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

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

Abstract

A review of the commercial trawl fisheries where *Nephrops* is a component of the catch was undertaken. These have considerable geographical coverage, ranging from Iceland to Portugal and into the Mediterranean. *Nephrops* is a highly important commercial species, valued at 208 million Euros (€) in 2001. The fisheries, with a few exceptions, are typically multi-species, 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 of other species 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 lack of parameterised selectivity data for many of the existing technical measures, making any population independent assessment of their effectiveness impossible. The report is divided into geographical areas and, for each of these, the fisheries are described, fleet adaptations to legislation are discussed and a review of the remedial measures that have been tested or applied is provided. Based on this information, fishery or area specific recommendations are made. In addition to the fishery specific recommendations, more general recommendations are also given.

1 Introduction

1.1 Background to the report

In recognition of the bycatch and discard problems associated with European *Nephrops* fisheries, in 2002/–2003, the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) conducted a review of available technical mitigation measures, with the following terms of reference:

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 Northeast 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.

During the WGFTFB meeting held in 2003 a number of presentations were given. These were based on recent research programmes aimed at reducing unwanted bycatch and discarding associated with specific *Nephrops* fisheries, abstracts for individual presentations can be found in ICES (2003a). In addition, a review document was presented and ratified by the working group. The document outlined specific problems associated with *Nephrops* fisheries where trawls are used, a summary of current legislation, available remedial measures and their effectiveness as well as providing general and fishery specific recommendations. The review document forms the basis of this *ICES Cooperative Research Report*.

While every attempt has been made to ensure that the legislation described in this report is up-to-date, the authors do not take responsibility for its accuracy and reference must be made to the appropriate national authority for the correct legal position.

The work in preparing this report is based on contributions from an *ad hoc* subgroup of the ICES Working Group on Fishing Technology and Fish Behaviour. The following people have contributed or provided comments on the contents:

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1.2 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* is also one of the most widely distributed commercial species, with a considerable geographic range; from Iceland (64°N) to the southern tip of Portugal (36°N) 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 multi-species with other components of the catch (fish or other crustaceans) being economically important. The importance of *Nephrops* varies considerably between fisheries. In some areas, *Nephrops* is the main component, with other species considered as bycatch, the opposite being true elsewhere. 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), bycatch limitations (minimum percentage target species), additional trawl design requirements 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 sub-divisions for legislative and biological considerations. The ICES Working Group on *Nephrops* (WGNEPH) treats the stocks on the basis of functional units (FUs), which are subdivisions of regional management units. Area charts showing these FUs together with WGNEPH management units and ICES areas are shown in Figure 1a, b, c and Table 1.

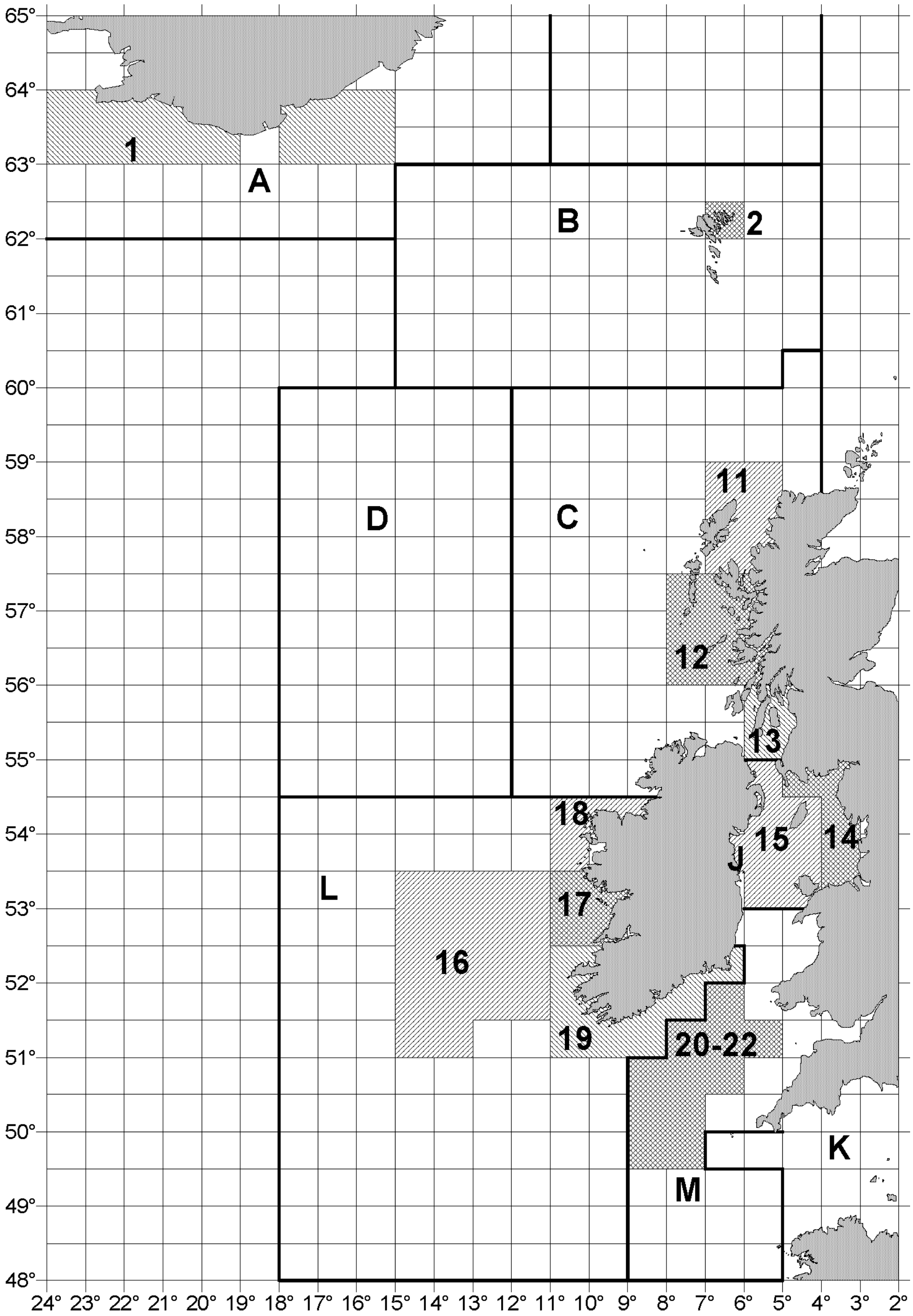


Figure 1a. *Nephrops* Management Areas and Functional Units in ICES Subareas V, VI and VII. Numbers and figures refer to the Management Area and Functional Unit given in Table 1.

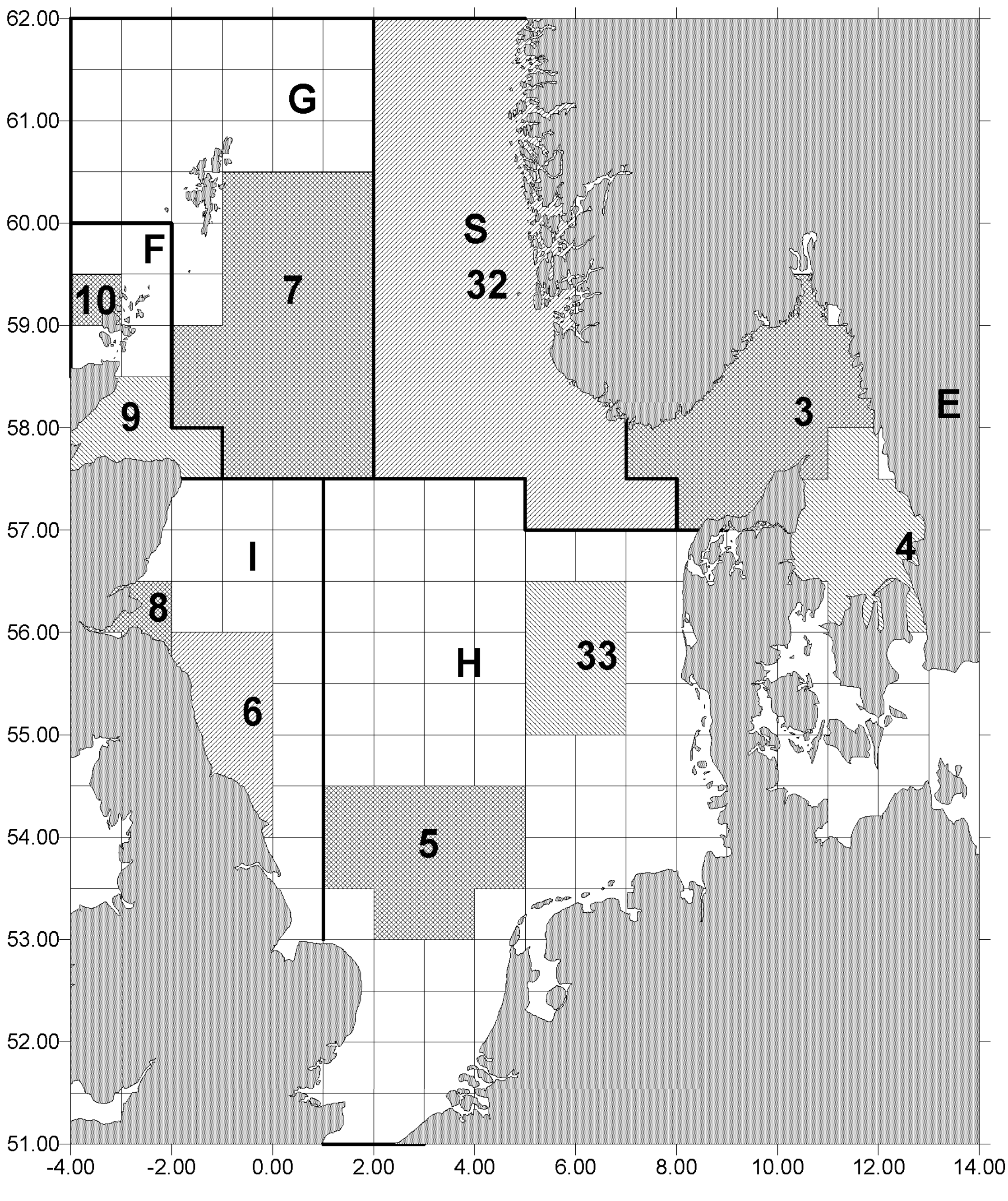


Figure 1b. *Nephrops* Management Areas and Functional Units in ICES Subareas IIIa, and IV. Numbers and figures refer to the Management Area and Functional Unit given in Table 1.

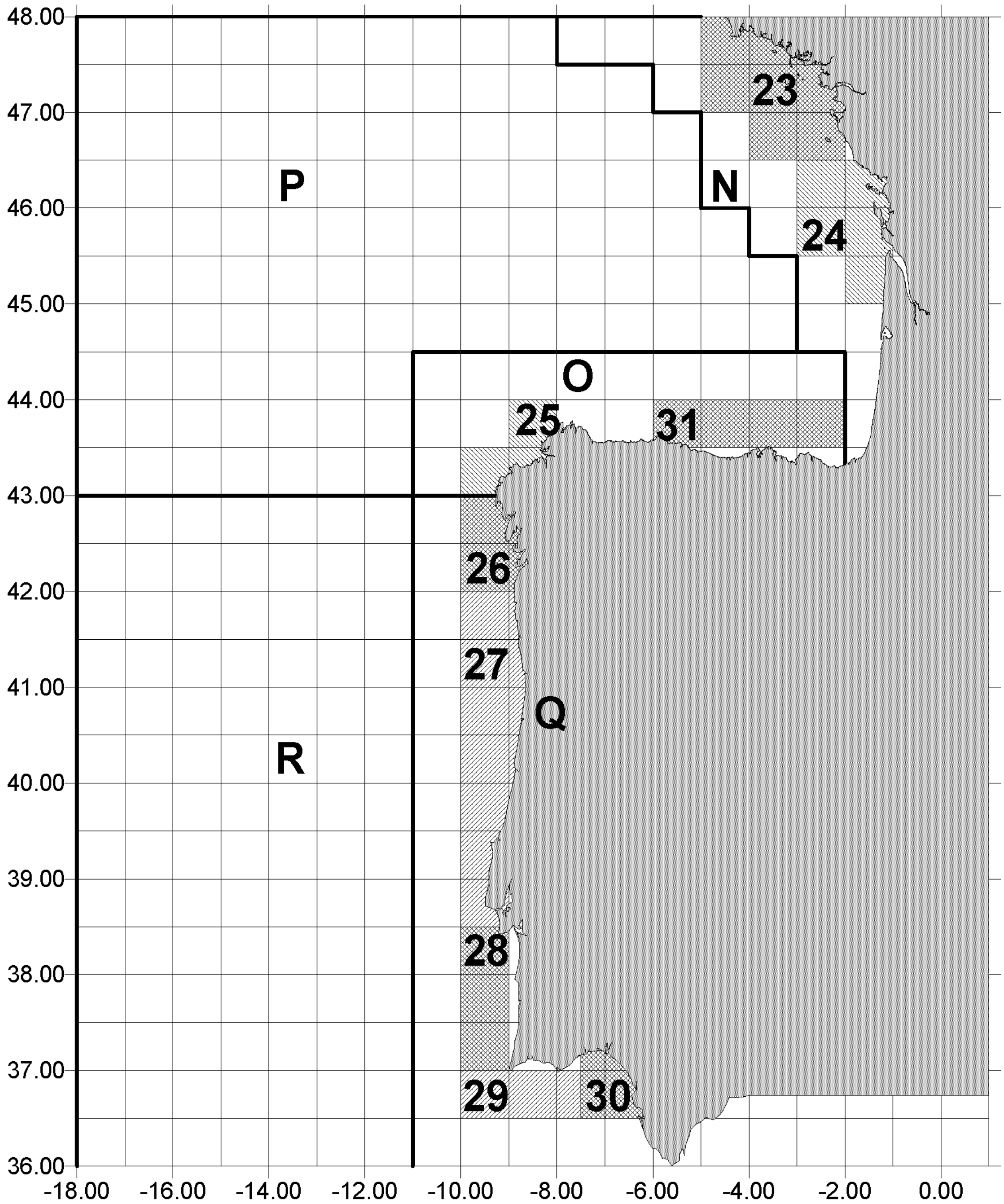


Figure 1c. *Nephrops* Management Areas and Functional Units in ICES Subareas VIII, IX and X. Numbers and figures refer to the Management Area and Functional Unit given in Table 1.

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	Faroe Islands
C	VIa	11 12 13	North Minch South Minch Clyde
D	Vb (EC) + VIb		None
E	IIIa	3 4	Skagerrak Kattegat
F	IVa, rect. 44–48 E6–E7 + 44E8	9 10	Moray Firth Noup
G	IVa, West of 2°E excl. MAF	7	Fladen
H	IVb,c East of 1°E excl. rect. 43F5–F7	5 33	Botney Gut Off Horn Reef
I	IVb, c, West of 1°E	6 8	Farn Deeps Firth of Forth
J	VIIa, North of 53°N	14 15	Irish Sea East Irish Sea West
K	VIId,e		None
L	VIIb,c,j,k	16 17 18 19	Porcupine Bank Aran Grounds Ireland NW coast 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 31	North Galicia Cantabrian Sea
P	VIIId,e		None
Q	IXa	26 27 28+29 30	West Galicia North Portugal South-West and South Portugal Gulf of Cadiz
R	IXb + X		None
S	IVa, East of 2°E + rect. 43F5–F7	32	Norwegian Deep

1.3 Evolution of *Nephrops* trawling

The directed fishing for *Nephrops* on a commercial scale began in the late 1950s. *Nephrops* were initially treated as an unwanted bycatch in a number of European trawl and seine fisheries. As markets for *Nephrops* developed, fishermen began to target them specifically, initially using seine nets but fished as otter trawls, using flat wooden otter boards to spread the gear. The nets were constructed from comparatively small mesh, 55 mm in the codends and lower bellies. They were rigged to give a low headline height (<2 m), increasing the spread of the crown and bosom. As *Nephrops* is a non-herding species, the width of the trawl bosom largely dictates the catching efficiency of the trawl, with the length of the wings and sweeps and bridles playing little part in the capture process.

Dedicated *Nephrops* trawls were then developed, particularly for the waters of the UK and Ireland. The traditional *Nephrops* trawl has a low headline; typically less than 2 m, with short wings, constructed from single polyethylene, 70 or 80 mm mesh throughout, although some trawls are constructed with a larger mesh size in the upper sections. Although fish are taken using this type of trawl, they are predominantly designed for the capture of *Nephrops*. This design was the precursor to what is known now as a 'Scraper' trawl. This is a low headline trawl, similar to the traditional *Nephrops* trawl but with extended wings and of a heavier construction. The extended wings increase the herding efficiency of groundfish species such as plaice and monkfish. As these are often preferred for more mixed fisheries, they typically have a larger mesh size, >100 mm, to comply with catch regulations. The dual-purpose trawls are similar in design to the scraper trawl but have an increased headline height, to enhance the capture of finfish such as haddock and whiting.

Initially, *Nephrops* trawling was conducted in areas with a fine, muddy substrate so requiring only a light groundgear, typically made from natural fibre (grass rope trawls). Not long after rubber-disc footropes were introduced and eventually became the norm. These were threaded through lead rings and hung in bights along the fishing line. As the fisheries developed, areas close to 'hard' or rocky ground became increasingly exploited. Such areas necessitated the use of more robust groundgear; so light hopper trawls were introduced. Now discs of up to 10" (250 mm) are routinely used, typically targeting a range of species.

1.3.1 Multiple rig trawling

The most radical change in the development of *Nephrops* trawling occurred in the mid 1980s with the introduction of multiple rigs, where two or more trawls are towed by one vessel. Danish fishermen were the first to introduce the concept, based on developments in the tropical shrimp fisheries in the Gulf of Mexico, where vessels traditionally towed multiple nets. The Danish fishermen adapted this, and used a two-wire system for towing twin shrimp trawls in the North Sea *Pandalus* fishery. This was then quickly adapted for *Nephrops* trawling, by towing two conventional long winged, low headline trawls. The technology was then introduced to the UK in the late 1980s and is now commonplace in much of the European *Nephrops* fleet.

By using multiple rigs, an equivalent horizontal spread can be obtained while greatly reducing the amount of netting when compared to a single net (Figure 2). The reduction in net size, and hence netting area, reduces the total drag. As a consequence for a given vessel power, a greater spread, approximately 20–30%, can be achieved for the same vessel power. For species such as *Nephrops*, monkfish and flatfish, the increased spread can increase the catching efficiency considerably, when compared to a single trawl. Sangster and Breen (1998), estimate for an equivalent swept area, the catches of *Nephrops* increased by 340%, monkfish by 81% and flatfish by 40%. The authors do note however, that differences in groundgear shape between the single and twin trawl may account for some of the catch differences. In the past few years, an increasing number of Danish and Dutch vessels have been using up to eight individual trawls.

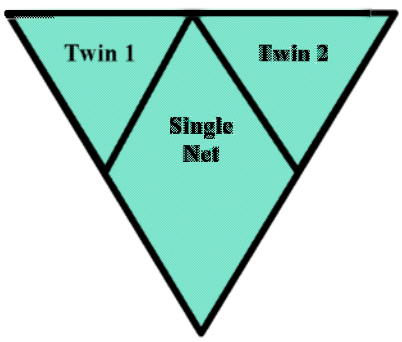


Figure 2. Representation of single and twin trawls having the same width.

1.4 General problems associated with most *Nephrops* fisheries

Before discussing regional differences in detail, there are a number of issues associated with almost all *Nephrops* trawl fisheries.

In common with many shrimp fisheries, the legal minimum mesh sizes (MMS) required is smaller than for most finfish species (with the exception of the Mediterranean). The MMS ranges from 40 to 95 mm, although *Nephrops* is retained with larger mesh sizes. Because the preferred habitat of *Nephrops* often overlaps that of other economically important species, bycatches and subsequent discarding can be considerable due to minimum landing size restrictions on the bycatch (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 codend 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; ICES, 1999). Much of this can be attributed to the poor selectivity characteristics of the gears, inconsistency with the minimum landing size (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* is caught, summarising the current technical measures and their effectiveness and discussing possible remedial action.

2 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 bycatch species) are reviewed. Considerable research has already been conducted into gear designs that refine the targeting of the catch and some measures have been introduced into legislation. A brief description of the main gear measures 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 bycatch species and those that reduce the overall bycatch through species selection.

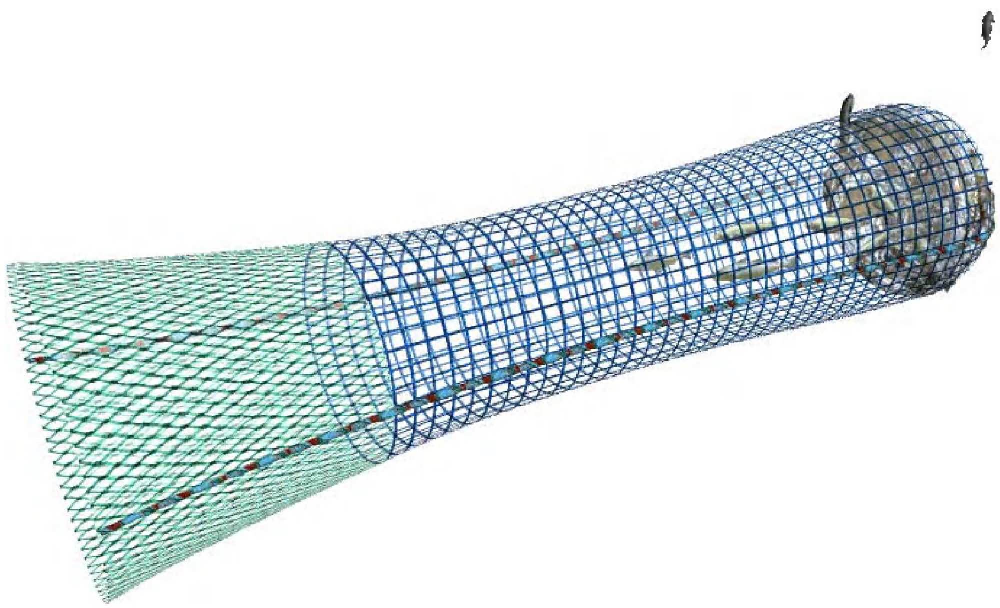


Figure 3. Full square mesh codend (Copyright 2004 reproduced with permission of FRS, Aberdeen).

2.1 Improving size selection

2.1.1 Codend design

One of the simplest measures is the alteration of the codend construction with the aim of increasing the area of open meshes. This can be done in a number of ways: increasing mesh size; constructing the codend entirely from square meshes (Figure 3) which do not close under tension and by increasing the diamond mesh opening by either restricting the number of meshes in circumference or hanging the codend netting on ropes shortened relative to the stretched length of the codend (Robertson and Shanks, 1989). For fish and prawns, the twine used in the construction of the codend can also influence selectivity. Restricting either the number of individual twines, the twine thickness or the twine stiffness reduces the mesh resistance to opening (O'Neill, 2002). Alteration of codend design can influence the retention of both *Nephrops* and fish bycatch. Additional devices such as strengthening backs and chaffing pieces may also affect selectivity. In many *Nephrops* fisheries strengthening bags are permitted around codends for added strength and to reduce abrasion. These strengthening bags have been shown to reduce 50% retention length for whitefish.

2.1.2 Square mesh panels

With the exception of mesh size and mesh construction, the square mesh panel (Figure 4) 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 codend is important in respect of effectiveness (Graham and Kynoch, 2001; Graham *et al.*, 2003).

2.1.3 Grids

Grids for improving finfish size selection are commonly used by vessels operating in the Barents and Norwegian Seas demersal fish fishery (Larsen and Iasksen, 1993) and research has been conducted in the North Sea demersal fishery (Graham *et al.*, 2004). Some experiments have been conducted on improving *Nephrops* size selection in both the North Sea and Kattegat and Skagerrak (Valdemarsen *et al.*, 1996; Robertson and Shanks, 1994; Anon., 2001a).

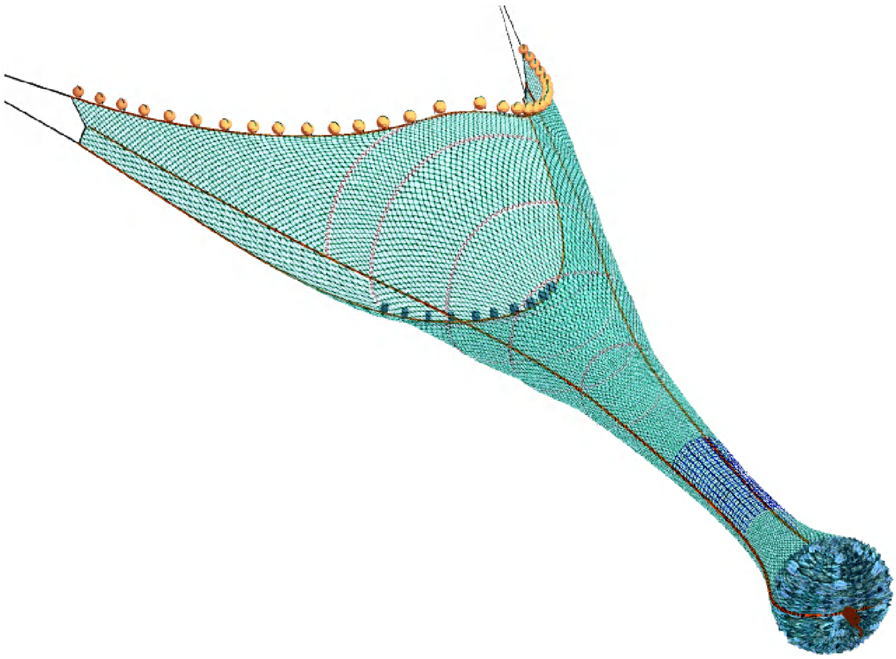


Figure 4. Square mesh panel inserted in a diamond mesh codend (Copyright 2004 reproduced with permission of FRS, Aberdeen).

2.1.4 Horizontal separator trawl

By utilising differences in vertical behavioural patterns at the mouth of the trawl, the horizontal panel separator trawl (Figure 5) 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.

Generally, separator trawls are designed with two separate codends and extensions, which are tailored to join at the upper and lower body of the trawl, divided by the panel. *Nephrops* and some finfish species, particularly cod and flatfish, will tire and fall back under the separating panel, while haddock and whiting tend to rise as they tire, 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 codends may have different specifications (e.g., mesh sizes), providing the opportunity to manipulate codend selectivity to suit the species entering each codend.

2.1.5 Large mesh upper panels

Recent EU (EC 2549/2000 and EC 2056/2001) regulations stipulate 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 (Figure 6). Some experiments have been conducted where the entire top of the trawl is constructed from larger mesh; the authors are unaware of any experiments that have assessed the effectiveness of the panel as per EU legislation specification.

2.2 Improving species selectivity

2.2.1 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 30 cm above the bottom sheet, allowing the passage of *Nephrops* and other species such as monk and flatfish into the codend, while guiding the cod, haddock and whiting out of the escape hole (Figure 7).

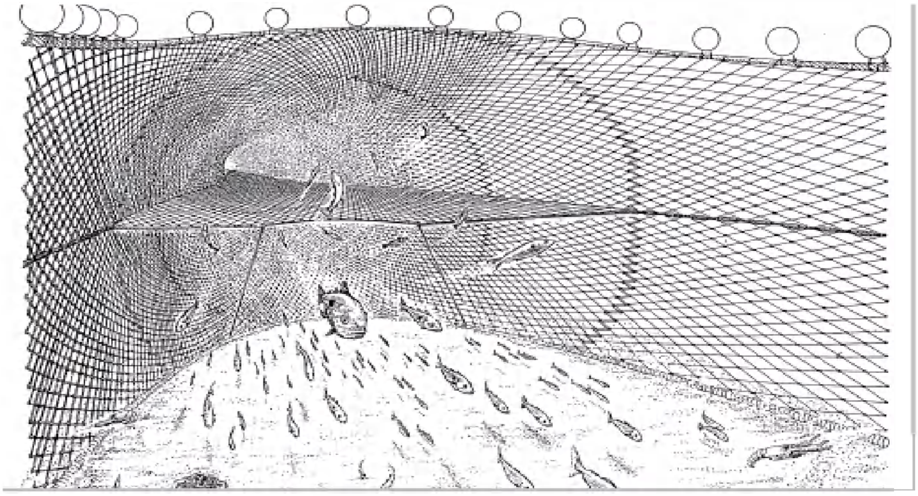


Figure 5. Horizontal separator trawl (Copyright 2004 reproduced with permission of FRS, Aberdeen).

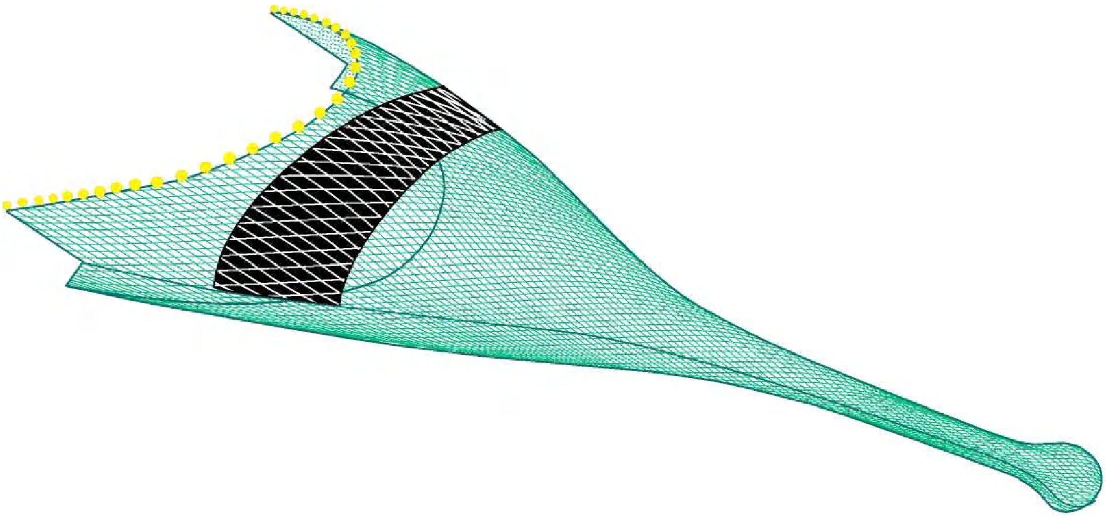


Figure 6. Large mesh panel inserted in the upper belly of a trawl (Copyright 2004 reproduced with permission of FRS, Aberdeen).

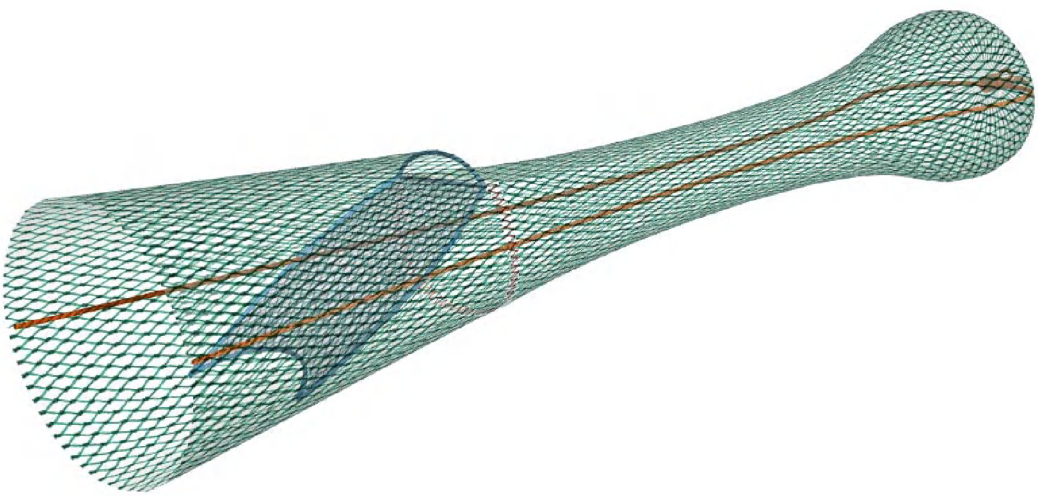


Figure 7. Inclined separator panel (Copyright 2004 reproduced with permission of FRS, Aberdeen).

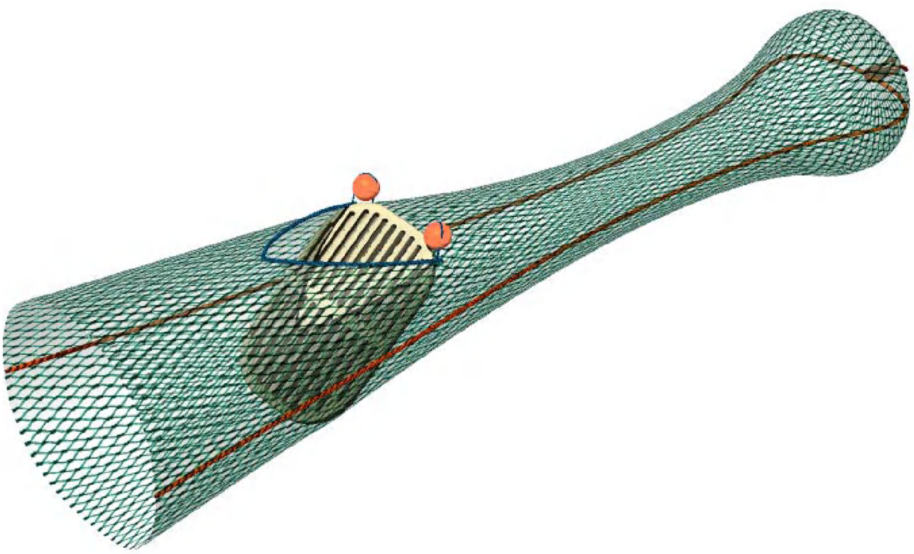


Figure 8. Nordmøre shrimp grid (Copyright 2004 reproduced with permission of FRS, Aberdeen).

2.2.2 Nordmøre Grids

The Nordmøre grid (Figure 4) is used widely in temperate and tropical shrimp fisheries to exclude unwanted bycatch of fish and other organisms e.g., turtles (Tucker *et al.*, 1997; Isaksen *et al.*, 1992). The device comprises a series of parallel bars spaced to allow the shrimp to pass through the grid into the codend while larger animals are diverted out of the trawl. 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. 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 as the finfish bycatch is of economic importance making total exclusion an uneconomic option, there are however, a number of exceptions where finfish bycatch is of minimal importance. However, several investigations in the use of grids have been conducted using double codends in a number of European fisheries (Anon., 2001a) in an attempt to retain marketable fish.

2.2.3 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, in the mouth area before entering the trawl. As *Nephrops* tend to keep low as they enter the trawl mouth, the only reason 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 fall back into the trawl. Thomsen (1993) first used such behavioural patterns to separate cod and flatfish by removing the upper belly, effectively extending the headline (Figure 9). 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 (haddock and whiting) from a *Nephrops* trawl but the results were inconclusive for cod. These designs tend to mimic the operation of traditional low headline *Nephrops* trawls that tend to have low finfish bycatches.

3 The European *Nephrops* fleet

3.1 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', September 2001 – September 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 (ICES, 1999) that the trawl design typically used has changed over recent years, with increasing use of dual purpose trawls with comparatively high headline heights, signaling a shift towards a more multi-species 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 which accounts for 2/3 in importance. Due to falling CPUE and market demand for *Nephrops* during the mid 1990s, the fleet is increasingly relying on the fish bycatch for economic survival.

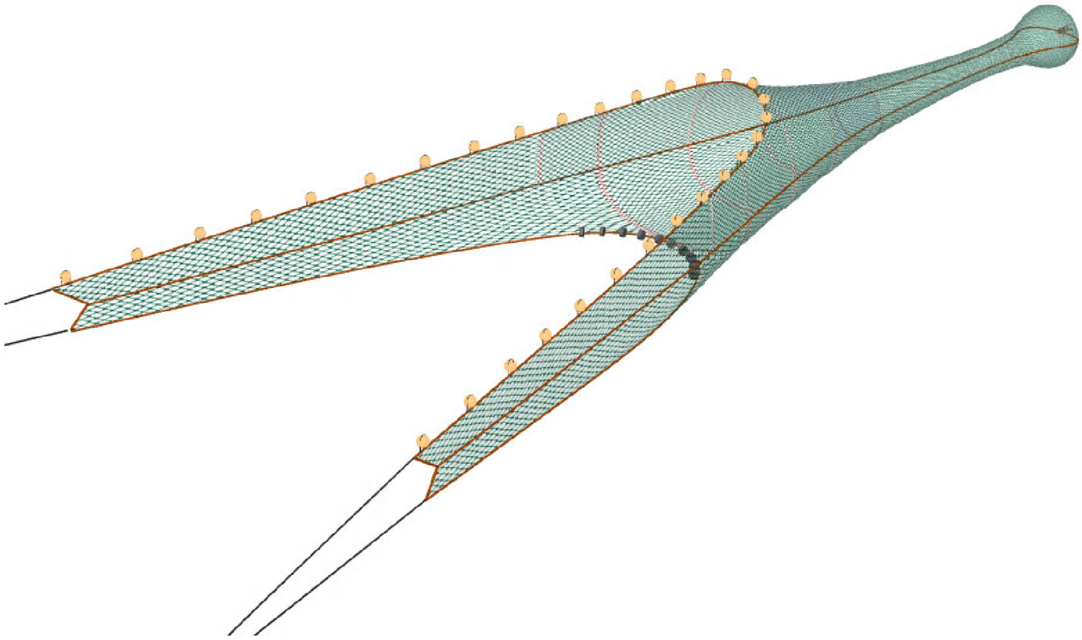


Figure 9. Modified *Nephrops* trawl with set back headline (Copyright 2004 reproduced with permission of FRS, Aberdeen).

3.1.1 Current legislation

Areas of operation are controlled and coupled with depth restrictions, where minimum trawling depth limits of between 55 and 60 fathoms (100–110 m) 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 (No. 543, 22.07.02) apply a minimum mesh size of 80 mm, with no restrictions on codend circumference or twine thickness. 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 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. An 80 mm 3 m long window was inserted in the codend of one trawl. Only a minor impact on gadoid catches was observed, albeit with only four hauls. The additional inclusion of a 135 mm 3 x 3 m 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.

3.1.2 Currents issues

No information has been obtained which identifies any specific issues with this fishery. Iceland has only recently started a discard sampling programme (ICES, 2002). No data have been obtained which describe the selective properties of gears used under current legislation applying in Icelandic waters.

3.1.3 Future actions and recommendations

Current legislation for MMS is 80 mm diamond mesh and for MLS is 30 mm CL.

Nephrops selection

- Considering the relatively small MMS and the lack of other codend restrictions, make an inventory of codend parameters (mesh size, twine type and thickness and codend circumference). Assess size selection of *Nephrops* for codend designs typical of the fleet and its suitability in relation to minimum landing sizes and market selection.

By-catch selection

- Obtain data on discards of all bycatch species, use to identify if existing legislation is adequate and consider modifying technical conservation measures.

- Determine the selective effect of the design features of the multiple panels - mesh size, twine construction, panel dimensions and position.

- Monitor changes in fleet activity to assess response to changes in legislation.

3.2 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 recording 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 with the remainder from Area IVa. Andersen *et al.,* (2003) identifies two principal fisheries for *Nephrops*, both in the Kattegat and Skagerrak. The directed *Nephrops* trawl fishery and the mixed-trawl fishery are defined by the mesh size ranges of 70–89 mm and 90–104 mm respectively. For the directed *Nephrops* trawl fishery in the Skaggerak, between 1999 and 2001, *Nephrops* accounted for between 42–47% by weight and 68–88% by value of total landings for this metier, the remainder being attributed to a bycatch of cod, plaice and monkfish. In comparison, *Nephrops* accounted for between 5–15% by weight, 20–40% by value of catches from the mixed-trawl fleet, with *Nephrops* increasing in importance over time. A similar pattern is shown for both metiers in the Kattegat fishery during the same time frame, with *Nephrops* increasing steadily in economic importance for the mixed-trawl fishery, from 20% in 1991 to 55% in 2002. These figures indicate that the traditional Danish whitefish trawling fleet is 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. In 2001 *Nephrops* landings were split by single trawls catching 42%, twin trawls 39% and creels 12%, and as bycatch in fish and shrimp trawls 7%. ICES (2001) reports that there is a general trend towards increasing use of the twin trawl since their introduction in the late 1980s. 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. 84% of the landings were from the Skagerrak and 16% from the Kattegatt. The log book data for single trawlers indicate a directed fishery 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 138 tonnes of *Nephrops* in 2001. Limited statistical data are available as to the number of Norwegian registered vessels engaged in the fishery and their associated catches. The data from fisheries logbooks are not routinely entered into the national database (ICES, 1999).

3.2.1 Current legislation

EU regulations (EC 850/98) set the minimum mesh size for *Nephrops* trawlers at 70 mm; coupled with the mandatory use of an 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 3 m if the engine power of the vessel exceeds 112 kW; below this a 2 m 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*. Codend twine thickness is limited to 8 mm single or 2 x 6 mm double. In order to overcome this catch composition 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 codends to limit the extent of *Nephrops* discarding. However, this is set to become mandatory under EU regulations (EC 2287/2003). As of 1 March 2004, for mesh sizes between 70 and 89 mm, the codend and extension piece must be constructed entirely from square mesh. Additionally, the bycatch rules in EC 2287/2003 state that the catch of haddock, hake and a number of flatfish species should not exceed 60% of the total catch.

In addition to the EU legislation, within the national waters of Sweden (3 nautical miles in the Kattegat and 4 nm in the Skagerrak) it is now mandatory to fish with species selective *Nephrops* trawls. This has resulted in the mandatory use of a Nordmøre style grid with a bar spacing of 35 mm to exclude fish from the catch. There are additional measures: a limit on the twine thickness permissible for construction of the codend to 3 mm single twine; the maximum diameter of groundgear is 10 cm, in order to restrict the use of rougher ground; the use of multiple rigs with more than two trawls is banned. Approximately 50% of Swedish *Nephrops* catches are taken within this coastal zone.

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 but 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.

3.2.2 Current issues

The fishery has historically suffered from a particularly acute level of *Nephrops* discarding, as high as 78% (by number) of the total catch (Valdemarsen *et al.,* 1996). This may be largely attributed to a mismatch between the legal minima for codend 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. For illustration, Figure 10 shows the estimated selection curve for a 70 mm codend as described by Polet and Redant (1994).

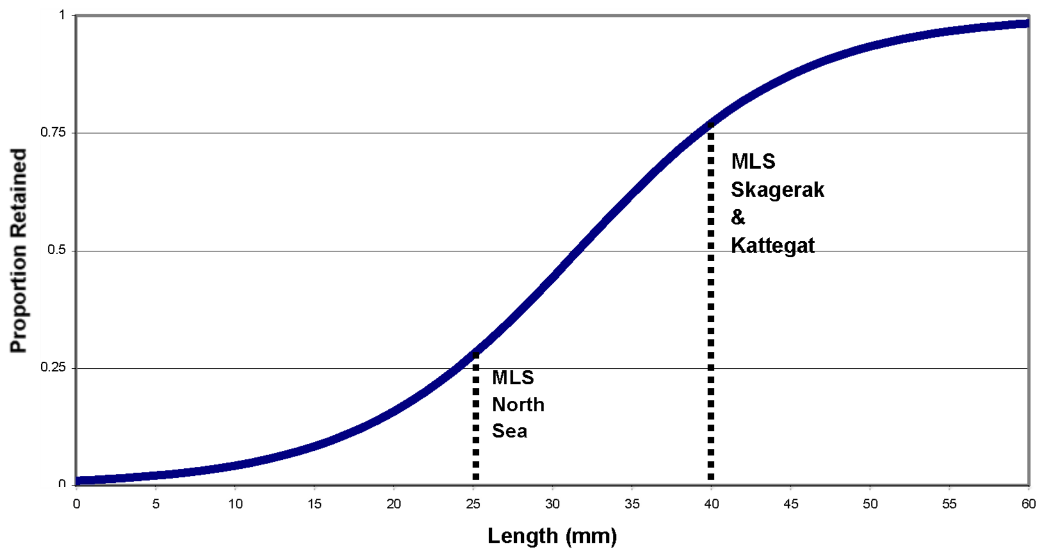


Figure 10. Selection curve as from Polet and Redant (1994) showing the minimum landing size for *Nephrops* in the Kattegat/-Skagerrak and North Sea.

The dotted lines show the 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. However, the mandatory introduction of the full square mesh cod-ends and extensions should reduce the degree of discarding associated with this fishery.

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. In the coastal fishery around Sweden, the mandatory introduction of a species selection grid coupled with the restriction on the size of permissible groundgear will reduce the degree of bycatch in the coastal zone.

3.2.3 Research on selective deveices

3.2.3.1 Square mesh codends

Ulmestrand and Valentinsson (Internal report, IMR, Sweden) assessed the effectiveness of a square mesh codend constructed entirely from 60 mm (71 mm with wedge gauge) square mesh netting and compared it with a conventional 70 mm (72 mm with wedge gauge) diamond mesh codend. The L50 for *Nephrops* increased from 18.6 mm to 24.6 mm carapace length when using the square mesh codend. The authors also noted a significant reduction in the level of fish bycatch retained. The square mesh codend in this assessment had a similar number of bars in circumference as meshes in the diamond mesh codend (~1:1 diamond to square ratio). Previous experiments (Larsvik and Ulmestrand, 1992) with a full square mesh 60 mm codend 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 codend circumference might have a significant impact on selection of square mesh codends in common with diamond mesh codends.

3.2.3.2 Grids

Valdemarsen *et al.* (1996) investigated the possibility of using grids to reduce the discarding of juvenile (<MLS) *Nephrops* by improving size selection using rigid grids. Two different 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 operated on the same principle as the Sort-V (Valdemarsen *et al.*, 1996). Both grids showed a reduced selection range (SR) compared to diamond mesh codends; 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 to assess the species selectivity using a 35 mm grid in combination with a 70 mm square mesh codend were carried out on four commercial *Nephrops* trawlers during autumn 2002 (abstracted in ICES, 2003a). The results from about 50 trawl hauls indicate a large reduction in the fish bycatches 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 bycatch species are caught and discarded each year. The mandatory use of a 35 mm grid in combination with a 70 mm square mesh codend would reduce the catch of legal sized fish to almost zero and of undersized fish by about 70%.

3.2.3.3 Mesh size

Stiansen and Lilleng (2001) conducted a catch comparison exercise, where they compared 100 and 120 mm codends. Reductions in cod, haddock and saithe were observed which showed indications of length dependency. Overall reductions in *Nephrops* catches were observed (~30%) when comparing the catches between the two codends, but with no apparent length dependency.

3.2.3.4 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 bycatch of 62% (by weight) with a 70 mm square mesh window fitted approximately 3.8 m from the cod-line of a 70 mm diamond codend. This window position is known to be highly effective but may not reflect commercial practice.

3.2.4 Future actions and recommendations

Current legislation for MMS is 70 mm (Square) and for MLS is 40 mm CL

Nephrops selection

- Assess if selectivity of 70 mm square mesh codend is suitable in relation to the minimum landing size and determine the effect of twine thickness, by comparing EU and Swedish specifications
- Assess the impact of protective codend attachments such as lifting bags and chaffing pieces

By-catch selection

- Introduce species separation devices, such as grids and large mesh panels in the target *Nephrops* fishery.
- Obtain selection data on the effect of square mesh panel position, mesh size and panel construction (mesh type, construction and dimensions).
- Assess designs of species separating devices that give similar selectivity to demersal fish trawls in the mixed-species fisheries. These could include cutaway headline and square or large mesh upper panels.

3.3 North Sea (ICES Areas IVa, b, c; FUs 5, 6, 7, 8, 9, 10, 32, 33)

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 1980s there has been a major shift to twin rig trawling. *Nephrops* is 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 a longer wings and increased headline height in comparison to traditional nets. They are designed specifically to catch gadoids and flatfish in conjunction with *Nephrops*; the fish component, 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 fish and *Nephrops*. Using 100 mm allowed the fleet to maximise revenue from both *Nephrops* and fish because they were not restricted by the catch composition regulations. The combination of the increased mesh size, the associated reduction in *Nephrops* catches, a general decrease in the gadoid stocks and a harsher limit on days at sea for whitefish vessels 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 Skagerrak) for 1999. ICES (1999) estimates that vessels using 100 mm codends took 60% of the Danish *Nephrops* catch. In light of the changes in mesh size for human consumption fisheries, these vessels may follow the example of the Scottish fleet by *reducing* their mesh size to 80 mm (Niels Madsen, pers. comm.).

Norwegian landings of *Nephrops* were predominately a bycatch from Norwegian vessels engaged in the *Pandalus* shrimp fishery. However, in latter years, due to greater landing restrictions on the *Pandalus* fishery, shrimp trawlers have started fishing specifically for *Nephrops* all year round. Between 1999 and 2001, the number of vessels registering *Nephrops* catches has risen from 159 to 185. 112 tonnes was landed in 2001.

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 bycatch of cod, haddock and whiting. Landings data suggest minimal activity by English vessels 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*. Bycatches 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, 1994a). 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 bycatch has resulted in operators being more vulnerable to the comparatively less stable *Nephrops* market.

The Dutch fleet 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. It is reported that 47 twin rig vessels had joined the fleet by 2003, comprising of 31 eurocutters and 16 larger cutters. Most vessels use 80 mm or 100 mm mesh size, the major target species are mullets, gurnards, whiting, *Nephrops* and plaice.

3.3.1 Current legislation

EU legislation (EC 2056/2001) stipulates that for trawls of mesh size ranging from 80 to 99 mm, a square mesh panel of a minimum 80 mm mesh must be fitted in the parallel extension of the trawl, although details of the required location are not specified beyond this. UK legislation (SI 2001/649, SSI 2000/227) requires at least a 90 mm square mesh panel in trawls from 80 to 119 mm and is more specific in terms of the positioning of the panel; the rear of the panel should be not more than 15 m from the cod-line. The length of the panel must be 3 m if the engine power of the vessel exceeds 112 kW, otherwise a 2 m panel may be used.

Regulations also restrict the permissible twine thickness and the circumference of the codend, both in EU and UK unilateral legislation. Under UK legislation, when fishing for *Nephrops,* the codend, extension and any square mesh panel must be constructed of single twine, of a thickness not exceeding 4 mm for mesh sizes 70–99 mm, whereas EU legislation restricts twine thickness to a maximum of 8 mm single or 6 mm double.

Under EU legislation, a maximum of 120 meshes round the codend circumference is permissible for all mesh sizes less than 90 mm. For this mesh size range, an additional panel must also 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.

3.3.2 Current issues

The Fladen fishery is typically multi-species in nature with the bycatch of other species of significant economic importance to the fishing fleets, often contributing 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 at present. Other fisheries, such as in the Farne Deeps and the Firth of Forth are predominately *Nephrops* fisheries where the bycatch of fish is of lesser 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 (1994b) observed fishermen'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 ~28mm 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 ICES (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 ICES (2001) 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 indicate the effect of the headline panel. It remains clear that there is still considerable discarding of roundfish 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. Regulations introduced in 2003 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 a considerable number of vessels, that previously targeted whitefish, have opted to use a smaller mesh size (<100 mm) in order to increase their monthly days allocation and have switched to *Nephrops* trawling. Although intended to reduce the fishing mortality on cod, this legislation may increase the degree of discarding of species associated with the *Nephrops* fishery such as haddock and whiting. In addition to encouraging the fleet to use smaller mesh sizes, resulting in poorer size selection, it will also result in high grade discarding due to the more stringent catch composition regulations associated with the mesh grouping and increase pressure on the *Nephrops* stocks and markets. This happening coincidentally at a time with the largest reported biomass of haddock in the North Sea in the last 30 years.

There is a lack of parameterised (length) data on selectivity to assess the relation between the length of *Nephrops* retained by current legal gear specifications and the minimum landing size. Much of the work has been through the use of catch comparison exercises, which do not provide absolute estimates of selectivity. This makes it problematic to compare results between trials due to population dependant effects, and to assess the potential stock benefits of particular devices.

3.3.3 Research on selective devices

3.3.3.1 Separator trawls

Main and Sangster (1985) achieved good separation of *Nephrops* from haddock. 100% of *Nephrops* were retained in the lower codend, while 89% of haddock entered the upper codend. Separation of whiting was less dramatic, with 55% entering the upper body of the trawl. No separation of cod and *Nephrops* was observed, with 100% cod being retained in the lower codend. Experiments in 2003 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.*, abstracted in ICES, 2003a). The authors note that the rigging 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 an industry standard trawl. The rigging of the panel is design specific and makes general introduction throughout 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 (Anon., 2003a) considered that such a device could be introduced into the fishery by the provision of incentives, such as reduction in bycatch limits, subsidy for new gear or permission to fish in closed areas or seasons when using more selective gear.

3.3.3.2 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 bycatch 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 bycatch of whiting and haddock was reduced by 63 and 65%. There was no significant change in the catches of cod or *Nephrops*.

3.3.3.3 Codend mesh size

The effect of codend mesh size was assessed in a previous FTFB *ad hoc* group (ICES, 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 any length dependant selection. Anon. (2002b) found no significant difference in catches of *Nephrops* comparing an 80 mm, 4 mm single twine cod-end with 120 meshes round and a lifting bag against a 100 mm, 5 mm double twine codend with 100 meshes round and no lifting bag. Both codends were fitted with a 90 mm panel, 9–12 m from the cod-line. Madsen *et al* (1999) and Polet and Redant (1994) both demonstrate, at least with codends constructed with comparatively thin twine, that the L25 is broadly compatible with the carapace MLS for the North Sea of 25 mm (28.6 mm for Madsen *et al.*, 1994 and 26.4 mm for Polet and Redant, 1994). However, it is clear that the data is highly variable and, like fish, the twine construction used in the codends may have a significant impact on size selection.

3.3.3.4 Codend geometry

Bova and Sangster (abstracted in ICES, 2003a) conducted a comparative study to determine the difference in *Nephrops* catch compositions between diamond mesh and square mesh codend 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 codends used during the study was 1:1, which was used to attach the extensions to the codends. Results were not consistent with some hauls failing to show clear length-related selection. These authors suggested that a possible explanation for variable codend selectivity was the physical shape and behaviour of *Nephrops* during capture.

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

3.3.3.5 Square mesh panels

There has been considerable research conducted in the North Sea on the efficacy of square mesh panels to reduce gadoid bycatches. 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 in these experiments vary considerably; in terms of panel position, panel/codend 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 of a 70 mm codend. 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 codend meshes). The results show a significant improvement in selectivity despite the fact that the panel was only 2 m long; although the panel mesh size was 10 mm above the legal minimum requirement and inserted only 4m from the cod-line, which is unlikely to reflect current commercial practice.

Anon. (2002b) describe experiments to assess the effect of panel position in the Fladen fishery in the Northern North Sea (see Section 3.3.1). They compared the current UK panel, 90 mm, 15–18 m from cod-line, with a 90 mm panel inserted closer to the codend (9–12 m). 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 30–33.5 cm fish, 25% for 33.5–41.5 cm. In addition, comparing the 15–18 m and 9–12 m positions, the rearmost position also released more whiting, 33% of fish 27–32 cm, few fish above or below these sizes were encountered during the trials. 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 codend twine thickness influences the selectivity of gadoids (Lowry and Robertson, 1997; Kynoch *et al.,* 1999). Anon. (2002b) suggests that it may also be an important factor determining the effectiveness of square mesh panels. Using a twin trawl a catch comparison exercise was conducted to compare panels constructed from knotless netting made from 2.5 mm high tenacity twine with knotted netting panels made of 5 mm double braided twine. A reduction in discarded and marketable catch of both whiting and haddock was noted, but demonstrating no evidence of length dependency. Further population independent selectivity experiments are required in order to formally assess the impact of such a design feature.

3.3.3.6 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* into two different codends, with appropriate mesh sizes to select roundfish and *Nephrops*. 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 degraded when debris blocked it (Figure 11).

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 in the

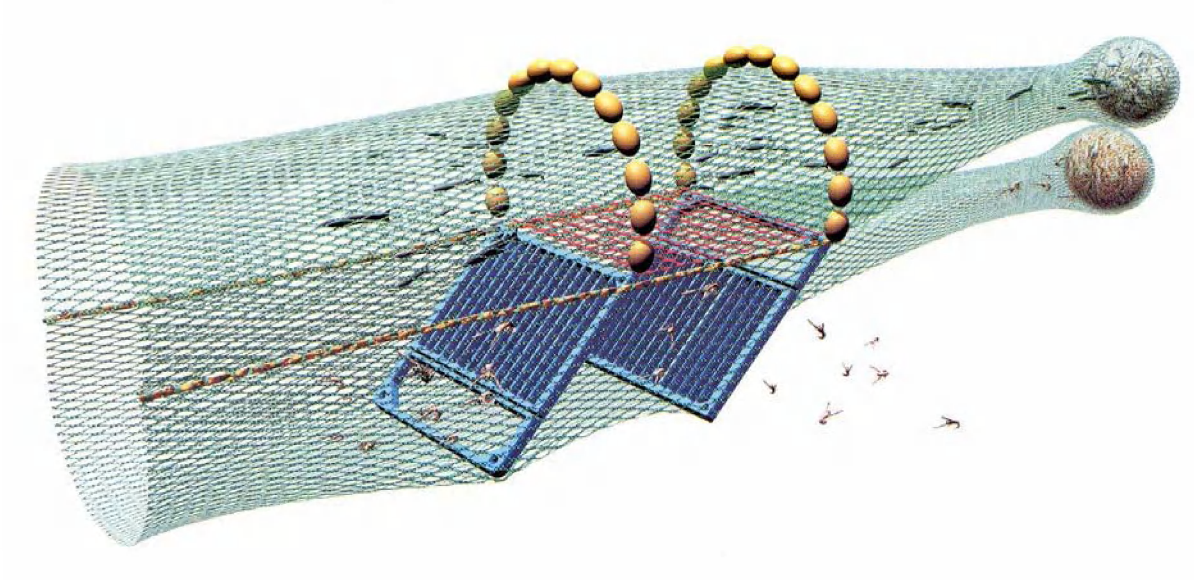


Figure 11. Grid system assessed in the EU Netrasel project (Copyright 2004 reproduced with permission of FRS, Aberdeen).

North Sea: one set in the Farne Deeps fishery off the NE of England, the other 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 mud/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. For all three species the probability of retention in the upper codend was found to increase with increasing length. The diversion of the largest *Nephrops* into the large mesh upper codend (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* (L50 ~22.5 mm, SR ~4.5 mm).

3.3.4 Future actions and recommendations

Current legislation for MMS is 80 mm and for MLS is 25 mm.

Nephrops selection

- Obtain parameterised selectivity data on codends defined by current legislation to provide a benchmark for future changes.
- Assess suitability of the size selection of current gear designs in relation to minimum landing sizes and market selection practices.
- Commission further research into improving *Nephrops* selection e.g., using grids, square mesh codends and other 'novel' grading or selection devices.

By-catch selection

- Obtain parameterised selectivity data on gear selectivity for whitefish defined by current legislation and commercial practice to provide a benchmark for future changes.
- Obtain selection data on the effect of square mesh panel position, dimensions, mesh size and panel construction (mesh type and twine diameter) in all North Sea *Nephrops* fisheries.
- Survey commercial fleet regarding positioning and specification of square mesh panels and, with reference to selection data, determine effectiveness in reducing bycatch.
- Assess designs of species separating device to develop a trawl that gives similar whitefish selectivity to that of demersal fish trawls. Options should include the cutaway headline, square mesh or large mesh upper bellies and horizontal separating panels with guiding ropes with careful consideration of the most suitable device for each fishery.
- Monitor changes in fleet activity to assess response to changes in legislation.

3.4 West coast in Area VIa

Legislatively speaking, the West coast of Scotland fishery is divided into two distinct areas, North of 56° and West of 07°30' and South of 56°. In relation to WGNEPH divisions, the Northern area comprises of the North and South Minch (FUs 11and12), while the southern area, Clyde is FU 13, although this is sub-divided for biological reasons between the Clyde and Isle of Jura fisheries. Scottish vessels dominate the fishery in Area VIa, with landings from all gears of ~11 000 tonnes in 1999.

Limited catches are also taken by Spanish and Irish vessels in the South Minch and Clyde, and to the west of the Hebrides, outside FUs. For Irish vessels in VIa, *Nephrops* is a small but valuable bycatch 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.

Scotland is the only country to report significant catches form the Minches (FU 11 and 12). In 2002, 4999 tonnes were taken from the two FUs using towed gear. The majority of the trawl caught *Nephrops* is taken using a single trawl (98%), using a mesh size of 70 mm. The inshore fisheries around the Hebrides tend to focus predominately on *Nephrops*, using traditional low headline scraper nets, with the economic importance of the fish bycatch being limited. ICES (2003b) 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. Assessments indicate that the whiting stock is in poor condition and considered outside safe biological limits, with a reduction of 40% in F being recommended.

3.4.1 Current legislation

With the exception of the Clyde Area, the current legislation governing *Nephrops* trawl fisheries on the West coast of Scotland was laid down by the North Sea and West of Scotland cod recovery plan (EC 2056/2001), which established measures additional to EC 850/98. This regulation was amended in 2003 by Annex XVII of EC 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 70–99 mm mesh size to 25 days at sea per month. Additional UK legislation has also been applied in the Clyde in recent years, aimed at protecting the aggregating cod in the south of the Clyde during February, March and April.

In certain areas restrictions are placed on vessels under Scottish legislation operating with the twin trawl (SSI No 2000/226). North of 56°N, 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 70–89 mm mesh with a lifting bag and 120 meshes round the codend but with 4 mm single twine. The use of square mesh and headline panels are compulsory in this fishery (see Section 3.31 for details). Since the introduction of limits on days at sea, some minor modifications to Scottish legislation have been introduced.

3.4.2 Current issues

The mesh size rules applying in the West of Scotland area are anomalous when compared to adjacent areas in the North Sea and in the area immediately to the South. The minimum mesh size for single trawls is 70 mm (80 mm in the North Sea) whereas for twin trawls the mesh size must be at least 100 mm (80 mm in both the North Sea and Area VII).

In some areas, the Isle of Jura fishery for example, significant quantities of undersized *Nephrops* is retained and discarded. ICES (2003d) report that discards can be high and that on average, between 2000 and 2002, 23–28% by number, and 11–18% by weight were discarded, with discarding reportedly higher in the south.

For the purposes of applying different mesh sizes to single and twin trawls, a single trawl is defined in UK and Scottish legislation (SI 2001/650; SSI 2003/166). It is not defined in European legislation.

The *Nephrops* fishery in this area is prosecuted mainly on inshore grounds by lower powered vessels (less than 400 hp). The case is often made that an increase in mesh size penalises smaller vessels because the more powerful vessels can tow faster to close up the codend meshes and thereby limit the perceived loss of marketable catch caused by the new larger mesh size.

3.4.3 Research on selective devices

Galbraith (1991) reports the results of horizontal separator trawl trials in the *Nephrops* fishery in the North Minch. Parallel tows on two sister vessels were made using a standard *Nephrops* gear on one and a separator trawl on the other with the separator panel set at 0.75 m above the footrope. The upper and lower codends of the separator gear had 90 and 70 mm diamond mesh. After 8 paired tows there was no evidence of a higher proportion of either whiting or hake consistently entering the top codend.

Sangster *et al.* (1990) describe trials in 1989 with a horizontal separator trawl in the North Minch *Nephrops* fishery on a research vessel. A twin trawl was used to compare the catches in a 90 mm top codend and a 70 mm lower codend attached to one net with those in a 70 mm standard codend attached to the other net. The separator panel was set at 0.9 m above the footrope. In 8 hauls the separator trawl performed well. The catches of marketable prawns and flatfish were similar in the standard and separator nets. For haddock and whiting there was no difference in total marketable fish. There were fewer fish less than MLS in the separator trawl, presumably due to more escapes from the 90 mm codend than the 70 mm codend and for this reason no conclusion can be drawn about separation ratios for small fish into the top and bottom codends. The great majority of marketable sizes of these species were retained in the top codend except in one haul, which was in very dark conditions (measured light level was $7*10^{-5}$ lux).

Twin trawl experiments to measure *Nephrops* codend mesh selectivity were conducted in the North and South Minches in August 2001 (Anon., 2002b). Codends made of 70 mm and 80 mm mesh (4 mm single twine with 120 open meshes) were compared with a 100 mm codend (5 mm double twine with 100 open meshes). All codends had strengthening (lifting) bags. It was found that no prawns greater than 21 mm escaped from the 70 mm codend. Significantly fewer (in number) *Nephrops* were caught in the range from 25–30 mm in the 80 mm than the 70 mm codend. There was no indication of length selection in either 70 or 80 mm codends whereas the 100 mm codend did show length-related selection. The data indicated a 50% retention carapace length of 26.7 mm for the 100 mm codend, giving a low selection factor of 0.27.

As part of an experiment in 1996/1997 to measure the survival of *Nephrops* escaping from codends, the selectivities of 67 mm full square mesh codends and 71 and 94 mm diamond mesh codends were measured using the covered codend method (Wileman *et al.*, 1999). A selection factor of 0.4 was found for the square mesh codend compared to 0.32 and 0.28 for the 70 and 100 mm diamond mesh codends. However, the square mesh netting was made from 4 mm single nylon twine whereas the diamond mesh netting was made from 4 mm double polyethylene, which is known to be a stiffer material.

3.4.4 Future actions and recommendations

Current legislation for MMS is 70 mm and for MLS is 20 mm.

Nephrops selection

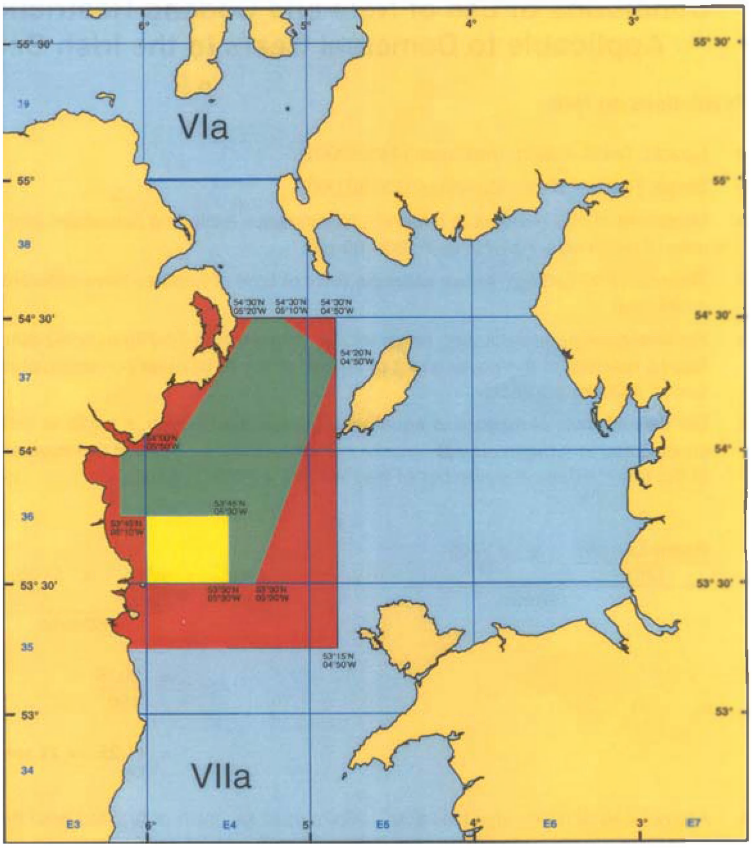
- Assess suitability of the size selection of current gear designs in relation to minimum landing sizes and market selection practices.
- Reduce anomalies between technical measures (mesh size) in this area and the adjacent areas for single and twin trawls.
- Assess whether there is a difference between the selectivity of similar codends on low and higher powered vessels.

By-catch selection

- Assess developments in the design of species separating devices to develop a trawl that gives similar whitefish selectivity to that of demersal fish trawls. Options should include consideration of the cutaway headline, square mesh or large mesh upper bellies and horizontal separating panels with guiding ropes.

3.5 Irish Sea (ICES Area VIIa; FU 14 and 15)

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 bycatch species. Approximately 30 English vessels are engaged in the summer fishery in the Eastern Irish Sea, predominately operating in the Eastern part, landing



Closed to all fishing with any demersal trawl, seine or similar towed net, any gill net, trammel net or similar static net or any fishing gear incorporating hooks from the 14th of February to the 30th of April 2003.

Fishing is permitted with a prawn net or a prawn net fitted with an inclined separator panel in the areas coloured green provided that:

A minimum of 35% live weight of prawns onboard
Only one mesh size range is carried onboard, 70–79 mm or 80–99 mm
No other type of gear is carried onboard
No mesh in any part of the net is greater than 300 mm

Fishing is permitted with a prawn net in this area provided that in addition to the above:
It complies with the provisions made for in the green zone
It includes a separator panel.

This map is for illustrative purposes only.
For legal text please refer to Annex V of EC regulation 2341/2002

Figure 12. Restricted areas in the Irish Sea in 2003, the provision to allow the use of semi-pelagic gear has subsequently been revoked.

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 2700 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*; in 1999 Irish vessels discarded around 1200 tonnes of small *Nephrops*.

3.5.1 Current legislation

In 1999 ICES indicated that the stock of cod in the Irish Sea was close to collapse. The prognosis in 2002 was 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 (EC 300/2001, replaced by EC 254/2002 and further amended by Annex V of Regulation EC 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 12). 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 (EC 456/2001) although this has been superceded 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 form of Statutory Instruments. Area derogations were introduced which allowed the use of an inclined separator fitted in the extension of *Nephrops* trawls (Section 2.2.1).

For mesh sizes in the range 70–99 mm where *Nephrops* is the target species, the catch composition must contain a minimum of 35% *Nephrops*. The codend must have no more than 120 meshes in circumference and that an 80 mm square mesh panel is required, either 2 or 3 m 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 comprise (by weight) a minimum of 35% *Nephrops* and a maximum of 5% cod. However, all codends 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 4 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.

3.5.2 Current issues

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 (ICES, 2003b). The bycatch 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 ICES (2003b) for whiting in the Irish Sea has been severe. Whiting are generally taken as a bycatch mainly on or near the *Nephrops* grounds, which are also the principal nursery ground for this species. Square mesh panel legislation was introduced for both the UK and Irish vessels in 1994 under UK national legislation in order to reduce the fishing mortality on juvenile whiting and haddock. ICES (2003b) report that while the effects of the panel have not been formally assessed, the fishery still generates substantial quantities of bycatch. 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.

ICES (2003b) 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 bycatch and discarding associated with the *Nephrops* fishery. The majority of whiting discards are 0 and 1-gp (52% and 38% respectively). The ICES Working Group (ICES, 2003b) recommendations for a rebuilding plan state that a substantial reduction in discarding of these age groups could facilitate the rebuilding of the stock. The authors note that the decline of adult whiting in the Western part of the Irish Sea may represent a decline in the overall Irish Sea stock, and that recovery would be enhanced by reducing the level of discards by enhancing the selectivity of *Nephrops* trawls. However, ICES (2003b) note that, in the worst-case scenario, the Western Irish Sea whiting may actually be a functionally discrete stock, in which case the stock has already collapsed. Under these circumstances, the stock would require a reduction in fishing mortality that would "…require a radical redesign of *Nephrops* trawls to reduce the whiting bycatch"

3.5.3 Research on selective devices

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 focused on the development and subsequent introduction of the inclined separator trawl.

3.5.3.1 Inclined separator

Galbraith and Mair (abstracted in ICES, 2003a) assessed the effectiveness of the inclined panel in the Clyde in 2001. Three designs were examined during these trials. A 80 mm codend was attached to the escape hole to retain the *Nephrops*/fish that would normally have escaped. Initially, an unacceptable proportion of the target species was 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 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 codend (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 codends.

Trials in the Irish Sea with the inclined separator fitted to a conventional trawl (as above) are reported by Anon. (2002a; 2003b). Catch comparison experiments on both single and twin rig trawlers have demonstrated that the device allows fishermen to operate within the 18% bycatch 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 the majority of whiting. 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 (1998). A similar improvement is reported for haddock, with almost all fish being separated with the inclined panel compared to 29–74% (Dunlin, 1998). Similar results were obtained by Hillis (1983; 1984) where a higher percentage of 0-group whiting were retained in the lower codend.

3.5.3.2 Square mesh panels

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 3 m) have shown that the effectiveness of the panel is influenced by its position (Graham and Kynoch, 2002; Graham *at al.*, 2003). 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.

3.5.3.3 Large mesh upper panel

A headline panel, having at least 15 rows of large 140 mm meshes, is required under current EU legislation (EC 2549/2000) although this is based on little or no scientific evidence. However, trials carried out off the west coast of Ireland suggest that the use of large mesh (200 mm) in the whole top sheet of the panel from the headline back to the codend joining round is effective, with reductions in catches of undersize whiting and haddock in the order of 34% (Anon., 2001b).

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. Reductions of 71 and 72% in haddock and whiting respectively were recorded compared to the net with no panel. This is achieved with a 5% loss of target species.

3.5.3.4 Horizontal separator trawl

The Sea Fish Industry Authority (Dunlin, 1998) 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 codend 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 effectiveness of the separator trawl is dependant on a number of circumstances. Experiments have shown, that when the retention of very small fish (<20 cm) is a problem, the horizontal separator is then less effective. However, when larger fish are involved and bycatch / quota restrictions apply, or quality is an important consideration, then the use of this technology is likely to be beneficial.

3.5.3.5 Codend design

The effect of twine thickness was assessed by Anon. (2000). They conducted a 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. Comparing the catches with the 3.5 mm codend, the 6 mm and 8 mm single codends caught 34 and 38% more *Nephrops* respectively.

A research programme recently funded by EU and member states (NECESSITY SSP8-CT-2003-510605 – 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.

3.5.4 Future actions and recommendations

Current legislation for MMS is 70 mm and for MLS is 20 mm CL.

Nephrops selection

- Obtain parameterized selectivity data for *Nephrops* with current technical measures.
- Identify *Nephrops* only fisheries and introduce appropriate gears.

By-catch selection

- Conduct selectivity studies on square mesh and large mesh headline panels and determine critical design parameters: position, mesh size and dimensions of headline panel.
- Assess effectiveness of horizontal separator with guiding ropes.
- Develop the above technologies to reduce considerably the fishing mortality on whiting.

3.6 Western waters (ICES Areas VIIa, b, c, f, g, h, j, k; FUs 14, 15, 16, 17, 18, 19)

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 part of the year. The fleet concentrates on *Nephrops* as the key target species, but diverts its effort to whitefish during periods of bad weather. The vessels tend to fish with 80 mm codends to avoid bycatch limits applied when using 70 mm. French vessels target other species of fish including cod (15% by weight), anglerfish (14%) whiting (10%) and megrim (8%) (ICES, 1999). In fiscal terms, 53% of the revenue is generated from *Nephrops* and the remainder from a mix of anglerfish (14%), cod (9%), megrim (6%) and whiting (4%) and other miscellaneous species (14%).

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

Fishing 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 bycatch 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 2123 tonnes in 2001. The main port is Dunmore East into which around 1200 tonnes valued at €2.9m were landed in 2001. Most of these 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 10–35 m participate in the fisheries in this area, with most of them in the 16–25 m size category. They tend to be multipurpose, targeting *Nephrops* only 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 to the West 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.

3.6.1 Current legislation

Under the European Commissions "Hake Recovery Plan" (EC 494/2002, amending EC 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 VIII provided that they do not exceed a 20% bycatch limit of hake, and have a minimum of 35% live weight *Nephrops* on board. The maximum permissible twine thickness is 6 mm single or 4 mm double. In addition, fishing with trawls with a codend mesh size of between 55 and 99 mm, and with fixed nets of mesh size less than 120 mm, is prohibited in two closed areas (Figure 13) (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 regulations (EC 494/2002) amended this regulation in 2002 and the blue areas were removed and therefore not subject to the 100 mm codend mesh size restriction. In the latest proposed consolidation of EC 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.

3.6.2 Current issues

The 1999 Working Group on *Nephrops* reports that there is considerable discarding of *Nephrops* in the Celtic Sea fishery. The present MLS for the area of 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 high. The authors suggest that ~55% of the total biomass in the catch was discarded during the same period. Whiting (41%) were the principal fish species discarded.

The region around 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.

3.6.3 Future actions and recommendations

Current legislation for MMS is 70 mm and for MLS is 25 mm.

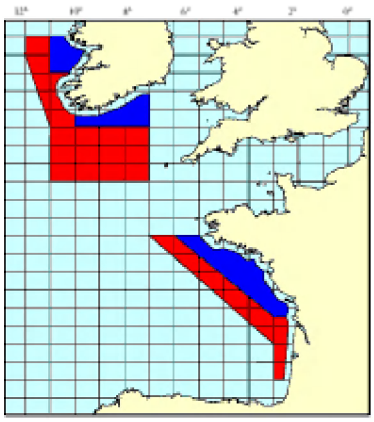


Figure 13. Restricted areas covered by the Hake Recovery Plan.

Nephrops selection

- Assess methods of improving *Nephrops* size selection such as square mesh codends and grids.
- Consider increasing legal MLS in light of landing sizes set by fishermen's organization

By-catch selection

- 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 extending further than current legislation.
- Assess the economic impact of increasing codend mesh size to 100 mm in *Nephrops* fisheries associated with the Hake Recovery areas.

3.7 Bay of Biscay (including North Galicia and Cantabrian Sea) – (ICES Areas VIIIa, b, c, d, e; FUs 23, 24, 25, 31)

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* is 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 Galicia, and West Galicia. 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 lands some *Nephrops*. ICES Subareas VI, VII, and VIIIa, b, were fished by a fleet of 153 vessels, in a mixed demersal fishery targeting, hake, megrim, angler fish and *Nephrops*, with bycatches of witch, fork-beard, ling, cephalopods etc., *Nephrops* is also an important bycatch in the Northern Portugal demersal trawl fishery.

3.7.1 Current legislation

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

3.7.2 Current issues

The ICES Working Group on *Nephrops* stocks considers 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 reports that over 70% of these are discarded and states, "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 Working Group on the Assessment of Southern Shelf Stocks of Hake, Monk and Megrim (ICES, 2003c) suggests that consideration should be given to withdrawing the exemption from the Hake recovery Plan enjoyed by inshore vessels under 12 m. The *Nephrops* grounds in the northern part of the Bay of Biscay are also important nursery areas for juvenile hake, and attempts have been made to develop a more selective trawl, but ICES (1999) notes that 'due to the persistent illegal market for small hake, there is very little interest for this gear', it is also dubious if the modifications were particularly effective for this species, see Section 3.7.3.

Discarding of *Nephrops* by the French fleet is quoted as being substantial (ICES, 1999) due to a MLS of 35 mm CL being set by the French fishermen's organisation. The current EU minimum is 20 mm CL. ICES (2001) comments that despite the increase in mesh size to 70 mm in 2000, the selectivity of *Nephrops* has not improved.

The biomass of *Nephrops* is in serious decline in both the North Galicia and Cantabrian Sea area, and ICES (2003d) has suggested a zero TAC in this area. The authors also note that in order to achieve this, all fishing activity where *Nephrops* is taken as a bycatch should be stopped. Subsequently, the EU Scientific, Technical and Economic Committee for Fisheries (STECF) has taken this advice and recommended that a recovery plan for *Nephrops* stocks in this area be implemented.

An improvement in the size selection pattern for *Nephrops* would benefit the regeneration of the stock in this area. ICES (2004) demonstrates the potential benefits of improving size selection. Figure 14 describes the output form a yield per recruit analysis model that demonstrates the long-term relative gain in yield for differing exploitation patterns. The y-axis shows the predicted improvements expressed as percentage gains in yield while the x-axis shows a range of possible scenarios. The vertical ar row shows the potential gain (~ 45%) with a 100% reduction in the capture of *Nephrops* aged 3-year-old and below. ICES (2004) concludes that larger long-term stock gains can be obtained by changing the fishing (selection) pattern than by reducing F overall.

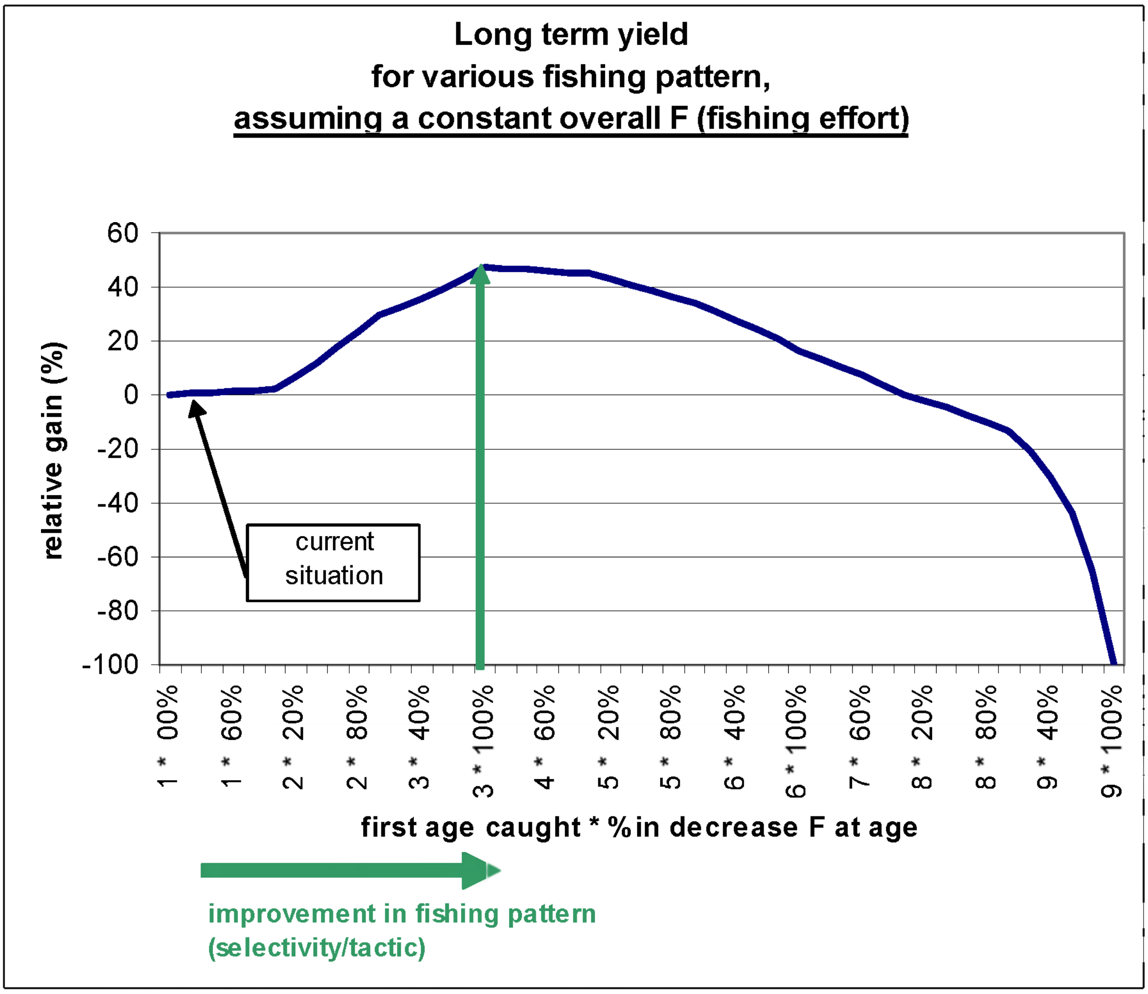


Figure 14. Bay of Biscay (FUs 23–24) Y/R analysis assuming a constant selection pattern and for various fishing pattern.

3.7.3 Research on selective devices

A number of devices are presently being tested under the auspices of an 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.

3.7.3.1 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, 3 m long panel was inserted at a variety of positions in the extension piece of the trawl but proved to be ineffective. In subsequent (ongoing) trials a 6 m long, 120 mm panel was inserted in front of the extension and 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, 2 m long panel (F. Théret, pers. comm.).

3.7.3.2 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% (F. Théret, pers. comm.).

3.7.3.3 Large mesh headline panels

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

3.7.4 Future actions and recommendations

Current legislation for MMS is 70 mm and for MLS is 20 mm.

Nephrops selection

- Improve size selection of *Nephrops*, using market demands as benchmark.
- Develop a trawl to increase age of first capture of *Nephrops*. Consideration should be given to full square mesh codends or novel grading systems such as flexible grids.
- Consider further increases in mesh size for the inshore fleet and assess impact on *Nephrops* and other species.
- Due to the extreme state of some of the *Nephrops* stocks, it may be necessary to develop trawls that release all sizes of *Nephrops*. Modifications to lower wings or belly sections, such as comparatively large square or diamond mesh panels in the lower bellies may assist with this objective.

By-catch selection

- Due to the continuing capture of hake below MLS and the potential impact on the hake stock, measures to improve size selection are urgently required. However, it is recognized that there may be implementation problems due to the market demands for small fish. Further evaluation of large mesh upper panels should be considered.

3.8 Portugal (ICES Areas IXa, b; FUs 26, 27, 28, 29, 30)

The Portuguese fleet fishes Southern (Algarve) and South-western coasts of Portugal, at depths from 150 to 800 m approximately, and in 2001 consisted of 33 vessels (ICES, 2003d) of which 28 were active. The fleet predominantly targets a mixed species fishery for *Nephrops*, rose (*Parapenaeus longirostris*) and red (*Aristeus antennatus*) shrimp 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 to 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 increased, attaining about 1400 and 300 tonnes respectively.

3.8.1 Current legislation

Vessel licenses are issued for all crustaceans rather than for any particular species due to the multi-species nature of the fishery. Vessels targeting fish may also catch crustacean, but this must represent a maximum of 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 banned from 1 September until 30 November, in shallower waters where juveniles are concentrated. In 2003 the fishery was closed during January.

3.8.2 Current issues

Fishing effort has increased due to the progressive modernisation of the fleet and consequent increase in efficiency. The decline of *Nephrops* stocks, which are considered severely overexploited, led to the increase in the capture of rose shrimp, which now contributes the highest landings, and also of red shrimp.

The mixed nature of the fishery and the extension of the depth range exploited from 150–600 m to about 800 m has altered the catch and bycatch composition considerably. In common with many other Southern European and Mediterranean fisheries, it is difficult to classify the individual economically valuable components of the catch as either target or bycatch. For instance, the commercial fish bycatch, especially hake and monkfish, normally of reduced importance, is perceived as important in periods of scarcity of crustacean, 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 in 1995 and 1996, Borges *et al*. (2001) estimated that an average 70% of the catch (by weight) was discarded. Discarding mainly occurs where the catch is of low economic value or is 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. ICES, 2003d recommends that a recovery plan be implemented for *Nephrops* in the Iberian Area (FU 26–30).

3.8.3 Research on selective devices

3.8.3.1 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 codend 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 the trawl into the two different codends. The large mesh in the fore panel was selected to allow smaller individuals or benthic animals to pass into the lower codend. 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 codend, while *Nephrops* was completely retained at the lower codend. Segregation of fish species to the upper codend was observed to be 88 and 70% for blue whiting and boarfish respectively, two non-commercial bycatch 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.

3.8.3.2 Grids

Fonseca *et al.* (submitted) tested a rigid grid with an escape hole which 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 bycatch 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).

3.8.3.2.1 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 70 mm) and a full square mesh codend 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 codend. 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 codends, but a higher L50 for the square mesh configuration. 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 codend geometry from diamond to square.

3.8.4 Future actions and recommendations

Current legislation for MLS, and for MMS is:

Nephrops selection

- Increase MMS to 70 mm and consider the potential of full square mesh codend considering recent experiments, the impact on both *Nephrops* and other species should be monitored. Due to the low stock status of *Nephrops*, it may be necessary to develop methods to exclude *Nephrops* (see Section 3.7.4).

By-catch selection

- 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.

3.9 Mediterranean

In recent years regulations governing various aspects of gear design have been introduced into the Mediterranean fisheries in order to improve the selection process. However, 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. Primarily due to increasing concerns relating to overfishing, recently there has been a strong effort towards the development of a common fisheries policy for the region.

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

3.9.1 Western Mediterranean

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

3.9.2 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 it rarely 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 overexploited. 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 multi-species trawl catch. There are about 36 large vessels fishing the northern Aegean Sea, with LOA ranging from 17–25 m 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 m with the 200–500 m band giving the best results. *Nephrops* is caught along with Blue Whiting, Hake, Flatfish, and three species of *Panead* shrimp. There are other less important species landed as well. *Nephrops* is found up to 80 mm carapace length and the population peaks at around 40 mm. Very few *Nephrops* is discarded from the trawl catches. Total catches of *Nephrops* in Northern Greece have fallen from 217 tonnes in 1989 to 122 tonnes in 1998. The CPUE data from 1975 to 1999 has fallen by a factor greater than 10% from 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 multi-species, 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 80–100 kg 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.

3.9.3 Current legislation

The minimum mesh size permitted in the entire Mediterranean area is 40 mm (EC 1626/94), with no additional gear related technical measures applied, The minimum landing size for *Nephrops* is 20 mm CL. 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). However, due to the limited scale of territorial waters in the Mediterranean, vessels can operate outside coastal waters during the closed season. The codend mesh size used is currently 40 mm full mesh.

Italian bottom trawls are made in knotless polyamide and have a low vertical opening (around 1 m). Previous studies on codend 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.

3.9.4 Current issues

Considering the present MMS in the Mediterranean, the obvious problem, for both target and bycatch, is the small size of the individuals retained. However, the discarding may not be as acute as 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, bycatches 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 juvenile 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 the *Nephrops* fisheries 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.

3.9.5 Research on selective devices

3.9.5.1 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 codends, 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 codend 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 codend while minimizing the shrimp/*Nephrops*. The 35/200 mm grid gave the optimum efficiency; the retention in the lower codend was 68, 70 and 50% for *Nephrops*, shrimps and hake respectively.

3.9.5.2 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.

3.9.5.3 Mesh size

(Mytilineo *et al.,* 1998) assessed the trawl codend selectivity on *Nephrops* using diamond meshes of 16 mm, 20 mm, 24 mm and 26 mm nominal side mesh size (half mesh). The cover codend method was applied for the sampling. The logistic function for the probability of retention by the codend 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 was lower than the legislated minimum landing size. It is suggested that mesh size should be much larger than 20 mm; the size legislated by EU 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 codend retained almost all individuals. The selectivity data for the 42 and 45 mm codends gave L50s that were below the length of first maturity, while the 52 mm codend gave a L50 just above first maturity. Although the 60 mm codend gave the highest L50, that would provide escapement of all first spawning individuals, the authors conclude that the selection ogive was 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.* (1997b) and Stergiou (1999) conducted experiments with three different trawl codends, 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 the 20 D and 20 S allow significantly more individuals to escape through the meshes and that 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 codend. 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 20 D. 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 codend 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 of escape (64%), mainly represented by small-size individuals. The experiment also showed that substantial selection can occur in the main body of the trawl.

3.9.6 Future actions and recommendations

Nephrops selection

- Improve mesh selection through increasing mesh size or codend construction e.g., square mesh while monitoring impact on other species with low MLS, e.g., hake (20 cm) or mullet (11cm).

By-catch selection

- Obtain parameterized data on the critical design components of codend construction i.e. codend mesh size, geometry and square mesh panel design.

4 Current 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 NECESSITY, 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.

5 Conclusions

5.1 General considerations

Many proposals have been made in this report for improving *Nephrops* selectivity through technical measures. It would be helpful also to indicate targets for these improvements - to what ultimate value should selectivity be increased? Medium and long-term analyses to determine the optimal exploitation of individual *Nephrops* stocks have been undertaken in the past by Working Group on *Nephrops* and should be repeated with up-to-date estimates of selectivity over a range of mesh sizes for the commercial gear specifications in use today. Having identified the optimal technical measures, a strategy should then be developed to reach these targets in the medium to long term, ensuring the viability of the fisheries throughout the process of change.

The report highlights that fisheries where *Nephrops* is caught are highly variable in terms of bycatch species, their relative economic importance and the gear types used. While there are similarities, each fishery should be considered separately in terms of applicable remedial measures, a broad-brush approach should be avoided.

Despite the mandatory introduction of devices that improve size selection of bycatch species such as the square mesh and headline panel, it is clear that further improvements are required, urgently in some instances. These may be achieved simply by modifying the existing legislation. In the case of fisheries where the square mesh panel is mandatory, the mesh size could be increased in combination with more stringent definitions of panel position and length.

5.2 Individual recommendations

- In order to assess future developments, a benchmark of population independent selectivity parameters appropriate to current legislation is required. It is a necessary prerequisite to examine whether the methods of measuring *Nephrops* selectivity should be improved.
- The relationship between *Nephrops* biology (age at first capture), selectivity, minimum landing size and fishermen's selection should be investigated in order to provide guidance on optimum exploitation patterns.
- The size selection of *Nephrops* is poor, resulting in a high degree of discarding in certain fisheries. The problems may be associated with low L50 or 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 all areas of the trawl, such as mesh size and shape, twine characteristics, mesh hanging ratio and the effect of codend attachments should be identified.
- The potential for improving *Nephrops* size selection by the use of other selective devices e.g., grids 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 conservation measures between adjacent areas should be considered.
- Methods should be developed to assess the economic impact of changes to technical conservation measures prior to introducing legislation.

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