Fisheries Technology Committee **ICES CM 2002/B:01**

Report of the

ICES-FAO Working Group on Fishing Technology and Fish Behaviour

Sète, France
6–8 June 2002

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International Council for the Exploration of the Sea

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1 EXECUTIVE SUMMARY

The WGFTFB meeting in Séte, France, considered research on five terms of reference, reports from the Study Group on Mesh Measurement Methodology, a subgroup reviewing the size selectivity of Baltic cod trawls and a subgroup compiling a manual on the selectivity of static fishing gear. Trawl performance modelling was reported to have progressed to such an extent that software is now commercially available that allows graphical visualization of a trawl with geometry, construction details and operational parameters specified by the user. Although it was recognized that trawl simulation could reduce the need for field trials, some members were sceptical about whether enough realism could be incorporated into the models to capture the variability seen in field trials. The use of archival tags on groundfishes was reviewed with emphasis on determining the timing and extent of daily and seasonal depth migrations, which were considered as possible factors affecting the catchability of trawl surveys. The use of technical measures, such as codend mesh size and selection grids, and the use of codend protection bags on size and species selectivity was reviewed. Although technical measures are usually tested under actual fishing conditions, concern was expressed that fishermen alter their gear in ways that thwart the intent of the technical measure or that inadequate enforcement allows fishermen to ignore legally required measures. Effectiveness of technical measures will be addressed again as a theme session at the 2003 ASC. The use of codend strengthening bags was shown to reduce the size of 50% selection and therefore to reduce the effectiveness of a specified minimum codend mesh size. In some cases strengthening bags are truly justified (e.g. to prevent seal damage or the bursting of netting with large catches), however other cases may be an attempt by fishermen to reduce the effective codend mesh size.

An FTFB subgroup working on a manual for the measurement of the selectivity of static gears, similar to the ICES manual for the selectivity of towed gears, reported that they expect to have a draft within one year.

An FTFB subgroup that reviewed the report of the IBSFC scientific meeting on technical measures reported that, for Baltic sea cod, trawls with diamond codends made of 4 mm double strand polyethylene twine having a mesh size of about 140 mm would produce the same L50 as trawls fitted with 120 mm BACOMA windows. This represents an increase of 10 mm above the minimum mesh size for polyethylene codends. The group found that there is currently insufficient data on polyamide codends to allow a similar type of analysis.

The proposed 2003 meeting of the FTFB will take place in Bergen, Norway, on 27 June to consider three terms of reference: 1) Assess gear related technical measures appropriate for improving species and size selectivity in *Nephrops* trawl fisheries, 2) To review the final report of the Study Group on Mesh Measurement Methodology (SGMESH), and 3) To review topics considered at the Symposium on Fish Behaviour in Exploited Ecosystems with emphasis on promising research approaches to increasing accuracy and precision of surveys and to reducing the impacts of towed gears on the seabed.

2 INTRODUCTION

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Date: 6–8 June 2002

2.1 Terms of Reference

In accordance with ICES Council Res. 2001/ 2B02 the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] (Chair: D. Somerton, USA) met in Sète, France from 6–8 June 2002 to:

a) consider recent advances in the modelling of fishing gears, with particular emphasis on selectivity, sea bed impacts and applications to fisheries management;

b) review the use and impact of chafers, net strengtheners and other codend construction materials that impact species and size selectivity of trawls;

c) review the use of archival tags to elucidate the role of fish behaviour on catchability;

d) consider the affects of fish behaviour on the selectivity of mobile and static gear;

In accordance with ICES Council Res. 2000/ 2BFT the Fishery Technology Committee recommends that: The Working Group on Fishing Technology and Fish Behaviour [WGFTFB] (Chair: Dr David A. Somerton, USA) met in Sète, France, from 6–8 June 2002 to:

Justification:

a) Recent advances in the modelling of fishing gears and netting materials has permitted more efficient investigation of the fish capture process. A recent EU funded project (PREMECS) made use of this research to develop a predictive model of codend selection. Other current research areas include the study of sea bed impact of towed fishing gears, the evaluation of fishing effort and the design of survey trawls.

b) The review of this subject at WGFTFB 2001 indicated that codend selectivity may be vastly improved with the reduction of chafers and associated attachments. In addition many FTFB members will conduct selectivity investigations in regard to these issues and will be prepared to report results in 2002.

c) The use of archival tags to elucidate diurnal and seasonal fish movement has increased in recent years as the cost and size of such tags has declined. Since diurnal and seasonal movement patterns influences the catchability of fish to assessment surveys, knowledge of these behaviours could allow the design of more efficient surveys.

d) Investigations on the affects of fish behaviour on selectivity are now being conducted by FTFB members. The most pertinent include: 1) trawl modifications to reduce the by-catch of non-target species, 2) grids and FDS in trawl gear, 3) artificial baits and larger hook sizes in longline fisheries and 4) modified gillnets that reduce bycatch.

Additionally, in accordance with CM2001/2B01 a sub-group of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] (Chair: D. Somerton, USA) met at ICES Headquarters, from 7–9 February 2002 to:

a) evaluate the findings of the IBSFC Scientific Meeting on Technical Measures for the Fisheries on Baltic Cod (Brussels, August 2001) and *inter alia*
    i) revisit the selection properties of the 130 mm diamond mesh size and the 125 mm polyamide diamond mesh size codends,
    ii) estimate the codend mesh size of a diamond mesh and of a polyamide diamond mesh giving selectivity properties corresponding to the 120 mm BACOMA window trawl,
    iii) review all information relevant to selectivity of gears used for cod fishing in the Baltic Sea.

The Working Group also reviewed the use of technical measures and evaluate their effectiveness with special emphasis on North Sea gadoid fisheries. This was undertaken in preparation for a theme session on this topic in 2003.

3 TOPIC: CONSIDER RECENT ADVANCES IN THE MODELLING OF FISHING GEARS, WITH PARTICULAR EMPHASIS ON SELECTIVITY, SEA BED IMPACTS AND APPLICATIONS TO FISHERIES MANAGEMENT

Benoit Vincent and Dominique Marichal (France) - Presentation of trawl gear simulation software

A close collaboration between IFREMER Institute and Ecole Centrale de Nantes enabled the development of a numerical method to simulate the dynamic behaviour of trawl gears. This method has been used to develop a commercial software named DynamiT that is both efficient and easy to implement whatever the step: description of the trawl gear, discretisation, calculation and the way the results are displayed. This software is based on a 2D pre-processor to input the trawl gear parameters and to generate an equivalent numerical structure made of bars. A 3D interface (post-processor) displays the simulation results and allows the user to analyse data and produce pictures and video animations. The numerical method allows the user to solve the dynamical problem using simple models of hydrodynamic forces that depend on external conditions (water velocity, bottom contact). Such a software main application areas are training for fishermen or related professions, analysis of a new trawls (first trials or comparison with other trawls) or more generally, optimisation of trawl gears, with particular applications to energy savings.

Discussion: Ingvar Huse and David Somerton asked if the model could account for different bridal angles and lengths. David Somerton asked whether the model could predict performance on different bottom types. Benoit Vincent answered that the model can take into account different bridal lengths but is always based on the assumption of a hard sand bottom.

Daniel Priour (France) - The objectives and main results of the PREMECS EU project

To date, sea trials are the only means of assessing the selectivity of codends. A capacity to assess, at the design stage, the influence of codend design, the netting material properties, the trawl rigging and towing speed, sea state and behavioural and environmental parameters on the selectivity of a codend would permit the initial testing of novel designs 'on shore' and lead to considerable savings and the ability to react more quickly to new challenges. Such a predictive model of codend selectivity is developed in this project. Main results: Firstly mathematical models of cod-end and trawl geometry are developed. Since codend geometry is determined by the interaction of the water flow, the catch size and the design and physical characteristics of the netting, information on each of these factors is required as input to the geometry model. Hence: measurements of the stress/strain and the flexural rigidity of codend twines were made; flume tank trials were held with codends to investigate the relationship between catch size and codend geometry; Secondly a stochastic model that simulates the fish selection process in the codend is developed. Up to 4 different populations of fish entering a codend can be accounted for. Fish are allocated a travel time down the codend, a maximum length of time they can remain in the codend, a time between escape attempts and a packing density for those swimming in front of the catch. An escape attempt is deemed successful if a fish can pass through the mesh opening. Mesh opening is obtained from the codend geometry model and is updated as the catch builds up at the back of the cod-end. At the end of a simulation a logistic selectivity curve can be produced for any combination of the 4 fish populations that entered the codend and estimates of the 50% retention length and the selection range can be found. Thirdly, in order to both calibrate and test the model the predictions are compared with the results of two sets of cod-end selectivity experiments. One data set was from the EU funded 'Study of factors affecting the variability of codend selectivity', the other from sea trials carried out in the Adriatic Sea as part of this project.

Discussion: Jacques Sacchi asked if physiological parameters of the fish were used; Chris Glass suggested that fish orientation has an affect on the fish selectivity determined by this program. Dick Ferro was concerned that escapement occurred even when meshes were indicated as closed. Daniel Priour explained that this depended on the stiffness of the webbing, that is, if the mesh is soft, fish can escape through closed mesh as long as the girth of the fish is sufficiently small. David Somerton asked what influenced webbing stiffness; Daniel responded that webbing stiffness was increased by the strain due to the drag of the catch. René Holst complemented the work as being important in making the unobservable, observable and asked if this program had the ability to account for the variability in the behaviour of the fish. Daniel Priour responded that he did not think that there was a way to account for variable behaviour at this time.

Barry O'Neill (UK) - A theoretical study of the factors which influence the measurement of fishing netting mesh size

A theoretical investigation is carried out of the mesh size measurement of an idealized mesh. It is assumed that the bending moment of the mesh bars is proportional to their curvature and the corresponding differential equations governing mesh bar deformation are analysed. The measurement method our analysis most approximates is that of the ICES gauge. The effect of twine bending stiffness, frictional resistance, boundary slope and gauge force on mesh measurement are all examined.

Discussion: Dick Ferro summarized the work by stating that the model indicates that the best way (i.e., minimum bias) to measure mesh was to use a thin gauge and apply a lot of force. Ulrik Jes Hansen asked if the percentages of error should be halved because model considers only one half of a mesh; Barry responded that this was correct. Pingguo He asked about the effects of measuring a mesh between bars instead of between knots; Barry indicated this had not been investigated. David Somerton asked whether the estimates of the percent error would change, as the webbing gets older; Barry explained that the model estimates presented were based on new webbing.

Antonello Sala (Italy) - Development of a fuel saving Italian bottom trawl

This paper was aimed at developing bottom trawl designs, for the Italian Fisheries that reduced fuel consumption. The new designs will include the use of new high strength material and the use of larger meshes in net areas where no negative effect on catching power is foreseen. It is essential that the new designs combine the features of large headline heights and good contact between the footrope and the seabed with a low towing resistance. A typical traditional trawl, commercially used in Italy, was selected as a basis for the development of the new design. This trawl became the reference (standard trawl) to which the changes introduced in the design throughout the study were compared. A model of the traditional trawl was firstly constructed. The geometry and towing resistance were measured in a flume tank for different rigging. Netting yarn diameters and breaking loads were measured in laboratory for all types of netting used in the standard trawl. Based on the results from the flume tank tests made on the standard trawl, a second model of an experimental trawl was designed with the aim of obtaining a larger vertical opening and a lower towing resistance. A mathematical model was used to estimate the effect on towing resistance when the netting area was reduced in different parts of the trawl. To reduce the netting area of the experimental trawl, a high strength Polyethylene fibre (Dyneema, commercially called Rubitech) was tested. This fibre has a higher strength than the Polyamide or the simple Polyethylene. The intention was to reduce the mesh bar diameter keeping constant the netting strength. Based on the results from the flume tank tests, full-scale trawls were designed and constructed. Knotted Rubitech, was used in the wing section of the Italian experimental trawl. Sea trials were made on a research vessel to measure the engineering performance of the trawls. During these tests a towed underwater camera was used to make a visual inspection of the trawls. The results from the sea trials and the flume tank tests show that it is possible to design trawls with up to 30% less fuel consumption and up to 40% more headline height in the Italian fisheries, when larger mesh sizes, new high strength materials and reshaped wings are introduced. Comparison of the results from the sea trials and the flume tank tests show that it is very difficult to accurately model in the flume tank trawl sections where the highly flexible Polyamide netting is used. An inspection of the knotted Rubitech netting after the commercial tests on the Italian experimental trawl showed that the stability of the knots in this type of netting was not sufficient to keep the meshes rightly shaped. Further product development is necessary before such material could be commercially used in the Italian fisheries. Finally, tests on commercial vessel were carried out to compare the fishing power of the experimental trawl to that of the standard trawl. Both the experimental and the standard trawls showed comparable catch rates.

Discussion: Ulrik Jes Hansen asked if the cost savings included the cost of fabricating the new net; Antonello responded that this was not considered in because fishermen build their own nets. Norman Graham asked if the new was being used by fishermen; Antonello responded that they were not at this time. David Somerton asked how the transfer of information between the scientist and fishermen is accomplished; Antonello explained that the research is conducted jointly with commercial fishermen and information about the new net is transferred by word of mouth. Daniel Priour asked about Rubitech, the netting material used in the new net; Antonello explained that Rubitech is the commercial name for mesh made by Dyneema.

Benoit Vincent, Dominique Marichal and Michel Répécaud (France) - Calculation of the fluid flow around otter boards

A close collaboration between IFREMER Institute and Ecole Centrale de Nantes enabled the development of a method of trawl numerical calculation. This method is both efficient and easy to implement whatever the step: description of the trawl gear, net meshing, calculation and the way the results are displayed. Assuming that the otter boards have a constant behaviour they are modelled using constant coefficients to achieve the calculations. Now, the new applications of these methods to both the impact studies and safety problems necessitate that we further investigate the otter boards more particularly. Experimental studies were conducted to achieve lift and drag curves regarding otter boards placed in a given position in which only one rotation angle around the vertical axis could be altered. Now, the otter boards might as well lay down or even look up as for pelagic otter boards. These efforts are measured in equilibrium positions; yet, we also want to proceed to dynamic simulations. Thus we also lack of knowledge regarding unstationary effects such as added mass. This is why we have started a thorough study of the otter boards using numerical models. For this purpose we have adopted a calculation code of fluid dynamics commercialised by FLUENT Company. The investigations bore on two types of otter boards, a pelagic and a deep sea one, and the numerical results were compared with the experimental results obtained in a flume tank. The numerical results reveal to be high rate. Then we have developed a method to interpolate the numerical results. This method enables to represent the lift and drag variations of the otter boards as a function of the list and swaying with only twice nine coefficients.

Discussion: Several questions were asked about the capabilities of the model presented; Benoit answered that the model could incorporate complex geometry, that it is based on viscous flow and not potential theory, and that the model, when completed, will be able to predict the percentage of the spreading force that is attributed to hydrodynamics and ground sheer. Dick Ferro asked if only half of the otter trawl was measured and if the board was considered symmetrical, which makes this a pelagic case; Benoit answered that it is a pelagic case but it is not symmetrical.

Benoit Vincent and Dominique Marichal (France) - Codend numerical calculations

The investigation and development of selective fishing gears requires a thorough knowledge of their components. This especially applies to codends. Codend selectivity greatly depends on the shape of the meshes (mesh surface, mesh extension ratio, but also its position versus the flow) and mesh side strain. Indeed, for juveniles to escape not only must they find a proper opening but also the shape of this opening must be adapted to their morphology. Depending on the extent of the mesh side strain the fish can more or less force their way out. In the same way, a seawater stream through some meshes may incite the juvenile to find a way out. It will be possible to investigate this point once the shape of the codend is established. Several studies have been achieved by our team and by other laboratories. Barry O'Neil (Marine Lab.) suggested conducting an analytical study of axisymmetrical codend shapes. Daniel Priour (IFREMER) applies to this investigation the method of finite elements. It is assumed in both these methods that the equilibrium shape of the codend is strictly axisymmetrical; now, we are going to demonstrate that, though this hypothesis often turns out to be right for a preliminary study, it is not quite true. These studies do not either take into account the distortions of each of the mesh sides. We had ourselves applied our own general methods to trawl dynamic calculation but these methods, unlike the present study, require a globalisation of the meshing. Leaving aside the gravity effects and assuming that the capture is evenly distributed, it is assumed that the shape of a codend offers a symmetry order about equal to the number of meshes constituting its perimeter; indeed, the greater the number of meshes, the closer we are to an axisymmetrical configuration. Thus, the study need only bear on a single row of meshes along a meridian line. Moreover, these meshes presenting a longitudinal symmetry our study is thus limited to the definition of the equilibrium of a single row of half meshes. On the other hand, as both the upstream and downstream sides of these meshes may undergo significant and quite different distortions it is necessary to achieve precise a modelling of these mesh sides. It must be noted that the shape of the meshes that enclose the capture varies rapidly from one row to another. Thus, the methods of globalisation of the meshing can only give approximate results. We have thus developed an original method towards the study of the equilibrium characteristics of a codend towed at constant speed. This method consists in applying the mechanical basic equations to the netting yarns constituting a row of half meshes. On account of the low amount of mesh sides to be calculated for this very row it is possible to avoid the globalisation step and thus to calculate each of the physical meshes. The preliminary study we achieved with a fluid dynamic calculation code (FLUENT) enabled us to assess that the effect of the capture on the net could be modelled by constant a pressure (equal to impact pressure (due to kinetic energy)) acting on the meshes in contact with the capture.

Discussion: Questions were asked about the ability of the model to consider square mesh windows, changing mesh geometry due to the catch, and the influence of the selvage ropes. Benoit responded that the model will not accept square mesh windows, and does not incorporate the variability associated with an increase in the stiffness of the webbing or different water flow around the selvage ropes. John Willy Valdemarsen asked if the model can show the effects of using square mesh. Benoit responded that the model, when completed would be able to model square mesh.

Topic Discussion: The discussion that ensued was focused primarily on the applicability of models to trawl behaviour. David Somerton asked about the parameters that go into a model and how a researcher attains these parameters; Benoit Vincent answered that all of the parameters can be attained from the fishermen, net manufacturers, or by measurement but cautioned against using net plans, which are often inaccurate. Although only 12 copies of the software have been sold to date, Barry O'Neill surmised that such models will be used more frequently to resolve questions before expensive sea trails begin. Dick Ferro cautioned that models must be validated against full-scale gear before we accept their output. Benoit Vincent pointed out that validation of models is often complicated by the variability of vessel parameters. Ulrik Jes Hansen expressed his concern that models can be used for simple situations but are not effective tools when evaluating complex gear, pelagic trawls, and door performance because all operational parameters are not considered. Thomas Moth-Poulsen explained that in his experience the problem with models is lack of knowledge in the true measurements of the trawl. Small variability that may exist in the gear can have a large affect on the performance of the gear.

4 TOPIC: REVIEW THE USE OF ARCHIVAL TAGS TO ELUCIDATE THE ROLE OF FISH BEHAVIOUR ON CATCHABILITY

Stephen Walsh (Canada) - Tank observations of the success of various DST's attachment techniques for flatfish

Four external attachment techniques were used to mount data storage tags on yellowtail flounder in a tank study to look at tag shedding and tag induced mortality. Two double attachment points, one single attachment point and an operculum dangler technique were examined for a period of 10 months. Each treatment group had fish and a control was used. This paper will discuss the results of these observations in relation to field studies.

Discussion: A question asked if there was a mechanism to stop lateral movement of the tags attached by single point; Steve responded that there was not and that the tags have been observed to spin. Henry Milliken asked if the fish in the study were uniform in size; Steve responded that they were. Marianne Farrington offered the knowledge of an angiogenic substance that aids in the healing process and may help the wounds of the fish.

Stephen Walsh (Canada) - Preliminary results from data storage tags attached to yellowtail flounder

Yellowtail flounder (*Limanda ferruginea*) is a Pleuronectid found in the northwest Atlantic from southern Labrador to Chesapeake Bay. On the Grand Bank off Newfoundland, Canada, it has been commercially exploited for 40 years. Little is known about the natural behaviour of this species. Starting in 2001, archival data storage tags were attached externally to 325 yellowtail flounder as part of a larger tagging program. These tags record information on date, time, temperature and depth every 32 minutes. The purpose of these tags is to examine diel and seasonal changes in temperature and depth occupied by the fish, as well as to supplement information from returns from conventional tags. Preliminary results on temperature and depth distribution from the data storage tags will be presented.

Discussion: Several questions were raised trying to ascertain what caused the up and down movements seen in the behaviour of the yellowtail flounder. Chris Glass asked if it could be correlated to spawning behaviour or movement on and off the bank, another scientist asked if it could be correlated to tidal cycles, and Norman Graham asked about bycatch devices in this fishery, alluding to the possibility the fish were being captured and were escaping from trawl gear. Steve Walsh mentioned that he did not feel the depth changes were due to movement of the fish on and off the banks because no fish were recaptured off the banks and that there were no bycatch reduction devices in this fishery. Steve also mentioned that they are working with an oceanographer to ascertain if the tidal cycles or other oceanographic situations might account for the movement.

David Somerton (USA) - Review of archival tagging activities at the Alaska Fisheries Science Center

In several distinct experiments, archival tags were attached to Atka mackerel, *Pleurogrammus monopterygius*, Pacific cod, *Gadus macrocephalus*, and walleye pollock, *Theregra chalcogramma*, to determine the timing and extent of daily and seasonal vertical migrations. Based on 14 returns, Atka mackerel are active only during daylight and begin making rapid vertical migrations of up to 100 m from their night-time resting depth soon after sunrise. The magnitude of the migrations decreases as average current velocity increases. Some male Atka mackerel cease vertical migration for a 1–2 month period in the summer when they are known to guard egg masses. Based on 170 returns, Pacific cod also display vertical migrations with daily periodicity, however they appear to be active 24 hours a day and the periodicity is relatively weak. Unlike Atka mackerel, cod have a post-tagging recovery period of approximately 7–10 days in which they occupy progressively deeper water until they ultimately reach the initial capture depth. No walleye pollock have yet been captured. For Atka mackerel at least, the daily vertical movements complicate stock assessment with bottom trawl surveys, which, in Alaska are only conducted during daylight hours.

Discussion: Ingvar Huse asked if the body cavity of the fish ruptured when captured. Norman Graham inquired about the method of capture of the fish and whether you could de-gas the fish to better help them, and Klaus Lange asked about the condition of the wounds at the attachment point of the tags. David responded that the fish were captured in traps, were often inflated and were usually healthy.

Ewan Hunter (UK) - The use of archival tags to elucidate diurnal and seasonal movement of North Sea plaice

Since December 1993, seven-hundred and eighty-four adult female plaice, *Pleuronectes platessa*, have been tagged with electronic data storage tags, and released throughout the North Sea, yielding 194 returns and 24 000 days of behaviour data. A method of geolocation using tidal (depth) data was employed to reconstruct the movements of individual plaice throughout their period at liberty. The results revealed extensive pre- and post spawning migrations throughout the North Sea, and seasonal subdivision of the population sampled. Spatially varying migration-linked changes in patterns of vertical activity were observed. Mid-water swimming activity was most extensive during migration, where the majority of plaice exhibited a nocturnal tidal activity rhythm. Mid-water swimming (and nocturnal tidal rhythmicity) was more pronounced in, but not exclusive to, plaice using selective tidal stream transport to migrate. By linking the spatial and temporal aspects of horizontal and vertical movement, our results demonstrate how interpretation of archival tag data can provide basic catchability information that would allow more accurate interpretation of existing fish assessment survey data and improvement in the design of future surveys.

Discussion: Ingvar Huse asked what causes the stocks of plaice to separate; Mike Pol asked if the aggregation of fish was related to spawning. Ewan responded that the aggregations are due to feeding but each aggregation showed site specific spawning fidelity. He further theorized that the groups have distinct temperature and depths preferences. David Somerton asked how the tidal depth change, which is used for geo-positioning, is separated from the depth change due to vertical fish movement. Ewan stated that the depth information, which is recorded every ten seconds, was omitted for geopositioning when depth changes between recordings were greater than three meters.

5 TOPIC: REVIEW THE USE OF TECHNICAL MEASURES AND EVALUATE THEIR EFFECTIVENESS, WITH SPECIAL EMPHASIS ON NORTH SEA GADOID FISHERIES

Dick Ferro (UK) - Some current issues in European legislation on technical measures relating to gear design

We are in a period of major change in European legislation on technical conservation measures relating to gear design. The aim is to help various recovery plans for stocks in waters controlled by the European Union, the Baltic States and Norway in particular. The measures are generally designed to improve selectivity in commercial fishing. However, they may also significantly affect: - the strength of gear components and hence safety of fishermen, costs of gear, operational practices and hence efficiency and finally enforcement capability. Fishery managers should take these aspects into account when deciding to introduce new technical measures. The presentation will address some of the current concerns in the fishing industry and elsewhere, such as: - What are the consequences of reducing twine thickness as mesh size increases? How to measure twine thickness? Do very compact twines cause lower selectivity than more loosely woven twines? What are the effects of limiting the number of meshes round a codend? How to detect quadrilateral meshes (k-netting) which is banned in the EU? Does the same codend show differences in selectivity between vessel types (e.g., side/stern) or between vessels of different size or between gear types (e.g., seine/trawl/pair trawl)? Gear technologists may have a role in ensuring that these issues are considered and appropriate solutions found.

Discussion: Ingvar Huse asked about the safety issues surrounding the use of smaller twine; Dick responded that the smaller twine is a safety issue because it breaks more easily than thicker twine while on or over the deck. Dick further explained that a consequence of limiting twine thickness of the may be the increase in the use of stiffer twines, which have separate effects on size selection. Erdmann Dahm asked about the legal definition of a codend in the UK. Dick replied that in the UK legislation the separation point between the codend and the extension is described, but that such definitions are still a bit ambiguous.

Questions about the role that FTFB could play in reviewing potential legal gear definitions before they are passed on to the legislators was then raised. Ulrik Jes Hansen stated that it is a sensible approach to have FTFB act as a advisory group to legislative measures. Bob Van Marlen asked how we should proceed with this idea, and stressed that there is a need for tackling these projects on a wider scale. Bob further commented that on a European scale, this is an idea that should be brought forward. FTFB’s role in advising / managing needs to be developed and a long-term strategy to tackle gear research and other issues needs to be developed. Steve Walsh ended the discussion by stating that the ICES integrated action plan for the Fishing Technology Committee, of which he is the Chair, stresses the importance of cross collaboration between ICES committees to advancing the role of FTFB. Thus there could be a better linkage between committees such as ACFM that may propose technical measures as solutions to fisheries problems and FTFB, which could evaluate the effectiveness of such technical measures.

Adnan Tokaç, Hüseyin Özbilgin and Zafer Tosunoðlu (Turkey) - Comparison of the selectivity of PA and PE codends

This study investigates the differences in the selective properties of a 40mm nominal PE, 36 and 40 mm nominal PA codends. The experiments were carried out in Izmir Bay in the Eastern Aegean Sea between 4 February 2002 and 22 March 2002. A conventional bottom trawl was operated onboard *R/V Egesüf*. Selectivity data were collected for red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), picarel (*Spicara smaris*) and common pandora (*Pagellus erythrinus*) by using hooped covered codend method. The data were analysed haul by haul for red mullet and annular sea bream but pooled for the other two species due to insufficient number of fish in individual hauls. Selectivity parameters were obtained by using logistic equation with the Maximum Likelihood Method. Three codends were tested in a total of 25 hauls of which 18 were accepted valid for picarel and 23 valid for the other three species. In general the PA made codends produced much higher L50 values than the PE codend. However, the SRs of the three tested codends were very close to each other. L50s of 40 mm PE, 36 mm PA and 40 mm PA codends, respectively, were found as 8.7, 8.5 and 10.3 cm for annular sea bream; 10.3, 14.5 and 16.1 cm for common pandora. There were not enough red mullet and picarel retained in the 40 mm PA codend to estimate the selectivity parameters. L50s of PE 40 mm and PA 36 mm codends, respectively, were 10.6 and 12.9 cm for red mullet and 12.3 and 13.2 cm for picarel. In general, it is thought that 40 mm PE netting, which is commercially used, has rather poor selectivity. On the other hand, 40 mm PA codend causes the loss of marketable fish. Amongst the three tested codends, 36 mm PA provides the most appropriate selection.

Discussion: Andy Reville asked about a possible error in one of the tables that were presented. The category PA 36 should be PA 40, PA 40 should be PE 40 and PE 40 should be PA 36. Thomas Moth-Poulsen explained that twine coating, which increases twine stiffness, could be used to equalize the selectivity of twine, counteracting the effect of mesh changes. John Willy Valdemarsen observed that, while this study was done with small mesh, he has done similar studies with larger meshes and found little difference between PE and PA mesh. Ulrik Jes Hansen commented that with larger meshes the greater swimming ability and power of larger fish become important in the selection process.

Hüseyin Özbilgin, Zafer Tosunoðlu, and Adnan Tokaç (Turkey) - Comparison of the selectivities of double and single codends

This study investigates the differences in the selectivities of 40 mm mesh size single and double codends. The experiments were carried out in the Bay of Izmir, in the Eastern Aegean Sea between 4–18 April 2002. A conventional, 600 meshes around the mouth, commercially used bottom trawl was operated onboard R/V Egesüf. Selectivity data were collected in nine hauls with single and nine hauls with double codends for red mullet (*Mullus barbatus),* annular sea bream *(Diplodus annularis),* picarel *(Spicara smaris)* and common pandora *(Pagellus erythrinus)*. Hooped covered codend method was used for data collection. Selectivity parameters were obtained by using logistic equation with the maximum likelihood method. Results show that the single codend has significantly higher L_{50} values than that of the double codend ($p < 0.05$), while the difference in the SRs were insignificant ($p>0.05$) for all the four species. L_{50}s of double and single codends, respectively, were found as 9.0 and 10.1 cm for red mullet; 7.7 and 8.7 cm for annular sea bream; 10.0 and 11.7 cm for picarel and finally 8.1 and 10.5 cm for common pandora. The results confirm that the use of double codend impedes the escapements of significant proportions of immature fish.

Discussion: Andy Reville asked for a definition of a double codend. Hüseyin explained that a double codend was one in which there was one codend inside another, thus two sheets of webbing. Antonello Sala asked if the alternate haul technique was used; Hüseyin responded that they used the covered codend method and they switched the codends every couple of days. Thomas Moth-Poulsen expressed concern over the low number of hauls conducted in the study and felt that variability might be an issue because the codends were switched infrequently. It was explained that this was a covered codend approach so this should not be much of an issue.

Rene Holst, and Ole Ritzau Eigaard (Denmark) - The effective selectivity of a composite gear: an industrial sorting grid in combination with a window panel

Juvenile fish of commercially important species like haddock, whiting and cod, will inevitably be caught in the industrial fishery for Norway pout in the North Sea, where very small mesh sizes are used to retain the main catch of target species. The by-catch of protected species has a negative impact on the catches in the human consumption fisheries. A new gear consisting of a grid in combination with a window panel was developed to remedy the unwanted by-catch. This paper presents the results of experiments testing this gear. Fish were collected from three compartments of the gear. This allowed for determining separate estimates of the selectivity of the grid and the window panel. These were combined to produce estimates of the effective selectivity of the composite gear. Due to intrinsic features of the effective selectivity, the usual descriptors of the selectivity, L50% and SR, do not apply here. New descriptors are introduced. The paper presents the results for Norway pout, haddock, and whiting.

Discussion: Andy Reville asked about the purpose of the grid as compared to a guiding panel. Rene responded that the grid was needed to get the fish to the window in the net. Ingvar Huse commented that they had completed a similar study in 1999. Rene responded that they had used the experiences from the previous work to design their study. Rene further commented that the gear is very flexible because you can control the selectivity by changing the bar spacing and mesh size of the window. He stated that one problem with this gear they have not solved is in multispecies fisheries with different minimum landing sizes for each species. Bob van Marlen asked if there was a problem when the gear encountered large catches. Rene responded that the experiment tried to get commercial sized catches and they had a catch of 40 tons without any problems.

Norman Graham(Norway) - Comparing the selectivity of a grid, a square mesh panel and a standard codend

Twin-trawl experiments were conducted to compare the selectivity of (i) a 120mm mesh codend (ii) a 120mm mesh codend fitted with a 110mm square mesh panel and (iii) a 120mm codend fitted with a 35mm selection grid. A total of 27 successful hauls were carried out using a Scottish twin rig trawler fishing a standard demersal whitefish twin-trawl. The vessel and gear are typical of those operating in the Norwegian economic zone. The average 50% retention length (L50) is estimated to be 35.4cm for the standard 120mm codend, 34.1 for the 120mm codend fitted with a 110mm square mesh panel and 37.0cm for the 120 mm codend fitted with the 35mm grid. The selectivity of the standard 120mm codend both with and without the square mesh panel show a high degree of variability between hauls. For the standard codend the estimated l50s range between 29.9 and 38.9cm while for the codend fitted with the square mesh panel they are in the range 27.1 to 37.2cm. On the other hand, the L50 s of the codend fitted with the grid have a much lower degree of variability, with minimum and maximum values of 35.5 and 38.6cm. The corresponding mean selection range are estimated to be 4.7cm (3.9 to 5.4cm) for the standard codend, 4.9cm (4.3 to 6.4cm) for the codend with the panel fitted and a sharper 3.6cm (2.9 to 4.8cm) for the codend with a grid in the extension. The L50 s of both the standard codend and the codend with the square mesh panel are shown to increase significantly with catch size. This dependency explains a large component of the between-haul variation of the L50 results for these cases. In general the catch sizes are low and for these two cases they are in the range 196 to 684kg. The selectivity of these two cases is similar to that of the 120mm codend with a grid in the extension for larger catches (i.e., > 500kg). In contrast, the cod-end with the grid in the extension does not exhibit a dependence on catch size.

Discussion: Ingvar Huse commented that this kind of work had occurred before and asked if this study found anything new. Norman responded that although similar work has been done, it is important to better understand the selectivity of cod, because of their recent decline in abundance. Norman was asked if there were different behaviours observed for the cod and haddock; he replied that haddock tend to follow the full length of the grid while cod tend to follow the lower panel. Erdmann Dahm asked what materials were used in the codend and if the study investigated the use of turned mesh for size selection. Norman responded that the codend was constructed out of 5 mm high tenacity twine and that the turned mesh technology had not been studied but was worth investigating. Dick Ferro commented that it looked like the panel was more effective than the grid. Norman responded that if you have predominantly small fish in the catch it appears that the grid provides better selection.

Barry O'Neill (UK) - Sea state induced vessel motion and codend selection

The relationship between sea state induced vessel motion and codend selection is investigated. The presentation is divided into three parts. Part 1 reports on sea trials to investigate the relationship between vessel motion and codend dynamics. By comparing the average period of longitudinal codend pulsing to the most important cyclic component of the tension in the trawl warps and the most important cyclic component of the linear accelerations of the fishing vessel, it is established that the pulsing of the codend is a response to sea-state induced vessel motion. Part 2 looks at the hydrodynamics and catch dynamics of a codend pulsing in a flume tank. Experiments are carried out on a half scale codend where the towing warp is attached to the rotating arm of a hydraulic motor and the catch is simulated using water filled balloons. Three categories of longitudinal codend motion are identified and a qualitative description of the hydrodynamic forces that are acting is presented. A number of observations are made concerning the catch dynamics and it is shown that, from a fixed reference frame, the displacement of the balloons is essentially linear and has no rotational component. It is concluded that the dynamic forces acting on the catch must generally be small. Part 3 analyses direct observations of the hydrodynamics, catch dynamics and fish behaviour of pulsing codends at sea. By comparing these observations with the results of the flume tank trials it is concluded that longitudinal pulsing of the codend is the predominant factor generating dynamic movement of the codend; that the dynamic forces acting on the fish ahead of the catch are small; and that the main component of the movement of these fish relative to the codend arises as a result of the displacement of the codend. In the light of these results, an analysis of recorded observations of fish in pulsing codends provides insight into some of the associated hydrodynamic and behavioural mechanisms that may affect the active and passive selection of fish in the codend. In particular, a cyclic tilting behaviour and reductions in flow speed are used to explain the dependence that is found between fish escape ahead of the catch and the codend motion. When allied to the result of part 1 of this study a direct link is established between sea state induced vessel motion and codend selection.

Discussion: Chris Glass complemented the research as being one of the nicest pieces of quantifiable behaviour research he has seen recently. Chris asked Barry to comment on what he thought was happening in terms of water flow ahead of the catch in the codend. Barry responded that the active fish in the catch are getting to the webbing and the water flow is aiding their escape from the codend. Ulrik Jes Hansen stated his hope that this research will look further at selectivity and the quality of the fish encountering the mesh. He cautioned that this study shows how the net reacts but this is representative of this net only. Other nets may respond differently. Pingguo He asked that when the net pulses forward, if the water within the cod end also moved forward. Barry answered that the water flow does move within the codend and this assists with fish escapement. Mike Pol asked if they had tried to estimate the sea state associated with the trials. Barry responded that they had not. Thomas Moth-Poulsen added that in his experience, they had witnessed a circular motion of fish in the codend.

Bob van Marlen (Netherlands) - Current state of affairs in the Selectivity Database

At this moment, CEFAS is developing a selectivity database and providing a short course for data inputers. The presentation will explain the structure of the database and show examples of data.

Discussion: David Somerton asked what the geographic coverage of the database would be. Bob responded that there are no restrictions and the parameters can be put in for any geographic location. Ingvar Huse asked if ICES Secretariat was going to support this database. Bob responded that the Secretariat could not commit themselves in the time frame needed. Bob stated that they would host this system for three years, after that time they will have to see where it goes. Thomas Moth-Poulsen asked if FAO might host the database. Bob replied that after three years anyone could host it.

Dick Ferro (UK) - Recent selectivity data from Scottish fisheries and the main conclusions

In the past two years or so the Scottish Executive has provided extra funding to FRS Marine Lab Aberdeen, Seafish Industry Authority Hull and North Atlantic College Shetland to study more selective gears. The three institutes have conducted around 20 selectivity or catch comparison trials to provide information on technical conservation measures being introduced by new EU and UK legislation. The effects on selectivity of different gear design features such as square mesh panels, twine thickness, mesh size, lifting bags and extension length have been measured. The presentation will review this work to make members of the Working Group aware of the new data. Some of the main conclusions and new findings will be presented. Publication of the detailed analysis will follow in due course.

Discussion: David Somerton asked if escapement under the footrope had been investigated. Dick replied that they were only looking at codend escapement, and they did not presently have the means to investigate whole net selectivity.

Rene Holst (Denmark) and George Petrakis (Greece) - Gill net selectivity for *Pagellus Bogaraveo* in the Ionia Sea

Pagellus bogaraveo (blackspot seabream) is a demersal species in the Mediterranean Sea. The fishery of the species in Greek waters is taking place at depths between 200 and 600 m, with gill nets and long lines. This paper presents the findings from a gillnet selectivity experiment using six different mesh sizes: 60, 68, 80, 88, 90 and 100 mm. The selectivity was estimated using the SELECT method for individual sets and a random effects model for fitting mean curves. A number of different uni-modal functional forms were assessed and they could only be marginally distinguished. The modal lengths (length at which the probability of a fish to be caught is maximum) of the 60, 68, 80, 88, 90 and 100 mm mesh size gill net were estimated to 207.5, 235.2, 276.7, 304.3, 311.2 and 345.8 mm. Due to sparseness of the data it was not possible to fit a bi-modal curve by individual sets. Population index, based on the pooled data sets, appeared highly sensitive to the choice of selection curve. The number of vessels working in this metier is reducing rapidly the last years due to the decline of the catches. The decline affected first the longliners and now the gillnetters. From interviews with the fishermen, it is reported that the average days at sea per vessel has declined from 106.4 ten years ago to 15.5 today for the longliners and from 156.4 to 57.3 for the gillnetters.

Discussion: There were no questions at the conclusion of this talk.

Terje Jørgensen (Norway), D. Galbraith (UK), N. Graham, (Norway), K. Hansen (Norway), R. Holst (Denmark), P.O. Larsson (Sweden), S. Mortreux, G.I. Sangster (UK), A.V. Solda l (Norway), and V. Tschernij (Finland) - Design, handling and selectivity properties of the Eurogrid

An EU funded project to develop a selective grid for the demersal towed gear fisheries in the North Sea and adjacent areas was initiated in 1998. Emphasis was put on designing a system that in addition to good selective properties was flexible enough to be operated by the wide range of vessel sizes, deck layouts and gear handling techniques used in the North Sea and adjacent water fisheries. The designed rectangular grid is made of polyamide, measures 150 x 75 cm, and is divided into two equal sections joined by an integrated hinge, allowing the grid to be folded. The grid is mounted into a netting section at an angle of 35 degrees. Supporting ropes are used to stabilize the grid angle. The handling of the grid was tested on board commercial vessels typical of the national fleets and was not found to present problems on board any of the vessels. Selectivity properties were estimated for the main target species (cod, haddock, saithe and whiting) for appropriate bar spacings. Attempts have been made to calculate the effective selectivity of grid and codend combined, as well as that of each selective device separately. A general model of mean selection length and selection range showed these variables to be significantly related only to bar spacing. The choice of experimental technique (twin trawl, covered codend) significantly affected the selectivity results.

Discussion: Ulrik Jes Hansen asked why the grid broke; Terje believed that it was the result of a large catch. Bob Van Marlen asked for the dimensions of the grid used in the study; Terje reported that the dimensions of the grid were 150 x 55 cm.

Iole Leonori and Fiorentini L.(Italy; Poster) - The effects of mesh size and number of meshes around the codend on red mullet and hake selectivity. Tests in the Adriatic Sea made for the PREMECS EU project

Selectivity data were collected in the Adriatic Sea as part of PREMECS project. The aim of this work was to collect further experimental data in the Mediterranean Sea by examining some codend design factors influencing mesh opening, in order to test the predictive ability of the codend selectivity model. In particular, the effects of mesh size and number of meshes around the codend were examined. Two sets of trials took place at two different periods of the year. The two target species investigated were red mullet (*Mullus barbatus*) in late summer, and hake *(Merluccius merluccius)* in spring, but data were collected also on the other abundant species caught. For all the species considered the number of mesh around the codend plays a role that is as important as the mesh size. In fact it was demonstrated that an increase in mesh opening from 46 to 56 mm could be made fruitless by an increase in codend circumference. The selectivity factor of red mullet was 2.4 for the standard circumference codends and for both mesh openings tested. For larger codends the selectivity factor decreased up to 1.8 and 1.3, respectively for 56 and 46 mm mesh openings. The hake selectivity factor, computed for the standard circumference codends, was respectively 2.5 and 3.1 for 46 and 56 mm mesh openings. For larger codends, the selectivity factor decreased up to 2.1.

6 TOPIC: REVIEW THE USE AND IMPACT OF CHAFERS, NET STRENGTHENERS AND OTHER CODEND CONSTRUCTION MATERIALS THAT IMPACT SPECIES AND SIZE SELECTIVITY OF TRAWLS

Zafer Tosunoðlu, Hüseyin Özbilgin and Hüseyin Özbilgin (Turkey) - Effects of the protective bags on the codend selectivity in Turkish bottom trawl fishery

This study investigates the differences of selectivity between a plain codend (C) and a codend surrounded with a protective bag (CP). The experiments were carried out in the Bay of Izmir in the Eastern Aegean Sea between 16 January and 14 February 2002. The experiments were conducted onboard R/V *Egesüf* (27 m LOA, 500 hp main engine) by employing a conventional bottom trawl commercially used in Turkish waters. The hooped covered codend method was used to obtain selectivity data. Eleven valid hauls (45 min towing duration and 2.5 knot average towing speed, 25–30 m water depth) were carried out both with C and CP. Data were collected for red mullet (*Mullus barbatus*), annular sea bream (*Diplodus annularis*), picarel (*Spicara smaris*) and common pandora (*Pagellus erythrinus*). Selectivity parameters were obtained by fitting the logistic equation using maximum likelihood. Selectivity of C and CP were found to be very similar for the species investigated except that the 50 % retention length (L50) of CP was 9 % higher than that of C for common pandora, and the selection range (SR) of CP was 32 % wider than that of C for picarel. L50 values for C and CP were found as 10.7 and 10.6 cm for red mullet, 8.6 and 8.6 cm for annular sea bream, 12.3 and 12.1 cm for picarel and, 10.3 and 11.2 cm for common pandora, respectively. These results show that the protective bags used in Turkish demersal trawling does not have a significant effect on codend selectivity for the species investigated. The codend tested here and commercially used in Turkish waters retains a significant number of immature fish and therefore needs to be modified in a way to improve its selectivity.

Discussion: Mike Pol asked if the reason for the need of a net strengthener, that is, attacks by dolphins and seals, was real. Zafer Tosunoðlu responded that dolphins and seals are plentiful in the waters around the fishing operation and sometimes tear the webbing, which causes a large loss in the catch.

Robert Kynoch (UK) - The effect of increasing mesh size and the removal of lifting / strengthening bags on haddock selectivity from codends used by the Scottish demersal trawl fleet

Selectivity trials were conducted to measure the selectivity of 110mm and 120mm codends and to assess the effect of lifting or strengthening bags on the selectivity of these codends. Results for haddock (*Melanogrammus aeglefinus*) demonstrate that an increase in mesh size from 110 to 120mm increased the 50% retention length by 9%. The removal of the lifting bag gave a 5% increase in L50.

Discussion: David Somerton asked about the ratio of the twine size between the codend and the lifting bag and who determined this ratio. Robert replied that the ratio of bag to codend mesh was approximately 2:1. Norman Graham asked if there was any catch size or weather effects noticed on the catch. Robert mentioned that the weather was consistently good throughout the study and the catches were also consistent between hauls. Ulrik Jes Hansen asked about the need for the lifting bag. Robert responded that the fishermen are now using high tenacity twine so the need may not be as great as it was before the development of these stronger twines. Dick Ferro commented that one of the results of this experiment showed that the L50 of the net was above the minimum landing size of the fish and that the use this net will result in the loss of marketable fish. Robert continued by explaining that many of the fishermen are frustrated because the minimum mesh sizes have increased faster than the minimum landing sizes, therefore they are often losing marketable fish. Norman Graham asked whether, to minimize this loss, it would be better to regulate mesh size at the L25 rather than the L50 level. Erdmann Dahm stated that he examined the affect of lifting bags and, for saith, found no effect when a lifting bag was used. Andy Reville asked Robert if he thought the lifting bag should be banned after viewing the results of his research. Robert replied that the fishermen believe that there is an effect on the selectivity of the codend due to the larger twine diameter in the lifting bag.

Topic Discussion

Norman Graham posed the question of whether the best type of selection is the sharpest (shortest selection range) or should selection be flatter so that we can leave older fish in the population to rebuild the stocks. David Somerton asked if there has been much work to determine whether fishermen are complying with the minimum mesh size laws. Thomas Moth-Poulsen responded that there is a lot of focus on how fishermen circumvent methods to increase the selectivity of gear. Erdmann Dahm commented that he believed at least half of the fishermen do not even comply with fishing regulations. Norman Graham commented that this depended upon the quality of the enforcement and that enforcement and punishment differed by the country. Ulrik Jes Hansen mentioned that fishermen stick to the technical measures that we come up with, they comply with the rules, but they make changes that reduces the effectiveness of the technical measures. Andy Reville commented that although many of us undertake selection experiments for some form of technical measure, even under the conditions of commercial fishing, we have not focused how effective these measures are after they have become legal gear restrictions. He said he would like to see proof of their effectiveness. Ingvar Huse responded that despite successful technical measures developed by researchers the only successful solution to overfishing is to reduce the number of vessels. David Somerton finished the discussion by reminding the group that the effectiveness of technical measures has been made a special topic at the 2003 Annual Science Conference and that there is a year and a half to think about the effect of using these technical measures.

7 TOPIC: CONSIDER THE AFFECTS OF FISH BEHAVIOUR ON THE SELECTIVITY OF MOBILE AND STATIC GEAR

James McDonnell (Ireland) - Inclined separator panel

Technical information on the Inclined Separator. Results from BIM trails. Technical information on the Dual codend. Fishing after the closed Box. Observation of fish behaviour in the Trawl body (cod, haddock, whiting, hake, monk and prawns).

Discussion: David Somerton asked about the legal system for managing bycatch in Ireland, if the Irish use the separator panel and if there are other species that the Irish required to be separated from the targeted species. James McDonnell responded that in order to fish for *Nephrops* in the closed areas, it was required to use the panel. He also mentioned that there are no other species where bycatch reduction devices are required. Andrew Reville asked if the wording of the legislation allowed fishermen to circumvent the device. James responded that he could provide the legislation and that some fishermen do circumvent the device. Thomas Moth-Poulsen asked about the dimensions of the panel and how far it is from the bottom of the net. James responded that the panel is adjustable but is usually fished 12–18 inches from the bottom of the net. Steve Walsh asked if the author had experimented with separating other flatfish species. James responded that no studies on other species have been performed. Erdmann Dahm asked if the author had observed good separation when fish were the same size as the prawns. James responded that the fish tend to rise and leave the net while the prawns tend to stay near the bottom where they are retained by the gear. Andrew Reville asked what percentage of the flatfish went up to the top of the net; James replied 90–95%.

Michael Pol - Cooperative design and testing of gillnets and trawl nets to target flatfish and avoid Atlantic cod *Gadus morhua*

Management measures in US Northwestern Atlantic waters have limited fishing for all species largely due to the status of Atlantic cod *Gadus morhua* stocks. Development and testing of trawl and gillnet gear that segregates cod from flatfish was conducted cooperatively with commercial fishermen. Improved species selectivity of gillnets was attempted by lowering floatline heights by 1) replacing the floatline with another leadline and 2) adding lead to the floatline ca. every 10 meters. Trawls were modified by 1) moving the headline far back following a Faroese design, 2) replacing 15.2 cm diamond mesh in the top of the net with 20.3 cm square mesh, and 3) shortening the legs of the net so that headline height off the bottom was ca. 0.5–1.0 m. The gillnet designs and the third trawl design sought to exploit the tendency of flatfish to remain very close to the bottom. Trawl designs 1 and 2 took advantage of the behaviour of cod rising slowly when pursued by trawl nets. Testing of all designs is in progress; preliminary results of gillnet testing show that the experimental nets perform similarly to standard flatfish gillnets. Results from trawl testing show dramatic (75–95%) reduction in cod catch rates with designs 1 and 2; losses of legal-sized yellowtail flounder, *Limanda ferrugineus*, ranged from 16–64%.

<u>Discussion</u>: Dave Somerton suggested that to offset the loss of flatfish while using the topless trawl, the herding affect of the trawl could be improved by increasing bridle length. Ulrik Jes Hansen offered his observation that in the gillnet fishery many people use polyethylene line and adjust the floatation by adjusting the diameter of the line. Jacques Sacchi stated that they have a similar situation and they use a vertical line between the leadline and the floatline.

Norman Graham (Norway) - Species selectivity in the Nephrops fisheries using selection grids

In order to reduce the levels of discarding of undersize fish in the European *Nephrops* fishery, experiments were conducted to separate *Nephrops* and fish into different codends using a selection grid. Trials were conducted on both otter and beam trawlers. This separation allowed different mesh sizes to be used in the fish codend and the *Nephrops* codend. Novel statistical analysis techniques were developed for the data obtained. The degree of separation was significant but varied depending on grid angle and bar spacing. During some trials, the grids also suffered from clogging with debris and mud. Various project partners undertook selectivity and catch comparison trials and the use of a secondary grid for improving size selection of *Nephrops* was assessed and found to be successful. The technology developed was also applied to the *Nephrops* fishery in the Aegean, where higher species diversity was encountered.

<u>Discussion</u>: Dave Somerton asked about the grid angle and how it was determined. Norman responded that the grid was equipped with a ScanMar grid sensor that gave readings in real time. Thomas Moth-Poulsen asked why grids were being used when square mesh panels have been shown to be effective. Norman responded that one of the problems with the square mesh panels is that they are often situated far back in the codend. When this is the case, the fishermen often loose a percentage of their catch through the panel when the net is retrieved. Robert Kynoch responded that they had used square mesh panels without any loss of *Nephrops* and, he felt that the square mesh panels helped reduce the amount of mud in the gear when the gear is fished on soft bottom. Andy Reville commented that this study showed several hauls that were classified as invalid. Andy is concerned that good information is being discarded when hauls are classified as invalid. Furthermore, he stated a desire to standardize the criteria used to classify tows as valid versus invalid. Ulrik Jes Hansen stated his belief that we need to add the amount of time the gear is deployed to selectivity reports. Dick Ferro stated that FTFB, as a group, needs to find a solution for separating *Nephrops* from fish. John Willy Valdemarsen proposed that a study group on this issue should be formed to examine this issue. Thomas Moth-Poulsen reminded the group that there was a study group on reviewing the selectivity of the *Nephrops* fishery and he could look into the feasibility of updating the previous report. Ingvar Huse stated that EU funding for research on the selectivity in the *Nephrops* fishery would be forthcoming, with a call for proposals to address this issue in January. Dave Somerton proposed that ad hoc group should be formed to look at this issue at the next FTFB meeting. Norm agreed to be Chair of the ad hoc group.

Paulo Fonseca, Aida Campos, Roger Larsen and Teresa Borges (Portugal; poster) - Sorting grids as a by-catch reduction tool in the Portuguese bottom trawl crustacean fishery

As happens for most of the similar fisheries around the world, the Portuguese bottom trawl fishery for crustaceans is characterised by the simultaneous capture of high a number of species, of commercial and mainly of non-commercial value, resulting in a high level of discarding. Recently, the discards in this fleet segment have been estimated at up to 70% of the total catch in weight [Borges *et al.* J. Appl. Icthyol., 17 (2001)].

Three crustacean species are targeted by about 30 vessels, the rose shrimp, *Parapenaeus longirostris*, the red shrimp, *Aristeus antennatus*, and the Norway lobster, *Nephrops norvegicus*, taking as a by-catch with commercially valuable fish such as the hake, *Merluccius merluccius* and the monkfish *Lophius* sp. However, the by-catch is mostly constituted of species little or no commercial value, including blue whiting *Micromesistius poutassou*, boarfish *Capros aper*, and the longspine snipefish *Macroramphosus scolopax*.

The problem of discards in this fishery has already been addressed through the use of square mesh windows [Fonseca *et al.,* ICES, CM 1998/BB:12] on the top of the codend, resulting in about 60% of the blue whiting escaping and 9% of rose shrimp lost. More recently, in May 2001, some tests were carried out using a ANordmore@ type sorting grid on board the IPIMAR's R/V Noruega. The system consisted of a funnel directing the catch towards the grid and the grid itself having a bar space of 25 mm and a 20 cm high lower section to facilitate the passage of the Norway lobster to the codend, mounted in an extension piece with a top escaping hole.

Preliminary results were encouraging since about 75% of the blue whiting and almost 50% of the boarfish were allowed to escape through the top opening, while the losses in weight of shrimp were 4.0 and 6.9%, for rose shrimp and red shrimp, respectively. However, a Norway lobster loss of about 10% was found in spite of the bottom opening. For the European hake and the monkfish the escape percentages were 43.9 and 56.5%, respectively.

8 CONCLUSIONS FROM THE STUDY GROUP ON MESH MEASUREMENT (SGMESH)

Ron Fonteyne (Belgium)

The Study Group met in Sète from 3–5 June 2002, prior to the WGFTFB meeting. Ronald Fonteyne (Chair) reported on the recent activities, which were mainly concentrated on defining new measuring forces for mesh opening measurements. The present 4 kg measuring force used with the ICES mesh gauge was defined in 1962 when this instrument was adopted for scientific measurements of mesh opening. According to textile practices a 4 kg measuring force is appropriate for meshes made of single twines with a linear density of around R8000tex. Therefore the mesh opening of netting made of thinner twines would be over-estimated, whereas meshes of thicker twines would be underestimated when using the ICES gauge. The Study Group performed a series of mesh measurements on selected netting materials representative of that currently used in commercial codends in the ICES area. The ICES 4 kg mesh gauge underestimates the mesh openings for most of these nettings. Based on these results and on the availability of an inventory of netting materials currently in use for codends (collected by the SG), the SG proposes to test new measuring forces for specific groups of nettings. The proposed new measuring forces are 100 or 130 N (approx. 10 or 13 kg) for larger meshes (e.g. > 55 mm) but remain 40 N (approx. 4 kg) for smaller meshes made of thinner twines. Before formulating final advice, these measuring forces will be tested on the previous measured netting samples and then compared with the results obtained by other mesh measurement methodologies. These tests are imperative to assure that transition to the new measuring forces will not be detrimental to any codend selectivity and should, therefore, deliver results similar to the present procedures set down in technical measures legislation.

The inventory of netting materials was updated with data from Spain and Italy.

The Study Group reaffirmed its earlier conclusion to maintain the definition of mesh size as given in the international standards (ISO/CEN). The Study Group drafted specifications for a suitable mesh measurement methodology and further recommended the use of one single methodology, using a longitudinal gauge, for scientific, enforcement and industrial purposes. A standardization of mesh measurement practices will eliminate bias due to different methodologies.

An ICES Cooperative Research Report on the Study Group's activities, results and recommendations will be drafted for the 2003 meeting.

The Study Group will have its final meeting in March 2003 in Ostend, Belgium. R. Fonteyne (Belgium) was reconfirmed as Chair for a second term. The Study Group Report will be presented to WGFTFB at its 2003 meeting in Bergen.

A report will be generated and presented at the next FTFB meeting in Bergen.

9 PROGRESS ON DEVELOPING A MANUAL FOR THE MEASUREMENT OF THE SELECTIVITY OF STATIC GEAR

Thomas Moth-Poulsen (Denmark)

Discussion: Thomas Moth-Poulsen indicated that the work for gill nets is nearly complete. To further develop sections on longlines, pots and traps, he will have a meeting with Henry Milliken, Marianne Farrington, and Pingguo He on the June 8. Henry Milliken and Marianne Farrington have worked on the longline and gillnet section and Pingguo He is being asked to help on the trap section. René Holst has been working on the modelling aspects of static gear and proposed that a modelling section should be included for each of the static gear sections. It was asked if ghost fishing will be incorporated in the manual. Thomas responded that it will not and that the manual is focused in the selectivity of commercial static gear. Norman Graham wondered if the manual would address the catch of marine mammals; Thomas replied that it will not. Steve Walsh asked about data standards for fixed gear selection studies; Thomas indicated that the manual will suggest a standard data format and will include a priority list for data collection. Steve Walsh asked if a draft of the report will be available at the end of the year and if it is the intention to come to the next meeting with a product; Thomas replied that it was.

10 EVALUATE THE FINDINGS OF THE IBSFC SCIENTIFIC MEETING ON TECHNICAL MEASURES

David Somerton (USA)

The full report of the FTFB subgroup to review the findings of the IBSFC Scientific Meeting are included as Appendix 3 of this document.

Discussion: Erdmann Dahm and Thomas Moth-Poulsen remarked that the conclusions needs to be reworded to eliminate possible confusion about whether an increase of 10 mm in the legal mesh size of PE double strand 4 mm diamond codends will produce the same L50 as that produced by the 120 mm BACOMA window. Ulrik Jes Hansen expressed his concern about the new minimum mesh limits, particularly that he had received the mesh recommendation just before Christmas and the legislators received it shortly after Christmas so there was little time for a review. The Danish version of the legislation had 26 severe errors, making it hard for legislators to understand. Bob van Marlen asked Dave Somerton if he could comment on the suitability of having a SELECT database to obtain the information for this study. David replied that the analysis would have been much easier if they had online access to the data in the SELECT database. Thomas Moth-Poulsen observed that the selectivity side trawlers and stern trawlers that haul the net over the side should be similar. David replied that they had found a difference between the two vessel classes.

11 EVALUATE THE PROPOSED FAO SPONSORSHIP OF WGFTFB

Steve Walsh (Canada), FTC Chair

Steve Walsh reviewed the recent history of the ICES and FAO interaction including the proposed co-sponsorship of WGFTFB and the final ratification of the proposal by both agencies.

Discussion: David Somerton initiated the discussion by asking if it would be appropriate to have FAO host the FTFB meeting in 2004. Mike Pole asked if having FAO sponsorship would result in larger, longer meetings. Steve Walsh replied that the meetings might get larger but not much larger. John Willy Valdemarsen stated that FAO sponsorship might make it easier for non-ICES countries to join WGFTFB.

12 FTC REVIEW OF WG AND SG STRUCTURE

Steve Walsh (Canada), FTC Chair

Steve Walsh explained that this year - the 100th anniversary of ICES - the organizational structure will be examined to determine if it is consistent with the new ICES strategic plan. The first question is whether the two Working Groups comprising the Fisheries Technology Committee adequately address the priority issues. An ad hoc group of FTC members has been reviewing the need for adding either or both of two new working groups, one focused on the design of surveys and the other focused on fish behaviour. A discussion of the strengths and weakness of such a reorganization followed without resolving the issue. Some feel that the structure of WGFTFB meetings are like mini-symposia because the time is often spent on the presentation of papers rather than the discussion of the topics and that this format is influenced by the relative large attendance. Therefore one perceived advantage of forming the two new working groups is that the groups would become smaller, more homogenous and more focused on fewer issues and therefore more similar to other ICES working groups. However, few of the of the attendees felt that the current format of the meetings would benefit solely from a reduction of attendance. One repeated suggestion was that the mini-symposium format could be changed if fewer papers were presented for each topic and, instead, a review paper was presented as an introduction to a more organized discussion. Negative aspects of the creation of new working groups included the realization by many that it would be difficult to maintain the concurrent meeting of all FTC working groups. Therefore, most would have to forego exposure to some areas of research that they now get by attending a larger, more heterogeneous meeting.

Dick Ferro proposed that one measure of whether the WGFTFB was doing the job it was intended to do is to examine its terms of reference in the council resolution originally forming the working group. If WGFTFB was performing the functions outlined in this document, then perhaps the exact format of the meeting is not important. Several members stressed the notion that the WGFTFB meeting serves a very important function by providing a forum where the rapidly developing field of fishing gear technology can be informally discussed among peers without the time lag inherent with reading published research.

13 NEW BUSINESS

13.1 Request by the International Bottom Trawl Survey Working Group for help in redesigning the standard survey trawl

Andrew Newton, Chair of the International Bottom Trawl Survey Working Group, has asked WGFTFB for help in choosing a design for a new trawl that is effective on both smooth and rough bottoms. David Somerton asked the group what could WGFTFB, as a group, provide the IBTS working group. Dick Ferro said that there has been recent work to address this need and that a large, multi-agency proposal, the NOAH proposal, was submitted to the EU but not funded. WGFTFB can offer some input, technical advice, and we could help assess the results of those trials. Ingvar Huse recommended that the IBTS should adapt an appropriate ground gear to the existing net. Dave Somerton recommended that one reasonable approach is to stratify the survey into rough and smooth areas, use the appropriate trawl in each strata, and calibrate the new rough bottom trawl to the current GOV trawl. Benoit Vincent gave a brief presentation on some attributes of a trawl that would make it a better sampling instrument that the commercial fishing designs currently in use. In particular, he considered designs that minimize the effects of horizontal herding either by mounting the doors at the wings, flying the doors off the bottom, or designing a trawl without doors. Further discussions will be conducted with the IBTS Working Group to clarify the type of help they need.

13.2 Place and Time for the 2003 and 2004 WGFTFB Working Group Meetings

The 2003 WGFTFB meeting will be held on 27 June, in Bergen, Norway, immediately following the ICES Symposium on Fish Behaviour in Exploited Ecosystems. The focus of the meeting will be to assess gear related technical measures appropriate for improving species and size selectivity in *Nephrops* trawl fisheries.

The venue for the 2004 WGFTFB meeting has not yet been finalized. Because of the recent agreement between ICES and FAO for FAO co-sponsorship of the WGFTFB working group, a proposal was made to have FAO host the 2004 WGFTFB meeting in Rome, Italy. Wilfried Thiele, FAO representative, agreed to work with FAO staff to determine it would be possible to host the meeting. WGFTFB would be notified by the end of September if the proposal is acceptable. If the proposal is declined by FAO, a previous offer by Thomasz Linkowski to host the meeting at the Sea Fisheries Institute in Gdydia, Poland will be considered. If the Polish offer proves to be unworkable, next to be considered is an offer by Hüseyin Özbilgin to host the meeting at Ege University in Izmir Turkey. The time of the meeting will be chosen once the venue has been determined.

14 NATIONAL REPORTS

14.1 Germany

A. Institute for Fishing Technology and Fish Quality, Hamburg (Erdmann Dahm)

1. Selectivity of cod trawls in the Baltic

Research on the influence of codend yarn diameter and/or yarn construction on the selective effects of the codend was continued. Single 8 mm and double 6 mm decreased the L50 by more than 10 cm compared to a codend made of single 4 mm. Any regulation issued in future without limitation of the yarn diameter seems therefore useless.

The newly legislated BACOMA- codend requires a square-mesh window made of knotless braided material. In own tests this material was replaced by ordinary knotted material of the same mesh size. The selective effects remained the same.

Again tests with a codend made of netting turned 90 degrees demonstrated superior selective properties. It is not even necessary to reduce the number of meshes in circumference as previously assumed if extension and codend are both made from this type of netting

2. Selectivity and bycatch in the shrimp beam trawl fishery

Research concerning the improvement of bycatch reduction in the shrimp beam trawl fishery (EU-Project DISCRAN) was finished by the evaluation of the results for the final report. 70 mm sieve nets have been compared with sorting grids with 20 and 30 mm bar distance. The results show a remarkable reduction of important fish bycatches by all three bycatch reducing devices. Less pleasing is the loss of commercial shrimp connected with their use, which can reach up to ca. 20%. The effectiveness of a 70 mm sieve net lies between that of a 20 and 30 mm sorting grid.

A further investigation dealt with additional measures to reduce the bycatches of fish in the same size as the shrimps. Increasing the codend mesh opening from 20 to 28 mm seems not to be an acceptable way to deal with this problem. Above 24 mm the losses of commercial shrimp become so high that such measure would find severe resistance from the commercial fishery.

3. Flatfish selectivity in the Baltic

Continuation of research dealing with flatfish bycatch in cod trawls brought no real progress as preliminary expectations concerning a possible positive influence of escape windows in the lower panel were not fulfilled. Neither square mesh windows nor windows filled with netting turned 90 degrees caused better flatfish selection. At present, there seems no other way than a mesh size increase to reduce the bycatch of undersized flatfish. However, in the targeted fishery for flatfish it seems reasonable to apply another mesh size as for the cod fishery. 125 mm are perfectly suited to obtain a L50 of 25 cm.

Continuous records of fish behaviour within the trawl with small UW-TV-cameras fixed under the upper panel helped to understand the efficacy of the different codend designs tested.

4. A new selection curve

A new selection curve based on the idea of a split retention (fishes with a chance to escape and fishes without that possibility) was developed and published

5. Contributions to the standardization of a new survey trawl for the Baltic

The part of the IFF in this EU-funded project consisted of technical performance measurements of the two chosen designs during research ship cruises and of the writing of a manual on construction and operation of the new standard gear.

6. Development of a precise baiter for longlines

The development into a simple precision baiter for pieces of fish and whole fish were continued. Tests at sea brought encouraging results though some technical bugs still have to be removed. Development work in the workshop was facilitated by the construction of a special test device

7. A new research ship

The planning of a research ship replacing FRS A Solea is in full progress. The new ship will fulfil contemporary requirements of noise reduction. Length and carrying capacity for scientists will be increased.

B Rostock University (Gerd Niedzwiedz)

1. Basic research

The Institute of Maritime Systems and Fluid Engineering participated in a research project aiming at the improvement of the selectivity of Baltic flatfish trawls, which was funded by the Federal State Mecklenburg-Vorpommern and the European Community. The contribution of the institute consisted in the development of theoretical tools enabling the researchers to model and calculate the performance of netlike objects in currents and to make considerations applying the theory of similarity on these models. Such theoretical work served for the preparation of experiments in the low speed wind tunnel operated by the university. Experimental work comprised as well the investigations in the wind tunnel covering a large number of different codend modifications as the full-scale operation of such codends aboard of commercial fishing boats. During the latter modern underwater observation techniques and hydroacoustic measuring methods were used. Based on the most important research results recommendations were given to create separate cod-end regulations for catching Baltic cod and flatfish.

2. Research-on-demand-projects

Re-calculation of trawl performance for commercial net manufacturers was conducted. Most of such orders came from a big Icelandic trawl producer. By means of the algorithms and models developed in Rostock and comprised in the program “RopeNetCalculator”, different trawl designs of the customer were checked and optimised according to his criteria.

The low-speed wind tunnel available at the institute since 1998 could be further accomplished with regard to its outfit of measuring tools. Depending on the task the measurement of forces as well as the record of flow characteristics may become necessary. Thus, e.g., resistance measurements at plane net walls became necessary in 2001 where the Reynolds number and the angle of attack had to be varied.

Towed shearing devices are not only applied in the trawl fishery but can also be a component of towed bodies used for seismic investigations at sea. It is aimed to keep such devices out of the turbulent zone behind the ship caused by the ships propeller if high quality seismic measurements with water and air guns are required. Shearing devices can be advantageous when used for this purpose. However, they require particular technical properties and handling technologies. Drawing on experience gained during the design of shearing devices for trawling such devices were designed and built at the Chair of Ocean Engineering and tested aboard the University research cutter “Gadus”. The customer has taken over these devices for further commercial application in April 2002.

3. Public relations

The top event in 2001 for the Chair of Ocean Engineering was the International Symposium DeMaT (Development and Evaluation of Maritime Technologies). In total, 44 scientists from 14 countries attended the meeting.

Main topics were: theoretical and experimental methods for the design of fishing gear, scientific investigations on the selectivity of trawl codends, interactions between maritime systems and the marine environment.

Twenty seven scientific contributions presented innovative methods, technologies, ideas and recent research results. Proceedings of the conference are bound to be issued in 2002 at the publisher “Neuer Hochschulschriftenverlag Rostock” and will contain all contributions to the conference. The uniform opinion of all conference participants was that particularly for the engineering aspects of fishing gear design a special platform is needed. They strongly supported to carry on with this symposium at the scientific level attained so far.

14.2 United States

A. Massachusetts Division of Marine Fisheries, Conservation Engineering Program (H. Arnold Carr (retired) and Michael Pol

1. Testing of low-profile, low cod bycatch gillnets - Phase II

Additional testing was conducted of two experimental gillnets designed with low vertical profiles against a standard cod Gadus morhua gillnet and a standard flatfish gillnet. One experimental net replaces the floatline with another leadline; the second adds lead to the floatline every 30 ft. Thirty-five overnight sets have been completed. Preliminary results indicated that catch rates of cod and commercial flatfish in the experimental nets were not different from standard flatfish gillnets. “Stand-up” cod gillnets using floats on the floatline caught cod at a greater rate and flatfish at a lower rate than the other three designs. The stand-up gear also appeared to catch larger cod. Data are still being analysed.

2. Groundfish trawlnets designed to reduce the bycatch of cod

Testing of two experimental trawl nets provided encouragement that Atlantic cod Gadus morhua could be separated from flatfish species. The Ribas and topless nets both modify the top half of a trawl net; the Ribas net by using 8-in (20.3 cm) square mesh; the topless net (based on a Faroese design) by removing much of the twine in the top of the net. Reductions of cod catch rates (kg/hr) exceeded 76% for the Ribas net; the topless design reduced cod catches over 93%. Yellowtail flounder, *Limanda ferrugineus*, catches, both kept and discard, were also reduced. Underwater video showed cod exiting the nets through the top mesh and through the gap made by the removal of twine. Testing was recently expanded to three vessels; data have been preliminarily analysed.

3. Improving the selectivity and utility of demersal hook fishing

Artificial baits using attractants made from seafood processing waste continued. Several bait formulas with different attractants and matrices were tested using underwater cameras to observe reactions of captive cod, *Gadus morhua*, in raceways and in more natural conditions. A preliminary conclusion is that cod react toward many bait formulas, but are highly selective when actually ingesting artificial bait. This work is a collaboration with Susan Goldhor of the Center for Applied Regional Studies.

4. Scup bycatch reduction in squid fishery

Two extension modifications were developed and tested on two commercial vessels and show potential for reducing scup, *Stenotomus chrysops*, bycatch in a *Loligo pealeii* fishery when large schools of scup are encountered. During 14 days of field testing in June-July and October 2001, a vee-shaped panel in the extension and a ring-grid both removed scup at mean rates ranging from 87–100%. Both excluders were used to direct scup through lateral fisheyes. When small (less than 9 cm FL) scup were present, they were not excluded, suggesting that these modifications may not be appropriate at all times.

5. Juvenile mortality reduction in demersal longline cod fishery

MaDMF, in collaboration with Marianne Farrington, New England Aquarium, tested two methods of improving survival of hooked juvenile cod, *Gadus morhua*,: removal using a flip technique and post-capture holding in potassiumsupplemented sea water. The flip technique resulted in less physical injury but no increase in survival after 72 hr of holding. Addition of potassium to counter a stress reaction also showed no increase in survival.

6. Development of an acoustic scallop dredge

In situ observations suggested that bay scallops, *Argopecten irradians*, react to the sound of outboard engines. Bay scallops and sea scallops, *Placopecten magellanicus*, held in aquaculture facilities and in the field were subjected to recordings of outboard engine noise with mixed results. Limited testing of DC pulses may lead to further research on the use of electricity.

B. Manomet Center for Conservation Sciences, Marine Conservation Program (Dr Chris Glass)

1. Bycatch reduction program, squid/scup fisheries

Research continued during 2001–2002 on bycatch reduction and improved selectivity in Atlantic longfin squid fisheries in the Mid-Atlantic region. As was demonstrated in 2000–2001, improved selectivity for larger squid can be achieved through the use of larger mesh (2.5"). However, developing methods and strategies to reduce bycatch and discard of scup has become a priority. Adding escape windows to induce escape behaviour in scup showed positive results for the inshore longfin squid fishery in Nantucket Sound during 2000. Research on the escape window continued with trials testing a 5.5" square mesh escape window configuration of 45 meshes behind the body of the net and ahead of the codend.

2. Multispecies groundfish fisheries, codend selectivity

Preliminary trials conducted in the Gulf of Maine groundfish fisheries indicate that composite codends (that is, codends fabricated with both square and diamond meshes) may be effective in reducing bycatch and discard of a range of groundfish species. During these preliminary trials, hauls were conducted in January, April and June 2001, comparing composite codends (6.5" square mesh over 6", diamond mesh; 6.5" square mesh over 6.5" diamond mesh) and a 6" hexagonal mesh codend to industry-standard (6" diamond or 6.5" square) mesh configurations. Using a covered codend technique, selectivity for individual species could be compared for each codend configuration. For a given population of cod, composite and hexagonal codends increased the selective efficiency of trawl gear. This is demonstrated by an increase of L_{50} from ~57 cm for a standard 6" diamond codend to ~65 cm for composite codend mesh configurations, resulting in an approximately 62% reduction in the bycatch of sub-legal cod. While the selective efficiency for cod was increased, the catch of legal sized flatfish (yellowtail flounder, winter flounder, dab) remained relatively unaffected.

3. Ex-It fish excluder

During September and December 2001, on two commercial fishing vessels, preliminary trials were conducted to test the effectiveness of the Icelandic bycatch reduction device, Ex-It, in reducing the inadvertent catch of undersized fish in the Northwest Atlantic multi-species groundfish fishery. Though originally designed to test 3 different grid spacings (50mm, 60mm, 70mm), this project has yielded substantial information on the selectivity of the 60mm bar spacing for two areas in the Gulf of Maine. At the time this study was conducted, the minimum landing size for cod was 48 cm, however this limit has been increased to 56 cm. Results indicate that for cod, the L_{50} was less than minimum landing size at 47 cm, while for haddock (minimum landing size is 48 mm) the L_{50} were both 53 cm. Flatfish were more variable with yellowtail and winter flounder exhibiting L_{50}s greater than minimum landing size (33 cm and 30.5 cm respectively) while dab and gray sole exhibited L_{50}s close to minimum landing size (35.5 cm). The results also suggest that the selective efficiency of the Ex-It may differ by both season and area. Work will continue to assess the selectivity of the Ex-It system in this multispecies fishery for the 50 mm and 70 mm bar spacings.

4. Future program for 2002–2003

Georges Bank Yellowtail Program

A new cooperative research program will begin that will attempt to demonstrate that George's Bank yellowtail flounder can be targeted without significant bycatch of cod and haddock in Closed Area II. The program will study reaction behaviour of target and non-target species and is designed to demonstrate that yellowtail flounder can be fished during particular times of the year without significant bycatch and discard of other species, particularly cod and haddock.

Square Mesh Escape Window for Scup Bycatch Reduction

Building on promising results from past trials with the scup escape window in the longfin squid fisheries, work will be continued to test scup escapement using square mesh escape panels. Work will be continued with the offshore longfin squid fishery.

Composite Codend for Groundfish

As the Gulf of Maine groundfish fishery continues to be a contentious issue, we will continue to provide data on gear modifications that enable bycatch reduction. Recent results show that composite codends significantly reduce bycatch, however, it is important to continue to test composite codends in multiple locations and at different times of the year.

C. University of New Hampshire (Pingguo He)

A project was started to design and test a double grid selectivity device to reduce cod bycatch in flatfish trawls in northeastern United States. The design involves an inverted primary grid and a secondary guiding grid to allow roundfish to swim through the primary grid and out of the net. A "self-clearing" mechanism was also tested in the flume tank to reduce the problem of grid clogs. Sea trials will be continued this spring and fall. A semi-pelagic shrimp trawl was designed in cooperation with Fisheries and Marine Institute in Canada. Sea trials will be conducted in Gulf of Maine pink shrimp fishery in the winter of 2002/2003.

D. Maine Dept. of Marine Resources (Daniel F. Schick)

The Department of Marine Resources (DMR) continued testing of several gear types for improving the size selectivity and reducing bycatch in the whiting (silver hake) fishery in the Gulf of Maine. For several years, the Maine whiting fishery used a 1–3/4 inch diamond mesh cod end and a 40 mm bar space "Nordmore" grate under experimental fishery status and while the bycatch of regulated species was low, the size of whiting retained was too small to meet management goals. To increase the size of whiting selected by the gear, research conducted in 2000 tested two grate bar spacings, 50 mm and 65 mm, and two cod end mesh sizes, 2.6 inch diamond and 2.2 inch square, against two control nets, both with 1–3/4 inch diamond cod end and one with a 40 mm bar space grate. The best combination of cod end mesh and bar spacing for retaining the desired size distribution of whiting and reducing the bycatch of Atlantic Demersal Finfish "regulated" species was the 2 inch bar space grate and either the 2.2 inch square mesh cod end (the 2.2 inch square mesh is measured as diamond mesh, stretched corner to corner and measured along the longest axis) or the 2.6 inch diamond mesh cod end. Both cod ends were roughly equivalent in performance.

The next gear tested in 2000 was a modification of the raised footrope used in the Massachusetts whiting fishery where the footrope is raised some distance above the chain sweep and connected to the sweep with dropper chains. The chain sweep was replaced with a roller frame and two dropper chain lengths, 30 inch and 42 inch were tested. The control net was a roller frame net with 1–3/4 inch diamond cod end and no grate. Separate trials were conducted with one trial using the 2.2 inch square mesh cod end paired with the 2.5 inch bar space grate and the other trial using the 2.6 inch diamond mesh cod end paired with the same grate. The results showed significant losses in bycatch, especially of flatfish, and little loss of whiting of the desired size compared to the control net and compared to the losses with the grate/cod end combinations without the raised footrope. The 2.2 inch square mesh cod end produced a greater escapement of small whiting than did the 2.6-inch diamond mesh cod end with either the 30 inch or 42 inch dropper chains. It was only through the use of the raised footrope with the larger bar space/cod end combination that the catch met the 5% maximum bycatch of regulated species.

In 2001, research tested the difference in catch and bycatch between a net with a raised footrope with 30-inch dropper chains to a roller frame and a net with a raised footrope with 30-inch dropper chains, but with no roller frame. Both nets had a 50 mm bar space "Nordmore" style grate and a 2.6-inch diamond mesh cod end. These were tested against a control net with the same bar space grate and same cod end, but with the footrope rigged down on top of the roller frame. The raised footrope with no roller frame produced 2.9% and 3% bycatch of regulated species by weight in two separate trials of 6 and 10 tows, respectively, well under the 5% limit. The control net caught 19% and 4.6% bycatch of regulated species by weight in the two separate trials. The raised footrope with the roller frame produced 4.3% and 8.8% bycatch of regulated species by weight in two separate trials of 6 and 9 tows respectively. The control net caught 19.3% and 8.5% regulated species by weight in the two trials.

The added reduction in bycatch of regulated species through the use of the raised footrope net with no roller frame when using the 50 mm bar space grate and 2.6 inch diamond mesh cod end configuration tested in 2000 qualifies this net configuration for use in a whiting fishery in the Gulf of Maine. What remains to be done is to change the regulations as to where this gear can be used.

Work in progress in 2002 is to test a 45 mm bar space grate with a 2.6 inch diamond cod end in the raised footrope net with no roller frame and a 50 mm bar space grate with a 3 inch diamond cod end in the same net. Both trials are aimed at improving the size selectivity for whiting and further reducing bycatch.

E. Massachusetts Institute of Technology Sea Grant College Program, Center for Fisheries Engineering Research (Clifford A. Goudey, CFER Director

1. Oceanographic and Fisheries Data Collection and Telemetry from Commercial F/Vs.
Sponsor: National Ocean Partnership Program

The Fleetlink system has been developed and demonstrated on three commercial fishing vessels. The system includes meteorological and environmental sensors, a P.C. controller and interface, satellite telemetry and Web based data dissemination. The system provides email communications for the boats and the means for entering and telemetering catch results for marketing and management purposes. The sensor data is intended to improve marine weather and fisheries resource predictions. More details are found at http://www.fleetlink.org/.

2. Sea Grant Technology Program in sea scallop mariculture. Sea Grant Program

This project is developing and demonstrating a towed sled for assessing the size and distribution of sea scallops on the seabed. Sled mounted camera, lights, computer, data storage, and batteries are combined with image processing software for identifying, sizing, and counting scallops *in situ*. The system can be used from commercial trawlers using a normal tow wire. Data and images are downloaded at the end of each tow.

3. Establishing a groundfish study fleet to improve stock assessments. NMFS/RSC and MIT Sea Grant

A study fleet of twelve vessels has been formed to report fine-scaled data on the catch and bycatch associated with the Gulf of Maine groundfishery. Inexpensive hardware has been developed to allow the electronic logging of catch, discards, and GPS position. Data is sent to a central archive via telephone line and the end of each trip. A Web-based system is used for data entry of vessel and gear specifications and for the retrieval of GIS-based data products by fishermen. The reporting system currently is available commercially from Thistle Marine LLC of Ellsworth, Maine (see: http://www.thistlemarine.com/products.asp#HMS110).

4. Adopt-a-Boat: commercial fishing vessels in K-12 education
Sponsor: Northeast Consortium

The Adopt-a-Boat program is a collaborative project between the fishing industry and educators. The goal is to use commercial fishing boats as a vehicle for teaching the complexities of marine resource utilization, marine ecology, and life as a fisherman to K-12 students and facilitate the presentation of a balanced picture of commercial fishing. In its first year we have established twelve vessel/classroom partnerships and facilitate their collaborative activities with logistic support, communications, and other state-of-the-art technologies. For more information visit the project Web site: http://www.adoptaboat.org.

5. The development and demonstration of a whale-free buoy for commercial fishing.
Sponsor: Northeast Consortium

A tapered inflatable buoy is being developed and evaluated as a way of reducing the risk of marine mammal entanglements in passive fishing gear. By eliminating the normally abrupt transition between the buoy line and the buoy, the line and buoy can be shed during an encounter.

6. Commercial trials of flexible trawling devices including soft trawl doors
Sponsor: Northeast Consortium

This project is exploring the application of flexible hydrodynamic devices as a way to control the shape and depth of trawls. The goal of the research is to reduce habitat impacts by relying less on heavy weight and rigid doors and to generate wider mesh openings for improved selectivity. Based on previous model tests, prototype devices will be tested aboard commercial trawlers to determine the effect on trawl shape and depth, contact with the seabed, and the influence on fish behaviour.

7. A preliminary evaluation of stretch-mesh catch controls.
Sponsor: Northeast Consortium

This project is evaluating a concept aimed at reducing the waste of resources associated with regulatory discards. The normal nylon or poly twine used in the codend extension will be replaced with bungee cord of the appropriate strength. Under normal fishing conditions where small or modest hauls are experienced, a trawl rigged with this "Stretch-Mesh" section will fish similar to a conventional net. However, when loaded, the selectivity of the trawl will be changed and only fish unable to pass through this enlarged mesh section would be retained.

8. A preliminary evaluation of inshore groundfish pots.
Sponsor: Massachusetts DMF/Northeast Consortium

We are looking at pot fishing for groundfish as a more ecologically defendable harvest method compared to current techniques. Preliminary work with 15 pots is occurring in the area of mid-coast Maine. Several important fishing parameters will be evaluated including mesh size, bait, soak time, tide, and time of day. We are also seeking to optimise such things as funnel design, bait location, and the use of funnel valves or triggers.

9. An international workshop on passive acoustics applications in fisheries.
Sponsor: MIT Sea Grant, ONR, NURC, SMAST/UMass

A workshop was convened 8–10 April 2002 to bring together a group of international experts in passive acoustics as it applies to fisheries, marine conservation issues and the identification of essential fish habitats. The "hands-on" workshop included thirty presentations on techniques and their application to fisheries issues worldwide. Proceedings are being prepared. More information can be found at: http://web.mit.edu/seagrant/acoustics/index.html.

F. National Marine Fisheries Service, Southeast Fisheries Science Center

1. Cooperative research on development of gear modifications and fishing practices to reduce turtle takes in the U.S. Atlantic pelagic longline fisheries

The Southeast Fisheries Science Center in cooperation with the U.S. Pelagic longline fishing industry is investigating the feasibility of gear modifications and/or fishing practices to reduce the incidental capture of endangered and threatened sea turtles by pelagic longline fishing gears. NOAA Fisheries gear specialists are working with fishers to gain insight into fishing gear and practices and to develop mitigation measures to reduce turtle interactions with sea turtles. Prototype mitigation techniques are being developed using captive reared turtles in controlled experiments and evaluated on commercial vessels in the Atlantic pelagic fishing grounds. Studies include evaluation of dehooker and line cutter prototypes to allow removal of fishing gear from turtles, bait types and hook designs developed to reduce hooking of sea turtles, satellite tags to determine distribution and behaviour of sea turtles and operational changes in fishing practice to reduce turtle interactions.

G. National Marine Fisheries Service, Northeast Fisheries Science Center

1. FSCS (Fisheries Science Computing System) - data entry at sea system

A sophisticated data acquisition system has been designed by the Office of Aviation and Marine Operations (OMAO) and the Northeast Fisheries Science Center (NEFSC) specifically to digitally collect all critical fishery-independent data aboard fisheries research vessels. The Fisheries Scientific Computer System (FSCS) is responsible for collecting such data as species, catch weights, individual fish lengths and weights, gender and maturity, as well as stomach content data. Station and oceanographic data are also collected and integrated into the system. Once data are collected for a given station, they are subsequently passed on to an ORACLE database ingestion application, which enables data to be audited before it is examined on shore.

FSCS now replaces manual data recording which shaves months off the time required to make cruise data available to researchers. The system performs all sub-sampling calculations and runs real time audit checks to find data entry errors. Data can be sent back to shore electronically to provide researchers with up to date catch information and to check for any inconsistencies. The hardware suite consists of two redundant network servers and each of the following at three sampling locations: PC with touch-screen terminal, electronic fish measuring board, electronic weight scale, bar code scanner and label printer. FSCS went fully operational during the 2001 NEFSC spring bottom trawl survey and is currently being implemented on the NOAA ships Albatross IV and Delaware II during bottom trawl, scallop and hydroacoustic surveys.

2. Survey Sensor Package (SSP)

The Northeast Fisheries Science Center has contracted the Woods Hole Group, an independent engineering company, to design a sensor system for use on the hydraulic clam dredge, scallop dredge, and other types of survey and long-term monitoring projects performed by NMFS. The SSP logs information from various sensors that measure water temperature, sea pressure, dredge pump manifold pressure, voltage of the three phase power supply, and the pitch and roll of the system. The system can be outfitted with other sensors that monitor a large variety of environmental variables. The SSP logs data from the sensors every minute and, when above water, transmits this information to an onboard computer. Presently this system is being utilized on the Delaware II and is intended to be used on commercial vessels as well as other research vessels.

14.3 United Kingdom

A. Marine Laboratory Aberdeen

1. Gear selectivity

The Marine Laboratory investigated a range of technical gear measures to be adopted as part of the cod recovery plan. Nine projects were undertaken to assess the use of gears on a range of vessels, large and small, and on different methods of fishing including seine net (fly dragging), pair trawl, twin and single whitefish trawl and *Nephrops* trawl. Codend selectivity was measured to assess the effects of mesh size, square mesh panel position, lifting/strengthening bags, extension length, netting colour and contrast, vessel towing speed, and fish sorting grids. The funding for most of this research was provided via a Fisheries Science/industry Partnership Group established by the Scottish Executive.

2. Technical changes in the Scottish fishing fleet

A fishing gear survey of the Scottish demersal whitefish fleet was undertaken by the Marine Laboratory as part of a PESCA funded initiative. The information mainly comprised codend and other gear details and will be used to estimate fleet selectivity.

3. Oil installation/fishing gear interaction

The Marine Laboratory continues to assess and advise on the impact of UK oil development and abandonment proposals and recommend suitable courses of action. A proposal to investigate the overtrawlability of the decommissioned Hutton field's cuttings pile was put forward.

4. Physical and mathematical modelling

A theoretical study of the factors influencing the mesh size measurement of an idealized mesh was carried out. The effect on mesh measurement of twine bending stiffness, frictional resistance, boundary slope, gauge force and gauge thickness were all examined. The measurement method this analysis most approximates is that of the ICES gauge.

5. Whole gear selectivity

This project is now in its second year of development trials. A 12 day cruise on FRV Scotia was undertaken to develop techniques using multibeam sonar in conjunction with self recording low light cameras, to provide a quantitative measure of the amount of fish passing through a number of critical points down the net. The data collected was compared to, and then validated against the actual catch recorded from the cod end. Tank-based trials of a laser stripe imaging system were also carried out to assess the behavioural reactions of fish to the laser stripe and to collect three-dimensional data on groups of free-swimming fish.

6. Fish Behaviour

Trials to assess the effect on fish escapes of high and low contrast panel/codend combinations were carried out during a 12-day selectivity cruise aboard a chartered fishing vessel. Useful techniques for observing fish escaping from panels and codends were developed. A follow up cruise is planned for late 2002.

7. Development of techniques for assessment of survival of fish escaping from codends

Work has continued on the development of improved sampling techniques for investigating post-escape mortality from towed fishing gears. This work has focused on developing a codend cover that has a minimal effect upon the water flow in and around the codend and, in addition, allows for the collection of captive fish in a non-damaging, static-water environment.

As a precursor to future work investigating the importance of fish condition in selectivity and potential escape mortality, a survey of gadoid fish in inshore and offshore areas in the North Sea and off the west coast of Scotland has been conducted. This work was funded by the Science/Industry Partnership and has provided basic biological data enabling a simple comparison of condition indices in these different populations.

14.4 Spain

A. AZTI (Technological Institute for Fisheries and Food)

1. A study to identify, quantify and ameliorate the impacts of static gear lost at sea

In collaboration with other European research centres, the study aims at evaluating the extent and impact of the loss of fishing gears in European waters. During its first year, a survey among the Spanish Cantabrian gillnet fishing fleet skippers was undertaken to characterize the importance of the phenomenon as well as to identify the main causes leading to the loss of fishing gears. Subsequently, two main simulation pilot studies have been carried out starting respectively in June 2000 and February 2001 in which different sets of tangle nets replicates were set in open sea (around 70 fathoms depth) and hauled at different soaking time periods during one year. The aim of the experiments was to mimic the loss of tangle nets (*rasco* nets targeting monkfish) and to study their evolution in summer and winter conditions respectively. Information on species caught and their stage were recorded in order to estimate the catch rate of the nets in the short, medium and long term. Preliminary tests were also carried out with the side scan sonar to determine the validity of this technology to detect of real net losses with poor results as well as with ROV. Generally speaking, the study characterises the main reasons for losing gillnets and quantify the amount of gear lost in the different types of gillnet fisheries. The results focus on the evolution of fish catch rate compared to commercial *rasco* nets. An estimation of the residual mortality of lost tangle net is provided and estimated Aghost catches@ are compared with the annual catches of the commercial fleet in the Cantabrian Sea (ICES sub-area VIIIc). Although the study shows that the residual catches due to lost nets are of minor importance (monkfish catches due to lost nets have been estimated to represent 1.22% of the annual commercial landings) recommendations are made so as to minimize the gear losses.

2. Trammel net selectivity studies in the Algarve (Southern Portugal), Gulf of Cadiz (Spain), Basque Country (Spain) and Cyclades Islands (Greece)

Trammel net is one of the main small scale fishing gears in south European artisanal fisheries. This project aims at characterising its fishing pattern in the main fishing *metiers*. A survey among fishermen of the Cantabrian Region (north of Spain) has defined the main trammel net fishing *metiers* characteristics (type of fishing gear, target species, fishing season, etc.) and the relative importance of each *metier* in terms of amount of fishing fleet involved in the activity. A complementary survey concerning the technical characteristics of the fishing gears has provided detailed data on the main types of fishing gears used. According to that data, experimental trammel nets were mounted with combination of two (500 and 600 mm stretched mesh opening) and three mesh sizes (90, 100 and 110 mm stretched mesh opening) in the outer and inner panels respectively. Fishing trials were performed during the year 2000 (12 fishing days by season). The study provides information on: a) technical data of commercial fishing gears; b) catch species composition and discards by combination of meshes and by depth strata; c) comparative catch rates for the main target species; d) method of capture; e) size and species (diversity) selectivity parameters; f) characterisation of the fishing metiers by means of multivariate analysis.

3. Study of the fishing pattern of the high opening trawl and pelagic trawl in the hake fishery of the Biscay Bay

Both high opening and pelagic trawls have played an important role in the Biscay Bay fisheries of hake during the last years. This project seeks to give an overview of their fishing patterns in terms of composition of the catches, level of discards, catch efficiency and codend selectivity. A program of seasonal observations onboard fishing vessels has been implemented to obtain data on catches and discards in a haul-by-haul basis. Moreover, several experimental seasonal fishing trials have been performed using the method of the alternate hauls to study the codend selectivity on board commercial fishing vessels. The project provides information mainly on: a) fishing gear characteristics and geometry when fishing; b) seasonal variation in the fishing strategy; c) codend size selectivity parameters for hake for the commercial fishing gears on a seasonal basis. The results of the project have been presented in the frame of the technical meetings promoted by the European Commission (DG Fisheries) to establish the recovery plan for the European northern hake stock.

4. AZTI Remote Sensing Service

AZTI has been studying remote sensing in relation with pelagic fisheries. AZTI HRPT Ground Station receives and processes data from NOAA, SEASTAR and FENGYUN satellites to obtain SST images and isotherms and chlorophyll 'a' concentrations maps. By means of HF transmission AZTI is sending these maps during the tuna-fishing season to the Basque coastal tuna fishing fleet. For the 2002 fishing season the Service has included altimetric and weather maps. The aim is to provide information in order to detect areas of maximum probability of catching tuna.

5. Improvement of the tuna attractiveness in the pole and line fishery

Tuna sound recordings have been obtained in the pole and line fishery. Feeding and swimming noises from albacore (*Thunnus alalunga*) when attacking the live bait have been recorded, analysed and filtered. Playback of these recordings will be made to study fish behaviour and the possibility of using as an acoustic stimulus.

6. Remote sensing application in the tuna purse seine fisheries

Tuna purse seiners use remote sensing information from different commercial companies to be able to detect areas for fishing by means of fish finding maps. The aim of this project is to install on board the tuna purse seiner a HRPT Portable Station. The skipper will use a friendly software to be able to process satellite information and obtain by himself location of oceanographic events (thermal boundaries, eddies, etc.) and plankton concentration to decide areas of fishing.

7. Artificial baits alternatives mainly based on fish waste

The aim is to develop an artificial bait for hake and other commercial deepwater species based on waste from fish processing plants. The bait should have better or similar effectiveness than the natural bait (such as sardine, squid and mackerel), a competitive price compared with the natural bait and will be more adequate than the natural bait for mechanised longline

14.5 Belgium

1. Selectivity and discards reduction of shrimp beam trawls

The study on the development of environment friendly fishing methods for brown shrimp (*Crangon crangon*) in the Belgian coastal waters was continued. The main aim of this study is to develop a shrimp trawl that (a) fishes in a species and length selective way, (b) reduces the unwanted by-catches, (c) thus reducing the impact of this coastal fishery on the environment and (d) improves the quality of the catches. The trials with sorting grids and sieve nets were concluded. Both systems are based on filtering the catch and are quite sensitive to clogging, especially the grid. In some seasons the sieve net can be a workable solution to reduce by-catches although 0-age flatfish are not sorted out to a great extent. The electric fishing trials at sea gave promising results with a significant reduction in by-catch and almost no losses of commercial shrimps. The results, however, depended on the season and probably water temperature (activity of the shrimps) influenced the results.

2. Evaluation of technical measures (North Sea cod recovery plan)

The recently implemented technical measure for beam trawls to protect cod B a large mesh panel in the front part of the top panel B was evaluated during three sea trips aboard RV Belgica. A twin beam trawl was used to carry out a catch comparison experiment. Unfortunately the cod catches were very low and whiting and poor cod were the only roundfish species caught in sufficient numbers to evaluate the selective net panel. No significant differences were found.

3. Mesh measurement

The EU project "Creating the conditions for a Combined R&D and Demonstration Project for the development of an objective mesh gauge" (Contract Q5AM-2000–00005) was completed. The objectives were: to seek partners for the development and construction of a new mesh gauge, to find solutions for exerting a stable measuring force, to investigate the legal aspects of mesh measurements for inspection purposes and to prepare and write a proposal for a Combined R&D and Demonstration Project for extensive testing of the new gauge(s). The Sea Fisheries Department was as co-ordinator of this Accompanying Measure; the other partners are the University of Aberdeen and the Dutch Fisheries Inspection Services. A proposal for a project the development proper of a new, objective, mesh gauge, called OMEGA, was submitted to the European Commission and favourable evaluated.

The activities in the frame of the ICES Study Group on Mesh Measurement Methodologies were co-ordinated. Seven institutes took part in further inter-laboratory test program to investigate the effect of measuring force and mesh gauge type on the measurement results.

4. Selectivity database

Cooperation was given to the EU-project SELDAT 2 aiming at the design and implementation of a selectivity database.

5. Ecological effects of fishing activities

The EU-project FAIR PL97–3809 "Reduction of adverse environmental impact of demersal trawls" was concluded. The main objective was to assess methods to reduce the adverse impact of demersal trawls on benthic marine organisms through changes in net design and alternative methods of stimulation. Various benthos escape devices were tested. A square mesh window in the belly of the net, just in front of the codend looks very promising.

14.6 Norway

A. Institute of Marine Research

1. Survival in the Barents Sea bottom trawl fisheries

During the years 1990–1995, several experiments were conducted to study survival of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius* virens) escapees in the northern bottom trawl fisheries. In these experiments no mortality was found among cod and saithe, and only a low mortality (about 5%) among haddock. However, after sorting grids were made mandatory in the bottom trawl fisheries in the Barents Sea north of 62^{o}N, the trawler fleet suspected the grids to add to the escapee mortality. Therefore, new survival experiments were conducted summer 2000 and 2001 in order to improve the confidence in the survival figures for gadoid species. No mortality was found among cod and saithe, while the mortality of haddock was higher than in previous experiments, although it varied considerably between parallels. A clear length dependency in mortality was demonstrated. It was also shown that mortality was higher among mesh sorted than grid sorted fish, but it is reason to believe that the methodological errors accounted for a high proportion of the observed mortality in all experimental groups.

2. Comparative selectivity experiments

A collaborative selectivity experiment was conducted with the Marine Laboratory, Aberdeen in which the selectivity of a three different codend/gear configurations was assessed. Namely, (i) a 'standard' 120mm codend, (ii) a 120mm cod-end with a 110mm panel included and, (iii) a 120mm codend with a 35mm Sort-V selection grid inserted in the extension. For haddock, the results showed that for the 'standard' and the codend fitted with the panel, the L50 varied considerably between hauls. This was attributed to differences in catch size. The data from the grid showed a far lower degree of variability. Estimates of selection range showed that this parameter was significantly sharper with the grid.

Limited data were obtained for cod and saithe, with the panel codend showing the highest L50, but these should not be over interpreted due to the relatively few hauls with each gear group.

3. The immediate effects of intensive experimental otter trawling

The immediate effects of intensive experimental otter trawling on marine benthic fauna and assemblages were assessed in a gravely arctic benthic ecosystem around Bear Island, Barents Sea. A BACI design (Before and After/Control and Impact) was adopted and replicate samples were collected using a Sneli epibenthic sledge. Trawling affected the benthic assemblage mainly through resuspension of surface sediment and through a relocation of shallow burrowing infaunal species to the surface of the seafloor. Immediately after trawling we found a significant increase in the abundance of a majority of the infaunal bivalves, some common burrowing gastropods and anthozoans, whereas a significant decline in the number of some amphipods, mysides and euphausides was observed.

4. Reduction of bycatch of King crab (*Paralithodes camtschaticus*)

Further trials on reducing the bycatch of king crab in cod nets in the Varanger fjord has been carried out. Comparative fishing trials with norsel mounted cod nets to standard cod nets showed reduced bycatch of king crab whilst the catch rates for cod showed no difference between the two types of gear. The behaviour of king crab towards crab and cod pots has been observed with an underwater video camera. Studies of escape and mortality in deliberately lost crab pots have also been carried out. The mortality was low and the crabs escaped from the pots relatively easily.

5. Fantared II - Retrieval of lost gillnets

From 13 August to 10 September lost gillnets were retrieved off the coast between Finnmark and Møre with a special retrieval device onboard a commercial trawler (M/S Haakoy 2). Both search for reported losses through interviews of fishermen and searching in intensive gillnet areas were carried out. During the survey period (90 trials) a total of: 207 gillnets, 9900 m long line, 2650m of buoy line, 2097m trawl wire and 6 anchors were retrieved. Fish catch in the gillnets was 5275 kg Greenland halibut (*Reinhardtius hippoglossoides*) and 335 kg cod (*Gadus morhua*) and ling (*Molva molva*).

6. Fantared II - Retrieval of deliberately lost gillnets in the Greenland halibut fishery

Gillnets were set out and retrieved at intervals from 1–70 days simulating loss of gillnets off the coast of Møre at 700m depth. All gillnets were retrieved during 3 weeks in June. Catch consisted of 95% Greenland halibut and 5% Roughhead grenadier (*Macrorus berglax*). Efficiency of gillnets stabilised after 45 days at approximately 20 % of that of commercial/initial catch rates.

7. Towing time in surveys

To decide the start and stop time for a survey haul the current method used in Norwegian surveys data from the door and height sensors of the trawl are used. When the trawl has its right geometry, the start time for the haul is recorded. A multisampling device was used to separate survey catches from: a) the time before the trawl had the right geometry, b) during sampling, and c) after the haul was defined to be ended, when the haulback started. Significant differences were found in mean length variance for several species. A bottom contact sensor showed that the trawl had bottom contact several minutes both before and after the sampling period was defined. A change in sampling strategy and use of bottom contact sensors may reduce this problem.

8. Food search behaviour

Swimming activity and food search behaviour in cod and ling have been studied by means of an acoustic tracking system. The swimming pattern of cod and ling is not characterized by “random walk” as the fish show a stronger tendency to swim in the same direction than to make turns. Cod often swim across the current direction, whereas this pattern is seldom seen in ling.

9. Selection in trawls and Danish seine

The separating panels used in Danish seine consist of a small meshed guiding panel in front of a square mesh horizontal separating panel. Experiments with a 200 mm panel has improved the separation between cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinnus*) as compared with 300 mm mesh size, indicating the species separation is a combined function of behaviour differences and size selection. The work will continue in 2002.

In 1997 a square mesh cod end for seine net was introduced. Handling of big catches more than ten tons, has given some practical problems, mostly due to the given diameter of a square mesh cod end. Fishermen used square mesh cod ends with wedge-shaped side panels of diamond meshes, which has improved handling properties of these four panel cod ends. Experiments performed by the Directorate of Fisheries and Institute of Marine Research did not show any difference in selectivity in square mesh codends with and without wedge-shaped side panels.

Experiments were conducted to assess selectivity of the Sort-X, the codend and the combined selectivity of both in bottom trawling for cod in the Barents Sea. The earlier parameters for grids were confirmed, but the parameters for codend alone was somewhat better than those obtained in the early 1990s, especially the selection range which was almost comparable to that obtained for the grid. This can either be due to experimental set-up, a new PE used in cod ends, or experimental methods. The results indicated that a mesh size of 148 mm would give the same L50 as a 55 mm grid combined with a 135 mm cod end.

Pelagic trawling for herring (*Clupea harengus*) during autumn in northern Norway has often been associated with big by-catches of 70 to 90 cm saithe (*Pollahcius virens*). Experiments with a sorting device comparable to the single grid used in bottom trawl fisheries with 60 mm bar distance gave a total release of saithe longer than 60 cm, and an almost zero-loss of herring. The experiments will continue in 2002.

10. Live fish technology

Experiments with catching live cod for aquaculture purposes were undertaken using seine net. Approximately 240 tonnes of live cod was caught and put into feeding pens. More than 80% of the cod caught was still alive after the catch process, transport onboard fishing boats and short-term storage in special flat bottom net pens. Similar experiments will be undertaken in 2002, but in a larger scale.

B. University of Tromsø:

During 2000 and 2001 several full scale fishing trials in the Svalbard area with off shore designs of the Nordmöre fish/shrimp separator grate were compared. Results showed that a 1.5 m W x 2.0 m L PE plastic grate had comparable selectivity characteristics to the commonly used steel grates (1.3 m W x 1.5 m L or 1.3 m W x 2.5 m L). The results were to some extent conflicting due to periods of small catch-rates of shrimps and the lack of more fish in the selection range. The overall exclusion of fish by-catch averages 96–97% by numbers, with slightly better figures for the PE grate. The plastic grates showed slightly lower capacity on small fish compared to the steel grates, when 19.0 mm bar spacing were tested, but a smaller loss of shrimps (0.8% by weight) were recorded compared to the steel grid (1.6% by weight). Using a 1.5 m long plastic grate with 22 mm bar spacing increased the L50% values for cod, and the loss of shrimps were a lot higher (4.4% by weight) compared to the longer grids with 19.0 mm bar spacing. On the bases of these results advises for construction and installation were taken into the Norwegian legislation.

14.7 Denmark

A. SINTEF Fisheries and Aquaculture

1. Flexible grids

Work has been continued on development of flexible grids for selecting different sizes of white fish. Thorough tests have lead to an approval of the grid by the Norwegian authorities along with a few other metal grids. The grid is made from bars of polyamide held together by a rubber framework. This selection device has the advantage that it is much easier to handle on the deck: it goes round the net drum and the weight is low.

The development is now aiming at modifying the grid to suit other fisheries like the North Sea fisheries where smaller nets and net drums are used, and Danish seine fisheries.

2. Calanus trawl

There has for some years been a small fishery for the copepod *Calanus sp.* in some Norwegian fiords. The gear used has been a large plankton net suspended by booms. A new trawl has now been designed and tested in model in the SINTEF

Flume tank at the North Sea Centre in Denmark. Recent full-scale tests have proven that the concept works, but the net has to undergo minor modifications strengthening the net.

Instead of booms the net is spread by large kites along the sides and has chain and floats to give a vertical opening. The mouth opening of the net tested was about 30 m5. This design is superior to the traditional in its much easier handling properties without any special requirements for hauling equipment. A commercial fishery for Calanus is supposed to be a relevant alternative for part of the fleet of coastal shrimp trawlers.

3. Flow patterns in tapered net sections

Continued tests have been done in the SINTEF Flume tank with tapered net sections. The main objective with these tests is to establish fundamental knowledge about the influence of design parameters on the flow patterns inside and around tapered net structures. During the autumn/fall of 2001, additional tests were done on two conical net sections. As in previous tests, the vertical and longitudinal water speed distribution was measured outside, as well as inside, the net sections. The results show that there is virtually no speed increase through a conical net section with net solidity = 0.58 and taper angle of 6 and 8 degrees. Based on the results, a new theory explaining the conditions for obtaining a significant speed increase has been developed and verified with numerical calculations done by the CFD-program "Femlab". The results were presented at the working group meeting "DEMaT=-01" in November in Rostock, Germany. Later this year, full-scale tests with conical structures made of impermeable material will be tested in the SFH flume tank, as a final verification of our calculations and theory.

4. Further development of CADTRAWL and CATS

The two computer programmes for design of trawls and dynamic simulation of trawls are now both rewritten and available for Win2000 and WinXP platforms. Many new features and speed bottoms have been added. The output from CATS - the shape and geometry of a trawl net - can now be viewed in 3D.

5. Active trawl control

The Norwegian company Scanmar AS is in co-operation with SINTEF Fisheries and Aquaculture developing an active trawl control system. The Norwegian Research Council funds the project.

A mathematical model and a conceptual solution for control are developed and are planned verified through model tests and sea trials. The aim is to precisely control the motion of the trawl in order to catch the desired fish species without disturbing the sea floor or hooking obstructions on the seabed.

As a project spin off a computer program is developed for calculation of a trawl door's orientation (roll, pitch and yaw), hydrodynamic angle of attack and hydrodynamic slip angle. These are calculated from the door's force and moment characteristics (hydrodynamic point of attack), and drag and lift coefficients. The inputs are forces acting in the door's body-fixed frame (hatchways, foils and so on) and forces acting in the earth-fixed frame (warp line forces, bridle/backstrop forces, buoyancy and gravity). The computer program is capable to calculate the dynamic response of the trawl door when the forces (or hydrodynamic characteristics) changes, but coefficients for added mass and damping coefficients have not yet been verified against experiments.

6. Numerical modelling of dynamic 3D net structure exposed to waves and currents

The fish farming and aquaculture industry are expanding, and the demand for suitable locations for fish farms is increasing. Fish farms are being installed at locations that are more exposed to waves, wind and current. Before installing a highly flexible fish farm structure it is however necessary to assess the behaviour of the structure when it is exposed to the environmental forces typical of the location. In contrast to the present day offshore oil installations, which are rigid body structures, the fish farms are complex flexible structures with infinite number degrees of freedom. This makes it necessary to develop new numerical tools for simulating the behaviour of such structure.

A full 3D dynamic model of a fish cage are being developed through the research program *3 Dimensional Netpen Movement and Mooring of Fishfarms*, which is funded by the *Norwegian Research Council.* Presently the model calculates the motion of and forces on a flexible net with the shape of a vertical cylinder. The top of the net cylinder is fixed at the free surface, weights are attached at the bottom of the cylinder, and the cylinder is exposed to regular waves and current. The hydrodynamic loads are calculated based on empirically based expressions of lift and drag coefficients as a function of angle of attack and solidity. No added mass is included in the model.

The model is under development, and currently modelling of the floater movement is being developed. Also refinements of the hydrodynamic load model are planned.

It has not yet been conducted any extensive verification of the model. Some simple verification against another 2D numerical model has been conducted, but model test are planned for the purpose of a full verification of the code.

14.8 France

1. Selectivity studies

Hake selectivity: this step concerns the Atlantic fleet. On account of the depletion of hake in that area the European Commission has decided of an emergency programme to spare this species. IFREMER has tested several gears at sea: trawl fitted with separator panel, square mesh panel, diamond-shaped mesh, double mesh panel. European project Eurogrid: this project aims at developing selective grids adapted to the various North-Sea fisheries fleets and enabling to spare gadoid juveniles. Contract funded by the Northern Provinces: Sauplimor project aims at protecting the place and cod juveniles fished by the artisan trawlers of Boulogne sur Mer harbour.

2. Impact studies

European project Ecodredge: The principle is to develop an innovative tool to collect scallops. Up to now three techniques have been tested: the Magnus effect; the foil; and the water jets. European project Eppromm: The aim of this project is to develop an acoustical repellent to reduce the impact of marine mammals on fish farming activities. European project Adepts: this project involves the use of acoustical repellents as a possible solution to the attack by the dolphins of the trammel nets used by Sicilian artisan fishery. Contract funded by Brittany Province dedicated to the physical impact on the sea bed of the fishing gears. The aim is to develop experimental methods to investigate the impact on the sea bed of the fishing gears and more particularly of their various parts. European project Fantared: this projects bears on the impact the loss static gears on both the resource and environment.

3. Resource assessment and identification

Acoustics: This programme bears on the development of tools and processing systems regarding acoustics applied to fisheries research. Movies+ project: development of a software dedicated to the input, visualization, archiving and processing of the detection data coming from the vertical sounders. Project bearing on the development of a multibeam fisheries sounder which will provide better and wider an angular resolution. OFIMER project bears on the investigation of the various process courses the sea products undergo aboard a trawler specialized in products offering a maximum freshness.

4. Technological developments

IFREMER has developed DynamiT, a new software for trawl simulations. Designed with trawl designers, fishing companies and research institutes involved in fisheries technology in mind, DynamiT offers a better understanding of trawl behaviour and helps to improve significantly trawl design. It is a new “dynamic” method of calculation of the mechanical and hydrodynamic behaviour of all net types.

APPENDIX 1: DRAFT RESOLUTION

The Working Group on Fishing Technology and Fish Behaviour [WGFTFB] (Chair: Dr. David A. Somerton, USA) will meet in Bergen, Norway, on 27 June 2003 to:

a) assess gear related technical measures appropriate for improving species and size selectivity in *Nephrops* trawl fisheries with particular emphasis on: 1) Describe and review current problems relating to size and species selectivity in specific *Nephrops* fisheries in the NE Atlantic and Mediterranean, 2) Review and report on existing legislative measures in force in *Nephrops* fisheries and 3) Review available technologies to improve size and species selection in the specific fisheries identified in item 1, assessing advantages and disadvantages in terms of technical suitability, biological effectiveness and cost/benefits to the fishing industry, 4) Recommend best options for the specific fisheries and, where necessary, propose further research or development required to produce effective solutions.

b) review the final report of the Study Group on Mesh measurement Methodology (SGMESH)

c) review the main topics of the Symposium on Fish Behaviour in Exploited Ecosystems to identify promising technological and methodological approaches to increase the accuracy and precision of surveys or to decrease the effects of fishing activities on the bottom

Supporting Information

Priority:	The current activities of this Group will lead ICES into issues related to the effectiveness of technical measures to change size selectivity and fishing mortality rates. Consequently these activities are considered to have a very high priority.
Scientific Justification:	a) Due to the comparatively small mesh size used in the *Nephrops* trawl fisheries, and the relatively high level of fishing effort, considerable quantities of juvenile commercial fishes are caught and subsequently discarded. Since this issue is currently being addressed by many ICES countries, a collective look at the by-catch reduction devices either in development or now in use by the fishing industry is warrented at this time. b) SGMESH will complete its investigation of mesh measurement methodology and produce a final report just prior to the FTFB meeting. c) The Symposium on Fish Behaviour will meet just prior to the FTFB meeting. Discussion of the issues raised at the Symposium will allow FTFB members to better plan research in support of the ICES Integrated Action Plan.
Relation to Strategic Plan:	This Group directly addresses the remit of the Fisheries Technology Committee, and its terms of reference are embodied in the scientific objective 3h of the ICES Strategic Plan
Resource Requirements:	The research programmes which provide the main input to this group are already underway, and resources already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants:	The Group is normally attended by some 50 members and guests
Secretariat Facilities:	None
Financial:	No financial implications
Linkages To Advisory Committees:	The question of bycatch reduction is of direct interest to ACFM, the WG on *Nephrops* Stocks, and the SG on Discards and By-catch Information.
Linkages To other Committees or Groups:	There is a very close working relationship with all the groups of the Fisheries Technology Committee. It also is of close relevance to the Working Group on Ecosystem Effects of Fisheries.
Linkages to other Organisations	The work of this group is closely aligned with similar work in FAO.

APPENDIX 2: LIST OF PARTICIPANTS

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APPENDIX 3: REPORT OF THE SUB-GROUP OF THE ICES-FAO WORKING GROUP ON FISHING TECHNOLOGY AND FISH BEHAVIOUR

Review of the Size Selectivity of Baltic Cod Trawls

7–9 February 2002

ICES Headquarters, Copenhagen

1. Introduction

The ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) was assigned, at the 2001 ICES Annual Science Conference, the task of forming a sub-group to meet at ICES Headquarters from 7 to 9 February 2002. The terms of reference for the sub-group are:

To evaluate the findings of the IBSFC Scientific Meeting on Technical Measures for the fisheries on Baltic cod (Brussels, 20 to 24 August 2001) and *inter alia*

i) to revisit the selection properties of the 130mm diamond mesh and the 125mm polyamide diamond mesh codends,
ii) to estimate the codend mesh size of a diamond mesh and of a polyamide diamond mesh giving selectivity properties corresponding to the 120mm BACOMA window trawl,
iii) to review all information relevant to selectivity of gears used for cod fishing in the Baltic Sea.

The Sub-group was to report by 28 February 2002 for the attention of ACFM and WGBFAS. The Acting Chair was Dr R Ferro (UK) in the absence of Dr D Somerton (USA). Members of the Sub-group are listed in Appendix 2.

The sub-group first considered its terms of reference (TOR) to clarify what could be accomplished with the available data. Under TOR (i), it was agreed that the data available would be analysed for (a) polyethylene (PE) diamond mesh codends constructed of 4mm double-strand twine and (b) polyamide nylon (PA) diamond mesh codends. There were no data on materials other than PE and PA. Under TOR (ii), available data would be analysed for codends of approximately 105 mm mesh installed with the BACOMA window. Comparison between these three codend designs would be made, taking account of the variance in all estimates. The term "selective properties" of a net used in the TOR could refer to either or both of the two selection parameters: length of 50% retention (L50) and the selection range (SR; i.e., the length range from the 25% to the 75% values on a selection ogive; Wileman *et al.,* 1966). For simplicity, the sub-group chose to focus its attention only on L50. Thus, using L50 as the reference criterion, the sub-group decided to estimate, for each diamond mesh trawl, the mean and confidence interval of the mesh size producing the same L50 as that of the 120mm mesh BACOMA window.

The final TOR (iii) suggested an examination of selectivity data for other gears. No new data were brought to the meeting for gears other than trawls and the information given in the Brussels report for gillnets was considered to be valid. As regards trawling, however, there were a number of relevant issues that the sub-group identified for discussion. These included: 1) the range of gears actually used by commercial Baltic fleets, 2) enforcement of technical measures, 3) the means by which the selectivity of gears may be manipulated and 4) alternative trawl designs that provide improved selectivity. The issue of alternative trawl designs is considered in Appendix 1.

2. Gear specification

2.1 Codend designs to be considered

In the TOR, three codend designs are mentioned: 130 mm diamond mesh codend, 125 mm polyamide diamond mesh codend and the 120 mm mesh BACOMA window codend. The three options refer to the new IBSFC Fishery Rules to become effective during 2002. It is necessary to be aware of the full specification of these designs in order to ensure that any analysis is undertaken on appropriate data. The relevant part of the new Rule 9.1 is as follows:

"It is prohibited to use trawls, Danish seines or gillnets having a mesh opening (measured when wet) smaller than that specified for the fisheries listed below:

a) Cod:

(i) Gillnets (implemented from 1st September 2002)	110 mm
(ii) Trawls and Danish seines with mesh size equal or larger than 105 mm applying BACOMA window with mesh size of and with specifications as laid down in Annex IV	120 mm

(iii) Trawls and Danish seines with mesh size equal or larger than 125 mm
made of polyamide in the extension and the codend and with single twine thickness of no more than 4.5 mm which may be used in own fishery zone

(iv) Trawls and Danish seines with mesh size equal or larger than 130 mm
made of all other materials with a single twine thickness of no more than 6 mm or with double twine thickness of no more than 4 mm."

The BACOMA window is described in detail in Annex IV of these Rules. Annex IV states that the carrying on board of a net having more than 100 open diamond meshes in any circumference of the codend, excluding the joining or the selvedges, shall be prohibited. It is not clear if this also applies to options other than the BACOMA codend. If it does not apply to the other trawls, then increasing the numbers of meshes round the circumference may reduce selectivity.

Option (iii) requires single twine polyamide codends of not more than 4.5mm thickness. Such codends are not used in the Baltic cod fishery and only one set of polyamide data (PL26) was available which complied with this limit on twine thickness. However, this codend also included a window.

It should be noted that the minimum mesh size ((iii) and (iv)) applies to the whole trawl (for flatfish trawls it is applied to the meshes of the last eight meters of the net measured from the codline with the meshes stretched lengthwise).

There may be some confusion over the terminology used in Annex IV in relation to 'lifting bags'. This term is commonly used as a synonym for 'strengthening bag' as defined in EU Commission Regulation 3440/84 and elsewhere. This is an additional layer of netting which is allowed to be placed around the codend to give added strength when lifting the codend out of the water. However, in Annex IV the implication is that this is the aftmost section of the codend aft of the lifting strop. In some European fisheries there are additional regulations on strengthening bags, concerning mesh size and overall dimensions.

Throughout this report mesh measurements will refer to the wedge gauge with 5 kg hanging weight, which is used by fishery inspectors according to IBSFC fishery regulations. Mesh measurements made with the ICES gauge with 4 kg tension were increased by 3.9% to give an estimate corresponding to the wedge gauge measurement (Ferro and Xu, 1996).

3. Data sets

3.1. Trawls with 4mm double twine diamond mesh codends made from polyethylene (PE) and other materials except nylon (PA) [Trawls conforming to Rule 9.1; iv]

Data were available for 28 experiments (Table 1) using codends made of nominal 4mm double PE twine, ranging in mesh size from 105 to 140mm. Twenty six of the experiments considered demersal trawls. Of these, 19 used stern trawlers hauling their nets over the side, 3 used stern ramp trawlers, and 4 used side trawlers, the most important vessel class in the Baltic cod fleet. The remaining 2 experiments considered pelagic trawls, but, since pelagic trawls may select fish differently than demersal trawls, these data were considered inappropriate to combine with the demersal data and therefore were not considered for analysis. In addition, data were available for 3 experiments that used twine types other than the standard 4 mm double-strand twine. These data were also not considered for analysis.

3.2 Trawls with diamond mesh codends made from nylon (PA). [Trawls conforming to Rule 9.1; iii]

Data were available for 6 experiments (Table 3), but these data included such a variety of nominal twine sizes (3, 6 and 8mm single and 3 and 4mm double twine) that it was considered impossible to model the selectivity of these codends in terms of twine and mesh size. As a consequence, the selectivity of a 125mm mesh, 4.5mm, single-strand, PA codend, as required under TOR(i) cannot be determined with the available data.

3.3 Trawls with a BACOMA window in the codend [Trawls conforming to Rule 9.1; ii]

Data were available from 5 experiments (Table 2), all using stern trawlers, with window mesh sizes ranging from 90 to 136mm. Data were also available for two experiments using pelagic trawls. However, these experiments utilized a codend mesh size of 125 mm, which was considered sufficiently larger than the legal minimum size (105 mm) to potentially allow escapement to occur through the meshes of the codend as well as the window. Because this could bias the results, the pelagic trawl data were not considered for analysis. In addition, data were available for experiments using codends with non-standard twine or mesh size (5 cases have codend twines of 4 or 7mm single, 4 cases have codend mesh sizes considerably greater than the standard 105mm). These data were also not considered for analysis.

3.4 Trawls with other specifications

Data were available for trawls with 3 further types of codend: 1) those made from netting in which the diamond meshes have been turned through 90°, 2) those where the hanging ratio has been set by attaching longitudinal ropes to the selvedges and 3) those in which multiple square mesh panels have been inserted around the top and sides of the codend. The group decided to concentrate analysis on just 2 categories: PE diamond mesh codends and BACOMA window codends, because the analysis of these data form the main subject of this report. Information on the selectivity of the other codend designs (item 4 above) is presented and discussed.

4. Methods of data analysis

The size selectivity experiments considered in this report were conducted by placing a small-mesh cover over the cod-end of a trawl such that the fish escaping through the meshes of a codend or window were retained but separated from the catch in the codend. The codend covers were held clear from the codend by hoops, floats or kites to prevent any masking effect. The fish catch in numbers by 1-cm length class from both the codend and the cover from each haul in an experiment will, in the sequel, be referred to as selectivity data. Selectivity data were obtained for 23 of the 28 experiments using diamond mesh PE codends (S2-S18, S20, D1-D3, D9-D10; see Tables 1–3) and for all 5 of the experiments using BACOMA windows (S1, S19, D4-D6).

The analysis proceeded in three phases. First, the data for each experiment were analysed to estimate L50 and the associated experimental error. Second, the relationship between L50 and the size of either codend or window meshes, by vessel class, was determined with linear models, weighting by the inverse of the variance of L50. Third, the mesh size needed in a diamond mesh codend to produce the same L50 as that of a codend with a 120 mm BACOMA window was determined from the estimated parameters for each codend and vessel type.

Estimates of L50 and the associated covariance matrix for each experiment were determined as follows. A logistic function was fit to the selectivity data for each haul using the maximum likelihood methods in Fryer (1991). In this process, overdispersion in the fit (error greater than expected for a binomial variable) was tested and, if significant, the covariance matrix was corrected according to Wileman *et al.* (1966). Haul-by-haul estimates of L50 and the associated covariance matrices for each experiment were then input into EC model, a commercially available software product (available from www.constat.dk) used to compute experiment-wise estimates of L50 and associated covariance terms. This software uses the methods of Fryer (1991) to include both the within and between-haul variability in the estimation process. The experiment-wise estimates of L50 and covariance terms are included in Table 4 for diamond codends and in Table 5 for BACOMA windows.

Development of a linear model to describe L50 as a function of the size of codend or window meshes proceeded as follows. For the BACOMA window experiments, which utilized only stern trawlers, a linear model was fit to L50 as a function of mesh size using statistical weights equal to the inverse of the variance of each L50 estimate. For the diamond mesh experiments, which utilized side, stern and stern ramp trawlers, the model fitting process proceeded similarly except that the model initially included a term for the effect of vessel class. Since the vessel effect was significant, separate, vessel-specific, analyses were indicated as the correct statistical approach. However, because the data for side and stern-ramp trawlers were considered to be insufficient for separate analyses, the analyses were instead conducted on all vessel classes combined and for stern trawlers alone. In all cases, the initial model chosen was: $L50 = a + b * mesh$, where *L50* is the estimated value of L50 in centimetres, *mesh* is the size of the codend or window meshes in millimetres used in each experiment and *a* and *b* are parameters. After the initial model was fit, significance of the intercept (a) was tested. If the intercept was not significant, then a model without an intercept was fit to the data. Once the best fitting model was determined, the mean value of L50 at either 120 mm (BACOMA window) or 130 mm (diamond mesh codends) and its standard deviation were then estimated.

The mesh size needed for a trawl with a diamond mesh codend to produce the same L50 as a trawl with a 120-mm BACOMA window was determined from the following relationship:

$$\hat{m} = \frac{L50 - a}{b}$$

Where *m* is the estimated mesh size, *L50* is the estimated L50 for 120 mm mesh BACOMA windows, *a* and *b* are the estimates of intercept and slope from the model fitted to the diamond mesh data. Using the delta method on the above relationship, the variance of the predicted mesh size was estimated as:

$$Var(\hat{m}) = \left(\frac{L50 - a}{b^2}\right)^2 Var(b) + \left(\frac{1}{b}\right)^2 Var(L50) + \left(\frac{1}{b}\right)^2 Var(a) + 2\left(\frac{L50 - a}{b^2}\right)\left(\frac{1}{b}\right) Cov(a,b)$$

5. Results

5.1 Estimate of L50 for a trawl with a 120mm BACOMA window

The initial fit of the model to the BACOMA window data indicated that the intercept was not significant (Table 6). Lack of significance of the intercept indicates that the selection factor (that is, L50/mesh size) is nearly constant and independent of mesh size. The model with a zero intercept had a highly significant fit (Table 6) with very little variation about the function line (Figure 1). The estimated value of L50 at 120 mm, the new minimum mesh size for BACOMA windows, was 45.2 cm (Table 8).

5.2 Estimate of L50 for a trawl with a 130-mm diamond mesh codend

For all trawlers combined, the initial fit of the model to the diamond mesh data indicated that both the slope and the intercept were significant (Table 7; Figure 2). The estimated value of L50 at 130 mm, the new minimum mesh size for diamond codends, was 40.85 cm (Table 8). For stern trawlers alone, the initial fit of the model to the diamond mesh data again indicated that both the slope and the intercept were significant (Table 7; Figure 3). The estimated value of L50 at 130 mm was 40.33 mm (Table 8).

5.3 Estimate of the mesh size of a diamond codend needed to produce the same L50 as a codend fitted with the 120-mm BACOMA window

For all trawlers combined, the mesh size needed to produce the same L50 as the 120-mm BACOMA window is 140.3 mm (Table 9), while for stern trawlers alone, the mesh size is 142.1 mm. Since the 95% confidence intervals about both estimates do not include 130 mm (Table 9), both values are significantly greater that the new legal minimum mesh size.

6. Discussion

The data analyses conducted in the “Report of the scientific meeting on technical measures for the fisheries on Baltic cod” from the 20–24, August, 2001 meeting in Brussels (henceforth referred to as the Brussels report), differs from the analyses in this study in three distinct ways. First, this report utilized the data from considerably more experiments than the Brussels report. For example, the Brussels report used the data from 10 experiments considering 4 mm double twine diamond mesh codends, including 2 that were conducted with pelagic trawls. In this study, data from 24 experiments were used, and the 2 experiments conducted with pelagic trawls were excluded because of concerns that they may not be representative of demersal trawls. Both studies included an analysis of the data combined over the three vessel classes of side, stern and stern ramp trawlers, but this study had sufficient data to consider stern trawlers alone.

The second difference in the analyses conducted by the two studies was the relative weight given to each experiment. In the Brussels report, the analyses were conducted with published values of L50, therefore each experiment could only be weighted by the number of hauls completed. In this study, however, the analyses started with the original selectivity data so that the error associated with the L50 value from each experiment could be estimated. This was considered necessary because the number of hauls may not be closely related to precision in L50 due to large between-experiment differences in the number or size range of fish sampled and the environmental conditions under which the experiment was conducted. Weighting experiments in the model fitting process by the inverse of the variance provides a more honest way of including experimental error in the estimation.

The third difference in the analyses between studies was the form of the model relating L50 to mesh size. In the Brussels report, the assumption was made that the selection factor, or the quotient L50 / mesh size, was a constant. With this assumption, the mean selection factor over all experiments was calculated, then the estimated L50 at 130 mm was determined by multiplying the mean selection factor by the appropriate mesh size. In this study, a linear model that included an intercept was fit to L50 and mesh size. Rather than assuming that the intercept was zero, which is equivalent to a constant selection factor, the hypothesis of a zero intercept was tested for significance. For the BACOMA experiments, the intercept was not significantly different than zero. However, for the diamond mesh experiments, the intercept was significantly different than zero and therefore necessary for an accurate prediction of L50 at 130 mm, especially when 130 mm is larger than the mesh size used in most of the experiments.

The last of these three differences may well be the most important in the determination of the diamond mesh size needed to achieve the same L50 as the 120 mm BACOMA window. Traditionally, selection factor has been taken to be approximately constant, at least over a short range of mesh sizes. However, the analysis of the data on 4mm PE diamond mesh codends found a significant increase in selection factor with increasing mesh size in the range from 105 to 140mm. There may be four main causes. First, the numbers of meshes around the codend circumference is not constant, tending to be lower for the larger mesh sizes. It is known that fewer circumferential meshes improve selectivity; this is the reason why recent legislation in several fisheries has limited the number of circumferential meshes to a maximum value. However, in this study codend circumference was included as an effect in the model, but was found to be not statistically significant. Second, as mesh size increases, a relatively smaller volume of catch will be taken due to increased escapement of small fish through the larger meshes. Experimental evidence indicates that selectivity is reduced with increasing catch size in the codend, but it was impossible in this study to investigate such an effect due to a lack of catch data for individual hauls. Third, as mesh size increases, mesh opening is less influenced by twine stiffness and relatively larger fish are able to escape. Fourth, the swimming power of fish increases with the muscle volume, therefore swimming speed, and perhaps the ability to escape through netting, increases at a rate greater than proportional to fish length. Since the change in selection factor with mesh size was not evident for the codends with a BACOMA window, the cause of such a change is likely due to one of the first three mechanisms described above.

The question of primary concern is whether the differences in data and analytic procedures between the Brussels study and this study lead to differences in the estimated values of L50 for a 130 mm diamond mesh codend or to differences in the mesh size needed to achieve the same L50 as that of the 120 mm BACOMA window. Considering the case of all vessel classes combined, the L50 for a 130 mm diamond mesh codend reported in the Brussels study was 40.30 cm while the value determined in this study was 40.85 (95% CI= 139.16–146.70), which is not statistically different. However, the mesh size needed to produce the same L50 as the 120 mm BACOMA window was 148 mm in the Brussels study while the value determined for the combined trawlers in this study was 140.43 mm (134.00–146.70), which is significantly smaller. This difference in the estimated mesh size is almost entirely due to the difference in whether the selection factor was assumed to be a constant or a decreasing function of mesh size.

If the intent of mesh sizes specified in Rule 9.1 is to achieve equality in L50 for all types of trawls, then our results indicate that equality could be achieved with an increase in the minimum diamond mesh size to 140 mm, that is, 10 mm larger than the current minimum mesh size. This value, however, may not be applicable to the Baltic cod fleet as a whole because the vessel types and methods of fishing used in the experiments are not a random sample of the fleet and may be unrepresentative. The results presented for combined vessel classes are dominated by a single vessel class, that is, stern trawlers (17 of 23 cases). However, most of the Baltic cod catch is taken by side trawlers and our analysis indicated that side trawlers and stern trawlers likely produce different selectivities when using the same trawl. Additional data for side and stern ramp trawlers are needed to determine whether there are important differences in selectivity between vessel classes. In anticipation that such differences are eventually found, the results for stern trawlers, the only vessel class for which there is currently sufficient data for a separate analysis, has been included in the tables.

Another cause for concern is that a significant proportion of the Baltic cod catch is taken with pelagic trawls. Although data from two experiments using pelagic trawls were available, both experiments used very large codend mesh size. Without a range of mesh sizes similar to that used in the experiments with demersal trawls, it is impossible to estimate a pelagic-demersal effect. In this study, however, since the potential effect of this was unknown, the data from the pelagic experiments was rejected from consideration. Again, more experiments using pelagic trawls are needed to resolve this issue.

7. References

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Table Legends for Tables 1–3

Demersal/Pelagic	D = Demersal		Window/Width	Multipanel codend
	P = Pelagic			Top panel codend
				No window
Commercial/Research	C = Commercial			
	R = Research		Construction	Yarn type + mesh direction
				(nothing = rhombic meshes)
Selectivity method	C = Cover			
	HC = Hooped cover		Hauling method	SR = Stern ramp or roller trawler
	A = Alternate			SS = Stern trawler hauling at side
				S = Side trawler
Ref No. includes nationality				
Nationality	D = Denmark		Not available	NA
	G = Germany			
	PL = Poland			
	R = Russia			
	S = Sweden			

Table 1. 4mm PE diamond mesh codends.

		Codend						Extension				Gear type	Vessel			Methodology	Fishing Log			Selectivity			
Set no.	Ref. No.	Mesh size mm (wedge gauge)	Twine size mm	Const-ruction	Mat-erial	Meshes round Circum-ference	Length # or m	Length # or m	Twine size mm	Constr-uction	Material	Demersal or Pelagic	Comm-ercial or Research	Hauling method	Vessel hp	Selectivity Method	Month-Year	ICES Sub-division	Depth range m	Haul by Haul data available?	L50 cm	SR cm	Number of hauls
Side trawler																							
43	S2	107.0	4.0	double	PE	100	49.5#	NA	NA	NA	NA	D	C	S	1182	HC	Jul-94	25	40 - 65	n	26.86	6.77	7
59	S18	119.2	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	S	620	HC	Aug-98	24	30 - 45	n	38.00	10.10	14
45	S4	120.1	4.0	double	PE	100	49.5#	NA	NA	NA	NA	D	C	S	1182	HC	Dec-94	25	36 - 63	n	37.22	12.12	11
58	S17	121.7	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	S	1005	HC	Aug-98	24	30 - 45	n	41.90	8.10	13
Stern/side trawler																							
28	D1	105.6	4.0	double	PE	92	6m	NA	NA	NA	NA	D	C	SS	290	HC	Jun-98	24–25	43 - 71	y	27.60	6.18	13
36	D9	107.4	4.0	double	PE	96	6m	NA	NA	NA	NA	D	C	SS	290	HC	NA	NA	NA	y	31.80	7.70	3
25	PL25	112.0	4.0	double	PE	100	62.5#	134#	NA	single	PE	D	C	SS	217	A	May-95	25–26	70	n	35.00	8.34	3
49	S8	119.3	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	898	HC	Nov-98	25	40 - 65	n	34.60	12.30	14
53	S12	119.3	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	563	HC	Nov-98	25	40 - 65	n	32.40	10.50	14
50	S9	119.4	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	898	HC	Mar-99	25	40 - 65	n	33.50	10.90	14
44	S3	119.5	4.0	double	PE	100	49.5#	NA	NA	NA	NA	D	C	SS	898	HC	Dec-94	25	34 - 61	n	35.12	8.51	11
47	S6	119.5	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	898	HC	Jun-98	25	40 - 65	n	36.60	12.10	14
48	S7	119.5	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	898	HC	Aug-98	24	30 - 45	n	36.30	10.10	14
54	S13	119.6	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	563	HC	Mar-99	25	40 - 65	n	33.80	7.90	14
56	S15	120.0	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	235	HC	Aug-98	24	30 - 45	n	37.60	10.10	9
51	S10	120.5	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	563	HC	Jun-98	25	40 - 65	n	34.40	9.40	14
52	S11	120.8	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	563	HC	Aug-98	24	30 - 45	n	37.70	8.00	14
57	S16	120.9	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SS	271	HC	Aug-98	24	30 - 45	n	36.40	9.50	14
29	D2	121.7	4.0	double	PE	92	6m	NA	NA	NA	NA	D	C	SS	290	HC	Jun-98	24–25	14 - 70	y	35.30	7.12	16
37	D10	122.8	4.0	double	PE	96	6m	NA	NA	NA	NA	D	C	SS	290	HC	NA	NA	NA	y	37.50	9.90	6
46	S5	140.0	4.0	double	PE	80	49.5#	NA	NA	NA	NA	D	C	SS	898	HC	Mar-95	25	40 - 65	n	45.03	11.69	10
61	S20	142.1	4.0	double	PE	80	49.5#	NA	NA	NA	NA	D	C	SS	442	HC	Aug-99	24–25	40 - 54	n	51.56	12.16	12
30	D3	143.5	4.0	double	PE	92	6m	NA	NA	NA	NA	D	C	SS	290	HC	Jun-98	24–25	43 - 71	y	45.70	8.40	15
34	D7	137.1	4.0	double	PE	80	6m	NA	NA	NA	NA	P	C	SS	520	HC	May-00	25	71 - 92	y	49.46	7.07	10
63	S22	137.1	4.0	double	PE	80	49.5#	NA	NA	NA	NA	P	C	SS	898	HC	Jun-00	25	89 - 94	n	48.71	7.61	7
Stern ramp/roller trawler																							
2	GPL2	121.9	4.0	double	PE	100	49.5#	100#	4	single	PE	D	R	SR	850	HC	Apr-99	24	35	y	33.02	7.81	9
41	R4	140.6	4.0	double	PE	NA	6m	18m	4.0	single	PE	D	C	SR	300	C	Dec-01	26	60 - 80	n	50.90	10.40	6
55	S14	121.1	4.0	double	PE	88	49.5#	NA	NA	NA	NA	D	C	SR	665	HC	Aug-98	24	30 - 45	n	32.10	15.40	14
Non-standard twines																							
1	GPL1	121.3	4.0	single	PE	100	49.5#	100#	4	single	PE	D	R	SR	850	HC	Apr-99	24	35	y	37.71	7.00	11
4	GPL4	122.0	6.0	double	PE	100	49.5#	100#	4	single	PE	D	R	SR	850	HC	Sep-01	24	35	y	28.99	7.93	8
6	G6	109.0	4.0	single	PE	NA	NA	NA	NA	NA	NA	D	C	S	300	HC	Aug-95	24	35	n	36.40	6.60	4

Table 2a. BACOMA window in ~105mm 4mm double PE codend.

		Codend						Extension				Window				
Set no.	Ref. No.	Mesh size mm (wedge gauge)	Twine size mm	Constr-uction	Material	Meshes round circum-ference	Length # or m	Length # or m	Twine size mm	Constr-uction	Material	Mesh size mm	Twine size mm	Constr-uction	Material	Length#
Stern/side trawler																
31	D4	105.3	4.0	double	PE	92	6m	NA	NA	NA	NA	108.4	4.9	single	PE Ultra Cross	60
32	D5	105.2	4.0	double	PE	92	6m	NA	NA	NA	NA	127.3	4.9	single	PE Ultra Cross	51
33	D6	105.5	4.0	double	PE	92	6m	NA	NA	NA	NA	136.3	4.9	single	PE Ultra Cross	48
42	S1	107.0	4.0	double	PE	83	49.5#	NA	NA	NA	NA	90.1	4.9	single	PE Ultra Cross	90
60	S19	105.0	4.0	double	PE	100	49.5#	NA	NA	NA	NA	125	4.9	single	PE Ultra Cross	66
Stern ramp/roller trawler																
7	GPL7	109.5	7.0	single	PE Ultra Cross	100	49.5#	100#	4	single	PE	109.5	7.0	single	PE Ultra Cross	82
8	G8	109.5	7.0	single	PE Ultra Cross	100	49.5#	100#	4	single	PE	109.5	7.0	single	PE Ultra Cross	82
9	GPL9	108.0	4.0	single	PE	100	49.5#	100#	4	single	PE	109.5	7.0	single	PE Ultra Cross	82
10	GPL10	108.0	4.0	single	PE	100	49.5#	100#	4	single	PE	97.9	4.0	single	PE Raschel	92
27	GPL27	108.0	4.0	single	PE	100	49.5#	100#	4	single	PE	109.5	7.0	single	PE Ultra Cross	64
Non-standard codend mesh sizes																
21	GPL21	115.3	4.0	double	PE	100	49.5#	100#	4	single	PE	126.8	4.0	single	PE	55
22	GPL22	115.3	4.0	double	PE	100	49.5#	100#	4	single	PE	132.6	4.5	single	PE Ultra Cross	53
35	D8	127.4	4.0	double	PE	86	6m	NA	NA	NA	NA	126.9	4.9	single	PE Ultra Cross	74
62	S21	125.0	4.0	double	PE	86	49.5#	NA	NA	NA	NA	137.1	4.9	single	PE Ultra Cross	74

Table 2b. BACOMA window in ~105mm 4mm double PE codend.

Window		Gear type	Vessel			Methodology	Fishing Log			Selectivity			
Width#	Position # from codline	Demersal or Pelagic	Commercial or research	Hauling method	Vessel hp	Selectivity Methodology	Month-Year	ICES Sub-division	Depth range m	Haul by Haul data available ?	L50 cm	SR cm	Number of hauls
Stern/side trawler													
1x24	4.0	D	C	SS	290	HC	Jun-98	24–25	15 - 84	y	41.13	6.01	17
1x21	4.0	D	C	SS	290	HC	Jun-98	24–25	14 - 70	y	48.30	7.06	16
1x20	4.0	D	C	SS	290	HC	Jun-98	24–25	43 - 69	y	51.69	7.56	14
1x20	3.5	D	C	SS	264	HC	Jun-94	25	40 - 60	n	32.52	4.47	13
1x20	3.5	D	C	SS	442	HC	Aug-99	24–25	40 - 54	n	46.00	12.10	12
Stern ramp/roller trawler													
3x16	5.5	D	R	SR	850	HC	Sep-98	24	35	y	39.54	5.44	8
3x16	5.5	D	R	SR	850	HC	Apr-98	24	35	y	42.09	5.79	14
3x16	6.5	D	R	SR	850	HC	Apr-99	24	35	y	40.45	6.17	10
3x18	6.5	D	R	SR	850	HC	Apr-00	24	35	y	37.50	5.45	10
1x25	3.5	D	R	SR	2600	HC	Nov-00	24	35	(y)	39.30	6.68	6
Non-standard codend mesh sizes													
1x25	3.5	D	R	SR	850	HC	Apr-01	24	35	y	44.79	6.24	5
1x24	3.5	D	R	SR	850	HC	Sep-01	24	35	y	45.07	11.31	3
1x21	4.0	P	C	SS	520	HC	May-00	25	71 - 92	y	49.46	5.23	11
1x21	3.5	P	C	SS	898	HC	Jun-00	25	89 - 94	n	50.29	7.61	7

Table 3a. PA codends.

		Codend						Extension				Window			
Set no.	Ref. No.	Mesh size mm (wedge gauge)	Twine size mm	Construction	Material	Meshes round circumference	Length # or m	Length # or m	Twine size mm	Constr-uction	Material	Mesh size mm	Twine size mm	Constr-uction	Material
3	GPL3	120.3	6.0	single	PA	100	49.5#	100#	4	single	PE	0			
5	GPL5	123.6	8.0	single	PA	100	49.5#	100#	4	single	PE	0			
26	PL26	109.0	3.0	single	PA	100	64#	138#	NA	single	PA	117	4	single	PA
38	R1	101.7	3.1	double	PA	100.0	9.7m	12.3m	3.1	double	PA	0			
39	R2	127.6	3.1	double	PA	84.0	9.8m	12.2m	3.1	double	PA	0			
40	R3	130.7	4.0	double	PA	NA	6m	18m	4.0	single	PA	0			

Table 3b. PA codends.

Window			Gear type	Vessel information			Methodology	Fishing Log			Selectivity			
Length#	Width#	Position # from codline	Demersal or Pelagic	Commercial or research	Hauling method	Vessel hp	Selectivity Methodology	Month-Year	ICES Subdivision	Depth range m	Haul by Haul data available ?	L50 cm	SR cm	Number of hauls
			D	R	SR	850	HC	Apr-00	24	35	y	31.71	6.96	7
			D	R	SR	850	HC	Sep-01	24	35	y	27.24	5.53	8
42	1x8	4	D	C	SS	217	A	May-95	25–27	70	n	39.00	4.80	1
			D	R	SR	1000	C	May-95	26	40 - 80	n	34.30	8.20	17
			D	R	SR	1000	C	May-95	26	40 - 80	n	41.60	6.60	11
			D	C	SR	300	C	Nov-01	26	50 - 60	n	45.10	13.70	4

Table 4. Experiment-wise estimates of L50 and SR for diamond codend trawls.

L50 (cm)	SR (cm)	Var (L50)	Cov (L50,SR)	Var (SR)	Vessel type	Gear type	Codend mesh size (mm)	Ref. No.
26.86	9.12	1.018	-0.539	1.005	side	demersal	107.0	S2
36.99	13.52	1.621	-0.930	1.793	side	demersal	120.1	S4
41.90	8.18	0.272	-0.110	0.098	side	demersal	121.7	S17
37.95	10.10	4.505	-1.291	4.745	side	demersal	119.2	S18
35.94	9.14	0.148	0.072	1.398	stern	demersal	119.5	S3
44.57	10.18	5.146	-1.142	2.754	stern	demersal	140.0	S5
36.18	13.32	0.712	-0.222	1.447	stern	demersal	119.5	S6
36.25	10.15	1.318	-0.577	0.350	stern	demersal	119.5	S7
33.42	13.15	0.523	-0.449	1.170	stern	demersal	119.3	S8
31.01	11.86	1.946	-0.923	0.990	stern	demersal	119.4	S9
33.82	9.79	0.985	-0.462	0.337	stern	demersal	120.5	S10
36.27	9.50	1.003	-0.616	0.539	stern	demersal	120.8	S11
29.86	11.40	2.209	-1.397	1.020	stern	demersal	119.3	S12
33.75	8.00	0.537	-0.014	0.126	stern	demersal	119.6	S13
37.63	10.12	0.359	-0.153	0.285	stern	demersal	120.0	S15
37.79	8.05	0.153	-0.082	0.157	stern	demersal	120.9	S16
51.63	13.29	0.955	0.684	2.114	stern	demersal	142.1	S20
48.71	7.89	0.500	0.095	0.124	stern	pelagic	137.1	S22
29.68	6.58	0.183	0.003	0.116	stern	demersal	105.6	D1
32.07	7.22	0.352	-0.081	0.067	stern	demersal	121.7	D2
46.45	8.36	0.656	-0.066	0.123	stern	demersal	143.5	D3
32.18	6.79	0.004	0.040	0.392	stern	demersal	107.4	D9
36.95	9.41	3.864	0.718	0.806	stern	demersal	122.8	D10
32.13	15.54	1.148	-0.388	1.957	stern ramp	demersal	121.1	S14

Table 5. Experiment-wise estimates of L50 and SR for BACOMA window trawls.

L50 (cm)	SR (cm)	Var L50)	Cov (L50,SR)	Var (SR)	Vessel type	Gear type	Window mesh size (mm)	Ref. No.
32.64	4.08	0.405	-0.092	0.144	stern	demersal	95	S1
46.20	11.46	1.350	-1.671	2.360	stern	demersal	127.1	S19
41.18	5.54	0.097	0.001	0.079	stern	demersal	108.4	D4
48.04	6.62	0.248	-0.043	0.126	stern	demersal	127.3	D5
51.44	8.09	0.776	0.247	0.308	stern	demersal	136.3	D6

Table 6. Parameter estimates of the L50 versus mesh size function – BACOMA windows.

Model with slope and intercept				
Parameter	value	Stan. Dev.	t value	P(>|t|)
Intercept (a)	-2.054	2.617	-0.785	0.490
Slope (b)	0.395	0.023	17.114	<0.001
Model without intercept				
Slope (b)	0.377	0.003	150.730	<0.001

Table 7. Parameter estimates of the L50 versus mesh size function – Diamond codends.

Combined Trawlers				
Parameter	value	Stan. Dev.	t value	P(>|t|)
Intercept (a)	-14.48	6.144	-2.36	0.028
Slope (b)	0.426	0.052	6.662	<0.001
Stern Trawlers				
Parameter	value	Stan. Dev.	t value	P(>|t|)
Intercept (a)	-12.224	5.620	-2.175	0.045
Slope (b)	0.404	0.048	8.413	<0.001

Table 8. Estimated L50 at the legal minimum mesh size.

Trawl type	Vessel class	Minimum mesh (mm)	L50 (cm)	SD	95% CI (cm)
BACOMA window	Stern trawlers	120	45.24	0.30	44.64–45.54
Diamond mesh	Combined trawlers	130	40.85	0.84	39.16–41.69
Diamond mesh	Stern trawlers	130	40.33	0.80	38.73–41.13

Table 9. Estimated diamond mesh size needed to produce the same L50 as a trawl with a 120-mm BACOMA window.

Vessel type	Mesh size (mm)	SD	95% CI (mm)
Combined trawlers	140.33	3.19	134.00–146.70
Stern trawlers	142.14	3.4	135.43–148.86

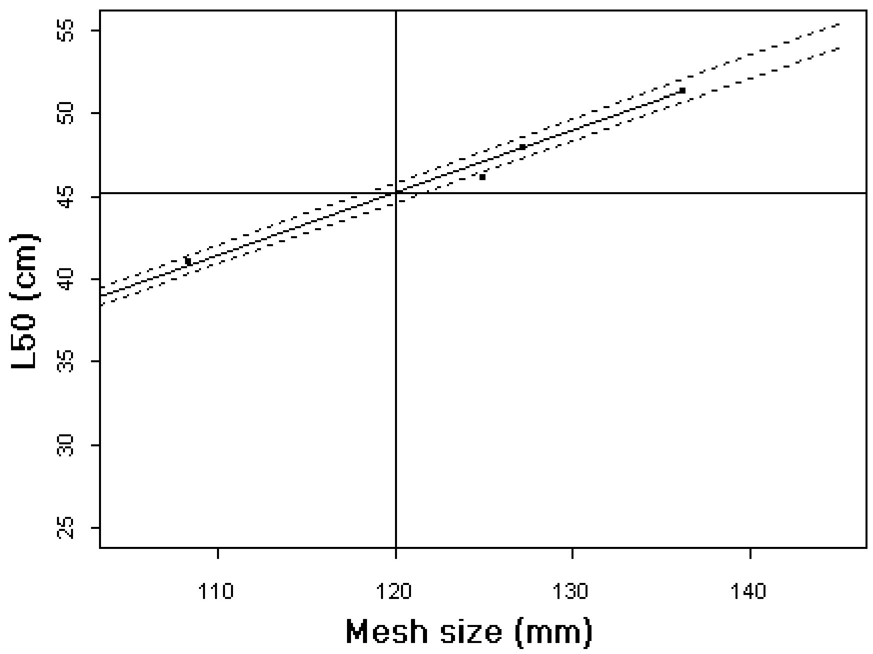

Figure 1. L50 versus window mesh size for BACOMA experiments. The solid line represents the predicted mean value of L50; the dashed line indicates the 95% confidence intervals. Also shown is the value of L50 at a window mesh size of 120 mm.

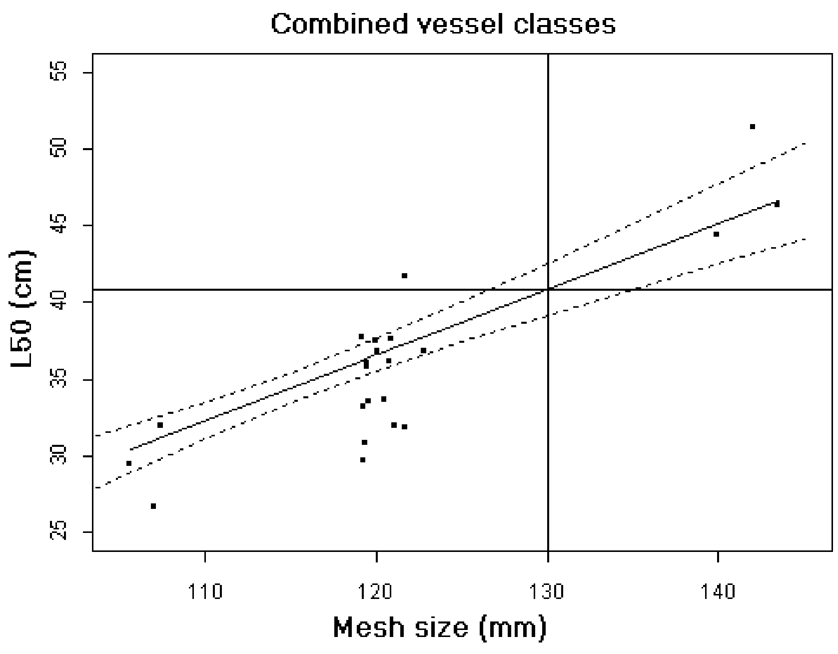

Figure 2. L50 versus codend mesh size for diamond mesh experiments – All vessel classes combined. The solid line represents the predicted mean value of L50; the dashed line indicates the 95% confidence intervals. Also shown is the value of L50 at a codend mesh size of 130 mm.

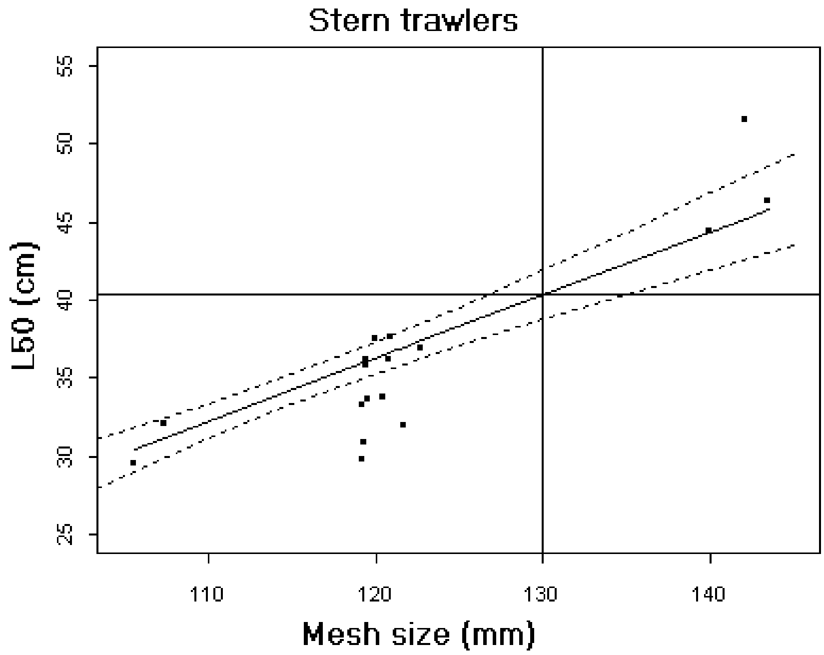

Figure 3. L50 versus codend mesh size for diamond codend trawls – Stern trawlers only. The solid line represents the predicted mean value of L50; the dashed line indicates the 95% confidence intervals. Also shown is the value of L50 at a codend mesh size of 130 mm.

APPENDIX A3–1: ALTERNATIVE NET DESIGNS WITH GOOD SELECTIVITY

In this report, attention was focused on two distinct approaches, considered by the IBSFC Fishery Rule 9.1, to modify a trawl with a standard diamond mesh codend for the purpose of controlling the retention size of cod. The first is to increase the size of retention by increasing the codend mesh size. The second considers that all escapement occurs through a square mesh window attached to the top of the codend and that the size of retention is increased by increasing the window mesh size. However other approaches to this have been considered, two of which are described below.

1) Codends with 90º turned meshes. Codends in which the mesh has been turned 90º from the standard orientation have the property that the meshes tend to remain more open when under a load than meshes with a traditional orientation. In Polish experiments (Moderhak 1997), turned-mesh codends were shown to have better selection properties than standard-mesh codends with the same mesh size and the selection properties were enhanced with increasing twine stiffness.
2) Hanging ratio. Russian experiments, reported at IBSFC Extraordinary Session (Brussels, 13–14 March 2001), demonstrated that selectivity could be modified by changing the hanging ratio (that is, number of meshes per unit of selvedge line). Thus small changes in the size of retention could be achieved, without a change in codend mesh size, by changing the hanging ration of the mesh.

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