**Seafish Marine Technology**

**Ken Arkley and Gary Dunlin**
**Date April 2003**

# Improving the selectivity of towed fishing gears

# New Prawn Trawl Designs to Avoid Capture of Unwanted Bycatch

 

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**Summary**
This report describes the process of conceiving, designing and evaluating a novel trawl for *Nephrops*.

The work fits into a sustained series of trials to reduce discard levels in towed gear fisheries.  Nearly all previous work was based on the selective release of certain elements of the catch; the work described here was predicated on avoiding the capture of non-target species in the first place.

This project was carried out in close co-operation with two well known trawl makers. The process involved model testing prototypes followed by sea trials of the most promising design variants in three separate fishing areas.

All the sea trials showed that the capture of haddock and whiting could be very substantially reduced – by >75% across all size ranges.  The major difficulty experienced was the relatively poor level of *Nephrops* catches.

This specific problem was progressively resolved through the course of this work. The trawl design is now on the threshold of being commercially acceptable in those *Nephrops* fisheries where finfish bycatch is largely unmarketable and not an important element of the overall value of the catch.

 

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# 1 Introduction

In 1997/98 Seafish started a programme of work to investigate ways of improving whitefish selectivity through the more effective use of technical conservation measures.

Interest focussed on UK *Nephrops* fisheries, some of which are generally recognised as having significant discard problems. The resulting report entitled *A Review of Technical Conservation Measures in UK Nephrops Fisheries* (Seafish Report No. SR508) identified some technical options for further investigation.

The second stage of the programme was designed to examine some of the options identified as results of phase one. The first to be investigated was the separator trawl. In 1998/99, gear engineering and commercial fishing trials were conducted using separator trawls on a range of vessels operating in the Irish Sea *Nephrops* fishery. This work is described in Seafish Report No. SR522, *Evaluation of bycatch reduction devices in UK Nephrops fisheries – The use of separator trawls in the Irish Sea.*

The next option to be considered under this programme was investigated using a slightly different approach to the preceding work on bycatch reduction devices. Up to this stage, effort had been directed at developing ways and means of reducing discarding by releasing the unwanted bycatch after it has been caught. This has often raised questions about the ultimate survival of escapees and the subsequent benefits to the fishery. This latest work places the emphasis on *avoiding* the capture of unwanted bycatch in the first place, thus precluding the question of survival.

The aim of the project was to design a trawl with attributes that reduced the potential for catching certain finfish species, whilst at the same time maintaining *Nephrops* catching performance. In other words, making the gear design more species-specific.

The gear is aimed at those *Nephrops* fisheries in which the bycatch of species such as haddock and whiting is of no commercial value and is even seen as a nuisance factor.

The work conducted within this project was initially funded from Seafish Levy income. The project received a welcome boost in 2001 as a result of additional financial support from the Scottish Executive when the project was selected for funding under the Industry Partnership Programme (IPP).

Most of the initial gear design and development work was carried out with Seafish funding. The project relied heavily on trawl design work coupled with modelling and testing at the Authority’s Flume Tank in Hull. The support from the IPP allowed the resultant prototype designs to be field tested under commercial conditions in a number of *Nephrops* fisheries around the UK.

The Partnership Programme involves collaboration with Industry and other R&D organisations. The aim is to encourage industry involvement in the direction of R&D within the catching sector to improve whitefish selectivity through the more effective use of technical conservation measures. The work involves both the development of new ideas and an ongoing effort to improve the effectiveness of existing measures. This approach provides for more effective use of resources and offers greater potential for achieving more sustainable fisheries.

The programme involves the Fisheries Research Services (FRS) of the Scottish Executive Environment and Rural Affairs Department (SEERAD), Seafish, North Atlantic College (Shetland Isles), with industry representation through the Scottish Fishermen's Federation.

The task of introducing new net designs, especially ones originating from the R&D sector as opposed to from commercial gear manufacturers, is always a difficult one. For this reason, this project was conducted in direct collaboration with established trawl designers/manufacturers. The credibility gained from this partnership would hopefully increase the prospects of commercial uptake of any successful designs resulting from this work.

All fieldwork was conducted using established prawn trawl vessels operated by experienced skippers with a vested interest in the work.

# 2 Aims and Objectives

The technical measures developed to date all rely on releasing the unwanted elements of the catch once they have entered the net. The objective of this exercise was to determine ways of changing the design, construction and rigging of the *Nephrops* trawl so as to exclude the unwanted roundfish bycatch prior to it entering the net. This would have to be achieved in a commercially acceptable manner without any detrimental effect on the *Nephrops* catching capability of the gear.

To achieve this a number of objectives were set as criteria for judging the outcome:

- To establish, at model and full scale if the design features of traditional *Nephrops* trawls could be modified to avoid capture of certain bycatch species.
- To establish if this could be achieved relatively simply and at low cost.
- To compare the dynamic characteristics and geometry of the modified designs with those of a standard net under a range of commercial fishing conditions.
- To compare the handling performance of the new designs with that of an unmodified net of similar dimensions.
- To compare the catching performance of the new designs with that of an unmodified net of comparable dimensions for both target (*Nephrops*) and bycatch species.
- To identify and quantify any commercial benefits of this technology. Possible benefits included a reduction in catch sorting time, an improvement in catch quality and hence value and savings in fuel consumption as a result of reductions in overall net drag.

In the process of redesigning the trawl to avoid roundfish capture, the aim was to at least maintain, if not improve, the *Nephrops* catching capabilities of the new designs. In this way, any short-term losses attributable to the loss of roundfish bycatch could then be offset by improved *Nephrops* catches. Such a trade-off would improve commercial acceptance and uptake of the new designs.

# 3 Materials and Methods

## 3.1 Approach

One of the most important elements of this project was the involvement of commercial fishing gear manufacturers in the trawl design process. It had been agreed in the early planning stages of this project, that any new trawl designs that emerged from this work would stand a much greater chance of commercial acceptability if they had the endorsement of reputable gear manufacturers.

With this in mind, two prominent Scottish gear designers/manufacturers were selected to collaborate on the project. J&W Stuart Ltd from Eyemouth and Scotnet UK Ltd from Fraserburgh both volunteered the benefit of their knowledge and services. Each company enjoys a strong reputation for the design and manufacture of *Nephrops* trawls both in the UK and abroad.

Discussions were held with the gear manufacturers and Seafish gear technologists to establish the basic design criteria required for the new trawl designs. It was accepted that the final designs would have to satisfy a balance between trying to achieve optimum selectivity and commercial acceptability.

Once the design criteria had been established, it was a case of where possible, applying them to existing, traditional *Nephrops* trawl designs. The intention was to stay, as close to the traditional basic design as the new design criteria would allow. The main areas of attention were:

- Headline height
- Wing length
- Removal of cover (square panel)
- Mesh size in the upper panels of the net, particularly the forepart.

Each gear manufacturer was asked to modify one of their established trawl designs to incorporate the design criteria as agreed through earlier consultations.

These designs were then scaled and built as models by Seafish gear technologists at the Flume Tank.

Following a series of tank tests and subsequent alterations, two promising designs, one from each manufacturer, were selected for building at full scale.

These full-scale trawls were then subjected to engineering performance trials in which all the relevant gear parameters were measured and compared to those of an equivalent standard *Nephrops*. The measurements obtained from this exercise were compared to those obtained from the respective scale models in the Flume Tank. This provided some limited model/full-scale correlation for the new designs.

The final stage of the evaluation process was to test the new trawl designs under commercial fishing conditions. Comparative fishing trials were required to assess the new trawl designs' ability to catch *Nephrops* whilst avoiding species such as haddock and whiting.

A more comprehensive model/full-scale correlation would be performed on completion of the full-scale sea trials. The intention would be to construct updated models of the final versions of the new designs. These would incorporate any changes resulting from the commercial usage of the new nets.

### 3.2 Net designs

Each manufacturer designed three versions of each net. Each version differed only in the overall length of the wings. Short, medium and long winged versions, in which each varied by approximately 5-6m were designed and built at model scale.

The bodies of both manufacturers' net designs were essentially the same. The principal differences were in the wing designs and the lengths of the crown or bosom sections.

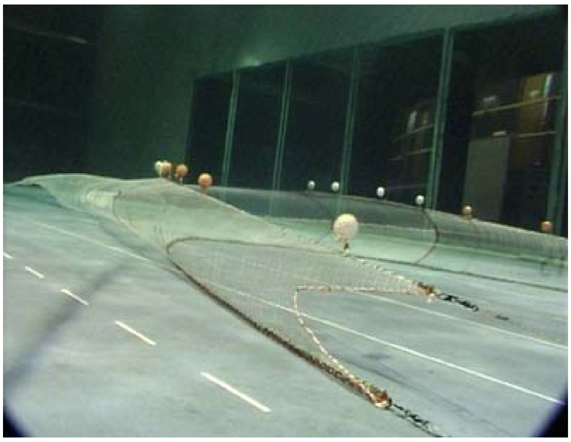


**Figure 1a: Scotnet design**

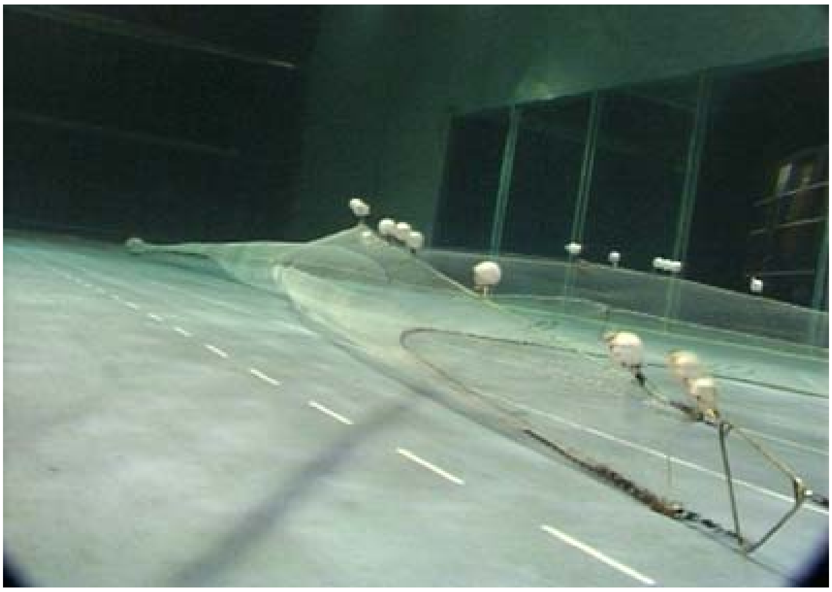


**Figure 1b: Stuart Nets' design**

In both manufacturers' designs the relative headline and footrope lengths were the same - approximately 28m (91ft) and 30m (100ft) for the Scotnet and Stuart Nets designs respectively. The bosom length in the Scotnet design (Figure 1a) was 3m (10ft) compared to 1.8m (6ft) in the Stuart net. (Figure 1b).

Mesh sizes in both designs were based on the legal minimum mesh size (MMS) for *Nephrops* i.e. 70mm. This mesh size was used for the construction of all the lower netting panels.

The upper panels in the forepart of the body of both designs were made in 200mm (nominal 8-inch) mesh. This is the largest mesh size that is currently readily available (Figure 2a).

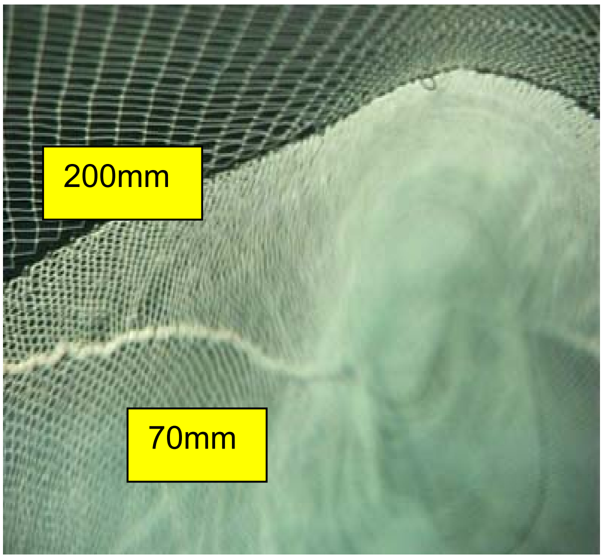



**Figure 2a: Showing variations in mesh size between top and bottom panels**

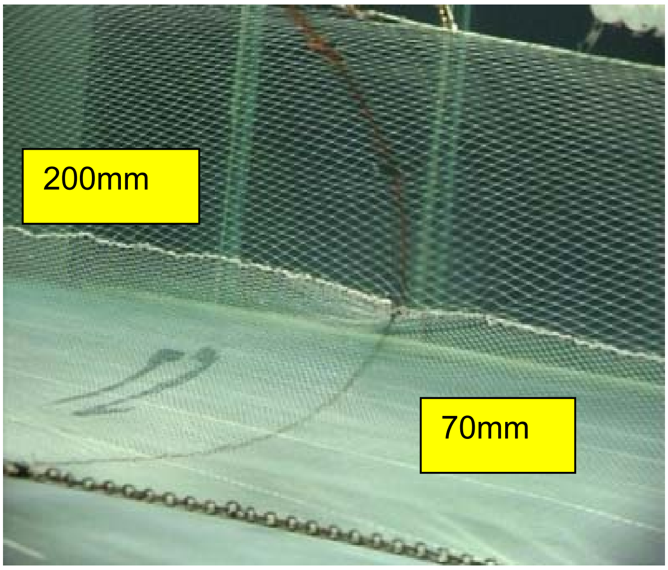



**Figure 2b: Showing variations in mesh size between top and bottom wings**

The Stuart design had this same mesh size in the top wings. The wings in this design were rigged in the conventional manner with the meshes cut and set on the bar (Figure 2b).

The Scotnet design incorporated a single wing arrangement made in 115mm mesh attached to 70mm mesh in the lower shoulder and 200mm mesh in the upper shoulder sections (Figure 3). In this arrangement the meshes were cut and set on a sideknot on the fishing line and on a sideknot 6 bar cut on the headline. The result of this was that the meshes were more closed along the length of the wing but retained the scope for opening to maintain good ground contact. This is a less conventional way of rigging prawn trawls but was expected to have certain merits in this application.

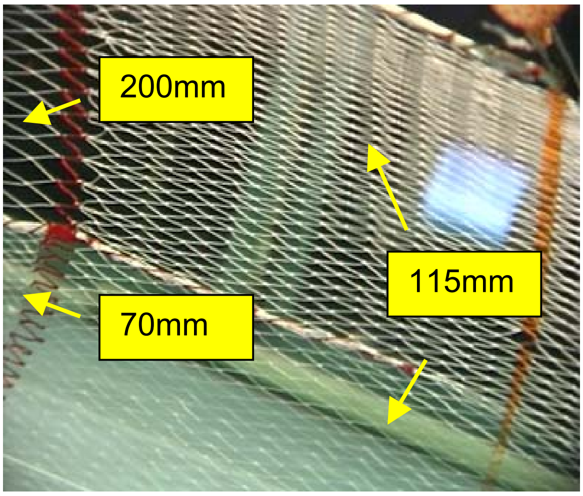



**Figure 3: Showing single wing arrangement on Scotnet design**

The wing-end arrangements on the two designs also differed. The Stuart net was rigged with a 609mm (24 inch) 'triangle' onto a straight-gabled wing-end (Figure 4a). This was in contrast to the Scotnet design, which had 'V' wings (Figure 4b).

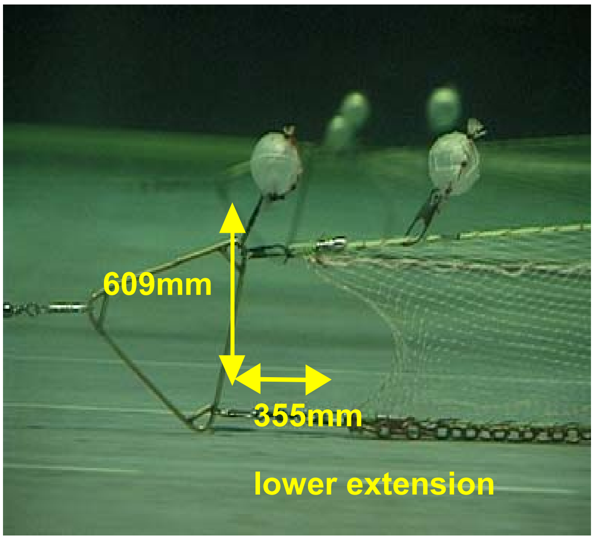



**Figure 4a: Stuart Nets wing-end**

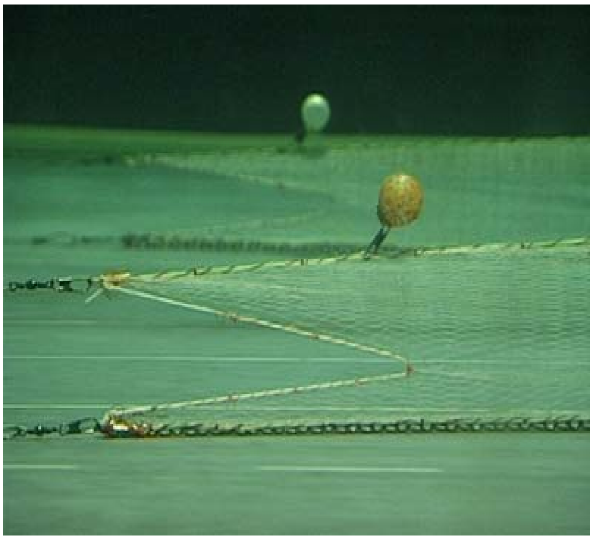


**Figure 4b: Scotnet wing-end arrangement**

### 3.3 Flume tank tests

The net designs were modelled at a scale of 1:7 and tested in the Seafish Flume Tank over a range of conditions. Following these tests the models were refined prior to full-scale manufacture of the most promising variants.

During the Tank tests, preliminary observations were made of all three wing-lengths for each design. Following these tests, the decision was made to concentrate attention on the short wing versions. Since the main objective was to avoid round fish capture; it was felt that a limited herding effect would be more easily achieved with the shorter wing arrangements. This arrangement was altered later to take account of overspreading problems associated with the short wing configurations in the full scale gears. For practical reasons, the decision was made to concentrate attention on the long winged versions of each of the designs. It was a case of offsetting potential herding effect against the prawn catching efficiency of the nets.

Initial tests were based on a predetermined spread, which produced the required footrope shape. The wing-end spreads achieved were equivalent to 35-40% of the headline length.

Warp:depth ratios were fixed at 3:1 and the main gear parameters were measured over a range of towing speeds equivalent to full scale speeds of between 1 and 1.75m/sec (2 and 3½ knots). The parameters measured included headline height, wing-end spread and net drag.

The different wing-end designs used in the two nets required the use of different sweep/bridle arrangements. The overall lengths were kept constant, but the configurations were slightly different. The sweep/bridle arrangements selected for testing at model scale were chosen to achieve what was expected to be the best compromise arrangement between limiting herding area and maintaining as near optimum net geometry in terms of targeting *Nephrops.* It was expected that these arrangements might change when taking into account other practical considerations associated with the full-scale gears.

The Scotnet design with the ‘V’ wing was rigged with 9.1m (5 fathoms) split bridles, connected to 27.4m (15 fathoms) single sweeps by a 1.8m (1 fathom) length of chain. The Stuart net was rigged with 0.6m (24ins) ‘triangles’ at the wing-ends and connected to 27.4m (15 fathoms) of single sweep. A further 9.1m (5 fathoms) section of sweepline connected by a similar 1.8m (1 fathom) chain section completed the arrangement.

The pre-set spread, in combination with the sweep/bridle set-up produced bridle angles in the region of between 8° and 10°.

The gear parameters were measured and observations recorded over a range of speeds. The results obtained are described in the results section, with the main gear parameters summarised in Tables 1 and 2.

### 3.4 The full-scale fishing gear

The full-scale nets were produced by their respective manufacturers in preparation for the instrumented engineering trials and subsequent commercial fishing evaluations (Figures 5 and 6).

On completion, both nets were measured accurately; this was to allow accurate models of the test gears to be made at a later stage in the project.

From observations made during the Tank tests, it was decided to rig both nets with a total of 38.4m (21 fathoms) of sweep/bridle arrangement. This consisted of a total of either 38.4m (21 fathoms) of single sweep, or a combination of 27.4m (15 fathoms) of single sweep in conjunction with 9.1m (5 fathoms) of split bridles separated by a 1.8m (1 fathom) length of 13mm short-link chain. The single sweeps were constructed in 22mm combination wire and the bridle arrangement was made up of 16mm combination wire for the headline leg and 18mm for the footrope leg.

Standard, 1.8m (6ft) Dunbar ‘V’ doors were selected to spread the nets under evaluation.

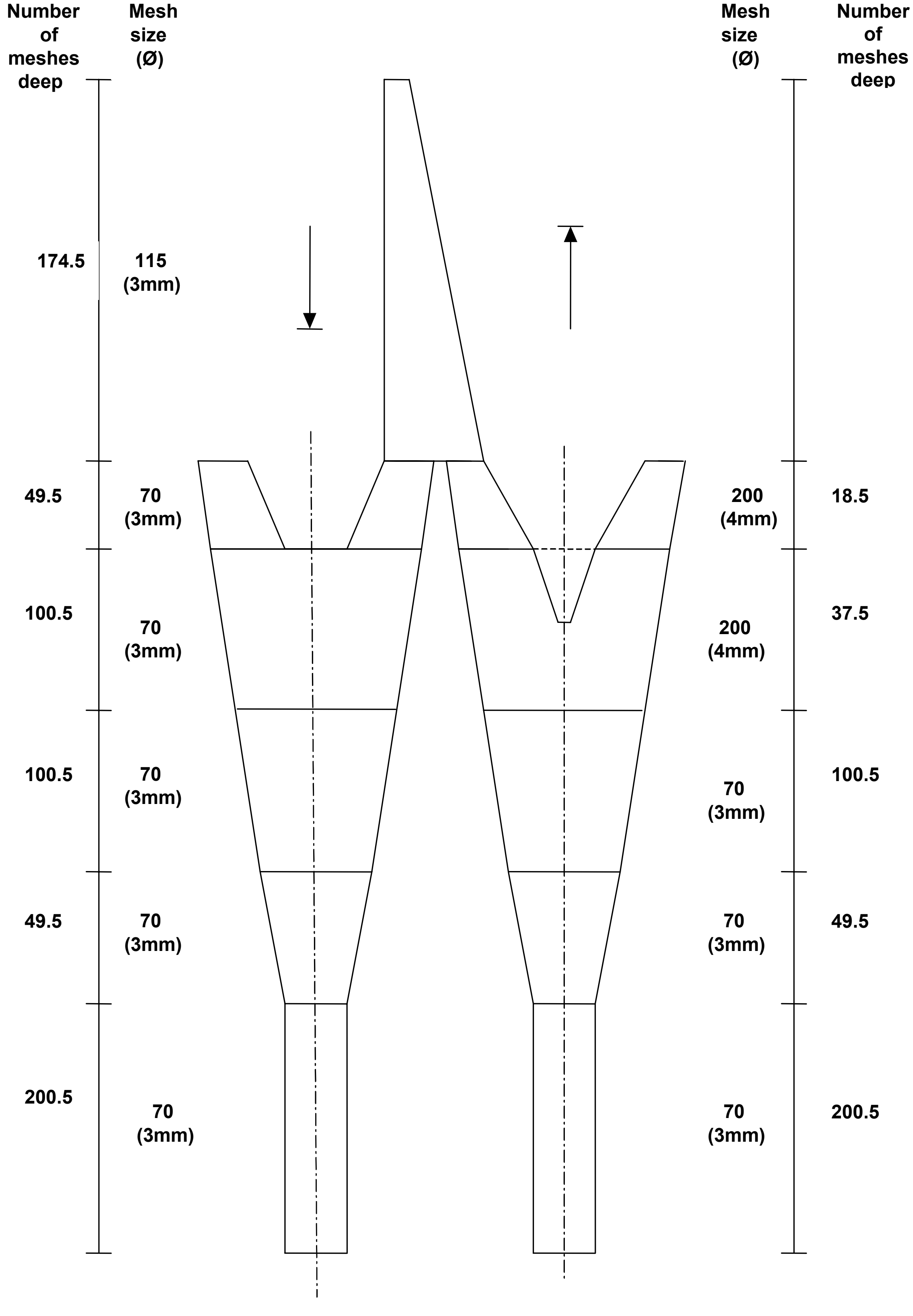



**Figure 5: Schematic diagram of the *Scotnet* version of the new prawn trawl design**

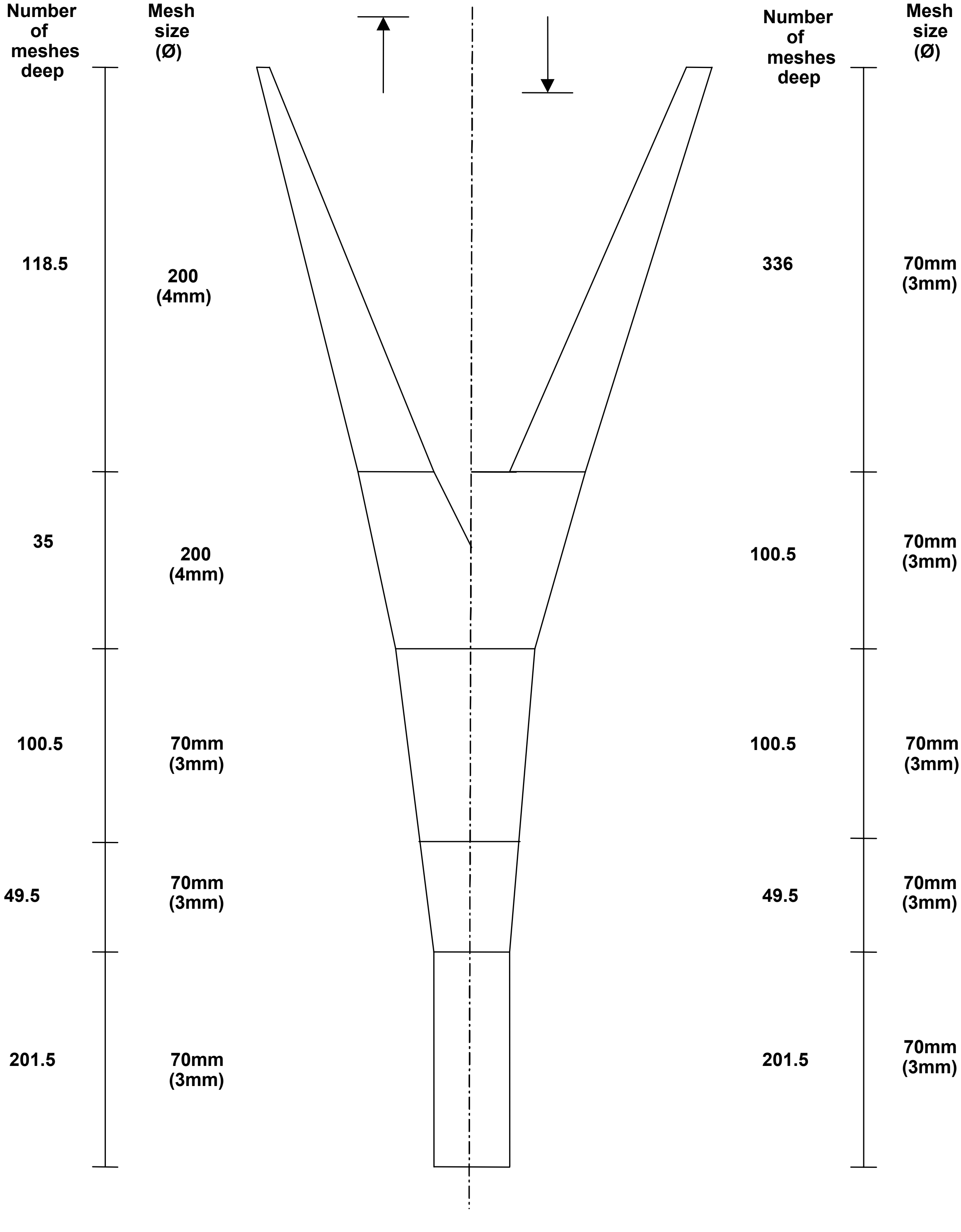



**Figure 6: Schematic diagram of the *Stuart Nets* version of the new prawn trawl design**

### 3.5 Instrumented performance trials

The two gear manufacturers were asked to nominate suitable vessels and skippers that they felt would be keen to help develop the new net designs.

The two vessels selected for this work were the MFV *Coquet Herald* (LH 94), operating out of Ullapool on the west coast of Scotland and MFV *Children's Friend* (LH 177), operating out of Eyemouth in the south east of Scotland.

The *Coquet Herald* was selected to conduct the instrumented trials on both new nets. Evaluations of each net's performance would then follow, under commercial fishing conditions, using both of the selected vessels. The Scotnet trawl was to be tested on the *Coquet Herald* and the Stuart Nets trawl onboard the *Children's Friend.*

The aim of this exercise was to measure all the main gear parameters for correlation with the results obtained at model scale and to establish the best rigging arrangements to enable the new trawl designs to be fished, and evaluated under commercial conditions in the two separate fisheries.

Unfortunately, due to a number of circumstances, the follow up commercial evaluations of the new net designs were unable to take place at this stage.

The parameters that were measured during the instrumented trials are listed below and the results have been summarised and presented in Table 3 in the results section.

| | |
|---|---|
| Door spread | **SCANMAR – Acoustic net monitoring system** |
| Wing-end spread | |
| Headline height | |
| Trawl speed | |
| Bridle angle | Calculated |
| Warp tension | Load cells |

### 3.6 Commercial fishing trials

At this stage of the project, opportunities to complete the commercial evaluations within the Seafish R&D programme were limited. However, Seafish involvement in the Scottish Executive-funded Industry Partnership Programme in 2001 provided funding opportunities to initiate a continuation programme. Financial support was made available to run a series of three comparative fishing trials in three separate *Nephrops* fisheries around the UK.

The three areas selected were:

- West coast of Scotland/NorthWest Highlands
- NE coast of England
- Clyde Estuary and approaches

The aim was to establish if the new designs could be made to work in a range of *Nephrops* fisheries dealing with varying conditions and catch profiles.

The instrumented gear trials identified a number of problems with the design and rigging of the prototype nets. This resulted in modifications being made to both nets prior to their further use in fishing trials. In addition, each net underwent modifications to suit the local conditions encountered in each of the fisheries in the three areas selected. These changes ranged from simple fine-tuning of the nets to complete changes of ground gears.

The Scotnet design was used in the West of Scotland fishery and the Stuart net in the NE coast and Clyde fisheries. The three trials were conducted at different times of the year (2001/02) to coincide with the relevant *Nephrops* seasons and suitable concentrations of bycatch.

The fishing trials were conducted as catch comparison exercises using a two-vessel arrangement.

Two similar vessels, using similar sized prawn trawls were selected to operate in partnership for the duration of the trials (~10 days of fishing).

The initial arrangement was for one vessel (chartered), to work with the experimental net and the other vessel to use their own standard prawn trawl for comparison. During these periods the vessel operating the experimental trawl was instructed to 'shadow' the partner vessel to try and sample similar populations of target and bycatch species.

The limitations of this type of comparative exercise were accepted on the understanding that the results were only expected to provide an indication of the relative performance of the experimental gears.

Each of the trials vessels carried a Seafish representative to record catch data and monitor the performance of the gear. Catch sampling entailed haul by haul quantification of the target species (*Nephrops*) and round fish bycatch species of haddock and whiting. Additionally, samples of the bycatch were measured to provide length/frequency data.

Whenever possible, prior to the commencement of the fishing trials, the opportunity was taken to obtain basic gear parameters for both the standard net and the experimental trawl using a Scanmar acoustic net monitoring system. These measurements helped to ensure that the gear geometry of each pair of nets was comparable.

### 3.6.1 West coast of Scotland/NW Highlands

The first 12 days of commercial trials were carried out from the Port of Mallaig on the West Coast of Scotland using two trawlers already prosecuting the *Nephrops* fishery in this area. The MFV *Minch Harvester* (OB 441) was chartered to fish with the new trawl design and operate in partnership with the MFV *Green Brae* (INS 208) which used its own, similar sized standard prawn trawl and trawl doors.

The vessels were both in similar power and size categories (177kW, 15.15m and 244kW, 17.07m respectively) and using similar trawls, doors and sweep/bridle arrangements.

The vessel using the standard *Nephrops* trawl was nominated as the lead vessel and the vessel using the experimental trawl shadowed its movements, as far as was practical, throughout the duration of the trials.

Each vessel had a Seafish representative onboard sampling catches and recording fishing details for comparison at the end of the voyage.

The sampling regime that was followed was the same for both vessels and designed to enable a good evaluation of the catch profile. The bulk catch was basketed onto a sorting table and the total catch was recorded in numbers of baskets. A sample basket from the bulk was taken at the start of the process and again from towards the middle of the catch. These baskets were sorted and the whiting and haddocks were measured and recorded. The final count of baskets was then used to calculate the raising factor, which was later applied to the recorded measurements.

The first five days of trials were restricted to Mallaig Bay due to adverse weather. Fishing activities were carried out on both soft and hard ground but the majority of tows were conducted on soft muddy bottom. Depths ranged from 38 to 75 fathoms and tows were usually between 4 and 5 hours duration.

The second half of the trials was conducted further afield and in deeper water. Results from early hauls in the trials gave positive indications of the new net design's capability of avoiding haddock and whiting bycatches. *Nephrops* catches however, were, apart from on one or two occasions, consistently below those of the partner vessel using the standard gear. Throughout the trip efforts were made to 'tune' the experimental net in an attempt to improve the nets performance with respect to the target species.

The trials were hampered by an additional problem at this stage. The *Green Brae* which was being shadowed as the partner vessel made a decision to move area of operation and to change trawl type in order to target prawns on harder ground. This decision meant that the experimental net could no longer be operated under comparable conditions. An alternative vessel had to be found in order to complete the trials.

The vessel that replaced the *Green Brae* was the *Azalea* (OB 80), 17.15m, 185kW. Operations were completed using this vessel. Reduced prawn catches from the experimental net continued to cause concern. Initially it was suspected that the headline of the experimental net, being longer than the footrope, allowed the net to overspread, resulting in reduced ground contact which was affecting the prawn catching performance of the net. The new net design did produce greater spread per length of headline but this was eliminated as the cause of the catch problem following a comprehensive series of rigging changes to 'tune' the net. It was then suspected that the problem lay, not in the net's ability to catch prawns, but in its ability to retain them.

The combination of very low headline height and large mesh panels in the upper sections of the net, combined with a modified water flow through the net, were seen as a potential source of prawn loss. A number of gear modifications were then carried out to investigate this line of thought. The largest mesh panels (200mm) were covered with 100mm netting to try and retain any prawns that may have been escaping from these areas of the trawl.

At this stage of the trial there was insufficient time to make more permanent changes to the net design. Although the situation improved, there was no firm evidence at this stage that the suspicions were correct. Further design changes were proposed.

#### 3.6.2 NE Coast of England

The second phase of this work was carried out in the prawn fishery on the NE coast of England centred on prawn grounds in and around the Farne Deeps

Fishing trials commenced in December 2001, operating from the port of Blyth in Northumberland using the vessels *Oceana* (BF 840) and *Osprey III* (BF 500).

These vessels are of similar size and power, (9.95m, 199Kw and 9.9m, 194Kw respectively), general design and layout and regularly operate together in various prawn fisheries around the UK. Both vessels were using the same size and style of prawn trawls and associated rigging arrangements. The nets were spread by Dunbar style 'V' doors (~1.8m) and 73m (40 fathom) of combination wire sweeps attached to 18m (10 fathom) of rubbered wire 'legs'. These sweeps were attached to the nets by 3.6m(2 fathom) of wire bridles and a spreader bar.

Because of the problems experienced in the previous trials as a result of not chartering both of the vessels selected for the work, it was decided to modify the working arrangements to ensure more control over the operations of both vessels.

The fishing trials were split into two halves. Each vessel operated with the experimental net as the 'shadow' vessel for a period of 5 days before swapping over to use a standard prawn trawl as the 'lead' vessel. All operations took place on commercial fishing grounds.

Prior to the fishing trials taking place, modifications to the rigging of the experimental net were made in light of the previous findings with respect to the suspected prawn loss through the large mesh top panels. Smaller mesh netting (100mm) was rigged in place over a section of the 200mm panel in the ‘baitings’ section of the net. This netting effectively formed a cover over the area of the panel where the prawn loss was suspected to be taking place. The 100mm netting formed a strip 37 meshes wide, covering the area along the selvage line of the net. The aim of this netting was to trap any prawns escaping through this section of the trawl.

The other potential problem experienced with the new design was that of overspreading of the net. The cut-away ‘V’ section in the top panel effectively lengthens the headline of the net making it longer than the fishing line. In order to reduce the resultant tendency to overspread, a short section of combination wire was inserted in the headline, between the quarters of the net, to make up the headline length to match that of the fishing line. This arrangement still presented a large open area in the mouth of the net to allow fish to escape before entering the net.

Apart from these alterations the experimental net was fished as it was at the end of the instrumented gear trials.

Some time was also allocated to establishing the basic gear parameters for both the experimental and the standard trawls. This was done using Scanmar acoustic net monitoring equipment. This exercise confirmed that both vessels were achieving acceptable and comparable gear parameters.

Both vessels were of similar design and deck layout, which enabled the same catch sampling procedures to be followed on each vessel.

When the vessels hauled, the catch was emptied into the hoppers. All discarded fish and assorted debris were quantified and recorded. This was done by filling the waste chute running outboard with baskets (and part baskets) of discarded material and recording how much was required. This waste chute was filled with varying discard content a number of times to obtain an average amount needed to fill it. The chute was then filled and emptied during the catch sorting process and the number of times that this took place was recorded. This figure was multiplied by the number of baskets required to fill the chute.

Sample baskets were taken away for measurement at a number of stages throughout the catch sorting operation. One was taken from the start, one near the middle and one towards the end to enable a good profile of discarded fish to be obtained.

The marketable fish (bycatch) being kept in the fishroom was sampled by measuring either all of the cod, haddock and whiting, or a representative amount of each species if large quantities were being caught. The live weight of *Nephrops* sorted for retention was also recorded after the catch was sorted.

Seafish personnel on both vessels used the same methods of sampling. Observations on general gear performance were also recorded.

### 3.6.3 Clyde Estuary and Approaches

The results from the second stage trials on the North East Coast gave similar indications of gear performance as the first trials. Good levels of round fish bycatch reduction were achieved, but at the expense of reduced catching performance for the target species, namely prawns. However, the temporary modifications to the large mesh panel in the baitings section did provide some indications that the poor results for prawns were more likely to be attributable to loss through the meshes rather than poor catching efficiency of the net itself.

For the final stage of this work, it was decided to make the mesh size changes more permanent. This entailed sending the net back to the net manufacturers to carry out the design changes. The details of these changes can be seen in Figure 7.

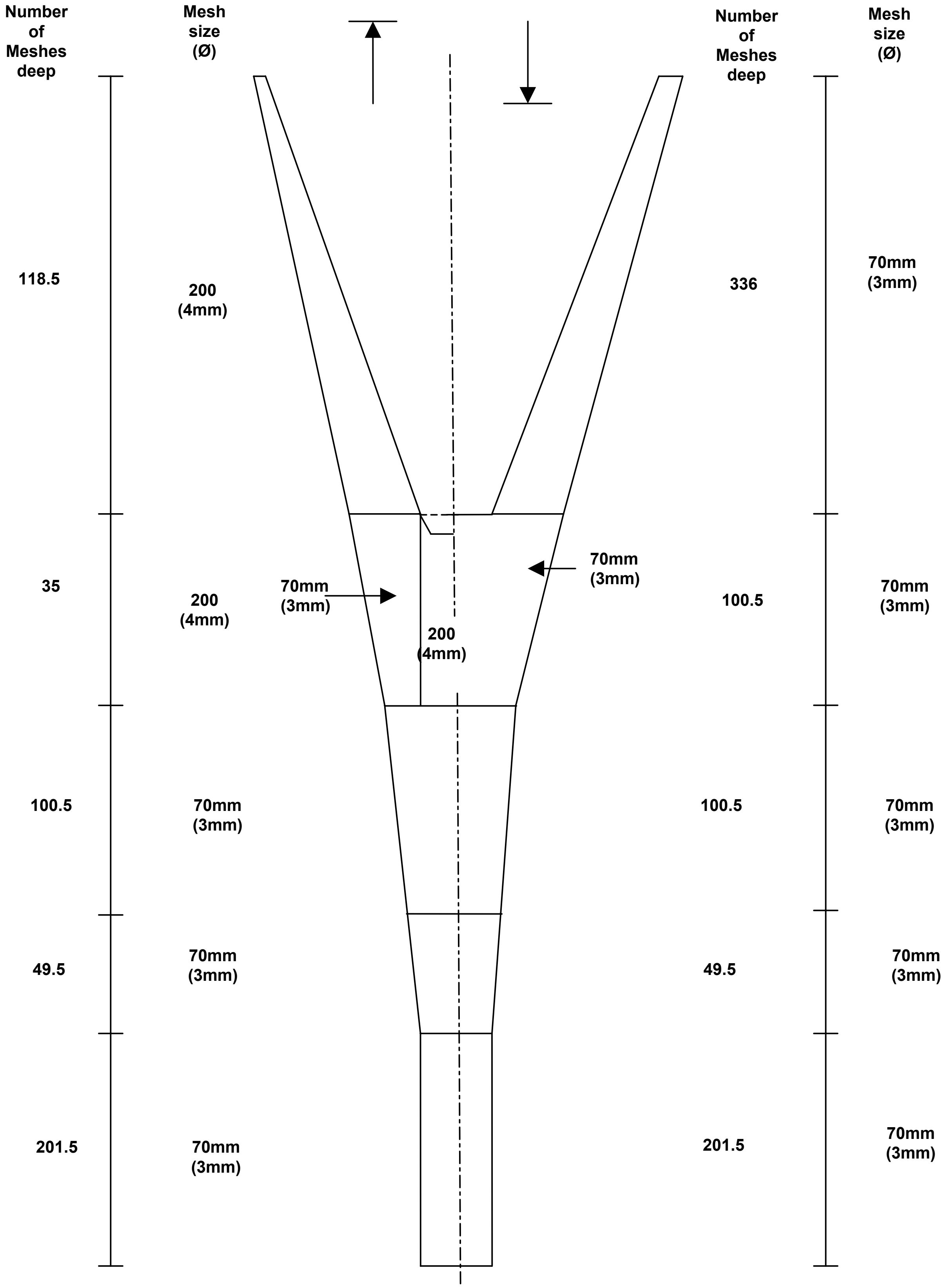



**Figure 7: Schematic diagram of the *Stuart Nets* modified final version of the new prawn trawl**

The net's ground gear was also changed to be compatible with the conditions encountered in the Clyde. A clean-ground 'grass rope' arrangement was used, as typical of the type being used by the vessels selected to conduct the trials.

The two vessels chosen for the final stage of the project were the MFV *Aeolus* (BA808) and the MFV *Spes Bona* (BA 107). Both vessels work out of the port of Troon.

The *Aeolus* is a steel vessel with a ¾ length shelter deck powered by a 215 kW engine. Her partner vessel for the trial was the wooden built *Spes Bona*. The *Spes Bona,* at 16.5m and 222kW is slightly larger than the *Aeolus* at 14.95m.

The trawl used for comparison was a single 500x70mm Stuart dual purpose prawn net rigged to 2m Dunbar 'V' doors by a ~61m (25 fathom single, 8 fathom splits and 1 fathom of chain) combination of sweeps and bridles.

The experimental trawl was rigged to 2m Dunbar 'V' doors by a ~95m (52 fathom single,2 fathom of wire splits) combination of sweeps and bridles.

Their normal prawn catching operations are worked on the basis of day trips landing into Troon.

The fishing trials commenced in late February, running into early March. The initial 12 day period allocated was extended by 3 days to try and make up for time lost due to very severe weather which hampered the exercise from start to finish.

For the first half of the trial the *Aeolus* used the experimental net shadowing the operations of the *Spes Bona.* This arrangement was alternated at the halfway stage conforming to the practices followed for the previous trials.

Seafish staff onboard each vessel monitored and recorded the catches of bycatch and prawns.

The sampling routines for this trial were essentially the same as those followed for the previous trials. When the vessels hauled the catches were emptied into the hoppers. All discarded fish and assorted debris was quantified and recorded. This was done by filling baskets with discarded material and emptying them outboard. A count was taken of baskets filled.

A basket was taken away for sub sampling at the start of the sorting, near the middle and towards the end to obtain a good profile of discarded fish. The fish being kept for landing was sampled by measuring either all of the cod, haddock and whiting or a representative sample of each species, if large quantities were being kept. The live weight of *Nephrops* sorted for retention was also recorded after the catch was sorted.

The usual method for recording *Nephrops* weights landed was to do a count of baskets at the end of sorting. A basket was taken to hold approximately 19kg of *Nephrops* live weight.  In the case of ‘tails’, one basket of tails was converted to live weight by using a raising factor of 3.  This method was used because vessels did not always land the catch every day.

In the Clyde area trials the *Nephrops* weights recorded were more accurate.  The market at Troon is an electronic one and catches are weighed and sold each evening, therefore exact daily weights of *Nephrops* landed were available for the duration of these trials.

Personnel on both vessels used the same methods of sampling.

# 4 Results

## 4.1 Flume tank tests

The initial observations of both net designs revealed one or two design faults. Both nets showed excessive strain lines emanating from the headline quarters. These strain lines followed the line of a bar. The simplest cure for this problem was to remove the area of netting bounded by the strain lines. This had the positive effect of increasing the open area above the fishing line and creating a much larger potential escape area for round fish swimming in the mouth of the net (Figure 8).

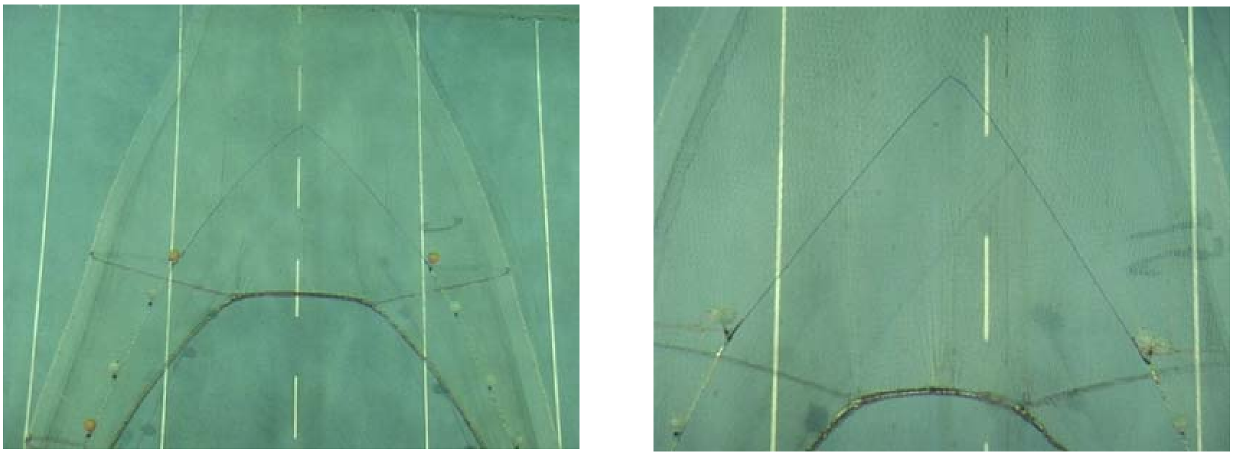


**Figure 8: Showing area of netting cut away from the top panel to create greater potential escape area**

It was noticeable from these tests that the large meshes in the top panels were wide open compared to those of the lower sheets (Figure 9).

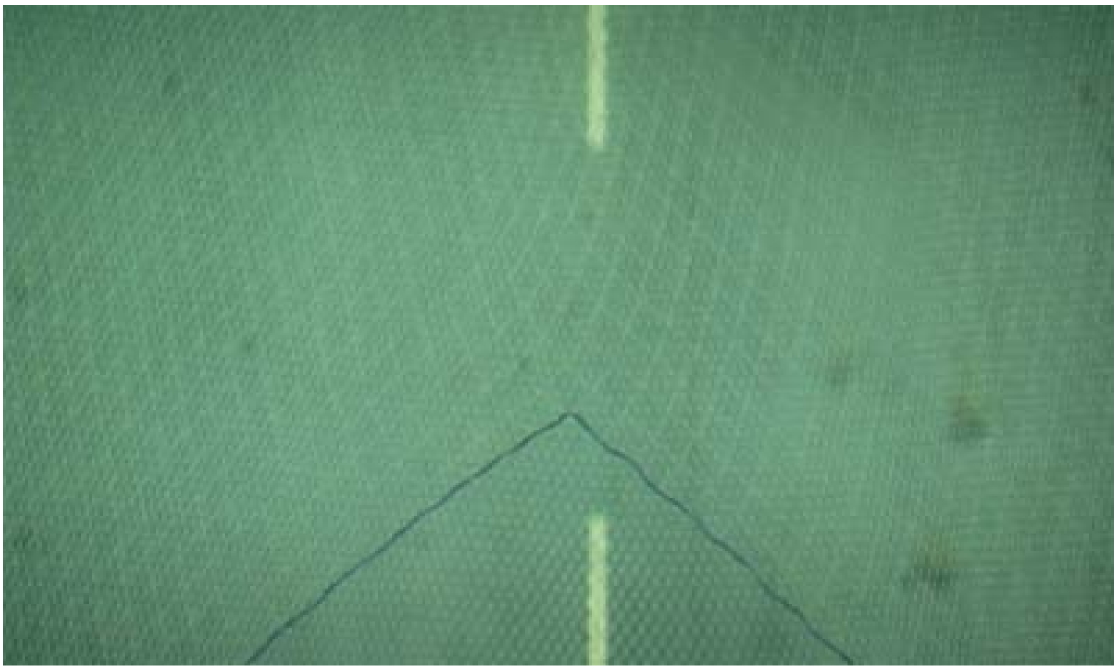


**Figure 9: Showing wide open meshes in the top sheets of netting**

This had the effect of shortening up the meshes in the top panels relative to the lower ones (Figure 10).

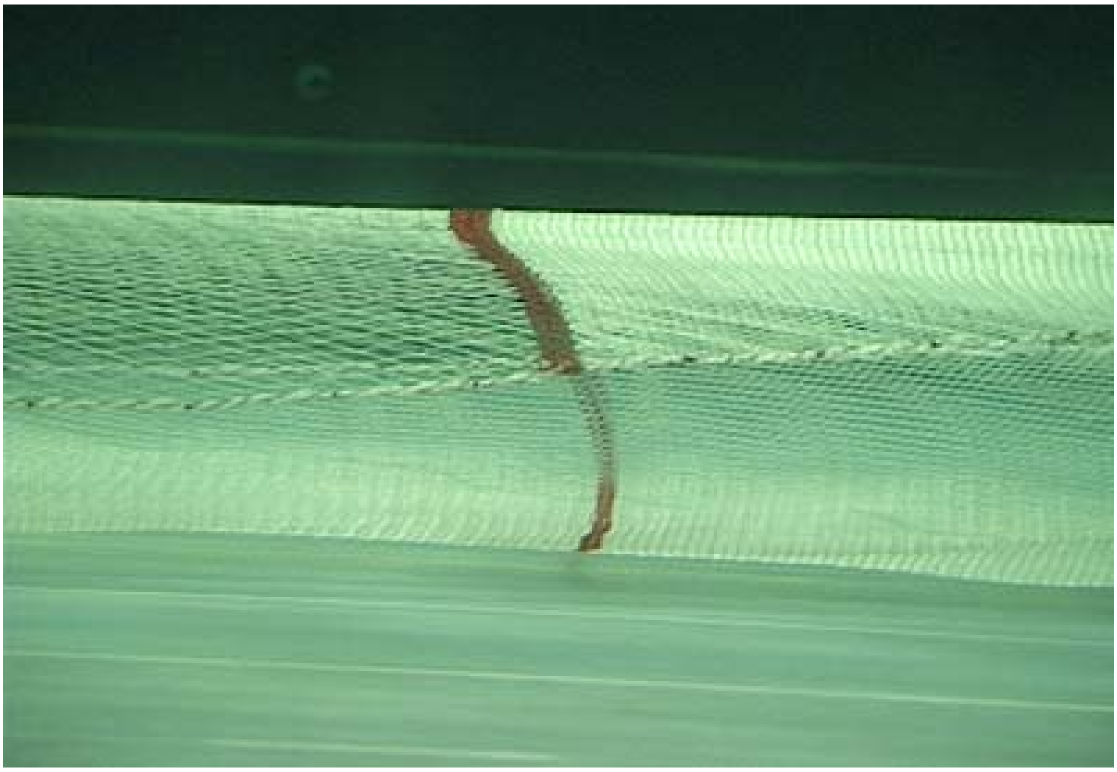


**Figure 10: Showing tension created in the top panels as a result of the more open meshes**

This contributed to the 'rippling' effect noticed in the belly section of the Scotnet trawl (Figure 11).

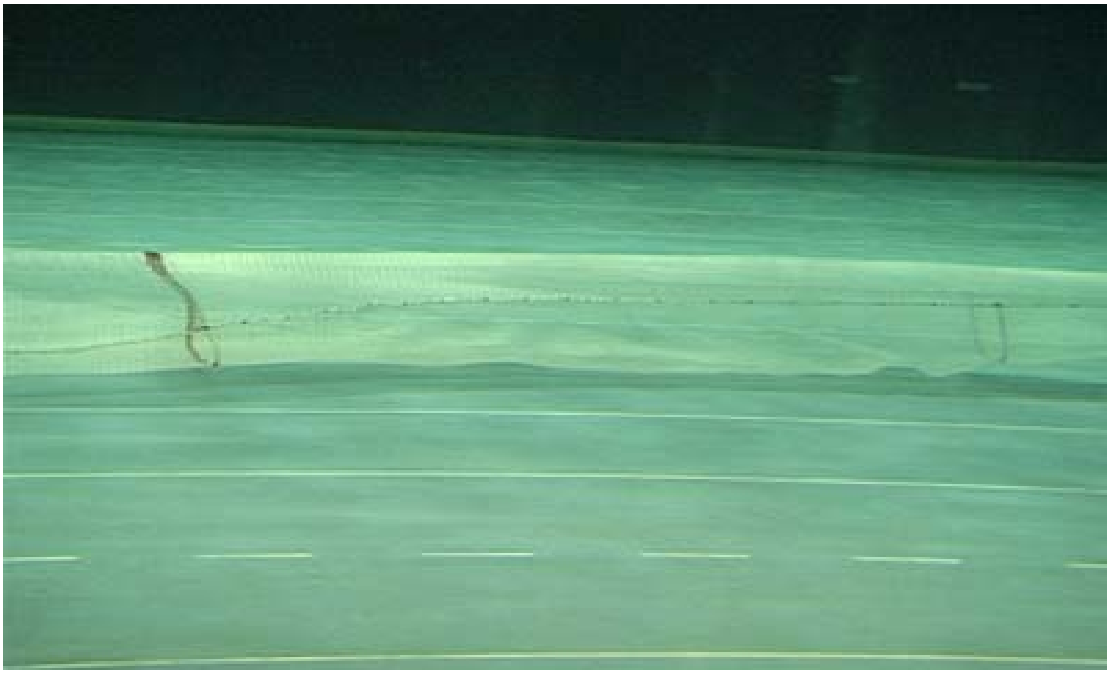


**Figure 11: Showing 'rippling' effect created by differences in mesh opening between top and bottom panels**

These open meshes, in conjunction with the increased open area above the fishing line produced as a result of the cutaway 'V' section at the back of the headline, created a much more open escape area for round fish rising in the mouth of the trawl (Figure 12).

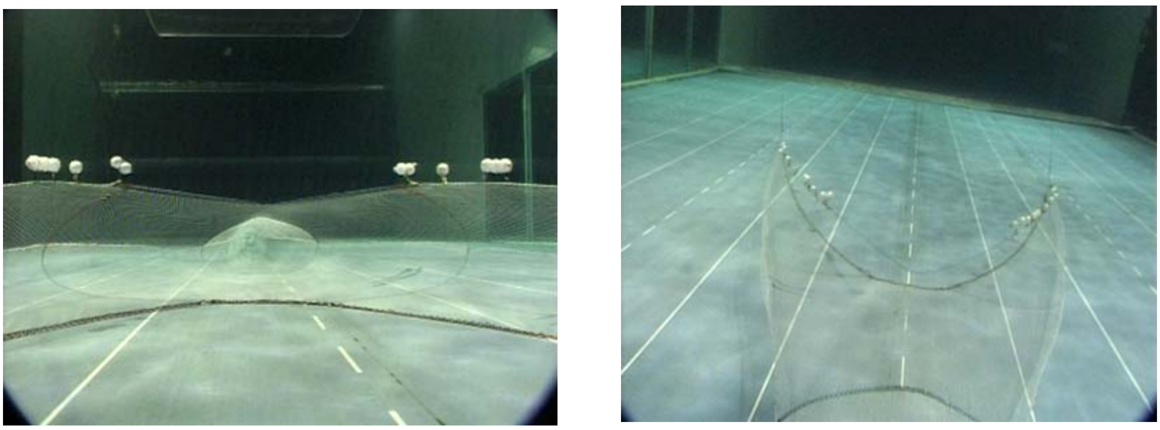


**Figure 12: Showing open area in the mouth of the net**

The model scale gear parameters obtained in the Flume Tank tests are summarised in Tables 1 and 2 for the Stuart Nets design and the Scotnet design respectively.

**Table 1 Flume Tank tests – Stuart Net Design**
(1:7 scale)

| | | | | | | |
|---|---|---|---|---|---|---|
| **NET** | Stuart – Short-wing version | | | | | |
| **Warp:Depth Ratio** | 3:1 | | | | | |
| **Trawl Doors** | Fixed spread – approx. 21.3m(70 ft) | | | | | |
| **Sweeps/Bridles** | 38.4m total – 27.4m singles + 9.1m splits +1.8m chain | | | | | |
| **Floatation** | Equivalent to 16×200mm floats. Includes 1 on each triangle. | | | | | |
| **Comments:** Triangles on wing-ends with floatation attached. | | | | | | |
| Approx. 35cm extension required in lower wing-end. | | | | | | |
| Spreads based on 35-40% of h/line length. | | | | | | |
| Strain lines from h/line quarters running down on a bar. | | | | | | |
| 1.8m. chain between 9.1 and 27.4m sweep sections. | | | | | | |
| | | | | | | |
| **Speed (knts)** | **2.0** | **2.25** | **2.5** | **2.75** | **3.0** | **3.5** |
| **Load Port (kg)** | 199 | | 233 | 295 | 322 | 326 |
| **Load Stbd (kg)** | 158 | | 206 | 261 | 285 | 353 |
| **Door Spread** | ≅ 21.3m (70ft) | | 21.3m | 21.3m | 21.3m | 21.3m |
| **Wing-end Spread** | 10.7m (35ft) | | 10.93m (35.87ft) | 10.86m (35.64ft) | 10.85m (35.6ft) | 10.85m (35.6ft) |
| **H/line Height** | 1.68m (5.5ft) | | 1.52m (5.0ft) | 1.22m (4.0ft) | 1.19m (3.9ft) | 1.1m (3.6ft) |
| **Comments:** Door spread readings are actually sweep spread at end of sweep since no doors were used for these trials (fixed door spread). | | | | | | |
| Floatation increased from original setting to equivalent of 16×200mm floats to lift slack netting in lower wings clear of the bottom. At 2.5k all netting in wings clear of bottom. Some minor 'rippling' effect at about mid wing length. | | | | | | |
| Chain footrope equivalent to about 12mm mid-link chain at full scale. | | | | | | |
| Top sheet just taking strain – 1$^{st}$ joining round just pulling forward in top sheet. Triangles stood upright with the addition of float. | | | | | | |
| Towing speed increases do not significantly alter gear geometry. | | | | | | |
| Triangular shaped section of netting removed from panel at the back of the h/line, bounded by the strain lines coming from the quarters. Possibility of leaving small crown (30–60mm) at the apex of this cutaway to even out any points of strain that may result. | | | | | | |

**Table 2 Flume Tank tests – Scotnet Design**
(1:7 scale)

| | | | | | | |
|---|---|---|---|---|---|---|
| **NET** | Scotnet – Short wing version | | | | | |
| **Warp:depth Ratio** | 3:1 | | | | | |
| **Trawl Doors** | Fixed spread – approx. 21.3m(70 ft) | | | | | |
| **Sweeps/Bridles** | 38.4m total – 9.1m splits + 27.4m singles | | | | | |
| **Floatation** | Equivalent of 9×8 inch floats | | | | | |
| **Comments:** No extension in this rig. | | | | | | |
| 1st joining round pulled forward in top sheet causing some 'rippling' in lower belly sheets. | | | | | | |
| Wings and shoulders well clear of bottom and standing up well. | | | | | | |
| **Speed (knts)** | **2.0** | **2.25** | **2.5** | **2.75** | **3.0** | **3.5** |
| **Load Port (kg)** | 161 | | 233 | 243 | 267 | 333 |
| **Load Stbd (kg)** | 151 | | 216 | 247 | 270 | 333 |
| **Door Spread** | 21.3m (70ft) | | 21.3m | 21.3m | 21.3m | 21.3m |
| **Wing-end Spread** | 11.3m (37.0ft) | | 11.2m (36.75ft) | 11.2m (36.75ft) | 10.9m (35.72ft) | 11.03m (36.2ft) |
| **H/line Height** | 1.71m (4.5ft) | | 1.1m (3.6ft) | 1.04m (3.4ft) | 0.99m (3.25ft) | 0.99m (3.25ft) |
| **Comments:** At 2.5k headline height lower than Stuart net. | | | | | | |
| Film taken at 2.5k. | | | | | | |
| Triangular shaped section of netting removed from back of h/line-corresponding to the area bounded by the strain lines developing away from the quarters. This produced much greater potential escape area for round fish. | | | | | | |

## 4.2 Instrumented performance trials

A series of instrumented gear trials took place in October 1999, onboard MFV *Coquet Herald.* The vessel was based in the Scottish West Coast port of Ullapool.

The main gear parameters were measured using SCANMAR gear-mounted acoustic monitoring equipment.

At this stage it was accepted that this net would require closer attention in order to establish a solution to the problem of bottom contact. No further tests were carried out at this stage. The gear parameter measurements obtained during the instrumented gear trials are summarised in Table 3.

**Table 3 Average daily results**

| Day/ Date | Net | Bridles | | Floats | Door spread | Wingend spread | | Headline height | Bridle angle | Warp load |
|---|---|---|---|---|---|---|---|---|---|---|
| | | single | double | | | Scanmar | actual | | | |
| Mon 4th | Scotnet disc net | - | 27.4m | | 27m | 10m | 10m | 2.2m | 18° | 1.4 T |
| Tue 5th | Stuart | 27.4m | 0 | 15 x 200mm | 35m | 14.5m | 18.1m | 2.2m | 19.6° | 1.35 T |
| Wed 6th | Scotnet | 27.4m | 9.1m | 12 x 200mm | 42m | 15m | 18.75m | 1.8m | 20° | 1.38 T |
| Thur 7th | Scotnet | 27.4m | 9.1m | 12 x 200mm | 42m | 15m | 18.75m | 1.8m | 20° | 1.38 T |
| Fri 8th | Stuart | 36.6m | 0 | 8 x 200 mm | 42m | 16.5m | 20.6m | Nil | 18.75° | 1.4 T |
| | Stuart | 36.6m | 0 | 8 x 200 mm | Ave 37m | 14m | 17.5m | 1.8m | 16.8° | |
| Sat 9th | Scotnet | 27.4m | 9.1m | 8 x 200 mm | 44m | 16m | 20m | 1.8m | 18.75° | 1.36 T |

Note: Scanmar wing-end spreads are readings taken 3m from the wing-ends.

Shortly after returning from these trials, the Scotnet design was examined by Seafish gear technologists in conjunction with the net's designer. Some minor modifications were agreed and carried out in preparation for further instrumented trials. This involved resetting the lower wing netting onto the fishing lines.

The instrumentation trials highlighted differences in the spreads achievable with these new modified designs. The Tank tests were predominantly conducted using fixed door spreads based on expected footrope spreads of 30-40% of headline length. The full-scale trial however, produced wing-end spreads considerably in excess of what was initially expected. This was mainly due to an oversight on the part of those involved at the design stage.

Traditional net designs are based on having the headline shorter than the footrope. This effectively constrains the spread of the wings of the trawl. With these new designs the headlines and footropes were initially of equal length. Cutting back the top panels increased the headline lengths relative to the footrope even further. The cutaway arrangement increased the headline lengths by 3m (10ft) for the Scotnet design and by 4.6m (15ft) for the Stuart Nets design. The overall result of these changes was to allow the trawl to spread much wider than traditional designs. It was therefore unrealistic to rely too heavily on the model/full-scale comparisons of spread. More realistic correlation would be sought following the completion of the commercial evaluations and the construction of new models of the final designs.

Since the headline height of the net is influenced by the spread, then there is the potential benefit that the increased spread could help to constrain the headline height. This was one of the new design criteria.

The results from these first stages of work were limited and incomplete. It was not therefore possible to draw many definitive conclusions at this stage. The remaining questions on gear performance would hopefully be answered after the new net designs had been tested under commercial conditions.

### 4.3 Commercial Sea Trials

**Table 4: Summary of data from commercial trials**

| AREA | SPECIES | NUMBERS SAMPLED | | TOTAL NUMBERS/ WEIGHT | | DISCARD RATE(%) | | CATCH REDUCTION (No./kg) | % REDUCTION. |
|---|---|---|---|---|---|---|---|---|---|
| | | STD | EXP | STD | EXP | STD | EXP | EXP | EXP |
| **MALLAIG** WEST COAST SCOTLAND 23 HAULS | COD | NA | NA | NA | NA | NA | NA | NA | NA |
| | HAD | 1343 | 430 | 21613 | 3340 | 37 | 29 | 18273 | 85 |
| | WHG | 2911 | 367 | 43743 | 2263 | 26 | 8 | 41480 | 95 |
| | *Nephrops* | NA | NA | 3376kg | 1734kg | NA | NA | 1642kg | 49 |
| **FARNE DEEPS** NE COAST UK 13 HAULS | COD | 231 | 220 | 231 | 220 | 0 | 0 | 11 | 5 |
| | HAD | 1122 | 399 | 4495 | 852 | 31 | 19 | 3643 | 81 |
| | WHG | 2223 | 626 | 21425 | 3364 | 60 | 73 | 18061 | 85 |
| | *Nephrops* | NA | NA | 872 kg | 600 kg | NA | NA | 272kg | 32 |
| **CLYDE** SOUTH WEST SCOTLAND 17 HAULS | COD | 161 | 143 | 342 | 372 | 66 | 78 | +30 | 0 |
| | HAD | 896 | 412 | 5755 | 1644 | 30 | 30 | 5111 | 71 |
| | WHG | 5100 | 1844 | 28654 | 8043 | 27 | 27 | 20611 | 72 |
| | *Nephrops* | NA | NA | 1302kg | 1245kg | NA | NA | 57kg | 4.5 |

During the trials from Mallaig, a total of 22 tows (see table 4) were used for comparison with a few being discounted due to the experimental vessel 'coming fast' on the ground resulting in damaged gear.

A total of 13 valid paired hauls were achieved over the 10 day period of fishing in the Farne Deeps, 6 hauls were sampled in the first 5 days on MFV *Osprey III* and 7 in the second half on the MFV *Oceana.* Only one haul was discounted, (during the first week), as a result of damage to the net.

Adverse weather conditions were encountered virtually every day during the trials in the Clyde area, despite this a total of 14 paired hauls were achieved over the duration of the trials.

### 4.3.1 West Coast of Scotland/NW Highlands

The indicators for evaluating the performance of the new trawl designs for the commercial sea trials were as follows:

- The quantity of prawns (*Nephrops norvegicus*) caught
- The quantity of (i.e. haddock and whiting retained in the experimental trawl as compared to the standard trawl.

The catch data for these trials are shown in Appendix (I) and summarised in Table 5.

**Table 5: Catch summary for West Coast of Scotland trials**

| **Species** | **Total No of fish caught** Standard Trawl | Experimental Trawl | **Percentage reduction in catch observed in experimental trawl** |
|---|---|---|---|
| Haddock | 21,613 | 3,340 | 85% |
| Whiting | 43,743 | 2,263 | 95% |
| *Nephrops* | 3,376 Kg | 1,734Kg | 49% |

As well as quantifying the catches of haddock and whiting, the data includes Length/Numbers plots showing the size range of fish encountered during the trials. These are shown in Figures 13 and 14 for haddock and whiting respectively.

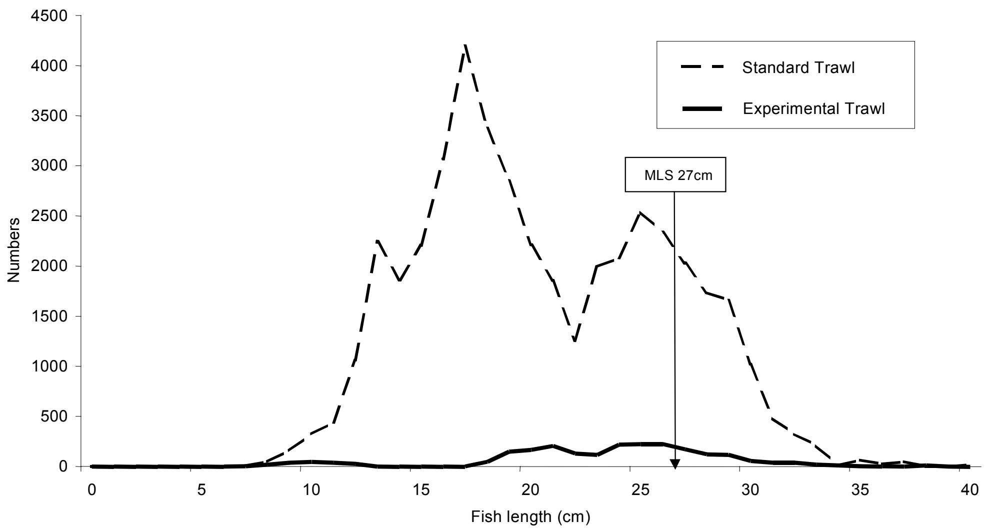



**Figure 13: Length/Numbers plot for Haddock (West Coast of Scotland)**

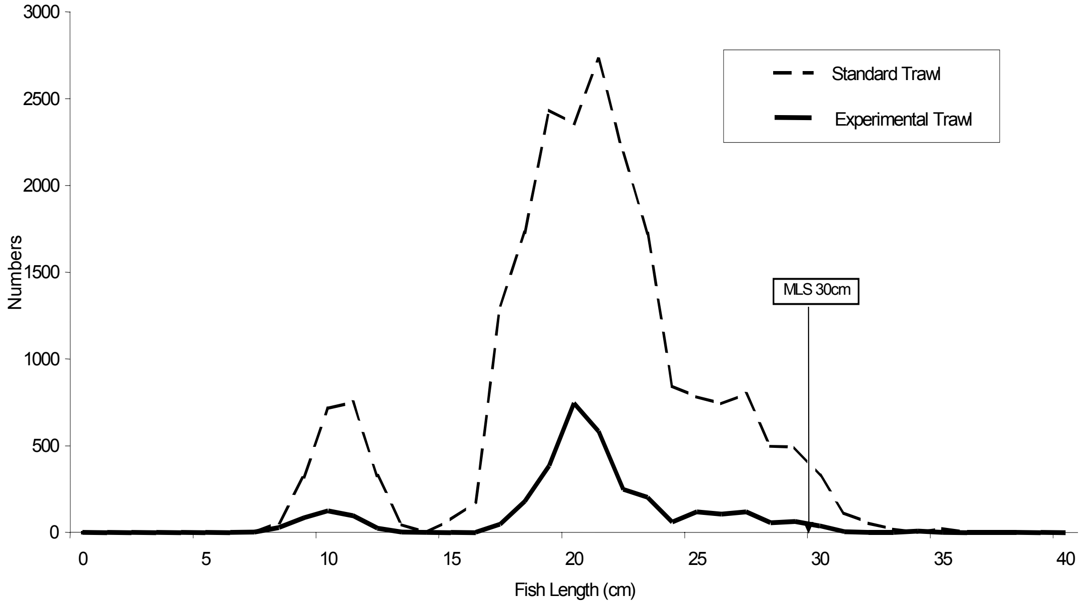
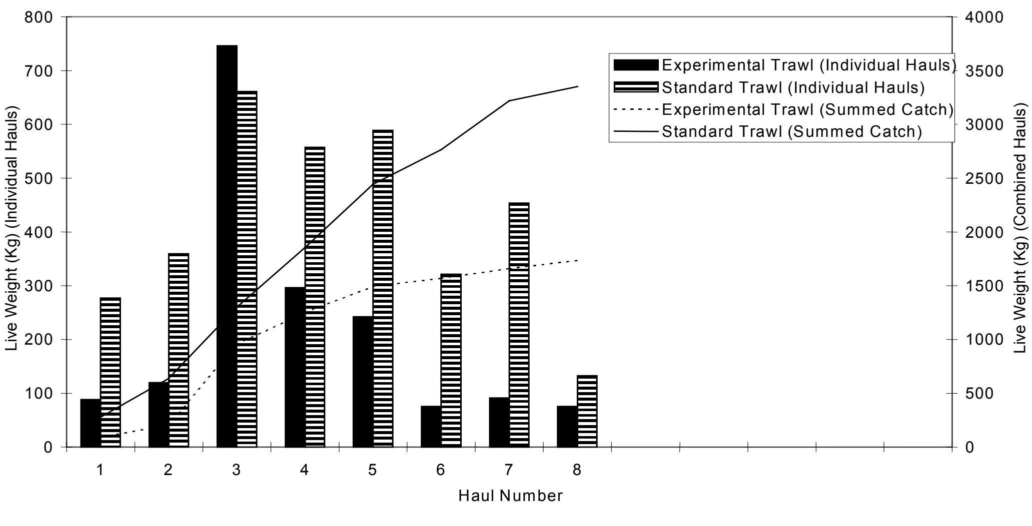



**Figure 14: Length/Numbers plot for Whiting (West Coast of Scotland)**

### *The quantity of by-catch species retained*

The experimental *Nephrops* trawl demonstrated effective by-catch reduction properties for whiting and haddock. The experimental trawl was observed to significantly reduce the retention of both of these species across all observed length classes (i.e. 7-35cm).

**Figure 15: Comparison of *Nephrops* catches (West Coast of Scotland)**



The experimental trawl reduced the retention of whiting in the cod end by 95%, whilst the retention of haddock in the experimental trawl cod end was reduced by a factor of 85%. These figures were based on the combined totals from the summed hauls from these sea trials.

***The quantity of target species (Nephrops norvegicus) caught***

The observed losses of the target species (*Nephrops norvegicus*) were significant and estimated to be around 49%. The experimental trawl therefore only caught 51% of the target species when directly compared to the performance of the standard trawl.

### 4.3.2 Sea Trials – NE Coast of England (December 2001)

The indicators for evaluating the performance of the new trawl designs for the commercial sea trials were as follows

- The quantity of prawns (*Nephrops norvegicus*) caught
- The quantity of haddock and whiting retained in the experimental trawl as compared to the standard trawl.

The catch details for these trials are shown in Appendix II and summarised in Table 6.

**Table 6: Catch summary for NE Coast UK Trials**

| **Species** | **Total No of fish caught** Standard Trawl | Experimental Trawl | **Percentage reduction in catch observed in experimental trawl** |
|---|---|---|---|
| Haddock | 4,495 | 852 | 81% |
| Whiting | 21,425 | 3,364 | 84% |
| *Nephrops* | 881 Kg | 587 Kg | 33 % |

As well as quantifying the catches of haddock and whiting, the data includes Length/Numbers plots showing the size range of fish encountered during the trials. These are shown in Figures 16 and 17 for haddock and whiting respectively.

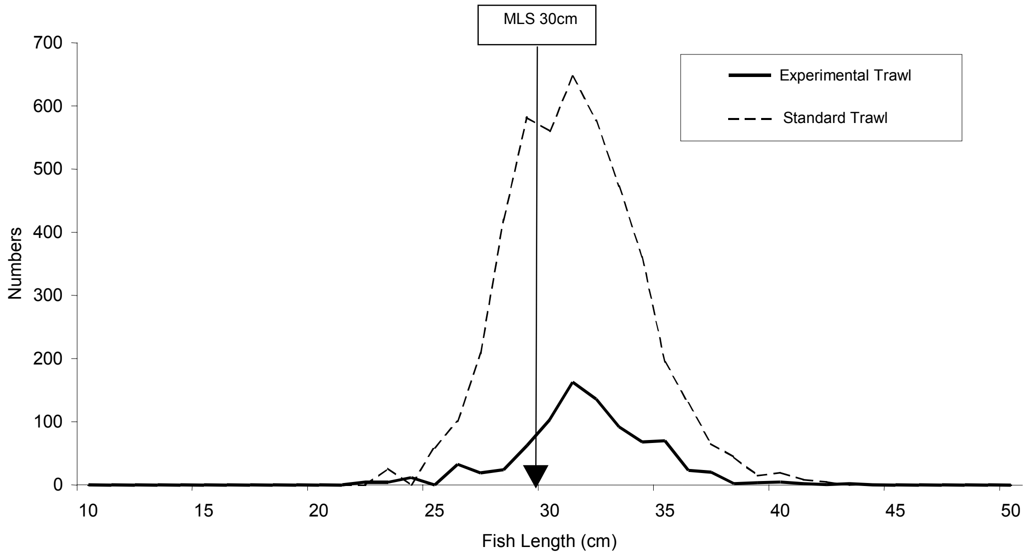



**Figure 16: Length/Numbers plot for Haddock (North East Coast trials)**

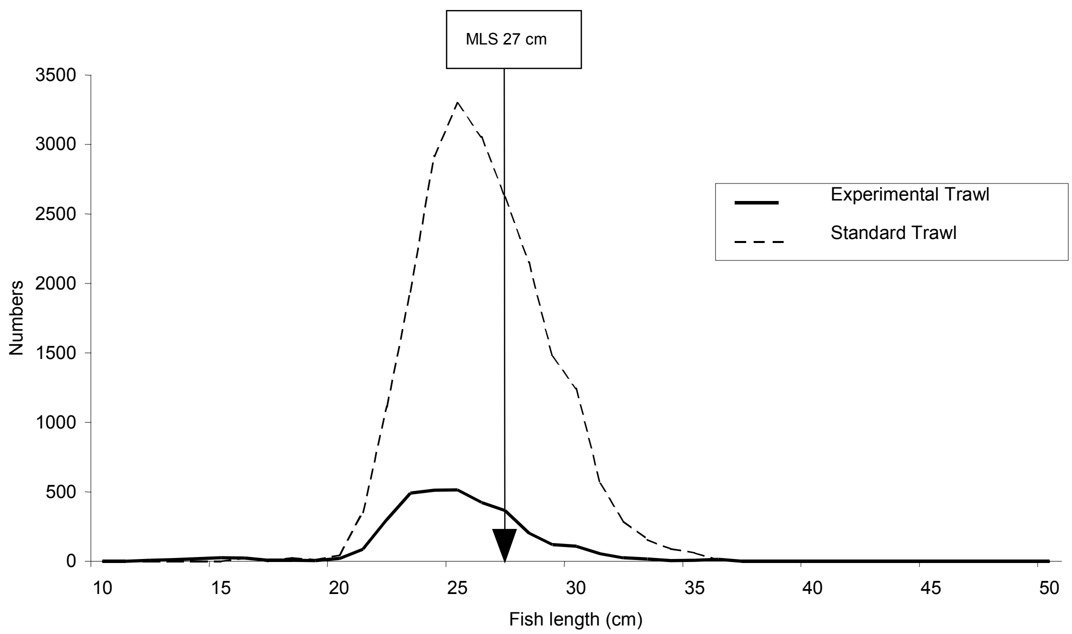



**Figure 17: Length/Numbers plot for Whiting (North East Coast trials)**

### *The quantity of by-catch species retained*

The experimental *Nephrops* trawl demonstrated effective by-catch reduction properties for whiting and haddock. The experimental trawl was observed to significantly reduce the retention of both of these species across all observed length classes (i.e. 20 - 40 cm).

The experimental trawl reduced the retention of whiting in the cod end by 84%, whilst the retention of haddock in the experimental trawl cod end was reduced by a factor of 81%. These figures were based on the combined totals from the summed hauls from these sea trials.

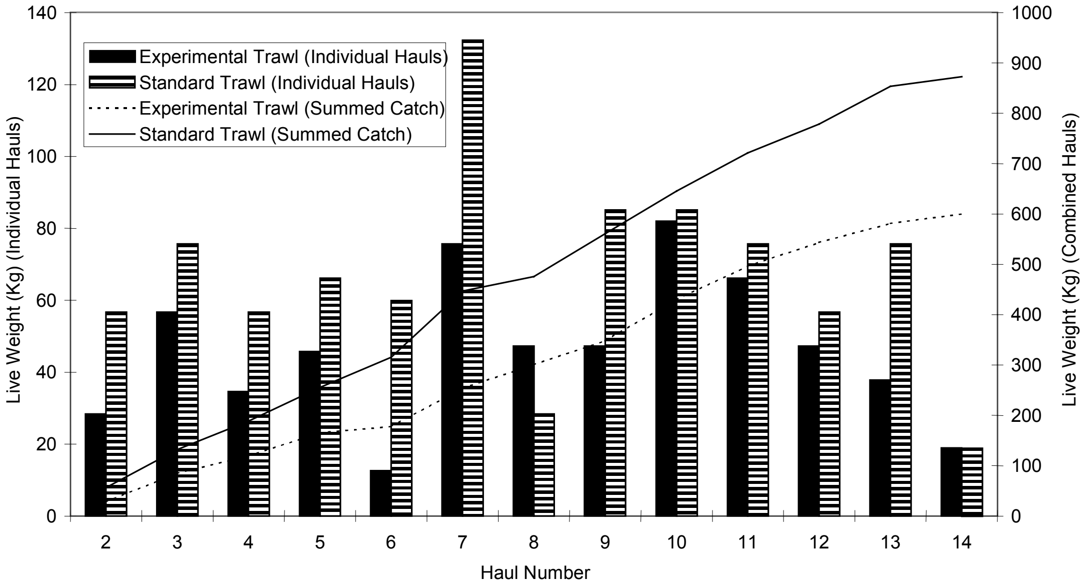



**Figure 18: Comparison of *Nephrops* catches (North East Coast trials)**

### *The quantity of target species (Nephrops norvegicus) caught*

The observed losses of the target species (*Nephrops norvegicus*) were significant and estimated to be around 33%. The experimental trawl therefore only caught 66% of the target species when directly compared to that of the standard trawl.

### 4.3.3 Sea Trials – Clyde Trials

The indicators for evaluating the performance of the new trawl designs for the commercial sea trials were as follows:

- The quantity of prawns (*Nephrops norvegicus*) caught
- The quantity of haddock and whiting retained in the experimental trawl as compared to the standard trawl.

The catch data for these trials are shown in Appendix III and summarised in Table 7. As well as quantifying the catches of haddock and whiting, the data includes Length/Numbers plots showing the size range of fish encountered during the trials. These are shown in Figures 19 and 20 for haddock and whiting respectively.

**Table 7: Catch summary for Clyde Trials**

| **Species** | **Total No of fish caught** Standard Trawl | Experimental trawl | **Percentage reduction in catch observed in experimental trawl** |
|---|---|---|---|
| Haddock | 5,755 | 1644 | 71% |
| Whiting | 28,654 | 8,043 | 72% |
| *Nephrops* | 1,302 Kg | 1,245 Kg | 4.5 % |

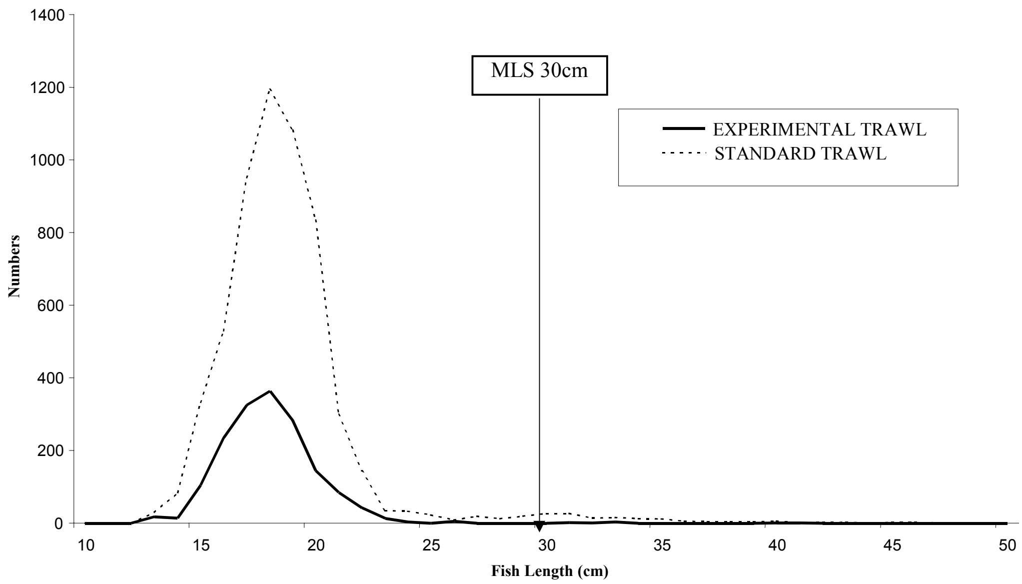
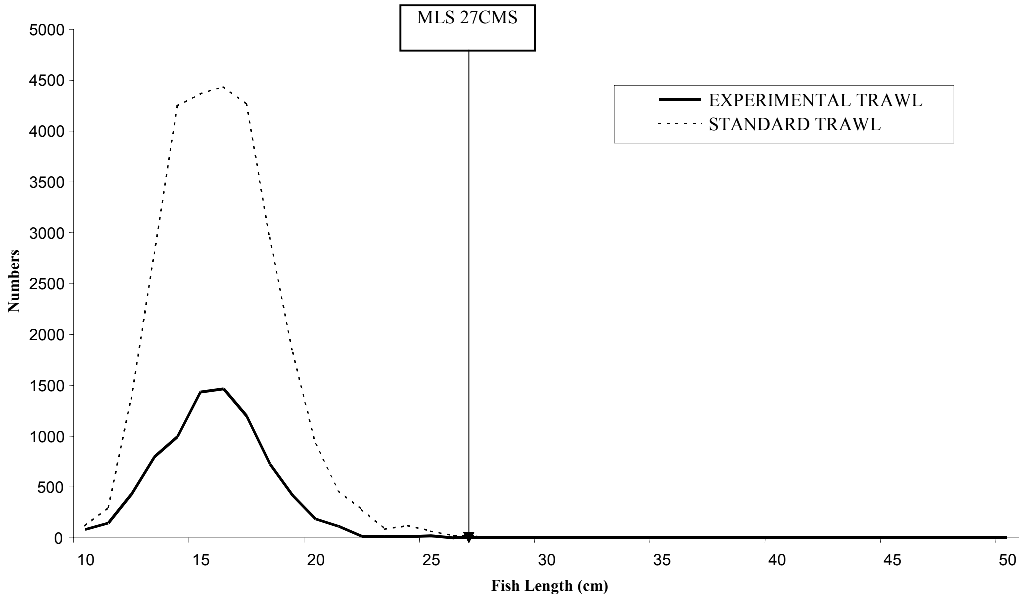



**Figure 19: Length/Numbers plot for Haddock (Clyde trials)**




## Figure 20: Length/Numbers plot for Whiting (Clyde trials)

### *The quantity of by-catch species retained*

The experimental *Nephrops* trawl demonstrated effective by-catch reduction for whiting and haddock. The experimental trawl was observed to significantly reduce the retention of both of these species across all observed length classes (i.e. 20 - 40 cm).

The experimental trawl reduced the retention of whiting in the cod end by 72%, whilst the retention of haddock in the experimental trawl cod end was reduced by a factor of 71%. These figures were based on the combined totals from the summed hauls from these sea trials.

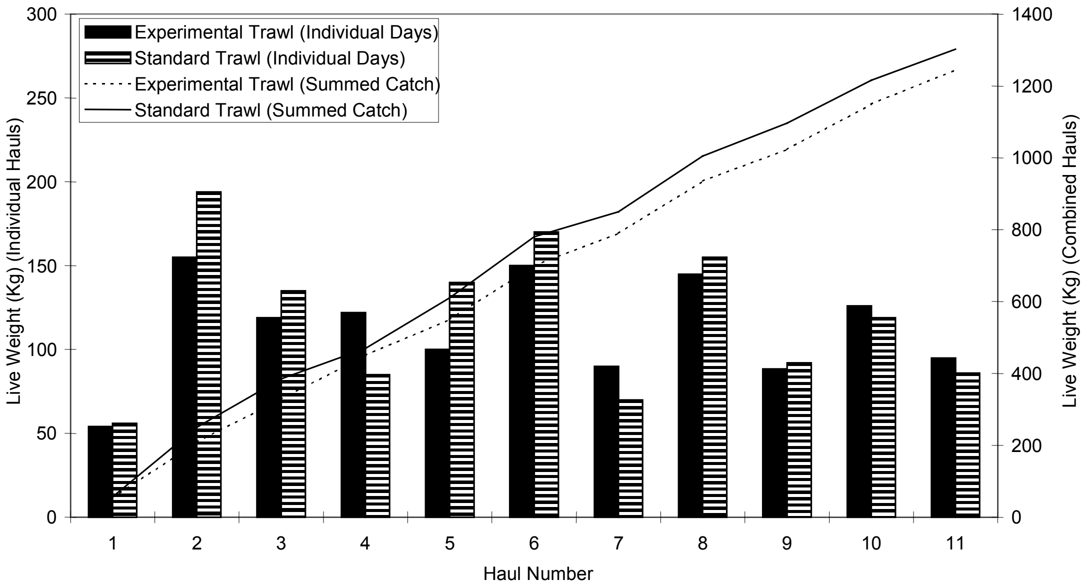



**Figure 21: Catch comparison of *Nephrops* catches (Clyde trials)**

### *The quantity of target species (Nephrops norvegicus) caught*

The observed losses of the target species (*Nephrops norvegicus*) were not significant and estimated to be around 4.5%(see figure 21). The experimental trawl therefore caught 95.5% of the target species when directly compared to that of the standard trawl.

# 5 Discussion

The indications from model tests in the Flume Tank and the instrumented gear performance trials were positive enough to progress to the commercial evaluation stage. However, from the outset of the sea trials, a number of problems were encountered which indicated that the transition from prototype design to a working, commercially acceptable net was not going to be as easy as expected.

The original design changes involving:

- shortening wing length to reduce herding effect;
- removing the square section, cutting back into the baiting section and reducing headline height to allow fish to escape in the mouth area of the net;
- dramatically increasing the mesh size in certain netting sections to aid escape, improve water flow and reduce drag,

all had the desired effect of reducing the bycatch of species such as haddock and whiting. The first two trials produced reductions in haddock and whiting catches of between 80% and 90%. This was achieved at the expense of reduced catches of *Nephrops* when compared to standard prawn trawls of a similar size. Losses of between 32% and 49% were experienced during the West Coast of Scotland and the North East Coast of England trials. This was obviously unacceptable in commercial terms.

Initially, it was thought that the changes incorporated into the new designs were affecting the prawn catching efficiency of the net. Changes to the headline length relative to the fishing line of the net as a result of the removal of the square or 'cover', in conjunction with the cutaway 'V' section in the baitings led to problems of overspreading of the net. This was initially thought to be the main culprit in the poor prawn catching performance observed with the new designs. Re-evaluations of the designs were made in consultation with the net makers and a number of possible solutions were identified.

It was clear at this stage that these possible solutions would mean that compromises would have to be made between bycatch reduction and maintaining prawn catching efficiency. This resulted in further experimental work being conducted during the course of the commercial trials. This had not originally been intended for this stage of the development process, but it was seen as unavoidable if the project was to reach any sort of conclusions.

During both the West Coast of Scotland, (Mallaig) and the North East Coast of England, (Blyth) trials, numerous gear changes were made to 'tune' the net's performance in an attempt to improve the prawn catches. Both the *Scotnet* and the *Stuart Nets* designs had already undergone changes back at their respective net maker's workshops. This resulted in reverting to the long-winged versions of each design to address the problems of overspreading. Overspreading of the gear results in reduced ground contact, which has a negative effect on prawn catching efficiency.

For the same reasons, the headline was modified by inserting a section of combination wire across the base of the cutaway ‘V’ section that effectively made the headline and fishing lines the same length. The cutaway ‘V’ section remained to maintain the increased escape area for any fish swimming in the mouth of the net. The result of this addition to the headline length was a noticeable reduction in the amount the net was allowed to spread at the wing ends. Changes to the ground gears were also made to improve ground contact.

Despite this ongoing process of changes to improve prawn-catching performance, the new designs struggled to compete with their standard counterparts during the trials. However, none of the modifications detracted from the bycatch avoidance capabilities of the gears. This aspect continued to impress the skippers and crews using the new nets. Catch sorting times were greatly reduced as a result of this benefit. Unfortunately, the reduced sorting times were also attributable to the reduced catches of *Nephrops.*

Having eliminated overspreading and/or ground contact as the problem, options for further investigation were limited. At this stage, the problem was approached from a different angle. The question was asked; could the reduction in prawn catches be attributable to prawn loss rather than poor catching efficiency? In other words, was it the case that the new designs were comparable in prawn catching performance to the standard nets, but losing prawns as a result of the new design features?

Earlier in the trials there had been some suspicion that the combination of reduced headline height, the large mesh sizes in the forepart of the net and the possibility of altered water flow patterns inside the mouth of the net, may have increased the risk of prawns being lost through the meshes in the bunt section of the trawl. The very low headline heights achieved with these nets meant that the selvedge lines were also close to the seabed. This brought the prawns into close proximity to the large mesh sizes (200mm) in the top sheets as they passed down the net.

To investigate the possibility that prawns were being lost from these areas of the net, an experiment was tried during the North East Coast trials. The areas of large mesh in the top sections of the net that were suspected of being close to the seabed were covered with smaller mesh netting in order to trap any prawns that may have been passing through at these points. The indications from this experiment did suggest that some loss of prawns was occurring. Prawn catching performance did improve during the second trial, but compared to the standard trawl, the catch rates were still well below commercially acceptable levels, (32% down on the standard comparable net compared to 51% in the NW Scotland trials).

Working on the assumption that prawn loss was a major factor, the net used in the Blyth trials was returned to the net manufacturer for further modifications prior to its use in the final trials in the Clyde Estuary.

The ground gear was changed to a ‘grass rope’ rig to be compatible with local conditions in the Clyde and the top panel of the net was replaced with one constructed of smaller, 70mm mesh with much narrower section of 200mm mesh remaining down the centre of the panel, away from the 'danger area', (see Figure 7 for details).

The results from the last series of trials in the Clyde seem to support the suspicion that prawn loss was the problem. Bycatch reductions of 71% and 72% for haddock and whiting respectively were achieved whilst maintaining the prawn catches within 4.5% of the standard net. This was seen as a significant improvement and deemed to be an acceptable performance by the skippers involved. It was felt that given time the gear could be 'tuned' to reduce the difference even further.

Although the initial intention had been to test the new designs for commercial acceptance in three separate fisheries, the problems encountered meant that in the time available, the results could only demonstrate a workable design for one of the three fisheries. However, there is now a much higher level of confidence in this final design and it is reasonable to assume, having demonstrated that the latest design changes work, that commercially acceptable prawn catches could be achieved in the other fisheries.

When considering the results in terms of the original objectives, the modelling and Flume Tank tests demonstrated that the design of traditional *Nephrops* trawls could be modified relatively easily to remove those features that contribute to the gear's roundfish catching capabilities. The potential herding area of the overall gear was reduced by a combination of reduction in sweep lengths, wing lengths, headline height and removal of cover netting. This was all achieved relatively simply with uncomplicated design and rigging changes. However, the engineering trials and subsequently the commercial fishing trials with full-scale versions of the modified gear established that the required gear parameters were more difficult to achieve. The desired end result was possible only by compromising between bycatch reduction and prawn catching efficiency.

It was also demonstrated that the modifications could be achieved at low cost. Essentially, most of the changes have resulted in the reduction in the amount of materials used in the construction of these gear designs compared to traditional nets of a similar size. The indications are that there are also potential benefits to be gained from the reduction in gear drag in the form of reduced fuel costs. However, insufficient data are available at this stage to confirm this.

The trials undoubtedly demonstrated a considerable reduction in the numbers of haddock and whiting in the resultant catches from the new designs. Closer examination of the results shows that both the experimental and the standard trawl were sampling similar populations of fish in each of the trials. During the Mallaig trials the catches were indicating two distinct year classes of both haddock and whiting, with the bulk of both species being below their respective MLS. The differences in catches between the two nets showed that the design changes were affecting fish across the whole size range. In other words, the benefits of the new gear design do not appear to be size specific for haddock or whiting. Some of the other TCMs examined have shown differences in performance, which appear to be related to size or age - dependant behaviour. For example, separator trawls do not appear to work as well for very small whiting or haddock (<15cm), but can achieve very good separation levels (typically70%+) for more mature, larger size classes above.

The results from the subsequent trials supported these findings in that large reductions in the numbers of larger haddock and whiting were recorded in the experimental net on the Blyth trial. At the other end of the scale, the Clyde trial produced predominantly juvenile haddock and whiting, with almost the entire bycatch being below MLS, peaking at about 16cm for whiting and 18cm for haddock. The new design clearly has positive benefits for both juvenile and larger haddock and whiting.

From the fishermen's point of view, the loss of larger fish may be disconcerting. However, the number/proportion of larger fish encountered is significantly smaller than the undersize juvenile bycatch. After considering the quality and returns from roundfish bycatch from prawn fisheries, it is fair to say that the benefits from the removal of juveniles from the catch should outweigh the losses.

Most of the questions appertaining to the performance of these trawl designs, in respect to their acceptance as a workable effective means of reducing discards, could only be answered after the commercial evaluations. Unfortunately, full appraisals were not achieved in all of the three fisheries selected due to the problems associated with prawn catching performance. Similarly, the identification and quantification of commercial benefits of the technology could only be ascertained on completion of sea trials under representative conditions. Unfortunately, more time than was expected was spent experimenting and making changes to try and improve the gears. It was not until the final stage of the work in the Clyde fishery that unhindered commercial appraisals were possible. Benefits such as reduced catch sorting times and improvements in catch quality have been demonstrated as being achievable with other technical conservation measures that separate catch from bycatch. The indications from this work are similar. The removal of the small fish element of the 'bulk' catch not only has benefits for the stocks of haddock and whiting, it significantly eased the catch sorting process for the crews onboard the vessels.

**Photographs showing the catches from the standard net (left) and the new design (right) clearly showing the difference in numbers of juvenile roundfish present.**

It is very difficult to perform accurate comparisons of two gear types in comparative fishing experiments, particularly when using two vessels. It is accepted that the results from this type of work can only be indicative of performance. Repeatability over long periods of time would help to confirm these results. However, the results obtained during this work do demonstrate that this type of gear can be used effectively to reduce roundfish bycatches of haddock and whiting in certain *Nephrops* fisheries. The necessary modifications to the gear can be achieved easily and at relatively little cost. It would be possible to alter existing nets retrospectively, or to incorporate the new design features into existing prawn net designs at the new net stage.

The new adjustments made prior to the Clyde trials indicated that the trawl was finally achieving close to its full potential. Further commercial proving trials were needed in order to fine-tune the trawl's performance to enable it to compete commercially and to convince fishermen that these new design features are a viable option.

# 6 Conclusions and Recommendations

The aims of this work were broadly achieved but this was a longer and more incremental process than originally expected. The novel approach to bycatch reduction is now at a stage where only a slight improvement in *Nephrops* catches will make the net an attractive option in some fisheries.

The catch data for target and bycatch species give cause for considerable encouragement. Further funding will be sought to support another stage of design modifications and sea trials.

No data were obtained relevant to net drag reduction and fuel saving but the trawls' characteristics indicate that there should be significant benefits.

# Appendix I - Catch data from West Coast of Scotland (Mallaig) trials

## EXPERIMENTAL *NEPHROPS* TRAWL DESIGN MALLAIG TRIALS HADDOCK RESULTS

| NEW *NEPHROPS* TRAWL | | | NORMAL TRAWL | | |
|---|---|---|---|---|---|
| SAMPLE TOTAL: | | 430 | SAMPLE TOTAL: | | 1343 |
| RAISED TOTAL: | | 3340 | RAISED TOTAL: | | 21613 |
| MLS (cm) | | 30 | MLS (cm) | | 30 |
| % UNDER MLS | | 29 | % UNDER MLS | | 37 |
| % RETAINED | | 71 | % RETAINED | | 63 |
| ***HADDOCK*** | | | ***HADDOCK*** | | |
| **CLASS cm** | **RAISED NUMBERS** | **FREQ. %** | **CLASS cm** | **RAISED NUMBERS** | **FREQ. %** |
| 0 | 0 | 0.000 | 0 | 0 | 0.000 |
| 1 | 0 | 0.000 | 1 | 0 | 0.000 |
| 2 | 0 | 0.000 | 2 | 0 | 0.000 |
| 3 | 0 | 0.000 | 3 | 0 | 0.000 |
| 4 | 0 | 0.000 | 4 | 0 | 0.000 |
| 5 | 0 | 0.000 | 5 | 0 | 0.000 |
| 6 | 0 | 0.000 | 6 | 0 | 0.000 |
| 7 | 4 | 0.001 | 7 | 0 | 0.000 |
| 8 | 29 | 0.009 | 8 | 56 | 0.003 |
| 9 | 86 | 0.026 | 9 | 320 | 0.015 |
| 10 | 127 | 0.038 | 10 | 715 | 0.033 |
| 11 | 97 | 0.029 | 11 | 752 | 0.035 |
| 12 | 25 | 0.007 | 12 | 326 | 0.015 |
| 13 | 4 | 0.001 | 13 | 44 | 0.002 |
| 14 | 0 | 0.000 | 14 | 0 | 0.000 |
| 15 | 0 | 0.000 | 15 | 75 | 0.003 |
| 16 | 0 | 0.000 | 16 | 175 | 0.008 |
| 17 | 47 | 0.014 | 17 | 1311 | 0.061 |
| 18 | 181 | 0.054 | 18 | 1729 | 0.080 |
| 19 | 384 | 0.115 | 19 | 2434 | 0.113 |
| 20 | 747 | 0.224 | 20 | 2357 | 0.109 |
| 21 | 584 | 0.175 | 21 | 2728 | 0.126 |
| 22 | 249 | 0.074 | 22 | 2186 | 0.101 |
| 23 | 203 | 0.061 | 23 | 1724 | 0.080 |
| 24 | 61 | 0.018 | 24 | 844 | 0.039 |
| 25 | 118 | 0.035 | 25 | 782 | 0.036 |
| 26 | 106 | 0.032 | 26 | 741 | 0.034 |
| 27 | 120 | 0.036 | 27 | 799 | 0.037 |
| 28 | 56 | 0.017 | 28 | 497 | 0.023 |
| 29 | 63 | 0.019 | 29 | 491 | 0.023 |
| 30 | 38 | 0.011 | 30 | 328 | 0.015 |
| 31 | 5 | 0.001 | 31 | 111 | 0.005 |
| 32 | 2 | 0.001 | 32 | 53 | 0.002 |
| 33 | 0 | 0.000 | 33 | 18 | 0.001 |
| 34 | 9 | 0.003 | 34 | 0 | 0.000 |
| 35 | 0 | 0.000 | 35 | 21 | 0.001 |
| 36 | 0 | 0.000 | 36 | 0 | 0.000 |
| 37 | 1 | 0.000 | 37 | 0 | 0.000 |
| 38 | 0 | 0.000 | 38 | 0 | 0.000 |
| 39 | 0 | 0.000 | 39 | 0 | 0.000 |
| 40 | 0 | 0.000 | 40 | 0 | 0.000 |

# EXPERIMENTAL *NEPHROPS* TRAWL DESIGN MALLAIG TRIALS WHITING RESULTS

| NEW *NEPHROPS* TRAWL | | | NORMAL TRAWL | | |
|---|---|---|---|---|---|
| SAMPLE TOTAL: | | 367 | SAMPLE TOTAL: | | 2911 |
| RAISED TOTAL: | | 2263 | RAISED TOTAL: | | 43743 |
| MLS (cm): | | 27 | MLS (cm): | | 27 |
| % UNDER MLS | | 8 | % UNDER MLS: | | 26 |
| % RETAINED: | | 92 | % RETAINED: | | 74 |
| | ***WHITING*** | | | ***WHITING*** | |
| **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** | **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** |
| 0 | 0 | 0.000 | 0 | 0 | 0.000 |
| 1 | 0 | 0.000 | 1 | 0 | 0.000 |
| 2 | 0 | 0.000 | 2 | 0 | 0.000 |
| 3 | 0 | 0.000 | 3 | 0 | 0.000 |
| 4 | 0 | 0.000 | 4 | 0 | 0.000 |
| 5 | 0 | 0.000 | 5 | 0 | 0.000 |
| 6 | 0 | 0.000 | 6 | 0 | 0.000 |
| 7 | 3 | 0.001 | 7 | 8 | 0.000 |
| 8 | 19 | 0.008 | 8 | 50 | 0.001 |
| 9 | 41 | 0.018 | 9 | 160 | 0.004 |
| 10 | 50 | 0.022 | 10 | 324 | 0.007 |
| 11 | 37 | 0.016 | 11 | 440 | 0.010 |
| 12 | 31 | 0.013 | 12 | 1060 | 0.024 |
| 13 | 1 | 0.000 | 13 | 2243 | 0.051 |
| 14 | 1 | 0.000 | 14 | 1862 | 0.043 |
| 15 | 1 | 0.000 | 15 | 2204 | 0.050 |
| 16 | 0 | 0.000 | 16 | 3065 | 0.070 |
| 17 | 0 | 0.000 | 17 | 4198 | 0.096 |
| 18 | 48 | 0.021 | 18 | 3375 | 0.077 |
| 19 | 148 | 0.065 | 19 | 2853 | 0.065 |
| 20 | 168 | 0.074 | 20 | 2212 | 0.051 |
| 21 | 207 | 0.091 | 21 | 1856 | 0.042 |
| 22 | 130 | 0.057 | 22 | 1256 | 0.029 |
| 23 | 117 | 0.052 | 23 | 1992 | 0.046 |
| 24 | 221 | 0.097 | 24 | 2080 | 0.048 |
| 25 | 226 | 0.100 | 25 | 2539 | 0.058 |
| 26 | 225 | 0.099 | 26 | 2336 | 0.053 |
| 27 | 172 | 0.076 | 27 | 2029 | 0.046 |
| 28 | 122 | 0.054 | 28 | 1735 | 0.040 |
| 29 | 117 | 0.051 | 29 | 1660 | 0.038 |
| 30 | 56 | 0.025 | 30 | 1021 | 0.023 |
| 31 | 38 | 0.017 | 31 | 482 | 0.011 |
| 32 | 40 | 0.017 | 32 | 322 | 0.007 |
| 33 | 22 | 0.010 | 33 | 208 | 0.005 |
| 34 | 14 | 0.006 | 34 | 14 | 0.000 |
| 35 | 3 | 0.001 | 35 | 66 | 0.002 |
| 36 | 3 | 0.001 | 36 | 28 | 0.001 |
| 37 | 1 | 0.000 | 37 | 50 | 0.001 |
| 38 | 10 | 0.004 | 38 | 0 | 0.000 |
| 39 | 0 | 0.000 | 39 | 0 | 0.000 |
| 40 | 0 | 0.000 | 40 | 21 | 0.000 |

# Appendix II – Catch data from North East Coast of England (Blyth) trials

## EXPERIMENTAL *NEPHROPS* TRAWL DESIGN BLYTH TRIALS WHITING RESULTS

| NEW *NEPHROPS* TRAWL | | | NORMAL TRAWL | | |
|---|---|---|---|---|---|
| SAMPLE TOTAL: | | 626 | SAMPLE TOTAL: | | 2223 |
| RAISED TOTAL: | | 3364 | RAISED TOTAL: | | 21425 |
| MLS(cm): | | 27 | MLS(cm): | | 27 |
| % UNDER MLS | | 73 | % UNDER MLS: | | 60 |
| % RETAINED: | | 27 | % RETAINED: | | 40 |
| ***WHITING*** | | | ***WHITING*** | | |
| **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** | **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** |
| 10 | 0 | 0.000 | 10 | 0 | 0.000 |
| 11 | 0 | 0.000 | 11 | 0 | 0.000 |
| 12 | 6 | 0.002 | 12 | 0 | 0.000 |
| 13 | 12 | 0.004 | 13 | 0 | 0.000 |
| 14 | 18 | 0.005 | 14 | 0 | 0.000 |
| 15 | 24 | 0.007 | 15 | 0 | 0.000 |
| 16 | 24 | 0.007 | 16 | 23 | 0.001 |
| 17 | 6 | 0.002 | 17 | 0 | 0.000 |
| 18 | 6 | 0.002 | 18 | 25 | 0.001 |
| 19 | 6 | 0.002 | 19 | 12 | 0.001 |
| 20 | 20 | 0.006 | 20 | 43 | 0.002 |
| 21 | 89 | 0.026 | 21 | 352 | 0.016 |
| 22 | 303 | 0.090 | 22 | 1114 | 0.052 |
| 23 | 490 | 0.146 | 23 | 1941 | 0.091 |
| 24 | 510 | 0.152 | 24 | 2915 | 0.136 |
| 25 | 513 | 0.153 | 25 | 3297 | 0.154 |
| 26 | 424 | 0.126 | 26 | 3054 | 0.143 |
| 27 | 366 | 0.109 | 27 | 2619 | 0.122 |
| 28 | 204 | 0.061 | 28 | 2151 | 0.100 |
| 29 | 119 | 0.035 | 29 | 1473 | 0.069 |
| 30 | 108 | 0.032 | 30 | 1243 | 0.058 |
| 31 | 54 | 0.016 | 31 | 558 | 0.026 |
| 32 | 25 | 0.007 | 32 | 287 | 0.013 |
| 33 | 15 | 0.004 | 33 | 156 | 0.007 |
| 34 | 5 | 0.001 | 34 | 89 | 0.004 |
| 35 | 7 | 0.002 | 35 | 61 | 0.003 |
| 36 | 13 | 0.004 | 36 | 8 | 0.000 |
| 37 | 0 | 0.000 | 37 | 4 | 0.000 |
| 38 | 0 | 0.000 | 38 | 4 | 0.000 |
| 39 | 0 | 0.000 | 39 | 0 | 0.000 |
| 40 | 0 | 0.000 | 40 | 2 | 0.000 |
| 41 | 0 | 0.000 | 41 | 0 | 0.000 |
| 42 | 0 | 0.000 | 42 | 0 | 0.000 |
| 43 | 0 | 0.000 | 43 | 0 | 0.000 |
| 44 | 0 | 0.000 | 44 | 0 | 0.000 |
| 45 | 0 | 0.000 | 45 | 0 | 0.000 |
| 46 | 0 | 0.000 | 46 | 0 | 0.000 |
| 47 | 0 | 0.000 | 47 | 0 | 0.000 |
| 48 | 0 | 0.000 | 48 | 0 | 0.000 |
| 49 | 0 | 0.000 | 49 | 0 | 0.000 |
| 50 | 0 | 0.000 | 50 | 0 | 0.000 |

# EXPERIMENTAL *NEPHROPS* TRAWL DESIGN BLYTH TRIALS HADDOCK RESULTS

| NEW NEPHROPS TRAWL | | | NORMAL TRAWL | | |
|---|---|---|---|---|---|
| SAMPLE TOTAL: | | 399 | SAMPLE TOTAL: | | 1122 |
| RAISED TOTAL: | | 852 | RAISED TOTAL: | | 4495 |
| MLS (cm): | | 30 | MLS (cm): | | 30 |
| % UNDER MLS | | 19 | % UNDER MLS: | | 31 |
| % RETAINED: | | 81 | % RETAINED: | | 69 |
| | ***HADDOCK*** | | | ***HADDOCK*** | |
| **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. %** | **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** |
| 10 | 0 | 0.000 | 10 | 0 | 0.000 |
| 11 | 0 | 0.000 | 11 | 0 | 0.000 |
| 12 | 0 | 0.000 | 12 | 0 | 0.000 |
| 13 | 0 | 0.000 | 13 | 0 | 0.000 |
| 14 | 0 | 0.000 | 14 | 0 | 0.000 |
| 15 | 0 | 0.000 | 15 | 0 | 0.000 |
| 16 | 0 | 0.000 | 16 | 0 | 0.000 |
| 17 | 0 | 0.000 | 17 | 0 | 0.000 |
| 18 | 0 | 0.000 | 18 | 0 | 0.000 |
| 19 | 0 | 0.000 | 19 | 0 | 0.000 |
| 20 | 0 | 0.000 | 20 | 0 | 0.000 |
| 21 | 0 | 0.000 | 21 | 0 | 0.000 |
| 22 | 5 | 0.006 | 22 | 0 | 0.000 |
| 23 | 5 | 0.006 | 23 | 26 | 0.006 |
| 24 | 12 | 0.014 | 24 | 0 | 0.000 |
| 25 | 0 | 0.000 | 25 | 59 | 0.013 |
| 26 | 33 | 0.039 | 26 | 101 | 0.022 |
| 27 | 19 | 0.022 | 27 | 208 | 0.046 |
| 28 | 24 | 0.028 | 28 | 420 | 0.093 |
| 29 | 63 | 0.074 | 29 | 582 | 0.129 |
| 30 | 104 | 0.122 | 30 | 560 | 0.125 |
| 31 | 163 | 0.191 | 31 | 647 | 0.144 |
| 32 | 136 | 0.159 | 32 | 577 | 0.128 |
| 33 | 92 | 0.108 | 33 | 473 | 0.105 |
| 34 | 68 | 0.080 | 34 | 361 | 0.080 |
| 35 | 70 | 0.082 | 35 | 195 | 0.043 |
| 36 | 23 | 0.027 | 36 | 130 | 0.029 |
| 37 | 20 | 0.023 | 37 | 65 | 0.014 |
| 38 | 2 | 0.002 | 38 | 44 | 0.010 |
| 39 | 4 | 0.005 | 39 | 15 | 0.003 |
| 40 | 5 | 0.006 | 40 | 20 | 0.004 |
| 41 | 2 | 0.002 | 41 | 9 | 0.002 |
| 42 | 1 | 0.001 | 42 | 6 | 0.001 |
| 43 | 2 | 0.002 | 43 | 0 | 0.000 |
| 44 | 0 | 0.000 | 44 | 1 | 0.000 |
| 45 | 0 | 0.000 | 45 | 0 | 0.000 |
| 46 | 0 | 0.000 | 46 | 0 | 0.000 |
| 47 | 0 | 0.000 | 47 | 0 | 0.000 |
| 48 | 0 | 0.000 | 48 | 0 | 0.000 |
| 49 | 0 | 0.000 | 49 | 0 | 0.000 |
| 50 | 0 | 0.000 | 50 | 0 | 0.000 |

# Appendix III – Catch data from Clyde Estuary (Troon) trials

## EXPERIMENTAL *NEPHROPS* TRAWL DESIGN CLYDE TRIALS HADDOCK RESULTS

| NEW *NEPHROPS* TRAWL | | | NORMAL TRAWL | | |
|---|---|---|---|---|---|
| SAMPLE TOTAL: | | 412 | SAMPLE TOTAL: | | 896 |
| RAISED TOTAL: | | 1644 | RAISED TOTAL: | | 5755 |
| MLS (cm) | | 30 | MLS (cm) | | 30 |
| % UNDER MLS | | 100 | % UNDER MLS | | 98 |
| % RETAINED | | 0 | % RETAINED | | 2 |
| ***HADDOCK*** | | | ***HADDOCK*** | | |
| **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** | **CLASS (cm)** | **RAISED NUMBERS** | **FREQ (%)** |
| 10 | 0 | 0.000 | 10 | 0 | 0.000 |
| 11 | 0 | 0.000 | 11 | 0 | 0.000 |
| 12 | 0 | 0.000 | 12 | 0 | 0.000 |
| 13 | 17 | 0.010 | 13 | 29 | 0.005 |
| 14 | 15 | 0.009 | 14 | 84 | 0.015 |
| 15 | 104 | 0.064 | 15 | 333 | 0.058 |
| 16 | 236 | 0.143 | 16 | 529 | 0.092 |
| 17 | 325 | 0.198 | 17 | 951 | 0.165 |
| 18 | 363 | 0.221 | 18 | 1194 | 0.207 |
| 19 | 283 | 0.172 | 19 | 1082 | 0.188 |
| 20 | 144 | 0.088 | 20 | 834 | 0.145 |
| 21 | 84 | 0.051 | 21 | 300 | 0.052 |
| 22 | 42 | 0.026 | 22 | 144 | 0.025 |
| 23 | 13 | 0.008 | 23 | 34 | 0.006 |
| 24 | 4 | 0.002 | 24 | 33 | 0.006 |
| 25 | 0 | 0.000 | 25 | 23 | 0.004 |
| 26 | 6 | 0.003 | 26 | 9 | 0.001 |
| 27 | 0 | 0.000 | 27 | 19 | 0.003 |
| 28 | 0 | 0.000 | 28 | 12 | 0.002 |
| 29 | 0 | 0.000 | 29 | 19 | 0.003 |
| 30 | 0 | 0.000 | 30 | 27 | 0.005 |
| 31 | 2 | 0.001 | 31 | 27 | 0.005 |
| 32 | 1 | 0.001 | 32 | 13 | 0.002 |
| 33 | 3 | 0.002 | 33 | 15 | 0.003 |
| 34 | 0 | 0.000 | 34 | 12 | 0.002 |
| 35 | 0 | 0.000 | 35 | 11 | 0.002 |
| 36 | 0 | 0.000 | 36 | 5 | 0.001 |
| 37 | 0 | 0.000 | 37 | 3 | 0.001 |
| 38 | 0 | 0.000 | 38 | 3 | 0.001 |
| 39 | 0 | 0.000 | 39 | 3 | 0.001 |
| 40 | 1 | 0.001 | 40 | 5 | 0.001 |
| 41 | 1 | 0.001 | 41 | 0 | 0.000 |
| 42 | 0 | 0.000 | 42 | 1 | 0.000 |
| 43 | 0 | 0.000 | 43 | 2 | 0.000 |
| 44 | 0 | 0.000 | 44 | 0 | 0.000 |
| 45 | 0 | 0.000 | 45 | 1 | 0.000 |
| 46 | 0 | 0.000 | 46 | 1 | 0.000 |
| 47 | 0 | 0.000 | 47 | 0 | 0.000 |
| 48 | 0 | 0.000 | 48 | 0 | 0.000 |
| 49 | 0 | 0.000 | 49 | 0 | 0.000 |
| 50 | 0 | 0.000 | 50 | 0 | 0.000 |

## EXPERIMENTAL *NEPHROPS* TRAWL DESIGN CLYDE TRIALSWHITING RESULTS

| NEW *NEPHROPS* TRAWL | | | NORMAL TRAWL | | |
|---|---|---|---|---|---|
| SAMPLE TOTAL: | | 1884 | SAMPLE TOTAL: | | 5100 |
| RAISED TOTAL: | | 8043 | RAISED TOTAL: | | 28654 |
| MLS (cm): | | 27 | MLS (cm): | | 27 |
| % UNDER MLS | | 100 | % UNDER MLS | | 100 |
| % RETAINED: | | 0 | % RETAINED: | | 0 |
| | ***WHITING*** | | | ***WHITING*** | |
| **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** | **CLASS (cm)** | **RAISED NUMBERS** | **FREQ. (%)** |
| 10 | 79 | 0.010 | 10 | 119 | 0.004 |
| 11 | 146 | 0.018 | 11 | 300 | 0.010 |
| 12 | 427 | 0.053 | 12 | 1366 | 0.048 |
| 13 | 794 | 0.099 | 13 | 2794 | 0.097 |
| 14 | 994 | 0.124 | 14 | 4247 | 0.148 |
| 15 | 1436 | 0.179 | 15 | 4366 | 0.152 |
| 16 | 1468 | 0.183 | 16 | 4435 | 0.155 |
| 17 | 1197 | 0.149 | 17 | 4264 | 0.149 |
| 18 | 729 | 0.091 | 18 | 2954 | 0.103 |
| 19 | 417 | 0.052 | 19 | 1822 | 0.064 |
| 20 | 184 | 0.023 | 20 | 922 | 0.032 |
| 21 | 112 | 0.014 | 21 | 461 | 0.016 |
| 22 | 14 | 0.002 | 22 | 277 | 0.010 |
| 23 | 11 | 0.001 | 23 | 85 | 0.003 |
| 24 | 13 | 0.002 | 24 | 119 | 0.004 |
| 25 | 22 | 0.003 | 25 | 66 | 0.002 |
| 26 | 0 | 0.000 | 26 | 20 | 0.001 |
| 27 | 0 | 0.000 | 27 | 14 | 0.000 |
| 28 | 0 | 0.000 | 28 | 4 | 0.000 |
| 29 | 0 | 0.000 | 29 | 6 | 0.000 |
| 30 | 0 | 0.000 | 30 | 7 | 0.000 |
| 31 | 0 | 0.000 | 31 | 2 | 0.000 |
| 32 | 0 | 0.000 | 32 | 1 | 0.000 |
| 33 | 0 | 0.000 | 33 | 2 | 0.000 |
| 34 | 0 | 0.000 | 34 | 1 | 0.000 |
| 35 | 0 | 0.000 | 35 | 2 | 0.000 |
| 36 | 0 | 0.000 | 36 | 1 | 0.000 |
| 37 | 0 | 0.000 | 37 | 0 | 0.000 |
| 38 | 0 | 0.000 | 38 | 0 | 0.000 |
| 39 | 0 | 0.000 | 39 | 0 | 0.000 |
| 40 | 0 | 0.000 | 40 | 0 | 0.000 |
| 41 | 0 | 0.000 | 41 | 0 | 0.000 |
| 42 | 0 | 0.000 | 42 | 0 | 0.000 |
| 43 | 0 | 0.000 | 43 | 0 | 0.000 |
| 44 | 0 | 0.000 | 44 | 0 | 0.000 |
| 45 | 0 | 0.000 | 45 | 0 | 0.000 |
| 46 | 0 | 0.000 | 46 | 0 | 0.000 |
| 47 | 0 | 0.000 | 47 | 0 | 0.000 |
| 48 | 0 | 0.000 | 48 | 0 | 0.000 |
| 49 | 0 | 0.000 | 49 | 0 | 0.000 |
| 50 | 0 | 0.000 | 50 | 0 | 0.000 |