Investigating technical measures for the improvement of *Nephrops* size selectivity in trawls

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Summary

Working closely with an Industry Working Group, Seafish produced 5 different prawn trawl modifications for evaluating in the Flume Tank and subsequent testing at sea. A sea trial was conducted during March 2004 on board a Scottish prawn trawler, based at the port of Peterhead, and fishing on the Fladen Grounds of the North Sea.

Results from the sea trials were limited. The 5 trawl modifications under test did not show any detectable selectivity characteristics for *Nephrops norvegicus (L.)* under commercial conditions. However, there was some information from other studies - some of which were still under way at the time of this study – which showed that it was possible to modify the selectivity of a prawn trawl using other types of device. The most successful of these devices were inclined grids and grilles, although there is concern that they might become obscured with mud and other debris during fishing, and lose their beneficial selectivity properties.

It was found that, during the sea trials, the selectivity characteristic of the crew matched the selectivity characteristic of two of the grid and grille type of device tested in other studies. This study recommended that such grid and grille type devices, with appropriate bar spacing, be evaluated for use in UK *Nephrops* fisheries. It also recommended that an inclined grid, fabricated from *Flexipanel*™ material, should be evaluated. This is because *Flexipanel*™ material was found to be particularly easy to handle on a net drum.

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1 Introduction

Increased pressure and reduced quotas on whitefish have resulted in the UK catching sector applying more effort in trawling for *Nephrops* as a target species within the last 5 years. This applies to vessels right across the size and power range in the UK fleet.

It is generally accepted that current technical conservation measures are not improving size selection of *Nephrops* (see, for example, Graham & Ferro, 2003) (5). The current expansion of targeted *Nephrops* fisheries has led to increases in the catches of very small prawns and markets becoming flooded with prawns that processors do not want. In turn, this is reflected in the poor prices being paid to fishermen, which leads to more pressure on fishermen to increase their landings still further in order to remain viable.

There is very strong industry support in the UK, from both the catching and processing sectors, to improve the size and quality of *Nephrops*.

Optimising the survival of undersized *Nephrops* by releasing them from the gear underwater, could reduce mortality rates. An EU funded study (Wileman *et al.*, 1999) (12) has estimated that average *Nephrops* mortality could be reduced from about 69% to about 18% if they were released from the trawl at the seabed. A reduction of the bulk catch taken on board the vessels in the cod-ends, could lead to an improvement in catch quality and therefore, catch value. A reduction in the workload of the crew could lead to better working conditions on board fishing vessels.

This study sets out to identify some likely candidate technical conservation measures which could improve the size selection of *Nephrops* at the point of capture.

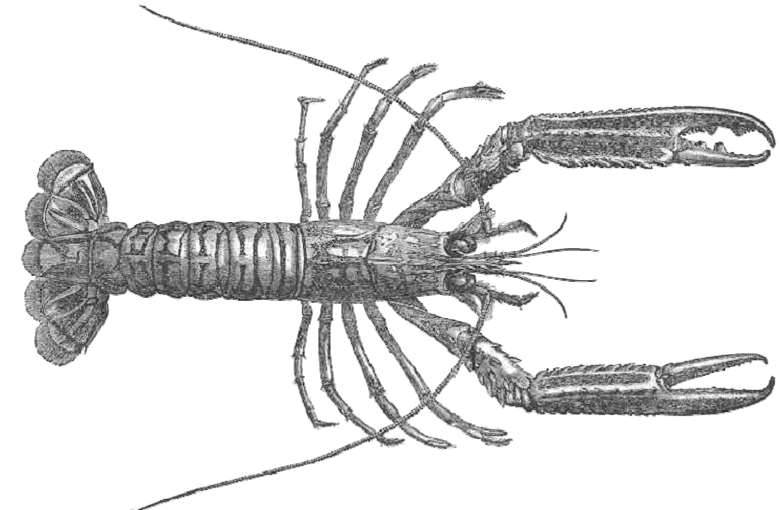
1.1 Project background

SEAFISH is actively involved with industry, encouraging the commercial use of a range of technical conservation measures (TCMs). These TCMs are aimed at addressing a variety of bycatch and discard related problems. All this is part of an ongoing programme of work - to develop and to encourage the adoption of sustainable fishing practices throughout the UK catching sector.

A considerable amount of SEAFISH resources has already been applied to reducing wastage in UK *Nephrops* fisheries by reducing the discards of finfish bycatches through the use of species selective gears (Arkley & Dunlin 2003; Dunlin & Reese 2003) (2; 3). However, as discussed above, attention also needs to be focussed on the size selectivity of *Nephrops*.

Refining the size selectivity of Nephrops trawls is very difficult because of the limited ways in which this species appears to respond to fishing gear and the species morphology. For this reason, it was proposed to investigate some innovative ideas through an exploratory scoping exercise, which was intended to establish those areas needed for precise study in future work. It is this that forms the basis of the work described here.

Nephrops norvegicus, Oban Sea Life Centre



***Nephrops norvegicus* (½ nat. size).**

Image courtesy of the freshwater and Marine Image Bank, University of Washington, USA (after Huxley T.H. 1896)

2 Aims & Objectives

The overall objective is to reduce the level of discarding and wastage of *Nephrops* by improving the selectivity of prawn trawls. To achieve this, there is a requirement for a practical mechanism for releasing or grading undersize prawns to reduce the catch sorting time and improve the catch quality and value. This mechanism should be simple in construction, easy to maintain and safe to use on a fishing vessel.

Three key sub-objectives within the study were:

1. To set up an Industry Working Group, and through that Group, identify a number of appropriate candidate technical conservation measures (TCMs) for evaluation.

2. To design, build and refine prototypes of the TCM designs using the SEAFISH Flume Tank facility at the Fisheries Development Centre, and to produce final versions suitable for retro-fitting into existing fishing gear.

3. To assess the TCMs at sea under commercial fishing conditions and to determine their relative effectiveness.

3 Materials And Methods

The programme of work was divided into 7 phases as specified in the FIFG Application for Fisheries Grant:

Phase 1: Project preparation and establishing an Industry Working Group
Phase 2: Fishing gear design and construction
Phase 3: Testing of prototype TCMs in the Seafish flume tank
Phase 4: Production of final TCMs for sea trial testing
Phase 5: Sea trials
Phase 6: Analysis and reporting
Phase 7: Dissemination of information

3.1 Phase 1: Project preparation and establishing an Industry Working Group

An independent statistical assessor provided comments on the draft project proposal (see Appendix I) and put forward some suggestions and amendments. It was made clear to the assessor that the proposed project was intended to be a scoping exercise.

An Industry Working Group (see Appendix II) proposed that 4 selectivity devices be put forwards for testing as a TCM in the project. These choices were later modified under Phases 3 & 4. The size of all selectivity panels was to be similar, wherever possible, at about 3m long x approx. 1m wide (see figure 7).

The Working Group had proposed to hold one meeting at the Fisheries Development Centre (FDC) Flume Tank, at which examples of all 4 of the options selected under Phase 1 could be observed for evaluation. However, this later proved impossible, and Seafish Gear Technologists completed the final prototype testing by February 27th 2004.

The Working Group had suggested using hexagonal mesh for one of the gear types, but obtaining this material in the correct grade was not possible.

3.2 Phases 2 - 4: Fishing gear options for investigation

The morphology and behaviour of *Nephrops* makes size selection using conventional diamond mesh netting in a standard cod-end design relatively ineffective at achieving consistent size selection (Ferro, pers. comm.). Novel designs were chosen to address this problem.

3.2.1 Flexi-Panels™

Grading Systems (UK) Ltd. of Shetland has developed a *Flexi-panel™*, which is a patented, passive grading device designed to size grade live fish in the aquaculture industry. It has been used to grade salmon and trout by size and to remove unwanted wild fish species which have entered suspended fish cages.

Other possible uses include improving species and size selection in fish traps (for cod) and improving size and species selection in towed gears. This technology has advantages over other size grading systems that have been used in capture fisheries in that it is very flexible, it can pass around a net drum, and is compatible with existing fishing gear designs.

SEAFISH and Grading Systems (UK) Ltd. (GS UK) both recognised the possibilities for this technology in commercial capture fisheries as a means of improving the selectivity of certain types of fishing gears in certain fisheries. GS UK expressed an interest in collaborating with SEAFISH to investigate some of the possible options for this technology.

A Flexi-panel™ arrangement positioned in the lower half of the extension of a trawl, just ahead of the cod-end was expected to provide a means of size-selecting *Nephrops* before they enter the cod-end.

For specifying the size of a Flexi-panel™ in a trawl, the length of the panel section was initially suggested to correspond to the length of a 50 mesh piece of the extension section of the trawl. The panel width was determined by the width of the extension netting in which it will be installed (about 1m). A rectangular shaped opening was recommended with the long edge being in line with the axis/direction of tow of the net.

Two gear variants using the Flexi-panel™ idea were put forward for testing:

1. A Flexi-panel™ with 25mm bar spacings, fitted in the lower half of the extension section of the trawl (variant 1, see figure 7).

2. A Flexi-panel™ with 15mm bar spacings, fitted in the lower half of the extension section of the trawl, and incorporating three sets of flow reduction bumps with an approach slope of 48° and a height of 11cm (variant 4, see figure 7).

3.2.2 A panel of diamond netting turned through 90º (T90)

This idea used a conventional panel of diamond mesh netting but with the 'run' of the netting turned through 90º, and known as T90 mesh (Hansen, 2004). The mesh of conventionally rigged netting close together as tension increases in the direction of tow. The netting can close almost completely - to the extent that the sideknots are touching. This restricts anything from escaping.

By using T90 netting, the meshes are prevented from closing completely by the construction of the knots in the netting weave. The end result is an open rectangular mesh shape, possibly better suited to *Nephrops* size selection compared with normal diamond netting.

A double-knot construction in the netting weave could further enhance this mesh configuration. The increased size of knot helps to prevent the meshes from closing. The double-knot weave also helps to stabilise the mesh shape which otherwise could be susceptible to mesh distortion through knot slippage, as the netting is working against its natural run.

The application of a stiffening agent and/or heat setting of the netting can also be used to further improve the overall mesh configuration.

It was proposed to construct a panel of T90 mesh from double-knotted Dyneema™ material for testing. Dyneema™ allows the use of smaller twine diameters than with conventional polyethylene (PE) twine, without compromising the twine strength or durability (variant 3, see figure 7).

3.2.3 A full cod-end made of Dyneema™ T90 netting

This option uses T90 mesh as described previously. In this arrangement it was proposed that the whole cod-end be constructed from the new netting configuration. It was anticipated that, because of the increased amount of netting used in this arrangement, and because it intercepts the whole catch, more of the catch would be exposed to the netting (variant 5, see figure 7).

3.2.4 A full cod-end made of polyethylene T90 netting

In the UK fishing industry, polyethylene netting material is more readily available and cheaper than Dyneema™ netting. For this reason it was desirable to assess the selectivity potential of T90 mesh in a conventional polyethylene material (variant 2, see figure 7). Polyethylene in T90 configuration is likely to distort when subject to tension when lifting the cod-end aboard the vessel. To avoid this, 10 rows of diamond mesh was added as a secure mounting point for the lifting becket. (This measure was not necessary for the Dyneema™ full cod-end (3.2.3, variant 5) because of the higher strength of the material.)

Both full cod-end types (3.2.3, variant 5, and 3.2.4, variant 2) also had several rows of diamond mesh along the end (figure 7), to allow for a secure mounting point for the cod-end closure (cod-line).

All 5 of these prototype gear variants were assessed in the flume tank before being put forward for sea trials.

3.3 Figures 1-6: Prototypes tested in the Flume Tank

Figure 1: *Flexi-panel*^{TM} with 25mm bar spacings (Variant 1)

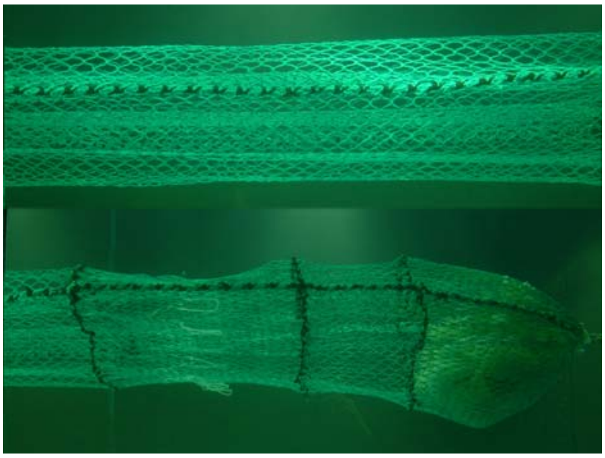


Figure 2: PE cod-end with mesh turned through 90º (T90) (Variant 2)

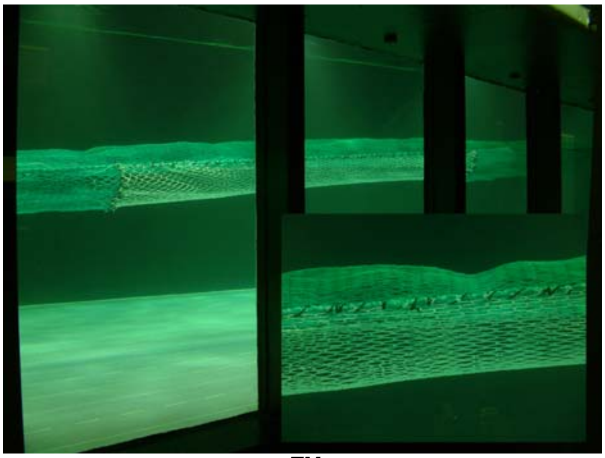


Figure 3: *Dyneema*^{TM} lower panel with T90 mesh (Variant 3)

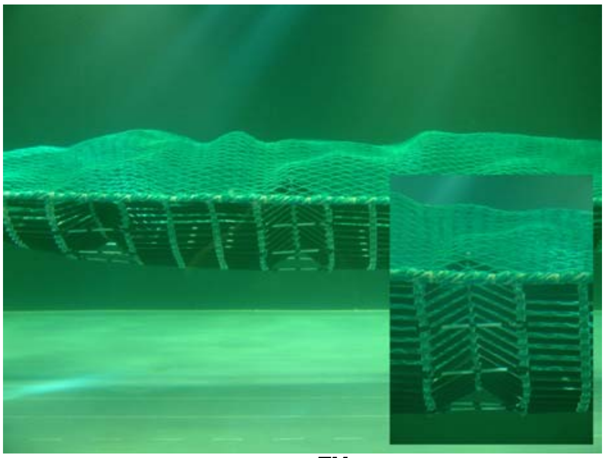


Figure 4: *Flexi-panel*^{TM}; bar spacings of 15mm; bumps with 48° slope (Variant 4)

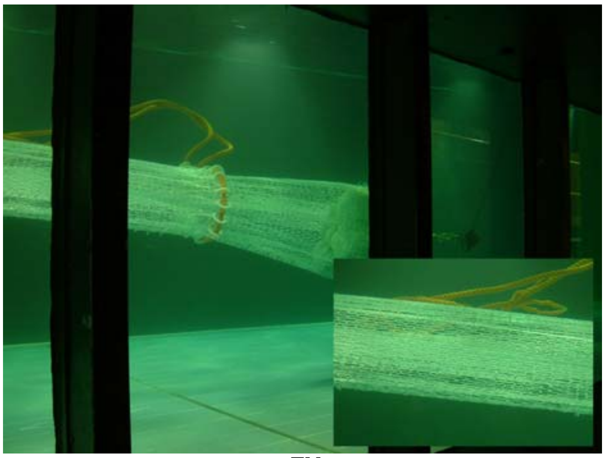


Figure 5: *Dyneema*^{TM} cod-end with T90 mesh (Variant 5)

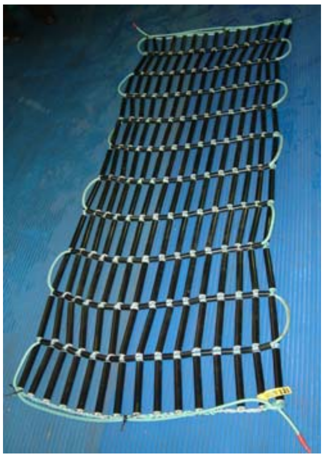


Figure 6: Entire *Flexi-panel*^{TM} with 25mm bar spacings (Variant 1)

3.4 Summary of 5 variants put forward for trials at sea

Variant 1: A Flexi-panel™ with 25mm bar spacings.

Variant 2: A full polyethylene (PE) cod-end made from 80mm diamond mesh, 4.5mm diameter twine, turned through 90º (T90).
Variant 3: A Dyneema™ mesh lower panel made from 80mm double-knotted diamond mesh, 2.5mm diameter twine, in T90 netting.
Variant 4: A Flexi-panel™ with 15mm bar spacings and incorporating three sets of flow reduction bumps with an approach slope of 48° and a height of 11cm.
Variant 5: A full Dyneema™ cod-end made from 80mm double-knotted diamond mesh, 2.5mm diameter twine, in T90 netting

3.5 Phase 5: Sea Trials

Sea trials were conducted from Peterhead in the North Sea during the first two weeks of March 2004. The commercial vessel used was the twin-rig trawler *Heather Sprig* BCK181, fishing on the Fladen Grounds north of 57°N. (See Appendix III for the log of the of individual hauls.)

Each of the 5 variants was deployed for two days. Each configuration was tested in a twin-rig trawl arrangement on both the port and starboard sides to ensure a fair comparison with a standard cod-end. This was intended to confound any differences between sides, as such differences are known to occur in twin-rig trawls.

The standard cod-end was constructed from 80mm polyethylene diamond mesh with a twine diameter of 4.5mm. The cod-end had 100 open mesh around the circumference, and measured approximately 3m in length.

Each of the entire trawls, together with the test gear variant, was alternated from the port to starboard side every three hauls. Each tow was for a 4 hour duration. The door spread of the gear was monitored using the vessel's acoustic Scanmar™ sensors, to check for consistent door-spread.

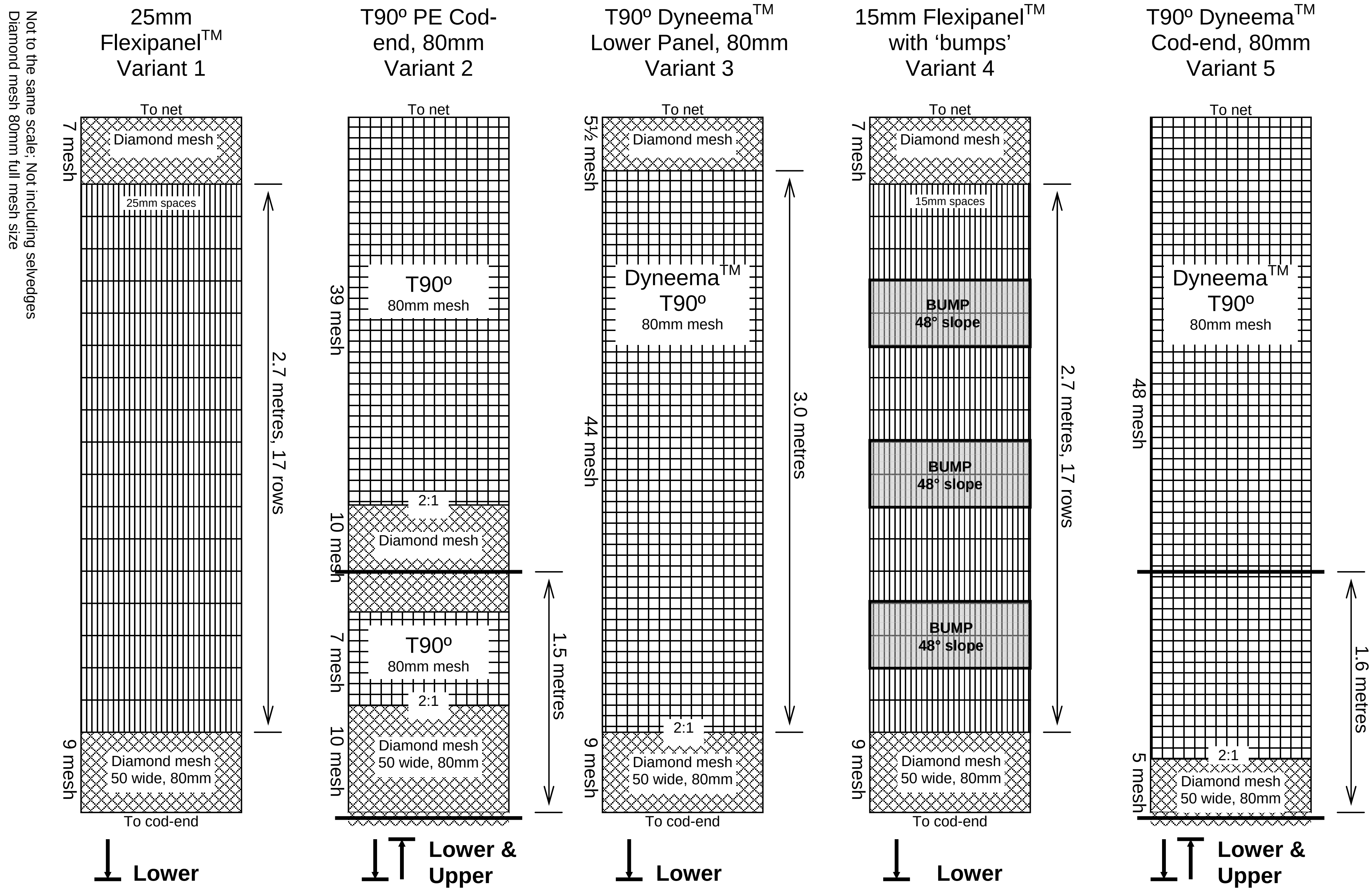


Figure 7: Specification of the gear variants tested at sea

3.6 Sampling

Catches from the cod-ends of each net were kept separate for sampling purposes. A key issue here was to avoid any “washing out” effect caused by leaving one cod-end in the water whilst the other was being sampled. An accurate bulk total was taken by counting baskets discarded outboard and quantifying the retained catch.

The process of ‘tailing’ *Nephrops* (removing the heads of small individuals and landing them as tails only) was avoided to minimise any inconsistency in defining the size at which a prawn would be discarded by the crew.

The total catch was divided into these elements:

1. *Nephrops* that would usually be discarded or tailed by the crew.
2. Whole *Nephrops* for retention, and
3. “Other” – comprising any finfish and any discarded material.

For the discarded catch component:

Basket samples were taken from the conveyor belt sorting area after it was cleared of debris. A basket sample was taken from near the start, middle and near the end of the catch, when possible. If the catches were small then all the discarded prawns were measured.

The remaining *Nephrops* sample was then quantified in three ways:

1. Count per unit weight using electronic scales
2. Count per unit volume using a $0.3m^3$ cube
3. Length-frequency measurements of samples taken from the cube. Measurements of *Nephrops* were all carapace length (CL) dimension.

For the retained catch component:

Baskets of *Nephrops* were levelled to the rim and the number of baskets retained was noted. Part-baskets were estimated by measuring empty basket depth.
Wherever possible, three random baskets of whole *Nephrops* were sampled and quantified by:

1. Count per unit weight using electronic scales
2. Count per unit volume using a $0.3m^3$ cube
3. Length/frequency measurements of samples taken from the cube.

The retained fish were recorded by basket volume.

A raising factor (multiplier) was used to multiply the retained or the discarded components of the catch when either there was insufficient *Nephrops* to entirely fill the sampling cube, or operational constraints necessitated a sample size less than the 100% capacity of the cube.

A raising factor was used to multiply the number of *Nephrops* sampled in the cube in proportion to the number of baskets of *Nephrops* that was caught.

30 sets of hauls were made with a twin-rig trawl during the sea trials. Each of the 5 test gears (variants) was deployed for 6 hauls; 3 hauls in each of the port and starboard positions. On the Fladen Grounds, the weather for hauls 1-24 was very similar, but catches were low. Mean catches for each haul were 2.4 baskets of retained *Nephrops*, 1.3 baskets of *Nephrops* classed as discarded, and 1.6 baskets of fish.

However, bad weather forced a change of grounds for hauls 25-30 (gear variant 5, the Dyneema™ T90 cod-end) and the catch of *Nephrops* was not sufficient to allow analysis for those hauls (the mean catch was 84 *Nephrops* per haul).

Phase 6: Analysis and reporting - See RESULTS and DISCUSSION section

4 Results

4.1 Box and whisker plot (figure 8)

The total catches per haul for each of the 4 variants under analysis were plotted using a 'box and whisker' representation, to check for overall similarities between variant and standard gears. The 'boxes' contain the lower and upper quartiles (25% & 75%) of the spread of the data, and the whiskers mark the spread of the 5% and 95% points of the data. Median values are marked with a line. This representation showed that there are three sets of data containing 'outliers' outside 95% of the spread of the data (marked 'X'). Two of the outliers are in variant 2 and one in variant 3. Those in variant 2 were left in place, since although they are some distance away from the median, they are consistent with each other. In variant 3, the outlier is far away from the median and so it was removed, together with the corresponding paired value from the standard gear.

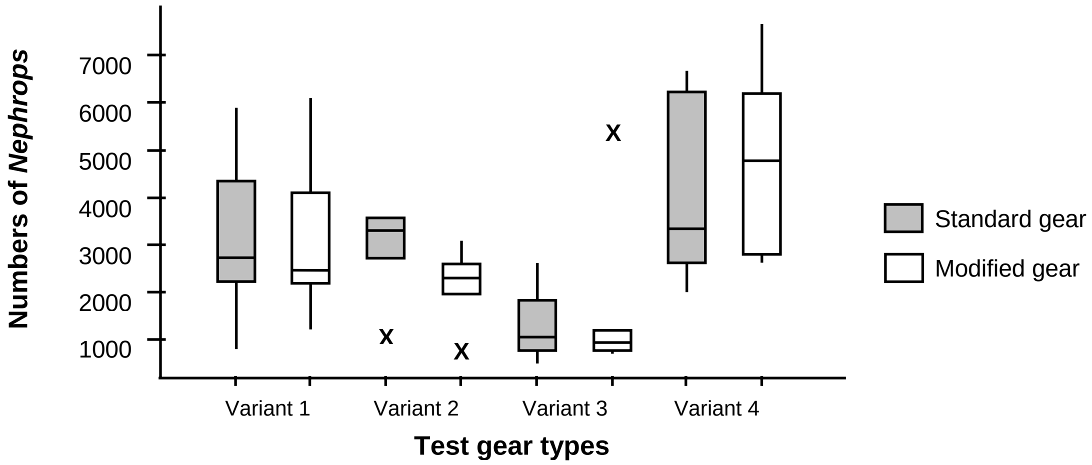


Figure 8 Box and whisker plot showing spread of data for standard and modified gears for the numbers of *Nephrops* per haul in each of the 4 variants

4.2 Analysis of variance (ANOVA): Catch, by haul

The data was examined for possible variation due to side, i.e. the port and starboard positions. The parameters used were the catch per haul for the size ranges above and below the minimum landing size of 30mm. It was found that there was no significant variation due to side in terms of catch per unit effort.

The data was examined for possible variation in total catch between hauls, due to whether the gear was modified or not. It was found that there was no significant difference across the measured size range due to whether the gear was modified or whether it was standard. The mean catch from all standard gear = 2814 per haul; mean catch from all modified gear = 2906 per haul.

The data was examined for variation in total catch between individual modified gear types across the measured size range. There was a significant difference between each set of hauls (daily variation). However, there was no significant difference between the different gear modifications. The same analysis was carried out for the fraction of the catch below the MLS to test for differences in possible selectivity, but the results were similar, i.e. there was no significant difference between the modified gear and the standard gear.

4.3 Catch, by size class

The next stage in the analysis was to determine whether any selectivity was beginning to occur in any of these 4 test gears. The catch size distributions and the relationship between the size distributions of the modified and standard gears are illustrated in figures 9, 10, 11, & 12. For each size class, the ratio of catch numbers from the modified gear to catch numbers from the standard gear was plotted with respect to size class.

$$\text{Ratio of catch numbers} = \left[\frac{\text{Numbers caught in modified gear}}{\text{Numbers caught in standard gear}}\right]_{\text{20mm to 55mm}} \qquad \textit{Equation 1}$$

The data for hauls 1-24 (gear variants 1,2,3 & 4) from the sea trial were first examined by comparing the ratio of catches taken in modified gears with those taken in standard gear. This was to determine whether there was any selectivity occurring over the size range that was measured (from 20mm to 55mm).

Two of the modifications were found to exhibit a distinctive characteristic:

1. It was found that the T90 PE cod-end tended to have a ratio of greater than 1.0 across the measured size range, i.e. that the modified gear tended to catch less than the standard gear over the entire size distribution.

2. It was found that the 15mm Flexipanel^{TM}, with bumps, tended to have a ratio of less than 1.0 across the measured size range, i.e. that the modified gear caught more than the standard gear.

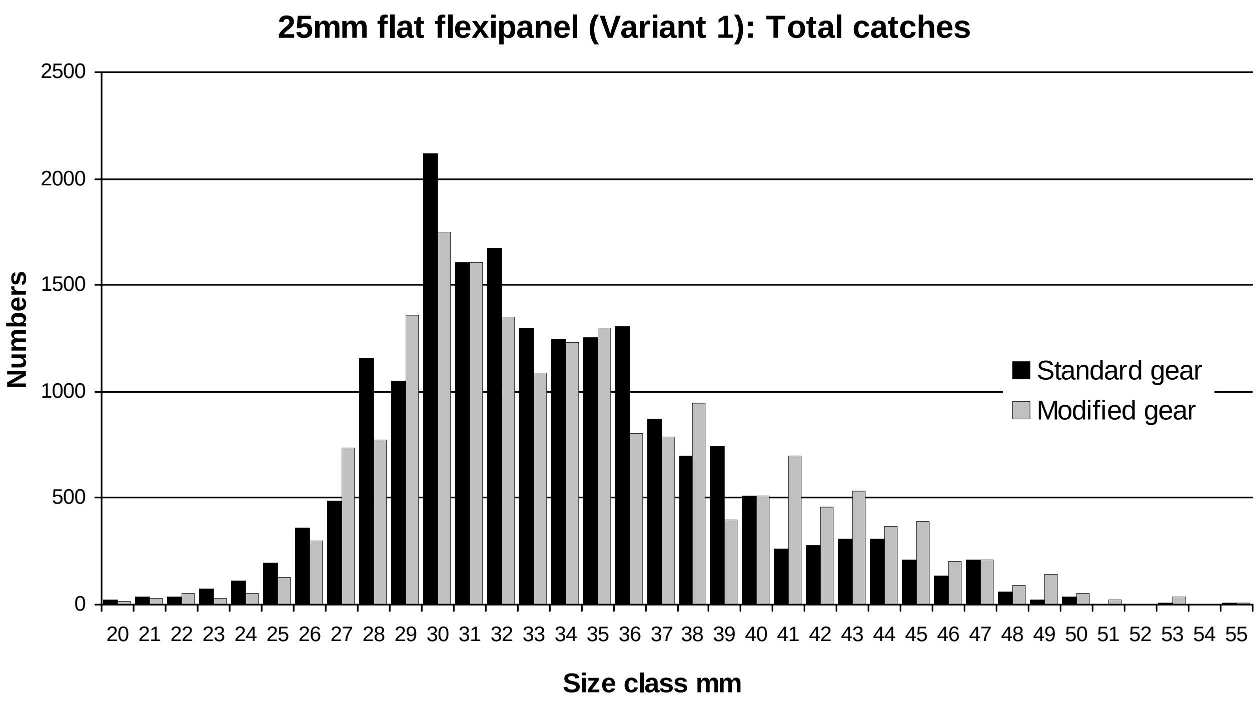


Figure 9 Size distribution showing catches taken with standard gear and modified gear (Variant 1)

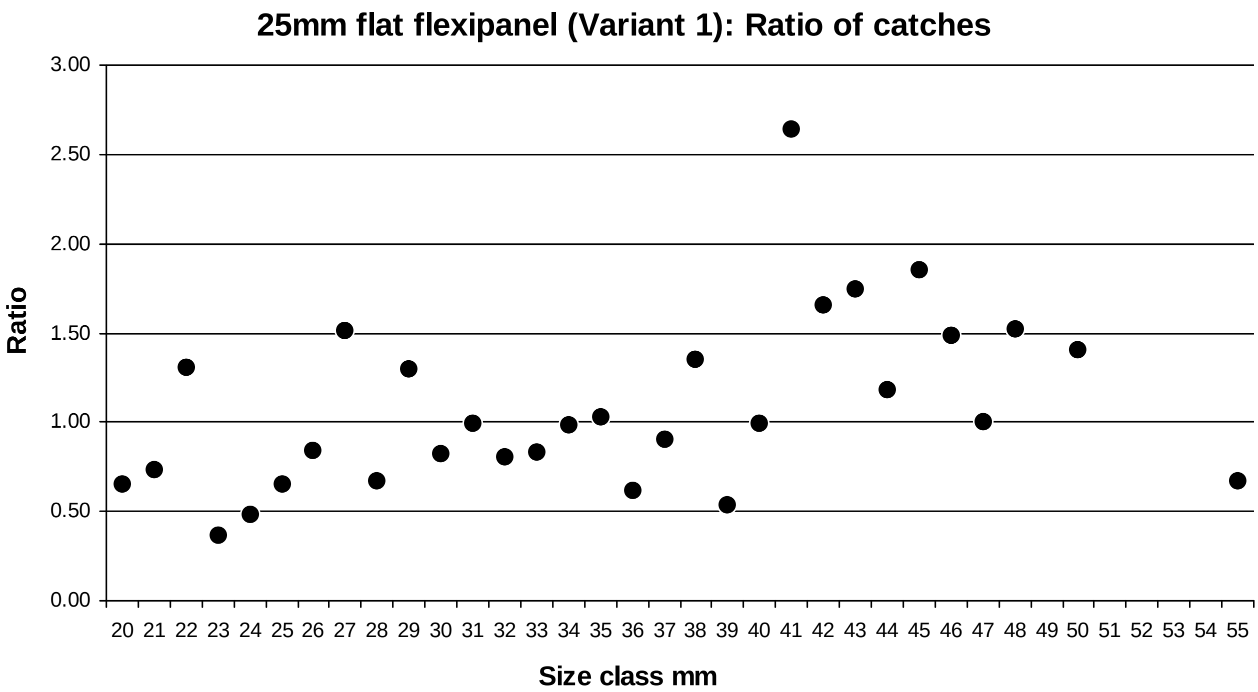


Figure 9a Illustrating how the ratio of catches between modified gear (Variant 1) and standard gear changes with respect to size class (selectivity)

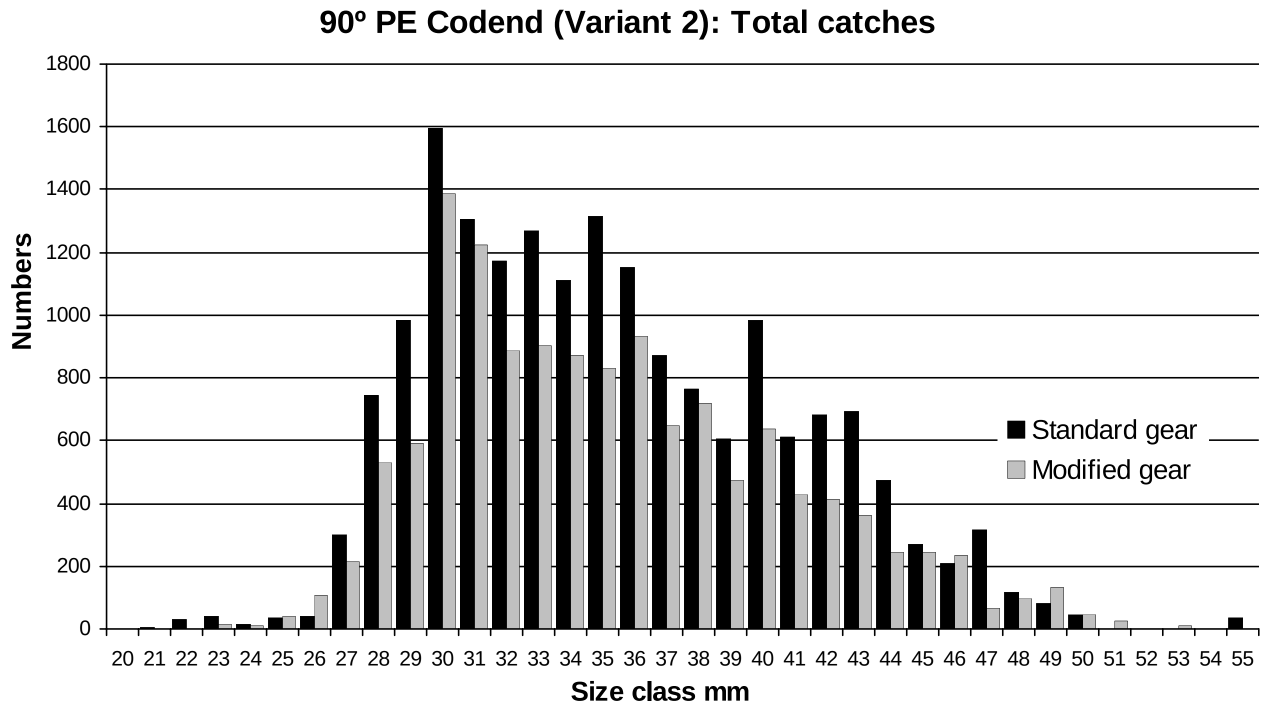


Figure 10 Size distribution showing catches taken with standard gear and modified gear (Variant 2)

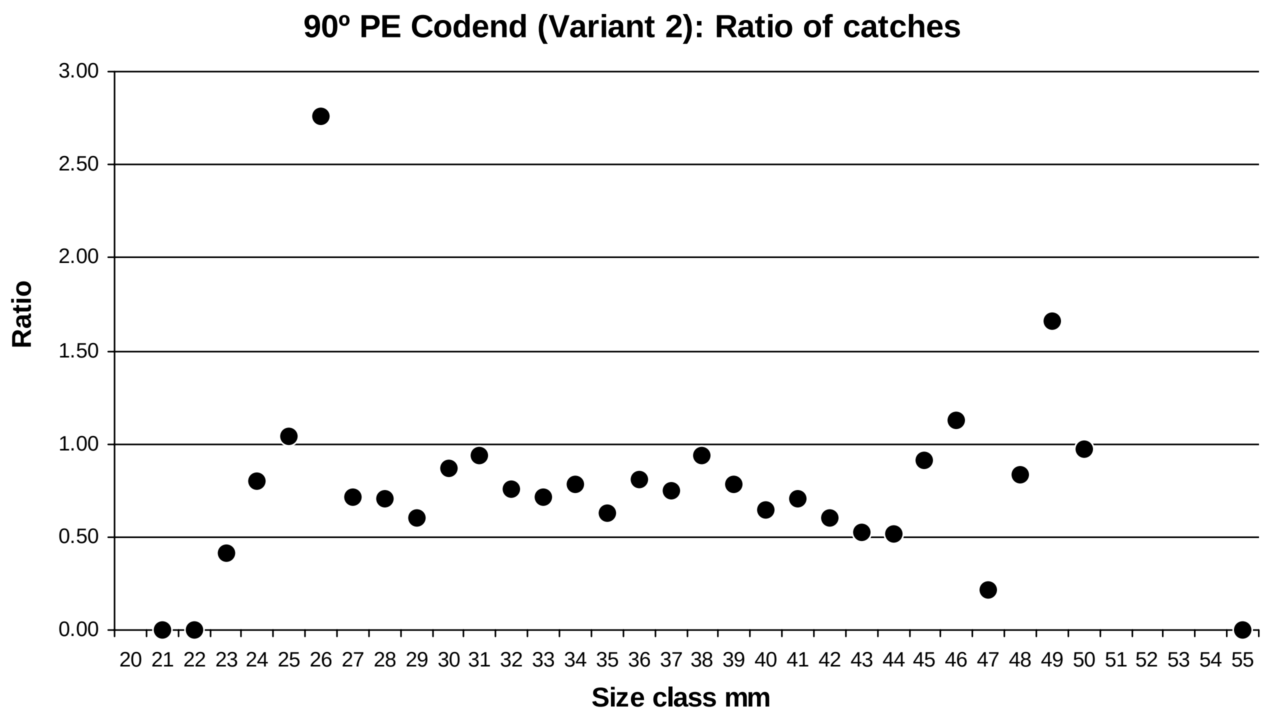


Figure 10a Illustrating how the ratio of catches between modified gear (Variant 2) and standard gear changes with respect to size class (selectivity)

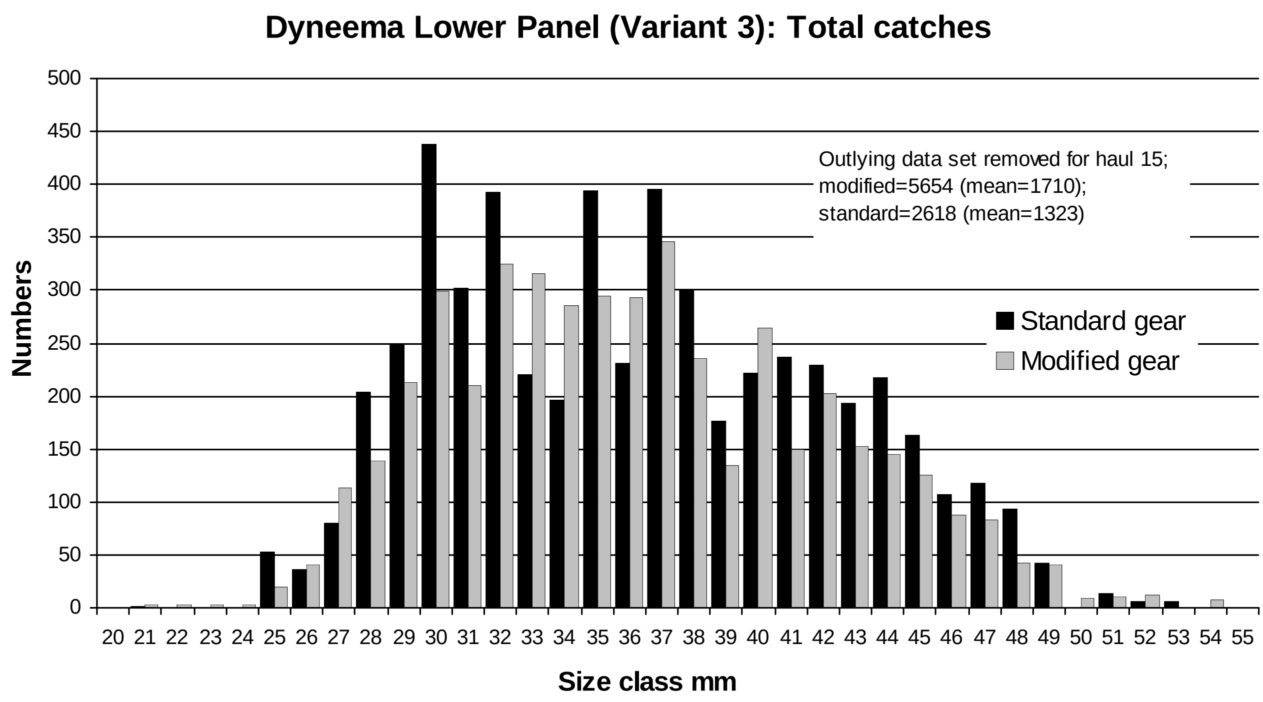


Figure 11 Size distribution showing catches taken with standard gear and modified gear (Variant 3)

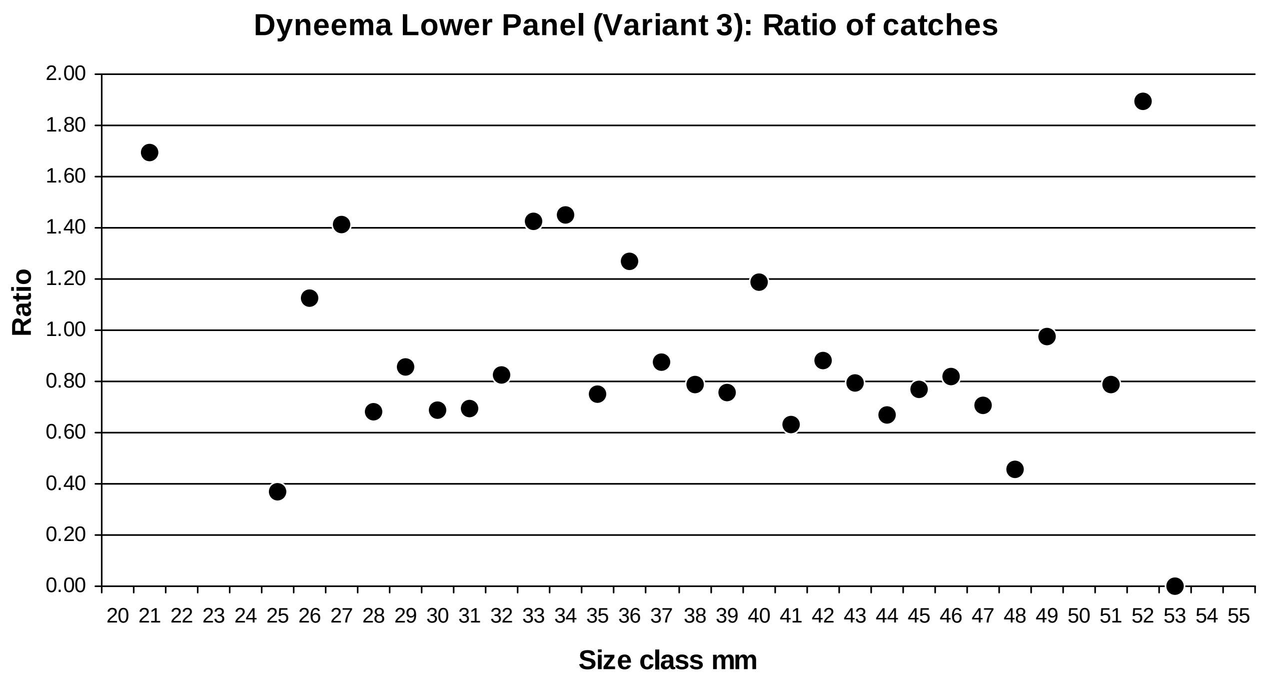


Figure 11a Illustrating how the ratio of catches between modified gear (Variant 3) and standard gear changes with respect to size class (selectivity)

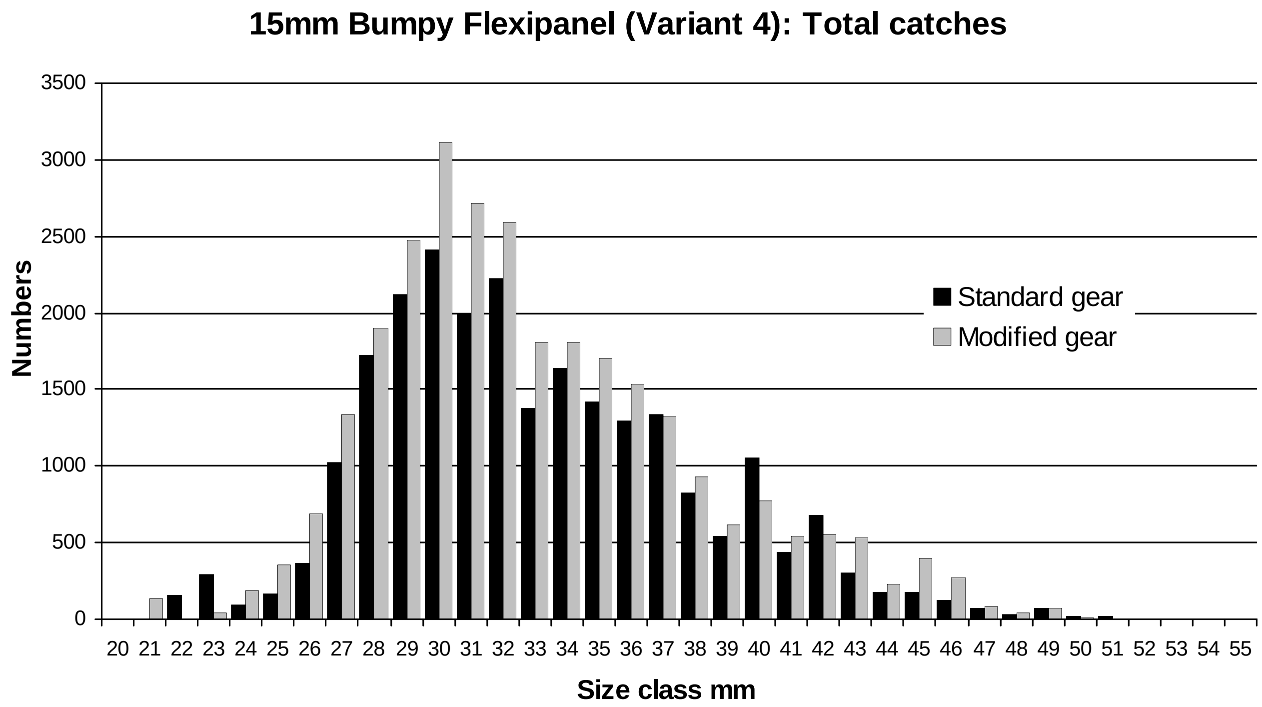


Figure 12 Size distribution showing catches taken with standard gear and modified gear (Variant 4)

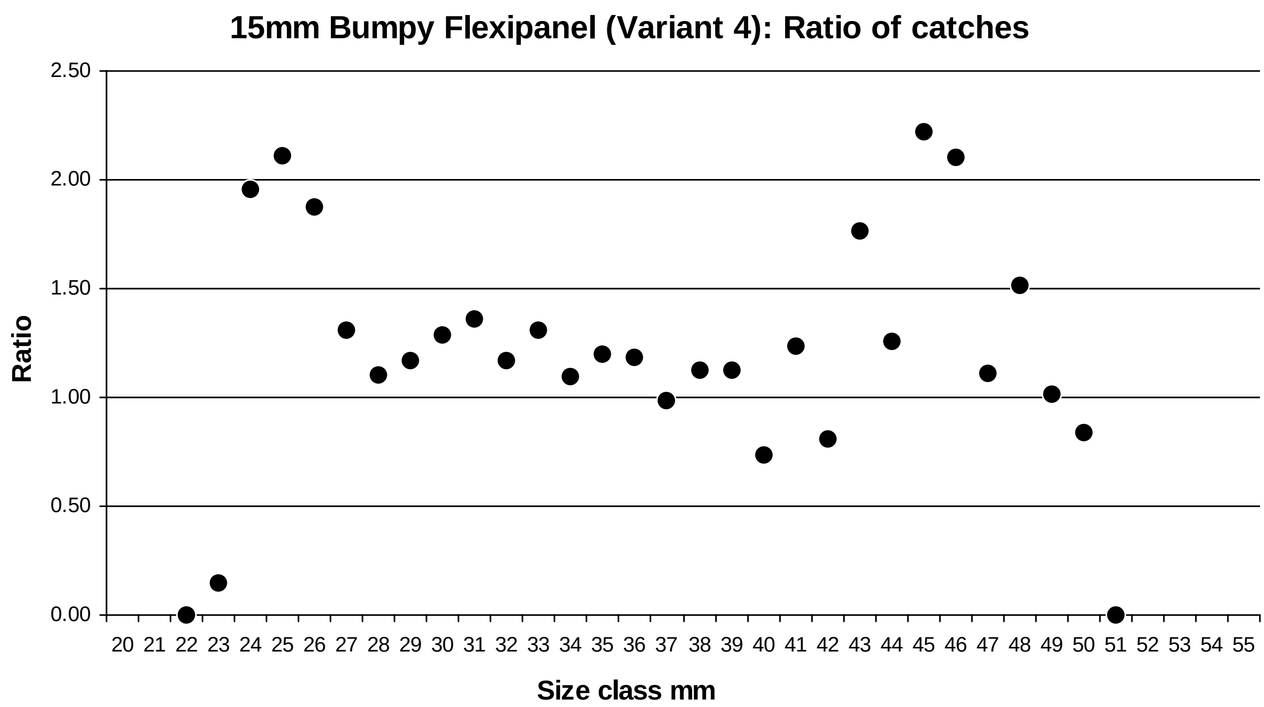


Figure 12a Illustrating how the ratio of catches between modified gear (Variant 4) and standard gear changes with respect to size class (selectivity)

5 Discussion

1. On a haul by haul basis, none of the gear variants examined in this study had any different catches when compared with the standard gear.

2. When the ratio of catches from modified and standard gears for each size class (4.3, equation 1) is plotted against size class, there is no evidence of selectivity (figures 9a to 12a). However, there is some evidence of differences in the overall catches for each gear variant.

The variation in catch between the modified and standard gears was small, compared with the variation between hauls. It is possible that there could be some selectivity occurring, but, in that case, having 6 replicates for each variant was insufficient to properly detect this. Future work might benefit from having more replicates with each gear type.

It is possible that the trawl itself had somehow become changed, due to the presence of the gear modification. However, this is difficult to account for and difficult to speculate further about.

5.1 Crew Selectivity

The market requirements for prawn sizes can be determined from examining how the fishing crew sorted the marketable prawns from the discarded prawns. It was therefore possible to establish the 'crew selectivity' from what was retained and what was discarded:

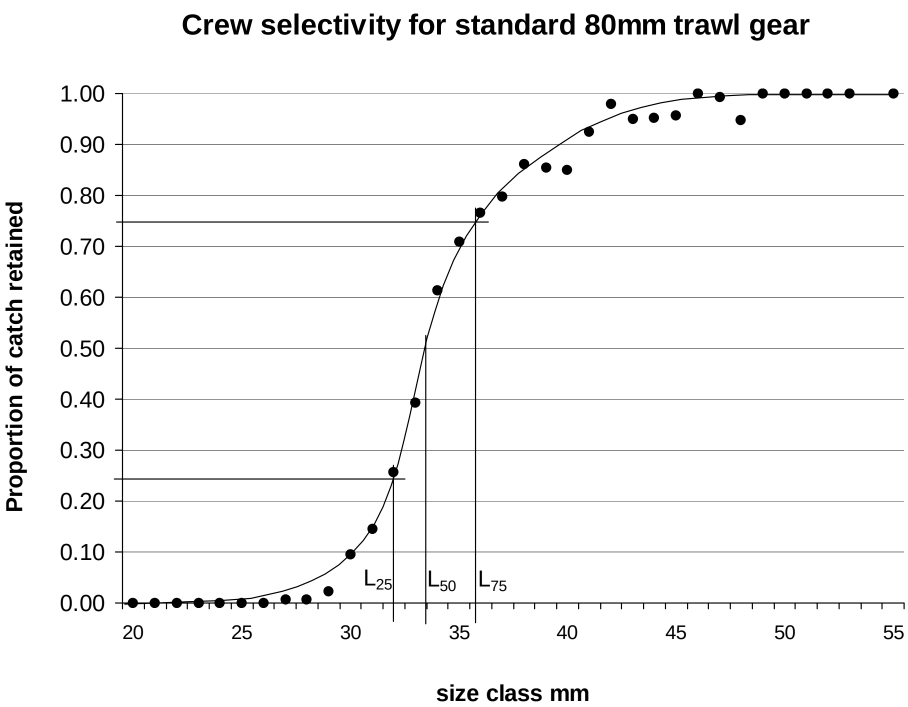


Figure 13 Illustrating the crew selectivity for retaining and discarding of *Nephrops* with 80mm diamond mesh – curve fitted by observation.

5.1.1 Matching trawl selectivity with crew selectivity
A logical step would be to match the size selectivity characteristics of the trawls with the size selectivity requirements of the crew, and hence to the requirements of the market.

From the crew selectivity in figure 13, the L_{50}[1] was about 32.5mm (by observation) and the selection range ($SR=L_{75}-L_{25}$) was about 4mm. The ideal fishing gear, for this case, would have these selectivity characteristics.

It should be acknowledged that the criteria which crews use for discarding are likely to change, depending on market requirements, operational constraints and minimum landing sizes in force in the area of operation. Nevertheless, having a trawl which has selectivity characteristics (L_{50} and SR) approximating to the requirements of the market could bring benefits to fishing crews (see Introduction).

5.1.2 Tailing *Nephrops*
Fishermen in the UK have the practice of ‘tailing’ small prawns which measure just above the minimum landing size[2]. Tailing is the removal of the *Nephrops* tails for landing, and the heads are discarded. In this way, fishermen can often get a better price for very small prawns (which would otherwise be wasted) than by landing them whole. Tailing is a very labour-intensive process that is usually disliked by fishing crews. Improving the size selectivity, and therefore improving the value, of a *Nephrops* fishery could influence the market, and perhaps lead to this practice becoming unnecessary. In this study, no tails were landed, but any *Nephrops* of tailable size were quantified to produce the graph shown in figure 13 previously.

5.2 Other means of improving size selectivity of *Nephrops* trawls
A review of the literature showed that a limited number of other studies have been completed on size selectivity for *Nephrops* using different fishing gear types. Table 1 shows the selectivity characteristics of each of the different fishing gear types, ranked in order of selection range (SR), i.e. those gears with the narrowest selection range (most selective) are listed first.

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[1] L_{50} is that length at which 50% of the catch is retained; L_{25} is that length at which 25% of the catch is retained, and L_{75} is that length at which 75% of the catch is retained. The selection range (SR) is the difference between the L_{75} and the L_{25}.

[2] Minimum sizes for *Nephrops* in the North Sea (except ICES areas VIa, VIIa and Region 3) are 25mm carapace length, 85mm whole length, and 46mm for ‘tails’. In ICES areas VIa, VIIa and Region 3, minimum sizes are 20mm carapace length, 70mm whole length, and 37mm for ‘tails’. In the Skagerrak, minumum sizes are 40mm carapace length, 130mm whole length (current at 2004). EU Technical Regulation 850/98.

No	Mesh size or bar spacing	Device	Number of mesh in circumference	Sampling method	No. of hauls	**L50**	95% confidence limits	**SR L75-L25**	95% confidence limits	Reference (list number)
1	22.4mm	Grid, metal, bottom-hung	na	Triple trawl	2	**38.5mm**	35.0-51.4mm	**7.8mm**	3.2-14.7mm	Valdemarsen, 1996 (11)
2	21.7mm	Grid, composite, bottom-hung	na	Triple trawl	5	**33.9mm**	32.5-35.8mm	**7.8mm**	5.9-9.9mm	Valdemarsen, 1996 (11)
3	22.4mm	Grid, metal, bottom-hung	na	Cover	2	**34.8mm**	33.7-35.6mm	**8.4mm**	6.8-10.0mm	Valdemarsen, 1996 (11)
4	21.7mm	Grid, composite, bottom-hung	na	Cover	18	**31.4mm**	30.6-32.0mm	**8.4mm**	7.4-9.4mm	Valdemarsen, 1996 (11)
5	70mm	Diamond mesh cod-end	100	Covered cod-end	13	**22.2mm**	21.6-22.7mm	**10.5mm**	9.8-11.2mm	EU Study contract FAIR-CT95-0753 (12)
6	22.4mm	Grid, metal, bottom-hung	na	Triple trawl	2	**40.4mm**	38.6-43.4mm	**11.2mm**	6.9-15.4mm	Valdemarsen, 1996 (11)
7	60mm	Square mesh cod-end	100	Twin-rig trawl	24	**32.2mm**	31.3-33.2mm	**11.9mm**	9.2-14.6mm	Ulmestrand & Valentinsson (in prep) (10)
8	20mm	Flexible plastic grille, bottom hung in a pocket	120	Cover	-	**31.0mm**	-	**12.0mm**	-	Larnaud, P. *et al,* 2004, in prep. ASCGG study, IFREMER / COFREPECHE 2004 (7)
9	60mm	Square mesh cod-end	100	Covered cod-end	15	**25.4mm**	25.1-25.8mm	**12.4mm**	11.8-13.1mm	EU Study contract FAIR-CT95-0753 (12)
10	22.4mm	Grid, metal, top-hung	na	Cover	10	**37.2mm**	36.6-37.7mm	**12.8mm**	11.3-14.3mm	Valdemarsen, 1996 (11)
11	70mm	Diamond mesh cod-end	100	Twin-rig trawl	28	**19.8mm**	14.4-22.5mm	**13.5mm**	8.6-18.4mm	Ulmestrand, 1996 (in 12)
12	21.7mm	Grid, composite, top-hung	na	Cover	8	**33.7mm**	31.7-35.2mm	**13.9mm**	9.6-18.3mm	Valdemarsen, 1996 (11)
13	60mm	Square mesh cod-end	65	Twin-rig trawl	17	**39.7mm**	39.2-40.3mm	**14.5mm**	13.3-14.7mm	Larsvik & Ulmestrand, 1992 (8)
14	21.7mm	Grid, composite, bottom-hung	na	Triple trawl	14	**36.9mm**	35.8-38.1mm	**14.5mm**	11.2-17.8mm	Valdemarsen, 1996 (11)
15	70mm	Diamond mesh cod-end	100	Covered cod-end	7	**18.2mm**	16.3-19.8mm	**15.6mm**	13.7-17.5mm	Ulmestrand & Valentinsson (in prep) (10)
16	60mm	Square mesh cod-end	100	Covered cod-end	5	**25.9mm**	24.6-27.0mm	**16.9mm**	14.7-19.0mm	Ulmestrand & Valentinsson (in prep) (10)
17	100mm	Diamond mesh cod-end	100	Covered cod-end	9	**24.5mm**	23.5-25.4mm	**20.3mm**	18.2-22.3mm	EU Study contract FAIR-CT95-0753 (12)
18	18mm	Flexible plastic grille, bottom hung in a pocket	120	Cover	-	**28.0mm**	-	**23.0mm**	-	Larnaud, P. *et al,* 2004, in prep. ASCGG study, IFREMER / COFREPECHE 2004 (7)
19	100mm	Diamond mesh cod-end, 5mm double twine	100	-	-	**26.7mm**	-	**-**	-	Anon., Industry/Science Partnership for Scotland Volume 1 (1)
20	25mm	Flexipanel with 25mm gaps, Variant 1	Equivalent to 100 diamond mesh in 80mm	Twin-rig trawl	6	**not found**	-	**not found**	-	This study
21	80mm	T90° cod-end, PE material, Variant 2	50	Twin-rig trawl	6	**not found**	-	**not found**	-	This study
22	80mm	T90° Lower panel in Dyneema, Variant 3	Equivalent to 100 diamond mesh in 80mm	Twin-rig trawl	6	**not found**	-	**not found**	-	This study
23	15mm	Flexipanel with 15mm gaps and bumps, Variant 4	Equivalent to 100 diamond mesh in 80mm	Twin-rig trawl	6	**not found**	-	**not found**	-	This study

Table 1 ***Nephrops*** **size selectivity: The range of devices tested in other studies, ranked by Selection Range (SR)**

The gear used in other *Nephrops* size selectivity studies can be divided into the following types:

1. Inclined grids and grilles
2. Square mesh cod-ends
3. Diamond mesh cod-ends

From Table 1, the gear type having selectivity characteristics which most closely match the crew selectivity identified in this study (see figure 13) is an inclined grid, with bar spacings of 22.4mm (see Table 1, No.1 & No.6, (Valdemarsen, 1996)) (11).

5.2.1 Inclined Grids

There are two kinds of inclined grid used in other studies: those that are mounted from the top surface of the net and hang downwards, and those that are mounted from the lower surface of the net. However, the L_{50} values was found to be similar for each type of mounting (Valdemarsen, 1996) (11), but the selection range values for the lower position were found to be from 34% to 40% less than for the upper position. The slope angle of the grids ranged from 30° to 45° but there was insufficient data to identify an optimum slope angle from the other studies.

Grids in other studies were made of metal, plastic or composite materials. The preliminary results from an extensive study in the Bay of Biscay, France (Larnaud, P. *et al*, 2004, in prep.) (7) showed good *Nephrops* size selectivity with a flexible grille made from plastic and installed in the lower part of the trawl extension with a slope angle of 45°, ahead of the cod-end.

One of the problems identified in other studies with grids appears to be the fact that they have a tendency to become obstructed with mud and seabed debris (Frid *et al.* 2001) (4); (Graham, 2004, pers. comm.). It is possible that the selectivity characteristics of a grid may therefore change during a towing period.

Another problem identified with grids is that the mesh around the periphery of the grid tends to be wide open. This allows a fraction of the *Nephrops* catch to escape before it encounters the grid.

5.2.2 Square mesh codends

Size selectivity data for Nephrops has been obtained with square mesh cod-ends in other studies by Ulmestrand and Valentinsson (2003, in prep) (10), Larsvik and Ulmestrand (1992) (8), and Wileman *et al.* (1999) (12). It is interesting to note that the Industry Working Group for this study did not endorse the idea of square mesh cod-ends for *Nephrops* size selectivity (Appendix II, point 7). Table 1 (No.7) shows selectivity characteristics obtained with 60mm square mesh codends of L_{50}=32.2 and SR=11.9 (Ulmestrand & Valentinsson 2004, in prep.) (10). Square mesh could therefore be a viable option for using in the North Sea *Nephrops* fishery.

5.2.3 Diamond mesh cod-ends

Trials with diamond mesh cod-ends in other studies tended to give higher SR values than either grids and grilles or square mesh cod-ends (i.e. tended to be less selective). Results from diamond mesh showed the least consistent selectivity characteristics. One study (Wileman *et al.* 1999) gave a 2mm difference in L50 values (22.2mm & 24.5mm) for a 30mm difference in mesh size (75mm and 100mm) (Table 1, No. 5 & 17). For this change in mesh size there was a corresponding change in selection range from 10.5mm to 20.3mm, i.e. a small change in L_{50} showed a disproportionately large change in selection range.

6 Conclusions

1. None of the gear types under test showed any detectable selectivity characteristics for *Nephrops.*

2. There is evidence to suggest that 6 replicates for each gear type was insufficient to detect any selectivity characteristics for each type.

3. All the gear types, except variant 2, were panels mounted in the lower part of the extension section of the trawl. It is likely that *Nephrops* are passing over these panels without having any interaction with them. Variant 2 was a T90 (mesh turned through 90°) cod-end made from polyethylene twine, but it also exhibited no detectable selectivity characteristics for *Nephrops.* Either there was no interaction with it, or the morphology of *Nephrops* prevents escape through the T90 polyethylene mesh.

4. There is limited information from other studies which shows that it is possible to quantify and to modify the selectivity characteristics for *Nephrops* with square mesh cod-ends, inclined grids and grilles, and diamond mesh cod-ends.

5. The most successful gear types from other studies tended to be inclined grids and grilles (see table 1). However, there is concern that grids and grilles might become obscured with mud and other debris under certain fishing conditions, and lose their beneficial selectivity properties.

6. By examining catches of *Nephrops* caught with standard 80mm codends, it was possible to establish the ‘crew selectivity’ from what was retained and what was discarded. The selectivity characteristic of the crew is a reflection of the requirements of the market, and should be matched by the selectivity characteristic of the gear (see 5.1 *Crew Selectivity*).

7 Recommendations

1. Variant 5 (T90 cod-end in thin, high tenacity, 80mm mesh Dyneema[TM] twine) was not properly evaluated during this study, due to operational constraints. It is therefore recommended to carry out a further evaluation of this device under more rigorous experimental conditions.

2. A recent French study (Larnaud *et al.* 2004, in prep.) has improved *Nephrops* selectivity by using a simple, flexible plastic grille. It might be possible to adapt and test a grille of similar design with appropriate bar spacings for the UK markets that purchase North Sea *Nephrops.*

3. It is recommended to construct and test an inclined grid device, fabricated from the same material that was used in the construction of the Flexipanel[TM] gear types. A Flexipanel[TM] inclined grille would be very easy to handle onboard a fishing vessel, and would require only minor modifications to install.

8 References

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12. Wileman, D.A., Sangster, G.I., Breen, M., Ulmestrand, M., Soldal, A.V., Harris R.R. 1999, Roundfish and *Nephrops* survival after escape from commercial fishing gear, final report, EC Contract No: FAIR-CT95-0753.

APPENDICES

APPENDIX I

Investigating technical measures
for the improvement of Nephrops size selectivity in trawls

An industry-centred conservation project funded through the Financial Instrument for Fisheries Guidance (FIFG) programme, administered by DEFRA

Statistical assessment
Fisheries Development Centre, Tuesday September 9th 2003

DEFRA has requested that Seafish undertakes to have the FIFG *Nephrops* selectivity study proposal assessed by an accredited statistician, in accordance with current standard practice. A meeting was held at the Fisheries Development Centre on Tuesday September 9th 2003 to hear the statistical assessor's remarks on the project proposal document.

Present:

Allan Reese, CStat, Independent Statistical Assessor
Bill Lart, Resource Development Officer
Julian Swarbrick, Gear Technologist (IT)

At the meeting, it was made clear to all that the proposed project was intended to be a scoping exercise which would establish areas for precise study in future work. Mr Reese was able to offer approval of the structure of the project, subject to the following 7 points (not all of which are statistical) that came out of a productive discussion:

1. The types of gear to be tested would need to be clearly defined, succinctly described and listed. The number of types under test must be kept small.

2. Because the trial is intended to demonstrate effects that can be subsequently investigated, the gear types might be configured at their most extreme, for example, using only the largest mesh of Flexi-panel™ at this stage.

3. The test gear types need to be prioritised into the allocated sea-trial time, and a protocol set out to define when and how the gear should be changed. (After a set number of hours, hauls, or whatever.)

4. Seafish should avoid diverting effort into considering finfish selectivity and just concentrate on *Nephrops* selectivity in the test gear designs. This means that if the experiments are concerned with making changes to selectivity in the lower half of the net for *Nephrops*, then no changes should be made in the upper half that could affect selectivity.

5. Alternating the control net from port to starboard sides of the twin-rig configuration would help to control for bias that might occur due to position in the twin-rig arrangement. The proposed tests of four rigs would allow two controls on each side, thus controlling additionally for time effects through the trial.

6. The data to be collected per haul need precise definition. The proposal implies that some length-frequency samples will be made of *Nephrops*, as well as gross weights and counts of numbers per unit weight. It was appreciated that measuring prawns would take up a lot of staff time, but such data are fundamental to a selectivity trial.

7. It is very desirable to check that each net is covering the same width of ground. To achieve that, the wing-end spreads of each net could be monitored with Scanmar sensors.

APPENDIX II

Investigating technical measures
for the improvement of Nephrops size selectivity in trawls

An industry-centred conservation project funded through the Financial Instrument for Fisheries Guidance (FIFG) programme, administered by DEFRA

A meeting with Industry Representatives held at the Thistle Hotel,
Aberdeen Airport, December 12th 2003

AGENDA

1. Project timescale and steps
2. Seafish proposals and the Flexi-panel system
3. Other possible configurations to be examined
4. Configurations to try at sea
5. Mesh sizes, bar spacings, twine diameters and panel sizes
6. Manufacture of the test gear
7. Date of next meeting at the FDC Flume Tank
8. AOB

MINUTES

Present:

Frank Armstrong, Skipper
Gary Dunlin, Gear Technologist, Seafish (Chair)
William Hepburn, Netmaker, Faithlie Trawls
John Smith, Skipper (retired),
George Jack, Skipper
Gordon Johnson, Grading Systems Ltd. of Shetland
Julian Swarbrick, Gear Technologist, Seafish

Apologies:

Walter Hay, Netmaker, Stuart Nets

The meeting opened at 14:30.

Gordon Johnson of Grading Systems Ltd. showed a section of Flexi-panel™ and described some of its applications.The team was of the consensus that prawns needed to be able to fall through the spacings in a selectivity device, rather than actively seek escape. The tubes in the panel can be made in diameters down to 20mm to allow for the internal securing toggle.

Seafish suggested there be about 3 different gear types to test, which would afford about 2 sea days each, all being well.

W. Hepburn indicated that 'mudding up' of the tubes in the grid might be a potential problem. The possibility of having smaller diameter tubing (15mm) to avoid this would be investigated by Grading Systems Ltd.

The team acknowledged that only the lower half of the extension requires to be altered – not the top half.

Some discussion was held regarding gap size to be used. 10mm was discussed as a starting point to allow for any 'riddling' effect. It was also seen as being a sufficiently conservative starting point to avoid loss of marketable *Nephrops.* 10mm, 12mm and 15mm gaps were all put forwards as candidate sizes to be tested in grids in the flume tank and to be reconsidered at a future meeting for sea trials. Grading Systems Ltd. offered to provide three samples with each of these gap spacings.

J. Smith raised the questionable legality of an escape grid – how would it be measured? Is it legal – would it require derogation for use?

Three other suggestions were put forwards for testing – hexagonal mesh, normal diamond netting at 90° and thin twine, double knot Dyneema^{TM} diamond netting at 90°. All these to be made at regulation minimum stretched mesh size.

It was decided that an ideal objective for a selectivity device would be to reduce bulk catches by at least 30% for the same amount of retained catch. Currently, some Group members were experiencing 50% discard rates, and catches with counts of 100 per pound (45 per kg).

Agreed points for action:

1. Four potential selectivity devices to be investigated in the project:

Device 1:
The Flexi-panel^{TM} (Grading Systems Ltd. of Shetland) as a panel 3m x 1m, gaps as specified.

Device 2:
Hexagonal mesh. A panel of this material to be tested in the flume tank, with a full-scale panel equivalent size of 3m x 1m. Performance of this material is to be evaluated at the next meeting when considering the sea trials.

Device 3:
Normal diamond mesh turned through 90° as a panel 3m x 1m, in the regulation minimum size for diamond mesh (80mm) in *Nephrops* trawls.

Device 4:
Double knotted, thin Dyneema^{TM} mesh turned through 90° as a panel 3m x 1m, in the regulation minimum size for diamond mesh in *Nephrops* trawls.

2. Gordon Johnson of Grading Systems Ltd. to investigate the feasibility of using a 15mm pipe diameter in place of the current 20mm diameter, to reduce the potential for mud ingress into the Flexi-panel^{TM} array.

3. The trial spacings between the Flexi-panel^{TM} bars to include 10mm, 12mm and 15mm.

4. Gordon Johnson of Grading Systems Ltd. to supply three prototype panels to the FDC as 1m x 1m sections, each with one of the above bar spacings, by week ending Jan 10th 2004.

5. Length of bars in the Flexi-panel^{TM} to be 150mm, purely as a convenient starting point. This to be monitored during the trials and any need for a change in length to be identified then.

6. The size of all selectivity panels to be the same, at 3m long x approx. 1m wide. It was suggested that a row of factory-fitted meshes to the leading and trailing edges of the Flexi-panel^{TM} device would greatly assist its proper fitting in a trawl.

7. It was considered that full square mesh cod-ends would not be viable and therefore not to be investigated further.

8. It was agreed that the panels should be rigged by the Seafish FDC, due to the small amount of materials involved.

9. The Clyde, the Farne Deeps and the northeast North Sea (Fladen Grounds) were all identified as areas having mixed prawn sizes in which to conduct sea trials around March 2004.

10. It was agreed to hold one meeting at the FDC Flume Tank, at which examples of all four of the test options could be evaluated. Date of this to be around the first week of February 2004 (subject to the availability of the tank).

The meeting closed at 16:15

APPENDIX III

Trials log of hauls: MFV *Heather Sprig* BCK181, March 02nd – March 11th 2004

Haul No.	Date	Time shot	Time Hauled	Position shot	Position hauled	Test gear variant	Position of test gear	Depth (m)
1	2-Mar-04	4:45	9:45	58º12'N 0º25'E	58º16'N 0º41'E	Variant 1 25mm flexipanel	starboard	150m
2	2-Mar-04	10:15	14:15	58º16'N 0º42'E	58º12'N 0º26'E		starboard	150m
3	2-Mar-04	15:00	19:00	58º12'N 0º26'E	25º16'N 0º42'E		starboard	150m
4	3-Mar-04	5:00	9:00	58º12'N 0º25'E	58º16'N 0º40'E		port	150m
5	3-Mar-04	12:00	16:00	58º16'N 0º39'E	58º11'N 0º25'E		port	150m
6	3-Mar-04	17:00	21:00	58º12'N 0º26'E	58º16'N 0º42'E		port	150m
7	4-Mar-04	5:00	9:00	58º20'N 0º32'E	58º20'N 0º14'E	Variant 2 90º PE cod-end	starboard	150m
8	4-Mar-04	10:00	14:00	58º20'N 0º16'E	58º19'N 0º33'E		starboard	150m
9	4-Mar-04	15:00	19:00	58º19'N 0º31'E	58º20'N 0º14'E		starboard	150m
10	5-Mar-04	5:00	9:00	58º20'N 0º34'E	58º20'N 0º17'E		port	150m
11	5-Mar-04	10:15	14:15	58º20'N 0º18'E	58º17'N 0º33'E		port	150m
12	5-Mar-04	15:00	19:00	58º17'N 0º33'E	58º19'N 0º18'E		port	150m
13	6-Mar-04	0:01	4:00	58º20'N 0º19'E	58º18'N 0º33'E	Variant 3 90º Dyneema panel	starboard	150m
14	6-Mar-04	5:00	9:00	58º18'N 0º33'E	58º20'N 0º15'E		starboard	150m
15	6-Mar-04	10:00	14:00	58º19'N 0º17'E	58º19'N 0º33'E		starboard	150m
16	6-Mar-04	16:00	20:00	58º19'N 0º32'E	58º20'N 0º14'E		port	150m
17	6-Mar-04	21:00	1:00	58º20'N 0º14'E	58º18'N 0º35'E		port	150m
18*	7-Mar-04	2:00	6:00	58º18'N 0º35'E	58º21'N 0º11'E		port	150m
19	8-Mar-04	6:30	10:30	58º20'N 0º14'E	58º19'N 0º32'E	Variant 4 15mm bumpy flexipanel	port	150m
20	8-Mar-04	11:05	15:05	58º20'N 0º30'E	58º20'N 0º13'E		port	150m
21	8-Mar-04	15:40	19:40	58º20'N 0º14'E	58º20'N 0º31'E		port	150m
22	9-Mar-04	4:55	8:55	58º20'N 0º31'E	58º20'N 0º12'E		starboard	150m
23	9-Mar-04	9:30	13:30	58º20'N 0º14'E	58º20'N 0º31'E		starboard	150m
24	9-Mar-04	14:15	18:15	58º20'N 0º30'E	58º21'N 0º11'E		starboard	150m
25	10-Mar-04	5:20	9:20	57º48'N 2º19'W	57º46'N 2º37'W	Variant 5 90º Dyneema cod-end	starboard	55m
26	10-Mar-04	10:00	14:00	57º47'N 2º39'W	57º52'N 2º51'W		starboard	55m
27	10-Mar-04	14:40	18:40	57º52'N 2º50'W	57º50'N 2º33'W		starboard	55m
28	11-Mar-04	3:55	7:35	57º48'N 2º19'W	57º46'N 2º36'W		port	105m
29	11-Mar-04	8:05	12:05	57º46'N 2º35'W	57º48'N 2º19'W		port	105m
30	11-Mar-04	12:50	15:10	57º48'N 2º21'W	57º45'N 2º29'W		port	105m

*Halfway point of the trial. Steamed for Peterhead at 07:00; arrived 16:00. Returned to grounds 06:00 on 8 March.