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THE CONFLICT BETWEEN STATIC GEAR AND MOBILE GEAR IN INSHORE FISHERIES

STUDY

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This document was requested by the European Parliament's Committee on Fisheries.

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Abstract

The majority of fishing vessels and fishers in Europe are engaged in inshore fisheries. These fisheries utilise a diverse range of fishing techniques that have been selected to suite the species and conditions in which they operate. This analysis describes the causes and consequences of conflict among different sectors, how these fishing gears operate, and the different ways in which they impact upon the marine environment. Solutions are proposed to reduce conflict through investment and innovative management approaches.

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LIST OF ABBREVIATIONS

CFP	Common Fisheries Policy
FAO	Food and Agriculture Organisation of the United Nations
ETP	Endangered, threatened and protected species
EU	European Union
F_{MSY}	Fishing mortality at a level that achieves maximum sustainable yield
FAD	Fish aggregation device
FTE	Full time equivalent
FMZ	Fishing management zone
MLS	Minimum landing size
MPA	Marine protected area
MSY	Maximum sustainable yield
NAO	North Atlantic Oscillation
ROFI	Region of Freshwater Infuence
TAC	Total allowable catch
VMS	Vessel Monitoring System

TECHNICAL TERMS

Benthic	Living on or in the seabed
Benthos	Organisms that live on or in the seabed
Biogenic	Formed by living organisms (e.g. an oyster reef)
Biota	All living organisms
Bioturbation	The mixing of sediment by organisms
Demersal	Living at or close to the seabed
Ecosystem engineer	An organism that structures habitat or populations

Epifauna	Organisms that live on or emerge from the surface of the seabed
Ghost Fishing	Fishing gear that has been lost or discarded that continues to catch and kill marine organisms
Infauna	Organisms that live within the seabed
Nepheloid	Water layer above the sea floor containing significant sediment
Pelagic	Living from midwater to the surface of the sea
Subsidy	Carrion is considered to be an energy subsidy to the seabed

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EXECUTIVE SUMMARY

Background

Inshore fisheries comprise the majority of vessels in terms of numbers across Europe. As a result they have an important socio-economic function particularly in rural economies. The range of fishing gears used by the inshore sector (small scale coastal fleets) is diverse and makes spatial management complex, particularly when fishers pursue the same species, or different species in the same area of the sea or seabed. This intense competition among different sectors, combined with the pressure of other users (e.g. windfarms) can lead to direct conflict resulting in damage to the fishing gear of one sector or another. Damaged, lost or otherwise discarded fishing gear can continue to fish to over one year, however the probability of lost gear continuing to ghost fish is idiosyncratic and highly dependent upon the circumstances. Pot and trap gear have the potential to ghost fish for the longest periods of time. Fishing gear zoning regimes have proved effective at minimising conflict among different sectors in a number of different circumstances. However, such arrangements are not common. These management systems are most vulnerable to violation by itinerant fishers from distant ports.

The natural environmental context of a location shapes the seabed and determines the organisms that can exist in that habitat. The intensity, frequency and extent of natural disturbance determine the degree to which a habitat and its associated species are likely to be affected by additional disturbance from fishing activities. In some circumstances fishing disturbance may have minimal effect compared to natural disturbance. In other circumstances fishing may cause long-lasting or irreversible changes. Understanding the distribution of habitats and their extent, and the overlying physical processes, provides the basis to evaluate the potential effects of fishing disturbance. Such an understanding enables the formulation of effective spatial management policies.

All fishing gears have the potential to affect or result in change to marine habitats and communities. Towed mobile bottom fishing gears have the largest environmental footprint, but often are used in areas that are resilient to fishing disturbance. Static fishing gears have a small environmental footprint, but when fished in areas of high species diversity and topographic relief they have the potential to have local impacts on those assemblages. Static fishing gears are more likely to ghost fish when lost or discarded and are associated with a wider range of negative interactions with endangered, threatened and protected species such as turtles and cetaceans. All fishing gears have the potential to be modified to improve their environmental performance to reduce bycatches of all species while maintaining catches of target species.

The effects of towed mobile fishing gear on seabed communities are well understood as a result of 25 years of research. Our ability to understand the effects of these fishing gears relies heavily upon a good understanding of the distribution, frequency and intensity and identity of these fishing activities, coupled with a detailed understanding of habitat distribution and overlying environmental parameters. It is possible to rank towed mobile bottom fishing gear based on their initial impacts which would indicate that scallop dredges and hydraulic dredges have the most negative instantaneous effects while otter trawls are the least damaging of these fishing gears. The development of policies that maintain fishing activities in currently productive fishing grounds would minimise negative environmental impacts on the seabed. The implementation of areas closed to fishing can result in a net negative outcome for seabed habitats and the associated animal communities.

The effects of static fishing gear on the seabed are poorly understood compared to the effects of towed mobile fishing gear. The majority of studies have focused on the effects of pots or traps. Studies to date indicate that these fishing gears have limited or no effects on seabed biota, however there remains the potential for cumulative effects if fishing activity was intense and coincided with habitats that are sensitive to disturbance. A single study outside Europe suggests that gill nets can have very localised effects on seabed biota. The effects of ghost fishing and issues related to the entanglement of endangered, threatened and protected species would appear to be a more serious issue in relation to static gears.

Depending on the environmental context, seabed habitats and their associated fauna can take from 100 days to >12 years to recover. It is important to understand the distribution of those habitats most sensitive and vulnerable to bottom fishing activities such that these may be protected appropriately. There exist many areas of the seabed that are highly resilient to the effects of fishing due to the environmental context in which they occur. Some areas of the seabed and their associated biology are so sensitive that they should be fished rarely if ever depending on the intended gear type proposed for use in those areas.

A number of recommendations are made for consideration by policy makers that encompass a wide range of issues from further research to fill knowledge gaps, innovation and incentives to adopt gear technology to mitigate environmental impacts, to investment in communication technologies among fishers and new experimental approaches to management.

Aim

The aim of the present study was to undertake an in-depth analysis and revision of the literature and scientific evidence of impacts, direct and long term, that different mobile gear like otter trawl, beam trawl, mussel and scallop rakes and clam dredgers have on the bottom ecosystem. It will also analyse what the main differences with the damage made by static gear to catch similar species are.

The note reviews the types of conflict in fisheries shared by mobile and static gear and how both systems perform in terms of selectivity and performance across Europe. The suitability of the different gears to be species-specific and to be size-selective is considered.

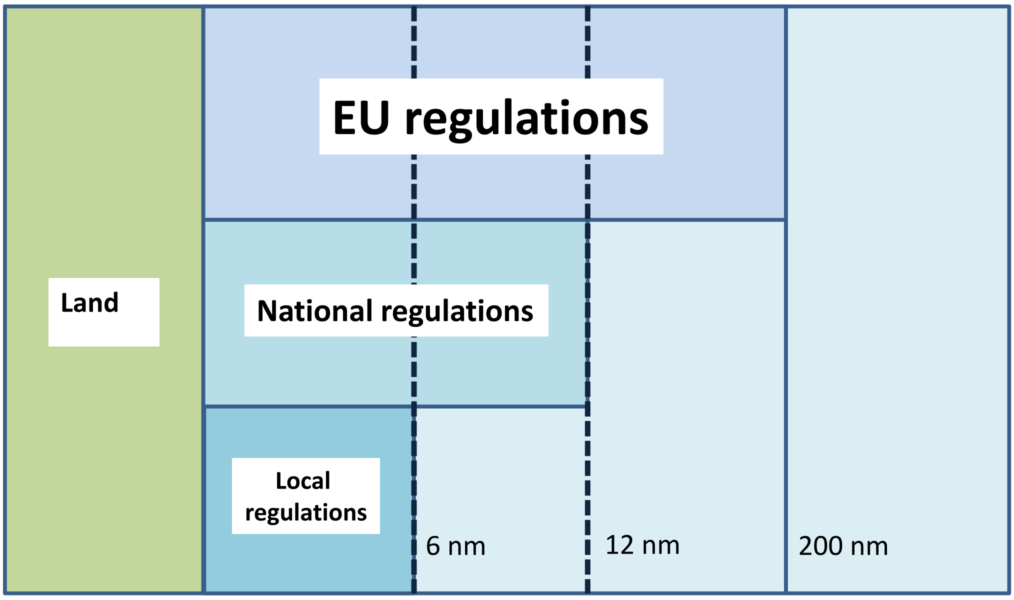
The note examines the political choices for the resolution of the conflict between static and mobile gear and makes substantiated recommendations for the management and conservation of the coastal waters in Europe and the steps that should be taken at European level.

1. INSHORE FISHERIES IN EUROPE

KEY FINDINGS

- Inshore fisheries comprise the majority of vessels in terms of numbers across Europe. As a result they have an important socio-economic function particularly in rural economies.
- The range of fishing gears used by the inshore sector (small scale coastal fleets) is diverse and make spatial management complex, particularly when fishers seabed.
- This intense competition among different sectors, combined with the pressure of other users (e.g. windfarms) can lead to direct conflict resulting in damage to the fishing gear of one sector or another.
- Damaged, lost or otherwise discarded fishing gear can continue to fish to over one year, however the probability of lost gear continuing to ghost fish is idiosyncratic and highly dependent upon the circumstances. Pot and trap gear have the potential to ghost fish for the longest periods of time.
- Fishing gear zoning regimes have proved effective at minimising conflict among different sectors in a number of different circumstances. However, such arrangements are not common. These management systems are most vulnerable to violation by itinerant fishers from distant ports.
- When compared to most mobile fishing gear, static fishing gears are usually more energy efficient per unit of fish landed and can be highly size selective for many species. However static gears are also associated with bycatches of endangered, threatened and protected species such as turtles and cetaceans.

Figure 1: A schematic diagram to show the three layers of regulation that may affect inshore fisheries and the distance from the coastline across which these legislations apply.



Source: MJ Kaiser

Inshore fisheries occur throughout European coastal states and occur primarily within 12 nm of the coastline. This zone is prosecuted mainly by small scale coastal fleets that are limited to inshore waters due to their need to remain in close proximity to suitable ports and harbours where they shelter and land their catches. In 2011 the small-scale fleet comprised 55% of the total EU fleet in terms of the number of vessels, 6% in gross tonnage and 25% in engine power (STECF 2013). The number of fishers employed in the EU fishing fleet in 2011 was 127,686 (excluding Cyprus, Estonia and Greece).The small scale fleet employs around 41% of the total number of EU FTE fishers (STECF 2013).

Although the regulations of the Common Fisheries Policy apply across the waters of all member states in relation to regulations on technical measures and fleet capacity, additional regulations may be imposed by the member state on the fisheries that operate within its inshore waters. For example, in England, regional management organisations (Inshore Fisheries and Conservations Associations) have enforcement and management responsibilities that extend out to the 12 nm from the coastline, but they have the power to make legal instruments that apply only within the area that extends to 6 nm from the coastline. Between the 6 nm and 12 nm territorial limit the national Government retains legislative responsibility (Fig. 1). For this reason, most small scale coastal fleets are potentially affected by up to three layers of legislation; over-arching EU legislation, national and local legislation. Non-U.K. vessels are excluded from waters that extend out to 6 nm from the coastline, whereas the situation is more complex between 6 nm to 12 nm from the coast where non-U.K. vessels may have historic access rights. The latter means that while national legislation may be enacted to control national fishing activities within the 6 nm to 12 nm zone, this legislation may not apply to non-U.K. vessels that have historic access rights to the same zone.

1.1. Sources of conflict in inshore fisheries

There are a number of different reasons why static gear and mobile gear fisheries may come into conflict. These conflicts can be categorised as competition for the same biological resource (i.e. the same target species), and competition for access to same area of the sea to fish for different target species. These conflicts are wide-spread but poorly documented and have been referenced mainly with respect to understanding the causes of lost and discarded fishing gear. For example, gear conflicts are documented as the main cause of lost fishing gear for the Baltic cod net fishery. In Greece, conflict between mobile and static gear sectors and between part-time/recreational and professional fishers also has led to gear loss and ghost fishing (Brown and MacFayden, 2007; MacFayden *et al.* 2009).

When fishers use different fishing techniques to catch the same species this may occur for a variety of reasons. Static gears are more easily fished from smaller vessels that require less initial investment and on-going maintenance. For this reason small-scale fisheries are often dominated by such vessels. Towed mobile bottom fishing gear usually demand more powerful vessels that generate enough force to tow the gear through the water and across the seabed, and need powerful winches to deploy and retrieve nets and catches. As a result these vessels are more costly capital items with high maintenance costs. Fishers may choose to fish with static rather than towed bottom fishing gear because the quality of the catch is superior and commands a higher price at market.

Certain fishing gear types may out-perform others in terms of environmental performance such that the catch perhaps qualifies for certification, whereas the same catch landed with a different technique would not. A good example of such a fishery would be the hake fishery off the coast of New England which is certified for line caught hake only. The hake could be caught with trawls, but the associated environmental impacts and bycatch issues mean that it would perform less well (in an environmental assessment) than the hook and line fishery. Similarly 'pole and line' caught tuna is considered more environmentally friendly than purse seined tuna due to the elimination of catches of endangered, threatened and protected species and other bycatch. In such cases it is simple enough to understand why mobile and static gear would come into direct competition for the same species in the same locality.

Areas that are heavily fished with static gear represent a navigation hazard to vessels and especially those using towed bottom fishing gear, particularly if the static gear is poorly marked. Ropes associated with static gear can foul and incapacitate propellers, towed bottom gear can become snagged and in extreme cases result in the sinking of the vessel (see MacFayden *et al.* 2009). In the absence of mutual cooperation, towed bottom gear fishers may resort to deliberately towing through the static gear, cutting it free and then resume fishing. EU legislation has strict guidelines for the marking of static gear, but for most small-scale fishers the expenditure required to meet these regulations is unfeasible and the regulations are not enforced. The frequency of loss of surface markers is another impediment to the successful implementation of these regulations. Even when there are lines of communication between different sectors, perpetrators that tow fishing gear away often justify their actions by citing that their attempts at communication with the other sector were ignored.

The other type of conflict occurs when static gear and mobile gear sectors prosecute different species that co-occur on the same ground. A good example would be trap fisheries for crustaceans (e.g. crabs, lobster and spider crab) that co-occur on ground inhabited by scallops that are fished for by scallop dredgers. In such fisheries the trap fishers exclude the scallop fishers from accessing fishing grounds that would yield potentially profitable catches. Again, scallop fishers may resort to towing through static gear in order to access beds of scallops (either deliberately or unintentionally).

MacFadyen *et al.* (2009) concluded that most losses of static gear result from unintentional interactions with towed bottom fishing gear. When fishers visit an area for the first time, they may be unaware of the location of areas with high densities of static gear. If the static gear is poorly marked the visiting fisher may accidentally tow into the gear and damage it. This problem is particularly acute at night. In all of these examples, it is usually the static gear that is most likely to be damaged or lost with the potential for ghost-fishing for short or very long periods of time (e.g. Kaiser *et al.* 1996; Erzini *et al.* 1997; Bullimore *et al.* 2001; Beata *et al.* 2009).

Such instances can be reduced by better communication. Furthermore, in the absence of a formalised penalty scheme or understood right of way in terms of access it often leads to the victim not being reimbursed for the gear that was damaged. MacFayden *et al.* (2009) reported that in the Baltic Sea losses of static nets from towed mobile fishing gear have reduced directly as a result of improved communications among skippers in the two sectors. Similarly, in the Western Approaches of the English Channel there is regular dialogue between French and English fishers that share positions of fixed gear. They have developed a long-standing system of demarcating blocks of the sea for use by static and towed bottom fishing gear that rotate on a six weekly basis (cited in MacFadyen *et al.* 2009; Jim Portus South West Producer Organisation, pers. comm.).

Box: Fishing representative quote

GEAR CONFLICT: AN INDUSTRY PERSPECTIVE

Two different examples from Scotland

"In Shetland we had no gear conflict during the time when I was there, which is interesting given the explosion of static gear that occurred before pot limits were introduced. But there was good communication within a distinct geographical area and within very distinct fishing areas. If anything, there was more tension within the static gear sector than there was between static and mobile fishers. In the North East [of Scotland] the issue is quite different with tension between displaced mobile vessels prosecuting the same fishing grounds. There is also a long-running and relatively frequent mobile /static gear issue [in relation to conflict]. This may have been caused by a number of issues that include; growing pot/trap numbers, problems with marking of gear, some instances of ground holding, poor communication and no legislative framework to allow the situation to be managed in a fair way. The lower financial value of the inshore sector (compared with the demersal and pelagic fleet) has meant that investment in dealing with the issues has been low" Jennifer Mouat, Scottish White Fish Producer's Association

Static fishing gear are also lost through poor weather or as a result of commercial shipping cutting surface marker buoys (Dahn buoys) or through deliberate acts of vandalism. Unfortunately there is no systematic recording of losses of static gear across Europe hence it is difficult to quantify the extent of the problem (note the FAO is currently working on a methodology to quantify ghost fishing due to lost fishing gear – pers. comm. P. Suuronen). Furthermore losses of static fishing gear due to negative interactions with the mobile gear sector are not formally recorded and often are inferred rather than witnessed directly. Nevertheless, studies of the attitudes of fishers in these different sectors underlines the very different world views they present and they frequently mention conflict with other sectors as a past and on-going problem (Blyth *et al.* 2002; Hart *et al.* 2002; Richardson *et al.* 2005; Dimech *et al.* 2009; Hajimichael *et al.* 2012).

Blyth *et al.* (2002) studied the inshore potting agreement in Devon U.K. This was a voluntary agreement put in place between static gear and mobile gear fishers in 1978. The agreement was instigated to minimise conflict among the different sectors and partitioned different areas of the sea for different uses (static gear only, mobile gear only, seasonally shared areas). Although the agreement had functioned for 25 years there were increasing incursions by mobile gear fishers into static gear only areas. In many cases, large vessels that were legally restricted to fish outside the 6 nm limit (due to engine size or gear restrictions) made illegal incursions during the hours of darkness when it would be impossible to see surface markers or Dahn buoys. When asked about their attitudes towards the agreement, its perceived benefit and the occurrence of negative interactions within and between sectors, the responses of fishers from each sector were markedly different but consistent within each sector. Static gear fishers all concurred that the voluntary agreement benefitted them, whereas mobile gear fishers saw no benefit in the system.

Hart *et al.* (2002) explored further the behavioural basis and motivations that underlie the strong differences in behaviour between the static gear and towed bottom fishing gear sectors. The static gear fishers fished well defined territories close to their home port. Many of these fishers had family ties to fishing that date back to the middle ages and many were related to each other. The majority were vessel owners and skippered their own vessels. In contrast, the problematic elements of the towed mobile fishing gear sector were from distant ports, they were crewed and skippered by 'employees' of a larger company and had no family ties to the area. Thus these vessels could break the voluntary code without fear of reprisals and had fewer long-term incentives to cooperate with the static gear sector. Eventually the U.K. Government formalised the legal basis of the gear zoning agreement. Notwithstanding, there is little by way of regulation or concordat between fishers to accommodate for the rogue element that free-ride the benefits of such systems.

In the NE Atlantic, a heavy burden of fisheries regulations applies to the commercial fisheries sector. However in the Mediterranean this burden of regulation is relatively light. As a result, fishers in Cyprus expressed the view that they are inadequately protected by legal instruments from unfair competition from 'recreational' fishers that land and sell catches without the need to comply with regulations (Hajimichael *et al.* 2012). Thus while there is a need for simplification in many of Europe's fisheries in terms of management and regulation, in other areas greater focus is required on effective policy instruments to ensure sustainable fisheries and to protect the commercial sector from uncontrolled exploitation by other actors.

1.2. Selectivity of different sectors in inshore fisheries

The fishing method, gear used and the types, sizes and power of vessels all have a bearing on by-catch rates that occur in specific fisheries. When a fishery operates in a region of high species diversity a large proportion of the catch tends to be by-catch (Hall and Mainprize 2005). When bycatches occur they will result in discards if the fishers have no quota for these species, they are illegal to land, or they are undesirable (to consumers) or inedible. Discarding is a ubiquitous problem for most fisheries (Hall and Mainprize 2005; Kelleher 2005; Catchpole *et al*. 2008; Poos *et al*. 2010), but the proportion of discards varies considerably between fisheries and among different gear types.

The wider ecosystem effects of discarding are not fully understood (Catchpole *et al*. 2005). In some cases they have contributed to the expansion and population increase in scavenging seabirds (Voitier *et al.* 2004), changes in fish species diversity (Greenstreet *et al.* 1999), changes in relative abundance in the fish assemblage (Jennings *et al.* 1999) and changes in predator-prey interactions (Christensen *et al.* 2003). In addition, the mortality associated with discards leads to a loss of potential income and food for humans. Discarding of undersized commercial fishes results in lost future income through the loss of potential growth and contribution to stock replacement. Up to 70% of the total value of the annual landings in the Dutch beam trawl fishery, and 42% of the annual landings in the UK roundfish fishery are directly lost due to the discarding of commercial species in the North Sea (Cappell 2001).

A global analysis of the proportion of bycatches (which includes all species, not just those that are commercially important) associated with different types of fisheries demonstrates that prawn fisheries (which would include *Nephrops*), and crab fisheries have the highest rates of bycatch. It is worth noting at this point that the survivorship of bycatch from crab fisheries in Europe is likely to be very high as the pots/traps are lifted frequently and the bycatch is known to be able to survive in these traps for many months (Bullimore *et al.* 2001). In finfish fisheries, the highest rates of bycatches were associated with flatfish fisheries and least in pelagic fisheries (Table 1, Hall and Mainprize 2005). Discarding rates of fishes are lower in many European fisheries. In the context of the forthcoming discards ban much more scrutiny will occur in relation to the performance of different fishing techniques. A recent study by Mangi and Catchpole (2013) provides some insight into the proportion of quota and non-quota species discarded in the U.K. which indicates that gill net fisheries have the lowest proportion of discards of commercially important species compared to all other sectors (Table 2).

It is possible to limit the amount of by-catch by exploiting the various behavioural and body-shape differences that occur among the target and non-target species. Multiple studies have demonstrated the utility of technical alterations to fishing gear such as the use of separator trawls, sorting grids, and escape panels/gaps (Cook 2003; Valdemarsen and Suuronen 2003). The range of gear modifications that have been designed to reduce bycatch is diverse and if implemented these could lead to substantial reductions in bycatch (Table 1; Hall and Mainprize 2005).

Table 1: Actual current catches and bycatches, and the estimated changes in catch and bycatches (million tonnes) if bycatch reduction innovations and behaviours were implemented. The estimates assume the median level of performance based on published studies in which fishing gears fitted with by-catch reduction devices were evaluated.

TARGET SPECIES GROUP	ACTUAL BYCATCH	MEDIAN CHANGE IN BYCATCH	ACTUAL CATCH	MEDIAN CHANGE IN CATCH	ACTUAL CATCH/ BYCATCH	CHANGE CHANGE IN CATCH/ BYCATCH
Prawns	9.51	4.66	1.57	1.57	605.7	296.8
Crabs	2.89	1.53	1.32	1.32	218.9	115.9
Flatfish	0.95	0.34	1.14	1.14	83.3	29.8
Demersal fish	7.16	2.04	28.47	28.47	25.1	7.2
Pelagic fish	5.52	0.91	37.09	37.09	14.9	2.5

Source: Hall and Mainprize 2005

Hall and Mainprize (2005) undertook a global analysis of the potential of fishing gear modifications to reduce bycatch across a range of fisheries. In all cases they concluded that if properly implemented, bycatch reduction measures could substantially reduce bycatch and hence discarding. Despite the enormous investment in such innovations, the continued use of unselective gear in some fisheries has maintained high levels of discarding (Catchpole *et al*. 2005). The continued use of unselective gear is partly a symptom of fishers' belief that the proposed fishing gear innovations will reduce their profitability. In addition, some technical gear modifications, such as benthos release panels, can reduce the saleability and price of the catch as a result of abrasion (Revill & Jennings 2005). Discard reduction strategies need to involve fishers in their development from the outset to ensure that the incentives to discard are addressed and that the modifications are compatible with fishers' and management objectives.

Table 2: Estimates of discard rates for a selection of different vessel segments in the U.K. fishery showing the average vessel length, the annual landings per vessel, the percentage of total discards and quota species discards.

VESSEL SEGMENT	AVERAGE VESSEL LENGTH (m)	ANNUAL LANDINGS PER VESSEL (t)	% OF TOTAL DISCARDS	% OF QUOTA DISCARDS
<10 m drift/fixed nets	8	21.6	16.7	6.0
Gill netters	18	146.0	6.8	2.5
<10 m demersal trawl/seine	10	27.0	16.7	5.9
Area VIIb-k trawlers 10-24 m	13	74.8	16.7	6.0
N.Sea beam trawlers <300 kW	14	74.9	15.6	5.7
N.Sea Nephrops < 300 kW	14	90.9	22.6	8.1
S.West beam trawlers <250 kW	20	129.2	16.6	6.0
S.West beam trawlers >250 kW	27	252.0	16.7	6.0
N.Sea Nephrops >300 kW	21	234.0	22.5	8.2

Source: Mangi and Catchpole 2013

1.3. Energy efficiency of different sectors

Innovations in fishing gear design are an important tool to help alleviate the issue of bycatch and discards. In addition, they are necessary to improve the fuel efficiency of food production from wild capture fisheries. In general, static and passive gears have the highest efficiency in terms of the energy consumed to catch and land a standard unit of fish (Table 3). Trawls and dredges demand much higher energy consumption to pull nets through the water. Thus changes in fisher behaviour and practices, and gear innovations that reduce drag on the seabed and through the water column, will reduce fuel consumption (e.g. Sala *et al.* 2011). Such innovations should be encouraged, however it should be noted that reducing the fuel costs for fishing acts as a subsidy that prolongs the use of unsustainable fishing practices. During the peak of fuel prices in the late 2000s a number of fishers changed from trawling to less fuel intensive and more selective techniques such as seine netting.

Table 3: **The value of landings, and their associated fuel costs, made by different sectors that fish in inshore waters for a selection of countries in Europe. (T=trawl, P=polyvalent, S=seine, note trawl includes dredges).**

MEMBER STATE	SEGMENT	TYPE OF GEAR	VALUE OF LANDINGS M EURO	FUEL COST M EURO	FUEL COST AS % OF LANDINGS
LT	Baltic trawlers <24m	T	3.40	1.00	29.4
FR	Mediterranean trawlers 18-25 m	T	68.80	12.60	18.3
LV	Gillnetters	P	5.60	1.00	17.9
DE	Baltic trawlers	T	12.60	2.10	16.7
UK	Scottish *Nephrops* trawlers	T	69.70	10.10	14.5
UK	Scallop dredgers	T	70.60	9.40	13.3
PT	Longliners	P	11.60	1.50	13.0
DE	Shrimp beam trawlers	T	55.0	5.10	9.3
SE	Gillnetters >=12m	P	3.80	0.30	7.9
DK	Danish gillnetters	P	49.10	2.70	5.5
ES	Galician purse seiners	S	36.0	1.80	5.0

Source: Anonymous 2006

2. THE CONTEXT OF THE NATURAL ENVIRONMENT

KEY FINDINGS

- The natural environmental context of a location shapes the seabed and determines the organisms that can exist in that habitat.
- The intensity, frequency and extent of natural disturbance determines the degree to which a habitat and its associated species are likely to be affected by additional disturbance from fishing activities. In some circumstances fishing disturbance may have minimal effect compared to natural disturbance. In other circumstances fishing may cause long-lasting or irreversible changes.
- Understanding the distribution of habitats and their extent and the overlying physical processes provides the basis to evaluate the potential effects of fishing disturbance. Such an understanding enables the formulation of effective spatial management policies.

Before focusing further on how particular fishing gears operate and interact with marine habitats and their associated communities, it is important to appreciate the effects of the environment on shaping these systems.

Any human activity that involves exploitation of marine natural resources will cause disturbance to marine habitats and their associated biological communities. This disturbance may have direct impacts such as the physical interaction of fishing gear with the seabed, or indirect impacts through the modification of species composition or population size-structure within populations of target and non-target species. To understand the degree to which fishing activities are likely to cause lasting and perhaps irreversible changes to marine seabed ecosystems it is essential to have an understanding of the environmental context in which those activities occur. Natural disturbances can occur across a wide range of spatial and temporal scales. In the context of the consideration of fishing activities the relevant time scales operate from days to decades and spatial scales operate from 100s m^2 to 1000s km^2 (Hall, 1994; Kaiser *et al.* 2011).

2.1. Natural large-scale processes

The North Atlantic Oscillation (NAO) is a good example of how physical processes can affect seabed habitats, particularly in coastal waters. Decadal changes in the NAO affect wind forcing and precipitation levels according to whether the NAO index is positive or negative. In years when the index is positive average wind speeds are higher leading to greater physical mixing of the water column which will affect the timing and persistence of stratification on the continental shelf of the North-east Atlantic. When in a negative phase, lower wind-speeds are associated with an increased incidence of anoxic events due to prolonged periods of stratification in coastal waters. The latter is particularly pronounced in enclosed bodies of water such as the Baltic Sea and the Adriatic Sea.

Shallow waters near the coast have high biological productivity and provide important nursery habitats for commercially important fish and diving and wading birds. Wind forcing also generates physical stress at the seabed in shallow water near the coast. Wave energy increases with exposure but attenuates with water depth. Wave stress is a direct controlling factor of the biomass and production of biological communities that live on the seabed (the benthos). This biomass initially increases with increasing depth and distance from the shore to a point where it reaches a maximum before decreasing again. Increasing levels of wind stress will decrease nearshore benthic production and lower coastal carrying capacity for fish species and other predators dependent upon the benthos for food (Hiddink *et al.* 2008).

Whenever the NAO is positive, increasing precipitation will elevate the amount of sediment discharged from rivers and it is associated with increased frequencies of extreme sediment discharge events linked with flash floods. Elevated inputs of freshwater discharge will affect the extent of density driven coastal currents in Regions of Freshwater Influence (ROFIs) leading to extended front systems that run in parallel with the coastline. In addition to these periodic changes in the oceanic regime, we can expect global climate change to greatly exacerbate the extreme nature of many aspects of physical forcing that influences habitat modification in marine systems. Increased sediment loading due to river discharge and wave erosion will affect turbidity in coastal waters and consequently will limit the depth zone in which seagrasses and seaweeds can grow.

Coastal waters are also subjected to currents that are generated by tidal rise and fall. However, the latter varies considerably across Europe with 10 m deviations in the Irish Sea compared with < 1 m deviation in the Mediterranean Sea and other enclosed water bodies. Tidal currents also generate physical stress at the seabed. Low to medium levels of tidal stress resuspend surficial sediments rich in organic material and hence help to supply food to particle feeding seabed biota. As tidal currents become more extreme they can begin to have negative effects on seabed biota as a result of scouring at the seabed.

2.2. Natural small-scale processes

The examples given above operate at large scales and influence both water column and seabed habitat properties. Other more localised natural forcing events can have profound impacts upon the habitat. Examples would include glacial scour that can remove entire habitats on a scale of a few km, localised seismic activity resulting in gas discharge or geothermal activity, localised coastal erosion and daily tidal scour, and carrion subsidies to the deep sea floor. Apart from the last example these individual processes operate at much larger scales than the modifying processes undertaken by individual biota. Such processes include grazing, predation and bioturbation. Despite the relatively small-scale of individual habitat modifying events (e.g. the burrowing activities of worms and crustaceans), the sum total of many individual events can equate to a significant disturbance process. When these organisms have a direct influence of the structure of the marine habitat they are termed ‘ecosystem engineers’. A good example of the latter is the commercially important Norway lobster *Nephrops norwegicus* that is a key bioturbator of mud sediments throughout Europe.

2.3. Habitat modification as an ecological process

In summary, natural forcing provides a background of habitat modification at generally large scales against which are caste the smaller-scale more localised natural forcing events and biological mediated modifying activities. Habitat modification creates disturbance which is a critical natural process in the maintenance of diversity in aquatic systems. Consequently, the sea floor is a patchwork of communities in different stages of recovery, succession or climax. It is against this natural background of disturbance and habitat modification that the impact and significance of human activities needs to be assessed.

2.4. Key limiting factors for animal and plant communities

Small-scale coastal fleets operate mainly within 12 nm of the coastline. Across Europe these coastal waters extend from the shoreline down to depths that typically range from 30 – 100 m depending on the gradient of the slope of the continental shelf. However in some northern fjordic coastal areas and in the Mediterranean (e.g. around the coast of Sicily), the continental shelf can merge with the continental slope and deep canyons down to depths of >400 m within 12 nm of the coastline. The key physical parameters that limit the biomass and productivity of seabed biota in coastal waters interact to define the environmental context of each area of the seabed. The key parameters that affect benthic communities are; wave erosion, tidal currents, turbidity (light penetration) and primary production (e.g. phytoplankton biomass).

The characteristics of the biological community that can inhabit a particular area of the seabed are determined by the surface geology of the seabed overlaid by the physical and biological processes in the water column above. For example, soft bodied borrowing worms are unlikely to dominate bedrock environments. In contrast, algae and soft corals that require a firm substratum to which they can attach are unlikely to be found in mobile sand habitats. There is a strong relationship between physical forcing and organism body-size. Low energy environments are characterised by organisms that have a larger body-sized, are slower growing (e.g. soft corals, sea fans, erect sponges), whereas high energy environments are characterised by small body-sized, fast growing species (such as polychaete worms and small bivalve molluscs).

2.5. The resilience of natural systems to fishing disturbance

Understanding how animal and plant communities are shaped by natural processes enables us to make predictions about the resilience of these communities to additional sources of disturbance such as those generated by fishing activity. Communities dominated by small body-sized organisms with fast growth rates will recover from fishing disturbance more quickly than larger body-sized organisms that are slower growing. Habitat stability is also a strong predictor of recovery rates of the associated animal and plant assemblages (Dernie et al. 2003). The more stable the habitat, the longer it will take for habitat recovery followed by benthic community recovery.

3. MOBILE AND STATIC FISHING GEARS USED IN INSHORE WATERS

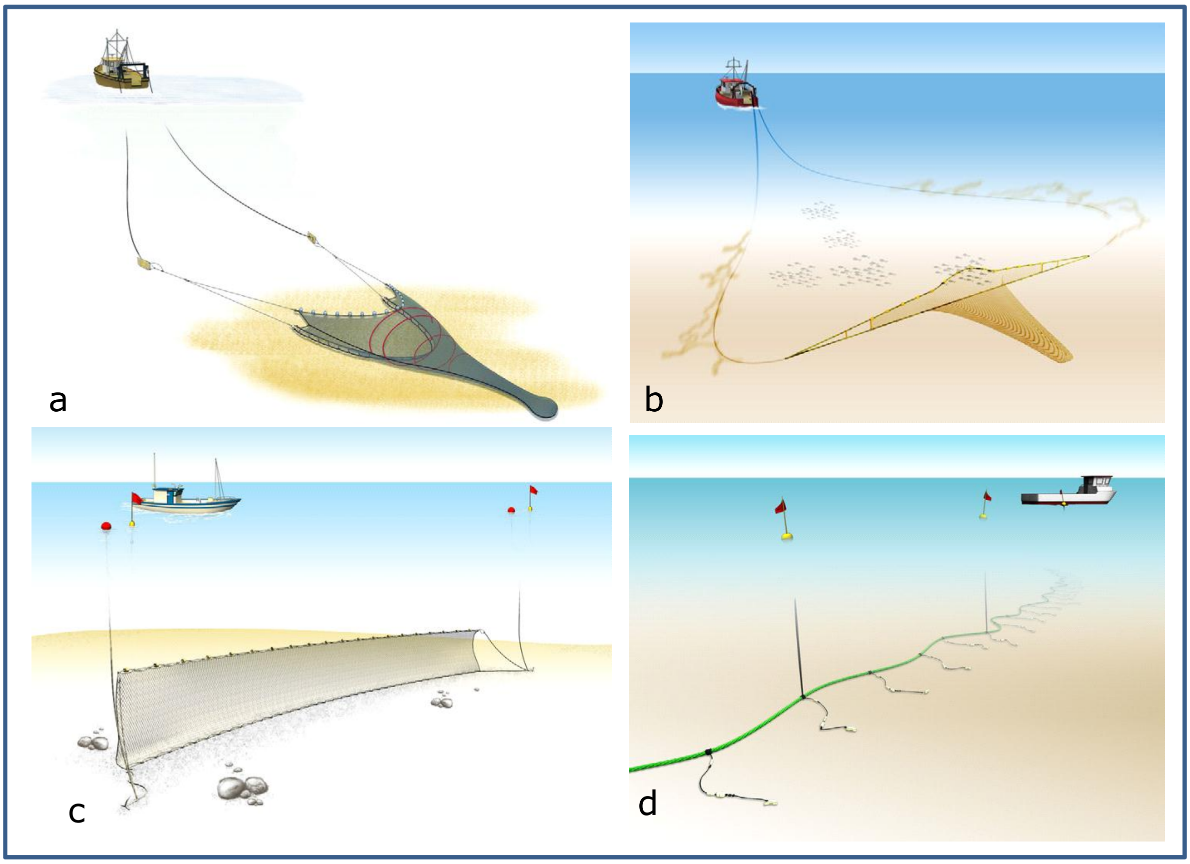
KEY FINDINGS

- All fishing gears have the potential to affect or result in change to marine habitats and communities.
- Towed mobile bottom fishing gears have the largest environmental footprint, but often are fished in areas that are resilient to fishing disturbance.
- Static fishing gears have a small environmental footprint, but when fished in areas of high species diversity and topographic relief they have the potential to have local impacts on those assemblages.
- Static fishing gears are more likely to ghost fish when lost or discarded and are associated with a wider range of negative interactions with endangered, threatened and protected species such as turtles and cetaceans.
- All fishing gear have the potential to be modified to improve their environmental performance to reduce bycatches of all species while maintaining catches of target species.

The main types of mobile and static fishing gear used in European inshore waters are listed in Table 4 and examples of these gears are shown in Figure 2. Mobile and static fishing gear that target species that live in, on or close to the seabed are those most likely to cause direct physical disturbance to the seabed and its associated fauna. Fishing gear that is used to fish for pelagic (mid to surface water) species are unlikely to have direct physical effects on seabed communities.

Mobile fishing gears are those that are towed from a fishing vessel, land based vehicle or by hand (e.g. push nets). Static gear are nets or traps that are actively deployed from a vessel or the shore but remain anchored to the seabed until they are retrieved. Some static gears are fixed in a permanent position and the catch is emptied periodically. Such traps (e.g. fyke nets and stake nets) are usually deployed very close to the shore in shallow water. Handlining, although an active fishing technique, will be considered a static fishing technique for the purpose of this review as the gear is moved vertically up and down in the water column rather than propelled across the seabed. Drift netting involves the deployment of panels of netting suspended from the water surface by floats. These may drift passively either attached to a fishing vessel or left to float freely.

Figure 2: Examples of different types of fishing gear. a) A towed bottom fishing otter trawl, b) a bottom set seine net, c) a bottom set gill net and d) a long-line.



Source: FAO and SEAFDEC

Table 4: The main different types of mobile and static fishing gear that are used in the marine environment in Europe that come into contact with the seabed. The broad categories of target species are shown in parentheses.

MOBILE FISHING GEAR	STATIC FISHING GEAR
Beam trawl (flatfish, some roundfish and brown shrimps)	Gillnet (primarily round fish)
Otter trawl (primarily roundfish, *Nephrops norwegicus*, queen scallops)	Trammel net (roundfish, flatfish, rays, certain crustaceans)
Pair trawl (*Nephrops norwegicus* and roundfish)	Handlining (roundfish and flatfish)
Seine net (roundfish and flatfish)	Longlining (all types of fish)
Dredges (surface dwelling and burrowing scallops and clams)	Pots and traps (crabs, lobsters, whelks, prawns, some fish)
Suction dredges (cockles, clams, worms)	Barrier traps (roundfish and flatfish)

Source: MJ Kaiser

In the following sections a description is given of how each fishing gear operates and how this determines its interaction with the seabed. In section 4 consideration is then given to our current understanding of the extent to which each of these fishing gears impacts benthic habitats.

3.1. Towed fishing gear

The majority of towed fishing gears can be described as either trawls or dredges. We consider these to be distinct from seine or purse nets that are towed into position around shoals of fish prior to being drawn closed and hauled in. As a result, seine nets affect only a limited surface area of the seabed. Purse nets (sometimes known as ring nets) are primarily targeted at midwater species and for this reason are rarely in contact with the seabed. Trawls are fished either in mid-water, just off or in direct contact with the seabed. In contrast dredges are exclusively used to capture species that live in or on seabed habitats, and thus they have been designed to maximise their contact with the seabed.

In common with all fishing equipment, trawls and dredges have been fine-tuned to exploit the behaviour and habitat preferences of the target species in different habitats so that they maximise the catch in the most efficient way. It is only recently that both the scientific community and fishing industry have shifted their attention to the design of fishing gears that maintain efficient catches while eliminating discards and other bycatches.

3.1.1. Beam trawls

Beam trawls are most commonly used in the North Sea, English Channel and Irish Sea. There are other variants such as the 'rastell' in Spain and the 'rapido trawl' in Italy. Beam trawls derive their name from the rigid beam supported by the two shoes at either end. The net is attached to the beam, shoes and ground rope that runs between the base of the shoes. Thus the mouth of the net is held open regardless of the speed at which the net is towed through the water. This means that beam trawls can be towed speeds of up to 7 kt depending on the habitat and target species. The shoes act as skiis that glide across the surface of the seabed and spread the load of the gear and prevent it from sinking into soft substrata. In some cases, these shoes have been replaced by wheels that reduce drag as the gear moves across the seabed.

Beam trawls are specifically designed to catch benthic target species such as brown shrimp and flatfish that live on or buried in the top few centimetres of the sediment. Various configurations of chains are attached between the beam shoes. These chains, called tickler chains, are designed to disrupt the surface of the seabed and disturb or dig out the target species. Small inshore vessels use shrimp beam trawls that are relatively light and have relatively few tickler chains fitted between the shoes. This single tickler chain disturbs the sandy substratum sufficiently to cause the shrimp to flee into the water column whereupon they are caught in the net. A greater number of tickler chains are added to the fishing gear when fishers target species that are buried more deeply than shrimp, e.g. flatfish such as sole, *Solea solea.* Cruetzberg et al. (1987) demonstrated that the catch of sole rose linearly with each extra tickler chain added to their beam trawl. The catch rate of some species levels out after the addition of a certain number of chains, thus fishers can fine tune the gear to maximise catch while ensuring the gear is kept as light as possible. As each chain passes over the sediment, it fluidises the sediment making it easier for the following chains to penetrate deeper into the substratum. Large beam trawls can be fitted with over 20 tickler chains and can penetrate soft sand to a depth of over 6 cm.

Beam trawls fitted with tickler chains tend to be fished over clean ground that has few rocks or obstructions on the seabed. Beam trawls can be fished over rougher (boulder) seabeds by adding longitudinal chains across the tickler chains to form a chain matrix (Fig. 3). In addition, a flip-up gear is fitted to the ground rope. The chain matrix prevents large boulders entering the net, while the flip-up gear forms a barrier to smaller rocks and debris. Despite these innovations, beam-trawls tend to catch large amounts of inert material or non-target benthic species that can rapidly fill the net, clog meshes (thereby reducing their sorting efficiency) and reduce the value of the catch by causing damage to the fish in the codend.

The economic need to reduce fuel consumption, improve catch quality, reduce sorting time and to reduce discards have led to considerable innovation in the design of beam trawls (see Table 3 and Section 1.3). However these innovations are relatively recent and remain under evaluation. The Dutch SumWing trawl is a hydrodynamic wing that eliminates the need for the heavy shoes or wheels that were used in traditional beam trawls. The electric pulse trawl removes the need for lateral tickler chains that penetrate the seabed and hence potentially reduces bycatches of benthic species and non-target fish species. However there are considerable concerns among the wider fishing community about the efficacy of this technique given the potential negative effects associated with over stimulation of fish and other species leading to injury and mortality.

Fishers have also reduced bycatch in beam trawls by inserting larger meshes in the belly of the trawl so that bycatch tends to fall out of the net as it moves across the belly meshes of the net (e.g. 'Project 50%'). While projects such as 'Project 50%' are encouraging in that they reduce the amount of bycatch material landed to the deck of the vessel, the organisms that pass through the net and remain on the seabed may be damaged by the tickler chains and consequently die as a result of these injuries (see Kaiser et al. 1994).

Figure 3: **A small beam trawl fitted with a chain matrix configuration as fished on rough ground by inshore fishing vessels.**

Source: Hilmar Hinz

3.1.2. Otter trawls

Otter trawls are used throughout Europe. They derive their name from the two otter boards or doors that are fixed between the sweeps and bridles (Fig. 2a). Otter boards are hydrodynamically designed so that as they are pulled at an oblique angle through the water they plane in opposite directions. This action holds the wings of the net open. The otter doors have to be towed at a certain speed (depending on their size) for this effect to be achieved. As a result otter trawls are towed more slowly than beam trawls (typically from 2.5 – 3.5 kts). The net is held open vertically by a series of buoys attached to the headline and a weighted foot-rope. The otter doors, the plumes of sediment that they create, and the warps attached to the net also have a herding affect and cause fish to aggregate directly in front of the mouth of the net.

Otter trawls are either fished on the bottom for demersal species such as cod, whiting and *Nephrops*, or in midwater for pelagic species such as herring and mackerel. When rigged for prawns or flatfishes such as plaice, tickler chains are added between the otter boards. However, it is more typical for the foot-rope of otter trawls to be fitted with rubber bobbins or rollers that bounce over obstructions and avoid catching benthic invertebrates, particularly when fished over rough ground (called a rockhopper otter trawl). Consequently, the catches of otter trawls generally contain less bycatch per unit of commercial catch when compared with the catches of beam trawls.

Each of the different components of the otter trawl have the potential to affect benthic habitats and communities to a lesser or greater extent. When the otter doors are in direct physical contact with the seabed, it is these that have the greatest effect of physical disturbance due to their weight and can sink up to 20 cm in soft mud habitats (Fig. 2a). However, in a single tow, the otter doors affect a proportionately small area of the seabed due to their small size relative to the rest of the gear (c.f. the length of the sweeps, bridles and ground rope).

3.1.3. Dredges

Dredges fall into two main categories, they are either mechanical or hydraulic dredges. Dredges are used to capture sedentary species such as scallops, clams and gastropods, that live either on the surface of the seabed or within the sediment. Mechanical dredges are operated by the largest range of vessel sizes and tend to have a simple design based on that of the beam trawl. It is often difficult to tell the difference between what some would define as a beam trawl and others a dredge (e.g. the rapido trawl used in Italy).

A typical dredge incorporates a heavy-duty bag or net attached to a rigid metal frame to which tooth bars or cutting blades of various designs are fitted. In some designs the belly of the bag is made of steel rings due to the abrasion incurred as the gear is towed over the seabed. The rigid rings have the advantage that they do not collapse when the gear is towed and permit bycatches of other organisms to escape, thus scallop dredge catches can be very clean (Fig. 4).

Figure 4: **A gang of four spring toothed Newhaven scallop dredges as fished by inshore fishing vessels.**

Source: Hilmar Hinz

In scallop fisheries, tooth bars with 11 cm long teeth are fitted to the base of the rigid frame and are designed to disturb scallops that lie slightly recessed in the sediment. This gear can become snagged on obstructions on the seabed hence fishers have overcome this problem by fitting springs and hinges to the tooth bar so that it bends back and springs clear of snags (Newhaven spring toothed dredge). These modifications have enabled scallop dredgers to access much rougher ground than would otherwise be possible. On snag free sandy grounds, larger dredges are deployed that have fixed tooth bars and diving vanes to improve the penetration of the teeth into the seabed (French dredge). Most scallop dredges are between 0.75 and 2 m wide and are fished in gangs. The largest scallop dredgers fish with up to 18 dredges per side. The largest dredgers fish up to 20 dredges either side of the vessel, however the number of dredges and engine power of vessels fishing in inshore waters is often restricted as a means of controlling effort and conflict with static gear fisheries. There are a large variety of dredge designs, each of which has been configured to improve the catch of the species in question. For example, in Portugal fishers use dredges fitted with teeth up to 30 cm long to capture razor clams (*Ensis* spp.) (e.g. Constantino *et al.* 2009). The resistance created by such a deep-digging dredge prevents small inshore boats fishing more than two dredges at a time.

Hydraulic dredges use jets of water or air to create a venturi effect, which lifts the dredgings up a pipe and onto the operating vessel for further processing on fixed or mechanical riddles. Some of these devices also use jets of water to fluidise the sediment directly in front of the dredge head. Hydraulic dredging barges are used to harvest lugworms, *Arenicola marina*, in the Dutch Wadden Sea. These worms are sold commercially to meet the demand for bait from recreational anglers. These barges operate on intertidal areas at high tide and create furrows 1 m wide and 40 cm deep (Beukema 1995). Hydraulic dredges operated from boats or mechanical dredges towed behind tractors are used to harvest cockles, *Cerastoderma edule*, and Manila clams, *Tapes philippinarum*, at mid to high tide on sandflats in northern Europe (Hall and Harding 1997). On a smaller scale, divers use hand-held suction dredges to remove razor clams, *Ensis siliqua*. Although the area excavated is relatively small, pits can be up to 60 cm deep (Hall *et al.* 1990).

3.1.4. Encircling nets

These nets tend to be used for those species whose schooling behaviour means that they are found in dense aggregations. Nets are either set from the shore or deployed by boat at sea, but in all cases the net is set around the fish and drawn closed. The net may consist of a simple panel of netting or may incorporate a codend at its centre. The latter design is used in Danish seining when the net is deployed at sea from a vessel. In this case, one end of the net is anchored and buoyed while the vessel steams away paying out the net in a circle eventually returning to pick up the buoyed end before hauling (Fig. 2b). A similar method of seining, Scottish fly-shooting, uses the same approach but instead of anchoring the vessels picks up the Dahn buoy once completing the set and moves forward at a speed of around one knot while winding in the ropes simultaneously. The fish captured using this technique are usually landed in excellent condition because they spend little time in the codend and command some of the highest prices at market. Although these gears have direct contact with the seabed they are retrieved slowly and their footprint on the seabed is small relative to trawls that are towed for hours at a time. Thus, although there have been no studies that directly look at the possible impact of this fishing technique on seabed habitats, it is likely that they have a relatively minor impact compared with bottom fishing trawls.

Purse seines can be extremely large and take entire schools of fish. This method is normally targeted at pelagic species such as tunas, sardines and mackerel. The fish are located using a variety of techniques, either sonar, by spotting schools from helicopters or from the feeding activities of seabirds that are attracted to smaller prey fish that have been driven to the surface by the feeding tuna below. Purse seines are set in the same manner as seine nets often using two vessels to deploy the net. The term 'purse' comes from the mechanism by which the net is closed as the lead line is drawn closed by the purse wire that runs through a series of loops at the bottom of the net. This method is so efficient that the catches are usually too heavy to drag aboard in the net, hence the fish are either scooped up using pan nets or more usually pumped aboard the vessel. In the Mediterranean fish aggregation devices (FADs) are used to concentrate fish whereupon the net is set around the FAD. As cetaceans and marine reptiles are often associated with schools of pelagic fish or are attracted to FADs, this can lead to bycatches and mortality of these organisms.

3.2. Static gear

The gears previously described are all actively fished, i.e. they require manipulation towards the target species by fishers or their vessels. In contrast, static gears are not worked as such, rather they operate passively and entangle or trap the target species that move towards or into them. Fishers improve their capture success by orientating static gear across migration routes, either across or with tidal currents and in close proximity to the refuges used by the target species. The time during which the gear is fishing is known as the 'soak time'. For most gears, there is an optimum soak time after which the catch rate decreases considerably. Fishers also need to consider the quality of their catch, as the longer fish remain in the gear the more decomposed they become and they are at risk from damage by seals and crustacean scavengers such isopods and amphipods. These scavengers are able to strip all the flesh from a fish within 24 hours. Hence, the frequency with which the gear is hauled will depend upon a combination of the cost of retrieval, catch rate and losses to catch degradation.

Set net fisheries have benefited greatly from the development of man-made materials such as monofilament nylon. Nylon nets are virtually invisible in water and the strength of the knots of each mesh increases as the material swells when immersed. Nylon is highly resistant to abrasion, hence the netting has the potential to last for many years. This is also one of the less attractive aspects of set netting. Set nets and pots are occasionally lost due to bad weather conditions or when towed away by other fishing vessels or commercial shipping. When lost, the static nets and pots can continue to fish for many years catching hundreds of organisms during this time. This is termed 'ghost-fishing' (MacFayden *et al.* 2009).

3.2.1. Gill, trammel and tangle nets

Gill nets derive their name from their main method of capture. As fish attempt to swim through the meshes of the net, fish become snagged by the spines on their gill operculi, fins or by their scales. The meshes of a gill net are uniform in size and shape, hence they are highly selective for a particular size-class of fish. Small, usually undersized, fish are able to swim through the mesh unharmed, whereas excessively large fish are unable to penetrate the mesh sufficiently to become trapped. Gill nets are basically a series of panels of meshes with a lead foot rope and a headline with floats (Fig. 2c). These 'fleets' of net are buoyed and anchored at either end to form a barrier. They can be set from the bottom to the surface of the water column. Gill nets are shot either across or with the tide depending on local tidal conditions and the target species. When set on the bottom across the tide, the net will tend to lie flat when the tide is running at its fastest, and will be fully extended at slack water. Hence, catch rate often varies according to the state of the tide. Gill nets are cheap to produce and can be deployed by hand from small boats or the shore. This also means that gill nets are a favoured method for individuals fishing illegally which makes the ecological and population impacts of this fishery difficult to assess accurately.

Trammel nets are similar in many ways to gill nets, but they are set mainly on the seabed. They incorporate three layers of netting, an inner small meshed net sandwiched between layers of large meshed net. As the target species swims through the large-meshed layer it meets the small-meshed layer. Swimming forward, the fish pushes the fine-meshed layer through the next layer of large-meshed netting and becomes trapped within a pocket of netting. These nets work in all states of the tide and are particularly effective for catching flatfishes, rays and crustaceans.

Tangle nets have much larger meshes than either gill or trammel nets. They are designed so that the meshes hang loose between the footrope and headline. As fish or crustaceans move over the net they become snagged on the loose mesh and can become totally rolled up in the netting. Tangle nets work particularly well for spiny organisms e.g. fishes such as monkfish (*Lophius* spp.), elasmobranchs, lobsters and spider crabs.

Gill, tangle and trammel nets have direct physical contact with the seabed, however they do not penetrate the seabed and will only impact upon surface dwelling or emergent animals, plants and algae. Direct physical effects will only occur as the gear moves back and forth in the tide or with wave action and on retrieval. Thus the environmental foot print of each net that is deployed is far lower than that for towed bottom fishing gears. Nevertheless, the effects of a high concentration of nets in a specific area could have cumulative effects on the seabed. However, this issue remains a matter of speculation given the limited scientific attention it has received to date.

3.2.2. Traps

Traps are among the most primitive of fishing techniques that have remained little changed. Generally, traps take advantage of the movements of fishes along a tidal gradient or migration route. The principle of most traps is the same around the world. There is usually a guiding mechanism (e.g. a wall of net or sticks) that directs the fish to the entrance of the trap from which there are a number of non-return chambers or a maze of passageways from which the fish are unable to return.

Pots are a form of trap that are most commonly used in crustacean fisheries, although they are also used to capture predatory fishes and gastropod (snails) such as whelks. Most pots are similar in design, they are made of a rigid frame with a mesh covering in which one or several entrances are inserted. The entrances are designed to prevent animals from escaping, although video observations indicate that in some simple designs the same crab will enter and leave the pot several times. Parlour pots are slightly more sophisticated in design as they have a separate internal chamber containing bait. This chamber incorporates a non-return type of entrance and is much more effective at retaining the animals once they are inside.

Pots are usually deployed in fleets anchored at both ends and marked by surface buoys. Small-scale fishing operations or artisanal fishers use single pots, but these are less efficient to set and retrieve. Most pot fisheries use bait, but some, such as the octopus fishery in the Mediterranean, take advantage of the refuge seeking behaviour of the fished species. In this particular fishery, empty amphorae are set on the seabed and left for several days during which time octopuses begin to occupy the empty vessels. Pots tend to be set for longer than other gears as it takes time for the bait within the pot to begin to attract the target species. Catch rate increases over several days as the feeding activities of animals consuming the bait increases the dispersion of chemical cues. Both crustaceans (crabs, lobsters and crayfish) and gastropods (whelks) follow odour trails borne by water currents.

As for set nets, the environmental footprint of potting is limited due to the static nature of the gear. However, pots are weighted and will have a direct physical impact on surface dwelling organisms to a greater or lesser extent. In addition, due to the robust nature of many pots, they have the capacity to continue fishing for many months or years if they are lost at sea particularly if they have non-return entrances the prevent animal escape (Bullimore *et al.* 2001). This issue will be discussed later in this document.

3.2.3. Long-lines

Long-lines are deployed to catch either demersal or pelagic species (Fig. 2d). Basically, the gear consists of a length of line, wire or rope to which baited hooks are attached via shorter lengths of line. Long-lines are often set in fleets that may be hundreds of metres long with hooks spaced a metre apart. Bottom-set long-lines are anchored at each end and are marked using surface buoys. Sub-surface long-lines may remain attached to the vessel at one end while they are fishing. The line is maintained at the required depth by a series of surface buoys and weights added along the long-line. Long-lines are highly selective as a result of hook size and bycatches of invertebrates are virtually non-existent (Løkkeborg and Bjordal 1992). However, sub-surface long-lines are known to catch diving seabirds and other endangered, threatened and protected species such as turtles. Current recommendations suggest that these long-lines are set below the depth to which these birds dive which can vary from 1 to > 20 m (Løkkeborg 2011). Cambiè *et al.* (2012) demonstrated that the use of large circle hooks could reduce catches of large juvenile and nesting turtles in long-line fisheries.

4. THE EFFECTS OF FISHING ON THE SEABED

KEY FINDINGS

- The effects of towed mobile fishing gear on seabed communities are well understood as a result of 25 years of research.
- Our ability to understand the effects of these fishing gears relies heavily upon a good understanding of the distribution, frequency and intensity and identity of these fishing activities, coupled with a detailed understanding of habitat distribution and overlying environmental parameters.
- It is possible to rank towed mobile bottom fishing gear based on their initial impacts which would indicate that scallop dredges and hydraulic dredges have the most negative instantaneous effects while otter trawls are the least damaging of these fishing gears.
- The development of policies that maintain fishing activities in currently productive fishing grounds would minimise negative environmental impacts on the seabed.
- The implementation of areas closed to fishing can result in a net negative outcome for seabed habitats and the association animal communities.

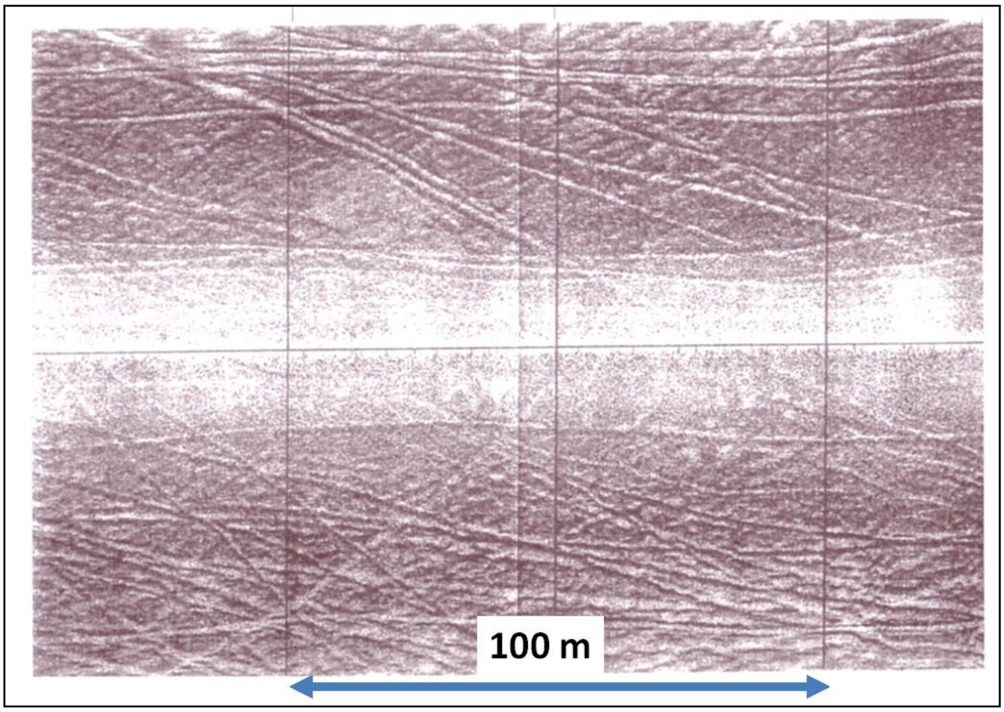
Fishing impacts upon the seabed in a number of different ways. Firstly fishing gear can change the physical structure of the seabed either by creating furrows or smoothing topographic features. Second, biota may be removed, disturbed, damaged or killed as a direct result of physical contact with fishing gear. Recovery of both the seabed and its biological components is a two stage process. In soft sediment environments the habitat may be reformed by natural physical processes, whereas in harder substrata this may not occur and the physical changes may be permanent. Thereafter biological recovery will occur either through active migration or through larval settlement into the disturbed areas of seabed.

4.1. Alteration of the physical environment and processes

Depending upon the habitat type, towed bottom fishing gears will modify surface topography of the seabed which has been demonstrated through the use of acoustic imaging of the seabed (Fig. 5) (e.g. Krost *et al.* 1990; Bergman and Hup 1992). In seabed habitats that have low topographic complexity, towed bottom fishing gears increase surface roughness, owing to the furrowing caused by trawl doors and other gear components. However, when seabed topography is more complex towed bottom fishing gears generally lower surface topography by smoothing ripples, mounds and other structures created either by animals or the physical environment. When these seabed features occur in highly dynamic environments they may be restored by physical processes over very short times scales of days to weeks.

The loss of smaller scale features may be of most concern for local ecosystem processes. Currie and Parry (1996) found that scallop dredging removed mounds and depressions caused by the burrowing activities of shrimps. These features typically accumulated unattached algae and seagrass creating localised patches of organic matter that in turn acted as a food source for invertebrates. This small scale patchiness is considered to be an important factor controlling the diversity and species composition of benthic animal communities (e.g. Hall 1994). Field observations and experimental studies indicate that juvenile demersal fish (such as hake and cod) benefit from protection from predators afforded by small physical features (sand waves, empty shells, small rocks etc) (Auster *et al.* 1996). Over time areas that are fished regularly will result in lower physical relief of the habitat. Recent analyses that have related habitat complexity to fish assemblage composition suggest that a reduction in habitat complexity would favour flatfishes more than demersal roundfish (Kaiser *et al.* 1999; Shucksmith *et al.* 2006).

Figure 5: **An acoustic images of a 100 m wide area of a soft mud sediment (*Nephrops* ground) in the Irish Sea showing multiple furrows made by the otter doors from otter trawlers. This particular area of seabed was fished at an exceptionally high density such that it was fished completely more than 15 times per year.**



Source: Bangor University

4.1.1. Effects of sediment resuspension

The direct physical contact of towed bottom fishing gear with the substratum can lead to the resuspension of sediments into the water column (see Lucchetti & Sala 2012). Although a small number of studies have quantified the geological effects of resuspension attributed to towed bottom fishing gear, the biological implications of sediment resuspension remain unsupported by direct evidence. This requires inferences to be made from our current understanding of the interaction between suspended material and the biological components of the ecosystem. Sediment resuspended as a result of bottom fishing will have a variety of effects including: the release of nutrients held in the sediment (Duplisea *et al.* 2002), exposure of anoxic layers, release of contaminants, increasing biological oxygen demand (Reimann & Hoffman 1991), smothering of feeding and respiratory organs.

Resuspended sediments subsequently resettle, either *in situ* or after transport by water currents. There are relatively few estimates of the magnitude of these processes (e.g.

Churchill 1989; Pilskaln *et al.* 1998; Planques *et al.* 2001; Ferré *et al.* 2008; Puig *et al.* 2012). Churchill (1989) monitored suspended sediment load at a depth of 125 m in the Middle Atlantic Bight, and concluded that most of the suspended sediment load was transported from inshore waters. Storms in shallower water accounted for most of the suspended sediment pulses, except for the most dramatic events during the fishing season, which coincided with intense fishing activity. However, in deeper water where storm-related bottom stresses have less influence, otter trawling activity was the main factor that accounted for the offshore transport of sediment at depths of between 100 and 140 m. However, Churchill (1989) calculated that the transport of sediment that resulted from fishing activities would not produce significant large-scale erosion over a period of a few years. Churchill's (1989) interpretation of these findings were largely inferential based on known patterns of trawling. However, more recent experimental, observational and modelling studies seem to confirm many of his assumptions.

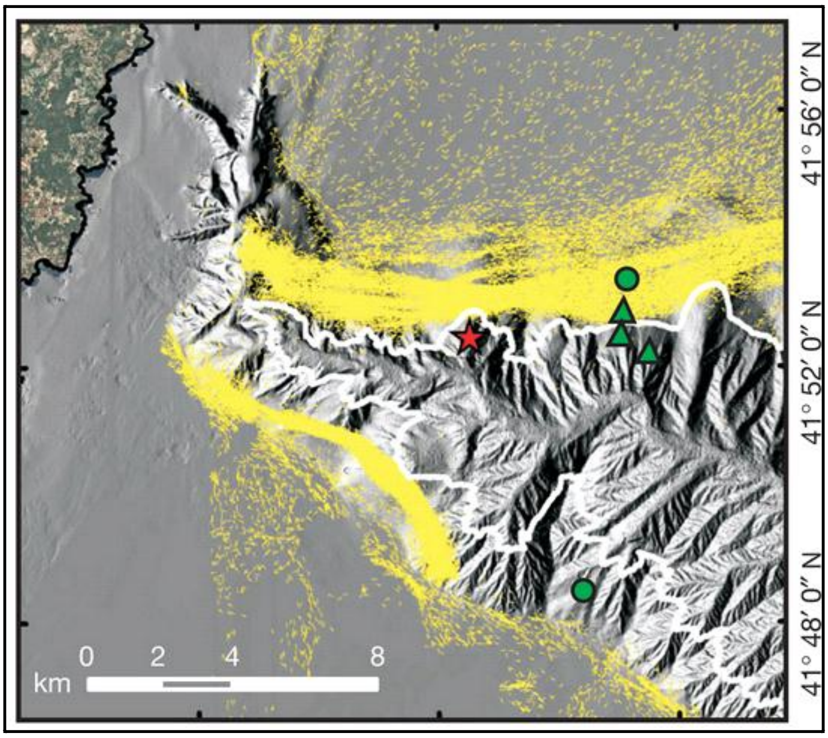
Palanques *et al.* (2001) undertook observations of the sedimentological consequences of trawling on continental shelf sediments. They used moored scientific instruments to quantify the effect of an experimentally fished otter trawl on the fine-mud sediment in water 20-40 m deep off the coast of Barcelona, Spain. They found that the disruption of the surface layers of the sediment led to elevated levels of tidally resuspended sediment for up to 5 days after the trawl disturbance event. This means that after a fishing disturbance event, tidal currents resuspended more muddy sediment than before due to the disruption to the structure of the sediment. The furrows made by the otter boards remained evident for at least one year after the initial disturbance which corroborates other observations of trawl marks in muddy sediments (e.g. Tuck *et al.* 1998). Ferré et al. (2008) modelled natural and trawl disturbance effects and concluded that natural processes (waves and currents) dominated sediment resuspension processes in inshore waters, but found that they accounted for one third of off-shelf sediment transport in deeper water further offshore. Diesing *et al.* (2013) modelled the relative importance of natural vs fishing disturbance at a North Sea and English Channel scale and found that fishing was an important source of resuspension in mud and deep circalittoral sediments. Direct observations by Puig et al. (2012) and Martín et al. (2013) have demonstrated that trawling in near coast deep water canyons reduces canyon topographic complexity and leads to elevated levels of sediment transport down canyons in turbidite flows and an increase in the depth and persistence of the nepheloid layer (Fig. 6). These geophysical changes will increase the environmental stress imposed on the seabed communities in these canyons and reduce their diversity.

Based on these studies, the effects of towed bottom fishing gear on sediment resuspension appear to be far less than natural sources of disturbance in nearshore shallow waters. However the magnitude of the effect of towed bottom fishing gear compared to natural sources of disturbance increases with increasing depth. The effects of towed bottom fishing gears are most pronounced in mud habitats and deeper areas offshore and where the continental slope drops down into canyons as occurs in many inshore areas around the Mediterranean Sea.

4.1.2. Effects on biogeochemical processes

At present little is known about the effects of trawling disturbance on functional processes, despite the expectation that sediment community function, carbon mineralisation and biogeochemical fluxes will be strongly affected by trawling disturbance. This is because trawling can reduce the abundance of bioturbating macrofauna that play a key role in biogeochemical processes and because the physical mixing by trawling unlike the mixing by macrofauna does not contribute directly to metabolic processes in the animal community (Duplisea *et al.* 2001).

Figure 6: Positioning data (small yellow arrows) of bottom trawling vessels fishing from 2007 to 2010 on the sides of a marine canyon off the coast of Spain. The symbols indicated where the scientists made their measurements of the effects of trawling that caused turbidite flows down the canyon.



Source: Puig *et al.* 2012

Duplisea et al (2001) used an existing simulation model of a generalised soft sediment system to examine the effects of trawling disturbance on carbon mineralisation and chemical concentrations. They contrasted the effects of a natural scenario, where bioturbation increases as a function of macrobenthos biomass, with those of a trawling disturbance scenario where physical disturbance results from trawling rather than the action of bioturbating macrofauna (which are killed by the action of the trawl gear). Simulation results suggest that the effects of low levels of trawling disturbance will be similar to those of natural bioturbators but that high levels of trawling disturbance cause the system to become unstable due to large carbon fluxes between oxic and anoxic carbon compartments. The presence of macrobenthos in the natural disturbance scenario stabilises sediment chemical storage and fluxes, because the macrobenthos are important participants in the total community metabolism. In soft sediment systems, where physical disturbance due to waves and tides is low, they suggested that intensive trawling disturbance may destabilise benthic system chemical fluxes, and that this instability had the potential to propagate more widely through the marine ecosystem.

More recently Van der Molen *et al.* (2013) examined simultaneously the effects of climate change and towed bottom fishing gear on biogeochemical processes. They found that towed bottom fishing gear reduced benthic biomass and increased benthic-pelagic nutrient fluxes. However, during the summer period there was a large decrease in the de-nitrification (the process of converting nitrate to ammonium) flux at sites that were stratified which would increase phytoplankton productivity in the water column. Thus during winter, when the water column is mixed the effects of trawling were not apparent. Allen and Clarke (2007) in a separate modelling study found that nitrification (the process of converting ammonia to nitrate which is important for primary production) increased when towed bottom fishing gear removed filter feeders from the benthic system. They also showed that recovery of the ecological processes would occur after 5 years unless the filter feeders had been removed permanently as might occur if reefs of bivalve molluscs such as horse mussels (*Modiolus modiolus*) or oysters (*Ostrea edulis*) are removed through fishing.

4.2. Effects of towed bottom fishing gear on seabed communities

In general, our understanding about the short term effects of towed mobile fishing gear have been informed through use of experiments conducted at sea. The results from such studies are informative and often have confirmed expectations of the type of changes that might occur as a result of fishing activity. Nevertheless, the utility of each study is perhaps limited to the environmental context of the location of the study and the fishing gear used. Furthermore, fishers often reject the applications of findings obtained using fishing techniques that have limited resemblance to their own practices which makes the application of policy difficult. Nevertheless, syntheses (meta-analyses) of the available information have provided a powerful way to inform our understanding of the generic effects of a wide range of towed bottom fishing gear.

There have been two meta-analyses of the available literature to date with the most recent paper extending the work of the earlier version (Collie *et al.* 2000; Kaiser *et al.* 2006). These analyses have revealed consistent patterns in the responses of benthic organisms to fishing disturbance, whether the magnitude of this response varied with habitat, depth, disturbance type and among taxa, and how the recovery rate of organisms varied with these same factors.

4.2.1. Effects of different fishing gears based on experimental studies

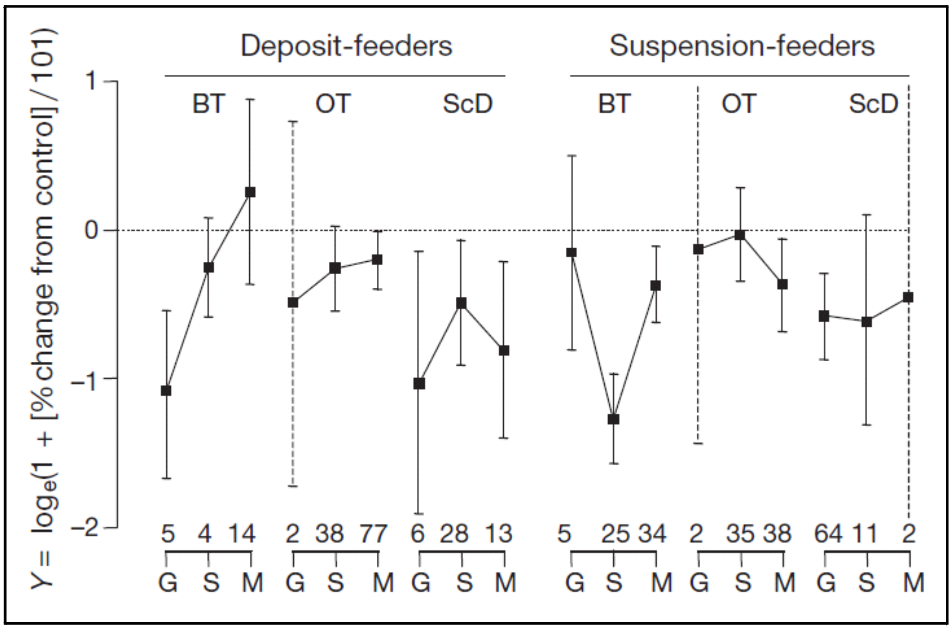
Taken overall, the three main types of towed bottom fishing gears (otter trawl, beam trawls and dredges) have quite different effects depending upon the habitat in which the gear is deployed. Dredges have consistently negative short term effects on animal communities with the effects of intertidal dredging more severe than scallop dredging. In contrast, the effects of beam trawls are least pronounced in sandy environments but more pronounced in more stable coarse sediment environments. The effects of otter trawls are similarly variable (Fig. 7).

Intertidal dredging has the greatest initial effects on the biota because fishers are able to use the harvesting machinery accurately, working the machinery in a systematic fashion. In addition, suction dredging directly removes the habitat. In contrast, fishers using towed bottom fishing gear in subtidal areas are unable to actually see precisely where their gear is fishing on the seabed, although technological advances in positioning systems are making it increasingly easier to achieve very accurate positioning of fishing gear on the seabed. It is also easier to study the impacts of intertidal fishing disturbances as the scientist can accurately collect samples from known (seen) impacted areas and adjacent undisturbed areas, whereas there is an inevitable increased chance of sampling error when collecting subtidal samples. For this reason it is much simpler (and less costly) to evaluate accurately the effects of intertidal fishing activities in contrast to subtidal fishing activities.

Based on experimental studies, otter trawling appears to have the least significant impact on fauna compared with other gears, particularly in soft-sediment (sand and mud) habitats (e.g. Tuck *et al.* 1998). However, these observations need to be treated with caution and are not supported by larger-scale comparative studies. The otter doors that hold the wings of the otter trawl open have the greatest impact on the sediment habitat. However, the otter doors constitute a small proportion of the total width of the gear which increases sampling error. More recent studies that have considered the effects of rockhopper otter trawls on seabed communities have shown these gears to have considerable negative short-term effects on emergent sessile epifauna such as sponges, sea pens, sea fans and corals (Prena *et al.* 1999; McConnaughey *et al.* 2000).

Beam trawls have a greater degree of physical contact with the seabed than otter trawls. However, these gears are other used in mobile sediment habitats inshore where the effects of these trawls on benthic communities are far less pronounced than in more stable habitats in deeper water (Bergmann & Hup 1992; Kaiser and Spencer 1996).

Figure 7: Mean initial response (up to 7 d after impact), with 95% CI, of deposit- and suspension-feeding fauna to (BT) beam-trawling, (OT) otter-trawling and (ScD) scallop-dredging in (G) gravel, (S) sand and (M) muddy sand/mud habitats combined. Dashed lines: confidence interval where only 2 points available for mean calculation, and hence some intervals extend outside plotted range). Values above x-axis: number of data points in each mean calculation. Adequate test for a significant initial impact: whether 95% confidence interval crosses zero-response line.



Source: Kaiser *et al.* 2006

Scallop dredges appear to have negative instantaneous effects on the abundance and biomass of benthic organisms whatever the habitat. The magnitude of these effects varies as for other fishing gear according to the habitat in which the fishing occurs. Thus while Simpson and Watling (2006) reported relatively few effects of scallop dredging on a naturally dynamic seabed in Maine, Hall-Spencer and Moore (2000) reported severe and long lasting (>4 yrs) effects of scallop dredging on a maerl (a slow growing calcareous alga) bed and associated fauna.

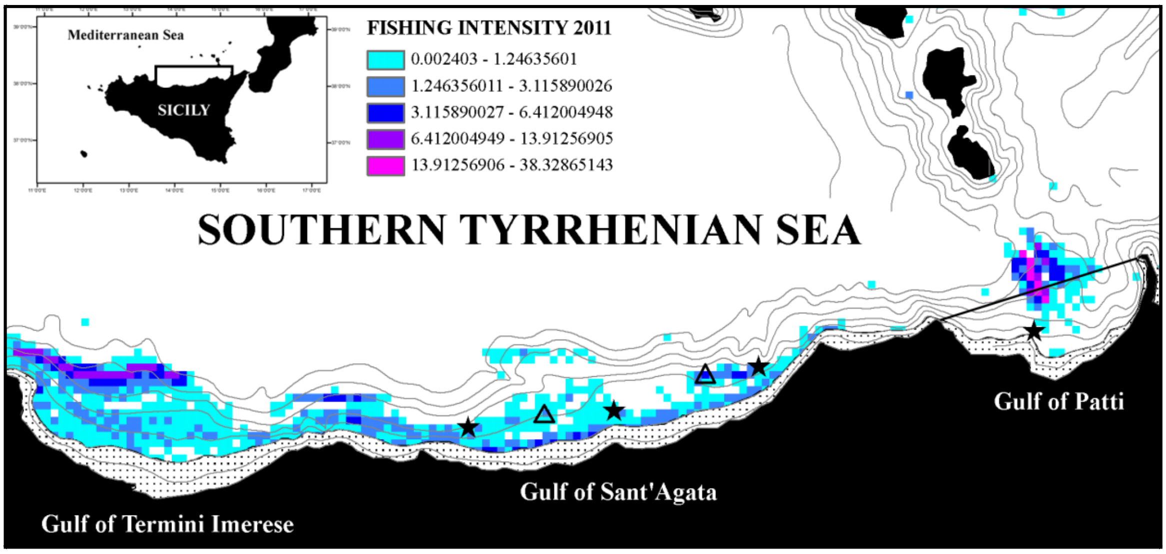
4.2.2. Comparing impacts of different types of towed bottom fishing gear

Only a few studies have compared the impacts and catches associated with different types of fishing gear. Kaiser *et al.* (1996) compared the effects of a 4 m beam trawl fitted with a chain mat with a scallop dredges. Both fishing gears had comparable physical effects on the seabed community, however the scallop dredges retained far less bycatch compared to the beam trawl. In a similar study Hinz *et al.* (2012a) contrasted the impact and bycatch associated with an otter trawl, scallop dredges and skid dredges that were used in the queen scallop fishery. The direct effects of the dredges were more negative than the effects of the otter trawl which also had lower bycatches of benthos. This study is interesting in that it highlighted that the tooth bar fitted to the scallop dredges is not the greatest source of physical impact on seabed biota, rather it is the uniform abrasion associated with the steel ringed bags that is responsible for most of the effects on the seabed community. Bergman and Van Santbrink (2000) compared the impacts of 4 m and 12 m wide beam trawls. In general the effects of both gears were similar on the benthic community although the chain mat configuration of the gear appeared to have less of an impact on benthic organisms compared to 'open gear' fished with tickler chains.

4.2.3. Impacts of towed bottom fishing gear at the scale of the fishing fleet

Small-scale experimental studies such as those highlighted in section 4.2.1. and 4.2.2. have been useful for establishing the instantaneous effect of a known impact intensity or frequency of fishing or for comparing the effects of one fishing gear with another. However, these studies are open to criticism in terms of how well they represent the effects of fishing disturbance at the scale of an entire fleet of fishing vessels for which the pattern of fishing and the distribution of those activities will be highly variable. The relatively recent innovation of vessel monitoring systems (VMS) has revolutionised our ability to map the intensity and frequency with which different areas of the sea are fished. Once mapped, VMS data illustrates that fishing is highly aggregated at scales >9 km^2 which means that while some areas of the seabed are fished intensively (more than 30 times per year) on an annual basis, other areas of the seabed are either never or are rarely fished (less than once every 8 years) (Fig. 8). This understanding presents a very different perspective to the erroneous statistics reported in the media during the 1990s that implied that the entire North Sea was fished between 2-3 times every year. The latter gives the impression every m^2 of the seabed is impacted by fishing. This is entirely misleading.

Figure 8: The distribution of fishing activity for >15 m vessels fishing off the coast of Sicily. The fishing activity is highly aggregated and consistent between years. Note that large areas of the sea are not subjected to fishing. The stippled area close to the coast delineates the 50 m depth contour within which no trawling is permitted. Although the Gulf of Patti is an area entirely closed to fishing (within the black line) there is clear evidence that fishers infringe the area to fish down the canyons that occur within this area.



Source: Mangano *et al.* 2014

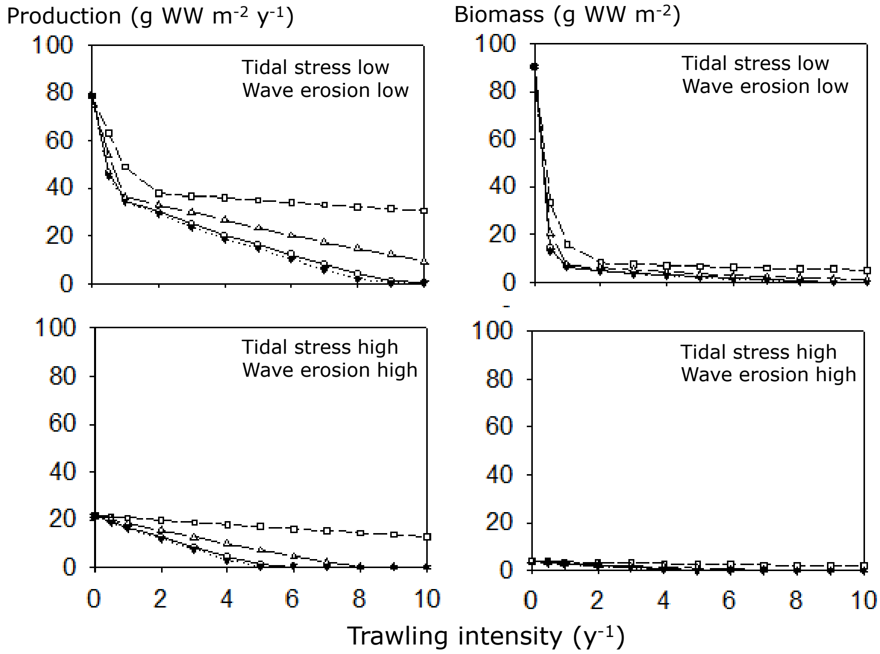
The knowledge of the distribution of fishing intensity gained from the use of VMS has meant that it has been possible to undertake comparative studies in which the benthic community and fish assemblage can be sampled and related to fishing intensity. In such studies, care is need to ensure that the survey design removes as many confounding environmental variables to ensure that the responses of the biological communities are attributed to the fishing disturbance and not some other environmental factor such as temperature, depth etc. The comparative studies undertaken to date have confirmed many of the insights gained from experimental studies but have also enabled predictive models to be developed that have helped us understand the wider consequences of fishing and the possible impact of management measures. A weakness of comparative approaches is that they do not permit an analysis that could differentiate between the effects of a number of different types of fishing activities that co-occur in the same location.

Hiddink *et al.* (2006a) quantified the responses of the benthic community across a gradient of fishing disturbance (otter and beam trawling) at four contrasting sites in the North Sea, each of which had different environmental characteristics. From their results they were able to develop a model that predicted the response of benthic community biomass and production to fishing disturbance in a range of different habitats and under different environmental conditions. The predictions of the model were upheld by confirmatory observations in the field. The models showed that community biomass is affected more than production by fishing disturbance. Furthermore biomass is reduced most severely during the initial interaction between fishing gear and the seabed. As fishing frequency increases the amount of biomass removed decreases steeply. The less pronounced response of production to fishing is caused by a compensatory increase in the productivity of some taxa (e.g. small bivalves and worms) and other competing animals are removed (Fig. 9).

Mangano *et al.* (2013, 2014) studied the benthic communities across a fishing intensity gradient at 36 sites across the continental shelf and slope off the coast of Sicily and Calabria (Italy) (Fig. 8). Their study also encompassed an area that had been closed to trawl fisheries for 22 years. Areas of the seabed where there was no fishing activity were characterised by bioturbating fauna such as burrowing shrimps. In contrast the latter were absent or uncommon in fished areas which were dominated by small worms and bivalves. They were unable to make robust conclusions regarding the effects of fishing on the upper slope due to a lack of adequate statistical power.

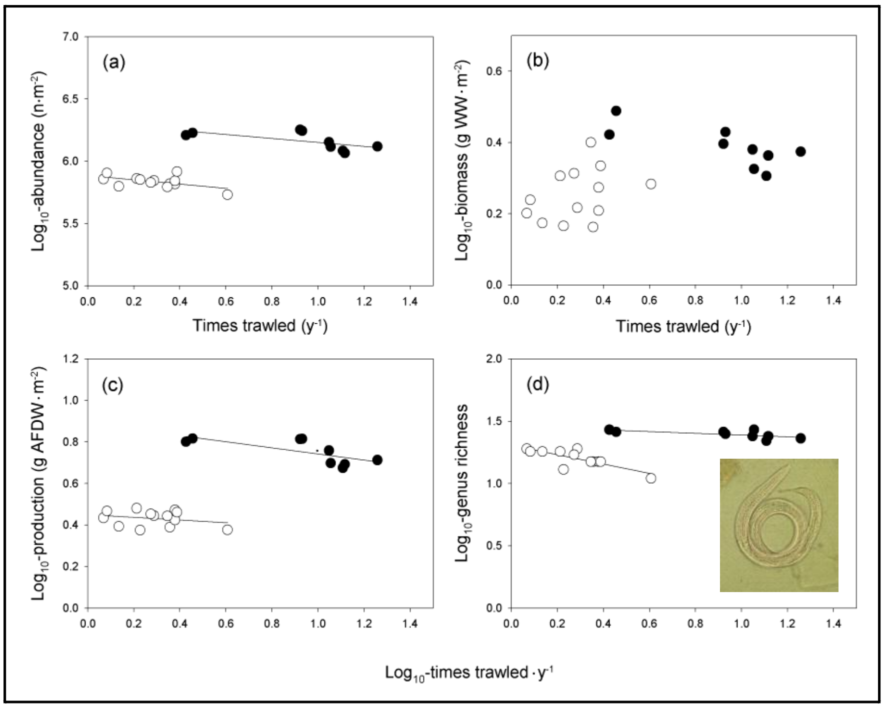
Hinz *et al.* (2009) undertook a similar study in the Irish Sea in which they studied benthic community responses across a gradient of fishing disturbance (otter trawling) at 15 sites in a *Nephrops* ground. They were able to detect clear and predicable community responses to increasing trawling intensity. Community biomass, abundance and diversity declined with increasing trawl intensity. Large emergent sessile species such as sea pens were absent from fished areas but occurred in those areas where there was little or no fishing activity. Hinz *et al.* (2008) found that meiofauna (animals smaller than 0.5 mm) also responded to a gradient of fishing intensity both in the Irish Sea and the Fladen Ground in the North Sea. Prior to this study small body size was considered to offer protection from the effects of trawling, however the change in meiofaunal composition is most likely related to disruption of the sediment habitat microstructure. Meiofauna are particularly important in benthic systems as they account for 50% of production and have a strong influence on microbial communities (Fig. 10).

Figure 9: **The effects of trawling intensity on production and biomass, of benthic communities found in four sediment types in the North Sea. Production, biomass, are given for two levels of shear stress (Pa), two levels of erosion (cm), and four sediment types. Open circle, gravel; solid triangle, sand; open triangle, muddy sand; open square, mud. WW = wet weight. Shear stress is created by tidal currents at the seabed, while erosion is generated by wave action that affects the seabed.**



Source: Hiddink *et al.* 2006

Figure 10: **The response of nematodes (inset image) in the Irish Sea (circles) and the Fladen Ground in the North Sea (triangles) which shows that diversity decreases with increasing fishing intensity**.



Source: Hinz *et al.* 2008

5. EFFECTS OF STATIC GEAR ON THE SEABED

KEY FINDINGS

- The effects of static fishing gear on the seabed are poorly understood compared to the effects of towed mobile fishing gear
- The majority of studies have focused on the effects of pots or traps. Studies to date indicate that these fishing gears have limited or no effects on seabed biota, however there remains the potential for cumulative effects if fishing activity was intense and coincided with habitats that are sensitive to disturbance.
- A single study outside Europe suggests that gill nets can have very localised effects on seabed biota.
- The effects of ghost fishing and issues related to the entanglement of endangered, threatened and protected species would appear to be a more serious issue in relation to static gears.
- Quantification of the issue of seabed disturbance, the quantification of the extent, intensity and amount of static gear fishing inshore waters and its overlap with habitats and species of conservation importance would appear to be a priority.

While there is a rich literature on the effects of towed mobile bottom fishing gear on benthic communities and habitats, there has been minimal attention paid to the potential effects of static fishing gears on seabed habitats. This is primarily because the main concerns surrounding the use of static gears focus on interactions with endangered, threatened or protected species (so called ETP species), and on the effects of 'ghost-fishing' gears lost through poor weather and deliberate or accidental interactions with towed fishing gears or vessels. Unlike towed bottom fishing gear, the environmental footprint of any single static gear deployment is very limited and will be restricted to the surface area over which the traps or set nets are dragged on retrieval, or the area swept as the gear moves about in the currents created by tides or waves.

Eno *et al.* (2000) undertook direct observations of the physical interaction of static gear with seabed habitats and biota. They observed *Nephrops* creels (traps) fished on a muddy seabed and crab pots (traps) fished over a mixed sediment and boulder seabed. In the case of the Nephrops creels, although sea pens (which are a key biological feature of conservation concern in mud habitats) were uprooted or flattened by the pots these were observed to be able to re-burrow into their normal posture. In the case of the crab pots fished over the mixed and boulder seabed, pink sea fans (a Biodiversity Action Plan species in the U.K.) were bent over but remained in situ and were flexible enough to prevent detachment as the pots were dragged over the seabed. However, colonies of ross coral (a calcareous bryozoan) were crushed or broken if impacted by the pot gear. They concluded overall that the effects were minor especially when compared with towed bottom fishing gear.

The problem with the study above is that it provides insight into only the instantaneous effect of static gear retrieval and does not address the potential effects of these gears fished over prolonged periods of time. Coleman *et al.* (2013) were able to address this issue through the use of an experimental fishing zone set up within an existing no take zone that had been enforced for over 10 years. They compared the benthic communities within the experimental fishing zone and the no take zone over a period of four years and found no significant difference between these two areas over that time. Hence, Coleman *et al.* (2013) concluded that the levels of potting exerted within the experimental fishing zone had no ecological effect on the benthic communities within that area. These findings are supported by those of Blyth *et al.* 2004 who compared the diversity of benthic fauna within trawl and scallop dredge exclusion zones to similar habitats on grounds exposed to towed bottom fishing gear. They found that the diversity of benthic communities and the biomass of structural fauna were considerably higher in the zone where only static gears were permitted to be used. Areas that were rotated between towed bottom fishing gear and static gear on a six monthly basis had high species diversity comparable to the areas where only static gears were fished, however the biomass was much lower and comparable to the areas open to fishing with towed bottom fishing gear.

There is some evidence from outside Europe that when long-lived sensitive biota are exposed to static gear fishing damage occurs to these species. Deep water long-lines, fish traps and crustacean traps were considered to have negative effects on sea whips and other emergent fauna in the waters of the Aleutian Archipelago, these effects were clearest at depths between 500 – 850 m where bottom trawling was absent. In shallower water the effects of towed bottom fishing gear masked effects that might have been associated with these static gears (Stone 2006; Heifetz et al. 2009). The problem with this study is that it is not easy to disentangle which gear type is responsible for the damage that occurs. Furthermore the traps used in the fishery are of considerable size (more than 2 x 2 x 1.5 m in dimension) and constructed of robust steel frames and far exceed the size of anything comparable in the Europe.

In a study undertaken off Baja California, Shester and Micheli (2011) undertook detailed observations of the habitat interactions and performance of four different types of static gear (set gill nets, drift gill nets, fish traps and lobster traps). They found that fish traps had the least discards associated with them and that set gill nets had discard rates comparable to commercial trawl fisheries. Furthermore they observed that the set gill nets caused significantly higher removal of biogenic emergent biota such as sea fans and kelp than the other gear types. They speculated that set gill nets could remove up to 2% of the emergent biota per year from the seabed in the area studied and made the point that this figure would be likely to increase if such fishing gears were concentrated in areas where emergent biota were prevalent. It is important to emphasise that while the findings of this study are interesting, the habitat studied is dominated by large structural biota and that such habitats are unusual in European waters. However, where these do occur they are likely to be of conservation interest and are quite likely to occur with marine protected sites such as Special Areas of Conservation. The estimated area of impact on the seabed in Shester and Micheli’s (2011) study is low (2%) but would increase if effort per unit area was increased.

In conclusion, there is a paucity of evidence to enable a robust quantitative assessment of the possible impacts of static fishing gear on benthic communities and habitats. The majority of evidence relates to pot/trap gears and in European waters these seem to have limited effects on benthic species and habitats. However there is some evidence that suggests that very large traps do have impacts but such gears are not used at present in Europe. There are no current regulations that limit the size of trap gear, hence this is an issue that may need to be addressed in future. Set gill nets do appear to have the potential to remove emergent biota from the seabed in areas where such biota are prevalent and hence the interactions between these gears and similar habitats warrants further investigation to understand the extent of the overlap of this gear and habitats. There is no specific evidence regarding the effects of trammel nets and long lines and how they might interact with seabed habitats.

6. RECOVERY RATE AFTER FISHING DISTURBANCE

KEY FINDINGS

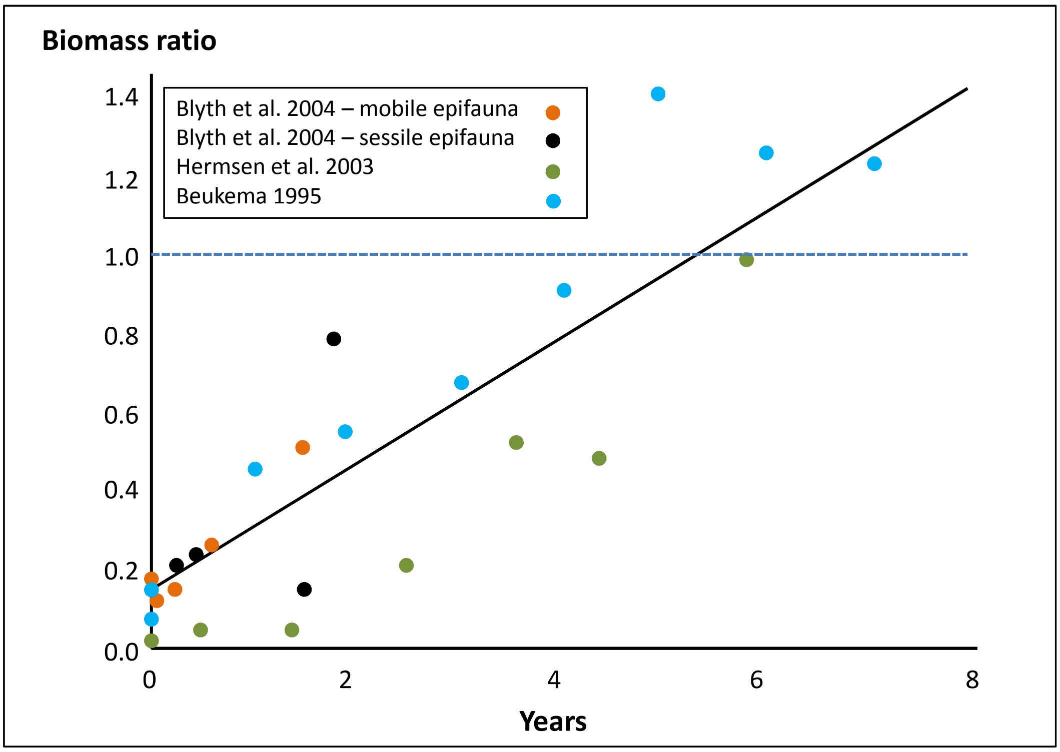
- Depending on the environmental context, seabed habitats and their associated fauna can take from 100 days to >12 years for recovery to occur.
- It is important to understand the distribution of those habitats most sensitive and vulnerable to bottom fishing activities such that these may be protected appropriately.
- There exist many areas of the seabed that are highly resilient to the effects of fishing due to the environmental context in which they occur.
- Some areas of the seabed and their associated biology are so sensitive that they should be fished rarely if ever depending on the intended gear type proposed for use in those areas.

While the short-term effects of bottom-fishing disturbance on seabed habitats and their biota are important, they are of less ecological and management relevance than the potential for recovery or restoration of communities and habitats. Studies of the effects of towed bottom fishing gear that have integrated a recovery component are rare due to the expense of undertaking such studies. No such studies exist for static gears. The meta-analyses of the limited data (Collie *et al.* 2000; Kaiser *et al.* 2006) indicate that some sandy sediment communities are able to recover within 100 days which implies that they could perhaps withstand 2-3 incidents of fishing disturbance per year without changing markedly in character. If this estimate for recovery rate for sandy habitats is realistic, this would suggest that areas of the seabed that are trawled more frequently than three times per year would be held in a permanently altered state. This expectation is supported by a number of studies.

Jennings *et al.* (2001) linked the size and species composition of North Sea benthic communities to patterns of chronic beam trawling disturbance. They found minimal evidence for trawling effects on size composition or benthic production in a series of sandy sites trawled up to 2.3 times per year. However, at another series of sites trawled up to 6.5 times per year, the most heavily trawled sites were characterised by a fauna of low biomass and low production that consisted of very small individuals. This study implies that for the habitat studied bottom trawling did not have adverse long-term effects on the benthic community at fishing frequencies of less than 3 times per year. Other comparative and experimental studies have demonstrated that the communities that live in dynamic mobile seabed habitats are highly resilient to the effects of towed bottom fishing gear. Sciberras *et al.* (2013) compared areas within a Special Area of Conservation (closed to scallop dredging) with areas that were seasonally opened to scallop fishing. Repeated acoustic surveys of the seabed showed that the sand ribbons that dominated the habitat moved considerably over short time scales. As a result the fauna was highly impoverished in terms of abundance and diversity apart from the target species that were the dominant fauna (scallops). Scallop dredging did not lead to changes in the benthic community which was dominated by natural seasonal variations and physical processes. McConnaughey *et al.* (2014) found similar results in the eastern Bering Sea off Alaska, where there were no community responses to the effects of otter trawling. Storm events in were seen to have a much stronger influence over benthic community composition, which was dominated by resilient species and mobile scavenging fauna.

Thus it would appear that dynamic high energy habitats and their associated fauna are reasonably resilient to the effects of towed bottom fishing gear. However, in lower energy environments, the fauna is dominated by larger-body sized fauna and those animals that form reefs or habitat features (pits and mounds). These fauna tend to be longer lived and consequently less resilient to fishing disturbance. Larger body size will also make fauna more vulnerable to physical damage and removal by fishing gear. A good example to illustrate this point is the occurrence of the large bivalve *Mya arenaria* in the intertidal zone of the Wadden Sea. While the majority of the benthos in this environment recovered within 6 months of lugworm dredging, the biomass of *M. arenaria* remained depleted for at least 2 years afterwards (Beukema 1995). This delayed recovery of larger-bodied organisms is no doubt even more important in habitats that are formed by living organisms (e.g. soft corals, sea fans, mussels) as the habitat recovery rate is directly linked to the recolonisation and growth rate of these organisms. A number of comparative studies that have utilised areas closed to fishing as comparators indicate that recovery times of 3 – 8 years are more typical for more stable habitats (Fig. 11) (e.g. gravels and cobble habitat) (Hiddink *et al.* 2006c; Lambert *et al.* 2014). Lambert *et al.* (2014) also found evidence that recovery rate was accelerated if areas of the seabed that had been disturbed were located <5 nm from unfished areas of the seabed. They also found that recovery rate was faster in areas when tidal shear stress at the seabed was higher (Fig. 12, Lambert *et al.* 2014). Lambert *et al.*'s (2014) study underlines the importance of maintaining viable adult stocks to provide a source of larvae for recolonisation of disturbed areas of the seabed. Marine protected areas would provide such a function, as does the aggregated nature of fishing that promotes a mosaic of disturbed and undisturbed patches of the seabed. Thus management measures that distribute fishing more uniformly across the seabed would undermine the recovery potential of the seabed habitats that are affected by that activity.

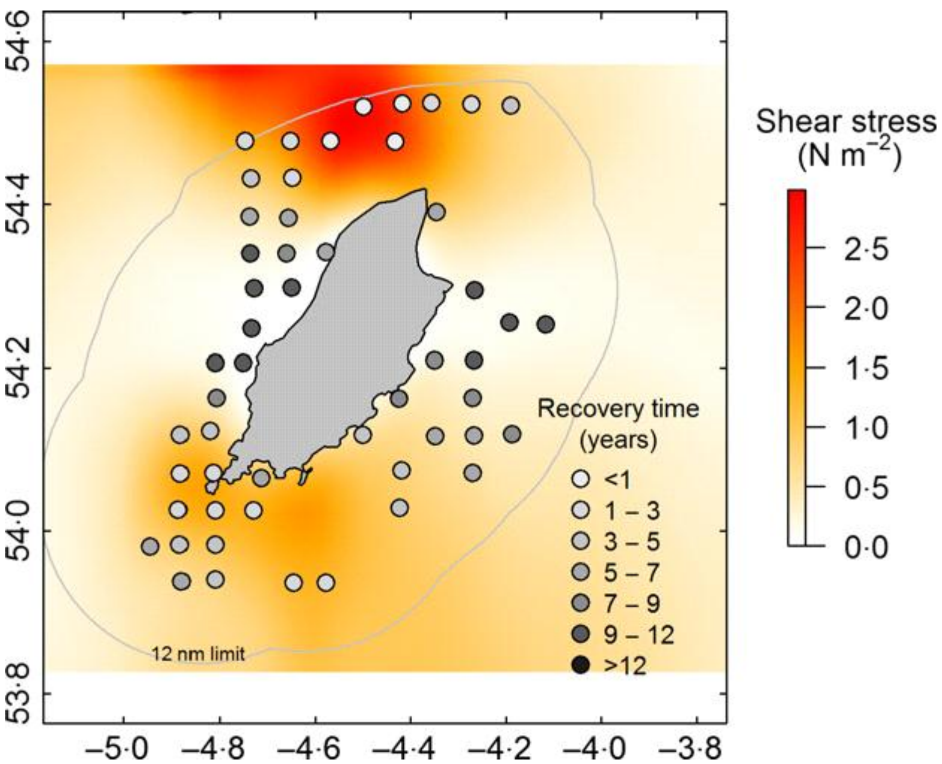
Figure 11: Recovery of the relative biomass of benthic communities after cessation of bottom-trawling. Data from Blyth *et al.* (2004), Hermsen et al. (2003), and Beukema (1995). The biomass ratio is defined as the ratio of the current biomass to the unimpacted biomass.



Source: Hiddink *et al.* 2007

Examples of studies of the impacts on longer lived species are rare. Sainsbury (1987, 1997) examined the impacts of otter trawling on sponge and coral habitats in Australia and found that recovery took from 10 – 15 years or even longer. If we extend these results to deeper water environments where cold water corals can live for hundreds of years, the effects of fishing can be expected to take centuries to recover. Any biogenic habitat constructed by long-lived species (e.g. horse mussel or oyster reefs, sea grass beds, maerl beds) will be sensitive to the effects of towed bottom fishing gears and recovery is likely to take from 5 years to decades. Comparative studies of areas previously exposed to fishing disturbance have shown sea fans (Hinz *et al.* 2011), soft corals and other epibenthos (Blyth *et al.* 2004) and sea grasses (González-Correa *et al.* 2005) to be absent, lower in abundance or degraded in areas that have been exposed to towed mobile bottom fishing activity. Once the disaggregation of the biogenic structure takes place, this fundamentally undermines the possibility of recovery.

Figure 12: **Estimated recovery time (years) of the absolute abundance of all species after fishing impact at stations sampled in the territorial waters of the Isle Man, UK, when a spatial scale of 1 km2 was used to detect the last fishing event. The colour gradient represents tidal velocity, measured as peak bottom shear stress. Areas of the seabed with higher shear stress have faster recovery times.**



Source: Lambert *et al.* 2014

7. POLICY RECOMMENDATIONS

KEY FINDINGS

- A number of recommendations are made for consideration by policy makers that encompass a wide range of issues from further research to fill knowledge gaps, innovation and incentives to adopt gear technology to mitigate environmental impacts, to investment in communication technologies among fishers and new experimental approaches to management.

The following sections make policy recommendations highlighting those initiatives that already contribute to the alleviation of the issue of conflict in inshore fisheries as well as those new or on-going initiatives that require development. Many of these initiatives will only work if fishermen are involved in the development of these ideas from the outset. The latter is inferred through these sections.

7.1. Rebuilding fisheries using F_{MSY}

Under the revised Common Fisheries Policy, a fishery mortality rate (F) that achieves maximum sustainable yield (MSY) is the desired management target for all pressure stock fisheries. F_{MSY} is a mortality target that will provide the conditions in which fish stocks have the opportunity to increase and sustain into the future moderate levels of fishing activity. In addition, F_{MSY} would achieve an overall improvement in the environmental performance of many of the fisheries discussed in this document and would reduce conflict within and among sectors.

Irrespective of the amount of fish landed, many of the wider ecosystem problems associated with fishing are directly related to the amount of fishing activity required to catch the fish that are ultimately landed. The use of total allowable catches (TACs) as a management tool to control the amount of fish landed does not restrain the amount of fishing activity (and hence the amount of fish or shellfish killed to achieve those landings) that occurs to achieve the target quota unless combined with effective technical measures such as 'days at sea'. Consequently when fish stock biomass is low, the use of TACs can exacerbate the mortality of under-sized fish and the wider effects of fishing on non-target species and habitats (see Table 5).

When the number of fish above the minimum landing size (MLS) is low, fishermen have to work harder (fish for longer) to achieve the total allowable catch (TAC), even though this is set lower than when the population size is high. This is because as fish become less dense, fewer and fewer locations will yield sizeable catches of fish over the MLS. In this situation the following are examples of the negative ecosystem effects that will occur:

- For demersal towed fishing gears: a greater number of tows are required to catch the fish to achieve the TAC.
- A greater proportion of fish under MLS are caught and killed or discarded.
- A greater number of tows mean that a larger area of the seabed is directly impacted by fishing gear. When the seabed is fished for the first time, this reduces the biomass of animals living on the seabed by 50% and reduces their overall production (the amount of animal material produced per unit time per unit area) by approximately 23% (see Figure 9). Thus increasing the area of seabed affected by towed fishing gear can reduce the food available for fishes that feed at the seabed and can reduce critical habitat for some species or certain life-stages (e.g. juveniles).

- For pelagic fishing gears: a greater number of tows or sets will increase the likelihood of incidental catches of cetaceans, turtles and seabirds.
- For static gears (pots, creels, long-lines, gill and tangle nets): a greater number of fleets of gear and longer soak time will increase the probability of incidental catches and entanglement of cetaceans, turtles and seabirds.

Table 5: Different fishing gear sectors showing the extent to which they have a negative (**** = most, * = least, n = none) effects on different components of the ecosystem and whether different management tools can alleviate these effects. Y = likely to alleviate problem, N = unlikely to alleviate problem, Y/N = may alleviate problem depending on objective.**

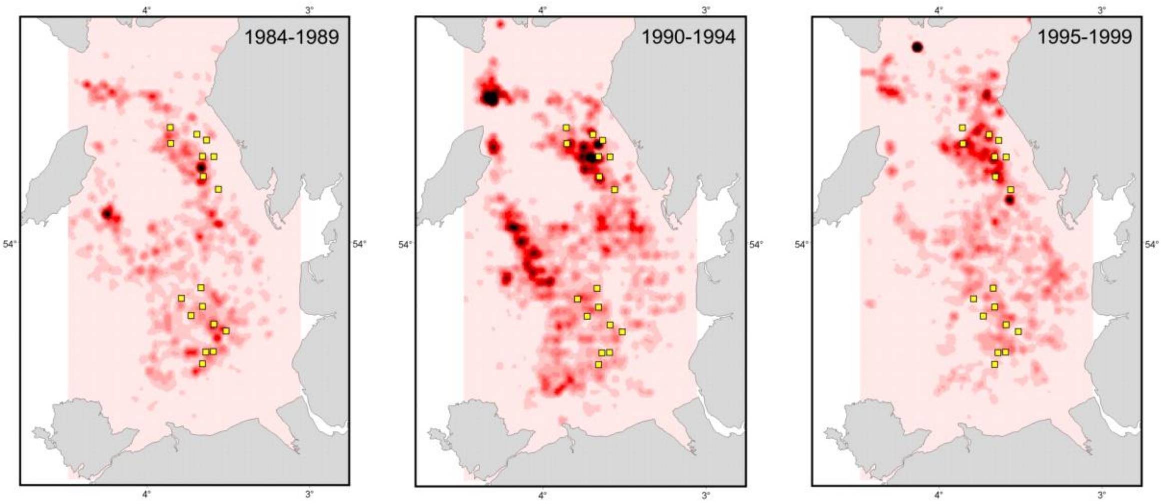
	ECOSYSTEM PROBLEM	EXTENT OF PROBLEM	F_{MSY}	TAC	AREA CLOSURES
Otter and beam trawls	Undersized by-catch	****	Y	N	Y/N
	Incidental by-catch	***	Y	N	Y/N
	Seabed disturbance	****	Y	N	Y/N
	Litter/ghost fishing	*	Y	N	N
Scallop dredges					
	Undersized by-catch	*	Y	N	Y/N
	Incidental by-catch	*	Y	N	Y/N
	Seabed disturbance	******	Y	N	Y/N
	Litter/ghost fishing	**n**			
Creeling/potting					
	Undersized by-catch	*	Y	N	Y/N
	Incidental by-catch	**	N	N	Y/N
	Seabed disturbance	*	N	N	Y/N
	Litter/ghost fishing	***	N	N	N
Gill and tangle netting					
	Undersized by-catch	*	Y	N	Y/N
	Incidental by-catch	****	Y	N	Y/N
	Seabed disturbance	*	Y	N	Y/N
	Litter/ghost fishing	***	Y	N	Y/N
Long-lining					
	Undersized by-catch	*	Y	N	Y/N
	Incidental by-catch	***	Y	N	Y/N
	Seabed disturbance	*	Y	N	Y/N
	Litter/ghost fishing	*	Y	N	Y/N

Source: MJ Kaiser

In contrast, when fish stocks are healthy and fish over the MLS are abundant, TACs can be achieved more rapidly with fewer tows, provided that i) the TACs are set at moderate levels and ii) that high-grading does not occur. The latter is likely to be discouraged with limits on the time that can be spent at sea. A reduction in the time required to land the TAC will alleviate most of the points raised above. As fish fill up their preferred habitat, concentrations of fish can be targeted such that the largest catches per unit effort are taken from preferred fish habitat. This effectively focuses fishing activity on a smaller area of seabed and reduces the extent of fishing impacts on the seabed (see Figure 13).

Recommendation 1: Put in place policy instruments and incentives to achieve F_{MSY} for as many fisheries as is practical given the complexities of mixed fisheries in Europe.

Figure 13: **A time series of data showing the spatial distribution of towed bottom fishing gears in the NE Irish Sea. The areas in light pink have either no or very little fishing activity. It is important to note that the pattern of fishing effort over time is consistent. In addition we can see how management measures that do not control the time spent at sea lead to an expansion of fishing disturbance to the seabed as shown for the period 1990-1994. This data is based on sightings from enforcement aircraft.**



Source: Kaiser 2005

7.2. Quantifying the footprint of inshore fisheries

The formulation of effective policies and relevant management advice is made difficult without appropriate information on the extent of the issue, in this case the distribution of fishing activities of static and mobile gear fishers. At present we have the data necessary for a good understanding of the distribution and intensity of fisheries undertaken by vessels over 12 m in length as these are now fitted with Vessel Monitoring Systems. A proportion of >12 m vessels fish in inshore waters. However, at a national level it has proved difficult for scientific advisory bodies and academics to have access to data that is disaggregated at the level of fishing gear type. EU directives relating to data confidentiality (for data less than 3 years old) necessitate that the appropriate authorities protect fisher confidentiality by aggregating data from all sectors that operate within a given area before it is released for wider scientific use. This means that for an area 3 x 3 nm fishing activity data from VMS records would include information from all towed bottom fishing gear within that area. The consequence of this is that it is impossible to determine which gear affects a particular area of seabed within that area, or which gear is responsible for most of the interaction with the environment. Limiting data access in this manner will lead to erroneous advice that often over-estimates the interaction between fishing gears and habitat and other conservation features (see Hinz *et al.* 2012b for a detailed analysis). An over-estimate of the extent and intensity of the interaction between fishing gear and habitat features could trigger the use of the 'precautionary approach' that would exclude all fishing activities, whereas access to more detailed information could provide the necessary evidence to inform a more proportionate approach to managing the interaction between fishing gear and the seabed.

An increase in the resolution of VMS data would greatly improve our ability to understand Good Ecological Status (GES) in the context of the Marine Strategy Framework Directive (MSFD). A recent study has evaluated the consequence of using VMS data points only versus interpolations of fishing activity between consecutive data points to establish the status of seabed impacted by bottom fishing gears. Using interpolated data provided a much more meaningful indication of the amount of seabed that is either unfished or in a state of recovery (Piet and Hintzen 2012). Such measures would be improved considerably if the recording rate of vessel positions was increased. This greater precision would show that GES is achieved for a greater proportion of the seabed.

Recommendation 2a: Make VMS data fully accessible to the science user community down to the level of gear type and protect fisher confidentiality by stipulating how the outputs are presented in publications or other media. Increase the polling frequency of current VMS systems to improve the precision of estimates of the footprint of the entire fleet.

In Europe 98.4% of the fleet is <15 m in length and in the U.K. approximately 86% of the fleet is in the <12 m category. At present we have no systematic means of recording the intensity and frequency of inshore fishing activities for vessels less than 12 m in length. Thus we know very little about the activities or distribution of the majority of vessels that fish in inshore waters (Breen *et al. in press*). Although fishers may be reluctant for their activities to be recorded, the lack of this information could potentially inhibit them from continuing to be able to fish in Natura 2000 sites and other areas with conservation status as under Article 6 of the EU Habitats Directive (92/43/EEC) they will be required to provide evidence of the impacts of their fishing activities within those areas if they are to be allowed to continue fishing. Thus inshore fisheries may be severely disadvantaged due to the lack of such data in the near future. Foresighted producer organisations are currently attempting to map their member's fishing activities using questionnaires and mapping techniques (P. Trebilcock pers. comm.).

However, questionnaire based mapping exercises are open to criticism about their objectivity. The production of cheap smart phone and other mobile applications that transmit data at minimal cost would seem the way forward. Producer organisations, fisher cooperatives or other independent bodies could be given responsibility for the collation and reporting of this data in conjunction with independent audit and scrutiny. Giving fishing organisations the responsibility to collate and report this data would increase buy-in and trust from participating fishers. Such data would show immediately those areas of inshore waters where the potential for conflict among different sectors is greatest and would help target efforts to mediate between these sectors. If this data was linked to landings records it would improve stock assessments by increasing the precision of scientific estimates of catch per unit effort.

Recommendation 2b: To understand better the extent and overlap of inshore fisheries with habitats and other sectors, fund, develop and install inexpensive phone or mobile application based position recording systems that generate data on fleet activity that is collated and reported by fisher organisations or independent entities.

7.3. Understanding static gear impacts on the seabed

We have a good understanding how towed bottom fishing gears interact with the seabed habitat and benthic communities as a result of several decades of research and current EU funded and international programmes. In contrast, our understanding of the direct and cumulative effects of static gear on the seabed and its associated biology is severely limited. A specific focus on the effects of static nets and long-lines is needed to address this data gap in relation to their interaction with the range of different habitats in which they occur across Europe. While the available evidence suggests that pot (trap) gear used in Europe has limited (or no) effect on benthic habitats and communities, we lack an understanding of the relationship between fishing intensity and the response of habitat and community features for any static fishing gear.

Recommendation 3: Target funds to fill the evidence gaps in relation to understanding how static gears across Europe interact with the seabed and its biological components and establish the pressure-state relationship.

7.4. Understanding what is impacted by inshore fisheries

Current EU initiatives to implement an ecologically coherent network of marine reserves (marine protected areas – MPAs) have brought into sharp focus the gaps that exist in our current knowledge of the distribution and extent of habitat features and species of conservation interest. This knowledge gap severely impedes our ability to assess the overlap between habitats and their associated biota with different fishing activities. The latter is important if we are to be able to assess the risk of fishing having adverse effects on conservation features. Given current knowledge gaps, the approach has been to apply the precautionary principle as a baseline position. In circumstances when evidence and data is inadequate, this may lead to a 'gold plating' approach that unnecessarily limits commercial fishing activities. Some EU countries, such as Ireland, have invested in comprehensively mapping their seabed resources and features. However most of the EU seabed remains unmapped with only point samples taken at a very coarse scale (typically between 10 km to 50 km apart). Moreover, seabed habitats have the highest diversity at small spatial scales in inshore waters due to the prevalence of physical processes that shape the seabed and its biota. Given the current focus on the interaction between fishing gear and conservation areas, investing in the comprehensive mapping of these areas would seem a high priority. Fishing activities that are displaced unnecessarily will inevitably lead to a greater concentration of fishing effort in inshore waters and will inevitably lead to a higher incidence of conflict among and within different sectors.

Recommendation 6: Undertake EU wide comprehensive mapping of habitats and biological assemblages in European conservation sites (as a priority) to improve the understanding of the extent of overlap between conservation features and inshore fishing activities.

7.5. Improving communication between different inshore fishery sectors

Incidents of conflict have in some cases lead to initiatives to improve dialogue and information transfer between different sectors in the inshore fleet. French and English fishers exchange positions of static gear locations with the towed bottom fishing sectors as a means of avoiding conflict. Annual coordination meetings occur to agree on the protocols for the mid English Channel static gear and towed fishing gear boxes that rotate on a 6 weekly cycle (section 1.1). Such coordination is effective but time consuming and takes time for relationships to develop between different sectors and different nationalities (MacFadyn *et al.* 2009; J. Portus South West Producer's Organisation, pers. comm.). Investment could be directed towards funding personnel at a regional level whose role was to act as a coordinator among different producer and fishing organisations to facilitate this information exchange. Given current advances in technology, it may be possible to develop a live interactive map to enable fisheries at a regional level to plot the location of their gear in real time so that other fishers would be able to avoid gear conflict based on the most current information. This information could be derived from 'gear in – gear out' technology with transmitters fitted directly to the fishing gear. This could apply equally to both static and mobile fishing gears and could integrate a facility for selective sharing of information (i.e. so that only those with whom a fisher wanted to share information could view that information). Such a system might be 'inward facing' initially, however it is possible to see how such a tool could be used by the industry to defend itself against inaccurate accusations regarding its behaviour.

Recommendation 5: Invest in 'facilitators' to help communication about fishing gear activities between different sectors and nationalities. Invest in IT technology and a suitable and secure platform to enable the development of real-time mapping of actively fishing gear to reduce conflict.

7.6. Integrated fisheries management for scallop and static gear fisheries

Scallop fisheries could be managed much more effectively to achieve greater profitability and yield while minimising disturbance to the seabed and its biota. In the Baie St Brieuc in France, fishermen cooperate in an enhanced scallop fishery in which a rotational closed area/open area policy is applied. A similar approach could be applied to wild capture scallop fisheries (i.e. without enhancement) and was tested recently in the Isle of Man, Irish Sea. Here, a large conservation area was designated within which areas were closed permanently to fishing, while other areas were demarcated for fishing after a period of time that allowed scallop biomass to regenerate. The fishing management zone (FMZ) was left closed for 5 years. Prior to reopening the FMZ it was surveyed to map scallop density. After consultation with the fishing industry only those areas with the highest densities of scallops were allocated for fishing. A catch limit was set and the producer organisation leased two vessels to undertake the fishing which was achieved in two days. The allowed harvest was achieved while only 3% of the seabed in the FMZ (FMZ total area 47 km^2) was impacted by scallop dredging. An energy efficiency calculation of the protein yield from this fishery rated it as more energetically efficient than beef, pig and egg production (Dignan *et al.* 2013).

This approach to managing scallop fisheries would require complex cooperation among fishers at much wider spatial scales, however the gains in profitability (from avoiding fishing low density scallop beds) and the environmental benefits derived from the preservation of natural capital on the seabed make it an exciting prospect. Indeed one can foresee extending the cooperation to include static gear fishers such that areas left fallow to allow scallop populations to rebuild could be fished by pot or static net fishers thereby removing scallop predators (crab) and further enhancing the fishery. Such an approach would require the use of some form of property rights to enable fishers to 'own' the right to fish the resources within specific areas of the sea.

Recommendation 6: Investigate in conjunction with the fishing industry the cost/benefits of a spatial management approach outlined in section 7.6 and implement some 'experimental management systems' to investigate the efficacy of this approach.

7.7. Reduce the ghost-fishing potential of static gear

One of the outcomes of conflict in inshore fisheries is the loss of static gear. It is clear that ghost fishing by static gears (nets and pots/traps) is an issue that needs more precise quantification in Europe. The prevalence and amount of ghost fishing gear is currently unknown in European waters. The probability of static gear continuing to 'ghost fish' is highly variable as demonstrated by a number of observational and experimental studies (Kaiser *et al.* 1996; Erzini *et al.* 1997; Bullimore *et al.* 2001; Revill & Dunlin, 2003; Beata *et al.* 2009). In North America, this issue is considered to be important from a fishing industry perspective as evidenced by industry initiated 'clean up' campaigns in which involve fishers voluntarily dragging the seabed to retrieve ghost-fishing gear (Bech, 1995). A high priority should be to reduce the ghost fishing potential of static gear. The use of escape panels and degradable components that incapacitate the catching potential of pot/trap gear after a fixed period of time should be investigated further and implemented as a mandatory objective. Initiatives that enable the quantification of the amount of fixed gear in use should be encouraged. This could be achieved through bar coding of rope and static gear components (monitoring at the point of sale). While it is relatively simple to neutralise the fishing capability of pot/trap gear, set nets are more problematic due to the costs of renewal of entire fleets of gear.

Recommendation 7: Investigate the potential and cost-effectiveness for 'rot out' and degradable components of static gear to reduce/eliminate 'ghost fishing' potential of these gears when lost at sea. Quantify the amount of static gear in use through monitoring at the point of sale and determine the amount of gear ghost fishing in EU inshore waters.

7.8. Technical innovation to reduce physical contact with the seabed

The minimisation of the contact of towed bottom fishing gear with the seabed has been the focus of a number of fishing industry/science partnerships over the last decade. Industry led innovations are to be encouraged. However, trials of gear innovation have been confined to small scale experiments rather than larger scale comparative management experiments at the scale of the fishery. A case in point is the innovation of the electric pulse beam trawl. This fishery is innovative and offers some interesting potential in terms of selectivity. However there remain concerns among many sectors of the commercial fleet and the recreational sector regarding the wider and as yet unquantified effects of this new innovation. Nevertheless a range of vessels have been licensed to fish with this gear but with no robust means of comparing their performance or environmental effects with standard beam trawls. A better approach would be to adopt an experimental approach to management whereby specific areas of the seabed are designated to be fished by the innovative gear while other comparable areas are fished with the standard gear. This would enable a much more robust evaluation of the effects and benefits of the innovative gear to be evaluated. Such an approach would certainly help unravel the issues surrounding the North Sea 'plaice box' where fishers report that the plaice have 'followed' the fishery due to changes in the production of prey species in response to intense trawling on the edge of the closed area.

Recommendation 8: Increase the use of experimental management regimes to evaluate new technical innovations and other management measures at a realistic spatial and temporal scale.

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