GHOST FISHING BY LOST FISHING GEAR

Final Report, August 2005

Reference: DG FISH/2004/20

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CITATION AND DISCAIMER

This report should be quoted as follows:

Brown, J, G. Macfadyen, T. Huntington, J. Magnus and J. Tumilty (2005). *Ghost Fishing by Lost Fishing Gear*. Final Report to DG Fisheries and Maritime Affairs of the European Commission. Fish/2004/20. Institute for European Environmental Policy / Poseidon Aquatic Resource Management Ltd joint report.

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Poseidon Aquatic Resource Management Ltd is a consultancy company that works globally on all aspects of fisheries and aquaculture. The company is based in the UK, but has offices in Belgium and France.

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Executive Summary

'Ghost fishing' is the term given to the continued fishing by fishing gear that has been lost or abandoned. It is largely confined to 'passive gears' such as gillnets, trammel nets, wreck nets, and traps. It is a phenomenon that has attracted attention over the past two decades given the sometimes graphic images of fish and other marine life entangled in lost nets, illustrating the potentially wasteful and destructive impacts of lost fishing gear. However, the real extent of the problem is not well known at the present time.

This report is the output of a six-month research project funded by the Environment Unit of DG Fisheries and Maritime Affairs of the European Commission. Evidence suggests that ghost fishing from 'active' fishing gears such as trawl nets and from 'static' pot fishing is not significant in European Union (EU) waters, and the focus of this project is therefore on ghost fishing in static set-net fisheries.

The work was carried out by the Institute for European Environmental Policy (IEEP) and Poseidon Aquatic Resource Management Ltd. It was based on detailed terms of reference, but in essence attempted to answer the following three questions:

1. What are the main gaps in our knowledge about the extent of ghost fishing?
2. Based on what we do know, to what extent is ghost fishing a serious issue in European Union waters?
3. If it is a problem, how effective are gear retrieval programmes and other management options in dealing with it?

The project involved a detailed literature review, brief surveys with selected fisheries in the EU, a workshop of industry participants and specialist fisheries researchers, and desk-based analysis and report writing.

Why is gear lost, and what happens to lost fishing gear

The causes of gear loss vary between and within different fishing areas and types of vessels. However some of the common causes, in decreasing order of relative importance, are:

- conflict with other sectors, principally towed gear operators;
- working in deep water;
- working in poor weather conditions and/or on very hard ground;
- working very long nets or fleets of nets; and
- working more gear than can be hauled regularly.

Once fishing nets are outside of the control of fishermen their ability to catch fish and crustacea declines over time, usually quickly at first and then more slowly but this can be highly variable. The extent and pattern of this decline depends strongly on environmental conditions. In shallow areas, wind and tidal currents result in nets being more quickly self-entangled and rolled up than in deep water areas where tides/currents are low, thereby reducing the ability of nets to catch fish more quickly. Marine fouling by colonising organisms also increases the visibility of nets to fish, so reducing their catching efficiency over time. The way in which nets are lost is also an important determinant of the extent to which nets continue to fish. Nets lost because of gear conflict (eg when trawlers tow through set-nets) may have little catching capacity if they are rolled up when towed through

When lost in shallow water on rocky ground conditions or on wrecks, it is believed that nets are generally fouled, broken up or rolled up within a year, and in many cases catch rates decline to less than 5 per cent of commercial catch rates within just a few months. In waters with weaker tidal currents, such as the Baltic, ghost catches of 4-5 per cent of commercial levels have been recorded after 27 months. The most extreme case is in the deep water net fisheries (where nets are set at a depth of more than 500 metres) in the northeast Atlantic where vessels fish for shark and monkfish. Research on this fishery suggests that the catching efficiency of ghost nets stabilises at 20-30 per cent of commercial catch rates after 45 days, and that some nets may continue to catch lower amounts of fish and crustacean more than eight years after being lost.

How significant is ghost fishing in EU waters, and what are the environmental impacts of lost gear

In relation to the total number of nets being used in EU waters, the rates of permanent net loss appear to be rather low – well below one per cent of nets deployed. This is largely because most nets are deployed in shallow waters, and after they are first lost a significant proportion of nets are then recovered through the use of global position systems (GPS); fishermen typically go to considerable lengths to recover nets given their cost. However, because the total length of nets being set is high, the total length of netting permanently lost may be significant, although exact figures are not available.

An exception to the low loss rates seen in most European fisheries is in the deep water net fishery in the north east Atlantic. Preliminary research suggests that around 25,000 nets may be lost or deliberately discarded in this fishery each year, with a total length of around 1,250 km. The water depths being fished and conflict with trawlers are conducive to net loss, while vessels use more nets than can be stowed upon retrieval. It is believed that the high level of net loss in this fishery is also a symptom of unsustainable fishing practices and fishing effort levels in the fishery more broadly, rather than a result of fishing in deep waters alone.

Given the fact that many static-net fisheries take place in shallow waters where catch rates of lost gear decline quickly, and rates of net loss are typically low, it is not felt that ghost fishing is a serious issue in most net fisheries in the EU. However, given the total length of netting that may be lost each year, such a statement should not be taken to mean that ghost fishing does not occur, or that steps should not be taken to reduce it. When considering a fishery as a whole, even if losses of fishing gear by individual vessels are small, the environmental and economic costs of ghost fishing across the fishery may be significant.

Furthermore, it is extremely important to note that the cause and extent of ghost fishing is very fishery specific, and one should not generalise about either the extent of the problem for set-net fisheries as a whole, or the solutions, given the wide range of different types of net fisheries within EU waters. However, ghost fishing in the deepwater net fisheries in the north east Atlantic appears to be of a different magnitude to all other net fisheries in the EU. The practices of deliberate dumping of nets, excessively long soak times (the time that the net is left in the water to fish), plus weak currents at the depths fished, all point towards significant levels of ghost fishing in these waters. It would certainly not be fair if in the minds of the public other net fisheries were tarnished with this same picture, given the generally wide awareness of the need to continually minimise net loss in many fisheries in the EU.

As well as considering the absolute environmental impacts of lost static gear, they must also be considered in the broader context, and as compared to the environmental impacts of other fishing methods. Mobile gears such as trawls have much greater impacts in terms of non-target species, catch and discards, as well as habitat and biodiversity damage than static gears. Static gears tend to be very selective; while marine habitat impacts are increased when nets are lost and marine mammals may occasionally become caught in certain situations, impacts are not considered profound or extensive and are certainly of an order of magnitude less than the impacts of trawl gear. However, lost static nets can be washed ashore causing negative aesthetic impacts along coastlines, and presenting a risk to birds which can become entangled.

The need for management measures to reduce ghost fishing

The need to reduce the amount of fishing gear that is lost is recognised in the international Codes of Conduct for Responsible Fisheries developed by the Food and Agriculture Organisation (FAO) of the United Nations. Furthermore, within the EU's Common Fisheries Policy (CFP) there is a clear legal basis for taking measures to address ghost fishing given that it impacts on fish stocks and the wider marine environment. In June 2004 the European Commission committed itself to addressing ghost fishing, and the European Council subsequently invited the Commission to take forward these commitments.

The management options for addressing lost gear can be classified into two groups: firstly those that are 'curative' and attempt to reduce the extent of ghost fishing once a net has been lost; and secondly, those that are 'preventative' and attempt to reduce net loss in the first place.

Curative initiatives include: reporting of gear loss prior to subsequent gear recovery campaigns; gear recovery/retrieval campaigns; or opportunistic gear recovery by demersal trawl surveys. Preventative initiatives include: the marking of gear; acoustic detection devices; zoning of fishing activities to avoid conflict; the use of bio-degradable gear; limiting gear use (eg restricting the length of nets used based on vessel size, placing limits on soak times); encouraging static net fishermen to switch to other fishing methods; requirements to register gear tied to onshore disposal and information about any gear lost at sea; and, increasing communication between different types of fishing vessels fishing in the same area. A broader strategic approach of establishing codes of good practice is considered to be especially important in linking different types of measures. While all measures have their relative merits, a clear management message to come from this project is that prevention is better than cure.[1]

There are already a number of voluntary and legislative measures in the EU to prevent and cure both net loss and abandonment. These include good communication between English net fishermen and French trawlers operating in the Western English Channel about gear location, Swedish gear retrieval programmes in the Baltic, and limitations on soak times in the Baltic cod fishery. However, there is certainly much scope for further improvement.

Costs and benefits of management options

This project has highlighted that management measures for reducing ghost fishing are rarely, if ever, based on an assessment of the costs and benefits of different management options. A 'knee-jerk' and politically appealing reaction to ghost fishing in both the EU and elsewhere in the world, is to undertake retrieval programmes to remove lost gear from the sea. However, the effectiveness of such exercises and the economic justification has never been fully demonstrated. This project has therefore developed a model for adaptation by fisheries administrations. The model can be used to assess many of the costs and benefits of retrieval programmes, as well as of other management measures. It is recommended that in association with other costs and benefits that are identified but less easily quantified, the model be used

1 The use of biodegradable gear however is unlikely to be effective in the short term because of the lack of available appropriate technology and lack of faith in the concept from industry. As a long-term measure however, based on research and development work with the industry and appropriate levels of finance, technical solutions could probably be found to current limitations.

by administrations when deliberating on how to reduce ghost fishing and which management measures should be adopted.

The model suggests that even if individual vessels lose small amounts of nets, total costs across a fishery could be significant. This is mainly because of potentially large numbers of vessels losing valuable fishing gear, and the loss of profits from the ghost catches themselves that could otherwise be made by the fishing fleet.

The sensitivity analysis conducted on the model suggests that key variables in net benefit/cost calculations are likely to be the number of vessels in the fishery, the cost of the retrieval programme, the number of nets lost, the value of the gear lost, and the percentage of lost nets that retrieval programmes are successfully able to recover. Less important appears to be the rate of decline of ghost catches over time, because retrieval programmes are always unlikely to prevent the high levels of ghost fishing immediately after fishing gear is lost, unless they take place very frequently.

The analysis supports two main arguments. Firstly that gear retrieval programmes may only be cost effective in a limited number of situations. And secondly, that preventative measures are generally preferable to curative measures because, by preventing gear loss, they can prevent the potentially high costs associated with ghost catches immediately after gear loss from occurring in the first place. This conclusion is likely to be valid regardless of the accuracy of the data used in the model, and even if a retrieval programme may itself result in a net benefit.

Future research

Knowledge about the extent of ghost fishing is still very limited. Some fisheries have not yet been researched at all (eg Greece where more than 16,000 vessels are engaged in net fisheries), and due to the costs and practical difficulties of underwater survey work and of simulating ghost catches through experiments, estimates of ghost catch rates are imprecise. These factors, combined with only partial knowledge about the amount of gear that is lost, means there are no overall estimates of the extent of the problem for the EU as a whole. There are also research gaps on the environmental impacts of ghost gear, for example on the impacts and extent of particulate matter from decaying nets entering the food chain. The environmental impacts of management responses, notably gear retrieval programmes, have also not been quantified. Of the information that is available on ghost fishing, the majority is largely biological and technical in nature with very little economic research available on the costs of gear loss and ghost fishing, or on the relative costs and benefits of different management responses.

Headline messages

This summary started by asking three questions. In attempting to answer them and to summarise the outputs of the project, several key messages from the study are:

- There remain significant gaps in knowledge about ghost fishing in EU waters. Priority research areas include a) quantifying the amounts of lost gear; b) assessing the extent to which lost nets continue to catch fish; c) assessing those fisheries for which there is virtually no information; d) estimating total ghost fishing catches in the EU; e) assessing the different types of environmental impacts of ghost fishing and management responses; and f) collecting economic data on ghost fishing and management responses.
- With the proviso about existing knowledge being imperfect, ghost fishing in set-net fisheries in the EU is probably not a significant problem, either in terms of its total

impact, or its environmental impact in comparison with 'active' fishing methods such as trawling.

- However, net fisheries in the EU are each very different and should therefore be judged individually. In deep water fisheries conditions are more conducive to net loss, and there is strong evidence of net dumping and significant levels of ghost fishing in the deep water north east Atlantic fishery for shark and monkfish. The problem of ghost fishing in this fishery appears to be of a different order of magnitude compared to other fisheries in the EU, and as such warrants immediate action and research by the EU, Member States and the industry involved.
- Appropriate management responses are likely to be variable for different fisheries, as are the research gaps, but prevention (ie Codes of Practices, improved communication between active and passive gear users) is almost certainly better than cure (retrieval programmes). Management responses should be better justified on the basis of the relative costs and benefits of different management options.

Acronyms

AAD ....Acoustic Avoidance Device
ACE ....Advisory Committee on the Ecosystem (ICES)
ACFM.....................Advisory Committee on Fisheries Management (ICES)
BIM ....Bord lascaigh Mhara
CFP.........................Common Fisheries Policy
CPR ....Continuous Plankton Recorder
COM.......................Commission Communication
CEC ....Communication from the European Commission
DEFRA...................Department for the Environment, Food and Rural Affairs
EC...........................European Community
EEZ.........................Exclusive Economic Zone
EU...........................European Union
FANTARED...........Redes Fantasmas (Ghost fishing in Spanish)
FAO ....Food and Agriculture Organisation
GPS.........................Global Positioning System
GRT ....Gross Registered Tonnage
ICES ....International Council for the Exploration of the Seas
IEEP ....Institute for European Environmental Policy
IMO ....International Maritime Organisation
IPA ....Inshore Potting Agreement
JNCC ....Joint Nature Conservation Commission
MARPOL ....Convention for the Prevention of Marine Pollution
MCS ....Marine Conservation Society
MPA ....Marine Protected Area
MSY ....Maximum Sustainable Yield
MT ....Metric tonne
NGO ....Non-Governmental Organisation
NOAA ....National Oceanic and Atmospheric Administration
NTZ ....No Take Zone
NWSC ....North West Straits Commission
RAC........................Regional Advisory Council
ROV ....Remotely Operated Vehicle
SAV ....Submergent Aquatic Vegetation
SCUBA...................Self-contained Underwater Breathing Apparatus
SSS ....Side Scan Sonar
STECF....................Scientific, Technical and Economic Committee for Fisheries
TED ....Turtle Excluder Device
ToR.........................Terms of Reference
UK ....United Kingdom
UN ....United Nations
VMS ....Vessel Monitoring System
WDFW ....Washington Department of Fish and Wildlife

1 Introduction

1.1 What is ghost fishing

The issue of ‘ghost fishing’ first gained global recognition at the 16th Session of the FAO Committee on Fisheries in April 1985, and can been defined as *the mortality of fish and other species that takes place after all control of fishing gear is lost by a fisherman*[2]. Ghost fishing occurs when passive gears such as gillnets, trammel nets, wreck nets, and traps, are lost or discarded and continue to catch commercially important species of fishes and crustaceans as well as non-commercial species of fishes and crustaceans, birds, marine mammals and turtles. Such ghost gears may also damage benthic habitats (abrasion, ‘plucking’ of organisms, meshes closing around them, and the translocation of sea-bed features), pose problems as a source of litter being washed ashore where it is unsightly, and can potentially entangle with active fishing gear and vessel propulsion systems, raising potential safety issues. Concern over ghost fishing has been heightened now that modern gears are mostly made of non-biodegradable synthetic fibres and persist in the environment. They can therefore theoretically continue to catch fish for long periods of time.

Over time, increasing catch weight causes nets to collapse and attracts scavenging organisms. Once the nets have been cleaned they may straighten out and resume ‘ghost-fishing’. The ultimate length of this cycle depends on environmental conditions. The effect of wind and currents may reduce nets into a self-entangled mass effectively reducing the catching area or break them up altogether. Marine fouling also increases the visibility of nets reducing their catch efficiency over time, so that the rate of ghost fishing gradually declines.

Pots too tend to pass through a cycle of ghost fishing. They tend to be baited when they are set. If the pot is lost, in time the bait or lost catch attracts scavengers, some of which are commercially important species. These scavengers may become entrapped and subsequently die, forming new bait for other scavengers.

1.2 Policy context

The FAO Code of Conduct recognises the impact of lost gears, stating that States should take appropriate measures to minimise catch by lost or abandoned gear (Articles 7.2 and 7.6.9). Under the ‘basic’ CFP Regulation (2371/2002), measures should be taken for resource conservation and management purposes, and the limitation of the environmental impact of fishing (Article 1). As a source of fishing mortality and impacts on the wider marine environment, there is therefore a clear legal basis for measures to address ghost fishing.

The Commission Communication on Promoting more Environmentally-friendly Fishing Methods (CEC, 2004), tabled in June 2004, identifies the need to address ghost fishing as part of the drive to tackle unwanted catches more broadly. It was noted that there is a need to take measures to identify ghost fishing gear, encourage the reporting of lost gear and to recover it from the seabed. To this end, the Commission committed itself to developing a set of pilot projects in 2004 covering a wide range of species, fisheries and areas within the Community, in cooperation with Member States, the fishing industry and NGOs. It was further stated that a pilot project would be developed during 2005 to address the problem of ghost fishing in Community waters, including a retrieval system to remove lost gears and methods to reduce the losses of gears. The June 2004 Council welcomed the Communication and invited the

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2 Some nuancing of this definition could be considered in cases where fishermen do not lose gear, but leave it in the water for longer periods than is deemed appropriate to retrieve catch in a marketable quality. However, the use of excessively long soak times, with high percentages of unmarketable catch as a result, is not thought to be common place, being largely confined to some deep water net fisheries such as that for monkfish and shark in the North East Atlantic.

Commission 'to develop a pilot project to address the problem of ghost fishing in Community waters which will include a retrieval system to remove lost gears, gear adjustments that lessen the impact of lost gears and methods to reduce the losses of gears'.

1.3 Project Terms of Reference and purpose

The terms of reference for this project are as follows:

- to compile all existing information and studies on monitoring the evolution of lost fishing gear, with particular emphasis on gillnets;
- to identify research gaps, particularly on the means to prevent gear loss and to improve their retrieval, in commercial fishing gears;
- to summarise existing knowledge on the environmental impact of lost gear and how this compares with the environmental impact of active commercial fisheries;
- to explore and summarise the estimated amount of gears lost and their catching efficiency within local fishing grounds;
- to assess the costs and benefits of a possible wide-ranged programme of retrieval of lost gear; and
- to draw-up a work programme for future management and research action.

Given the policy context stated above, this project is therefore intended to assist the Commission in determining how to take forward its commitments on addressing ghost fishing, thereby meeting the Community's commitments under the basic Regulation.

This project builds upon previous initiatives, in particular the EU wide projects called FANTARED and FANTARED 2 (EC Project Nº 94/095: incidental impact of gill-nets; EC contract FAIR-PL98-4338, A study to identify, quantify and ameliorate the impacts of static gear lost at sea) that examined the impact of lost gill-nets in different fisheries. This past work focused on the incidence of net loss and the biological impacts as well as some management options. A key difference with this work will therefore be the consideration of environmental impacts, the economic cost/benefits analysis of gear retrieval programmes and drawing up of a work programme for future management and research.

1.4 Study methodology

To complete the tasks itemised above, an approach was adopted for the study, based on a number of steps.

STEP 1 – On initiation of the study, an internal **project planning meeting** took place in Brussels. The planning meeting was used to discuss:

- the timetable for each team member's inputs;
- initial ideas on key fisheries to be examined in detail during the project;
- reporting formats;
- literature review and survey strategies;
- technical issues of assessing costs and benefits; and
- study management and quality control.

STEP 2 - A literature and web search was then undertaken to identify the key scientific literature available on the subject as well as the major research institutions that have worked on ghost fishing (see Appendix A and Appendix B for a full bibliography of references reviewed, and the methodology employed). The literature review also identified key fisheries of interest for the study.

STEP 3 – Surveys were then used to complement and build upon the results of the literature review. Questionnaires (see Appendix C for detail and methodology) were targeted at the specific fisheries identified during Steps 1 and 2. They were telephone and port-based with fishermen operating in the key fisheries identified. The survey work was an important step in the project to generate information both for the workshop (Step 5) and for the costs/benefit analysis conducted in Step 6.

STEP 4 – The results of the survey and of the literature and web search were summarised in a **briefing paper**, which presented options for a possible programme of retrieval of lost gear and identified the needs for future management and research actions.

STEP 5 – This briefing paper and comments from the European Commission then formed the basis of a two-day **consultation workshop with key stakeholders,** held in Brussels**.** The workshop was attended by some key institutional figures and fishermen from each of the selected fisheries (see Appendix D for workshop report). The objectives of the consultation was a preliminary prioritisation of management actions for different gear types and fisheries of a wide-range of management programmes of retrieval of lost gear and priorities for future management and research actions.

STEP 6 – Following the workshop, the study team estimated and analysed **the costs and benefits of different management possibilities** from an environmental, social, and economic perspective.

STEP 7 - The results of the study were presented in this **Report**, based on comments made by the European Commission on a draft version. This Report has also been disseminated publicly, including making it available on both IEEP's and Poseidon's web-sites.

Table 1 Study planning

Step	Completed by
Step 1 – Planning meeting	Mid-December 2004
Step 2 – Literature and web search	Mid-February 2005
Step 3 – Survey	End-March 2005
Step 4 – Briefing paper and meeting with Commission	Mid-April 2005
Step 5 – Stakeholder workshop	Mid-May 2005
Step 6 – Analysis of costs/benefits of management options	Mid June 2005
Step 7 - Preparation of Draft and Final Reports	End-June 2005

2 Existing information and studies on lost fishing gear

This section examines existing information and studies on the amount of gear lost and the evolution of lost gear, with particular emphasis on gillnets. Until the mid 1990's there was very little research into ghost fishing by bottom set gill, tangle or trammel nets, both globally (Carr *et al,* 1992) or in European waters. Much of what had been done had been undertaken in the waters of North America. With increasing concern over the effects of lost gear in European wasters, the European Commission funded the FANTARED 1 and 2 projects (EC Project no 94/095 and EC contract FAIR-PL98-4338), pan-European studies into the extent, impact, causes and preventative measures of ghost fishing. It represents the most comprehensive work undertaken in Europe into ghost fishing by static nets and pot fisheries.

Under the FANTARED 2 work, fishermen surveys were conducted, covering a significant part of European static gear fisheries in Norway, Sweden, Portugal, France, Spain and the UK. These fisheries are characterised by their diversity of fishing gears used, target species and the depths and conditions of the fishing grounds. The fishermen surveys and field research (eg net deployment and direct observations through diving and sonar) covered the following areas:

- the importance and reasons for gear loss;
- the areas where the losses occur;
- lost gear retrieval attempts and degrees of success;
- the operational factors determining the loss rate of fishing gear; and
- the degree of interaction among the different fishing methods in the same fishing areas which would lead to an eventual loss.

Following an overview of the scientific framework of ghost fishing mortality and the causes of gear loss, key findings of the FANTARED work in each of the fisheries are summarised by eco/Regional Advisory Council (RAC) region with additional information provided from other literature where relevant and available, including that from outside the EU. Details of the FANTARED methodology and findings can be found in the project report. A concise overview of the work is also reported by Dunlin (2000).

It should be noted that the results of the FANTARED work are now several years old, so the current situation in some fisheries may have somewhat changed. It was noted during the course of the project workshop, in particular, that since the FANTARED projects fleet sizes tend to have declined and net loss rates have also reduced with improved marking of gear and communications (eg through the advent of GPS and mobile telephones). Total net loss and loss rates are therefore likely to be lower than reported below. The causes of gear loss may also have changed with technological developments, but this will again vary by fishery. The causes of gear loss are important in terms of affecting lost gear evolution, as well as for developing prevention and mitigation measures. As such, they are discussed in section 3.1.

2.1 Lost gear evolution and mortality – the scientific framework

Gear loss rates and catching efficiency form the basis of estimating mortality in ghost fishing gear. Catching efficiency is itself determined by the evolution of the lost gear. Attempts have been made to estimate these factors with limited success. The mortality attributed to ghost fishing gear is dependent on the following factors:

- species present;
- species abundance;
- species vulnerability; and

- ghost gear status.

These factors were reviewed by ICES (2000). Species present and species abundance, both in regard to mortality, are well-recognised parameters relating to the rate of mortality. Species vulnerability is a less understood parameter. Species vulnerability relates to becoming entrapped, enmeshed, entangled or otherwise caught by the gear. This results in the species becoming more vulnerable to predation or becoming less able to maintain life functions (eg feeding, oxygen exchange, or seeking protection or defence from oceanographic disturbances).

The effective ghost fishing rate of the gear is dependent on what initial fish capture characteristics remain and the level of exposure of the area to the elements. Synthetic materials have replaced natural materials in many fish capture devices. This includes mobile trawls, gillnets and pots.

2.2 Demersal gillnets

2.2.1 Baltic Sea

Under FANTARED 2, active Swedish gill-netters operating in the Baltic Sea in 1998 were randomly selected, and interviewed (Figure 1). Gear loss was experienced among those vessels operating in open sea conditions, either in coastal waters or in distant grounds. However, it was only among those fishermen targeting demersal species, (turbot and cod) with bottom nets, that regular gear loss was a usual phenomenon.

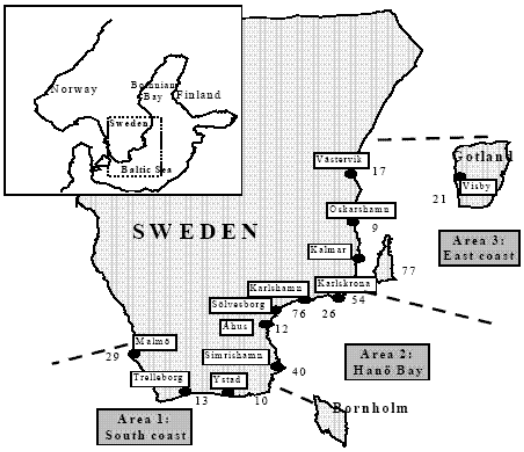

Figure 1 Swedish research areas

Source: FANTARED 2

Net loss

Data was only presented by region (Table 2). The total estimated loss per year was around 1,500 nets, 155-165 km in length, equating to 3.6-3.8 nets per active vessel. Static gear loss as a problem in the Baltic Sea is most notable in the bottom gillnet fishing fleet fishing in the open sea area well off the coast.

Table 2 Net loss in Swedish net fisheries

	Estimated length of ghost nets/yr/km	Percentage of nets used lost per year	Number of nets lost
South coast	15.36	0.07	142
Hanö Bay	36.8	0.04	342
East coast	100.4	0.28	931
Other	3.6	0.08	33
Total	**156.1**	**0.1**	**1,448**

Because fishing gear conflicts are the main reason for gear loss the areas with higher gear loss rates could be identified. It seems that eventual 'ghost nets' appear in two types (a) longer fleets found apparently in the vicinity of the conflict area and (b) small remnants found randomly over a larger more undefined area.

In subsequent gear retrieval work carried out in Swedish waters, based on the amount of netting retrieved in 61 towed tracks, it was estimated that the targeted areas of 260 km² can host 380 km of netting with a cod catch between 6 and 10 tonnes (Tschernij and Larsson, unpublished). The 712 retrieved cod weighed around 709 kg (see section 3.5.2).

Net evolution and catch rates

Twenty four nets were set experimentally to investigate gear evolution and catch rates. These are reported at length in the FANTARED 2 report and also in Tschernij and Larson (2003). As with the other country cases, the methodology, conditions and assumptions employed are too extensive to account here and the reader is directed to the original sources for further details. The nets were demonstrated as continuing to catch after loss, with catch rates dropping off to around 20 per cent after three months. This is due to net degradation from storms and currents and capture of fish. From this point, catches continued even though the nets were biofouled and hence visible. Catches appeared to stabilise at around 5-6 per cent after 27 months. This catching efficiency was believed to continue over several years.

It was estimated, depending on the chosen retrieval rate scenario of nets by trawlers, that the total catch of cod by lost nets during the 28 month study period could be somewhere between 3 and 906 tonnes. Compared to the total weight of reported and landed cod catch from the same area and time period (28,345 tonnes) the lost net catch is between 0.01 and 3.2 per cent. Even this was considered an overestimate as lost gears nearly always encounter trawlers so are damaged more than those in the experiment. Additionally, commercial landings do not include all fishing related mortality eg discards.

2.2.2 North Sea and English Channel

Surveys carried out as part of FANATRED 2 in the UK, France and Norway cover the area of the North Sea and English Channel.

Net loss

Three significant UK métiers were identified and surveyed under FANTARED 2 (Figure 2)

- hake fishery in the English Channel and Western Approaches;
- wreck fishery in all United Kingdom waters; and
- the tangle net fishery around the Lizard – a peninsula in Cornwall.

Key:
T = Tangle net métier
H = Hake net métier
W = Wreck net métier
= Experimental sites

Figure 2 Location of UK métiers surveyed

Source: FANTARED 2

Results were presented by fishery and are summarised in Table 3.

Table 3 Net loss in UK net fisheries

Métier	Vessels in métier	Type of net loss	Total net loss (km/year)	Equivalent to (nets/year)	Pieces of Netting lost
Tangle	18	Towed gear conflict	24	263	
Hake	12	Towed gear conflict	12	62	
Wreck	26	Snagged on wreck	n/a	n/a	884

- Wreck métier

The *most frequent net loss* occurred in the wreck fishing métier where netting is lost on every fishing trip amounting to 884 pieces of net lost per year or 34 pieces per vessel per year. In all cases the loss of pieces of netting was attributed to it being snagged up on the wreck and either tearing along floatline or leadline. In every instance the main frame of the net (floatline and leadline) was recovered. Pieces were defined as being anything from a few meshes to whole panels and nets were regularly overhauled and torn netting replaced.

- Tangle métier

The *greatest whole net loss* occurs in the Tangle fishing métier where a total of 24km of nets are lost per year. Of the total amount lost, an average of 35 per cent or 13 km is recovered in varying states of repair. The losses were all attributed to conflict with scallop dredgers, beamer trawlers or trawlers. Losses incurred were either whole fleet loss or partial fleet loss dependant on the angle at which the intrusion into the fleet was made.

- Hake métier

A significant reduction in vessel numbers through decommissioning was mirrored in the net losses incurred in the hake fishery métier. A raised total of 12km of netting was reported of which 50 per cent or 6km was recovered. As in the tangle net fishery, the loss was entirely blamed on gear conflict, with trawlers being highlighted as the main culprits. Whole fleet loss or partial fleet loss was described as the type of loss with part fleet loss being the most common type.

FANTARED 2 also interviewed fishermen on circumstances and causes of nets loss in the different fishing harbour or landing points in the East Channel and North Sea coasts in France (Table 4).

Table 4 Net loss métiers in the East Channel and North Sea, France

	Length of loss net/boat/year (km)	Percentage lost nets/boat/year
Flatfishes & monkfish	1.5	0.42
Cod	1.2	0.24
Wreck	0.4	0.33
Seabass	0.8	2.11
Sole & plaice	2.8	0.20
Plaice	1.1	0.37
Cuttlefish	nc	Nc
Total	**5.5**	

Net evolution and catch rates

The results of net loss simulations and wreck surveys around the UK were reported in the FANTARED 2 report and Revill and Dunlin (2003).

- Wreck site

Following deployment the net quickly snagged on the wreck and bundled up at the ends. This reduced the fishing area from approximately 225m^2 to a little over 40m^2 after 10 weeks. Both the fishing areas of the net and the catch rates were seen to rapidly decline over time. Much of the integrity of the net was damaged, probably by abrasive forces resulting from the close contact with the wreckage. Catch rates decline to 18 per cent after 10 weeks and to zero in 10-12 months.

Eleven wrecks were also surveyed by divers. Twenty seven nets were observed ranging from full size to only a few centimetres in area. They were partially bundled or broken and no animals (dead or alive) were found in them.

- Snagged net

After 12 months the fragments were observed to have become further snagged on the wreckage with a section of netting stretched and spread out over approximately 10m^2 of hull plating from the wreck. This section of the netting was found to have entangled one edible crab (alive) on the first visit by divers.

- Open ground

Monitoring of the experimental fleets on open ground was by sequential retrieval using a grapnel. Each of the retrieved replicates produced different results after four weeks in the water. One of the fleets was virtually intact and appeared to be operating at around 90 per cent efficiency after four weeks but contained no gadoid species or hake in the net. Another was at 50 per cent efficiency while the third was lost. In both nets the bulk of species captured were crustacea. This suggests that for much of the time the net was not standing vertically and that it contained decomposing fish for some of the time. Very few skeletal remains were seen and both replicates were clear of marine growth and colonisation. These observations were similar to those made by Pilgrim *et al* (1985). Based on these findings, the authors were confident that, for all open ground shelf areas the impact of lost nets is extremely limited because they encounter currents and gears.

The lack of replicates means that definitive assessments of impacts of lost nets could be made. The general conclusions drawn, however, were that nets lost under these conditions are an insignificant source of unaccounted mortality.

The FANTARED 1 work, that informed the FANTARED 2 project, included setting nets off the coast of southwest Wales (reported in Kaiser *et al* 1996). Two types of fixed gear, a gill and trammel net, were set one kilometre offshore from a rocky coastal area in southwest Wales, UK. One end of each net was cut free to simulate net loss. The nets were then allowed to fish continually for 9 months, during which time they were surveyed by divers. Several hours after both nets had been set, a large number of dogfish were caught, causing the nets to collapse. Catch rates began to decline within a few days of the initial deployment, probably related to a decline in the effective fishing area resulting from entanglement of fish and biofouling. To begin with, more fish than crustaceans were caught, although this reversed after 43 days. The catch of fish approached zero 70 and 22 days after deployment for the gill and trammel nets respectively. It was estimated that the gillnet caught 226 after 70 days and 839 crustaceans after 136 days, while the trammel net caught 78 fish after 22 days and 754 crustaceans after 136 days. Even though the nets were damaged by storm action, the work demonstrated that lost nets could continue to catch commercial crustacean species for at least 9 months after initial loss.

The work did not include any replicates, nor did they attempt to estimate total net loss and hence ghost catch.

2.2.3 South-western Waters

Surveys covering south-western waters where carried out in the Cantabrian region (Spain), the Algarve (Portugal) and Brittany (France).

Net loss

- Cantabrian Region

A survey of gillnetting in the Cantabrian region (Spain) was carried out under FANTARED 2 (Figure 3). This region covers four maritime provinces (Asturias, Cantabria, Vizcaya and Guipúzcoa) with over 500 km of coast. Twelve métiers were studied: beta/Red mullet, beta/Hake, miño/Sole, miño/Several species, miño/Shellfish, miño/Scorpion Fish, trasmallo/Red mullet, rasco/Monkfish, volanta/Hake, miño/Monkfish, trasmallo/Inshore species and BETA marisquera/Shellfish.

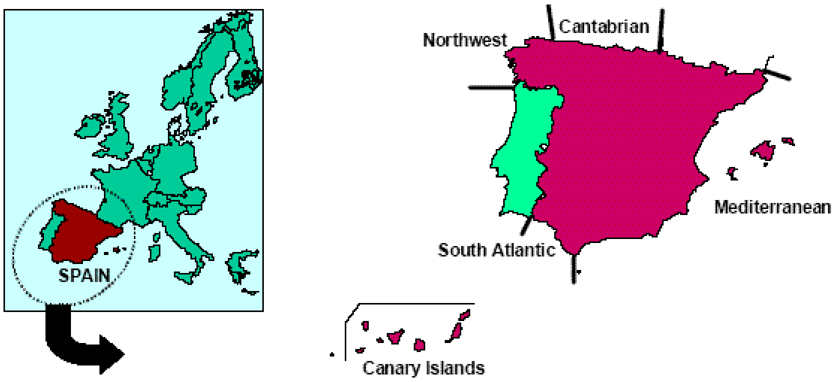

Figure 3 Location of Cantabrian region

Source: FANTARED 2

An average net loss rate of 13.3 nets per vessel was found. This loss is higher for vessels of over 10 GRT (16.2 nets/vessel), than those of smaller tonnage (10.4 nets/vessel).

The métier with the highest number of net losses per vessel (27.9 nets/vessel/year) is that of rasco/monkfish. Other fishing métiers with high losses, are those bottom set net fisheries close to the coast (beta marisquera/shellfish, trasmallo/red mullet, trasmallo/coastal species) with losses ranging between 7 and 15 nets/vessel/year. The rest of the fishing métiers have losses of less than 4 nets/vessel/year

Extrapolation to the entire fleet by fishing métiers (Figure 4), the biggest losses occur in the rasco/monkfish métier with 2,065 nets lost, 86 per cent of which are due to trawl. Another fishing métiers with important losses (774 nets/year) is that miño/different species (41 per cent due to storms and 38 per cent marker dhan loss). It is worth highlighting the fishing métier of red mullet with betas (58 per cent of the nets due to storms and 36 per cent to catching on the bottom), beta/hake (storms: 43 per cent; trawl: 34 per cent) and trasmallo/red mullet (storms: 98 per cent) since they lose between 550 and 650 nets per annum. The rest of the fishing métiers, practised mainly in shallow waters (except for the volanta/hake métier), have annual losses of between 100 and 500 nets per annum.

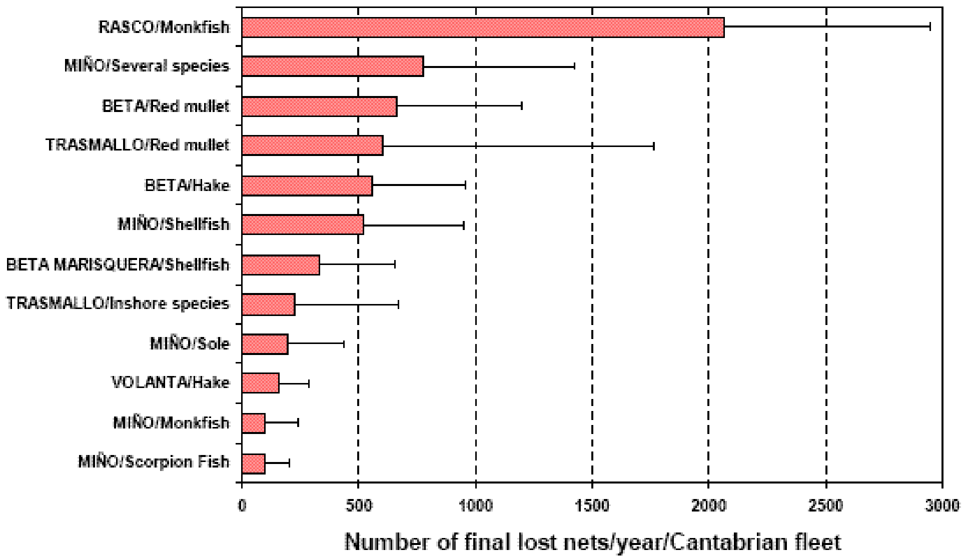

Figure 4 Net loss in the Cantabrian fleet per year by métier

Source: FANTARED 2

- Algarve

Under the FANTARED 2 project, net fishermen in the local, coastal and hake fisheries of the Algarve (Portugal) were interviewed about the extent and causes of gear loss and retrieval rates. This work is also reported in Santos *et al* (2003a). The number of nets lost in these fisheries was considered to be very low because of fishermen's success in retrieving their nets. It was estimated that the mean number of panels effectively lost by boat per year were 3.2, 6.0 and 7.4, for the local, coastal categories and hake métier, respectively. The rate of net loss is slightly higher in the hake category due to the greater distance from shore and water depths that they operate in.

- Brittany

Fishermen were surveyed under FANTARED 2 on circumstances and causes of nets loss in the different fishing harbour or landing points on Brittany's north and west coast.

The results concern 3 métiers:

- flatfishes and monkfish trammel métier;
- spider crab trammel métier and cod gillnet métier; and
- wreck gillnet métier targeted on cod and Pollack.

Overall, the average length of lost net was between 0.8 to 2.8 km per year and per boat The proportion of net loss by year are generally less than one per cent of the length fleet set per year excepted for seabream, seabass, crawfish and wreck nets.

Table 5 Net loss by métier in Brittany, France

	Length of loss net/boat/year (km)	**Percentage lost nets/boat/year**
Flatfishes & monkfish	4.96	0.50
Spider crab	0.3	0.04
Wreck	0.23	2.81
Total	**5.49**	

Net evolution and catch rates

- Cantabrian Region

Twenty seven tangle nets used for targeting Monkfish were deployed in the Cantabrian region. The results of this were reported in Sancho *et al* (2003) and FANTARED 2. Catch rates were equivalent to those of commercial gears after 135 days but no monkfish were caught after 224 days. The cumulative monkfish catches in 50m length nets were estimated to be 2.37 fish. This gave rise to a total of 18.1 tonnes for the entire ghost catch, which constituted 1.46 per cent of the total commercial landings in the area. This was considered an overestimate given that the studied nets were not trawled away. As a concluding point, a very worst case estimate of ghost catch was put at 4.46 per cent of total commercial landings, or 55.3 tonnes.

There was a clear evolution in the composition of captures by 'abandoned' nets with time (1 year period), shifting from a dominance of fish to a dominance by scavenging crustaceans and molluscs. Changes in the physical characteristics of the nets could not be directly observed underwater in these experiments, but likely included loss of surface fishing area, entanglement of nets, sinking of headrope and colonisation of nets by bio-fouling organisms (Erzini *et al*. 1997). These physical changes are expected to alter the physical entangling capabilities of the nets and increase the visual detection of the nets by fishes. The physical increase of bio-fouling might influence in an unknown way the interactions of crustaceans and molluscs with the abandoned gear.

- Algarve

As part of the FANTARED 2 work described above, and reported in Santos *et al* (2003b), Nets were deployed during spring and autumn approximately 6.5 miles off the city of Faro (Algarve, Portugal) in 65-78 metres of water. Despite seasonal differences it was demonstrated that once a net is lost in the water there is a progressive reduction in its efficiency (of a negative exponential type), which may reach null values after a certain amount of time. Negligible values were reached after 3 and 5 months, for nets lost during spring/summer and autumn/winter periods, respectively. Biofouling was a key factor in the decline in catching efficiency.

The impact of the nets in terms of the total catch in numbers was estimated as 116 and 413 specimens per 100 m of lost net, for the spring/summer and autumn/winter experiments, respectively. In terms of weight this equates to 29.8 and 90.1 kg per 100 m of lost net. Of this, catch, 9 and 86 hake specimens were taken per 100 metres of lost net, for the spring/summer and autumn/winter experiments, respectively, which was equivalent to 20.6 and 27.6 kg per 100 metres of lost net. Based on these figures and gear loss estimates, it was hake loss due to gear loss was estimated to be between 733 and 7,000 specimens and between 1.677 and 2.247 tonnes of hake per year by the Algarve fleet. This is equivalent to a maximum of 0.3 per cent of the total catch (684 tonnes in 1999).

The FANTARED 1 work, which informed the FANTARED 2 project, included setting nets off the Algarve in shallow water. This was partly to develop methodology for the follow up work that came in FANTARED 2. This is reported in Erzini *et al* (1997). Four 100m lengths of monofilament gill and trammel nets were set in 15-18 metres of water and cut lose to simulate lost gear. Divers monitored catch rates and gear structure. Similar patterns were observed in all the nets, with a sharp decrease in net height and effective fishing area, and an increase in visibility within the first few weeks. Net movement was negligible except in the case of interference from other fishing gears. Catch rates were initially comparable to normally fished gillnets and trammel nets in the area, but decreased steadily over time. No sea birds, reptiles or mammals were caught in any of the 8 nets. Catches were dominated by fish (89 per cent by number, at least 27 species), in particular by sea breams (*Sparidae*) and wrasses (*Labridae*). The fishing lifetime of a 'lost' net was found to between 15 and 20 weeks under the study conditions. It was estimated that 100 m lengths of gillnet and trammel net will catch 314 and 221 fish respectively over a 17 week period. When the nets were surveyed in the following spring, 8 to 11 months after being deployed, they were found to be completely destroyed or heavily colonised by algae and had become incorporated into the reef.

The catch rate figures in both of these studies are considered largely indicative because the conditions were not truly representative of real fishing conditions. Nets were set in shallow waters (particularly in Erzini *et al*, 1997) so are subjected to more light and hence biofouling. This would cause ghost catch rates in real conditions to be underestimated. Predation from species such as conger eel could also have led to under estimates. Conversely however, they were not subject to being towed away, which is the most common cause of net loss in the fishery and would cause the nets to be damaged. The work does however provide an insight into the magnitude of ghost fishing rates and also the factors in determining how this changes over time.

2.2.4 Mediterranean Sea

Fishermen were surveyed under FANTARED 2 on circumstances and causes of net loss in the fishing harbour or landing points on the French Mediterranean coast (Table 7 and Table 6). Only in the hake gillnet fishery was an estimate made of total net loss. In the other fisheries estimates were considered particularly unreliable. The large-scale gillnet fisheries of the central and eastern Mediterranean, most notably Italy and Greece, were not covered by any of the FANTARED programmes.

Table 6 Net loss by métier in the Mediterranean Sea, France

Métier	Length of loss net/boat/year (km)	Percentage lost nets/boat/year
Crawfish	1.2	1.60
Hake	1.2	0.20
Sea bream	1.2	3.20
Scorpion-fish	1.1	1
Red mullet	0.7	0.50
Sole	0.85	0.25
Total	**6.25**	

Table 7 Net loss in the French Mediterranean hake gillnet fishery

type of vessels	number	min fleet length/day (km)	max fleet length/day (km)	nb fishing days	min total set/year (km)	max total set/year (km)	percent lost	min lost net/year	max lost net/year
coastal	32	2	4	90	5760	11520	0,15	8,64	17,28
offshore	65	4	8	70	18200	36400	0,2	36,4	72,8

While there does not seem to be any research on the rate of gear loss in the central and eastern Mediterranean, or their subsequent impacts, a number of studies into gillnet and coastal fisheries indicate that gears are lost eg Baino *et al*, 2001; Sacchi *et al*, 1995.

Net evolution and catch rates

Data for estimates of catch rates were very incomplete. However, it was roughly estimated that 46 hake and 36 crawfish could be caught per kilometre of lost gillnet leading to an annual loss of hake and crawfish respectively of between 2,072 to 4,144 and from 1,605 to 3,209. For the hake fishery this equated to between 0.27 per cent and 0.54 per cent of the total commercial landings.

Baino *et al* (2001) examined a 1,200 m trammel net lost in 20-35 m water after four months of ghost fishing. By this stage, only 1/3 of the net was still fishing, with a catch of around 20 per cent of normal 'controlled fishing'. On hauling, 80 per cent of the biomass consisted of various seaweeds and corals, whilst six per cent was live fish and one per cent dead fish. The authors concluded that 'during the four month period the trammel must have fished some hundreds of kilograms of commercial species'.

2.2.5 Norwegian North Sea

Gear loss

Under the FANTARED 2 work, the Norwegian fleet and fisheries combinations were divided into seven fleets and five métiers:

Fleets

a) coastal vessels between 8.0 and 12.9 m North Norway
b) coastal vessels between 8.0 and 12.9 m Southern Norway
c) coastal vessels 13.0 to 20.9 metres N.N
d) coastal vessels 13.0 to 20.9 metres SN
e) deap sea long liners, southern Norway
f) vessels 21 metres and more, northern Norway
g) deap sea gill-netters southern Norway

Métiers

1. spawning fishery for saithe
2. coastal fishery for cod
3. fishery for monkfish
4. fishery for Greenland halibut
5. fishery for blue ling and ling

The number and proportion of nets lost in each métier per year are summarised in Table 8 and discussed further below.

Table 8 Net loss in Norwegian métiers

	Per cent lost	**Number nets lost**
Spawning Fishery for saithe	0.09	431
Coastal fishery for cod	0.02	187
Fishery for monkfish	0	0
Fishery for Greenland halibut	0.04	5
Fishery for blue ling and ling	0.04	62

- Spawning Fishery for saithe

All fleets participated in this fishery. Only in the offshore fishery (fleets 5 and 7), was loss of gear reported. Of the total nets deployed in this métiers 431 nets (0.09 per cent) were lost and not retrieved.

- Coastal fishery for cod

In this métier 0.1 per cent of the total deployed nets were lost. Of these 78 per cent were retrieved by the vessel. Fleets number 3 and 6 were responsible for most of the loss. A total of 187 nets were permanently lost (0.02 per cent).

- Fishery for monkfish

In this métier 0.07 per cent of the gear was lost in 1998 and 1999. All of these nets were reportedly retrieved.

- Fishery for Greenland halibut

In this fishery the total loss of gear amounted to 0.61 per cent of the total nets deployed. This is the métier with the highest loss. However 93 per cent of the nets are retrieved and only 5 nets (0.04per cent) were lost completely.

Despite these reportedly low loss rates, between 1983 and 1997 the Norwegian net retrieval programmes recovered 6,759 gillnets with the most conspicuous catches found in Greenland halibut nets from depths over 500m along the continental slope (unpublished data, Norwegian Directorate of Fisheries, reported in Humborstad *et al* (2003)).

- Fishery for blue ling and ling

This métier was regarded as the fishery where loss of gear is most likely to occur. The FANTARED 2 survey found that 0.13 per cent of the deployed nets were lost. However, 67 per cent were retrieved and only 0.04 per cent of the nets (62 nets) were lost and not retrieved.

In the Norwegian gillnet fisheries a relationship between water depth and loss rates was found (Figure 5). (Hareide in FANTARED 2, in Hareide *et al*, 2005)

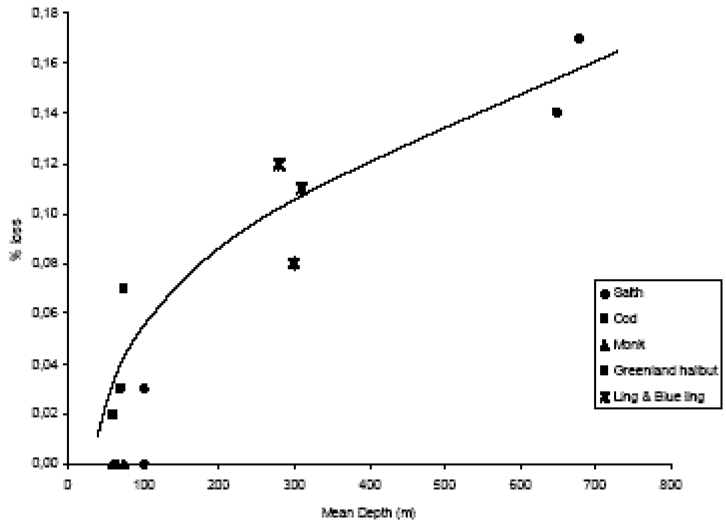

Figure 5 Loss of nets (percentage of deployed nets) by depth in Norwegian gillnet fisheries for the years 1998-2000

Source: Hareide in FANTARED 2, in Hareide et al, 2005

Net evolution and catch rates

- Shallow water gillnets

In the FANTARED project, three fleets of six monofilament gillnets were set in Bjørnefjorden, to the east of the Island of Huftarøy in Austevoll, southwest Norway. Two of the fleets were set at a depth of 120 m, and one at 160 m. All stood on a hard clay and stone bottom. The results were not analysed and are too poorly reported to permit reliable interpretation.

- Deep water Greenland halibut fishery

Humborstad *et al*, (2003) monitored nets set at over 500 metres in the Greenland halibut fishery off mid Norway. They found that the catching efficiency of gillnets decreased with soak time, presumed to be due to weight of the catch causing the headline height to decrease. After 45 days efficiency was 20-30 per cent of equivalent nets in the commercial fishery. These rates corresponded to 28-100 kg per day per gillnet. Catch rates stabilised at this level and the nets continued to fish for 'long periods of time'. The authors report that Norwegian net retrieval programmes haul nets that have been fishing for more than eight years. Furevik and Fosseidengen (2000) report that investigations on the Norwegian deep slope gillnet fishery for Greenland halibut suggest that these nets can fish for at least 2-3 years and sometimes even longer.

2.2.6 North East Atlantic deep water net fisheries

Building on the findings and concerns from the FANTARED work, the DEEPNET project (Hareide *et al*, 2005) examined the deep water and upper slope net fisheries of the north east Atlantic in more detail. This included an estimation of gear loss. It was considered that the amount of fishing gear used in the deep water net fisheries, the length of the fleets, and the fact that the nets are unattended much of the time combine to make it highly likely that large quantities of nets are lost. Such is the concern over the effect of lost fishing nets in these waters that under the 2005 EC-Norway Agreement, the Head of the Community Delegation informed the Norwegian delegation that the EC intends to develop net retrieval programmes in Community waters (Anon, 2004a).

Net loss

As well as net losses there is also evidence of illegal dumping of sheet netting in the north east Atlantic deep water net fisheries (largely north and north west of the UK and Ireland). The vessels involved in the deep water net fisheries are not capable of carrying their nets back to port and only the headline and footropes are brought ashore while the net sheets are discarded, either bagged on board, burnt or dumped at sea.

The amount of lost and discarded nets is not known. Hareide *et al* (2005) note that anecdotal evidence from one shark vessel suggests from a typical 45 day trip approximately 600 x 50m sheets of net (30km) are routinely discarded after having been damaged. Taking the level of effort to be in the region of 1,881 days (based on the German and UK effort data in Hareide *et al,* 2005), then a crude estimate of gear loss by these vessels is made to be in the region of 1,254km of sheet netting per year.

Based on the relationship between water depth and net loss rate (Figure 5) and estimates of net loss in the Greenland halibut net fishery, it was estimated that in the deep slope fisheries these vessels lose approximately 15 nets (750 m) per day.

Net evolution and catch rates

It is not known how much and for how long nets in the deep water fisheries fish after they are lost. However, given the similar environmental conditions Hareide *et al* (2005) assumed that their evolution and hence catch rates are at least as great as those in the Greenland halibut fisheries studied in FANTARED 2. Very little information is available about the impacts of abandoned sheet netting.

2.2.7 Net fisheries outside Europe

Work has been carried out on lost gillnets in a number of fisheries outside Europe, most of which have been in North American waters. Concern heightened in the early-1980s over the biological and social impacts of persistent garbage and debris in the world's oceans, including by lost fishing gear. This lead to four international conferences and workshops being were convened on marine debris (1984, 1989, 1994 and 2000) to define the scope and magnitude of the marine debris issue (Shomura and Yoshida, 1984; Shomura and Godfrey, 1990; Coe and Rogers, 1997, McIntosh *et al*, 2001) and to consider appropriate monitoring, educational, and regulatory responses. While all are relevant to lost fishing gear, the fourth in 2000 focused specifically on this issue. The reader is directed to these proceedings for more thorough discussion of the proceeding discussion and ghost fishing from a largely North American / Pacific perspective more broadly.

An overview of the work undertaken in fisheries outside Europe is given here. The case seems to be that much of this work tends to be opportunistic and fragmented in the sense that gear evolution is studied or catch rate of a gillnet, without estimating the implications for fisheries as a whole. As such, much of the knowledge base on ghost fishing appears to have been pieced together over time. This is not to say that it is unreliable or of no value, but more that it is a reflection of the practical challenges studying the effects of lost gear pose.

The first documented work on lost gillnets appears to be that of Way (1977) in Atlantic Canada. A number of other studies followed (eg High, 1985 and Carr *et al*, 1985) but most tended to be in response to specific incidents of loss or following some opportunistic identification of an accessible lost net.

Gillnets studied in inshore waters of North America demonstrated a collapse in net and subsequent decline in catch rates over time in the same way as those in the FANTARED work. Carr *et al*. (1992) deployed two 100m sections of 130 mm stretched gillnets at 20 m depth in Buzzard bay, Massachusetts, USA. Over a two year period skates, dogfish and a number of finfish were caught early on while lobster and other crustaceans continued to be caught throughout the study. A two year fishing life was also observed in Canadian nets by Way (1976).

Studies have included pelagic or drift gillnets. Gerrodette *et al* (1987) monitored 113mm mesh 9m deep monofilament nets (50, 100, 350 and 1000m in length). They found that the nets collapsed soon after deployment and that relatively few fish or other organisms were caught in the bundle of netting. Mio *et al* (1990) deployed five pelagic gillnets of 2000m length and similarly concluded that they formed a large mass of netting within four months.

Way (1976) reported investigated ghost catch by nets in the deeper waters of Newfoundland and found that they continue catching over several years, although at much reduced levels. High (1985) also observed continued catching after three years of fish and seabirds in pieces of lost salmon gillnet, despite biofouling.

Ten gillnets (91 meters depth each) caught about 9,090 kg of cod in Placenta Bay, Newfoundland (ICES 2000). These nets were actively fished less than six months before being retrieved as ghost gear.

Carr and Cooper (1987) estimated that in protected, near-shore locations where depths are less than 30 metres gillnets may continue to catch fish at a reduced, yet substantial, rate of 15 per cent of normal the gillnet rate if roundfish and flatfish are present.

Although fifteen years ago, Breen (1990) undertook a review of ghost fishing and the work undertaken at the time. He reported that lost herring gillnets in British Columbia, Canada, continued catching fish for seven years, while Erzini *et al* (1997) report that eight year old gillnets retrieved in Norwegian waters were found to contain fish.

Studies that have attempted to estimate the amount of lost nets in a given area using ROVs or by net retrieval include Barney (1984), Carr and Cooper (1987), Cooper *at al* (1987) and Carr *at al* (1985). Fosnaes (in Breen 1990) estimated an annual loss rate of Newfoundland cod gillnets of 5000. Way (1977) retrieved 148 and 167 nets in 48.3 and 53.5 hours of trawling with a grappling device over two years. Carr and Cooper (1987) estimated that in an area $64km^2$ traditionally fished by gillnets there were 2,240 lost nets. Canadian Atlantic gillnet fisheries were estimated to suffer a two per cent loss rate (8,000 nets per year) up to 1992 (Anon 1995, Chopin *et al* 1995). The US National Marine Fisheries Service estimates that

0.06 per cent of driftnets are lost each time they are set, resulting in 12 miles of net lost each night of the season and 639 miles of net lost in the North Pacific Ocean alone each year (Davis, 1991, in Paul, 1994[3]). More recently, Anon. (2001) (in FANTARED) reported losses of 80,000 net between 1982 and 1992 through out Atlantic Canadian waters.

Nakashima and Matsuoka (2004) investigated the catching efficiency of lost bottom set gillnets through setting nets in three experiments for up to 1,689 days. The nets were observed through underwater observation. Catching efficiency declined to five per cent in 142, during which period the total number of ghost-fishing mortalities was 455 fish. Ghost fishing for red sea bream, *Pagrus major* and jack, *Decapterus* sp. occurred in the first short period and for filefish *Stephanolepis cirrhifer*, over a longer period.

2.2.8 Summary extent of net loss within European waters

Based on the work undertaken in European waters, the loss of static fishing gears appears to be common in some fisheries. In relation to the total number of nets being set however, the rates of permanent net loss appear to be rather low – well below one per cent of gear deployed annually. To a large extent this is because the level of recovery of nets in most shelf fisheries that are subject to minor damage is now very high because of the almost universal adoption of GPS by fishing vessels (FANTARED 2). However, because the length of nets being set is very high, the total length of netting permanently lost can also be high. The extent of net loss in the fisheries discussed above are summarised in Table 9. While loss rates are generally below one per cent, the length of netting lost each year in those fisheries studied alone is over 209 km. Applying a loss rate of one per cent to the total number and length nets set in European fisheries would provide a rough estimate of total loss per year.

As noted in section 2.2.6, a possible exception to the low loss rates and numbers is in the deep water net fisheries in the north east Atlantic. The estimated figures for these fisheries dwarf even the totals from those fisheries studied elsewhere, with a total number of 25,080 nets lost per year at a length of 1,254km.

Table 9 Summary of net loss in selected European fisheries

Fishery	Estimated length of ghost nets/yr/km	Percentage of nets used lost per year	Number of nets lost	Pieces of Netting lost
Swedish net fisheries	156.1	0.1	1,448	
UK net fisheries	36		325	884
Spanish net fisheries			~5,500	
French Mediterranean fisheries	6.25			
French North and West Brittany fisheries	5.49			
French North sea and East Channel	5.5			
Selected Norwegian net fisheries		>0.1	685	
Total	**209.24**		**7,958**	
Deep water net fisheries	1,254		25,080	

3 http://www.earthtrust.org/dnpaper/waste.html

2.2.9 Summary of net evolution and catching efficiency

Gear evolution is a key variable in determining catching efficiency. Vertical profile and invisibility are the primary characteristics that make gillnet gear effective. Mesh size is also important but less than the former two characteristics (ICES, 2000). Other factors relating to the rate of mortality of gillnets are depth and sea bottom type. Together with the availability of vulnerable species, the lost gear's exposure to environmental incidents such as storms and surge and fouling are thus key determinants of the effective mortality rate/catching efficiency of ghost gillnets.

The work under FANTARED and wider international studies show that while nets may be set in a wide range of environmental conditions, their evolution and catches show some similar patterns and tendencies. Catching efficiency of lost nets also generally show the same pattern, with changes in species composition over time in most cases, typically from fish to crustaceans.

On rocky bottoms, gillnets may maintain a nearly horizontal configuration with some vertical profile (about one metre altitude) as they are caught around rocks (Carr, 1988). Dependent on the level of exposure to the elements, however, catch rates can near zero over a 8-11 month period as the nets become destroyed and fouled (Erzini *et al*., 1997).

Static nets fished on open bottoms experience an initial sharp decrease in net height followed by a prolonged period of slow decrease in net height and increased degradation and tangling due to catches and biofouling. Fishing rates may nonetheless continue at not insignificant rates, of up to 15 per cent of normal gillnet rates in some cases (Carr and Cooper, 1987; Brothers, 1992).

Nets deployed on wrecks and rocky bottoms tend to degrade rapidly and/or are tangled in the structure of the wreck, resulting in reduced catch rates within months of being set. While studies in Canada showed that nets set in very deep water continued to fish for many years, the effective fishing lifetime of the nets in the FANTARED study were not more than 6 to 12 months in most cases. The exception was the Baltic where catch rates of 4-5 per cent of commercial rates were still being recorded after 27 months.

2.2.10 Summary of ghost catches within European waters

Estimates of ghost catches in European fisheries are both limited and approximate. This is even the case in the FANTARED work, which covered a range of countries with studies spanning several years. To summarise:

- ***Baltic Sea*** – the total catch of cod by lost nets during the 28 month study period could be somewhere between 3 and 906 tonnes. This is between 0.01 and 3.2 per cent of the total weight of reported and landed cod catch from the same area and time period.

- ***Southwestern waters*** – total ghost catch of monkfish in tangle nets in the Cantabrian region gave rise to a total of 18.1 tonnes for the entire ghost catch, which constituted 1.46 per cent of the total commercial landings in the area. A very worst case estimate of ghost catch was put at 4.46 per cent of total commercial landings, or 55.3 tonnes. Hake ghost catch was estimated to be between 733 and 7,000 specimens and between 1.677 and 2.247 tonnes of hake per year by the Algarve fleet. This is equivalent to a maximum of 0.3 per cent of the total catch (684 tonnes in 1999).

- ***Mediterranean Sea*** – an annual loss of hake and crawfish was estimated as being 2,072 to 4,144 and from 1,605 to 3,209 respectively in the French Mediterranean hake gillnet fishery. For the hake fishery this equated to between 0.27 per cent and 0.54 per cent of the total commercial landings.

The FANTARED work concluded that while impacts on crustacean stocks are difficult to estimate, the Mediterranean work showed 1,500-3,000 individuals possibly being taken by lost nets. Comparison with catch data was not possible because of its absence.

Despite the limitations of these estimates, most of the fisheries that were examined the losses of commercial species attributable to lost static gears were small compared to commercial catches and also compared to other sources of such discarding. Estimated ghost catches are generally believed to be well under one per cent. Even these figures are considered an overestimate as the most common cause of lost gears is gear conflicts. It is thus common for the lost nets to encounter trawlers, so become damaged more than those studied in the experimental work. Furthermore, commercial landings do not include all fishing related mortality eg discards.

A notable exception to this is believed to be in the deep water net fisheries where conditions (eg water depth) are conducive to both high net loss rates and ghost catch (see section 2.2.6). However, there are currently no reliable estimates as to what the ghost catch rates may be in these fisheries.

One of the main conclusions to come from the FANTARED work and the associated multi-stakeholder workshop was that there is concern over the levels of net loss in the southern Baltic Sea because of the tendency for lost nets to retain a significant fishing capacity for many months. The deep water net fisheries were also singled out for further research and management attention.

2.3 Fish and crab pots

The availability and quality of the information for estimating annual trap loss rates varies considerably. Pot fisheries in three regions have been studied in Europe to the authors' knowledge:

- pot fisheries of the UK;
- traps off of Portugal; and
- red king crab pots of Norway.

These are summarised here with a more general review of the literature, followed by an overview of the causes of pot losses and a summary of gear evolution and catching efficiency.

2.3.1 North Sea and English Channel

Pot loss

In 1999 Seafish in the UK undertook a government funded study to, *inter alia,* investigate the extent and nature of problems associated with ghost fishing by shellfish traps that become permanently lost in UK waters (Swarbrick and Arkley, 1999). The project team undertook a survey of fishermen's experiences of gear loss in the Southwest and Northeast of England and on the West Coast of Scotland. The survey quantified effort levels, identified the main reasons for losing shellfish traps and looked at fishermen's perceptions of the phenomenon.

The survey showed that most fishermen do not believe that lost traps pose a threat to stocks. Many of those interviewed had recovered traps lost for varying periods of time and they seldom contained any catch. In most cases they were damaged and had no residual fishing capability. A more significant source of unaccounted mortality on shellfish species was claimed to be from netters, beam trawlers and scallop dredgers. The authors noted there are some objective catch data which support these assertions. It should be noted however that since this research, there some concerns were raised in the workshop that the loss of parlour pots may be an increasing problem because of their efficiency in retaining crabs (eg Philip MacMullen, Seafish, pers com)

While average loss rates were reported in relation to other results eg perceptions of ghost fishing, the results are presented such that total loss rates cannot be deduced.

Pot evolution and catch rates

A fleet of twelve pots set off the coast of Wales caught a minimum of 7.08 spider and 6.06 brown crabs per pot per year and killed a minimum of 6.06 brown crabs and 0.44 lobsters per pot per year (Bullimore *et al* 2001). Other species caught in the traps included velvet swimming crab, lobster, ballan wrasse, dogfish, and triggerfish. The pots continued to catch animals into the second year of the experiment. The catch rate declined as an inverse function of time and reached a minimum between 125 to 270 days after initial deployment in August 1995. After this period, catch rate increased again, although it did not attain the rates associated with the beginning of the experiment. Pot loss rates and hence total mortality was not estimated.

2.3.2 South-western Waters

Surveys were conducted in 10 ports of the Algarve, South of Portugal, in 2003, stratified by the two main regions as part of FANTARED 2, for both local and coastal fleet components of boats licensed to fish with octopus traps Figure 6.

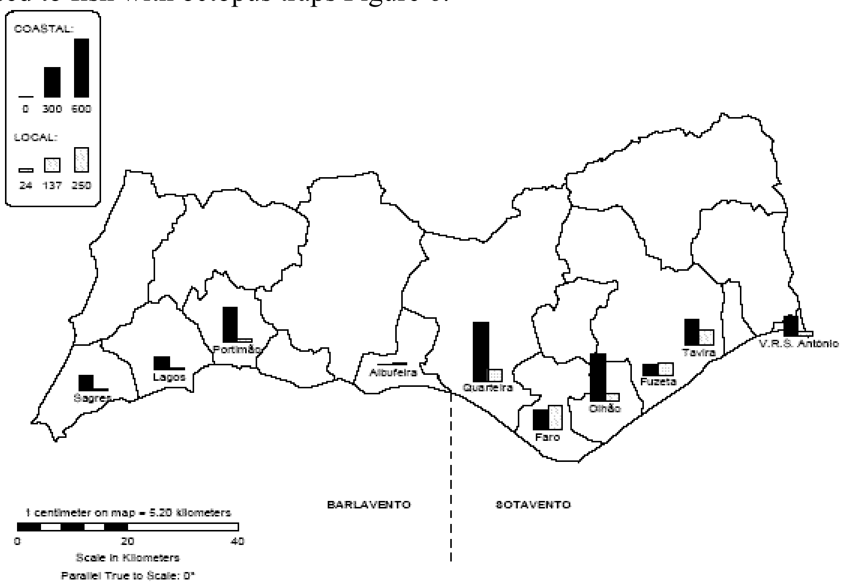

Figure 6 Location of Portuguese ports surveyed

Source: FANTARED 2

Pot loss

The average number of octopus traps lost at sea per vessel and per year for each port and fleet type is presented in Table 10. On average, the number of small traps (used mostly to catch octopus) lost at sea is higher for the coastal fleet than for the local fleet. In terms of fishing zone, the losses are higher in the Sotavento than in the Barlavento on average (Table 10).

Table 10 Pot losses in Portuguese fleets

Fleet	Zone	Trap type	
		Octopus traps	Cuttle fish traps
Local	Barlavento	30.9 ± 55.4	78.8 ±147.5
	Sotavento	145.6 ± 102.2	13.5 ± 11.1
Coastal	Barlavento	213.0 ± 213.8	11.3 ± 19.3
	Sotavento	318.5 ± 207.8	10.0

Regarding the big traps (used mostly to catch cuttlefish), the results regarding the fleets are the opposite, such that the local fleet loses more traps than the coastal fleet. In terms of fishing zone, there are again more losses in the Sotavento than in the Barlavento (Table 10).

Absolute figures for permanently lost pots were not determined, even though the recovery rates were estimated. The recovery rates were moderate to high for the Barlavento 'coastal' fleet. In the Barlavento local fleet, the boats that attempted to recover traps had a high success rate. In the Sotavento, most of the boats had medium success in recovering the traps, both in the local and in the coastal categories (Table 11). However, because these figures appear to give success rates for those boats that attempt to recover pots, they do not necessarily relate to the numbers actually recovered.

Table 11 Percentage of pots recovered by Portuguese fleets

Fleet	Zone	Sucess in recovering lost traps		
		High	Medium	Low
Local	Barlavento	68.2	18.2	13.6
	Sotavento	33.3	50.0	16.7
Coastal	Barlavento	40.0	60.0	0.0
	Sotavento	30.0	40.0	30.0

Pot evolution and catch rates

Further to this industry survey work, the FANTARED 2 study included pot deployment off of Faro. However, it was concluded that lost pots should have no impact on octopus stocks as they were observed entering and leaving the traps freely. There were no reports of other species becoming trapped.

2.3.3 Norwegian North Sea

As part of FANTARED 2, and reported in Godøy *et al*, (2003), an experiment was set up whereby pots were deliberately 'lost' for periods of between 5 days and 1 year. A new design of rectangular collapsible pot was the main gear used, while in a single 5 days trial the traditional conical pot was used. In a string of four pots, for example, all 92 tagged individuals left the pots after 4 months, while 61 new crabs entered them. Very few dead crabs were found in the pots. While there were limitations to the experiment design, it was concluded that lost pots do not substantially contribute to crab mortality in these fisheries. The size of the crabs increased with soak time in the rectangular pots, while it decreased with soak time in the conical pots.

2.3.4 Pot fisheries outside Europe

The effects of lost pots have been studied more systematically than in net fisheries (FANTARED 2). In particular, the high value trap fisheries in North America which have been investigated systematically for many years (eg Blott, 1978; Stevens *et al*, 1993; and High and Worlund, 1979).

Pot loss and catch rates

Anecdotal reports of lobster pot loss rates off New England, U.S. run as high as 20–30 per cent per year (Smolowitz 1978). The reported catch of lobster in pots lost off the New England coast was 5 per cent of the total lobster landings in 1976 (Smolowitz 1978). Along the Maine coast the pot loss rate reported in 1992 was 5–10 per cent (ICES, 2000).

In a one year study of Dungeness crab pots of British Columbia, Canada, the loss rate of crabs from ghost pots was estimated to be 7 per cent of the reported catch (Breen, 1987). This was from an estimated annual trap loss rate of 11 per cent.

A study in Louisiana, USA, resulted in a total catch per pots averaging 34.9 blue crabs, 25.8 died and 21.7 escaped per pot (Guillory, 1993). The turnover of blue crabs was fairly rapid; two-thirds of blue crabs entering the trap either died or escaped within 2 weeks. Conservatively assuming a total of 5,000 commercial trap fishermen each using 200 traps and an annual trap loss/abandonment rate of 25 per cent, approximately 250,000 derelict traps are added each year in the Gulf of Mexico (Guillory *et al*, 2001), with ghost fishing leading to a loss of 4 to 10 million blue crabs each year in Louisiana (GSMFC, 2001). This figure underestimates the actual number of derelict traps because of the cumulative addition of derelict traps over time and exclusion of traps used by recreational fishermen. However, not all derelict traps continue to fish because some are located on land or emergent vegetation, and older derelict traps eventually deteriorate and become incapable of ghost fishing.

Stevens *et al* (2000) conducted a pot retrieval programme off the coast of Alaska using sonar to locate pots and trawl gear to retrieve them. 147 pots were recovered, of which 97 contained organisms. Tanner crab was the most abundant species, with pots having a mean catch per pot of 1.54. The survey was limited in providing a snapshot however rather than estimating ghost fishing mortalities rates.

In the snow crab (*Chionoecetes opilio*) trap fishery in the Gulf of St. Lawrence it was estimated that over 19,000 traps were lost at sea between 1966 and 1989 (Chiasson *et al* 1999). This equates to an average of around 792 traps per year. Hébert *et al* (2001) demonstrated a ghost mortality rate of 94.6 per cent in this fishery. Based on a mean catch rate of 51kg per haul, 1,000 gears were calculated as resulting in killing 84,194 snow crabs, or 48.2 tones per year. It was also demonstrated that catches increase in the new season again to their saturation level, due to the self-baiting effect, which re-initiated a ghost fishing cycle.

A field study of catch rates of lost fish traps in fishing grounds nears Muscat and Mutrah, Sultanate of Oman (Al-Masroori *et al*, 2004), ghost fishing mortality was estimated at 1.34 kg/trap per day, decreasing over time. An exponential model was used to estimate trap ghost fishing mortality. It predicted a mortality rate of 67.27 and 78.36 kg/trap during 3 and 6 months respectively, with trapped fish having a value of 55.565 RO/trap (US$145) and 64.725 RO/trap (US$168) respectively. This was not related to total catch value. In an earlier study (Al-Masroori, 2002) it was estimated that trap loss rates might be as high as 20 per cent in this fishery. In the trap fishery of Kuwait financial losses due to ghost fishing may reach 3-13.5 per cent of total catch value (Mathews *et al*, 1987 in Al-Masroori *et al*, 2004).

Pot evolution

In a study on the effect of soak time on legal and non-legal sized red king crabs, Pengilly and Tracy (1998) (in FANTARED 2) found that the ratio of non-legal to legal size decreased with increasing soak time. the average size of crabs caught increased with longer soak times.

Guillory (1993) found that smaller blue crabs (*Callinectes sapidus*) were more likely to escape than larger individuals. Zhou and Shirly (1997) (in FANTARED 2) found that in box-shaped king crab pots the escape rate ranged from 12.5 per cent for legal males to 56.3 per cent for females. They also observed that legal-sized male crabs had the lowest rate of attempted escapes.

High and Worlund (1979) found that the percentage of legal-sized king crabs increased over time in rectangular pots, while it decreased in snow crab pots. They also incidentally observed that snow crabs (*Chionoecetes opilio*), which are considerably smaller than king crab, were more active. Smaller king crabs may be more active than larger ones, and are thus more likely to leave the rectangular pot first.

Comparative fishing trials with rectangular and conical pots in Northern Norway showed that the rectangular pot caught more and larger crabs (Unpublished, in FANTARED 2).

Tagged crabs have been observed to leave the pots after a period of time. High and Worlund (1979) placed tagged king crab in several types of pots and found that those that escaped after 10-16 days had a lower return rate to the pots than those in the control groups. Crabs that escaped after one to four days had almost the same return rate as those in the control group

Tanner crabs (*Chinoecetes bairdi*) that were starved for periods of up to 90 days did not raise their feeding rates after starvation, and suffered mortalities of 40-100 per cent during prolonged holding with access to food (Paul *et al* 1994, in FANTARED 2). Dungeness crabs (*Cancer magister*) that received similar treatment suffered 40-80 per cent mortality, while the control group, which was fed continuously for 230 days, suffered 20 per cent mortality. More crabs might be susceptible to stress caused by capture, handling, and captivity. In the wild these stresses might translate into poorer ability to forage, feed, reproduce or survive, even after escape from a pot.

All the FANTARED trials with rectangular pots showed that smaller crabs were the first to leave the pots. This may be because smaller crabs had an easier passage through the entrance from inside the pot.

2.3.5 Summary extent of pot loss within European waters

Estimates for pot loss rates are lacking. While the FANTARED work looked at this in Portuguese trap fisheries, and reported loss rates to be low because of successful retrieval, the results are not presented in a manner that permits deduction of total gear loss. The same is true for the studies undertaken in the UK pot fisheries. In both cases however, loss rates were not considered to be high enough to warrant concern because of low loss rates to begin with, high retrieval rates and those pots being lost being subject to damage because of gear conflicts.

2.3.6 Summary of pot evolution and catching efficiency

As with bottom set static nets, the effective catching efficiency of potting gear is dependent primarily on the availability of vulnerable species and the lost gear's exposure to environmental incidents such as storms and surge and fouling.

Pots tend to pass through a cycle of ghost fishing. They tend to be baited when they are set. If the pot is lost, in time the bait or lost catch attracts scavengers, some of which are commercially important species. These scavengers may become entrapped and subsequently die, forming new bait for other scavengers. In some fisheries, entrapped animals may escape over time.

The FANTARED work supports the findings from the studies in fisheries outside the EU. With the exception of the wire fish traps, the other types of traps studied in the FANTARED project (crab traps – Norway, octopus traps – Portugal) did not show significant degradation over the course of the project. However, unlike nets the catch rates of pots depend to a large extent on the bait and once this has been eaten or has degraded, catch rates decline sharply. In the case of the octopus and the fish traps from Portugal there are essentially no catches three months after deployment. While fish were found to be less able to escape from traps, escape rates for octopus and the king crab were high. Post escapement mortality due to retention in pots for prolonged periods (days or weeks) is a possibility in the case of the crabs. There is little information concerning such unaccounted mortality and this is an area that was considered warranting further research.

Key points to come from the FANTARED and other studies were that catching efficiency is as variable as pot loss rates. Catching efficiency is dependent upon gear design, species behaviour and seasonality, and that entry, escapement and mortality rates is a dynamic process.

2.3.7 Summary of ghost catches within European waters

Although estimates of pot loss rates are largely lacking, ghost catches from pots and traps appear to be believed to be low because of successful gear retrieval and escapement of trapped organisms.

The Norwegian and Portuguese experiments under FANTARED indicate that the unaccounted mortality arising from lost pots and traps is fairly low. The Norwegian work showed that the target species of king crab were able to escape from the traps to some extent with smaller crabs having a better escape rate than the larger. It was concluded that gear loss is not a problem, in particular when compared to other sources of mortality.

The Portuguese work with octopus traps showed that the impact of lost traps on local resources is difficult to estimate. While a large number of octopus traps are lost, most of the catch consisted of octopus. Few other species are caught in these traps. No octopuses were found in the experimental traps after three months and the laboratory experiments showed this species exiting at will. Other species, especially small reef fishes were observed inside the traps, although it is possible that they were using the traps as a shelter and were able to enter and leave freely.

It was found that although escapement from the larger fish traps studied in Portugal ('murejona' fish traps) is harder, the overall impact of ghost fishing fish traps is probably low due to the relatively small numbers lost and also because their lifespan is short compared to the octopus pots.

The ghost catch rates in European fisheries thus appear not to be as high as those reported in some North American fisheries, where levels may be up to seven per cent of commercial catch, or even 20 per cent in fishing grounds nears Muscat and Mutrah, Sultanate of Oman.

2.4 Bottom trawl gear

The larger diameter synthetic multifilament twine common to trawl nets is the key factor that reduces ghost fishing mortality in lost trawl gear. The material has a larger diameter than gillnet monofilament and is visible or of such a size that it can be sensed by the fish. Although lost trawl gear will often be suspended by floats and form a curtain that rises well from the bottom, many of the losses form additional habitat for such organisms as ocean pout, wolfish, and cod and 'substrate' for attaching benthic invertebrates such as hydroids, and sea anemone (Carr and Harris, 1995).

Diving observations, using SCUBA, submersibles and ROVs (Remotely Operated Vehicles) have shown that on deep depth substrate and bottom locations where currents are at a minimum, trawl gear usually has an overburden of silt. The webbing is thus quite visible or detectable. Trawl netting, though is often found floating or just subsurface. Much of the synthetic twines are buoyant and sometimes the twine buoyancy is augmented by the trawls buoyant floats that remain attached to major pieces of trawl webbing. This will attract pelagic marine species; invertebrates such as the attached tunicates and barnacles, and pelagic invertebrates. This webbing, though visible, will attract other marine species that can become entangled (Laist, 1994, in ICES 2000).

2.5 Fish weirs, demersal longlines, and jigging

There is evidence of gear conflicts between the deep water gillnetters and the Spanish longline fleet (Anon, 2005c), particularly around an area called the 'Coral grounds', 70-80 miles South west of Ireland in 400-500 metres. As with fish weirs, seine nets and jigging, however, the mortality rate from lost demersal longlines is usually low (ICES, 2000; Huse *et al*, 2002). Such lost gear may persist in the environment however where it is constructed of monofilament. Ghost mortality is a function of the gear type, the operation, and the location in regard to active ocean features and elements.

3 Prevention and mitigation of gear loss and ghost fishing with special reference to retrieval programmes

3.1 Causes of gear losses

The causes of gear loss are important, both in terms of affecting lost gear evolution (section 2) and for developing prevention and mitigation measures. The causes of the losses (reasons and extent) vary between and within fisheries and fishing métiers, although some common features characterise the losses, particularly the conditions in which they occur. These factors were investigated in key European fisheries under the FANTARED 2 project and are summarised here in decreasing order of relative importance:

- conflict with other sectors, principally towed gear operators;
- working in deep water ;
- working in poor weather conditions and/or on very hard ground;
- working very long fleets; and
- working more gear than can be hauled regularly.

These factors are discussed below in more detail.

There is generally a high economic motivation to retrieve lost fishing gears by using a creeping type gear. In some cases fishing gear losses are therefore temporary and nets are retrieved in a short or long time, depending on the circumstances of the loss. The losses are permanent in other cases, after several failed attempts at net retrieval.

Generally, increasing fishing depth and rougher ground conditions make the retrieval of lost gears more difficult because the use of the creeping gears is less efficient on those grounds.

Losses occurring on ‘open’ fishing grounds are mainly due to interactions with mobile fishing gears. Examples of these include the cod gillnet fisheries in the Baltic; saithe, ling and blue ling métiers in Norway, hake netting in the UK, monkfish fishing with tangle nets in Northern Spanish waters and the hake fishery practiced by the ‘coastal’ Portuguese fleet.

The open ground fisheries usually account for the biggest amount of fishing gears lost. This permanent loss of gears is related to the fact that mobile gears usually move static gears away from their original position making them hard to find. The losses usually involve several panels of nets or a whole fleet.

Gear conflicts vary over time. In some areas, losses due to trawling had reduced in recent years due to improved communications between the skippers from the two sectors. In other areas new ground gears opened hard ground to trawlers that had previously been inaccessible. This has resulted in a greater number of net losses due to trawling.

Gear conflicts are not restricted to static and towed gears. In some areas netters, liners and potters can all be in competition for the grounds. These conflicts however are considered to be much less serious and the gears are not usually moved any distance.

In some fisheries (eg Greenland halibut fishery in Norway) on the continental slopes a common reason for permanent losses is often a combination of rough bottom and strong currents that result in the snagging (or ‘hooking’) of the nets on the bottom. In other slope fisheries, gillnets are set to run down the slope whilst trawlers typically fish at constant depth along the slope – that is at 900 to the gillnets. The retrieval of the nets in these circumstances has little chance of being successful because of the adverse conditions.

Generally speaking, in inshore fisheries the loss of gears has less catch impact than offshore and the claimed retrieval rates are much higher. Thus, although some gear conflicts still occur producing significant losses (for example the trap fisheries in South Portugal) they are not so frequent. In Northern Spanish waters trawling is banned by national fishing regulation under 100 metre depth and this effectively prevents gear conflicts from occurring in inshore waters.

The fisheries on wrecks (British and French fisheries in the Mediterranean) report quite substantial amounts of fishing gears lost by snagging of the nets on the bottom. The retrieval of the gears on those cases is quite complicated and the results are very variable (ie pieces of netting and/or ropes, large bundles of nets badly tangled are recovered).

Sometimes fishermen report temporary losses due to the disappearance of the marker dahns on both ends of the fleet. This commonly occurs when dahns are submerged by the effect of strong currents, dhan ropes are cut by vessel propellers or intentionally cut. In those cases the gears are almost always retrieved using creeping gears because of the almost universal use of satellite location technologies (GPS) among the fishing fleet.

Losses due to storms are less frequent as usually fishermen are aware of approaching rough weather from weather forecasts and avoid this risk. However, both these and those due to trawling, have the lowest net retrieval rates as the nets are usually moved away from the place they were set making the search very difficult.

In the deep water fisheries that were the subject of the DEEPNET work (Hareide *et al,* 2005), dumping of sheet netting was also a major reasons for gear 'loss'.

3.2 Prevention and mitigation

The FANTARED work included an exhaustive identification and discussion of ghost gear prevention and mitigation measures. This work is both the most recent and most specific to EU fisheries than anything else in the literature. The FANTARED work classified the management options for addressing lost gear into two groups (Table 12).

It is important to note that gear may be a) 'lost' and/or b) 'discarded/abandoned'. The methods used for reducing a) lost fishing gear, and b) discarded fishing gear, may therefore need to be different (Smith, 2001). Fishing gear may not be 'lost', but just not easily retrievable, or can become lost when marker buoys are cut by passing vessels or by trawl or seine warps breaking during the fishing process. In some cases, fishing vessels need to cut gear adrift for safety reasons in very bad weather conditions or when they have snagged an underwater obstruction. Given that the loss of fishing gear under these circumstances represents a financial loss to the operator, it is more than likely that an attempt will be made to recover it. The amount of time and effort spent retrieving gear is related to its value, the probability of recovery and the opportunity cost of carrying on fishing. Abandoned fishing gear, on the other hand, implies that the gear has no financial value to the fisher and that leaving it in the sea is a convenient means of disposal for the careless and irresponsible fisher.

Table 12 Preventative and curative ghost fishing measures

Preventive measures	Curative measures
Reducing risks of conflict eg zoning of active and passive fishing	Reporting of gear loss for subsequent gear recovery campaigns
Reducing risks of snagging eg gear modification	Gear recovery campaigns
Reducing efficiency of ghost nets eg biodegradable components	Opportunistic gear recovery through demersal trawl surveys
Reducing fishing effort eg net numbers, soak time, vessel numbers	
Improving gear recovery eg attachment of transponders	

In addition to these categories of measures a broader strategic approach of establishing codes of good practice and the changed behaviour that should flow from them was identified as a key to linking them both. It is also important to improve communications between fishermen, and between fishermen and enforcement agencies. Such codes can further be useful in demonstrating to the public that the industry is proactively addressing gear loss.

This work was taken beyond the level of academic study to the practical level of working with the fishing industry of the UK, Spain, Portugal, France, Sweden and Norway in developing a netting code of conduct of good practice to minimise gear conflict and gear loss and to agree measures to mitigate the impact of lost gear on commercially important stocks. The points over which agreement was met were:

- only setting the amount of gear that can be handled regularly and efficiently;
- marking gear properly, including the identity of the vessel;
- paying close attention to weather patterns and not setting gear when poor weather is expected;
- ensuring that gear is set in such a way as to avoid conflict with other users, and taking appropriate precautions when fishing in areas of high marine traffic;
- always carrying net retrieval gear aboard; and
- always attempting to retrieve lost gear and reporting its loss where possible.

Regional additions include using radar reflectors, using certain surface buoy combinations for strong current conditions, tagging nets and specifying minimum standards for gear construction.

In the DEEPNET study of the deep water net fisheries (Hareide *et al,* 2005), a number of fishery specific recommendations targeted at addressing net loss and ghost fishing were made (Table 13).

Related to the marking and identification of fishing gear, the European Commission commissioned a project in 1995 on the development of methods and techniques based on acoustic technology for locating nets on the surface from nets laid on the bottom of the sea (CONTRONET, 1995).

The objectives of the project were *inter alia* to investigate methods for locating underwater nets from the surface and to test and recommend the most suitable acoustic locating methods.

Table 13 Possible deep water fishery management measures identified by Hareide *et al*, 2005

Recommendation	Positives	Negatives
The introduction of restrictions on the length of gear deployed at a given time either by overall length or per fleet of nets. Such restrictions were introduced in the north east Atlantic drift net fisheries for Albacore tuna.	Reduce fishing effort	Difficult to enforce and hard to monitor, although VMS does provide a level of control.
The certification of fishing gear through labelling	Provide better information of fishing effort	Legal responsibility, problems with damaged or repaired gear and potentially easy to circumvent
A requirement that vessels cannot leave gear at sea whilst landing.	Reduces discarding through extended soak times	Difficult to enforce and hard to monitor, although a combination of VMS and adequate marking of gear will provide a level of control
All gears to be marked clearly at either end	Reduce the amount of lost gear and also reduce hazard to other fishing vessels	Difficult to enforce and original EU proposals were too complex to be enforceable
The introduction of measures, which stop the practice of stripping the headline and leadline of nets and dumping of used netting at sea.	Reduce the dumping of nets at sea.	Difficult to enforce and potentially could have the opposite effect.
The spatial management of effort by gear sector, separating towed and static fishing gears	A proven method of reducing the amount of gear conflict and net loss	Probably difficult to administer and enforce in offshore areas and international waters.
Closed areas to protect ecologically sensitive habitats, such as hydrothermal vents, deep water corals or other characteristic habitats eg seamounts.	Reduce the amount of lost gear and protect sensitive habitats	Difficult to monitor and enforce if areas are too small but VMS will allow monitoring of bigger areas. Widespread objection from other sectors of the industry

The study concluded that geophysical and acoustic instruments were the most appropriate methods for underwater detection. Acoustic methods (echo-sounder and sonar) were the most successful in detecting nets. Optical methods however had limited success. Active acoustic devices were too expensive and therefore not employed during the study. However, the study found that passive acoustic reflectors make a net detectable over a wider range of approach angles. The project finally recommended the use of a miniature, codified passive-sonar-transponder (microchip) to identify nets. The microchip can be inserted within either the headline or the footrope. The chip would be inexpensive when mass-produced and can be easily incorporated in the net elements during net manufacture. However, the codified identification information can only be detected and deciphered at very short ranges (up to 120 cm).

3.3 European preventative instruments

The International Maritime Organisation (IMO) Convention for the Prevention of the Pollution from Ships (commonly referred to as MARPOL 73/78) specifically prohibits the abandonment/dumping of fishing gear (Annex V, Regulation 3). The accidental loss of fishing gear is however recognised under Annex V, Regulation 6., All ships of 400 gross tonnage and above, or certified to carry 15 persons or more, must provide a Garbage Record Book to record all disposal and incineration operations (Annex V, Regulation 9). The date, time, position of the ship, description of the garbage and the estimated amount incinerated or discharged must be logged and signed. The books must be kept for a period of two years after the date of last entry.

MARPOL has been ratified by all 25 EU Member States. It has further been transposed into the national law of the EU countries in which the deepwater netting vessels are flagged (ie UK, Germany and France) as well as Ireland in whose waters the fishery is partly prosecuted[4]. Panama has also ratified MARPOL although the extent to which it has been transposed into national law requires further investigation[5].

At the EU level there are two notable sets of gear marking requirements that should play a role in preventing ghost fishing. The European Commission recognised the importance of marking of fishing gear in 1994 with the adoption of the Communication ‘Fishing with Passive Gear in the Community - the need for management, its desirability and feasibility’ (CEC, 1994). This followed the FAO Recommendations for the Marking of Fishing Gear, which provides legal and technical measures that can be taken by national administrations to ensure that the abandonment of fishing gear is minimised (FAO, 1991).

In March 2005 the European Commission adopted a Regulation (Commission Regulation 356/2005) requiring passive gear (longlines, entangling nets, trammel nets and drifting gillnets) to be marked with the vessel registration numbers. The requirements apply both to gear that is actively fishing as well as gear being carried on board vessels. Such marking is intended to improve the enforcement of technical regulations such as mesh size, hook numbers and effort limitations. The introduction of such tractability should also discourage the dumping of gear that is reported in the deep water fisheries in particular.

The marking requirements are limited to identifying the vessel to which it belongs. Soak times, setting dates or mesh sizes are not included, all of which would improve further the monitoring of these fisheries. The Regulation does not apply to waters within 12 nautical miles. This will leave many areas, most notably the Mediterranean, rather vulnerable. While this is a further weakness, many of the Baltic countries, where ghost fishing is of particular concern due to low water movements, have domestic regulations on marking requirements in

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4 In the **UK** MARPOL 73/78 and Annex V is transposed through the 1995 Merchant Shipping Act and the Merchant Shipping (Prevention of Pollution by Garbage) Regulation, which entered into force on 1 July 1998. In **Germany** MARPOL 73/78 and Annex V have been transposed by the Gesetz zu dem internationalen Uebereinkommen von 1973 zur Verhuetung von Meeresverschmutzung durch Schiffe und zu dem Protokoll von 1978 zu diesem Gesetz (MARPOL Gesetz). **France** has integrated MARPOL 73/78 into their Environmental Code (Articles L.128-10 to L.128-31). In **Ireland** the Sea Pollution Act, 1991 was enacted to give effect to MARPOL 73/78 and also applies to garbage (Annex V). The disposal of garbage is also covered by the Sea Pollution (Prevention of Pollution by Garbage From Ships) (Amendment) Regulations, 1997.

5 **Panama** has ‘approved’ the MARPOL 73/78 Convention with Ley 17 de 1975 (UNEP, 1999), although it is not clear whether it has since transposed Annex V, which covers gear dumping.

their inshore waters. The Commission Regulation nonetheless applies to deep water fisheries in Community waters, which is its primary purpose.

An unfortunate implication of the marking requirements applying to gear being carried on board vessels is that it may create an incentive for skippers to dump back at sea any abandoned gear that they may themselves retrieve in the course of fishing, rather than returning it to port for disposal.

A second set of gear marking requirements are contained in the Council Regulation 812/2004, which lays down measures concerning incidental catches of cetaceans in fisheries. The regulation requires driftnets, which are only used in the Baltic until 2008, to be marked with radar reflectors so that their position can be determined.

3.4 Locating lost gear

In addition to fishermen interviews, FANTARED 2 employed seabed surveys to try and determine the extent and nature of gear losses. The aim of these surveys was to investigate the potential for relatively rapid and cost effective inspections of the grounds. The seabed surveys also aimed to establish whether remote observation techniques (or divers in some cases) could be used for locating lost gear.

Side scan sonar (SSS), remotely operated vehicles (ROV) and divers were employed. Once gillnets were detected by SSS or ROV they were retrieved using a trawler equipped with heavy retrieval gear or grapnel equipment. However, not much lost gear was found and retrieved. The localisation of lost traps by divers, however, was deemed to be successful.

Experience and success rates with the use of SSS were mixed:

- SSS could detect gillnets on soft bottoms, whereas on hard bottoms the signals from gillnets were masked by the stronger bottom echoes. However, areas with lost gillnets are normally on very hard bottom and therefore the use of SSS proved to be of limited practical use;
- SSS was used to locate wrecks, but only the superstructure of the vessel could be observed. For the localisation of gillnets this was not sufficient.
- Problems occurred while operating the SSS at greater depth due to difficulties maintaining its stability.
- While the SSS detected several target in the depth of 50-100 meters, it could not differentiate between lost and commercial nets.
- In general it was experienced that the SSS gave imprecise detection of lost nets. Especially the detection of nets on wrecks seemed difficult, except when the gillnet fleet was set with some distance apart from the wreck.

The use of ROVs also received mixed results. In general it was concluded that the use of ROVs was not very successful. The manoeuvrability of the ROV tended to be hampered by currents, while ROVs did manage to detect lost gillnets on wrecks in deep calm waters.

Underwater surveys by divers were demonstrated to be an appropriate method of quantifying lost traps in shallow waters and in wreck-based studies, but were otherwise of limited use.

A general conclusion of the seabed surveys was that the tested location methods were of limited success. One reason may have been that the trawlers had divided the nets into several pieces, or that precise information where lost gillnets could be found was not available.

3.5 Retrieval programmes in Europe

There is generally little published information on gear retrieval programmes. What has been produced is largely documented in internal government reports and covers methodology, success rates and lessons from gear retrieval programmes. Many of these factors were reviewed as part of the FANTARED work, which itself also employed gear retrieval as a research methodology.

In EU waters, to the consultants' knowledge gear retrieval programmes are, or have been, only used in net fisheries in Sweden and Poland. Efforts are currently being made within BIM and Seafish, amongst others, to develop a programme for deep water net fisheries of the north east Atlantic. Retrieval programmes are also routinely employed by Norway.

3.5.1 Gear retrieval research

FANTARED 2 used gear retrieval as a research method for determining the extent of gear loss. A range of methods was used, including:

- a method developed by Sweden in which two vessels tow a 100 m long gear in between them;
- grapnel equipment, consisting of one or two anchors and a block of cement, connected by a 220 m long rope. The grapnel equipment was towed from a boat to 'creep' for nets;
- bottom trawling ('creeper'); and
- heavy retrieval gear which is also employed by Norwegian retrieval programmes (Figure 10).

While several methods were employed, only the efficiency of the Swedish gear was analysed. It was concluded that the Swedish gear was not suitable for operations in areas with rough ground because of the danger of losing the entire equipment. It was also observed that the employed gear was only able to retrieve 27 per cent of the located netting, because most nets used by Swedish fishermen are not strong enough to be towed on uneven or rocky bottoms.

3.5.2 Baltic Sea retrieval programmes

In the Baltic Sea gear retrieval programmes have been carried out by Sweden and Poland. Building on the work of FANTARED 2, an experiment was conducted by the Swedish Institute of Marine Research in 2002 to evaluate the results of a four-year development project. The objective of the programme was to design and construct an efficient and cost-effective retrieval system for removal of lost or abandoned gillnets from costal fishing grounds (Tschernij and Larsson, unpublished). The expedition carried out in August 2004 was the fourth in succession following a similar expedition in June 2003. The primary aim was to evaluate the efficiency of new developed retrieval gear ('Large Scale Retrieval Systems', Figure 7) and to compare the efficiency of the new gear to the efficiency of that more usually used ie 'the traditional hook and line'. Both of these were different to the gear employed during FANTARED. A secondary objective was to establish an estimation of the momentary amount of lost nets.

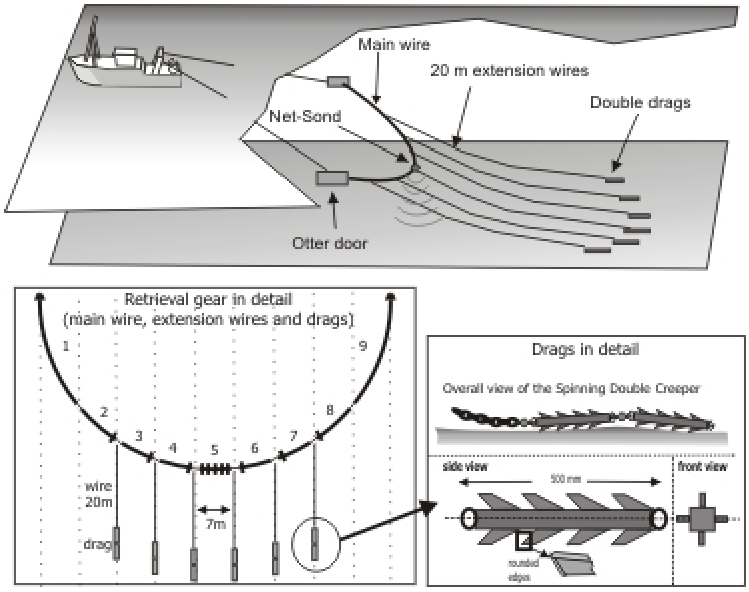

Figure 7 The rigging and construction of the LSR-system

Source: Tschernij et al, unpublished

In the 2004 expedition, three vessels were equipped with retrieval gear. One was a stern trawler made for pelagic trawling using the new Large Scale Retrieval System. The others were experienced gillnet vessels using hook and line equipment. The survey was conducted for nine days along the Swedish South coast. With the help from fishermen the areas of gear conflict could be identified and the operation area was mapped accordingly (Figure 8). The area was then divided into three sampling areas: (1) off-shore reefs operated only by gillnet vessels, (2) coastal waters with conflicts operated mostly by Swedish fleets and (3) 'coastal or off-shore' fishing grounds with conflicts operated by multi-national fishing fleets.

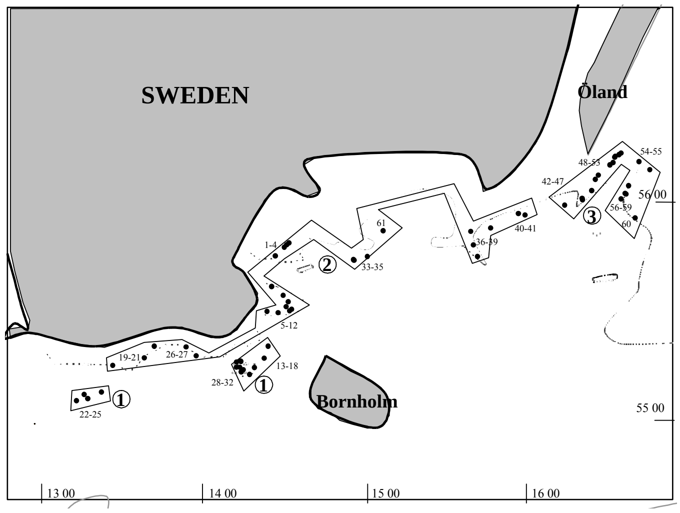

Figure 8 Area of operation for the Baltic Sea retrieval programme

Tschernij and Larsson, unpublished

The three vessels together removed 25 km of nettling from the sea. Of this amount the one vessel using the new retrieval equipment retrieved 50 per cent. The new gear had a relative net retrieval efficiency 2.4 times higher than the alternative gear (Table 14). The cost of retrieving one kilometre of lost netting using the new retrieval gear was approximately €600, which is €200 less than with the alternative gear.

Table 14 The overall results for the three participating vessels

Vessel	Metod	No of tracks	Tot. tow time (h)	Retrieved (km)	% zero retriev.	% fleets 0<x<1km	% fleets x>1km	No of cod caught	Efficiency m/h
Kungsö	Test	61	47.1	12.49	54	38	8	204	265.0
Trion	Ref-1	56	55.5	7.46	64	30	5	425	111.0
Mulan	Ref-2	66	57.1	5.03	82	15	3	83	
Total		183	159.7	25.0	123	50	10	712	156.4

Table 15 Estimated cod catch by area and vessel

	Catch kg per vessel				kg per km netting	
Area type	Kungsö	Mulan	Trion	Total kg	method-1	method-2
1	14	0	380	393	3.6	57.9
2	61	0	2	63	14.6	12.1
3	128	83	42	253	28.6	19.4
Total	203	83	423	709	16.3	28.4

The Sea Fisheries Institute in Poland carried out a net retrieval programme in 2004 (Anon, 2004b). The project was conducted for 10 days with an estimated cost of €15,000. The Sea Fisheries Institute considered the project to be of limited success because lost gear is not considered a major problem, as also suggested by the local industry (pers com *Zbigniew Karnicki,* Deputy Director, Sea Fisheries Institute, Poland). The retrieval gear used however was not well suited to the Baltic region. Being sourced from Norway, it was designed for deeper and rougher grounds, and therefore too heavy for the conditions and fishing gear being retrieved in the Baltic.

3.5.3 Norwegian gillnet retrieval

Permanent routine retrievals are only known to be operated by Norway. The Directorate of Fisheries has organised retrieval surveys annually since 1980. In the period 1983 – 2003, 9,689 gillnets of 30m standard length (approximately 290km) have been removed from Norwegian fishing grounds. In 2004 a lost gillnets retrieval survey was conducted with the aim of removing as much lost gear from fishing grounds as possible (reported in Kolle *et al* 2004). Hareide *et al* (2005) report that the key to success in this operation is accurate positional information to enable well-targeted retrieval effort. This is possible through a scheme that is supported by fishermen and operated with a broad consensus as to its value.

The 2004 survey used information gathered by the Directorate since 2000 through questionnaires regarding the position and amount of lost gear. Skippers of 210 gillnet vessels were contacted either directly in ports or by telephone and information on position and depth for 860 lost nets were collected. Of these nets, 699 were Greenland Halibut nets, 30 were nets targeting ling, 27 saithe, 90 cod and 12 redfish.

According to the amount of reported lost fishing nets the area of operation was chosen along the north coast of Norway (Figure 9).

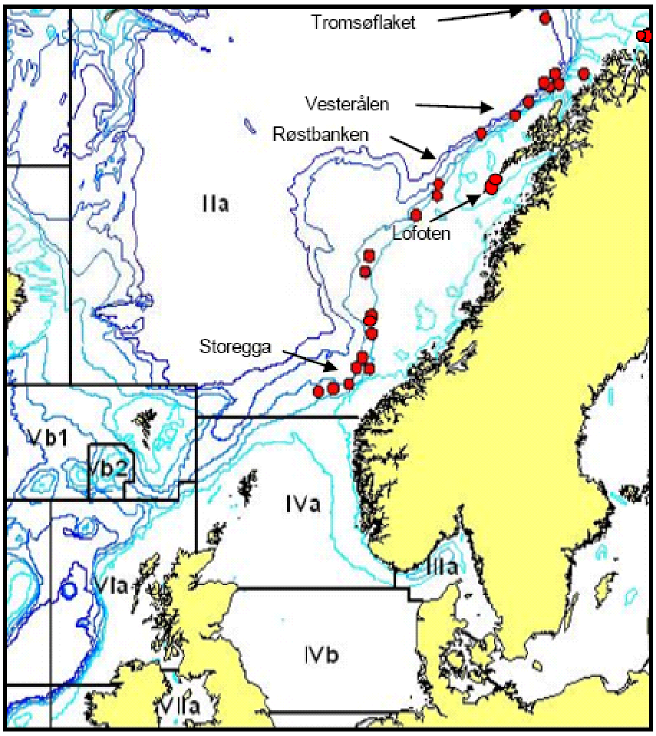

Figure 9 Positions of lost nets reported in 2004

Source: Kolle *et al* 2004

For the survey a trawler was equipped retrieval equipment ('creeper'), which is used as standard on these surveys, with lost nets being hauled onto a net drum of the survey vessel (Figure 10). The deck arrangements included a single trawl lane, two main trawl winches (12 tons), two sweeper winches, two Gilson winches, one net drum and a crane.

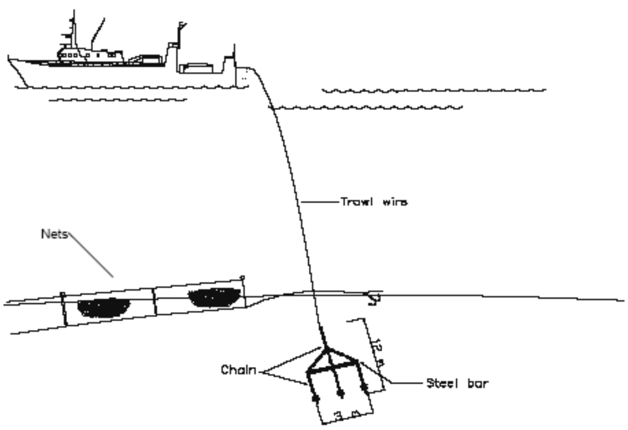

Figure 10 Retrieval gear used by the Norwegian Directorate of Fisheries.

Source: Anon, 2005b

In a total of 103 hauls, 589 nets were retrieved from depths between 500 and 800 meters. Of these 465 were Greenland halibut nets from depths between 500 and 800 meters together with quantities of longlines, dhan lines, anchors etc. Of the 8,935 kg of fish in the retrieved nets, 7320 kg was Greenland halibut, with 42 per cent of the halibut still alive. The fleets, varied between 30 and 50 nets, of 30 meters each. The normal length of fleets was 35 nets. The fish caught per fleet varied between 0 and 1,700kg. The mean catch per net was 15,17 kg per fleet. In the Greenland halibut nets the catch was highest (Table 16).

The total cost of the Norwegian gear retrieval survey is around €181,500 (NOK 1.5 million) (Table 17). While the boat is hired on a tender, so varying cost between years, boat hire and fuel account for two thirds of total costs.

Table 16 Total catch of fishing gear, fish and crabs during the Norwegian annual retrieval survey for lost gear in 2004

	N.Norw.	S. Norw.	Total
Number of hauls	61	42	103
Number of nets			
Greenland halibut nets (500-800 m)	272	193	465
Ling nets (150-400m)	1	59	60
Cod nets (100 -200 m)	44	0	44
Halibut nets (150 m)	0	5	5
Saithe nets (50-150 m)	15	0	15
Total number of retrieved nets	332	257	589
Catch (kg)			
Greenland halibut (*Reinhardtius hippoglossus*)	3840	3480	7320
Cod (*Gadus morhua*	20	0	20
Ling (*Molva molva*)	0	200	200
Tusk (*Brosme brosme*)	0	600	600
Redfish (*Sebastes marinus*)	30	50	80
Rough head grenadier (*Macrourus berglax*)	230	0	230
Skates (*Raja hyperborea & Raja radiate*)	0	200	200
Deep water crab (*Lithodes maja*)	285	0	285
Fish and crabs total	4405	4530	8935
Other fishing gear			
Dan lines (m)	4952	4200	9152
Longlines (m)	1200	0	1200
Dredges/ anchors (no)	6	4	10
Wire (m)	50	0	50

Table 17 Cost of the Norwegian gear retrieval survey

	Cost, NOK	**Cost, €**
Boat hire and fuel for one month	1.1 million	133,000
Collecting information (Fishermen's survey)	0.12 million	14,520
Survey labour cost, travel, report writing etc.	0.28 million	33,880
Total cost	**1.5 million**	**181,500**

The gillnets that are retrieved during the survey up are sent to a refuse disposal plant. The crew on the vessel recycle some of the gear, such as rope, floats and anchors, but this is not organized.

3.5.4 North east Atlantic

Norway, the UK (Seafish) and Ireland (BIM) are working together to develop a gear retrieval programme. Discussions are at an advanced stage, with a proposal currently with DG Fisheries and Maritime Affairs and the UK Department for Environment, Food and Rural Affairs (DEFRA) on establishing a pilot programme.

The planned survey builds upon the FANTARED and DEEPNET (Hareide *et al,* 2005) work, experiences of Norway (described above) and sporadic attempts at the retrieval of nets lost in Irish waters, which were reportedly largely ineffectual given the huge area, over which these fisheries are conducted (Anon, 2002, reported in FANTARED 2). The survey aims to retrieve as much lost nets as possible. It is planned to potentially extend the survey to a second area west of Scotland, which has been identified as an area with potentially large amounts of lost gear (reported in Anon, 2005b).

A survey on lost nets is planned for August/September 2005 on the Rockall bank and the adjacent slopes (North East Atlantic) in depths between 200 and 1,200 meters (Figure 11), funded and managed by the BIM and the Marine Institute in Ireland (Anon, 2005b). An Irish registered trawler suitable for the work will be contracted through BIM and the Marine Institute.

The study is based on Norwegian experiences with retrieval programmes and will employ the same methodology and equipment. It will consist of two phases: the first phase involves an intense period of information gathering, including interviews of gillnet skippers in order to obtain positional data on lost nets. Information will also be obtained from NEAFC, the Scottish Fisheries Protection Agency and the Irish Navy.

The second phase will be the survey itself: A commercial stern trawler with the appropriate deck layout, adequate winch power and capacity and a large wide net drum from hauling lost gear will be hired for the survey (Figure 10). An approximate breakdown of the costs of the study is given in Table 18.

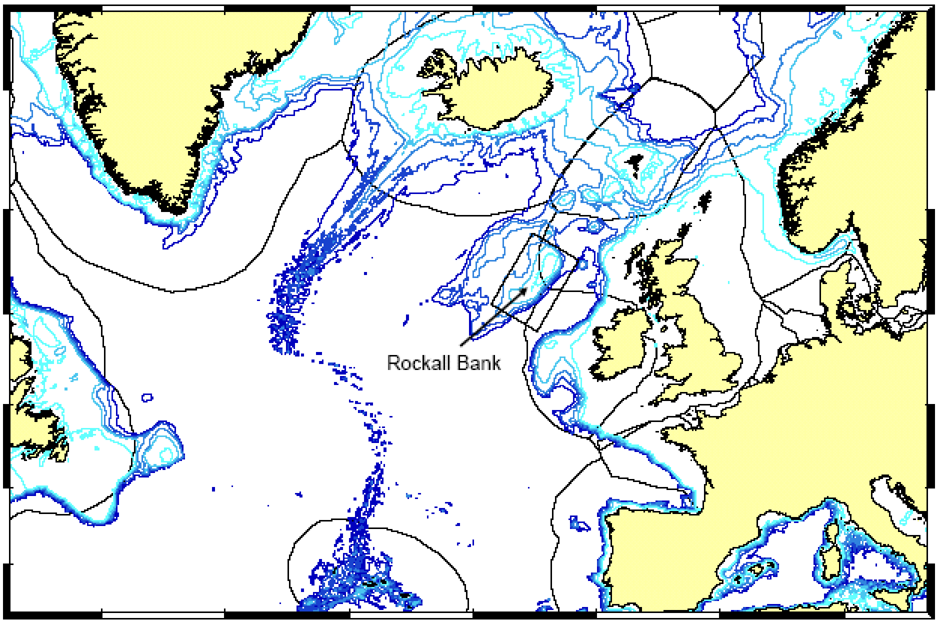

Figure 11 Proposed survey area

Source: Anon, 2005b

Table 18 Estimated costs for deep water pilot retrieval survey

Budget Item	Total Cost in €
Boat hire 20 days at €5,000 day	€100,000
Fishermen's Survey (consultant time costs)	€15,000
Retrieval Gear	€15,000
Total	**€130,000**

Source: Anon, 2005b

3.6 Retrieval programmes outside Europe

Outside of European waters, several countries operate ad hoc gear retrieval programmes in response to well publicised or exceptional events taking place. One of the best known of the ad hoc exercises takes place in Hawaii and is well described in Donohue *et al* (2001). There a gyre in the Pacific tends to direct marine debris towards the north-western Hawaiian Islands. Some of this is 10-20 years old and much is trawl and seine netting. Retrieval programmes have also been employed in Canada and Greenland. A pot retrieval programme has been trailed off the coast of Alaska with mixed success.

Canada

Fisheries retrieval programmes in Canada date back to at least 1976 when the Department of Environment in Newfoundland carried out a project to locate and recover lost gillnets.

The purpose of the project was to retrieve as many nets as possible but also determine the effectiveness of the designed gear and to ascertain to what degree, if any, the ghost nets were fishing and what effects they were having on groundfish stocks. During a preliminary phase of the project as much information about lost gillnets was gathered from local fishermen as possible. According to this information the operation area was selected (Trinity Bay and Cape Bonavista). A vessel was chartered for 20 days and equipped with 'creeping gear', 'drag gear' and 'retrieval gear'. In total, 148 nets were retrieved Newfoundland (at a depth of 256-351 meters) resulting from 67 hours of towing. They contained 3053 kg of groundfish and 1463 kg of crab. The average amount of groundfish taken by one 'ghost net' was approximately 20 kg, the average amount of crab was 10 kg. On the average, 86 per cent of all species taken were alive, 11 per cent were dead and 3 per cent decayed. However, 98.7 per cent of all crabs taken were still alive.

In the same year in Notre Dame Bay (approximately 347 meters deep), 167 nets were recovered in 54 tows. However, more recently (1990), attempts to survey lost nets on the Grand Banks (up to 179 meters) did not detect any gear. Fifteen hours were spent in trying to retrieve gear, using the same equipment used in 1976. No gear was recovered.

A later report from 1995 (Bech, 1995a) is largely technical in content, reporting on methodology and results. There is no discussion of costs or benefits. It was noted that there was a recovery rate of 12 per cent (12 nets), which was similar to a 1984 programme rate of 15 per cent. Of those recovered, none were 100 per cent effective at fishing, 33 per cent were fishing at a 75 per cent effectiveness, 58 per cent at 25 per cent and 8 per cent were totally ineffective. It was concluded that in this fishery the effect of ghost fishing is not as high as believed but that lost nets do cause problems for long-liners.

A second report in 1995, a study on 'Prevention of Ghost Fishing in Atlantic Canada', (Bech, 1995b) undertaken by the Fisheries and Marine Institute of Memorial University for the Department estimated the cost of lost gear retrieval as follows:

- design and testing of practical retrieval equipment $305,000 (€198,250)
- ghost gillnet retrieval (Atlantic-wide program) $800,000/year (€520,000/year)
  (Limited focus to selected areas only)

The prevention of lost gillnets was considered much more cost effective. Unlike retrieval programs, which have recurring yearly costs, prevention has a one-time, upfront cost. Specific prevention measures were identified as:

- limiting the amount of gear to that which can be handled properly by a particular size vessel and crew;
- the implementation of de-activating technologies and biodegradable materials;
- marking of gear and return incentive programs; and
- the implementation of acoustic detection systems to assist in the initial and subsequent retrieval of gears during normal operation or in the event of gear loss.
- Another option is to prohibit the use of gillnets. Although many would argue that this might be seen as a step forward for conservation, the same could also be said for many other gear types.

A 1998 Standing Committee on Fisheries and Oceans report to the Canadian Fisheries and Oceans Department noted that projects designed to retrieve gillnets using special equipment had been undertaken, with mixed success (Standing Committee on Fisheries and Oceans, 1998). At the time the Department of Fisheries and Oceans Canada was reviewing these options (DFO, 1998).

USA

In Washington State (USA) the Northwest Straits Commission (NWSC) in conjunction with the Washington Department of Fish and Wildlife (WDFW) started a program to identify and remove derelict fishing gear in 2001. The Commission has identified four fundamental steps for a successful recovery program:

- locating gear;
- verifying and setting priorities for removal;
- removing gear; and
- reusing, recycling and disposing of gear.

In 2005, NWSC and WDFW organized a gear retrieval project, which was funded by the National Oceanic and Atmospheric Administration (NOAA) to remove derelict fishing gear in Burrows Bay, Washington (NRC, 2005).

The operation was conducted for eight days. The project used divers to retrieve the nets, which had previously been identified during dive surveys conducted by WDFW. A total of 50 gillnets were retrieved. Of the 50 gillnets removed, 32 (64 per cent) were characterised as newer nets and 18 (36 per cent) was considered older nets. However, all but five of the gillnets removed were believed to present some level of lethal threat to marine life due to their generally good condition and/or the presence of suspensions off the seabed.

In 2002, the Washington Department of Fish and Wildlife developed guidelines for the removal of derelict fishing gear. These guidelines address the different types of derelict fishing gear commonly found in the Washington's marine environment, the circumstances under which removal should be attempted, the qualifications of the removal team, common methods that may be employed to locate and remove derelict gear, procedures for determining that the project can be conducted in accordance with the guidelines, disposal or recycling options, and the removal and disposal documentation and reporting process (WDFW, 2002).

Greenland

In June 1995, a gillnet retrieval project was set up in the area outside Ilulkssat, between Nuuaarsuk and Kingitoq in Greenland to clean the traditional Greenland halibut fishing grounds of lost nets (Bech, 1995). The survey consulted local fishermen about the areas with a high number of lost gillnets.

Dredging was conducted from 30-foot fishing vessels and a small shrimp trawler. A special type of grapnel consisting of a steel pipe with barbs welded on with 90º space was used for the dredging.

Within 7 days a total amount of 101 dredges retrieved 12 gillnets and 80 longlines. The nets were retrieved from depths between 200 to 350 meter, surfacing a total catch of 375 kg fresh Greenland halibut. However, the project concluded that the retrieval gear used was ineffective due to the fact that the barbs often broke or bended and retrieved fishing gear was lost easily during the hauling process.

South Korea

In South Korean waters there is an international fishery for Alaska Pollock, which straddles the country's 200 mile zone. Reports of high levels of net loss prompted the government to fund a retrieval programme, which has run since 1998. An (2001) (in FANTARED 2) described the retrieval of over 10 tonnes wet weight per nautical mile towed in several of these exercises although these extraordinary amounts have not been explained comprehensively (FANTARED 2).

Australia

On 30 November 2004 the Australian Government Minister for the Environment and Heritage, Senator Ian Campbell announced that the Gulf of Carpentaria will be cleared of derelict fishing nets and other debris under a $2 million Australian Government programme to save threatened marine and coastal animals from entanglement[6]. At present this largely entails a beach clean ups although gear retrieval may be considered as part of the programme

Alaska pot retrieval

Stevens *et al* (2000) used a pot retrieval system based on sonar identification as part of a study into the extent of ghost potting. Sonar was considered a very effective tool for locating pots and allowed targeted retrieval using trawls. However, random trawling for pots was more efficient in retrieving pots in some cases. There was no feasibility study or evaluation of the methodology as an ongoing management tool as it appeared to be used only for the purposes of the research programme.

3.7 Key lessons from retrieval programmes

Drawing on the research from FANTARED, the literature and experiences reviewed above and the review of gear retrieval by Smith (2001), a number of lessons can be summarised.

The type of gear suited for gear recovery varies with environmental conditions, with a range of gear types illustrated in Appendix E. The typical recovery method consists of dragging a creeper designed to snag the gear along the sea bottom until the gear is found. With light gear, such as traps and lines, the effect of tide and/or wind on the vessel is sufficient to generate a dragging motion. Where there is little or no wind or tide, the vessel must use power to drag the creeper slowly along the sea bottom. Too much tension on the creeper wire should be

[6] see http://www.deh.gov.au/minister/env/2004/mr30nov04.html

avoided as the lost line or trap attachments could break. In this respect, when there are very strong tides, the vessel must tow the creeper slowly against the current.

With heavy gear, the creeper operation can be much more active. The vessel's power can be used to a greater extent and a far higher tension can be kept on the creeper wire. In such cases a weight must be connected to the wire some distance ahead of the creeper to ensure that good ground contact is made and that the creeper moves horizontally. Monitoring the tension in the wire carries out the creeping operation. Successful contact with the gear is indicated by an increased tension.

Another method of retrieving fishing gear or any other item lost on the seabed is to use a different type of fishing gear (generally trawls). Although this may not be as effective as creepers, the cost of lost fishing is, to a certain extent, avoided. However, the vessel must fish in the same area as that in which the gear was lost. Attachment of the creeper to the toes of the net increases the chances of snagging lost gear.

A simple fishing ground clean up method on relatively clean ground is to sweep the area with a trawl net. Even if recovery is not complete, the damage done to set nets and/or traps would be sufficient to ensure that ghost fishing does not continue. This system should not be used on or close to reefs or in very shallow water. In the latter case it could cause danger to the vessel and its crew.

Knowing the exact location of lost gear greatly enhances chances of recovery. Close to shore this can be achieved by using landmarks; artisanal fishers are skilled in this method. The fall in the cost of GPS systems also means that in most cases the position can be known and recorded in offshore waters.

It should be stressed that the research into gear retrieval and lessons from programmes employed routinely is that there are several drawbacks with curative measures that mean they should not be relied upon to resolve the problem of gear loss:

- only small areas of fishing ground can be covered in retrieval campaigns so very precise information on the location of lost gears is essential – requiring, in turn, accurate reporting of gear losses by fishermen;
- they do not prevent fishermen from suffering economic losses through lost gear, lost fishing time and lost catch;
- retrieval gears have a limited recovery efficiency;
- lost gears remain at sea for a period of time between loss and retrieval often resulting in some catch of commercial species; and
- the retrieval of gears is costly.

Source: FANTARED 2

4 Environmental Impact of Lost Gear

This section examines the impact of lost gear on the marine environment. It provides a review of research conducted to date, including an assessment of how the catch characteristics of gear changes over time after it is abandoned and the implications for the capture of target and non-target species. The section also includes a brief comparison of the environmental impacts of lost gear in relation to 'active' passive and mobile gears in order to set these impacts in context. The section is then completed with a brief analysis of the economic consequences of gear loss to maritime users, including the fishing industry.

4.1 Review of the known environmental impacts of lost gears

Lost fishing gear (eg where the fisherman lacks control over the type and duration of fishing) may impact on the environment in a number of different ways.

- continued catching of target species;
- capture of non-target fish and shellfish;
- entanglement of sea turtles, marine mammals and sea birds in lost nets and debris;
- ingestion of gear-related litter by marine fauna;
- physical impact of gears on the benthic environment and the; and
- the ultimate fate of lost gear in the marine environment.

4.1.1 Continued catching of target species

Previous literature describing the continued catch of target species is covered in section 2.

4.1.2 Capture of non-target fish and shellfish

As control over fishing gear is lost, so too is the selectivity of the gear for the original target species. This loss in specificity may result from (i) alteration in the mesh size as the net is distorted, (ii) changes in gear transparency and detectability, (iii) translocation of the gear to different environs and (iv) accumulated catches may act as bait for other species that get entangled or entrapped in the gear. As a result, the gear may start catching other fish and shellfish species that may or may not have a commercial value.

Work conducted in Wales with gill and trammel nets (Kaiser *et al*, 1996) with a mesh size of 100 mm showed how fish catches declined over the first month of immersion. The headline of both gears collapsed soon after deployment, from a mean height of 1.71 m to 0.31 m for the gillnet and 1.23 to 0.08 m for the trammel net. Fish catches (mainly dogfish *Scyliorhinus* spp) were replaced by those of scavenging crustaceans, mainly the spider crab *Maja squinado* in both gears. The levels of crustacean catch peaked after some 30-50 days after deployment, coinciding with the lowest height of the nets. The gradual cessation of fishing was attributed to a reduction in net size and degree of entanglement as the net rolled up.

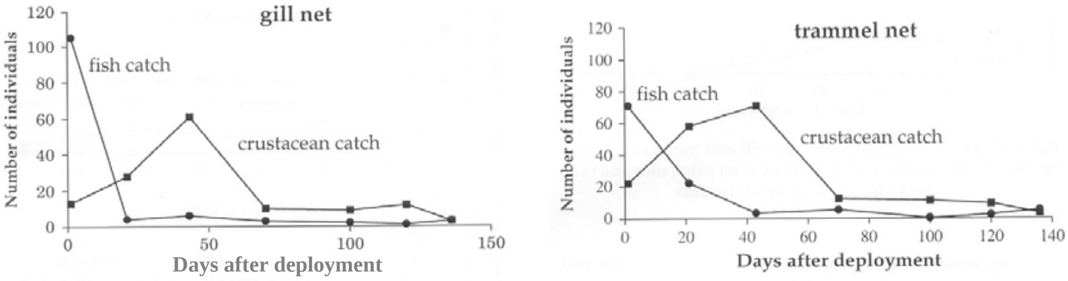

Figure 12 Change in catch composition of 'lost' gill and trammel nets
Source: Kaiser *et al*, 1996

In an earlier study, Carr *et al* (1992) assessed the impact of simulated ghost gillnets on inshore fish populations, and looked at modifications to nets which might solve the derelict net problem using a control and three experimental gillnets set in southern New England inshore waters. They were observed by divers using still and video cameras over a two year period. Findings indicated that nets remaining on the bottom continue to fish even when the vertical profile has been reduced. However, like Kaiser *et al* (1996), the species makeup of the catch changes with a reduction in net height, resulting in increased capture of crustaceans.

As reported in section 2.2.3, Erzini *et al*. (1997) carried out an experimental study of gillnet and trammel net ghost fishing in shallow (15–18 m) rocky bottoms in the Atlantic waters off the coast of the Algarve in southern Portugal. The results of the study indicated that abandoned gillnets yielded more catches than trammel nets as measured by the mean number of fish caught by 100 m-length pieces of nets after 120 days of deployment on the bottom (gillnets: 344 fish specimens entangled; trammel nets: 221 fishes entrapped). Whilst catches decreased gradually over time, nets continued to catch fish four months after the experiments had started. *Osteichthyes* were the most numerous group among the 39 species recorded, accounting for 89 per cent of the total specimens in number. The other groups included molluscs, gastropods and crustaceans. *Sparidae* species, however, made up about 33 per cent of total catches in numbers. There is evidence suggesting that nets lost in deep water may have an even longer effective fishing life span, running to years. The results of the study mentioned above also implicated ghost fishing in disturbing demersal food-webs in a similar way to that reported for trawl discards. The authors described considerable scavenging pressure on entrapped fish by octopuses, cuttlefish, conger eels, moray eels and wrasses (*Coris julis*), which could have led to an underestimate for the actual fishing capacity of discarded nets.

The continued fishing by lost pots was evaluated experimentally by Bullimore *et al* (2001). A fleet of 12 pots were set in a manner to simulate ghost fishing, again off the coast of Wales, UK. The original bait was consumed within 28 days of deployment yet the pots continued to fish, mainly for spider crab (*M. squinado*) and brown crab (*Cancer pagurus*), with a catch that declined against time reaching a minimum around 4-9 months after the experiment began, although they rose again later, possibly linked to rising water temperatures. The actual mortality of crustaceans was difficult to estimate as some were able to escape and the pots were not under continual observation (dive surveys were conducted at 1, 4, 12, 27, 40, 69, 88, 101, 125, 270, 333, 369 and 398 days after initial immersion). Non-target species such as the Ballan wrasse (*Labrus bergylta*) were also observed in the trap, especially towards the end of the experiment, when crustacean levels were lower.

The papers reviewed above are the sum of known publications describing the experimental assessment of *in situ* ghost fishing. As such, they can only be used to present a broad picture as to patterns and trends in non-target catch in lost gear, which are likely to vary considerably, depending upon gear configuration and local conditions.

4.1.3 Entanglement in and ingestion of lost nets and debris

Lost gear, especially that of persistent synthetic material, can impact marine fauna in two main ways (Shomura and Yoshida, 1985 and in Laist, 1997):

- entanglement, whereby the loops and opening of debris entangle or entrap animals and their habitats; and
- ingestion, whereby debris is intentionally or accidentally ingested.

Incidence

The most comprehensive review of the impacts of marine debris globally, including lost gear has been undertaken by Laist (1997). Entanglement was considered by far the most likely cause of mortality than ingestion. Fishing gear (monofilament line, nets, and ropes) was found to be the most significant source of entanglements in all documented records for sea turtles, coastal and marine birds, marine mammals and fish and crabs. The greatest source of this material was considered to be commercial fishing operations, although recreational fishing and cargo vessels ships were also considered potential sources.

Effects

The effects of entanglement are largely mechanical. They result in exhausting and eventual drowning; impair mobility, feeding and reproduction. The affected animal may become snagged on underwater or land-based features such as rocks or trees or else, resulting in trauma. All of these impacts may be modified by behaviour, such as diving depth and time spent at sea.

Impacts

It has been estimated that over one million birds and 100,000 marine mammals and sea turtles die each year from entanglement in, or ingestion of, plastics (Laist, 1997). Furthermore, at least 135 species of marine vertebrates and 8 species of marine invertebrate have been reported entangled in marine litter (Laist, 1997). However, the species-level impacts of entanglement in marine debris are unclear. For most seabirds (particularly procellariiform seabirds, penguins, grebes and loon, toothed whales and fish), evidence is lacking or based on isolated or infrequent reports. In this case, entanglement is unlikely to have an effect at a population level. Species such as Gray whales, California sea lions, northern elephant seals, northern gannets, herring gulls and shags have large or increasing populations where entanglement may be a chronic low-level source of mortality but having little effect on population numbers. However in the case of endangered or threatened species such as some sea turtles, even low-level entanglement may affect populations directly and so be an obstacle to population recovery.

Ingestion of litter by animals usually occurs when litter items are mistaken for food, or by secondary ingestion with prey items. In certain seabirds, ingested items can be passed from parent to chick by regurgitation (Fry *et al*, 1987). The occurrence of litter ingestion can reach 100 per cent in some seabird species. Day, (1985) reported that at least 50 species of seabirds were known to ingest plastic debris, though this figure is now known to be closer to 111 species (Laist, 1997). Those seabirds which are most susceptible to ingesting plastic particles are surface-feeders (albatrosses, shearwaters, petrels, gulls) or plankton-feeding divers (auklets, puffins) (Day, 1985). A study carried out by Robards *et al* (1995), of seabirds collected over the period 1988-1990 reports that plastic ingestion by seabirds has significantly increased since a similar study by Day (1980) of data collected in 1968. The offending litter items are almost invariably plastics, which are ubiquitous in the marine environment deriving from many sources (Robards *et al*, 1995). These items can result in physical damage, mechanical blockage and impairment of foraging ability (Laist, 1987). Plastic debris can gradually accumulate in the guts of some animals. Some species may be able to regurgitate or excrete debris, but plastics do not appear to pass through the intestines of sea birds as there is a marked absence of debris from droppings.

Much of the data in Laist's review and subsequent work relates to species outside the EU. While this is useful for drawing lessons, species of direct relevance to the EU for which evidence is available appears largely confined to northern gannets and herring gulls. Perhaps most significant however is that relating to sea turtles, which are considered to be particularly vulnerable to the effects of entanglement and are afforded protection under the habitats Directive.

Notable cases of reported impacts of lost gear on non-commercial species include the following:

EU cases

- A gillnet set experimentally in inshore waters of the UK by Kaiser *et al* (1996) caught three shags when brought into the shore by wave action. While this may be unrepresentative of normal fishing operations which are in deeper waters, this is thought to be a potential problem when nets are washed ashore and may vary seasonally according to breeding habitats of birds such as auks (Teixeira 1986);

- It is reported that 90 per cent of the 30,000 gannet nests on Grassholm Island (in the UK's Bristol Channel) now contain plastic (MCS, 1999). This indicates the extent of plastic pollution in surrounding waters as gannets collect almost all their nest material at sea. Young gannets' feet can often become entangled, resulting in serious injuries.

- Entanglement in static fishing gear and abandoned nets are thought to cause a serious impact on monk seal (*Monachus monachus*) in the Mediterranean, as reviewed by Johnson and Karamanlidis (2000). This is a population suffering rapid decline despite being listed as a critically endangered species[7] and fishing related mortality considered as unacceptable. Prior to the establishment of a protected area, the extensive use of gillnets constituted a major threat to the survival of the small surviving monk seal colony in the Desertas Islands of Madeira. It was reported in 1998 that animals had been dying frequently by entanglement in lost nets (Anselin and van der Elst (1988), in Johnson and Karamanlidis (2000)). It was subsequently reported that a major clean-up operation, coupled with an initiative to have fishers convert from net gear to long lines effectively solved the problem (Neves (1991), in Johnson and Karamanlidis (2000)). It is not currently known what the situation is now in this and other areas.

[7] Monk Seal are listed as Critically Endangered on the IUCN Red List and as an Appendix I species under CITES. It is also listed as an Appendix II species under the Bern Convention, as an Appendix I and Appendix II species under the Bonn Convention, and as an Annex II and Annex IV species under the EU habitats Directive.

Non-EU cases

- In 1978, 99 seabirds of five species, two salmon sharks, one ragfish and over two hundred chum and silver salmon were found in a 1.5km long lost salmon driftnet in the western North Pacific (DeGange and Newby 1980);
- Off Newfoundland, it was estimated that over 100,000 marine birds and mammals were killed in a four year period by ghost fishing (JNCC, 2004);
- The incidence of entanglement of marine mammals in floating synthetic debris in the Bering Sea has been related to the growth in fishing effort and the use of plastic materials for trawl netting and packing bands. In the north east Pacific, it was estimated that 15 per cent of the mortality of young fur seals (*Callorhinus ursinus*) could be attributed to net debris, with the average seal expecting to encounter 3 to 25 pieces of net debris annually (Fowler, 1987 in Goñi, 1999).
- In Australia, Australian sea lions are most frequently entangled in monofilament gillnet that most likely originates from the shark fishery, which operates in the region where sea lions forage. In New Zealand fur seals are most commonly entangled in loops of packing tape and trawl net fragments suspected to be from regional rock lobster and trawl fisheries (Page, 2004).

4.1.4 Physical impact of gears on the benthic environment

Gillnets have little impact on the benthic fauna and the bottom substrate (Huse *et al*, 2002). The bottom line of gillnets are produced of lead ropes of various dimensions. Cod net lead ropes, for example, often have a diameter of 12 mm and a weight of 250g/m. The pressure on the bottom sediments is therefore very low. Gillnets may be dragged along the bottom by strong currents and wind during retrieval, potentially harming fragile organisms like sponges and corals. In many areas where gillnets are used, the water is deep or the current is periodically strong, necessitating the use of heavy anchors (>100kg) which may cause localised impact.

In general, passively-fished *traps* are advocated on an environmental basis for having a lesser impact on habitat than mobile fishing gear such as trawls and dredges (Rogers *et al*., 1998; Hamilton, 2000; Barnette, 2001) as well as being a less energy intensive fishing method (Brown and Tyedmers 2005). The potential physical impacts of ghost traps depend upon the type of habitat and the occurrence of these habitats relative to the distribution of traps (Guillory 2001). In general, sand- and mud-bottom habitats are less affected by crab and lobster traps than sensitive bottom habitats such as submergent aquatic vegetation (SAV) beds or non-vegetated live bottom (stony corals, gorgonians, sponges) (Barnette, 2001). Research on pot fishing in UK waters also suggested that pot fishing does not have immediate detrimental environmental impacts (Eno *et al,* 2001)

Observations of the physical impacts of ghost blue crab traps in the Gulf of Mexico suggest that crab and lobster traps have a low impact on SAV habitat (Barnette, 2001). Stephan *et al*. (2000) concluded that although each individual trap has a relatively small footprint, Atlantic Coast SAV habitat could be impacted because of the large number of crab traps.

The impact of derelict traps on sensitive habitats differs from that of actively-fished traps. The effects of trap deployment and recovery would be less in derelict traps than in actively-fished traps while the opposite would be true for the effects of smothering. Jennings and Kaiser (1998) suggested that the frequency and intensity of physical contact are important variables when evaluating the effects of fishing gear on the biota. Derelict traps, while individually occupying a small area, may impact SAV because of their large number and potential smothering effect (Guillory 2001).

Accumulation of litter in offshore sinks may lead to the smothering of benthic communities on soft and hard seabed substrates (Parker, 1990). Once on the seabed, accumulations may smother sea life, or inhibit water movement to the extent that they contribute to the creation of anoxic mud (Rundgren, 1992). When in general circulation in the sea, or resident in temporary sinks, these litter items may also smother plants and animals on the sea shore, provide solid attachment for species that would not usually occur there, in addition to providing nuclei for sand dune formation.

Lost gears, especially large nets, can impact benthic environments through smothering, abrasion, 'plucking' of organisms, meshes closing around them, and the translocation of seabed features. For instance, fishermen complain that lost nets in Algarve are at such a level that they interfere with normal fishing practices, possibly leading to further gear loss, and that reefs are smothered to the extent that reef fish may have reduced access (Erzini *et al.,* 1997). However Erzini's studies also suggest that nets may eventually became incorporated into the reefs and provided a complex habitat through firming a base for colonising animals and plants. This was also supported by anecdotal information from gillnet fishermen in southwest England surveyed as part of this project. Carr and Milliken (1998) noted that in the Gulf of Maine, cod reacted to lost gillnets as if they were part of the seafloor. Thus, other than damage to coral reefs, effects on habitat by gillnets are thought to be minimal (ICES 1991, 1995, Stephan *et al*., 2000).

4.1.5 Fate of gear in the marine environment

Once lost fishing gear have ceased to fish as they degrade and break up, they may still pose a threat through (i) its accumulation on the strand line and its contribution to beach litter and (ii) the eventual fate of the constituent materials in the marine environment.

Contribution of lost fishing gear to marine litter

Lost gear has a negative aesthetic impact as a source of litter at sea and on beaches, and can potentially entangle with active fishing gear and vessel propulsion systems. The significance of the aesthetic impact of fishing gear as a source of litter will vary by region. The aesthetic impacts will be particularly important in areas where tourism is significant, such as the Mediterranean.

A study into the economic and social impacts of marine debris in the northeast Atlantic (Hall 2001) identified lost ropes and nets as a problem both on beaches and to the fishing industry. Golik (1997) reviewed the types, quantities and behaviour of debris in the Mediterranean Sea. There appears to be very little research into the incidence and impact of marine litter, including that originating from fishing, in the Mediterranean (Golik, 1997). Bingel (1989, in Golik, 1997) attempted to estimate the quantity of fishing gear lost in the Mediterranean Sea, based on an extrapolation of data from the Turkish industry losses based on vessel numbers, coastline length and shelf area (Table 19).

Table 19 Estimations of fishing gear loss in the Mediterranean Sea

Basis of Extrapolation	Gear Loss t/year
Vessel Numbers	3,342
Coastline Length	2,803
Shelf Area	2,637

Source: Bingel, (1989) in (Golik, 1997)

Evidence from a five country UNEP survey suggested that fishing gear was generally relatively rare along the beaches of the Mediterranean (UNEP/IOC/FAO 1991, in Golik, 1997).

In the UK, fishing debris such as line, nets, buoys and floats is the second biggest source of beach litter at 14.1 per cent (Figure 13) (MCS, 2005). During the 2004 Beach Litter Survey for the UK, 266.8 items of fishing debris were found per kilometre of beach surveyed. It would appear that fishing as a source of litter is on the increase, been the highest recorded in 2003 (Marine Conservation Society, 2004). The proportion of litter originating from fishing gear is also over twice that reported in nationwide beach clean ups in the USA, where fishing or boating gear comprised 6.1 per cent of the total litter items collected by number in 1988 (O'Hara, 1990). Included were 1,281 metal crab or fish traps.

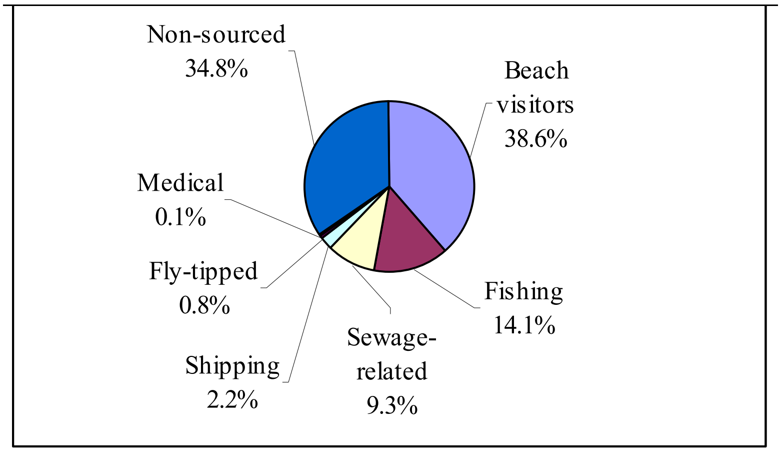

Figure 13 Sources of beach litter

Source: MCS Beach Watch 2004 results (MCS, 2005)

The longer-term fate of lost fishing gear is as yet unknown. Modern plastics will last up to 600 years in the marine environment (see Table 20), depending upon water conditions, ultraviolet light penetration and the level of physical abrasion. Furthermore, the impact of microscopic plastic fragments and fibres, the result of the degradation of larger items, is not known. A recent paper by Thompson *et al* (2004) examined the abundance of microplastics in beaches, estuarine and sub-tidal sediments and found to be particularly abundant in sub-tidal sediments (see Figure 14a). In a related experiment, the same authors examined the levels of plastic archived in plankton collected though Continuous Plankton Recorder (CPR) regularly since the 1960's and found a significant increase in abundance over time (see Figure 14b). Small quantities of microscopic plastics were also added to aquaria containing amphipods (detritivores), lugworms (deposit feeders) and barnacles (filter feeders). This indicates the possibility of plastics being incorporated into the food chain. However there is no information at present on the likely impacts, such as the ability of these plastics to adsorb, release or transport chemicals, nor their toxic effects.

Table 20 Degradation rates of different materials in the marine environment

Material	Degradation Rate (years)
Cotton rope	1
Untreated plywood	1-3
Plastic bag	10-20
Commercial netting	30-40
Foamed plastic buoy	80
Aluminium can	80-200
Plastic bottle	450
Monofilament fishing line	600
Glass bottle	1 million

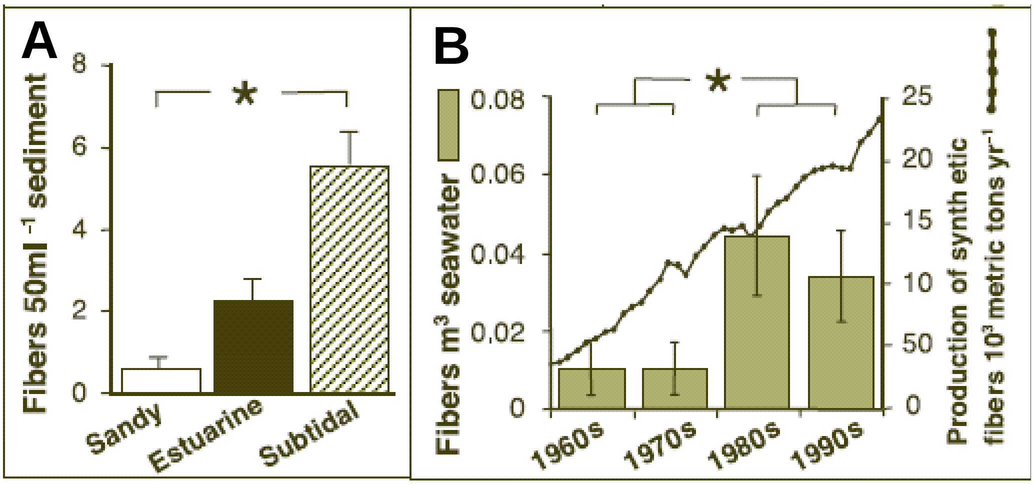

Figure 14 Presence of plastic microfibres in sediments (A) and CPR samples

Source: Thompson *et al*, 2004

4.2 Comparison with mobile gears

A comparison is made below between the environmental impact of static gears (both when under control and after control has been lost eg when they are ghost fishing) and mobile gears such as bottom trawls and dredges. The objective of this comparison is to set the impact of ghost fishing in context.

The main impacts of each gear class are summarised in Table 21. This comparison has been prepared at a broad level but is relevant none the less.

Table 21 Comparison of the environmental impacts of mobile and active gears

Area	Mobile gears	Static gears	
		Controlled (eg set and retrieved regularly)	***Uncontrolled (eg ghost fishing)***
Target species	• Essentially non-selective unless targeted at mono-specific shoals in pelagic trawls	• Usually highly selective	• Selectivity for target species reduces over time as nets are distorted and tangled.
Non-target species	• High levels of bycatch, especially in bottom trawls and dredges	• Some incidental catch that can be minimised through optimum rigging options and soak times.	• Can attract a wide range of scavengers that can become entrapped, die and therefore induce further scavenging.
'Icon' species eg sea turtles, marine mammals and sea birds	• Turtles caught in shrimp trawls, mammals in pair trawls	• Interactions with icon species in active fishing gear are rare but can occur eg by-catch of porpoises in the Danish gillnet fishery in the eastern North Sea.	• Interactions increase with potential for entanglement in net fragments (seals), as they are washed up in shallow waters (esp. birds)
Habitat and benthic biodiversity	• Widespread, significant and penetrative damage from dredges. Beam and otter trawls also impact benthos, reducing complexity and biodiversity over wide areas.	• Limited and localised damage from footropes and anchors. Benthic impact from traps also very limited, although may be significant on a local level when extensive fleets are deployed.	• With most gears being light, impacts are restricted to smothering of rocky reefs and wrecks. Gear on cleaner ground tend to roll-up and eventually become integrated into the substrate.

In summary, mobile gears have much higher impacts in terms of non-target species catch and discards, as well as habitat and biodiversity damage (see Box 1). These impacts are widespread. Actively fishing static gears tend to be very selective and have negligible habitat impacts, although they may occasionally incur incidental catch of marine mammals in certain situations. Once control of these nets is lost, the potential for habitat damage is more likely, but still not considered profound nor extensive. There is also increased potential for entanglement of marine mammals and sea birds as net fragments are washed inshore.

Box 1 Impact of towed versus static gears on benthic communities

An evaluation of areas under the Inshore Potting Agreement (IPA), implemented in 1978 to restrict the use of towed gears in inshore areas, found that areas restricted to static gears only had significantly greater total species richness and biomass of benthic communities than those subjected to towed gear usage (Blyth *et al*, 2004). The authors also postulated a greater than 2 year benthic community recovery period and advocated the use of zoned fishery management to allow some sectors of the fishing industry to retain access to fishery resources while protecting benthic species and habitats. Such zoning would also reduce the level of gear conflict that might lead to gear loss in the first instance.

4.3 Costs as a source of marine litter

Lost gear can incur a number of costs as a source of marine litter, both to the fishing industry itself and to other users of the marine environment.

Marine litter results in lost revenue for fisheries, due to the time and effort involved in sorting debris from the catch, while larger items may actually tear fishing gear. Attempts have been made to quantify these costs, although no attempt has been made to assign costs by litter sources. Costs associated with the time spent to clear and repair nets and from lost catch due to contamination can reach up to $2,900 per incident, and amounted to between €8,750 and €44,000 annually based on one incident per year and a 40-hour working week (Hall, 2001). Fouled propellers and pierced hulls can also endanger human life, if the vessel cannot return to port, or cannot steer to avoid collision (Global Marine Litter Information Gateway, 2004). Some estimates put the cost of marine litter for the UK fishing industry at over €33 million a year (Environment Agency, 2002).

An ENCAMS survey of beach users found that a clean beach was the biggest factor influencing a visit to the beach. While fishing debris such as line, nets, buoys and floats is the second biggest source of beach litter in the UK at 14.1 per cent (MCS, 2005), broken glass and sanitary items are the biggest cause of offence to beach users (ENCAMS, 2003). Nonetheless, lost gear will contribute to the need to clean up beaches and ports. In England and Wales local authorities, industry and coastal communities spend approximately €20 million a year to clean up coastal marine litter (Environment Agency, 2004). Harbour authorities also have to pay for the costs of keeping navigational channels clear of litter, with UK harbour authorities spending up to €38,000 per year in some ports, to clear fouled propellers and remove debris from the water (Hall, 2001). Unfortunately there are no figures on the sources of this litter by group.

5 Research gaps

This study was required to focus on net fisheries in particular, but it should be noted that the research gaps identified below also generally apply to pot fisheries and other non-net métiers as reliable estimates for total pot loss in EU fisheries are lacking. As a result, total ghost fishing mortality estimates are also lacking with available information largely confined to the UK and Portugal. Data on ghost fishing mortality and gear loss for bottom trawl, demersal longline, jigging and fish weir gears is minimal (ICES 2000).

5.1 Research gaps identified in literature review

As with fisheries science in general, uncertainty is a major factor in the reliability of the research into ghost fishing, and is likely to remain so. With this in mind, specific research gaps into the net loss in EU fisheries largely fall under the following headings.

5.1.1 Total gear loss

Estimates for total net loss in EU fisheries is lacking, as evidenced by Table 9. However, based on the EU research done to date, and supported by research elsewhere, net loss is unlikely to exceed one per cent of the total number of nets set. What this means in absolute terms (ie actual total numbers) is not known. Where this loss rate may be an exception, and where further research is required, are the deep water net fisheries of the north east Atlantic.

5.1.2 Total ghost fishing mortality

Due to a lack of knowledge on total gear loss, the extent of total ghost fishing mortality is unclear This is compounded by the fact that the research to date has been undertaken in conditions that are not entirely representative of the broad range of conditions encountered in fishing. Studies have largely been conducted in shallow waters that are of higher energy and subject to biofouling more than waters generally fished in. This is because of the practicalities of surveying deeper set nets.

In the deep water net fisheries of the North East Atlantic (section 2.2.6), it is not known how much and for how long nets continue fishing. Similarly, very little information is available about the impacts of abandoned sheet netting, which is reportedly commonplace in these fisheries.

Apart from the paper by Baino *et al* (2001), there does not appear to be any documented research on ghost fishing in the eastern Mediterranean. There is also no information on gear loss in the deep waters of the Mediterranean, where persistence of nets, and hence ghost fishing, could be more of a problem. A number of papers on gear selectivity in Greek waters (Petrakis *et al*, 1996; Sacchi *et al*, 1995; Stergiou *et al*, 1994; Stergiou *et al*, 1996; Stergiou *et al*, 1997) have raised the likelihood of ghost fishing but have not confirmed or quantified its existence. The most recent comprehensive review of the environmental impacts of fishing in the Mediterranean (Tudela, 2004) also noted that ghost fishing 'has attracted scant attention'.

5.1.3 Member State and fishery level estimates

The above research gaps hold true for both Member State and fishery level estimates, as well as the EU level. This is particularly the case in the fisheries of the ten new Member States and the eastern Mediterranean. A notable example is the driftnet fisheries of the Baltic, which includes Finland, Sweden, Denmark and Poland. Gillnet loss in the Baltic is considered as a potentially important management concern, therefore these driftnet fisheries are also likely to present issues, not least because they are implicated with the bycatch of the critically endangered Baltic population of harbour porpoise. While research has been done on net loss in Sweden, no work has been done in Germany or Denmark and very little in Poland, where gillnetting effort has increased in recent years (pers com Zbigniew Karnicki, Sea Fisheries Institute, Poland).

In terms of geography, the central and eastern Mediterranean were not covered by FANTARED and have received very little other investigation in terms of the level of ghost fishing and its impacts. Given the size and complexity of the inshore fleets operating in Italy and Greece, this is a major gap that warrants attention.

5.1.4 Environmental impacts

There is a lack of data on the biological environmental impacts of lost nets in European waters. In almost all cases, a direct, absolute measure of the extent to which entanglement occurs or affects species at the population level does not exist (Laist, 1997). There are two main reasons for this. First, most data have been gathered on beaches where animals haul out, roost or strand. As a result, records are limited to animals that survive long enough to swim ashore or that become entangled close to shore. Second, many entanglements involve fishing nets and line, and it is rarely possible to determine if entangled animals encountered their burden of gear when nets or line were active or after the gear was lost (see Table 22). Reports of fish species entanglement were considered by Laist (1997) to be especially incomplete, although the work of FANTARED has since filled this gap to some extent.

Table 22 Factors complicating the analysis of marine entanglement trends

Detection	Sampling and reporting biases
Entanglements occur as isolated events scattered over wide ranges	Virtually no direct, systematic at-sea sampling has been done and there are few long-term surveys.
Entangling debris is not easily seen on live animals at sea because animals may only be partially visible at great distances	Sampling methodologies are inconsistent
Dead animals are difficult to see because they float just beneath the surface and may be concealed within debris masses	Strandings represent an unknown portion of total entanglements
Dead entangled animals may disappear quickly because of sinking or predation.	Shore counts of live entangled animals are biased toward entanglement of survivors carrying small debris
	Entangled animals spend less time ashore and more time foraging at sea
	Some entanglements reflect interactions with active rather than derelict fishing gear
	Many entanglement records may remain unpublished or anecdotal and cannot be compared geographically or temporally
	Few data is available for periods before 1980

While many of these data limitations are difficult to address, Laist (1997) considered there to be a need to better document and monitor entanglement rates. At sea observations of sea turtles were considered especially promising as well as land-based surveys for entangled seals and seabirds that come to shore to nest and breed. Indeed, in the context of the EU, research should be undertaken in these two areas, focusing on those species afforded protection under the habitats Directive, including cetaceans, Mediterranean Monk seal and Saimaa seal, otters, turtles, houting, and the European and Adriatic Sturgeon.

In addition, as noted above in section 4, there is a lack of EU and national level data on both the incidence and aesthetic impact of lost fishing gear as a source of marine litter. The most comprehensive data available covers fishing gear as a source of marine debris in the UK, with some estimates for the Mediterranean region as a whole.

5.1.5 Impact and feasibility of management measures

A research gap is an evaluation of the FANTARED-developed code of conduct. Significant efforts were employed in this work with a range of stakeholders and international input. It would be useful to know how successful and replicable the work was and the factors in determining this. This would then support the decision on whether to pursue this as a management option in other fisheries, and the factors to consider in developing such codes.

There is virtually nothing documented on the economic feasibility and costs/benefits of gear retrieval programmes. What has been done is largely restricted to estimations of the costs of ghost fishing (and hence the cost of having no clear up programme) in terms of value of ghost catch, (eg Al-Masroori, 2002, Mathews *et al*, 1987 in Al-Masroori *et al*, 2004) and, separately, the cost of gear retrieval programmes (eg Tschernij et al, unpublished). There is also nothing in the literature on the relative costs/benefits of different management measures being used as a basis for prioritisation of different management approaches.

5.1.6 Gear retrieval programmes

Identifying the specific research gaps in implementing successful gear retrieval programmes is made difficult by the lack of systematic documentation on the issue. Indeed, this in itself is a specific research gap as it makes it difficult for management authorities to develop effective gear retrieval programmes.

Specific research gaps that can be flagged therefore include:

- documentation of the different retrieval methods;
- quantification and comparisons of the different retrieval methods in terms of costs, effectiveness, environmental impacts and efficiency; and
- negative environmental impacts of retrieval methods.

While FANTARED and Smith (2001) report on different methods employed and available, they do not compare them in terms of methodology, costs or effectiveness. The FANTERED report is also written in a very technical language, making it difficult to understand for non-technical and non-English speaking people.

In addition to these research gaps, there is a lack of international cooperation in developing cross-border retrieval programmes, projects and data collection/analysis. All projects are national in nature eg the Norwegian, Swedish and Polish projects. Lost nets and the causes of net loss do not respect boundaries, therefore cross-border co-operation would be useful.

5.2 Research gaps identified during study workshop

A number of specific research gaps were identified during the workshop discussions held as part of this study (Appendix D).

In terms of generic research issues the workshop concluded that:

- the eastern Mediterranean needs an assessment of the extent of - and reasons for - gear loss and ghost fishing;
- tools are needed for measuring the cost effectiveness and impacts of different management methods;
- a carefully structured research programme specific to the deep water fisheries project needs to quantify the level of gear loss, evolution of ghost fishing and soak times. Like the eastern Mediterranean, this was not covered by FANTARED;
- there needs to be financial resources allocated to critical research needs. It was noted that 2007 EU financial provision is now up for Council consideration; and
- there is a need for specification of the requirements for, and preparation of, generic 'Principles and Criteria' for a Code of Practice for reducing gear loss through good operational practices. This would need a representative, stakeholder-driven workshop.

Some additional research areas were identified by the individual fisheries working groups, detailed below.

5.2.1 Deep water fisheries of the North East Atlantic

From the workshop discussion and the DEEPNET report, it is clear that the deep water North East Atlantic fishery probably represents a ghost fishing problem which is of a level of magnitude greater than in other fisheries. Nevertheless, much is still not known about the fishery and current practices. Research gaps can be summarised as follows:

- basic fisheries data (catch composition, discards, effort, landings by species);
- evaluation on volume of net loss;
- evolution of lost nets – data from Norway is in cold water, which may be different to warmer waters;
- decay rate of catches (soak time and ghost fishing cycles);
- actual levels of 'ghost netting' in the fisheries
- testing retrieval exercise – using gear retrieval to survey the grounds to help determine the extent of the problem;
- effect of sheet net dumping;
- cost/benefit analysis of ghost fishing and management measures;
- the economics of the fishery and the extent to which it is apparently profitable to deliberately discard large quantities of gear; and
- appropriate legislative and voluntary mechanisms to reduce ghost fishing.

5.2.2 Eastern Mediterranean net fisheries

The workshop highlighted that there is a need to start with an attempt to better understand the basic extent of gear loss and its impacts in Eastern Mediterranean net fisheries, as essentially nothing is known. As a result, current research gaps include:

- reasons for gear loss;
- evolution of nets/traps;
- key métiers resulting in ghost fishing;
- quantification of gear loss and the extent of ghost fishing;
- economic/social impacts;
- impacts of retrieving gears in terms of (i) creeping impacts and (ii) removing concreted gears;
- technical problems related to a number of different management options; and
- an ecosystem approach to fisheries management mechanisms appropriate to solving ghost fishing.

5.2.3 Western Channel net fisheries

No additional specific research gaps for Western Channel net fisheries were identified during the workshop beyond those already presented above and as indicated in section 5.1 (being research gaps identified during the literature review).

5.2.4 Baltic

Some research gaps associated with different management measures for the Baltic can be found in section 2.2.1.

6 Selection of key fisheries for detailed review

6.1 Introduction

Based on the review of information available on the extent of ghost fishing in EU fisheries, Table 23 summarises the main EU net and pot fisheries reviewed together with a summary of the key ghost fishing related issues, and presents a justification for the selection of a few fisheries for consideration in more detail through a brief survey and discussion at the study workshop.

The fisheries that have been selected for further research are highlighted in grey. These are:

1. Baltic cod net fishery of Sweden and Denmark;
2. net fisheries of Greece;
3. English and French net fishery in the western English channel; and
4. the deep water net fisheries of the north east Atlantic.

In selecting these fisheries, key European environmental NGOs (WWF, Greenpeace and Seas at Risk) were contacted to enquire whether there were any fisheries that they had particular concerns over ghost fishing. Other than the Mediterranean drift net fisheries (Sergi Tudela, WWF Spain, pers com), no fisheries were highlighted as a source of concern.

Because of the varying degrees of information already available on these fisheries and the incidence of lost nets and ghost fishing in each case, the follow up research undertaken for each one differs. In the case of the Greek fisheries, no research has been undertaken on lost nets. The Baltic and English Channel survey however will build upon the work done under FANTARED. Although there are still information gaps, the deep water fisheries have been studied in greater depth and the data available is sufficient to permit some analysis of the feasibility of a gear retrieval programme. There is also some sensitivity surrounding the fishery with the release and subsequent press coverage around the DEEPNET report (Hareide *et al*., 2005). Coupled with interview fatigue amongst those participating in the fishery and the relationships being developed by the DEEPNET team, a further survey was not conducted in this fishery.

Table 23 Review of ghost fishing in key EU net and pot fisheries.

Fisheries warranting particular investigation are shaded grey.

Region	Fishery	Countries	Effort levels	Issues	Reason selected / not selected
Baltic	Salmon drift net fisheries	Poland, Finland, Sweden, Denmark, Russia	• seasonal fishery, peaking September-October and April-May (CEC, 2003); • 24 per cent decline in 2001 compared to 2000 (CEC, 2003); • ~ 120 EU vessels (CEC, 2003) • complete drift net ban in the Baltic Sea on 1 January 2008 (EC, 2004); • phasing out of drift nets from 1 January 2005: fleet size is to be progressively reduced by 40 per cent in 2005, 60 per cent in 2006, 80 per cent in 2007 and 100 per cent on 1 January 2008 (EC, 2004)	• fishery implicated with bycatch of endangered and protected harbour porpoise; • little current or wave action, reducing break up of lost nets.	• While potentially significant ghost fishing issues, fishery is being phased out, therefore not selected for further research.
	Herring net fisheries	Estonia, Latvia, Lithuania, Poland	• Estonia <104 vessels. (Estonian Maritime Administration, 2004) • Latvia 60 vessels (cod and herring) (Anon, 2004c) • Lithuania 19 vessels (cod and herring) (Anon, 2004c) • Poland. 248 vessels (cod and herring) (FAO 2001a)	• little current or wave action, reducing break up of lost nets.	• Vessels typically tend to nets while set over night (FAO, 2001b). Rates of loss therefore not believed to be high. Nets also set midwater so less prone to snagging, damage and loss.

Region	Fishery	Countries	Effort levels	Issues	Reason selected / not selected
	Cod net fisheries	Sweden, Finland, Denmark, Latvia, Lithuania, Poland	• Sweden 398 vessels (Anon, 2004c) • Finland 13 vessels (Anon, 2004c) • Denmark 380 vessels) (Anon, 2004c) • Latvia 60 vessels (cod and herring) (Anon, 2004c) • Lithuania 19 vessels (cod and herring) (Anon, 2004c) • Poland. 248 vessels (cod and herring) (FAO 2001a)	• ghost catch of Swedish cod net fisheries estimated to be between 0.01 and 3.2 per cent; • considered an over estimate as lost gear is damaged by trawlers, so reducing ghost fishing efficiency. Discards also not included in fishing mortality, so ghost mortality relatively even smaller problem; • little current or wave action, reducing break up of lost nets. (FANTARED 2; Tschernij and Larson, 2003)	• Estimated rate of net loss considered high enough to warrant further investigation. • Only the biological impacts have been considered. A three per cent loss rate could be economically significant given value of cod fishery. • There is a need to cross check net loss figures and subsequently value the cost of ghost fishing. • Retrieval programmes have been ongoing since FANTARED although funding is a constraint.
Mediterranean	Drift net fisheries	France, Italy, Morocco, Turkey, Algeria	• drift nets still in use, despite EU, IATTC and GFCM ban; • offending EU Member States pledged to phase out drift net use; • particularly large illegal fleet remains in Morocco (Tudela, 2004; Tudela *et al*, 2005; Anon, 2005)	• high bycatch (eg cetaceans, turtles) levels in these fisheries; • entanglement in static and abandoned nets believed to have serious impact on monk seal populations (Johnson and Karamanlidis, 2000)	• While potentially significant ghost fishing issues, fishery is being phased out, therefore not selected for further research.

Region	Fishery	Countries	Effort levels	Issues	Reason selected / not selected
	Coastal gillnet fisheries	Spain, France, Italy, Greece, Slovenia, Malta, and Cyprus	• Spain ~ 3000 • France ~ 1,500 • Slovenia ~ 10 • Italy 6,000 -8,000 vessels • Greece ~ 16,330 vessels • Malta < 1,700 vessels • Cyprus 500 fulltime + part time vessels (STECF, 2004)	• loss rates generally less than one per cent; • roughly estimated that French hake fishery ghost catch equates to between 0.27 per cent and 0.54 per cent of the total commercial landings. (FANTARED 2; Erzini *et al,* 1997; Santos e*t al,* 2003a)	• Currently no information on loss rates in eastern Mediterranean, where gillnetting is a common method. • particularly high effort in Greece, therefore economic impacts may be high, warranting further examination.
North Sea, Irish Sea and western approaches	Wreck nets	Denmark, UK, France	• Denmark 435 vessels • UK 100 vessels • France 400 vessels	• while losses are high, it is mainly confined to small section of netting (net panels) designed to tear off; • because of high currents and tangling into reef, catch rates quickly decline to 18 per cent after 10 weeks and to zero in 10-12 months FANTARED 2, Revill and Dunlin (2003)	• while biological and economic impacts have not been quantified, the low level of net loss and nature of net evolution suggests that the wreck fisheries are not of significant concern.

Region	Fishery	Countries	Effort levels	Issues	Reason selected / not selected
Western Approaches	Gill, trammel and tangle nets	France UK Ireland	• France 400 • UK 100 • Ireland 200 (FANTARED 2)	• net loss considered to be under one per cent; • major cause is gear conflict, rendering lost nets of limited fishing • exception is (high value) bass fishery, where loss rate is over two per cent and due to gear conflict only half of the time (FANTARED 2; Revill and Dunlin, 2003; Pilgrim at al, 1985; Kaiser *et al* 1996; Sancho *et al,* 2003)	• if loss rate is high enough, combined with high value fisheries, economic impact may be high; • fishery provides geographical balance to the survey work; • vessels numbers higher in western channel than East
Eastern Channel & Southern North Sea	Gill, trammel and tangle nets	France UK	• France 340 • UK 30 (FANTARED 2)	• net loss considered to be under one per cent; • major cause is gear conflict, rendering lost nets of limited fishing • exception is (high value) bass fishery, where loss rate is over two per cent and due to gear conflict only half of the time (FANTARED 2; Revill and Dunlin, 2003)	• vessel numbers lower than Eastern Channel, therefore western channel selected in preference
North east Atlantic	Deep water and upper slope monkfish and shark net fishery	UK, Germany and Panama registered, operating from Spain	• UK 23 vessels • Germany 6 vessels • Panama 2 vessels (Hareide *et al,* 2005)	• the amount of fishing gear used in the deep water net fisheries, the length of the fleets, and the fact that the nets are unattended much of the time combine to make it highly likely that large	• A fishery of concern (see issues) and work ongoing into the development of retrieval programmes (Hareide and Connelly pers com).

Region	Fishery	Countries	Effort levels	Issues	Reason selected / not selected
				quantities of nets are lost; • evidence of dumping of sheet netting; • estimated net loss figures for these fisheries dwarf even the totals from those fisheries studies elsewhere, with a total number of 25,080 nets lost per year at a length of 1,254km; • stocks are overexploited and biologically vulnerable (eg slow growing) (FANTARED 2, Hareide *et al*, 2005)	• under the 2005 EC-Norway agreement the Head of Community Delegation informed the Norwegian Delegation that the EC intends to develop such schemes in Community waters. (Anon, 2004a)
	Pot and trap fisheries	UK, Portugal, Ireland, France	• UK ~ 300 >10m vessels (DEFRA, 2005), • Portugal ~ 290 vessels (FANTARED 2) • Ireland ~ 800 - 1200 (DCMNR, 2005) • France ?	• loss rates and subsequent ghost fishing efficiency considered to be low enough not to warrant concern (FANTARED 2; Bullimore *et al*, 2001; Swarbrick and Arkley, 1999; Santos *et al*, 2003a)	• While estimates are patchy, loss rates and subsequent ghost fishing efficiency is considered to be low enough not to warrant further consideration here; • project focus is on net fisheries.

6.2 Findings of the survey (and some comments from the workshop)

This section provides some key findings of the surveys conducted as part of the project, with additional comments generated at the workshop (see Appendix C for detail and methodology). As noted above, surveys were completed in:

- the Baltic cod net fishery of Sweden and Denmark;
- net fisheries of Greece; and
- the English and French net fishery in the western English channel

The deep water net fisheries of the north east Atlantic were not surveyed due to sensitivity issues discussed in section 6.1, and coverage by other researchers. The study by Hareide *at al.* (2005) in particular can be considered as a baseline survey of ghost fishing issues in this fishery.

It is important to stress the context and the main purpose of the surveys that were conducted. The surveys were conducted within the framework of a limited budget that only allowed for around 20 days of survey work. This meant that the main intention of the surveys was not to generate statistically meaningful results from the key fisheries covered. In addition, it is acknowledged that one cannot have 100 per cent confidence that the responses provided by interviewees in all cases reflected the true picture. However great efforts were made to use experienced interviewers with links to the fisheries concerned, and those conducting the surveys reported that they had great confidence in the data collected.

The representativeness of the surveys in different fisheries depends greatly on the size of the fisheries concerned. For example, in the Western English Channel, interviews with 23 fishermen may provide a relatively meaningful output given the relatively small number of vessels operating in this fishery and the limited geographical area concerned. In Greece by contrast, a survey of around 30 interviews is clearly less representative given the many thousands of small-scale net fishermen operating over a vast area.

The surveys were only therefore intended to provide a brief mechanism for the consultants to:

a) engage with some sections of the industry, especially with regard to their views about different management measures;
b) gauge any major trends in ghost fishing issues;
c) provide some additional information that could build on/corroborate the work of FANTARED (where similar fisheries were covered);
d) provide background information to be as discussion points at the project workshop;
e) provide some very limited first-stage research into fisheries that were not covered by FANTARED, and for which no published information on ghost fishing is available eg eastern Mediterranean; and
f) Provide some quantitative outputs to be used in the cost benefit analysis in section 5.

6.2.1 Baltic cod net fishery of Sweden and Denmark

Eleven fishermen were interviewed during the study in Sweden, one each from Hörvik, Brantevik, Boda, Hällevik, Nogersund, and five from Simrishamn. In addition, 15 fishermen were interviewed in Denmark, 3 from Nexø, 4 from Rønne, 2 from Klintholm, 2 from Marstal, and one each from Rødvig, Tejn, Svaneke, and Bagenkop.

Extent of gear loss and issues around net recovery

Nets are generally lost when fishing in waters of 25-60m depth. A significant proportion of fishermen reported that typically each year no nets are lost, while a smaller number reported some gear loss each year, typically around 3-5 nets and representing for each vessel a total of a few hundred metres of net, rather than thousands of meters. Generally less than 50 per cent of nets lost are recovered in Sweden, although Danish fishermen report that almost all nets are recovered.

The main determinants of successful recovery appear to be the reason for loss in the first place; fishermen report that where nets are trawled away, it is virtually impossible to recover them at sea (although Danish trawlers catching nets are reported to deliver them to the harbour, where they can be identified because they have tags with vessel number etc).

Trawling/gear conflict, along with merchant shipping, appear to be the major cause of net loss. Bad weather and nets being caught on the seabed are also significant causes of gear loss. In such cases, because each net is positioned with GPS and manually plotted, lost nets may be easily recovered. Due to the fact that trawled nets are likely to be bundled up and therefore to have little ghost fishing potential, these findings imply that the extent of ghost fishing may not be significant. In addition, the problem is reported to have been declining and was a much bigger problem in previous years. In Denmark in particular, interviews suggest that ghost fishing is not a significant issue for the following reasons:

- 10-15 years ago there was an illegal fishery in Polish territory with nets used with no/insignificant buoys and no identification marks. This has now stopped;
- before the development/common use of GPS and other electronic aids a significant amount of nets were lost by fishermen - this is no longer the case;
- because of the relatively high cost of net panels everything possible is done to retrieve them;
- there is a very good communication between the trawlers and the static gear fishermen;
- fishing with nets is to a high degree restricted to areas where trawling is not going on - this is also why nets are rarely lost in deep water areas where trawlers primarily fish (and where the problem with ghost fishing could be most serious because of weaker currents);
- fishing with nets is declining – there are fewer vessels and many are changing to other fishing techniques (longlining/hooks); and
- small quotas make net-fishing in the Baltic of less interest to fishermen from other parts of Denmark (especially from the west coast).

Attempts at net recovery are generally made using a hook that is dragged along the bottom (either home-made or bought for around €50-300), and unless it is known that net loss has been caused by trawling or merchant shipping activity, attempts are always made to recover lost nets. Given that the extent of net loss is not itself high, fishermen on average spend no more than a few hours each year looking for lost nets.

When nets have reached the end of their useful life, they are generally disposed of in containers in the harbour, with the costs of disposal already contained as part of port fees, so there appears little economic incentive for fishermen to deliberately discard nets at sea to avoid onshore costs of doing so.

Management measures

Generally fishermen felt that mandatory reporting of lost gear could be useful, although it would be of limited benefit for nets lost due to trawling activity. The Swedish Board of Fisheries has been retrieving lost gear each summer for the last four years (section 3.5), and better information on where gear was lost would make such searches more efficient. An international database was also suggested in interviews as being potential useful considering the number of foreign fishermen in the area, some of whom are thought not to drag for lost gear.

A maximum soak time of 48 hours is already in place in Sweden, and marking of buoys with radio-transmitters is also already mandatory enabling nets/buoys to be found (but does not stop some trawlers) and so there was no support for additional gear modifications.

Fishermen sometimes have agreements with the trawlers from the home port and communicate daily with them, and while some domestic trawlers certainly also cause problems, it is reported that it is generally the external trawlers that result in lost nets, including Finnish and Polish fishermen. This suggests that improvements in international communication mechanisms might help.

Some efforts were reported to set up codes of practice by associations and the Board of Fisheries in Sweden, but no one appears to have taken up responsibility for implementation. However, codes of practice were generally supported by those interviewed, especially if extended to fishermen in other countries.

Additional comments made the workshop

No specific comments were made at the workshop by the Baltic Working Group on the survey conducted

6.2.2 Net fisheries of Greece

Whilst FANTARED examined the gillnet hake and the trammel crawfish/spiny lobster fisheries in the western Mediterranean, it did not cover the eastern Mediterranean. An examination of available literature reveals that, despite the large number of vessels using gillnets in shallow inshore waters, no work has been specifically conducted on the level of gear loss and the subsequent impacts of ghost fishing and gear degradation. Therefore these interviews were exploring new ground.

The interviews were conducted in Halkida (12), a port at the point where the island of Euboia very nearly joins the mainland; on Spetses (8), an island in the Gulf of Argolis, off the east coast of the Peloponnese; and in Koilada (7), a port on the mainland of the Peloponnese, northwest of Spetses.

The fishermen interviewed were on the whole fairly representative of the coastal fishing sector, in that there were only 4 or 5 who were relatively young (< 50), fished on a relatively large scale (turnover of €30,000 or more), and used GPS. The remainder, like the sector, are struggling to make ends meet, or (in a few cases) supplement their pensions, and are generally more 'subsistence' in nature than truly commercial.

It should be stressed that these 27 interviews cover a very small proportion of the 17,000 fishermen spread throughout the extensive coastal fisheries of Greece. Furthermore, the Greek small-scale fisheries are characterised by a wide range of métiers, targeting different species with various net types and configurations, conducted by large numbers of both full-time and part-time fishers. As such, they cannot be considered representative and thus provide only a glimpse of the nature of ghost fishing in these and other eastern Mediterranean waters. As a result, the comments made at the workshop are particularly useful in adding to the findings of the survey.

Extent of gear loss and issues around net recovery

None of the fishermen interviewed stated that they lose net panels, or indeed fleets, on a regular basis, and gear conflict with trawlers was not reported. Rather, they tend, especially in the north Euboean gulf, and in certain areas around Spetses, Trikeri and Dokos, to snag their nets on a fairly regular basis. As an indication, only one or two of the interviewees stated that they snag their nets less than once a week. However, snagging does generally not result in 'net loss', rather just in small fragments of nets being left in the water when nets are tugged free.

Because of the fairly parlous financial state of the coastal net fishers (resulting from falling stocks, an aging population, and competition from poorly policed and often irresponsible trawlers and purse seiners), the fishermen report that they can not afford to abandon nets. Taking into account that weather conditions and tides / currents are not generally challenging, they will go to considerable lengths to retrieve a snagged net, generally leaving only small pieces of the net behind and picking up all the floats, weights and ropes. Thus while their losses are practically never in terms of a panel, or gear, in the course of a season, if they are unlucky with snagging, it could be that they replace a hefty proportion of the net with pieces that they patch in. However, these small pieces of net fragments are not thought to be a problem in terms of ghost fishing as they are likely to quickly roll up being devoid of floats/markers.

Again, because of the near-subsistence level of the majority of the fishermen interviewed, they rarely have a GPS, or the know-how to use one effectively. However, they fish very much the same grounds, within sight of land, year in year out, and know from bearings on fixed points ashore almost exactly where they have laid the net, in the unlikely event that both markers are lost.

Nearly all fishermen perceive dolphins (and to a lesser extent turtles and seals), which are all apparently making something of a comeback in the area, as their major problem in terms of net damage, although it does not result in nets being lost, just portions of them being unusable. Almost all fishermen made some mention of this problem although it is not clear whether it resulted in bycatch.

Because they nearly always retrieve lost gear, and because floats and lead lines last for at least 3 years, they tend to strip the old net off the ropes, and dispose of it in the municipal tip. There is therefore no cost involved and no incentive to discard nets at sea.

These findings imply, in corroboration with the FANTARED work in the western Mediterranean, that ghost fishing is probably not a significant issue in the eastern Mediterranean, at least in relative terms per vessel. Small fragments of net lost by many thousands of fishermen could however add-up to constitute a problem.

Management measures

These questions were difficult to explain to most fishermen given that net loss and ghost fishing was not seen as significant issue, and the results were correspondingly a little inconclusive. However, meaningful comments appeared to be that most were in favour of establishing a code of practice (although its relevance for an aging and poorly-educated population may be questionable), and of mandatory reporting of losses, to the extent that the body to which the report would go to could then dispatch divers to retrieve the net.

Additional comments made at the workshop

The Mediterranean Working Group stressed the extremely limited sample number and geographic representation of the survey, together with its inability to focus on the extensive part-time fishery nor stratify different fishing métiers. As such, it provides a useful snapshot in an otherwise un-researched area, but the Working Group highlighted the need for further, more extensive investigations, such as those undertaken in the western Mediterranean by FANTARED 2.

The Mediterranean Working Group considered the following:

- contrary to the survey results, gear conflict is a major issue in many Greek fisheries (both between mobile and static gear, and between part-time/recreational and professional fishermen) and this is likely to lead to a high level of gear loss;
- linked to this is the fact that the majority of Greek inshore vessels lack basic radio and radar equipment, which impedes inter-metier communication on gear placement;
- there is some evidence of the deliberate discarding of gear, for instance in the Central Greek *Nephrops* fishery (Vassilopoulou, HCMR, pers com) in shallow waters (50-100 m);
- lost traps may also contribute to ghost fishing. In addition, net fragments attached to traps and other underwater objects are both unsightly for the dive tourism business as well as a safety hazard to fishermen and divers;
- there is apparently a low bycatch of marine mammals in gillnets but these animals, especially dolphins and seals are attracted to the nets and will frequently damage or destroy them, leading to a loss of net fragments into the environment; and
- the onshore disposal costs are rarely a barrier to responsible disposal – however such facilities need to be well publicised, placed and coordinated.

In summary, the Mediterranean Working Group considered that there is an urgent need to better characterise gear loss and subsequent ghost fishing impacts in the small-scale fisheries of the central and eastern Mediterranean. This could be initiated through a workshop to assist identification of the different métiers involved and to develop a stratified work programme along the lines of the FANTARED programme.

In addition, when discussing management measures, the Working Group considered that the drivers of ghost fishing that need to be dealt with through management measures may include:

- interactions with other marine users (intentional and unintentional) and deliberate discarding (thought to be primary drivers). Discarding gear because of damage. Damage being caused by both general snagging and dolphin (and other marine mammals) interactions;
- extent of full- or part-time fishing – part-time may be more susceptible to losing gear;

- the weather conditions during November to February can be a driver of gear loss;
- long soak time for sole and crawfish trammel nets; and
- depth of fishing for red seabream.

6.2.3 Western Channel net fisheries

Eighteen French fishermen and five English fishermen were interviewed during the study, five from Le Conquet, two from Newlyn, and one each from a range of other small fishing harbours/ports.

Extent of gear loss and issues around net recovery

More than two-thirds of all fishermen interviewed reported that, in a typical year, they lose no nets at all. For the smaller number of fishermen who did report losing nets (generally fishing at between 50 and 100m), it was reported that typically only one net was lost a year, and 50-75 per cent of lost nets would subsequently be recovered. Key determinants of the percentage of nets lost that were recovered (using 'creeps') were cited as being: the strength of tides; good GPS fix on the original point of loss; the weather; echo sounders on buoys; and knowledge of trawl activities. An additional interesting comment made was that the larger fleets of lost nets are far more easily relocated than smaller net fragments. In summary it would appear that ghost fishing is not a serious issue in the western English Channel net fishery.

Causes of gear loss were strongly centred around weather and bottom snagging, with very little reported as lost due to gear conflict. This may in part be due to existing levels of communication between different fleet segments. For example, every first day of the neap tide one fisherman in the southwest of the UK collates the location of static nets and informs the producer organisation, which in turn tells French producer organisations.

Disposal of unwanted gear in France takes place through a number of mechanisms: it goes to a waste collection centre for sorting and recycling; it can be returned to a manufacturer; municipal trucks from the city come to collect 'big bags' with unwanted gear inside. In the UK, nets may be disposed of in skips in harbours (with costs contained within harbour dues) or are supposed to be disposed of industrial waste. However, associated charges for industrial waste mean that nets are either bagged as normal waste and taken to community tips, or 'fly-tipped'. But in neither France or England does it appear that fishermen ever just discard unwanted nets at sea.

Management measures

Fishing gear is generally already well marked by all fishermen, although it would appear that gear loss may be more prevalent for part-time/amateur fishermen who may insufficiently mark their gear, and that management measures might do well to focus on these fishermen. There was also little support from those interviewed for mandatory reporting of losses, principally due to the fact that the small amounts of gear that is lost is usually recovered anyway, either by the fishermen concerned or by another fishermen. Gear modifications too, were generally felt unnecessary/unwanted, as gear is carefully adapted to the local conditions in which it is used. Regarding codes of practice, there already appears to be a good awareness within the industry of the need not to dispose of gear at sea, and indeed of collecting and delivering to shore any lost gear that fishermen may find while fishing, so a formal code of practice may not be necessary as losses are not intentional. Therefore for those losses that may be unavoidable, eg on the few occasions that gear is lost due to conflict with trawlers, better communication between the two groups could perhaps be of benefit. Overall it seems that fishermen were reluctant to have any additional regulation or requirements imposed on them, given that the scale of the problem is perceived to be minimal.

Additional comments made the workshop

Some additional comments made at the workshop were that:

- there are many different types of fishing métiers in the western channel; and
- while there is some danger that fishermen interviewed could have been reluctant to describe accurately the extent of net loss, the overall impression is that ghost fishing in this area is of very little concern, and there was therefore some concern about the fishery having been selected for inclusion in the survey as part of the project as it might imply to others that ghost fishing was a significant issue.

6.2.4 Deep water fisheries in the North East Atlantic

While not covered in the survey as part of this project for the reasons stated above, the Deep water Working Group at the workshop made the following observations:

- it is difficult to get any information on this fishery given the unregulated nature of the fishery and the participants involved;
- the proposed DEEPNET project is intended to provide data on the fishery – little is currently little known and there is much misreporting;
- the characteristics of this fleet/fishery are:
    - deep water/offshore;
    - large vessels;
    - economically motivated; and
    - large by-catch and discards.
- the DEEPNET report was based mainly on indirect sources of information:
    - 2 gillnet skippers;
    - 7 long-line skippers;
    - 8 trawl skippers;
    - 1 agent;
    - 2 net makers;
    - 3 PO managers;
    - 8 UK harbour masters an port authorities; and
    - 1 Irish fisheries officer.
- a more accurate survey would need direct input from skippers and/or observers;
- additional accurate information is vital to address the real problems and to assess the status of the stocks;
- there could be a difference between the practices of skippers working for large companies as opposed to skippers/owners. Former crews may be poorly skilled and motivated purely by profit, whilst smaller boats may demonstrate more responsibility and a longer-term view towards resource sustainability;
- cable-layers always clear nets with grapnels so might be a source of information; and
- the NEAFC secretariat has no powers to propose any restrictions / legislation unless called for by Member States, and management measures could be pushed through by contracting parties, especially if it is a joint proposals.. But they do have a VMS database to determine in what international areas the fishery is prosecuted (although

notification is thought to be poor). There are now 5 contracting parties, and joint proposals of 3 contracting parties tend to be successful.

In addition, it is useful to reproduce here the executive summary of the DEEPNET report Hareide *at al*. (2005) which reports on the survey undertaken by the DEEPNET research team:

‘Since the mid-1990s, a fleet of up to 50 vessels have been conducting a gillnet fishery on the continental slopes to the West of the British Isles, North of Shetland, at Rockall and the Hatton Bank. These vessels, though mostly based in Spain are registered in the UK, Germany and other countries outside the EU such as Panama. The fishery is conducted in depths between 200 and 1200 meters, with the main target species being monkfish and deep water sharks. These fisheries are not well documented or understood and they seem to be largely unregulated, with little or no information on catch composition, discards and a high degree of suspected misreporting.

It is reported that fishing effort by longlines, trawl and gillnets has increased significantly since the development of the fisheries. During the same period of time stocks of deep water sharks have been falling to ~ 20 per cent of original levels in less than ten years. Vessels currently participating in the fishery are reported to use up to 250km of gear, and the nets are left fishing unattended and hauled every 3-10 days with trip lengths varying between 4–8 weeks.

The total amount of nets constantly fishing at the same time by the fleet is conservatively estimated at between 5800 and 8700 km and the vessels leave their gear fishing whilst they land their fish. Some vessels work in groups of two or three so that there is some tending of the gear while the other vessels return to port to land. The amount of fishing gear used in the fisheries, the lengths of the fleets, and the fact that the nets are unattended much of the time, make it very likely that a large quantity of nets are lost, while there is also evidence of illegal dumping of sheet netting. The vessels are not capable of carrying their nets back to port and only the headline and footropes are brought ashore while the net sheets are discarded, either bagged on board, burnt or dumped at sea. These vessels are competing on the same grounds as demersal trawlers and long liners. There is obvious conflict between the sectors which is strongly suspected of adding to the amount of lost nets.

The total amount of loss and discarding of nets is not known, although anecdotal evidence suggests up to 30kms of gear are routinely discarded per vessel per trip. It is not known how much and for how long these nets are fishing after they are lost. Norwegian investigations in the deep slope gillnet fishery for Greenland halibut have shown that gear losses can be significant and that the nets can fish for at least 2-3 years and sometimes even longer. The long soak times in these fisheries result in a high proportion of the catches being unfit for human consumption. The Norwegian Coastguard from their inspection of a UK vessel in Norwegian waters observed high discard rates of monkfish. The percentage of the catch that was discarded varied between 54 and 71 per cent per fleet (average fleet 19km) with an average 65 per cent of the monkfish being discarded. This was from nets that had been deployed with soak times of between 4-10 days (96-240 hours). Only data for the monkfish catch were recorded during these inspections and there is only limited information available on discarding of other species but it is suspected to be similarly high.’

7 Assessment of the costs and benefits of management options, and related prioritisation of management options

7.1 Introduction and description of types of costs and benefits

Ghost fishing has a number of costs/negative impacts that may be environmental, social, or economic/financial in nature. By inference, reducing ghost fishing through certain management measures (see Table 12 and Table 13) will have certain benefits. However, these management interventions may themselves have associated costs. Table 24 presents some of the possible costs and benefits of reducing ghost fishing, some related to preventative management measures and some related to curative measures.

Table 24 Summary costs and benefits of reducing net loss and ghost fishing

	Costs	**Benefits**
Environmental	• Some negative impacts of removing lost gear form the sea on scavenger species that may depend on 'ghost' nets and pots • Potential costs in terms of resource productivity of removing lost gear from the sea, if fouled ghost nets are acting as reefs rather than actively catching fish • Some ghost nets may be better left alone rather than retrieved, if already completely bio-fouled and embedded in the seabed • Potential habitat damage from retrieval gear	• Reduced unintended fish mortality of commercial/target species • Reduced unintended mortality of non-target species (marine mammals, birds, reptiles, etc) • Reduced abrasion, 'plucking' of organisms, and translocation of sea-bed features • Reduced littering of beaches • Reduced synthetic particulate matter in the marine environment from nets that eventually decompose • Management measures may help to provide better information on the extent of ghost fishing and related environmental impacts
Social		• Enhanced employment in fishing communities resulting from increasing catch levels associated with reduced unintended fish mortality • Improved recreational, tourism and diving benefits with reduced levels of lost gear on beaches and at sea
	• Could potentially impact (positively or negatively) on some gear manufacturers and employees if fishermen switch gear	

Economic	• Potential costs to fishermen from modified gear in the form of:
	   o Increased costs of nets
	   o Possible reduced target/intended catch rates
	   o Reduced handling efficiencies
	• Cost (to fishermen or administrations) of retrieval programmes/activities to remove
		• Enhanced income/value-added resulting from reduced ghost fishing mortality which is therefore able to be caught by fishermen
		• Multiplier effects of increased fishing income
		• Reduced gear/engine entanglement with lost/discarded gear, resulting in less sorting/disentanglement time, more fishing time, and reduced costs of any gear lost as a result of

	Costs	Benefits
	lost/discarded gear, or other management measures eg costs of time required for better communication, costs of better marked gear, etc • Management costs of monitoring the extent of ghost fishing and the impacts of any management measures • Costs of further research required • Management costs of enforcement of any new regulations associated with management options	of any gear lost as a result of entanglement[8] • Improved incomes associated with measures to reduce number of lost nets, through a reduction in lost gear and associated lost fishing time involved with searching for lost gear, and reduced time purchasing and rigging new gear • Improved catches if fish are not 'wary' because the number of ghost-nets is reduced • Management measures allay consumer fears/concerns about ghost fishing, which otherwise may affect purchases and impact on demand for fish, either generally and/or from gillnet fisheries specifically.

7.2 Costs and benefits of gear retrieval programmes and other management measures

7.2.1 Model specification

The project terms of reference require a particular focus on retrieval programmes through 'an assessment of the costs and benefits of a possible wide-ranged programme of retrieval of lost gear' (see section 1.3). The focus on retrieval programmes is felt to be especially relevant given the extent to which a number of countries/administrations are already engaged in such activities, or are planning to do so, but without any detailed economic assessment of whether the benefits of doing so outweigh the costs.

While a qualitative description of 'the costs and benefits of a possible wide-ranged programme of retrieval of lost gear' is provided in Table 24 above, a quantitative model is also described and presented below which can be used for assessing the costs and benefits of individual gear retrieval programmes, undertaken on a yearly basis.

It has not been possible to quantify with any great confidence the costs/benefits of particular retrieval programmes in different fisheries within the scope of a relatively small study such as this. Indeed, many of the participants of the workshop held as part of this study argued strongly against presenting fishery-specific models for the fisheries considered in detail as part of the study, because:

a) this could be viewed by some as an implicit accusation that the extent of ghost fishing in such fisheries was significant, when it may not be; and
b) the surveys conducted as part of this study are not representative enough to be used as a base for quantitative information about the extent of ghost fishing in different fisheries.

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8 Marine litter (some of it from lost gear) may result in lost revenue for fisheries, due to fouled propellers and blocked intake pipes, and can also endanger human life, if the vessel cannot return to port, or cannot steer to avoid collision

While acknowledging these points, the model presented below contains the basis on which the costs and benefits of gear retrieval programmes can be quantified in different fisheries. The model is loosely based on operational and gear loss data collected for the western Channel gillnet fishery during the survey work undertaken during this project, and available from other published costs and earnings studies[9]. As noted in section 6.2 however, given the small sample size the data are not claimed to be representative of the western Channel fishery specifically. The model should not therefore be thought of as attempting to definitively assess the costs/benefits of a retrieval programme in this fishery. Rather, the data is used to populate a template model of a hypothetical gillnet fishery exploited by vessels of around 16m in length, with data that might be considered to be broadly indicative.

It is hoped that the model will serve as a template for fisheries administrations to adapt/improve, and to use in making informed quantitative decisions about whether to engage in retrieval programmes[10].

Description of the model is broken down into two sections. The first presents the necessary variables associated with a current situation where ghost fishing is taking place. The second presents the variables and results associated with the costs and benefits of reducing ghost fishing through gear retrieval programmes or other management measures. The right hand columns in the model tables below provide some notes and assumptions about the model's construction.

While not within the terms of reference, the study team have also considered the costs/benefits associated with other management measures, particularly preventative measures. The model therefore also shows in the grey shaded rows the cost/benefit variables that could be quantified for preventative measures. Additional quantifiable variables might include:

- the value of saved leisure time resulting from fishermen spending less time searching for lost gear, if management measures reduce the extent to which gear is lost in the first place;
- the value-added that could be generated through additional fishing if less time spent locating lost gear resulted in greater catches being made (of non-quota species);
- costs of gear modification to reduce ghost fishing once nets are lost eg use of biodegradable materials (noting that the workshop conducted as part of this study did not provide support for such measures);
- costs of better communication and/or development and implementation of codes of conduct;
- costs of monitoring the extent of ghost fishing and the impacts of any management measures;
- costs of enforcement of any mandatory/regulatory management measures; and
- value of gear that is prevented from being lost where management measures are successful in reducing gear loss.

In addition to the types of quantifiable costs presented in the model there may be other costs/benefits of gear retrieval programmes and other management measures (see Table 24), which would generally be more difficult to quantify without considerable financial resources being deployed on additional studies. Such quantification may itself not be cost effective, but these other types of costs and benefits should also considered as part of the decision-making process about whether to engage in retrieval programmes. Such costs/benefits could include:

[9] Watson et al, 2001

[10] Please contact the authors for the actual spreadsheets used for the model's development if required.

- bio-economic benefits of stock improvements ie fewer ghost catches of quota and non-quota controlled species could cause stock biomass to increase, thereby resulting in higher quotas and overall catches;
- environmental costs/benefits of retrieval programmes in a specific fishery;
- social costs/benefits of retrieval programmes
- income multiplier benefits of higher catches resulting from increased stock biomass following reduced ghost fishing;
- reduced gear/engine entanglement with lost/discarded gear, resulting in less sorting/disentanglement time, more fishing time, and reduced costs of any gear lost as a result of entanglement; and
- improved catches if fish become less 'wary' because number of ghost-nets is reduced.

7.2.2 Current costs of ghost fishing and operational/background data

Table 25 presents information on the necessary data required for the model in terms of a) gear use and related costs; b) operational costs and earnings data; and c) the extent of net loss and associated costs.

For this hypothetical fishery, the model illustrates that economic costs of ghost fishing per vessel are over €10,456 per year, with costs for the fishing fleet as a whole estimated at slightly less than €420,000. These figures are made up of almost equal contributions from the depreciated value of the lost gear, and the lost value-added from the ghost catches.

In terms of the comparison of ghost net catches compared to active catches, over the course of one year, ghost catches for one fleet (ie combination of net panels) are estimated at 15 per cent of the catches made by a similar fleet under the control of a fishermen (assuming nets are fished for 200 days per year). Over a one-year period these ghost catches also represent 5 per cent of the total active catches made for each vessel ie from all the fleets of nets used by that vessel. Importantly, this figure of 5 per cent of active catches is at the top-end of the estimates provided in the literature for the western channel fisheries.

The declining ghost catch rate over time is based on a negative exponential function (see Figure 15) with rapidly declining ghost catch rates as suggested in the literature. On a daily basis ghost catches are assumed to decline quickly so that after 90 days the ghost catch from a lost fleet is equivalent to 5 per cent of the active catches for a fleet under the control of a fishermen. After 90 days, the decline in catch rates slows down considerably, allowing for continued small levels of ghost catches.

Table 25 Current Position and Costs of Ghost Fishing

No. of vessels	**40**

	Current Situation		**Notes**
	Per vessel	**Total fleet**	
Gear data			
net length used (m)	37,000	1,480,000	Data from interviews. Gear costs affecting the value of both nets lost, and potentially of those recovered under retrieval programmes
number of nets used per fleet	100	100	
number of fleets used	3	3	
average soak time (hrs)	48-72	48-72	
cost of each net panel (Euro)	€ 75	€ 75	
cost of nets per fleet (Euro)	€ 7,500	€ 7,500	
cost of nets used (Euro)	€ 22,500	€ 900,000	
cost of markers & floats per panel (Euro)	€ 20	€ 20	
cost of markers & floats used per fleet (Euro)	€ 2,000	€ 2,000	
cost of markers & floats used (Euro)	€ 6,000	€ 240,000	
total cost of nets and markers/floats (Euro)	€ 28,500	€ 1,140,000	
average life span of nets (months)	12	12	Affecting depreciated value at time of retrieval
average life span of markers/floats (months)	24	24	
Cost and earnings (per year)			
landings (tonnes)	75	3,000	Operational costs and earnings determining value-added based on UK costs and earnings studies and interviews), and the value-added from ghost catches that could otherwise be caught by fishermen, if management measures put in place
revenue (Euro)	€ 302,737	€ 12,109,472	
average value of landings (€per tonne)	€ 4,036	€ 4,036	
fishing expenses (Euro)	€ 211,561	€ 8,462,432	
non fishing expenses (Euro)	€ 65,763	€ 2,630,532	
total expenses (Euro)	€ 277,324	€ 11,092,964	
net profit (Euro)	€ 25,413	€ 1,016,508	
crew earnings	€ 103,710	€ 4,148,392	
value-added (crew earnings + profit)	€ 129,123	€ 5,164,900	
number of crew	4.0	160	
crew earnings per man	€ 25,927	€ 1,037,098	Affecting earnings per hour/cost of leisure time, which can be saved by management measures to reduce gear loss

	Current Situation		Notes
	Per vessel	Total fleet	
% of catch not quota controlled	30%	30%	Programmes reducing net loss and therefore time spent looking for nets will result in additional available fishing time but resulting increased catches and value-added only possible for non-quota controlled species. This applies equally to increased value-added from fish caught by fishermen rather than by ghost nets that may result from retrieval or other management measures
days fished	200	8,000	Affecting earnings per hour/cost of leisure time, which can be saved by management measures to reduce gear loss
hours fished	1,600	64,000	
value-added per hour (Euro)	€ 81	€ 81	
crew earnings per hour (Euro)	€ 65	€ 65	Affecting value of lost leisure time
value of non quota catch per hour (Euro)	€ 57	€ 57	Affecting cost of lost value-added from fishing time lost
value added as % of revenue	43%	43%	
value added per tonne fish caught	€ 1,722	€ 1,722	Affecting lost value added prevented
catch per fleet (tonnes)	25	25	Affecting difference between active catch and ghost catch, and therefore ghost catches prevented from management measures
catch per fleet per day (tonnes)	0.125	0.125	
Data on lost fleets and associated costs			
No. of fleets lost per year	1	40	Affecting value of lost fleets and value of recovered fleets. Cost of lost fleets is a depreciated value of 50% of purchase cost
Cost of fleets lost (Euro)	€ 4,750	€ 190,000	
Time spent looking for nets (hrs)	2	80	Affecting value of time saved if nets not lost following improved management measures
% of time spent looking that would otherwise be fishing time	75%	10%	Affecting the extent to which time saved from reduced net loss can be used to generate additional value-added from fishing
% of time spent looking that would otherwise be leisure time	25%	90%	
Cost of lost leisure time (Euro)	€ 10	€ 389	30% of earnings per hour commonly used as appropriate valuation of leisure time in cost/benefit analysis
Cost of lost value added from fishing time lost (Euro)	€ 36	€ 1,453	Only value-added from non-quota catch included

	Current Situation		Notes
	Per vessel	Total fleet	
Ghost fishing catch as % of total active catch	15%	15%	Variable comparing active catch over one year to ghost catch for one fleet, based on declining catching ability of ghost nets over time. Assumption made that ghost catches decline following a negative exponential curve ie rapidly at first (to 5% after 90 days as per data from the literature review on Channel fisheries) and then more slowly thereafter. Ghost catches represent 5% of total vessel active catches per vessel which is the top-end estimate suggested in literature review
Value added lost from fish caught in ghost nets rather than by active gear	€ 5,660	€ 226,384	Value-added lost through ghost fishing only included for non-quota controlled catches. Percentage of value-added made from quota and non-quota species considered the same, but this assumption could be refined to reflect a higher value-added from quota species
Total cost of ghost fishing (lost nets, fish ghost caught and time spent by fishermen) (Euro)	***€ 10,456***	***€ 418,226***	**ie costs that would be reduced/eliminated if ghost fishing was not taking place**

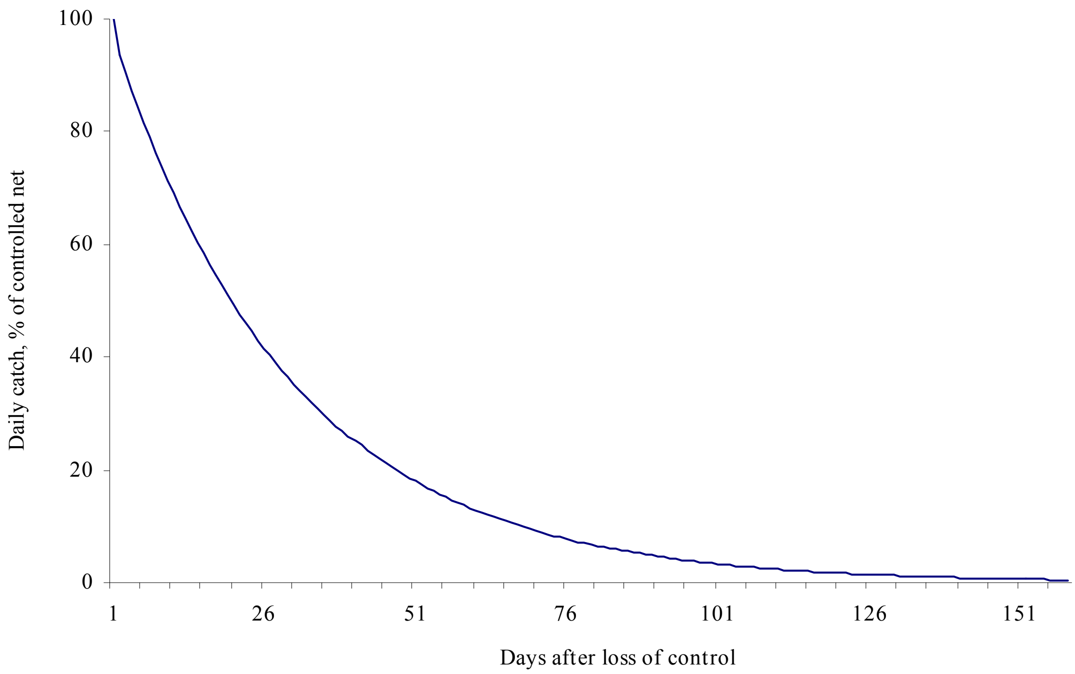


Figure 15 Decline in catch rate of ghost nets assumed in model

7.2.3 Costs and benefits of retrieval programmes and other management initiatives

The costs of the retrieval programme in the model are based on the steps identified in the current retrieval programme conducted by Sweden (Table 26).

Table 26 Process of the Baltic retrieval programme conducted by Sweden

Gear Retrieval Steps	Cost
1. Determine areas of net loss with industry. Based on good communications between industry and researchers.	Labour time of fishermen (2 person days) and scientists (2 person days) to discuss appropriate area for survey. Information collected in advance of planned gear retrieval programmes
2. Hire retrieval vessel (normal commercial vessel rather than a research vessel. Medium sized stern trawler with 2 net drums)	10 sea days at > 12,000 Kr./day (€1,100/day)[11]. Costs depend on time of year – it is cheaper during the summer cod closure, although earlier times of year are favoured
3. Retrieval gear development costs – suitability varies by region eg Norwegian gear not suitable to Baltic conditions	2 years, 3 people part time (2 person months)
4. Purchasing of retrieval gear eg sweeps, hooks, otter doors (of special size)	Approximately €1,000
5. Dispose of retrieved gear	Costs borne by Port Authorities in Sweden and Denmark.
6. Retrieval gear maintenance	Dependent on frequency of retrieval work and nets recovered, but generally very low – €100/year
7. Evaluation	5 person days to evaluate the weight and length of netting, weight and length of fish caught in net. Attempts have been made to look at the value of cod catch related to the total cost of harvest, but there are many uncertainties. Could potentially look at trends in nets being caught per retrieval effort (NRPUE)

The resulting costs would appear to be relatively modest, and as shown in the model below are around €50,000 (Table 27). It should be noted however that the costs of retrieval programmes will always be strongly based on the agreed area of coverage as this determines the number of days of vessel hire/use that are required. Vessel numbers and patterns of activity in an area (ie how concentrated fishing is in one area) will impact strongly on the percentage of total lost nets that are retrieved, and therefore the resulting benefits of a retrieval programme.

In addition, in deeper water the costs of retrieval programmes could be considerably greater given the need for larger vessels and increased power of retrieval hydraulics. For example, the DEEPNET team have recently costed a pilot retrieval programme for the deep water monkfish/shark fishery in the north east Atlantic at €130,000 (Table 18). This compares to the Norwegian retrieval programmes that are estimated to cost around €181,500 (Table 17).

[11] Hire costs in other countries may vary considerably depending on differences in vessels necessary, and basic differences in costs for similar items between countries;

Table 27 Quantitative costs and benefits of management measures (variables that could be quantified for preventative measures in grey shaded rows)

Retrieval programme / other management measures	With management measures in place		Notes
	Per vessel	Total fleet	
Benefits			
% of lost fleets found by retrieval programme	50%	50%	Only applicable to retrieval programmes. No nets assumed to be re-usable on recovery due to tangling/balling, but model able to be adapted to include a depreciated value of usable nets if required. Time after loss that gear is recovered affects both the value of the gear itself, and the ghost catches prevented for the remainder of the year. % of lost nets found with retrieval programme likely to depend greatly on the area of retrieval activity in relation to the areas fished in by vessels.
% of markers & floats reusable	75%	75%	
% of nets re-usable	0%	0%	
average age of markers & floats at recovery (months)	6	6	
depreciated value of markers & floats recovered	€ 563	€ 22,500	
average age of fleets at recovery (months)	6	6	
depreciated value of fleets recovered	€ 0	€ 0	
catch as % of active catch at time of retrieval	0.21	0.21	
ghost catch prevented (tonnes)	0.008	0.32	For retrieval programmes, ghost catch prevented based on average time after loss that nets are recovered and what their ghost catching ability would be for the remainder of the year. For preventative measures, would be calculated based on the reduction of ghost catches over a whole year which in turn would be dependent on what % of net loss was prevented. For both, only value-added prevented from non-quota species included.
lost value added prevented	€ 4	€ 164	
value of gear loss (and value of fish in gear at time of loss) prevented by preventative management measures	€ 0	€ 0	Not applicable to retrieval programmes, but could be costed under management programmes to reduce gear loss in first place, based on value of gear and % of net loss prevented
saved loss of leisure time spent looking for nets	€ 0	€ 0	Not applicable to retrieval programmes, but savings in leisure time could include reductions in time to purchase and rig new nets, as well as time spent not having to look for lost nets
saved loss of fishing time spent looking for nets	€ 0	€ 0	Not applicable to retrieval programmes
Total benefits	***€ 567***	***€ 22,664***	
Costs			
Planning retrieval		2,000	4 man days at €500/day
Vessel hire for retrieval		11,000	10 days at €1,100 per day, but very dependent on area to be covered
Retrieval gear development		30,000	2 man months over 2 years - need specific retrieval gear for different fisheries to be

Retrieval programme / other management measures	With management measures in place		Notes
	Per vessel	Total fleet	
			effective
Purchase of retrieval gear		1,000	
Evaluation of retrieval programme		2,500	5 man days at €500
Costs of other management measures eg better communication between fleet segments, better marking on gear, development of Codes of Practice, etc			Not applicable to retrieval programmes but could be costed
Management and enforcement costs of new regulations			
Total costs		***€ 46,500***	
Net Benefits/Costs (+ = benefit, - = cost)		**-€ 23,836**	
Benefit/cost Ratio		**0.49**	

The model shows that, using the input data assumed, a benefit/cost ratio of 0.49 is achieved with net costs of –€23,836. This demonstrates that the costs of the retrieval programme specified for the fishery as a whole (€46,500) outweigh the benefits (€22,664) for the fishery by more than a factor of two. Benefits per vessel of the retrieval programme would be limited to just over €500 per vessel.

While the model is based on estimated data, several tentative conclusions can nonetheless be drawn. It is apparent that by the time a retrieval programme is implemented, ghost nets may typically only be making very small ghost catches due to the rapid decline in catch rates over time. The benefits of preventing this ghost catch may therefore be minimal unless very large quantities of netting is being lost and/or nets are lost in deepwater with little current/tidal activity, thereby reducing the rate of decline in catch rates. This means that in the context of the overall costs of ghost fishing, retrieval programmes may only reduce these overall costs to society by small amounts. In addition, while not factored into the model, it is very likely that the benefits of retrieval programmes may be limited where nets are lost in areas of high trawl activity, as in such cases trawlers can be expected either to pick up, or ball up, a large proportion of lost nets resulting in reduced ghost fishing catches in comparison to active catches.

These factors support two main arguments:

- gear retrieval programmes may only be cost effective in a limited number of situations; and
- preventative measures are generally preferable to curative ones because, by preventing gear loss, they can prevent the potentially high costs associated with ghost catches immediately after gear loss from occurring in the first place. This conclusion is likely to be valid regardless of the accuracy of the data used in the model presented above, and even if a retrieval programme may itself result in a net benefit.

7.2.4 Sensitivity analysis

The model was tested for sensitivity to key variables to assess how the benefit/cost ratio might change with changes in these variables (Table 28). This is also useful to demonstrate how administrations might assess key variables in their assumptions when undertaking such a cost/benefit analysis. The results are presented below, and suggest that even with changes to individual variables of 50 per cent, the benefit/cost ratio fails to become positive ie greater than 1.

The final column in the table below shows the switching value for each variable. This is the value of the variable that would be required for the benefit/cost ratio to become positive ie for the benefits to outweigh the costs. The table shows that in all cases, variables would need to change significantly for the benefit/cost ratio to become positive.

The sensitivity analysis conducted on the model suggests that key variables to net benefit/cost calculations are likely to be the:

- number of vessels in the fishery;
- cost of the retrieval programme;
- number of nets lost;
- value of the gear lost; and
- percentage of lost nets that retrieval programmes are successfully able to find.

Less important appears to be the rate of decline of ghost catches over time, because retrieval programmes are always unlikely to prevent the high levels of ghost fishing immediately after fishing gear is lost, unless they take place very frequently.

Shaded rows in Table 28 indicate especially important variables for the resulting benefit/cost ratio in the model. It should be noted however that variables have been tested individually to assess their impacts on the benefit/cost ratio. In the case of vessel numbers, for example, an increase in vessel numbers would in reality be expected to result in a decline in the percentage of lost nets found given a constant retrieval programme size and hence cost. The vessel numbers may therefore be less important in driving the benefit/cost ratio than implied when changing only one variable at a time.

Table 28 Sensitivity analysis of cost/benefit model

Variable	Base case	Change to (50% change in variable)	Resulting benefit/cost ratio /1	Switching value /4
Base Case			*0.49*	
Vessel numbers	40	60	0.73	82
% of lost gear found	50%	75%	0.73	>100%
Vessel numbers % of lost gear found /2	40 50%	60 30%	0.51	N/a
Cost of retrieval programme	€46,500	€75,000	0.3	€22,664
Total ghost catch over one year by one fleet /3	3.65 tonnes	5.475 tonnes	0.52	10.7 tonnes
Ghost catch by lost fleet as a % of all active vessel fleets	5%	7.5%	0.52	14%
Number of days after net loss that daily ghost catches = 5% of active catches	90	133	0.52	262
Number of nets lost per year per vessel	1	1.5	0.73	2.1
Number of nets per fleet Fleets used	100 net panels/fleet 3 fleets	50 net panels/fleet 6 fleets	0.24	N/a
Cost of nets and markers/floats for one fleet	€9,500	€14,250	0.73	€19,475

Notes:
/1 a benefit/cost ratio of less than 1 indicates that benefits do not outweigh costs
/2 One would expect the percentage of lost gear found by retrieval programmes to fall with increasing numbers of vessels in the fishery, given the same numbers of days of retrieval activity
/3 ie change to a less rapid decline in ghost catches
/4 the value of the variable that would result in a positive benefit/cost ratio with all other variables remaining constant

7.3 Workshop findings on the appropriateness and prioritisation of management options

Discussion at the workshop generated some interesting recommendations about different management options for different fisheries. An overall conclusion, supporting the supposition in the text presented above and the FANTARED conclusions (section 3.7), is that prevention is almost certainly better and more cost effective than cure, but that a retrieval programme for the deep water fishery in the north-east Atlantic may be necessary/appropriate.

In addition, the recommendations of the workshop about the appropriateness of different management options implicitly incorporate the views of the participants about the costs/benefits of different management measures, given the perceived causes of ghost fishing, the specificity of the characteristics of different fisheries, and the resulting potential effectiveness of different management options in reducing ghost fishing. As a result, the outputs of the workshop Working Groups are presented in the following tables.

7.3.1 Baltic cod fisheries

Table 29 Appropriateness of different management measures for the Baltic

Management Option	Research Gaps	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Identification marking		High	Low – frequent changes in net type & mesh size makes marking problematic	Depend on mark	High	Low
Reporting losses	Cross checking reported net loss with gear sales. These correlated in Sweden but have not been checked elsewhere ie Denmark and Poland	High	Medium – illegally used nets are not reported lost	Requires GPS marking which everybody has	High	Medium
Acoustic detection systems	Technical development to make use practical	High (technical point of view)	High	Low – problems with shooting & hauling gear	Low (0) form a practical and economic perspective is unacceptable	High
Zoning schemes	Cooperative research and work between industry groups and other stakeholders to developing zooming schemes on a fishery by fishery basis	High – already used in Sweden. In Poland? Not in Denmark. Voluntary scheme highly preferred	High	Requires navigation systems (standard use)	Medium – voluntary zoning of some areas only preferred to maintain flexibility	Medium. Requires industry agreement, between Pos/companies/individuals
Biodegradable gear	Do not know? Development and application perhaps?	Medium – apparently attractive option		Questions over which parts of gear should be biodegradable	Unknown because it is a unknown option	

Management Option	Research Gaps	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Gear use limits length per individual fleet	Research on optimum length limits.	High	High	Marks , buoys	High	Medium - easy to control but control of total length a easier
Soak time limits		High	High	Marks , buoys	High	High – easy to control
Retrieval programmes		High	Medium	Special retrieval gear is needed to be effective, with industry participation.	high cost	Medium
Use of alternative gears	Relative impacts of alternatives	Medium	Medium – alternatives may be more damaging eg trawling, economically less viable or suitable only part of the year eg longlining	Requires extra investment	low - medium	High
Mandatory returning of trawl retrieved nets		High	High	Requires storage space on trawls and disposal	Medium – some reluctance among trawlers because of extra costs/time/space requirements/effort	Low

7.3.2 Western Channel fisheries

In the western Channel fishery Working Group, management measures were coded as having very (V), quite (Q), or low (L) relevance, effectiveness, etc

Table 30 Appropriateness of different management measures for the western Channel

Management Option	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Identification marking (Making Accountable)	V	Q	L	Q	V accountability
Reporting losses	V	V	L	V (combined with CoC)	Q (in conjunction with other measures)
Acoustic detection	L	L range limited	V	L	L
Zoning schemes	V	V reduced conflict	L	V esp. if voluntary	V
Biodegradable gear	L	Q	V	L lack of confidence in strength of gear, esp. mixing panels & poor calibration of degradability	Q
Gear use limits (carriage)	V	V	L	Q (in conjunction with gear tagging)	Q difficult to regulate at sea
Soak time limits	V	V	V	Variable with metier	L
Retrieval programmes	V	V	L	V	Q
Use of alternative gears (spatial schemes)	V	V	L	L conservative inertia	Q
Incentive schemes	V	V	Variable	V (need defining benefits)	V
Rigging options	Q	Q	L	Q	V
CoPs	V	Q	L	Q need consensus	L

Note: In the coding of management measures by this Working Group, 'relevance' was considered as being the sum of other columns ie overall appropriateness, rather than relevance to the particular characteristics/determinants of ghost fishing in the fishery.

The workshop report contains some further details of points raised and issues discussed (Appendix D). However, it is worth highlighting that in the western channel fishery there are several relevant developments such as a declining fleet and the remaining skippers being more professional and progressive. There are also good levels of communication and good practice. Ghost fishing is thus not perceived to be a major problem, and the management measures that were recommended as above are essentially suggested with a view to building on what is already in place.

7.3.3 Eastern Mediterranean net fisheries

In the eastern Mediterranean Working Group, participants first considered the appropriateness of different management measures, and then provided both a prioritisation of these measures based on a coding system[12], as well as some comment on the costs/benefits of different management tools as follows:

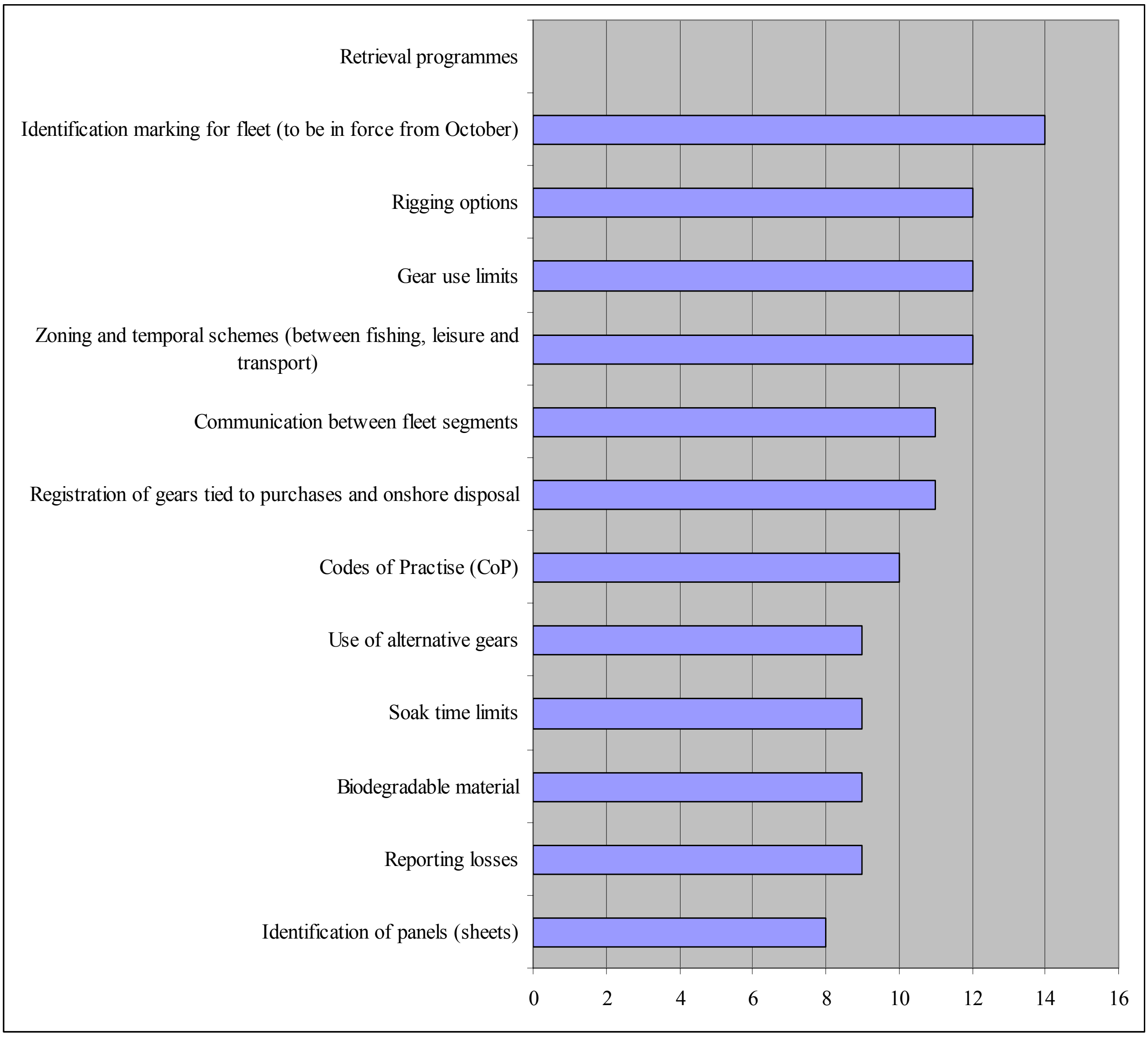
[12] High = 3 points, Medium = 2 points, and Low = 1 point

Table 31 Appropriateness of management measures for the eastern Mediterranean

Management Option	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Identification marking for fleet (to be in force from October)	High	High	None	High (any cost issues)	Not difficult, but general enforceability issues
Identification of panels	High	Low	Not viable because small fragments lost rather than whole nets and cant tag sheeting as opposed to head ropes. Need more research on cost effective methods	Low	Not difficult, but general enforceability issues
Reporting losses	High	Medium	Numbers of fleets lost can be obtained, harder to report fragment loss Difficulties for fishermen to mark lost location	Medium-Low	Difficult (unless allied to gear registration)
Zoning and temporal schemes (between fishing, leisure and transport)	High	High	Difficult to agree and mark areas without GPS	High if well and sensitively managed	Not difficult, but general enforceability issues
Biodegradable material	Medium	Medium	Technology to time degradability of gear so that same as active gear	Low unless same price and lifespan	Easy
Gear use limits	High	High	None	Low	General enforceability issues
Rigging options	High	High	Need to demonstrate benefits	Higher with professionals	Not difficult, but general enforceability issues
Soak time limits	Low (but may be medium for crawfish)	Low	No	Low	General enforceability issues

Management Option	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Codes of Practise (CoP)	High (esp. regional approach)	Low to medium	None	High	Low - difficult
Use of alternative gears	Depends on extent of problem and metier	-	Some to identify other effective metier in that area	Low	General enforceability issues
Retrieval programmes	Unknown as Do not yet know extent of problem	Unknown as Do not yet know extent of problem	Difficult to target retrieval areas	High	-
Registration of gears tied to purchases and onshore disposal	High	High	Maybe some IT and management issues	Low	Not difficult, but general enforceability issues
Communication between fleet segments	Medium	Medium	Large numbers of non-sector fishermen, and highly mobile trawl fleet – difficult to know how to contact them	Low unless funded	Not difficult

Table 32 Prioritisation of management measures for eastern Mediterranean



NB: Retrieval programmes were not scored as not thought appropriate given the lack of information currently available.

Table 33 Costs and benefits of management measures in the eastern Mediterranean

Management option	Score	Costs	Benefits
Identification marking for fleet (to be in force from October)	14	Marking tools;	Reduced conflicts and net loss;
Zoning and temporal schemes (between fishing, leisure and transport)	12	Consultation; GPS equipment; VMS/central control; patrol vessels/aircraft;	Highly reduced conflicts and net loss; reduced illegal fishing
Gear use limits	12	MCS costs; reduced income	Reduced risk of net loss; reduced illegal fishing
Rigging options	12	Trials & research; new rigging costs	Reduced risk of net loss
Registration of gears tied to purchases and onshore disposal	11	IT & registration costs; scheme administration; on-board storage; onshore disposal costs and administration	Prevents discarding at sea; better risk assessment;
Communication between fleet segments	11	Radio	Reduced conflicts and net loss; safety at sea
Codes of Practise (CoP)	10	Development and printing; cost to fishermen depends on implementation of other management measures;	Reduced conflicts and net loss; improved safety at sea; good image to consumers
Reporting losses	9	Lost fishing and leisure time; administration costs	Prevents discarding at sea; better risk assessment; improved location of lost gears
Biodegradable material	9	Material costs; increased gear loss (!); increased gear mending; some loss of income	Reduced ghost fishing; good consumer image;
Soak time limits	9	Reduced income; MCS costs;	Reduced risk of net loss; lower discard rates
Use of alternative gears	9	Research, investment costs; possible reduced income over transition	Reduced ghost fishing; good consumer image;
Identification of panels (sheets)	8	Marking tools;	Prevent discarding of nets and subsequent ghost fishing

7.3.4 *Deep water fisheries in the North East Atlantic*

The deep water fisheries Working Group made some general comments about management, as well as prioritising a few management measures. The DEEPNET report also contains information on management measures, which is also presented in Table 34.

General comments

There is a need for:

- more information;
- greater levels of inspection of vessels;
- regulations focussing on reducing effort, number of nets and soak time;
- a retrieval survey to identify problem and almost certainly prove that it is a problem;
- simulation of the loss of gear and the evolution of nets; and
- study into the effect of soak time; what should the optimal soak time be to reduce discards.

Prioritisation of management measures

- highest priority should be given to collecting information;
- technical regulations; and
- retrieval survey.

Table 34 Deep water fishery management measures

Recommendation	Positives	Negatives
The introduction of restrictions on the length of gear deployed at a given time either by overall length or per fleet of nets. Such restrictions were introduced in the northeast Atlantic drift net fisheries for Albacore tuna	Reduce fishing effort	Difficult to enforce and hard to monitor, although VMS does provide a level of control
The certification of fishing gear through labelling	Provide better information of fishing effort	Legal responsibility, problems with damaged or repaired gear and potentially easy to circumvent
A requirement that vessels cannot leave gear at sea whilst landing	Reduces discarding through extended soak times	Difficult to enforce and hard to monitor, although a combination of VMS and adequate marking of gear will provide a level of control
Mesh sizes for fixed gears in Region 3 to be harmonised with Region 1 and 2, in particular for hake and monkfish	Stop the use of small mesh sizes in Region 1 and 2	None

Recommendation	Positives	Negatives
All gears to be marked clearly at either end	Reduce the amount of lost gear and also reduce hazard to other fishing vessels	Difficult to enforce and original EU proposals were too complex to be enforceable
The introduction of measures, which stop the practice of stripping the headline and leadline of nets and dumping of used netting at sea	Reduce the dumping of nets at sea	Difficult to enforce and potentially could have the opposite effect
The spatial management of effort by gear sector, separating towed and static fishing gears	A proven method of reducing the amount of gear conflict and net loss	Probably difficult to administer and enforce in offshore areas and international waters.
Closed areas to protect ecologically sensitive habitats, such as hydrothermal vents, deepwater corals or other characteristic habitats eg seamounts	Reduce the amount of lost gear and protect sensitive habitats	Difficult to monitor and enforce if areas are too small but VMS will allow monitoring of bigger areas. Widespread objection from other sectors of the industry

Source: Hareide *at al*. (2005)

8 Conclusions and recommendations relating to a work programme for future management and research action

This final section considers some generic requirements of a work programme for future management and research action, as well as some of the key specific requirements of the four fisheries examined in detail as part of this study. The reader is referred to section 5 for a justification of the fisheries selected, and section 7.3 for more detailed information and prioritisation of management measures.

While the focus of this project is on the EU, and so the recommendations are directed as such, the work drew on international research and management experience. Many of the conclusions and recommendations are therefore applicable to countries beyond the EU.

8.1 Extent of ghost fishing

- Each fishery is very different and should be judged on its own merit. The causes and extent of net loss varies considerably.
- Perhaps of over-riding importance is that a key finding of both the literature review and workshop is that the deep water gillnet fisheries targeting deep water shark and monkfish almost certainly represent a problem that is of a greater scale than all other net fisheries in European waters. As well as posing problems in this fishery, the practices pose a threat to the reputation of all other gillnet fisheries. Ghost fishing in other fisheries considered during the study is of far less concern, and it is important that they are not tarred with the same brush as the deep water fisheries. However, even in these fisheries some ghost fishing may occur, and therefore future management and research actions may also be appropriate, although less pressing.
- Baltic fisheries are of some concern, although the situation seems to be both area-specific and improving for a number of reasons. Some mitigation measures are in place, especially in Sweden and Denmark.
- The extent of gear loss and ghost fishing is unknown in the eastern Mediterranean. Ghost fishing probably occurs at a low level but may be an issue due to the large numbers of fishermen involved.
- Levels of gear loss in the Channel fisheries are not thought to be significant, due to the high degree of communication, gear value, industry awareness and the relatively small numbers of vessels involved.
- The impact of ghost fishing has to be taken in the context of overall catches and the environmental impacts of other (active and passive) gear, and when compared to the environmental impacts of active gear are probably minimal.
- The fate of lost gear varies under different conditions – FANTARED showed that gears in shallower dynamic conditions tend to stop fishing earlier sometimes after just a few months, while gear lost/discarded in deep water with little tidal/current activity can continue to fish for years rather than months. In all cases however, the catching efficiency of lost nets decreases rapidly at first, with the rate of decline in catching efficiency decreasing over time.

8.2 Management options

- The lack of perfect knowledge about ghost fishing should not be taken as a reason for inaction – a wide range of management initiatives could be undertaken immediately at relatively low cost.

- The prioritisation of management options at the workshop was very different between fisheries – serving to emphasize that different approaches are essential at regional or fisheries-specific levels. The ranking of management options as presented in section 7.3 provides direction for future management action in the fisheries considered as part of this study.
- Management priorities should focus on preventing loss of nets in the first place, with Codes of Practice, zoning and good communication all useful tools as demonstrated by the western Channel fisheries.
- Specific steps need to be developed specifically for deep water fisheries, both in EU and international waters. These include enforcing existing laws and developing new measures.
- Towed gears are a major source of gear loss in some fisheries, so measures to reduce conflict are especially important.

8.3 Retrieval programmes

- While gear retrieval programmes may be considered necessary where there is a high concentration of lost nets, as a curative management measure, preventative measures should take priority. At the least, gear retrieval programmes should be used in conjunction with preventative measures.
- Only small areas of fishing ground can be covered in retrieval campaigns so very precise information on the location of lost gears is essential – requiring, in turn, accurate reporting of gear losses by fishermen.
- Self-retrieval by fishermen immediately after loss is preferable to government-organised retrieval programmes.
- Government-organised retrieval programmes may be more appropriate (and essential for continuation of the fishery) for deeper fisheries where the risk of gear loss may be unavoidable.
- The relative costs and benefits of retrieval programmes should be evaluated before taking a decision to deploy them.
- Key variables to net benefits/costs of retrieval programmes are likely to be the number of vessels in the fishery, the cost of the retrieval programme, the number of nets lost, the value of the gear lost, and the percentage of lost nets that retrieval programmes are successfully able to find. Less important appears to be the rate of decline of ghost catches over time, because retrieval programmes are always unlikely to prevent the high levels of ghost fishing immediately after fishing gear is lost, unless they take place very frequently.
- Retrieval programmes may have wider benefits in terms of reducing consumer concern and the negative impacts on other gears.
- The environmental impacts of gear retrieval techniques need to be considered, especially in sensitive habitats. Good location information is essential to improve efficiency and therefore reduce impacts.
- Net retrieval programmes may be less necessary in areas of high trawl activity, where nets are picked up over time, providing nets are landed ashore.
- Because only small areas of fishing ground can be covered, retrieval programmes are not considered a reliable research tool to estimate gear loss.

8.4 Key environmental issues

Lost fishing gear may impact on the environment in a large number of different ways, including:

- continued catching of target species;

- capture of non-target fish and shellfish;
- entanglement of sea turtles, marine mammals and sea birds in lost nets and debris;
- ingestion of gear-related litter by marine fauna;
- physical impact of gears on the benthic environment; and
- the ultimate fate of lost gear in the marine environment with particulate matter being introduced to the food chain.

When comparing static gear with mobile gears, mobile gear has much higher impacts in terms of non-target species catch and discards, as well as habitat and biodiversity damage. Actively fishing static gears tend to be very selective and have negligible habitat impacts, although they may occasionally incur incidental catch of marine mammals in certain situations. Once control of these nets is lost, the potential for habitat damage is more likely, but still not considered profound nor extensive. There is however increased potential for entanglement of marine mammals and sea birds as net fragments are washed inshore.

8.5 Key research areas

A number of research areas have been highlighted in this report, and generally relate to both individual Member States and the EU as a whole. They include:

- rates of gear loss. In most fisheries knowledge is limited while in others no research has been conducted at all (eg Greece where more than 16,000 vessels are engaged in net fisheries);
- ghost fishing mortality. The costs and practical difficulties of underwater survey work and of simulating ghost catches through experiments means that estimates of ghost catch rates are imprecise;
- biological environmental impacts in European waters. In almost all cases, a direct, absolute measure of the extent to which entanglement occurs or affects species at the population level does not exist;
- the above factors combined means there are no overall estimates of the extent of the ghost fishing problem for the EU as a whole;
- incidence and aesthetic impact of ghost fishing nets as a source of marine litter;
- the ultimate fate and impact of lost gear ie particulate matter;
- the impact, feasibility and costs/benefits of different management measures, tailored to particular fisheries;
- economic valuation of net loss and ghost fishing impacts;
- the environmental impacts of management responses, notably gear retrieval programmes, have not been quantified
- specification of Codes of Practice for minimising gear loss in particular fisheries; and
- some technical issues related to different management measures eg marking of gear.

8.6 Headline messages

In closing, and so attempting to summarise the project outputs, several key messages from the study are:

- There remain significant gaps in knowledge about ghost fishing in EU waters. Priority research areas include a) quantifying the amounts of lost gear; b) assessing the extent to which lost nets continue to catch fish; c) assessing those fisheries for which there is virtually no information; d) estimating total ghost fishing catches in the EU; e) assessing the different types of environmental impacts of ghost fishing and management responses; and f) collecting economic data on ghost fishing and management responses.

- With the proviso about existing knowledge being imperfect, ghost fishing in set-net fisheries in the EU is probably not a significant problem, either in terms of its total impact, or its environmental impact in comparison with 'active' fishing methods such as trawling.

- However, net fisheries in the EU are each very different and should therefore be judged individually. In deep water fisheries conditions are more conducive to net loss, and there is strong evidence of net dumping and significant levels of ghost fishing in the deep water north east Atlantic fishery for shark and monkfish. The problem of ghost fishing in this fishery appears to be of a different order of magnitude compared to other fisheries in the EU, and as such warrants immediate action and research by the EU, Member States and the industry involved.

- Appropriate management responses are likely to be variable for different fisheries, as are the research gaps, but prevention (ie Codes of Practices, improved communication between active and passive gear users) is almost certainly better than cure (retrieval programmes). Management responses should be better justified on the basis of the relative costs and benefits of different management options.

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Appendix B Literature review methodology and sources of information

A literature and web search was undertaken to identify the key scientific literature available on the ghost fishing as well as the major research institutions that have worked on the issue. The literature review also identified key fisheries of interest for the study.

The review covered the identification of reasons for gear losses, the evolution of lost fishing gear and the evaluation of the environmental impacts of lost gear. Its also focused on identifying gaps in the research already done and in presenting a list of monitoring and retrieving programmes and any data resulting from them. Both EU Member States and those outside were considered.

Information was generated from a wide variety of sources. These included:

- databases of journal abstracts (eg Agricola 1992-2001/2, CAB International Abstracts 1992-2002, Econlit 1969-2002, Sociological Abstract 1986-2001/2, Aquatic Science and Fisheries Abstracts 1992-2002, Aquatic Biology, Aquaculture and Fisheries Resources Abstracts 1992-2002);
- individual requests made to staff at research institutions known to the consultants; and
- the Internet using search engines such as Google.

The search strategy for all journal databases and website searches was based on the following key words:

- ghost fishing;
- unintended fishing;
- lost fishing gear;
- pot loss;
- pot retrieval;
- net loss;
- net retrieval;
- trap loss;
- trap retrieval;
- unintended fishing;
- phantom fishing;
- discarded fishing gear;
- abandoned gear;
- gear retrieval;
- gear identification
- gear recovery;
- redes fantasmas;
- reti fanstama;
- mortalité halieutique fantôme;
- pêche fantôme; and
- FANTARED.

Individuals and institutions involved in key research were also contacted directly by telephone and email about their work.

Appendix C Survey questionnaires and methodology

Step 3 of the study methodology entailed conducting primary research into the selected fisheries through surveys:

1. Baltic cod net fishery of Sweden and Denmark;
2. net fisheries of Greece;
3. English and French net fishery in the western English channel; and
4. the deep water net fisheries of the north east Atlantic.

The purpose was to fill information gaps identified during the literature review and to generate data for both the workshop and the cost benefit analysis. Because of the varying degrees of information already available on these fisheries and the incidence of lost nets and ghost fishing in each case, the follow up research undertaken for each one differed. In the case of the Greek fisheries, no research had been undertaken on lost nets before. The Baltic and English Channel survey however built upon the work done under FANTARED. Although there are still information gaps, the deep water fisheries have been studied in greater depth and the data available was sufficient to permit some analysis of the feasibility of a gear retrieval programme. There was also some sensitivity surrounding the fishery with the release and subsequent press coverage around the DEEPNET report (Hareide *et al*., 2005). Coupled with interview fatigue amongst those participating in the fishery and the relationships being developed by the DEEPNET team, a further survey was not conducted in this fishery.

Questions were developed and translated into a Microsoft Access database. Questions were asked relating specifically to each gear type being used. As illustrated below, these included the technical and cost specifications of gears used, catch rates and compositions, loss rates and causes and recovery rates and factors. More generic information was also asked in relation to reducing gear loss.

The questionnaire was piloted and modifications to the questionnaire design made where necessary. It was then rolled out in the selected fisheries. Thirty fishermen was the target number of interviews for each fishery, split between countries in the Baltic and Channel fisheries. In some cases however this was not possible because of reluctance on behalf of interviewees and fishermen been out at sea for long periods of time. While not desirable, this was not considered a significant problem as very similar findings were generated after several interviews:

Fishery	Countries surveyed[13]	Number of Interviews
Baltic cod net fishery	Sweden	11
	Denmark	15
Greek net fishery	Greece	27
Western English Channel net fishery	England	5
	France	18
North east Atlantic deep water net fisheries	None	0
Total		***76***

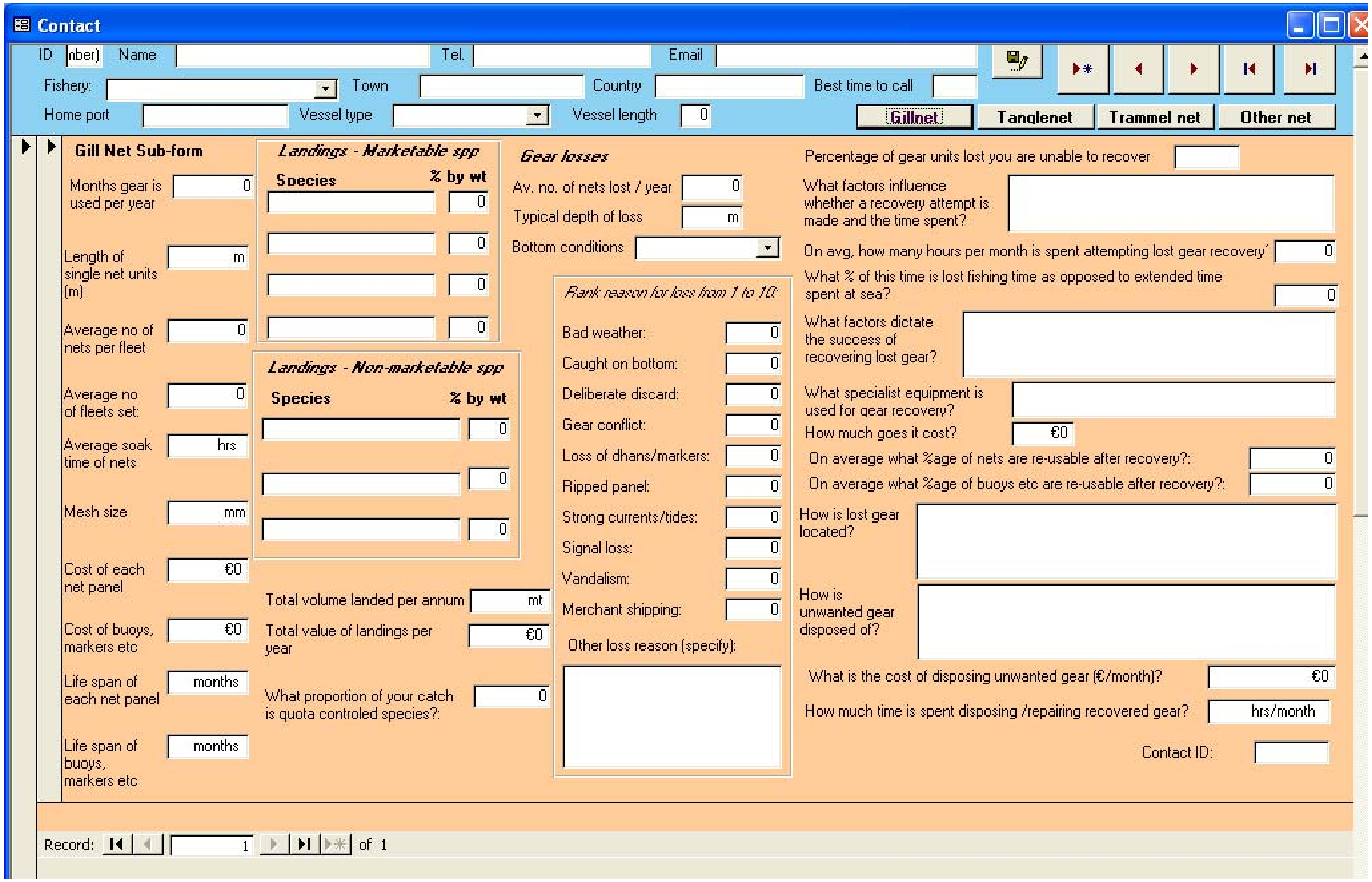
Fishermen were identified in different ways, depending on the fishery. In Sweden the industry has been actively working with government researchers on the issue of lost nets. Cooperative individuals were therefore identified by the National Board of Fisheries. In Denmark no work had been done on gear loss or retrieval. Interviewees were therefore randomly selected. This was also the case in

[13] Interviews completed by IEEP (Sweden), Carsten Krog (consultant - Denmark), HCL (Greece), Poseidon (England), and Oceanic Development (France)

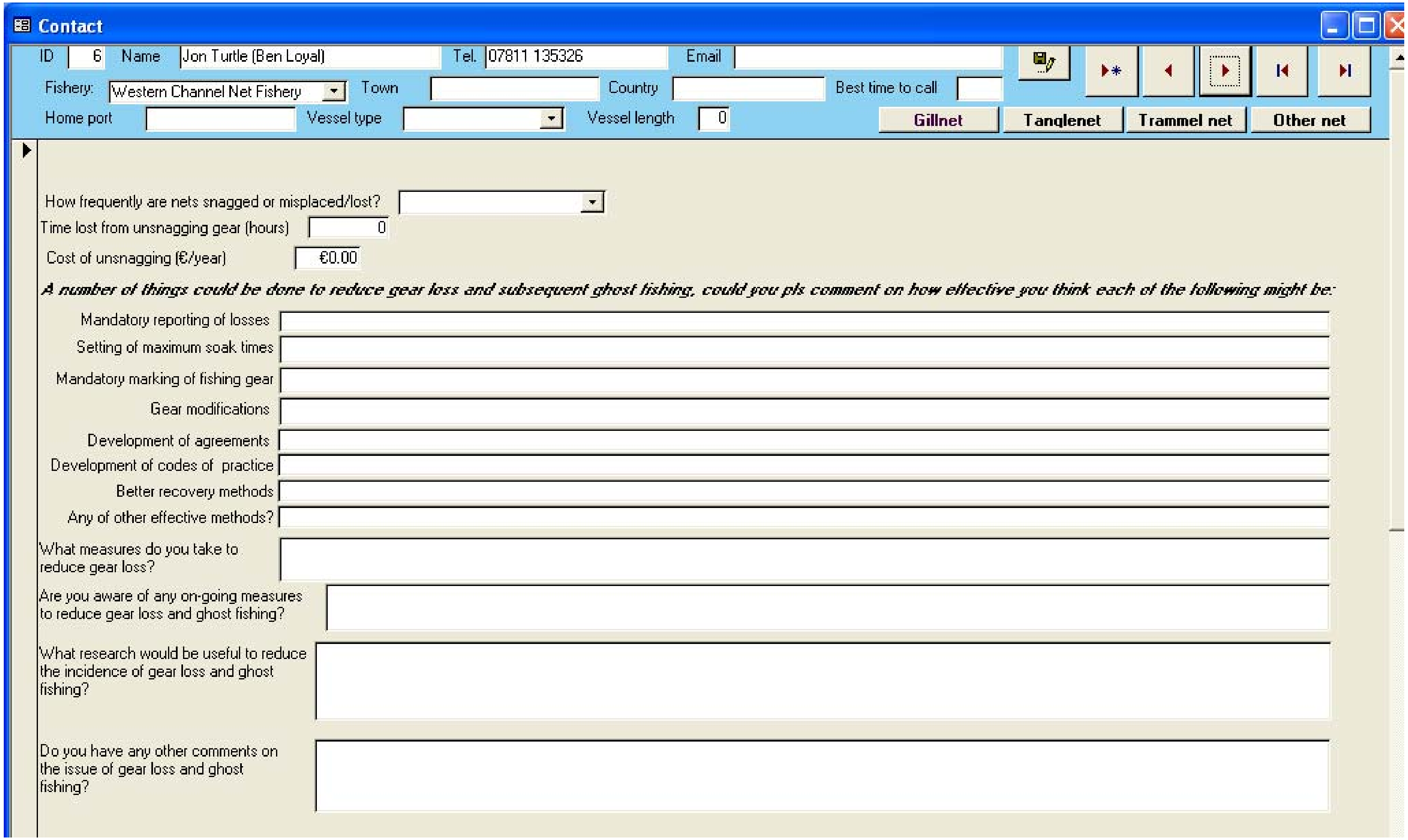
England and France, although efforts were made to select cooperative fishermen and those that had been involved in the FANTARED work previously.

Fishermen from the Baltic and Channel fisheries were interviewed by telephone as the interviewers had good contacts that were willing to cooperate. Because of difficulties in locating Greek fishermen, interviews were conducted at the portside, with interviewees randomly selected within this context.

Form A: Gear Specific Information (separate sub-forms for gillnets, tangle nets, trammel nets and other nets)



Form B: Generic Information



Contact

ID 6 Name Jon Turtle (Ben Loyal) Tel. 07811 135326 Email

Fishery: Western Channel Net Fishery Town Country Best time to call

Home port Vessel type Vessel length 0

Gillnet Tanglenet Trammel net Other net

How frequently are nets snagged or misplaced/lost?

Time lost from unsnagging gear (hours) 0

Cost of unsnagging (€/year) €0.00

A number of things could be done to reduce gear loss and subsequent ghost fishing, could you pls comment on how effective you think each of the following might be:

Mandatory reporting of losses

Setting of maximum soak times

Mandatory marking of fishing gear

Gear modifications

Development of agreements

Development of codes of practice

Better recovery methods

Any of other effective methods?

What measures do you take to reduce gear loss?

Are you aware of any on-going measures to reduce gear loss and ghost fishing?

What research would be useful to reduce the incidence of gear loss and ghost fishing?

Do you have any other comments on the issue of gear loss and ghost fishing?

Appendix D Workshop report

Introduction

This Workshop Report documents the discussions held over the course of a two day consultation workshop on 10-11 May 2005 held in Brussels. It was part of a six month, European Commission funded, 'Ghost Fishing by Lost Fishing Gear' project.

The workshop was attended by some key institutional figures and fishermen from selected European fisheries (Annex I). The main purpose/objectives of the workshop were to provide:

- a review of work on ghost fishing to date;
- a review of the survey work completed under the current project;
- identification of research gaps, particular on management measures;
- prioritisation of management measures in different fisheries; and
- input to the cost/benefit analysis of gear retrieval programmes and other management measures.

The wider project is intended to assist the European Commission in determining how to take forward its commitments on addressing ghost fishing. The terms of reference for the project are as follows:

- to compile all existing information and studies on monitoring the evolution of lost fishing gear, with particular emphasis on gillnets;
- to identify research gaps, particularly on the means to prevent gear loss and to improve their retrieval, in commercial fishing gears;
- to summarize existing knowledge on the environmental impact of lost gear and how this compares with the environmental impact of active commercial fisheries;
- to explore and summarise the estimated amount of gears lost and their catching efficiency within local fishing grounds;
- to assess the costs and benefits of a possible wide-ranged programme of retrieval of lost gear; and
- to draw-up a work programme for future management and research action.

This project builds upon previous initiatives, in particular the EU wide projects called FANTARED and FANTARED 2 (EC Project Nº 94/095: incidental impact of gill-nets; EC contract FAIR-PL98-4338, A study to identify, quantify and ameliorate the impacts of static gear lost at sea) that examined the impact of lost gill-nets in different fisheries. This past work focused on the incidence of net loss and the biological impacts as well as some management options. A key difference with this work is therefore the consideration of environmental impacts, the economic cost/benefits analysis of gear retrieval programmes and drawing up of a work programme for future management and research.

The contents of the report reflect that fact that much of the discussions focused on commenting on a draft project report. As such the comments are not always fully elaborated but are in note form and should be considered within this wider context.

Day 1: Tuesday 10 May 2005

Opening Session

James Brown of the Institute for European Environmental Policy (IEEP) welcomed the workshop participants (see Annex I Workshop Participants) on behalf of IEEP and Poseidon. He thanked everyone for coming, the European Commission for funding the project, and the Centre for providing conference facilities. After some housekeeping announcements and a process of round table introductions, a brief overview of ghost fishing was provided along with some background on the project. Key differences between this project and previous work were highlighted, namely the focus on wider environmental impacts, and the costs/benefits of different management measures. The main purpose/objectives of the workshop were discussed and included:

- a review of work on ghost fishing to date;
- a review of the survey work completed under the current project;
- identification of research gaps, particular on management measures;
- prioritisation of management measures in different fisheries; and
- input to the cost/benefit analysis of gear retrieval programmes and other management measures.

Session 1: Review of the economic, social and environmental impacts of ghost fishing and experience in retrieval programmes

This session was divided into a number of short presentations on the following issues:

Work done to date

Key points made included:

- some work has been going on since the 1960's. Fantared represents a key piece of work, and was different from previous work in that it was a more systematic approach. It was also intended to examine the vivid and rather un-scientific information on static gear fisheries using gear deployment observation, interviews, seabed surveys, divers, ROVs, sonar, and 'creepers';
- key reasons for loss were gear conflicts, depth of fishing and the type of gear deployed;
- outcomes were that: for nets in bad weather or strong tides or that were trawled, they rolled up or were bio-fouled rather fast; drop off in fishing performance was rapid with the same pattern in most fisheries; in inshore waters most nets were lost in the autumn and quickly affected by bad winter weather; longer periods of ghost fishing were possible in enclosed areas; most serious problems were found in deep water with low energy and multiple gear use;
- a final workshop of the Fantared project derived a code of practice. Recommendations included: fishermen's associations should adopt a code; a special meeting of Baltic Sea Fisheries Commission was held and to set up a forum to discuss issues raised by deep water fisheries; and
- the deep water fishery off the west coast of the UK is not well covered. The DEEPNET project is intended to provide data on the fishery – little is known and there is much misreporting. What is known is that about 30 vessels are involved, vessels are fishing 200-1200m, and catch composition is such that sharks are a target species in over 800m, and monkfish are target species in upper slope fishery. Some information is also known on the spatial distribution of activities from VMS records. One gillnet fleet may be as much as 25km. One vessel may use 150-250km at one time, and may only haul nets every 1-3 weeks so discard rates are 60 per cent of monkfish. There is little communication between trawlers

and netters. Little is known about the economics of the fishery. The project is not just focussing on ghost fishing, but on wider sustainable fisheries issues.

Results of the literature review

Key points made included the fact that FANTARED represents the most comprehensive study globally, but other work has been ongoing. General conclusions are that net loss is rather low, but that there are research gaps on: total number of nets lost; total ghost mortality (as studies to date are often unrepresentative in terms of gear observations); and new Member State issues. For pots and other gears, research gaps are similar, but ghost fishing by pots, bottom trawls, longlines, etc., are not thought to represent a problem. In terms of broad research gaps: work so far is rather biological in nature and there is little economic quantification of either ghost fishing or management options; little is known about whether animal entanglement takes place in controlled passive gear, or in lost ghost gear.

Results of the project survey

Key points made included: socio economic impacts were the focus of the follow up research in the four key fisheries. Qualitative results were presented, with more quantitative analysis to be conducted as part of the cost benefit analysis. The results largely confirmed the FANTARED conclusions. In the Baltic net loss was a declining issue because of a reduced illegal fishery, mandatory gear marking and the use the GPS. Improved communications was identified as a potential way of further reducing gear loss. In Greece, net loss was also generally low. Snagging of nets is common, but typically results in tearing of fragments rather than loss of panels. An interesting point consistently raised was, that dolphin interaction is high because of increased populations in the area. Because of low net loss, ideas on management options were not forthcoming. Net loss in the Channel was again quite low. However, the main cause was weather and snagging rather than gear conflict because of good communications between fleet segments and countries. In France, spatial management of activities was well organised, minimising gear conflict.

Economic and socio-economic aspects of ghost fishing

A brief introduction was made to some of the costs of ghost fishing that will be considered later in the project, and which would be explained later in the workshop.

Environmental impact of ghost fishing

Key points made included: impacts include the impact on target species themselves, as well as non-target species more broadly, including benthic impacts. The pattern of impact is similar in all cases. Catching efficiency/impacts decline over time as biofouling comes into play. Impacts in comparison with controlled gear and more active gear appears to be negligible. Entanglement is the main cause of mortality resulting from lost gear. Data is incomplete however.

Experiences in retrieval programmes

Key points made included: given the Commission's interest in retrieval programmes, it is important for us to consider the various forms and the associated issues. There are various forms of retrieval gear used, all of which are rather crude in their design. In terms of effectiveness, accurate location is paramount because only small areas can be covered at a time. This requires cooperation with industry. On the whole programmes are inefficient and costly, and do not prevent the economic losses to fishermen.

Comments

A number of comments were made on the above presentations.

- codes of practice may not be 'wanted' by industry but may be useful to demonstrate to the public that fishing is being conducted responsibly. Related to this is that economic costs may include costs to industry if consumers change behaviour if they perceive ghost fishing as an issue;
- deep water fisheries of the Mediterranean have not been considered before;
- the gear retrieved in Hawaii is often lost trawls and purse seines, which are used as FADs;
- parlour pots may be an increasing problem in Europe because of their efficiency of retaining crabs;
- impact of lost gear once it has broken down into particulate matter needs considering because no one knows the impact of bioaccumulation;
- the validity of the results could be questioned: were respondents honest and reliable? The report should be more explicit about potential survey problems. Have questions been asked about how much gear fishermen buy each year, and how much the lose;
- loss rates in Greece may be low but because of high vessel numbers, total loss may be high. Contrary to survey findings, there is gear conflict in some fisheries/areas. In some cases it is believed that some nets are dumped when they reach the end of their life. Dolphins, seals and turtles are also creating increasing problems for inshore fishermen, damaging nets and potentially becoming entangled. How much of an issue they are for ghost fishing is not clear. The low interview numbers are not representative and the fisheries are highly variable;
- the incidence of net loss may vary by operator type. In particular, professional versus recreation fishermen. Difficulty of doing research with part-time or unregistered fishermen; and
- it is important to consider the impact of lost gear as a source of marine litter/debris divided into impacts at sea and onshore.

Session 2: Development of Working Groups and Agenda

Group Discussion Topics

The study team presented their thoughts about how the breakout groups might work, and what was intended in terms of the outputs of the discussion groups might be. It was explained that 4 working groups would be established based on the four fisheries selected for detailed investigation under review. The framework of the outputs of each group was presented and working groups were requested to:

- review the literature review and comment on any missed references not included;
- review of the survey results;
- management measures and their relevance, effectiveness, technical issues, and acceptability to the industry. It was agreed that it would be necessary to take ghost fishing in the context of overall management problems in that fishery, and drivers of fishery; and
- research needs for management needs/measures.

Agreement of Working Groups, Agendas and Process

Agreement was reached on the membership of the Working Groups (see Annex I Workshop Participants), the detailed agendas and the processes to be used.

Session 3: Day 1 Group Discussions

Generic Points

Literature review:

Need to aggregate different fisheries by environmental factors. Need to divide fisheries into four main aggregates instead of the 15 or so.

Three Norwegian studies on trying different technical devices to recover nets, (ii) gear physical aspect and (iii) gear evolution.

Otherwise no other literature.

Briefing document:

Definition of ghost fishing could be debated to be expanded beyond gear that is out of control. But if a net is left for 2-3 weeks it may be considered ghost fishing and its impact greater. Maybe include mortality of fish that is unaccounted (unaccounted mortality) when the gear is retrieved. Could have implications for limiting soak time for each metier.

The greatest cost of ghost fishing may be the loss of reputation of the fishery. This needs to be included in the cost/benefit analysis of retrieval programmes.

Management options:

Identification: useful for both identifying your own gear as well as determining who has lost nets.

Reporting losses will not happen. But will only report loss of nets if trawled over and compensation is possible. Difficult to enforce.

Acoustic detection: has been discussed for many years but no good solutions. Still trying to come up with a cheap technical solution. Deep water makes signal loss a real issue. Up to 2000-3000 m.

Zoning: tried off Rockall, so would be effective. No technical issues. Fishermen would not accept but would be easily enforced.

Biodegradable gear: loss of control over strength of gear is a major inhibitor. Maybe use if zinc couplings that are easier to predict and measure. But expensive.

Gear limitations are essential and most important of this fishery. Is enforceable to a certain degree and supported by VMS gear (but not usable in law). Doubts over whether VMS can detect gillnet shots (no increase in exhaust temperature or boat speed).

Soak time limits: essential to reduce soak time and to stop excessive discard. No technical issues but would not be acceptable. VMS data might be usable but would need detailed analysis of the fishery.

Codes of practice: does not work in this fishery. Crisis has been so major that fishers do not cooperate.

Retrieval: is worth conducting on an annual basis, both in determining level of gear loss and to reduce ghost fishing. Also helps setting of anchors for other fishers.

Other gears: maybe trawls (own environmental issues) but long lines are not possible, as target species is changing to crabs.

Attending gear: many vessels come ashore with no net sheeting left on board. Needs to be stopped immediately.

Communication: does not work at this stage. Need to use VMS.

Review of management research needs

See own paper.

Baltic Working Group

A. Review of Literature

section 2 is basically OK. No particular comments except:

- major omission of nets supplied with registered lost and crosschecking. Only relevant to the Swedish fisheries. Needs to be extended to other States in the Baltic and the rest of Europe. Cross-correlation of sales and losses;
- section 5: lost nets forming artificial reefs attracting invertebrates as well as other fishes, amongst which are young cod. Mortality implications are unknown;
- no real documentation about communication between different métiers as well as between different regions operating the same gears, especially over ghost fishing issues;
- section 3: Doubts over the view about the Danish fishermen claiming limited damage to the retrieved nets – Swedish fishermen consider gears in poorer condition;
- limit of 48 hour soak time already introduced in the Baltic; and
- general observation is that attention should be made to improving cooperation over gear conflicts as well as experiences in gear loss etc., as well as solutions.

B. Review and comment on survey findings

No comments.

C. Appropriateness of Management Options

See Annex III.

D. Review of Management Research Needs

No Comments.

Western Channel Fisheries

A. Review of Literature

- were not clear on why the Channel fisheries was chosen. Also worried about Table 12, with wrong references. Bottom p 33 (S NS mentions Pilgrim etc);
- needs to be better information on information sources as well as caveats on sample sizes etc. eg gear loss rates in the Mediterranean <1 per cent;
- cod net fisheries in Baltic – very limited research gaps;
- section 3.2.3: Did not believe everything said especially number of lost nets. Maybe nets were lost in spring and recovered in autumn, so there was ghost fishing mortality;
- part-timers maybe unfairly blamed – what is the level of part-time netting?;
- codes of practise are a small price to pay and are maybe a necessary framework for fishers;
- all English /French channel fisheries/métiers are lumped together. Not so, needs to be disaggregated. Do not be so categorical! and

- need to balance loss from ghost fishing vs trawl.

B. Review and comment on survey findings

No comments.

C. Appropriateness of Management Options

See Annex III

D. Review of management research needs

No comments.

D. Review of management research needs

Mediterranean Coastal Gillnet Fisheries

A. Review of Literature

- spell check on FANTARED. In western Mediterranean Fantared 2 focus on gillnet hake (100-200m) and trammel crawfish/spiny lobster (200m);
- east Mediterranean not included in Fantared. SELMED HCMR project on static gear in Mediterranean (not specifically on ghost fishing);
- university of Pisa study on shallow waters. Claudio Viva (not specifically on ghost fishing).
- George Petrakis HCMR. On red sea bream and hake in 'deeper' (on drop-off 200-800m) Mediterranean waters (not specifically on ghost fishing);
- FAO Study on impact of fishing gear on the environment in the Mediterranean (FAO/RAC-SPA);
- compilation of biological studies for European Commission (check);
- check referencing in Bibliography;
- workshop to define small-scale fishing metier – then focus on metier with greatest catches and do research study on extent of ghost fishing; and
- traps – while ghost fishing not an issues impacts on other gears (stuck on other gears), aesthetic impacts for divers, safety of divers.

B. Review and comment on survey findings

- stress unrepresentative sample;
- fishery very variable in area – metier – targeting different species…this is typical of small-scale fisheries in other areas of the Mediterranean;
- important to differentiate full-time and part-time/recreational fishery;
- there are some mobile gear interactions;
- importance of very large vessel numbers;
- important to find out more on the amounts of net fragments snagged, and what might happen to them in terms of their evolution;
- there is evidence of deliberatively discarded gear. In some areas of central Greece there is discarding of nephrops nets in trammel net fishery (10-50m). Evidence but not quantified;
- many of smaller vessels no VHF…need to differentiate between vessel size;
- dolphins, seals and turtles feeding on catch in net, but not thought to be caught themselves. Dolphins can follow vessels to nets; and
- costs of onshore disposal may be limited, but need dedicated onshore responsibility to ensure there isn't littering on land.

C. Appropriateness of management options

The drivers of ghost fishing that need to be dealt with through management measures:

- interactions with other marine users (intentional and unintentional) and deliberate discarding (thought to be primary drivers). Discarding because damaged. Damage due to both general snagging and dolphin (and other animal) interactions;
- extent of full- or part-time fishing – part-time may be more susceptible to losing gear;
- weather November to February can be a driver of gear loss;
- deliberate long soak times to mark fishing grounds for trammel sole;
- long soak time for trammel crawfish; and
- depth of fishing for red seabream.

The appropriateness of different management options were then discussed and described in Annex III.

D. Review of management research needs

- start with basics on extent of problem as basically know nothing (reasons for loss, evolution of nets/traps, key métiers resulting ghost fishing, quantification of loss, economic/social impacts);
- research on the impact of lost gears in Mediterranean environmental conditions;
- research on the impact of retrieving gears in terms of (i) creeping impacts and (ii) removing concreted gears;
- some research areas associated with technical problems in table above; and
- Ecosystem approach to development of fisheries management mechanisms appropriate to solving ghost fishing.

Comments on retrieval programmes in the Mediterranean and Southern Europe

- different methods depending in when the gears were lost and the management mechanisms in place eg whether they have buoys attached;
- some gears may be best left *in situ* as would be more damaging to remove – but needs some research; and
- gear retrieval may not be appropriate as only small fragments are lost, not whole nets and fleets.

Deep water Gillnet Fisheries

A. Review of Literature

- there is little deep water literature to be reviewed. The briefing paper covers most of the existing literature;
- there are three Norwegian studies on 'Technical devices to recover lost gear', on 'Gear physical characteristics' and 'Gear evolution'; and
- additionally there is a study on 'Norwegian retrieval – annual reports 1983 to 2003' (only available in Norwegian).

B. Review and comment on survey findings

It is quite difficult to get any information of this fishery.

- the DEEPNET report describes the fishery and its main problems;
- DEEPNET report was based mainly on indirect sources of information;
    - 2 gillnet skippers
    - 7 long-line skippers
    - 8 trawl skippers
    - 1 agent
    - 2 net makers
    - 3 PO managers
    - 8 UK harbour masters an port authorities
    - 1 Irish fisheries officer
- an accurate survey would need direct input from skippers and/or observers;
- additional accurate information is vital to address the real problems and to assess the status of the stocks;
- there is evidence in this fishery of deliberate ghost-fishing through extended soak time; and
- the characteristics of this fleet are:
    - this deep water/offshore;
    - large vessels;
    - economically motivated; and
    - large by-catch and discards.

C. Appropriateness of management options

See Annex III.

D. Review of management research needs

This fishery was not covered by FANTARED project. Significant need for additional research:

- basic fisheries data (catch composition, discards, effort, landings by species);
- evaluation on volume of net loss;
- evolution of lost nets – data from Norway is in cold water, which may be different to warmer waters;
- decay rate of catches (soak time and ghost fishing cycles);
- testing retrieval exercise (funding?) – using gear retrieval to survey the grounds to help determine the extent of the problem;
- effect of sheet net dumping; and
- Cost/benefit analysis of ghost fishing and management measures.

Other comments:

- only 1 observer – but results are confidential;
- multi-tension winches have reduced accidental gear loss and only issue is gear conflict. New radar and communication has reduced this to very low levels (<1 per cent and provable);
- contrast of large companies and small, individually owned skippers. Former crews are often poorly skilled and motivated purely by profit. Smaller boats tend to have more responsibility and a long-term view towards resource sustainability;
- cable-layers always clear nets with grapnels so might be a source of information, esp. of deep water fisheries; and
- NEAFC has no powers to propose any restrictions / legislation. But do have a VMS database to determine in what international areas the fishery is prosecuted. But notification is very poor. Any management measures can be pushed through by contracting parties, especially if it is a joint proposals. Now five contracting parties. A joint proposal of three contracting parties will tend to be successful.

Day 2: Wednesday 11 May 2005

Session 4: Costs and Benefits of Retrieval Programmes

Introduction

Need to assess both quantifiable and non-quantifiable costs.

Also policy issue over specifying a retrieval programme for a fishery where gear loss is not an issue, as this might send out the wrong message.

Baltic Fisheries

Management Option	Relevance	Already in Use	Costs/Benefits
1. Gear use limits length per individual fleet	High (easy to implement)	Is in use but is weak (to global)	
2. Soak time limits	High	Yes	
3. Retrieval programmes		Yes in Sweden, partly in Denmark, Pilot Project in Poland	Reduction of ghost mortality; removal of other debris eg lead from jigs. Difficult to quantify
4. Reporting losses	High	No	
5. Identification marking	High	Only used for buoys	
6. Mandatory returning of trawl retrieved nets	High	No	
7. Zoning schemes	High – already used in Sweden. Not in Denmark. Voluntary scheme highly preferred	Partly – voluntary in Denmark, Sweden & Germany. Probably not Poland	
8. Acoustic detection systems	High (technical point of view)	No	
9. Use of alternative gears	Medium	Partly	
10. Biodegradable gear	Medium – apparently attractive option	No	

Gear Retrieval Steps	Cost
1. **Determine areas of net loss** with industry. Based on good comms between	Labour time of fishermen (2 person days) and scientists (2 person days). Information collected in advance of planned gear retrieval

industry and researchers.	programmes
2. **Hire retrieval vessel** (normal commercial vessel rather than a research vessel. Medium sized stern trawler with 2 net drums)	10 sea days at > 12,000 Kr./day (€1,100/day); different hire costs in other countries?; 1 day spent steaming. Days required varies by sweeping area and fishing effort levels; costs depend on time of year. Is cheaper during the summer cod closure, although earlier times of year are favoured because of unpleasant conditions.
3. **Retrieval gear development costs** – suitability varies by region eg Norwegian gear not suitable to Baltic conditions	2 years, 3 people part time (2 man months)
4. **Purchasing of retrieval gear** eg sweeps, hooks, otter doors (of special size)	Approximately €1000
5. Dispose of retrieved gear	Costs borne by Port Authorities in Sweden and Denmark. Other MSs?
6. Retrieval gear maintenance	Dependent on frequency of retrieval work and nets recovered, but generally very low – €100/year
7. Evaluation	5 person days. Weight and length of netting, weight and length of fish caught in net. Try to look at value of cod catch and relate to total cost of harvest. But many uncertainties. Maybe look at trends in nets being caught per retrieval effort (NRPUE)

Western Channel Fisheries

Priorities

- General arrangements in western Channel
  - good communication is key to reducing conflict;
  - effective communication ≡ informal zoning;
  - general consensus as to what is good practice;
  - French run their own zoning arrangements – alternating access to Decca-based boxes;
  - potting/beaming zone-setting agreed annually via social event;
  - consider funding inter-sector liaison meetings;
  - many specific measures available to achieve ‘no excuse for not knowing who’s doing what & where; and
  - pool resources & appoint liaison officer, possibly within regional framework.
- Trends in netting
  - fleet shrunk;
  - remaining skippers more professional and progressive; and
  - crew profiles changing – often English as second (?) language.
- Specific elements of good practice
  - choose area, dialogue with others fishing;
  - shoot gear in square pattern;
  - stay as close to gear as possible/work buddy system;
  - only ~10 days fishing/month;
  - use of AIS improves other vessel response;
  - need to look at means of agreeing and publicising good practice;
  - use web sites;
  - draw on existing models;
  - pre-empt problems through adaptive approach;
  - vessel accreditation schemes – 2nd/3rd party certification;
  - real-time self-management;
  - ensure port-based disposal facilities (MARPOL annex V);
  - restrict gear to what can be carried; and
  - generally do not leave gear out – but note threshold time levels.
- Managing gear loss

- hake gillnets & prime tangle nets;
- some wreck netting:
    - weak foot ropes;
    - Do not over-fish wrecks;
    - limit wreck net effort to match resource?; and
    - avoid some wrecks.
- use gear positional information;
- assume gear still in place;
- systematic creeping search; and
- driven by gear & catch value.

Costs & benefits

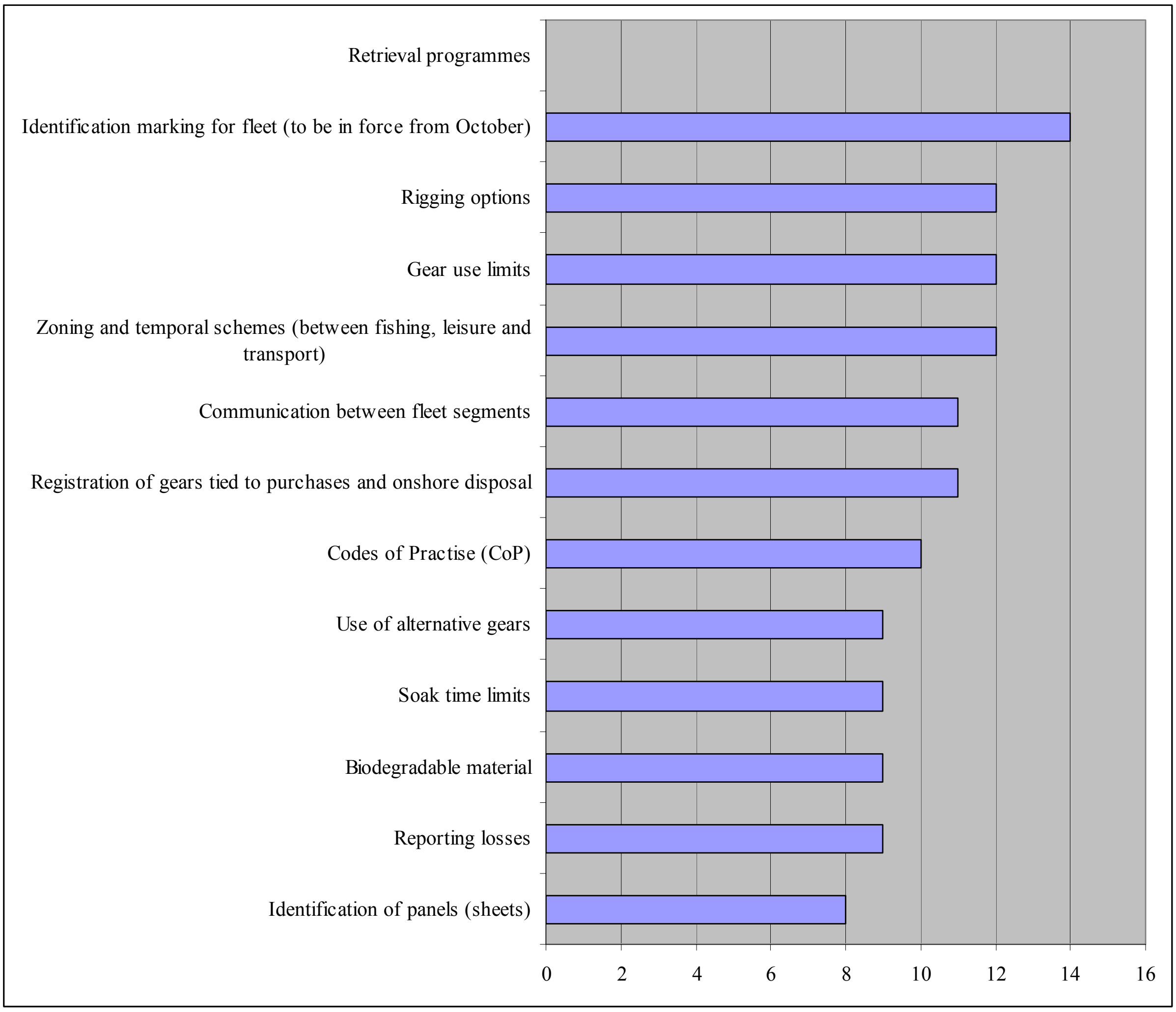
Costs	Benefits	
Access to grounds	Retrieval	Zoning – mutual benefit?
	Record gear usage / disposal	Reduce lost fishing time/gear & catch costs – need to quantify Benefits limited in areas where trawling is common
		Demonstrate accountability

Net costs – turbot net, 50m £60 rigged

AIS gear: costs £1,600 – £2,500 allows receiving and transmitting of vessel identification. Maybe brought down from 300 mt to 50 mt to increase coverage. Would need grant funding.
Building code of practise may be difficult in a diverse and large shall-scale fishery

Mediterranean Coastal Fisheries

Prioritisation of Management Options



Costs and Benefits

Management option	Score	Costs	Benefits
Identification marking for fleet (to be in force from October)	14	Marking tools;	Reduced conflicts and net loss;
Zoning and temporal schemes (between fishing, leisure and transport)	12	Consultation; GPS equipment; VMS/central control; patrol vessels/aircraft;	Highly reduced conflicts and net loss; reduced illegal fishing
Gear use limits	12	MCS costs; reduced income	Reduced risk of net loss; reduced illegal fishing
Rigging options	12	Trials & research; new rigging costs	Reduced risk of net loss
Registration of gears tied to purchases and onshore disposal	11	IT & registration costs; scheme administration; on-board storage; onshore disposal costs and administration	Prevents discarding at sea; better risk assessment;
Communication between fleet segments	11	Radio	Reduced conflicts and net loss; safety at sea
Codes of Practise (CoP)	10	Development and printing; cost to fishermen depends on implementation of other management measures;	Reduced conflicts and net loss; improved safety at sea; good image to consumers
Reporting losses	9	Lost fishing and leisure time; administration costs	Prevents discarding at sea; better risk assessment; improved location of lost gears
Biodegradable material	9	Material costs; increased gear loss (!); increased gear mending; some loss of income	Reduced ghost fishing; good consumer image;
Soak time limits	9	Reduced income; MCS costs;	Reduced risk of net loss; lower discard rates
Use of alternative gears	9	Research, investment costs; possible reduced income over transition	Reduced ghost fishing; good consumer image;
Identification of panels (sheets)	8	Marking tools;	Prevent discarding of nets and subsequent ghost fishing

Deep water Gillnet Fisheries

General comments

- need for more information;
- need for inspection;
- need for regulations focussing on reducing effort, number of nets and soak time;
- retrieval survey to identify problem and prove that it is a problem;
- need to simulate loss of gear and evolution of nets; and
- need to study effect of soak time…what should be the optimal soak time to reduce discards.

Prioritisation of management measures

- highest priority to collect information;
- technical regulations; and
- retrieval survey

Retrieval survey

- already planned research by Ireland and UK maybe. Will probably concentrate on Rockall, west Hebrides and Porcupine
- timing – summer in August
- vital to have basic information
- 30 day detective retrieving with one or two vessels
- gear to be used will be Norwegian type of creeper
- evaluation – scientific report

Problems

How to operate at sea to ensure good communication at sea with vessels left nets. Conclusion is that can manage.

Session 5: Summary Comments and Key Messages

Extent of ghost fishing:

- fisheries all very different and should be judged on their own merit!
- *deep water gillnet fisheries* targeting deep water shark and monkfish are in a league of their own – and a threat to the reputation of other gillnet fisheries. However much of the information is indirect and needs further verification.
- *Baltic fisheries* of some concern, although the situation seems to be both area-specific and improving for different reasons. Some mitigation measures are in place, esp. in Sweden and Denmark.
- the extent of gear loss and ghost fishing unknown in *eastern Mediterranean*. Ghost fishing probably occurs at a low level but may be an issue due to the large numbers of fishermen involved.
- levels of gear loss in the *Channel fisheries* are not thought to be significant, due to the high degree of communication, awareness and the relatively small numbers of vessels involved.
- towed gears are a major source of gear loss in some fisheries

- the impact of ghost fishing has to be taken in the context of overall catches and the environmental impacts of other (active and passive) gear.
- the fate of lost gear varies under different conditions – FANTARED showed that gears in shallower dynamic conditions tend to stop fishing earlier.

Literature review:

- covered all the available literature but needs tidying up
- some points need further justification or context setting
- ToR requires the report to focus on gillnets but other gears (pots, long lines, etc) are mentioned.

Survey:

- need to have clear objectives of the survey (as not a scientific report)
- fisheries very different in metier, geographical scale and socio-economic structure
- needs to stress the unrepresentative nature of the survey, esp. in the Mediterranean, but this was only meant as a snapshot. The limited budget meant that the survey was limited.
- such surveys are often subjective and often struggle to get verifiable information.
- deep water fisheries were not surveyed for reasons explained in the report.

Management options:

- the prioritisation of management options was very different between fisheries – serves to emphasis that different approaches are essential at regional or fisheries-specific levels.
- management priorities should focus on preventing loss of nets in the first place, where CoP, zoning and good communication are useful tools as represented by the western Channel fisheries.
- specific regulations need to be developed specifically for deeper water fisheries, both in EC and international waters.

Retrieval programmes:

- self-retrieval by fishermen immediately after loss is preferable.
- these maybe more appropriate (and essential for continuance of the fishery) for deeper fisheries where the risk of gear loss maybe unavoidable.
- may have wider benefits in terms of reducing consumer/NGO concern and the negative impacts on other gears from snagging.
- gear retrieval techniques and approaches need to consider their own environmental impacts, esp. in sensitive habitats. Good location information is essential to improve efficiency and therefore reduce impact extent.
- net retrieval programmes may be less necessary in areas of high trawl activity providing nets are landed ashore.

Key Research Areas:

- the eastern Mediterranean needs an assessment of the extent of - and reasons for - gear loss and ghost fishing.
- tools for measuring the effectiveness of different management methods.

- carefully structured research programme specific to the deep water fisheries project needs to quantify the level of gear loss, evolution of ghost fishing and soak times. Like the eastern Mediterranean, this was not covered by FANTARED.
- additional research areas have been identified by the individual fisheries working groups.
- there need to be financial resources allocated to critical research needs. 2007 EC financial provision now up for Council consideration.
- prepare generic 'Principles and Criteria' for a Code of Practise for reducing gear loss through good operational practises. This would need a representative, stakeholder-driven workshop.

Annex I Workshop Participants

A. Participant Details

Participants		Organisation	Contact
Team	1 James Brown	IEEP. Project team Leader	jbrown@ieeplondon.org.uk
	2. Graeme Macfadyen	Poseidon ARM Ltd	Graeme@consult-poseidon.com
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	16. Mike Kaiser	University of Bangor, UK	michel.kaiser@bangor.ac.uk
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	20. Robert Misund	Directorate of Fisheries, Norway	Robert.misund@fiskeridir.no
	21. Jarl Magne Silden	Boat skipper, Norway	Via: nilsroar@online.no
Facilitator	22. Phil MacMullen	Seafish, UK	P_MacMullen@Seafish.co.uk
	23. Dirk Langstraat	Independent consultant	dirklangstraat@hetnet.nl
	24. Nils-Roar Hareide	Heride Fisheries Consultants Ltd	nilsroar@online.no

A. Working Groups

	Baltic Gillnet Fishery	**Western Channel Gillnet Fishery**	**Mediterranean Coastal Gillnet Fishery**	**Deep water Gillnet Fishery**
Facilitator	Dirk Langstraat	Phil MacMullen	Tim Huntington	Nils-Roar Hareide
Members	Tore Johnsson Maciej Tomczak Per Olav Larsson	Nicky Chapman Paul Trebilcock Mike Kaiser Mike Pawson	Sylviane Troger Celia Vassilopoulou Jacques Sacchi Pedro Lino	François Theret João Neves Dominic Rihan Robert Misund Jarl Magne Silden

Annex II Workshop Agenda

Day One: Tuesday, 10th May 2005

09.30 - 10.00 Opening Session (James Brown)

- Welcome note, introductions and house keeping
- Overview of ghost fishing as an issue
- Background of Project
- Purpose of Workshop
- Appointment of day 1 Chair

10.00 – 11.30 Session 1: Review of the Economic, Social and Environmental Impacts of Ghost Fishing and Experience in Retrieval Programmes

- Work done to date (Phil MacMullen)
- Results of the literature review (James Brown)
- Results of the project's survey (Graeme Macfadyen)
- Economic and socio-economic aspects of ghost fishing (Graeme Macfadyen)
- Environmental impact of ghost fishing (Tim Huntington)
- Experiences in retrieval programmes (John Tumilty)

11.30 – 11.45 Coffee

11.45 – 12.30 Development of Working Groups and Agendas (Tim Huntington)
Planning of tasks to be achieved by the sub-groups and expected outputs (30 mins), in terms of:

Day 1: Group Discussion Topics

- Review of literature review (sections 2 and 5) (James Brown and Tim Huntington)
- Review and comment on survey findings (section 3) (Graeme Macfadyen)
- Appropriateness of management options: (John Tumilty)
    - relevance
    - effectiveness
    - technical issues
    - acceptability
- Review of management research needs (section 4) (James Brown)

Day 2: Group Discussion Topics

- Costs/benefits of different management options (Graeme Macfadyen)
- Communication methods around new management initiatives (Graeme Macfadyen)
- Prioritisation of management options by fishery and gear type (John Tumilty)
- Agreement of Working Groups, Agendas and Process (15 mins)

12.30 – 14.00 Lunch

14.00 – 16.00 Day 1 Group Discussions (facilitated)

16.00 – 16.15 Tea

16.15 – 17.30 Preliminary Presentation of Day 1 Group Discussion Results

Evening: Drinks and Dinner

<u>Day Two: Wednesday, 11th May 2005</u>

09.00 – 9.15 Election of chair and reflection on objectives and the progress of Day 1

09.15 – 11.00 Day 2: Group Discussions (facilitated)

- Costs/benefits of different management options
- Communication methods around new management initiatives
- Prioritisation of management options by fishery and gear type

11.00 – 11.15 Coffee

11.15 – 13.00 Presentation and Discussion of Breakout Group Deliberations

13.00 – 14.00 Lunch

14.00 – 15.30 Wrap-up and Conclusions – recommended work programme

- mitigation
- prevention
- research

16.00 Participants depart

Annex III Appropriateness of Management Options (Matrices)

A. Baltic

Management Option	Research Gaps	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Identification marking		High	Low – frequent changes in net type & mesh size makes marking problematic	Depend to mark	high	low
Reporting losses	Cross checking reported net loss with gear sales. These correlated in Sweden but have not been checked elsewhere ie Denmark and Poland	High	Medium – illegally used nets are not reported lost	Requires GPS marking which everybody has	high	medium
Acoustic detection systems	Technical development to make use practical	High (technical point of view)	High	Low – problems with shooting & hauling gear	Low (0) form a practical and economic perspective is unacceptable	High
Zoning schemes	Cooperative research and work between industry groups and other stakeholders to developing zooming schemes on a fishery by fishery basis	High – already used in Sweden. In Poland? Not in Denmark. Voluntary scheme highly preferred	High	Requires navigation systems (standard use)	Medium – voluntary zoning of some areas only preferred to maintain flexibility	Medium. Requires industry agreement, between Pos/companies/individuals
Biodegradable gear	Do not know? Development and application perhaps?	Medium – apparently attractive option		Questions over which parts of gear should be biodegradable	Unknown because it is a unknown option	
Gear use limits length per individual fleet	Research on optimum length limits.	High	High	Marks , buoys	High	Medium - easy to control but control of total length a easier
Soak time limits		High	High	Marks , buoys	High	High – easy to control
Retrieval		High	Medium	Special retrieval	high cost	Medium

Management Option	Research Gaps	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
programmes				gear is needed to be effective, with industry participation.		
Use of alternative gears	Relative impacts of alternatives	Medium	Medium – alternatives may be more damaging eg trawling, economically less viable or suitable only part of the year eg longlining	Requires extra investment	low - medium	High
Mandatory returning of trawl retrieved nets		High	High	Requires storage space on trawls and disposal	Medium – some reluctance among trawlers because of extra costs/time/space requirements/effort	Low

B. Western Channel Fisheries

Management Option	**Relevance**	**Effectiveness**	**Technical Issues**	**Acceptability**	**Enforceability**
Identification marking (Making Accountable)	**V (BAR CODING?)**	**Q**	**L (COST)**	**Q**	**V accountability**
Reporting losses	**V**	**V**	**N**	**V (combined with CoC)**	**Q (in conjunction with other measures)**
Acoustic detection	**L**	**L** range limited	**V**	**L**	**L**
Zoning schemes	**V**	**V** reduced conflict	**L**	**V** esp. if voluntary	**V**
Biodegradable gear	**L**	**Q**	**V**	**L** lack of confidence in strength of gear, esp. mixing panels & poor calibration of degradability	**Q**
Gear use limits (carriage)	**V**	**V**	**L**	**Q** (in conjunction with gear tagging)	**Q** difficult to regulate at sea
Soak time limits	**V**	**V**	**V**	**Variable** with metier	**L**
Retrieval programmes	**V**	**V**	**L**	**V**	**Q**
Use of alternative gears (spatial schemes)	**V**	**V**	**L**	**L** conservative inertia	**Q**
Incentive schemes	**V**	**V**	**variable**	**V** (need defining benefits)	**V**
Rigging options	**Q**	**Q**	**L**	**Q**	**V**
CoPs	**V**	**Q**	**L**	**Q** need consensus	**L**
Relevance influenced by other factors					

C. Mediterranean Coastal Fisheries

Management Option	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Identification marking for fleet (to be in force from October)	High	High	None	High (any cost issues)	Not difficult, but general enforceability issues
Identification of panels	High	Low	Not viable because small fragments lost rather than whole nets and cant tag sheeting as opposed to head ropes. Need more research on cost effective methods	Low	Not difficult, but general enforceability issues
Reporting losses	High	Medium	Numbers of fleets lost can be obtained, harder to report fragment loss Difficulties for fishermen to mark lost location	Medium-Low	Difficult (unless allied to gear registration)
Zoning and temporal schemes (between fishing, leisure and transport)	High	High	Difficult to agree and mark areas without GPS	High if well and sensitively managed	Not difficult, but general enforceability issues
Biodegradable material	Medium	Medium	Technology to time degradability of gear so that same as active gear	Low unless same price and lifespan	Easy
Gear use limits	High	High	None	Low	General enforceability issues
Rigging options	High	High	Need to demonstrate benefits	Higher with professionals	Not difficult, but general enforceability issues
Soak time limits	Low (but may be medium for crawfish)	Low	No	Low	General enforceability issues
Codes of Practise (CoP)	High (esp. regional approach)	Low to medium	None	High	Low - difficult
Use of alternative gears	Depends on extent of problem and metier	-	Some to identify other effective metier in that area	Low	General enforceability issues

Management Option	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability
Retrieval programmes	Unknown as Do not yet know extent of problem	Unknown as Do not yet know extent of problem	Difficult to target retrieval areas	High	-
Registration of gears tied to purchases and onshore disposal	High	High	Maybe some IT and management issues	Low	Not difficult, but general enforceability issues
Communication between fleet segments	Medium	Medium	Large numbers of non-sector fishermen, and highly mobile trawl fleet – difficult to know how to contact them	Low unless funded	Not difficult

D. Deep water Fisheries

Management Option	Relevance	Effectiveness	Technical Issues	Acceptability	Enforceability	Bio effect
Identification marking	Y	Y	Min. distance btw. markers	N	Y	
Reporting losses	Y - important	N	N–compliance/E-Logbook	N	N (Y if retrieved)	
Acoustic detection systems	Can be developed	?	Cost / range, particularly in deep water	?	?	
Zoning schemes	Y, already effective in Rockall	Y	N	N	Y with VMS	Increase effort
Biodegradable gear	N		Can't predict degradability Expensive to apply biodegradable links to all floats			
Gear use limits	Essential	Y	N	N	Possibly but requires accurate and frequent VMS	Better quality
Soak time limits	Essential	Y	N	N	Y but requires accurate and frequent VMS and accurate information on each vessel specification	Better quality
Code of practice	Y	Maybe. There is little interest amongst fishermen to cooperate				
Retrieval programmes	Y (annual)	Y	Need info & coop	Y	na	
Use of alternative gears			Longlining could be used in deep water shark fishery, but not shelf monk fishery. Monks can be taken by trawl			
Attending gear	Essential	Y	N	N	Y	
Comm. Improve (gear conflict)	Y	Maybe				

Appendix E Typically used retrieval gear

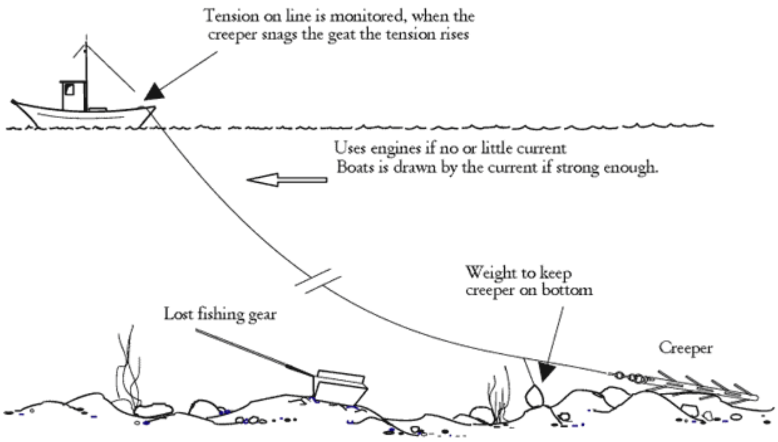
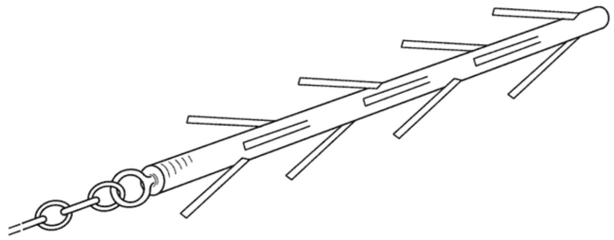


Figure 1 Arrangement for creeping for fishing gear



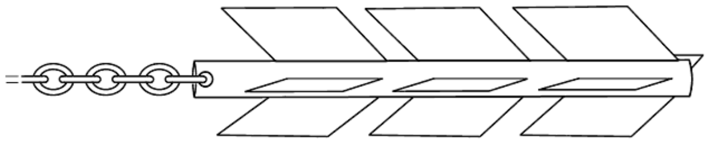


Figure 3 Plate creeper (Various sizes according to the gear)

Figure 2 Rod creeper (Various sizes according to the gear)

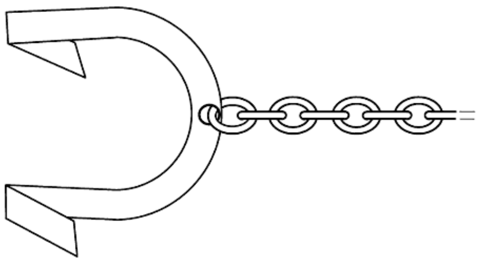


Figure 5 Chain creeper (Various sizes according to gear)

Figure 4 Horseshoe creeper (Generallly used for lines)

After Smith, 2001