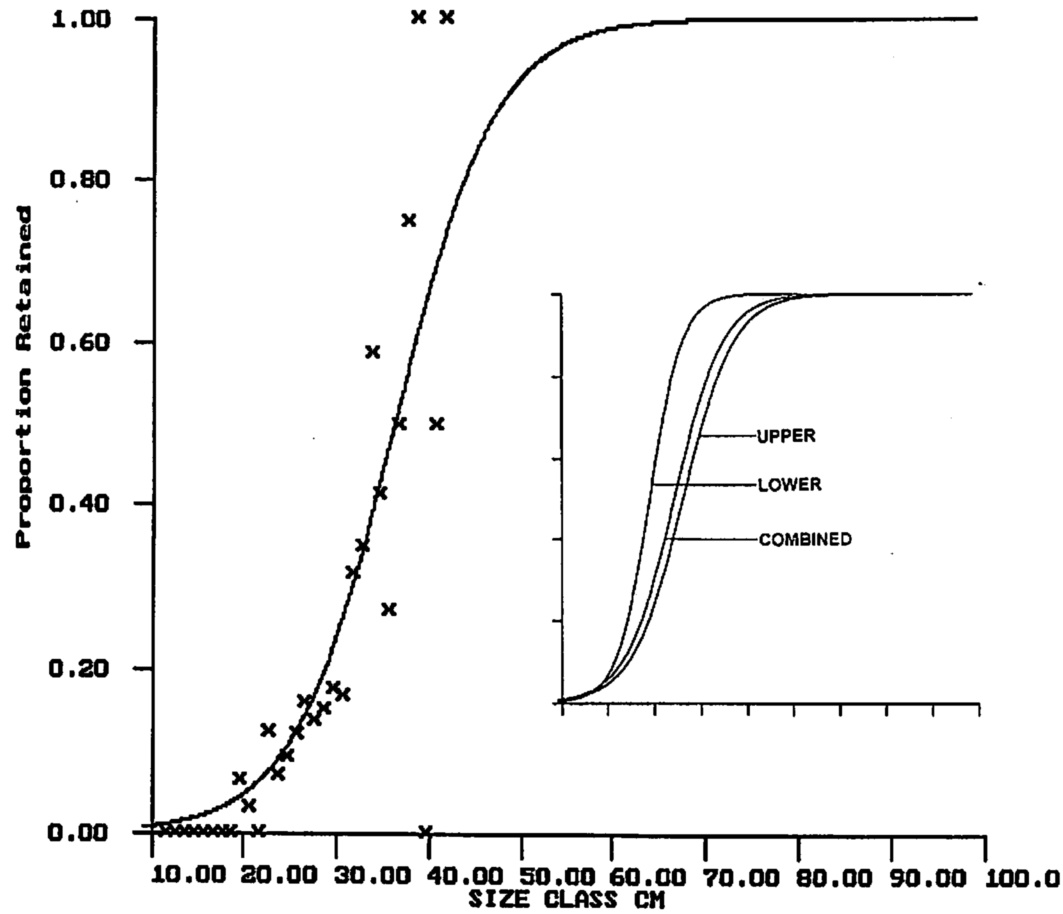


Fig. 14

WHITING 100MM UPPER CODEND AGGREGATE CURVE



Whiting 100mm upper codend

Whiting 100mm upper (cf. 60mm upper control):

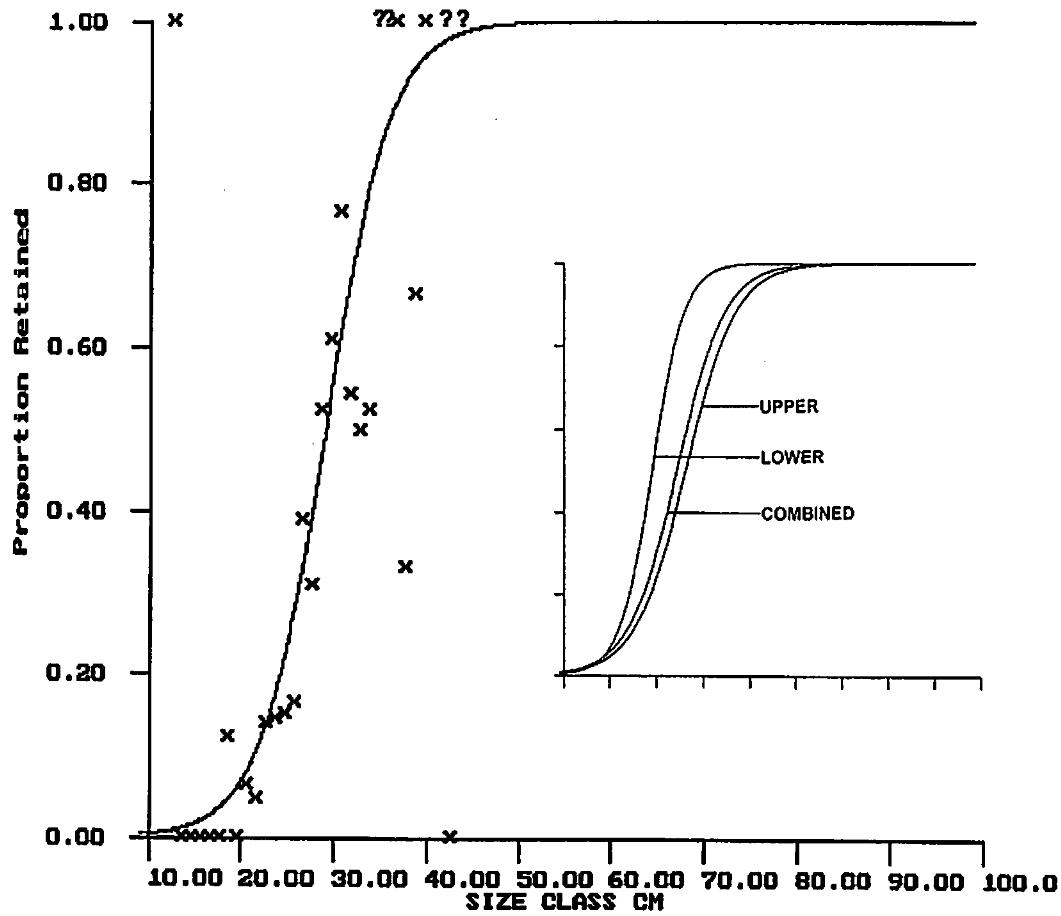
Haul	Retention lengths 50%	25%	75%	Selection Factor	Range	No. in SR Large	Small	n 100mm	n 60mm
1	44.53	36.37	52.7	4.45	16.31	4	14	36	315
2	47.61	20.52	74.7	4.76	54.11	15	53	15	67
7	34.95	28.32	41.58	3.50	13.25	73	201	100	377
8	37.94	34.48	41.39	3.79	6.91	12	20	39	578
10	36.91	31.45	42.36	3.69	10.89	11	35	38	304
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
16	24.46	17.39	31.54	2.45	14.13	11	13	14	16
19	38.15	28.82	47.47	3.82	18.62	5	9	6	28
20	25.02	7.22	42.81	2.50	35.54	12	28	12	28
Means:	36.2	25.57	46.82	3.62	21.22	17.88	46.63	32.5	214.13
Max:	47.61	36.37	74.7	4.76	54.11	73	201	100	578
Min:	24.46	7.22	31.54	2.45	6.91	4	9	6	16
Aggregate:	37.69	31.77	43.6	3.77	11.81	122	358	295	1861

Rejected data sets (included in aggregate):

Haul	Retention lengths 50%	25%	75%	Selection Factor	Range	No. in SR Large	Small	n 100mm	n 60mm
12	29.29	42.98	15.59	2.93	-27.4	0	0	19	56
15	58.48	36.87	80.48	5.85	43.16	1	0	16	92

Fig. 15

WHITING 100MM LOWER CODEND AGGREGATE CURVE



Whiting 100mm lower codend

Whiting 100mm lower (cf. 60mm lower control):

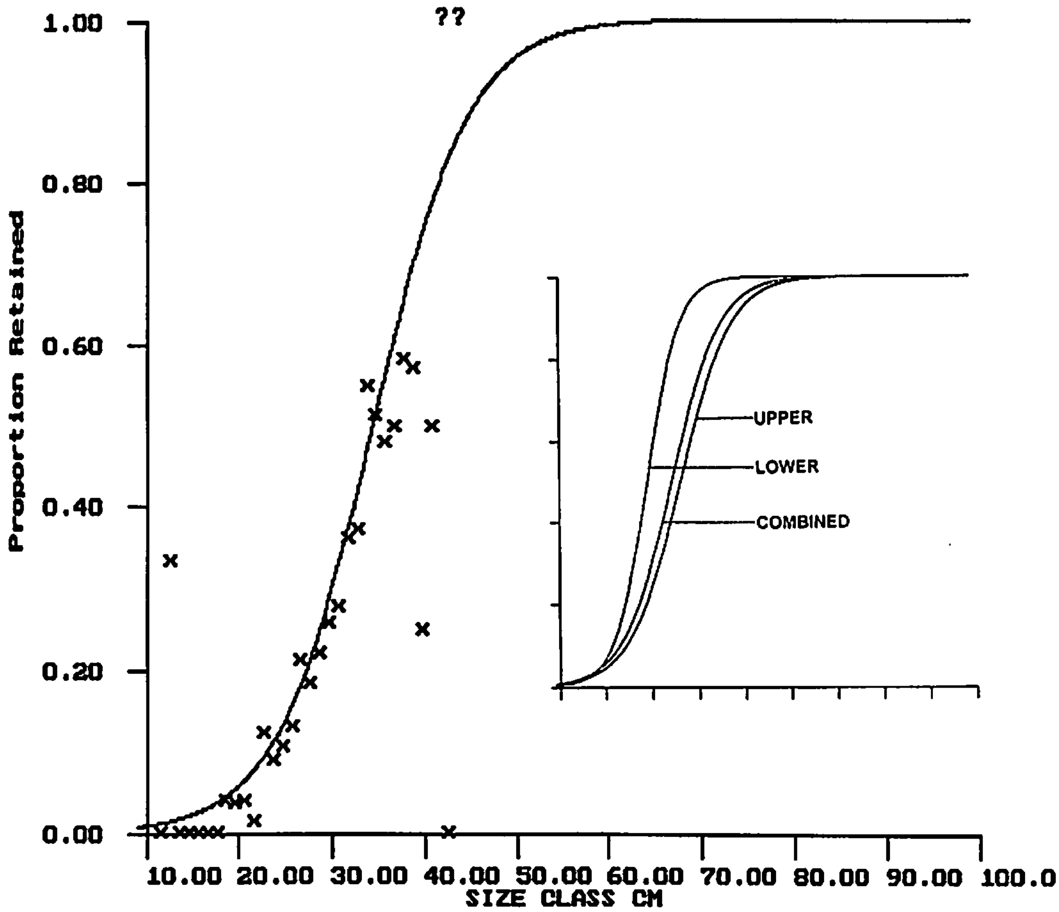
Haul	Retention lengths 50%	25%	75%	Selection Factor	Range	No. in SR Large	Small	n 100mm	n 60mm
1	32.61	28.3	36.92	3.26	8.61	35	75	45	160
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
8	28.52	27.31	29.72	2.85	2.41	15	41	60	205
10	34.89	29.11	40.66	3.49	11.54	9	21	20	126
12	31.82	28.86	34.77	3.18	5.91	9	18	14	61
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
Means:	31.96	28.4	35.52	3.20	7.12	17	38.75	34.75	138
Max:	34.89	29.11	40.66	3.49	11.54	35	75	60	205
Min:	28.52	27.31	29.72	2.85	2.41	9	18	14	61
Aggregate:	30.52	26.72	34.33	3.05	7.6	143	343	219	819

Rejected data sets (included in aggregate):

Haul	Retention lengths 50%	25%	75%	Selection Factor	Range	No. in SR Large	Small	n 100mm	n 60mm
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	21
7	35.99	1.54	70.43	3.60	68.81	65	152	65	152
15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	77
16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	11	1
19	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	8
20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	8

Fig. 16

WHITING 100MM UPPER + LOWER COMBINED AGGREGATE



Whiting 100mm upper and lower codends combined together

Whiting 100mm uppers + lowers combined (cf. 60mm uppers + lowers):

	Retention lengths			Selection		No. in SR		n	n
Haul	50%	25%	75%	Factor	Range	Large	Small	100mm	60mm
1	37.77	31.89	43.66	3.78	11.76	32	119	81	475
2	31.89	25.73	38.05	3.19	12.3	13	31	18	88
7	35.27	25.77	44.78	3.53	18.99	135	401	165	529
8	34.5	31.37	37.64	3.45	6.26	48	133	99	783
10	37.03	31.05	43	3.70	11.93	14	57	58	430
12	33.23	27.89	38.57	3.32	10.66	23	61	33	117
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
19	38.32	31.6	45.03	3.83	13.41	5	11	6	36
-	-	-	-	-	-	-	-	-	-
Means:	35.43	29.33	41.53	3.54	12.19	38.57	116.1	65.71	351.14
Max:	38.32	31.89	45.03	3.83	18.99	135	401	165	783
Min:	31.89	25.73	37.64	3.19	6.26	5	11	6	36
Aggregate:	35.82	30.17	41.48	3.58	11.3	263	769	514	2680

Rejected data sets (included in aggregate):

	Retention lengths			Selection		No. in SR		n	n
Haul	50%	25%	75%	Factor	Range	Large	Small	100mm	60mm
15	48.1	38.15	58.05	4.81	19.88	1	2	16	169
16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	25	17
20	24.69	3.08	46.29	2.47	43.16	13	36	13	36

Fig. 17

Fig 18 (a) Cod, 60mm upper codend, 10 hauls, none with no fish, mean numbers per haul = 8 fish, total for all hauls = 75 fish.

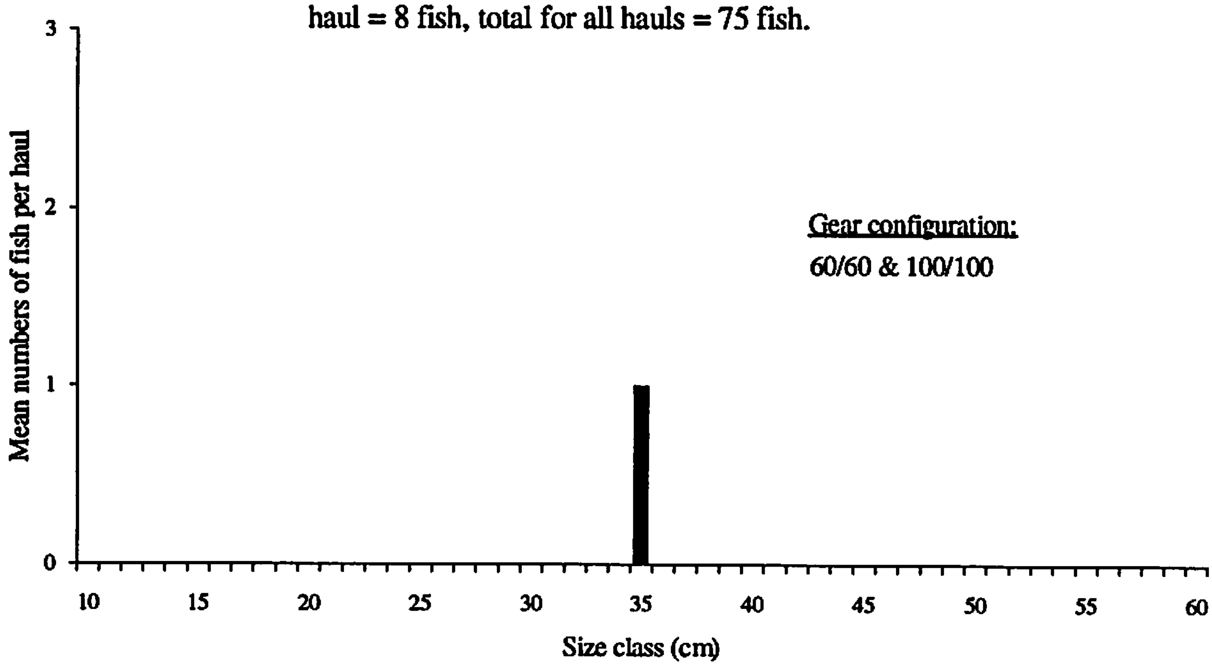


Fig 18 (b) Cod, 100mm upper codend, 10 hauls, 5 with no fish, mean numbers per haul = 5 fish, total for all hauls = 27 fish.

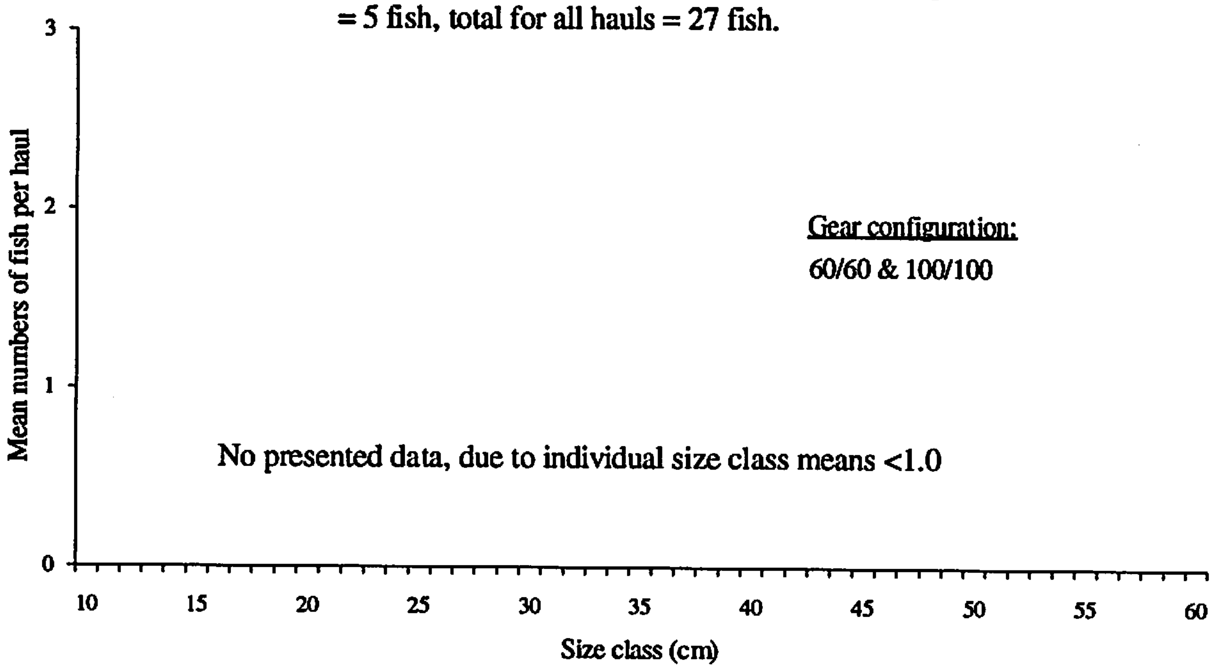


Fig 19 (a) Cod, 60mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 49 fish, total for all hauls = 490 fish.

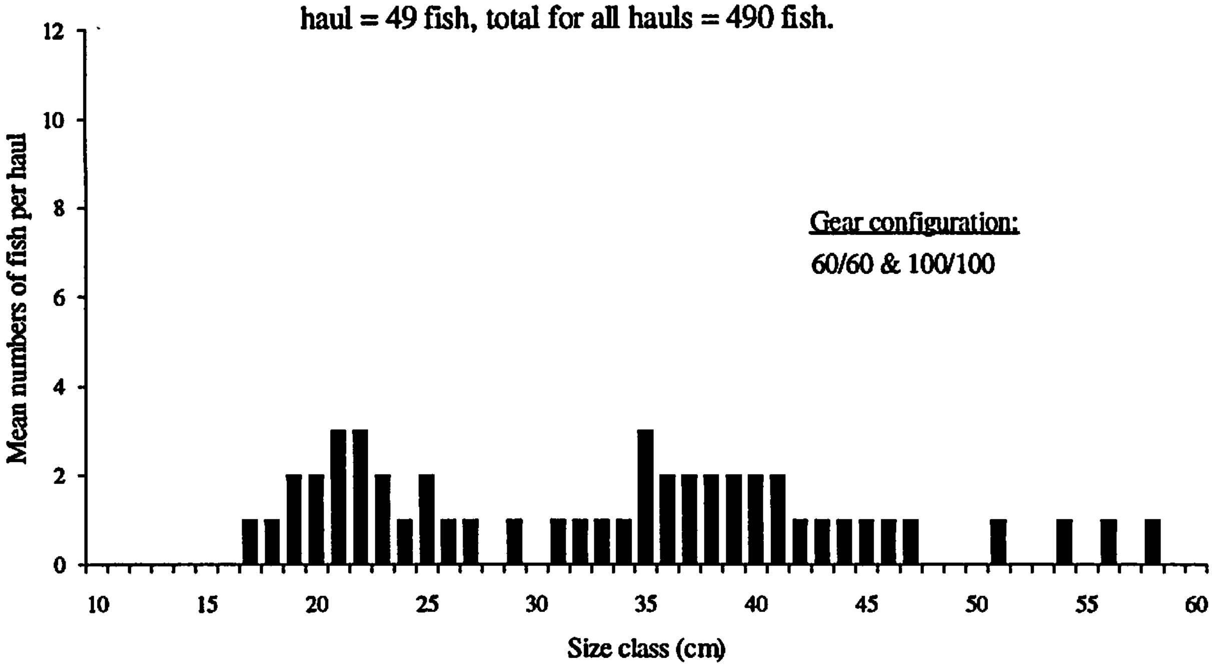


Fig 19 (b) Cod, 100mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 27 fish, total for all hauls = 272 fish.

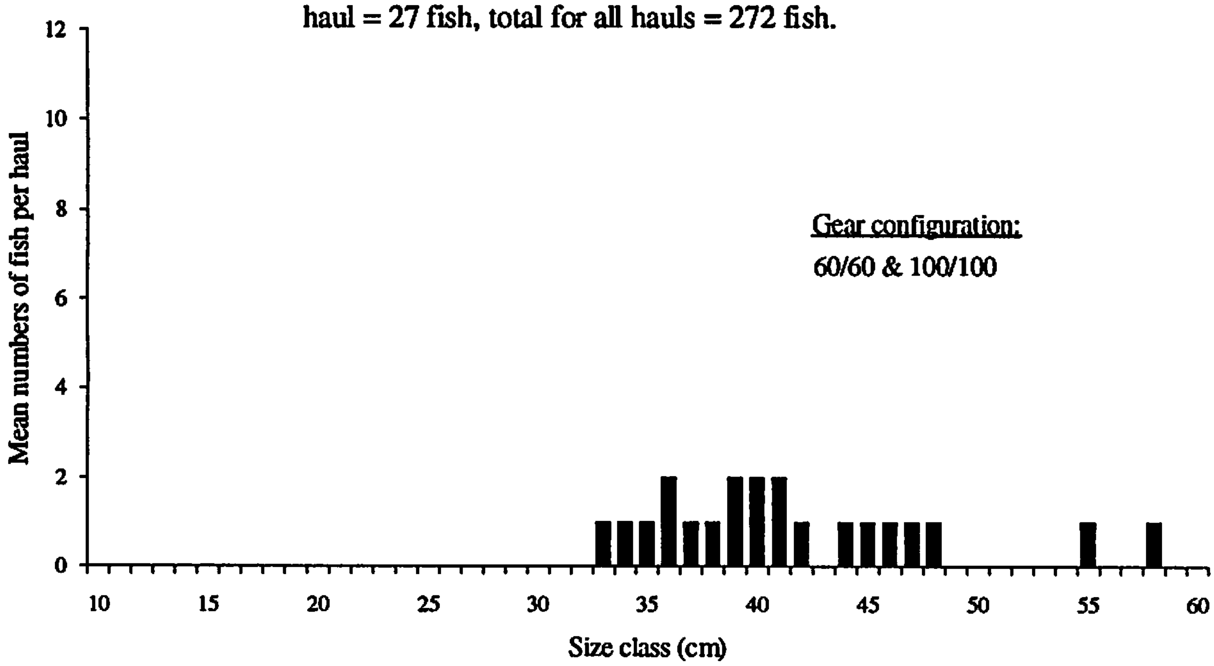


Fig 20 (a) Cod, 60mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 52 fish, total for all hauls = 521 fish.

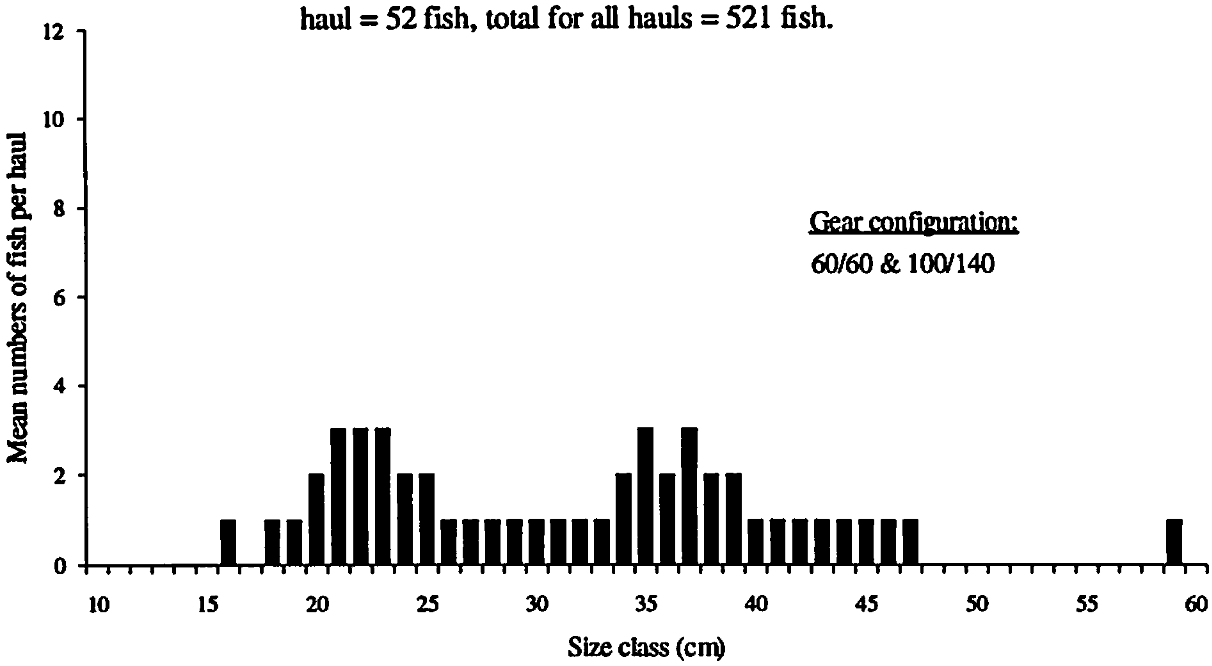
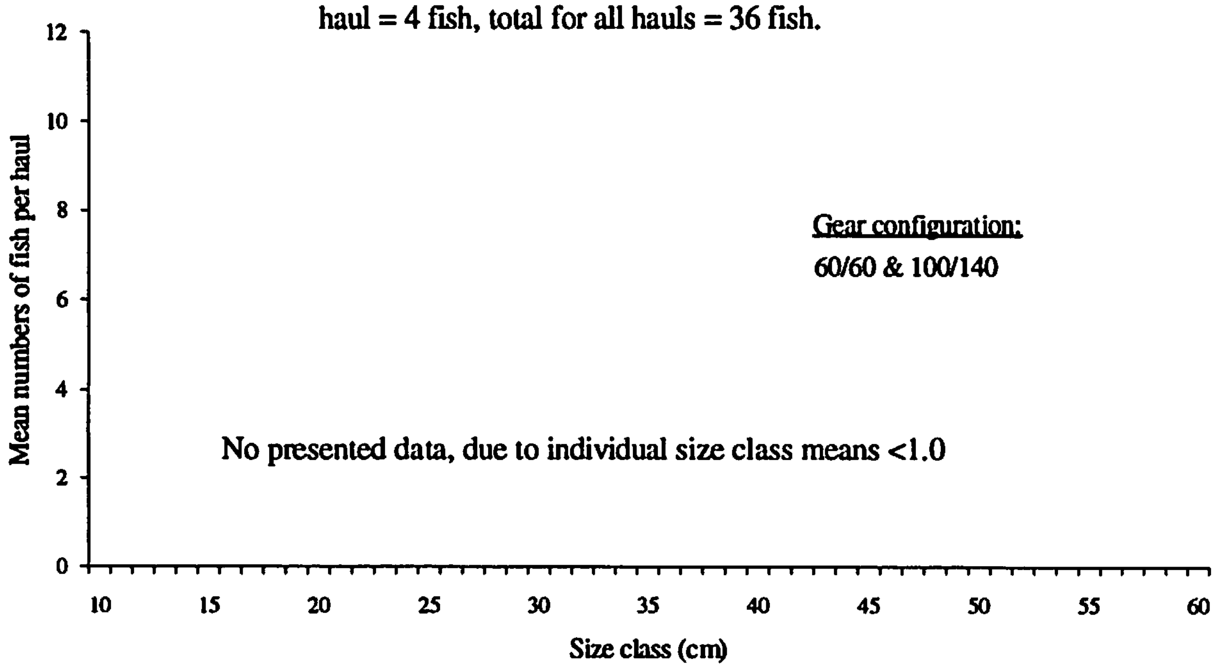
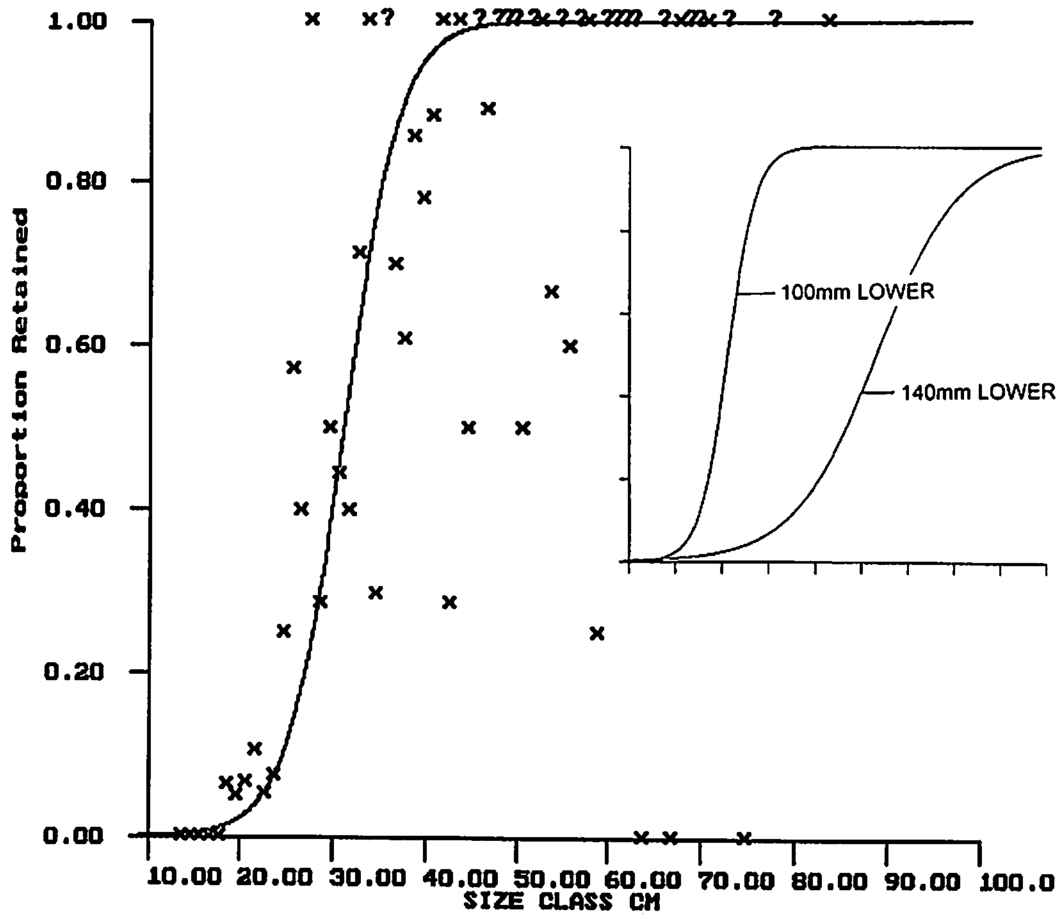


Fig 20 (b) Cod, 140mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 4 fish, total for all hauls = 36 fish.



COD 100MM LOWER CODEND AGGREGATE CURVE



Cod 100mm lower codend

Cod 100mm lower (cf. 60mm lower control):

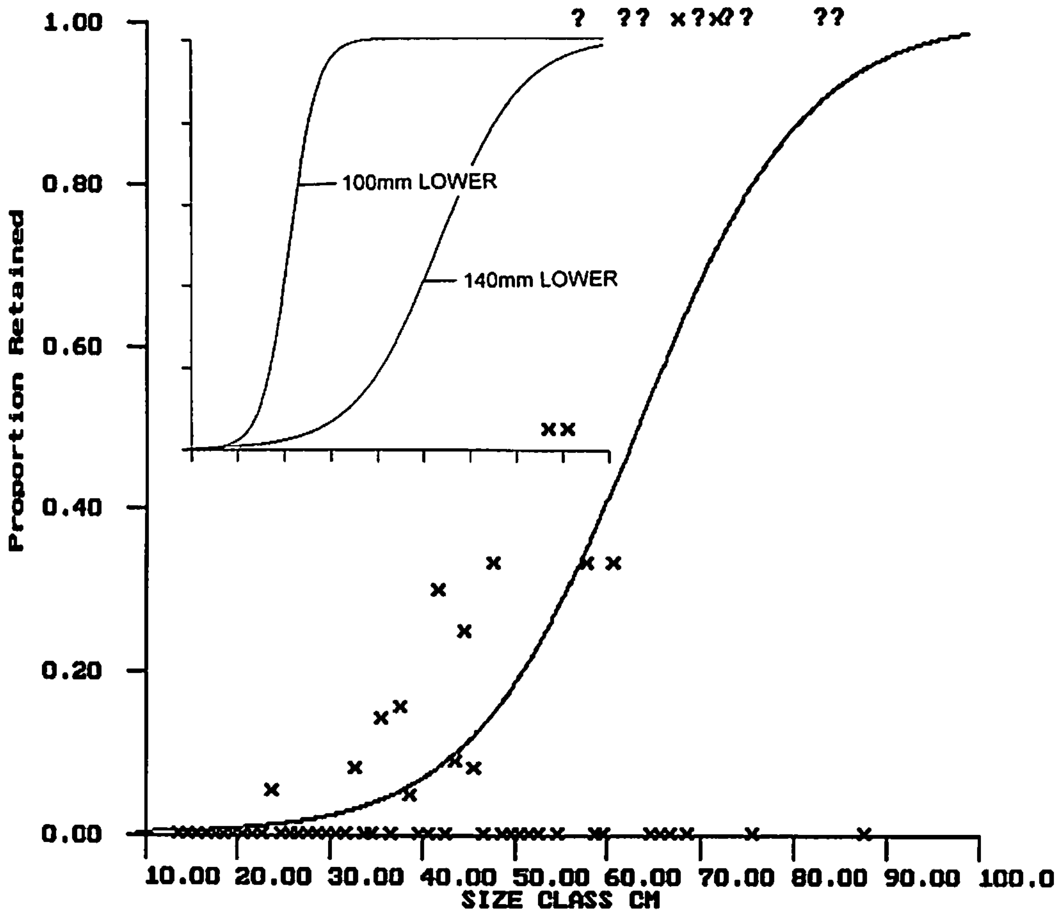
	Retention lengths			Selection		No. in SR		n	n
Haul	50%	25%	75%	Factor	Range	Large	Small	100mm	60mm
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
7	36.1	25.97	46.22	3.61	20.22	14	26	19	60
8	30.16	22.56	37.77	3.02	15.19	8	24	23	60
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
Means:	33.13	24.27	42	3.31	17.71	11	25	21	60
Max:	36.1	25.97	46.22	3.61	20.22	14	26	23	60
Min:	30.16	22.56	37.77	3.02	15.19	8	24	19	60
Aggregate:	32.62	29.35	35.89	3.26	6.52	33	59	272	490

Rejected data sets (included in aggregate):

	Retention lengths			Selection		No. in SR		n	n
Haul	50%	25%	75%	Factor	Range	Large	Small	100mm	60mm
1	n/a	n/a	n/a	n/a	n/a	n/a	n/a	27	35
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	58	85
10	50.62	38.58	62.66	5.06	24.05	3	13	9	72
12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	22	26
15	n/a	n/a	n/a	n/a	n/a	n/a	n/a	22	43
16	n/a	n/a	n/a	n/a	n/a	n/a	n/a	8	5
19	929	1724	134.2	92.90	-1588	0	0	46	59
20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	38	45

Fig. 21

COD 140MM LOWER CODEND AGGREGATE CURVE



Cod 140mm lower codend

Cod 140mm lower (cf. 60mm lower control):

	Retention lengths			Selection		No. in SR		n	n
Haul	50%	25%	75%	Factor	Range	Large	Small	140mm	60mm
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
Means:	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Max:	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Min:	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Aggregate:	64.65	54.88	74.43	4.62	19.53	15	33	36	521

Rejected data sets (included in aggregate):

	Retention lengths			Selection		No. in SR		n	n
Haul	50%	25%	75%	Factor	Range	Large	Small	140mm	60mm
3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	60
4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4	60
5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	54
6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	59
9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	32
11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	82
13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2	57
14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	11	58
17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	42
18	n/a	n/a	n/a	n/a	n/a	n/a	n/a	10	17

Fig. 22

Fig 23 (a) Plaice, 60mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 12 fish, total for all hauls = 116 fish.

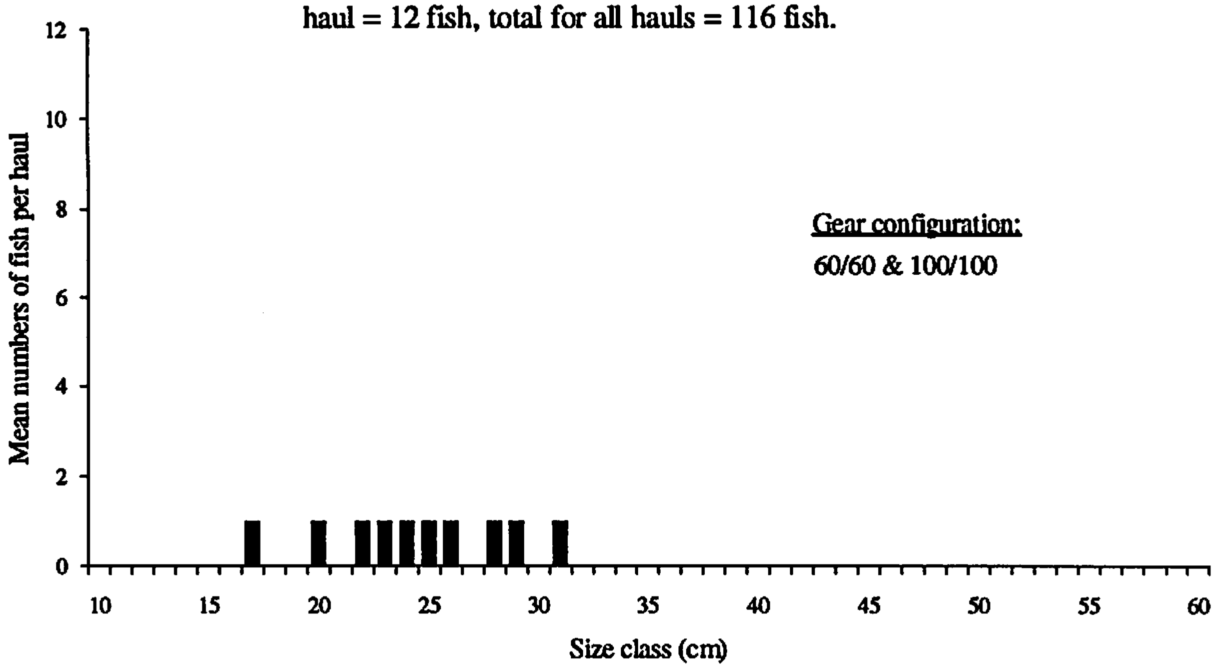


Fig 23 (b) Plaice, 100mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 9 fish, total for all hauls = 94 fish.

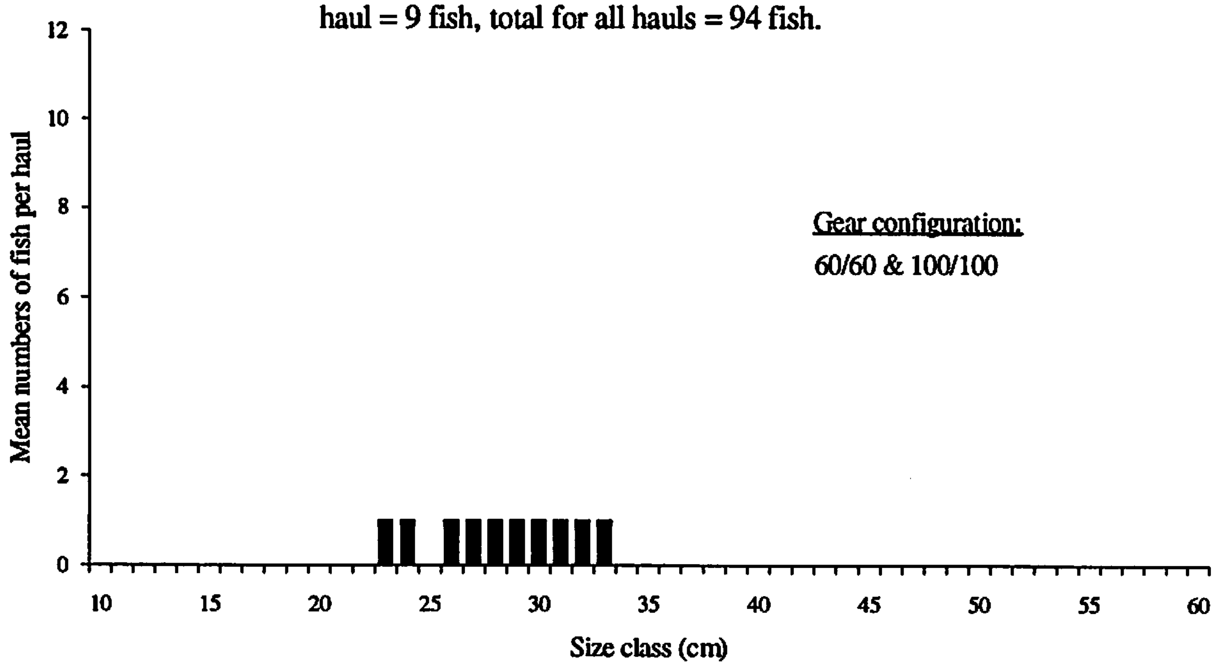


Fig 24 (a) Plaice, 60mm lower codend, 10 hauls, none with no fish, mean numbers per haul = 20 fish, total for all hauls = 198 fish.

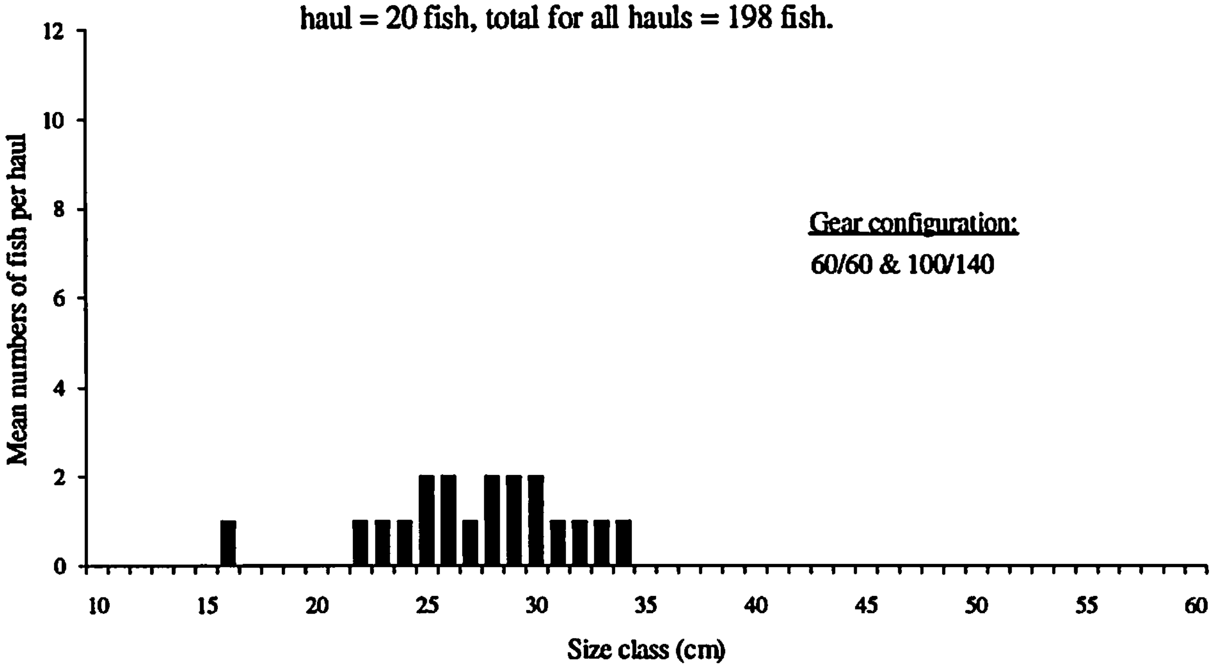


Fig 24 (b) Plaice, 140mm lower codend, 10 hauls, 2 with no fish, mean numbers per haul = 5 fish, total for all hauls = 41 fish.

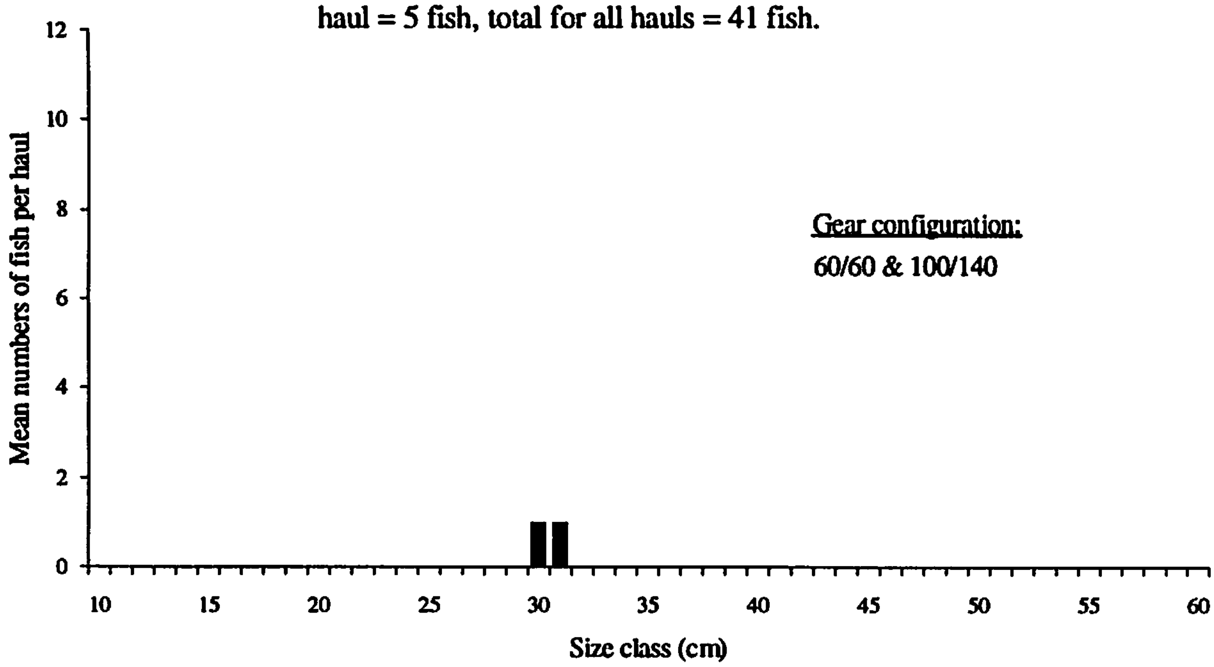
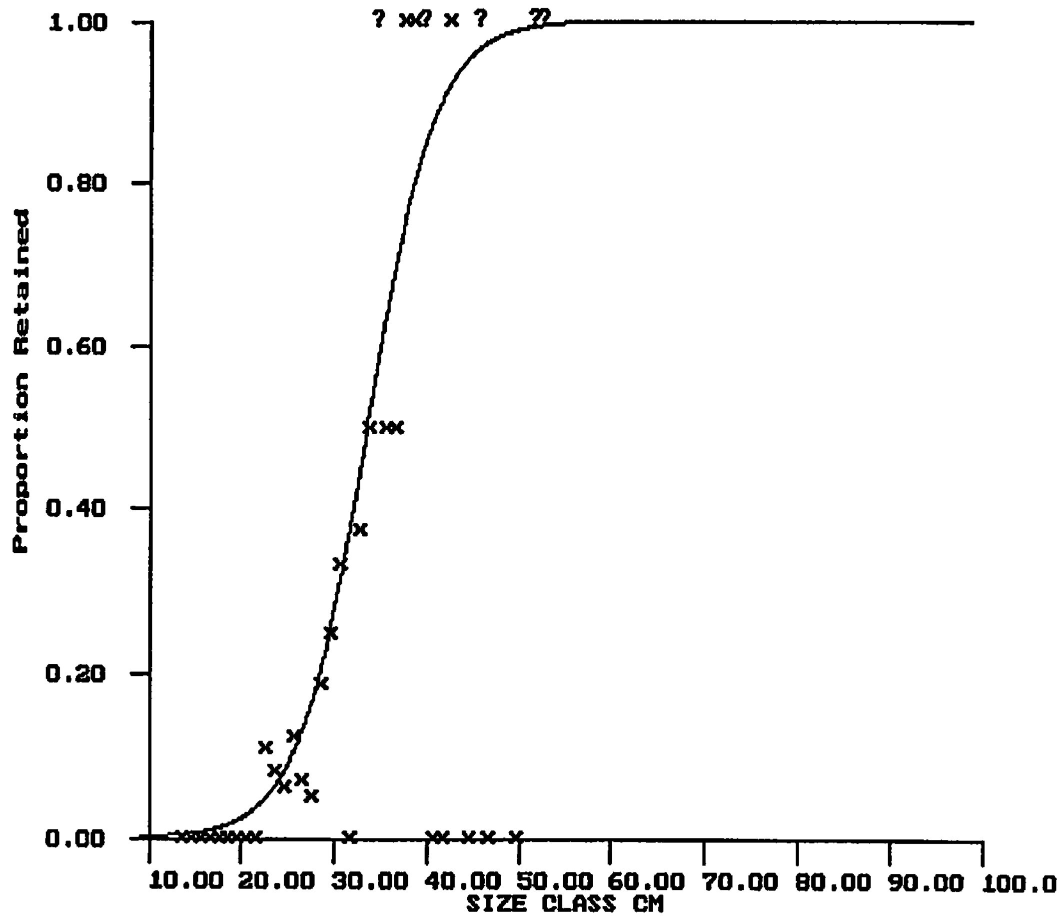


Fig. 24

PLAICE 140MM LOWER CODEND AGGREGATE CURVE



Plaice 140mm lower codend

Plaice 140mm lower (cf. 60mm lower control):

Haul	Retention lengths 50%	25%	75%	Selection Factor	Range	No. in SR Large	Small	n 140mm	n 60mm
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
18	33.64	28.75	38.53	2.40	9.77	7	21	11	65
Means:	33.64	28.75	38.53	2.40	9.77	7	21	11	65
Max:	33.64	28.75	38.53	2.40	9.77	7	21	11	65
Min:	33.64	28.75	38.53	2.40	9.77	7	21	11	65
Aggregate:	34.99	30.98	39.01	2.50	8.02	19	49	41	198

Rejected data sets (included in aggregate):

Haul	Retention lengths 50%	25%	75%	Selection Factor	Range	No. in SR Large	Small	n 140mm	n 60mm
3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4	21
4	n/a	n/a	n/a	n/a	n/a	n/a	n/a	6	13
5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3	28
6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	5	29
9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	7
11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	7
13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7	13
14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4	9
17	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	6

Fig. 25

MODELLED CUMULATIVE SIZE DISTRIBUTIONS WITH RESPECT TO LENGTH FOR WHITING

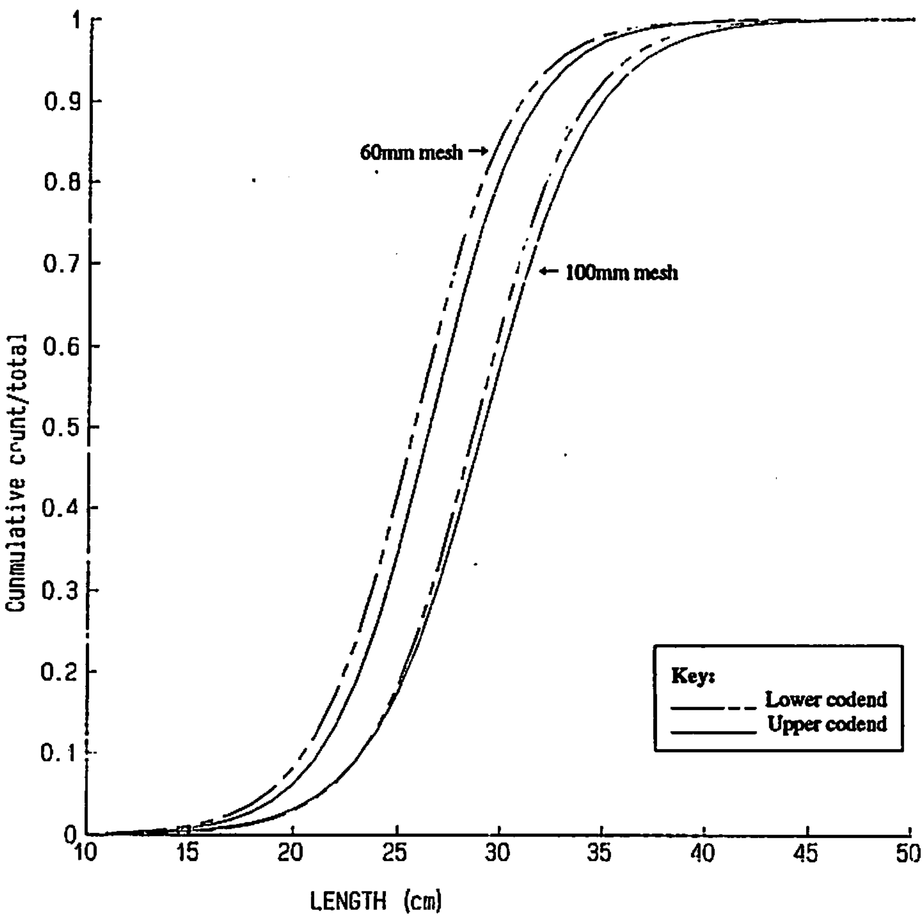


Fig. 26

APPENDIX I

REPORTED RESULTS FROM COMMERCIAL VESSELS OPERATING SEPARATOR TRAWLS

MFV JANET M - SEPARATOR TRAWL

RESULTS FOR HADDOCK AND WHITING (NUMBERS ONLY)

Total Hauls: 5

Haul No.	WHITING Number in Codend			Haul No.	HADDOCK Number in Codend	
	Lower	Upper			Lower	Upper
1	16	232		1	1	105
2	38	174		2	0	23
3	11	464		3	1	12
4	20	435		4	1	26
5	5	348		5	3	42
TOTAL	90	1653		TOTAL	6	208
Percentage Separation	95%			Percentage Separation	97%	

MFV JANET M

SPECIES: COD

Separator Trawl; 100mm standard codend on top & bottom; lifting bag on top codend. 5 hauls sampled.

TOP CODEND		BOTTOM CODEND	
Sample total:	306	Sample total:	1212
Raised total:	306	Raised total:	1212
Minimum landing size:	35cm	Minimum landing size:	35cm
% Discards:	63%	% Discards:	68%
% Retained:	37%	% Retained:	32%

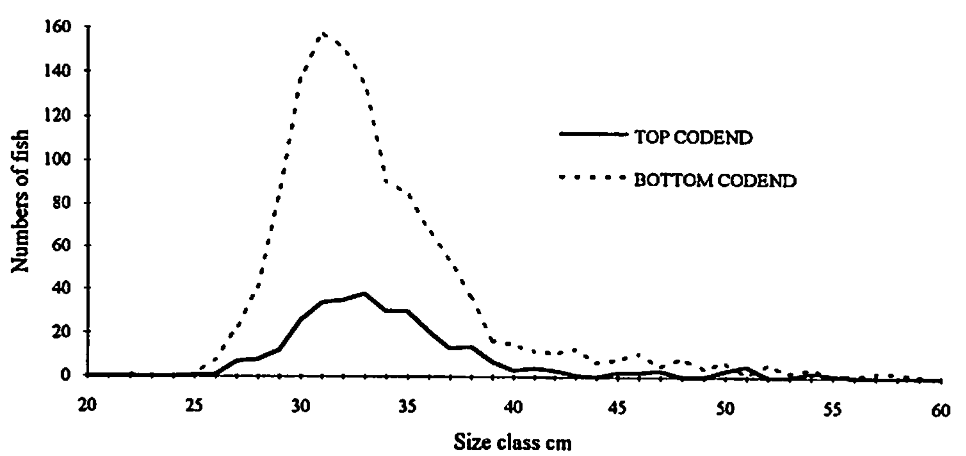
DIFFERENCES BETWEEN GEARS (% and numbers)		
Reduction in Discards:	77%	637 fish
Loss in Marketable:	70%	271 fish

Class cm:	Numbers:	Frequency %:	Class cm:	Numbers:	Frequency %:
20	0	0.00%	20	0	0.00%
21	0	0.00%	21	0	0.00%
22	0	0.00%	22	1	0.08%
23	0	0.00%	23	0	0.00%
24	0	0.00%	24	0	0.00%
25	1	0.33%	25	1	0.08%
26	1	0.33%	26	8	0.66%
27	7	2.29%	27	22	1.82%
28	8	2.61%	28	41	3.38%
29	12	3.92%	29	84	6.93%
30	26	8.50%	30	137	11.30%
31	34	11.11%	31	158	13.04%
32	35	11.44%	32	151	12.46%
33	38	12.42%	33	135	11.14%
34	30	9.80%	34	91	7.51%
35	30	9.80%	35	85	7.01%
36	21	6.86%	36	68	5.61%
37	13	4.25%	37	54	4.46%
38	14	4.58%	38	37	3.05%
39	7	2.29%	39	17	1.40%
40	3	0.98%	40	15	1.24%
41	4	1.31%	41	12	0.99%
42	3	0.98%	42	11	0.91%
43	1	0.33%	43	13	1.07%
44	0	0.00%	44	7	0.58%
45	2	0.65%	45	8	0.66%
46	2	0.65%	46	11	0.91%
47	3	0.98%	47	5	0.41%
48	0	0.00%	48	9	0.74%
49	0	0.00%	49	4	0.33%
50	3	0.98%	50	7	0.58%
51	5	1.63%	51	1	0.08%
52	0	0.00%	52	6	0.50%
53	0	0.00%	53	2	0.17%
54	2	0.65%	54	4	0.33%
55	1	0.33%	55	1	0.08%
56	0	0.00%	56	1	0.08%
57	0	0.00%	57	2	0.17%
58	0	0.00%	58	2	0.17%
59	0	0.00%	59	1	0.08%
60	0	0.00%	60	0	0.00%
TOTAL:	306		TOTAL:	1212	

EC SIZE GROUPINGS:			
Grade:	Upper	Lower	Differences (L-U)
5	34% (103)	29% (352)	5% (249)
4	4% (11)	3% (332)	1% (22)
3	0	0	0
2	0	0	0
1	0	0	0

% separation in catch attributable to the separator panel: 80%

Number of fish represented by this: 1214



Vessel GEORGE WETHERELL Date 30-11-93 Gear Type

Haul	Upper codend					Lower codend					Total					% Catch in UPPER codend					% Catch in LOWER codend				
	A					B					A+B					(A / (A+B)) x 100					(B / (A+B)) x 100				
No.	Cod	Had	Whit	Flats	Other	Cod	Had	Whit	Flats	Other	Cod	Had	Whit	Flats	Other	Cod	Had	Whit	Flats	Other	Cod	Had	Whit	Flats	Other
1	39	1	160	—	1	161	—	14	6	18	200	1	174	6	19	19.5	100.0	91.9	/	5.3	80.5	/	8.1	100.0	94.7
2	54	—	47	1	11	165	—	12	13	17	219	—	59	14	28	24.6	/	79.7	7.1	39.3	75.3	/	20.3	92.9	60.7
3	45	1	67	—	11	187	—	11	18	36	232	1	78	18	47	19.4	100.0	85.9	/	23.4	80.6	/	14.1	100.0	76.7
4	21	—	45	—	8	87	—	6	4	11	108	—	51	4	19	19.4	/	88.2	/	42.1	80.5	/	11.8	100.0	57.9
5	42	5	107	—	4	159	—	10	16	12	201	5	117	16	16	20.9	100.0	91.4	/	25.0	79.1	/	8.6	100.0	75.0
6	22	1	91	—	4	197	—	11	13	11	219	1	102	13	15	10.0	100.0	89.2	/	26.7	89.9	/	10.8	100.0	73.3
7	34	3	60	1	5	170	1	8	7	31	204	4	68	8	36	16.7	75.0	88.2	12.5	13.9	83.3	25.0	11.8	87.5	86.1
8	31	2	68	1	4	155	—	6	3	28	186	2	74	4	32	16.7	100.0	91.9	25.0	12.5	83.3	/	8.1	75.0	87.5
9	35	34	60	1	3	230	20	10	30	18	265	54	70	31	21	13.2	63.0	85.7	3.2	14.3	86.8	37.0	14.3	96.8	85.7
10	32	28	58	—	4	227	15	9	24	16	259	43	67	24	20	12.3	65.1	86.6	/	20.0	87.6	34.9	13.4	100.0	80.0

MFV GEORGE WETHERELL - SEPARATOR TRAWL CATCH DATA

APPENDIX II

GEAR GEOMETRY/PARAMETER RESULTS
(MFV HEATHER SPRIG)

GEAR GEOMETRY/PARAMETER RESULTS FOR *MFV HEATHER SPRIG (BCK181)* TRIALS 1994

DATE	TIME	HAUL NO.	FILE REF		PORT NET GEOMETRY (m)				STBD NET GEOMETRY (m)			TENSIONS (tonnes)				VESSEL SPEED (kts)	WARP OUT (fms)	DEPTH (fms)
			Scanmar	Delta	Codend Config. (upper/ lower)	Headline Height	Wing Spread	Otterboard Spread	Codend Config. (upper/ lower)	Headline Height	Wing Spread	Port Warp	Centre Wire	Stbd. Warp	Total Tension	Over Ground		
28 MARCH 1994	0552 0824	12[1]	H20	H20	60/60	3.25	8.42	-	100/100	3.06	8.73	1.29	1.76	1.38	4.43	2.5	100	32
			H21	H21	60/60	3.23	7.85	-	100/100	3.19	8.64	1.38	1.70	1.40	4.48	2.5	100	32
			H22	H22	60/60	3.08	7.96	-	100/100	2.94	9.02	1.41	1.76	1.46	4.63	2.5	100	32
	Average					3.18	8.07			3.06	8.77	1.36	1.74	1.41	4.51	2.5		
	1032 1226	12[2]	H23	H23	60/60	3.1	8.09	-	100/140	3.02	8.62	1.25	1.61	1.29	4.15	2.5	100	29
			H24	H24	60/60	3.2	8.15	-	100/140	3.1	8.64	1.27	1.70	1.28	4.25	2.5	100	29
	Average					3.15	8.12			3.06	8.63	1.26	1.65	1.285	4.20	2.5		
	1348 1612	13	H25	H27	60/60	2.98	8.99	-	100/140	3.08	8.94	1.42	1.72	1.42	4.56	2.5	100	32
			H26	H28	60/60	2.95	5.02	-	100/140	3.04	9.02	1.38	1.76	1.46	4.60	2.5	100	32
	Average					2.97	9.0			3.06	8.98	1.40	1.74	1.44	4.58	2.5		
	1810 2040	14	H27	H27	100/140	2.98	9.0	-	60/60	3.10	8.95	1.4	1.74	1.41	4.54	2.5	100	33
			H28	H28	100/140	2.95	9.02	-	60/60	3.04	9.02	1.45	1.76	1.44	4.65	2.5	100	33
	Average					2.97	9.01	-	60/60	3.07	8.98	1.42	1.75	1.43	4.59	2.5	100	33

contd..../

DATE	TIME	HAUL NO.	FILE REF		PORT NET GEOMETRY (m)				STBD NET GEOMETRY (m)			TENSIONS (tonnes)				VESSEL SPEED (kts)	WARP OUT (fms)	DEPTH (fms)
			Scanmar	Delta	Codend Config. (upper/ lower)	Headline Height	Wing Spread	Otterboard Spread	Codend Config. (upper/ lower)	Headline Height	Wing Spread	Port Warp	Centre Wire	Stbd. Warp	Total Tension	Over Ground		
29 MARCH 1994	0539 0815	15			100/100				60/60			No Scanmar - charging				2.5	100	32
	1015 1115	15F[2]	H30	H30	60/60	3.28	-	58.44	100/100	3.72	37.52[3]	1.23	1.58	1.25	4.06	2.5	100	29
			H31	H31	60/60	3.30	-	60.10	100/100	3.75	38.8	1.25	1.60	1.25	4.10	2.5	100	29
	Average					3.29		59.27		3.73	39.16	1.24	1.59	1.25	4.08	2.5		
	1540 1810	16	H32	H32	60/60	3.48	21.0[4]	60.1	100/100	3.51	-	1.31	1.75	1.30	4.36	1.5	100	31
			H33	H33	60/60	3.41	21.4	59.1	100/100	3.40	-	1.40	1.8	1.41	4.61	1.5	100	31
	Average					3.44	21.2	59.6		3.45	-	1.35	1.77	1.35	3.38	1.5		
	1932 2202	17	H40	H40	60/60	3.18	23.4	51.0	100/140	3.13	-	1.5	1.9	1.40	4.8	2.5	100	31
			H41	H41	60/60	3.2	23.0	56.1	100/140	3.16	-	1.45	1.8	1.46	4.71	2.5	100	31
	Average						23.2	53.5		3.15		1.47	1.85	1.43	1.75	2.5		
30 MARCH 1994	0706 0936	18	H50	H50	100/140	3.38	9.43	-	60/60	3.26	9.18	1.18	1.84	1.22	4.24	2.2	100	17
			H51	H51	100/140	3.02	9.31	-	60/60	2.98	8.97	1.16	1.80	1.16	4.12	2.2	100	17
			H52	H52	100/140	3.21	9.36	-	60/60	3.10	9.01	1.17	1.81	1.17	4.15	2.2	100	17
	Average					3.2	9.36			3.11	9.05	1.17	1.81	1.18	4.17	2.2		
	1100 1330	19	H60	H60	100/100	3.37	9.05		60/60	3.12	9.12	1.06	1.72	1.18	3.96	2.0	100	24
			H61	H61	100/100	3.39	9.01		60/60	3.13	9.14	1.08	1.76	1.08	3.92	2.0	100	24
	Average					3.38	9.03			3.125	9.13	1.07	1.74	1.13	3.94	2.0		
	1445 1720	20	H62	H62	60/60	3.3	9.06		100/100	3.02	8.99	1.12	1.70	1.14	3.96	3.0	100	23
			H63	H63	60/60	3.7	9.06		100/100	3.06	9.4	1.24	1.80	1.31	4.35			
	Average					3.5	9.06		100/100	3.04	9.19	1.18	1.75	1.22	4.15	3.0		

1. 3 separate samples during the same tow
2. Invalid tow - fast
3. Outer wings
4. Inner wing space

APPENDIX III

HAUL DETAILS
(MFV HEATHER SPRIG)

Haul Details, MFV Heather Sprig BCK 181, off Whitby

Haul No.	Date	Port		Starboard		Shot time	Haul time	Bulk catch baskets				Ground	Position shot	Position haul
		Net	U/L	Net	U/L	GMT	GMT	PU	PL	SU	SL			
HAUL 1	21-Mar-94	A	60/60	B	100/100	13:02	15:32	2.00	2.50	0.50	1.30	Sand	54° 34'.08N 00° 33'.17W	54° 30'.11N 00° 25'.08W
HAUL 2	21-Mar-94	A	100/100	B	60/60	17:17	19:47	0.30	3.00	0.30	2.60	Sand	54° 31'.09N 00° 16'.60W	54° 26'.07N 00° 10'.11W
FAST	21-Mar-94	A	100/100	B	60/60	21:32	22:00					Sand	54° 25'.85N 00° 09'.84W	-
FAST	22-Mar-94	A	100/100	B	60/60	06:45	07:20					Sand/stones	54° 29'.30N 00° 26'.39W	-
HAUL 3	22-Mar-94	A	100/140	B	60/60	08:29	11:04	0.50	0.60	5.00	3.00	Sand/stones	54° 31'.44N 00° 35'.44W	54° 35'.44N 00° 32'.94W
HAUL 4	22-Mar-94	A	60/60	B	100/140	12:35	15:05	0.75	2.00	0.30	0.50	Sand/stones	54° 35'.32N 00° 33'.45W	54° 38'.28N 00° 40'.63W
HAUL 5	22-Mar-94	A	60/60	B	100/140	16:15	18:45	0.60	2.00	0.25	0.50	Sand/stones	54° 36'.41N 00° 40'.62W	54° 33'.14N 00° 31'.59W
HAUL 6	23-Mar-94	A	100/140	B	60/60	06:30	09:00	0.25	0.50	0.30	2.00	Sand/stones	54° 26'.39N 00° 09'.67W	54° 31'.45N 00° 17'.01W
FAST	23-Mar-94	A	60/60	B	100/100	11:04	12:25					Sand/stones	54° 28'.51N 00° 14'.94W	-
HAUL 7	24-Mar-94	A	60/60	B	100/100	11:33	14:06	2.50	3.00	0.60	2.00	Sand/stones	54° 30'.11N 00° 24'.84W	54° 33'.74N 00° 32'.02W
HAUL 8	24-Mar-94	A	100/100	B	60/60	15:31	18:01	0.50	2.30	3.25	3.00	Sand/stones	54° 33'.32N 00° 31'.16W	54° 29'.09N 00° 23'.58W
HAUL 9	24-Mar-94	A	100/140	B	60/60	19:35	22:06	0.50	0.60	2.25	2.50	Sand/stones	54° 32'.31N 00° 29'.10W	54° 27'.71N 00° 22'.47W
HAUL 10	25-Mar-94	A	60/60	B	100/100	06:21	08:51	1.60	3.00	0.25	1.50	Sand/stones	54° 33'.61N 00° 31'.86W	54° 29'.22N 00° 22'.46W
HAUL 11	25-Mar-94	A	60/60	B	100/140	10:06	12:36	0.75	2.25	0.30	0.75	Sand/stones	54° 29'.00N 00° 24'.46W	54° 33'.52N 00° 32'.16W
FAST	25-Mar-94	A	100/100	B	60/60	13:55	16:27					Sand/stones	54° 31'.86N 00° 28'.78W	54° 34'.91N 00° 36'.56W
HAUL 12	28-Mar-94	B	60/60	A	100/100	05:52	08:24	0.25	2.00	0.30	2.00	Sand/stones	54° 28'.48N 00° 24'.02W	54° 33'.92N 00° 31'.96W
FAST	28-Mar-94	B	60/60	A	100/140	10:32	12:26					Sand/stones	54° 33'.48N 00° 31'.53W	54° 30'.42N 00° 26'.10W
HAUL 13	28-Mar-94	B	60/60	A	100/140	13:48	16:12	0.50	3.00	0.30	0.60	Sand/stones	54° 31'.95N 00° 27'.28W	54° 30'.92N 00° 25'.76W
HAUL 14	28-Mar-94	B	100/140	A	60/60	18:10	20:40	0.25	1.30	1.30	2.50	Sand/stones	54° 32'.72N 00° 28'.35W	54° 29'.89N 00° 18'.11W
HAUL 15	29-Mar-94	B	100/100	A	60/60	05:39	08:15	0.30	2.00	1.00	2.50	Sand/stones	54° 33'.20N 00° 31'.33W	54° 27'.24N 00° 22'.13W
FAST	29-Mar-94	B	60/60	A	100/100	10:15	11:15					Sand/stones	54° 34'.48N 00° 31'.21W	54° 33'.40N 00° 29'.03W
HAUL 16	29-Mar-94	B	60/60	A	100/100	15:40	18:10	0.13	1.00	0.10	0.75	Sand/stones	54° 30'.13N 00° 24'.96W	54° 33'.07N 00° 30'.18W
HAUL 17	29-Mar-94	B	60/60	A	100/140	19:32	22:02	1.00	2.00	0.30	0.10	Sand/stones	54° 33'.02N 00° 30'.40W	54° 28'.65N 00° 23'.58W
HAUL 18	30-Mar-94	B	100/140	A	60/60	07:06	09:36	0.50	2.25	0.75	3.00	Hard	54° 31'.45N 00° 38'.15W	54° 34'.80N 00° 18'.26W
HAUL 19	30-Mar-94	B	100/100	A	60/60	11:00	13:30	1.00	3.00	1.00	4.00	Hard	54° 36'.75N 00° 48'.91W	54° 34'.20N 00° 42'.42W
HAUL 20	30-Mar-94	B	60/60	A	100/100	14:45	17:20	1.50	3.00	0.75	1.50	Hard	54° 35'.90N 00° 44'.26W	54° 30'.61N 00° 32'.87W

Haul Details, MFV Heather Sprig BCK 181, off Whitby

Haul No.	Tow speed	Depth (fm)	Warp out (fm)	Wind	Sea	Comments
HAUL 1	2.5	31	100	Var 3	Slight	Fine day. Nets arranged P=A; S=B.
HAUL 2	2.5	32	100	Var 4	Slight	Fine day.
FAST	2.5	32	100	SW 5-6	Mod	Dark. Fast after 1 hr.
FAST	2.4	31	100	SSW 5	Mod	Cold. Dull.
HAUL 3	2.5	32	100	SW 4	Mod	Not so cold.
HAUL 4	2.4	31	100	W 5-6	Mod	Bright sun.
HAUL 5	2.4	27	100	W 5	Mod	Bright sun.
HAUL 6	2.5	31	100	Var 3-4 incr 6	SW swell	High cloud.
FAST	2.5	32	100	SW 8 occ 9	V rough	Came fast after 1 hr 21 min. Storm. Sheltered inshore at Robin Hood's Bay.
HAUL 7	2.5	32	100	WNW 6	Mod to rough	Bright, cold day.
HAUL 8	2.5	32	100	WNW 4	Mod	Dull. High cloud.
HAUL 9	2.5	31	100	W 2	Slight	Dark.
HAUL 10	2.5	30	100	Nil	Flat calm	Fog. Oily calm.
HAUL 11	2.5	30	100	NW 1	Calm	Rain, low cloud, poor visibility
FAST	2.5	32	100	NW 2-3 incr.	Slight	4/8 cloud, sun, good visibility. Bellies badly ripped in stbd net. 8hrs mending.
HAUL 12	2.5	32	100	Var 1-2	Slight swell	Nets swapped, ie P=B; S=A. Scanmar on. P lr. wing, stbd net, slight damage.
FAST	2.5	29	100	SW 2	Slight	Scanmar on. Fast after 2 hrs.
HAUL 13	2.5	32	100	SW 2	Slight	Scanmar on. 1 hr towing with tide.
HAUL 14	2.5	33	100	SW 1	Slight	Scanmar on. Cloud & mist.
HAUL 15	2.5	32	100	WNW 4-5	Slight	Scanmar charging. Sun; wind increasing.
FAST	2.5	29	100	NW 5	Slight	Scanmar on. Fast after 1 hr. Port wing, port net damaged. 4 hrs mending.
HAUL 16	1.5	31	100	NW 4	Slight	Scanmar on. Very strong head tide
HAUL 17	2.5	31	100	NW 3	Slight	Scanmar on. Slack water. Dark.
HAUL 18	2.2	17	100	SW 3 incr SE 8	Slight	Closed area inside 3 miles. Damaged port net belly slightly. Haul counted. Scanmar on. Big cod.
HAUL 19	2	24	100	SSE 6	Mod	Closed area ground. Good run of big cod. Scanmar on.
HAUL 20	3	23	100	SE 7 incr 8	Mod	Closed area ground. Another good run of big cod. Scanmar on.

APPENDIX IV

MESH MEASUREMENTS MADE USING ICES NET GAUGE SET AT 4KG

Codend Mesh Measurements

60mm mesh (top c/e; 3 knots) Dry,new						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
55						
56						
57						
58					1	2
59	1				3	
60	1	1			1	2
61		3		1	2	
62	4	4		3	5	4
63	5	5	3	2	3	4
64	1	2	2	2		3
65	4	5	8	8	2	3
66	4		3	2	1	1
67			4	2	2	1
68						
69						
70						
71						
TOT	20	20	20	20	20	20
mean	64					

60mm mesh (top c/e; 3 knots) Halfway stage						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
55						
56						
57						
58						
59						
60					2	
61	2				1	
62	2			2		
63	3	1	1	3		5
64	2	1	1			1
65	7	2	6	6	6	5
66	3	3	3	6	6	5
67	2	7	6	2	3	2
68		4	3		2	2
69		1		1		
70		1				
71						
TOT	21	20	20	20	20	20
mean	65					

60mm mesh (top c/e; 3 knots) End of trial						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
55						
56						
57						
58	1					
59	1	3	1			
60	5	3	3	2	1	1
61	2	1	2	1		
62	4	2	4	5	3	2
63	1	2	5	2	1	2
64	5	2	3	2	2	
65	1	3	2	4	6	6
66	1	1	1	1	1	4
67	1	2	1	4	4	4
68				1	3	1
69		1				
70						
71						
TOT	22	20	22	22	21	20
mean	64					

60mm mesh (bottom c/e; 4 knots) Dry, new						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
55						
56						
57						
58	1					
59		1				
60	5	3				
61	4	3	2		1	
62	4	2			6	
63	3	3	3		4	2
64		3	2	1	2	4
65	1	4	8	9	5	7
66		1	3	4	1	3
67						
68	2		2	3	1	
69				1		
70				2		1
71						
TOT	20	20	20	20	20	17
mean	64					

60mm mesh (bottom c/e; 4 knots) Halfway stage						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
55						
56						
57						
58						
59						
60						
61		1		1		
62		1		2	1	
63		1		3	1	3
64	3	2		1	2	3
65	6	3	4	3	7	8
66	6	6	5	4	2	2
67	3	3	3	2	3	4
68	2	2	5	4	2	
69			2		2	
70		1				
71			1			
TOT	20	20	20	20	20	20
mean	66					

60mm mesh (bottom c/e; 4 knots) End of trial						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
55						
56						
57						
58						
59						
60				1	2	2
61		3			1	
62		2	2	3	1	2
63	4	4		1	2	2
64	5	6	2	2	2	5
65	6	4	11	5	4	2
66	2		4	1		4
67	3	1	1	6	2	3
68				1	5	
69					1	
70						
71						
TOT	20	20	20	20	20	20
mean	65					

Codend Mesh Measurements

100mm mesh (top c/e; 1 knot) Dry, new						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
91						
92						
93						
94						
95	1	3				
96	1	6				1
97	1	3	1	1	1	1
98	5	6	1	1	1	
99	2	2	2	2	1	1
100	6		5	9	13	12
101	3		7	3		4
102	1		3	2	4	1
103			1	2		
104						
105						
106						
107						
TOT	20	20	20	20	20	20
mean	99					

100mm mesh (top c/e; 1 knot) Halfway stage						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
91						
92						
93			1			
94						
95			1	1		
96	1	2		1		1
97	1	2	2	1	2	4
98	2	2	2	2	1	
99	4	2	3	5	4	4
100	5	3	8	6	11	5
101	4	4	2		2	4
102	1	2		1		2
103	2			1		
104		2	1	2		
105						
106						
107		1				
TOT	20	20	20	20	20	20
mean	100					

100mm mesh (top c/e; 1 knot) End of trial						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
91						
92	1					
93						
94					1	
95						
96	5	3	1	1	1	
97	3	3	2		1	1
98	3	1		4	3	4
99	3	5	1	10	2	2
100	5	8	9	3	8	9
101		2	2	2	3	1
102			5		1	3
103						
104						
105						
106						
107						
TOT	20	22	20	20	20	20
mean	99					

100mm mesh (bottom c/e; 2 knots) Dry, new						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
91						
92						
93						
94		1				
95	1	2				
96	5	1		1	1	1
97	1			4	1	1
98	3	7	3	1	3	2
99		4	2	4	1	2
100	9	4	7	5	7	14
101	1	1	6	3	4	
102			2	2	2	
103					1	
104						
105						
106						
107						
TOT	20	20	20	20	20	20
mean	99					

100mm mesh (bottom c/e; 2 knots) Halfway stage						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
91						
92						
93						
94						
95						
96				1	2	2
97	1		2		2	3
98		3	2		5	4
99	7	3	2	6	2	5
100	5	7	8	5	4	4
101	3	2	1	2	4	2
102	3	3	2	4		
103		1	1	1	1	
104	1	1		1		
105			1			
106						
107						
TOT	20	20	19	20	20	20
mean	100					

100mm mesh (bottom c/e; 2 knots) End of trial						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
91					1	
92		1				
93						
94		2				
95	1					
96	3	3				
97	3	5		2		1
98	4		1	2		1
99	3	6	2	3	2	4
100	8	1	10	6	8	8
101			1	4	3	3
102		1	3	3	5	2
103			3		1	1
104		1				
105						
106						
107						
TOT	22	20	20	20	20	20
mean	100					

Codend Mesh Measurements

140mm mesh (bottom c/e) Dry, new						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
135					1	
136	2					
137						
138	1				1	
139	3					
140	2	1			5	3
141		1		1		
142	3	3		1	3	7
143	1	3	3	1	4	2
144		2		3	2	
145	1	2	2	4	2	6
146	1	4	5	3	1	1
147	3	4	4	2	1	1
148	1			3		
149	1		2			
150	1		1	2		
151			2			
152			1			
153						
154						
155						
TOT	20	20	20	20	20	20
mean	144					

140mm mesh (bottom c/e) Halfway stage						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
135						
136						
137						1
138						
139						
140	1		1	3		4
141	2					1
142	2	2	1	4	1	4
143	2	2	2	1	4	3
144	1	3	2	4	2	4
145	4	7	7	4	5	2
146	1	6	2	1	4	1
147	6	4	5	2	1	
148	1	1		1	1	
149					1	
150						
151						
152					1	
153						
154						
155						
TOT	20	25	20	20	20	20
mean	144					

140mm mesh (bottom c/e) End of trial						
	Top		Mid		Btm	
mm	U	L	U	L	U	L
135						
136						
137						
138					1	
139					2	
140	3			1	2	2
141				2	1	
142		5	2	3	4	5
143	1	7	4	3	2	3
144	1	1	4	2	2	4
145	6	3	5	6	2	4
146	2	3	1	2	1	2
147	6		3	3	2	
148	1	1			1	
149						
150			1			
151						
152						
153						
154						
155						
TOT	20	20	20	22	20	20
mean	144					

Key:
c/e = codend
U = Upper surface of codend
L = Lower surface of codend
Top = Region of mesh near to joining round with the extension
Mid = Region of mesh halfway along the codend from either end
Btm = Region of mesh near to the codline at the codend tip
TOT = Total number of observations
mean = mean mesh size from all observations