Reducing Drag in Towed fishing Gears-

Fishing Trials to Evaluate the Performance of a Trawl Constructed from T90 (‘*turned mesh’*) Netting

Date: February 2008

Author: Ken Arkley

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Working with the seafood industry to satisfy consumers, raise standards, improve efficiency and secure a sustainable future.

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ISBN No. 0 903941 89 9

SEAFISH Research and Development

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Fishing Trials to Evaluate the Performance of a Trawl Constructed fromT90 (*'turned mesh'*) Netting

Summary:

This report describes a demonstration trial of a single-rig, demersal whitefish *'Rockhopper'* trawl constructed entirely of T90 or *'turned mesh'* netting. This is the first time that T90 technology has been used in this way in the UK.

The trawl used for this trial was designed and constructed by Icelandic trawl manufacturer, *Fjardanet* which has been pioneering this technology for a number of years. Descriptions of the fishing gear used are included. The report describes some background to the development work and the concept of T90 technology.

Eight days of commercial fishing trials were carried out in January 2008 using the Shetland based vessel *Mizpah* operating on local fishing grounds about 50 miles NE of Lerwick. Despite being hampered by poor weather a total of 21 hauls were completed.

The aim of the trials was to evaluate the performance of the T90 trawl with reference to fuel savings as a result of the reduced netting drag associated with this technology. This was done by measuring the main gear performance parameters and comparing them with those of the vessel's existing gear of the same general dimensions.

Some catch sampling was undertaken to examine other reported attributes of T90 trawls such improved catch rates, size selection and catch quality.

From a gear performance perspective the T90 trawl compared well with the vessel's own trawl. The information gathered on the fuel efficiency aspects of the gear however did not show any significant benefits from the T90 trawl despite indications that the netting drag had been considerably reduced, (~20%).

The findings from the catch data were inconclusive. There were some indications of larger size ranges of some species being caught and retained by the T90 trawl but the findings did not appear to bear out the findings and experiences of the Icelandic fishermen to the same extent. There was more loss of marketable size grades of some species, particularly whiting associated with the T90 trawl. This was thought to be as a result of the more consistent mesh opening noted throughout the T90 trawl. The positive side of this was that there were no discards recorded. There was no noticeable difference in catch quality detected.

The results showed that the combination of the T90 trawl fitted with a conventional diamond mesh codend of the same mesh size produced the best commercial results.

The results were insufficient to draw any firm conclusions on the overall effectiveness of the T90 trawl and a number of proposals for further work have been highlighted.

Table of Contents:

1. Introduction

The catching sector of the UK fishing industry, through the two main national federations, (National Federation of Fishermen's Organisations, NFFO and the Scottish Fishermen's federation, SFF) have asked Government to collaborate in developing practical ways of assisting the UK fleet to survive the transition to the new era of high fuel costs.

On a wider scale, the European Commission has been asked by a wide range of European fisheries stakeholders to support research and development projects into increasing fuel efficiency in fishing operations. This includes applying new technologies with a view to decreasing fuel consumption e.g. reducing the overall drag of fishing gears.

SEAFISH is collaborating with the catching sector to identify ways to reduce fuel dependency and to help disseminate the results/information throughout the industry.

The project described in this report is part of a SEAFISH programme of work aimed at reducing the environmental impact of fishing operations. Areas of investigation include: improvements to fuel efficiency, (by reducing the overall drag of fishing gears); improving selectivity; reducing benthic impact; reducing wastage and improving catch quality.

SEAFISH is continually investigating and developing ideas that contribute to achieving this aim. Technologies that have the potential for addressing more than one of these areas at any one time are considered 'value for money' and worthy of attention. The use of T90 or 'turned mesh' netting for whole trawl construction was identified as having the potential to meet a lot of the programme aims.

The project concentrated on improving fuel efficiency by examining a means of reducing the biggest contributory factor to the overall drag of the fishing gear i.e. the netting itself. In demersal towed gear the trawl netting can contribute up to 50% of the overall drag of the system.

Although the primary objective was to investigate potential fuel savings through drag reduction, other attributes of this technology were also examined. The aim was to demonstrate benefits of the T90 technology to UK skippers as a viable approach to improving the efficiency of their gear. This is from the point of view of reducing drag, whilst at the same time demonstrating the potential of the technology for improving selectivity and catch quality.

T90 technology takes advantage of increased mesh opening for a given mesh size when compared with conventional netting configurations. This results in the use of less netting material for a given size of fishing gear, hence the potential for reductions in drag. The selectivity benefits of using 'turned mesh' or T90 netting have been acknowledged for some years now. Other benefits such as improved water flow and catch quality have been investigated more recently.

The T90 technology has been developed for whole trawl application by the Icelandic trawl manufacturer *Fjardanet. Fjardanet* is based in Akureyri in Northern Iceland

and is part of the *Hampidjan* group. To date (February 2008), *Fjardanet* has produced 21 full trawls and supplied numerous trawl sections constructed from T90 netting to Icelandic skippers. Icelandic experiences have demonstrated improved catches, improved catch quality and fuel savings as a result of the reduced gear drag. The commercial success of the *Fjardanet* trawl designs and the experiences of Icelandic fishermen using them, prompted SEAFISH to investigate this technology for UK application.

2. Background

The concept of *'turned mesh'* or T90 technology is not new. The selectivity of T90 netting has been investigated since the late 1980s. Previous investigations have concentrated on the application of this netting configuration for use in codends and extension sections as a means of improving size selectivity. More recently, the emphasis has changed to investigating the drag characteristics of this material and the potential fuel saving as a result of incorporating the netting into other sections of a trawl.

The Icelandic net manufacturer *Fjardanet* based in Akureyri, supported by its parent company *Hampidjan* took the development a number of stages further by producing a full commercial trawl design in T90 netting.

Fjardanet has been working with *'turned mesh'* netting for the construction of both demersal and pelagic trawl codends, extensions and belly sections for a number of years. It was their net designer and marketing manager, Hermann Gudmundsson that came up with the idea and the design for a full trawl constructed in T90 mesh. This was following their experiences and positive feedback from skippers using T90 netting in the bellies and codends of groundfish trawls targeting cod. They found that the new designs filtered out large proportions of undersize cod and the nets had the added benefit of being easier to tow.

Following encouraging results from scale model tests in the SINTEF Flume Tank in Hirtshals, Denmark, *Fjardanet* was confident enough to go into full scale trials which were conducted on board the Icelandic Marine Institute's research vessel (FRV *Arni Fridriksson*).

Supported by underwater observation and filming of the gear in operation, the trials enabled minor adjustments and modifications to be made to the prototype trawl prior to full commercial evaluation. This was carried out by putting the trawl on board a trawler belonging to the Icelandic Fish capture/processing company *Samherji HF* on a 'sale or return' basis.

The skipper was completely satisfied with the performance of the trawl and compared to the vessels standard gear caught more and better quality fish.

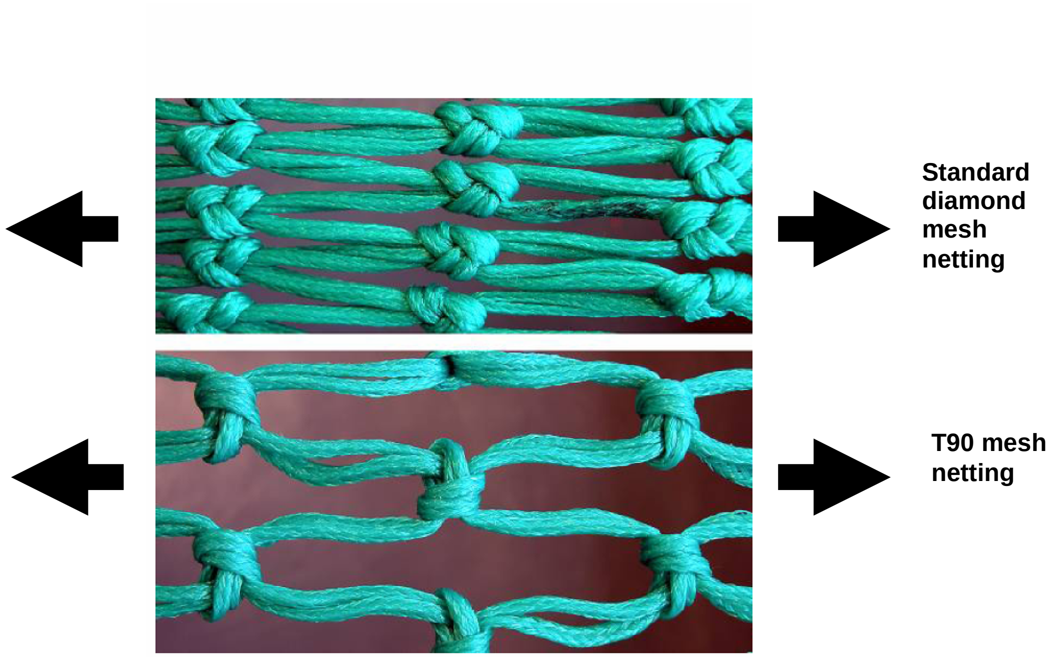
The skipper commented on the ease at which the net was towed compared to a standard trawl of the same headline/groundgear length. This is not surprising considering that the amount of netting required for the construction of a T90 trawl is significantly less than with standard diamond meshes. Approximately one-third less netting is required, thus reducing the twine surface area and drag of the netting.

Fjardanet continues to produce full T90 groundfish trawls for Icelandic skippers with more and more showing considerable interest.

2.1. Mechanical properties

The introduction of new netting configurations for the construction of fishing gear, for whatever reason; (improving selectivity, reducing netting drag etc.) invariably raises questions from gear technologists and fishermen alike about the practicalities and usability of the new materials. The main concern is usually that of strength.

With T90 netting, which results in changing the direction of stretching forces acting on the turned meshes, the stability of the meshes must be established as being at least comparable with that of conventional netting if it is to be acceptable as a practical alternative. Knot slippage resulting in changes in mesh size and mesh deformation is unacceptable from the point of view of both selectivity and gear performance.



Photograph courtesy SINTEF

Turning meshes through 90º does not result in the decrease of their resistance to breaking force. An increase of tensile force has been registered of about 10% to 25% for meshes of 1.1mm to 1.8mm bar thickness, respectively.

Trials ([1] *Moderhak 2000*) have demonstrated that the common perception that turned mesh netting is weaker, (lower resistance to tensile force) than conventional netting is not the case. As expected, the resistance to tensile force varies with twine diameter but is not affected by mesh bar length. However, factors such as material type, quality and treatment do influence tensile strength. The knots used in the construction of the netting play an important role in the process of stretching as they act as a sort of 'shock absorber' delaying the point at which the mesh twine breaks. It appears that the knot in the 'turned mesh' configuration provides better resistance to the shearing forces involved in mesh breakage.

More recent testing ([2] *Moderhak and Niemiro 2005*) confirmed earlier findings ([1] *Moderhak 2000*) indicating increased breaking strength of T90 meshes as compared with standard meshes in the range of 10% - 25% depending on netting material and twine diameter. Turning conventional netting through 90º increases the elasticity of the mesh, in particular netting constructed of PE twine.

The wider opening of the meshes achieved by the T90 configuration, (due in part to the construction of the knot and partly to the orientation of the mesh bars as they come away from the knot), results in a codend with a relatively large circumference and cross-sectional area. This produces a much more stable codend in a water flow when compared to narrow, standard diamond mesh constructions.

(1) Moderhak, W. 2000. Preliminary investigations of the mechanical properties of meshes turned through 90º. Bull. Sea Fish. Inst., Gdynia, 1 (149): 11-15

(2) Moderhak, W. and T. Niemiro 2005. Mechanical properties of twine and netting used in Baltic fisheries. Bull. Sea Fish. Inst., Gdynia, 3 (166): 27-37

2.2. Selectivity properties

Research vessel and commercial fishing vessel trials to examine the selectivity of T90 codends have demonstrated improved selectivity is possible for certain species such as cod ([3] *Moderhak 2000*). There are also indications of other benefits such as the ability to capture greater numbers of marketable fish (cod). Reports from commercial experiences (Icelandic fishermen) support these observations.

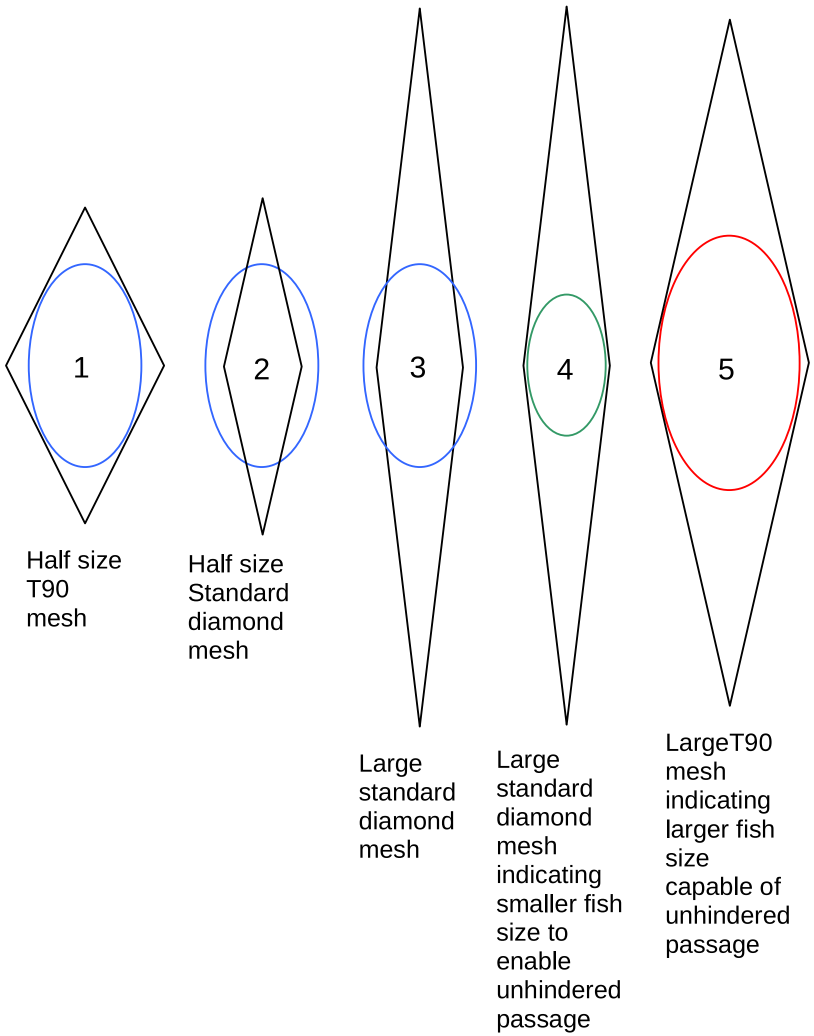
Improved water flow through netting meshes, particularly in the region in and around the codends may significantly improve the selectivity of the gear by stimulating fish inside the codend to follow the increased water flow out through the meshes.

Underwater observations of fish behaviour seem to support the idea of changes to water flow (increased speed) influencing fish reactions to the gear. The two main responses observed are: 1) the fish will tend to turn to face the increased water flow and try to maintain station until exhausted, at which point they fall back towards the end of the net, or : 2) turn with the flow towards the increased outflow through the meshes. At this point, fish size relative to mesh opening will determine whether the fish escapes or is retained.

From a selectivity perspective it is therefore advantageous to be able to manipulate or alter this flow pattern. In simple terms the aim is to allow a greater amount of water to enter the codend and/or to make the passage of water out through the netting easier, the simplest way being to increase and maintain mesh opening in the netting. Increased flow and reduced pressure will help indicate potential escape routes for fish. Investigations on fish (cod) behaviour have shown that increased radial flow rates in certain areas of the trawl (codends in particular) result in greater numbers of fish escaping.

Fish escaping through smaller meshes of a greater opening would sustain less skin/mucous/body damage than those passing through larger, closed meshes.

(3) Moderhak, W. 2000. Selectivity tests of polyamide and polyethylene codends made of netting with meshes turned through 90º.
Bull. Sea Fish. Inst., Gdynia, 1 (149): 17-25



It is possible for a fish of a given size to pass through T90 mesh of a mesh size compatible with its body shape and size without incurring injury/damage caused by forces exerted on the fish by the mesh bars (1)

The same size fish attempting to pass through the same mesh size in standard diamond mesh configuration would have to work against the forces exerted by the mesh bars resulting in removal of protective body slime and/or injury and without guarantee of release (2)

Even by doubling the standard diamond mesh size, the same size fish would still encounter similar problems. However, assuming the same twine constructions throughout the force required to open the mesh would be reduced (3)

On this basis the size of fish which would be able to pass through the larger standard diamond mesh with the same level of ease would be considerably smaller (4)

The equivalent larger mesh size in T90 configuration would allow passage of a much larger fish without incurring damage and/or injury (5)

2.3. Catch quality aspects

Deterioration of fish quality starts from the point of capture, significantly in the area of containment namely the codend. There are often obvious visual indicators of this in the form of scale removal, skin damage and crush injuries etc. However, other damage such as sub-cutaneous bruising, pressure damage to flesh, internal bleeding etc. may not become apparent until the later stages of processing, and by which stage the shelf-life has already been significantly reduced.

The factors that influence this process are, amongst others; the quantity and type of catch retained in the codend; the turbulence from water flow within the codend; the movement of the codend as a result of water flow in and around the codend; the size, rigging and construction material of the codend itself; and the length of time that the catch is exposed to these conditions, i.e. tow duration.

Clearly it is advantageous from a quality perspective to try and keep captured fish alive throughout the whole fishing process, from net to vessel. From a gear technology point of view it is therefore desirable to try and modify gear designs to reduce the effects described above which can have a negative affect on the condition of the fish.

Underwater observations of fishing gears have revealed that codends undergo a lot of vertical and lateral motion, undulating up and down and swaying from side-to-side during the duration of a tow. This creates a lot of the unfavourable conditions for fish within the codends that result in the problems previously identified.

Work has been done ([5]*Hansen et al. 1996,* [6]*Hansen 2004*) to develop codend designs to reduce these adverse effects. Some of the most effective developments have involved the use of T90 netting.

When compared to standard diamond mesh codends, the swinging and oscillation movements of T90 codends during towing are much less apparent. The subsequent motion of the catch within the codend is also significantly reduced ([6]*Hansen 2004*). Changes in towing speed and catch size affect the codend motion and turbulence within the net to a lesser extent than for standard codend designs. With standard netting, as the catch increases there is an increase in drag on the codend. Model experiments indicate that T90 constructions show only marginal or no increase in drag with increasing catch load ([6]*Hansen 2004*).

Improving the conditions within the codend to reduce damage to the catch can clearly have benefits for retained catch quality. These benefits should also apply to escapees. It is reasonable to assume that under improved conditions those fish able to escape should have a better chance of survival thus reducing incidental mortality.

Both commercial experiences (Icelandic fishermen) and scientific research ([1] *Moderhak 2000*) have indicated benefits for catch handling and quality. The condition of the fish in catches from T90 trawls and codends, even from relatively long tow times, has been observed as being significantly and consistently better than that from standard trawls. The catch remains alive for longer when compared to standard trawls. This is related to better water flow through T90 trawls and codends due to the more open nature of the T90 netting. This affects the flow parameters such as water velocity and flow intensity through the netting in general and in particular in the codend ([4]*Moderhak 1993*). This improved water flow is thought to influence the size composition of the fish retained. The larger, generally stronger swimming fish are encouraged into the codend region of the trawl more quickly in this improved flow environment. There appears to be less tendency for the fish to swim forward in the trawl and therefore reduces chance of escape.

Section of a T90 extension showing consistent mesh opening

Another practical benefit of this improved flow is that catches have fewer tendencies to be spread through the main body or the extension of the trawl. This reduces catch handling time and risk of damage by removing the need to shake fish down to the codend prior to emptying.

(4) Moderhak, W. 1993. Some problems of water flow through trawl codends.
ICES C.M. 1993/B: 11

(5) Hansen, U.J., L.H. Knudsen, P. Nielsen & E.M. Andersen, 1996: Development of fishing gear for Fishing Vessel 2000
Danish Institute for Fisheries Technology and Aquaculture (confidential)

(6) Hansen, U.J. 2004. Performance of a trawl codend made from 90º turned netting (T90) compared with that of traditional codends.
ICES FTFB WG meeting, Gydynia, April 20 – 23, 2004

3. Approach

In 2007 SEAFISH Gear Technologists approached the Icelandic net manufacturer *Fjardanet* to obtain information on their development work with T90 trawls and to gather evidence of the commercial performance of their new gear.

During a visit to *Fjardanet* in Akureyri, Iceland, SEAFISH Gear Technologists set up a collaboration arrangement with *Fjardanet's* net designer currently pioneering this technology, to design and construct a whitefish T90 trawl based on a UK trawl design, to be trialled by a UK vessel.

The objective was to demonstrate the T90 concept to UK skippers by transferring the Icelandic technology and evaluating it as a viable means of reducing towed gear drag and assessing its potential for improved selectivity, catch quality and for application to other gear designs and fisheries. Some of these elements were also examined as having potential to improve gear designs for the targeting of squid.

Working with *Fjardanet's* gear designer and Marketing Manager Hermann Gudmundsson, SEAFISH gear technologists designed a demonstration trial of the T90 technology.

The first stage was to identify a suitable vessel and a UK gear design for conversion to T90. Since *Fjardanet's* experience has been almost exclusively with relatively large and powerful Icelandic trawlers, it was decided that the SEAFISH trial should focus on the larger horsepower sector of the UK fleet currently predominantly based in Scotland. SEAFISH put out a request for interested skippers operating single-rig demersal whitefish trawlers in the 750hp to 1000hp category, that were operating 2-panel groundfish 'rockhopper' trawls targeting mixed, demersal finfish species. Following a tender process in July 2007, the Shetland based vessel *MIZPAH* (LK173) skippered by David Robertson was selected to carry out the demonstration trials.

MIZPAH (LK173)

***MIZPAH* (LK173):**

Built: Cambletown 1988
Steel, transom stern, full shelterdeck

Length: 26.88m

Breadth:7.5m

Draft: 3.66m

GRT: 254

Engine: Caterpillar

Power: 578kw/775hp

At the time of the trials the vessel was using trawls produced by *Jackson Trawls* of Peterhead, Scotland. Following discussions with *Jackson Trawls* outlining the objectives of the project, permission was granted for the conversion of a Jackson *'Hopper'* trawl design to T90 configuration.

The brief given to the *Fjardanet* net designer was to produce a T90 version of the vessel's own net allowing a certain amount of design freedom as required by the T90 concept but whilst remaining within the constraint of maintaining the overall frame size, (fishingline lengths) of the original design.
As the project was designed to demonstrate possible reductions in the overall drag of the gear, the net manufacturer was also given some freedom to modify twine diameters (and mesh sizes to some extent), but without compromising the integrity of the gear. Due to differences in trawl design and construction between Icelandic and UK net makers some problems were encountered with material availability when it came to matching netting materials, this resulted in some compromises with regard to mesh size and twine diameters.

Manufacture of the T90 trawl by *Fjardanet* was completed in December 2006

To try and ensure that the Icelandic gear design would be compatible with UK fishing conditions, the net was designed to fit on to a groundgear arrangement typical in size and construction of that being used by the *Mizpah.*

3.1. Gear details

The general rigging arrangement for the trawls used during these trials is shown in figure (1).

The trawl doors used were manufactured by the US firm NETS Systems and were $5m^2$ in area. The trawl doors were rigged with 5 fathom (9.14m) double chain backstraps and connected to the trawl with 30 fathoms (54.86m) of 26mm wire single sweep and 30 fathoms (54.86m) of split bridles. The upper bridle was made up of 18mm wire and the lower bridle of 16mm mid-link chain.

Identical groundgears were used on both nets, (both manufactured by local riggers, LHD Ltd.). The groundgear was a typical *'Rockhopper'* arrangement as used by most vessels operating in Shetland waters (see figure (2)). The rig was made up of 3 main sections; mid; shoulder; and wing or toe sections rigged on 24mm wire.


The mid-section consisted of 1 x 19’10’’ (~6.0m) length of 24mm wire with 24 x 18’’ (457mm) rubber *‘Rockhopper’* discs. The discs were separated by 1 x 7’’ x 7’’ (178mm x 178mm) rubber spacers. Extra weight in the form of 6 x 2kg lead washers was evenly distributed over the length of the centre section.

***‘Rockhopper’* groundgear – mid-section**

The shoulder sections (x 2) were rigged on the same length of wire, half rigged with 18’’ (457mm) *Rockhopper’* discs (x 12) and half rigged with 16’’ (406mm) discs (x 13). The same additional weights were distributed between the same size spacers.

***‘Rockhopper’* groundgear - Shoulder-section**

The wing sections (x 2) consisted of 16 x 16'' (406mm) discs with 2 x 7''x 5'' (178mm x 127mm) spacers between each disc except for the last two discs in each section which were separated by one spacer. Additional weight was added as for the other two sections.

The *toe-end* of the groundgear was finished off with a *'bumper-bobbin'* arrangement forming the connection to the groundgear extension chains (2 x ~10.5m x 16mm mid-link) via a 12'' *'bouncer pin'*. (See photos for details).

The groundgear was attached to the fishingline of the net using 8mm, 3-strand PP/PE rope fastened through the top hole of the '*Rockhopper'* discs.

Both trawls were rigged with the same floatation, namely 58 x 11'' (280mm) deepwater trawl floats evenly spaced over the full length of the headline. These were attached using the same rope used for the groundgear attachment.

Outline schematic diagrams of the two trawls tested during these trials are shown in figure (3).

The mesh sizes for the vessel's own net are given as inside mesh measurements whereas for the *Fjardanet* design they are given as full mesh (knot centre to knot centre).

More detailed information regarding the net designs supplied by the respective net manufacturers has not been included in the report at this stage as a matter of confidentiality. More detailed information on the T90 design will be made available at a later stage after further work has been carried out.

From the Figure (3) it can be seen that both nets were based on the same frame size, i.e. the same headrope and footrope lengths. The T90 conversion involves a reduction in the amount of material used for the construction of the trawl and results in changes to the panel taper rates in some of the netting sections. There were some differences in mesh sizes and twine diameters between the two designs. Problems with material availability as a result of differences in commercial mesh sizes between Icelandic and UK manufacturers resulted in some compromises having to be made. This resulted in the mesh sizes in some panels not being as closely matched as had originally been expected.

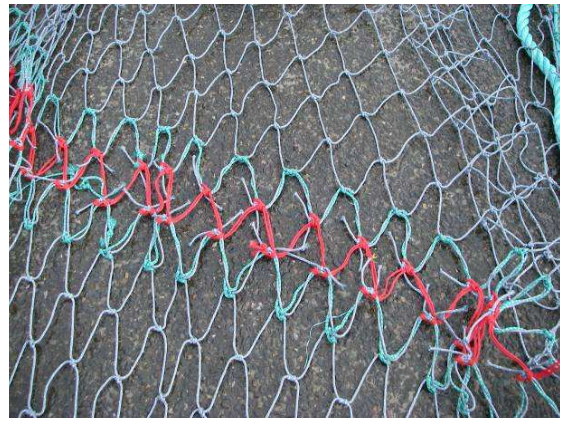
As compromises with mesh sizes had to be accepted, it was felt acceptable that the *Fjardanet* net designer was given the freedom to introduce other measures that would contribute to the reduction in netting drag. The use of lighter twine construction was advocated where necessary and/or appropriate. To this end high performance polyethylene (HPPE) twines were used for the construction of the T90 netting. This allowed smaller diameter twines to be used in some areas without compromising the strength of the gear.

Nominal twine surface areas (excluding codends and extensions) for each of the two nets under test were calculated for comparison. The T90 trawl had almost 40% less than that of the vessel's own Jackson net, (104.5m^2 and 173.7m^2 respectively).

Some of the trawl construction methods used by the Icelandic net maker differed from those used by the UK makers. Additionally, the T90 configuration required different approaches and methods of construction compared to standard diamond mesh netting.

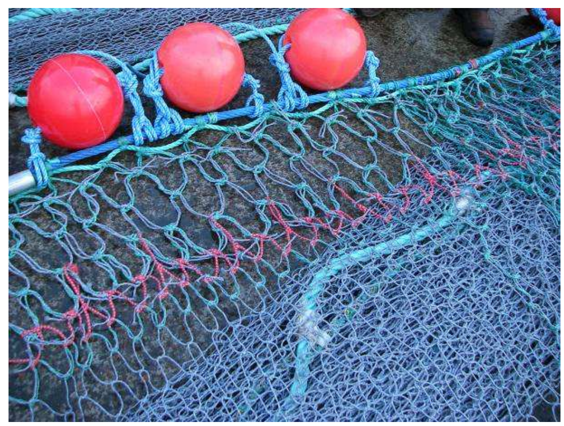
General images of T90 trawl

T90 trawl being prepared for sea trials



Panel join in T90 netting

Lower wing netting



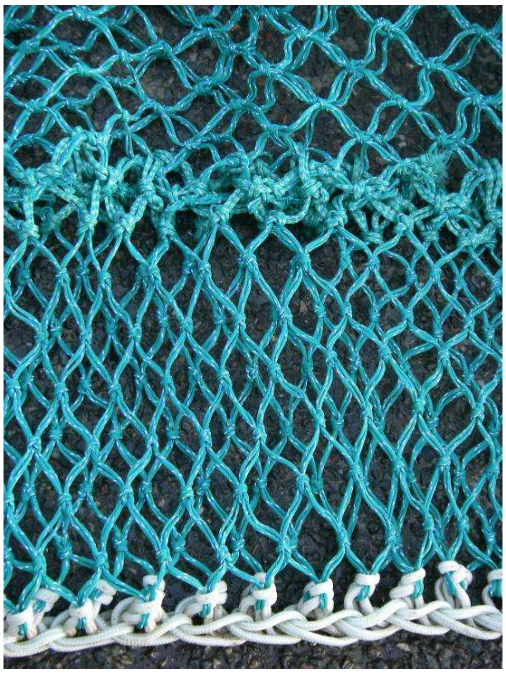
Centre (crown) section of square showing panel join

Join between extension and codend

Crown meshes in belly panel showing bolsh attachment to fishingline

The general codend arrangements used on both trawls are shown in figure (4). The T90 codend was narrower (~33%) in mesh count as a result of the T90 construction.

The rigging of the T90 codend was substantially different using a completely different approach to codend closure. The last section of the codend (four meshes) was constructed in conventional diamond mesh netting for ease of closure. The T90 codend was closed/secured using what is termed an *'Alaska'* knot. This is effectively a *'chain'* knot or lacing which results in the codend maintaining a rectangular shape when closed. This is in contrast to the conventional method which has the meshes tightly gathered together around the codline.



T90 codends showing conventional diamond meshes and *'Alaska'* knot closure

T90 codends with catch onboard Icelandic vessel

The T90 codend was also rigged with selvedge ropes as per Icelandic practice.

T90 codends and extension showing selvedge ropes

3.2. Fishing Trials

The MFV *Mizpah* was chartered for a period of up to 10 days in January 2008 to carry out sea trials to evaluate the performance and handling of the T90 trawl construction. The trials also incorporated time to carryout observations on the vessel's existing conventional gear to establish some baseline data for comparison with the T90 trawl. The original plan was to collect data on the vessel's own net on a separate trip prior to the T90 trials. However, due to delays with the construction of the T90 trawl, a shortage of time prevented a separate trial taking place and so both trawls were evaluated on the same trip.

The exercise combined engineering performance trials to measure relevant gear parameters with some commercial fishing trials to evaluate other aspects of the gears performance such as selectivity and influence on catch quality. The T90 trawl was compared to the vessels existing gear of the same/similar overall dimensions.

The engineering trials entailed the fitting of gear performance monitoring equipment (SCANMAR) to the gear and underwater cameras as required and/or conditions allowed. SCANMAR distance sensors were attached to the wingends of the trawls to measure horizontal mouth opening and on the centre of the headline to record vertical opening. A speed sensor was also attached to the headline to record the speed of the trawl through the water. Distance sensors were attached to the trawl door backstraps to measure the horizontal distance between the doors. Underwater loads cells were used on some tows to measure the load exerted by the trawls plus sweep/bridle arrangements. These were connected at the junction between the trawl door backstraps and the sweeps.

The commercial fishing trials followed the vessels normal operating practices, targeting the normal range of groundfish species for which the vessel has quota. Operations took place on the fishing grounds that the vessel would normally be fishing on at the time of the trials. The vessels normal gear rigging arrangement was used (see Figure (1).

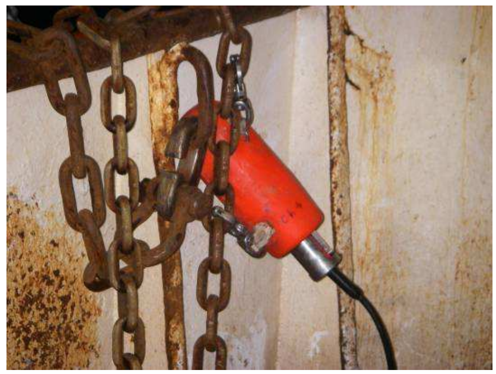
The main objective was to demonstrate the fishing performance by measuring the main gear parameters such as door spread, headline height, wingend spread, net speed, towing loads and fuel consumption. The other attributes of the gear were evaluated by monitoring catch rates, catch quality and catch profiles with particular interest in selectivity and discards. The aim was to see if the gear could achieve results similar to those observed by Icelandic skippers who have consistently reported improved catches, improved catch quality and fuel savings.

Over the period between 18th and 30th January two SEAFISH Gear Technologists were based in Lerwick in the Shetland Islands to prepare the trawl and groundgear and carry out the sea trials. During eight days of fishing a total of 21 tows were carried out, often in very poor weather conditions. At one stage the trials were halted for a period when the vessel returned to Lerwick for shelter as a result of severe weather.

The vessel's own trawl with standard codend was used on 7 occasions and compared with 6 hauls with the full T90 trawl. A further 4 tows were conducted using the T90 trawl fitted with the vessel's standard diamond mesh codend/extension and using the vessel's own trawl fitted with the T90 codend and extension.

The intention was to monitor all tows for gear performance using a combination of vessel's own instrumentation and SCANMAR acoustic net monitoring equipment. Down time due to equipment maintenance/failure meant that on some tows some gear parameters were not recorded. However, sufficient data were collected to enable gear parameters to be established for most net configurations under examination.

SCANMAR distance sensor on trawl door



SCANMAR load cell measuring tension behind the trawl doors

A series of tows was set aside for camera work and more specialist instrumentation (load measurements).

The underwater camera was used on a limited number of tows when and where conditions were suitable. Due to poor water clarity it was difficult to obtain much useful film of the gear. Some images of the mouth of the trawl were obtained giving an indication of the net rigging on the fishingline and groundgear and showing consistent mesh opening achieved by the T90 netting.

The underwater film confirmed the gears ability to traverse rough ground without sustaining damage to the net.

Fishing operations took place in an area approximately 50 miles north east of Lerwick on traditional grounds used at that time of year. The vessel was targeting mixed groundfish species including cod, haddock, whiting, saithe and mixed flatfish species

Catch monitoring was carried out on 16 tows comparing the standard Jackson net (vessel's trawl) rigged with conventional diamond mesh codend/extension with the full T90 net, (8 hauls with each configuration). The retained catch was recorded using the vessel's existing catch handling practices. All retained catch was sorted by species and size grade, weighed, boxed and iced in ~48 kg boxes. All catch weights were recorded by species for each haul on the wheelhouse computer and logged on a daily basis.

Samples from each size grade were taken to produce a range of fish lengths per size grade for each 24 hour sampling period, (4 tows). A minimum of 3 samples per grade were taken at each sampling period, (~100kg) for each species. These data were used for the retained catch information in the results section.

The discarded element from each monitored haul was sampled and measured to provide numbers at each length category (1cm) for the main species discarded.

4. Results

4.1. Gear measurements

The vessel towed at speeds between 2.5 and 3 knots in depths of 70 – 80 fathoms. Warp: depth ratios of between 2.5:1 and 3:1 were used to achieve the gear measurements recorded.

Table (1) shows the average measurements for the main gear parameters monitored during the trials.

Table (1): **Gear parameters for the trawls under test**

Parameters Measured		Jackson Trawl Conventional ext/codend	T90 Trawl T90 ext/codend	Jackson Trawl T90 ext/codend	T90 Trawl Conventional ext/codend
Warp: depth		2.4:1	2.5:1	2.8:1	2.9:1
Speed over ground (knots)		2.6	2.8	3.0	3.0
Depth (Fathoms)		79.3	69	77.6	71.3
Headline height (m)		6.2	6.6	5.5	6.05
Wingend spread (m)		24.0	21.3	19.35	21.95
Door spread (m)		92.0	91.6	/	/
Towing load (t) (SCANTROL)	**Port**	4.0	4.0	4.0	4.1
	Stbd	3.95	3.9	4.0	4.0
Fuel consumption (litres/hour)		121.3	122.3	131.7	124.2
Engine revs.		1613	1610	1621	1601
SCANMAR loads (t)	**Port**	*2.22	*1.85	/	/
	Stbd	*2.32	*1.8	/	/

Measurements are averages from 16 representative tows, 4 for each configuration

***Readings taken from two tows only**

Door spreads for the T90 and the vessel's own net were very similar and indicated bridle angles of approximately 15º. There were slight differences in the wingend spreads and headline heights between the two nets. The T90 trawl achieved on average 0.4m extra height but showed on average 2.7m less wingend spread. These figures were consistent with what was expected for these gears to operate effectively.

Indications of the relative drags of the two gears were obtained from acombination of measurements. Warp tension readings were obtained from the vessel's SCANTROL autotrawl system which gave an indication of the total loads in the trawling system. SCANMAR underwater load cells were fitted behind the trawl doors to measure the drag of the trawl net itself. Engine speed (revolutions per minute) and fuel consumption (litres per hour) were recorded from wheelhouse instrumentation.

The total loads recorded from the SCANTROL system were consistent and indicated no significant difference between gears. Similarly, the averaged fuel consumptions and engine speeds did not indicate any noteworthy changes. However, the towing loads measured by SCANMAR load cell behind the trawl doors did show a more marked difference between the T90 and the vessel's own trawl. This averaged out at approximately 20% reduction in load in favour of the T90 trawl.

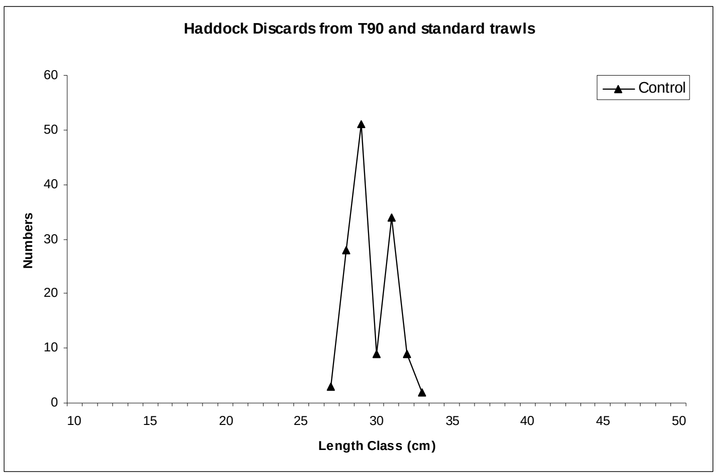
4.2. Catch Results

4.2.1. Discards

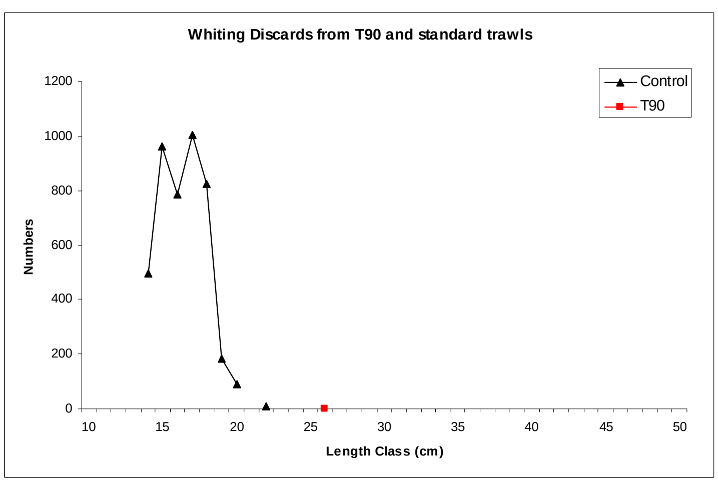
Discards from both trawls were relatively low from all tows sampled.

Cod:
No cod discards were recorded for either net.

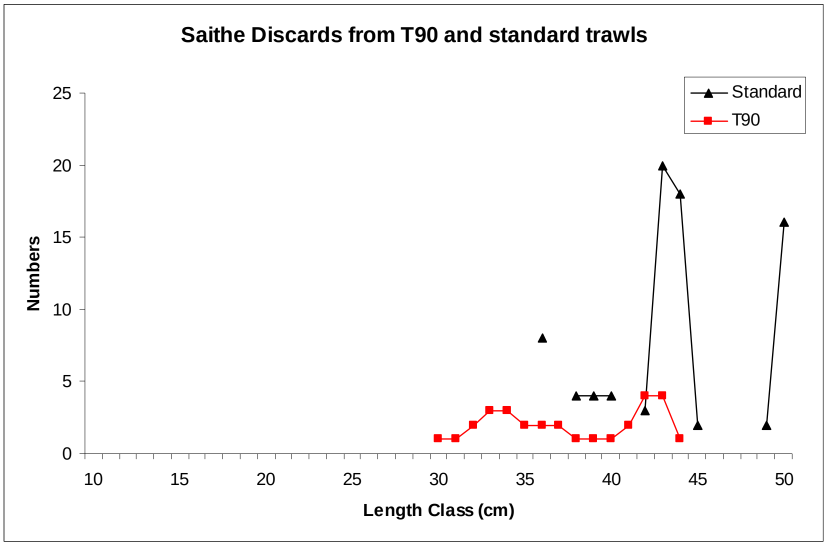
Haddock:
No haddock discards were recorded from the hauls with the T90 trawl and very few were measured for the standard (control) trawl. All fish below the minimum landing size (MLS) of 30cm were obviously discarded but the vessel also discarded some haddock just above MLS which would have been at the low end of the size range of grade 4.



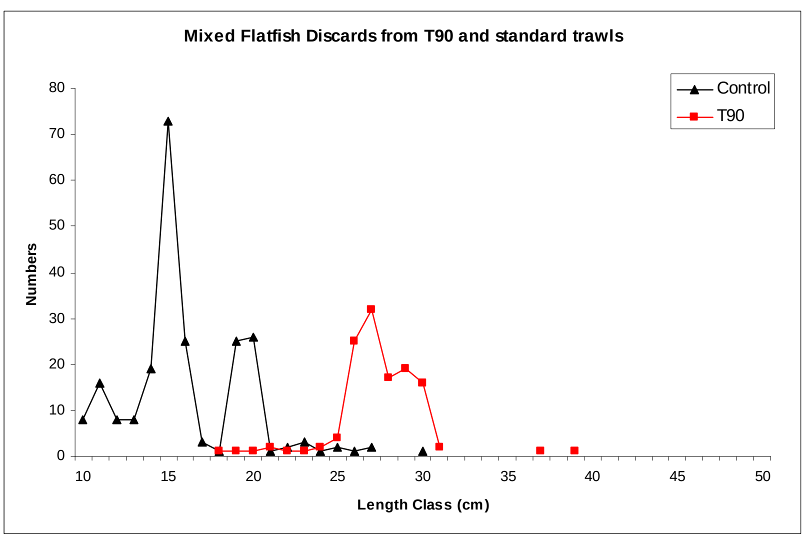
Whiting:
Whiting was the only species with any notable numbers of discards but as with haddock it was only the standard trawl that retained them.



Saithe:
Although some saithe were retained it was generally only the higher grades. There was discarding of saithe from both trawls but these fish were all above MLS (30cm). This practice was influenced by market and quota conditions.

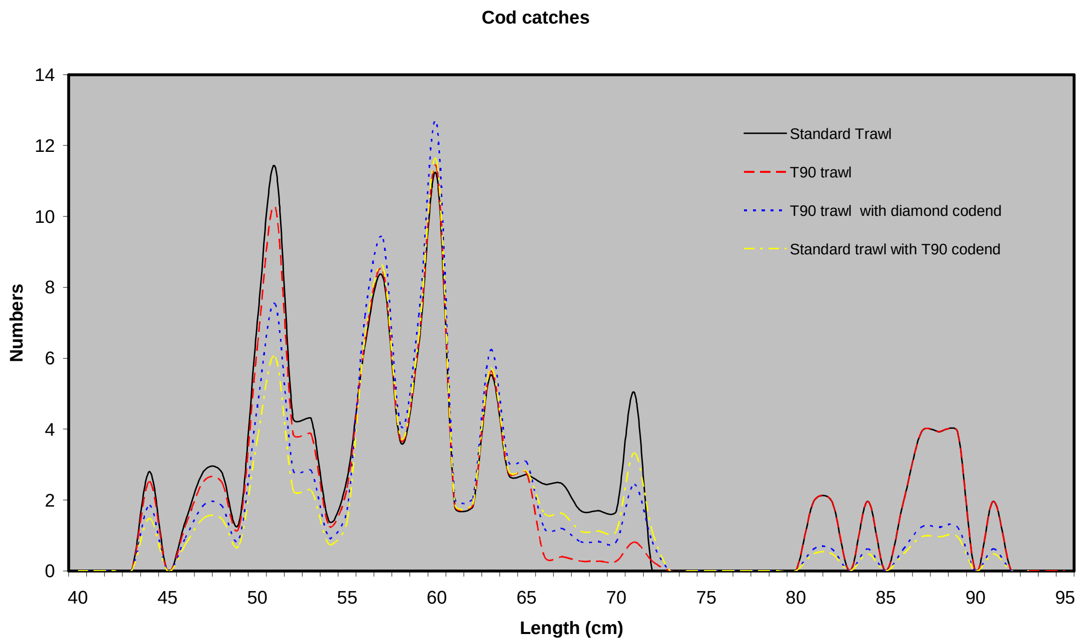


Mixed flatfish species:
The numbers of flatfish caught with both trawls were relatively small. For the purposes of recording catch data the numbers of plaice, lemon sole, megrim and witch have been grouped together. From the discarded mixed flatfish species figures it can be seen that the standard trawl was retaining more small flatfish than the T90 trawl.

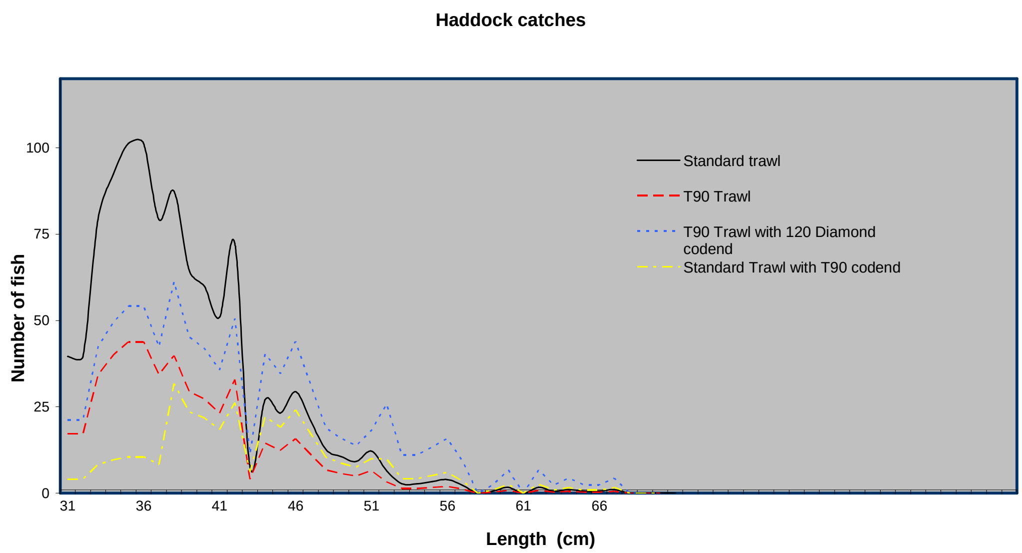


4.2.2. Retained Catch

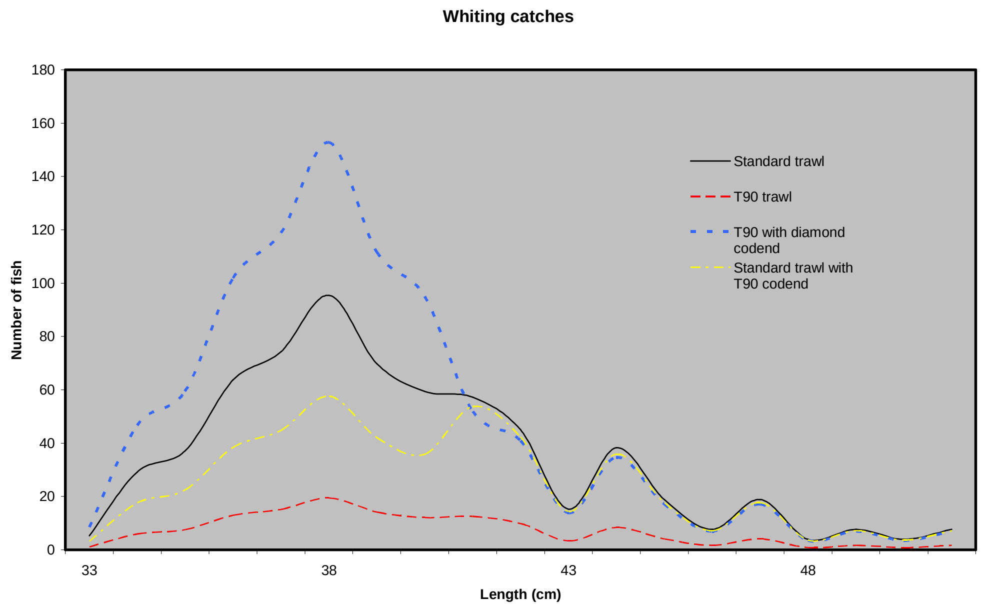
Cod:



Haddock:



Whiting:



Whiting catches
Number of fish
Length (cm)
0
20
40
60
80
100
120
140
160
180
33
38
43
48
Standard trawl
T90 trawl
T90 with diamond codend
Standard trawl with T90 codend

Table (2): **Summary of catch data for trawl configurations examined**

	Catch weight (kg) for each trawl configuration examined			
Catch by EC grade	**Standard trawl with standard codend**	**T90 trawl with T90 codend**	**T90 trawl with standard codend**	**Standard trawl with T90 codend**
Haddock 1	52.6	91.4	113	87.9
Haddock 2	96	83	127.7	78.9
Haddock 3	182.2	51.5	143.3	66.6
Haddock 4	211.2	28.8	230	22
Total (kg)	**542**	**254.7**	**501**	**255.4**
Cod 1	/	/	/	/
Cod 2	157	43.5	49.5	38
Cod 3	59	10.5	31.5	43
Cod 4	104	78	115	106
Cod 5	48	43	32	25.5
Total (kg)	**368**	**175**	**228**	**212.5**
Saithe 1	30	66	157	11.6
Saithe 2	42	18	177	105.4
Saithe 3	96	/	48	131
Lythe	/	59.5	112.2/	42.7
Total (kg)	**168**	**143.5**	**494.2**	**290.7**
Whiting 1	/	/	/	/
Whiting 2	196	39.7	313.3	118.5
Whiting 3	156	34.2	141.3	146.5
Whiting 4	48	/	43	0.2
Total (kg)	**400**	**73.9**	**497.6**	**264.8**
Mixed flatfish inc. Monkfish	1	213.1	104.9	127.5
Total (kg)	**1**	**213.1**	**104.9**	**127.5**
Squid	55.3	7.5	/	49.8
Total (kg)	**55.3**	**7.5**	**/**	**49.8**
Total catch value (£)	**2 384.24**	**1 338.43**	**2 391.07**	**1 899.42**

Note: *The catch value is based on the same price per kg for each grade of each species for each trawl configuration examined.*

4.2.3. Catch Quality

The quality of the catches from each net was monitored visually by SEAFISH staff onboard that made some subjective observations primarily relating to how lively the fish were as they came onboard, appearance with respect to external damage as a result of interaction with the gear and/or other elements of the catch. From these observations there was no noticeable difference detected between the catches from the standard and the T90 trawls.

5. Discussion

5.1. Gear performance

It must be emphasised that the results obtained from this trial should only be considered as indicative of the performance of the gears under examination.

The limited amount of data collected and the constraints imposed by the weather conditions and limitations of the equipment mean that definitive conclusions can not be drawn from this exercise.

The trials were designed as a demonstration exercise to provide an insight into the T90 full trawl concept and to gain an indication of the potential of this technology for further application in other gear designs and fisheries as a means of primarily improving fuel efficiency and secondly improving selectivity and catch quality.

The general geometry and performance of the two trawls under test were considered satisfactory from the point of view of being matched for the comparative purposes of the trial.

Unfortunately, the information gathered on the fuel efficiency aspects examined did not appear to support the observations and experiences of the Icelandic fishermen who have been the forerunners in the development of this technology. The reduced twine surface area associated with the T90 design (~40%), when compared to the vessels own standard trawl of the same general size was expected to produce a noticeable reduction in the overall drag of the trawl system. The only indication of drag reduction was given by the SCANMAR load cells reading the tensions behind the trawl doors. Although these reductions were quite large (~20%), this result came from a small number of tows where this parameter was recorded and therefore may not be reliable. This drag reduction was not supported by the total load readings obtained from the SCANTROL system or reflected in the relative fuel consumptions associated with each gear type.

Considering the variations in conditions experienced during the trials (weather, towing speeds etc.) it may be reasonable to suggest that the indications from the fuel consumption measurements are not representative or reliable over such a short period of time (insufficient data/samples).

General observations of SEAFISH staff and crew indicated that from a gear handling perspective, the T90 trawl posed no additional problems or concerns compared to standard gears.

Some of the crew commented on the lighter twine constructions used in the T90 net and questioned whether it would be as strong as there normal construction. Over the duration of the trial there were no problems associated with these differences.

5.2. Catch Results

Every effort was made to maintain similar conditions and fishing grounds, species mix etc. for the duration of the catch sampling exercises. It must be accepted however that variations do occur and that these may influence the results.

From the point of view of discards, neither the standard trawl nor the T90 showed any significant level of size related discards over the range of species sampled.

The relatively low numbers of fish sampled for the catch comparisons make it difficult to draw conclusions about the relative performance of the T90 and standard gears. However there are some indications which tend towards supporting the observations and experiences recorded by Icelandic fishermen in that the T90 configurations appear to catch and retain more of the larger size grades of fish, particularly haddock. It was evident however that the larger grades of whiting were escaping from the T90 net. Whiting as large as 50cm were regularly meshed in the T90 codend and large whiting were observed swimming out of the codend/extension while the net was on the surface during hauling.

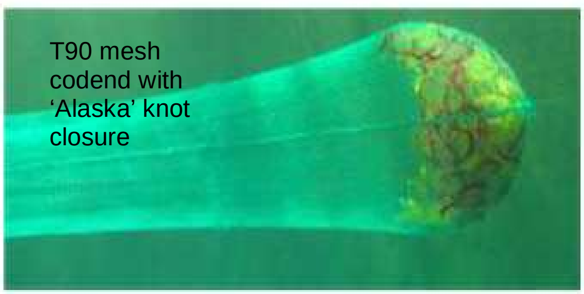
Example of the size of whiting meshed in T90 codend (~50cm)

It is reasonable to assume that if the meshes in the T90 trawl do have a more consistent mesh opening compared to the standard trawl, then more escapes could be occurring over larger areas of the main body of the trawl.

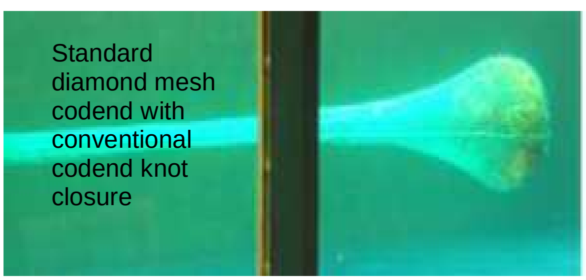
From a commercial perspective, the loss of relatively large numbers of marketable size grades of any commercial species from a T90 net is likely to be unacceptable if there is not some benefit or advantage to offset this. In the case of T90, the Icelandic experience has been an improvement in the numbers of larger fish retained. This observation could not be demonstrated with any confidence in this trial.

The summary of catch data in Table (2) does indicate that the combination of the T90 trawl with a standard codend/extension may be a workable commercial option where smaller grades of fish are an important component of the overall catch. Over the four 24 hour sampling periods for which the data are given for the four net configurations, the catch values indicate that the T90/standard codend combination came out on top.

No conclusions could be drawn from the observations on catch quality. Here again there was some expectation based on Icelandic findings that the T90 configuration would show benefits. The T90 codend construction in combination with the *'Alaska'* knot for securing the codline was seen by the crew to have merit from the point of view of allowing more freedom for fish movement within the codend. This is perceived to be a benefit for fish quality by reducing the risk of crushing damage associated with large catches. Research work carried out by SINTEF at the Flume Tank in Hirtshals, Denmark has demonstrated how improved water flow in and around the codend can reduce codend oscillation which is thought to help preserve fish condition within the codend, ([6]*Hansen*).



Images of model codends in the Flume Tank showing the relative shapes and potential influence on catches.



The limited results and observations from these trials can only be considered as indicative of the relative performance of the two trawl types. Further trials would be required to confirm the indications observed here.

6. Further Work

SEAFISH is continuing its programme of work investigating ways of reducing the environmental impact of fishing gears into 2008/09. This will include follow up work to this project to examine other gear designs and fisheries that could benefit from the T90 concept.

In light of the results from this trial it is suggested that the development of this specific T90 technology would benefit from additional work. It is recommended that additional fishing trials be conducted with the existing gear, on a commercial basis, over a longer time frame in a fishery specifically targeting larger size grades of fish.

There is a requirement to establish more definitive data with respect to the fuel saving attributes associated with the T90 technology in order to offset what appear to be the more selective properties of T90 netting.

Further work should include:

- Further collaboration with Icelandic net makers and introduction of the T90 concept to UK net makers to aid the development of this technology

- Scale modelling and Flume Tank testing of existing and any new designs developed in order to optimise rigging and performance.

- Underwater observations of the T90 trawl to better understand how the technology works and observe fish behaviour /reactions to the T90 gear.

- Investigation of more specific applications of this technology in directed squid fisheries.

7. Acknowledgements

The following people and organisations are gratefully acknowledged for their participation and contributions to this project.

Hermann Gudmundsson	Fjardanet
Jon Einar Marteinsson	Fjardanet
Skipper and crew	MFV *Mizpah*
Michael Humphrey	SEAFISH
Mike Montgomerie	SEAFISH
LHD Shetland Ltd	Lerwick
Jackson Trawls Ltd	Peterhead

8. References

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(2) Moderhak, W. and T. Niemiro 2005. Mechanical properties of twine and netting used in Baltic fisheries.
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(3) Moderhak, W. 2000. Selectivity tests of polyamide and polyethylene codends made of netting with meshes turned through 90º.
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(4) Moderhak, W. 1993. Some problems of water flow through trawl codends.
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(5) Hansen, U.J., L.H. Knudsen, P. Nielsen & E.M. Andersen, 1996: Development of fishing gear for Fishing Vessel 2000
Danish Institute for Fisheries Technology and Aquaculture (confidential)

(6) Hansen, U.J. 2004. Performance of a trawl codend made from 90º turned netting (T90) compared with that of traditional codends.
ICES FTFB WG meeting, Gydynia, April 20 – 23, 2004

Figure (1): **General trawl gear rigging arrangement used during trials**

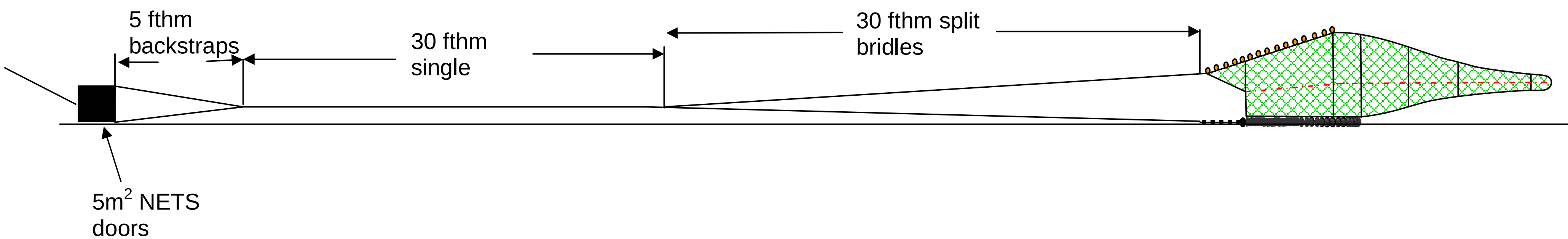


Figure (2): **Ground Gear specification –'*Rockhopper*' rig**
(Shown as half rig)

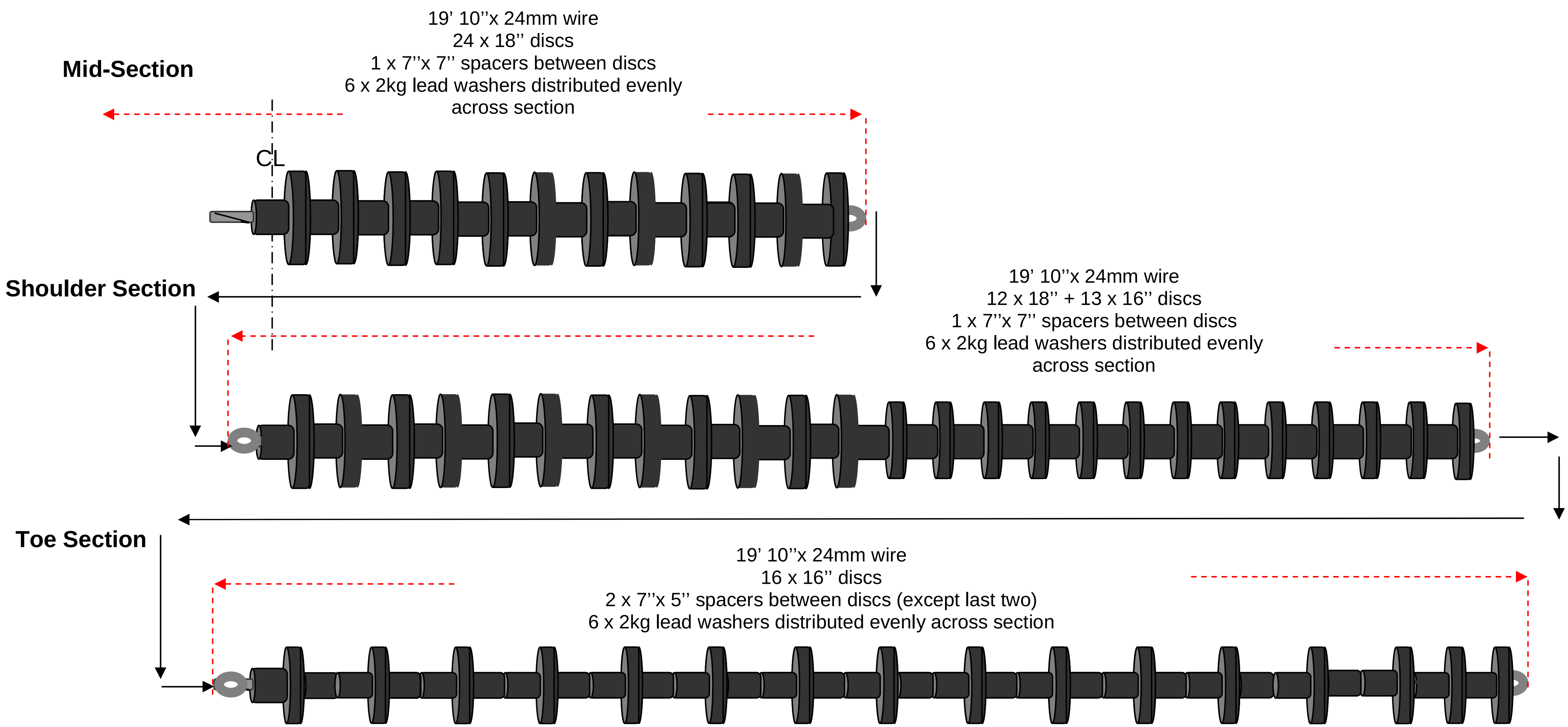
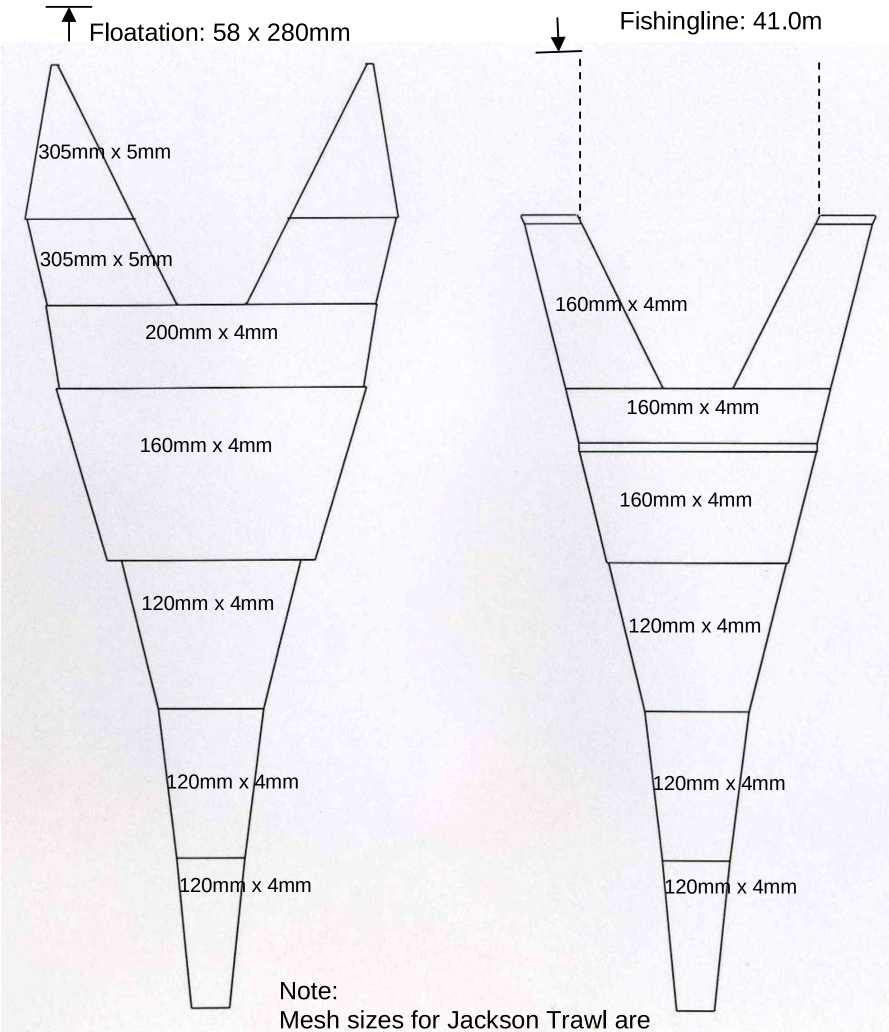


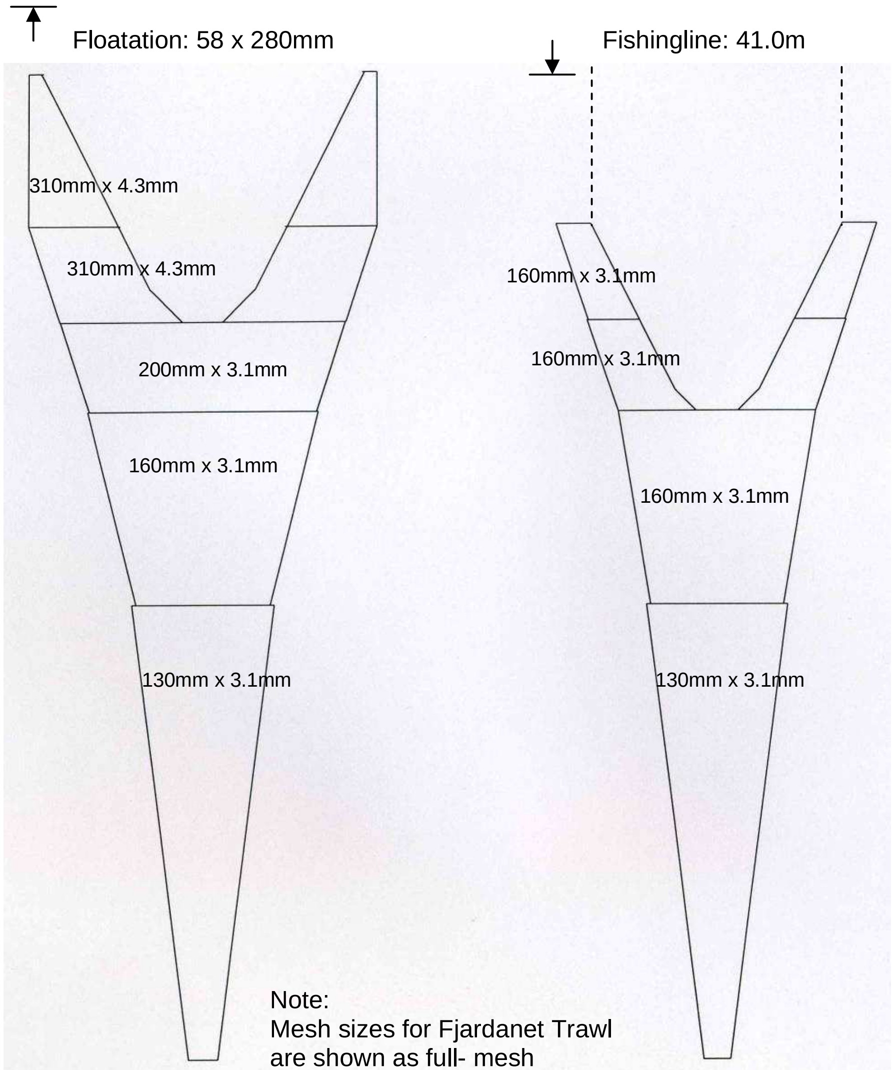
Figure (3): **Outline schematic showing relative shape and size of trawls under test**

Jackson Trawl



Note:
Mesh sizes for Jackson Trawl are shown as inside- mesh measurement

Fjardanet T90 Trawl



Note:
Mesh sizes for Fjardanet Trawl are shown as full- mesh measurement

Figure (4): **Codend arrangements for the standard and T90 trawls**