Improving Selectivity in Towed Fishing Gears

Investigating the use of low diameter twine for the construction of square mesh panels

Seafish Report No. SR 539

December 2001

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Summary

This report describes work carried out with funding support from the Scottish Executive within the framework of the Industry Partnership Programme. It involved a fishing trial to compare the performance of a square mesh panel made from heavy, high density double knotted netting with that of one constructed from a low diameter, high tenacity knotless material. It resulted from the introduction of legislation making square mesh panels (SMPs) mandatory in a number of UK fisheries. In some circumstances panels can be constructed of double 5mm, high density PE knotted netting. Whilst conforming to the minimum requirements of the legislation, the selective properties of the square mesh panels in this configuration are questionable. The fishing trial was arranged with an established twin rig trawler to evaluate the performance of the two square mesh panel configurations in a typical mixed species, ground fish fishery with the emphasis on catching *Nephrops*.

The aims of this exercise were:

- To compare the catch compositions from trawls fitted with a low diameter, knotless netting SMP and a heavy, double knotted netting SMP respectively., both in the same mesh size.
- To try to reduce discards of haddock and whiting by the use of a low diameter, high tenacity knotless netting SMP
- To maintain the catches of the main target species (*Nephrops*).
- To evaluate the use of 'Dyneema' for SMP construction in *Nephrops* trawls.
- To assess the suitability of using 'heavy' double twine knotted netting for the construction of square mesh panels.

Catch data for haddock, whiting and cod were collected from a total of 18 valid paired hauls. The square mesh panel configurations were changed between nets to give 9 hauls with each configuration on each side of the twin trawl arrangement.

All the aims of the trial were achieved with the exercise demonstrating that there is scope for improving the effectiveness of square mesh panels within the current regulations. The combination of low diameter twines and knotless netting construction produced significant reductions in the numbers of haddock and whiting bycatches during these trials when compared to the much heavier, double twine knotted material. This was achieved without affecting the catches of other target species, namely *Nephrops*, cod and flatfish.

Whilst demonstrating the benefits of the low diameter material, this exercise also highlighted the drawbacks associated with using double, knotted netting, (particularly in heavy twine diameters), for the construction of square mesh panels. The inherent stiffness of the heavy twine combined with the netting's tendency to revert to its diamond configuration posed problems during construction and throughout the trials. The resultant knot slippage, individual mesh and overall panel distortion clearly affected panel performance.

1 Introduction

Seafish has been involved in an Industry Partnership Programme, funded by the Scottish Executive, with the aim of encouraging direct industry collaboration with research and development organisations. The main thrust of the work is to improve the selectivity of UK fisheries through the more effective use of technical conservation measures. This approach of industry involvement in the direction of R&D within the catching sector is a welcome one. It 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 work involves both the development of new ideas and an ongoing effort to improve the effectiveness of existing measures.

The project described in this report was carried out with funding support from the Scottish Executive within the framework of this Industry Partnership Programme.

This initiative gave Seafish the opportunity to further its ongoing programme of work investigating ways of improving the selectivity of towed demersal fishing gears. Recent efforts have concentrated on improving the performance of square mesh panels in a range of gear types and fisheries.

Square mesh panels have been a mandatory requirement in UK *Nephrops* fisheries since the early 1990's. Recent changes to UK fisheries legislation (August 2000 and April 2001)* introduced regulations governing the requirement to fit square mesh panels to all demersal towed gears except beam trawls.

This latest legislation applying to white fish nets allows the use of netting of the same specification as the codend to be used for the construction of the square mesh panel. In certain circumstances this can result in panels being constructed of double 5mm, high density PE knotted netting. Whilst conforming to the minimum requirements of the legislation, the selective properties of the square mesh panels in this configuration are questionable.

Twine thickness and related stiffness greatly influence the selectivity of netting by restricting mesh opening. This report describes a fishing trial to compare the performance of a square mesh panel made from heavy, high density double knotted netting with that of one constructed from a low diameter, high tenacity knotless material. The aim being to demonstrate any differences between the two extremes of specification allowed within the current legislation.

A fishing trial was arranged with an established twin rig trawler to evaluate the performance of the two square mesh panel configurations in a typical mixed species, ground fish fishery with the emphasis on catching *Nephrops*.

The criterion for measuring performance was the quantity of juvenile/undersize round fish bycatch species, such as haddock and whiting, retained by the nets fitted with the two panel variations.

The exercise was conducted as an evaluation following normal commercial operating practices.

(Square-Mesh Panel Council Reg. (EC) No 850/98. The Sea Fish (Specified Sea Areas) (Regulation of Nets and Other Fishing Gear) (Scotland) Order 2000 No.227) and The Sea Fish (Specified Sea Areas) (Regulation of Nets and Other Fishing Gear) Order 2001 No.649).

2 Background

The current UK regulations governing the use of square mesh panels in white fish trawls are basically the same as those for the *Nephrops* fisheries. The only significant differences are those relating to position within the net and twine diameter of the codend, extension and square mesh panel. The latter are restricted to single twine netting not exceeding 4mm.

Within the industry, there are a significant number of vessels targeting *Nephrops* using white fish gear, i.e. using minimum mesh sizes of 100mm. This releases them from the tighter restrictions on twine diameters for codends, extensions and subsequently square mesh panels.

It is accepted that an increase in twine thickness and its related stiffness adversely affects net selectivity. To a certain extent, this knowledge has been used by some fishermen to negate the conservation benefits of increases in minimum mesh sizes.

It is in these situations that there would appear to be scope for improving the performance of square mesh panels, particularly with regard to the materials used in their construction.

The panel's primary function in *Nephrops* trawls is that of species selection, i.e. to release round fish bycatch species such as haddock, whiting and pout without affecting the target catch. The aim is to reduce discarding of juvenile finfish.

Vessels targeting *Nephrops* with white fish mesh sizes, (without the use of codend lifting covers), do not have any white fish bycatch restrictions. They therefore aim to maximise catches of finfish and *Nephrops*. In these circumstances, the role of the square mesh panel becomes one of size selection rather than species selection i.e. the panel is expected to release only those fish below the minimum landing size (MLS).

For the gear technologist the problem lies in finding the right configuration, that will reduce the level of discarding without losing too many fish of marketable size.

During the capture process, fish passing down the extension of the trawl are presented with an escape opportunity as they are forced past the square mesh panel. Their opportunity to escape is influenced by the time they spend in the region of the panel and competition for available escape gaps, i.e. open square meshes. This is dictated to a certain degree by the speed at which they are pushed back down the net as a result of the towing speed and the catch rates that are encountered. In general terms the panel will provide more opportunity for escape at lower towing speeds and lower catch rates. Similarly, for a given towing speed, the opportunity for escape should increase with an increase in panel area.

When targeting *Nephrops*, towing speed is generally 25-30% slower than that for white fish and catches of the predominant round fish species would be expected to be lower than for targeted white fish fisheries. Options for improving panel performance are therefore limited to optimising panel position and increasing the escape area of the panel. The work in this report aims to address the latter.

The minimum square mesh panel area, (length and width) is regulated by legislation. Similarly, the minimum mesh size of the panel is defined. The only other factor influencing the potential escape area of the panel is the specification of the netting used for its construction. The main considerations here are twine diameter/stiffness and whether the netting is of knotted or knotless construction.

For a given area of square mesh panel, the aim is to maximise the potential escape area for the main bycatch species of haddock, whiting and pout.

3 Aims and Objectives

The overall objective of the programme within which these trials took place is to reduce discarding by improving the selectivity of demersal towed fishing gears. The principal mechanisms for achieving this are improvement of existing technical conservation measures (TCMs) and the development of new ones. Here the aim is to improve the effectiveness of an established TCM within the scope of the current fisheries regulations.

The aims of this exercise were:

- To compare the catch composition from a trawl fitted with a square mesh panel constructed from low diameter, knotless netting, with that from a net fitted with a panel made from heavy, double knotted netting, both in the same mesh size.
- To determine if discard reductions could be achieved for haddock and whiting by the use of low diameter, high tenacity knotless netting for the construction of square mesh panels.
- To determine if any reductions in round fish bycatch could be achieved without adversely affecting the catches of the target species (*Nephrops*).
- To determine if the Dyneema panel material is a practical option for panel construction in *Nephrops* trawls.
- To assess the suitability of using 'heavy' double twine knotted netting for the construction of square mesh panels.

Twelve days of sea trials were carried out during October 2001. The exercise was split into two 6-day periods with the aim of achieving 5 fishing days from each. They were conducted on the basis of normal commercial fishing practices using an established three warp, twin trawl arrangement. For much of this time the weather conditions were very poor.

4 Materials and Methods

4.1 Approach

This work was conducted under the Industry Partnership Programme and initiated in response to concerns raised by fishermen about the effectiveness of square mesh panels in certain applications. Such feedback is essential if partnerships between industry and the scientific community are to work effectively at producing technical solutions to industry problems. The fishermens'acceptance of the problem is the first step towards finding a solution. Working with fishermen that have a genuine interest in resolving a problem greatly improves the chances of success.

Square mesh panel technology has been demonstrated to be an effective means of improving selectivity. However, the benefits of this TCM are in danger of being eroded as a result of the use of inappropriate materials and practices.

There has been much feedback from fishermen questioning the effectiveness of this technology in certain fisheries. Anecdotal evidence suggests that many of the problems stem from the unsuitability of the materials used in the construction of the panels.

Mesh size for mesh size, 'heavy' double braided netting has long been known to have less selective properties than thinner single twine netting. However, fishermen have made arguments for the use of these materials for codend construction on the grounds of strength and durability. As a result, this type of material continues to be used and is currently allowed for the construction of square mesh panels in white fish trawls.

Since the introduction of square mesh panel legislation, the industry has struggled to access suitable materials for the construction of square mesh panels that are both effective and satisfy the regulations.

Suitable knotless netting has been developed but it has not been readily available in the UK. This has lead to net manufacturers and fishermen using standard netting materials, which are far from ideal for square mesh applications.

The effectiveness of any TCM introduced to promote more selective fishing practices can be enhanced by using the best materials available. The development of modern 'high performance' polyethylene (HPPE) fibres such as Dyneema* now provides other netting alternatives with the potential for improvements in mesh selectivity.

This trial was initiated to investigate the suitability and effectiveness of a HPPE netting material for the construction of square mesh panels. It aimed to demonstrate that there is still scope for improvement using square mesh technology.

The approach taken was to compare panel constructions that were considered as the worst and best case scenarios as dictated by legislation and/or practicality, i.e. comparison of a heavy, stiff double braided knotted material with a light, low diameter knotless single braided one.

A third, intermediate option was included in the programme for testing, if sufficient time allowed. This was a panel constructed from single braided knotted PE twine.

The trials were conducted as a twin trawl catch comparison exercise following normal commercial operating practices. The vessel selected for the work is an established twin rig trawler having been involved in twin rig trawling for *Nephrops* for a considerable number of years and operated by a very experienced skipper and crew.

The exercise was designed to limit interference with normal haul by haul procedures whilst at the same time trying to maintain an acceptable degree of scientific rigour with regard to the collection of catch data.

All codends and extensions, including the square mesh panels, were provided by Seafish to ensure comparability for these sections of the gear. The trawls used for the trials were the vessel's own and accepted as being as near identical as could be established. Gear geometry was monitored throughout the trials using the vessel's own acoustic monitoring system which provided information on door spread, headline height etc. Data provided by the skipper indicated that there was a slight bias towards the gear on one side of the twin rig arrangement. This was accounted for by swapping the nets over from one side to the other at the halfway stage of the trials.

The trials were split into two consecutive 6-day trips with the intention of conducting 5 full days of fishing in each trip

Two Seafish representatives were present for the duration of the trials to carry out the catch sampling procedures and general observations.

Dyneema is a trademark of DSM High Performance Fibers.

4.2 Vessel details

The Buckie registered, twin rig trawler *Heather Sprig* (BCK 181) was selected for this work (Figure 1). The vessels main port of operation is Peterhead.

The vessel concentrates its operations in the northern North Sea targeting ground fish species including *Nephrops*, cod, haddock, whiting, saithe and flatfish. The average trip length is 6 to 8days.

The vessel operates as a twin rig trawler using the three-warp system.

Figure 1: MFV *Heather Sprig*

Vessel details:

Registered Length	18.6m
Breadth	6.86m
Depth:	2.81m
Tonnage:	49.96t
Main Engine:	Deutz developing 413kw

4.3 Gear details

The two nets used in the twin trawl set-up were as near identical as is practically possible to arrange. They were those normally used by the skipper when targeting *Nephrops* and groundfish. The nets were of fairly typical 'scraper' trawl design by *Pisces Nets* of Peterhead. Ground gears consisted of 200mm (8-inch) rubber discs in the centre section of the footrope and 150mm (6-inch) discs in the wing sections.

The basic dimensions of the trawls are shown in Figure 2.

The nets were rigged to 2.1m (7 feet) Skagen double cambered 'V' doors by a combination of 3.7m (2-fathom) bridles and 128m (70-fathom) single sweeps. The sweep line was made up of 2 x 55m (30-fathom) combination wire lengths plus 1 x 18m (10-fathom) length of rubber covered wire.

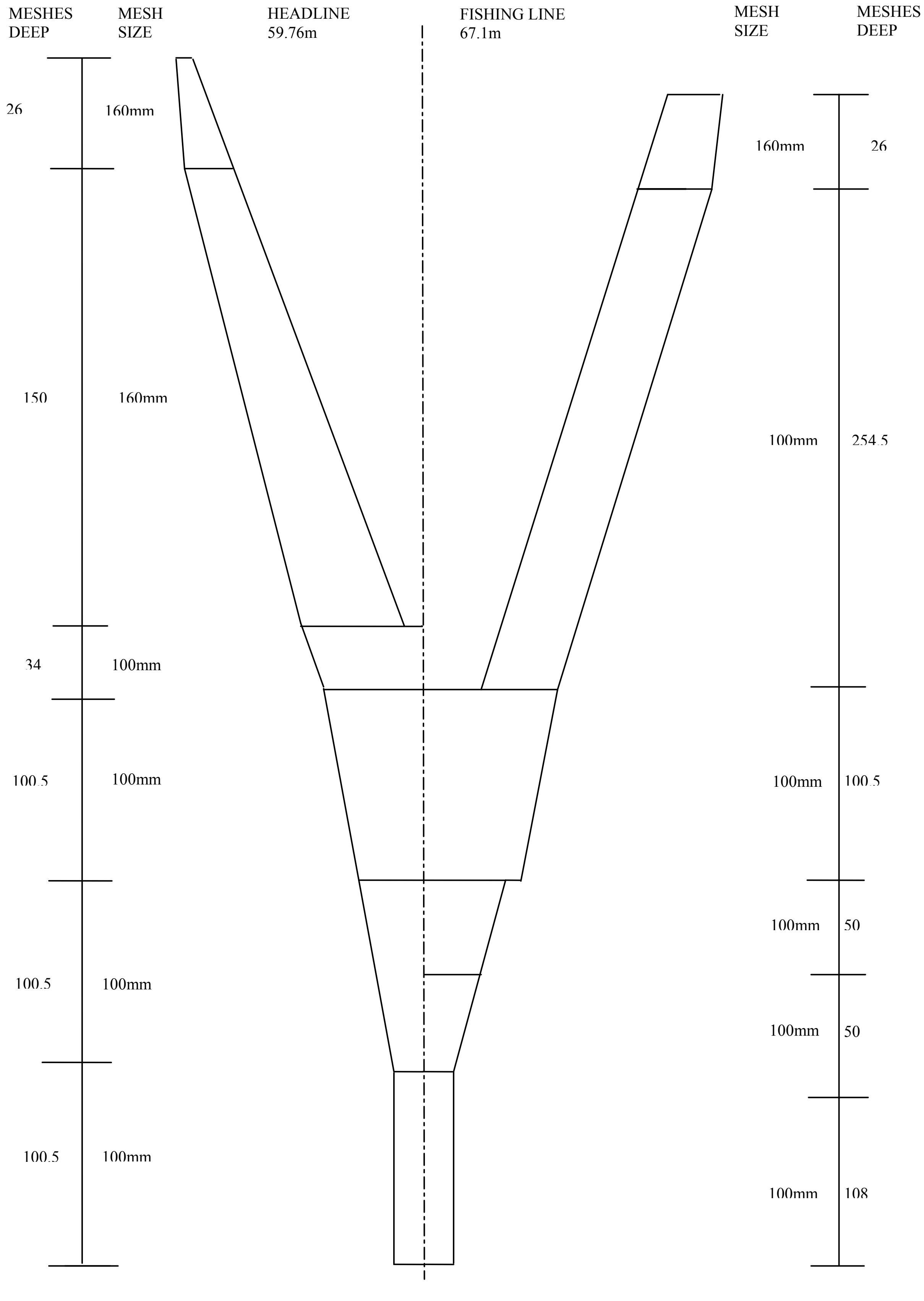

Figure 2: Schematic drawing of trawls used during the trials

Seafish supplied the codends and extensions for both nets to the skipper's specification. The codends were constructed in nominal 100mm mesh in double 5mm braided PE twine. The extension sections were constructed of nominal 100mm mesh in single 5mm-braided PE. The mesh size of the square mesh panels was nominally 90mm. Actual average measurements by wedge gauge were 102mm for the codend netting 103mm for the extension netting, 92mm for the Dyneema panel, 94mm for the ‘heavy’ double mesh panel and 92mm for the single 5mm braid knotted panel (not tested). Panel positions conformed to current square mesh regulations for nets incorporating 100mm mesh, i.e. positioned 9m from the codline. All panels were similar lengths at just over 3m.

Details of the square mesh panels options under consideration are shown in Figure 3.

Control:
1 x ~3m panel
5mm heavy,
double braided
knotted netting
construction

Option 1:
1 x ~3m panel
2.5mm braided
Dyneema, Ultracross
knotless netting
construction

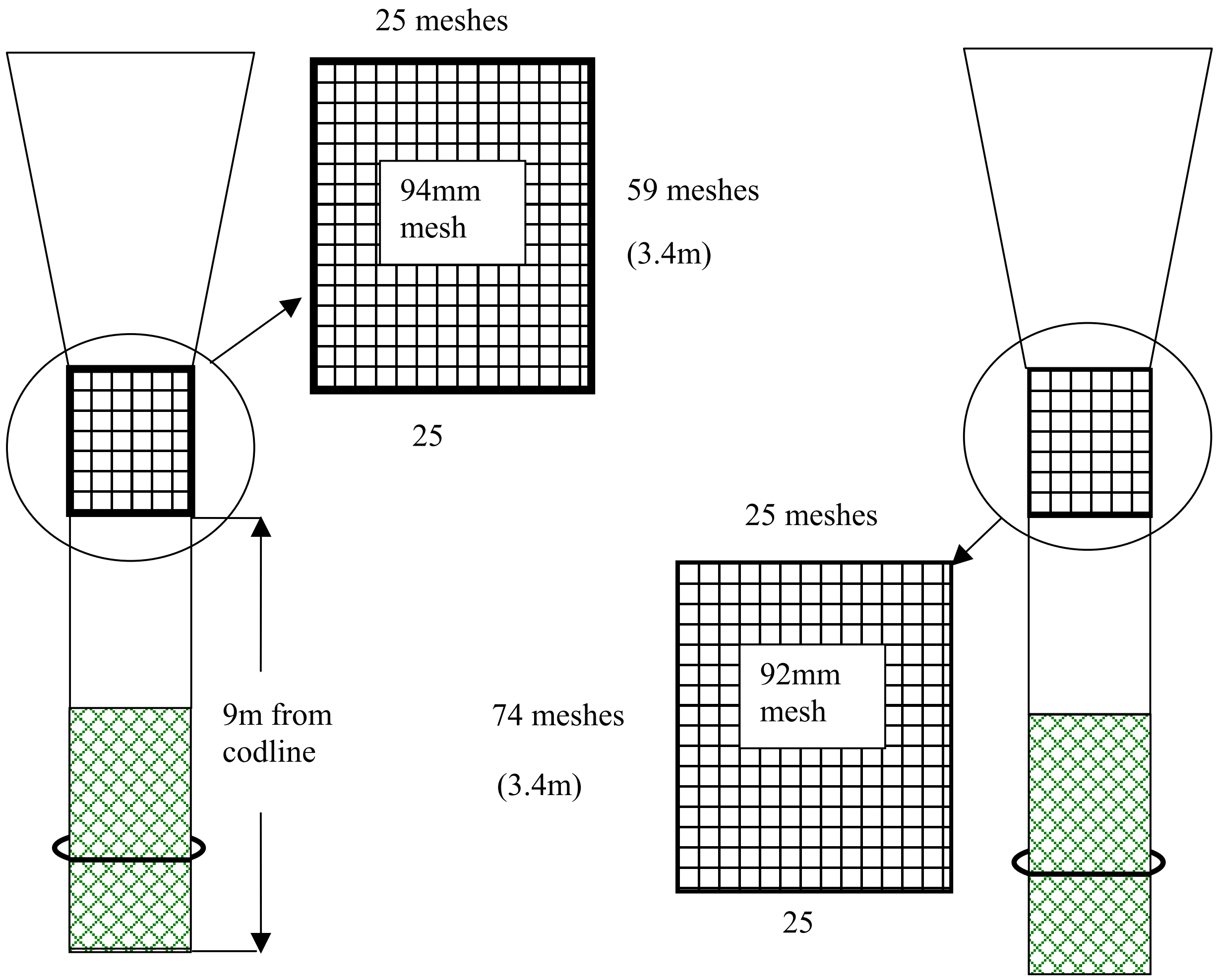

Figure 3: Details of square mesh panel arrangements used during trials.

Current legislation stipulates that square mesh panels '*shall be constructed of knotless netting or of netting constructed with non-slip knots'*. The knotted netting panels were constructed from braided PE, which had been heat set to help stabilise the knots to resist knot slippage. The Dyneema material was in the form of Ultracross™ knotless netting. This construction is used to ensure that there is no knot slippage which can result in mesh distortion.

Square mesh panels are constructed from normally produced diamond mesh netting 'turned on the square' i.e. the run of the netting is turned through 90º. In this configuration, the netting has a tendency to try and return to its original diamond shape. This results in distortion of the overall panel shape. This tendency is more pronounced when using heavier and stiffer twine. When using knotted netting, particularly in double twine, the combination of twine stiffness, knot construction and the tendency to revert to the diamond shape, all combine to distort the shape of the meshes in the panel. This distortion reduces the potential escape area of the individual meshes reducing the effectiveness of the panel. This mesh distortion and the resultant effect on the panel shape are shown in Figures 15 and 16.

4.3.1 Dyneema

Dyneema is the trademark of DSM High Performance Fibers of the Netherlands. It is claimed to be the strongest fibre in the world. It is classed as a high performance polyethylene fibre (HPPE).

The density of Dyneema is less than one; in other words it will float in water. The tenacity of Dyneema twines can be up to 15 times that of good quality steel. Elongation at break point is as low for Dyneema fibres as for other high performance fibres, but due to a very high tenacity, the energy required to break the fibres is high.

The combination of low density and high strength makes Dyneema attractive as a material for the construction of netting and ropes.

The material is resistant to water, most chemicals, UV light and micro-organisms. The high molecular weight PE used to produce the Dyneema fibre is also well known as an engineering plastic used for its superior wear and abrasion resistance.

All of these characteristics have enabled a twine material to be produced with high strength at low diameter and weight, which in combination with the Ultracross netting construction, provides further options for improving square mesh panel selectivity.

4.4 Trials Procedures

The trials were run over a period of 12 days during October 2001. The exercise was split into two 6-day periods with the aim of achieving 5 fishing days from each. They were conducted on the basis of normal commercial fishing practices using an established three warp, twin trawl arrangement.

The skipper dictated the area of operation, following the normal pattern for the time of year but with the brief to target *Nephrops* grounds with an abundance of round fish bycatch species such as haddock and whiting. In this case, fishing took place in the northern North Sea (ICES IVa).

The trial vessel carried two Seafish representatives to make observations and record all relevant catch data.

The vessel sailed from Peterhead and commenced fishing in the area that the vessel had been operating in during its previous trip. The species mix encountered satisfied the requirements of the trial. The trials were hampered by adverse weather conditions and coupled with a gradual tailing off of catches, the vessel steamed to finish off the first half of the trip in a different area.

At the end of the first half of the trials, the codends, extensions and square mesh panels were swapped between nets to limit the affect of any bias between nets or sides in the twin rig arrangement.

The second half of the trial continued to be hampered by very poor weather. Catches were inconsistent, resulting in the vessel moving between grounds in search of the right species mix. A total of 18 valid hauls were completed. Towing times averaged 5 hours and fishing took place throughout the 24-hour period.

4.4.1 Catch Sampling

Gear handling arrangements on the *Heather Sprig* allow for one codend at a time to be hauled onboard, (standard practice). This results in the second codend remaining in the water at the stern of the vessel whilst the first codend is being emptied. In this situation, there are concerns that catch is washed out from the codend by wave and vessel motion, particularly in poor weather. Every precaution was taken to limit this effect. Hauling time was reduced to the minimum whilst maintaining constant tension on the codend remaining in the water.

The catches from the two nets were kept separate by the use of a split fish hopper. All discarded fish and assorted debris from each codend were quantified, sampled, measured and recorded. Similarly, the retained catch was quantified; this included finfish and *Nephrops*. The marketable finfish were sampled by grade, measuring all the retained cod, haddock and whiting when quantities were small, or by measuring representative samples when large quantities were being caught.

The discarded elements of the catches were quantified by baskets, they being the remainder of the catch on the sorting conveyor, after the sorting operation. Representative samples of the discards were collected throughout the sorting operation, (beginning, middle and end) for measurement. Fish length data were recorded from the samples and raised to represent the total catches for each codend on each haul.

Sampling problems were experienced as a result of very bad weather. This necessitated processing all the catches from both codends from one haul before shooting the gear for the next tow. This added approximately 1.5 hours on to each tow but was necessary to keep the sampling accurate and consistent.

Haul by haul observations were made on the general handling and performance of the square mesh panel arrangements.

5 Results

The main indicator species used to assess the performance of square mesh panels in exercises of this nature are haddock and whiting. This is based on their generally positive escape responses to devices of this type. Additionally, these species normally make up the bulk of the round fish bycatch in *Nephrops* fisheries. It is the level of discarding of these species that these technical measures aim to address.

Although the numbers of haddock encountered during the trials were sufficient to enable a reasonable assessment of performance, whiting numbers were much lower (by a factor of 8), producing a less reliable indication.

Data for cod were also collected. This species is of limited value in assessing panel performance, however cod catches do help to give an indication of general net performance and therefore some data have been included.

Throughout the exercise, the affects of the panels on the target catch of *Nephrops* were monitored. No losses of *Nephrops* were attributable to either of the panel configurations under test. For the cod end with the Dyneema panel, approximately 230 kg (36 stones) of whole *Nephrops* were caught and for the double panel 216kg (34 stones).

From the outset, the trials were hampered by very poor weather conditions and relatively poor catch rates. Despite these drawbacks, the overall results do however give a good indication of the relative performance of the panel materials under test.

Catch data for haddock, whiting and cod were collected from a total of 18 valid paired hauls. The square mesh panel configurations were changed between nets to give 9 hauls with each configuration on each side of the twin trawl arrangement.

5.1 Haddock

The size of haddocks retained during these trials ranged from 12 to 47cm, the predominance of fish being between 20 and 33cm with the peak size range at 27-28cm i.e. below the minimum landing size (MLS) of 30cm. This meant that most of the haddocks caught (~75%) were discards (Table 1, Appendix 1). In practical commercial terms, this figure would be greater than 90% when taking into account the actual minimum size to which the crew save fish to ensure that no sub-legal fish are landed. In reality, the 'minimum landing size' is probably closer to 33cm.

The performance of the two panel configurations can be compared by examining the Length/Numbers plot for the total catch over the whole trial (Figure 4). It can be seen that both nets in the twin rig retained the same size range of fish. The noticeable difference however, is the far greater quantity of fish retained by the net fitted with the double twine panel, more than twice the number. This indicates that, for the given mesh size under consideration, the low diameter panel worked more effectively for the size range of haddocks encountered. The proportions of the total catches that were below MLS for each panel type were similar at 75% for the Dyneema panel and 72% for the double twine panel.

When considering fish sizes above MLS, the difference in numbers retained indicated a loss of marketable catch from the net fitted with the Dyneema panel. This is not too much of a concern when targeting *Nephrops*, but could be seen as a problem in a white fish net.

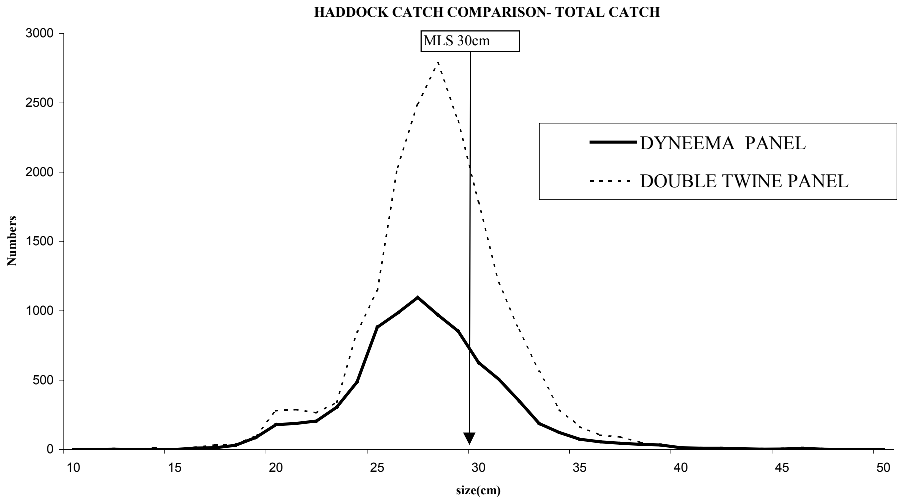

Figure 4: Length/Numbers plot for the total catch of haddock

When the catch data for haddock are separated into the two halves of the trial, the Length/Numbers plots (Figures 5 and 6) show very similar catch results indicating similar populations of fish being sampled, Tables 2 and 3, Appendix 1 give details.

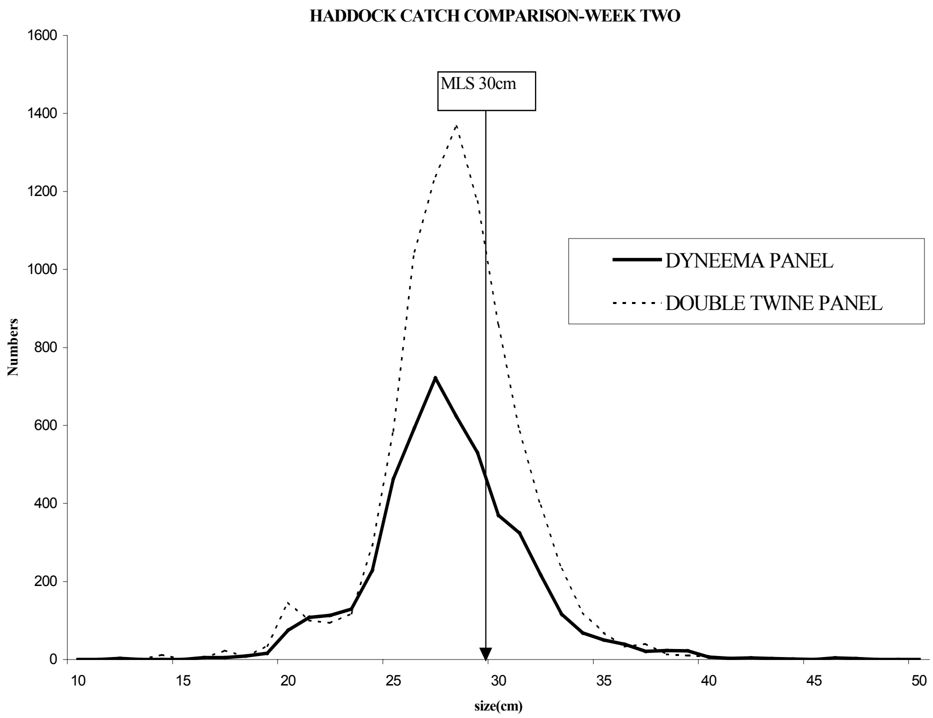

Figure 5: Length/Numbers plot for week one haddock catch

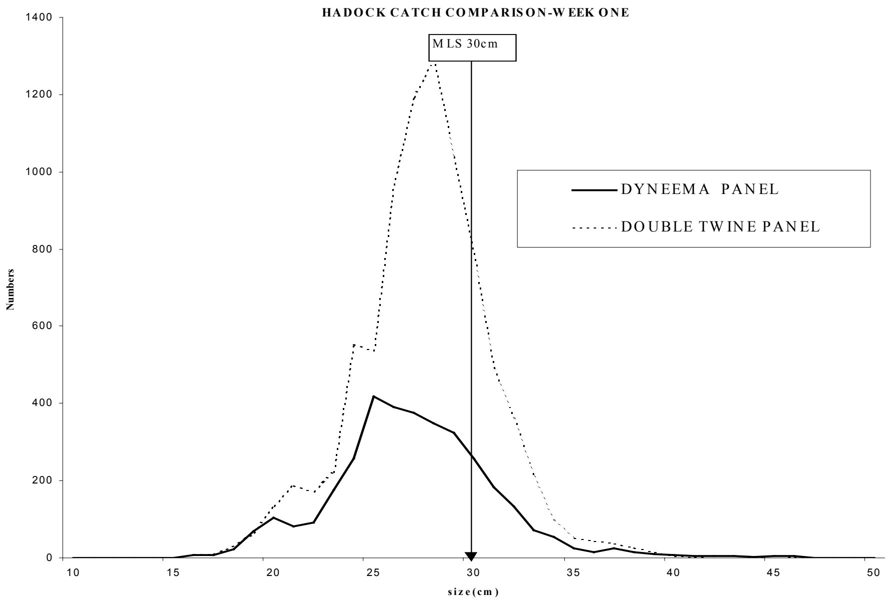

Figure 6: Length/Numbers plot for week two haddock catch

Similar results were achieved with the two panel variants when fitted in either net of the twin rig set up. This indicated that any bias in catching performance that may have been present in the twin rig arrangement had little or no influence on the panel performance. Figures 7 and 8 show how the haddock catches compared for the double twine and Dyneema panels when switched between sides in the twin trawl arrangement.

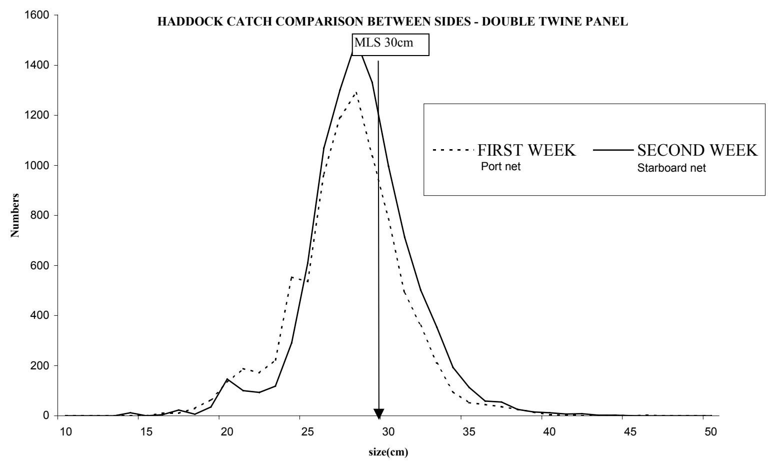

Figure 7: Between sides catch comparison for haddock – double twine panel

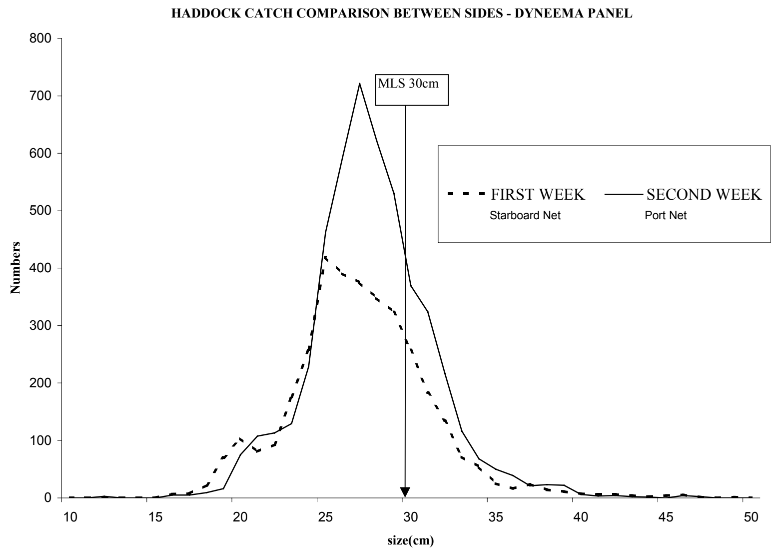

Figure 8: Between sides catch comparison for haddock – Dyneema panel

The number of fish retained by the net fitted with the Dyneema panel was 54% less than that retained by the net with the double panel. There was a 52% reduction in the numbers of haddocks below MLS in favour of the Dyneema panel.

Observations showed that very few fish became enmeshed in the double twine panel. Of the limited number of 'stickers' in the Dyneema panel, the majority was in the size range 32-34cm.

5.2 Whiting

Whiting are normally a very good indicator species for judging the performance of square mesh panels. They generally show very positive escape reactions when encountering this type of device. Unfortunately, the numbers of whiting caught during this exercise were very low and as a consequence their contribution to the results was limited.

The size of fish caught ranged from 21 to 40cm, with one or two individuals reaching up to 48cm. The majority of fish were in the range 26 to 35cm. The peak length was 31cm. Catch data for this species are shown in Table 4, Appendix 1. The catches were spread thinly between hauls and of the total catch the percentage of fish below MLS was 16% and 13% for the net with the Dyneema panel and the double twine panels respectively.

Figure 9 shows the Length/Numbers plot for the total catch of whiting. Because of the relatively low numbers caught, the results for whiting are less significant. They do however, follow a similar trend to that observed for haddock. The catch from the net with the Dyneema panel produced 29% less whiting, by number, than the net with the double twine panel. The numbers of fish below MLS were 16% less from the Dyneema net.

The net with the double twine panel retained more larger whiting (30cm+), this suggested that the Dyneema panel was releasing fish significantly greater than the MLS. This is not unexpected given that the indications from the haddock results were that fish in excess of 30cm were able to escape from the low diameter mesh panel. This can be explained by the differences in morphology between these two species. It is difficult to determine the maximum size of fish that would be able to pass through this mesh configuration as a result of the small numbers of fish, which these indications are based on. As for haddock, the loss of marketable whiting is of lesser concern when considered as a bycatch in a targeted *Nephrops* fishery compared to a directed finfish fishery. The whiting catch split between weeks one and two is shown in Figures 10 and 11 with further details contained in Tables 5 and 6 in Appendix 1.

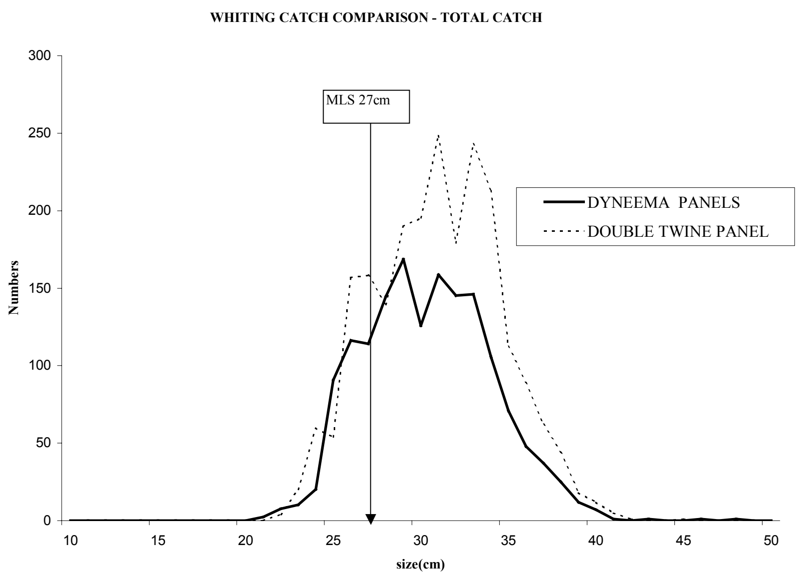

Figure 9: Length/Numbers plot for the total catch of whiting

Examination of the week by week catches (figures 10 and 11) shows similar results to those for haddock indicating similar populations of fish sampled for both trips. Similarly, there was no indication of bias influencing the performance of the panels.

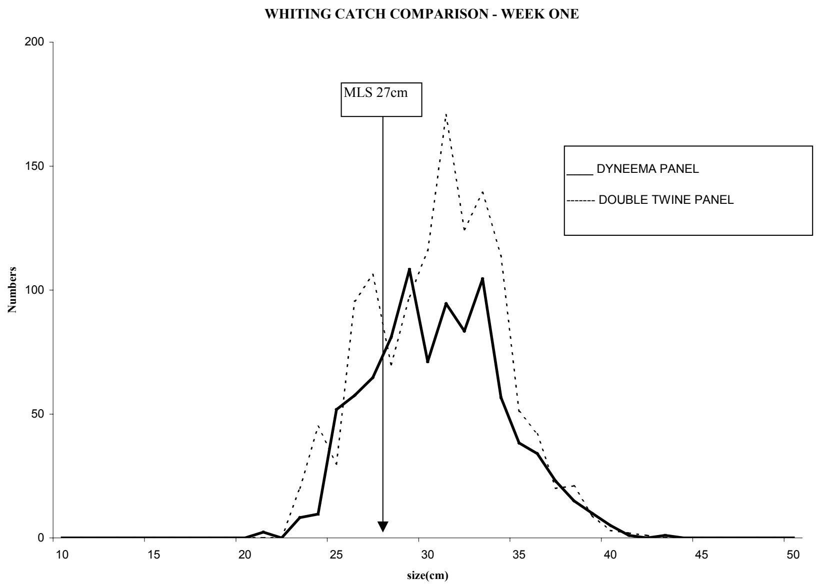

Figure 10: Length/Numbers plot for week one whiting catch

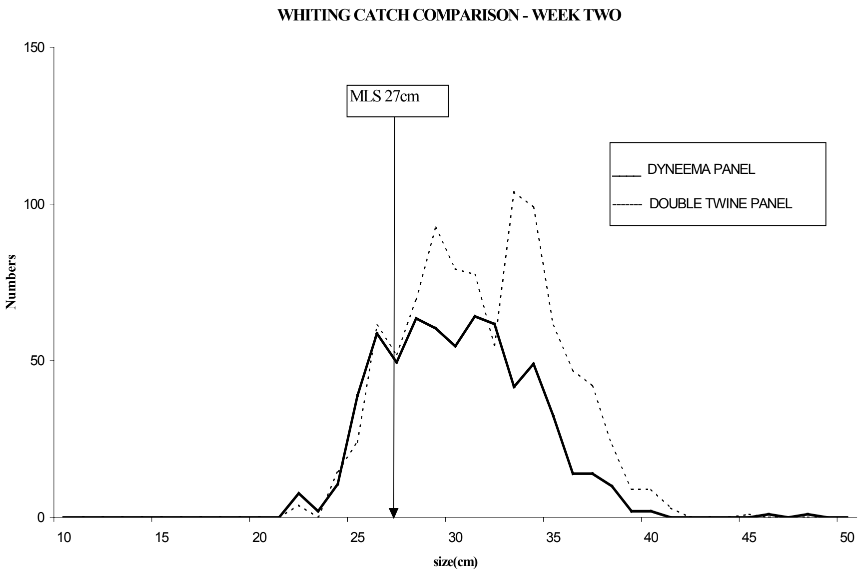

Figure 11: Length/Numbers plot for week two whiting catch

5.3 Cod

Cod are known to show little or no response to square mesh panels sited in the upper panels of trawls in the positions under test in this trial. Cod data were included in this experiment as an indicator of the general catching performance and comparability of the two nets in the twin trawl configuration. The catch data shown in Table 7, (Appendix 1) and in Figure 12 show very similar results for the two test panels despite very low numbers of fish being caught.

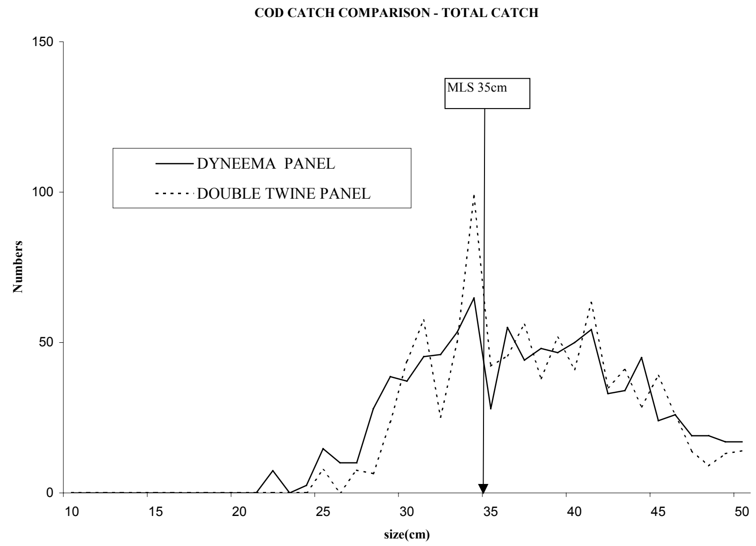

Figure 12: Length/Numbers plot for the total catch of cod

The Length/Numbers plots for the two separate weeks, (Figures 13 and 14) representing the change over of panels between nets, supports the results for the other species indicating no influence of side or net bias on the results.

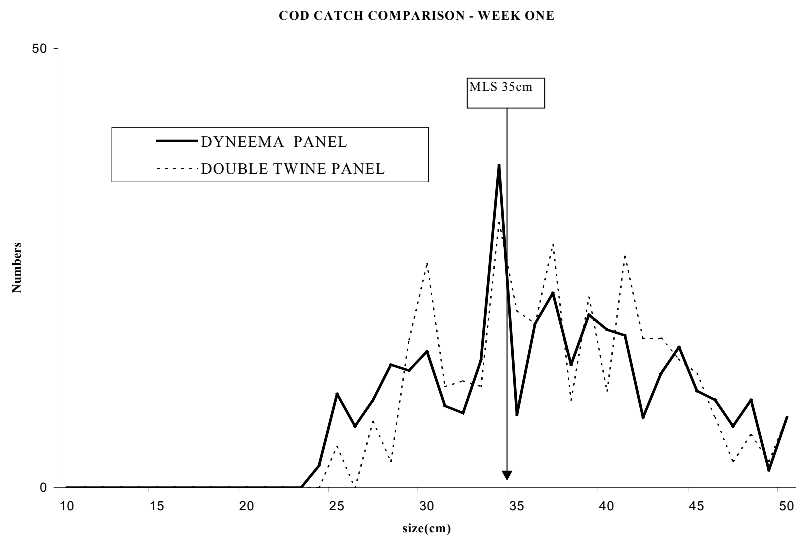

Figure 13: Length/Numbers plot for week one catch of cod

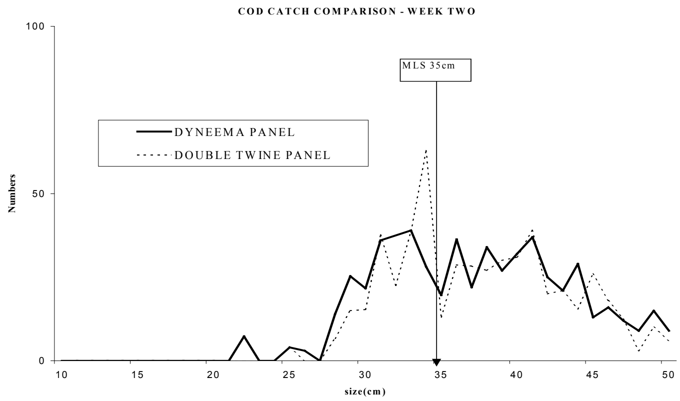

Figure 14: Length/Numbers plot for week two catch of cod

5.4 General Observations

Both the double twine and the Dyneema panels under test were put together by Seafish Gear Technologists. This enabled an appraisal of the suitability of the respective materials from the point of view of construction and rigging.

Both panel materials were supplied in standard, diamond mesh configuration and subsequently cut out 'on the square' to form the panels. This process immediately highlighted one of the drawbacks of the double twine material as a consequence of the combination of knotted construction and inherent stiffness associated with thick, high-density PE twines. The double twine material had a strong tendency to return to its original diamond mesh shape, (Figure 15). This made the rigging operation more difficult. It also resulted in the completed panel section being out of shape, with the individual meshes showing signs of distortion and inconsistent mesh opening, (Figure 16).

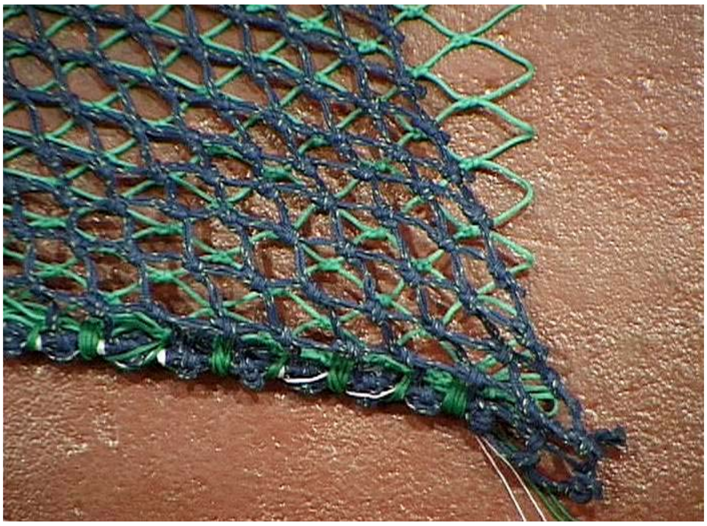

Figure 15: Double twine panel showing signs of mesh

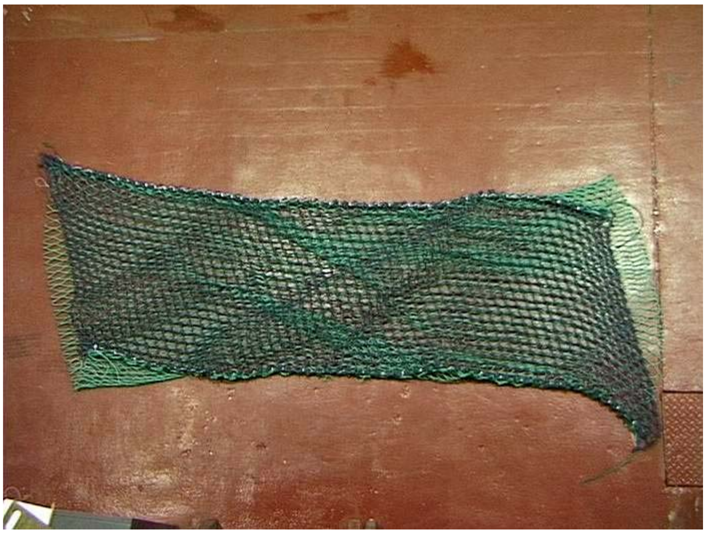

Figure 16: Double twine panel showing signs of overall panel distortion

The problem of mesh distortion with the double twine material was even more evident when the panel was examined at the end of the fishing trials. As can be seen from figure 17, the individual mesh openings have been reduced. This is as a result of the mesh bars that run in the lateral direction across the panel width, twisting and shortening. The resultant mesh shape is more rectangular than square. There was also evidence of knot slippage and irregular mesh shapes across the whole panel area. Attempts to correct these changes by applying force to the netting were ineffective. It is not unreasonable to expect that this distortion would progress with time and use.

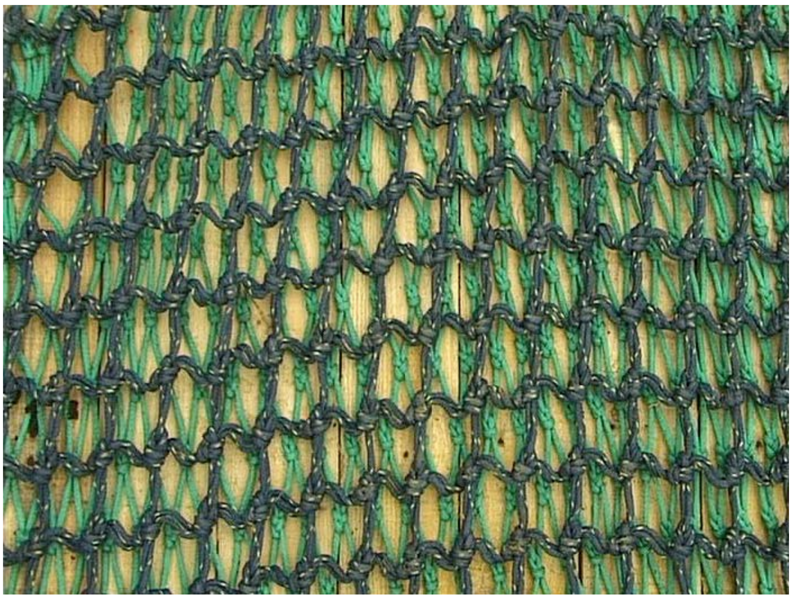

Figure 17: Double twine panel showing mesh distortion at the end of the trial period

In contrast, the Dyneema netting panel showed little or no tendency to distort at all stages of construction or rigging. Regular, consistent mesh shape was maintained throughout the trials. Post trial examination showed the Dyneema panel to be in the same condition as it was at the start. The 'before and after' situations for the Dyneema panel are shown in Figures 18, 19 and 20. The panel remained flexible and more manageable compared to the double twine material from construction through to the end of the trials.

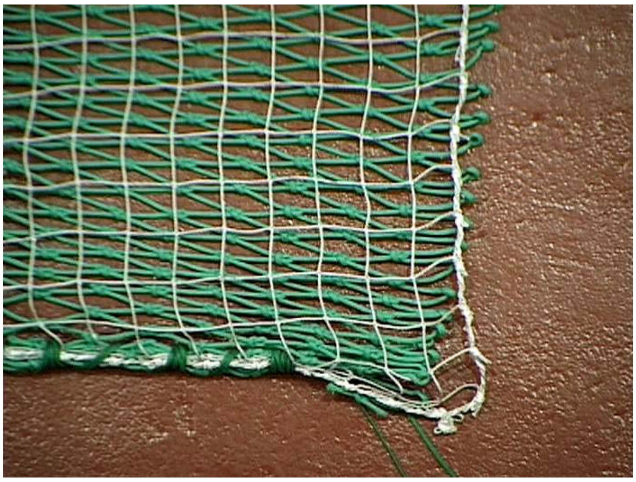

Figure 18: Dyneema panel showing consistent regular square meshes

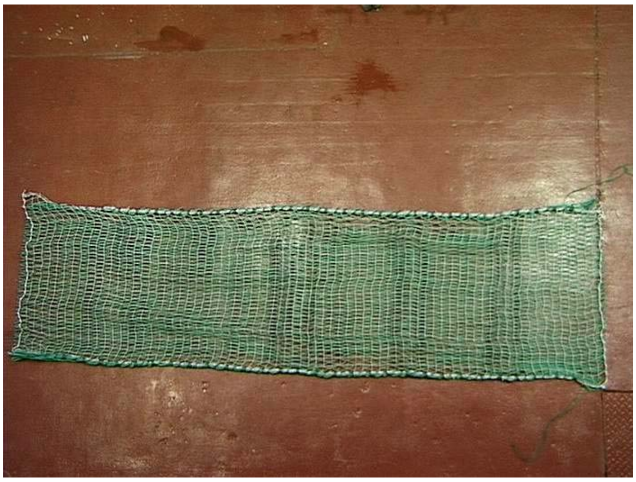

Figure 19: Dyneema panel showing overall panel shape with no distortion

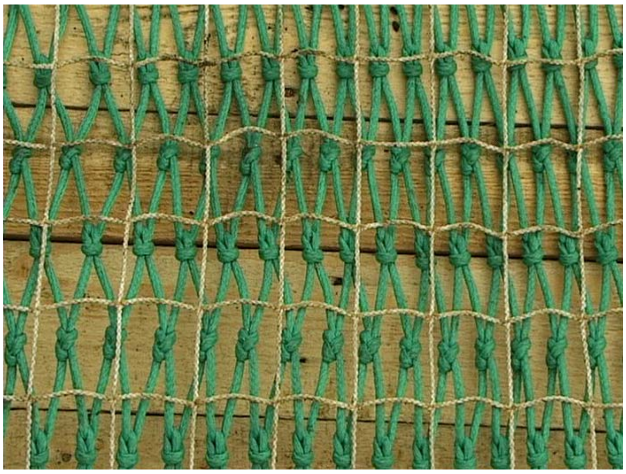

Figure 20: Dyneema panel showing consistent square meshes at end of trial

6 Discussion and Findings

All the aims of the trial were achieved. This exercise demonstrated that there is still scope for improving the effectiveness of square mesh panels within the scope of the current regulations.

Selecting the most suitable materials for the construction of bycatch reduction devices clearly has benefits. The combination of low diameter twines and knotless netting construction produced significant reductions in the numbers of haddock and whiting bycatches during these trials when compared to the much heavier, double twine knotted material. This was achieved without affecting the catches of other target species, namely *Nephrops*, cod and flatfish.

Species	Panel configuration	Sample Nos.	Raised Nos.	Reduction in numbers	Reduction in numbers <MLS
Haddock	***Dyneema panel***	4401	8396	***54%***	***52%***
	Double twine panel	6343	18225		
Whiting	***Dyneema panel***	1012	1560	***29%***	***16%***
	Double twine panel	1258	2205		

Whilst demonstrating the benefits of the low diameter HPPE material, this exercise also highlighted the drawbacks associated with using double, knotted netting, (particularly in heavy twine diameters), for the construction of square mesh panels. The inherent stiffness of the heavy twine combined with the netting's tendency to revert to its diamond configuration posed problems during construction and throughout the trials. The resultant knot slippage, individual mesh and overall panel distortion clearly affected panel performance.

The superior properties of Dyneema compared to standard PE come at a price. Currently (November 2001) the cost of Dyneema twine is approximately six times that of standard PE. Additionally, in the form of Ultracross knotless netting, the cost of Dyneema increases to approximately 18 times that of standard, knotted PE netting.

On the face of it, this is prohibitively expensive. This high cost is offset to a certain degree by taking into account the savings in weight, (netting is sold by weight), that are possible as a result of the significantly reduced diameters. Dyneema Ultracross netting has high tenacity, extremely high durability, excellent mesh stability and a high level of abrasion resistance that result in a product which will have a considerably longer working life compared to one made from standard PE, based on the findings and observations from this work.

There is one other major constraint to consider, that of availability. Currently, availability of Dyneema Ultracross netting is limited to one North American manufacturer.

Consultations with American suppliers NET Systems Inc. have identified opportunities for bringing down the cost of the production and supply of Dyneema UC netting in square mesh configuration suitable for use in square mesh selection panels. By cutting the sheet netting in a particular way they are able to reduce wastage and produce panel material at a more competitive price for their US customers. It appears that there is scope to reduce the large price differential that currently exists between standard PE material and Dyneema UC netting for customers outside of the USA. This would greatly improve the prospects of commercial uptake of this material.

If after taking into account all the *pros* and *cons,* the Dyneema Ultracross option is still considered to be cost prohibitive, other options are available. This work has demonstrated that, in principle, the use of low diameter twines for the construction of square mesh panels has discard reduction benefits. There is still scope for improvement by considering gear options/specifications between the two ends of the spectrum examined in this work. Other combinations of twine specification and netting construction are available. The aim is to achieve consistent mesh shape and stability with the lowest practical twine diameter.

7 Acknowledgements

Seafish gratefully acknowledge the following:

The Scottish Executive for its financial support to this work conducted under the Industry Partnership Programme.

The skipper and crew of the twin rig trawler MFV *Heather Sprig* for their services and co-operation during these trials.

Skipper John Smith for his participation in these trials acting as industry observer and being actively involved in the catch sampling and data collection on behalf of Seafish.

Appendices

Appendix I: Catch Details

Table 1: Details of total haddock catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		4401	SAMPLE TOTAL		6343
RAISED TOTAL		8396	RAISED TOTAL		18225
MLS (cm)		30	MLS (cm)		30
% DISCARDS		75	% DISCARDS		72
% RETAINED		25	% RETAINED		28
HADDOCK TOTAL			HADDOCK TOTAL		
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	3	0.000	12	0	0.000
13	0	0.000	13	0	0.000
14	0	0.000	14	12	0.001
15	0	0.000	15	0	0.000
16	11	0.001	16	14	0.001
17	12	0.001	17	33	0.002
18	31	0.004	18	35	0.002
19	86	0.010	19	99	0.005
20	179	0.021	20	279	0.015
21	188	0.022	21	289	0.016
22	206	0.025	22	264	0.015
23	305	0.036	23	340	0.019
24	486	0.058	24	845	0.046
25	882	0.105	25	1145	0.063
26	984	0.117	26	2035	0.112
27	1096	0.131	27	2494	0.137
28	971	0.116	28	2788	0.153
29	854	0.102	29	2369	0.130
30	627	0.075	30	1783	0.098
31	507	0.060	31	1202	0.066
32	351	0.042	32	863	0.047
33	188	0.022	33	563	0.031
34	122	0.015	34	289	0.016
35	75	0.009	35	165	0.009
36	55	0.007	36	104	0.006
37	45	0.005	37	91	0.005
38	37	0.004	38	51	0.003
39	33	0.004	39	29	0.002
40	13	0.002	40	16	0.001
41	9	0.001	41	9	0.000
42	10	0.001	42	9	0.000
43	6	0.001	43	2	0.000
44	3	0.000	44	4	0.000
45	4	0.000	45	1	0.000
46	9	0.001	46	2	0.000
47	3	0.000	47	0	0.000
48	0	0.000	48	0	0.000
49	1	0.000	49	0	0.000
50	0	0.000	50	0	0.000

Table 2: Details of week one haddock catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL	1740		SAMPLE TOTAL	3010	
RAISED TOTAL	3504		RAISED TOTAL	8531	
MLS (cm)	30		MLS (cm)	30	
% DISCARDS	76		% DISCARDS	75	
% RETAINED	24		% RETAINED	25	
HADDOCK WEEK ONE			HADDOCK WEEK ONE		
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	7	0.002	16	10	0.001
17	7	0.002	17	10	0.001
18	22	0.006	18	29	0.003
19	70	0.020	19	64	0.008
20	103	0.029	20	133	0.016
21	81	0.023	21	188	0.022
22	93	0.026	22	171	0.020
23	176	0.050	23	223	0.026
24	258	0.074	24	554	0.065
25	419	0.120	25	536	0.063
26	391	0.111	26	967	0.113
27	375	0.107	27	1193	0.140
28	348	0.099	28	1290	0.151
29	324	0.092	29	1037	0.122
30	258	0.073	30	787	0.092
31	183	0.052	31	489	0.057
32	135	0.038	32	361	0.042
33	72	0.020	33	210	0.025
34	54	0.015	34	96	0.011
35	25	0.007	35	52	0.006
36	16	0.005	36	45	0.005
37	24	0.007	37	36	0.004
38	14	0.004	38	26	0.003
39	11	0.003	39	14	0.002
40	7	0.002	40	4	0.000
41	6	0.002	41	2	0.000
42	6	0.002	42	1	0.000
43	4	0.001	43	0	0.000
44	2	0.001	44	2	0.000
45	4	0.001	45	0	0.000
46	5	0.001	46	2	0.000
47	1	0.000	47	0	0.000
48	0	0.000	48	0	0.000
49	1	0.000	49	0	0.000
50	0	0.000	50	0	0.000

Table 3: Details of week two haddock catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		2661	SAMPLE TOTAL		2465
RAISED TOTAL		4892	RAISED TOTAL		9694
MLS (cm)		30	MLS (cm)		30
% DISCARDS		74	% DISCARDS		68
% RETAINED		26	% RETAINED		32
HADDOCK WEEK TWO			HADDOCK WEEK TWO		
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	3	0.001	12	0	0.000
13	0	0.000	13	0	0.000
14	0	0.000	14	12	0.001
15	0	0.000	15	0	0.000
16	5	0.001	16	4	0.000
17	5	0.001	17	23	0.002
18	9	0.002	18	6	0.001
19	16	0.003	19	35	0.004
20	75	0.015	20	146	0.015
21	108	0.022	21	100	0.010
22	113	0.023	22	93	0.010
23	129	0.026	23	118	0.012
24	228	0.047	24	292	0.030
25	463	0.095	25	609	0.063
26	593	0.121	26	1069	0.110
27	722	0.147	27	1302	0.134
28	623	0.127	28	1497	0.154
29	531	0.108	29	1332	0.137
30	370	0.076	30	997	0.103
31	324	0.066	31	713	0.074
32	217	0.044	32	502	0.052
33	116	0.024	33	353	0.036
34	68	0.014	34	193	0.020
35	50	0.010	35	113	0.012
36	39	0.008	36	59	0.006
37	21	0.004	37	55	0.006
38	23	0.005	38	25	0.003
39	22	0.004	39	15	0.002
40	6	0.001	40	12	0.001
41	3	0.001	41	7	0.001
42	4	0.001	42	8	0.001
43	2	0.000	43	2	0.000
44	1	0.000	44	2	0.000
45	0	0.000	45	1	0.000
46	4	0.001	46	0	0.000
47	2	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

Table 4: Details of total whiting catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		1012	SAMPLE TOTAL		1258
RAISED TOTAL		1560	RAISED TOTAL		2205
MLS (cm)		27	MLS (cm)		27
% DISCARDS		16	% DISCARDS		13
% RETAINED		84	% RETAINED		87
WHITING TOTAL			WHITING TOTAL		
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	2	0.001	21	0	0.000
22	8	0.005	22	4	0.002
23	10	0.007	23	20	0.009
24	20	0.013	24	60	0.027
25	91	0.058	25	54	0.024
26	116	0.074	26	157	0.071
27	114	0.073	27	158	0.072
28	145	0.093	28	139	0.063
29	169	0.108	29	190	0.086
30	126	0.081	30	195	0.089
31	159	0.102	31	248	0.113
32	145	0.093	32	179	0.081
33	146	0.094	33	243	0.110
34	106	0.068	34	213	0.097
35	71	0.045	35	112	0.051
36	48	0.031	36	89	0.040
37	37	0.024	37	62	0.028
38	25	0.016	38	44	0.020
39	12	0.008	39	18	0.008
40	7	0.004	40	12	0.005
41	1	0.001	41	5	0.002
42	0	0.000	42	1	0.000
43	1	0.001	43	0	0.000
44	0	0.000	44	0	0.000
45	0	0.000	45	1	0.000
46	1	0.001	46	0	0.000
47	0	0.000	47	0	0.000
48	1	0.001	48	0	0.000
49	0	0.000	49	0	0.000
50	0	0.000	50	0	0.000

Table 5: Details of week one whiting catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		596	SAMPLE TOTAL		722
RAISED TOTAL		921	RAISED TOTAL		1277
MLS (cm)		27	MLS (cm)		27
% DISCARDS		14	% DISCARDS		15
% RETAINED		86	% RETAINED		85
WHITING WEEK ONE			WHITING WEEK ONE		
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	2	0.003	21	0	0.000
22	0	0.000	22	0	0.000
23	8	0.009	23	20	0.016
24	10	0.010	24	45	0.035
25	52	0.056	25	30	0.023
26	58	0.062	26	96	0.075
27	65	0.070	27	106	0.083
28	81	0.088	28	70	0.055
29	108	0.118	29	97	0.076
30	71	0.077	30	116	0.091
31	95	0.103	31	171	0.134
32	84	0.091	32	124	0.097
33	105	0.113	33	139	0.109
34	57	0.062	34	114	0.089
35	38	0.042	35	51	0.040
36	34	0.037	36	42	0.033
37	23	0.025	37	20	0.016
38	15	0.016	38	21	0.016
39	10	0.011	39	9	0.007
40	5	0.005	40	3	0.002
41	1	0.001	41	2	0.002
42	0	0.000	42	1	0.001
43	1	0.001	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

Table 6: Details of week two whiting catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		416	SAMPLE TOTAL		536
RAISED TOTAL:		639	RAISED TOTAL		928
MLS (cm)		27	MLS (cm)		27
% DISCARDS		18	% DISCARDS		11
% RETAINED		82	% RETAINED		89
WHITING WEEK TWO			WHITING WEEK TWO		
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	8	0.012	22	4	0.004
23	2	0.003	23	0	0.000
24	11	0.017	24	15	0.016
25	39	0.061	25	24	0.026
26	59	0.092	26	61	0.066
27	50	0.077	27	52	0.056
28	64	0.099	28	70	0.075
29	60	0.094	29	93	0.100
30	55	0.086	30	79	0.086
31	64	0.100	31	78	0.084
32	62	0.097	32	55	0.059
33	42	0.065	33	104	0.112
34	49	0.077	34	99	0.107
35	33	0.051	35	61	0.066
36	14	0.022	36	47	0.051
37	14	0.022	37	42	0.045
38	10	0.016	38	23	0.025
39	2	0.003	39	9	0.010
40	2	0.003	40	9	0.010
41	0	0.000	41	3	0.003
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	1	0.001
46	1	0.002	46	0	0.000
47	0	0.000	47	0	0.000
48	1	0.002	48	0	0.000
49	0	0.000	49	0	0.000
50	0	0.000	50	0	0.000

Table 7: Details of total cod catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		723	SAMPLE TOTAL		607
RAISED TOTAL		961	RAISED TOTAL		902
MLS (cm)		35	MLS (cm)		35
% DISCARDS		37	% DISCARDS		36
% RETAINED		63	% RETAINED		64
COD TOTAL			COD TOTAL		
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	7	0.008	22	0	0.000
23	0	0.000	23	0	0.000
24	3	0.003	24	0	0.000
25	15	0.015	25	8	0.008
26	10	0.010	26	0	0.000
27	10	0.010	27	8	0.008
28	28	0.029	28	6	0.007
29	39	0.040	29	24	0.026
30	37	0.039	30	44	0.049
31	45	0.047	31	58	0.064
32	46	0.048	32	25	0.028
33	54	0.056	33	50	0.056
34	65	0.067	34	99	0.110
35	28	0.029	35	42	0.047
36	55	0.057	36	46	0.051
37	44	0.046	37	56	0.062
38	48	0.050	38	38	0.042
39	47	0.049	39	52	0.057
40	50	0.052	40	41	0.045
41	54	0.057	41	63	0.070
42	33	0.034	42	35	0.039
43	34	0.035	43	41	0.045
44	45	0.047	44	29	0.032
45	24	0.025	45	39	0.043
46	26	0.027	46	26	0.029
47	19	0.020	47	14	0.016
48	19	0.020	48	9	0.010
49	17	0.018	49	13	0.014
50	17	0.018	50	14	0.016

Table 8: Details of week one cod catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		234	SAMPLE TOTAL		226
RAISED TOTAL		362	RAISED TOTAL		362
MLS (cm)		35	MLS (cm)		35
% DISCARDS		39	% DISCARDS		34
% RETAINED		61	% RETAINED		66
COD WEEK ONE			COD WEEK ONE		
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	0	0.000	22	0	0.000
23	0	0.000	23	0	0.000
24	3	0.007	24	0	0.000
25	11	0.029	25	5	0.013
26	7	0.019	26	0	0.000
27	10	0.028	27	8	0.021
28	14	0.039	28	3	0.008
29	13	0.037	29	17	0.046
30	16	0.043	30	26	0.070
31	9	0.026	31	12	0.032
32	9	0.023	32	12	0.034
33	15	0.040	33	12	0.032
34	37	0.101	34	30	0.083
35	8	0.023	35	20	0.056
36	19	0.052	36	19	0.052
37	22	0.061	37	28	0.076
38	14	0.039	38	10	0.028
39	20	0.054	39	22	0.060
40	18	0.050	40	11	0.030
41	17	0.048	41	26	0.073
42	8	0.022	42	17	0.047
43	13	0.036	43	17	0.047
44	16	0.044	44	15	0.040
45	11	0.030	45	13	0.036
46	10	0.028	46	8	0.022
47	7	0.019	47	3	0.008
48	10	0.028	48	6	0.017
49	2	0.006	49	3	0.008
50	8	0.022	50	8	0.022

Table 9: Details of week two cod catch

DYNEEMA PANEL			DOUBLE TWINE PANEL		
SAMPLE TOTAL		489	SAMPLE TOTAL		381
RAISED TOTAL		599	RAISED TOTAL		543
MLS (cm)		35	MLS (cm)		35
% DISCARDS		36	% DISCARDS		37
% RETAINED		67	% RETAINED		66
COD WEEK TWO			COD WEEK TWO		
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	7	0.012	22	0	0.000
23	0	0.000	23	0	0.000
24	0	0.000	24	0	0.000
25	4	0.007	25	4	0.007
26	3	0.005	26	0	0.000
27	0	0.000	27	0	0.000
28	14	0.023	28	7	0.012
29	25	0.042	29	15	0.028
30	22	0.036	30	15	0.028
31	36	0.060	31	38	0.069
32	38	0.063	32	23	0.041
33	39	0.065	33	39	0.071
34	28	0.047	34	63	0.116
35	20	0.033	35	13	0.024
36	36	0.061	36	29	0.053
37	22	0.037	37	28	0.052
38	34	0.057	38	27	0.050
39	27	0.045	39	30	0.055
40	32	0.053	40	31	0.057
41	37	0.062	41	39	0.072
42	25	0.042	42	20	0.037
43	21	0.035	43	21	0.039
44	29	0.048	44	16	0.029
45	13	0.022	45	26	0.048
46	16	0.027	46	18	0.033
47	12	0.020	47	13	0.023
48	9	0.015	48	3	0.006
49	15	0.025	49	10	0.018
50	9	0.015	50	6	0.011