**Fisheries Technology Committee** **ICES CM 2003/B:07**
**Ref. ACFM**

**Report of the**

# ICES-FAO Working Group on Fishing Technology and Fish Behaviour

**Bergen, Norway**
**27–28 June 2003**



International Council for the Exploration of the Sea

Conseil International pour l'Exploration de la Mer

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# 1 EXECUTIVE SUMMARY

The Fishing Technology and Fish Behaviour Working Group met 27–28 June 2003 in Bergen, Norway, to consider six terms of reference, including reports from the Study Group on Mesh Measurement Methodology, the subgroup reviewing the size selectivity of 90° turned mesh in Baltic cod trawls and the subgroup compiling a manual on the selectivity of static fishing gear. For the ToR to assess gear related technical measures for improving species and size selectivity in *Nephrops*, the working group considered a summary report (Appendix 5) as well as seven individual contributions. One recurring theme in these presentations is that *Nephrops* is typically caught with other marketable fish or invertebrates in mixed species fisheries. This complicates the problem of size selection because the mesh or grid size appropriate for *Nephrops* may quite different than that for other marketable species. Technical measures that first sort by species using, for example, a grid, then select by size using an appropriate mesh size seem to provide a means to reduce discard. However, *Nephrops* fisheries vary greatly in both the relative proportion of *Nephrops* in the catch and the species/size composition of the other marketable species, therefore the most effective approach to the use of technical measures for discard reduction is also likely to vary.

The Study Group on Mesh Measurement Methodology reported that the final report would be available at the 2003 ASC. The main conclusion from the group is that the current technology for measuring mesh size (i.e., the wedge and ICES gauge) are not always appropriate for the full spectrum of sizes and types of netting now utilized by the fishing industry. As an alternative, the group proposed a new type of electronic gauge that is able to precisely apply a specified lateral force on the netting. A prototype of this gauge was demonstrated on several types of netting.

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 the they are considering submitting a manual on gillnet selectivity, a gear better researched as compared to longline, pot and trap fisheries. Once this manual is approved by the WGFTFB, the other static gear sections would follow and contain the same format as the gillnet section.

The group evaluating the selective properties of trawls with codends constructed of 90° turned mesh reported that data from 15 experiments conducted by Polish and German scientists were analysed (Appendix 4). Although a statistical model relating the size at 50% selection (L50) to mesh size and several experimental covariates was successfully fit to the data, the data were insufficient to allow prediction of minimum mesh sizes producing the same L50 value as that produced by the BACOMA 120 mm window. The reasons for this include: 1) there were too few experiments, 2) the experiments were conducted on a variety of gear types rather than focused on only a few, and 3) the mesh sizes considered did not include mesh that was sufficiently large. Although the FTFB did not recommend appropriate minimum mesh sizes, the utility of turned mesh codends was recognized and a ToR for the 2004 meeting to again consider this issue was proposed.

Due to concern over inadequacies in the mini-symposium format of most FTFB meetings and to better accommodate research priorities from FAO, a new approach to directing the Working Group will be tried. A steering committee (SC) will be formed comprised of two members chosen by the FTFB Chair and one member from FAO. Each year the SC will research potential topics to determine their appropriateness for ToR. For each topic, the SC will also choose a convenor for that topic who will have the responsibility of soliciting contributions, corresponding with the contributors and creating a summary document.

The 2004 meeting of the FTFB is proposed to take place in Gdynia, Poland, on 20, 21, 23 April. A joint session with the FAST Working Group will occur on 22 April. The proposed ToR for the joint meeting is included in the FAST report.

# 2 DIRECTIVE

WGFTFB: The Fishing Technology and Fish Behaviour Working Group shall initiate and review investigations of scientists and technologists concerned with all aspects of the design, planning and testing of fishing gears used in abundance estimation, selective fishing gears used in by-catch and discard reduction; and benign environmentally fishing gears and methods used to reduce impact on bottom habitats and other non target ecosystem components, including behavioural, statistical and capture topics. The Working Group's activities shall focus on all measurements and observations pertaining to both scientific and commercial fishing gears, design and statistical methods and operations including benthic impacts, vessels and behaviour of fish in relation to fishing operations. The Working Group shall provide advice on application of these techniques to aquatic ecologists, assessment biologists, fishery managers and industry.

## 3 INTRODUCTION

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Venue: Bergen, Norway
Date: 27–28 June 2003

### 3.1 Terms of Reference

The **ICES-FAO Working Group on Fishing Technology and Fish Behaviour** [WGFTFB] (Chair: D.A. Somerton, USA) will meet in Bergen, Norway, from 27–28 June 2003 to:

a) assess gear-related technical measures appropriate for improving species and size selectivity in *Nephrops* trawl fisheries with particular emphasis on:

   i) describe and review current problems relating to size and species selectivity, in specific *Nephrops* fisheries in the NE Atlantic and Mediterranean,

   ii) review and report on existing legislative measures in force in *Nephrops* fisheries,

   iii) review available technologies to improve size and species selection in the specific fisheries identified in item i), assessing advantages and disadvantages in terms of technical suitability, biological effectiveness and cost/benefits to the fishing industry,

   iv) evaluate, based on (iii) the 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;

d) review future working practices and meeting organisation following the co-sponsorship of the Working Group by FAO;

e) review the draft of the Static Gear Selectivity Manual;

f) evaluate the selective properties of trawls using 90$^{o}$ turned diamond meshes and advise on appropriate mesh sizes corresponding to the agreed BACOMA gear. Evaluate selectivity of diamond mesh of 130 mm and 140 mm taking into account all new available information on the matter [ACFM request].

WGFTFB will report by 15 July 2003 for the attention of the Fisheries Technology Committee and ACFM.

**Supporting Information:**

Priority: The current activities of the 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 warranted 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.

d) The Group is in the process of discussions with FAO personnel about their involvement in the WG. It is also carrying out a review of the structure of FTC according to the ICES Integrated Action Plan to see our present structure can meet the demands of the Action/Strategic Plan. A Norwegian proposal will be considered. This discusses their vision of how FTFB should be organized to meet these new demands for a global WG, which is what FTFB has become since the joint sponsorship agreement with FAO. They have presented this proposal to FTC and will present it to this meeting.

e) This is an ongoing item to consider a draft prepared by Poulsen.

f) This is a repeat of a request from IBSFC to take into consideration new data from Poland and Germany.

## 4 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

**Steve Walsh (Canada)**

A discussion of the significant highlights from the ICES Symposium on Fish Behaviour in Exploited Ecosystems identified three key areas that WGFTFB should consider in its future work. Observational tools employing the latest technology in acoustics, telemetry and optics now permit wider use in studies of natural fish behaviour and behaviour reactions to fishing gears. However, one continuing drawback is species identification which requires further refinement of these tools and related imaging software. The symposium reinforced the concept that those working in the area of 'real world observations' related to fishing gear studies need to place more emphasis on observing and quantifying fish behaviours, and also in identifying problems with quantifying behaviour. A major area where research is lacking is in quantifying learning behaviour in fish and its possible effect on field observations. Learning behaviour in fish needs to be investigated further.

Unaccounted mortality in fish that come into contact with fishing gears or that related to discards and live releases was discussed. The WGFTFB noted that there was concern about the lack of understanding of stress and stress induced mortality in fishes. The symposium noted that stress does not necessarily result in death and that death could occur at a later date as a result of behavioural impairment, i.e., increase in predation risk. In addition, it was noted that the use of blood plasma cortisols and lactates levels as indicators of stress in fish cannot be used as predictors of mortality. Those WGFTFB participants working on selectivity of fishing gears need to consider the effects of post-gear mortality related to behaviour impairment in fish that pass through meshes of fishing gears.

The effect of seismic surveys on fish was the third major item discussed. Most research studies have concluded that there is minimum or no physical effect of seismic sound on fish. Clear evidence was given at the symposium that fish hearing can be severely damaged and that detection of this damage is not immediate. Such damage could result in behaviour impairment and hence an increase in predation risk in fish exposed to seismic blasts. These results should be investigated further as indirect (unaccounted) mortality associated with seismic work may be significant.

## 5 REVIEW THE REPORT OF THE STUDY GROUP ON MESH MEASUREMENT (SGMESH)

**Ron Fonteyne (Belgium)**

An overview was given of the work performed over the past 4 years, leading to a recommendation for a new mesh measurement methodology. The final SG meeting was held in Oostende (Belgium) on 19–21 March 2003, and concentrated on the analysis and discussion of the inter-laboratory tests made to determine the most appropriate measuring force for the measurement of mesh opening, the proposal for a new mesh measurement methodology and the need for further standardisation in this matter. The ultimate aim is that the new methodology will be used by scientists, fisheries inspectors and the industry. Hence the Study Group was of the opinion that advice from inspection services and netting manufacturers should be sought in this matter and invited representatives of these services to its final meeting.

The Group came to the following conclusions:

1. A variable force proportional to twine linear density would be preferred but there are practical difficulties with this approach, principally the accurate measurement of linear density or twine diameter at sea.
2. It follows that two groups of netting are recommended to which two standard forces apply for:
    a) netting under 55 mm mesh size and
    b) netting of 55 mm or greater mesh size.
3. A longitudinal force is preferred to a perpendicular force and this confirms the principle of mesh measurement used in the present ICES gauge.
4. Analysis shows that a measurement force of 40 newton would be appropriate for the smaller, 100 newton for the larger mesh.
5. A force of 40 newton can be exerted by the current ICES gauge but 100 newton is out with the range of this instrument. The group is aware that a new gauge is being developed with a capacity of 180 newton but this instrument will not be available until 2005. It is recommended that in the meantime for scientific work the ICES 4 kg gauge be used but the results should be converted to 100 newton equivalent using a conversion formula.
6. In most cases the measurement of 40 meshes would be sufficient for a precision of 1 mm at 95% confidence limits. If this is not the case after 40 meshes then measurements should continue until such precision is attained.
7. It was noted there is variance in all methods of mesh measurement studied and this is attributed mainly to the variability of material.

The Study Group recommends that all participants should as far as possible adhere to the conditions set out above, whether they be scientists, inspectors, netting manufacturers, net makers or fishermen. As advice derived from selectivity data determines mesh size regulations it is logical that all stakeholders should use the same system of mesh measurement. If these findings are accepted it will be necessary to change existing legislation and standards.

**Discussion:**

Following the presentation, Ron was asked about the cost of the mesh measuring device. Ron stated that the unit will cost about 1200 Euros, though this price could come down as production increases.

He was also asked to clarify if it were true that 40% of meshes that were just legal would be reported as illegal by the unit using the proposed force of 100 newtons. He reported that 40% of meshes just legal would be reported as nonconforming though most meshes are sized above the minimum mesh size so this should not be a problem.

A draft ICES Cooperative Research Report edited by the SGMESH Chair was discussed and will be finalized by the 2003 ASC.

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

**Thomas Moth-Poulsen (USA)**

The ICES Static Gear Manual has had a history extending back to 1998 when it was first suggested to formulate a Static Gear Manual. Arne Carr was appointed Chair of the group until his retirement when Thomas Moth-Poulsen assumed responsibility for the project. In 2002, an Ad Hoc group was formed, which included M. Farrington, H. Milliken, P. He,

to complete the project. Since the 2002 meeting, a draft gillnet manual has been produced that can serve as a template for the pot, trap and longline sections. A final gillnet version will be produced by the October 2003 ICES Annual Science Conference.

A draft of the gillnet section was presented that was patterned on a protocol developed during a series of European gillnet cooperative projects. The protocol has proved effective because it has resulted in the production of an array of good datasets on gillnet selectivity of commercial nets.

Discussion:

Concerns were raised on whether procedures for long line and pot selectivity research had developed to the same extent. It was explained that the gillnet section was more advanced because more work on gillnet selectivity has been conducted. There was discussion about submitting the gillnet section without the other sections, yet it was resolved that the three sections would be combined into one manual and the same statistical approach should be applied to all sections.

Candidates with experience in longline and pot selectivity were invited to take the responsibility for these sections and to comment on the draft gillnet manual.

## 7 TOPIC: EU PROJECT ON SELDAT2

**B. van Marlen (The Netherlands)**

The database is centrally hosted at CEFAS, Lowestoft. The participants, who work from client applications with custom designed user interfaces, create standardised selectivity data which is then be sent to CEFAS by e-mail. A hierarchical structure is followed where experiments contain gear tests, that, in turn, contain individual hauls. So the uppermost level is the experiment, and the lowest is the haul. The database contains selectivity parameters (alfa, beta, covariances) and not the length frequency distributions (raw data). Each participant received a range of codes for their experiments. Items such as vessels, gear, gear components (cod-end, grid, window, small mesh cover, etc.) can be put in separately, with identification codes to be chosen by the person inputting the data. An online catalogue is maintained to provide information about the contents of the database. Users can access the database and extract various reports. Information about this database; its contents are published on www.seldat.net. Access to this site requires a login ID and a password which can be given on request by Bob van Marlen (Tel: +31 255 564780; E-mail: bob.vanmarlen@wur.nl). A web-based tool to analyse selectivity data was made by ConStat and is placed on the website of RIVO, at the URL: www.rivo.dlo.nl/ECWeb (please note that the website is under revision)

The following table summarises the data was put into the database as of June 2003, with more to be expected in coming years:

| **Institute** | **# experiments** | **# gear tests** | **# hauls** |
|---|---|---|---|
| RIVO | 7 | 37 | no haul data |
| CLO-DZ | 3 | 14 | 319 |
| IPIMAR | 10 | 32 | 410 |
| IMR-NO | 2 | 2 | 27 |
| BFAFI | 4 | 13 | 131 |
| **Total** | **26** | **98** | **887** |

## 8 TOPIC: ASSESS GEAR RELATED TECHNICAL MEASURES APPROPRIATE FOR IMPROVING SPECIES AND SIZE SELECTIVITY IN *NEPHROPS* TRAWL FISHERIES

### 8.1 Principal findings of FTFB ad hoc group on *Nephrops* fisheries

**Norman Graham, (Norway)**

The full report from this ad-hoc group can be found in Appendix 5.

The *Nephrops* fisheries of the NE Atlantic and Mediterranean – A review and assessment of fishing gear design.

A review of the commercial trawl fisheries where *Nephrops* are a component of the catch was undertaken. These have considerable geographical coverage, ranging from Iceland to Portugal and into the Mediterranean. *Nephrops* are a highly important commercial species, valued at 208 million euro in 2001. The fisheries, with a few exceptions, are typically multispecies, with the relative economic importance of *Nephrops* varying considerably between fisheries. Due to the smaller mesh size used in comparison to demersal fish fisheries, the degree of discarding can be high. Additionally, due to the poor trawl selection characteristics, high grading and legislative restrictions, the discarding of *Nephrops* is considerable in certain fisheries. A range of gear related technical measures are applied in order to mitigate discard levels, but further improvements are required. There is a considerable lack of parameterised selectivity data for many of the existing technical measures, making any population independent assessment of their effectiveness problematic. The report is divided into geographical range, for each of these, the fisheries are described, fleet adaptations to legislation are discussed, a review of remedial measures tested and applied is provided. Based on this, fishery/area specific recommendations are provided. In addition to the fishery specific recommendations, more general recommendations are given, these are:

- In order to assess future developments, a benchmark of population independent selectivity parameters based on current legislation is required.
- Relationship between *Nephrops* biology (age at first capture), selectivity, minimum landing size and fishermen's selection should be investigated in order to provide optimum selectivity goals.
- The size selection of *Nephrops* is poor, resulting in a high degree of discarding in certain fisheries. The problems are not associated with low L50 but the absence of length related selection. Any improvements to reduce discards need to take account of potential loss of marketable catch associated with large selection range.
- The mechanisms of *Nephrops* selection should be investigated and the principal factors affecting size selection in the cod-end and extension, such as mesh size and shape, twine type, circumference, lifting bags and grids should be identified.
- Potential for improving *Nephrops* size selection in areas of the trawl other than the cod-end should be considered
- The development of *Nephrops* trawls that give broadly similar selection for whitefish as a whitefish trawl is urgently required.
- Harmonisation of technical measures between adjacent areas should be considered.

**Discussion:**

There were several comments on the work presented. The presenter was congratulated for looking at selectivity in several sections of the trawl and it was suggested that this work would be a good connection to working with FAO because FAO has identified the *Nephrops* fishery as having a very high discard rate.

### 8.2 Sea trials with species-sorting grid installed in *Nephrops* trawls

**Mats Ulmestrand and Daniel Valentinsson (Sweden)**

About 50 trawl hauls were carried out on four commercial *Nephrops* trawlers during autumn 2002 in order to increase species selectivity by the use of a sorting grid. Results show that a grid with 35 mm bar space, in combination with 70 mm square mesh, using a cod-end and extension piece of 8 m total length, significantly reduce the by-catch of fish. There was no significant reduction of full-sized *Nephrops*. Current regulations for *Nephrops* trawls, specifying 70 mm diamond mesh, imply that more than 1800 tonnes of protected undersized commercial by-catch species are caught and discarded each year. Assuming that trawling effort does not change, the results from this study indicate that discards in the Skagerrak/Kattegat *Nephrops* trawl fishery could be reduced to one fourth of current level, i.e., to about 400 tonnes per year. This study shows that the introduction of a 35 mm grid and 70 mm square mesh cod-end in the *Nephrops* trawl fishery in Skagerrak and Kattegat would significantly reduce the mortality of by-catch species. Furthermore, the resulting improvement in species selection would simplify management of the target species.

**Discussion:**

A brief discussion ensued after this presentation. The researcher was questioned about the survivability of *Nephrops* in this fishery and there was a comment that this device could be used in the trawl restricted areas. The researcher commented that they thought the survivability was quite high.

## 8.3 The Use of Inclined Separator Panels in Irish *Nephrops* Fisheries

**D.J. Rihan and J.McDonnell (Ireland)**

As a result of serious concerns over the state of cod stocks in the Irish Sea, the EU introduced closed areas and seasons in the Irish Sea for the first time in 2000. During this first closure period, trials on board the twin-rig vessel "Northern Dawn" were carried out to assess the effectiveness of an experimental separator panel fitted to a *Nephrops* trawl at facilitating the release of cod. Results revealed that the panel proved effective, with a significantly reduced number of cod being retained by the experimental net compared to a standard *Nephrops* trawl. Good separation of other whitefish species such as haddock and whiting from *Nephrops* was also observed. Owing to the effectiveness of the separator panel tested in 2000, under EU Regulation 300/200, fishing with *Nephrops* trawls with separator panels fitted was permitted within a defined part of the closure area in 2001. Observations on three vessels over the duration of the closure during 2001 indicated results very similar to those attained in 2000 with release rates of cod for all size classes of 68%. Since these trials, experimentation has been carried out with the inclined separator panel in the *Nephrops* fisheries off the South-west coast of Ireland in the Celtic Sea and also the important *Nephrops* fishery on the west coast of Ireland at the back of the Aran Islands. Again the results have shown the potential advantages of the panel as a simple and inexpensive technical conservation measure. Subsequently after the trials in the Irish Sea and other areas, four skippers from ports in the South-west have now voluntarily fitted panels as a means not only to reduce the level of juvenile fish retained but also by using a top retainer codend of an appropriate mesh size placed over the escape opening at the top of the panel, improved the quality of the marketable fish by-catch.

**Discussion:**

The researcher was asked if they has estimated the selectivity parameters and assessed the losses of the target species. The researcher explained that they had tried unsuccessfully to estimate the selectivity parameters and they had not seen much of a loss of the targeted species.

## 8.4 Species separation in the Firth of Clyde *Nephrops* fishery

**Derek Galbraith (Scotland)**

The inclined separator panel has been permitted in certain closed areas of the Irish Sea since February 2000 as part of the cod recovery plan to protect spawning cod. A short panel of netting is installed in the last tapered section of the net ahead of the cod-end. A gap of around 30cm is provided under the leading edge of this panel to allow *Nephrops*, monk and flatfish to pass through into the cod-end while cod and other roundfish are diverted upwards to an escape opening. A similar design using an additional cod-end attached to the escape aperture allows the diverted roundfish to be retained in an upper cod-end of appropriate mesh size, but this gear has not yet been introduced into legislation. FRS carried out fishing gear experiments on *Nephrops* grounds in the Firth of Clyde cod closure area early in 2002. The trials were carried out with chartered fishing vessel Fair Morn (BA 19) and both the above net designs were deployed to investigate roundfish and *Nephrops* escapes. Escape ratios for spawning cod averaged around 80%. A similar favourable separation was achieved for haddock but a significant proportion of the *Nephrops* catch was also released.

**Discussion:**

In a joint project (TE1.126 PT/DK), something similar was tried but did not proceed because the rigging was difficult and it was determined to be commercially unfeasible. The results were published in ICES conference 1996 in Reykjavik. Yet, Irish fishermen are using this panel design successfully, and it was mentioned that the reason may be because their legislation is strict and requires the panel in order to fish. The presenter was asked if the fishermen make their own gear and if it was easy to inspect. The presenter mentioned that any manufacturer can make this panel, but it is probably not easy for inspectors to inspect this panel for compliance.

## 8.5 Further Investigations into the use of Low Diameter Twines for the Construction of Square Mesh Panels

**Ken Arkley, (England)**

A series of sea trials were carried out on a twin rig trawler targeting *Nephrops*. The aim was to investigate the potential for increasing the release of unwanted by-catch species such as haddock and whiting. The work here built on previous knowledge of the influence that twine diameter had on size selection of fish. The development of high performance polyethylene (HPPE) twines raised the possibility of using low diameter twines in square mesh panels and improving

their selective performance. Panels made from HPPE twines were used in various mesh constructions and their performance was compared to panels made of standard PE netting. The results showed a significant improvement in performance attributed to the use of the low diameter twines. They also show that cheaper and more widely available constructions can be used to equal effect.

**Discussion:**

The presenter answered a couple of questions regarding the structure of the materials presented. He mentioned that the high performance polyethylene twines had 40% more mesh opening per unit of area, thus by using this twine you achieve more escape area. He also mentioned that the twine should be treated to minimize knot slippage.

### 8.6 An industry-centered conservation project: Commercial proving trials of a new prawn trawl design

**Gary Dunlin (England)**

This project covered sea trials using a new design of *Nephrops* trawl. The design aimed to minimise the by-catch of non-target species by precluding their entering the net, rather than releasing them post-capture. Two vessels of similar size and power were used to test the new trawl against commercial trawls in the Farne Deeps fishery (NE England) over a fifteen day period through December 2002 and January 2003. Catches from each vessel were sampled in identical manners and the new trawl used by both vessels to negate any bias towards either vessel or Skipper. The new design of *Nephrops* trawl reduced the retention of whiting in the cod end by 65%, whilst the retention of haddock in the experimental trawl cod end was reduced by a factor of 63%. The experimental trawl also appeared to reduce the retention of cod by 11%mainly in the smaller size classes (15 to 30cms). These figures were based on the combined totals from the summed hauls from these sea trials. There were no observed losses of the target species (*Nephrops norvegicus*)

**Discussion**:

Questions related to this topic centered on clarifying the net and study design. The opening was described and it was explained that the tests were conducted with a control and experimental net being fished side-by-side using similar vessels. Further clarification about the process and an explanation that the design took three years to get working was presented.

### 8.7 Using a Nordmøre-type sorting grid for by-catch reduction in the Portuguese crustacean trawl fishery

**Paulo Fonseca[1]; Aida Campos[1]; Roger Larsen[2]; Teresa Borges[1]; Karim Erzini[1]**
**([1] Portugal, [2] Norway)**

By-catch and discards are a common problem to all fisheries, its magnitude depending on the type of fishery (gear used, target species, local biodiversity), and on legislation and economical issues. Crustacean trawling is generally characterised by huge by-catches and consequently by high discards ratios both of undersized target species and of low valued or non-commercial species. The Portuguese crustacean trawling is no exception with recent studies showing that discards can reach up to 70% of total catch (Borges *et al*, 2000). This situation poses a threat not only for the management of target and commercial fish by-catch species stocks, but also concerning the ecosystem impact of the discarded species whose survival is generally low. Previous attempts to address this problem through the use of oblique separator mesh panels associated to square mesh windows or square mesh windows alone had limited results. Therefore, it was decided to try out the efficiency of a rigid sorting Nordmøre-type grid in excluding some of the most captured non-commercial by-catch species, such as the blue whiting, *Micromesistius poutassou*, and the boarfish, *Capros aper*, evaluating simultaneously the losses for the crustacean target species and commercially valuable fish by-catch. The grid was made in stainless steel with overall dimension 1.50 x 0.79 m in height and width, respectively, it was mounted in a 3 m long extension piece, and had a working angle of about 481. Bars were 10 mm diameter, spaced by 25 mm. In the lower part of the grid a 20 cm height section without bars allowed for Norway lobster to enter directly to the codend. A total of 41 valid hauls were carried out during 2001, and only 15 in 2002. Results from both years varied considerably, with higher escape percentages (in weight) being registered in the later survey. For commercial species, figures for 2001 and 2002 were: Norway lobster, *Nephrops norvegicus*, (10/12%), rose shrimp, *Parapenaeus longirostris* (4/9%), red shrimp, *Aristeus antennatus* (7/10%) hake, *Merluccius merluccius* (43.9/61.7%). For the unwanted by-catch these figures were 74.7/73.2% and 47.7/62.9% for blue whiting and boarfish, respectively. Although the level of exclusion of the non-commercial by-catch is very encouraging, short-term losses for crustaceans,

particularly of *Nephrops* where the escapees corresponded to larger individuals, raises some concern towards fishermen acceptance of mandatory use of grids.

**Discussion**:

A question was asked about the bar spacing (25 mm) on the grate and whether the grate was clogged by skates or monkfish. It was explained that there are so few monkfish in the area that this is not a problem.

### 8.8 A Comparison of the Selectivity of Diamond and Square Mesh Cod-ends used on the Fladen Ground *Nephrops* Fishery

**David J Bova and Graham Sangster (Scotland)**

A comparative study was carried out to determine the difference in *Nephrops* catch compositions between Diamond mesh cod-end and Square mesh cod-ends selectivity for *Nephrops*. The Square mesh sizes tested were nominally 80 mm and 90 mm. The Diamond mesh sizes were nominally 100 mm and 110 mm. The joining ratio for the cod-ends used during the study was 1:1, which was used to attach the extensions to the cod-ends. Results were not conclusive between Square mesh and Diamond mesh but L50 values were obtained. An encouraging result was the 110 mm diamond mesh gave an L50 value of 40.3 mm carapace length. A possible explanation for differences between the test cod-ends was the physical shape and behaviour of *Nephrops* during capture.

**Discussion:**

Minor comments were expressed about the materials used and the methodology. One participant stated that it is not surprising that they were not able to get clear selectivity for *Nephrops* while another participant mentioned that there has been some success in attaining *Nephrops* selectivity in the past.

### 8.9 Initial Results from a Modified Separator Trawl

**Graham Sangster David J Bova, and R J Kynoch (Scotland)**

Results from an experimental modified separator trawl show that it is possible to split the catch such that the majority of Cod, Haddock and Whiting are separated from *Nephrops* and flatfish. These significant results are quite different from the results from a separator with no modification. Ropes were attached to the footrope and leading edge of the separator panel to guide roundfish upwards over the panel to the top cod-end. The leading rope length is critical in achieving separation of mixed species.

**Discussion:**

A couple of questions were asked about the 30 cm spacing that was chosen for the ropes and the presenter explained that the spacing was chosen from past research that showed that this spacing was the optimal for eliciting an optomotor response while still allowing species separation. Another participant asked if the diving reaction of cod always occurs. It was stated that there was good evidence that this is a predominant reaction.

## 9 TOPIC: RECENT ADVANCES IN THE EU-PROJECT SURVEYTRAWL

**Christos Maravelias, Costas Papaconstantinou, [1]Irene Huse, [1]Ingvar Huse, [2]François Théret, [2]Benoit Vincent ([1]Norway, [2] France)**

The trawls used today to sample demersal fish are normally slightly modified commercial fish or shrimp trawls. Such trawls are designed to capture commercial species, and do not lend themselves well to representative sampling, mainly due to the herding effect of trawl doors, sweeps and bridles. The impact of herding is different for different species and size groups of the same species, and both inter- and intra-specific effects can be quite large.

The SURVEYTRAWL project intends to provide the strategic basis and initial design for a new survey trawl, which will represent a good compromise in terms of being non-herding and non-selective, and with stable and consistent operation. The final objective is to produce a new trawl with minimum herding effect and very good stability.

To avoid the herding effect, three different trawl and associated rigging concepts will be studied. The netting part of the three trawls should be very similar for each concept, but the riggings will be very different. The three designs will be tested by means of numerical simulation, using DynamiT software, to verify whether the designs represent hydrodynamically viable options.

Recent advances of the project will be presented, including:

- a review of existing survey trawls and relevant behaviour studies in order to facilitate the initial design of prototype survey trawls and associated rigging,
- simulation results for each concept, main advantages and drawbacks.

**Discussion:**

Several questions were asked relating to types of gear that could be considered. Participants asked if the group had considered beam trawls, pair trawling, nets with kites in place of doors and nets without legs. One participant emphasized that the issue of the gear was not as important as determining the efficiency of any gear that is being used.

## 10 TOPIC: EVALUATE THE SELECTIVE PROPERTIES OF TRAWLS USING 90 DEGREE TURNED DIAMOND MESHES AND ADVISE ON APPROPRIATE MESH SIZES CORRESPONDING TO THE AGREED BACOMA GEAR. EVALUATE SELECTIVITY OF DIAMOND MESH OF 130 MM AND 140 MM TAKING INTO ACCOUNT ALL NEW AVAILABLE INFORMATION ON THE MATTER.

**David Somerton (USA)**

*The full report of the FTFB Ad Hoc group to address this ToR is included as Appendix 4 of this document.*

The first part of this term of reference was considered in a report "Review of the size selectivity of Baltic cod trawls with turned-mesh codends" authored by David Somerton in collaboration with Dick Ferro, Niels Madsen and Rene Holst (Appendix 4). The report considers the data from 15 experiments examining the selectivity of Baltic cod trawls with turned-mesh codends. The experiments considered a range of mesh sizes and trawl configurations varying in twine material, twine size, twine number, and codend circumference. The analysis proceeded by first estimating the mean values of the size of 50% selection (L50) and selection range (SR) for each experiment, then fitting a statistical model to L50 as a function of mesh size and the experimental covariates. Mesh size, twine material and twine number were found to be significant predictors of L50. Although the model had a fairly good fit (r square =.84), it was considered to be insufficient for predicting the mesh sizes needed to produce the same L50 as that produced by the BACOMA 120 mm window. This insufficiency was twofold. First, the experiment was not balanced among the covariates. While 9 of the 15 experiments considered single strand polyethylene (PE) mesh only 1 considered double strand polyamide (PA) mesh. Since a minimum mesh size would have to be determined for each twine material, because twine material was a significant predictor of L50, the predicted values of minimum mesh size for codends other than single strand PE would be supported by very few data. Second, 14 of the 15 estimated values of mean L50 for the experiments were less than the L50 of the BACOMA 120 mm codend (45.2 cm). To avoid extrapolation beyond the range of data in the prediction of minimum mesh size, the experiments need to include mesh sizes that are sufficiently large to produce L50 values that bracket to BACOMA L50 value. An additional shortcoming was that the experiments were conducted aboard research vessels. Previous studies have documented that the L50 values obtained by research vessels can differ considerably from values obtained by commercial trawlers when both are using the identical design of trawl. To obtain data that would be more sufficient to produce minimum size estimates, it was recommended that more experiments be conducted which are focused on a single type of codend (say, single strand PE) that include larger mesh sizes. It was also recommended that such experiments be conducted on commercial trawlers during normal fishing operations.

The second part of the term of reference "Evaluate selectivity of diamond mesh of 130 mm and 140 mm taking into account all new available information on the matter" was not addressed because of confusion over its interpretation. If the intent of this ToR is to re-evaluate whether 140 mm is still an appropriate mesh size for single strand PE diamond codends after including all new experimental data in the analysis, then it is recommended that such an analysis be patterned after the 2002 FTFB study which considered both BACOMA window and diamond mesh data. The reason is that the 140 mm value was determined as the mesh size needed to produce the same L50 as the BACOMA 120 mm window codend. Therefore the appropriateness of the 140 mm mesh size depends both on the data for BACOMA window codends as well as that for diamond mesh codends. New BACOMA data is available because discussions at the FTFB indicated that BACOMA window experiments have been recently conducted by Swedish, Russian, Polish and

German scientists. It is therefore recommended that any re-evaluation of the current 140 mm minimum mesh size also include a re-evaluation of the selectivity of the BACOMA window.

**Discussion:**

There were several questions following this presentation. Most of the questions were similar to those explained in the report and focused on the applicability of presenting selectivity data when there was scarce data to support any conclusions for all but the single strand Polyethylene (PE) twine. There was a suggestion that the data might be analysed differently to more realistically represent between-experiment variability. In addition, there was concern about using selectivity data obtained on research vessels since ICES has stated that there is less confidence in selectivity data obtained on research vessels as compared to commercial vessels. The question was raised about the value of having a narrow selection range. It was suggested that turned mesh, which has been shown to have a narrower selection range, might be considered beneficial as compared to standard diamond mesh which has a wider selection range. There was a general consensus that what was presented was an alternative to diamond mesh codends and there should be more work on this, using larger mesh sizes, to adequately assess the values of L50 that could be achieved using this mesh. Furthermore, it was expressed that turned mesh and the BACOMA window both showed promise in reducing the catch of sublegal fish by decreasing the selection range of commercial trawls.

### 10.1 Selective properties of 90° Turned Mesh cod-ends

**Waldemar Moderhak (Poland), and Harold Wienbeck (Germany)**

Turned mesh was first presented at the 1993 Annual Science Conference of the ICES in Dublin and subsequently published. The investigations on characteristics of selective cod-ends with meshes turned 90° have been carried out by both by the Sea Fisheries Institute, Gdynia, Poland an by the Institute for Fishery Technology and Fish Quality, Hamburg, Germany.

Studies on the properties of turned-mesh cod-ends were conducted on board of the Polish research vessel BALTICA. Beginning in 1998, the research work was also conducted on the German research vessels SOLEA and WALTHER HERWIG III.. In 2000, turned cod-ends investigations were also conducted on commercial fishing vessels, to examine the selective properties and durability of this gear during normal commercial fishing operations.

Turned mesh codends are constructed from standard diamond mesh netting but have the orientation of the netting relative to the direction of trawling turned through 90°. Therefore, the production of netting for turned mesh codends does not require any changes in machinery or production technology in net factories. The turned cod-ends are made of polyamide (PA) or polyethylene (PE), single or double twine netting, and constructed as one or two panels. The turned mesh cod-end extension is made of netting similar to cod-end construction. The length of the cod-ends tested was approximately 7 m (in the stretched state) with a circumference adjusted to the construction of a belly end. Extensions used during the research were 14 m long.

Experiments were conducted to compare the selectivity of turned mesh codends to that of codends equipped with a BACOMA window. Selectivity (L50), selection range (SR), selection factor (SF), and selectivity efficiency (Eta) were compared for Cod < 38 cm in the cod-end. A test of the durability of turned 90° netting during normal commercial fishing was performed for three years on two Polish fishing vessels aiming to study both the usefulness for commercial fishing as well as to collect data of undersized cod retention.

The turned mesh cod ends have the following advantages: very good selective and protective properties (sharp selective curve, small by-catch), wide acceptance by Polish fishermen, better fish condition and survival rates, simple construction, low price, stability during towing, better breaking strength of turned netting, easy netting availability, short fishing operation time, and improved catchability. Presently, no disadvantages of the turned meshes cod-end have been recognized.

Codends with meshes turned through 90° can increase selectivity and fish protection in fisheries, because they have the following properties: 1) they retain a small number of juvenile fish, and 2) they have a small by-catch of other round fishes and a by-catch of flatfish comparable to that retained by other cod-ends constructions.

**Discussion**:

The questions regarding this presentation concerned the stiffness of the twine of the meshes and how this will affect selectivity. It was mentioned that twine stiffness greatly affects selectivity and as twine stiffness increases, the mesh

openings increase. The authors indicated that their findings agree with those from selectivity measurements on commercial vessels, with L50 differing by only by 1.5 cm. One comment raised was that the main advantage of turned mesh codends is that they produce more knife-edge selectivity or a smaller selection range than traditional diamond mesh codends. However, while achieving a small SR may be beneficial in the short-term in reducing discards, some authors (MacLennan, Shepherd, Pope, and Gislason, 1992. ICES J Mar Sci. 49:425–430) argue that in the longer term a narrow SR could be bad for stocks because the mortality on fish of length >L50 is actually increased and the yield from stocks may be more unstable.

## 11 OLD BUSINESS

### 11.1 The report of the Study Group on Survey Trawl Gear for the IBTS Western and Southern Areas [SGSTG]

The International Bottom Trawl Survey WG requested, at the 2002 WGFTFB meeting, that FTFB provide expertise in the development of a new design for a survey trawl that would be effective throughout the IBTS Western and Southern areas. After discussions at the 2002 WGFTFB and again at the 2002 Fishing Technology Committee meeting, it was recommended that the best way of attacking this problem was to form a new Study Group reporting to both the FTC and the RMC. The Study Group on Survey Trawl Gear for the IBTS Western and Southern Areas (SGSTG) was subsequently formed and met for three days (12–14 February 2003). The following is the Executive Summary from the first meeting of the SGSTG.

- The group made a review of the IBTS data uses and needs defining different areas depending on most important target species and type of grounds. Two main kinds of areas were defined: areas with target species more benthic (megrims, *Nephrops*, anglers) and dominated by soft grounds (mainly IX, VIIIc and part of VIIIb ICES divisions) and areas with semipelagic target species (mackerel, horse mackerel and gadoids) and hard grounds.
- The group defined the ideal characteristics of a bottom trawl sampling gear for the area regarding basic design, ground gear contact, vertical and horizontal opening, mesh size, robustness, towing speed, herding effect, stability and costs. These definitions were used to assess the suitability of the different gears reviewed by the group.
- The group also made a review of gears used in surveys in IBTS surveys in the area and their suitability to sample the species and ground types previously defined. Among all the gears GOV and Porcupine baca were found suitable to be used as sampler in most in the areas, being the first more adequate for rough grounds and the second for benthic species, both having a similar geometry (vertical and horizontal opening).
- Different gears used in different areas and ongoing projects to design new sampling gears were presented to the group. Although most of them presented several characteristics desirable for a sampling gear, none of them satisfied all the needs or were available to be used within a short time period.
- The need to take a decision in a short period and the idea of not introducing a dramatic break in the existing time-series made advisable to choose the GOV and Porcupine baca as candidates for a standard gear in all the area. Several modifications to both of them were proposed in an attempt to improve their sampling performance and robustness. The group decided a schedule of trials and tests of these modifications during 2003 and it was decided to review the results on the next meeting in 2004. After this review a decision on the gears used in each survey will be taken.
- The rest of terms of reference were postponed to the next meeting considering that no work can be done this year and that there was not time to discuss them. Those ToRs deal with defining intercalibrations to be performed and their scope to maintain continuity in time-series, and recommend appropriate survey design for multi-vessel/gear permutations such as stratification, overlap, and the combining of data to provide appropriate indices of abundance and biodiversity indices of stock and regional scales were postponed to the next meeting.

## 12 NEW BUSINESS

### 12.1 Place and Time for the 2004 FTFB Working Group Meeting

The Next WGFTFB meeting will occur April 20, 21 23 in Gdynia, Poland. There will be a joint meeting with the WGFAST on April 22. Terms of Reference for the 2004 meeting are provided in Appendix 1.

There was discussion concerning the formation of an *ad hoc* group to review the potential sources and magnitude of unaccounted mortality in fisheries and associated issues. The proposed group would: 1) work by correspondence on a continual basis, 2) report to FTFB on a regular basis at least once every three years – summarizing current knowledge on unaccounted mortality, 3) make *ad hoc* reports on arising issues of particular importance to FTFB, and 4) review and make recommendations on methods used to estimate escape mortality from towed fishing gears. A decision on such a

group was postponed for further consideration because its intended duration was longer than the usual duration of *ad hoc* or Study Groups. However, the utility of a long-term association of researchers within FTFB working on similar topics was recognised and the means to achieve this functionality will be explored before the 2004 FTFB meeting.

Due to concern over inadequacies in the mini-symposium format of most FTFB meetings and to better accommodate research priorities from FAO, a new approach to directing the Working Group will be tried. A steering committee (SC) will be formed comprised of two members chosen by the FTFB Chairman and one member from FAO. Each year the SC will research potential topics to determine their appropriateness for ToR. For each topic, the SC will also solicit a convener for that topic who will have the responsibility of soliciting contributions, corresponding with the contributors and creating a summary document.

There was a recommendation by the WGFTFB for a Theme Session at 2005 ICES Annual Science Meeting on:

> The development of effective and acceptable gear modifications and alternative fishing tactics to reduce the by-catch and mortality of cetaceans, pinnipeds and sea turtles in trawl and static gear fisheries. Conveners: Someone from FTFB and someone to be announced from LRC (Appendix 2).

# 13 NATIONAL REPORTS

## 13.1 Belgium

### 13.1.1 Agricultural Research Centre Ghent - Sea Fisheries Department -- R. Fonteyne and H. Polet

**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 concluded. The discarding problem has been quantified, its biological and economical consequences estimated and sorting grids, sieve nets and alternative stimulation (electric pulses) have been tried as technical means to reduce discarding. All results on the shrimp work of the last seven years has been collected in a PhD thesis and is planned to be published by the end of this year.

**Reduction of cod by-catches in beam trawls**

In the frame of the EU Cod Recovery Plan, the technical measure for beam trawls – a large mesh panel in the front part of the top panel – has been evaluated and found to be not very effective for whiting and poor cod in small beam trawls. For larger beam trawls, having a large mesh panel stretching further back in the net, by-catch reduction is expected to be more pronounced. This was confirmed by experiments in a 4m beam trawl with a complete top panel in large meshes. In this case, the reduction of the whiting catch was doubled to almost 50%. Unfortunately, no sufficient numbers of cod were caught but it can be expected that this panel will not release significant numbers of cod.

The EU-project "Research on effective cod stock recovery measures" (RECOVERY) (Contract Q5RS-2002–00935) has been started and aims at a reduction of cod by-catches. A first series of trials have been carried out on the Dutch RV TRIDENS with a lowered headline and a square mesh panel in the cod-end. The data have not been analysed yet but the first impression is positive. Further experiments are planned.

**Mesh measurement**

The EU R&D and Demonstration Project "Development and testing of an objective mesh gauge" (OMEGA) started in September 2002 with SFD as coordinator. Research institutes and fisheries inspection services from Belgium, France, Germany, Italy, the Netherlands, Spain and Scotland are involved as well as a Belgian and a Dutch instrument maker. A first prototype has been built and was evaluated. A modified instrument will be extensively tested in the lab and at sea. Details on the project can be found on the OMEGA website www.dvz.be/omega.

SFD also coordinated the activities in the frame of the ICES Study Group on Mesh Measurement Methodologies. The final SG meeting (Oostende, 19–21 March 2003) was attended by scientists, fisheries inspectors and representatives from the industry (netmakers) and the EU. Based on mesh size measurements made with different measuring forces a new standard measuring force was defined. A recommendation for a new mesh measurement methodology was made. An ICES Cooperative Research Report was written.

**Selectivity database**

The EU-project SELDAT 2 aiming at the design and implementation of a selectivity database was concluded.

**Balancing Impacts of Human Activities in the North Sea**

The sustainable management of the North Sea is a very complex theme due to the interaction between the social, economic and ecological dimensions of the use-functions of the Belgian part of the North Sea. A project (Balancing Impacts of Human Activities in the North Sea – BALANS) was started aiming to develop a first conceptual balancing model "Sustainable Management of the North Sea" for the policy makers and the users of the North Sea. The purpose is the correlation and the balancing between the different social, economic and social dimensions, through the elaboration of indicators, via the development of a conceptual policy model. As this type of research concerning the marine environment is still in an embryonic phase, the research boundaries are strictly limited to the use-functions sand- and gravel extraction, fisheries and related shipping.

## 13.2 Faroe Islands

### 13.2.1 Faroese Fisheries Laboratory (Kristian Zachariassen (krizac@frs.fo) and Bjarti Thomsen (bjartit@frs.fo)

**Flatfish trawling**

As a result of the work to improve the selectivity in the flatfish fishery in Faroese waters a mandatory sorting grid was introduced in 1997. Further experiments have been made to make this grid more flexible for use on net drums. Some vessels have adopted a hinged grid.

Experiments, evaluated by underwater video recordings, have been done to improve the ground-gear and tickler chain system on the flatfish trawl. Replacement of the tickler chains by rolling brushes showed less sediment disturbance and less debris in the trawl without loss of fishing efficiency. Studies to reduce the impact on the bottom from the ground-gear will be continued.

**Seize selectivity in shrimp trawling**

To reduce the catch of small shrimps, experiments using grids and square mesh codend were carried out. The effect of square mesh codends was negligible. The best results were obtained with the size sorting grid in front of the mandatory Nordmøre grid. However, a reasonable reduction in small shrimps could not be obtained without loss of a large proportion of larger shrimps. These experiments were made in cooperation with a Canadian trawler and a Faroese trawl factory.

**Cod and Greenland halibut tagging**

Since 1997, more than 20000 cod have been tagged on various locations on the Faroe Plateau. More than 5000 cod have been recaptured, and stomach content has been available for more than 1000 of these fish. Analysis of this material provides valuable understanding of the migration patterns and feeding behaviour of cod on the Faroe Plateau. Some of these results were reported to the ICES 2003 Symposium in Bergen. A smaller scale tagging experiment on Greenland halibut was initiated in 2002.

**Salmon tagging**

In a Nordic project 112 post smolt and pre adult salmon were tagged using data storage tags (DST). The salmon was caught and released in the open waters north of the Faroes using a purpose built surface trawl with the codend formed as a fish-cage.

**Effects of seismic shooting**

The Faroese area has been opened for oil exploration. In this context an experiment was undertaken to test the impact from seismic shooting on fish. Caged salmon smolt and adult rainbow trout were exposed to airgun shooting at different distances. The sound pressure level was monitored by hydrophone while underwater video recordings monitored the fish reaction. At maximum sound level pressure of 185 dB only subtle fish reaction was observed.

Fishermen's opinion on the impact from seismic shooting on fishing has been revealed by an extensive questionnaire survey. The majority were convinced that seismic shooting had negative impact on the success of fishing. The effect was believed to last for 1–2 weeks. However, the effect of seismic shooting could not be verified by logbook data.

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## 13.3 FRANCE

### 13.3.1 IFREMER Fishing Technology Department

**General mission**

The Fishing Technology Department of IFREMER main mission is to develop and improve selective and environment respectful fishing gears.

**Selectivity**

A national project with the National Fishing Comity aims at improving the bottom trawl selectivity for the Bay of Biscay. First trials with Nephrops selective supple grids have been led aboard the oceanographic vessel GwenDrez. First results point out an improvement of the selectivity, that is not sufficient yet, and show that the chosen material fit perfectly for this application. Trials will be carried on to optimise the grid position. The next step will be to use this grid on professional fishing vessels (started in 2003) so as to transfer it to the whole fishing fleet.

A model of monk fish supple grid, that has been studied previously, has been designed and tried on several Bigouden professional fishing boats. They are satisfied with the results. After some improvement, this device could be deployed on the whole fleet targeting monk fish.

The numerical modelling of trawl selectivity is being carried on. The European projects PREMECS II, coordinated by IFREMER, aims at developing within 3 years a tool designed for scientists to evaluate and propose decision-makers, technical measures for sustainable fishing. This model will be completed by a modelling of the fish behaviour in the trawl.

**Acoustic repulsive devices for marine mammals**

Two studies carried out in the Mediterranean Sea as a part of a European project have been ended in 2002. The objective was to repel dolphin from fishing nets. In this area, dolphins are not caught by nets but just come to feed them selves. The repulsive devices where very efficient and dolphins did not show any familiarization effect. Nets on which repulsive devices have been put have not been damaged.

**DynamiT**

The Fishing Technology Department of IFREMER has been developing fishing gear simulation software for more than 10 years. Recent calculation methods allow the development of a commercial trawl gear simulator: DynamiT. This software enables the optimisation of an existing trawl and its rigging in order to improve its efficiency or to decrease its GO consumption. It can also be used to assess a new trawl concept, with a very low coat, instead of or prior to sea trials.

An important part of the development of DynamiT is dedicated to the user interface in order to make it friendly. This software has been especially designed for research institutes, net makers, training organisations. Even sea surveys are carried out to improve the models realism.

## 13.4 GERMANY

### 13.4.1 Institute for Fishing Technology and Fish Quality, Hamburg (Erdmann Dahm)

**Technical- biological investigations:**

**Selectivity of cod trawls in the Baltic**

Work on this subject concentrated in 2002 on the effects of using 130 mm diamond codends. Short after the introduction of this alternative to the 120 mm Bacoma – codend fishermen detected the much worse selectivity of it, particularly if made from very stiff netting yarn in sheath- core- construction, and switched to it in majority. With L50ies of 33 cm instead of 45 cm as intended this lead to massive discard problems of undersized cod. Research done demonstrated the true magnitude of this deterioration. A turned-meshes- codend with 25 mm lower mesh opening gave the same results as the legal diamond codends with 130 mm mesh opening and made of double 4 mm or single 6 mm netting yarn and proved again the superior selective properties of this codend construction.

**Selectivity and by-catch in the shrimp beam trawl fishery**

During the last years a considerable diminution of the fish by-catch of beam trawls for brown shrimps could be achieved by joint international research and by means of sorting grids and sieve nets. However, this is a size depending effect and the small sized meshes still catch a considerable amount of small flatfish of the approximate size of the target species. Research done focused on expected behavioural differences between fish and shrimp by offering the fish an escape window of bigger square meshes in the lower panel. Results are not very satisfying at the moment indicating that the expected effect might not be as big as anticipated. A significant loss of small flatfish was always accompanied by a similar loss of marketable brown shrimp.

**Flatfish selectivity in the Baltic**

Legal codends for cod made from double-yarn netting showed similar selective properties for the target species flounder as a special codend for this fishery with 125 mm mesh opening,

**Alternative catching technology for herring**

A lampara-like seine net hung up at the surface by floats was tested in technical tests in the coastal spring herring fishery in Eastern Germany. Main aim is to develop a gear less or not detrimental to the habitat. Shooting and hauling technology works principally but catching trials have still to be made.

**Optimisation of gillnets to avoid unwanted by-catch of porpoises**

There are three lines at present followed to suppress the unwanted by-catch of small cetaceans in gillnets. The use of reflectors or inclusion of barium sulphate into the netting yarn has already been tried elsewhere with varying success. The work of the institute was focused on the investigation of deterring panels made of very large meshes and of thick netting as recommended by Dutch scientists. It was detected that gillnets fitted out this way had a significantly reduced catchability compared to nets without deterring panels. The acceptance of such construction by commercial fishermen will be rather low, particularly if the by-catch of porpoises is a very rare event in the German fishery. However, there are some prospects of minimizing the detrimental effects of the chasing panel by modification of the construction and additional weight at the lead line.

**A new theoretical model for the combination of stock assessment and selectivity**

A theoretical study issued by a scientist of the institute tries to combine the Beverton-Holt- model and real selectivity functions to optimize the exploitation of a stock. For the Baltic it shows that the present exploitation regime is far beyond a possible economic optimum.

**<u>Technical investigations:</u>**

**Development of a precise baiter for longlines**

The development work with the device was continued. Sufficient baiting rates of more than 90% were achieved as well on an experimental testing device in the lab as in practical trials at sea.

**A new research ship**

Though the keel-laying ceremony for the new FRV “Solea” has happened the institute is still actively involved into details of the fitting out. The completed ship is bound to be delivered in April 2004.

**Progress with a cableless video- transmission system**

Taking into regard experience gained during a Dutch-German cooperation in the Atlantic the design of the device has been further improved. It incorporates now an inflatable collar improving the safe handling and giving extra lift. Thus, it is possible to add a further video recorder storing data from a video channel not transmitted. It further enables to fit in a radar transponder improving the safe recovery of the device.

## 13.5 The Netherlands

### 13.5.1 RIVO-DLO (B. van Marlen)

**Electric fishing**

Work continued on the development of an electrified beam trawl in collaboration with the Ministry of Agriculture, Nature Management and Fisheries and a private company. The system was upgraded from a 7 m to a 12 m prototype, and reduced in size enabling it to be fitted on a conventional beam. Experiments are continued this year. Work planned is aimed at a detailed comparison of catch and by-catch, and monitoring catches and economic performance during a long-term commercial trial.

**Release of cod from demersal trawls**

Project RECOVERY addresses the current critical level of the cod stock in the North Sea and the Irish Sea in support of the EU Cod Recovery Plan and started in November 2002. The objective is to develop novel species-selective gear prototypes for three mixed-species demersal trawl fisheries (i.e., demersal otter, *Nephrops*, and beam trawling) in the North and Irish Seas. The participants are: Netherlands Institute for Fisheries Research (RIVO) IJmuiden, Netherlands, Institute of Marine Research - Department of Marine Resources (IMR), Bergen, Norway, Sea Fish Industry Authority, (SEAFISH), Hull, England (UK), Fisheries Research Services (FRS) - Marine Laboratory, Aberdeen, Scotland (UK), Centre for Agriculture Research - Sea Fisheries Department (CLO-DvZ), Oostende, Belgium, Danish Institute for Fisheries Research - Department of Marine Fisheries (DIFRES), Charlottenlund, Denmark, CONSTAT, Hjørring, Denmark, and Queens University of Belfast (QUB), Belfast, Northern Ireland (UK). Trials on the Dutch and Belgian gears were carried out in the fall of 2002 and the spring of 2003.

**New projects**

A very large project called NECESSITY (*Nephrops* and Cetacean Species Selection Information and Technology) with two tasks was proposed in the European sixth framework programme, and is now in the contract negotiation phase. The aims are to find solutions to decrease the by-catch of cetaceans in pelagic fisheries, and to decrease the various by-catches in the European Nephrops fisheries. It is expected to commence next year and will have a duration of 38 months, involving 23 partners.

**Selective gears (national programme)**

Work has been done to avoid the by-catch of seals in coastal set nets, to monitor the by-catches in coastal fisheries and to investigate the potential for more selective fyke nets in inshore waters.

## 13.6 NORWAY

### 13.6.1 Institute of Marine Research, Bergen

**Instrumentation**

Two trials were conducted with a 3D acoustic sonar system (Echoscope) with the objective of observing gadoid behaviour in the mouth of a demersal trawl. The sonar was mounted on the headline and pointed into the mouth of the trawl at angles between 30–450. A large amount of data has been collected. This has made it possible to track individual fish over a horizontal distance of approximately 6m and vertical distances of 4–5m, obtaining x, y and z coordinates. These will be used to build up a three dimensional image of fish movements. During the second phase of the trials, species identification of the individual echoes was attempted by using the echoscope in conjunction with optical systems. This proved problematic due to depth and water turbidity, further experiments are planned next year.

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## Size and species selectivity

### Sorting grid in herring trawl

Pelagic trawling for herring (*Clupea harengus*) during autumn in northern Norway has often been associated with high by-catches of cod (*Gadus morhua*) and saithe (*Pollachius virens*). Experiments with a sorting device similar to the single grid (Sort-V) used in bottom trawl fisheries with 60 mm bar distance gave a significant reduction of by-catch, but also an unacceptable high herring loss when trawling on high-density aggregations of herring. This was probably due to capacity problems of the grid. Further experiments will be conducted late autumn 2003.

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### Comparative selectivity of 55 mm sorting grid and 135 mm diamond mesh in bottom trawl

Experiments were conducted to assess the selectivity of a metal sorting grid (Sort-X, 55 mm bar spacing), a diamond mesh cod-end (135 mm diamond mesh) and the combined selectivity of both, in bottom trawling for cod (*Gadus morhua*) in the Barents Sea. L50 for the trawl fitted with a grid was higher than for a trawl without a grid, but the selection interval was not significantly different. The data suggests that a 150 mm cod-end would give approximately the same size distribution in the catch as a trawl fitted with a 55 mm sorting grid and a 135 mm diamond mesh cod-end.

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### Comparative selection in the North Sea bottom trawl fisheries

In cooperation with Marine Laboratory, Aberdeen, comparative selectivity experiments have been conducted in the North Sea. The experiments showed that a decrease in the number of meshes in the circumference of a cod-end reduces the by-catch of under-sized fish. Further, a trawl with 120 mm cod-end and Flexigrid with 35 mm bar spacing did not improve the selectivity compared to a 120 mm cod-end without a grid.

Contact Norman Graham, norman.graham@imr.no.

### Selectivity in shrimp (Pandalus borealis) trawling in the North Sea

Experiments in the North Sea shrimp fisheries where the trawl was fitted with sorting grids of 19 and 22 mm bar spacing, showed a generally low shrimp loss, but the loss of large roe shrimps was larger with 19 than 22 mm spacing. The loss of fish by-catch was similar for the two different bar spacing with the exception of blue whiting (*Micromesistius poutassou*).

Contact John Willy Valdemarsen, john.willy.valdemarsen@imr.no.

### Size selection of king crab (*Paralithodes camtschaticus*) in pot fisheries

In the pot fisheries for king crab (*Paralithodes camtschaticus*) in Northern Norway by-catch of small crabs has been a major problem. Fishing experiments showed that fitting the pots with circular escape openings reduces the by-catch problem to a minimum. The size of the escape openings can be adapted to fit the minimum legal size of crabs.

Contact Dag Furevik, dag.furevik@imr.no.

## Unaccounted mortality

### Some aspects of trawl induced unaccounted mortality

Trawling with heavy ground gears whirls up considerable amounts of mud and dust in the water column. On high intensity fishing grounds these mud clouds may be semi permanent. Tank experiments were conducted to study the effect of mud clouds on the physiology, particularly gill function, of cod (*Gadus morhua*). Concentrations of 500 mg/l of mud in up to ten days did not lead to mortality of cod.

Contact Terje Jørgensen, terje.Jorgensen@imr.no, or Odd Børre Humborstad, odd-boerre.humborstad@imr.no.

Experiments where small collecting bags were fixed underneath the fishing line of a bottom trawl in the Barents Sea fisheries for cod (*Gadus morhua*), showed that a surprisingly large fraction of cod of a broad size range escaped under the ground gear. The escapement was length dependent and followed a logistic selection curve with L50 of approximately 40 cm and a selection interval of about 30 cm. Fish abundance effects the size selection. The mean escapement of cod, haddock and saithe (irrespective of length), were found to be 36.6, 23.7 and 5.9% (respectively). A significant fraction of fish collected in the bags showed skin wounds that may have been caused by fish been overrun by the discs of the ground gear.

Contact Olafur Arnar Ingolfsson, olafur.ingolfsson@imr.no.

**"Survival"**

A new EU project "Survival" started up in October 2002. The aim of the project is to look at different aspects of survival of haddock (*Melanogrammus aeglefinus*), cod (*Gadus morhua*) and whiting (*Merlangius merlangus*) in bottom trawl fisheries. Partners are FRS, Marine Lab., Scotland, DFU, Denmark, IMR, Norway, and The North Sea Museum, Denmark. The main objectives of the project are: 1) To develop improved methods for survival studies. 2) To study seasonal variation in survival. 3) To study survival of fish escaping at surface during hauling. 4) To study the survival of fish in high intensity fishery areas.

Contact Aud Vold Soldal, aud.soldal@imr.no, or Irene Huse, irene.huse@imr.no.

## Fishing gear development

**New generation cod trawl**

IMR has in cooperation with SINTEF, Hirtshals developed a new fish trawl design including a ground gear that consist of rubber plates arranged along the fishing line. Reduced drag compared with traditional Norwegian fish trawls and a ground gear that has inherent spread force are major features of the design. The development includes numeric simulation, flume tank testing in 1:10 scale, at sea trials in 1:2 scale (this autumn) and finally full scale testing (next year).

Contact John Willy Valdemarsen, john.willy.valdemarsen@imr.no.

**Development of new krill trawl**

A new trawl concept for krill fishing, based on dividing the trawl into nine separate cod-ends, is developed and tested in flume tank (1:10). The gear performs technically well in the tank experiments, and a prototype full-scale trawl will be built and tested in fishing experiments for krill and possibly mesopelagic fish.

Contact John Willy Valdemarsen, john.willy.valdemarsen@imr.no.

**Live fish technology**

Experiments with catching live fish for aquaculture purposes were undertaken using seine nets and purse seine. The survival rate of cod (*Gadus morhua*) caught by purse seine was compared to that of cod caught by Danish seine. When cod was caught at greater depths than 50–60 m, there survival of purse seine caught cod was not higher than for cod caught by Danish seine.

Contact Bjørnar Isaksen, bjoernar.isaksen@imr.no.

## Environmental effects of fishing

**Effects of otter trawling**

The 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. Trawling affected the benthic assemblage mainly

through resuspension of surface sediment and through a relocation of shallow borrowing 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.

Contact Odd Børre Humborstad, odd-boerre.humborstad@imr.no.

**Scavenging after bottom trawling**

Experimental bottom trawling and stomach sampling was carried out off the coast of Finnmark, Northern Norway, in August 2002, in order to determine whether cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) move into recently trawled areas to feed on animals killed or exposed by a trawl passage. Preliminary results indicate increased feeding activity after trawling and change of diets for haddock and small cod.

Contact Odd Børre Humborstad, odd-boerre.humborstad@imr.no.

### 13.6.2 SINTEF Fisheries and Aquaculture, Trondheim, Norway and Hirtshals, Denmark

**New Generation Cod Trawl**

SFH and IMR have a 3-year project with the objective to develop a new generation cod trawl. The aim is to develop a trawl with lower towing resistance, less impact on the seabed and a better selectivity compared to industry standard. The project also deals with other topics like catch efficiency, quality of the catch and easy maintenance.

Contact: Kurt Hansen, Hirtshals, kh@sintef.dk

**Gentle cod-end: 90º turned netting**

Despite the fact, that the quality of the catch in trawls often is poor, very little has been done to improve the situation. This project is committed to find solutions to this and two subjects are believed to give results. One is a reduction in the turbulence found in the pear-shaped cod-end. The turbulence is 'washing' the fish round, and in the 'grinding' process the layer of mucus and scales are removed. The other subject is finding net materials with a more smooth or gentle inner surface.

The Flume tank at the North Sea Centre Flume Tank has been used to test several different half-scale cod-ends. The smallest cross-section area and the flow have been measured and the waving action has been recorded. The cod-ends were filled with ½-liter (1 pint!) plastic bags with water, simulating fish, equivalent to a full-scale catch of around 450 kg.

The results have so far revealed that the standard cod-end with two selvedges have a very narrow entrance and are waving from side to side. Inside the cod-end the 'fish' are being thrown against the net wall, just as can be seen on full-scale underwater video recordings.

Several attempts were made to reduce the turbulence, and two solutions were found to give considerable improvements: a full square-mesh cod-end (netting turned 45º) and a cod-end with the netting turned 90º. The cross section area is around 12 times larger in the 90º cod-end, indicating that the large cod-end will let out more water and thereby reduce the turbulence. This is confirmed by an almost non-moving cod-end.

The cod-end will be fitted with a lifting bag made from knotless netting, making the inner side more gentle to the fish. Full-scale cod-ends will be tested at a later stage and the quality of the catch measured.

It must be noted that a gentle cod-end preserving the quality of the catch, will also improve the survival rate of the small fish escaping from the trawl. The use of the cod-end therefore also has implications for the exploited resources and for fisheries management.

Contact: Ulrik Jes Hansen, Hirtshals, ujh@sintef.dk

**Fine Meshed Pelagic Trawls**

A new project has just been initiated on establishing a theoretical basis for describing and predicting the flow in small-meshed pelagic trawls. The background is the growing interest in exploitation of marine zooplankton and small fish, motivated by the growing demand for feed for the aquaculture industry.

Several attempts have been done to exploit for instance krill, but a to a sustainable and economic exploitation of such resources requires improved and new technology. Pelagic trawls are believed to be suitable for harvesting this resource, but a better understanding of the flow is necessary, especially because there will be a strong dependency between efficiency, quality of the catch and the flow through the net.

Contact: Svein Helge Gjøsund, Trondheim, svein.h.gjosund@sintef.no (Ulrik Jes Hansen, Hirtshals, ujh@sintef.dk)

**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 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.

Contact: Harald Ellingsen, Trondheim, harald.ellingsen@sintef.no

***Calanus* Trawl**

Continued full scale tests have been conducted over the past year. A large trawl was made and tested in Trondheims Fjord. Some improvements were made, especially for strengthening the net, and it has later been tested in other localities in Norway. The handling of the net has been important and it has therefore been tested against vessel type and size. Small Danish Seiners have been found to be especially suitable for the gear, due to the presence of a power block to retrieve the net.

Contact Snorre Angell, Trondheim, snore.angell@sintef.no

**Distant learning/demonstration/training/instruction from the Flume Tank**

The North Sea Centre Flume Tank has recently been equipped for Video Conferences. It is therefore possible to follow demonstrations in the flume tank without being present. This has great implications for classes from schools and universities, research laboratories and vessels, and others, which have difficulties in finding funds for the travel expenses, board and lodging – and justify such in cases where only a few hours of tank hire is required. 3 movable and 3 fixed cameras plus the computer readings are mixed and can be transmitted to the customer sitting in a videoconference studio abroad.

Contact: Ulrik Jes Hansen, Hirtshals, ujh@sintef.dk

### 13.6.3 The Norwegian College of Fishery Science (NFH), University Of Tromsö

**Development of a zooplankton trawl for commercial harvesting**

A selfspreading trawl (no beams, no otter boards) of 45 $m^2$ opening in the mouth has been tested successfully. The trawl is built from ordinary plankton net (500 μm mesh) and is towed from a single warp at approx. 1 knot. Tests performed

during the summer of 2002 revealed catch rates of *Calanus finnmarchicus* in excess of 100 kg/hour. A special arrangement allows for selective *Calanus*-catches, i.e., removal of jelly fish and fish larvae. The trawl is used in a commercial fishery for *Calanus* this season.

**Development of a mechanised system for releasing fish from the hook of longlines during the hauling operation.**

One aim is to remove the "gaff hook" from coastal (and later on also in the offshore longlining). Focus during the project were directed towards fish handling, quality of fish, ethical standards in fisheries and safety on board for crew members.

**Shrimp Trawls and Grids**

Shrimp trawls were tested with two types of plastic (PE and PA) sorting grids (Nordmöre type) in the Arctic shrimp fishery. The experiments were made with single trawl- and triple trawl configurations. The experiments resulted into the legislation of the PA. grid, termed the Cosmos Nordmöre grid (so far used by the largest vessels only).

**Studies on behaviour in the vicinity of the ground rope (rock-hoppers) of fish trawls with an aim of increasing the efficiency of fish trawls**

Observations made during February and March this year show that too many fish are lost below the groundrope - with an uncertain faith for escaping fish. Pre-spawning cod were filmed at depths of 300–400 m in February, and only a smaller fraction were caught in normal densities of fish. In some extreme situations 7 out of 10 fish escaped below the rock-hopper (21" discs). Several fish (cod) were resting (or sleeping?) at the seabed and had almost no response to the trawl as the groundrope passed them.

**Exit Windows**

Preliminary tests with "Exit Window"-like panels in the cod-end were made with a two-belly design trawl, allowing for one test- and one control cod-end, showed interesting properties of size-selectivity.

Contact Roger Larsen, rogerl@nfh.uit.no

## 13.7 POLAND

### 13.7.1 Acoustic activities 2002–2003, joint with the WG objectives (Andrzej Orlowski)

Apart from acoustic estimation of pelagic fish resources following items were included into research:

- analysis of thermal conditions and the biomass of pelagic fish in the Polish EEZ,
- performing and analysis of 24h acoustic experiment on fish behaviour in small selected area in the southern part of the Gotland Deep, comparing it to long-term results and environmental background,
- elaboration of T-macrosounding visualizations to present acoustic data vs. environmental factors,
- initiation of PhD research on acoustic studies of bottom properties in the southern Baltic.

All work mentioned above are reported in papers indicated below:

Orlowski A. Influence of thermal conditions on biomass of fish in the Polish EEZ. Fisheries Research 2003, 63/3, 367–377.

Orlowski A. Acoustic studies on environmental pressure on 3D fish distribution in the Baltic. Annual Journal: Hydroacoustics Volume 5/6, Polish Acoustic Society, Gdańsk, 2002/3: 29–40/2002.

Orlowski A. Acoustic experiment on diel fish behaviour cycle performed in the Gotland Deep. Annual Journal: Hydroacoustics Volume 5/6, Polish Acoustic Society, Gdańsk, 2002/3: 19–30/2003.

Orlowski A. Acoustic semi-tomography in studies of structure and function of marine ecosystem. ICES Journal of Marine Science, xxxx-xxxx, (in print).

Orlowski A. Acoustic studies of clupeoid diel behaviour in the Baltic, paper for ICES Symposium on fish Behaviour in Exploited Ecosystems, Bergen-Norway, 23–26 June 2003.

## 13.8 SPAIN

Fishing Technology related projects carried out at AZTI (Technological Institute for Fisheries and Food) by the Fishing Gear Technology Area.

A study to identify, quantify and ameliorate the impacts of static gear lost at sea (FANTARED 2 – EC-FAIR-CT98–4338) in collaboration with other European research centres, the study aims at evaluating the extent and impact of the loss of static fishing gears in European waters. The first approach of the study has been to characterize the main reasons for loosing gillnets and quantify the amount of gear lost in the different types of gillnet fisheries. Later on an experiment to characterize the fate of experimental lost tangle nets (rasco nets) was carried out in order to study their evolution both in summer and winter starting conditions. Information on species caught and their stage were recorded to estimate the catch rate of the nets in the short, medium and long-term. 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 "ghost catches" are compared with the annual catches of the commercial fleet in the Cantabrian Sea (ICES subarea 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.

The final report of the project has been submitted in 2003.

**Technical study of the artisanal fisheries of the Basque Country in order to establish the basis for their regulation.** (Financial Support: Department of Agriculture and Fishing/Basque Government)

Artisanal fisheries are seen as an important fishing sub-sector for the maintenance of the coastal communities. The study aims at compiling the previous technical information regarding fishing gear performance to provide the basis for the improvement of the present regional fishing regulation. Special attention is paid to the gillnet fisheries which have experience the more dramatic changes in the last years in terms of fishing effort. Fishing trials at sea are planned to improve the knowledge of the species and size selectivity of the small gillnet fisheries targeting a wide variety of fish species. The project is under way.

**AZTI Remote Sensing Service** (Financial Support: Department of Agriculture and Fishing/Basque Government)

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.

The project is under way.

**Improvement of the tuna attractiveness in the pole and line fishery** (Financial Support: Department of Agriculture and Fishing/Basque Government)

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. The project is under way.

**Artificial baits alternatives mainly based on fish waste.** (Financial Support: EU, Contract Nº Q5CR-2000–70427).

The aim is to develop 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.

The project is under way.

**Mechanization and automatization of the mackerel hauler/reel in the hand line fishery.** (Financial Support: Department of Agriculture and Fishing/Basque Government).

In the mackerel fishery with hand lines a large number of hooks are moving dangerously on the deck. To improve safety on board, an automatic hauler for catching mackerel will be developed that will coil the lines with hooks in the reel.

**Development of an electronic log-book for the Basque fishing fleet.** (Financial Support: Department of Agriculture and Fishing/Basque Government)

In the last years, AZTI has been providing to the Basque fishing fleet with an electronic catch reporting system for on board utilization. An improvement of the system will end in an electronic log-book (e-logbook) were satellite communication via INMARSAT and land facilities are involved.

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### 13.9 UK (Scotland)

#### 1. Species / size selection

Four cruises on chartered commercial vessels were carried out by FRS Marine Laboratory, Aberdeen. In February 2002 trials with an inclined separator panel (Irish Sea panel) were made in the Firth of Clyde *Nephrops* fishery to investigate the release of spawning cod and other roundfish by-catch while retaining target species. Good species separation was obtained but significant losses of *Nephrops* were also experienced. In August that year joint experiments with IMR Bergen carried out in the Norwegian sector of the North Sea examined the effect of cod-end circumference, flexible grids and BACOMA escape panels on the selectivity of a 120 mm diamond mesh cod-end. Later in the year on the Fladen grounds *Nephrops* size selection was compared using both diamond and square mesh cod-ends and in March 2003 a modified horizontal panel separator trawl was tested in the Moray Firth. An assemblage of parallel ropes rising from the footrope guided the majority of cod, haddock and whiting into the upper cod-end whereas most plaice, lemon sole and dabs were taken in the lower cod-end. The results of both cruises involving *Nephrops* are presented at the theme session of this meeting.

#### 2. Technical changes in the Scottish fishing fleet

Gear trials were undertaken on two under 10m Nephrops vessels to compare the gear performance of the new design of 'super' under 10m vessel with that of an older design of under 10m vessel. A survey of cod-end and other gear details of whitefish fleets used to estimate fleet selectivity continues.

#### 3. Oil installation / fishing gear interaction

FRS assesses and advises on the impact of UK oil development and abandonment proposals. A project is now under way to investigate the over-trawlability of large diameter pipeline bundles.

#### 4. Whole gear selectivity

During a 12 day cruise on FRV Scotia in November 2002 trials were carried out to assess the feasibility of twin trawling with two GOV survey trawls. A further 10 day trial in May 2003 was carried out with twin GOV trawls to compare the performance of two different ground gears.

#### 5. Fish Behaviour

A second cruise to assess the effect on fish escapes of high and low contrast panel / cod-end combinations was carried out in August 2002 using a Remote Controlled Television Vehicle on a chartered fishing vessel. Further useful techniques for observing fish escapes were developed.

## 6. EU shared cost projects

EUROGRID - An additional comparative fishing cruise was carried out on a chartered Norwegian vessel and final reports submitted to Commission. A short video tape describing the project was produced.

OMEGA -This new project entails the development and testing of an objective mesh gauge. FRS, together with other partner institutes and fishery inspectorates, is carrying out acceptance trials with prototype mesh measurement instrumentation.

## 13.10 UNITED STATES

### NORTHEAST

### 13.10.1 Massachusetts Division of Marine Fisheries - Conservation Engineering Program (Thomas Moth-Poulsen and Michael Pol)

**Sweepless Raised Footrope Trawl**

The sweepless raised footrope trawl reduces bottom contact compared to the raised footrope trawl by using only "drop chains" to weight the fishing line of the net. The net design is easier to rig and less likely to entangle ghost gear such as lobster traps. This program offered incentives to fishermen to adopt this net when fishing for silver hake. A video was produced for distribution explaining the benefits of the net modifications to encourage voluntary adoption.

**Square Mesh Codend Selectivity Measurements**

Fishermen from the port of Gloucester developed a square-mesh codend selectivity study to examine the effects of increased mesh size in demersal groundfish trawls. A covered codend method with hoops was selected based on advice from the Division of Marine Fisheries. Sea trials are currently underway.

**Further Testing of Cod-Avoiding Trawl Net Designs**

Larger-scale testing of two successful Atlantic cod-avoiding trawl designs is planned for fall 2003. The two designs, one removing much of the top square, and the other replacing much of the top square with 203 mm square mesh, reduced cod catch rates when targeting flatfish by >72% when tested on smaller (<20 m) fishing vessels.

### 13.10.2 New England Aquarium -- (Marianne Farrington with H. Arnold Carr, Michael Pol, Mark Szymanski and Henry Milliken)

**Selectivity and Survival of Atlantic Cod (*Gadus morhua*) in the Northwest Atlantic Longline Fishery**

Fleet effort, discard survival and gear selectivity of the longline fishery in New England remains largely unexamined. Previous work by New England Aquarium and Massachusetts Division of Marine Fisheries has documented selectivity and survival in Atlantic cod (Gadus *morhua*) sublegal-sized by-catch. Those findings concluded that although not all undersized fish died, survival was compromised when fish were mechanically removed from hooks by force.

Subsequent research compared different strategies for removing fish automatically from longlines. Several characteristics considered essential for a successful protocol were discussed with fishermen and engineers creating a unique opportunity to investigate whether several designs could improve survival by decreasing physical injury to the fish. After several false starts, a method already being employed by fishermen was modified. Briefly, a gaff was used to immobilize a circle hook and the tail of the fish is flipped over the barb. This process was converted into a one-man procedure by transferring hauling operations to a foot pedal.

Effectiveness of this method was investigated two ways: holding fish for 72 hours and sampling blood chemistry. After meetings with fishermen, fishing practices were designed to use two vessels: a 12-meter commercial longline vessel for fishing and a 27-meter trawler for handling all the equipment for the survival and biochemistry studies. Cod were removed from the longline gear mechanically ("snub") or by the alternate method ("flip"). Additional cod were caught by jig and used for comparison (controls). Survival was ascertained by placing fish in cages that were retrieved after 72 hours.

The 72-hour survival was 30% for snubbed fish while 41% of the flipped fish remained alive. However these data were not found statistically significant despite the distinct difference in the apparent severity of injuries (G-test for independence (□=0.1), G adjusted = 1.44, df = 1, p = 0.23). Some inconsistencies in handling and stress due to caging may have obscured any difference in survival. Evidence suggested that small sample size might have confounded our results. Biochemical analysis revealed that a subset of fish from a related study carried out at the same time could be added to the snub totals and re-evaluated. Although the survival percentages were not very different, the additional data did find significant differences in the survival for fish removed by the tail flip method (G adjusted = 3.20, df = 1, p = 0.074).

The physiological responses to fishing were also measured to determine the relationship between fishing protocol and survivability. Normal blood profiles were inferred from cod that were caught by hand jigging and bled within one minute from the set of the hook. Control values were obtained from cod that were captured by jigging, not bled and then held in cages along with longlined fish for 72 hours to observe their survival.

Without exception, the serum cortisol levels measured in jigged cod hovered near the limit of detection. Since the secretion of cortisol is a primary response to stress in fish, this result was a reliable indication that other adjustments in the blood may not have occurred and would reflect the normal ranges for the concentration of the components found in cod blood.

Except for potassium ion and glucose, all physiological parameters measured from cod taken directly from the longline were significantly elevated over normal values regardless of dehooking protocol. These values were similar to previous results and indicate that longline-caught cod experienced a moderate level of stress. Lactate, sodium ions, cortisol and hematocrit values remained significantly elevated from normal values after 72 hours. In addition, lactate, sodium and chloride ions, osmolality, cortisol and hematocrit control values were elevated over normal values indicating some aspect relating to the holding process was stressful and may have contributed to the ambiguous observations between dehooking methods.

### 13.10.3 Manomet Center for Conservation Sciences - Marine Conservation Program (Dr Chris Glass)

**Codend Selectivity**

This project was designed to provide high quality scientific information on the selective efficiency of various codend configurations to allow better and more effective management of fish stocks. In particular, following recent developments in fisheries management in New England, codends made of larger mesh size are likely to become mandatory for groundfish fishing, i.e., projected minimum mesh sizes of 6 ½" diamond and 7" square will substitute the current 6" diamond and 6½" square. We tested 4 codends, designed to accommodate new mesh regulations, in various configurations: 2 single mesh codends and 2 composite codends, based on promising results obtained in previous studies with composite codends that showed a 62% reduction in the catch of sub-legal cod. The 4 codend configurations were: 1) 6½" diamond mesh; 2) 7" square mesh; 3) composite 7" square mesh in the top panel and 6½" diamond mesh in the bottom panel; 4) composite 7" square mesh in the top panel and 7" diamond mesh in the bottom panel. Covered codend techniques were employed and selectivity analysis of this data is currently being completed.

**Georges Bank Yellowtail Program**

A new cooperative research program has begun that will attempt to demonstrate temporal and/or spatial overlap/separation between target and non-target species in Closed Area II on Georges Bank. Information gathered by this program will be used to identify by-catch issues, which will help in the continued development of novel by-catch reduction systems.

**Continued Square Mesh Extension for Scup Escapement**

Building on promising results from past trials with a scup escape window in the longfin squid fisheries, work has been continued to test scup escapement using square mesh escape panels in the offshore longfin squid fishery. A section of 5½" square mesh was inserted in the extension 50 meshes ahead of the codend. The square mesh netting extended around the circumference of the extension forming a square mesh section as opposed to a window. The remainder of the extension and codend were constructed with 1 7/8" small mesh netting. This extension configuration was compared to standard commercial gear using the alternate hauls technique. Overall, the 5½" Square Mesh Extension Section configuration proved to be effective for reducing discard of scup while maintaining target catch. Analysis showed an L50 of 8½" fork length (equivalent to approximately 9" full length) for scup with no reduction in squid catches. This configuration also showed an overall reduction of discard of scup by over 66%. One very obvious and significant

outcome from this research is the demonstration that fishing nets can be redesigned in a simple and inexpensive way to reduce the by-catch and discard of scup. Further testing and development is planned for 2003–2004.

**Rigid Mesh Escape Panel**

This program investigates the potential of a rigid, large mesh panel for selecting for larger fish in the multispecies groundfish fisheries in the Gulf of Maine. Rigid mesh is used in aquaculture to sift or size-grade fish in water and this program attempted to assess its applicability and its potential to reduce by-catch and discard. The panel, inserted along the net between the extension and the codend, measured 2 m in length and was constructed of elongate meshes 60 mm wide x 200 mm long. The panel extended around the entire circumference of the net. The experimental codend, equipped with the rigid mesh panel, and a conventional codend were towed in alternate tows and their catches were compared. Both codends were made of 6" diamond meshes. Further studies are required to fully evaluate the potential of this by-catch reduction device.

**Inclined Separator**

This program was designed to look at methods for separating flatfish from round fish (particularly cod) in conventional towed fishing gears. A version of the inclined separator panel used in Irish Sea *Nephrops* fisheries was tested. Results indicate that significant separation between upper and lower sections of the net, in terms of weight, occurred for cod, monkfish and gray sole, which were more abundant in the upper section, and crustaceans (specifically crab and lobster), which were more abundant in the lower section. These preliminary investigations demonstrate the potential to separate cod from other groundfish species and implications for reducing cod by-catch and discard are significant. Further large scale trials are planned for 2003–2004.

### 13.10.4 University of New Hampshire (Pingguo He)

Grid devices and separator panels to separate roundfish and flatfish were designed and tested in a flume tank. Sea trials are continuing. A "RollerGrid" was designed and tested and will be continued this summer and fall. A semi-pelagic shrimp trawl with doors off bottom was designed and tested in a flume tank in cooperation with the Marine Institute in Canada. Sea trials conducted in the Gulf of Maine pink shrimp fishery during the winter of 2003 showed promising results with catch rates comparable to those of commercial operation by other vessels. Further sea trials are scheduled during the winter of 2004. A project to test shallower gillnets to reduce cod was initiated in 2002 and will be continued in summer of 2003. A project to determine selectivity of five codend mesh sizes/shapes has been initiated, and sea trials are continuing.

**SOUTHEAST**

### 13.10.5 NOAA Fisheries Southeast Fisheries Science Center - Mississippi Laboratories Harvesting Systems and Engineering Division

**Preliminary Results from Comparative Tests of Enlarged TED Escape Openings for Shrimp Retention in the Southeast U.S. Shrimp Fishery**

All shrimp fishers operating in offshore waters of the southeastern United States will be required to enlarge their turtle excluder device (TED) escape openings by August 15, 2003 to allow for the exclusion of leatherback (*Dermochelys coriacea*), adult loggerhead (*Caretta caretta*), and green sea turtles (*Chelonia mydas*). The new TED requirements allow fishers to choose between two enlarged TED escape opening modifications: the 71-inch (180 cm) opening, and the double-cover opening. Both TED opening modifications will require adherence to specific dimensions for the escape hole cut, and the exit hole cover, or flap. Most existing TED frames can be easily modified to meet the new requirements. From January through August, 2002, NOAA Fisheries observers collected information on catch rates of shrimp aboard commercial shrimp trawlers operating in the Gulf of Mexico and southeast Atlantic. Testing included the seasonal shrimp openings in Texas, Louisiana and Mississippi. Comparisons were made between nets equipped with the double-cover opening (experimental opening) and smaller, minimum openings for the Gulf of Mexico and southeast Atlantic (control openings). There was no statistically significant difference in shrimp CPUE between experimental and control TED openings ($P < 0.05$).

**Western Atlantic pelagic longline fishery sea turtle mitigation research**

NOAA Fisheries in cooperation with the U.S. pelagic longline fishery implemented a three year research program in the Western Atlantic Ocean to develop and evaluate sea turtle mitigation measures. Five potential mitigation techniques

were evaluated during 687 research sets in 2001 and 2002. Data were collected to evaluate the effectiveness of the mitigation measures and to investigate variables that effect sea turtle interaction rates with pelagic longline gear. A significant reduction in loggerhead catch may be achieved by reducing daylight soak time. 18/0 circle hooks and mackerel bait were found to significantly reduce both loggerhead and leatherback sea turtle interactions when compared with industry standard J hooks and squid bait. Also, circle hooks significantly reduced the rate of hook ingestion by the loggerheads, reducing the post-hooking mortality associated with the interactions. The combination of 18/0 circle hooks and mackerel bait was found to be the most efficient mitigation measure for both loggerhead and leatherback turtles. Mackerel bait was found to be more efficient for swordfish than squid bait and circle hooks were more efficient for tuna than J hooks.

**ALASKA**

### 13.10.6 National Marine Fisheries Service - Alaska Fisheries Science Center (Ken Weinberg)

**Estimating capture probability for red king crab *Paralithodes camtschaticus***

Estimation of the capture efficiency of a survey trawl for red king crab was conducted with an auxiliary net attached below the trawl to capture crabs that escape under the footrope and a video camera used to photograph and identify common factors contributing to the escape process. Length-dependent capture probabilities were computed by fitting a logistic model to the proportion captured by sex. The fitted model predicts male capture probability to be 41.9% at 23 mm, the smallest male encountered during our experiment, 72.2% at 95 mm, the size at which the management stock assessment model assumes 100% vulnerability to the survey trawl, 84.1% at 135 mm, the size at which males enter the fishery; and 92.7% at 184 mm, the largest male crab encountered in our experiment. For female crabs, the model predicted capture probability to be 65.2% at 51 mm, the smallest female captured in our experiment, 69.8% at 90 mm, the size at which the management model assumes 100% vulnerability to the survey trawl, 74.7% at 135 mm, the same size that males enter the fishery, and 77.4% at 162 mm, the largest female crab encountered in our experiment. Model variability, as indicated by the 95% confidence bounds, is greatest at the ends of our size ranges due to low sample frequency.

In situ data collected from a trawl mounted video camera were used to determine the importance of certain crab behaviours associated with the capture (escape) of individual crabs. As determined by stepwise regression, the selected logistic model predicted capture probability was significantly higher when a crab was standing when struck by the footrope rather than crouching, and higher when a crab was hit along its body axis rather than from the side. Capture probability also increased as a function of increasing crab size, increasing footrope distance from the bottom and when artificial light was provided for the video camera.

## APPENDIX 1: PROPOSED TERMS OF REFERENCE FOR THE 2004 WGFTFB MEETING

a) The Working Group on Fishing Technology and Fish Behaviour [WGFTFB] (Chair: Dr Norman Graham, Norway) will meet in Gydnia, Poland, on 20, 21, 23 April 2004 to:

b) To review and assess the effects of colour and contrast in netting materials and gear components on fish behaviour and catchability in survey and commercial situations.

c) To assess efficiency increases in fish capture operations including (1) identification of advances in technology and practices, which increase fishing efficiency, (2) quantification of such advances wherever possible; (3) review of work undertaken in this field.

d) Evaluate the effect of fishing gears on the seabed with special reference to mitigation measures in mobile gears and the effects of stationary gears on sensitive environment.

e) Consider the selective properties of turned-mesh codends, including the effect of mesh size on both L50 and SR.

f) Review new technologies or fishing gear research leading to standardization in bottom trawl surveys.

**Supporting Information**

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| 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: | **Term of Reference a)**<br><br>It is widely acknowledged that environmental conditions, such as the underwater light field have a significant effect on fish catchability (e.g., ICES Coop. Res. Rep. 215, Wileman *et al* (1996)). Past and current studies have also examined the effect of netting colour and contrast on the behaviour of fish. No synthesis of this work has been made but there are potential implications for both commercial and survey fishing operations. In particular the WG will: (1) review past studies on the use of the colour and contrast of fishing gear to modify fish behaviour and improve size and species selectivity; (2) identify current initiatives in this field and also studies encompassing the effect of varying light conditions on fish reactions to fishing gear; (3) gather information on the range of coloured twine in use commercially and the rationale behind these choices.; and (4) compile a list of recommendations on the use of coloured netting to improve selectivity in commercial nets and also possible techniques for improving the efficiency of survey trawls. (AN #s 1.12.5,1.13,1.13.2,3.18)<br><br>**Term of Reference b)**<br><br>Increases in the technical efficiency of fish capture in commercial operations is not currently accounted for, in estimates of fishing effort. Such efficiency increases may therefore undermine management protocols, which utilize estimates of fishing effort as a management tool. (AN #s 3.13)<br><br>**Term of Reference c)**<br><br>The effect of bottom tendering towed fishing gears on the seabed has received considerable attention in recent years. While it is important that the effect be quantified, studies to reduce the effect should be encouraged and strengthened. WGFTFB will review and evaluate recent work and discuss current status on the effect of towed gears such as bottom trawls and dredges and will put special emphasis on mitigation measures to reduce the effect through modification of gear designs and operational methods. In addition, a review and evaluation of the possible effects of stationary fishing gears including but not limited to gillnets, longlines, traps and pots on sensitive environments such as coral reefs, sea mounts, near shore communities and mollusk beds. (AN #s 2.3, 3.17)<br><br>**Term of Reference d)**<br><br>Unintentional mortality of juvenile cod continues despite the recent increase in minimum codend |

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| | mesh size to 140 mm for commercial bottom trawling in the Baltic sea. Experiments on trawls equipped with turned-mesh codends indicate that size selection is more nearly knife-edged and therefore, like the size selection by the BACOMA window, easier to control to obtain better escapement of sub-legal fish. Considering the current crisis in the management of Baltic cod, review of the selective properties of turned mesh codends is critically important. (AN #s 1.12, 3.16)<br><br>**Term of Reference e)**<br><br>Standardization of trawl survey methodology can lead to reduced variability in catchability between sampling sites, between research vessels and over time. Such standardization might be increased through the introduction of new technology, changes in the gear or changes in the methodology for using the gear. Renewed interest in trawl standardization has been motivated by a recent US review of standardization in NMFS trawl surveys and the addition of a similar standardization review as a term of reference for WGIBTS and other ICES trawl survey working groups.(AN #s 1.12.5,1.13,1.13.1) |
| 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 Goals 1 to 5 of the ICES Strategic Plan |
| Resource Requirements: | The research programs 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 questions of by-catch reduction and survey standardization are of direct interest to ACFM and seabed damage is of direct interest to ACE. |
| Linkages To other Committees or Groups: | This work is of direct relevance to the Working Group on Ecosystem Effects of Fisheries, WG on Fishery Systems, WG on International Bottom Trawl Surveys, Baltic Committee, Marine Habitat Committee, Resource Management Committee and Living Resources Committee |
| Linkages to other Organizations | The work of this group is closely aligned with similar work in FAO (AN #s 5.8). |

## APPENDIX 2: THEME SESSION PROPOSALS

There was a recommendation by the WGFTFB for a Theme Session at 2005 ICES Annual Science Meeting on:

The development of effective and acceptable gear modifications and alternative fishing tactics to reduce the by-catch and mortality of cetaceans, pinnipeds and sea turtles in trawl and static gear fisheries. Conveners: Someone from FTFB and someone to be announced from LRC.

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| 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: | The by-catch of cetaceans, pinnipeds and sea turtles in fishing operations is an issue of growing concern globally to organizations such as the European Commission and FAO, under pressure from NGO's and the general public. The FAO's Code of Conduct on Responsible Fishing defines responsibilities for fishing nations, and Article 7 of the Code states that "States should take appropriate measures to minimize… catch of non-target species, both fish and non-fish species, and negative impacts on associated or dependent species, in particular endangered species". However, whereas much effort has been put into devising methods of minimising by-catch in gillnet fisheries, there has been very little published work so far on attempts to minimise marine mammal by-catch in trawl fisheries, and in particular pelagic trawl fisheries. Given the current state of research into this topic, notably in European fisheries, it is an opportune moment to review and evaluate all work and identify proven solutions in both trawl and static gear fisheries, with potential for technology transfer into other fisheries with similar by-catch problems.<br><br>The objectives are therefore to:<br><br>• Review cases studies that illustrate the use of gear modifications and alternative fishing tactics to reduce the by-catch of cetaceans, pinnipeds and sea turtles.<br>• Assess the effectiveness of such measures in terms of acceptability to the fishing industry, costs including enforcement and predicted benefits to cetacean, pinnipeds and turtle stocks.<br>• Assess and identify potential solutions in other fisheries to reducing by-catch by employing similar technologies or methods. |

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*N-M = Non-Member.*

## APPENDIX 4: REVIEW OF THE SIZE SELECTIVITY OF BALTIC COD TRAWLS WITH TURNED-MESH CODENDS

**Report of the**

**ICES Working Group on Fishing Technology and Fish Behaviour**

Review of the size selectivity of Baltic cod trawls with turned-mesh codends

The ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) formed a subgroup in Fall 2001 to examine the selection properties of Baltic cod trawls. The report of the subgroup, which was entitled A Review of the size selectivity of Baltic cod trawls@ and included in the 2002 WGFTFB annual report (CM 2002/ B:01), found that the length of 50% selection (L50) for trawls equipped with the 120 mm BACOMA window was 45.2 cm and that the mesh size needed for trawls equipped with 4 mm PE (polyethylene) diamond mesh codends was 140.3 mm to achieve the same L50. At the time, the available data for codends constructed of PA (polyamide) and codends constructed of diamond mesh rotated by 90 degrees was considered by the subgroup to be insufficient to allow a similar analysis. At the 2002 ICES Annual Science Conference, however, the FTFB was requested to re-examine this issue for turned-mesh codends. The specific wording of the Term of Reference is "Evaluate the selective properties of trawls using 90□ turned diamond meshes and advise on appropriate mesh sizes corresponding to the agreed BACOMA gear. Evaluate selectivity of diamond mesh of 130 mm and 140 mm taking into account all new available information on the matter@. In the following, the first part of this term of reference will be considered

**Data sources and methods of analysis**

Data from 15 cruises (Table 1) examining the selective properties of turned-mesh codends, using the covered codend methodology described in Moderhak (1997), were supplied by German (Dr E. Dahm) and Polish (Dr W. Moderhak) scientists. A variety of trawl configurations was examined on these cruises including variations on twine type (PE and PA), number of twines (single and double twine mesh), twine thickness (4.0 and 3.5 mm), and codend circumference (ranging from 96 to 46 meshes round) besides variation in mesh size (Table 1). Rather than the raw data (cod catch by size for the codend and cover), the data supplied consisted of the 2 selectivity parameters (L50 and SR) and the associated variance-covariance matrix, calculated using commercial software (i.e., CC2000 from ConStat), for each haul on each cruise.

For each of these cruises, the cruise mean values of the selection parameters, and the variance-covariance matrix, was computed with the methods of Fryer (1991) to include between-haul variability using commercial software (i.e., EC model from ConStat). The cruise - mean values of L50, SR and the associated variance- covariance matrix are shown in Table 2.

To estimate the change in L50 with a change in mesh size, a linear model was fit to the data, weighted by the inverse of the variance of the L50 estimates, considering twine thickness, material, number of strands and codend circumference (meshes around) as covariates. Twine thickness and meshes around were treated as continuous variables; twine number and material were treated as factor variables recoded as binary variables (1 strand=0, 2 strand=1; PE=0, PA=1) Because the data were few in number and unbalanced among the covariates, the following stepwise selection process was used to find the most parsimonious model from a model initially considering all covariates and first order interactions as candidate terms. First, a model was fit to the data including only the main effects. Second, the model was refit including all interactions with the main effect having the least significance in step 1. If all of these interactions were non-significant, then the interactions and the least significant main effect were eliminated. If any of the interactions were significant, then that interaction and the main effect were retained. Third, the model was refit and the next least significant main effect and its interactions were then considered in a process that was repeated until all terms were significant. Fourth, to further simplify the model, if the significance of any interaction rested on a single observation, the interaction was considered insignificant.

Once the best fit of the linear model had been obtained, L50 was predicted as a function of mesh size and specific combinations of significant covariates: $L50 = a + b^* M + c$, where M is the mesh size in mm, a is the intercept, b is the slope and c is a linear function of the significant covariates and interactions.

**Results**

In the development of a model to best describe the relationship between L50 and mesh size, the stepwise covariate selection procedure initially eliminated twine thickness and codend circumference as significant predictors. The best model (Table 3), includes mesh size, twine type, twine number and the interaction between mesh size and twine number. However, a plot of the predicted values (Fig. 1) indicated that the interaction of mesh size and twine number was due to the exceptionally low value of L50 at the smallest mesh size. Because of the uncertainty due to the reliance on a single observation, a simpler model without the interaction was chosen instead (Table 4, Figure. 2) with the intention of providing predictions that would be more robust to the future addition of experimental data. Predictions of the mesh size needed to produce the same L50 (45.25 cm) as the Bacoma 120 mm codend for codends constructed of 1 and 2 strand, PE and PA mesh were not included because of problems related to the data. These problems included: 1) uncertainty due to the low number of experiments conducted for each the different types of turned mesh codends and 2) the need to extrapolate the predicted values beyond the range of mesh sizes considered in the experiments (see Figure 2). Because of these problems, the standard error associated with any predicted mesh size would be quite large.

**Conclusions**

The Working Group reviewed the results of these analyses along with additional information provided and noted that in order to draw valid conclusions, one needed to consider the statistical methodology and the validity of the data in the analysis.

*a) Statistical methodology*

The data from the selectivity experiment represent a rather complex structure (hierarchical with random effects at various levels) and therefore require advanced methodology for analysis. The choice of methods used here was therefore pragmatic and is a reasonable approach having the potential for drawing valid conclusions provided that the data carry sufficient information.

Potential improvements in the model include the addition of catch size as a dependent variable, because several studies have shown that catch size can have a significant effect on selection. In addition, future analyses could be improved by considering variability in the selection parameters between experiments as well as between hauls. Using appropriate statistical procedures, such an approach would reflect the random variability more realistically and provide simultaneous estimates of L50 and SR.

*b) Validity of data*

The selectivity data analysed represent a range of different conditions, but it is not clear if the data are valid for addressing the specific questions posed.

All the data were collected on research vessels and yet the results are to be extrapolated to commercial fisheries. The ICES Manual of Methods of Measuring the Selectivity of Towed Fishing Gears (Wileman *et al*. 1996) strongly recommends 'that a commercial vessel is used if the experiment aims primarily to measure the selectivity of a commercial fishing gear'. It then continues to say that 'the use of a research vessel might be preferred to a commercial fishing boat in some circumstances however, to ensure availability of the same vessel for a series of cruises to maximise control over the experiment or to provide specialised facilities'.

A range of mesh sizes for turned mesh codends was tested from 99 to 124 mm. The L50s estimated for each experiment were lower than the target L50 of 45.2 cm suggesting that mesh sizes outside the tested range would be necessary. This raises concern about the validity of the inherent linear assumption of the relation between L50 and mesh size over a wider range than tested. Inference outside this range is furthermore subject to higher variation.

At the outset, the whole experiment was not designed for the purpose of demonstrating the variation of selectivity with key codend design variables. The range of cases tested for each variable is not balanced. There are only two values of twine thickness and 9 out of 15 values of meshes around are near to 95. Neither of these variables was found to be significant in the developed model although it has been found in a number of studies that they have a significant effect. It is not clear if this is due to the lack of information.

**Summary**

Because of the uncertainty with data quality described above, the Working Group concluded that the model should not be used to estimate the mesh sizes with equivalent selective properties to the Bacoma 120 mm codend.

Consideration should be given to the use of commercial vessels and a wider range of mesh size, twine thickness and meshes round the codend circumference to provide data in a balanced design. The Working Group noted with interest the positive developments in the use of turned mesh codends and recommends that a full review of their selective properties should be carried out at the next annual meeting.

**References**

Fryer, R. 1991. A model of between-haul variation in selectivity. ICES Journal of Marine Science 48:281–290.

Moderhak, W. 1997. Determination of the selectivity of cod codends made of netting turned through 90 degrees. Bulletin of the Sea Fisheries Institute, Gdynia 140:1–14.

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Table 1. Experimental characteristics of the 15 cruises examining the selectivity of Baltic cod by turned-mesh codends. These data were considered as covariates in a linear model describing the relationship between L50 and mesh size.

| Cruise | Twine thickness | Twine number | Twine material | Meshes around | Mesh size |
|---|---|---|---|---|---|
| 423 | 4.0 | 1 | PE | 96 | 111.4 |
| 431_1 | 4.0 | 1 | PE | 96 | 103.4 |
| 431_2 | 4.0 | 1 | PE | 96 | 112.6 |
| 440_1 | 4.0 | 1 | PE | 96 | 100.7 |
| 440_2 | 3.5 | 1 | PA | 96 | 105.3 |
| 447_1 | 4.0 | 2 | PE | 92 | 103.7 |
| 447_2 | 4.0 | 1 | PE | 96 | 100.8 |
| 457 | 4.0 | 1 | PE | 50 | 100.6 |
| 473 | 3.5 | 2 | PA | 46 | 103.6 |
| 481 | 3.5 | 1 | PA | 96 | 105.3 |
| 490 | 4.0 | 2 | PE | 92 | 99.1 |
| 497 | 4.0 | 2 | PE | 60 | 103.0 |
| Baltica 96 | 3.5 | 1 | PA | 54 | 123.6 |
| Baltica 97 | 3.5 | 1 | PE | 80 | 102.5 |
| 506 | 4.0 | 1 | PE | 64 | 109.4 |

Table 2. Estimated mean values of L50, SR and the variance-covariance matrix for each of the 15 cruises. Also included is the Selection Factor (SF) calculated for each cruise.

| Cruise | Number of hauls | L50 | SR | Var(L50) | Cov(L50,SR) | Var(SR) | SF |
|---|---|---|---|---|---|---|---|
| 423 | 7 | 42.182 | 7.534 | 0.445 | -0.207 | 0.315 | 3.79 |
| 431_1 | 6 | 37.520 | 5.635 | 0.625 | -0.203 | 0.118 | 3.63 |
| 431_2 | 5 | 40.929 | 8.029 | 0.158 | -0.031 | 0.779 | 3.63 |
| 440_1 | 10 | 40.355 | 5.266 | 0.181 | -0.053 | 0.434 | 4.00 |
| 440_2 | 10 | 42.683 | 5.641 | 0.161 | -0.023 | 0.083 | 4.05 |
| 447_1 | 10 | 39.399 | 6.466 | 0.860 | -0.099 | 0.078 | 3.80 |
| 447_2 | 9 | 40.573 | 4.799 | 0.330 | 0.041 | 0.105 | 4.03 |
| 457 | 9 | 37.857 | 4.578 | 0.674 | -0.136 | 0.234 | 3.76 |
| 473 | 8 | 40.467 | 5.819 | 0.258 | 0.040 | 0.188 | 3.91 |
| 481 | 11 | 42.693 | 6.052 | 0.352 | -0.065 | 0.444 | 4.05 |
| 490 | 14 | 33.777 | 6.456 | 0.114 | -0.002 | 0.158 | 3.41 |
| 497 | 11 | 39.306 | 6.338 | 0.383 | 0.794 | 3.415 | 3.82 |
| Hol | 6 | 47.912 | 5.248 | 0.350 | -0.083 | 0.748 | 3.88 |
| Baltica | 5 | 36.244 | 8.555 | 1.533 | -0.940 | 1.281 | 3.54 |
| S506D0 | 9 | 41.427 | 4.498 | 0.092 | -0.029 | 0.090 | 3.79 |

Table 3. The coefficients of the linear model relating L50 to mesh size and the experimental covariates for the 15 experiments. This is the best model as determined by a stepwise selection process. The $R^2$ value for the regression was 0.93.

| Coefficients | Value | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 16.5823 | 6.1086 | 2.7146 | 0.0218 |
| meshsize | 0.2258 | 0.0569 | 3.966 | 0.0027 |
| twine.number | -94.3156 | 27.0846 | -3.4823 | 0.0059 |
| twine.type | 2.3452 | 0.6897 | 3.4001 | 0.0068 |
| meshsize:twine.number | 0.8999 | 0.2671 | 3.3687 | 0.0071 |

Table 4. The coefficients of the linear model relating L50 to mesh size and the experimental covariates for the 15 experiments. This model was derived from the model in Table 3 after the interaction term was deleted. The $R^2$ value for the regression was 0.84.

| Coefficients | Value | Std. Error | t value | Pr(>\|t\|) |
|---|---|---|---|---|
| (Intercept) | 13.254 | 8.398 | 1.578 | 0.143 |
| meshsize | 0.255 | 0.078 | 3.253 | 0.008 |
| twine.number | -3.108 | 1.019 | -3.050 | 0.011 |
| twine.type | 3.010 | 0.921 | 3.269 | 0.008 |

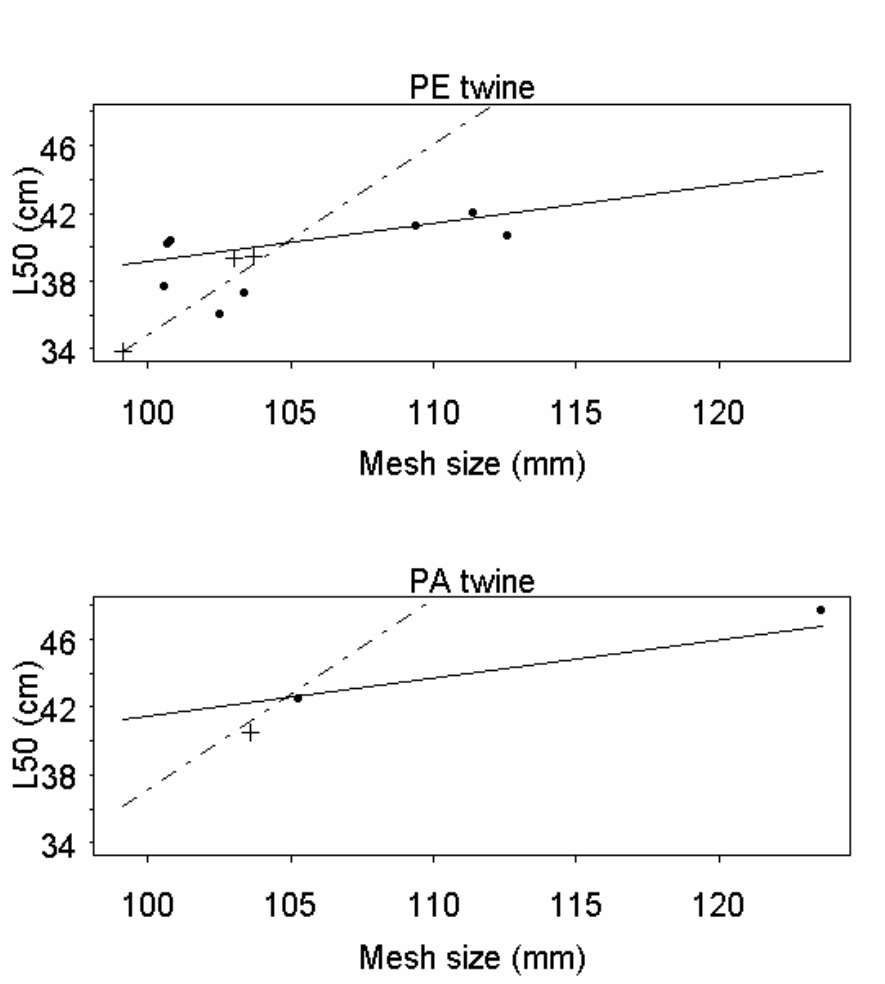


Figure 1. The fit of the linear model including an interaction term between twine number and mesh size. Dots and a solid line represent the data and the fit for single twine codends. Pluses and a dashed line represent the data and the fit for double twine codends. Note the low value of L50 for the PE double twine codend at the smallest mesh size, which has a strong influence on the significance of the interaction term.

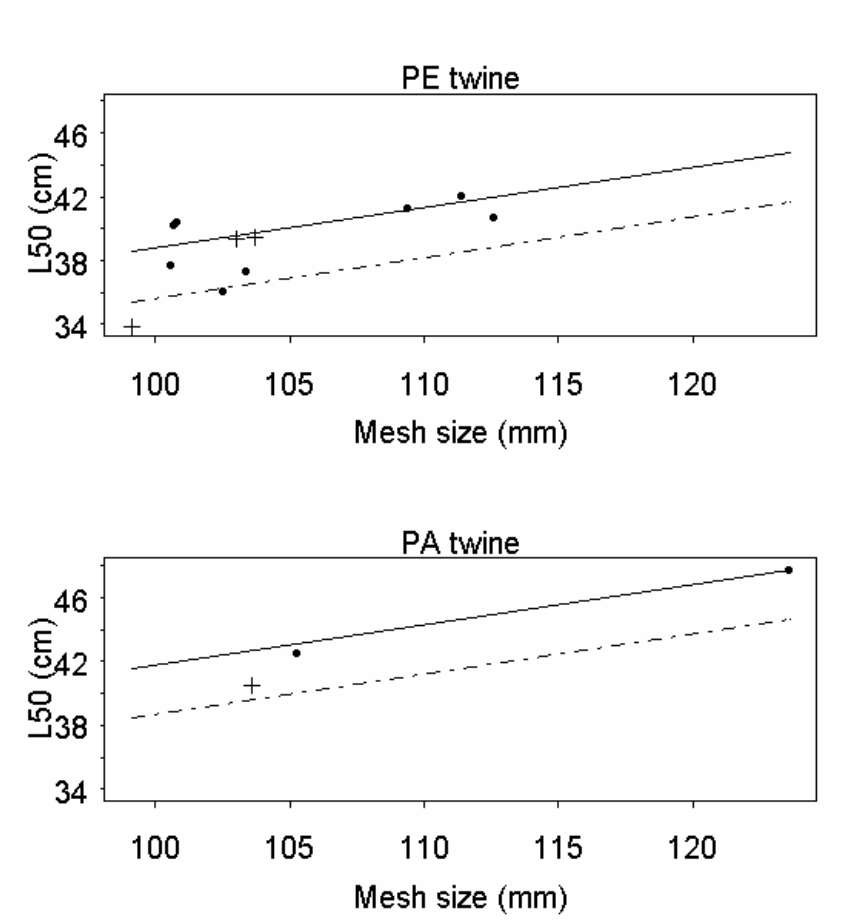


Figure 2. The fit of the linear model with the interaction between twine number and mesh size deleted. Dots and a solid line represent the data and the fit for single twine codends. Pluses and a dashed line represent the data and the fit for double twine codends

## APPENDIX 5: THE *NEPHROPS* FISHERIES OF THE NE ATLANTIC AND MEDITERRANEAN – A REVIEW AND ASSESSMENT OF FISHING GEAR DESIGN

**The *Nephrops* fisheries of the NE Atlantic and Mediterranean – A review and assessment of fishing gear design**

Report of the ad hoc FTFB special topic group.

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International Council for the Exploration of the Seas (ICES)
Working Group on Fishing Technology and Fish Behaviour (WGFTFB)

*Terms of Reference*

1) *Describe and review current problems relating to size and species selectivity in the NE Atlantic and Mediterranean Nephrops fisheries*

2) *Review and report on existing legislative measures in force in Nephrops fisheries*

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.*

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| | |
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**Abstract**

A review of the commercial trawl fisheries where *Nephrops* are a component of the catch was undertaken. These have considerable geographical coverage, ranging from Iceland to Portugal and into the Mediterranean. *Nephrops* are a highly important commercial species, valued at 208 million euro in 2001. The fisheries, with a few exceptions, are typically multispecies, with the relative economic importance of *Nephrops* varying considerably between fisheries. Due to the smaller mesh size used in comparison to demersal fish fisheries, the degree of discarding can be high. Additionally, due to the poor trawl selection characteristics, high grading and legislative restrictions, the discarding of *Nephrops* is considerable in certain fisheries. A range of gear related technical measures are applied in order to mitigate discard levels, but further improvements are required. There is a considerable lack of parameterised selectivity data for many of the existing technical measures, making any population independent assessment of their effectiveness problematic. The report is divided into geographical range, for each of these, the fisheries are described, fleet adaptations to legislation are discussed, a review of remedial measures tested and applied is provided. Based on this, fishery/area specific recommendations are provided. In addition to the fishery specific recommendations, more general holistic recommendations are also given.

**Introduction**

*Scale of European Nephrops fishery*

The European fishery for *Nephrops norvegicus* is highly valuable for a significant proportion of the European demersal trawl fleet. In 2001, the total EU landings were 56,000 tonnes, valued at €208 million. *Nephrops* are also one of the most widely distributed commercial species, with a considerable geographic range, from Iceland (640N) to the southern tip of Portugal (360N) and into the Mediterranean as far as the Aegean Sea, with more than 30 individual stocks assessed by ICES in the N.E. Atlantic. Unlike the majority of temperate shrimp fisheries, such as the *Pandalus* fishery, which target a single-species, the *Nephrops* trawl fisheries are generally multispecies with other components of the catch (fish or other crustaceans) being economically important. The importance of *Nephrops* (by value) varies considerably between fisheries. In some, *Nephrops* form the main component, with the other species considered as by-catch, the opposite being true in others. There is also a large range of management measures applied between regions, including variations in minimum landing sizes (MLS) for both *Nephrops* and fish, minimum mesh sizes (MMS), by-catch limitations (minimum percentage target species), additional trawl modifications and operational restrictions.

Due to the large regional differences in fleets, gears, catch composition and legislative policy, this report is roughly divided in terms of ICES management areas with additional subdivisions where necessary for legislative and/or biological considerations. The ICES working group on *Nephrops* divides the stocks based on functional units (FUs), which are considered under more regional management units. Area charts showing these FUs together with ICES *Nephrops* Working Group (WGNEPH) management units and ICES areas are shown in Figures 1a, b, c and Table 1.

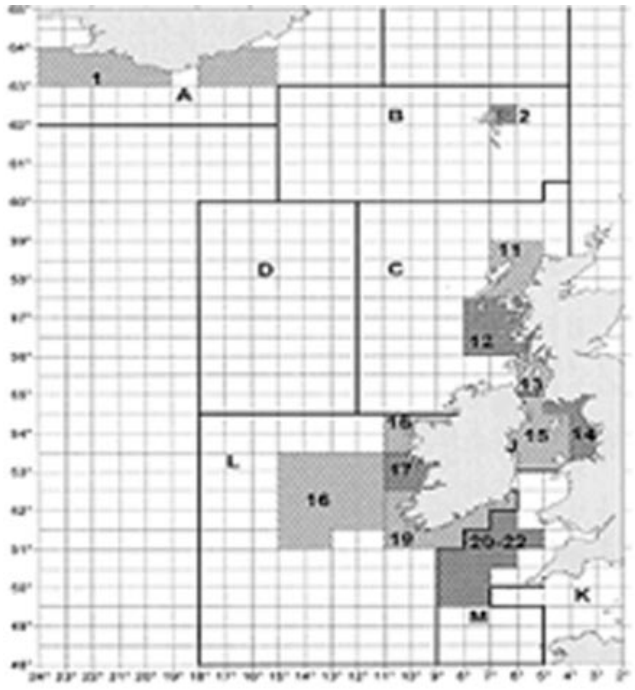


Figure 1a. *Nephrops* management areas and functional units in ICES subareas V, VI and VII. Numbers and figures refer to the management area and functional unit given in table 1.

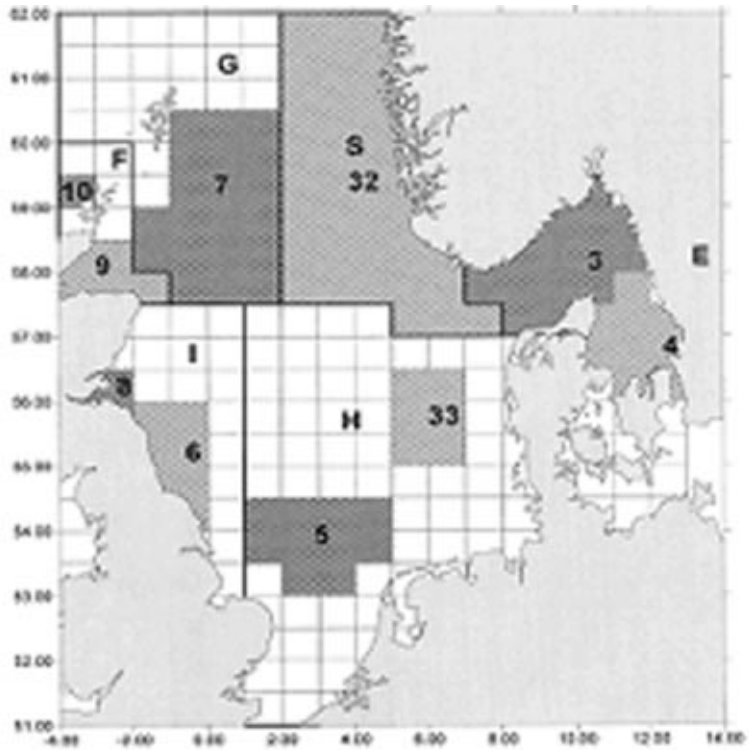


Figure 1b. *Nephrops* management areas and functional units in ICES subareas IIIa, and IV. Numbers and figures refer to the management area and functional unit given in table 1.

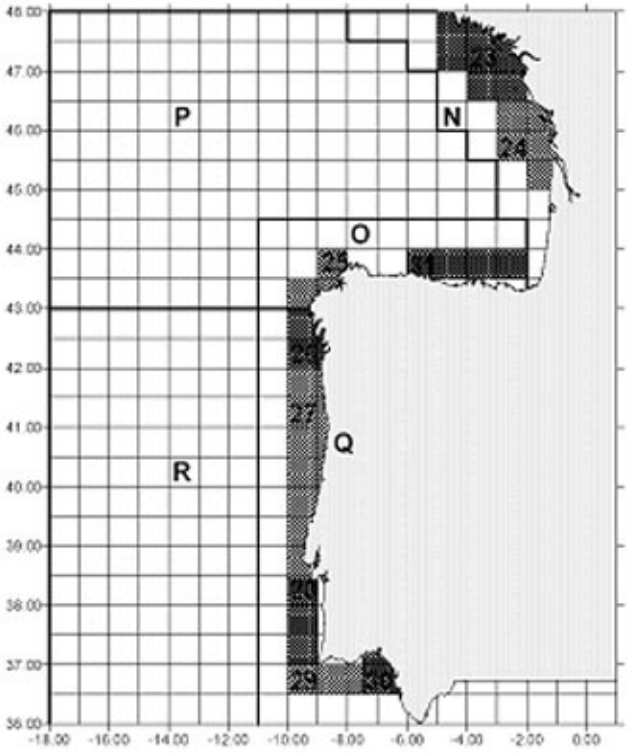


Figure 1c. *Nephrops* management areas and functional units in ICES subareas VIII, IX and X. Numbers and figures refer to the management area and functional unit given in table 1.

Table 1. Description of management areas with their *Nephrops* Working Group labels and the functional units contained within them.

| WG label | ICES description | Functional Units (FUs) or groupings thereof when treated as one in assessments | |
|---|---|---|---|
| A | Va | 1 | Iceland |
| B | Vb (non EC) | 2 | Faeroe Islands |
| C | VIa | 11 | North Minch |
| | | 12 | South Minch |
| | | 13 | Clyde |
| D | Vb (EC) + VIb | | None |
| E | IIIa | 3 | Skagerrak |
| | | 4 | Kattegat |
| F | IVa, rect. 44-48 E6-E7 + 44E8 | 9 | Moray Firth |
| | | 10 | Noup |
| G | IVa, West of 2° E excl. MA F | 7 | Fladen |
| H | IVb,c, East of 1° E excl. rect. 43F5-F7 | 5 | Botney Gut |
| | | 33 | Off Horn Reef |
| I | IVb,c, West of 1° E | 6 | Farn Deeps |
| | | 8 | Firth of Forth |
| J | VIIa, North of 53° N | 14 | Irish Sea East |
| | | 15 | Irish Sea West |
| K | VIId,e | | None |
| L | VIIb,c,j,k | 16 | Porcupine Bank |
| | | 17 | Aran Grounds |
| | | 18 | Ireland NW coast |
| | | 19 | Ireland SW and SE coast |
| M | VIIf,g,h, excl. rect. 31E1 32E1-E2 + VIIa, South of 53° N | 20+21+22 | Celtic Sea |
| N | VIIIa,b | 23+24 | Bay of Biscay |
| O | VIIIc | 25 | North Galicia |
| | | 31 | Cantabrian Sea |
| P | VIIId,e | | None |
| Q | IXa | 26 | West Galicia |
| | | 27 | North Portugal |
| | | 28+29 | South-West and South Portugal |
| | | 30 | Gulf of Cadiz |
| R | IXb + X | | None |
| S | IVa, East of 2° E + rect. 43F5-F7 | 32 | Norwegian Deep |

*General Problems associated with most Nephrops fisheries*

Before discussing these regional divisions in detail, there are a number of problems associated with almost all *Nephrops* trawl fisheries, with the size of the problem depending on the individual fishery.

In common with many shrimp fisheries, the minimum mesh size (MMS) required for the retention of *Nephrops* is smaller than for most finfish species (with the exception of the Mediterranean). The MMS ranges from 40 to 80 mm, although *Nephrops* are retained with larger mesh sizes. Because the preferred habitat of *Nephrops* often overlaps that of other economically important species, by-catches and subsequent discarding can be considerable due to minimum landing size restrictions on the by-catch (Stratoudakis *et al* 2001; Evans *et al* 1994).

Discarding also occurs in some fisheries in order to satisfy specified landings criteria. In many fisheries, catch composition regulations are applied in order to discourage fishermen who traditionally target finfish, from reducing their cod-end mesh size to retain *Nephrops*.

As well as providing data on the scale of fish discarding, several authors also describe a high rate of *Nephrops* discarding (Redant and Polet, 1994a; Evans *et al*, 1994, Anon 1999). Much of this can be attributed to the poor selectivity characteristics of the gears, inconsistency with the MLS or high grading of the catch for legislative or marketing considerations.

It is not the intention of this work to provide an in-depth review of discarding associated with the *Nephrops* trawl fishery. Others have comprehensively covered this. However, Alverson *et al* (1994) ranks the *Nephrops* trawl fishery as fifth in the 'top number based discard to landed target catch ratios for global trawl fisheries'. This report provides a synopsis of the main trawl fisheries where *Nephrops* are caught, to identify and summarise the current technical measures and their effectiveness and discuss possible remedial action.

**Overview of available remedial measures**

Prior to reviewing the existing legislation, the mechanisms that are available for controlling species and size selectivity (for both target and by-catch species) are reviewed. Considerable research has already been conducted into mitigating measures and some have been introduced into legislation. A brief description of the main gear measures available is provided in this section, a review of their assessment and effectiveness on a fishery-by-fishery basis is provided in more detail in subsequent regional sections.

The range of remedial measures can be broadly split into two categories, those that improve size selection of target or by-catch species and those that reduce the overall by-catch.

**Improving size selection**

*Cod-end design*

One of the simplest measures available is the alteration of the cod-end construction, in terms of mesh size or geometric form. Alterations in geometric form include constructing the cod-end entirely from square mesh or increasing the diamond mesh opening by either restricting the number of meshes in circumference, or by hanging the cod-end meshes on shortened ropes (relative to the stretched length of the cod-end) around its circumference (Robertson and Shanks, 1989). For fish and prawns, the twine used in the construction of the cod-end can also influence selectivity, for example by restricting the number of individual twines used, the twine thickness or twine stiffness. Alteration of cod-end design can influence the retention of both *Nephrops* and fish by-catch.

*Square mesh panels*

With the exception of mesh size and mesh construction, the square mesh panel is one of the most common 'additional' devices tested, and was first introduced into legislation in 1992 in the Northern European *Nephrops* fisheries for improving the size selection of gadoids (Briggs, 1992; Armstrong *et al*, 1998). The panel relies on utilising escape behaviour and assisting escape by maintaining an open mesh structure irrespective of longitudinal mesh tension, unlike diamond mesh, which tends to close as longitudinal strain is applied. Recent research on fish trawls has shown that as well as panel mesh size, panel position relative to the cod-end is important in respect of effectiveness (Graham and Kynoch, 2001; Graham *et al*, 2003).

*Grids*

Grids for improving size selection are commonly used by vessels operating in the Barents and Norwegian Seas demersal fish fishery and considerable research has been conducted in the North Sea demersal fishery (Larsen and Iasksen, 1993). Some experiments have been conducted on improving *Nephrops* size selection in both the North Sea and Kattegat and Skagerak (Valdemarsen *et al*, 1996; Robertson and Shanks, 1994).

*Horizontal separator trawl*

By utilising differences in vertical behavioural patterns at the mouth of the trawl, the horizontal panel separator trawl (Figure 2) was developed in order to segregate species into specific areas within the net. A single panel of netting is inserted horizontally within the trawl, dividing the trawl into upper and lower components; the separating panel may start level with the groundrope centre or further aft.

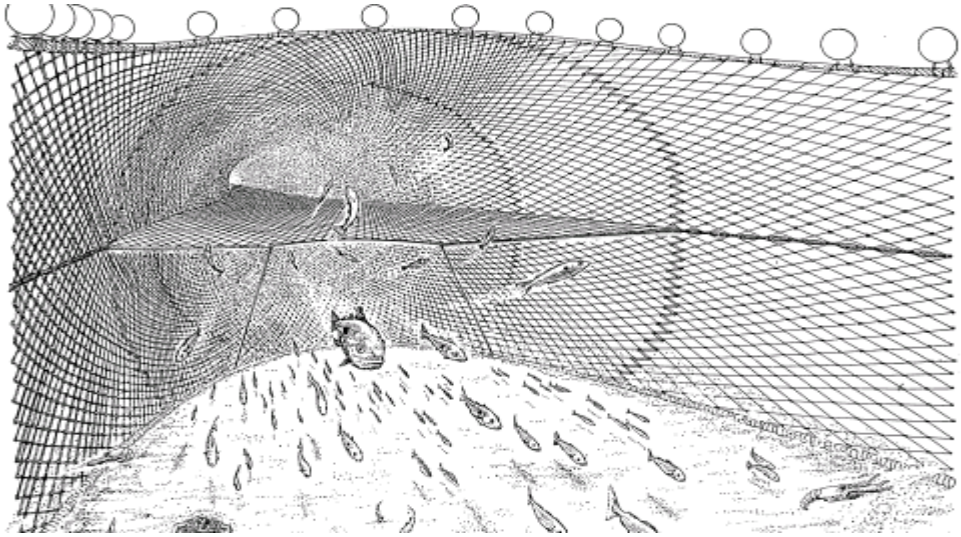

Figure. 2. Horizontal separator trawl.

Generally, separator trawls are designed with two separate cod-ends and extensions, which are tailored to join at the upper and lower body of the trawl, divided by the panel. *Nephrops* and some species, particularly cod and flatfish, will tire and fall back under the separating panel, while haddock and whiting tend to rise as they become progressively exhausted, passing over the panel and into the upper portion of the trawl (Main and Sangster, 1982, 1985; Wardle 1983). As the fish are reacting to visual cues, visibility may influence effectiveness. The upper and lower cod-ends may have different specifications (e.g., mesh sizes), providing the opportunity to manipulate cod-end selectivity to suit the species entering each cod-end.

*Large mesh upper panels*

Recent EU legislation (EU Council Regulation 2549/2000) stipulates that a panel of large mesh netting (140 mm and 15 meshes long) is inserted in the square (cover) of the trawl directly behind the headline (headline panel). The operating principle is to provide an escape opportunity for roundfish as they rise and fall back into the trawl. Some experiments have been conducted where the entire top of the trawl is constructed from larger mesh.

**Improving species selectivity**

*Inclined separator trawl*

The separator panel is fitted into the modified extension piece of a standard *Nephrops* trawl to divert cod and other

whitefish species towards an escape hole in the top of the trawl (Anon 2002a). The panel starts 50 meshes above the codend with the leading edge approximately 30cm above the bottom sheet, allowing the passage of *Nephrops* and other species such as monk and flatfish into the cod-end, while the guiding cod, haddock and whiting out of the escape hole.

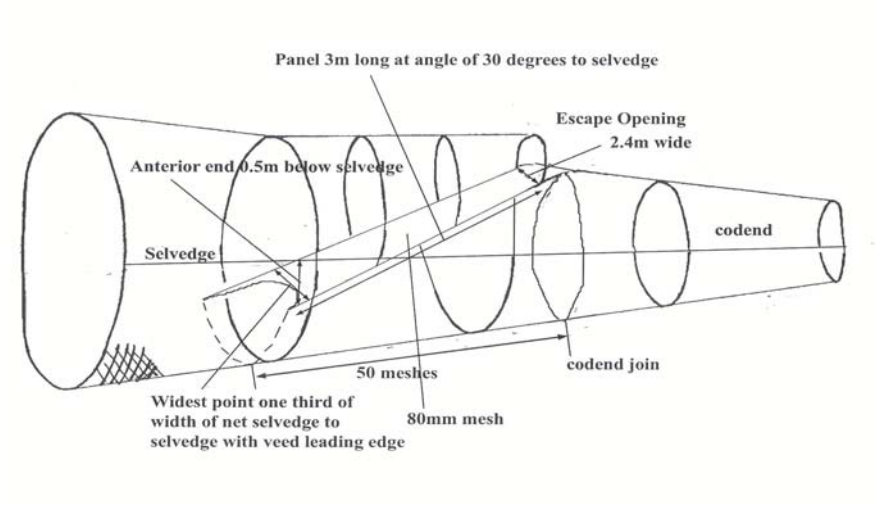


Figure 3. Inclined separator panel.

***Nordmøre Grids***

The use of the Nordmøre grid is widespread in many temperate and tropical shrimp fisheries for the exclusion of unwanted by-catch (Isaksen *et al*, 1992). It is commonly used in the temperate *Pandalus* shrimp fishery and in tropical fisheries for the exclusion of turtles as well as fish. The device operates by utilizing size differentials between the target species and the by-catch. In comparison to shrimp fisheries, relatively little work has focussed on the potential use of grids in the *Nephrops* fisheries with respect to species selectivity.

It is possibly due to morphological reasons that few experiments have assessed their effectiveness in *Nephrops* fisheries. The hard exoskeleton and large claws are not conducive to easy passage through grid bars and in addition, in many of the *Nephrops* trawl fisheries, the fish by-catch is of economic importance. Furthermore the juveniles of the finfish by-catch are liable to pass through the grid and be retained with the *Nephrops*. The conventional shrimp grid design used in the *Pandalus* fisheries, which is designed to maximise the exclusion of fish, is not an ideal option in the majority of *Nephrops* fisheries for economic and practical reasons. However, several investigations in the use of grids have been conducted (Anon 2001a).

*Open top or cut away trawls*

The previous devices operate by selecting fish once they have entered the trawl. However, recent experiments have shown that it is possible to allow fish to escape, before or in the mouth area of the trawl. As *Nephrops* tend to follow the lower parts of the trawl, the only requirement for having an upper panel above and forward of the ground-gear in a *Nephrops* trawl is to maintain the capture of fish that tend to rise as they enter the trawl. Thomsen (1993) first used such behavioural patterns to separate cod and flatfish by removing the upper belly, effectively extending the headline. A model *Nephrops* trawl, with an extended headline, was assessed in a flume tank in 1993 (Hay, BSc Thesis). Recent trials by the Sea Fish Industry Authority in the UK (Arkley and Dunlin, 2003a; 2003b) have shown that by extending the headline in conjunction with a large mesh panel behind, it is possible to exclude some finfish species from a *Nephrops* trawl. These designs tend to mimic the operation of traditional low headline *Nephrops* trawls, that tend to have low finfish by-catches.

**The European *Nephrops* fleet**

*Iceland (ICES area Va, FU 1)*

The Icelandic *Nephrops* fleet principally operates off the Southern and South Eastern coast of the island (ICES area Va). In the 'quota year', Sept. 2001 – Sept. 2002, the fleet of 35 vessels landed 450 tonnes of *Nephrops*. All vessels participate in other fisheries outside the peak *Nephrops* season (May-August). It is reported (Anon, 1999) that the trawl design typically used has changed over recent years, with increasing use of trawls with comparatively high headline heights, signalling a shift towards a more multispecies fishery. The recent introduction of rock-hoppers into the fishery has expanded the range of available grounds for *Nephrops*. The use of twin trawls is limited to 4–6 vessels. In a 'good' season, *Nephrops* can account for 2/3 for the total landings, however this has shifted in recent years to where cod, haddock, redfish, monkfish and witch accounts for 2/3 in importance. Due to a falling a CPUE and market demand for *Nephrops* during the mid 1990s, the fleet is increasingly relying on the fish by-catch for economic survival.

*Current Legislation*

Areas of operation are restricted coupled with depth restrictions, where minimum trawling depth limits of between 60 and 55 fathom are applied. In addition, the Icelandic authorities do not allow a targeted whitefish fishery when using *Nephrops* trawls and if the authorities consider the whitefish catch excessive, the vessels entitlement to operate in the *Nephrops* fishery is revoked. All fish and *Nephrops* must be landed

Technical measures (Regulation No. 543, 22.07.02) apply a minimum mesh size of 80 mm, with no restrictions on cod-end circumference or twine thickness stipulated. The upper square of the trawl must be constructed from a minimum of 135 mm diamond mesh. It is mandatory to fit 2 square mesh windows with at least 200 mm mesh size. The fore window has to be at least 4 m long and shall be positioned at the forward end of the upper belly. The aft window has to be approximately 2 meters behind. This is supported from earlier experiments conducted by Thorsteinsson (1993). These indicate that the current legislation has a positive effect on the reduction in gadoid catches. He assessed the effectiveness of two square mesh panel designs by conducting a catch comparison trial using a twin-trawl arrangement. A 80 mm 3m long window was inserted in the cod-end of one trawl. Only a minor impact on gadoid catches was observed, albeit with only four hauls. The additional inclusion of a 135 mm 3x3m panel inserted in the upper belly section of the trawl showed a marked effect on the catch rates of haddock and whiting (42 and 58% reduction respectively) with no marked effect on *Nephrops* catches.

*Problems associated with the Icelandic fishery*

No information has been obtained which identifies any specific issues with this fishery. Iceland has only recently started a discard sampling programme, and as such the available data are poor (Anon 2002b). No data have been obtained which describes the selective properties of the current legislation used in Icelandic waters.

*Recommendations*

- Considering the relatively small MMS and the lack of other cod-end restrictions, an inventory of cod-end parameters (mesh size, twine type, thickness and circumference) should be made. Size selection of *Nephrops* should be assessed on cod-end design(s) typical of the fleet and its suitability assessed in relation to minimum landing sizes and market selection.
- Discard data should be used to identify if existing legislation is adequate and consideration given to modifying technical measures.
- The critical components of the multiple panels used - mesh size, panel dimensions, twine construction and position – should be identified.

*Skagerrak and Kattegat (ICES area IIIa, b; FU 3 and 4)*

Vessels from Denmark, Sweden and to a lesser extent Norway are the principal countries targeting the fishery, with Denmark having the highest landing. In 1999, Danish vessels landed 3491 tonnes with a total value of 340 million DKK. Of this, 26% and 38% were taken from the Kattegat and Skagerrak respectively. Andersen *et al* (2003) identify two principal fisheries for *Nephrops*, both in the Kattegat and Skagerrak. The directed *Nephrops* trawls fishery and the mixed-trawl fishery, both defined by mesh size, 70–89 mm and 90–104 mm respectively. For the directed fishery,

*Nephrops* accounted for 42–47% by weight, and 68–88% by value taken in the Skagerrak, with a by-catch of cod, plaice and monkfish. The relative importance in *Nephrops* for the mixed fleet is 5–15% by weight, 20–40% by value. There are indications that the traditional Danish whitefish trawling fleet are increasingly targeting *Nephrops* due to the general decrease in catching opportunities for gadoid species.

The Swedish *Nephrops* trawler fleet consists of approximately 60 specialised *Nephrops* vessels. The Swedish *Nephrops* landings were split by single trawls catching 42%, twin trawls 39% and creels 12%, and as by-catch in fish and shrimp trawls 7%. Anon (2001b) report that there is a general trend towards increasing use of the twin-trawl. These vessels typically target both fish and *Nephrops*. A total of 1243 tonnes were taken by the Swedish fleet landing in ports on the West coast of Sweden, with a total value of 101 million SEK. Landings were split as 84% in the Skagerrak and 16% from the Kattegatt. Since 1989, there has been a steady increase in the use of twin-trawls. The log book data for single trawlers are directed for *Nephrops* during the whole period while the twin trawler show a shift to target both fish and *Nephrops* in recent years. Total Swedish trawling effort sharply decreased between 1992 and 1996, and has been at a relatively low level since then. Over the same period of time, the LPUEs first increased to the highest overall LPUE for the whole period, then decreased slightly again in 2000 and 2001. In 2002 LPUE of the *Nephrops* directed single trawlers increased again. A similar trend is seen in the Danish fishery.

Norwegian vessels landed a total of 400 tonnes of *Nephrops* in 1999, which was valued at 2.4 million NOK, although some of this can be attributed to the Norwegian Deep fishery in IVa. Limited statistical data are available as to the number of Norwegian registered vessels engaged in the fishery, but there are indications of increased activity of Norwegian vessel operating in ICES areas IVa and IIa.

*Current Legislation*

EU (EC Regulation 850/98) regulations set the minimum mesh size for *Nephrops* trawlers at 70 mm; coupled with the mandatory use of a 80 mm square mesh panel. 'The panel must be placed in the top half or top sheet of a net in front of any extension piece or at any point between the front of any extension piece and the posterior of the cod-end'. The length of the panel must be 3m if the engine power of the vessel exceeds 112 kW; below this a 2m panel may be used. By using a mesh size of 70 mm, in common with EU legislation applied elsewhere, the vessel's landed catch composition must be at least 30% *Nephrops*. Cod-end twine thickness is limited to 8 mm single or 2x6 mm double. In order to overcome this restriction, some Swedish vessels opt to use a larger mesh size (90 mm). Approximately 10–15% of the coastal fleet also voluntarily use 70 mm full square mesh cod-ends to limit the extent of *Nephrops* discarding. The current regulations are due to be reviewed.

For vessels engaged in the *Nephrops* fishery in Norwegian territorial waters, the MMS is 70 mm provided the cod-end is constructed entirely from square mesh netting, 80 mm if diamond mesh. No twine thickness legislation applies and the use of lifting (strengthening) bags is prohibited. A vessel is classified as a *Nephrops* trawler only if 50% or above (by weight) of the catch is *Nephrops*, otherwise the vessel is considered as a whitefish trawler and must comply with the current mesh regulations (120 mm MMS). In addition, it is illegal to discard, i.e., any fish below minimum catch size (MCS) must be landed and are counted against the vessel's quota. If the catch below MCS exceeds 15% of the total, then the fishing area is closed.

*Size and species selectivity problems*

The fishery suffers from a particularly acute level of *Nephrops* discarding, as high as 80% (by number) of the total catch (Ulmestrand and Valentinsson; Internal report, IMR, Sweden). This may be largely attributed to a mismatch between the legal minima for cod-end mesh size and landing size. Although problematic in other Northern European fisheries, where the MMS is broadly similar (70–80 mm), the comparatively high MLS, 40 mm carapace length compared to 25 mm in the Northern North Sea compounds the problem. Figure 4 shows the estimated selection curve for a 70 mm cod-end as described by Madsen *et al*. (1999). The two arrows show MLSs for the North Sea and Kattegat/Skagerrak. It can be seen that in the Kattegat and Skagerrak, a considerable proportion of *Nephrops* below MLS (40 mm) will be retained, whereas in the North Sea, a smaller proportion below MLS (25 mm) will be captured. The problem may be even more acute when the L50 estimates (ca. 18 mm) obtained by Ulmestrand and Valentinsson (see section 3.2.3.1) are applied.

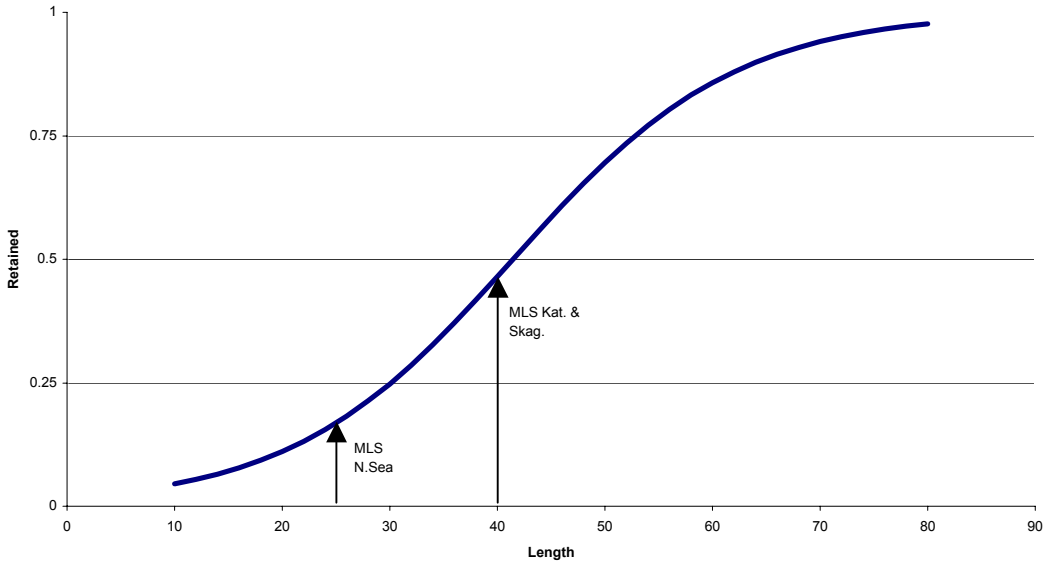


Figure 4. Selection curve as from Madsen *et al*. (1999) showing the minimum landing size for *Nephrops* in the Kattegat /Skagerrak and North Sea.

In addition to the high level of *Nephrops* discarding observed, the discarding of marketable species of fish is also considerable despite the legal requirement for the square mesh panel. A sampling programme (EC Study 98/097) conducted in the Skaggerak *Nephrops* fishery between 1995 and 2000 indicated discard levels of cod (61%), saithe (39%), haddock (75%), whiting (99%) and hake (24%). Similar levels were recorded in the Kattegat fishery.

*Remedial measures*

***Square mesh cod-ends***

Ulmestrand and Valentinsson (Internal report, IMR, Sweden) assessed the effectiveness of a square mesh cod-end constructed entirely from 70 mm square mesh netting and compared it with a conventional 70 mm diamond cod-end. The L50 for *Nephrops* increased from 18.3 mm (95% CI 16.3–19.8) to 32.3 mm (95% CI 31.3–33.2) carapace length when using this cod-end. The authors also noted a significant reduction in the level of fish by-catch retained. The square mesh cod-end in this assessment had a similar number of bars in circumference as the diamond mesh cod-end (~1:1 diamond to square ratio). Previous experiments with a full square mesh 60 mm cod-end with a reduced number of bars to 60 in circumference (1:1.7), provided a higher estimate of L50 (40.1 mm). Therefore, it should be considered that cod-end circumference might have a significant impact on selection of square mesh cod-ends in common with diamond mesh cod-ends.

***Grids***

Valdemarsen *et al* (1996) investigated the possibility of using grids to reduce the discarding of juvenile (<MLS) *Nephrops* by improving size selection in the *Nephrops* fishery in the Skagerrak and Kattegatt. Two different grid arrangements were assessed in 1993 and 1994. A bottom-mounted grid was attached to the lower panel of the extension piece and sloped backwards at 30 degrees. The roof-mounted grid system operates on the same principle as the Sort-V (Valdemarssen *et al.,* 1996). Both grids showed a reduced selection range (SR) compared to diamond mesh cod-ends; the bottom-mounted grid gave significantly sharper selection than the roof mounted grids. For the 1993 experiments, the SR for the bottom and top mounted grids was 8.4 and 12.8 mm respectively; for the 1994 experiments, the SR was 8.4 and 13.9 mm respectively.

Recent Swedish trials in order to assess the species selectivity using 35 mm grid in combination with the 70 mm square mesh cod-end were carried out on four commercial *Nephrops* trawler during autumn 2002 (unpublished). The results from about 50 trawl hauls indicate a massive reduction in the fish by-catches of all sizes, without any significant loss of

legally sized *Nephrops*. Current regulations for *Nephrops* trawls, specifying 70 mm diamond mesh, imply that more than 1800 tonnes of protected undersized commercial by-catch species are caught and discarded each year. An introduction of a mandatory use of 35 mm grid in combination with 70 mm square mesh cod-end would reduce the catch of legal sized fish to almost zero and undersized fish with about 70%. According to available literature, this gear modification is the most efficient device for species selection in *Nephrops* trawls.

***Mesh size***

Stiansen and Lilleng (2001) conducted a catch comparison exercise, where they compared 100 and 120 mm cod-ends. Reductions in cod, haddock and saithe were observed which showed indications of length dependency. Overall reductions in *Nephrops* catches were observed, but with no apparent length dependency.

***Square mesh panels***

Ulmestrand and Larsson (1991) conducted a catch comparison exercise with a twin trawl with and without a panel fitted. They obtained reductions of whiting by-catch of 62% (by weight) with a 70 mm square mesh window fitted approximately 3.8m from the cod-line of a 70 mm diamond cod-end.

*Recommendations*

Increase L50 to match current MLS (e.g., 70 mm square mesh cod-end)

Introduction of species separation devices, such as grids, square mesh cod-ends and large mesh panels in the upper belly in the target *Nephrops* fishery.

Consider a reduction in the limits of twine size, meshes round the cod-end circumference and minimum length of square mesh cod-end and extension piece.

***North Sea (ICES areas IVa, b, c)***

Vessels from Scotland, Denmark, England, Netherlands and Belgium are the principal operators in the North Sea fishery, with Scotland having the highest landings, not only in the North Sea but in Europe overall.

Scottish vessels operating in the North Sea target *Nephrops* mainly on the Fladen, Firth of Forth and Moray Firth grounds. Since the mid to late 1980s there has been a major shift to twin rig trawling. *Nephrops* are the single most economically important species landed in Scotland, with an estimated value of €77 million in 2001. Scottish East Coast vessels typically use dual-purpose *Nephrops*/fish nets, which have an increased headline height in comparison to the traditional design. These are designed specifically to catch gadoids in conjunction with *Nephrops* and the fish component, principally haddock and whiting, accounts for a considerable proportion of the fleets income.

Prior to the increase in MMS for whitefish vessels (from 100 mm to 110 mm in 2002 and 120 mm in 2003), many Scottish twin rig vessels operated with the previous whitefish MMS while targeting both gadoids and *Nephrops*. Using 100 mm allowed the fleet to maximise revenue from both *Nephrops* and fish by avoiding the catch composition regulations. The combination of the increased mesh size, the associated reduction in *Nephrops* catches and a general decrease in the gadoid stocks has resulted in many operators reducing their mesh size and increasing their effort on *Nephrops*.

In common with the Scottish fleet, Danish vessels also operate on the Fladen grounds typically using multiple rig trawls, but landing statistics also show a considerable proportion of Danish activity being attributed to IVb. The North Sea landings accounted for 36% of Denmark's total (remainder from the Kattegat and Skagerak) for 1999. Anon (1999) estimates that vessels using 100 mm cod-ends took 60% of the Danish *Nephrops* catch. In light of the changes in mesh size for human consumption fisheries, it is probable that these vessels may follow the example of the Scottish fleet by reducing their mesh size to 80 mm (Personal communication with Niels Madsen).

*Nephrops* catches attributed to Norwegian vessels operating in IV has increased due to greater restrictions on the *Pandalus* fishery as these vessels are now specifically targeting *Nephrops*.

The principal English fishery takes place in the Farne deeps (IVb) during the winter months (October to April) with around 100 vessels engaged. 2400 tonnes of *Nephrops* were reported in 1999. There is a considerable by-catch of cod,

haddock and whiting. Landings data suggest minimal activity in other areas of the North Sea.

The Belgian activity centres on the Botney Gut and Silver Pits areas in the central North Sea. The fleet has decreased considerably over the last 15 years, in the early 1990s the fleet consisted of 20 so called 'specialist *Nephrops* trawlers'. Between 1992 and 1998 the fleet size fell to 7 vessels. The peak of the season is through the summer and early autumn, and other vessels occasionally join the fishery through this period. Vessels shift to other fisheries for relatively long periods of time (several days to weeks). The Belgian fleet, as well as using otter trawls, also use beam trawl to catch *Nephrops*. By-catches of roundfish and flatfish are of particular importance to the Belgian fleet, with finfish making up as much as 48% of the catch and accounting for 55% of the overall revenue (Redant and Polet 1994b). However, with the recent declines in roundfish and flatfish stocks, in terms of quantity and revenue, *Nephrops* now ranks as the most important species, comprising 34% by weight and 45% by value of all Belgian *Nephrops* trawler landings. It is also noted that the lack of fish by-catch has resulted in operators being more vulnerable to the comparatively less stable *Nephrops* market.

The Dutch fleet (10–15 vessels) has rapidly expanded over the past few years. They participate in the Southern North Sea, Botney Gut – Silver Pit fishery. The fleet comprises both beam trawlers, using 'high' beam shoes, and in recent years, dual-purpose beam/twin-rig trawlers have also joined the fleet.

*Current Legislation in the North Sea*

If the *Nephrops* catch exceeds 35% of the total catch on board a square mesh panel must be fitted to the trawl... EU legislation stipulates a minimum panel mesh size of 80 mm, while UK unilateral legislation requires 90 mm and is more specific in terms of the positioning of the panel; the rear of the panel should be not more than 15m from the cod-line. The length of the panel must be 3m if the engine power of the vessel exceeds 112 kW, otherwise a 2m panel may be used.

Regulations also restrict the permissible twine thickness and the circumference of the cod-end, both in EU and UK unilateral legislation. Under UK legislation, when fishing for *Nephrops*, the cod-end, extension and any square mesh panel must be constructed of single twine, of a thickness not exceeding 4 mm for mesh sizes 70–90 mm, whereas EU legislation restricts twine thickness to a maximum of 8 mm single or 6 mm double. For both UK and EU legislation, the maximum number of mesh in circumference permissible is 120.

An additional panel must be inserted at the rear of the headline of the trawl. The panel must be 'attached directly to the headline of the net or to no more than three rows of netting material of any mesh size attached directly to the headline, extending towards the posterior of the net for at least 15 meshes and constructed of diamond meshed netting material of which no individual mesh is of size less than 140 mm'. This is somewhat ambiguous in its description, as there appears to be no restriction on the width of the panel.

*Current issues in the North Sea*

The Fladen fishery is typically multispecies in nature with the by-catch of other species of significant economic importance to the fishing fleets, often contributing to 40–60% of the total income (personal communication with Scottish selling agents). The use of devices that exclude fish are therefore not economically viable for the fleet. Other fisheries, such as in the Farne Deeps and the Firth of Forth are predominately *Nephrops* fisheries where the by-catch of fish is of minimal economic importance.

There is evidence from both fishermen and the scientific literature that on occasion, there can be considerable high grading of *Nephrops*. Redant and Polet (1994a) observed fisherman's discarding practices in two seasons, June and September in the Southern North Sea in 1993. During the summer fishery, high grading was minimal and the L50 for the catch retained by the fishermen was ~28 mm carapace length (CL). In September, however, the L50 increased considerably to ~33 mm. This is attributed to the fact that catch sizes tend to be larger during this period increasing sorting times, which results in a less rigorous size selection due to time constraints on the crew. Another factor may be the markets ability to absorb *Nephrops* with CL below ~30 mm, leading to deliberate high grading. High grading in the Belgian fishery was reported as being considerable by Anon (1999).

Evans *et al* (1994) also noted a large proportion of discarded *Nephrops* in the Farne Deep fishery, they estimated that 37% of the males and 36% females discarded were above MLS. Many of these were either 'soft shelled' or damaged, but the authors note that high grading was more acute when overall catch rates were higher. These authors also estimate a high rate of *Nephrops* discarding overall, 63% by weight and 85% by number. It should be noted that subsequent to the collection of this data, there has been an increase in MMS to 80 mm. Estimates of fishermen's selection from the

Farne deeps reported by Anon (2001b) estimate an L50 of ~30 mm, with a relatively tight selection range of ca. 5 mm.

Although some of the fish discarding problems may have been alleviated by the introduction of the square mesh panel and the large mesh panel behind the headline, the impact is difficult to gauge. No scientific evidence has been published to support the headline panel. It remains clear that there is still considerable discarding for both economic and legislative reasons.

It is likely that the problem of discarding may increase due to the recent introduction of effort limitation for the demersal trawl fleets in the North Sea under the emergency cod recovery legislation. In many instances, vessels predominately engaged in whitefish trawling, have an entitlement to fish for *Nephrops* provided they have quota allocations. The recent regulations have stipulated that vessels operating with mesh sizes above 100 mm are limited to 15 days per month while vessels using smaller mesh sizes are entitled to 25 days/month. Anecdotal evidence suggests that some operators, who previously targeted whitefish, have opted to use the smaller mesh size in order to increase their monthly days allocation. Although intended to protect or limit the fishing mortality on cod, this legislation may have negative consequences for other demersal species. It may encourage high grade discarding due to the catch composition regulations, thus along with the reduction in mesh size, increasing the capture of smaller fish due to the increase in fishing effort.

There is a lack of parameterised (length) data on selectivity to assess the relation between current legal gear specifications and minimum landing size. Much of the work has been through the use of catch comparison exercises making the formation of a definitive overview problematic.

*Remedial measures tested*

**Separator trawls**

Main and Sangster (1985) achieved good separation of *Nephrops* from haddock. 100% of *Nephrops* were retained in the lower cod-end, while 89% of haddock entered the upper cod-end. Separation of whiting was less dramatic, with 55% entering the upper body of the trawl. No separation of cod was observed, with 100% being retained in the lower cod-end along with the *Nephrops*. Recent experiments have demonstrated that separation of cod may be achieved by the inclusion of guiding ropes attached between the fishing line and the leading edge of the horizontal separator panel (Sangster *et al* unpublished). The authors note that the length of the guiding ropes is a critical feature in achieving good separation. This device may have some potential considering the current status of North Sea cod. From a commercial and administrative perspective, the production of a separator trawl is approximately 30% more expensive than a industry standard trawl. The rigging of the panel is design specific and as such makes any blanket introduction into the fleet problematic, as each design would have to be assessed and modified individually. Main and Sangster (1985) observed that the panel height was critical in terms of separation efficiency. Legislation would therefore be difficult to frame and enforce. A recent EU technical experts group considered that such a device could be introduced into the fishery by the provision of incentives, such as reduction in by-catch limits, subsidy for new gear or permission to fish in closed areas or seasons when using more selective gear.

**Large mesh/cut away trawls**

The Sea Fish Industry Authority conducted an extensive series of trials in the Farne Deeps fishery on the NE coast of England with the objective of producing a '*Nephrops* only' trawl (Arkley and Dunlin, 2003a, 2003b). Large reductions in the by-catch of haddock and whiting were obtained by removing the upper panel (square/cover) so that the headline centre was level with the footrope centre and introducing large mesh (200 mm) for 35 meshes immediately behind the new headline. Using catch comparison between two similar vessels, the by-catch of whiting and haddock was reduced by 63 and 65%. The owner of the vessel has requested to use the trawl voluntarily basis.

**Cod-end mesh size**

The effect of cod-end mesh size was assessed in a previous FTFB ad hoc group (Anon, 1995). A significant, positive relationship between mesh size and both L50 and SR was found. However, recent experiments have shown inconsistent results, with a high proportion of hauls failing to show a relation between length and selectivity parameters. Anon (2002c) found no significant difference in catches of *Nephrops* comparing a 80 mm, 4 mm single twine cod-end with 120 meshes round and a lifting bag against a 100 mm, 5 mm double twine cod-end with 100 meshes round and no lifting bag. Both cod-ends were fitted with a 90 mm panel, 9–12 m from the cod-line. Madsen *et al* (1999), using the asymmetric complementary log-log function to describe *Nephrops* selectivity, demonstrates that the L25 obtained (26.8 mm) with a 70 mm standard cod-end is broadly compatible with the carapace MLS for the North Sea of 25 mm.

**Cod-end geometry**

Bova and Sangster (unpublished) conducted a comparative study to determine the difference in *Nephrops* catch compositions between diamond mesh and square mesh cod-end selectivity for *Nephrops*. The square mesh sizes tested were nominally 80 mm and 90 mm. The diamond mesh sizes were nominally 100 mm and 110 mm. The joining ratio for the cod-ends used during the study was 1:1, which was used to attach the extensions to the cod-ends. Results were not conclusive between square mesh and diamond mesh but L50 values were obtained. An encouraging result was the 110 mm diamond mesh gave an L50 value of 40.3 mm carapace length. These authors suggested that a possible explanation for differences between the test cod-ends was the physical shape and behaviour of *Nephrops* during capture.

It is clear that *Nephrops* selectivity by diamond mesh netting is poor. There is a need to control all aspects of cod-end design including mesh size, twine size and meshes round the circumference. The lifting bag may also have an effect although no data are available.

**Square mesh panels**

There has been considerable research conducted in the North Sea on the efficacy of square mesh panels to reduce gadoid by-catches. However, it is problematic to compare the data between experiments due to a number of factors. The majority of earlier experiments were conducted as catch comparison exercises so that it is inappropriate to compare results, because of variations in populations. The gear types tested between experiments vary considerably; in terms of panel position, panel/cod-end mesh size and panel length. It is clear that the panel has an impact in reducing the catch of roundfish but it is difficult to be definitive about the magnitude of this effect.

Madsen *et al* (1999) found a significant increase in L50 for both haddock and whiting when a 2 m long; 90 mm square mesh panel was inserted with the aft edge 4 m in front of the cod-line. L50 increased from 25.2 to 28.1 cm and 31.4 to 35.1 cm for haddock and whiting respectively. No significant change in L50 for *Nephrops* was observed. Interestingly, the selection range (SR) also increased significantly with the inclusion of the square mesh panel, although this may be a consequence of two distinct selection processes (selection due to the panel and selection through the cod-end meshes). The results show a significant improvement in selectivity despite the fact that the panel was only 2m long although the panel mesh size was 10 mm above the legal minimum requirement.

Anon (2002c) describe experiments to assess the effect of panel position in the Fladen fishery in the Northern North Sea (see section 3.3.1). They compare the current UK panel, 90 mm, 15–18m from cod-line, with a 90 mm panel inserted closer to the cod-end (9–12m). Shifting the panel further aft, resulted in a reduction of haddock below MLS of 43% when compared to the legal position, with losses of marketable fish; 39% for 30–33.5cm fish, 25% for 33.5–41.5cm. In addition, comparing the 15–18m and 9–12m positions, the rearmost position also released more whiting, 33% of fish 27–32cm, few fish above or below these sizes were encountered during the trials. Interestingly, the effect on *Nephrops* catches of moving the panel further aft is somewhat confusing when compared to the current legal position (see section 3.3.1), the panel reduced the capture of small *Nephrops*, but increased the catch of larger ones. It would be desirable to obtain length based parameter estimates for all three species with each of the panel positions to compare gear selectivity with current MLS.

It is well established that cod-end twine thickness influences the selectivity of gadoids. However, Anon (2002c) reported that the thickness of twine used to construct square mesh panels can also be an important contributory factor. Using a twin trawl a catch comparison exercise was conducted to compare 2.5 mm high tenacity twine with 5 mm double braided twine. The retention of haddock below MLS was reduced by 52% but catches of marketable fish were also reduced. No impact on *Nephrops* caches was noted. Similar trials were conducted in 2003 to evaluate a range of mesh constructions in reduced twine diameters (2.5 mm-1.5 mm) compared to the regulation requirement of 4 mm. By-catch reductions were reduced by between 25 and 61% for haddock and 38 and 52% for whiting without any loss of *Nephrops* (Arkley and Dunlin, 2003a, 2003b).

**Selection grids**

Recent experiments in the North Sea (Anon., 2001a) investigated the use of selection grids in the *Nephrops* fishery. The results showed that it was possible to segregate fish and *Nephrops* catches into two different cod-ends, where appropriate mesh sizes were used to select roundfish and *Nephrops* respectively. A secondary grid was installed in some of the experiments in order to improve the size selection of *Nephrops*, which also showed potential. However, the performance of the grid was dependant on the level of debris caught.

Three bar spacing (25, 30 and 35 mm) were assessed in conjunction with a horizontal gap along the lower edge of the

grid (150 and 200 mm high) that was intended to facilitate the passage of *Nephrops* into the cod-end. Two sets of trials were conducted in the North Sea, in the Farne Deeps fishery off the NE of England and in the Fladen/Moray Firth fishery off the NE of Scotland. Results of the two trials were variable. The trials in Scottish waters suffered from problems due to the grids being blocked with debris and difficulties in maintaining grid angle, which was shown to be critical for the efficiency of the grid. The grids successfully segregated *Nephrops* from haddock and whiting in both trials, and a length dependency was found for all three species. The probability of retention in the upper cod-end was found to increase with increasing length. The diversion of the largest *Nephrops* into the large mesh upper cod-end (and subsequent escapement) would be unacceptable to the fishing industry. Trials with a secondary grid (15 mm spacing) for size selection provided sharp selection for *Nephrops* (SR ~4.5 mm).

*Recommendations*

- Obtain data on effect of square mesh panel position, mesh size and panel construction (mesh type and twine diameter) in all *Nephrops* fisheries.
- Obtain parameterised data on current legislation to provide a benchmark
- Survey fleet on positioning of square mesh panel and compare with selectivity data
- Monitor changes in fleet activity to assess response to changes in legislation
- Assess and utilise fishermen's selection as selectivity targets where appropriate
- Assess cutaway headline and square mesh or large mesh upper bellies, to develop a trawl that gives similar whitefish selectivity to that of demersal fish trawls
- Further develop horizontal separator trawls with guiding ropes to improve separation of roundfish from *Nephrops*.
- Further investigations to improve *Nephrops* selection e.g., using grids, square mesh cod-ends and other 'novel' grading or selection devices.

*West of Scotland (ICES area VIa and VIb)*

Scottish vessels dominate the fishery in area VIa, with landings from all gears of ~11,000 tonnes in 1999. Limited catches are taken in area by Spanish, Irish and Scottish vessels. For Irish vessels in VIa. *Nephrops* are a small but valuable by-catch for around 8–10 vessels operating at Stanton Bank and in Donegal Bay for mixed species such as megrim, monkfish and hake. Landings in 2001 were around 100 tonnes valued at €0.4m. The inshore fisheries around the Hebrides tend to focus predominately on *Nephrops* only, using traditional low headline scraper nets, with the economic importance of the fish by-catch being limited. Anon (2003c) and Stratoudakis (2001) note that considerable discards of both haddock and whiting can be attributed to the *Nephrops* fisheries in VI due to the small mesh size employed. The assessment for whiting is poor, and considered outside safe biological limits, with a reduction of 40% in F being recommended.

*Current Legislation in area VIa for the West Coast of Scotland*

With the exception of the Clyde area, the current legislation governing *Nephrops* trawl fisheries on the West coast of Scotland was laid down under the auspices of the North Sea and West of Scotland cod recovery plan (Commission Regulation (EC) No 2056/2001), which established additional measures to 850/98. This regulation was amended in 2003 by Annex XVII of Regulation (EC) No. 2341/2002, which establishes fishing effort and additional conditions for monitoring, inspection and surveillance for the recovery of certain cod stocks. This regulation covers the Clyde Area and effectively limits vessels targeting *Nephrops* with 80–99 mm mesh size to 25 days at sea per month.

In certain areas restrictions are placed on vessels under UK national legislation operating with the twin trawl (SSI No 2000/226). In the Minches if twin trawls are used, a mesh size of 100 mm or above must be used without a lifting bag and with not more than 100 meshes round the circumference but with up to 5 mm double twine. By comparison, vessels using a single trawl may use 70–99 mm with a lifting bag and 120 meshes round the cod-end but with 4 mm single twine. Since the introduction of limits on days at sea, some minor modifications to Scottish legislation have been introduced.

*Irish Sea (VIIa)*

The Northern Ireland fishery predominately takes place in the West of the Irish Sea and the fleet consisted of around 80 vessels of which a small proportion visit the Eastern Irish sea fishery as of 1994. This is a mixed fishery with whiting, cod, hake and haddock being the main by-catch species. Approximately 30 English vessels are engaged in the summer

fishery in the Eastern Irish Sea, predominately operating in the Eastern part, landing approximately 6500 tonnes. The Irish fleet consists of around 48 vessels most of which are twin-rig otter trawlers. The main ports are Howth, Clogherhead and Skerries with landings approximately of 2,700 tonnes in 2001 with a value in excess of €7m. Irish activity is concentrated in the Western Irish Sea, an area that is also an important nursery ground for whiting and a spawning ground for cod. There is also considerable discarding of small *Nephrops* and in 1999 Irish vessels discarded around 1,200 tonnes of small *Nephrops*.

*Current legislation in the Irish Sea*

In 1999 ICES indicated that the stock of cod in the Irish Sea was close to collapse. The prognosis in 2002 is no better, the most recent advice has warned of the lack of mature fish in the stock and requested the continuation of measures to alleviate this situation. As a consequence of this, the EU introduced "urgent temporary technical measures" (EC 304/2000), over and above the minimum requirements laid out in the root regulation EC 850/98. This and subsequent modifications to the regulations (300/2001, replaced by 254/2002 and further amended by Annex V of Regulation 2341/2002) established a seasonal closed area, prohibiting the use of any demersal trawl, seine or gill, trammel, tangle or similar static gear incorporating hooks (Figure 4). The establishment of this closed area was introduced to protect cod during their spawning period, a seasonal closed area (February to April) was also introduced in the Clyde (456/2001) although this has been superseded by the new effort control regulations for the West of Scotland Area. The Clyde closure is no longer in force but subsequent closures have been achieved through national legislation in the from of Statutory Instruments. Area derogations were introduced which allowed the use of an inclined separator fitted in the extension of *Nephrops* trawls.

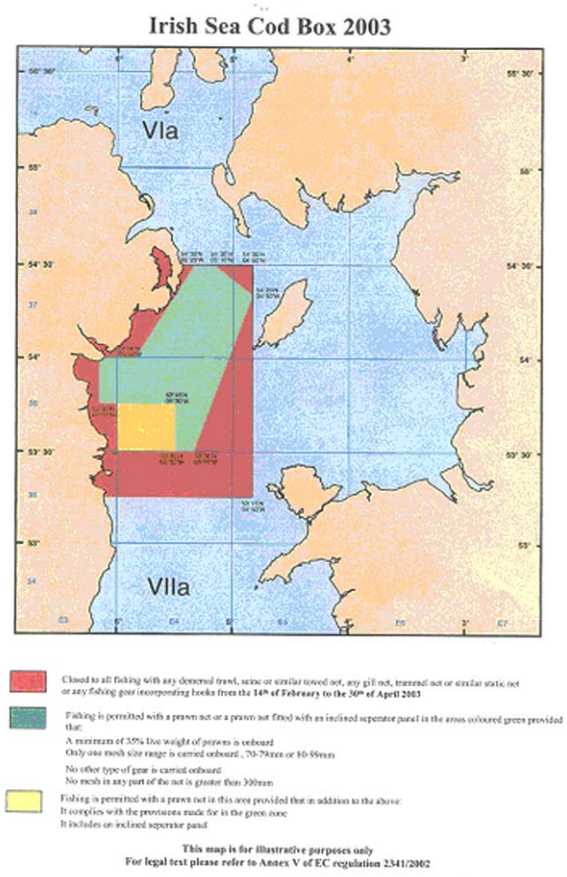


Figure 5. Restricted areas in the Irish Sea in 2003, the provision to allow the use of semi-pelagic gear has subsequently been revoked.

For mesh sizes in the range 70–99 mm where *Nephrops* are the target species, the catch composition must contain a minimum of 35% *Nephrops*. The cod-end must have a minimum of 120 meshes in circumference and that a 80 mm square mesh panel is required, either 2 or 3m in length dependant on vessel power. Panel position is governed by the same EU regulations as for the North Sea. A headline panel with a MMS of 140 mm must be fitted to any demersal towed net of 70–99 mm in the Irish Sea. Catches taken with any demersal trawl in the Irish Sea closed areas must have a minimum of 35% and 5% cod. However, all cod-ends and the extension piece, irrespective of mesh size must be

constructed from a maximum 4 mm double or 6 mm single twine.

The inclined separator (Figure 3) is intended to exclude cod, while maintaining catches of *Nephrops* and other species such as flatfish. The separator is allowed in the restricted area shown in **Figure**. 5 provided the capture of cod does not exceed 18% of the total weight of marine organisms retained on board. If the capture of cod does exceed that limit, the vessel must cease fishing activity in the area for a minimum of 24 hours.

*Current problems in the Clyde and Irish Sea*

These measures will have gone some way to protect cod, but the current restrictions are likely to be replaced by long-term cod recovery measures recently proposed (COM (2003) 237 final) by the EU Commission to cover the next 5–10 year period until stocks recover sufficiently. These proposals apply to the Irish Sea and are based around effort limitations i.e., days at sea. High levels of haddock and whiting discards are also reported throughout the year (Anon, 2003c). The by-catch of haddock associated with UK(NI) and Irish vessels is mostly attributed to the *Nephrops* fishery in the Western Irish Sea and to the south of the Isle of Man. The introduction of the cod recovery plan resulted in a reduction of effort in these areas, although the haddock stock is presently, relatively robust, improved selectivity would be beneficial in the long-term.

The most recent advice for whiting in the Irish Sea has been severe. Whiting are generally taken as a by-catch mainly on or near the *Nephrops* grounds, which are also the principal nursery ground for this specie. Square mesh panel legislation was introduced for both the UK and Irish vessels (SI No. 264) in 1994 under national legislation in order to reduce the fishing mortality on juvenile whiting and haddock. Anon, (2003c) report that while the effects of the panel have not been formally assessed, the fishery still generates substantial quantities of by-catch. Although the inclined separator trawl and seasonal closures associated with the cod recovery plan, may have reduced discarding from previous years, the summer peak in the activity of the *Nephrops* fishery is not influenced by the regulation.

Anon (2003c) recommend that fishing mortality should be reduced to the lowest possible level and a rebuilding plan be implemented. This should include provision, amongst other measures, to reduce the by-catch and discarding associated with the *Nephrops* fishery. The majority of whiting discards are 0 and 1-gp (52% and 38% respectively). The ICES WG (Anon 2003c) recommendations for a rebuilding plan state that a substantial reduction in discarding of these age groups could facilitate the rebuilding of the stock. In the worst-case scenario, the stock would require a reduction in fishing mortality that would "…require a radical re-design of *Nephrops* trawls to reduce the whiting by-catch"

*Remedial measures tested*

In light of the introduction of the cod recovery plan, the main focus in recent years has been on technical measures to reduce the fishing mortality on cod. A number of experiments, both in the Irish Sea and Clyde area have centered on the development and subsequent introduction of the inclined separator trawl.

Galbraith and Mair (unpublished) assessed the effectiveness of the inclined panel in the Clyde in 2001. Three designs were examined during these trials. An 80 mm cod-end was attached to the escape hole to retain the *Nephrops*/fish that would normally have escaped. Initially, an unacceptable proportion of the target species were being lost through the escape hole, so modifications were made to the depth of the separator panel and framing ropes around the leading edge. However, this did not reduce the problem. It was hypothesized that there was insufficient distance between the ground-gear (bosom) and the separator available for the target species to settle back onto the lower bellies of the trawl, a 100 mesh deep extension was inserted to try to alleviate this problem but no improvement was observed. An additional design was tested which included a secondary cod-end (100 mm) to retain the legally sized component of fish diverted through the escape hole. The results demonstrated reasonable separation of fish but showed considerable losses of *Nephrops*. Some indications of size dependency were noted. The results should be treated with some caution due to the low number of hauls obtained and comparisons between the separators complicated due to the differences in designs and the two different mesh sizes used for the upper cod-ends.

Trials in the Irish Sea with the inclined separator fitted to a conventional trawl (as above) are reported by Anon (2002a, 2003b). Experiments on both single and twin rig trawlers have demonstrated that the device allows fishermen to operate within the 18% by-catch limit. Separation of between 65 and 85% for cod is reported over all length classes. Almost all haddock are separated with this device and also a large proportion of whiting (over 50%). It is estimated that the trawl fitted with the separator caught considerably less cod per kilo of *Nephrops* than the traditional trawl. The author compares the separation achieved by the inclined panel and a conventional horizontal separator trawl and concludes that the inclined version has considerably higher separation efficiency. The inclined panel demonstrated good separation of small whiting (more than 50% escaping) compared to 27% for the horizontal panel as reported by Dunlin (1999). A similar improvement is reported for haddock, with almost all fish being separated with the inclined panel compared to

29–74% (Dunlin, 1999). Similar results were obtained by Hillis (1983; 1984) where a higher percentage of 0-gp whiting were retained in the lower cod-end.

A number of agencies have been testing the effectiveness of square mesh panels in low headline nets in the Irish Sea since the 1980s. UK authorities first introduced the panel into legislation in 1992, followed by Ireland in 1994 (Briggs, 1992; Armstrong *et al*, 1998). Several studies on whitefish trawls (having higher headlines of over 3m) have shown that the effectiveness of the panel is influenced by its position (Graham and Kynoch, 2002; Graham *et al,* 3003). These authors state that the panel is more effective, the further aft the panel is placed. However, Armstrong *et al* (1998) used catch comparison techniques to estimate the optimum position of a panel in a traditional Irish *Nephrops* trawl. They concluded that the panel is more effective when placed further forward.

A headline panel, having at least 15 rows of large 140 mm meshes, is required under current EU legislation although this is based on little or no scientific evidence. However, trials carried out off the west coast of Ireland suggest the use of large mesh (200 mm) in the whole top sheet of the panel from the headline back to the cod-end joining round is effective, with reductions in catches of undersize whiting and haddock in the order of 34% (Anon, 2001c).

As part of the Sea Fish Industry Authority large-scale programme to develop a '*Nephrops* only' trawl (see section 3.5.3), parallel haul experiments were conducted in the Clyde area with a large mesh (200 mm) panel fitted to an extended headline. A reduction of 71 and 72% of haddock and whiting respectively was recorded between the two gears. This is achieved with a 5% loss of target species.

The Sea Fish Industry Authority (Dunlin 1999) assessed the potential of the horizontal separator trawl in the Irish Sea. This is the latest in a series of experiments studying the potential of the horizontal panel started by Hillis (1984; 1983) in the early 1980s. The target species for discard reduction were whiting and haddock. It was found that the success in discard reduction was strongly related to the size of the fish. Where fish were small, typically less than 20 cm, the separation to the upper cod-end was very poor. Above this size, separation was good, comparing well with the levels found in other fishing trials. In these circumstances discard levels were reduced and the quality of the retained fish was markedly better than that from a conventional net. As a result these fish made a higher price on the market. This advantage was sufficiently strong for two of the three skippers involved to buy the experimental nets. One has been used on a regular basis.

However, as with many technical conservation measures, the separator trawl is very effective in some circumstances. Where very small fish are a problem then it is less effective. Where larger fish are involved, by-catch or quota restrictions apply, or quality is an important consideration then the use of this technology is likely to be beneficial.

The effect of twin thickness was assessed by Anon (2000). They conducted a simple catch comparison exercise carried out in the Irish Sea on board an Irish vessel testing 80 mm x 3.5 mm single twine against 80 mm x 6 mm (current legal maximum) and 80 mm x 8 mm single twines. Considerable reductions in *Nephrops* catches of 34% and 38% respectively were found.

Two research programmes recently funded by EU and member states (RECOVERY, QLRT-2001–00935 and NECESSITY, – see Section 4) aims to assess the effectiveness of various gears including large mesh upper panels, inclined separator panels and a reduced headline net in the Irish Sea and Clyde using vessels from Northern Ireland.

*Recommendations*

- Continued use of inclined separator and extension of the area in which the panel must be used until cod stocks recover
- Obtain parameterized data on current technical measures
- Assess effectiveness of horizontal separator with guiding ropes
- Tune square mesh and large mesh headline panels and determine critical design parameters: position, mesh size and dimensions of headline panel
- Develop technology to greatly reduce F on whiting
- Identify *Nephrops* only fisheries and introduce appropriate gears

***Western waters***

The French fleet operating in the Celtic Sea consists of around 90 vessels, accounting for ~70% of *Nephrops* landings

form the area. Around 20 of these vessels fish on the Porcupine Bank (FU 16) during some times of the year. The fleet concentrates on *Nephrops* as the key target species, but diverting their efforts to white fish during periods of bad weather. The vessels tend to fish with 80 mm cod-ends to avoid by-catch limits when using 70 mm. French vessels target other species of fish including cod (15% by weight), anglerfish (14%) whiting (10%) and megrim (8%) (Anon, 1999a). In fiscal terms, *Nephrops* accounts for 53% of the revenue, the remainder a mix of anglerfish (14%), cod (9%), megrim (6%) and whiting (4%).

The Spanish fleet on the Porcupine Bank (~30 vessels) is broadly split into two categories, larger vessels fish with whitefish trawls in the multispecies fishery for hake, megrim and anglerfish with *Nephrops* forming an important by-catch. The lower powered vessels specifically target *Nephrops*, especially during the summer months, with fish considered as a by-catch.

The season on the Porcupine bank is strictly seasonal, from May to December. For French vessels, *Nephrops* represents around 2/3 of the landings by weight with an important by-catch of anglerfish. In terms of revenue, *Nephrops* accounts for 82% and anglerfish 12%. There have been developments in the trawl designs used by the fleet, with the recent introduction of rock-hoppers and twin trawls. About 75% of the fleet target other species when catch rates are low for *Nephrops*

The Celtic Sea Fishery is currently the second most important prawn fishery for Irish vessels, with landings of approximately 2,123 tonnes in 2001. The main port is Dunmore East into which around 1,200 tonnes valued at €2.9m was landed in 2001. Most of this came from the productive Smalls grounds in the Eastern Celtic Sea. There are several other distinct grounds such as the East Labadie, West Labadie, Cockburn bank as well as important areas closer inshore on the Galley Head grounds, Ballycotten and other inshore bays of the south-west coast. Landings from these grounds were in the region of 700 tonnes in 2001. Up to 50 vessels in the size range 10–35m participate in the fisheries in this area, with most of them in the 16–25m size category and tending to be multipurpose only targeting *Nephrops* when environmental conditions are suitable and targeting demersal whitefish at other times. There are significant discards of hake, whiting and haddock as well as other species such as megrim, horse mackerel and herring. There is also considerable discarding of small *Nephrops*, particularly in the Smalls fishery.

On the west coast the grounds at the back of the Aran Islands are very important (2001 landings were 877 tonnes), particularly to the Rossaveal fleet. Further offshore the Porcupine Bank grounds yield valuable catches of large *Nephrops* during the summer months, although landings have declined in the last few years. There are approximately 25 vessels involved in the fisheries, using twin and single rig *Nephrops* trawls. The fleet is mainly based in Rossaveal and Dingle, although vessels from the east coast ports of Howth, Clogherhead and Kilmore Quay participate in the fisheries at certain times of the year.

*Technical measures in force*

Under the European Commissions "Hake Recovery Plan" (Regulation EC No 494/2002, amending regulation No 1162/2001), the minimum mesh size for all trawl fisheries in both areas VII and VIII is 100 mm, unless hake comprise less than 20% of the total amount of marine organisms on board. This does not apply to vessels of length less than 12 m and which return to port within 24 hours of departure from port. Vessels targeting *Nephrops*, however can use 70 mm MMS in areas VII and VII provided that they do not exceed a 20% by-catch limit and have a minimum of 35% live weight *Nephrops* on board. In addition, a prohibition of fishing with trawls with a cod-end mesh size of between 55 and 99 mm, and with fixed nets of mesh size less than 120 mm, in two closed areas (Figure 6) (shown in red), though during 2001 nets of 70–99 mm were permitted in the inshore sectors (shown in blue) of these areas, subject to Member States with vessels affected in this area carrying out extensive observer schemes. These regulations were initially intended to reduce the catches of small hake in fisheries taking place in hake nursery areas. Commission Regulation 494/2002 amended this regulation in 2002 and the blue areas were removed and therefore not subject to the 100 mm cod-end mesh size restriction. In the latest proposed consolidation of Regulation 850/98, however, the area has once again been changed to encompass the entire blue and red areas and including the coastal waters inside the Irish and the French 12 miles limits right up to the coastlines.

*Problems associated with Celtic Sea*

The 1999 WG on *Nephrops* report that there is considerable discarding of *Nephrops* in the Celtic Sea fishery. The present MLS for the area as 25 mm CL is probably compatible with the 80 mm mesh size used by the fleet. High grading occurs due to the French fishermen's organisations setting a minimum landing size of 35 mm for marketing purposes. Rochet *et al* (2002) estimate that 20% of the *Nephrops* catch taken by the French *Nephrops* fleet was discarded in 1997. Considering the relatively small mesh size used in comparison to MLS of fish species caught in the fishery, intuitively, discarding should be These authors suggest that ~55% of the total biomass in the catch was

discarded during the same time period. Whiting (41%) were the principal fish species discarded.

The fishery at the back of the Aran Islands has been recognised as a nursery area for hake, haddock and whiting and at certain times of the year discarding of these species is a major problem. The offshore fishery at the Porcupine Bank is a much cleaner fishery but widespread discarding of unwanted species such as argentine and boar fish can occur.

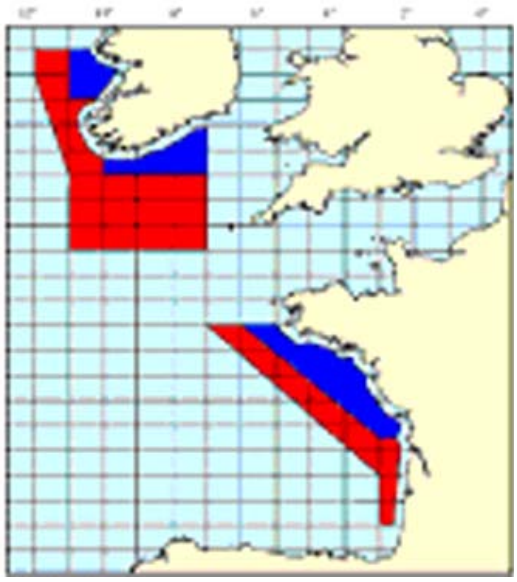

Figure 6. Restricted areas covered by the Hake Recovery Plan.

*Recommendations*

- Assess methods of improving the size selection of *Nephrops* such as square mesh cod-ends and grids
- Use MLS set by fishermen's organization as a benchmark
- Investigate critical design parameters of headline and square mesh panels to improve size selection of haddock, hake and whiting.
- Assess the effectiveness of large mesh upper panels
- Assess the economic impact of increasing cod-end mesh size to 100 mm in *Nephrops* fisheries associated with the Hake Recovery areas.

*Bay of Biscay (including North Galicia and Cantabrian Sea) – (VIIIa, b, c, d, e)*

The Bay of Biscay fishery is much larger and has between 250 and 300 trawlers fishing for *Nephrops*. About half this fleet targets other species when catch rates of *Nephrops* are low. *Nephrops* accounts for 37% of the landings (by weight) but contribute 60% of the revenue to the fleets. Hake and anglerfish constitute the other major components, 17 and 9% by weight and 11% and 8% in economic terms respectively. There is an increasing trend in the use of twin-rig trawls in this fishery.

The Spanish fleet fishes the Cantabrian Sea, North Galacia, and West Galacia. The vessels are single trawlers fishing a mixed demersal fishery with *Nephrops* representing 3% of the landings but 12% of the revenue. Suitable grounds are found on the upper slope of the continental shelf at depths of up to 500 meters. The fleet in the early 1990s consisted of about 180 vessels. The gulf of Cadiz had around 273 vessels fishing in the mixed demersal fishery, which catches some *Nephrops*. ICES sub areas VI, VII, and VIIIa, b, was fished by a fleet of 153 vessels, in a mixed demersal fishery targeting, hake, megrim, angler fish and *Nephrops*, with by-catches of witch, fork-beard, ling, cephalopods etc. *Nephrops* are also an important by-catch in the Northern Portugal demersal trawl fishery.

*Technical measures in force*

For ICES subareas VIII a, b, d and e, the legal requirements are the same as given in section 3.6.1.

*Problems associated with Bay of Biscay fishery*

The ICES WG on *Nephrops* stocks consider that size selection of *Nephrops* requires urgent attention. *Nephrops* in the range 19–26 mm CL contribute ~40% of the catch (by number) for both male and female. However, it is reported that over 70% of these are discarded. As such "any selective device preventing any catch of this age would improve the status of the stocks. In the absence of such a device or if its implementation is delayed, a significant reduction is needed in order to rebuild the stocks at levels of the early 1990s."

Despite the introduction of the increased mesh size in certain areas, the WG on the Assessment of Southern Shelf stocks Hake, Monk and Megrim (Anon, 2003d) suggests that consideration should be given to the vessels with exemption from the Hake recovery Plan (inshore vessels under 12m). The *Nephrops* grounds in the northern part of the bay of Biscay are also important nursery areas for juvenile hake, attempts have been made to develop a more selective trawl but Anon (1999), see section 3.7.3

Discarding of *Nephrops* by the French fleet is quoted as being substantial (Anon, 1999) due to a MLS of 25 mm CL being set by the French fishermen's organisation. The current EU minimum is 20 mm CL. Anon (2001b) report comments that despite the recent (2000) increase in mesh size to 70 mm has not improved the selectivity of *Nephrops*.

The biomass of *Nephrops* is in serious decline in both the North Galica and Cantabrian Sea area, and as such Anon (2003a) has suggested a zero TAC in this area. The authors also note that in order to achieve this, all fishing activity where *Nephrops* are taken as a by-catch should be stopped. Subsequently, the STECF have taken this advice and recommended that a recovery plan for *Nephrops* stocks in this area be implemented.

*Remedial measures tested*

A number of devices are presently being tested under the auspices of a part EU funded project "program of improvement of trawl selectivity in the Bay of Biscay – ASCGG" The research is ongoing and the following sections provide details of preliminary results.

**Square mesh panels**

Square mesh panels have been tested in the Bay of Biscay with the objective of reducing the capture of juvenile hake. Initially, a 70 mm, 3m long panel was inserted at a variety of positions in the extension piece of the trawl but proved to be ineffective. Subsequent (ongoing) trials with a 6m long, 120 mm panel was inserted in front of the extension demonstrated a significant reduction in the retention of mature and juvenile hake of between 30 and 50%. Trials are presently being undertaken on 'smaller' vessels with a 100 mm, 2m long panel.

**Grids**

Research is continuing in the region to assess the effectiveness of flexible grids for improving size selection of *Nephrops*. Initial results with a grid having a bar spacing of 20 mm, placed in the lower part of the extension are encouraging, demonstrating a sharper selection and a reduction in discarding of *Nephrops* by 50%.

**Large mesh headline panels**

Current research being conducted on large meshes placed in the panels in the first part of the trawl (cover/square). Preliminary results suggest that the panel is ineffective and that additional large mesh panels were requires in the upper and lower wings of the trawl. The results indicate that there is an improvement in selectivity for both hake and *Nephrops* but are highly variable between trials. The panel appears to be more effective on low headline (vertical opening less than 2m) trawls in comparison the trawls used by larger vessels.

**Future actions**

Improve size selection of *Nephrops*, using market demands as benchmark

Develop a trawl to exclude *Nephrops*

*Portugal (ICES IXa, b)*

The Portuguese fleet fishes south (Algarve) and South western coasts Portugal, at depths from 150 to 800 m, approximately, and in 2001 consisted of 33 vessels (Anon, 2003a) of which 28 were active. The fleet predominantly target a mixed species fishery for *Nephrops*, rose (*Parapenaeus longirostris*) and red shrimp (*Aristeus antennatus*) and, in smaller quantities, the giant red shrimp, *Aristaeomorpha foliacea* and the scarlet shrimp, *Aristaeopsis edwardsiana*. A significant part of *Nephrops* (10–15%) is landed by fish trawlers. Up until the late 1980s *Nephrops* was the principal target species, but catches have decreased considerably from a peak of 2000 tonnes in the 1970s to approximately 200 tonnes by 2000. Concurrently, landings from rose and red shrimps have increase attaining about 1400 and 300 tonnes respectively.

*Current legislation*

Vessel licenses are issued for all crustaceans rather than for any particular species due to the multispecies nature of the fishery. Vessels targeting fish may also catch crustaceans, but this must only represent 5% of the overall catch. Management of the stocks is accomplished by TAC and quotas (only for *Nephrops*) and a complex array of technical measures. The present MMS is 55 mm but for 2003 crustacean trawlers can apply for the simultaneous use of 70 mm. There is a mandatory minimum crustacean catch of 30%. MLS (cephalothorax length) are defined only for *Nephrops* (20 mm), rose shrimp (24 mm) and red shrimp (29 mm). Fishing for rose shrimp is interdicted from the 1st of September until the last day of November, at shallower waters where juveniles are concentrated. For 2003 the fishery was closed during January.

*Current problems*

The increasing fishing effort that management measures have been unable to prevent, has been aggravated by the progressive modernisation of the fleet and consequent increase in efficiency. The decay of *Nephrops* stocks, which are considered severely overexploited, led to the increase in the capture of rose shrimp, which is now the most captured species, and also of red shrimp.

The mixed nature of the fishery and the extension of the depth range exploited from 150–600m to about 800m has altered the catch and by-catch composition considerably. In common with many other Southern European and Mediterranean fisheries, it is difficult to classify or label any economically valuable component of the catch as target or by-catch. For instances, the commercial fish by-catch, especially hake and monkfish, normally of reduced importance, is perceived as important in periods of scarcity of crustaceans, which further complicates the management of the fishery. Monteiro *et al*. (2001) estimated that between 1998 and 1999, of the 91 species caught only 26 were landed, the remaining vertebrates and invertebrates were discarded. In another study, dated from 1995 and 1996, Borges *et al*. (2001) estimated that an average 70% of the catch (by weight) was discarded between. The main reasons for discarding are small or null economic value of by-catch species or catch below minimum landing or market size.

In common with the *Nephrops* stocks in area VIII (see above), the stock in area IX is also in a precarious state. The STECF (2002) recommend that a recovery plan be implemented for *Nephrops* in the Iberian area (FU 26–30). In relation to fishing technology, the STECF recommend that 'practical management measures be discussed that can help achieve the goals of the recovery plan'

*Remedial measures tested.*

**Separator trawls**

Campos *et al* (1996) assessed two types of sorting devices with various mesh configurations, an oblique sorting panel mounted in the rearmost part of the trawl dividing a twin cod-end arrangement. The separating panel consisted of two components. A leading upward sloping forepart, constructed from either 120 or 80 mm netting, was installed with the purpose of guiding larger individuals or higher swimming fish into the upper cod end, while the rear part of the panel, a horizontal panel of 55 mm netting, divided trawl into the two different cod-ends. The large mesh in the fore panel was selected to allow smaller individuals or benthic animals to pass into the lower cod-end. This was then assessed in conjunction with a square mesh panel fitted above the sorting panel having mesh sizes of either 70 or 100 mm. The effectiveness of a 100 mm square mesh panel without the guiding panel was also assessed. The sorting panel alone (120 mm) resulted in 10% of the total weight for shrimp being guided into the upper cod-end, while *Nephrops* was completely retained at the lower cod-end. Segregation of fish species to the upper codend was observed to be 88 and 70% for blue whiting and boarfish respectively, two non-commercial by-catch species, and 55% for horse mackerel. The inclusion of the square mesh panel, resulted in the rejection of 64, 10 and 30% of blue whiting, boarfish and horse

mackerel respectively with the 70 mm window, while these figures were improved by increasing the panel mesh size to 100 mm, particularly for boarfish, for which 60% of the total catch was excluded from the trawl. By reducing the guiding panel mesh size from 120 to 80 mm, although the separation of fish improved, higher fractions of shrimp and *Nephrops* catches were guided towards the upper trawl section, with substantial losses through the square mesh window. The results obtained for the square mesh panel alone were poor. Active escape behaviour was observed only for blue whiting, with 55% of the total catch in weight escaping through the square mesh panel.

**Grids**

Fonseca *et al* (2002) tested a rigid grid with an escape hole was open to the surrounding water allowing those animals not passing through the grid to escape. A lower horizontal gap along the base of the grid was included in the design at the base to facilitate the passage of *Nephrops*. Although the retention of the non-commercial by-catch of blue whiting (*Micromesistius poutassou*) and boarfish (*Capros aper*) was reduced by 73.1% and 74.7% by number respectively; 46.9 and 47.7% by weight, losses of target species were also considerable. The losses, by number and weight were; *Nephrops* (4.5; 9.8%), rose shrimp (3.9; 4.0%) and red shrimp (5.3; 6.9%); for fish, monkfish *Lophius* spp (46.9; 56.5%) and hake *Merluccius merluccius* and (32.2; 43.9%). A first simulation of the economic consequences (Borges *et al.,* 2002) suggests that these losses would be relatively small (8% or less).

**Mesh size/geometry**

Campos *et al* (2002, 2003) addressed the problem of codend selectivity for the three main crustacean species, *Nephrops*, rose shrimp and red shrimp, by testing three diamond mesh size (55, 60 and 70mm) and a full square mesh cod-end constructed from 55 mm netting. Catch rates for *Nephrops* were generally small and problems were encountered in obtaining estimates for *Nephrops* due to high retention at all length classes in the test cod-end. Using the AIC criterion, the models with the best fits showed that for *Nephrops* there was no significant difference in L50 for the three diamond mesh cod-ends, but a higher L50 for the square mesh configuration. However, mesh configuration (diamond to square) and by increasing mesh size was found to give a significantly higher selection. Mesh size and mesh configuration were found to affect the selectivity of rose shrimp, with a higher L50 for increasing mesh size and altering the cod-end geometry from diamond to square.

***Recommendations***

- Increase MMS to 70 mm and consider the potential of full square mesh cod-end considering recent experiments
- Consider the development of a trawl to exclude *Nephrops*
- Apply and assess existing mitigation measures such as square/large mesh panels and define optimum design parameters for improving selectivity of hake, blue whiting and boarfish.
- Continue development of species selective devices but considering economic impact on the fleet

*Mediterranean*

In recent years regulations governing various aspects of gear design have been introduced in order to improve the selection process. In the Mediterranean, it is only in the last few years that there has been a strong effort towards the development of a common fisheries policy. In comparison, in northern European waters there has for some time been considerable effort towards common fisheries policy principally because of over-fishing. Research in northern waters had primarily been direct through the effort of ICES and latterly by the EC. In the Mediterranean over-fishing has been of some concern but the only efforts that have been made are national and this has led to a generally fragmented policy with individual regulation of individual countries waters. Although the General Fisheries Council for the Mediterranean (GFCM) is an equivalent body to ICES, it does not have any regulatory power.

Currently, traditional Mediterranean trawls are produced with fine and non-selective mesh size (MMS 40 mm) and fishing boats are involved in multispecies fisheries, landing several different species of different economic value. The non-selective nature of the trawls has meant that there is a high rate of discarding and that many undersized individuals of commercial species are landed illegally. Improvements of selectivity is therefore of prime importance, through various methodologies. Previous studies for improvement of fishing gear selectivity in the Mediterranean have been very few but include investigations into different sized cod-ends in the bottom trawl fishery of the Adriatic Sea (Jukic and Piccinetti, 1988; Tokac *et al*., 1998; Fiorentini *et al*., 1999), and investigations into the use of square mesh cod-end

(Stergiou *et al.,* 1997). Stewart (2001) provides an extensive review of the most recent review of selectivity studies conducted in the in the Mediterranean, in which the author reviews 116 relevant papers.

*Western Mediterranean*

Spanish demersal trawlers target *Nephrops* in depths of 300 to 500m typically, *Nephrops* represent 10% of the total economic landings of the fleet which operates form the Catalan coast. In common with the other Southern European fisheries, this is also highly multispecies. The fishery is conducted on a narrow shelf and on the continental slope, which are highly steep and crossed by many submarine canyons, as a consequence, by area, the level of fishing effort is intensive.

*Eastern Mediterranean*

As with the Western Mediterranean, the Eastern fishery is characterized by a wide variety of species, both marketable and discarded and the small mesh size used, with *Nephrops* being part of an assemblage of target species. Countries principally involved are Italy (Adriatic) Greece and Turkey (Aegean).

Italy has the highest landings of *Nephrops*. The official annual landing of *Nephrops* by the Italian fleet is around 2700 tonnes. *Nephrops* is an important economic component of the mixed species fishery, but rarely it ranks first by weight in the landing of trawlers exploiting the so-called "*Nephrops* grounds". Specialised otter bottom trawlers exploit this species. The fishery is characterised by a seasonal pattern, with catches declining during the winter and increasing during spring and summer. The fisheries are subject to technical measures such as minimum landing size and, in some areas, by no take zones, but these measures are not adequately enforced. In several areas the state of the stock(s) is unknown. In general, however, different analyses indicate situations from moderate exploitation to weakly over-exploited. Evaluations of *Nephrops* resources are currently derived from MEDITS survey (Mediterranean Trawl Survey) although the time-series is not yet long enough to show sound and reliable time trend modifications of recruitment indexes and of relative abundance of the available demographic fractions.

In Greece there is not a directed *Nephrops* fishery as in Western Europe. *Nephrops* form a part of a multispecies trawl catch. There are about 36 large vessels fishing the northern Aegean Sea, with LOA ranging from 17–25m and up to 800 HP and undertaking 1–2 day trips. From June to September the grounds are usually closed to trawling. Trawling takes place in depths ranging between 200 and 650 Mt with the 200 - 500 Mt band giving the best results. *Nephrops* are caught along with Blue Whiting, Hake, Flatfish, and 3 species of Penaeid shrimp. There are other less important species landed as well. *Nephrops* are found up to 80 mm carapace length and the population peaks at around 40 mm. Very few *Nephrops* are discarded from the trawl catches. Total catches of *Nephrops* are falling in Northern Greece from 217 tonnes in 1989 to 122 tonnes in 1998. The catch per unit effort CPUE from 1975 to 1999 has fallen by a factor greater than 10% of 1975 levels, and it is predicted to continue to fall with current levels of effort.

The Turkish fishery in the Northern and Eastern Aegean is similar to that of Greece, being highly multispecies, the principal target species being hake, *Nephrops*, monk, several species of shrimp and whatever other species are marketable. In 1998 it is estimated that 18–25% of the catch is comprised of *Nephrops*, with 480 tonnes being landed. A series of interviews with fishermen suggested that the CPUE of *Nephrops* has been decreasing since 1998; average catches of 80 – 100kg per day, now diminished to 30 –50 kg. There are no reliable catch or discard data available, although fishermen say that on occasion large quantities of juvenile hake are caught, some sell this portion of the catch, while others discard. Over 30 trawlers operate in the international waters of the Aegean Sea during the late spring and summer, this effort shift from national waters is due to a seasonal closure being applied during these months.

*Current Legislation*

The minimum mesh size permitted in the entire Mediterranean area is 40 mm (Regulation (EC) 1626/94), with no additional gear related technical measures applied. Turkey applies national legislation, setting the MMS at 44 mm. In many of the countries some form of effort limitation is applied. The Spanish fleet operating in the Western Mediterranean is only permitted to trawl during the day (06:00 – 18:00). Closed seasons for demersal trawling fleets are applied in both Greece (June – September) and Turkey (1 April – 15 July). The cod-end mesh size used is currently 40 mm full mesh. In Greece the MLS for *Nephrops* is 20 mm carapace length and 70 mm total length, no MLS is applied in Turkey.

Italian bottom trawl are made in knotless polyamide and have a low vertical opening (around 1 m). Previous studies on cod-end selectivity were carried out mainly in the Adriatic Sea (Jukic and Piccinetti, 1988, Fiorentini *et al*., 1999) demonstrated that current mesh sizes in use do not permit the escape of undersized hake and *Nephrops*. Fishing effort is

controlled by a ban on trawling during weekends, official holidays, and some other appropriate measures (such as closed seasons and areas) are also in force in the Italian waters. Due to the different times of the year and localities when and where juveniles make up a large proportion of the catch, the institution of closed seasons for bottom fisheries change along the Italian coast. In general the closed season is 45-days long and range from July to October. It is obligatory in the Adriatic Sea but not compulsory in the Tyrrhenian and Ionian waters.

*Current Problems*

Considering the present MMS in the Mediterranean, the obvious problem is the small size of the individuals, both target and discarded species retained. However, the discarding may not be as acute as the seen in the Northern European fleets as the MLS applied are typically appropriate for the mesh size used. In addition, there is a considerable market for small and/or juvenile fish and shellfish, however, the MLS are below the size of first maturity for many species. There is however, a discard problem with many species, both marketable and non-marketable, this is hardly surprising considering the species diversity seen in these fisheries. In the Western area, by-catches of hake, blue whiting, fork beard, angler (monk) and conger are reported. In view of the life history of angler and hake, these species demonstrate clear signs of exploitation. Peak effort in the Adriatic *Nephrops* fishery coincides with large concentrations of juveniles whiting, poor cod, hake and blue whiting on the fishing grounds. Consequently, large numbers of these fish are discarded being of a size too small even for the Mediterranean consumers. A comparative study of the discards from *Nephrops* fishery in the Central Adriatic and West Scotland grounds revealed higher discards per kg of *Nephrops* landed in the Adriatic, but much lower discards when the total landed catches are compared (Wieczorek *et al*., 1999). These results reflect the alimentary preferences of the Italian consumers that make it possible to land small-sized species and undersized fish discarded in other fisheries. Size frequency distributions obtained for demersal species suggest most of the stocks are fully exploited or over-exploited.

*Remedial Measures tested*

**Grids**

The grid technology developed in the Northern European fisheries under the auspices of the NETRASEL project was also tested in the Aegean Sea to assess the suitability for species segregation into two cod-ends, with particular focus on separating *Nephrops* and shrimp from Hake (Anon 2001a). Three different grids were tested, (i) a 35 mm bar spacing with a lower gap of 200 mm (35/200), (ii) 30/150 and (iii) 25/200. Length dependant models were derived for all three species, which demonstrated that the probability of retention in the upper cod-end was length dependant for *Nephrops* and hake for all three grids. The trials were partially successful in that some degree of separation was obtained, but selection of the optimum grid configuration is a compromise between maximizing the amount of hake segregated into the top cod-end while minimizing the shrimp/*Nephrops*. The 35/200 mm grid gave the optimum efficiency, the retention in the lower cod-end was 68, 70 and 50% from *Nephrops*, shrimps and hake respectively.

**Square mesh panels**

Catalano and Smith (1994) assessed the use of a 52 mm square mesh window in the mixed fishery in the southern Aegean Sea. Although a wide range of species was caught, few escaped through the square mesh window. The lack of success is attributed to the lack swimming ability of the small fish encountered.

**Mesh size**

Mytilineo, *et al* (1998) assessed the trawl cod-end selectivity on *Nephrops* using diamond meshes of 16 mm, 20 mm, 24 mm and 26 mm nominal side mesh size [half mesh] The cover cod-end method was applied for the sampling. The logistic function for the probability of retention by the cod-end was used for the estimation of selectivity parameters from all data combined. The results indicated that the 16 mm mesh size was not selective and that almost all individuals were retained. The 24 mm and 26 mm mesh size showed quite similar results and were a little more selective than the 20 mm mesh size. None of the experimental mesh sizes proved to be adequate for *Nephrops*, since all estimated L50 were lower than the length at first maturity and L25 were lower than the legislated minimum landing size. It is suggested that mesh size should be much larger than 20 mm; the size legislated by E.U. for the Mediterranean.

Sarda *et al* (1993) conducted experiments with five different mesh sizes (38, 42, 45, 52 and 60 mm) to determine the size selectivity of *Nephrops*. The 38 mm cod-end retained almost all individuals. The selectivity data for the 42 and 45 mm cod-ends gave L50s that were below the length of first maturity, while the 52 mm cod-end gave an L50 just above first maturity. Although the 60 mm cod-end gave the highest L50, that would provide escapement of all first spawning individuals, the authors conclude that the selection ogive that too flat to be effective, and that the regulation of mesh

selection would not appear to be an optimum means of fisheries regulation.

Stergiou *et al.* (1997) and Stergiou (1999) conducted experiments with three different trawl cod-ends, 14 mm (bar length) diamond mesh (14 D), 20 mm square mesh (20 S), and 20 mm (bar length) diamond mesh (20 D). The results indicated that i) the 20D and 20S allow significantly more individuals to escape through the meshes ii) the mean weight of the retained individuals for 20 D is significantly larger than those for 14 D and 20 S. The retained proportions for *Nephrops norvegicus* did not differ considerably for the three meshes. The proportion of *Nephrops* population retained was 0.80 for 20 D, 0.85 for 20 S and 0.99 for 14 D. The direct estimation of L50 for 14 D was not possible because of the very small number of specimens escaping through that cod-end. The 20S had higher and sharper selectivity than 20 D (higher 50% retention length and selection factor, lower selection range) and retains fewer undersized individuals than 20D.Yet, the 50% retention lengths for 20 D and 20 S were both lower than the length at 50% maturity, which indicates that even the use of 20 D and 20 S may provide little opportunity for reproduction. However, care should be taken in interpreting these values, as the cod-end cover used was not supported, which may have resulted in cod-end masking.

Dremière *et al*. (1999) carried out sea trials in order to evaluate the escapement through the body or under the footrope of the sampling trawl used for the MEDITS programme. *Nephrops* had the highest rate (64%), mainly represented by small-size individuals. The experiment also showed that substantial selection can occur in the main body of the trawl.

*Future actions*

The results from Stergiou *et al.* (1997), Stergiou (1999) and NETRASEL project indicate that the use of appropriate mesh sizes in codend might be effective in Greek trawl fishery under certain conditions. Also the use of selection grid was proved to be functional in the *Nephrops* fishery in N. Aegean Sea. However, further experiments and improvements should be made to advance the selectivity of grids and further studies should be made in order to comprise grids as one of the tools for a better management and protection of demersal resources in Greek waters.

Work conducted by Ege University in Turkey (EUFF) demonstrated that the use of polyamide (PA) cod-ends (as opposed to polyethylene [PE]), square mesh escape windows, reductions in the cod-end circumference and grids all had a positive effect on the selectivity of most of the targeted fish species. Such applications should be tested in areas where *Nephrops* is one of the target species (Huseyin Ozbilgin, personal communication)

**Continuing work**

Despite the raft of technical measures associated with the *Nephrops* fishery, in many cases, the discarding of target and non-target species is still high. It is clear that further developments are needed to improve the size and species selectivity. However, the EU is trying to address many of the issues relating to fish discards. A recently approved EU project, currently at the negotiation stage, is more wide ranging in terms of gear development and geographical coverage.

The NECESSITY project covers almost all of the EU/Norwegian *Nephrops* fisheries, from the Kattegat and Skagerrak, North, Irish and Celtic Seas, Iberia, Portuguese and Mediterranean waters, specifically focusing on improving fish selectivity. The list is considerable:

- Nordmøre grids - ICES areas IXa, IIIa, IVb, VIIb;
- Inclined separator panels - IVb,a, VIIg;
- Square mesh panels - IXa; Mediterranean fisheries.
- Large mesh headline panels – VIIb, Via, IIIa.
- Large mesh panels in beam trawls – IVb
- Reduced headline height in beam trawls – IVa

This project will not only provide valuable data on existing legislation, but also an important opportunity to compare the suitability of individual measures over a range of highly diverse fisheries. Although the project does include a limited amount of work on *Nephrops* selection, this area still requires urgent attention.

**Conclusions**

- In order to assess future developments, a benchmark of population independent selectivity parameters based on current legislation is required.
- Relationship between *Nephrops* biology (age at first capture), selectivity, minimum landing size and fishermen's selection should be investigated in order to provide optimum selectivity goals.
- The size selection of *Nephrops* is poor, resulting in a high degree of discarding in certain fisheries. The problems are not associated with low L50 but the absence of length related selection. Any improvements to reduce discards need to take account of potential loss of marketable catch associated with large selection range.
- The mechanisms of *Nephrops* selection should be investigated and the principal factors affecting size selection in the cod-end and extension, such as mesh size and shape, twine type, circumference, lifting bags and grids should be identified.
- Potential for improving *Nephrops* size selection in areas of the trawl other than the cod-end should be considered
- The development of *Nephrops* trawls that give broadly similar selection for whitefish as a whitefish trawl is urgently required.
- Harmonisation of technical measures between adjacent areas should be considered.

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