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NECESSITY

NEphrops and CEtacean Species Selection Information and TechnologY

Scientific Support to Policy (SSP)

Area 1.3 – Modernisation and sustainability of fisheries, including aquaculture-based production systems

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Thematic Priority: **8.1.B.1.3. Task-5 Species Selective Fishing**

NECESSITY Final Publishable Activity Report

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Project coordinator organisation name: IMARES Revision: [draft]

List of contents

Project summary 4
Specific project information 6
Problem description 6
***Nephrops* fisheries** 6
Pelagic fisheries - cetaceans 6
Task-Group aims 6
Nephrops fisheries 6
Pelagic fisheries -cetaceans 7
Nephrops fisheries – approach and results 7
Potential mitigation measures studied 7
Major findings concerning modified Nephrops gears 8
  Sorting Grids - Kattegat/Skagerak 8
  Sorting Grids – North Sea 9
  Sorting Grids – Bay of Biscay 9
  Sorting Grids – Portuguese waters 11
  Sorting Grids – Catalan Sea (Mediterranean) 14
  Square Mesh Panels - Kattegat/Skagerak 14
  Square Mesh Panels – North Sea 15
  Square Mesh Panels - Kattegat/Skagerak 15
  Square Mesh Panels – North Sea 16
  Square Mesh Panels – Bay of Biscay 16
  Square Mesh Panels – Scottish West Coast 16
  Inclined Separator Panel – Irish Sea (Smalls) 18
  Beam trawl modifications – North Sea 19
  Codend modifications – North Sea 21
  Codend modifications – Mediterranean 21
  Cut-away trawl – North Sea 22
  Coverless trawl – North Sea 23
  DynamiT™ software development by IFREMER 24
  BehavioRis™ software development by IFREMER 24
  Statistical planning, modelling and analysis 25
  Major findings concerning biological effects of modified Nephrops gears 25
Gear replacement studies 28
Alternative tactics 30
Evaluation of economic repercussions 31
Pelagic fisheries - cetaceans – *approach and results* 41
General 41
Biological studies 41
  Bycatch rates and distribution 41
  Population identity, size of the population & population dynamic parameters 42
Changes in fishing tactics 44
  Relationship of bycatch incidences with fish discards 44
  Operational factors 44
  Spatial or temporal closures 44
  Diurnal patterns 44
  Fishing behaviour 45
Exclusion devices 45
  Barriers in front part of net 45
  Exclusion grids in the rear part of the net 48

Acoustic deterrents 49
Development of an inter-active device 50
Effectivity of deterrent signals 50
Effectivity of deterrent systems 51
Effect of deterrent signals on echolocation 53
Behavioural Work 53
Major findings of this study 54
Excluder Devices 54
Acoustic Deterrents 55
Recommendations 55
Dissemination and communication 56
Summary of major conclusions 56
***Nephrops* fisheries 56**
Pelagic fisheries - cetaceans 56
Acknowledgements 56
List of presentations and published papers 57

Project summary

In project NECESSITY (contract 501605) twenty three institutes and their respective sub-contractors were working together in two Task Groups, i.e. **Nephrops** and **Cetaceans** to develop alternative gear modifications and fishing tactics in collaboration with the fishing industry to reduce by-catches in the relevant Nephrops and pelagic fisheries, without reducing the catch of target species significantly.

The project consists of ten work packages, as follows:

WP1: Management and co-ordination
WP2: Statistical planning, modelling and analysis
WP3: Species selective Nephrops gears
WP4: Alternative tactics Nephrops fisheries
WP5: Biological effects Nephrops fisheries
WP6: Cetacean by-catch and alternative tactics
WP7: Gear modifications pelagic trawls - Cetaceans
WP8: Impact on Cetacean stocks
WP9: Socio-economic repercussions
WP10: Dissemination and implementation

The duration of the project was 38 months. Special emphasis was given to disseminating the results of the work to the fishing industry and recommending proper implementation of alternative gears and fishing tactics, as well as knowledge transfer between partners from North-West Europe and the Mediterranean. Biological and socio-economic effects were also evaluated.

The main objectives were:

- To develop effective and acceptable gear modifications (by-catch reduction devices) and alternative fishing tactics in co-operation with the fishing industry to reduce the by-catch and mortality of non-target fish species in European *Nephrops* fisheries, and determine the biological effects and socio-economic repercussions of using these.

- To develop effective and acceptable gear modifications (by-catch reduction devices and acoustical deterrents) and alternative fishing tactics in co-operation with the fishing industry to reduce the by-catch and mortality of cetaceans in European pelagic fisheries, and determine the biological effects and socio-economic repercussions of using these.

List of participants	
Partner No	**Organisation**
1	Netherlands Institute for Fisheries Research - Department of Biology and Ecology + BFAFi
2	Centre for Environment, Fisheries and Aquaculture Science, Lowestoft Laboratory
3	Fisheries Research Services - Marine Laboratory
4	Sea Mammal Research Unit
5	Sea Fish Industry Authority
6	Institut français de recherche pour l'exploitation de la mer
7	Centre de Recherche sur les Mammifères Marins
8	Finnish Game and Fisheries Research Institute
9	Danish Institute for Fisheries Research
10	ConStat
11	Danish Research Institute of Food Economics (Fødevareøkonomisk Institut)
12	Institute of Marine Research - Norway
13	Institute of Marine Research - Sweden
14	An Bord Iascaigh Mhara
15	University College Cork, Dept. Zoology and Animal Ecology
16	Centre for Agriculture Research - Sea Fisheries Department
17	Instituto Nacional de Investigação Agária e das pescas
18	Instituto de Ciencias del Mar (Consejo Superior de Invesyigaciones Cientificas)
19	AZTI Fundación
20	Istituto di Scienze Marine - Consiglio Nazionale delle Ricerche
21	National Centre for Marine Research
22	Institute of Marine Biology of Crete
23	Ege University, Fisheries Faculty (Fish Capture Section)

Specific project information

Country/Geographical area: North Sea, North-East Atlantic, Irish Sea, Mediterranean Sea.

Duration: 2004 – 2007.

Coordinating/Organisational body: Wageningen IMARES B.V. (former RIVO)

Funding instrument: EU STREP (Specific Targeted Research) under the 6th European Research Framework Programme.

Website: http://www.rivo.dlo.nl/sites/necessity

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Problem description

Nephrops fisheries

Depending on the fisheries, *Nephrops* are either targeted directly or form a valuable sub-component of the catch. The incidental capture of large numbers of young fish species is a common feature of all European *Nephrops* trawl fisheries. Despite the varied regulations in force, high levels of discarding prevail. The spawning stocks of these discarded fish are below biological safe limits and, in some cases, show a high risk of stock collapse.

Pelagic fisheries - cetaceans

Since the late 1980s, the annual stranding of large numbers of dead dolphins has been noted during the winter months on the French Atlantic and English Channel coasts. Forensic pathology confirmed that a large proportion of these animals have died in fishing operations and pelagic trawlers have been implicated in many cases. The pelagic trawl fisheries of this region are complex and varied, with over twelve target species and six nations involved and at least three major gear types. It became clear that some of these fisheries have relatively low or non-existent cetacean by-catch rates, while one or two others clearly have higher by-catch rates. However, for the majority there was insufficient information to assess by-catch rates.

Task-Group aims

Nephrops fisheries

- To develop novel species-selective gear prototypes and alternative fishing tactics in co-operation with the fishing industry for use in the European *Nephrops* fisheries.
- To evaluate the potential biological and economic impacts of the technologies and strategies developed above.

- To distribute the results to relevant sectors in the fishing industry and contribute to the implementation of the technologies and strategies developed above.

Pelagic fisheries -cetaceans

- To review the current status of knowledge of cetacean by-catches in pelagic fisheries using existing data sources and oncoming data collection programmes. Furthermore, to collect additional biological data (age, year of maturity, causes of death) of landed cetaceans.
- To develop new species-selective gear prototypes and alternative fishing strategies in co-operation with the fishing industry for pelagic trawl fisheries where cetaceans by-catch may occur.
- To compare the effectiveness of commercially available acoustic deterrents (‘pingers’) on cetaceans.
- To adapt or develop acoustic deterrents systems including an interactive acoustic ‘pinger’ in co-operation with a manufacturer.
- To evaluate the potential biological and economic impacts of the technologies and strategies developed above.
- To distribute the results to relevant sectors in the fishing industry and contribute to the implementation of the technologies and strategies developed above.

Nephrops fisheries – approach and results

Potential mitigation measures studied

A range of gear modifications to diminish by-catches in the *Nephrops* fishery in the various nations participating was studied in this project. The problem is that in many fisheries usually a mixture of species is caught, some of which are targeted (e.g. *Nephrops*), whilst others are not wanted, or subject to restrictions to avoid stock collapse (e.g. cod and hake). As gears and practices vary among fleets targeted solutions were sought for each case.

The selection devices were based on two principles: offer escape opportunities to non-target species without blocking their passage, or block the passage of non-target species and guide these out of the net. Examples of the first principle are: cut-away top panels, large mesh top panels, square mesh windows, and of the second principle: an inclined separator panel, and a rigid sorting grid.

Apart from modifying existing towed gears a group within the project investigated the by-catch reducing potential of changing gear type, e.g. from towed gear to passive gears.

The gear development work consisted of designing gear modifications in cooperation with the fishing industry, testing these at model scale in a flume tank, and selecting the best options for further testing and development at sea. Underwater observation equipment was used where possible.

As results and potential solutions vary among different fisheries a range of options are described below.

Major findings concerning modified Nephrops *gears*

Sorting Grids - Kattegat/Skagerak

A clean Nephrops fishery in Swedish waters can be created using a grid with 35 mm bar spacing and a 70 mm square mesh codend (Figure 1 , Figure 2). This is acceptable because it would allow for extra days at sea and access to closed areas. The Minimum Landing Size (MLS) for Nephrops is 40 mm in this area. This only works because the MLS matches the selectivity of the codend. The mixed element of the Nephrops fishery requires another device *e.g.* a 120 mm square mesh panel.

Figure 1: Grid used in Swedish Nephrops fishery – with codend

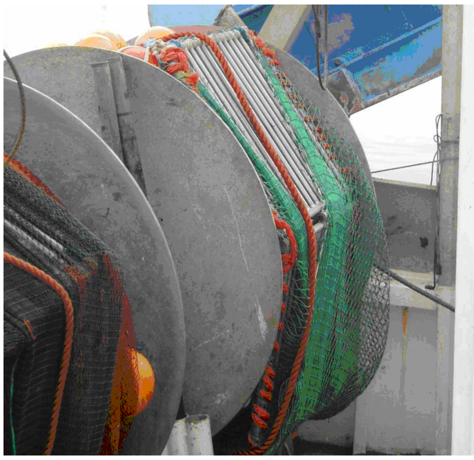


Figure 2: Grid used in Swedish Nephrops fishery – on the netdrum

For the Danish Case a similar grid was tried as for the Swedish fishery, but with no guiding panel, and with a bar spacing in the upper section of the grid of 80 mm and with a diamond mesh codend (Figure 3, Figure 4). The Danish results were different with a higher loss of marketable Nephrops. Another reason may have been the inexperience of the fishermen using grids. The MLS for Nephrops is also 40 mm. There are different incentives within the Danish and Swedish days at sea bills. Generally fishermen need the extra income from landed bycatch. By legislation Swedish fishermen have to use grids in order to get access to valuable Nephrops grounds, which is not the case for Danish fishermen. Consequently there is more flexibility in the use of gears in Sweden.

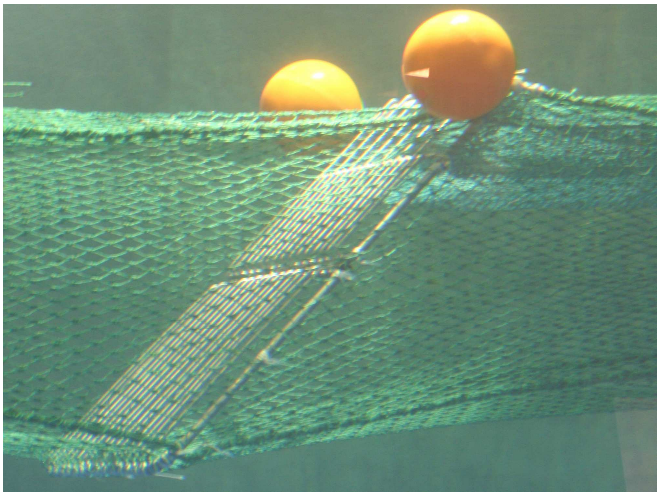


Figure 3: Grid used in Danish Nephrops fishery – model

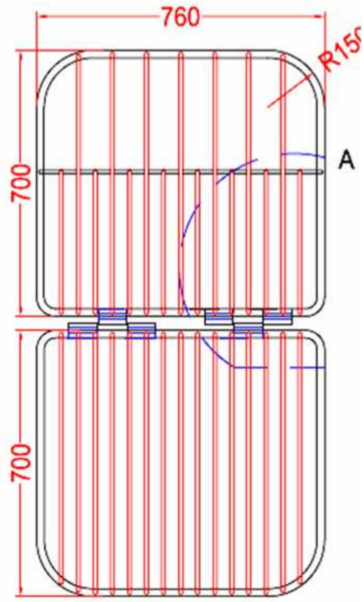


Figure 4: Grid used in Danish Nephrops fishery – dimensions

Sorting Grids – North Sea

The set up of the grid was the same as used in Sweden with 35 mm bar spacing, 70 mm square mesh and 80 mm diamond mesh. There was an unacceptable loss of small Nephrops above MLS (here 25 mm). There is potential for the use of the grid, but it needs to be combined with an appropriate codend mesh size. With the 80 mm diamond, small fish (undersized) were still retained.

Sorting Grids – Bay of Biscay

The French grid in the lower panel of the extension (cylindrical bars, spacing 13 mm) is useful in reducing Nephrops discards in the mixed fishery (Figure 5, Figure 6, Figure 7, and Figure 8). There were no practical problems when using the grid. It is unclear if it improves the selectivity for fish. Additional work was carried out on a grid with 20 mm bar spacing, and the results included very high commercial loss of Nephrops, considering the MLS of 28 mm (cephalothorax length) in the Bay of Biscay, with no improvement in selectivity on hake. However, combining a 13mm bar spacing grid with the square mesh panel of an appropriate mesh size may improve the selectivity for fish. Further work is necessary to optimise the square mesh panel. The efficiency observed on the SMP (blue whiting, horse mackerel and hake) should be improved by extending it on the top of the extension. During the project the French MLS (total length) was increased from 85 mm to 90 mm.

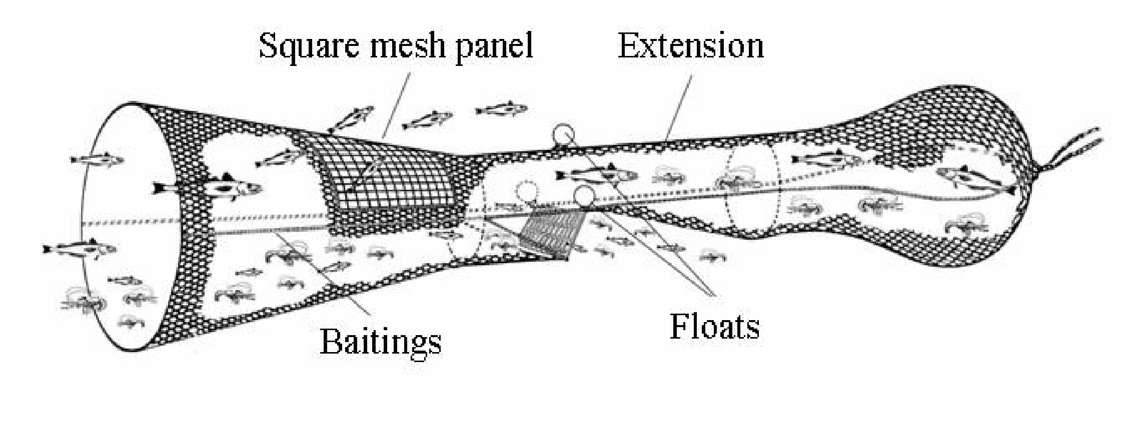


Figure 5: Principle of panel and grid in the Bay of Biscay

Figure 6: SMP (100 mm mesh size) used in the Bay of Biscay

Figure 7: Flexible "Evaflex" grid used in the Bay of Biscay

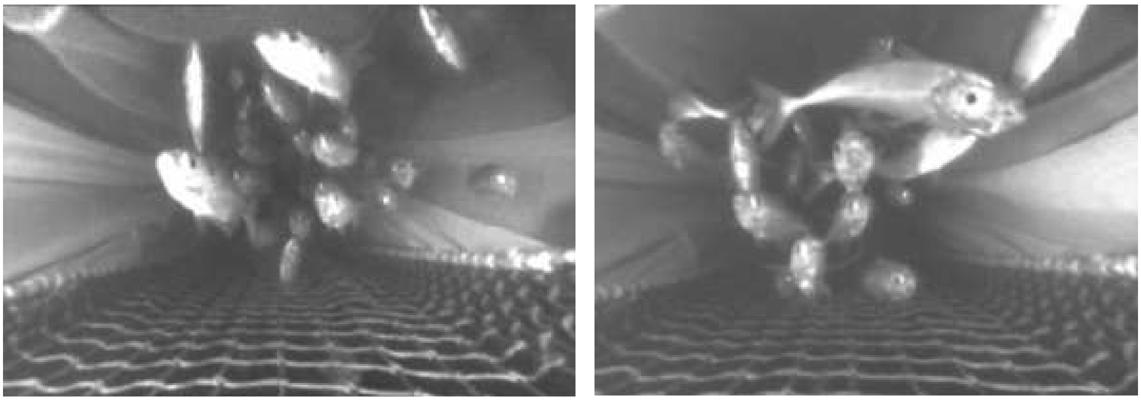


Figure 8: Underwater footage - French trials - horse mackerel swimming along with the gear in a collecting bag above the SMP

Sorting Grids – Portuguese waters

The MLS for Nephrops is 20 mm (carapace length), and the length at 50% maturation is about 30 mm in these waters. The commercial value of rose shrimp in the catch can be more important than that of Nephrops. Three different designs of sorting grids were tested (Figure 9 - Figure 13), corresponding to three different fishing options. GCRUST1 was designed to exclude fish by-catch, GCRUST2 to separate crustaceans from fish by-catch in two different cod-ends, and GCRUST3 to sort out immature Nephrops.

A square mesh cod-end 60 mm mesh size was also tested aiming at sorting Nephrops by size. GCRUST1 was effective mainly in excluding large fish, small individuals could pass through grid bars being retained in the cod-end. There was some loss of commercial-sized Nephrops through the top opening. The objective of GCRUST2, to separate between target species and by-catch, was not fully achieved, and thus commercial testing was not carried out. With GCRUST3, immature Nephrops and shrimp were well sorted out, while immature fish such as hake was almost entirely retained. Grid designs tested onboard commercial vessels (GCRUST1 and GCRUST3), although efficient, were perceived as difficult to be adopted by fishers due to clogging (GCRUST3) and the escape of commercial fish bycatch (GCRUST1).

A full square mesh codend (SMC) would be a better and simpler option to exclude undersized fish and Nephrops (although a 60 mm mesh size proved to be too large). It was extremely efficient in sorting out blue whiting and undersized hake, with no loss of marketable fish This mesh configuration proved to be efficient in the management of both crustacean and fish species. Further work should include a smaller mesh size in the square mesh codend.

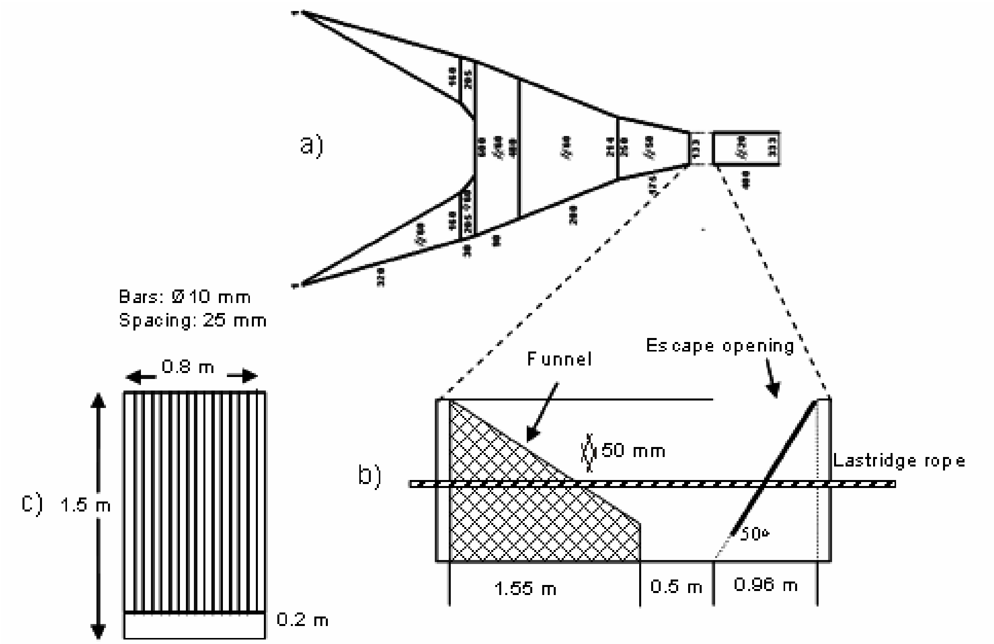


Figure 9: Grid sorting system (GCRUST1) tested in Portuguese Nephrops fishery

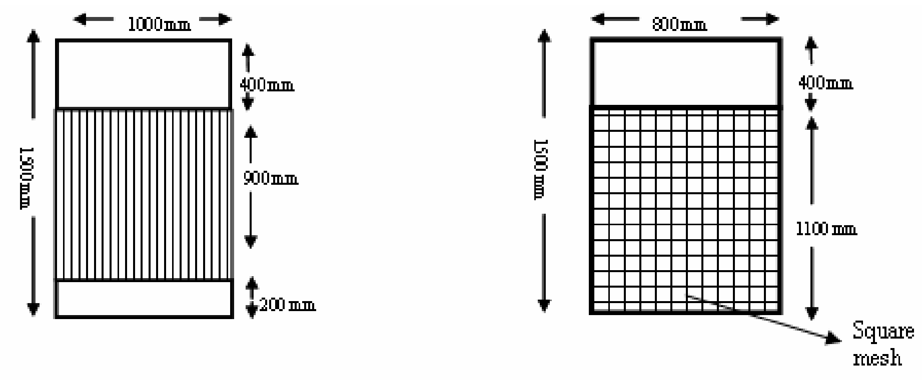


Figure 10: Grids (GCRUST2 and GCRUST3) tested in Portuguese Nephrops fishery - alternative designs

Figure 11: Photo of GCRUST1 - Portuguese sea trials

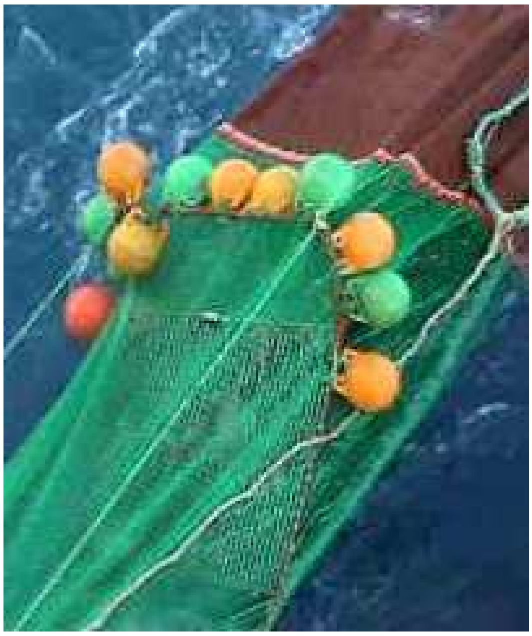


Figure 12: Photo of GCRUST2 – Portuguese sea trials

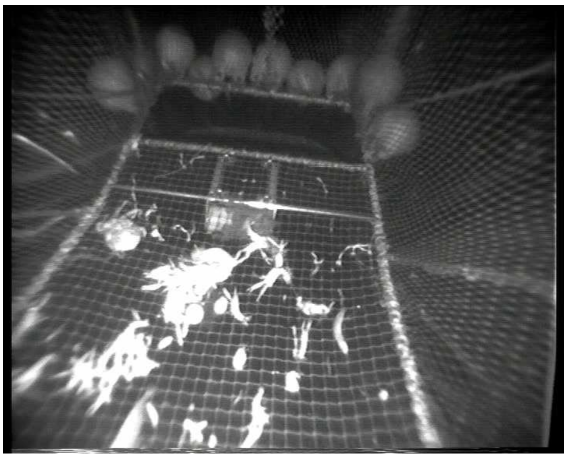


Figure 13: Underwater footage of GCRUST3 – Portuguese trials

Sorting Grids – Catalan Sea (Mediterranean)

A flexible grid with 20 mm spacing was tested in the multispecies fishery in the Catalan Sea (Figure 14). It resulted in escapement of Nephrops with L50 of about 20 mm CL, being equal to the Mediterranean MLS. This grid would apply well to the upper slope waters. The current diamond mesh of 40 mm used in codends is not selective and the grid improves the selectivity for all species. In general there is 40% discarding depending on season and depth. A 40 mm square mesh codend would be a better solution compared to the grid for the fishery in shallow waters, because it reduces the selection range for all species. It also would reduce discards for the main target species. More work is needed on the grid to improve the rigging which could reduce the selection range. The economic loss in shallow waters was 30%, but only 5% in deeper water. Where there is a reliance on fish by-catch, the grid gives an economic penalty of reducing the by-catch.

Square Mesh Panels - Kattegat/Skagerak

Selectivity characteristics comparable to a conventional codend were achieved with a square mesh escape panel SMP (6-9 m from the rear of the codend with 120 mm mesh, and a length of 3 m and a width of 1 m) added (Figure 15, Figure 16). The effect of installing the SMP is a reduction in bycatch of cod and haddock, but also an increase for plaice, Nephrops and hake, but also a loss of marketable whiting and haddock. The panel has been implemented into the legislation (extra days per month if using the panel).

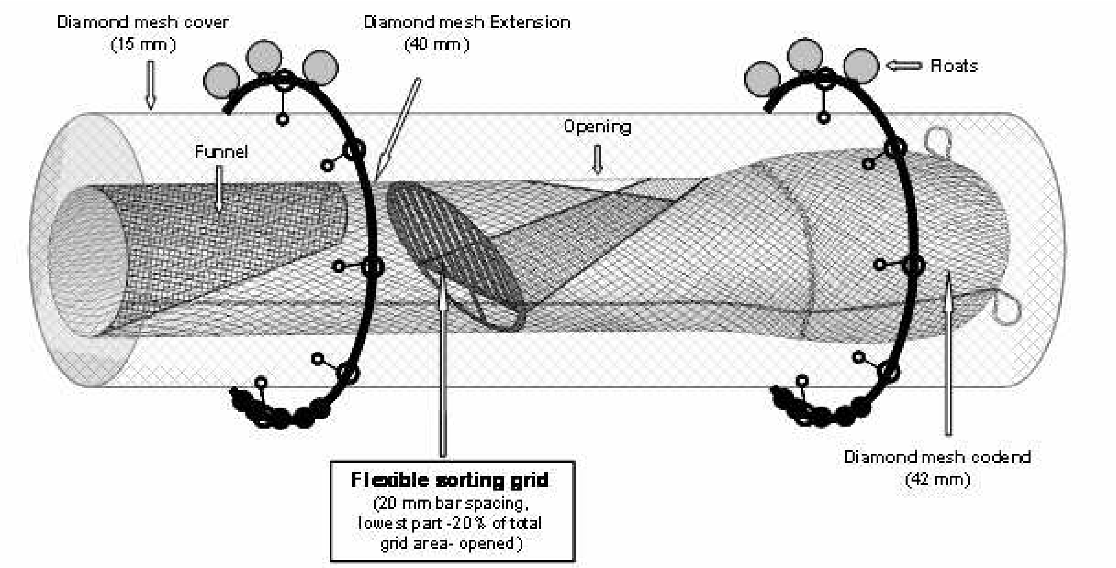


Figure 14: Sorting grid with guiding funnel used in the Catalan Sea

Square Mesh Panels – North Sea

The conclusions for the Skagerrak/North Sea were similar to those found in Denmark, but the L50 for cod was higher. Different joining ratios were used.

Square Mesh Panels - Kattegat/Skagerak

Selectivity characteristics comparable to a conventional codend were achieved with a square mesh escape panel SMP (6-9 m from the rear of the codend with 120 mm mesh, and a length of 3 m and a width of 1 m) added (Figure 15, Figure 16). The effect of installing the SMP is a reduction in bycatch of cod and haddock, but also an increase for plaice, Nephrops and hake, but also a loss of marketable whiting and haddock. The panel has been implemented into the legislation (extra days per month if using the panel).

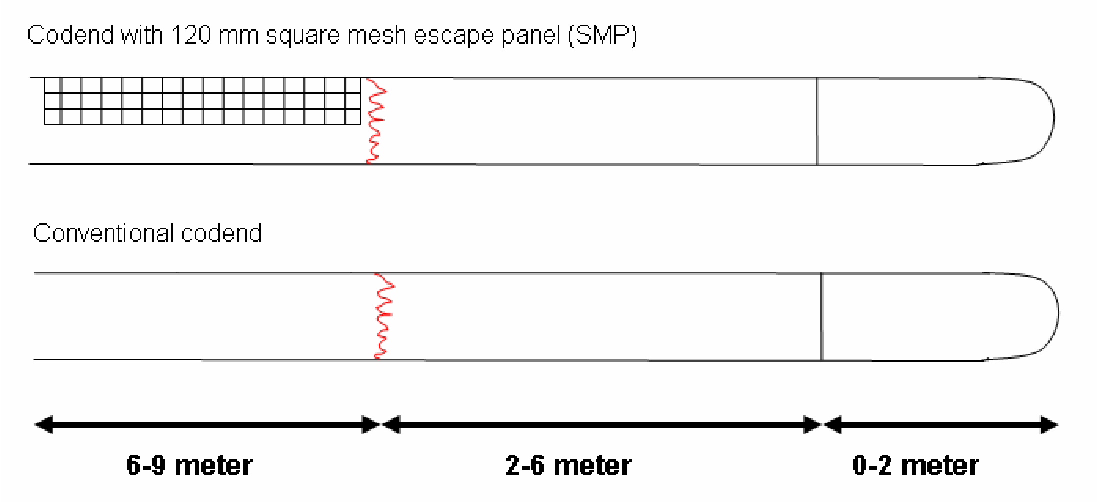


Figure 15: SMP and conventional codend used in Denmark

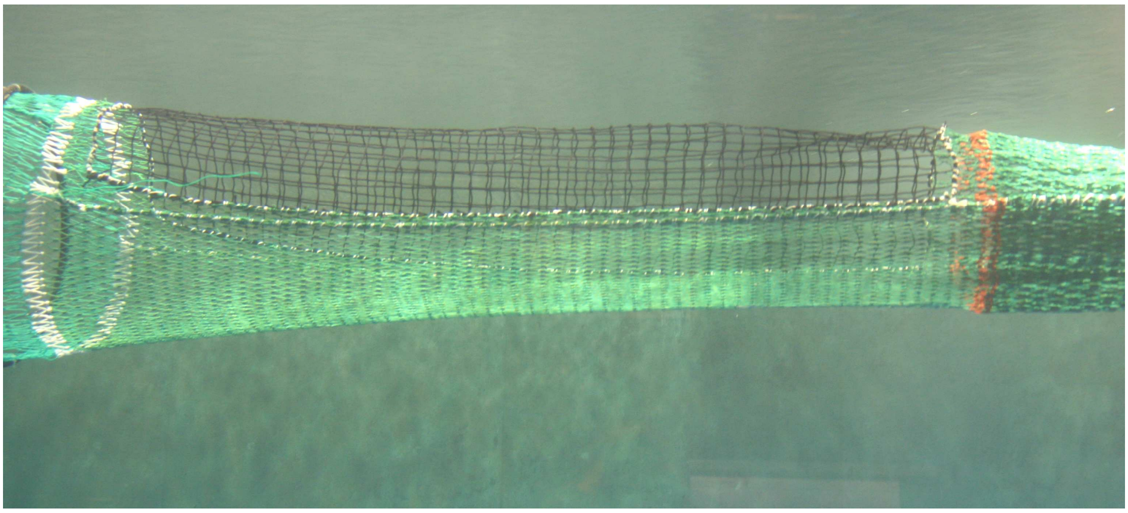


Figure 16: SMP model flume tank SEAFISH, Hull, UK

Square Mesh Panels – North Sea

Trials were done with a secondary SMP tested in two positions and the effect of replacing an existing SMP with one constructed of Dyneema™. The secondary SMP (at 20.6-23.6 m distance from the rear) and the alternative Dyneema SMP (at 9 to 12 m) demonstrated improved escapement of juvenile fish with 42% and 40% reduction in discards in numbers respectively. Dyneema is more expensive and may be more difficult to obtain than current twines. There is potential for substantial improvements in effectiveness of SMPs. However, the relative importance of twine thickness, twine colour and size of SMPs is not yet clarified. This means that selectivity can be improved with the SMP, but we don't know the most important variables.

Square Mesh Panels – Bay of Biscay

The gear modification found was a 70 mm square mesh panels in the sides of the extension on top of selvedge rope, panels 3 m long, 20 cm high (Figure 18). This configuration was relatively efficient in releasing blue whiting, horse mackerel and hake. There was a surprising "efficiency" on the selection of Nephrops, but commercial losses occurred (12% > 8.5 cm or 8% > 9 cm). This configuration might be used for Celtic Sea Nephrops with a higher MLS (L50 = 35mm). Further development of this gear design is needed (e.g. with a square mesh panel on the top of the extension and codend).

Square Mesh Panels – Scottish West Coast

A 3 m long square mesh panel (SMP) with an inclined guiding panel was used in a standard 80 mm diamond mesh codend (Figure 17). The SMP was 14.3 to 17.3 m from the codline. The mesh size of the SMP was chosen as 100 mm to suit the expected size range of fish on the grounds. The aim of the design was to improve the effectiveness of the panel without moving it nearer to the codline since there may be losses of marketable Nephrops and whitefish if the SMP is too close to the codline. The whitefish should be lead towards the SMP thereby improving their chance of escape.

A possible improvement was found in the release of whiting but not of haddock. The retention of Nephrops was unchanged in the new gear. Selection parameters for whiting and hence the effect on the whiting stock were estimated.

Trials of 15 days were not sufficient and further development of the four panel section with the guiding panel is needed in order to optimize the design. Trials are also needed on other gear designs and species, e.g. cod.

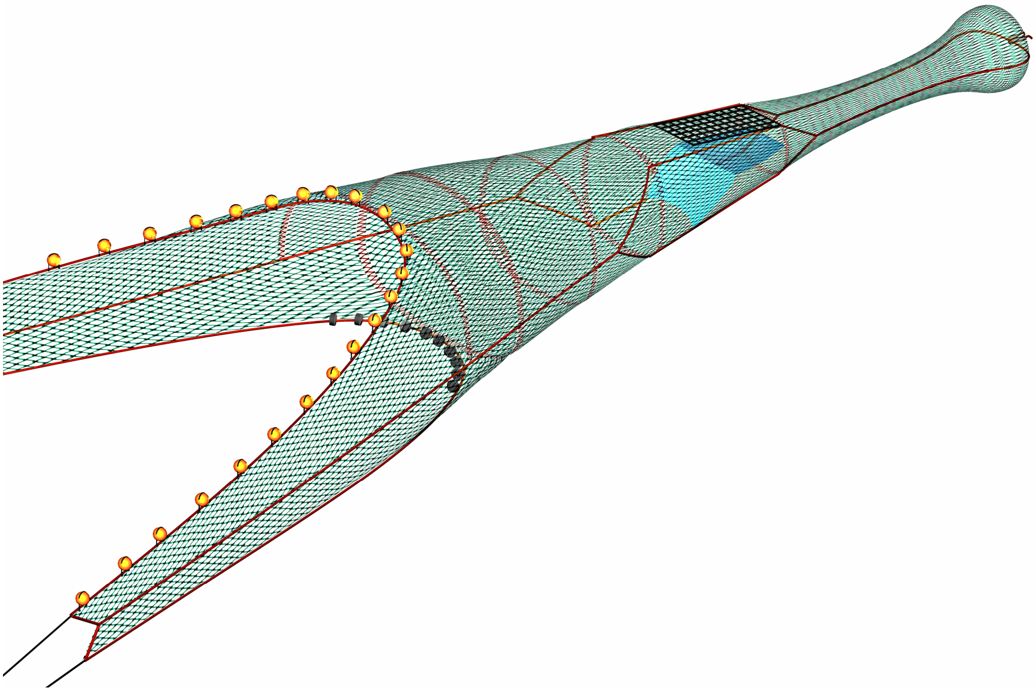


Figure 17: Diagram of experimental net with square mesh panel (black) and an inclined guiding panel (blue) underneath. A gap between the leading edge of the inclined panel and the belly netting allows prawns to pass under the guiding panel into the codend.

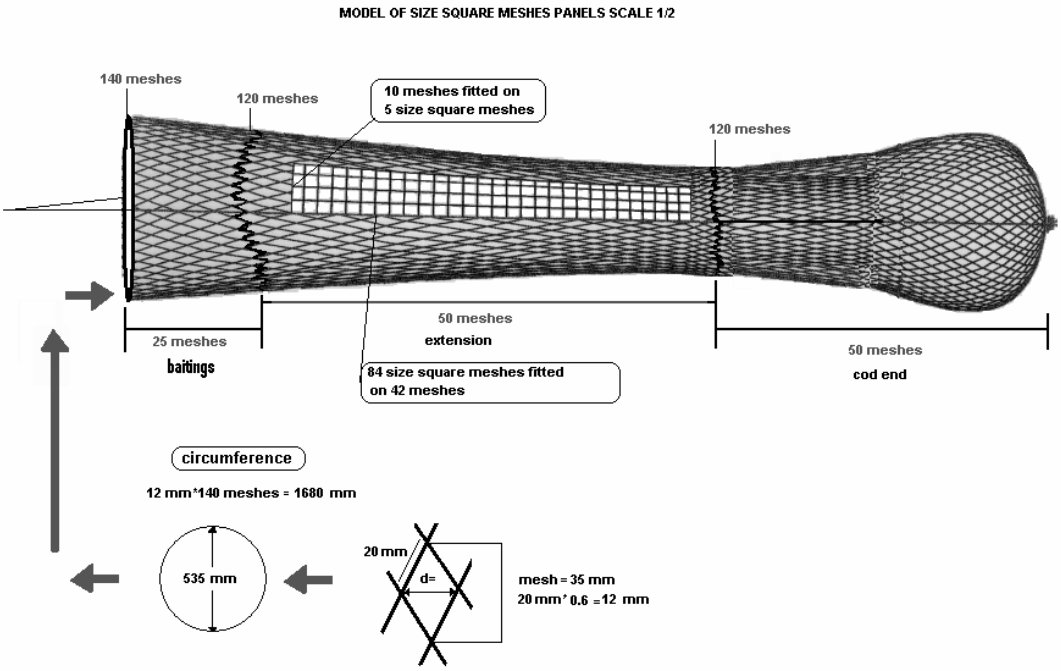


Figure 18: Model of SMP used in the Bay of Biscay

Inclined Separator Panel – Irish Sea (Smalls)

The panel developed here is applicable to a single species Nephrops fishery (Figure 19, Figure 20). There are many different design alternatives. The separation performance is sensitive to the height of the panel above the bottom sheet. There is current legislation for the Irish Sea concerning their use.

A good separation of whiting and haddock was found (between 70-90%), but also some loss of marketable Nephrops (ranging from 30-35%). More cod data are needed. A possible adaptation is a large mesh retaining codend over the escape hole to keep larger fish (an idea proposed by the industry). Irish fishermen prefer it to the Swedish grid (which is more rigid). However, it is easy to circumvent legislation

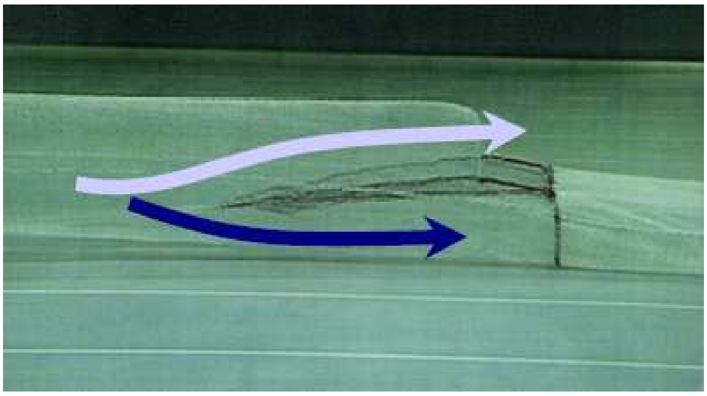


Figure 19: Inclined Separator Panel – model showing working principle. Light blue arrow is non-target species, dark blue is target species

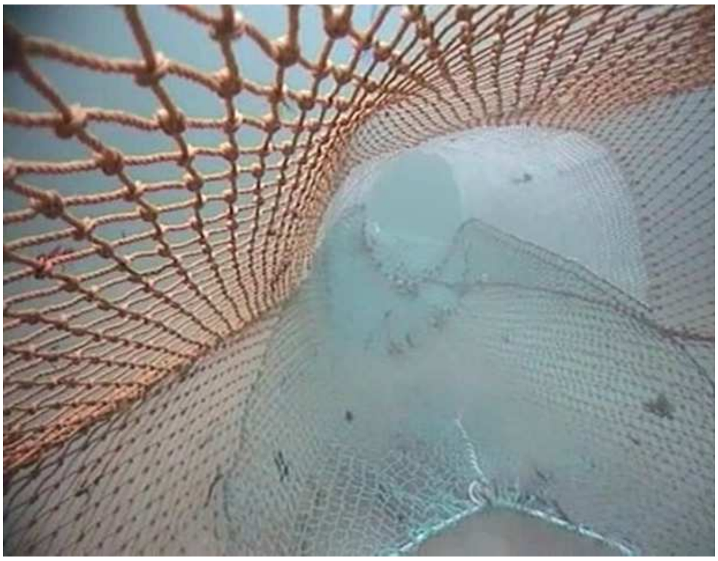


Figure 20: Underwater footage of Inclined Separator Panel

Beam trawl modifications – North Sea

A lowered headline (15 cm height instead of 70 cm), and a cod-end with square mesh window (80 mm mesh size) were tested in a Nephrops beam trawl by ILVO.

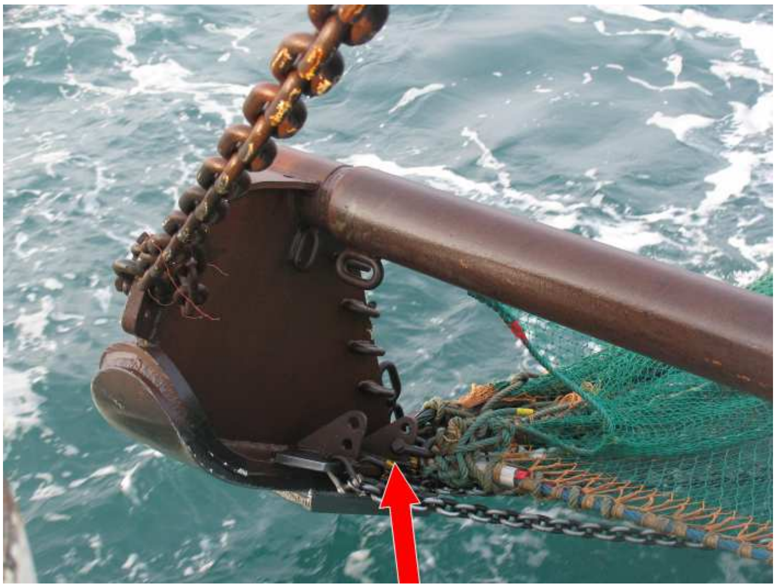


Figure 21: Lowered headline in Nephrops Beam Trawl

<u>Finding for the lowered headline:</u>

The catch separation is negligible.

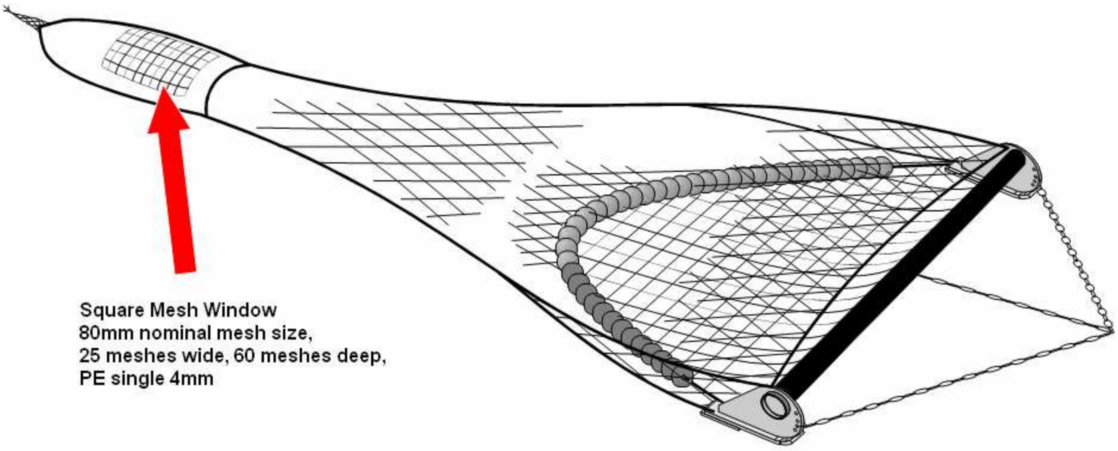


Figure 22: Square Mesh Window in Nephrops Beam Trawl

<u>Findings for the SMW:</u>

The selection improves strongly for whiting and gurnards, but slightly for flatfish. There was not enough data for cod, due to lack of fish on the grounds.

Codend modifications – North Sea

Work was undertaken on codends with different twines and mesh size. Experiments were done on small vessels in the wintertime.

The configurations tested were: codend of 120 mm mesh (mean mesh size 123 mm stretched), double twine 5 mm thick, against 80 mm mesh (mean mesh size 81mm stretched) with single 4 mm twine. This trial demonstrated that if the mesh size increase is large enough, attempts to circumvent its usefulness as an unwanted fish species reduction device will be unsuccessful. The configurations tested in this trial were: codend of 100 mm (mean mesh size 102mm stretched) with single 4 mm twine, against 80 mm (mean mesh size 81mm stretched) using single 4 mm twine.

The combined effect of increasing mesh size and stipulating single twine construction can be effective. Both resulted in significant reductions in discards of cod, haddock, plaice and whiting.

In both trials large numbers of commercially sized Nephrops were lost when the mesh size was increased, whether the mesh was constructed of double twine or single. The catches and earnings of smaller vessels in particular are very vulnerable to mesh size increases even in moderate weather conditions.

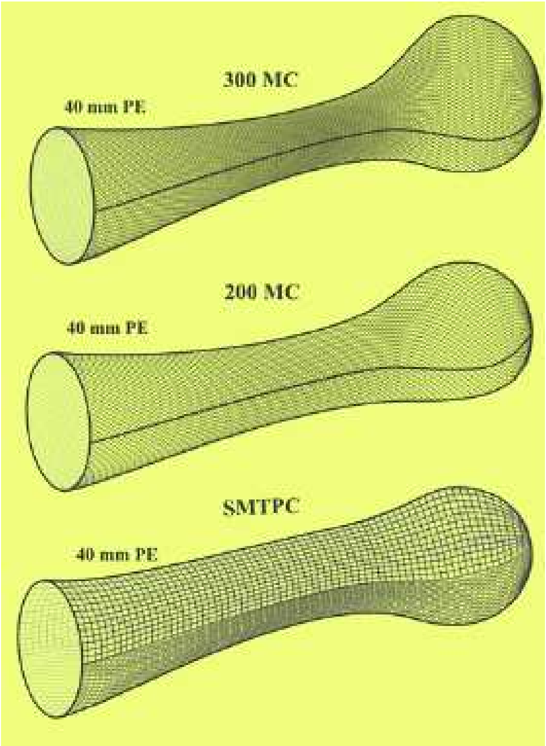
Codend modifications – Mediterranean

Turkey - Selectivity of commercial and five new codends in the Aegean Sea
To reduce the fish and crustacean juvenile bycatch in the Aegean Sea demersal trawl fisheries Ege University Fisheries Faculty tested five different types of codend (narrow, square panels, larger diamond mesh, larger square mesh top panel and total square mesh codend) and compared with the current commercial trawl codend (40 mm diamond mesh).

The Fisheries Faculty conducted two 15 day sea trials in August 2004 and August 2005. A total of 67 hauls was carried out aboard commercial trawler 'Niyazi Reis'. Discard and selectivity data were collected for two crustacean (Norway lobster and rose shrimp) and five fish species (hake, blue whiting, greater forkbeard, blackbelly rosefish, and fourspotted megrim) in commercial and five new design codends.

Results show that the presently used commercial codend (40 mm, PE material, diamond mesh) is rather unselective to release sufficient amount of juveniles. The narrow codend, square mesh netting and larger mesh size all provide relatively better selectivity for most of the species, however, with some loss of marketable catch.

There is not a single codend that can be suggested in this highly mixed fishery. Although the full square mesh codend shows significant improvement in selectivity for many species with only less than 3.5% loss in marketable catch, attention needs to be paid to the reduction in the selection of flatfish. There is a need for more detailed investigation on the biological and economic impacts of the gear changes in this fishery.



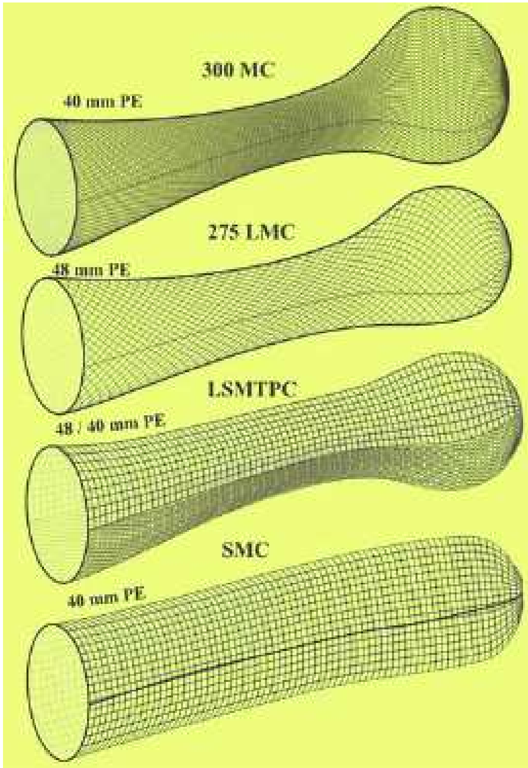


Figure 23: Codends tried in Turkey - August 2004

Figure 24: Codends tried in Turkey - August 2005

Italy (Adriatic Sea)

Three types of codend were tested with the same netting (40 mm mesh opening): larger circumference than commercial (diamond), square mesh codend and traditional commercial (40 mm diamond).

Emphasis should be put on the importance of the hanging ratios in the joining round of square to diamond mesh. Improvements were found in the selectivity of some of the main commercial species.

Cut-away trawl – North Sea

This alternative consists of simple technology and is particularly good for a single species Nephrops fishery, but not so attractive for mixed fisheries (Figure 25).

A reduction was found in all size ranges of haddock, whiting and hake (with no change in selectivity). However, no reduction was observed in cod, or flatfish. There was no loss of marketable Nephrops, and possible gains were even found.

The design is attractive to fishermen due to improved catch quality. It is difficult to circumvent legislation, as the design is straightforward and easy to check. It was tested over a full size range of vessels (<10, 10-23 m)

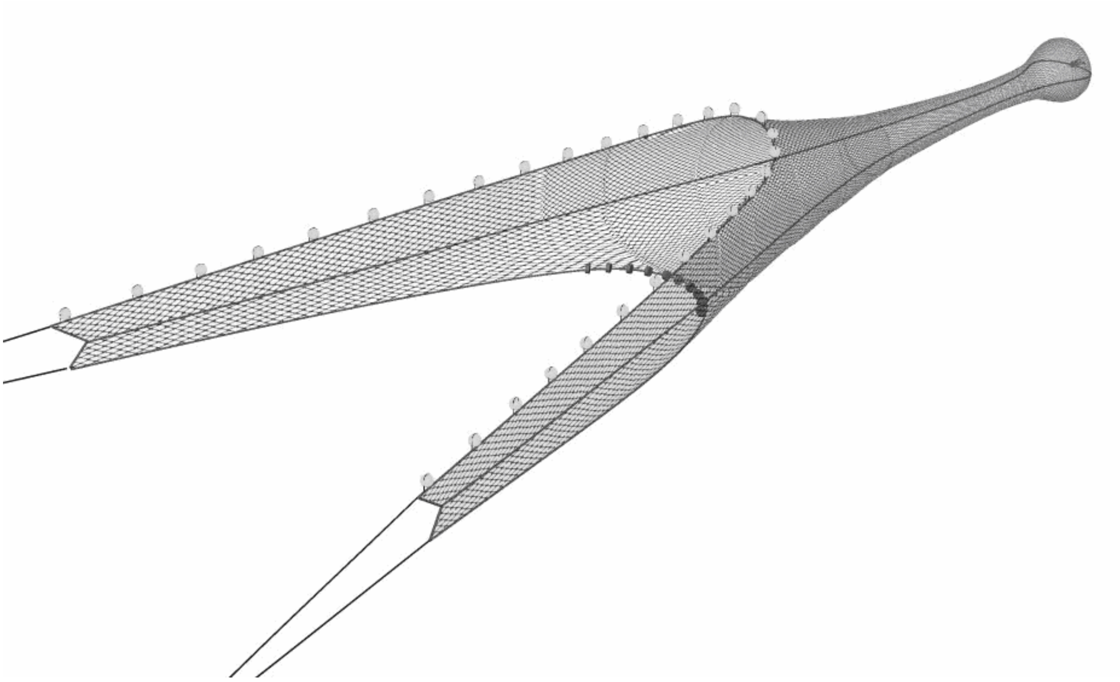


Figure 25: Cut-away trawl (© FRS Aberdeen)

Coverless trawl – North Sea

The results from the first trials on MFV "Margaret Mary" were quite positive (reductions for whiting and hake), but the results from the second trip were totally contradictory. The design is most suited to single species fisheries. Unknown are an area/depth effect and a gear/vessel effect, and problems were indicated at greater fishing depths.

Fishermen considered the coverless trawl to be a sensible approach (Figure 26), and circumvention is not an issue, as the gear modification can be easily recognised.

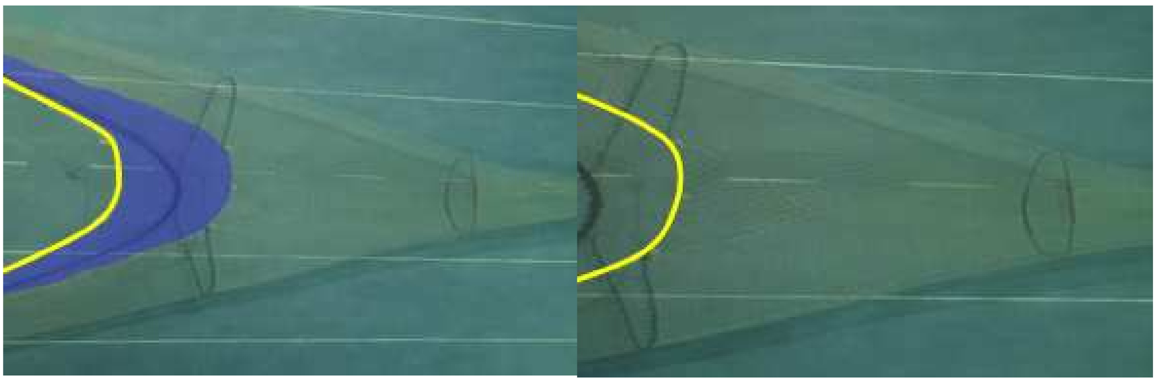


Figure 26: Scale models of a coverless trawl

DynamiT™ software development by IFREMER

A new release of this software with improvements was developed during the project. A mechanical simulation of grids, square mesh panels and separator panels in trawls can now be made (Figure 27). A demo version is available.

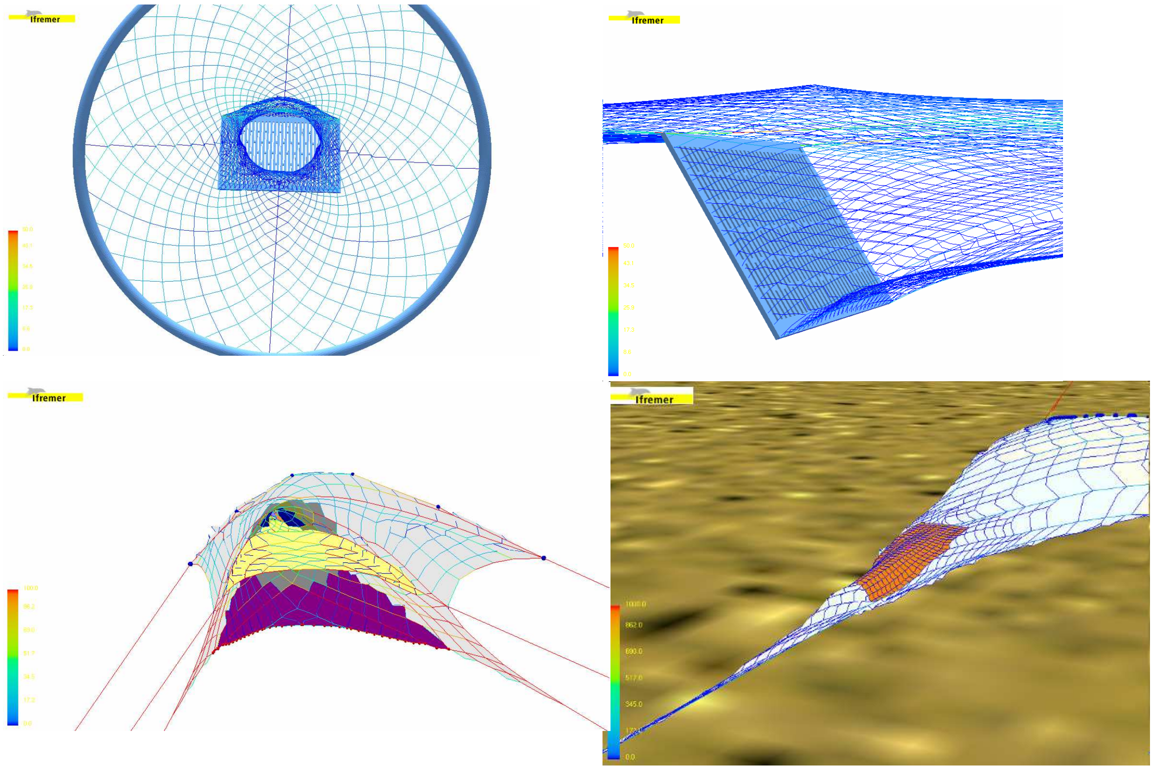


Figure 27: DynamiT™ output examples by IFREMER

BehavioRis™ software development by IFREMER

The development of the BehavioRis™ software has been undertaken to simulate the behaviour of hake and Nephrops in the trawl and around different devices (grids, etc., see Figure 28 and Figure 29). The software can be used as a starting point for predicting selectivity.

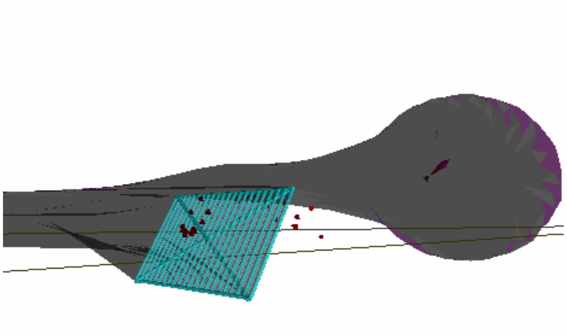


Figure 28: Simulation of Nephrops meeting and passing through the grid

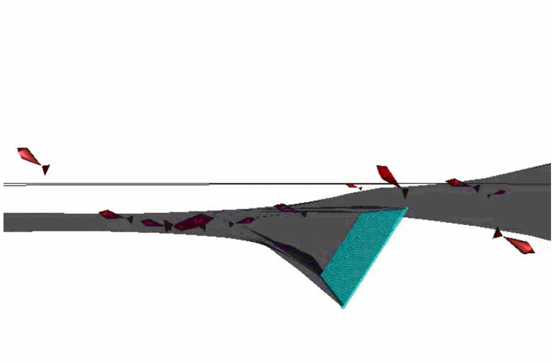


Figure 29: Simulation of hake facing the grid

Statistical planning, modelling and analysis

A data recording tool in Microsoft EXCEL™ was completed and adapted. A power analysis program iPower™ was completed, which runs on the internet, and is publicly available. It is useful for planning selectivity experiments. The URL is: www.constat.dk/iPower. Additional bootstrap methods (in R) for sparse data and individual hauls were developed, although not fully validated yet. Two project workshops on selectivity analysis were held (one in Izmir and one in Copenhagen). Coherent methods have been developed for catch comparison and selectivity analyses. Predictive models were made for an SMC in the Mediterranean, and a 120 mm SMP in the North Sea.

Major findings concerning biological effects of modified Nephrops gears

In various nations the biological effects of introducing more selective gears were evaluated.

For the **North Sea** the conclusions were:

Using FLR Model and ICES parameters, forecasts made for different devices (Dyneema panel, grid and SMC, double SMP, Cut-away trawl, 100 mm diamond mesh codend, see Figure 30). If discarding were eliminated in all North Sea fisheries, stocks would increase by 41% cod, 14% haddock and 29% whiting in 10 years. Eliminating discarding in the Nephrops fishery would increase stocks by 2% cod, 1% haddock and 13% whiting, reflecting the relative proportion of catches. For cod and haddock, the introduction of a grid with a square-mesh codend was the only scenario in which it gave notable increase in stock number. For whiting, stock numbers increased under all scenarios, but landings were highest in the ‘no discarding in any fishery’ scenario owing to limit of somatic growth (*i.e.* whiting do not grow large enough to be caught).

For **Portuguese waters**:

The use of sorting grids or square mesh panels has a consequence for male Nephrops stocks. Forecasts were made concerning catches, SSB, changes in mean weight (revenue proxy). If the exploitation pattern is to be altered, the adoption of square mesh codends seems to be an appropriate choice. Improving selectivity is not enough, by itself, to rebuild SSB. A relatively fast increase in the mean weight of catches may compensate for a short-term decrease in landings in numbers. The impact on other crustaceans, namely the rose shrimp, has to be taken into account.

For the **Bay of Biscay**:

The consequence of introducing any one of three devices (SMP and 13 mm grid, 20 mm grid, two SMPs) on Nephrops biomass, landings and discards was evaluated.

For all devices the results were (with slight differences between devices):

- An increase in Nephrops biomass.
- An initial decrease, followed by a gradual increase in landings.
- A large decrease in discards.

Discards of hake are reduced by using the square mesh panel on the top of the baitings. Around 25% of under-sized hake are spared by this device. Given the current assumption on the growth pattern for this species and the estimate (recalculated) total amount of discards, the estimate fishing mortality for the younger ages are very small and well below the assumed natural mortality. Consequently the impact of the tested selective device appears to be quite low. Thus these results must be dealt cautiously and a firm conclusion cannot be drawn before achieving further investigations of the assumptions used. For instance, the ICES WGHMM (2005) showed that when using a higher growth pattern (deduced from tagging experiments) the impact of a reduction in discards would be more significant.

For the **Catalan Sea**:

A mass-balance ecological model in the ECOPATH/ECOSIM modelling environment with pelagic and demersal habitats, and various trophic levels was used to evaluate the effects of changing selectivity of square mesh codends and using a sorting grid on the ecosystem under three scenarios. A time span of 5 years running was required for the model to reach stability. A total of 20 years running time span after reaching stability produced the model outputs. Four fleets fishing in the Catalan Sea were studied.

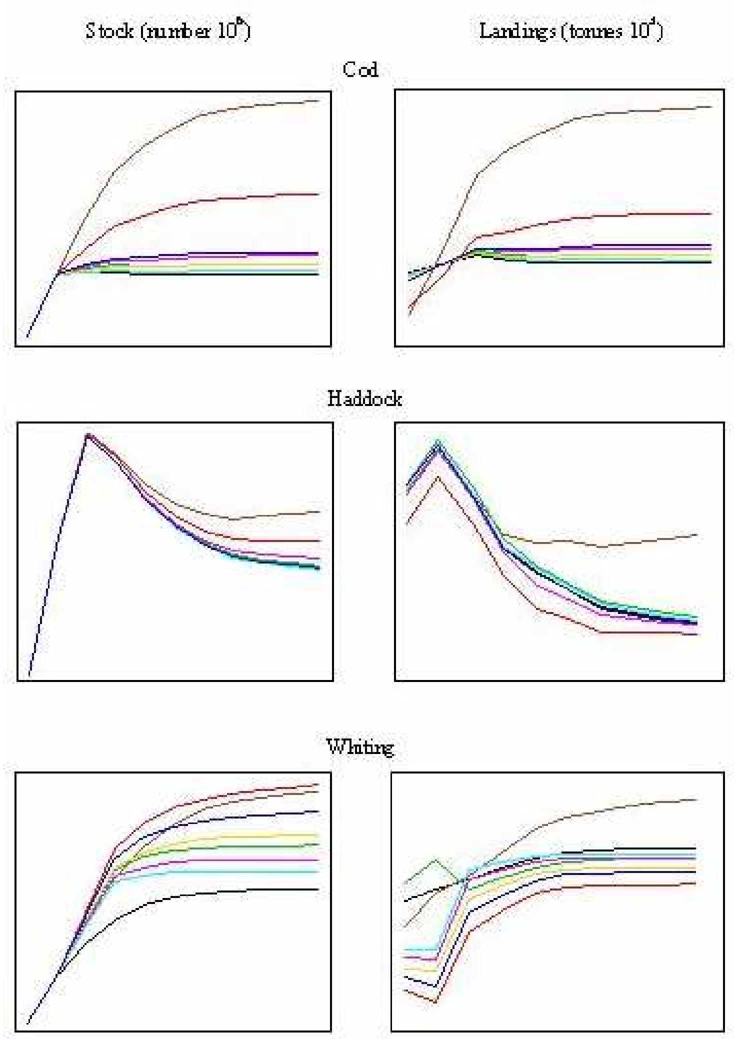


Figure 30: North Sea case. Model output for forecast stock (number 10^6) and landings (weight) of North Sea cod, haddock and whiting comparing the baseline run (black) with the scenarios of no discarding in any fishery (brown), no discarding in *Nephrops* fisheries (green) and the following trawl designs in *Nephrops* fisheries: Dyneema SMP (pink), grid and SMC (red), two SMPs (turquoise), Cutaway trawl (yellow) and 100 mm codend (blue).

The major findings were that an improvement of trawl selectivity has noticeable and complex (direct and indirect) effects on target and non-target demersal species (and the whole ecosystem), the biomass and catch of various commercial species (anglerfish, adult hake) would increase. In addition the biomass and catch of invertebrates (supra-benthos, Norway lobster), juveniles and small-sized fish species (juvenile hake, blue whiting) would decrease. However, these measures improving selectivity are not sufficient to recover overexploited stocks. A larger reduction of fishing effort is needed.

Gear replacement studies

Studies were carried out on the potential replacement of towed gear with static gear in Italy (creels or traps) and Greece (creels and gill nets).

The **Italian** findings were:

Three trap designs were tested: a Croatian, an Italian (Adriatic), and a Scottish one. The performance was also compared with a trawl and underwater observations were made. The work was carried out at 200 m depth in the Adriatic Sea.

Figure 31: Croatian creel

Figure 32: Italian creel

Figure 33: Scottish creel

Biologically, the use of baited traps to harvest Nephrops in the Adriatic Sea is a sound alternative to bottom trawling, as:

- By-catch and discards are dramatically reduced.
- The size-selection of creels with respect to Nephrops is greater.
- The sex-composition of Nephrops catches was very similar between the two gears within the same size-range, thus ruling out the problem of traps catching too many females, especially ovigerous ones.

However, economically, the use of baited traps to harvest Nephrops was not feasible. A very high scavenger activity was present in the area. Thus, despite there being a high density of Nephrops, relatively few actually were attracted to or entered the creels. Further work needs to be done on reducing scavenger activity.

The most efficient creel type was the Scottish type.

Findings in **Greece**:
Monitoring of commercial Nephrops trap fishery (Greek trap, metal frame, 28 mm plastic square mesh) and mixed gillnet fishery (48 & 52 mm mesh) occasionally targeting Nephrops were carried out along with underwater behaviour observations of the traps and trawling (40 mm diamond mesh). In addition, selectivity studies were carried out using mesh sizes of 17, 22, and 28 mm diagonal fixed plastic square mesh with the Greek trap type and gillnets with 48, 52, 56 and 60 mm diamond mesh nets.

The trap catch is seasonally variable, catches are dominated by Nephrops (54-83%, mean CPUE 100 Nephrops per 100 traps), discarding is low and by-catch is very limited. Traps are highly selective for Nephrops. The selectivity experiments showed that the large mesh (commercial size) is much more selective than small and medium mesh sized traps (there were no differences between small and medium mesh size). In the large traps almost all Nephrops caught were above

30 mm CL (and above size at maturity SOM), while in the small and medium mesh size traps up to 15% of Nephrops were below 30 mm CL. The estimated L50 for the large mesh sized traps was well above MLS and SOM and for the medium mesh trap above MLS but below SOM. The estimated Lo for gillnets were above SOM. The Nephrops proportion in gillnet and trawl catches was low (17% and 12% respectively) with 10% and 27% of Nephrops caught below 30 mm CL. In addition, traps do not seem to attract berried females out of their burrows with trawl catches having higher percentages of berried females than traps.

Behaviour observations using the commercial trap indicated a 30% catch rate, but 100% interaction of Nephrops with the trap. Nephrops go in and out of the trap. Other species in the trap may disturb Nephrops from entering the trap.

Although the current legal mesh size, along with a number of precautionary measures (closed season, maximum number of traps per day per vessel), was set with no strong science background, the current legislation is backed-up by the findings of the selectivity experiments.

Out of area trials (in a deep ground off Mytilini island) further backed up the Pagasitikos Bay trials with similar results for Nephrops while highlighting the possibilities for extending the Nephrops trap fishery into deeper waters where topography or closures prevent trawling (Figure 34).

Figure 34: Out of area trials. Creel bycatch (mostly deep water rose shrimp, and blackbelly rosefish) (left) and Nephrops Catch (right) for small (bottom), medium (middle) and large (top) mesh traps in Mytilini.

Alternative tactics

For a number of cases the potential of reducing bycatches by changing fishing tactics has been studied.

Data on the Nephrops fishery were collected for the Bay of Biscay, and analysed statistically to identify the key factors that play a role in the high discards of hake and Nephrops in this area (Figure 35).

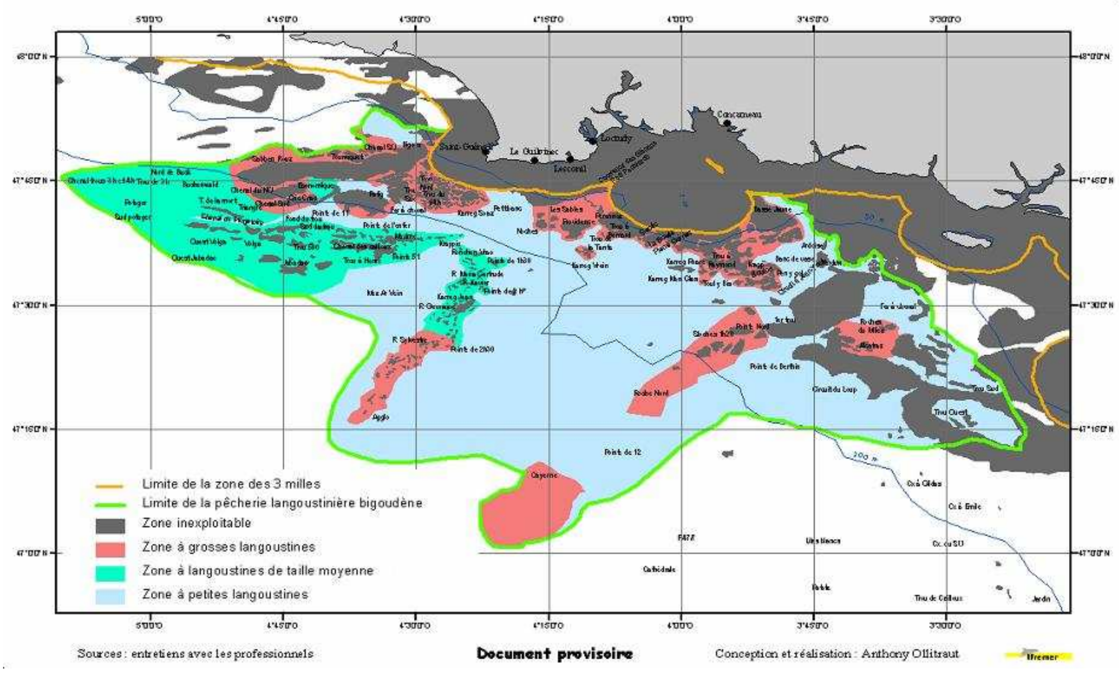


Figure 35: Example of mapping Nephrops trawling activities related to target sizes (Bay of Biscay)

The conclusions that were drawn from statistical analysis are given hereunder :

- For hake, a seasonal closure located in the central zone (and near the coast) may be a good management decision :
  - In May or June because young hake join the coastal nurseries at that period, while at this time of the year the Nephrops trawlers have a heavy activity.
  - Or between December and February because the discards expressed in weight by haul are at their highest, and less trawlers fish Nephrops at that time (thus this measure should not have a heavy impact on the fishermen’s turnover).
- Regarding Nephrops, the central zone is also where the higher discards occur. The higher discard rates occurring in June, July and August, the simulations should bear on closures at that time of the year.

The model (ISISFISH) used to test these new management rules did not permit to close so precise zones. Thus the zones investigated are the ICES rectangles 24E5 and 24E6 (see Figure 36) which are the most worked by the Nephrops fleet. The period which seems to be the most interesting for Nephrops <u>and</u> hake is June. Closures could be decided for this month.

Thus three scenarios was tested :

1. Closure 1 : 24E5 in June
2. Closure 2 : 24E6 in June
3. Closure 3 : 24E5 and 24E6 in June

It should be noted that the simulations take into account the effort transfer, in other words, the position of the fishermen in view of such a measure will be to work another zone. This is of course a strong assumption since most vessels are small vessels which could hardly go elsewhere than in the rectangles just off their home port. Thus, the results of this simulation should be treated with caution.

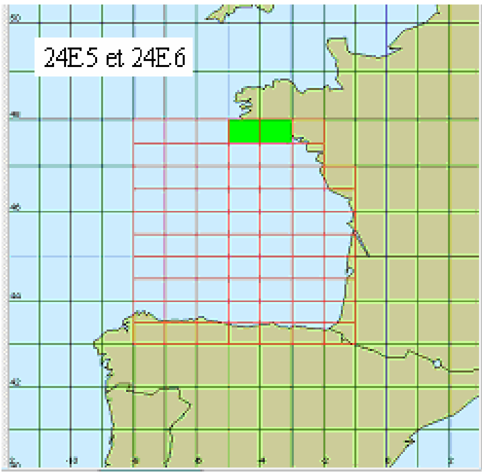


Figure 36: Scheme of the areas tested for seasonal closures

The simulation shows that a closure of one or two ICES rectangles would have no significant impact on the biomass and landings of Nephrops or hake. This may be due to the fact that the fishery occurs in many other rectangles and that reports of fishing effort on others areas are assumed by the model. This is probably a strong assumption given the size of the vessels concerned by the closure tested. Anyway, such a measure should also be assessed by economic simulations which should take into account the gains and losses for the whole fleets together with the gain for the stocks and biodiversity.

Evaluation of economic repercussions

Method

Vital for success in any new innovation is to obtain commercial acceptance by the users (the fishing industry). This called for an economic evaluation of the newly developed gears and practices. A group in the project worked on defining the proper methodology for doing this through Cost Benefit Analyses and Cost Effectiveness Analyses, and was fed with technical and biological data resulting from experiments.

Cost Benefit Analysis is a method to weigh the profitability of investments taking into account future income and expenses and using discount rates, thus taking into account the time value of money. Discounting benefits and costs take into account that present production and consumption is valued higher than future production and consumption. The discount rate takes this into account. Execution of a CBA requires that different projects are compared with the aim to find the best project in economic terms. The method requires that the various effects concerning a project are expressed in monetary terms, and this may go beyond closely linked earnings and income. Some external effects can be the willingness to pay for whale survival, or to reduce discards. The criterion calculated is called Net Present Value (NPV), and the concept is explained in more detail below.

Formally, the problem is expressed as in (1). Execution of a CBA requires that different projects are compared with the aim to find the best project economically. The most limited case is where one project (the base line) continues as hitherto, and the other project comprises implemented changes. Formula (1) is showing the model for the base line:

(1) $$NPV_j^0 = \sum_{t=0}^{T} \frac{\sum_{i=1}^{I} H_{i,t}^0 * p_{i,t}^0 - C_t^0 - G_t^0 + V_t^0 - U_t^0}{(1+d)^t} - I_j^0$$

Where index *i* is species; *j* is fleet segment; and *t* is time. NPV^0 is net present value (profitability of investment) in the base case, *H* is landings (harvest); *P* is fish price; *C* is variable costs; *G* is fixed costs; *V* is external effects (net) for example willingness to pay for whale survival, or is discard is considered ecological harmful. *U* is management costs (information gathering, administration, monitoring, control and enforcement). Finally, *I* is investments costs in gear, and *d* is the discount rate.

For a project with changes the formula looks:

(2) $$NPV_j^1 = \sum_{t=0}^{T} \frac{\sum_{i=1}^{I} H_{i,t}^1 * P_{i,t}^1 - C_t^1 - G_t^1 + V_t^1 - U_t^1}{(1+d)^t} - I_j^1$$

The variables in (2) are the same as for (1) but different data inputs will be used for different projects. Therefore, the decision rules as to whether the new project should be accepted or rejected is the difference between *NPV* for the whole fleet, compared for projects of the same duration, as shown in (3) and (4):

(3) $$\sum_{j=1}^{J} NPV_j^1 > \sum_{j=1}^{J} NPV_j^0 \text{ ; accept}$$

(4) $$\sum_{j=1}^{J} NPV_j^1 < \sum_{j=1}^{J} NPV_j^0 \text{ ; reject}$$

This decision rules means that if a change in gear yields higher net present value for the whole fishery i.e. all pertinent fleet segments the project should be accepted, and *vice versa*. That means on the other hand that some fleet segments may be worse off by the gear change while others may come better off.

The calculation that is accomplished by using equations (1)-(4) requires information about all the variables *H, P, C, V, M, I,* and *d*. Information about landings, *H,* is derived from biological models in which catches (landings including discard) are estimated. In age structured models the number of fish for example at age 1 in year 1 is reduced to the number of fish at age 2 in year 2 and so forth. This decay is caused by natural mortality and by fishing mortality. The share that is caught is the proportion between fishing mortality and total morality (natural and fishing). Further, only the fish caught above minimum size are landed. The rest is either discarded or landed illegally and will, therefore, not appear in the recorded landings of a vessel.

Major findings concerning economic repercussions of modified Nephrops gears

A Cost Benefit Analysis (CBA) was carried out for a number of cases. Results from the most data-rich case from Kattegat/Skagerrak are presented below.

The model has been applied to a number of other selectivity trials some of which concern Nephrops and the "by-catches" of demersal fish species. Some of the trials concern pelagic trawling and the opportunities to avoid by-catches of porpoises by using various devices fitted on the trawl.

A number of species are subject to stock assessments. Officially published data from ICES are used. In general, no assessment is published for Nephrops in terms of age or length composition. For cod, haddock, whiting, hake and plaice information is published. Stock assessments in terms of age composition, fishing mortality rates, and natural mortality is used as input in the stock projections that form basis for the estimations of future landings in the base line case and the cases with gear changes. The following Map of management areas for Nephrops shows where the trials have taken place (Figure 37).

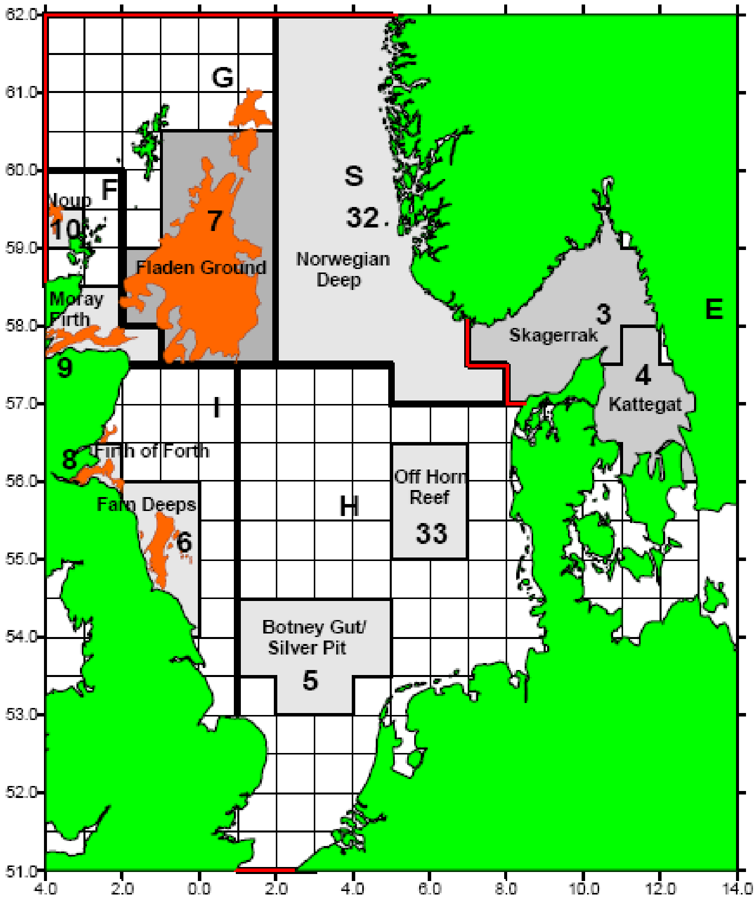


Figure 37: Management areas for Nephrops

Source: ICES, WGNSSK Report 2006, Figure 3.1.1

The considered case in Skagerrak and Kattegat comprises the economic repercussions for Danish fleet segments.

The investigated cases are one with 90 mm mesh size and one with 90 mm mesh size including a 120 mm window in the upper part of the cod end of the trawl. The design of the trawl and the placing of the panel is aiming at being neutral with respect to Nephrops i.e. no catch changes are assumed for this species. Further it is assumed that landings of all other species except cod and plaice (and Nephrops) are constant. This latter assumption is made because of lack of data for other species either with respect to published stock information (assessment) from ICES or selectivity information from the trials.

The cost benefit model applied to these cases is the most extensive one including economics and stock dynamics. Base year is chosen to be 2003 to make biological assessments publish in report from ICES, and economics fit together in a year in which gear changes in term of panels or windows were not yet implemented.

The Danish fleet with vessel lengths below 24 m has been subdivided into three segments to make up a total of four segments. Danish vessels below 12 metres and above 40 metres do not target Nephrops. For these segments costs and earnings data are available and shown in table 1.

The landing value comprises all species caught. The variable costs comprise fuel, ice, provisions, landings and sales costs. Gross margin is calculated as the difference between the two items: landings and variable cost, and this measures forms bases for the net present value in the cost benefit analysis.

Table 1: Cost and earnings for Danish vessels at vessel level. Base year 2003. Values x1000 €

Length	Landings value	Variable costs ‘)	Gross margin	Labour costs	Margin **)
12-15m	144	65	79	89	-10
15-18m	213	100	113	111	2
18-24m	404	191	213	186	27
24-40m	691	374	317	253	64

*) Variable cost before remuneration of labour and capital

**) Before remuneration of capital

Source: Cost and earnings statistics, Institute of Food and Resource Economics

Nephrops, cod, and plaice are less important in terms of weight while they are very important in terms of value not least for the smaller vessels. This picture is influenced by the fishery for “industrial” species (for fishmeal and –oil) that is executed by the larger vessels as part of their yearly fishing pattern. Other important species in the catch composition are sole, anglerfish and haddock. There are no recorded selectivity measures for these species, however, from the trials. Therefore, they are kept constant in the subsequent calculations

To apply the selectivity model as part of the CBA, a series of biological data are required in terms of stock composition on age groups in the base year, natural mortality, fishing mortality, length and weight of the fish. The data used are extracted from ICES’ reports (ICES WGBFAS 2006 for cod, and ICES WGNSSK 2005 for plaice).

Recruitment for cod is taken as the average recruitment 1980-2004 at age one, which is 9.864 millions with a maximum at 20.984 millions and a minimum at 0.894 millions. Natural mortality for all age groups is assumed to be 0.2.

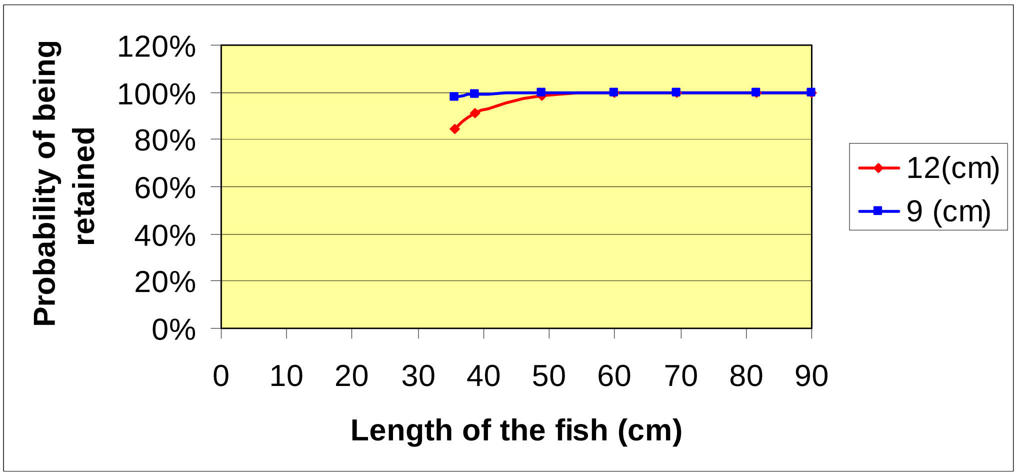
Recruitment for plaice is taken as the average recruitment 1978-2004 at age two, which is 51.008 millions. The estimated maximum recruitment was 134.6 millions and estimated minimum recruitment was 25.7 millions. Natural mortality for all age groups is 0.1.

Cod, plaice (and other species) are caught by the use of different gear types in particular gill net and trawl. It is assumed the fishing mortality induced by gill net is unchanged, and the impact on fishing mortality caused by changes in the trawl fishery is partitioned according to the trawler share of the total landings of these species in Kattegat/Skagerrak. The trawlers’ share appears from Table 1, and the figures for Kattegat are chosen for the CBA calculations.

Selection estimates are obtained for Nephrops, cod, plaice, whiting, and witch. Estimates are used for cod and plaice but disregarded for Nephrops, whiting, and witch. For Nephrops no stock estimates based on age structures are available, and the same goes for whiting and witch, which are of less importance.

Selectivity ogives are calculated and presented in Figure 38. The ogives are shown for age groups 1 (average length 35 cm) and upwards for cod and age 2 (average length 27 cm) and upwards for plaice. This implies that the effect of the gear change on the 0-age group for cod and 0-1 age groups for plaice are disregarded. As no information is recorded for younger age groups inclusion of these would require estimating a growth equation for all age groups.

Cod



Plaice

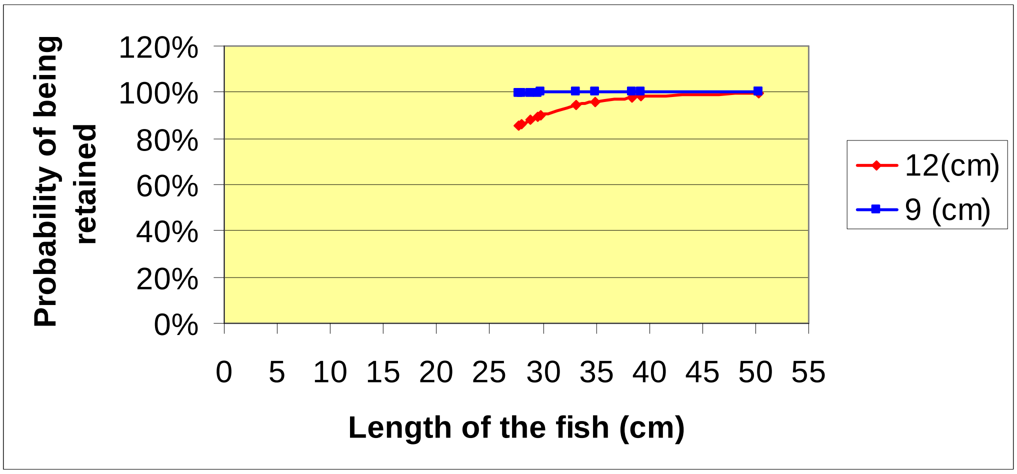


Figure 38: Selectivity curves for the Kattegat/Skagerrak trial (Source: the Danish NECESSITY trial team)

Applying the change in selectivity to the biological projection model, the changes between the base line and case with 120 mm panel in landings are shown in Figure 39 for cod and plaice in value and in weight. For example when the landings have become stable from 2011 the landing value of cod is nearly 2% higher as compared to the base line.

Figure 39: Projected changes in landings of cod and plaice with 120 mm square mesh panel

It is noted that the change in value is stronger than the change in weight for both species reflecting that the unit price increases in the long run due to a change in landing composition towards older and larger fish that fetch a higher price. There is a small fluctuating decrease in cod landings in the beginning of the period, and a strong decrease in plaice landings. The calculations are based on ICES stock assessments which entails that the age composition in 2003 is “uneven”. This is reflected in the beginning of the projection period. After seven year the system goes towards “equilibrium” i.e. no change in “the changes”.

The comparison of the base case, i.e. without gear change, and the case with gear change has been performed by use of equations (1-4). A number of simplifying assumptions have been used and are summarized below:

H: landings are constant for all species except cod and plaice
P: fish prices are constant for all species except cod and plaice, where price is a function of grade
C: variable costs are kept constant
G: fixed costs are kept constant
V: external effects (net) are disregarded i.e. for example discard is not considered ecologically or ethically harmful.
U: management costs (information gathering, administration, monitoring, control and enforcement) are kept constant
I: investments costs in gear is assumed to be the same with and without gear change
D: the discount rate is fixed at 5 %
T: the time horizon is fixed at 10, 20, and 30 years

Results from this run are shown in Figure 40 as regards the difference in gross revenue between the gear change case and the base case. The impact on the larger trawlers of the gear change is the strongest. This is caused by the relatively higher share of cod and plaice in landings by these trawlers. The projection is shown for 10 years. This period is long enough to make the stock reach a biological equilibrium, as constant recruitment and mortality rates are assumed.

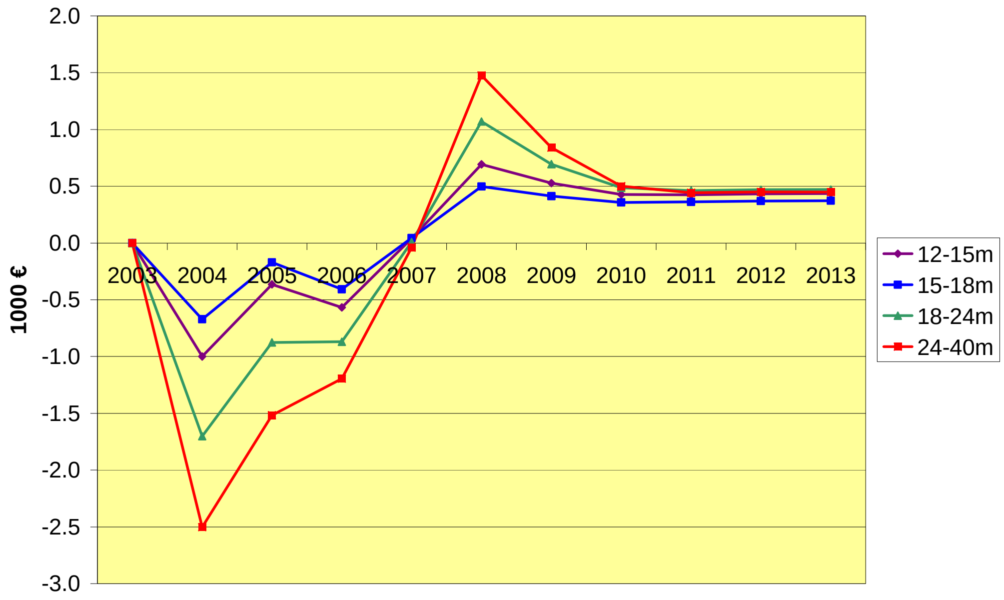


Figure 40: Increase in gross revenue at vessels level

As a consequence of the assumptions about the costs, the indicator used to calculate net present value is the gross margin defined as gross revenue minus variable cost exclusive of crew share. In fact the decision rule would come out with the same choice of case even if NPV of gross revenue was used. The result is presented in Table 2.

The fishermen will put emphasize on the short period at 10 years, and probably even shorter, while society will put emphasize on 20-30 years. The result shows that should not (would not) be accepted by the fishermen in total. On fleet segment level, the smaller vessels will benefit over 10 years while the larger would not. Over a long time horizon 20-30 years all segments will benefit.

The direction in which the NPV would move as a result of changes in the assumptions is shown in Table 3. It is to bee expected that the fishermen will execute their fishery at the lowest possible costs. Consequently, a gear change would lead to cost increases for the fishermen.

Table 2: Net present value (NPV) over 10; 20; and 30 years

Vessel level				Segment level				
Length	10	20	30	Length	No. of vessels	10	20	30
		000 €					000 €	
12-15m	0.5	2.5	3.8	12-15m	39	217	326	39
15-18m	0.7	2.4	3.5	15-18m	55	203	294	55
18-24m	-0.4	1.8	3.2	18-24m	-42	172	304	-42
24-40m	-1.7	0.4	1.7	24-40m	-106	24	104	-106

NPV=gross revenue minus variable costs (before remuneration of labour and capital)

Table 3: Impact of assumptions

	NPV increase	NPV decrease
C: variable costs increase		X
G: fixed costs increase		X
V: external effects (net) positive	X	
U: management costs increase		X
I: investments costs in gear increase		X
D: the discount rate increase		X
Broader design of analysis to include gill net and seine	X	

As all costs are kept constant, cost increases will lead to lower net present value and therefore to less incentives to acceptance. External effects are of little interest to the fishermen, but they are of interest to society. If a higher value is placed here, the NPV will increase from society's point of view.

The used discount rate at 5% is used in many public projects, but considered high for example compared to the HM Treasury's (United Kingdom) recommendation at 3.5%. On the other hand surveys indicated that the private discount rate could be as high as 20%.

The general conclusion is that from society's point of view the positive effect of introducing a 120 mm panel in Nephrops trawls cannot be rejected. There is a positive net present value for a period longer than 10 years, and below ten years a positive effect arises for the small vessels while a negative effect results for the larger vessels. It has to be noted, however, that it is assumed that landings of Nephrops will remain unchanged, while for cod and plaice together a positive effect will occur. Other demersal species are assumed to remain unchanged between the base line and the case with gear changes.

The effect is small and most sensitivity analyses regarding trawls will tend to impact the net present value negatively. An instant positive effect will occur for gill netters and seiners that are very dependant on cod and plaice. This effect is not evaluated in the project.

Reference

AER, Concerted Action, *Economic performance of selected fishing fleets.* Annual report from the Concerted Action (Q5CA-2001-01502) Economic Assessment of European Fisheries, 2004, ISBN 90-5242-958-8. http://www3.lei.wur.nl/ca/

Hans Frost, Jan-Tjeerd Boom, Erik Buisman, James Innes, Sebastien Metz, Philip Rodgers, and Kees Taal (2007). *Economic Impact Assessment of Changes in Fishing Gear.* NECESSITY project. (Annex 9.1 to second periodic activity report).

Pelagic fisheries - cetaceans – *approach and results*

General

The main objective of the cetacean work is to develop effective and acceptable gear modifications (bycatch reduction devices or acoustic deterrents) to reduce the bycatch and mortality of cetaceans in pelagic trawl fisheries. In developing effective mitigation measures and assessing the effects of such measures it is recognised that it is essential to gain a better understanding into the biology of cetaceans, stock sizes, incidental capture and relationship with fisheries, and behaviour in the vicinity of pelagic trawls. To date acoustic deterrent devices and excluder devices such as rigid sorting grids and rope barriers have been tested, while limited behavioural work on the reaction of cetaceans to the mitigation devices has also been attempted. Given the frequency of interactions of cetaceans with trawls appears sporadic, most testing has concentrated on fisheries where bycatch is highest to increase the likelihood of providing statistically significant results. Several of the partners, collectively have also resorted to carrying out experiments with acoustic deterrent devices in more controlled environments (direct playback/bow riding), where the presence of cetaceans is well known and the frequency of encounter is high. A standardised methodology for carrying out these experiments has been developed that provides a quick and cost-effective way of testing acoustic deterrent signals on wild animals.

Biological studies

In order to understand the magnitude and complexity of the problem it is essential to collect information on bycatches of cetaceans in various pelagic fisheries, and to find out the significance of these bycatches in relation to the size of populations. To this end, various existing schemes of bycatch data collection were used by UCC, USTAN and CRMM.

Biological samples from cetaceans caught in trawls were used to determine population characteristics, and to investigate whether any relationship exists between bycatch and fish discarded from trawlers at sea, or whether dolphins are feeding on the trawl target species (stomach analyses).

Bycatch rates and distribution

Bycatch occurs in several pelagic trawls and very-high-vertical-opening (VHVO) trawl fisheries having demersal, small pelagic or large pelagic target species. The cetacean bycatch is a sporadic phenomena (usually less than 10% of tows have bycatch). The highest rates are found in the sea bass fishery. Maps were produced showing the distribution of stranded animals and bycatches related to various fisheries (Figure 42, Figure 43).

Common dolphins (*Delphinus delphis*) are the most common bycatch species (>95%), but although season and area are thought to be important factors in determining bycatch rates, no simple co-incidence of high areas of fishing effort with high areas of dolphin density was evident.

Furthermore, information on dolphin distribution in the winter time, when bycatch rates are highest, is very poor.

Population identity, size of the population & population dynamic parameters

Biological samples were used from stranded cetaceans diagnosed as having died in fishing gear and from animals taken directly from tuna and bass nets to determine population characteristics and to investigate whether any relationship exists between bycatch and fish discarded from trawlers at sea (stomach analyses).

Extensive genetic analyses showed no evidence of differences in population structure for common dolphins between areas in the Northeast Atlantic which suggests that all common dolphins in the eastern Atlantic north of Portugal belong to the same biological population.

More is now known about the common dolphin biology than three years ago at the start of the project. A number of biological parameters were determined for this species. The pregnancy rates have been found to be 28% and the calving interval 3.5 years, which compares well with previous findings. The life-time output may reach about 5 calves per female, with 3-4 as an average estimate. It has also been established that dolphins are not feeding on sea bass in the bass fishery, as no sea bass have been found in any of the stomachs examined.

The total summer abundance of dolphins in the European shelf area has been recalculated by re-examining several previously conducted abundance surveys, and has been put at about 250,000 animals in a total area of 1.8 M km^2 (ICES Sub-areas VI,VII and VIII, or 43^oN to 60^oN and as far west as 18^oW). The total documented bycatch of common dolphins in pelagic trawls is most likely to be at least 1000 per year, though bycatch estimates are still very uncertain in many fisheries. Defining what a sustainable level is, is a complex task, and depends critically on what the conservation objectives are and how conservative one wishes to be. The project has provided a number of different possible outcomes for such analyses based on examples used in cetacean conservation frameworks from around the world.

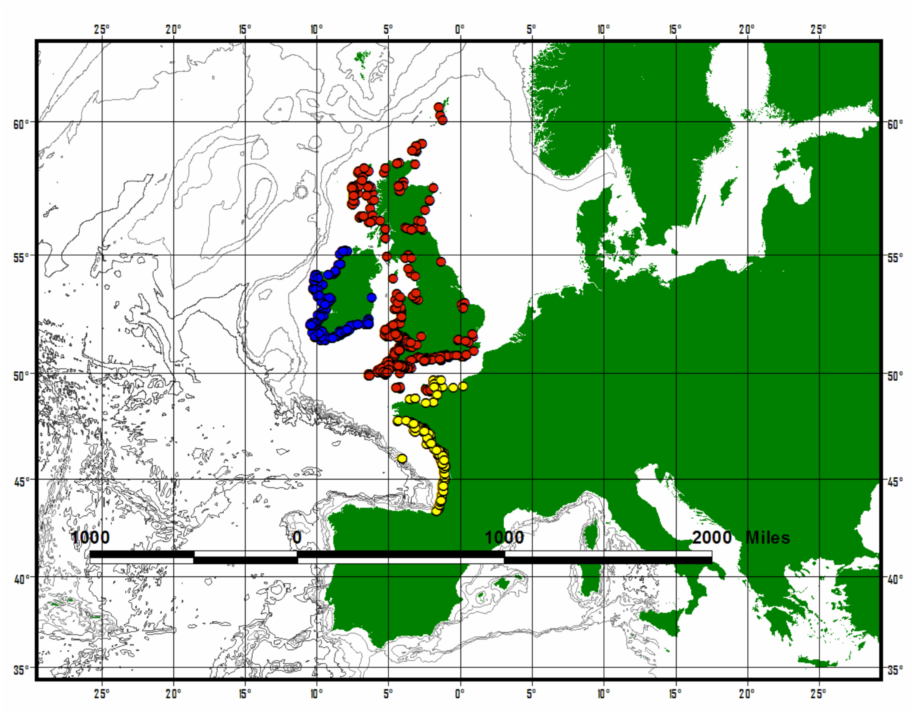


Figure 41: Distribution of stranded dolphins

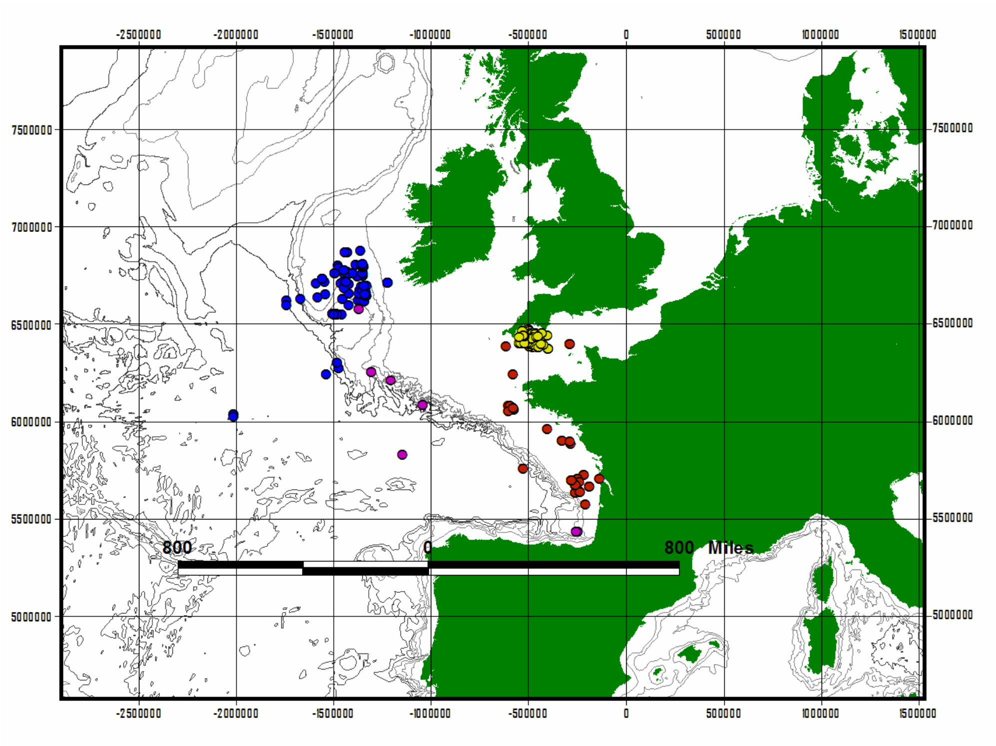


Figure 42: Distribution of sampled bycaught animals. Yellow = UK bass pelagic trawl fishery, red = French bass pelagic trawl fishery, pink = French tuna pelagic trawl fishery, blue = Irish tuna driftnet fishery

The frequency of interactions of cetaceans with trawls appears sporadic, and this greatly impedes any attempt to develop solutions (such as changes in fishing tactics, use of exclusion devices, acoustic deterrents).

Changes in fishing tactics

Relationship of bycatch incidences with fish discards

The hypothesis that Atlantic white-sided dolphins (*Lagenorhynchus acutus*) may scavenge for discarded fishes in the wake of freezer trawler and thus become more vulnerable to bycatch when the net is being hauled is under study in the Dutch pelagic fishery with data from 1993 to 1998. However such an hypothesis of a “discards effect” in the Dutch mackerel fishery cannot be generalised to all the pelagic trawl fisheries to explain the cetacean bycatch. It must be pointed out that both the sea bass and tuna pair trawling fisheries are well known to have a very small discard rate, and very different discard practices, yet these fisheries have amongst the highest cetacean bycatch in the investigated pair trawling fisheries, although their main cetacean bycatch is common dolphin rather than white-sided dolphins.

Operational factors

The occurrence of common dolphin bycatch was analysed in relation to a range of operational variables in the pelagic fisheries e.g.: target species, nationality, area, depth, vessel size (hp), fishing gear type, maximum mesh size, codend mesh size, fish detection system used, tow duration, tow speed, main fish bycatch rate, discarding practices, deck lights being switched on/off. No strong correlation was found with any operational variable however, indicating alternative tactics may not be of primary importance. The statistical analysis showed that the most important factors explaining bycatch were fishing areas and months but these variables explained only a small part of the observed variability of the data.

Spatial or temporal closures

Spatial and temporal closures of fisheries are only effective if the spatial or temporal frame is large enough to encompass a suitably high proportion of bycatch events. It is therefore necessary to know something about the spatial and temporal (seasonal) distribution of bycatch events. Information on bycatch and on the seasonal distribution of cetacean populations in ICES Divisions VII and VIII were collated to enable any such closures to be evaluated. However, there is limited information on the distribution of dolphins during the critical winter months, and although high bycatch rates have been observed in at least two separate areas, it is not known whether this is entirely due to higher animal densities in those places compared with other places, nor is it known whether these areas are likely to remain areas of high bycatch rates in the future.

Diurnal patterns

Some reports state that bycatches occur mostly at night, or at dawn and dusk. While this is not the case in all fisheries it is possible that it is for some and, if confirmed, this information could be used in promulgating a mitigation strategy. During the project more data were analysed revealing the circumstances of bycatch events. In the bass fishery, where bycatch rates appear to be highest, trawl tows operate over many hours often including hours of darkness and daylight. It is therefore hard to be sure exactly how important the hours of darkness are, and bycatches certainly do also occur in daylight hours. The diurnal pattern may affect the fish catch and in the tuna fishery all the tows are made at night.

Fishing behaviour

There have been several other suggestions that haul-back procedure, headline height, offal discarding practices, deck lighting arrangements and the use of certain sonar equipment may all contribute to increasing cetacean bycatch probability. None of these suggestions have been tested rigorously anywhere.

Exclusion devices

Following evaluation of a variety of gear modifications at a workshop held at the flume tank in Boulogne-Sur-Mer (France) and selection of the most appropriate devices in consultation with fishermen and netmakers, several partners have tested excluder devices in different fisheries, although most effort has been in the bass fishery. These devices were mainly panels or ropes in front part of net and exclusion devices such as grids in the rear part of the net.

Barriers in front part of net

Such barriers are made or ropes or net barriers. When placed inside the nets the barrier has to be associated with escapement devices.

The first configuration designed by IMARES consisted of a series of ropes hung within the pelagic trawl net to determine if such ropes would prevent the entry of dolphins further into the net. Sea trials with BFAFi on FRV “Walther Herwig - III” in 2005 showed that such an arrangement of ropes could successfully be rigged inside the net, but this arrangement has adverse effects on fish catches.

Given the observations of fish escaping with this device it was decided following initial trials that this design should not be further tested. Sea trials using a tunnel barrier installed in the mid-section of a trawl showed, that this configuration did not affect fish catches, but as no reactions were directly observed from cetaceans, the effectiveness as a release or scaring device is still unknown (Figure 43).

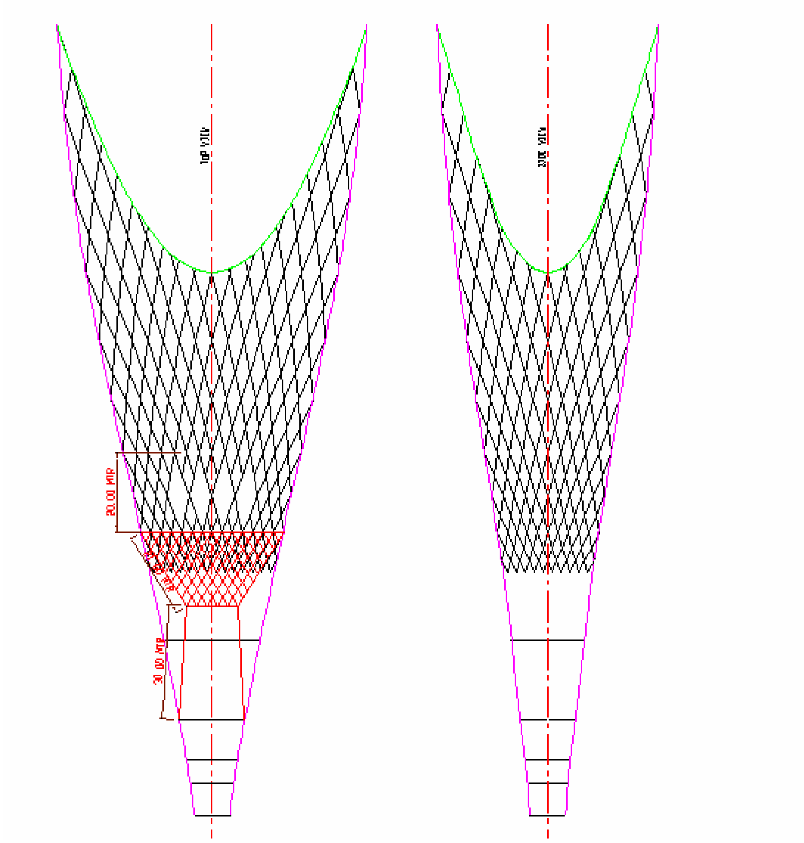


Figure 43: Tunnel barrier designed by IMARES and MARITIEM, tested on FRV "Walther Herwig - III" in 2006.

Different types of barriers and escape holes were tested by IFREMER on research and commercial vessels in February 2006. The two devices tested are described on Figure 44 and Figure 45. One of the square mesh panels tested was also fitted with stainless steel studs to reinforce the acoustic reflectivity of the barrier to dolphin echolocation.

The conclusions were that the first one (400 mm square meshes barrier, fitted at the level of the 200 mm meshes, with two escape holes equipped with bungee cords on the top) was not fully effective, even though 2 dolphins were observed escaping (Figure 33). The second one (large barrier fitted far forward at the junction between the 800mm side meshes and the first 4m side meshes –"shark teeth"-) may be efficient, but this still remains to be proved. Nevertheless due to its large size (42.40 m x 16 m), this device may increase drag to unacceptable levels from a commercial fishing perspective or cause net damage.

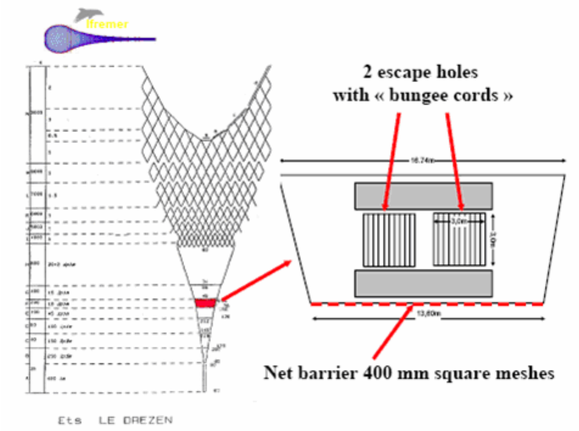


Figure 44: Design of escape holes by IFREMER – LE DREZEN

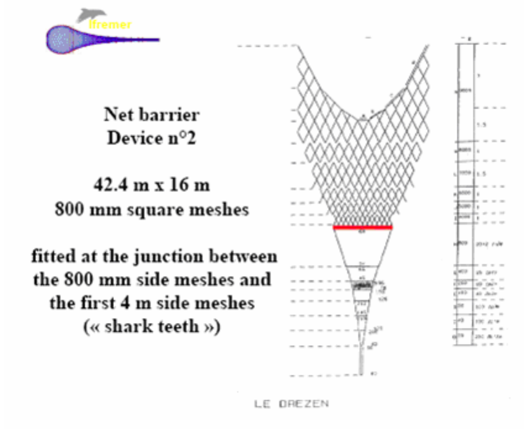


Figure 45: Design of net barrier by IFREMER – LE DREZEN

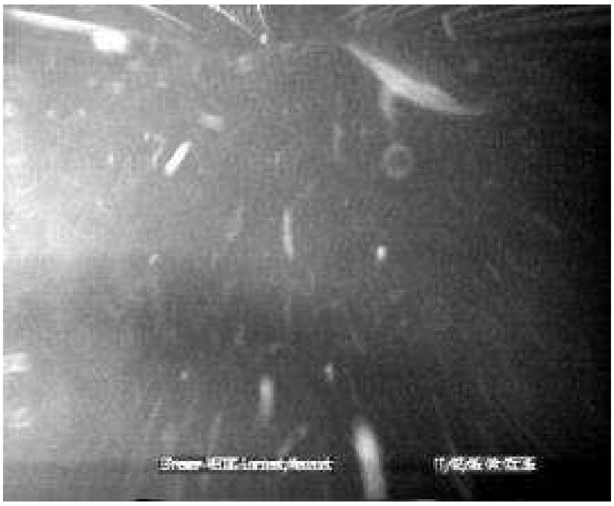


Figure 46: A dolphin on the upper part escaping through the bungee cords (©IFREMER)

AZTI made trials for testing of the escapement device design agreed with industry under commercial fishing conditions (Figure 47, Figure 48). The underwater recording provided confirmation of the previous results on the physical performance of the escaping device and its apparent non-effect on target and non-target fish behaviour. Unfortunately encounters with dolphins were limited during the trials. The net of the control vessel, fishing without the escapement device, did catch a common dolphin on one occasion and during the following tow a group of dolphins was sighted on the surface moving between the two vessels whilst towing but no animals were subsequently caught. No other animals were caught or observed. The main output of the trials was confirmation of the best configuration of the escapement device with different combinations of two netting cover materials in terms of hydrodynamic performance. The second important result was that target and non-target fish behaviour records showed that no fish escaped through the device and that the device (including the vertical rope barrier) did not affect the behaviour of fish.

Figure 47: Escape holes designed by AZTI – model tests

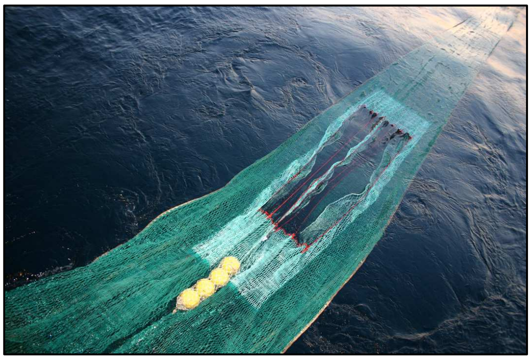


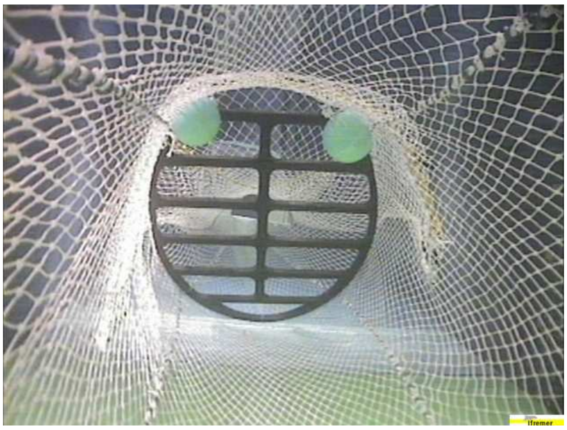
Figure 48: Escape holes designed by AZTI – sea trials

USTAN also tested a rope exclusion panel and Dyneema-netting panel unsuccessfully. A rope exclusion curtain between the large mesh section of the net and the small mesh section readily became entangled preventing fish capture, while a large mesh panel in the same area caused unacceptably high levels of gear drag, and again no fish were caught.

Exclusion grids in the rear part of the net

Rigid exclusion grids have been used successfully to eject three other species of marine mammal from hoki and squid trawls in New Zealand and Australia. Using this technology an exclusion grid was tried out in the Scottish and French pair trawl fishery for bass, after design studies at model scale were carried out in the flume tank of IFREMER, Boulogne, France (Figure 49, Figure 50) and with the active participation of industry.

Observations by USTAN and IFREMER have shown common dolphins on separate occasions escaping through various escape hatches at the top of the trawl. Several others have been seen to approach the exclusion device but did not appear to recognise the escape hatch as a potential escape route. Some of these were reported to be swimming weakly or possibly in a catatonic state. Escaping animals appeared in good health and were swimming strongly. One was seen swimming clear apparently towards the surface (Figure 51). Importantly no problems were found with handling a flexible grid and it could be easily handled on board commercial fishing vessels. Loss of commercial catch could be avoided by appropriate design of the escape hatch, although blocking of one grid design was observed in cases of very large bass catches.



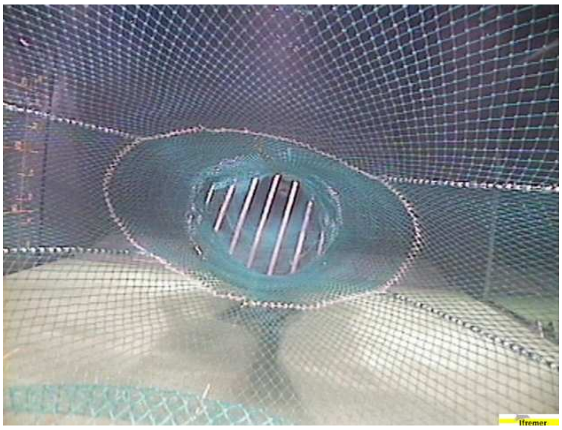


Figure 49: Grid configurations tested in the flume tank of Boulogne, France by IFREMER - flexible version

Figure 50: Grid configurations tested in the flume tank of Boulogne, France by IFREMER - rigid version

The critical issue that remains to be resolved with exclusion devices is not so much the barrier design, but the escape mechanisms. These need to be obvious enough and possibly numerous enough, that dolphins will use them (which we now know they are able to do), while at the same time designed so as to keep fish inside the net.

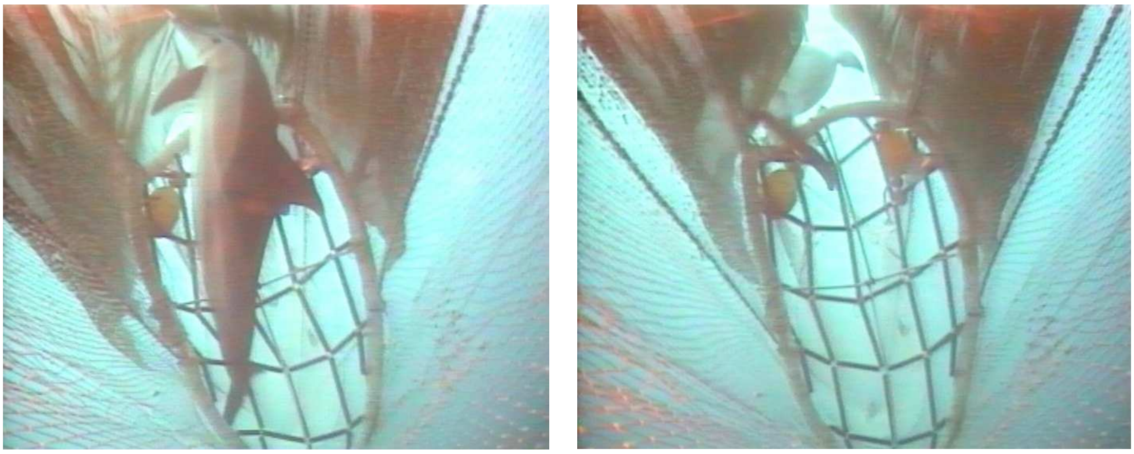


Figure 51: A common dolphin escaping then escaped in front of a grid system inside a pelagic trawl (© USTAN)

Acoustic deterrents

Acoustic deterrents are small self-contained battery operated devices that emit regular or randomised acoustic signals, at a range of frequencies, and typically loud enough to alert or deter animals from the immediate vicinity of fishing gear. The first commercial pingers were designed to keep harbour porpoises from demersal gillnets, and several devices have also proven effective in deterring dolphins from entanglement in both demersal and surface gillnets with no significant reduction in fish catch. A trawling operation generates increased noise levels emitted by the vessel and the trawl itself, which may mask echo-location signals of cetaceans. In order to be effective acoustic deterrents used on trawls should be detectable by cetaceans, and therefore produce sound levels above the ambient noise level, while at the same time not interfering with dolphin echo-location signals.

The development of an interactive device was immediately started and also trials were made by several partners with some of the existing acoustic deterrent devices. Most recently two somewhat louder acoustic devices appear to show promise in reducing bycatch of common dolphins in pelagic trawls while having no effect on the fish catch.

Development of an inter-active device

BIM in Ireland sub-contracted the UK-based acoustics company, Aquatec Subsea Ltd., to develop an interactive acoustic deterrent device (AQ636). A prototype of this device was delivered in February 2005 with sound characteristics consisting of (broadband) sound levels around 157 dB rms re 1µPa at 1m, a variety of swept frequency modulated signals between 10kHz and 80kHz with significant harmonic energy above this up to 160kHz, 300ms signals and randomised signal intervals not greater than 15s. The device was tested successfully at a dolphinarium at the Kolmarden wild animal park in Sweden (March 2005) with captive bottlenose dolphins and again in direct playback experiments with bow riding bottlenose dolphins in the Shannon Estuary in July 2005 with significant evasive behaviour observed. However, subsequent similar experiments with wild common dolphins carried out by BIM in conjunction with DIFRES in the Celtic Sea off the south coast of Ireland and in the Alboran Sea off Spain gave no significant deterrent effect with the device. Thus it was concluded that the interactive device works as designed and responds consistently to common dolphin vocalisations. This is desirable from a "noise pollution" perspective and may also delay potential habituation effect. However, the signal produced by this device currently does not have a significant deterrent effect on common dolphins. An effective deterrent signal i.e. a noise which will displace or act as an acoustic barrier towards common dolphins, is required if the interactive deterrent which responds to vocalisations from the animals is to work.

Effectivity of deterrent signals

Numerous signal types are used by the various pingers on the market. It is now clear that these signals are to some extent species specific, and some signals appear to be more effective in deterring groups of common dolphins. A specific sequence is needed to evoke a reaction. More research is needed to find species and context specific differences, and we still do not know enough about why some pingers work and some do not. Some systems are more directional than others and may have the advantage of creating smaller and more focused exclusion areas rather than widespread exclusion of animals from a fishing area.

Several behavioural trials were performed to assess the reaction of dolphins to a variety of sound sources and sound levels, and more recently these have been focused entirely on common dolphins. Experiments were done on bow-riding animals under various acoustical deterrent signals from a sailing vessel in the Alboran Sea by DIFRES. Two different set-ups were used (Figure 52, Figure 53). The results were not very conclusive, but the testing system and protocol developed proved to be useful for developing further experiments.

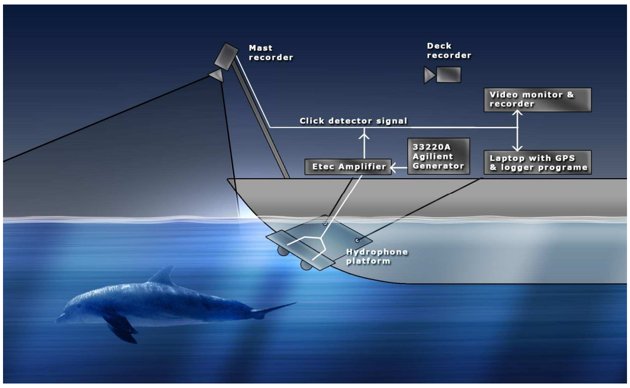


Figure 52: Tests on dolphin behaviour under deterrent signals by DIFRES in Alboran Sea – experimental set-up 1

Figure 53: Tests on dolphin behaviour under deterrent signals by DIFRES in Alboran Sea – experimental set-up 2

Effectivity of deterrent systems

IFREMER worked with the French iXTrawl Company with the idea of adapting existing gear monitoring equipment to produce a directional deterrent signal. A device called “CETASAVER” was produced in several versions. The most updated version (Cetasaver_3) has sound characteristics consisting of (broadband) sound levels around 178 dB rms re 1µPa at 1m, a variety of swept frequency modulated signals and impulse sounds between 30kHz and 150kHz with significant harmonic energy above this up to 300kHz, 100-1000ms signals and randomised signal intervals not greater than 4s. During September 2005 and August-September 2006, IFREMER & CRMM conducted a series of experiments to compare the effects of deterrent devices (commercial pingers and prototypes Cetasaver) on common dolphins. These experiments took place in South Brittany area (near Les Glenan Archipelago). Apart from the STM-DDD device, which was designed to prevent depredation by bottlenose dolphins around fish farms, no other types of commercially available acoustic deterrent devices were found to be effective at deterring common dolphins and therefore were not considered to have any potential for use in pelagic fisheries. The trials, however, did provide some evidence that specific acoustic signals, produced by the Cetasaver device and the STM-DDD device were found to have a deterrent effect on common dolphins (Figure 54).

However, no strong deterrent effect or evasive behaviour was later observed in trials carried out using the device and more or less similar methodology in the Alboran Sea or in the Celtic Sea off Ireland. No definitive reasons for these contrasting results can be put forward, although it should be noted the tests in the Alboran and Celtic Sea were with foraging animals, while the Glenan experiments were with travelling groups of animals. It is clear, though, that major inter and intra-specific differences exist among cetacean species and groups of animals. For instance acoustic signals that had a strong effect on bottlenose dolphins may have no effect on common dolphins and vice-versa.

Figure 54: Common dolphins surfacing exposed to DDD-signal in the Bay of Biscay

Following the Glenan experiments, USTAN and IFREMER observed reductions in common dolphin bycatch in the bass fishery with DDD02F and CETASAVER_7 devices in trials in the bass fishery on board commercial vessels. Data from these trials are limited, however, and more observations of hauls using these devices will be required in order to obtain unequivocal results but reductions of 50-80 % have been observed. The results of these trials largely concur to show that the device seems to have a mitigation effect but with less than 100 % success.

Following these trials, in April 2007 it was decided to test the Cetasaver on common dolphins in the wild off the south coast of Ireland where the DDD had failed to induce any evasive behaviour. During these later trials no deterrent effect on one group of wild common dolphins was observed with this device when tested in frontal conditions. No definitive reasons for these contrasting results can be put forward, although it should be noted the tests in the Alboran and Celtic Sea were with foraging animals, while the Glenan experiments were with travelling groups of animals. But it seems that the device is not effective on all groups of animals.

The results suggest that the Cetasaver_7 does not totally eliminate the bycatch of common dolphins but there is some evidence on the basis of the 108 tows observed that it decreases the bycatch rate. Due to the sporadic nature of bycatch, however, this result is not statistically significant and more hauls are required. A possible explanation, however, could be that although acoustic devices may not have a deterrent effect in pelagic trawls, they alert or permit animals to associate the signal from these devices with the mouth of the trawl. Perhaps an acoustic signal could assist in locating an escape route for dolphins.

The results from limited trials by USTAN using the DDD-02F in the UK bass pair trawl fishery were encouraging. Two pairs of boats used the devices, and both reported that they were effective, though not 100% so. Only 20 hauls were observed by independent monitors, and in two of these the devices were not working and both times a bycatch event was recorded. In 18 other tows with the devices working no bycatch was recorded. Further independently monitored trials will be required to be surer of the effectiveness of these devices.

Experiments in the wild suggests that (1) pingers can be effective, (2) the receiving beam pattern is directional for the high frequency signals produced by pingers, (3) a variability in the reaction behaviour is observed between groups (or areas or motivational states). This suggests that the efficiency is unlikely to be 100% with either of the two systems currently being tested (CETASAVER, DDD).

Sea trial experiments showed that DDD and Cetasaver may have a mitigation effect. However the quantification of this effect is not finished as the significant level is difficult to get through statistical analysis when the mitigation effect is less than 100%.

Effect of deterrent signals on echolocation

Experiments were done by IMARES in the dolphinarium of Brughes, Belgium to determine if particular sounds could negatively affect the echolocation abilities of bottlenose dolphins (*Tursiops truncatus*). An animal in captivity was trained to echolocate objects at a certain distance undisturbed and then confronted with a range of possibly interfering signals (Figure 55, Figure 56).

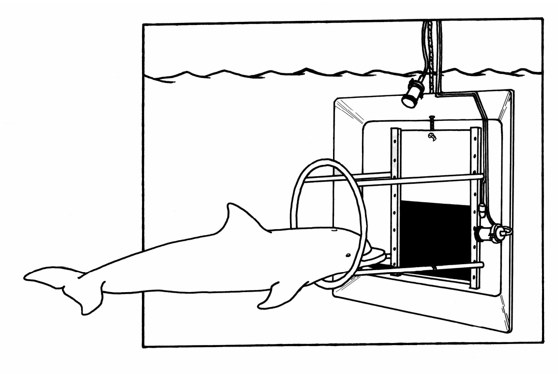


Figure 55: Tests on dolphin behaviour under deterrent signals in Brughes, Belgium – experimental set-up

Figure 56: Tests on dolphin behaviour under deterrent signals in Brughes, Belgium – Live test with animal

The results so far showed that the animal produced higher amplitudes in echolocation signals when noise was applied. This study confirms that bottlenose dolphins increase their sound level in noisy environments.

Behavioural Work

Unfortunately, the low frequency of dolphin encounters during the experimental fishing trials has meant that only limited underwater filming of dolphin behaviour inside trawls equipped with escapement devices or acoustic deterrents has been achieved. IFREMER and USTAN have recorded some observations of reaction to escapement devices but behaviour does not seem to be uniform. Observations have been limited to in and around the vicinity of escapement devices and there is still little information on behaviour of cetaceans around the mouth of trawls. The observations of animals actively escaping from trawls have indicated that dolphins are quite able to use escape hatches and other exits and that survival is likely to be very high. Some animals, however, have been observed in an exhausted state in front of excluder devices and if such animals are subsequently passively released from the trawl (i.e. washed out of the net through escape holes) then survival of such animals would almost certainly be very low. This would be a source of unaccounted cetacean mortality that would in practice be difficult to estimate.

Similarly apart from the preliminary trials carried out with the DIDSON system by DIFRES, no other acoustic detection equipment has been successfully deployed or tested on pelagic trawls. Devices such as TPOD's have proved to be of limited value and in many cases unreliable. The trials with the DIDSON showed this to be a technically feasible solution and the system is able to distinguish common dolphins at a range exceeding 30m, however, the fact that this is normally a cabled system means deployment in pelagic trawls is problematical. Costs are also a limiting factor although such technology is constantly evolving and could be adapted in the future specifically for this purpose.

The critical issue that remains to be resolved with acoustic deterrents is to identify better the signal characteristics of the two deterrent systems. These need to make further experiments on common dolphins in the wild. Developments of the systems should be aimed at optimising the exclusion area and producing an interactive system efficient on common dolphins. More trials in the sea bass fisheries are required to be sure that the two acoustic systems are having a significant deterrent effect in the fisheries.

Major findings of this study

Given the differences in the design of the vessels, trawls, fishing operations and the characteristics and behaviour of the target species there is no universal solution for all pelagic fisheries in which cetacean bycatch is an issue. The sporadic nature of bycatch occurrences in fisheries makes the provision of statistically significant results on the effectiveness of any device (excluder or acoustic deterrent) difficult and the bass fishery is the only fishery where this may be possible. There are still only limited information/observations of the behaviour of cetaceans in and around pelagic trawls. Any information gathered strongly suggests behaviour is not uniform, making the development of mitigation devices still extremely difficult. The observations made of animals actively escaping from trawls fitted with excluder devices have indicated survival is likely to be very high and this is encouraging. Animals, however, have been observed in an apparently exhausted state in front of excluder devices and if such animals are washed out of the net through escape holes then survival of such animals would almost certainly be very low.

Excluder Devices

None of the excluder devices tested have proven to be fully effective. At best, based on the results of trials completed, reductions in bycatch of around 20% have been achieved. Positioning of the device within the trawl remains critical and underwater observations suggest that, as far forward in the trawl as is practically possible is the best position. Rigging and handling of some devices remains a limiting factor and some devices tested have increased net drag to unacceptable levels from a commercial fishing perspective. Some of the devices tested have also given unacceptably high losses of commercial fish catch. This remains a pre-requisite for fishermen, although many of the trials carried out have suggested that if escape holes are covered then marketable fish losses can be kept to a minimum. The overall conclusion from this work with excluder devices is that at present they provide a means to reduce rather than eliminate cetacean bycatch but in designing such devices factors such as net design and the behaviour and characteristics of the target fish species need to be taken into account.

Acoustic Deterrents

From the work completed with acoustic deterrent devices there is some evidence that specific acoustic signals are effective at deterring cetaceans, however, it is clear that major inter and intra-specific differences exist among cetacean species. For instance acoustic devices that had a strong effect on bottlenose dolphins had no effect on common dolphins. The CETASAVER device developed by iXtrawl and IFREMER and the STM-DDD device (commercial device) were found to have a deterrent effect on common dolphins in the Bay of Biscay but no strong deterrent effect or evasive behaviour was observed in trials carried out in the Alboran Sea or in the Celtic Sea off Ireland using this device and similar methodology. The reasons for these contrasting results are unclear, although it should be noted the tests in the Alboran Sea and Celtic Sea were with foraging animals, while the French experiments in the Bay of Biscay were with travelling groups of animals.

USTAN and IFREMER have observed reductions in common dolphin bycatch with STM-DDD and CETASAVER devices in trials in the bass fishery. Data from these trials are limited, however, and more observations of hauls using these devices will be required in order to obtain definitive results. The observed reductions in cetacean bycatch in the bass fishery are at odds with some of the results of observational experiments using the same devices with free swimming common dolphins, which showed no significant deterrent effect with these same devices. One possible explanation, however, could be that although acoustic devices do not have a deterrent effect in pelagic trawls, they may alert or permit animals to associate the signal from these devices with the mouth of the trawl. It is also felt that the background noise associated with large pelagic vessels and trawls used in e.g. Dutch pelagic fisheries make the use of acoustic deterrents an unlikely solution to reduce bycatch effectively on such vessels. The noise of the gear and vessel would appear to mask the deterrent signals produced by the device based on noise recordings carried out by IMARES.

Recommendations

It is recommended from the work completed that testing of excluder devices in fisheries where acoustic devices are identified as not being a potential solution, e.g. Dutch pelagic fisheries, should continue to fine-tune these devices. In fisheries where acoustic devices are seen as a viable option, e.g. bass, Albacore tuna and hake fisheries, further research to resolve the issues regarding appropriate acoustic signals for different cetacean species should also be continued, given that the methodology developed for carrying out these experiments is now well developed and cost effective (though continued work with exclusion devices should not be ruled out in those fisheries where it may also work). Investigation as to whether the theory concerning acoustic devices acting as alerts rather than deterrents should be explored, although in practice this may be difficult to prove conclusively. Given the continued deficit in knowledge of cetacean behaviour in and around trawls, the future use of underwater camera and novel acoustic detection systems like e.g. DIDSON should be further explored as this will be essential to fully understanding the causes of cetacean bycatch and the further development of practical solutions to reducing bycatch.

Sea trials were conducted in the sea bass fisheries with fishermen from France and UK during the last months of this study. In these trials reductions of 40-80 % were observed but the exact level of effectiveness cannot be quantified without further sea trials.

Dissemination and communication

It is important to develop new practices in close contact with end users (fishermen) to gain acceptance, and therefore a range of communication mechanisms were created within the project, ranging from a website, personal contacts, industry liaison groups, and the production of suitable dissemination material. All the development phases were carried out in consultation, e.g. model tests in a flume tank were often accompanied by demonstration to and discussion with the fishing industry. These communications served to give guidance to further development, and avoided following dead end tracks.

The project is summarised in an inter-active DVD containing information of the work in the various areas for both Task Groups.

Where appropriate project results were published in ‘peer reviewed’ scientific journals.

Summary of major conclusions

Nephrops fisheries

Effective gear modifications that can reduce by-catches in Nephrops trawling without affecting the target species catch were developed. However, each sector requires a specific design. The introduction of such techniques is hampered when income losses of fishermen from by-catches that are now released at sea are not compensated.

Pelagic fisheries - cetaceans

It is difficult to completely avoid the bycatch of cetaceans in pelagic trawls. Excluder devices in nets can offer escape opportunities for these animals, but they do not always make use of these in the designs that have been tested so far. The technical means of observing and recording the behaviour of animals in the net were produced and tested. Several exclusion device ideas were tested and we have learned a lot, but there are still more ideas that we can test. But testing takes a long time with seasonal fisheries, and in the meanwhile the acoustic solution seem to be more likely to produce a faster result. Effective acoustic deterrents are a tantalising possibility, and two deterrent systems have been identified as being effective on dolphins in the wild. These are now being tested on trawls and observed accordingly in the UK and French sea bass fisheries, and preliminary results from recent sea trials conducted by USTAN and IFREMER are encouraging.

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