Moving Towards Low Impact Fisheries In Europe

Policy Hurdles & Actions

SEAS AT RISK

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Contents

List of Tables:

List of Figures:

1 Summary

1.1 Introduction

Fisheries have impacts on the marine environment other than those that arise from the removal of a proportion of the population of the target species. These may be direct, such as impacts on marine populations or habitats from unselective gear, destruction of the seabed or interactions with rare or endangered species. Fishing impacts may also be indirect, for example contributing to climate change via the carbon emissions of fishing vessels.

In this report, we i) rank EU fishing fleets according to their direct and indirect environmental impacts (as far as possible), from most to least environmentally damaging; ii) consider the hurdles that fishermen face in trying to switch from an environmentally damaging fishing technique to a less damaging one; and iii) consider the policy actions that could be taken at EU, Member State and/or local level to reduce or eliminate some of these hurdles.

We analyse the relative impacts of different fishing techniques and fleets using fisheries data published by the European Commission and other published studies. We analyse the hurdles and potential policy actions using a series of 19 case studies taken from fisheries operated by European Union Member States. Information for the case studies was gathered either from published sources or from interviews with people in or close to the industry. Due to the sensitive nature of some of the information presented in the case studies we are obliged to keep sources anonymous where anonymity was requested, however as much information is provided as possible.

1.2 Part 1 – Analysis of environmental impacts by gear and fleet

The European Commission categorises fishing gears into three groups: towed, mobile and passive. Towed gears include all types of trawls and dredges. Passive gears (also known as 'fixed' gears) include fixed or drifting gillnets and trammel nets, fixed or drifting longlines and handlines. Mobile gears (intermediate between passive and towed) include seines, towed longlines and trolling lines. In terms of vessel numbers, the most commonly used gears in the EU are passive gears (fixed gillnets and trammel nets). In terms of total vessel tonnage or power, the most commonly used gear is towed – the demersal otter trawl.

We first consider direct environmental impacts. It is clear that different types of gear will have different types of impact – selectivity, bycatch, habitat impacts and impacts on vulnerable species vary a great deal by gear. Gears that rank highly for one type of impact may rank low for another. We assessed gears according to these four types of impact (using a series of published studies) to produce a ranking according to the type of fishery. For pelagic fisheries, drifting gillnets were considered the most damaging, particularly in terms of their impacts on vulnerable species. Lines were considered the most environmentally friendly option for pelagic fisheries, while midwater trawls and purse seines were intermediate. For demersal fisheries, dredging and beam trawling were considered to have the highest impact, followed by other demersal trawls, then nets. Again, lines were considered the best option to minimise direct environmental impacts.

Secondly we consider carbon emissions. We found it much more difficult to rank gears by carbon emissions. An important consideration is whether carbon emissions are assessed per unit weight of catch or per unit value (i.e. per kg or per €). If they were calculated per unit weight, high-volume fisheries (usually fisheries for small pelagic species) tended to rank high – however we note that the produce of these fisheries is usually processed into fish meal to produce other types of animal protein – if the emissions per unit value of the final product were considered, doubtless these fisheries would perform a lot less well. If carbon emissions are calculated per unit value of catch, fisheries for very high value species tend to perform best. It was, however, possible to draw general conclusions from this analysis, if tentatively, as follows: i) generally demersal trawl fisheries and offshore longline fisheries both performed badly in terms of emissions per unit catch; ii) towed and mobile gears generally performed worse than passive gears; iii) with some exceptions, small vessels performed better than medium-sized vessels – however there was no evidence that medium-sized vessels performed better than large vessels (but data was sparse for this comparison); iv) depleted, poorly managed stocks led to higher emissions per unit of catch. The most striking result from our analysis, however, was the high and unexplained variability between fleets and Member States.

1.3 Part 2 – Analysis of hurdles to reducing environmental impacts

We identify three types of changes that could be made to reduce environmental impacts in a fishery: i) technical changes to vessel or gear that do not involve significant changes to the nature of the fishery (gear type, target species and area of operation); ii) changes to the gear type used by the fishery; and iii) changes at the level of whole fisheries – i.e. promoting some fisheries and eliminating others.

For technical changes (9 case studies), the major hurdles to change were not specifically related to public policy, but instead were i) technical; ii) financial and iii) lack of knowledge. Particularly for carbon emission impacts, it was clear that some vessels and fleets operated much closer to best practice than others, and that most fishermen were aware of some but not all of the possible innovations. For direct impacts, changes (mainly involving adaptations of gear) had variable and sometimes unpredictable impacts on different sectors of the fleet.

For changes in gear type (6 case studies) hurdles were more significant and more likely to be related to the policy and regulatory environments. These included i) inflexibility in the management system (particularly related to quotas – different gear types produce a different spectrum of bycatch, for which a fishing operation may not have a right to quota); ii) gear conflicts (passive gear cannot be used where a lot of towed gear is in operation); iii) reduction in total catch ('good' gears often catch less than 'bad' gears – particularly where trawls are substituted for other gears); iv) unforeseen environmental impacts of the new gear type. The hurdles identified above for technical changes (knowledge, technical ability and cost) also applied even more strongly to these changes.

For wider changes in fisheries (3 case studies) we consider fisheries that might be considered 'benign' and 'malign'. Few serious attempts have been made to eliminate very high-impact fisheries and we note a tendency instead to export them to third countries or other management regimes. It might be easier in policy terms to support benign fisheries – from our analysis it appears that mussel fisheries probably fall in this category having low carbon emissions per unit of catch and, in general, low direct environmental impacts.

1.4 Part 3 – Analysis of policy actions to support change

From the above case studies, we also identified policy actions that may reduce or remove some of the hurdles to change in EU fisheries. These are presented below:

- Decision-making by policy makers should be transparent and should follow stated EU policy (e.g. no subsidies which increase capacity, fisheries management according to the precautionary approach). This should apply to EU fisheries policy both inside and outside the EU. The information that supports management should likewise be public.

- It is clear that fisheries targeting well-managed stocks have lower environmental impacts, both direct and carbon-related. Where fish are more abundant, it requires less fishing effort to achieve the same volume of catch, therefore resulting in less incidental bycatch, habitat degradation and fuel consumption.

- Good fisheries management involves higher costs, for example to fund the research necessary to make sound decisions and to fund effective enforcement of the decision. Member States should recognise that meeting these costs are vital if fisheries are to result in sustainable economic benefits.

- The sustainable exploitation of depleted fish stocks will only be possible after a temporary (but meaningful) reduction in fishing effort. Further studies linking fish abundance and the economic performance of fishing fleets would be useful, particularly to support decision-makers when facing communities dependent on the economic returns from a depleted stock.

- Involving the fishing industry and other stakeholders in decision-making is vital. The case studies show clearly that the most innovative ideas for reduction of environmental impacts in fisheries come when policy-makers and the industry work closely together. Dialogue has improved markedly in recently years, but there remains a need to move from consultation to real participation. We note that the small-scale fleet is still largely excluded from this process in many Member States.

- The current regulatory regime micro-manages most fisheries in the EU, and prevents fishermen the flexibility required to innovate. If the management regime were to step back and give fishermen space in which to operate as efficiently as possible, the process of improving the sustainability of fisheries would likely progress more swiftly. This requires that regulators, scientists and other stakeholders have an excellent oversight of the fisheries within their sphere of influence and that stakeholders engage in meaningful dialogue underpinned by mutual respect – this is conspicuously absent in many instances at the present time.

- Hidden subsidies and other perverse incentives that maintain the apparent economic viability of environmentally damaging fishing operations need to be urgently addressed and removed – likewise regulatory obstacles to innovation should be dealt with.

- For technical changes, it would be hugely beneficial to review best practice operations across EU fisheries (or even more widely) followed by a dissemination of information about how fishermen can reduce their carbon emissions and direct environmental impacts. This could usefully take the form of a central data repository that is open to all. Rising fuel prices give fishermen a significant incentive to participate in this process. This process should also reveal the regulatory obstacles to implementation of best practice, which can then be dealt with.

- It may be considered appropriate to provide some kind of support to fishermen in reducing their impacts – this might be in the form of training, technical advice or even loans. However it is extremely important that this support does not provide a de facto subsidy for increasing overall capacity – bearing in mind that if vessels owners can operate more efficiently they will have extra funds to invest in increasing their fishing capacity.

- Balancing policy between fleet sectors: We note above that in general, the small-scale fleet in the EU has lower environmental impacts per unit of catch than the large-scale / offshore fleet. This is because the small-scale fleet has lower carbon emissions and because it tends to use more benign gears. However, from a policy perspective, the large-scale fleet is much easier to deal with: it is easier to engage with, easier to manage, and easier to enforce. Compliance with regulations is therefore higher. Various policy initiatives, such as decommissioning, Regional Advisory Councils, quota distribution, Individual Transferable Quotas and other rights-based systems have tended on balance to favour the large-scale fleet. In particular, we note that the quota distribution system in many (perhaps most) Member States has not been good for the profitability of the small-scale fleet and has in addition led to a significant amount of discarding, high-grading or landing of 'black fish'. A lower-impact future for EU fisheries will require policy-makers to shift the balance towards the small-scale fleet, making more of an effort to engage with this group and adapting the management system to better reflect their operational requirements.

- Gear conflicts can be eliminated by marine spatial planning – low-impact passive gears can only enter a fishery if they are given room to operate away from towed gears.

- There should be a presumption of zero discarding. At the same time, the management regime needs to adapt to ensure that this is possible for fishermen. For example, if fishermen catch alongside the target species a species for which they do not have quota, their only choice at present is to discard or illegal land the fish. In general, fishermen abhor discarding and, we believe, would be willing to work with policy makers to ensure that a discard ban can be introduced in a coherent way. Converting trash fish to Surimi products is a booming industry in Southeast Asia for example.

- Support to improve the quality of the end product will increase income per unit of catch and should make the sector more viable and more sustainable. It is particularly important if EU fisheries are to compete with an influx on to the EU market of cheap tropical farmed fish.

It is clear that revising the CFP to include all these recommendations will not be a straightforward process.

In the context of the reform of the CFP, Seas At Risk are promoting a shift to low impact fisheries, through:

- Preferential access to fish resources for low impact fisheries;

- Elimination of overcapacity using environmental and social criteria, ensuring that the most sustainable vessels remain in the fleet;

- Phasing-out of fuel tax exemptions and other perverse subsidies;

- Redirection of subsidies to training/education programmes promoting low impact fisheries;

- Introduction and promotion of spatial planning, with zones set aside for low impact fisheries, especially those using passive gears.

2 Introduction

2.1 Introductory remarks

Despite the social and economic importance of capture fisheries, attempts to exploit marine resources sustainably have been largely unsuccessful; Europe is no exception (see figure 1 below). Management failures have led to widespread concerns, often accompanied by high-profile media reports (as, for example, the recent book and film 'End of the Line'), that fishing is causing irreparable damage to the marine environment. There is a growing awareness among Europeans that fishing can be destructive to the marine environment through overfishing, habitat modification and the incidental capture of endangered species. Furthermore, most fisheries consume surprisingly large volumes of fossil fuels to land their catch. Globally, fisheries burned almost 50 billion litres of fuel in the process of landing about 80 million tonnes of marine fish and invertebrates; 620 litres of fuel for every tonne on average (Tyedmers et al., 2005). Scientists warn that climate change, leading as it inevitably will to rapid changes in environmental conditions, will further increase the pressure on fish stocks and marine biodiversity. Improving the outlook for marine biodiversity as it strives to adapt to human impacts, requires that direct anthropogenic impacts, of which fishing is the most severe, be managed and minimised. If this is not done, unsustainable fishing and climate change risk drastically reducing the social and economic benefits that Europeans obtain from their seas. The fishing industry has become "a primary culprit in an ecological crisis of global dimensions" (SOFIA, 2008).

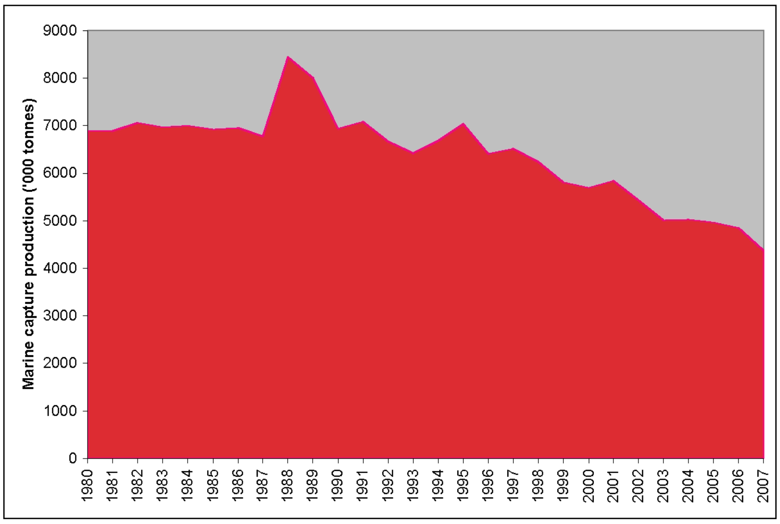

Figure 1: Capture production of marine fishes by European nations' fishing fleets between 1980 and 2007 (FAO Fisheries and Aquaculture Information and Statistics Service, 2009)

Not all fisheries are equal, or equally bad. It is unfair to tarnish the fishing industry as a whole as irresponsible and, as this report explains, the diversity of fisheries, even within a fleet, often makes generalised statements unhelpful and simply adds to the hostility that already exists between industry and conservationists. Both sides have made mistakes: some environmental organisations have frequently ignored or understated the social and economic contribution of the fishing industry to coastal communities, and numerous examples exist of the fishing industry hampering or rejecting attempts to better understand and regulate for the good of fish stocks and marine ecosystems. Between these extremes however, the majority of fishermen, environmentalists, regulators and the public share a common interest in securing the social, economic and ecological benefits afforded to us by healthy European seas (although opinions about how to get there differ greatly). While the need for meaningful action is pressing, a balance must be struck between short-term priorities and long-term environmental and social ambitions. Decisions will need to be made based on value judgements about the costs and benefits associated with social, economic and environmental factors. This requires decision-makers to be informed of the relative merits and externalities of different fisheries, including the environmental and carbon costs associated with each type of fishery. The objective of this report is to contribute to decision-makers' understanding of how fishing impacts vary as a result of gear type and operating environment. The intention is that the report enables decision-makers to have more understanding of which fisheries are viable if social and economic benefits are to be sustained into the future. The report continues by discussing policy suggestions and considerations that, taken together, will ideally contribute to the reform of the CFP into a mechanism that encourages cooperation among resource users and regulators to achieve sustainable fisheries throughout Europe.

Fishing is not alone in facing adverse media pressure: mining, oil production, aviation and road transport industries are also being pressured to adapt their practises in the interests of our shared future. It is recognised that fishing is part of Europe's heritage – past and hopefully future. The aim is that this report contributes to policy-makers' understanding of how a reformed Common Fisheries Policy could safeguard the contribution of Europe's fisheries to the social and economic fabric of all Member States. As Europeans, we share the responsibility to see that the next generation can become fishermen or fisherwomen if they so want.

2.2 Structure of the report

Part 1: Inventory of EU fishing techniques and comparison of their direct and indirect (carbon-related) environmental impacts

In the first section of the report we examine EU fishing techniques, including the relative environmental impacts and interchangeability of different gear types. A discussion of the direct impacts and carbon emission impacts of fishing in general leads to examination of the efficiency of European fleets in the context of environmental impacts, including a synthesis of publicly available studies.

Part 2: Analysis of hurdles to switching to lower impact fishing methods

Section two presents an analysis of hurdles to changes and draws on a number of case studies that provide insight into how the fishing industry is adapting to changing economic conditions and adverse publicity. The case studies are organised as follows:

- Changes involving introduction of technical measures;
- Changes involving different gear types;
- Changes involving whole fisheries.

Lessons and conclusions are extracted from each case study, which have been synthesised to inform output three.

Part 3: Using policy to improve how fishermen operate

Section three presents an analysis of policy hurdles for the uptake of measures reducing environmental impacts, and policy suggestions to address these hurdles. Policy recommendations and suggestions presented follow the format of section two, i.e., policy for the introduction of technical measures, different gear types and then whole fisheries. Broader policy considerations are also discussed.

2.3 Information about the report and acknowledgements

This report has been prepared by MacAlister Elliott and Partners Ltd. (MEP) for Seas At Risk (SAR). Seas At Risk, founded in 1989, is the European federation of environmental organisations working for the protection and restoration of the marine environment. Seas At Risk intend the report as part of their submission to the process of public debate on the renewal and restructuring of the CFP, as outlined above.

The main authors of the report are Dr Jo Gascoigne and Edward Willsteed. Additional contributions are acknowledged from Dr. Miles Hoskins, Dário Mendes Alves, Ulf Löwenberg, Stephen Akester, David Elliott and Dr. Simon Wilson. The content of the report and any errors remain the responsibility of MacAlister Elliott and Partners.

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3 Part 1: Inventory of EU fishing techniques and comparison of their environmental impacts

3.1 Inventory and classification of EU fishing techniques

The European Commission publishes a list of fishing gear types, along with estimated vessel numbers using each gear. This list is given in Annex A.

The Commission classifies fishing gear in three categories.

1. Passive gear – gear that is placed on the seabed and does not move until lifted by the fishing vessel (e.g. anchored nets and lines, pots etc);

2. Towed gear – gear that is towed across the seabed (trawls and dredges);

3. Mobile gear – gear that involves movement of the fishing vessel to deploy but is not actively towed (seine nets and trolling lines)

A given gear type in the Commission's classification (Annex A), might in practice have a range of different attributes. For example, for a demersal otter trawl, attributes such as the size of net; size, shape and weight of doors; length of groundline; presence or absence of tickler chains or 'rockhopper' discs; mesh size of the main net; mesh size of the cod end; and presence of escape panels will affect to some extent the environmental impacts of the gear. However, it is impossible to assess each refinement of each gear separately, so here we stick to the broad categories outlined above, and in some cases group categories together where their actions are clearly similar or where some gear types are used only by a very small number of vessels.

This has led us to the list of gear types shown in Table 1, somewhat simplified from the Commission list (Annex A).

Table 1: List of gear types used in this report.

Passive gear	Towed gear	Mobile gear
• Set gillnets • Drifting gillnets • Trammel nets • Traps • Handlines / pole and line • Demersal longlines • Pelagic longlines (not towed)	• Demersal seines • Demersal beam trawls • Demersal otter trawls • Midwater trawls • Boat dredges • Hand dredges • Mechanised / suction dredges	• Purse seines • Small seines • Trolling lines (including towed pelagic longlines)

These gear types can be ranked according to importance using the EU fisheries data in three ways: in terms of vessels numbers, total vessel tonnage or total engine power. These rankings give different results, indicating that some gears are typically used by large numbers of small inshore vessels, while others are used by smaller numbers of large offshore vessels (Table 2).

Table 2: Gears ranked in order from most to least important in terms of i) number of vessels; ii) total GT and iii) total engine kW (for raw data see Annex A). The gears that rank high in terms of vessel numbers are more important for the inshore coastal fleet, while the gears that rank high in terms of GT are more important for the offshore fleet, with engine power giving a more mixed or overall picture.

Ranking by vessel numbers (high to low)	Ranking by total GT (high to low)	Ranking by total kW (high to low)
• set gillnet • demersal longline • trammel net • traps • demersal otter trawl • purse seine • handline / pole and line • boat dredge • beam trawl • drifting gillnet • pelagic longline • midwater trawl • trolling • mechanised / suction dredge • demersal seine • hand dredge • small seine	• demersal otter trawl • midwater trawl • purse seine • set gillnet • beam trawl • demersal longline • pelagic longline • boat dredge • traps • trammel net • handline / pole and line • drifting gillnet • mechanised / suction dredge • demersal seine • trolling • hand dredge • small seine	• demersal otter trawl • set gillnet • purse seine • traps • midwater trawl • demersal longline • beam trawl • trammel net • boat dredge • pelagic longline • handline / pole and line • drifting gillnet • mechanised / suction dredge • trolling • demersal seine • hand dredge • small seine

In terms of vessel numbers, 46 % of vessels use gill or trammel nets. 11 % use demersal longlines, another 11 % use traps and 10 % use demersal otter trawls – accounting together for nearly four EU fishing vessels out of five. In general, it is clear that passive gears are important for a high proportion of vessels – mainly small – although small otter trawls are also commonly used by small vessels.

By contrast, 37 % of tonnage is accounted for by vessels using demersal otter trawls, suggesting this is the gear of choice for much of the large offshore fleet. Midwater trawls account for a further 18 % and purse seines 12 %, accounting for two thirds of the fleet tonnage in total. Overall, active gears are more important for larger vessels. (The raw data for these calculations is presented in Annex A.)

3.2 Interchangeability of gears

There are many different types of environmental impact: carbon emissions, impacts on habitats, impacts on other species and impacts on the target population (discussed further below). Different types of impact are important in different types of fishery. For example, a pelagic longline fishery for tunas may have an impact on populations of large vertebrates such as sharks, turtles and birds, while a purse seine tuna fishery may have impacts on tuna populations by unselective fishing by size and species. Likewise, a beam trawl fishery for sole may have impacts on populations of benthic invertebrates, while a trammel net fishery can catch and drown harbour porpoises. It is difficult to rank these impacts against each other without having to make value judgements about the relative importance of, say, tunas and turtles, or sea pens and porpoises. This makes it difficult, in principle, to say whether a change in gear type is desirable in a given fishery, since generally it involves exchanging one type of impact for another.

Basque pole and line – photo by Michael Stockwell

However, it is obvious that not all types of fishing are interchangeable with each other. It is not possible to switch from a demersal trawl to a pelagic longline to target the same group of species in the same ecosystem. Thus it is in practice irrelevant to try and rank these two gear types against each other since the hurdles that EU fishermen will face in switching from one to the other are in most cases insurmountable – different vessels, gear, fishing location, market, knowledge, quota entitlements, licensing arrangements, organisations, management structure etc.

To assess which gears are in reality interchangeable with which, we can look at the species which are targeted by the gear types listed above. It is clear from this list that the same species can usually be caught with a variety of different fishing methods – giving scope in theory for fishermen to switch to the fishing gear and technique that causes the minimum environmental damage in their geographic context (table 3).

Table 3: List of fishing techniques by target species

Species group	Methods of capture
Pelagic fish	
Small pelagics: sardines, anchovy, sprats, pilchards, herring etc.	small seine, purse seine, midwater trawl, drift net
Mackerel	purse seine, midwater trawl, pelagic longline, handline and pole-line, trolling lines
Tuna	purse seine, pelagic longlines, handline, trolling lines, driftnet
Pelagic sharks	pelagic longline, driftnet, gillnet
Swordfish and similar large pelagics	pelagic longline, driftnet, gillnet
Demersal fish	
Whitefish: cod, haddock, saithe, redfish, hake etc.	otter trawl, demersal longline, demersal seine
Bass	set and drifting gillnets, handline and pole-line, otter trawl
Eels: adult and glass	demersal longline (adult), otter trawl, pair trawl (glass)
Flatfish: sole, plaice etc.	beam trawl, otter trawl, set gillnet, demersal seine
Demersal sharks: rays, dogfish etc.	otter trawl, gillnet, demersal longline
Deep water demersal fish	otter trawl, longline
Sand eels	otter trawl
Grouper, snapper, bream and other reef-associated demersal species	set and drift gillnet, trap, line, otter trawl
Invertebrates	
Cockles	boat dredge, hand dredge, mechanised dredge
Mussels: adult and seed	boat dredge, hand dredge
Oysters: native and Pacific	boat dredge, hand dredge
Clams: palourde etc.	boat dredge, mechanised dredge
Scallops	boat dredge, dive
Lobster: clawed and rock	traps, trammel net
Nephrops	otter trawl, trap
Crabs	trap, trammel net
Shrimp: *Crangon*,*Pandulus* etc.	beam trawl, otter trawl
Whelks	trap
Squid	trolling line, midwater trawl
Cuttlefish	otter trawl, trap, tangle net
Octopus	otter trawl, trap

From table 3, we can group these gear types into four groups by target fauna. Gears in the same group should be to some extent interchangeable (Table 4).

Table 4: Gear groupings by target fauna

Pelagic fish	Demersal fish	Infaunal invertebrates	Epifaunal invertebrates
purse seine small seine midwater trawl drifting gillnet pelagic longline trolling line handline / pole and line	otter trawl beam trawl demersal longline demersal seine set gillnet trammel net trap handline / pole and line	boat dredge hand dredge mechanised dredge	trap trammel net otter trawl beam trawl dive

Thus in principle a purse seine fishery might be able to switch to become a longline or handline fishery, but not an otter trawl fishery; while a beam trawl fishery could switch to use gillnets or trammel nets, but not midwater trawls.

3.3 Direct environmental impacts

In this report, we distinguish 'direct' environmental impacts – impacts on marine populations, habitats and ecosystems via the direct action of fishing or fishing gear – from indirect impacts, acting via climate change partly driven by the carbon emissions from fishing vessels.

We first consider direct environmental impacts of fishing.

3.3.1 Direct impacts of fisheries – brief review

It has been known by marine ecologists for a long time that fisheries have major impacts on marine ecosystems, not only by removing the target species but also by the removal of other species, the destruction of benthic habitats by fishing gear and the knock-on effects on predators, prey, scavengers and other species that may come into contact with fishing gear or vessels (Morgan and Chuanpagdee 2003).

Fishing obviously has impacts on the target species by increasing mortality rates and reducing the size of the population – managing these impacts has been the focus of fisheries science and management for many years. Some gear types are selective as to size by regulating mesh or hook size (e.g. many net and line fisheries) but some are very unselective (e.g. purse seines, many trawls). Such unselective fisheries may catch juveniles as well as adults - apart from being a wasteful practice (because individuals are caught at a low average size – termed 'growth overfishing'), these fish do not then enter the reproductive population (running the risk of 'recruitment overfishing'). Imposing minimum sizes on these fisheries may not help since juveniles may then be discarded dead. Certain fisheries can be more selective than by size alone – e.g. trap fisheries for crustaceans where egg-bearing females are often discarded (alive).

The impacts of demersal fishing gear in particular have been widely documented – not only large epibenthic organisms such as soft corals and sponges are affected, but also small benthic organisms, even as far as nematode communities (Hinz et al. 2008). For example, the exploitation of previously untrawled areas by otter trawls can result in a reduction in the abundance of benthic invertebrates of more than 60 %, depending on the substrate (Kaiser et al. 2006). In heavily trawled areas such as the southern North Sea, commercial trawl fisheries (otter and beam trawls) have been shown to reduce biomass of benthic invertebrates by 56% and production by 21% (Hiddink et al. 2006).

Other non-target species affected by fisheries include animals caught as a 'bycatch' (i.e. not the main target species although still frequently sold) – such as sharks in tuna and swordfish longlines. Global populations of large predatory fish are at 10 % of historic levels (Myers and Worm 2003) due to fisheries and bycatch impacts. Many commercial species are also caught as bycatch in other fisheries – e.g. plaice and dab in sole fisheries and cod in haddock and saithe fisheries. These may be retained and sold, but are frequently discarded if they are below minimum landing size or if the fishing company or vessel in question does not have quota for that species. Birds, turtles and cetaceans may also be caught as unwanted bycatch in longline, purse seine and various net fisheries.

Fisheries may also have impacts via knock-on trophic effects in the ecosystem. For example, the large drop in sea lion numbers in Alaska is believed to be due to the impact of offshore fisheries on their main prey (Alaskan pollack). This decline in sea lions has in turn led to a reduction in prey for orcas who have started killing sea otters in unprecedented numbers (Estes et al. 1998). Many other such trophic cascades may be taking place unnoticed in our seas among less charismatic and well-studied species.

Recent research by scientists participating in the EU-led HERMES[1] project suggests that fishing impacts also transmit to areas well beyond those where fishing takes place. Looking at datasets of fish abundances between depths of 800m to 4,800m, scientists observed significant drops in the overall abundance of fishes from all depths between 800m and 2,500m following the start of commercial fishing (Bailey et al., 2009). This finding is remarkable because the maximum depth for deep-water trawling is about 1,600m. The decline in abundance was especially pronounced for species with ranges falling within fished areas and declining numbers were unrelated to changes in prey abundance or natural fluctuations. Given the increase in exploratory deep-water fishing by Spain, France, Ireland and Norway in particular, the implications of this finding are profound and show that our understanding of the impact of fishing on ecosystems is incomplete.

3.3.2 Assessing different types of impact

The operation of each type of gear, as well as a description of the main impacts, is given in Annex B.

To assess whether fisheries can switch to less damaging fishing methods, we first need to categorise the different interchangeable fishing techniques in terms of their environmental impact – so that we can see what possible switches exist to reduce direct impacts.

First, we have to consider what type of impacts are important, since a given gear type may have different degrees of impacts on, for example, benthic habitats and porpoises. Rather than inventing these ourselves, we have conducted a brief review of some other analyses of fishing impacts, to see whether a consensus already exists. This review is presented in detail in Annex C.

Our aim in compiling a list of direct environmental impacts of fisheries was i) to be inclusive, so that impacts were not excluded; ii) to ensure as far as possible that impacts did not overlap (for clarity); and iii) to keep the list relatively short – i.e. the impacts somewhat general. This lead us to a list of types of impact as follows:

1. Selectivity for target species and size
2. Impacts on unwanted bycatch species, including from ghost fishing
3. Impacts on habitats
4. Impacts on mammals, birds and other vulnerable species

We use this list as a starting point to consider the relative impacts of different fishing techniques. For details of how we reached this list, please see Annex C.

1 Hotspot Ecosystem Research on the Margins of European Seas (www.eu-hermes.net)

3.3.3 Ranking of gear types by direct environmental impact

In this section we consider each of the 17 gear types in Table 1 above against the four types of environmental impact above, and categorise them in order of severity of impact where possible. We used three reports (Hoskins 2006, Morgan and Chuanpagdee 2003 and Broeg 2008) to help with this ranking (see also further details in Annex C).

- Survey for Invest in Fish South West (UK)

In this study (Hoskins 2006), questionnaires were sent out to four different groups of stakeholders and the respondents were asked to rank their level of concern about each impact for each métier. The stakeholders were: commercial fishermen / industry (5 responses), scientists / managers (15 responses), NGOs (6 responses) and recreational users (16 responses).

A summary of the responses in terms of ranking of métier by severity of impact from high to low is given in Table 5 below.

Table 5: Gear rankings from a survey of fisheries and marine conservation professionals in SW England. From data provided by Miles Hoskins (Coastal and Marine Environmental Research Ltd.).

Impact	Ranking (highest impact first)
1 Selectivity	trawls > nets > dredge > lines > traps
2 Bycatch	beam trawl and dredge > otter trawls > nets and midwater trawl > lines and traps
3 Habitat	dredge > beam trawl > otter trawl > demersal nets and traps > lines and midwater gears
4 Vulnerable species	midwater trawl > nets > longlines > demersal trawls > others

- 'Shifting Gears' report

The Shifting Gears report (Morgan and Chuanpagdee 2003) ranks gears in terms of their overall impact, based on a workshop with various fisheries professionals. The ranking is robust to the type of professional (i.e. commercial vs. scientific) and their geographic area of expertise. Generally participants ranked gears with significant habitat impacts as having a higher overall impact than gears with bycatch impacts.

Overall, the ranking was as follows:
Demersal trawls > gillnets and dredges > traps and longlines > midwater trawls, purse seines and hook and line.

- WWF report

The report by WWF Germany (Broeg 2008) ranks the various gear types as in Table 6:

Table 6: Gear ranking according to Broeg 2008

Impact	Ranking (highest impact first)
1 Selectivity	demersal trawls > purse seine, midwater trawl, nets > lines > traps
2 Bycatch	demersal trawls, drifting gillnets > purse seine, midwater trawl, demersal gillnets, longline > traps
3 Habitat	demersal trawl > demersal lines > demersal nets > traps and midwater gears
4 Vulnerable species	drifting gillnets > purse seine, demersal gillnets, pelagic longlines > midwater trawl > demersal longline > demersal trawls > traps

Discards – photo by Edward Willsteed

- Conclusions : ranking gears by impact

For selectivity, there is broad general agreement that the least selective gears are trawls. Trammel nets are also considered unselective, but gillnets are somewhat better. Lines and pots are generally considered to be more selective. There is less agreement on seines and midwater trawls – they are unselective in principle but the catch is often quite monospecific because a single school or a small number of schools of fish are usually targeted.

For discards / bycatch, demersal trawls and dredges are considered overall to have the worst impacts. Nets come next, while lines and pots are usually ranked low in terms of discard impacts. There is limited agreement on purse seines and midwater trawls.

Habitat impacts are the most straightforward, with clear consensus that dredges and demersal trawls (particularly beam trawls) have the greatest impact. Other demersal gear such as demersal seines, nets, traps longlines come next, then midwater and pelagic gears.

For vulnerable species there are only two rankings that can be used. In both, nets, pelagic longlines and midwater trawls score relatively high for impacts, and purse seines also scores high in one (it is not included in the other). Demersal gears such as trawls, dredges, handlines and traps score low.

Overall, gears for pelagic species mainly have impacts on vulnerable species, while active demersal gears (trawls and dredges) have the worst habitat impacts. Discard impacts are most likely with active gears, while selectivity is lowest for trawls and nets.

By cross referencing these conclusions with Table 4 above, we can start to rank the interchangeable gears in the order of their direct environmental impact. There are some problems: in particular i) there is limited agreement on the impacts of some pelagic gears (notably purse seines and midwater trawls, and ii) demersal seines are not included in any of the rankings above. For these gears, we used an informal survey of colleagues (six responses) plus our own experience to position them in the ranking below (Table 7).

Table 7: Interchangeable gear groupings by target fauna, ranked by direct environmental impact from high to low

Impacts	Pelagic fish	Demersal fish	Infaunal invertebrates	Epifaunal invertebrates
Bad ↓ Good	drifting gillnet midwater trawl purse seine = pelagic longline trolling line handline	beam trawl otter trawl trammel net set gillnet demersal seine demersal longline trap = handline	mechanised dredge boat dredge hand dredge	beam trawl otter trawl trammel net trap dive

One objective of fisheries policy should therefore be to focus on fishing techniques at the top of each of these four lists – notably trawl fisheries and mechanised or heavy dredge fisheries – and try and replace them with fishing techniques further towards the bottom of the lists (assuming that this is compatible with reducing carbon-related impacts – see below).

3.4 Indirect environmental impacts – carbon emissions

3.4.1 Carbon emissions from fisheries

The first general analysis of fossil fuel consumption by global fisheries comes from Tyedmers et al. (2005). They calculate that fishing accounted for 1.2 % of global oil consumption – about the same as that of the Netherlands – 50 billion litres of fuel or 620 litres per tonne live weight of seafood. Carbon emissions average 1.7 tonnes per tonne live weight seafood. The energy content of the fuel burned is more than 12 times that of the resulting catch.

However, it is important to note that according to the data collected by Tyedmers et al. (2005), this represents a more efficient system in terms of edible protein per unit CO2 emitted than many animal culture systems, including intensive Western-style milk, pig, egg and beef culture and most types of intensive fish farming. Also, while beyond the scope of this study, it is worth noting that capture fisheries are also low-impact in terms of other inputs, such as volume of water used per tonne of final product, in comparison with other sources of protein for human consumption. Nonetheless, improvements are certainly possible.

3.4.2 Calculating carbon emissions

The analysis of carbon emissions over the production of a product is a relatively new field, although standard techniques for such analyses are emerging (e.g. UK standard PAS 2050). However, these techniques all require the collection of detailed information, much of which is not easily available in the case of specific fisheries (although it has been done for certain specific cases – e.g. Ziegler and Valentinsson 2007, Schau et al. 2009).

For EU fisheries specifically, a variety of studies have looked at the issue of carbon emissions by different fishing fleets, vessels or gear types. The synthesis of these studies into a larger meta-analysis is hampered by the fact that these studies use different techniques and different units. For example, the amount of final product may be in terms of live weight, weight on the quayside or final processed weight. It may include only the target species of the fishery, or the total landings of all species. It may be expressed in terms of weight or in terms of value. Likewise, carbon emissions may be in terms of tonnes CO2 emitted, carbon equivalents or volume or value of fuel consumed. These different units of measurement are not comparable with each other without a great deal of information about the fishery: percentage of a given species in the catch, weight loss during processing on board and after landing, market value of each species, cost of fuel etc.

In our approach, therefore, we have had to work around the fact that most existing studies cannot be directly compared with each other, and data from disparate sources cannot easily be synthesised into a larger quantitative analysis. We have considered the question from two angles: i) we have analysed a large dataset (EU fisheries data – see Annex A) looking for patterns across Member States and by gear type; and ii) we have analysed a variety of studies separately and tried to draw out overarching trends from the conclusions of each study. The first analysis has the advantage of being very generalised across the EU, but the disadvantage that measures of carbon emissions are very indirect (generally mean engine power in kW). The second approach involves more direct measures of carbon emissions (usually in terms of fuel consumption or costs) but is more piecemeal and only covers some Member States. These two analyses are presented in Annex D. Their joint conclusions are presented in the next section.

3.4.3 Conclusions – which fisheries have low carbon emissions?

From the synthesis and analysis of fisheries data and published studies (from the EU and elsewhere) presented in Annex D, we can draw several conclusions. Firstly, the 'answer' depends a great deal on what you mean by 'carbon efficient'. If the desired outcome is to maximise value of catch per unit of fuel consumption (which is presumably the objective of fishermen, and possibly also of those who would like to minimise the biomass being removed from the sea), the best performing fleets are (in general) those targeting high value species and/or selling to a discerning high priced market. If the desired outcome is to maximise volume of catch per unit of fuel consumption (which might be a policy aim in a world where food must be produced with minimum carbon cost), the best option is to focus on high volume, low value fisheries such as small pelagics – however, in many cases, the landings of small pelagic fisheries are destined for reduction to fish meal, so that the end output volume in terms of edible protein (as beef or chicken, for example) is many times smaller than it first appears.

The second broad conclusion is that the relative carbon efficiency of fisheries is highly variable, with different studies drawing different conclusions and a distinct lack of clear patterns emerging. A clearer picture of good and bad performance over the EU fishing fleets will require a much more in-depth analysis of specific, comparable fleets, than has been possible above. On the other hand, this conclusion implies that in many fisheries there is room for significant improvement without drastic changes in fishing practice.

Having said that, however, it seems possible to make the following tentative conclusions:

- Demersal trawlers generally perform badly, particularly in terms of carbon emissions per unit volume of catch, as do offshore longliners. In terms of unit value of catch, results are more variable.

- Vessels using passive gear and seines usually perform better than vessels using towed gear.

- Offshore and distant-water fisheries generally perform badly, except when considering volume for small pelagics.

- Small vessels usually perform better than medium or large vessels in terms of catch value, but not necessarily in terms of volume. Medium-sized vessels may perform better or worse than the largest vessels.

- There is no evidence from this study that artisanal type fleets are more fuel efficient per unit volume or value of catch than more commercial or industrial type fleets. This may be because they operate in a way that makes them difficult to compare with other fleets, or may be because fleets with a high proportion of old vessels are inefficient.

- When fuel consumption per unit volume of catch is considered, small pelagic fisheries usually perform best.

- Poorly managed and depleted stocks lead to higher fuel consumption.

- In terms of specific fisheries, crustacean trawl fisheries appear to perform consistently badly, while mussel fisheries appear to be particularly efficient.

- There may be enormous differences in efficiency between EU fishing fleets that are superficially similar in terms of vessel size, gear and target species.

Having drawn these conclusions, however, our instinct is that it is likely to be unproductive to use the above analysis as a general means for preferring one type of fishery over another, since there will usually be an exception to be found. We would propose that further work on this topic could be more productively channelled into supporting the existing fishing fleets to operate as efficiently as possible. The very variability that we found in the efficiency of operation of different fleets suggests that many fleets could make significant improvements in their carbon emissions per unit catch by operating more like their most efficient peers.

However, it is clear that some vessels are likely to have high emissions per unit of catch – old and inefficient beam trawlers, for example. In this case, it may be productive to use policy to encourage their removal from the fishery, although these types of public interventions have be to carefully planned to avoid subsidising the effective increase in overall fishing capacity via the replacement of older vessels with newer, more efficient vessels.

3.5 Overall conclusions to Part 1

3.5.1 Ranking fishing techniques by environmental impacts

For direct environmental impacts, the general conclusion (summarised from Table 7 above) is that whatever the fishery, dredges and trawls have generally the highest impact, followed by nets and seines, followed by lines and traps. More specifically, the direct impacts of beam trawls and mechanised dredges are highlighted as particularly severe. The exception is impacts on vulnerable species, where pelagic gears and nets have worse impacts than demersal towed gears.

In terms of indirect impacts (i.e. carbon emissions), it is much harder to draw general conclusions from a confusing pattern. However, we conclude that demersal trawls have higher impacts than passive gears (nets, traps, handlines) in most cases. Mobile gears are variable – seiners generally being more efficient than longliners. Small vessels are usually (but not always) better than medium and large vessels. The most striking aspect of the data we have collected is, however, its variability, and comparisons between similar fleets to pinpoint best practice might be a more productive route than trying to rank disparate fleets. It is also noteworthy that well-managed stocks lead to efficient fisheries, while depleted stocks lead to high carbon emissions.

Overall, and with many exceptions, these two separate analyses lead to broadly similar conclusions – i.e. the ranking of fishing gears in terms of direct impacts and carbon emissions are similar. Desirable changes to fisheries to reduce both types of impact are therefore similar: essentially a move from active to mobile or passive gear – and more specifically a move away from heavy trawls and dredges. A move away from larger offshore vessels towards smaller inshore vessels is also beneficial for carbon emissions, and probably also in terms of direct gear impacts in many cases – e.g. for otters trawlers the doors used on small vessels will be lighter than those used on large vessels.

3.5.2 Switch to less damaging techniques

Having outlined in general terms the changes to fisheries that are desirable, it is useful to consider them in more detail in terms of the nature and magnitude of the change to the fishery and thus their feasibility, and also the nature of the hurdles faced by fishermen trying to make these switches.

We have identified three types of changes that fisheries could make to become more environmentally sustainable:

1. Technical measures: This category includes relatively straightforward changes to existing gear, vessels or operating procedures. Examples might be refitting or maintaining a vessel or engine to make it more fuel-efficient[2], altering gear to include bycatch excluder devices (such as the cod-friendly eliminator trawl or the turtle excluder devices fitted to shrimp trawls), or changing operational procedures to reduce environmental impacts (such as setting longlines only at night to avoid bird bycatch). These types of measures are reviewed extensively in Broeg 2008.

2. Changes of gear type: The second category of change is one which would involve a more significant change to the operation of the fishery – such as a switch to using a different type of gear. The objectives of these changes would be to move a given fishery for a given species away from gears at the top of the lists in Table 7 above towards gears at the bottom of the lists, or to move the fleet away from gears and vessels which are carbon inefficient to vessels which are more carbon efficient (our data (see Annex D) suggest this would involve a change from large or medium-sized to small vessels, from active to passive gears and from offshore to inshore fishing – but we emphasise that the specifics of a particular system need to be investigated).

3. Changes of fishery: The third category of change to consider is more drastic still – when it is considered that a particular fishery should not exist at all. This may be if the target species is endangered or protected, or if it is a keystone species in the ecosystem, or if the direct or indirect impacts resulting from the fishery are considered unacceptable, and no switch (of types 1 or 2) appears to be possible.

Clearly for each of these types of change, the hurdles for fishermen are different and the policy implications in terms of reducing these hurdles are also different. For the implementation of technical measures there may be hurdles related to policy, but there are more likely to be hurdles related to costs (upfront and ongoing if it reduces catches) and training. For changes in gear, policy-related hurdles are likely around the regulatory measures on the fishery – quotas, approved gear types and so on. The policy questions raised by the possibility of eliminating a whole fishery are obviously significant at local, national and EU level.

We next turn in Part 2 to the question of the hurdles faced by fishermen in making these three types of change, and in Part 3 to the policy implications of trying to tackle these hurdles.

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2 We note that given the existing over-capacity in most EU fisheries, it is not desirable from the point of view of direct environmental impacts to make fishing vessels operate more efficiently – although from the perspective of reducing carbon emissions it clearly is. This conflict cannot be resolved until levels of effective fishing capacity in EU fisheries are more appropriate to the size and productivity of fish stocks. Until that point, public policy initiatives that favour increased efficiency need to be balanced with initiatives that reduce overall effective fishing capacity. We return to this point in the final part of the report.

4 Part 2: Hurdles to change: problems in switching to lower impact fishing methods

4.1 Analysis of hurdles: methodology and problems

In Part 1 we assessed which types of fishing are the most damaging, as well as the changes that might be feasible for these fisheries to reduce impacts. In Part 2 we turn to the question of the hurdles faced by fishermen in trying to make changes to fishing practices to reduce environmental impacts (whether direct or carbon-related).

Our methodology for analysing hurdles has been mainly through the use of case studies. For the case studies, we have identified a series of changes that are theoretically possible, and then investigated how they might work in practice. In most cases, the changes were identified by finding a fishery that operates in several different ways, some more damaging than others, and then posing the question as to how the more damaging types of operations could 'switch' to operating like the lower impact types.

In terms of collecting data for case studies, we have used i) internet and literature searches; ii) personal experience and iii) discussions with individuals directly involved in the different fisheries. We found that in most cases, good data (particularly on fuel consumption patterns) were not in the public domain, and could only be obtained by personal discussions with individuals involved directly in the fishery. However, we did not find that such data were easy to elicit from fishing vessel owners and fishing companies. Several of the case studies originally identified had to be abandoned for lack of access to data, and in these cases we have tried to identify new ones that play a similar role or illustrate a similar point. Where data from individuals have been used, it has usually been on the condition of anonymity, so that in many of the case studies below, the fishery (or even the Member State) is not identified, to ensure that the data source remains anonymous.

As above, we have grouped 'changes' into three categories: i) introduction of technical measures; ii) changes of gear or vessel and iii) changes to whole fisheries. This output is structured so that these categories of changes are considered in turn. In each section, we first consider in general terms the types of changes that could be made, then present the case studies, then at the end summarise the lessons drawn from the case studies.

4.2 Changes involving introduction of technical measures

4.2.1 Types of changes

In terms of minimising direct impacts, most work has been done on technical measures to reduce unwanted bycatch. This includes trawls with larger or square mesh panels and sorting grids, traps with escape gaps and biodegradable panels, nets with acoustic pingers (to avoid cetacean bycatch), longlines with weights and streamer lines (to avoid birds) etc. To reduce habitat impacts, trawls may be fitted with rollers, the number of points of contact with the sediment can be reduced, or they may be made of more lightweight materials. The various possibilities are reviewed in detail in Broeg 2008 and van Marlen et al. 2009.

To reduce carbon emissions there are likewise a large number of possible technical modifications: reducing speed, adding a bow bulb, carbon filters, engine and hull modifications and maintenance, weight reduction (for vessel and gear) and so on. Such technical modifications usually reduce fuel consumption by 5-20%, but can result in saving of up to 40% for highly fuel-intensive fisheries (e.g. beam trawlers) (van Marlen et al. 2009).

Some of these possible technical modifications are considered in more detail below, in a series of case studies.

4.2.2 Case studies

- Case study 1: Selective gear - the eliminator trawl

To illustrate in general terms the hurdles faced by fisheries in the introduction of even rather straightforward operational changes, we consider the case of the introduction of the 'eliminator trawl' (or a variant of the design) in an EU groundfish fishery. The fishing company in question has requested to remain anonymous. The fishing operation takes place mainly in the North Sea.

The 'eliminator trawl' is a Canadian invention that was designed to catch haddock and other groundfish species with a minimum of cod bycatch. It was designed and introduced as a consequence of the Grand Banks cod stock collapse, and it works by taking advantage of differences in gear avoidance behaviours by different gadoid species. In the eliminator trawl, the mesh on the top-front of the trawl is in very large panels (or can even be replaced by lines), allowing the cod to escape through the top of the trawl, while the other species are carried back into the cod end. The trawl is relatively successful at reducing cod bycatch while maintaining catches of other groundfish species (usually haddock) (Beutel et al. 2006, van Marlen et al. 2009).

Fishing vessels targeting groundfish in the North Sea have had in recent years significant problems due to the very low cod quotas permitted under the North Sea Cod Recovery Plan (CRP). Once the cod quota is used up, fishing companies are obliged to discard further cod catches in EU waters – and cannot legally catch cod at all in Norwegian waters. In addition, they are obliged to discard cod below the minimum legal landing size. In the early years of the CRP (2007 and 2008) many lost significant amounts of money for this reason – and in addition, fishermen hate discarding their catch, feeling that it is wasteful and unproductive from a management point of view. There is thus a clear incentive, both economic and emotional, to use the eliminator trawl.

However, the fishing company found three significant hurdles to using the eliminator trawl:

4. The eliminator trawl also cut catches of the target species, by between 5% and 20% per tow – perhaps even more in some fisheries.

5. The eliminator trawl is not as easy as a standard demersal trawl to deploy and retrieve, because it has a tendency to get tangled up easily. They found that the crew needed significant amounts of training before it could be deployed properly. It is also not as easy to repair as a standard trawl, resulting in increased costs through downtime and training.

6. They found that they could not introduce gear into a fishery as they wished – modifications to fishing gear need to be approved by a national authority. In this case, the company had made some of their own modifications to the eliminator trawl, considering that it made it more effective at allowing cod to escape. This meant that the approval process could not be based on the approval of the standard eliminator trawl in other countries. The main problem was, however, that it was not clear which organisation in the country concerned was responsible for giving approval to modifications of fishing gear, nor was it apparent what kind of information they would require in order to approve it.

The fishing company in question found its way around these hurdles, although it was not straightforward, nor cost-free. They teamed up with a scientific organisation who put observers on board the fishing vessels to demonstrate independently that the gear cut cod bycatch, and did not have other negative impacts. This data was communicated to the relevant government agency, who found a way to approve the gear. Crew on selected vessels were trained in the use of the trawl. Company policy is now that the eliminator trawl will be used when the company reaches 90% of its cod quota – i.e. it is not used systematically, because of the deployment difficulties and the loss of target species.

Since this process was finalised, cod quotas have been eased as evidence accumulates that the stock is starting to recover. This means that to date the eliminator trawl has never been used, except for trial / scientific purposes.

The lessons from this case study can be summarised as follows:

- The cost implications to fishermen or fishing companies from even relatively minor changes such as this should not be under-estimated as a hurdle, particularly since profit margins in many EU fisheries are small. A slight reduction in catch, or an increase in crew numbers or training, or a hiatus in landings from a given vessel may all be significant barriers to change unless support can be offered.

- We had assumed with this case study that there would not be administrative barriers to this kind of change; however this turned out not to be the case. The problem for the fishing company was not so much that the gear had to registered, but rather that it was not clear how or with whom it should be registered. This hurdle may be specific to the Member State concerned, but it might be worth reviewing and clarifying these types of rules at national or EU level if such changes are to be encouraged.

- Technical changes such as the eliminator trawl may not work equally well in all fisheries. Even fisheries that operate on the same stock with the same gear may be surprisingly different in the composition of their bycatch due to small differences in the area and depth of operation, type or brand of gear, gear configuration on a given vessel and so on. The introduction / imposition of the eliminator trawl in some EU fisheries may not have been appropriate. The best sources of advice on this issue are the fishermen themselves.

- Case study 2: Reducing fuel use - converting fresh-fish to freezer vessels

Many EU stocks are exploited by both freezer vessels and vessels landing fish fresh on ice. Generally, freezer vessels work further offshore, but fresh-fish vessels also work surprisingly far from port – they may for example cover the whole North Sea from a port anywhere around its coast, or fish the eastern Atlantic waters off Scotland, Ireland and the Faroes, landing into ports in Scotland and Ireland. Generally, they commute to port for landing about every 10 days, compared to roughly every month to six weeks for freezer vessels. Fishermen may get better prices for fresh fish than frozen but usually this does not compensate for the extra fuel costs involved, the loss of fishing time taken up by commuting and the costs of freighting the catch from remote ports to the market by road transport.

Clearly from the perspective of carbon emissions per unit of catch, the 'commuting' of fresh-fish vessels back and forth to port every 10 days and the frequent use of road transport is not desirable, and in most cases freezer vessels are likely to be more carbon efficient. (This may not, however, always be the case, because they may be larger and work further offshore. The operating of the freezer plant at sea also has a carbon cost, although this is not usually significant compared to the carbon cost of fishing (Seafish, 2008)).

For this case study, we talked to a major EU whitefish company. This company has a fleet of eight large fishing vessels, of which three are freezer trawlers and the other five are fresh-fish trawlers. The company formerly split its fishing effort evenly between whitefish (mainly in the North Sea) and deep-water species (off western Ireland and Scotland). However in recent years, it has made a policy decision to move away from the deep-water trawl fishery, feeling that this fishery was destined to be regulated out of existence and it was thus not a good long-term bet. (There may also be some sense in the company of disquiet about the environmental issues around this fishery although they did not say so.)

The overall objective of the restructuring (with a timetable dependent on the funds available for refitting) is to convert the fleet from a mixed activity dominated by fresh-fish vessels to an entirely freezer-trawler whitefish fleet. From the point of view of this report, this represents two desirable changes – a move away from a very problematic fishery and a move towards more a fuel-efficient fishing strategy. Here we consider the move from fresh-fish to frozen vessels.

The estimated cost of the refit, per boat, including the freezer equipment and a restructuring of the factory deck (processing area) is around € 2 million – more if the vessel needs to be lengthened. The work will take 1-4 months to complete, resulting in a loss of catch of 250-1000 tonnes landed weight of catch. At € 1.20 per kg for saithe[3], this is a loss of up to € 1.2 million (although the costs of fishing are saved for that time period). It is thus clear that a fishing company cannot make these changes quickly, but has to undertake them gradually over a long time period, one vessel at a time, as income permits. Big increases in fuel costs or cuts in quotas would significant impair the ability of fishing companies to make this kind of investment.

The lessons from this case study can be summarised as follows:

- If changes are perceived to be in the long-term interests of the fishery or fishing company, and if those in charge of planning are forward-thinking, changes can be achieved to improve the environmental impacts of a fishing operation (although the changes may not be put in place solely or even mainly for environmental reasons).

- That being said, to make such proactive changes, fisheries need time available to be able to plan and budget for these changes, since they usually need to happen gradually rather than instantly. For the most part, fishermen and fishing companies think a great deal about the future of their fishery on relatively long time-scales (decadal or more) – it might be useful if there was a process of dialogue with policy-makers considering this kind of time-scale rather than (as is usually the case) questions of immediate concern such as setting TACs or regulations for the immediate future.

- Case study 3: Reducing bird bycatch - toothfish longlining

Patagonian toothfish (also known as ‘Chilean sea bass’) is the most important fishery in the Southern Ocean in terms of value. Several EU fleets are involved – both France and the UK have EEZs in the area. The fishery is relatively new, having started in the 1980s. The information in this case study comes from Croxall (2008) and from discussion with the author and with a representative of an EU toothfish fishing company.

Scientists first noticed a decline in albatross populations on nesting grounds – several of which were monitored as part of long-term surveys. However, it took a while for this to be connected to the new longline fisheries, and when the connection was eventually made, it was via indirect methods – because there were no observers on board vessels and no requirement for vessels to report bycatch.

3 This is a rough average since the price depends on season and size grade. Based on ex-vessel price of saithe at Hanstholm auction, Denmark; see http://www.hanstholmfiskeauktion.dk/default.asp?V_LANG_ID=7&RND=40

An intensive research campaign eventually made the connection, and pinpointed a number of technical measures that can be taken by longliners to reduce or eliminate bird mortality. These are now a requirement for toothfish longlining in the Southern Ocean (the area under the jurisdiction of Regional Fisheries Management Organisation CCAMLR) and are basically implemented by all legal toothfish vessels. There have been no reported catches of albatross by these vessels for the last two years, and catches of petrels are also an order of magnitude lower than previously.

The measures are as follows:

- Use of proper weighting on the longline to ensure a minimum sink rate;
- Longlines only to be set at night;
- No dumping of offal during longline setting;
- The use of a 'streamer line' – basically a bird scarer that is deployed above the longline as it goes out to keep birds away.
- International observers on board at all times.

The implementation of these control measures came about partly as a result of lobbying by NGOs and scientists, and partly as a result of pressure from some national governments in the region (notably New Zealand). But CCAMLR (the over-arching management agency) also deserves credit for acting promptly on the basis of the best available scientific information, for dealing with the problem in an inclusive way – involving all stakeholders, and for continuing to adapt management based on ongoing scientific input. The role of observers onboard fishing vessels has also been very important in i) pinpointing the source of bird mortality; ii) assessing the effectiveness of management measures and iii) ensuring that such measures continue to be implemented correctly by fishermen.

In this case there were two factors which helped significantly in taking decisive action: i) a charismatic species; and ii) a relatively straightforward solution to the problem that could be implemented by fishermen without significant economic losses. An equivalent example in EU waters might be the banning of fisheries in the most important areas of cold water corals (although the majority of areas are still unprotected). Nonetheless action could have been taken more quickly than it was.

The key lesson from this case study seems to be that is it important for managers to have a real understanding of what actually goes on onboard fishing vessels. If more information had been available to scientists about the bycatch of birds on these fishing vessels, a three-year delay between identification of the problem and the implementation of management measures might have been avoided – or been shortened. Cold water coral areas might also have been protected quicker if more information was available about the contents of deep-water trawls in Scottish and Norwegian waters when this fishery first started (also in the 1980s). Such information is available in two ways: i) observer programmes; and ii) a real dialogue (based on some degree of mutual trust) between fishermen, scientists and managers. In both of these there is room for improvement in EU fisheries at present.

- Case study 4: Real-time area closures in the North Sea

As discussed above in Case study 1, the North Sea Cod Recovery Plan has led to significant problems with discarding of over-quota and undersized cod. The problem has been particularly with juvenile cod, because while the adult part of the stock is very depleted, a couple of years of good recruitment led to relatively high densities of juveniles in some areas. In an attempt to reduce cod discards, the Scottish and UK governments have been experimenting with a programme of real-time area closures in areas where bycatch of juvenile or spawning cod is high. Essentially, the process is as follows (see MFA 2009):

1. Fishermen report in to the Scottish Fisheries Protection Agency (Scotland) or the Marine Fisheries Agency (England) if they find a high proportion of juvenile cod in tows in a particular area;

2. The SFPA / MFA decide whether or not to close the area – if they do they notify the owners of all vessels in or near the area (located using VMS) and give them a deadline (usually around 12 hours) to leave. The closed area is 7 square nautical miles, centred on the area where high bycatch is reported.

3. The areas automatically reopen after 21 days.

Southend-On-Sea, Edward Willsteed

Initially, these closures were only mandatory for UK vessels, which were compensated with additional days at sea. However, fishermen from other EU member states fishing in the same area supported the measure – because they could easily understand the logic and could see that it would contribute to the recovery of cod stocks. They therefore mainly complied with these area closures, despite receiving no compensation. This system is now being extended to all EU vessels and the whole North Sea, and there is generally good support for it in the industry.

This initiative has been very successful because it was designed in cooperation with fishermen and is implemented with their support; and because the logic and benefits of it are clear to fishermen – unlike quotas which in their view simply lead to more discarding and waste. It has been successful because i) it is based on knowledge about what actually happens onboard fishing boats; ii) management agencies engaged with fishermen in a constructive way; and iii) managers and scientists had the imagination to look beyond quotas and days at sea as fisheries management techniques.

Regarding this last point, we note that the EU fisheries management system has become locked into the idea that the only (or at least main) way to manage commercial fisheries is via an annual TAC for each stock. While some lip-service is paid to the idea of incorporating ecosystem-level considerations into these stock assessments[4], these TACs are for the most part based on single-species stock assessment models using fisheries and survey data. But as noted above, TACs are frequently a wasteful tool. Fishermen have quota allocations (whether individual or from a pool) for a large number of commercial species – a necessity since very few fisheries are truly single-species.

4 See information and latest advice on the ICES website http://www.ices.dk/indexfla.asp

It is highly unlikely that all these quotas will be used up the same rate – and discarding is often the consequence. In addition, keeping track of quota allocations, not to mention running weekly or monthly quotas and fisheries closures when the TAC is reached, is a major headache for fishermen. We know of one large fishing company that has one full time employee dedicated solely to keeping track of quotas and other regulations – of course, small fishermen do not have that luxury.

This case study shows that it may be time to look beyond the TAC as the main tool for fisheries management in the EU. As noted above, fishermen and managers working together can sometimes arrive at more imaginative solutions, which are easier to implement (given modern technology such as VMS and email), less administratively burdensome for fishermen and more beneficial to fish stocks. The current system cannot be replaced overnight, but real dialogue between policy-makers and the industry may throw up some surprises.

- Case study 5: Improving product value for the same carbon footprint

We note above that the carbon footprint of a fishery can be assessed in terms either of the volume or the value of the catch, and that we reach different conclusions in each case. For fishermen and fishing companies, however, the landed value of the catch is clearly the most important. Fishermen can improve their carbon footprint per unit value in two ways: i) use less fuel for the same catch, or ii) improve the value of their catch for the same fuel. In this case study, we look at a fishing company trying this second approach.

Perhaps the most impressive fishing vessels in the European fleet (from the purely technological point of view) are the 'super-seine' vessels operating in the Indian Ocean. These vessels are large, sleek, high-speed craft that use the latest technology to target schools of skipjack and yellowfin tuna, primarily for the canning market. One vessel can catch more than 20 tonnes of tuna in a single day.

Sources within the Indian Ocean regional fisheries management organisation (IOTC) and working within the Indian Ocean European purse seine fleet indicated that large purse seine vessels burn about 20 tonnes of fuel per day, or 40 litres per mile. Vessel steaming costs reach about US$13,000 per day. The price of skipjack tuna in mid-2009 was about US$1,250 per tonne. Assuming a catch of 20 tonnes per day, the catch value would be about US$25,000. Thus fuel costs are a significant proportion of the costs in this fishery, with fuel consumption roughly one tonne for every tonne of tuna caught.

In this fishery, the skipjack tuna (the main target species) is caught mixed up with juvenile yellowfin and bigeye tuna – both much more valuable species if the fish are landed at marketable size for steaks or sashimi. However, the bulk handling of the catch on board most super-seiners means that these other species (mainly juveniles) also go for canning. There is also a significant seine fishery for yellowfin tuna caught specifically for canning.

Sapmer, a large French fishing company based in La Reunion has recently completed an analysis of the tuna industry. They have concluded that, at € 1 per kg, landing yellowfin for canning is not sensible – leading them to sell their two conventional purse seiners. Instead, the company has invested about € 80 million in the design and construction of three 90-metre tuna purse seiners equipped with high-tech onboard freezing systems – by freezing fish quickly to -40oC the product can compete with longline-caught product on the Asian market. This means prices of around US$ 6,900 per tonne (longline yellowfin, July 2009) rather than US$ 1,500 for canning (purse seine mixed skipjack and yellowfin, July 2009). The carbon footprint of these purse seine vessels is comparable with standard purse seiner vessels, but the carbon footprint per unit value is more than 4.5 times improved (perhaps somewhat less than this in practice, because the hold capacity of these vessels is lower, meaning more 'commuting' to offload catch, and of course low temperature freezing consumes some fuel). The impact on yellowfin tuna stocks, already under some pressure in the Indian Ocean, is also significantly less for the same profitability.

The impetus for this change has not, of course, been environmental so much as economic. Firstly, it is, frankly, wasteful to fish juveniles of a high value species such as yellowfin tuna to put in sandwich filling – as Sapmer seems to see more clearly than the other EU purse seine companies. Secondly, Sapmer has experience of operating in much more strictly regulated fisheries (notably the French toothfish fishery – see above). They predict that similar types of regulation – individual quotas, proper licensing and reporting arrangements and observers – will eventually be implemented by the Indian Ocean Tuna Commission, despite political wrangling up to now. The focus on quality rather than quantity is one measure that should preserve the viability of Sapmer's tuna fleet into the future.

From this case study, we note that regulation, or even the threat of regulation, can play a role in getting fishing companies to rethink their fishing strategies and turn them in a more sustainable direction – however, nothing helps more than hard economics. Fishermen do not generally want to adhere to wasteful practices and where they have the flexibility, funds and imagination to make improvements they often will.

(We also note, parenthetically, that the role of the EU in the IOTC and in Indian Ocean tuna fisheries more generally is a murky one. The EU is the largest funder of IOTC, and therefore the main contributor to tuna fisheries management in the Indian Ocean - but EU interests also invest significant funds in attempting to ensure that regulation by IOTC does not hinder the operations of their purse seine fleet. This pattern of behaviour is repeated in other RMFOs – see below.)

- Case study 6: Changes in Belgian and Dutch beam trawl fisheries

Beam trawl fisheries, along with Nephrops trawling, have been the major targets of EU environmental campaigners in fisheries in recent years. The Belgian research institute, ILVO Technology and Food, have been involved with the Belgian fishing industry for many years, warning that environmental and fuel issues needed to be addressed if the industry was to survive into the future. High fuel prices experienced in recent years initiated more involvement between Dutch and Belgian fishery research institutes and the industry and have led to a series of improvements within the fishery. In both countries, research institutes have been pushing the industry to improve their practises voluntarily to avoid the need for new legislation and increased regulation. The sharp increase in fuel prices provided the incentive for fishermen to start making progress and it is perhaps indicative of the fishing industry that the most troubled fisheries are the ones which are making the biggest strides towards improvement. The increasing popularity among European consumers of sustainably-sourced seafood options has also not gone unnoticed by the beam trawl operators.

One difficulty regarding modifications to beam trawl gear is that where the target species need to be stimulated to rise from the seabed into the net (as is the case with high value species including soles and plaice), the modified gear must still somehow interact with the seabed to obtain decent catches. Innovations within the Dutch beam trawl sector have focussed on two approaches: the use of alternative gears and modifications to traditional beam trawls[5].

Alternative gears include the use of 'fly-shoot' (or Danish) seines and outrigger trawls[6] instead of beam trawls. While not practical during winter months when weather is bad, the Dutch kenniskring information exchange groups report that beam trawlers under 1200hp have reduced fuel consumption by about 40% using outrigger trawls. Gear costs are also reduced, as there is less net abrasion and no chains to wear out and replace. For bigger trawlers, from 1200hp to 2000hp, however, the nets are too small to be profitable.

5 This case study is based on discussions with individuals involved (e.g. members of the Producer Organisation and Dutch and Belgian researchers.

6 Lighter but larger trawls held out from the side of the boat on a gantry or outrigger – giving a larger swept area for the gear. For general descriptions of gears see Annex B.

Innovations to traditional beam trawls include the 'SumWing', 'Pulskor' and 'HydroRig' fishing gears. The 'SumWing' is the result of collaboration between an engineering company, HFK Engineering, and three fishing companies and is in essence a wing that flies through the water as opposed to a traditional beam dragged over the seabed. The system does however still use tickler chains and therefore relies on mechanical contact to scare fish into the trawl. Six large beam trawl vessels in the Dutch fleet are operating with SumWing trawls and more vessels are expected to adopt the technology. For a 2000HP beam trawl vessel, the investment cost for installation of a SumWing system is about € 50,000, a payment that would require between 1 ½ to 2 years to be paid off in fuel savings.

The 'Pulskor' system is an electro-trawl being tested by Dutch vessels in conjunction with Dutch and Belgian universities (e.g., Wageningen and Ghent universities). The system uses electrical impulses to stimulate fish and shrimp out of the seabed into the net. Results have been promising and it appears there is some selectivity improvement also: trials report a trend of catching less small soles than conventional beam trawls. The system does not rely on contact with the seabed or tickler chains and is a substantial improvement over traditional beam trawls in terms of seabed impacts. Cost and reliability are likely to be issues of concern for fishermen, and we also note that this system cannot be deployed commercially as it has not yet been approved for use by the EC.

A combination SumWing/Pulse trawl is being trialled in the Netherlands, so far with encouraging results. The system does away with tickler chains and is a substantial improvement, environmentally speaking, on standard beam trawling. A Dutch fishing company is operating this dual system on 3 vessels in its fleet, each of which is regularly landing more than conventional vessels in the same fleet.

The Dutch Ministry for Agriculture and Fisheries provides a subsidy fund for innovation in the fishing chain. The subsidy was granted to a consortium consisting of VCU (a Fishing cooperative), the fishing company Geertruida Ltd., Wageningen IMARES Ltd. and research institute DELTARES. The consortium is developing the 'HydroRig', which utilises vortices in the trawl net to stimulate fish from the seabed rather than mechanical contact.

All three innovations outlined above reduce friction with the seabed[7] and therefore incur significant fuel savings that should go some way towards compensating for the cost of investing in new gear. In terms of acceptance among fishermen, further trials are required and this requires capital investments. The beam trawl fleet operates under marginal economic viability (if at all when one considers fuel subsidies or tax breaks) and it is highly unlikely that private capital could be raised from operators of these vessels. Research and development would probably need to be funded by Member State governments and the European Union if progress is to be made and uptake among fishermen encouraged. It is also a good option to change gear without having to change vessel (which would be a major hurdle).

In terms of reducing the carbon footprint, the use of wheeled beam shoes and lighter metal frameworks has resulting in fuel improvements of 5% to 10%. Changing the gear and modifying operational methods has seen a reduction in fuel usage by big beam trawlers from 5,000 or 6,000 litres per day to about 3,500 litres per day[8]. The use of top panels and 300mm mesh has also resulted in increased selectivity with haddock and whiting bycatch reduced, although bycatch and discard levels are still significant in this fishery (Figure 2). The catch of sole is reported to be unaffected by these modifications, since larger, marketable sole are retained.

7 The fundamental design of beam-trawl gear, and many innovations based on this type of gear, still impact with the seabed via the shoes.

8 By way of comparison, Curtis et al. (2006) estimated daily fuel consumption figures for UK sector vessels to be: white fish trawlers greater than 24m, from 2,500 to 3,750 litres; white fish trawlers less than 24m, from 1,250 to 2,500 litres; twin-rig nephrops trawlers, from 1,250 to 2,750 litres; scallop dredgers, from 1,250 to 3,750 litres; seine-netting vessels, from 500 to 1,000 litres; under-10m mobile gear vessel, from 125 to 500 litres; and under-10m static gear vessels, from 13 to 250 litres.

Figure 2: A typical catch from a Belgian beam trawler, showing the high levels of unwanted bycatch. Photograph courtesy of the WAKO II project, ILVO [Photo copyright ILVO, with thanks to Jochen Depestele] – see: http://www.ilvo.vlaanderen.be/Default.aspx?alias=www.ilvo.vlaanderen.be/wako

These modifications, while encouraging, are insufficient. ILVO believes that spatial planning would be the best tool for the CFP to regulate where beam trawl impacts are permitted. In sandy grounds with low natural biodiversity and high natural disturbance (usually tidal) – relatively common in parts of the southern North Sea – beam-trawling impacts are less intrusive than at sites where biodiversity is higher and habitats are more susceptible to disturbance. Conflicts with other gear types could also be avoided using some kind of zoning, and with modern VMS, enforcement would be straightforward. But it is important to consider the impact of zoning on fuel consumption, as in some cases limited areas where beam trawling can take place may require vessels to steam further (and faster if restricted by days at sea limits) to reach suitable alternative grounds.

- Case study 7: Introduction of 'veils' to Crangon fisheries

In 2003, a series of technical measures were introduced into the EU fisheries for Crangon crangon (brown shrimp) to reduce discarding of juvenile commercial fish species. In 1996-7, the UK Crangon fleet alone (accounting for around 2% of the total EU fishery) was estimated to be discarding 9.9 million plaice, 1.3 million sole, 12.9 million whiting and 4.6 million cod (individuals per year) (van Marlen et al. 1997).

The main technical measure to reduce these discards was an introduction of a 'veil' or sorting grid inserted into the net, which would allow juvenile fish to be released while retaining shrimp in the cod end. Prior to introduction of the regulation, the costs and benefits of the veil were estimated, with the largest impact assumed to be a loss of market-sized shrimp of between 8% and 30% (Innes and Pascoe 2007). The cost of purchasing and rigging the veil were assumed to be minimal.

The reality after the introduction of this measure was somewhat different (Innes and Pascoe 2007). While there was some loss of catch, fishermen reported some incidental and unanticipated benefits of using the veil (aside from the ecological benefits of reduction in bycatch):

- The veil reduced the amount of sand and crabs entering the codend, improving the quality of the catch;
- For small vessels without automated catch sorting, the veil greatly reduced the amount of time spent sorting the catch – a major benefit to these vessels.
- The veil also reduced catches of non-market size shrimp (fry).

The main complaint by fishermen was not related to reduction in catch rate, but rather that in weedy areas the veil tended to get fouled and clog up, resulting in loss of catch for that tow and a time consuming process of cleaning. Experienced shrimp fishermen found that they could deal with this by altering the gear set up, but more part time shrimp fishermen found it a major problem.

In terms of the required investment by fishermen in the gear, the outcome was likewise not as anticipated. It did not turn out to be straightforward for fishermen to buy and rig the veil into their existing nets themselves – it was reported that most fishermen had to buy a new net ready rigged, at some expense. Again, full time shrimp fishermen were prepared to bear the expense and eventually become expert at setting up the gear, however this was a significant disincentive for part time fishermen to continue to participate in the fishery (Innes and Pascoe 2007).

Overall, the lessons from this case study are:

- Costs and benefits of technical changes to fisheries are hard to predict;
- Costs and benefits do not fall equally on all fishermen – in this case, the smaller vessels run by full-time shrimp fishermen benefited overall, while the larger vessels and part-time shrimp fishermen bore most of the costs;
- The practical and logistical difficulties of making changes to fishing gear or practices should not be underestimated.

- Case study 8: Improvements made to single trawls in Scotland

Fishermen are by no means ignorant of the criticism they come under and are, admittedly slowly, trialling and installing innovative gear that is less damaging to the environment. Innovation is often driven by the increasing costs associated with fishing, particularly the increasing cost of fuel. This case study provides an example of a fishery where modifications are being trialled and adopted – an example of effective cooperation between fishermen, scientists and policy-makers (information from Seafood Scotland[9]).

- Progressive increases to mesh size have reduced undersized capture and discards. Cod end mesh size has increased to 120mm (from 90-100mm) for basic towed gear. This has increased the age of capture of most demersal species of fish.
- Introduction through regulation of compulsory square mesh panels[10] (SMPs) has greatly improved selectivity. Further research into different mesh size SMPs and alternative positions in net configuration were carried out in 2006 with Scottish industry and are ongoing.
- Towed gear SMPs have a minimum dimension of 80mm or 90mm depending on trawl type. Many Scots fishermen now operate voluntarily with SMPs of up to 120mm, which increases the escape capacity of the panel.
- Twine materials have improved, allowing net manufacturers to construct trawls from thinner twine, which in turn makes them lighter and gives less drag under tow, hence interaction with and damage to the seabed is reduced and fuel costs have reduced as well (Dyneema).
- Many vessels now use footropes equipped with larger diameter discs, which raise the footrope from the seabed. This reduces seabed damage and can acts as a selectivity aid to allow bottom-dwelling fish species to avoid capture.

9 See http://www.seafoodscotland.org/

10 A given mesh size of square mesh netting is effectively much larger than diamond mesh with the same size measurement. This is because diamond mesh has a tendency to close up flat under towing (depending on the orientation of the knots) while square mesh remains open.

This case study shows that when fishermen, scientists and public policy-makers have a good relationship and can work together, big strides can be made in selectivity and efficiency.

- Case study 9: Future potential for marine diesel engines

Marine diesel engines are coming under increasing scrutiny as major polluters. As a result, considerable effort is being devoted to the reduction of their emissions. The issue with diesel engines is the fuel and the volume of CO_2 released during their operation. In general, diesel fuel comprises about 86.5% by weight of carbon and some 13.5% hydrogen. Emissions also include SOx, which is also damaging to the environment. Approximately 0.3% of the exhaust gases are particularly harmful, notwithstanding the carbon output.

In 2004 the world's two leading marine engine manufacturers, MAN Diesel and Wärtsilä Corporation, supported by the European Union, agreed a large scale Cooperative Research Project – HERCULES-ß – with the objective of maximising fuel efficiency while reducing emissions. The project's industrial partners account for about 80% of the global market for marine engines. The project was entitled 'Higher efficiency engines research and design on combustion with ultra-low emissions for ships'. The project was completed in 2007[11].

The HERCULES Project developed new technologies to drastically reduce gaseous and particulate emissions from marine engines and concurrently increase engine efficiency and reliability, hence reduce specific fuel consumption, CO_2 emissions and engine lifecycle costs.

The principal aim of HERCULES-ß was to improve the efficiency of marine diesel propulsion systems to a level of more than 60% to reduce fuel consumption and CO_2 emissions. A concurrent aim is to achieve ultra low exhaust emissions from marine engines by the year 2015.

It is not uncommon to find 50-year old engines in fishing vessels operating off the coasts of Europe. Fishermen are loath to change engines until they are beyond economic repair however when they do, there are options available that greatly reduce emissions and save fuel costs for fishermen - however the most modern technology is often beyond the financial reach of the smaller fishing businesses. Any kind of public subsidy that risks enhancing overall fishing capacity is clearly undesirable, particularly with the state of many stocks in EU waters parlous. Having said that, fisheries management by inefficiency is also undesirable, faced as we are by the pressing need to reduce EU carbon emissions. This is clearly a difficult area (as already noted); but within the context of a policy framework that aims to reduce capacity to appropriate levels, it may be possible to include measures that allow small-scale fishermen to operate with the most fuel-efficient engines.

4.2.3 Conclusions from Case Studies 1-9

The above case studies show that in general technical changes in fisheries to improve environmental performance are possible without significant policy-related hurdles – although there may be administrative issues between fishermen and management agencies. Generally speaking, fishermen are prepared to make these changes under the following conditions:

- They can clearly see and understand the benefits (this does not necessarily mean that the benefits have to accrue to them directly);
- They don't perceive a significant risk of losing catch and money, at least in the long run;

11 See www.ip-hercules.com

- They are given sufficient timing and flexibility to plan and budget for the changes;
- They are given support if necessary (e.g. from scientific research or to support short-term losses).
- The threat of regulation in the future may also spur fishermen to act.

Where these conditions are met, many fishermen may be prepared to make technical changes that reduce either their direct environmental impact or their carbon emissions, or both. As regards carbon emissions, the spike in the price of red diesel early in 2009 was certainly a wake up call, and many fishermen realise that eventually the price will return to those levels and stay there, rendering many EU fisheries unprofitable unless action is taken. Now is thus a good time to take action to support such changes, while fishermen still have some room to manoeuvre. Many changes to increase fuel efficiency of fisheries, or the economic return on the catch, are likely to benefit both fishermen and the environment.

Having said that, it is also clear from the case studies that even relatively minor technical changes in a given fishery may have unpredictable costs and benefits to fishermen – costs and benefits are also distributed differently between fishermen, even within a given fleet.

The case studies also highlight the need for managers to understand fishing operations, and the constructive role that real dialogue between fishermen and managers can play in finding practical solutions to environmental issues. Good understanding and interaction between managers, scientists and fishermen pays dividends from the point of view of i) long-term planning in fisheries; ii) innovation in gear and techniques to improve environmental performance and iii) rapid detection and solving of environmental problems in new fisheries.

4.3 Changes involving different gear types

4.3.1 Types of changes

The analysis in Part 1 focussed largely on this type of change. The general conclusions were that the following changes are desirable to reduce environmental impact:

- Away from towed gears (trawls and dredges) towards mobile gears (seines or trolling lines) or passive gears (nets, handlines and traps);
- Within passive gears, away from nets towards lines or traps;
- Away from larger offshore vessels towards small inshore vessels (noting that the very large vessels may be the same or better than medium sized vessels in terms of carbon emissions).

4.3.2 Case studies

- Case study 10: North Sea saithe fishery – otter trawl to demersal seine?

The fishery for saithe (Pollachius virens) is one of the largest fisheries in the North Sea, with a TAC of 126 000 tonnes in 2009 (ICES 2009). Fishing fleets from at least five EU countries and Norway target saithe in significant quantities. The fishing gear of choice for the fishery is overwhelmingly the demersal otter trawl.

The demersal seine (sometimes called a 'Danish' or 'Scottish' seine depending on the means of deployment) can be used as an alternative to an otter trawl to target whitefish species (cod, haddock, saithe, whiting etc.). It looks roughly similar to a trawl but has no otter boards (trawl doors) – the elements of a trawl that make most impact on the bottom, as well as being heavy and therefore fuel-costly to tow. The seine is also operated differently, being in essence deployed round in a circle and then towed (more slowly than a trawl) until the circle closes flat, trapping the fish in the codend[12]. Under most conditions it is, however, not as effective at catching fish as an otter trawl (Table 8).

Table 8: Advantages and disadvantages of the demersal seine relative to the otter trawl are given in the table below (information from Icelandic fisheries[13]).

Advantages of demersal seine relative to otter trawl	Disadvantages of demersal seine relative to otter trawl
• Requires less power (lower fuel consumption per unit catch) • Cheaper than a trawl • Less bulky to store than a trawl – can be used more easily on smaller vessels • Can be used on small patches of good ground interspersed with very rough ground – inaccessible to trawlers	• Cannot operate on rough ground that is accessible to heavy 'rockhopper' otter trawls • Requires relatively calm weather and low current for deployment • Difficult to use at night or in fog • Harder to deploy – more work by crew • Requires good navigation / fish finding skills because covers smaller area • Cannot be moved without hauling in and resetting

The above table probably shows why the demersal seine is not the gear of choice for demersal fisheries in most of the EU – the otter trawl is the dominant gear for both large-scale / offshore and small-scale / inshore fisheries.

For the purposes of this case study, two large fishing companies in two different Member States were asked about whether they would consider the possibility of switching some or all of their vessels from otter trawl to demersal seine.

In both cases, the fishing companies were sceptical. There were specific objections relating to the saithe fishery: i) it is not clear that the demersal seine is effective in catching saithe and ii) it is not clear that it operates effectively at the depths at which saithe is usually targeted.

They also had more general practical objections in regard to switching gears (of more interest here):

1. Effectiveness: In both cases, the companies were sceptical that the gear would work as well as an otter trawl (and Table 8 above suggests that they are right, under most conditions).

2. Training: Both companies noted that introducing new gear to fishing vessels required major training for captains and crew, with associated loss of earnings while the crew climbed the learning curve with the new gear. They both also made the point that getting qualified crew for fishing vessels (particularly freezer vessels that are at sea for several weeks at a time) is becoming more and more difficult, and crew do not always stay working on the vessel for long. Many of the larger offshore EU fishing vessels now look to some of the new Member States or outside the EU for qualified crew.

12 Information from Seafood Scotland see http://www.seafoodscotland.org/index.php?option=com_content&task=view&id=183&Itemid=73

13 See http://www.fisheries.is/

3. Cost: While the new gear obviously costs a certain amount of money, refitting the vessel to run the gear may well cost more. Time is also lost when the vessel is out of commission for refitting. More importantly, they may lose catches for quite a long period – indefinitely if the gear is not as efficient.

4. Catches / quota track record: The introduction of a new gear is likely to lead to reduced catches at least in the short term (due to refitting / crew training / inexperience in operation). Aside from the cost issue, the point was made that quota allocations are often based on a vessel or company track record in catches. Fishing companies thus perceive it to be important that they are seen to be using most of their full quota allocation – otherwise they may run the risk in the future of having it reduced, if they have not used it in a certain reference period. These reference periods are usually decided upon retrospectively – i.e. fishing vessels or companies cannot plan changes to avoid these reference periods. In practice, fishing companies may be able to explain in advance to the PO or other body from which they obtain quota that they are involved in an experiment, and can usually appeal against disadvantageous reference periods. In some Member States (not in all) they can sell quota to recoup some losses if it is not used. However, they see it as an unnecessary risk.

5. Bycatch: Very few fisheries are completely monospecific, even if they have one target species, such as the saithe fishery. If the mix of bycatch species is different in a different gear, they may run the risk of catching species for which they have no (or insufficient) quota. The company also would not know the market for these species.

6. Administrative problems: One company questioned whether it was even possible for them to change gear type in the context of the regulatory framework of the fishery, without incurring significant administrative difficulties. This was just a hypothesis, but the case study of the eliminator trawl above suggests that it may contain an element of truth.

On a more philosophical level, both companies tended to reject the idea that their activities were damaging the environment – and hence they reject the thesis that they need to change gear type at all. They both made the point that the North Sea has been trawled for many years. It was also suggested that there were easier and less risky ways in which they could save fuel – engine replacement and maintenance, reducing steaming speed, using more modern light-weight trawls with lower drag. These types of investments were more likely to be considered than a wholesale change of the type of gear used.

- Case study 11: Southern North Sea sole fisheries

Sole is one of the most important commercial species fished in the southern North Sea (ICES area IVc). In terms of value per tonne, it is the most valuable of the principle commercial fish species caught, valued at € 7,975 (£ 7,250) per tonne in 2008 (MFA, 2008). Cod, by way of comparison, was valued at € 2,200 (£ 2,000) per tonne in the same year. Sole is targeted by various types of vessels, including small and large beam trawlers operating across the area, small otter trawlers and netters operating closer to home. The Total Allowable Catch for sole from area IV in 2008 was 14,396 tonnes, of which 9,974 tonnes was allocated to Dutch vessels, 1,380 tonnes to Belgian vessels, 930 tonnes to UK vessels and 677 tonnes to Danish vessels. Small otter trawlers catch the majority of the UK quota and beam trawlers catch the majority of the Dutch and Belgian quota.

The direct and carbon-related environmental impacts of beam trawlers, as well as some of the modifications fishermen have made to reduce them, have already been discussed in Case Study 6 above. Here we consider the relative impacts of the different types of gear, and the potential for the fishery to move towards the least damaging option.

Large beam trawl vessels landing to the Dutch and Belgian auctions supply between 4 and 5 tonnes of sole per trip (about 5 days) during the peak winter months. During summer months, vessels land between 1 to 2 tonnes of sole per trip. Interestingly, Danish gillnet vessels also land to the Dutch market during the summer months, supplying 1 to 2 tonnes of sole per week also. Gillnet vessels clearly incur much reduced fuel bills and some beam trawl vessels have converted to gill netting with varying degrees of success, as discussed in the next set of case studies below.

Comparing the beam trawl catch with small-scale landings by UK vessels is not straightforward as obtaining data for small-scale fisheries is notoriously difficult. A proportion of the 2008 UK quota for soles in Area IV was allocated to the under-10m vessels. Ongoing data collection as part of a large civil works development in the Thames estuary provides insights into the workings of the small-scale fleet operating in this area, one of the most productive sole spawning grounds in Europe. There are approximately 64 licensed under-10m vessels located within the Thames estuary ports ranging from otter-trawlers to small netting vessels about 5m in length. Not all these vessels have quota to fish for soles and not all the vessels are operated fulltime. Assuming trawlers do have quota for sole (which is really the only target species that would ensure their economic survival), there are about 20-35 trawlers operating each with a license for 1 to 2 tonnes of sole per month during the sole season (from late March to late October). While in theory these trawlers could land about 12 tonnes of sole in a year, based on quota and additional bycatch allowances, in practise a trawler of about 100kW lands between 4 to 5 tonnes of sole per year, about the same amount landed by a large Dutch beam trawler in one week. The small-scale fleet in the Thames estuary is probably landing somewhere in the region of 100 tonnes of soles per year.

The catch composition of the small-scale vessels operating in this fishery is very mixed – one trawler-operator provided us with a list of 75 species that had come up in his trawl over the last few years – this from one of the most human-impacted estuaries in Europe. While many of the incidentally caught species are landed and sold alongside the sole, many are not – including commercially valuable species. Juveniles of other flatfish species such as plaice and dab are usually discarded. The market for dabs is also poor for most of the year and fishermen on small trawlers often do not bother to retain the dabs unless fishing has been particularly poor that day. In recent years cod has been discarded in large quantities because of lack of quota, despite relatively high local abundances being reported. Discard rates of more than 80% by volume are common based on observer trips aboard a variety of under-10m vessels. Thus a switch from beam trawls to otter trawls would not necessarily bring many benefits in terms of bycatch reduction, although there may be benefits as to fuel consumption and habitat damage.

The research institute ILVO in Belgium (see above) has just started a project to look into the potential environmental benefits of switching this fishery from a beam trawl to a trammel net fishery, in the hope of reducing all three of the main impacts: bycatch, habitat impacts and fuel consumption. The project is at an early stage, but already one snag has arisen to this idea – a significant mortality of harbour porpoises in trammel nets. A significant number of Dutch former Beam trawlers are already turning to trammel nets. In the Netherlands bycatch of harbour porpoise appears to be less of a problem (although it still exists). Instead, environmental concerns have centred around the unlimited length of the nets, recently limited to 25 km by the Dutch authorities. Nonetheless, the small er vessels in the fleet have just been certified sustainable by the Marine Stewardship Council (MSC), while some of the larger vessels are certified by Friends of the Sea.

This case study again highlights the potential benefits to be gained by close cooperation between scientists and fishermen, but also demonstrates that in switching gears, one type of environmental impact may be exchanged for another. Small fisheries may be able to operate in a very clean manner (e.g. by handlining or using small seines) but any fishery that lands significant quantities is likely to have some environmental impact, regardless of the gear type. This means that if policy-makers want to support changes away from certain gear types towards other gear types, they may well end up having to make value judgements about the relative importance of different impacts. In this case, to be simplistic, are plaice, dab and starfish more or less important than porpoises? Are both more or less important than sole and sole fishermen? These are, in the end, policy questions.

A second highlight from this case study is, again, that switching gears from one with a higher catch per unit effort (CPUE) relative to the less environmentally damaging methods would, in this example, leave the market with a serious shortfall in supply of a high demand, high value fish. In simplistic terms, the economic hole left behind could provide an opportunity for increased numbers of alternative vessels fishing with 'friendly' gear, although the reality would be tempered by the limited range over which 'friendly' gears would be viable. There is a sole fishery certified by the MSC as sustainable in the English Channel, whose produce is of interest on the Dutch market, however an interviewee from an auction house in the Netherlands observed that the harvest is measured in tens of tonnes, not in the thousands of tonnes demanded by the Dutch and Belgian markets; however the recent certification of some Dutch vessels may change this.

The ongoing work by MacAlister Elliott & Partners with fishermen in the Thames estuary has enabled an insight into the operations and economics of different fishing methods operating in the same location, as well as valuable observations about behavioural obstacles to change. As a general rule, there is no reasonable average that one can ascribe to a category of vessel operating in the Thames estuary in terms of costs and earnings. Similar vessels experience annual gross earnings ranging from about € 20,000 to € 70,000. For comparable boats, this variance is chiefly explained by differences in how the vessel is operated (e.g., number of days fished) and the experience of the master of the vessel. The size of engine is also important in many cases, with high-powered vessels (i.e. less fuel efficient ones) being significantly more profitable.

Relevant to this study is the finding that vessels operating drift or set nets are in some cases earning more than small trawlers, in terms of gross earnings (this also appears to be true in Dutch sole fisheries[14]). One fisherman who operates both trawls and gill nets reported a much better return when he goes netting. This is in part because the fuel expense of netting is significantly less and also because the retained species are more valuable (the soles are larger and bass are also caught). When asked why he didn't switch to netting full-time, the fisherman responded that he prefers trawling! It was also pointed out that switching to netting (something this fisherman has been forced to invest in for reasons beyond his control) initially resulted in losses being experienced as the fisherman was required to learn new techniques and fishing grounds. This final point, that changes in behaviour incur some cost to fishing businesses is discussed further in Case Study 19.

The lessons from this case study are:

- Trawlers, especially beam trawlers, supply markets with the vast majority of high demand, high value flatfish. Any reduction in fishing effort will have significant implications for markets and ancillary industries.
- Discards among the beam trawl and otter trawl fleet are very high, much to the dismay of fishermen as well as conservationists.
- Switching to alternative fishing gears may have unintended consequences that require policy-makers to make value judgements about the relative costs and merits of impacts, in this case the value of reducing seabed impacts against the cost of cetacean mortality.
- Obtaining accurate data about the contribution of small-scale fisheries is more difficult than it should be. Fisheries exhibit significant variance even among similar fleets, further complicating the understanding of fleet contributions based on a small sample set.
- What seems logical from an outsider's perspective does not necessarily seem logical or desirable to a fisherman.

14 Visserij In Cijfers (WUR-LEI 2009)

- Case study 12: Introduction of twin-rig trawls in Italy

Italian demersal fisheries are very multi-species, and often include a high proportion of juveniles in the catch, since in Italy there is a strong market for small fish. As for other Mediterranean demersal fisheries, management is not by catch quotas for individual species (as is usually the case in northern European fisheries) but rather by effort management and technical measures. However, there is concern about the health of many of the most important stocks (hake, sole, red mullet, Nephrops and many other species).

In 2005-6, an EU-funded project carried out experiments on the Adriatic coast of Italy to test Danish twin-rig technology as a replacement for standard demersal otter trawls (van Marlen et al. 2009, section 6.8.3). The aim was to reduce benthic impacts and fuel consumption and also to improve product quality. The experiment was extremely successful – the twin-rig trawls covered a significantly greater swept area with each tow than a standard otter trawl, without increasing the fuel consumption. This meant that for the same amount of fishing effort and fuel costs, fishermen increased their catches by 30%, and catch quality was also improved because fishing trips could be shorter.

Twin trawl – photo by Edward Willsteed

Concerns have been expressed about this experiment, however, from the point of view of stock management. If management were by quotas, this would simply be a more efficient way for fishermen to catch the same quota as before (assuming good enforcement). However, in this mixed-species fishery, quotas are impractical. But management by effort limitation risks failing when fisheries become more efficient – this 'successful' experiment may bring some environmental improvements but at the expense of a big increase in overfishing which may make the situation worse.

The lessons from this case study are:

- Different environmental goals may conflict with each other – increased fuel efficiency per unit of catch may lead to overfishing unless management can respond;

- Management by quotas, while unsatisfactory in many ways, is more able to respond to changes in fishing efficiency than management by effort limitation. Management by effort limitation can only be successful if i) it is very responsive to changes in fisheries and ii) it is combined with a reduction in fleet capacity to appropriate levels.

- Case study 13: Nephrops fisheries

Aside from beam trawls, the other big North European fishery that has come under fire for bycatch, habitat damage and carbon emissions in recent years has been Nephrops (Norway lobster or scampi) fisheries, which use an otter trawl with a heavy tickler chain. While 9 litres of fuel is used for every kg of

Nephrops caught in an unselective trawl (or 4.3 litres of fuel per kg total landed catch), only 2.2 litres of fuel is use for a kg of Nephrops caught by creel (a type of trap) (Ziegler and Valentinsson 2007). Another advantage of the creel is that the quality of the end product is higher – bringing a better return per unit volume of catch and per unit of carbon emitted. Creels also cause significantly less habitat damage and have much lower discard rates (Ziegler and Valentinsson 2007). So could Nephrops trawlers switch to fishing with creels?

We posed the question to a contact familiar with the operation of both trawl and creel Nephrops fisheries around the east and west coasts of the UK (where Nephrops is now the most important fishery in terms of value of landings). Essentially, there are two significant hurdles to this change.

The first hurdle is a straightforward economic hurdle. Creel fisheries land a low volume, high value live catch to a high-end market, while trawl fisheries land a high volume but lower quality frozen catch to a more mass market. The retained bycatch of whitefish (around 30% of the catch for trawls without selectivity grids) is also an important part of the profit. With their existing marketing structure, trawl fisheries would become instantly unprofitable if they started landing the same volumes per trip as creel boats. If they marketed to the same people as the creel boats they would probably swamp the market. Add to that the investment in gear and refitting vessels, and the change would probably bankrupt the company.

The second hurdle is a more general policy hurdle. The main Nephrops grounds for the UK trawling companies are the North Sea (the Farne Deeps, the Silver Pits and the Fladen Ground, for example) and the west of Scotland and Ireland. These areas are also important areas for groundfish fishing – not only by UK vessels but also by French, German, Irish, Norwegian, Danish and Polish boats, among others. The vast majority of these vessels are demersal trawlers. As already clear from the case study on beam trawlers above, towed gear and fixed gear such as Nephrops creels cannot easily share the same fishing grounds without coming into conflict. It is essentially impossible for any vessel to start a fixed gear fishery in these areas without the gear being lost to a trawl. From a policy point of view, if creel fishing were considered the desirable outcome in these areas, some kind of zoning would have to be put in place to restrict access by trawlers. If this were done, it is quite likely that fishermen would find a way to catch and market Nephrops using fixed gear from these areas – but some significant damage may be done to livelihoods on the way.

However, it is possible with sufficient political will to switch crustacean fisheries forcibly from trawls to traps. In 2003 precisely this was done in the Californian spot prawn fishery, after it was decided that the rate of discarding of depleted rockfish species in the trawl fishery was unacceptable (Morgan and Chuanpagdee 2003). A limited number of licences for trawl vessels to convert to traps were made available, but other than that, spot prawn trawlers were required to look for fishing opportunities in other fisheries[15]. The consequences for businesses and communities are not clear.

The lessons from this case study are:

- Market hurdles may be important – it is hard to switch a high-volume low-value fishery over to a low-volume high-value gear without damaging the income of both fisheries by increasing the quantity of high-value product available on to a limited market, and thus risking a collapse in the price;
- Passive and towed gears are often incompatible in the same areas – a switch to passive gears in these areas requires some kind of zoning to avoid gear conflicts;
- Such switches have been achieved in other areas – it is not clear from the data available in the public domain what the economic and social consequences were for fishing companies and communities, but this example may bear more investigation.

15 Project by Earth Economics – see http://www.eartheconomics.org/projects/marine/spotprawn/2005workshops/pdf/Spot_prawn_workshop_proceedings.pdf

- Case study 14: Deep-water trawling, longlining and gillnetting

Deep-water trawling along the edge of the European Atlantic continental shelf is a relatively recent and very controversial fishery. Target species are mainly sabre or scabbardfish, monkfish, blue ling and various species of grenadiers, but the fishery can land around 30 species. In the early days of this fishery, catastrophic damage was done to cold water coral reefs off the west coasts of Ireland, Scotland and Norway. The most important coral areas are now closed, but the majority of areas in which coral has been observed are still trawled[16]. Stocks of deep-water sharks declined by 80% over the course of the 1990s, presumably due to deep-water fishing (Hareide et al. 2004).

Deep-water fishing is also possible using other fishing gears – notably demersal longlines, which are the gear of choice in, for example, the Southern Ocean demersal fishery for Patagonian toothfish and a few other species. In this area, longlining is the gear type of choice for demersal fishing, since it is recognised that its impacts on habitats and other species is far lower than for trawling (although its carbon footprint may be just as bad – see above) (CCAMLR 2006, 2008a, 2008b). EU demersal longline fisheries also exist closer to home, mainly targeting cod – although the vessels in this fishery are mainly Icelandic and Norwegian rather than from the Community. Is it possible for an EU deep-water trawl fishery to switch to demersal longlining? The question was put to a French fishing company (that prefers to remain anonymous).

Aside from the issues of cost and training, which come with any change in operations, the more fundamental hurdle to this change came from the multi-species nature of this fishery – which does not even have a defined target species. One of the reasons why longlining is preferred in many fisheries (demersal and pelagic) is that it is a fairly selective method of fishing, both as regards species and as regards size. This is because the hook size and the bait can be manipulated to attract and capture only particular species of fish of particular sizes – other species may not be attracted to the same bait, and smaller or larger sizes will not be caught by the hook. It is therefore not obvious how a truly multispecies fishery such as this one could operate using longlines.

There is, however, also a deep-water gillnet fishery operating in the same area, targeting monkfish and deep-water sharks. Based on the general analysis above (Part 1) we might assume that this fishery was preferable to the bottom trawl fishery, and try to promote a switch from trawl to gillnet. However, a closer analysis of this fishery (Hareide et al. 2004) suggests that this would not be a wise strategy, since the fishery in question has major environmental problems. The vessels use up to 250 km of gear per vessel (an estimated total of 5000-8000 km of gear fishing at any given time). Gear is left in the water all the time, being hauled up every 3-10 days or so, and left soaking when the vessels return to port. The vessels are in general not capable of carrying all their nets back to port, so damaged or unwanted nets are bagged onboard and either burned or dumped at sea. Gear conflicts with trawlers are suspected to lead to more lost gear. Anecdotal evidence suggests that up to 30km of netting is routinely discarded per vessel per trip. Evidence from the Norwegian deep gillnet fishery for Greenland halibut suggests that these discarded nets can fish for at least 2-3 years and sometimes even longer.

The long soak times in these fisheries result in a high proportion of the catches being unfit for human consumption. An inspection by the Norwegian Coastguard of a UK-registered Spanish vessel in Norwegian waters observed discard rates of monkfish of 54-71% (Hareide et al. 2004).

16 See OSPAR Distribution maps for threatened or declining habitats. http://data.nbn.org.uk/hosted/ospar/ospar.html – select map for Lophelia pertusa.

The lessons drawn from this case study are the following:

- On very sensitive species such as deep-water sharks, no 'environmentally-friendly' fishing gear may exist. All fisheries on these species have to be very carefully managed to be sustainable, whatever the gear. The level of management required seems to be beyond the EU (and most other fisheries management agencies) at present.

- It is not always true that static gear fisheries are an improvement on towed gear fisheries. In this case, it is hard to decide which out of the deep-water trawl fishery and the deep-water gillnet fishery is more inappropriate, although we note that CCAMLR has (provisionally) banned deep-water gillnet fishing in the area under its management (CCAMLR 2006), but only restricted deep-water trawling (CCAMLR 2008a). The NEAFC is also reported to have banned deep-water gillnet fisheries.

- Some gears – such as longlines – are quite highly selective. This is usually an advantage, but if the fishery in question targets a wide range of species, the hurdles associated with switching to a more selective gear are hard to surmount.

- Case study 15: Swedish cod fisheries

Ziegler and Hansson (2003) investigated the comparative carbon emissions of different Swedish cod fisheries (gillnets vs. trawls) in some detail. They found that gillnets and trawls are typically not interchangeable. Gillnet fisheries operate in shallow archipelago waters, while trawls operate in deeper water. If the spatial operation of trawls were to be restricted (e.g. by zoning), it is possible that the use of gillnets would spread to deeper water, but there are significant concerns about deepwater gillnet fisheries, as set out above.

Fuel costs account for about 5% of gillnet vessel gross earnings, 10% for trawlers. Gillnets are significantly more efficient in terms of fuel consumption per unit of catch (0.34 litres of fuel/kg landed cod vs. 1.41 l/kg landed cod for the trawlers). However, the trawlers have higher catch per unit of effort when measured in terms of time at sea.

Ziegler and Hansson suggest a series of policy measures that would lead to noticeable reductions in environmental impacts (including emissions):

- Increasing the percentage of catch landed by passive gears, pair-trawling, Danish seines, long-lining; reducing the percentage landed by otter trawls. Note, however, that a straight one-for-one switch of otter trawlers to gillnetters would lead to a marked reduction in the supply of cod to the market, since trawlers have much higher landings per unit time.

- Using cleaner fuel (e.g., EC1 versus EC3 diesel[17]); and

- Employing better engine technology, fuel management and optimisation of speed.

The study highlights one of the fundamental issues regarding switching gears, that a reduction in effort based on the more damaging forms of fishing would result in a shortfall in supply that would require time and ingenuity to make good, and that would result in significant opposition. It is logical that a decline in more environmentally damaging forms of fishing would eventually lead to an increased abundance of target species (barring unforeseen factors, for example the lack of recovery apparent in the Grand Banks cod fishery) through habitat recovery and decreased fishing mortality. However, economic and political realities in the short-term present a major obstacle to any policy put forward that would result in significant decrease in market supply, even if temporary.

17 Environmental Class 1 (EC1) diesel has a maximum sulphur content of 10ppm (wt.), whereas Environmental Class 3 (EC3) diesel has a maximum sulphur content of 350ppm (wt.) (www.dieselnet.com/standards). European countries generally offer subsidies to incentivise the uptake of EC1 over EC3 fuel.

4.3.3 Conclusions from Case Studies 10-15

From these case studies we can see that there are very significant hurdles for a fisherman or fishing company to change overnight the gears that they use. There are of course hurdles of cost and practicality (detailed below), but the fundamental issue is that no two types of fishing gear really do exactly the same thing. Thus a change of gear usually brings with it a need for much broader changes in the whole fishing operation: the regulatory framework, fishing grounds, vessels and crew, markets and so on. Nonetheless, it is clear that changes in gear in specific fisheries are possible if the political will to drive change is there, or if fishermen can be supported so that they have the space to take risks.

Aside from this broad point, specific policy hurdles identified above include the following:

- Quotas are an inflexible management tool and they lead to inflexibility in fisheries. Specifically, fishermen must have quota for (most of) the species that they catch – this includes the main target species (one or more) plus other species that are caught incidentally and retained. This means that the set of quotas that a fishing vessel or fishing company has is often specific to a given fishery with a given gear. If a new gear type produced a new set of bycatch species, or caught species in different proportions, the quota availability would not match these new catches. Note that this is less of an issue for small vessels who in most Member States have quota allocation from a pool. In addition, fishermen are concerned that if catches are not maintained, they run the risk of losing entitlement to quota. In practice, it may be possible to get around this hurdle (e.g. by agreement with Producer Organisations) but it illustrates the wider point that fishermen feel hemmed in by regulation to the point where they are reluctant to take risks.

- Having said that, when changes come in to a fishery that significantly improve efficiency, these risk having an impact on rates of overfishing, unless management can respond. Management by quotas is inflexible as to the amounts of target species available to fishermen, and thus can cope with these types of changes – however management by effort limitation typically cannot. When significant changes are proposed to multi-species fisheries managed in this way, managers will have to be very aware of possible impacts on target stocks.

- Different gear types come into conflict fishing in the same location – specifically, passive gears such as nets and traps are frequently damaged by or lost to towed gear. Fishermen operating in these areas cannot change to using passive gears if other fishermen using towed gears continue to operate. The solution to this would be some kind of marine spatial planning or zoning. Areas which exclude towed gear to allow passive gear fishermen to operate have been very successful in inshore areas in many Member States – there is no reason why these types of arrangements cannot be extended offshore. We note, however, that marine zoning risks leading to higher fuel consumption for some vessels due to longer steaming distances (but fuel consumption for steaming is typically relatively small compared to fuel consumption for fishing – van Marlen et al. 2009).

- The same financial and logistic hurdles have been identified as for the technical changes above, but more acute. If these kinds of changes in gear are imposed, there will be significant livelihood implications for some fishermen. Some kinds of gears simply cannot catch as much product as others – this is why demersal trawls are so popular in the first place. However, if quality can be substituted for quantity, fishermen may be able to maintain incomes while significantly reducing their environmental impacts.

- Few fishing gears are completely free from environmental impacts, and different gear types have different types of impacts. Thus policy-makers may need to choose between different impacts when they make decisions about, for example, zoning for different types of fishing gear.

4.4 Changes involving whole fisheries

4.4.1 Types of changes

Policy-makers may decide that the impacts of certain fisheries are simply unacceptable, and that none of the above changes are likely to make any significant improvement – or they may want to encourage more general changes to the EU fishing fleets – perhaps to encourage coastal and artisanal fleets at the expense of large offshore vessels. These sorts of wholesale changes are obviously the hardest of all in policy terms, and require national or European-level policy decisions – they cannot be carried through at the level of a particular fishery.

These sorts of changes could obviously be very variable, but here we consider two possibilities as case studies: a fishery that might be considered as having unacceptable impacts on the environment and a fishery that, conversely, policy-makers might want to encourage as environmentally benign.

4.4.2 Case studies

- Case study 16: Spanish octopus fishing and EU fishing agreements

The Spanish industrial octopus fleet is based in the Canary Islands (some also in Andalucía) and fishes in the waters of Mauritania and Guinea Bissau under EU fishing agreements[18]. The vessels are large (mean size of Canary Island-based vessels 450 GT) freezer trawlers, and sell frozen mainly to Japan.

The large trawls used by the industrial vessels are likely to cause habitat damage, particularly in the rocky-type habitat normally preferred by octopus. They are also unselective, tending to land under-sized animals: the Spanish vessels operating in Mauritania are reported to have complained that the minimum size of 500 g is too high – meaning that they are 'forced' to fish outside their designated zone. The minimum size in Portuguese waters is 750 g. In addition, the resource in Mauritania appears to be overfished, with scientists gathered together by the Mauritanian fisheries research institute suggesting that a 40 % reduction in effort is needed to bring the stock back to maximum productivity[19].

It is hard to imagine that this industrial fleet would be welcome in EU waters, where they would compete with artisanal fishing vessels exploiting the same resource. The artisanal vessels are small (mean size 8 GT) and target octopus using jigging lines with hooks, traps and clay pots, landing fresh on to the local market. It is also hard to see how they could maintain their high catches (150 tonnes hold capacity in each vessel) if they switched to using the less damaging methods of the artisanal fleet. Traps and pots cannot be automated to the same extent as trawling, and cannot cover nearly so much ground in a given time period. It is possible that a large volume fishery could be maintained using very high numbers of traps, but this would require enormous investment in gear and vessel refitting from a fleet, which is already operating on the margins of profitability for a lot of the time. It is also questionable whether carpeting the seafloor in traps is all that much better than trawling it.

Thus here is an example of a fleet with environmental impacts (direct and carbon-related) that are not welcome in EU waters. The solution that has been found has been to export it, so that instead of competing with artisanal fishermen in the EU the fleet competes with artisanal fishermen in Mauritania and Guinea Bissau. In Mauritania, for example, there is a local octopus fleet, partly made up of artisanal vessels using nets and pots (pirogues with high-powered outboard engines, for the most part) and partly made up of trawlers from China. A reduction or elimination of EU fishing effort from Mauritanian waters might allow this fleet to exploit the resource in a somewhat more sustainable way. Balanced against that, however, is the € 86 million annual fee paid to Mauritania by the EU for fishing rights, which makes up around a third of Mauritania's national income (see previous two footnotes). It is highly debatable whether the EU fishing fleets operating in Mauritanian waters (demersal trawlers,

18 See http://ec.europa.eu/fisheries/cfp/external_relations/bilateral_agreements_en.htm

19 The ACP Courier April-May 2008 – see http://www.acp-eucourier.info/The-controversial-example.280.0.html

midwater trawlers and a few tuna boats as well as octopus) bring in a combined additional income of € 86 million to the public purse in the EU from this fishing agreement. Therefore, unless this sum can be considered to be 'development aid', it is essentially a subsidy to these fleets to keep them fishing but away from EU waters.

- Case study 17: Bluefin tuna

The eastern Atlantic stock of northern bluefin tuna is in very poor shape, with a catastrophic decline in catch per unit effort and mean individual size seen over the last few decades. Many environmental groups, as well as the scientific committee of ICCAT, the management body, have proposed a fishing moratorium as the best means of ensuring some kind of recovery of the stock.

In the 2008 meeting of contracting parties to ICCAT (Marrakesh, November 2008), the advice put forward by ICCAT scientists was for a TAC of 15000 tonnes (the proposal by scientists for a moratorium being rejected without discussion). This proposal was supported by several member states including the USA and (initially) Japan. The EU countered with a proposal for a TAC of 22000 tonnes (i.e. ~50% above the recommended level), and allegedly threatened Caribbean members with trade retaliation on bananas if they did not provide support. The same EU proposal also cut a proposed closure during the main spawning period from two months to two weeks.

What went wrong? Why can the EU not in this case act according to its own rules, which require fisheries to be managed in accordance with scientific advice and with the precautionary principle? It is not clear why the EU acted as it did in this case, but the assumption has to be that the Member States involved in the fishery felt that the economic and/or social impacts associated with a big decline in bluefin tuna quotas were politically unacceptable – even at the price of more long-term pain as the stock remains on the edge of collapse. It may also be that while the impacts of the loss of this fishery would be felt mainly in southern European Member States (notably France, Spain and Italy – also Greece, Malta and Cyprus), environmental campaigning and awareness is more concentrated in northern European Member States. Thus the governments of Member States concerned in the bluefin tuna fishery feel more political pressure from fishing than green interests, while in most northern European fisheries the reverse is true. However, the UK, which is a contracting party to ICCAT separate from the EU due to its EEZs in the South Atlantic, also went along with the EU proposal – northern European countries are not blameless.

Nonetheless, this case study must call into question the ability of the EU to make drastic changes to fisheries that are environmentally unacceptable. The main hurdle to such changes in this case seems to be a lack of political will. In particular, if there is no will to make such changes from the area in which the pain will be felt, then other parts of the EU cannot easily force change through. Thus it is not enough for some parts – even most parts - of the EU to consider that a fishery is 'unacceptable': this decision has to come from the region or Member State in which the fishery operates. A recent report estimates that over the last decade, illegal fishing of Bluefin tuna in the Mediterranean has been worth about € 3 billion[20] – a significant proportion to EU Member States. It may thus be no wonder that politicians find it difficult to act.

It is noteworthy also that this fishery is not managed within the structure of the Common Fisheries Policy for transnational fisheries (i.e. scientific advice from ICES is put to the Fisheries Council of Ministers for debate and decision-making) but rather by a separate RFMO (i.e. ICCAT). If the debates about the moratorium and TAC for bluefin tuna were taking place in Brussels instead of in Morocco or other third countries around the Atlantic, would the EU feel obliged to follow an approach more consistent with the policy that it preaches for its own fisheries? A similarly unsustainable approach by the EU in other RMFOs suggests that this is a serious issue for global fisheries management.

20 See http://www.timesonline.co.uk/tol/news/environment/article6888276.ece

The main lesson from this case study and the previous one is that the EU does not have a good track record in taking brave decisions about damaging or unsustainable fisheries – either to improve them or to eliminate them. Instead, the solution appears to be to export the problems outside the EU, or to prefer a solution that minimises short-term economic pain over one that maximises long-term sustainability. It may also use hidden subsidies to maintain these fleets, even in the face of severe environmental impacts.

- Case study 18: Mussel fisheries

Edward Willsteed La vilaine mussel barge

It is striking from the analysis previously that mussel fisheries appear to have a much lower carbon footprint per unit volume and value of catch than most other fisheries. The direct environmental impacts of mussel fisheries are also usually low – particularly for rope and raft culture. Bottom mussel culture generally uses small dredges, but in the context of mussel beds (where mussels deposit a layer of 'mussel mud' separating them from the substrate below) even this dredging is relatively benign. There have been questions about the impacts of mussel fisheries in some areas (e.g. in regard to spat dredging and competition with birds in the Wadden sea) but these impacts can usually be managed (e.g. by setting aside a fixed amount of biomass for feeding birds).

So should policy-makers be encouraging us all to eat mussels? More generally, if fisheries can demonstrate their environmental credentials, do they deserve some kind of public support? Obviously, subsidies in fisheries are best avoided, and even 'good' subsidies are probably a precedent to avoid. However, perhaps there could be a system analogous to the system of car tax in many Member States, where the cost of tax is linked to the carbon emissions of the vehicle – so in the same way, there could in theory be a sliding scale in the cost of fishing licences based on their impacts. There could also be support for marketing and promoting, as long as it did not amount to subsidy.

- Case study 19: changes to fishing practises due to fuel prices rises

This final case study is a general review of the impacts on EU fisheries of the fuel price increase in 2006, and the changes in operation that came out of it.

The financial performance of European fishing fleets has been directly affected by the increasing fuel prices, resulting in many operators examining their options and experimenting with various measures in an effort to improve their return on fuel expenditure. The rise in the cost of fishing led to behavioural changes by fishermen, the subject of a study by Curtis et al. (2006), which highlights some of the barriers to change experienced by fishermen. These barriers are relevant to many of the points raised within the preceding case studies. The various measures and responses are discussed briefly below before the report continues by examining policy implications and options (table 9).

Table 9: Measures taken by fishermen to improve fuel efficiency and the acceptance/effectiveness of the measure (adapted from Curtis et al. 2006).

Fuel efficiency measure	Estimated industry uptake	Barriers to uptake	Costs	Benefit
Change trip planning practises	High		Low	Medium
Reduce towing speed	High	Knowledge and practicality		Low
Reduce steaming speed	High	Knowledge and practicality		Medium
Change landing port	Medium	Knowledge	Low	Medium
Replacing engine	Low	Cost	High	Medium
Change fishing method	Low	Knowledge, practicality, cost, regulation, practicality	High	Low
Change target species	Low	Regulation, knowledge	Medium	Low
Stop fishing temporarily[1]	Low	Cost	Low	Low
Modify gear	High	Knowledge, practicality, cost, regulation, practicality	Low	High
Preventative maintenance	Low	Knowledge and cost	Low	Medium
Fit gear monitoring unit	Low	Cost	Medium	Low
Reduce crew costs	Low	Practicality		Low

Pertinent points relating to the measures in Table 9 include:

- Reducing towing speed: below a certain speed, fish are able to outswim the net. There are also safety considerations, e.g., small beam trawlers do not handle the sea well at low speeds. Above a certain speed (about 4 knots), efficiency drops.

- Reducing steaming speed: where vessels' fishing grounds are offshore, days at sea restrictions can influence whether vessels optimise their speed or not. Nonetheless, reducing steaming speed is one of the key measures that would improve fuel efficiency.

21 This measure was only observed in the beam trawl fleet.

- Change of landing port: this decision depends partly on fish prices at a certain port influencing business efficiency as vessels may be inclined to travel further if they can achieve a higher price at a more distant port.

- Replacing engines: many engines are outdated, and vessels with 50-year old technology are not uncommon. Modernising engines through privately raised capital is unlikely and will probably only take place when engines break down and are beyond economic repair[22]. Changing an engine often also entails modifying or replacing the gearbox, shaft and propeller, incurring additional costs.

- Change of fishing method and/or target species: examples includes changing from beam trawling to otter trawling, single trawling to pair trawling, and whitefish trawling to Nephrops trawling. Changing to pair trawling reduces fuel costs by about 20% to 30% as trawl doors are no longer required. Obstacles to change include the availability and cost of licenses, the availability and cost of quota units to buy or rent, and the cost of refitting the vessel and purchasing new gear. Knowledge is also an obstacle, with fishermen likely to experience a temporary decline in earnings as they adapt to new gear and/or new grounds. There may also be problems with obtaining the necessary quota – particularly if the new gear has a different spectrum of bycatch species. There are issues of practicality also as skippers and crew are not familiar with the techniques involved in netting. In addition to that, netting is only suitable during certain times of the year.

- Temporary cessation of fishing: in certain cases, it may be more economically efficient to vessels to rent or lease quota than to go to sea. This is one of the methods by which Individual Transferable Quotas can improve the efficiency of fishing, whereby those operations that are most efficient at fishing would result in the greatest returns and it would therefore be economically logical that operators unable to match the more efficient operators would obtain the greatest benefit by leasing or selling their quota to the efficient operators. Temporary cessation of fishing is in practise not a long-term solution as any vessel reliant on crew would lose the crew and the means to operate the vessel.

- Gear modifications: as drag caused by a net accounts for about 80% of fuel consumed, any changes can yield notable benefits. Typical changes among the beam trawl fleets include operating with lighter gear and using wheels rather than shoes at the ends of the beams to reduce friction. For trawling, the use of lighter twines and modern twine materials is shown to reduce drag as is using larger mesh sizes. For example, trial fishing on a twin-rig demersal trawler operating new nets, identical to the old nets other than a reduced twine diameter from 4mm to 3mm, resulted in a reduction in drag of 6%, giving approximately a 6% reduction in fuel consumption per tow. For a vessel with an annual fuel bill of £200,000, a 6% saving would equal £12,000 per year (Ward et al., 2005). Changes to trawl door shape, size and weight can also reduce drag. Fishermen can also reduce headline heights to reduce the drag of the net. These changes, if not done correctly, can have a detrimental effect on the performance of the net and knowledge sharing is important if more fishermen are to have the confidence to modify their fishing gear. Informal interviews with fishermen from Spain, France and the UK in the course of this study suggest that gear modifications result in notable fuel savings and, importantly, can also improve the quality and price per kg of fish.

- Vessel maintenance: this is often the first budget to be cut by vessel owners when finances are tight. In some cases this occurrence is prevented by insurance companies insisting on good practise, which is confirmed by vessel surveys. Reducing maintenance is clearly a short-term strategy with safety implications and increases the likelihood of greater losses in the longer term due to increased vessel downtime. Maintenance can also impact fuel efficiency, for example marine growth on the hull can increase resistance by more than 30% for a badly fouled hull. Regular maintenance should extend to more than the hull and engine: faulty or worn components in the vessel power system can increase fuel consumption resulting in costs far exceeding the cost of replacing a component.

22 For example: 23.8m beam trawler: approximate cost of new engine and gearbox: £70,000. Estimated annual saving in fuel consumption and lubricating oil: £31,945 (Seafish, 2006).

The final point above raises a concern about how tight margins can lead to dangerous practises. Where fishermen would once consider only whether a vessel was capable of fishing in certain conditions, in recent times other factors may influence the decision of vessels to head to sea, including recent quality and quantity of landings, the supply of fish to the market and the potential for a high return when market supply is low. It is important that if fishermen are put under further pressure to improve their environmental record, they are not pressured into operating dangerously.

Lessons from this case study are:

- Barriers to uptake fall into four broad categories: knowledge gaps, capital availability, regulation and practicality.
- Some fuel saving measures are straight-forward to implement and result in significant savings for individual vessels. If uptake of these measures spreads across whole fleets, the reduction in emissions would be significant and well worth the investment required in information dissemination and training.
- As mentioned in other case studies, economic pressures often force changes in fishing operations that coincidentally result in environmental benefits or reduced fishing impacts.
- Economic pressures can result in cost saving measures being pursued that put lives at risk.

4.4.3 Conclusions from these case studies

Can policy-makers intervene to support whole fisheries that they consider benign and discourage (or prevent) fisheries they consider environmentally unacceptable? Clearly in principle they can – but the former is likely to be a whole lot easier than the latter. In the case of supporting a fishery, or a type of fishing, the balancing act is clearly to provide support without actively subsidising. We note that car tax in many EU countries is now on a sliding scale depending on the carbon emissions on the vehicles – could fisheries taxes or licences follow a similar model?

In the case of trying to eliminate (or at least significantly scale back) a fishery that much of the EU considers to be morally unacceptable, however, the EU appears at present to be powerless – or at least, unwilling to exercise any moral leadership. It also does not seem to consider, at present, that the standards required of fisheries management in the EU should apply globally. It is clear that there are very significant hurdles to making changes of this kind, which are probably impossible without concerted political will, which clearly does not exist at present. It seems to us that a vital element of the CFP review (perhaps the most vital element from the global perspective) is to stress that the standards that the EU imposes on itself in its own waters (theoretically at least) should also be imposed on EU operations and EU fisheries management responsibilities elsewhere in the world.

The final case study shows that many changes are possible to improve efficiency. While high fuel prices have been a driver for such change (e.g. in 2006 and 2008), they also, paradoxically, prevent fishermen from making adaptations by cutting their margins to the point where no investment is possible. The recent collapse in fuel prices due to the economic crisis has provided a window of opportunity to some fisheries to improve fuel efficiency in the expectation that fuel prices will eventually rise again. EU-funded projects (see for example van Marlen et al. 2009) have provided significant support for this process. A review and dissemination of best practice in this area could be very valuable – and the time for it is now, before fuel prices again cut fishermen’s room for manoeuvre.

5 Part 3: Using policy to improve how fishermen operate

5.1 Summary of the main policy hurdles

The main policy hurdles for the various types of changes are outlined in detail in Part 2 via a series of case studies – here we review them briefly.

5.1.1 Policy hurdles for technical changes

The case studies above show that while there are policy/regulatory hurdles to making technical changes to operation, the main issues are more of education, cost, logistics and practicality. However, the case studies indicate that in most cases, fishermen are willing to make such changes, at least once the benefits of change are apparent from their position. Fishermen understand that criticism of their environmental impacts is growing, often have incentives to reduce bycatch and increase selectivity (to avoid discarding) and are also keenly aware of rising fuel prices. The case studies demonstrate that in many cases these technical changes provide both environmental and economic improvements[23]. It is critical that the economic benefits of change be emphasised to encourage voluntary uptake. The increasing number of vessels in the beam trawl fleets investing in gear modifications that result in reduced drag and reduced contact with the sea bed are a good example of a win-win scenario in this respect. However, in some cases, technical changes that result in increased efficiency may threaten the resource base (as in the Italian demersal fishery example) – this demonstrates the importance of managers understanding and reacting to what fishermen are doing.

Policy-makers could do a lot more to support fishermen making changes in this area, and here is where the most significant improvements to fisheries are likely to come in the short term. Policy change is necessary to create an enabling environment that stimulates transition to more ecologically and economically (and ultimately socially) sound fishing techniques rather than maintaining the current system of enforcing change through regulation; this is at least the perception of many in the fishing industry. Fishermen, regulators and conservation agencies[24] often engage in adversarial debates about how to make progress, resulting in science being sidelined by what are highly politicised issues. While all parties generally concede that their overall objective is the same (healthy oceans providing maximum economic and food security benefits), it is abundantly clear that there is a lack of common direction in reality, resulting in obstacles to progress. Fishermen feel pressured and backed into a corner, regulators feel battered from all sides and conservationists feel nothing is happening fast enough. There is a clear need for a common direction to be acknowledged and acted upon using sound science and good policy.

5.1.2 Policy hurdles for more significant changes

More significant policy hurdles exist that make more drastic alterations to fisheries, such as changes in gear type or wholesale changes in the types of fishery in a given area, much more difficult to accomplish (if indeed they are desirable). Aside from the financial, logistical and educational issues identified above, these hurdles include issues around the management system, bycatch and discards, gear conflicts, markets, spatial planning, hidden subsidies, reduction in effort or export of effort to third countries and political will in various Member States.

23 More accurately, most environmental improvements to date have come about as a result of economic-savings measures.

24 We recognise that the fishing industry, regulators and conservation agencies are diverse in nature, form and opinion across the EU. However it is probably true in most cases that when pressured by external forces, a fishing company in, for instance, Vigo would side with a fishing company in Zeebrugge, and an NGO in Athens with an NGO in Estonia.

More generally, such changes must be considered carefully on a case-by-case basis. The deep-water fisheries case study (Case Study 14) shows that it is not always clear that gear type X is better than gear type Y – different gear types have different types of impacts, especially in the absence of effective management, and if policy-makers want to impose such changes on fisheries, they must make informed, positive choices about what types of impact and fisheries are acceptable and what are not. This may depend a great deal on the particular fishery in question – the outcome of Part 1 of this report shows that generalisations are dangerous.

5.2 General policy environment for fostering change

Perhaps the starting point before thinking about policy actions would be for policy-makers to come to an equal understanding of the baseline: what is the current situation, what are the issues and what options are available to rectify the issues? The last point would need to be accompanied by impact analyses that encompass economic, ecological and social factors to enable decision making based on sound science and understanding of the consequences of policy change. The outcome of the CFP consultation will hopefully be a common vision of what Europe envisages its fisheries to look like in 20 or 50 years time[25]. This is a vital step that could then be viewed in context of the baseline situation, enabling the development of a practicable plan to reach the end point of sustainable European fisheries. In the context of the specific measures outlined below, policy could then be enabled that creates positive incentives for the industry to reach this end point. This would result in a policy towards the industry that is coherent and long-term, to the benefit of all concerned.

In many cases the fishing industry has proved itself adept at responding to environmental impacts and reducing fuel consumption in imaginative ways (see for example several of the case studies above). It is likely that fishing industry will also respond to the impacts of climate change on shifting populations – perhaps with faster, longer-range, more efficient fishing vessels, on-board processing and alternative means of transport. There may well be new opportunities that arise because of climate change. Perhaps the first goal of policy should be to foster an industry that is capable of responding to changing conditions by itself. This requires a more long-term management structure, so that fishermen are able to plan rather than being hemmed in by a domineering and unpredictable regulatory environment. This in turn requires that the issue of over-capacity is dealt with, since a light regulatory touch is impossible to achieve with the current mis-match of fishing capacity and fishing opportunity.

Having said that, it is clear that not all fishermen act responsibly (see for example Case Study 14 on deep-water fisheries). Policy-makers also have a role to play in obliging these fishermen to change their actions, and more generally to direct and increase the rate of change in the industry towards more environmentally responsible fishing practices. An example of this type of initiative that could be replicated is where North Sea cod fishermen obtain 'conservation credits' (usually in the form of additional days at sea) for using CCTV on their vessels to monitor catches. More generally, this type of policy making may require policy-makers to make explicit decisions about the types of impact that are and are not acceptable – something that has not been done up till now, except in a few cases where public opinion has forced a decision that a particular impact (usually involving marine mammals or other charismatic fauna) is not acceptable.

5.3 Policy actions for technical changes

We now turn to specific policy actions which may enable fishermen to overcome hurdles to reducing their environmental impacts. According to our analysis, the main hurdles faced by fishermen in making technical changes are not strictly related to public policy, but it is clear that public policy could do better at providing an enabling environment for these types of changes.

25 The EC Green Paper on the CFP reform is a good starting point, providing a positive vision of where Europe's fisheries could be providing a common direction is found and a clear, defined methodology with indicators and milestones is developed, ratified and implemented by all Member States.

5.3.1 Transparency in policy making

In determining what policy is required and how to implement it, policy makers need to consider diverse factors including, among others, best available scientific knowledge about the stocks and ecosystems, technology advances available to fisheries, fishing business economics, environmental costs of fishing, the value of ecosystem goods and services, and so on. While one would expect policy makers to be supported by technical and scientific advisors during their deliberations, this process should be transparent. There are numerous examples in fisheries where industrial lobbying has resulted in policy being ratified that conflicts with scientific advice (Case Study 17 on bluefin tuna being an excellent example). This type of lobbying usually benefits large industrial fisheries at the expense of small coastal fisheries and conservation.

5.3.2 Providing information for policy-makers

The EU has at its disposal significant information resources that could support policy-makers – however, information is often disparate and inaccessible. The formation of a central data repository or a web that links relevant information via one portal would be invaluable.

5.3.3 Review and dissemination of best practice

It is also clear that more could be done to share information between fishermen across administrative or national borders. Discussions with fishermen suggest most fishermen know some of the modifications that would reduce fuel usage but rarely are they aware of all of them. The above analysis also suggests that different fishing fleets may have widely differing carbon footprints per unit of catch, although the reasons are not clear. Widespread publication of the modifications above (and any others we have missed) could result in a percentage of fishermen modifying their behaviour in the right direction, which would be a success. After all, if the fishermen themselves are not always aware of how they can save money, it is reasonable to think that the remainder of society, including regulators, are less well-informed and could be doing more to encourage behavioural shifts.

A simple policy objective would be to instigate training days for fishermen (optional or even as a license condition), to increase awareness of possible modifications to fishing vessels, gear and behaviour that would reduce direct impacts and carbon emissions and conserve energy, but there may also be others we have not found. Fishing encompasses an enormous range of subjects including naval architecture, gear technology, ecology, business economics, ecosystem valuation, marketing and finance to name but a few and fishermen, or at least representatives from producer organisations, would appreciate easy access to clear information that would support their efforts to improve the industry. Fishermen regularly weigh up costs and benefits, often without access to complete information resulting in sub-optimal decisions. Ensuring access to information and training would be a quick and effective way of reducing fishing impacts, especially once fishermen become aware of the financial benefits of doing so. The regional management councils in the USA reportedly have compulsory training for their members.

An EU-wide review of best practice and support for implementation of best practice across all the Member States would also be an extremely valuable exercise. Various EU projects have already started on this work (e.g. see van Marlen et al. 2009), so perhaps the main need is not for further scientific research so much as practical support for education and implementation with fishermen.

5.3.4 Removing regulatory obstacles to technical innovation

An enormous number of different technical changes can be made to fisheries to reduce their direct environmental impacts and their carbon footprint. It is probably not an exaggeration to say that most EU fisheries could make some kind of improvement in this regard without too much difficulty. Some of the most important of these changes are listed in Annex E. There may well be others that we have not found.

Some of the potential modifications listed in Annex E would at present incur regulatory obstacles. For example, newly constructed under-10m vessels designed for British fisheries are known as 'rule-beaters'. These vessels are slightly under 10 metres and are essentially small offshore trawlers, with a length to beam ratio of 2.5:1. 'Rule-beaters' are attractive for fishing company operators, as they are powerful vessels able to maximise quota allocations while operating in the less regulated under-10m fisheries. However the full underwater profile of this hull design is less efficient in terms of fuel consumption and less effective in heavy seas than longer vessels with a length to beam ratio of 3:1 or 4:1. In this example, it could be useful for regulators to return to the rulebook to see if current regulations enable the fishing industry to operate in the most effective way in terms of economic, ecological and social factors.

Under 10 m rule beater – photo by David Elliott

5.3.5 Product quality

An indirect way of reducing environmental impacts through technical modifications is by focusing on quality rather than quantity. With declining catches a common trend in European fisheries, vessels and their crew need to focus on maximising the return from their catch. Where vessels experience increased marginal benefits as a result of good post-harvest practises, this may incentivise a focus on quality rather than a race to maximise landings through increased effort. Support for good post-harvest practises, such as ensuring that fish are properly iced and that ice doesn't melt and freeze around the fish generally results in higher returns per kilogram of fish landed on any given day in comparison with lower quality fish of the same size and species.

Having said that, Case Study 13 (Nephrops) shows that it is unreasonable to expect all large-volume, low value fisheries to switch towards more small-volume high-value methods without seriously distorting the market, with a risk of damaging the 'good' fishery as well as the 'bad' one. It is also hard to take policy decisions that will result in a big decline in the amount of product reaching the market – it is likely that this product will be replaced by something else from elsewhere, so the consequences of this type of decision may be at best unpredictable. Having said that, the increasing availability of cheap whitefish in the EU from tropical aquaculture (tilapia and pangas XXXX) may mean that EU whitefish fleets may have a strong market incentive to switch towards a higher value product.

5.3.6 Good management

Where stocks are in poor shape due to overfishing and poor management, fisheries suffer from increased fuel consumption and emissions due to increased time spent searching or sweeping. Norwegian research has demonstrated a positive relationship between increased CPUE and reduced fuel consumption. Healthy fish stocks are therefore one measure that contributes to more fuel-efficient (and economically sustainable) fisheries. This is likely to mean for most Member States that issues such as over-capacity and hidden subsidies needs to be addressed. This is a very complex policy issue beyond the scope of this report to consider in detail – various policy tools are available, including the allocation of fishing rights, limited licensing, decommissioning and buy-backs, all with their benefits and disadvantages.

Policy recommendations for adoption of improved technical measures to reduce fishing impacts including greenhouse gas and particulate emissions:

- Development of a common methodology for measuring emissions and impacts of fishing to support the establishment of a baseline and targets for improvement;
- Development of a transparent central data repository with information for stakeholders, decision-makers and policy advisors, supported by EU-wide reporting requirements in standardised format (including fleet statistics);
- Support the creation of the 'snow-ball' effect with regard to research and development into alternative gears, efficient engines and reduction of particulate emissions;
- Launch widespread awareness and training campaigns targeting the uptake of measures designed to improve the fuel consumption of fishing vessels and the reduction of environmental impacts from fishing;
- Create knowledge sharing forums (such as the Dutch Kenniskring information groups) where fishermen can exchange information about technological advancements with research institutes and gain access to reliable, transparent information about gear switches or modifications.
- Provide fishermen with access to information from research institutions and other fishing fleets, including information about how and where modifications have been applied and what benefits can be expected; investment costs, rates of return and access to financial support mechanisms or favourable banks
- Investigate the feasibility of an EU-wide audit system whereby Member States inspect vessels and provide information to a national database (linked to the EU-wide database) categorising fisheries operating in each country. This would enable interventions to be focussed on the most damaging fisheries. Fuel use could be monitored in the same way as fish landings and vessels could be required to reach a defined standard of fuel efficiency to obtain or renew a license;
- Development of best practise guidelines by each Member State or region (to ensure applicability to local or regional fisheries), covering gear types, vessel operations, quality and post-harvest practises;
- Investigate the switch from perverse subsidies to positive subsidies that incentivise change in the right direction, e.g., support to research initiatives, financial support to make good short-term losses while fishermen adapt to new practises, low-interest loans to support uptake of new technology, funding of information dissemination and awareness raising initiatives, and so on.
- Examine the non-capture sections of the fishing industry to identify areas where technology and innovation might modernise the sector, for example the use of electronic marketing systems to encourage a more equal distribution of fish away from single market entry points to avoiding a local price drop.
- It is quite possible that the fishing industry could become more streamlined, with fishermen placed in greater contact with the market and encouraged to exploit niche markets. Removing middlemen has the potential to enable fishermen to receive a greater financial return on their efforts.
- Financial and technical support for fisheries seeking certification against best practise guidelines or third party certification schemes if appropriate. Possible secondary support enabling access to receptive markets.

5.3.7 Over-capacity – a warning

Despite i) not having good measures of fishing capacity at present and ii) many years of decommissioning policies of one kind or another, it is generally acknowledged that most EU fishing fleets suffer from significant over-capacity. One of the main reasons why decommissioning has not been effective is ‘technological creep’. Despite the reduction in the number of fishing vessels, new vessels are significantly more capable than old vessels, and improvements in technology and materials enable old vessels to improve their efficiency. A comparison of two under-10m Scottish Nephrops vessels operating twin-rig trawls provides an example; a 2001 9.98m vessel (239kW) covers a swept area 45% higher every hour and operates at 22% higher gear power than a 1992 12 kW 9.99m trawler (Penny, 2007).

Many of the proposals we make for improving the fuel efficiency of fishing vessels (see Annex E for details) imply an increase in capacity via technological creep. Public policy which supports these kinds of innovations (particularly if it involves financing) risks inadvertently subsidising unsustainable increases in fishing capacity. Fisheries policy needs to be ‘joined up’ otherwise there is a risk of policies conflicting with each other. The relative priorities put on capacity reduction vs. carbon emission reduction will depend on the fishery in question (this is another policy question) but it is important to bear in mind that over-capacity leads in a straight line to over-exploitation of stocks and inefficient operation of fisheries- with associated increases in carbon emissions.

Capacity and efficiency in small-scale fisheries in the Mediterranean (Idda et al., 2009)

The Northwest Sardinian fleet is composed largely of ‘artisan’ trawlers operating close to shore. Although comprising 78% of the Sardinian fleet, small-scale vessels contribute only 45% of the total production. The small-scale fleet is however a vital component of the social fabric of coastal communities in Northwest Sardinia, employing a remarkably large percentage of the local population. Fishing effort is restricted using a combination of technical measures and temporal closures.

By measuring the relationships between fixed and variable inputs and outputs the study found evidence of inefficiency in the fleet that, if addressed, would enable each vessel to improve its earnings without need for capital investment or increasing the capacity of the vessels. In fact, a reduction in inputs (such as nets) and more efficient utilisation of existing resources would reduce costs (such as savings on net maintenance and reduced fuel consumption per vessel). By using resources efficiently and without increasing the number of days at sea, each vessel should be able to increase annual earnings from about € 17,500 by about € 2,000. The study found evidence that the fleet is hindered by overcapacity of about 20% that contributes to vessels not utilising the maximum number of days at sea allowed by regulators. If overcapacity were addressed and technical efficiency improved, vessel earnings could in theory be improved up to about € 28,000.

In terms of policy, most if not all Member States have functioning marine fisheries agencies with extensive knowledge of local fisheries that is far more comprehensive than tonnage and power alone. This knowledge would be well utilised if accurate registers of fleet capacity were developed and accessible to decision-makers, based on capacity considerations described above. Accurately identifying the capacity of fleets combined with spatial knowledge of where they operate provides the opportunity to prioritise interventions and to use more telling indicators to monitor a reduction in capacity (such as metres of net deployed). A more comprehensive understanding of capacity can identify where a reduction in capacity would benefit a local fleet economically. This would undoubtedly make negotiations with local fleets easier.

A second policy thought arising from the above is that decommissioning should result in the capacity of a decommissioned vessel being removed from any form of fishing, including fisheries outside Europe. Overfishing and overcapacity are global phenomena and it is irresponsible to merely shift the problem to nations with even less capacity to deal with it.

5.4 Policy actions for gear and fishery changes

As discussed previously, more drastic possible changes to fisheries include changing a gear type towards one that is more selective by size or species, less damaging to habitats and/or more carbon efficient, or even by promoting 'good' fisheries and suppressing 'bad' fisheries.

It is clear from above that the policy hurdles to this type of change are much more significant, including the type of management system (e.g. quotas vs. effort control), the level of regulation, lack of flexibility to act, gear conflicts, conflicts between fleets, hidden subsidies which maintain 'bad' fisheries, and the need for policy-makers to make active choices between types of impacts, or between the environment and fishermen.

5.4.1 The management system

- Moving away from TACs and quotas

The existing single-species quota system which dominates EU fisheries management inhibits change in a variety of ways. The current system allocates quota based on the track record of a given vessel. This system prohibits experimentation by fishermen with different gear types as they may not be able to receive quota for their desired target species or it might not be available. Beam trawl vessels in the Netherlands that switched to gillnetting report that the conversion ratio of beam trawl track record to gillnet quota is poor, for example 5 days of beam trawling equates to a gillnet quota of 1 day. While this would appear to be a measure designed to retire capacity, it does not allow fishermen who wish to remain in the industry to make experimental shifts to fishing methods that may be environmentally and socially desirable. Furthermore, quotas force fishermen to act inefficiently (e.g. by discarding). This increases the carbon footprint of many fisheries and results in increased direct impacts per unit catch. The existing quota system is easy to cheat, particularly for small-scale fishermen landing in small ports (see below). Other forms of management such as closed seasons and areas or effort limitations are easier to enforce and give fishermen more flexibility.

However, all management systems have their drawbacks – we saw in Case Study 12 (Italian bottom trawls) that effort management has failed in maintaining stocks at healthy levels in the Mediterranean, and that it may be difficult for it to respond to changes in fishing practices ('effort creep') unless capacity can be maintained at appropriate levels. Effort management may also force fishermen to act inefficiently (e.g. if days at sea limitations force fishermen target species outside the main season). Closed seasons can also lead to discarding if they vary for different species, and closed areas (temporary or permanent) may increase fuel consumption. The best management solution for a given area or fleet will depend a great deal on local circumstances. It is, however, clear, that fisheries management cannot any longer be 'laissez faire' – management needs to be backed up by a constant information stream, good communication with fishermen, a good understanding of what really happens on board fishing vessels and good scientific advice. Good fisheries management is therefore expensive – but vital.

- Spatial planning

We saw from several case studies that if all gears are allowed to fish at the same grounds, then usually only trawling or dredging can happen in reality, as fixed gear deployed in the area runs the risk of being towed away and lost. Although there are areas of fishing ground that are only suitable for certain types of fishing gear (e.g., flat, sandy areas of the Southern North Sea lend themselves to trawling), it is feasible that the cessation of trawling in areas where shellfish recruit could lead to the development of ground that would be viable for netting.

Spatial planning thus has the potential to encourage the expansion of less damaging fisheries and restrict more damaging forms to areas characterised by low diversity and high natural disturbance. Spatial planning has been employed with good results in many coastal areas around Europe where distinct gear types were in conflict (often shellfish pots with trawls). Spatial planning is also likely to feature more in future coastal fisheries management as no-take fishing areas expand to protect areas of essential fish habitat, such as spawning or juvenile nursery grounds. Spatial closures can increase the carbon footprint of some vessels that are forced to steam to more distant grounds, although it seems likely that the environmental benefit of the area closure would outweigh the environmental cost of increased carbon emissions.

The success of the real time area closures in the North Sea (Case Study 4) shows that imaginative combinations of spatial closures in time and space, backed up by modern technology, could be an attractive solution in many cases. There are also strong ecological arguments for permanent closed areas (Royal Commission on Environmental Pollution 2004).

- Avoiding discards

Discards are not in the interest of fishermen, ecosystems or society as a whole. Where survival rates of discards are low, there is no sense in returning the material to the sea, even if it is unmarketable. Given the increasing demand for fishmeal in animal feed, it seems logical that some industry could be developed to make use of trash fish. The fishmeal industry in Europe currently exploits species (such as sandeels) that underpin large food webs and where cascade effects are likely. There are, however, issues with obliging fishermen to retain all discards – mainly to do with lack of economic efficiency (because the hold capacity may fill up with unprofitable catch). However, it seems likely to us that if a ban on discarding is put in place (and signalled to fishermen well in advance) this will provide a powerful incentive for the industry to develop more selective fishing gears, and to find markets for previously discarded species – the more so if they are given support to do so. Such a ban would require strict enforcement such as onboard observers or cameras.

- Giving back management responsibility to the industry

We saw from several of the case studies that increased flexibility in the management system could encourage fishermen to experiment with gears that are less deleterious. For example, the changes in fish behaviour with seasons, e.g., increased aggregations of cod during winter, suggest that fishermen might be able to employ different gear types at different times of year: trawling during winter and netting during summer, for example. However, any changes to fisheries regulations and policy should include fishermen in the planning, development and implementation stages, as it is they who have the knowledge to know what is feasible and what is not. In general, the industry has been given too little responsibility in recent years, which is partly perhaps a direct result of the increasing size of the regulatory authorities. Regulators should recognise and make use of the vast experience contained within the industry. It is reasonable to assume that when fishermen feel confident that they have a say in the direction of their fisheries, they will become more responsible stewards of the resource, with positive impacts on the cost of management, regulation and enforcement. This requires a paradigm shift away from the current method of regulation towards real co-management. The EU fisheries management system has made strides in recent years in terms of consultation with the industry (or at least, certain parts of the industry) – for example in the development of the 'Regional Advisory Councils' (RACs), although the industry is still very sceptical at the extent to which these have influenced policy. The EU needs to continue moving in this direction, and specifically, needs to move from consultation to participation.

5.4.2 Small inshore vessels vs. large offshore vessels

Southend-on-Sea – photo by Edward Willsteed

Small inshore vessels often feel themselves in conflict with the larger offshore vessels. These vessels may have many times the quota allocation of the coastal fleet – in fact a single offshore vessel may land a bigger volume of a given species than an entire coastal fishery. Inshore fishermen frequently express the view that these offshore fisheries are the culprits when it comes to stock declines and habitat damage, and do not understand why they should be heavily regulated when their catches are, as they perceive it, negligible in comparison.

From the analysis in Part 1 and Annex D, it is fairly clear that when it comes to environmental impacts, these coastal fleets are on the whole better than the large offshore vessels. It is likely that their carbon emissions per unit catch are lower, and it is clear that the 'good' gear types are overwhelmingly used only by coastal or artisanal fishermen, while the 'bad' gear types are dominant in the offshore fleet. In addition, the vast majority of fishermen are coastal fishermen, but they account for a minority of catches, so that the socio-economic and employment benefits per unit of catch are also greater.

However, EU fisheries policy, and policy in many Member States, has tended up till now to favour the large offshore fishing companies over the small owner-operator fishing vessels. Examples of this might be that decommissioning is focussed on this fleet, or that quota allocations favour the large offshore vessels. (In the UK for example, the offshore fleets is <10 % of vessels, but has > 90% of quotas – a statistic much quoted by coastal fishermen who in some cases have enlisted the support of the anti-EU UK Independence Party to support their case.)

There seem to us to be a variety of reasons for this favouritism towards the larger vessels, some logical, some less logical:

- A few big offshore vessels landing in a few large fishing ports are much easier to monitor and manage than a large number of small coastal vessels landing in a large number of small harbours. Fisheries surveillance has to expend a disproportionate amount of effort to monitor small-scale fisheries in terms of the relative volume of landings.

- Small-scale fishermen are often their own worst enemy. Under-reporting and mis-reporting of landings of quota species, illegal gear, retention of undersized animals and other contraventions of the conservation regulations are by no means unusual in small-scale fisheries across the EU. By contrast, the risk (financial, administrative and in terms of reputation and risk to future license and quotas) associated with getting caught is usually sufficient these days to keep large operators more or less on the straight and narrow (with some exceptions). Many owner-operators will argue that they are obliged to cheat to keep going in the face of unfair regulation – and this may be the case, but the situation as it stands does not help anyone.

- The large fishing companies expend time and effort in participating in the management system – they sit on committees, participate in the RACs (see below) and lobby in Brussels. With some exceptions, small-scale fishermen have not been successful in this regard. In many Member States they are not organised into a coherent representative body, and participate in management only at the local level. There are, however, some exceptions to this – perhaps France and Spain, with their systems of relatively powerful 'Comités de Pêche' and 'cofradías' would be a good example for some other Member States to follow.

- Greater quota flexibility, introduced in many Member States (ITQs, quota leasing and other forms of transferability) makes the overall fishery more efficient, in the sense that it concentrates quota in the hands of those best equipped in terms of resources to make most efficient use of it – this usually means large fishing companies not small operators. . Even within coastal fleets, quota may become concentrated in the hands of some 'super-operators', often with more modern and powerful boats than the rest of the fleet. There are ways round this problem, but unless ITQs and other 'rights' based management systems are carefully designed and implemented, they may have unintended social consequences.

It is clear that many small coastal vessels are not a direct substitute for a few large offshore boats – offshore fisheries are often targeting stocks to which the coastal fleets do not have access. However, given the greater social and environmental benefits associated with the small-scale fleet, it does not seem logical that the result of fisheries policy should be to steer EU fisheries towards fewer, larger vessels. This issue should be explicitly addressed by the new CFP in the context of maximising the social benefits and minimising the environmental impacts of fisheries in the EU. Various possible policy actions are set out below.

- Quotas

It is to our mind questionable whether quotas work at all as a management technique for many small-scale and coastal fisheries. Their total catch is often a small proportion of the whole, the multi-species nature of most of these fisheries leads to enormous discarding problems when quotas are exceeded, fishermen often find quota management very onerous, and it is tempting (and often easy) to cheat. Could these fisheries be permitted to land everything they catch – or even obliged to do so – and managed instead via some combination of effort controls, limited licensing, closed seasons and areas and other technical measures (minimum sizes, gear restrictions etc.)? A large range of fisheries management tools are available that would appear to be more appropriate and easier to enforce. Many or all of these management measures are already in place in many small-scale fleets, and may work well or not – that is a matter for local fisheries management rather than for the CFP – but quotas imposed from Brussels have not worked well for these fleets.

- Dialogue

The main vehicles for stakeholder engagement in fisheries policy in the EU at present are the RACs. We consider the operation of the RACs more generally below, but note here that the majority of fishermen's representatives on the RACs tend to come from the large fishing companies – i.e. representing a small minority of fishermen. This is partly because these fishermen tend to follow the policy agenda more closely, and partly because active participation in a RAC is financially onerous for a small organisation and even more so for an individual who is self-employed. The RACs may meet every few months in different Member States and sub-committee meetings may be even more frequent

- Decommissioning

Decommissioning is the main tool used to try and alleviate the chronic overcapacity in EU fishing fleets (aside from export to impoverished third countries). But decommissioning policy in some Member States has tended to focus on the small coastal fleets rather than the large offshore fleets. That's not to say that there is no over-capacity in these fleets – there often is – but many stocks are shared in common and decommissioning of much fewer of the large vessels might open up fishing opportunities for the coastal fleets, with an associated reduction in environmental impacts. Of course, decommissioning may work in the long run because fewer young people in the EU are thinking that fishing is a good career choice. Coastal fisheries may thus shrink of their own accord and in some instances are doing so already. Smaller vessels tend to be operated by owner-operators who are more susceptible to diminishing returns. Large companies often operate on tight margins also, but through economies of scale are more able to absorb or adapt to changing operational conditions. Large companies are also the recipient of greater assistance from Member State governments than small individual operators, either through indirect subsidies or tax breaks. Many of the larger EU fishing companies are also employing crew from around the world to reduce wages and because young Europeans do not see fishing as a viable career. This suggests the large Gross Registered Tonnage (GRT) fleet is less likely to shrink over time.

5.4.3 Flexibility

It is clear from several case studies that in many cases, fishermen report that they lack the flexibility or confidence to take actions to change what they do – even as far as straightforward technical modifications. Fishermen feel very over-regulated, and are constantly expecting new regulations to come along, fisheries to be closed and re-opened without warning, fishing grounds to be lost to Wind farms and marine parks and so on. Large fishing companies may well have an employee whose role is purely to keep track of quotas and other regulations as they come and go – but small fishermen have no such luxury.

We have to face the fact that until the EU really faces up to the issue of over-capacity in fisheries, this situation is likely to continue – while there are too many fishermen chasing too few fish, their activities have to be constrained. Effort and money has been put into capacity reduction in fisheries for many years, with some successes but overall mixed results. Perhaps this process would be helped if some target endpoint for the amount of fishing capacity which is desirable in EU waters should be built into the new CFP (perhaps divided up by Member State) so that capacity reduction strategies have something to aim for.

Nonetheless, if policy-makers would like to encourage fishermen to be more experimental in finding ways to address carbon emissions, bycatch or other environmental problems, they need to give fishermen some space to experiment. Perhaps if management were sufficiently precautionary, it could also be set for longer periods than currently – with some kind of monitoring in place. For many stocks there are already rules in place that constrain inter-annual variation in the TAC except under exceptional circumstances – this is to avoid wild fluctuations from year to year in the amount fishermen can catch, and seems reasonable. However, for fishermen who get their quota allocations from a pool (i.e. the coastal fleet) fisheries may be closed at very short notice when the quota is exhausted, then re-opened again at short notice when new agreements are made or quota swaps negotiated. This type of micro-management makes planning extremely difficult and seems frankly unfair.

5.4.4 Dialogue

The main vehicles for stakeholder engagement in fisheries policy in the EU at present are the RACs – Regional Advisory Councils. These are a big step forward from nothing at all, but they are far from ideal. There is a distinct lack of engagement with the fishing industry at a representative level. Small-scale fishermen, as noted above, have very little say in what happens and in general it would appear that the large industrial operators have the greatest say in shaping policy decisions despite representing a small fraction of the fishing community. In addition, the emphasis is on consultation rather than participation.

Without exception, the fishermen we have talked to who participate in the RACs did not feel that their voices could be heard via this mechanism (although they did feel it was important to participate anyway – to 'show willing' and so that NGOs were not allowed to dominate the debate[26]). The large fishing companies we spoke to felt that for getting their point across, direct lobbying in Brussels was more useful to them than participation in the RACs. Thus fishermen who do not have the resources or know-how for such direct lobbying (or even to participate in the RACs) are at present disenfranchised at EU level.

26 It is important to note that NGO representatives dispute this description of RAC meetings.

At Member State level, the situation is highly variable, with some Member States (such as France and Spain) having good structures to ensure that small-scale fishermen can have a voice. However, since for most important stocks, the management regime is controlled at EU level, this has not usually helped them. Nonetheless, a review and dissemination of best practice at Member State level (or even global level) and a consideration of how this can be applied at EU level could be very valuable.

6 Conclusions

6.1 Conclusions to Part 1: Changes to improve sustainability of EU fisheries

In terms of direct environmental impacts (bycatch and habitat impacts), dredges and trawls have generally the highest impact, followed by nets and seines, followed by lines and traps. The direct impacts of beam trawls and mechanised dredges on habitats are highlighted as particularly severe. The exception is impacts on vulnerable species such as birds and cetaceans, where pelagic gears have more severe impacts than demersal towed gears.

In terms of carbon emissions, it is harder to draw general conclusions. Overall, however, it is possible to say that demersal trawls have higher impacts than passive gears (nets, traps, handlines) in most cases. Mobile gears are variable – seiners generally being more efficient than longliners. Small vessels are usually (but not always) better than medium and large vessels. Well-managed stocks lead to efficient fisheries, while depleted stocks lead to high carbon emissions. However, we stress again the variability of the data, and propose that comparisons between similar fleets to pinpoint best practice might be a more productive route than trying to rank disparate fleets.

Desirable changes to fisheries to reduce both direct impacts and carbon emissions are somewhat similar in most cases: essentially a move from active to mobile or passive gear – and more specifically a move away from heavy trawls and dredges. A move away from larger offshore vessels towards smaller onshore vessels is also usually beneficial – but again we stress the need for a case-by-case analysis.

6.2 Conclusions to Part 2: Hurdles to making changes

As regards technical changes such as modifications to vessels or gear to improve efficiency and reduce bycatch, the main issues are education, cost, logistics and practicality – i.e. not generally policy related. The hurdles are not significant where technical changes provide both environmental and economic improvements, and where fishermen have the flexibility (economic and in terms of planning) to implement them. In some cases, however, technical changes that result in increased efficiency may threaten the resource base, while in other cases technical changes (such as bycatch reduction devices) may lead to the fishery operating less efficiently – policy makers need to understand and react to these trade-offs. More generally, policy-makers could do more to provide an environment in which fishermen are free to experiment and innovate – and are guided to experiment and innovate in the desired direction. This might entail precise policy objectives and targets, more constructive and more inclusive dialogue with the industry, dissemination of best practice, a regulatory environment more conducive to long-term planning and possibly direct financial and technical support.

When more significant changes to fisheries are proposed (such as a change in gear type), more significant policy hurdles also exist. Aside from the financial, logistical and educational issues identified above, these hurdles include issues around the management system (particularly in regard to quotas), bycatch and discards, gear conflicts, markets, spatial planning, hidden subsidies, reduction in effort or export of effort to third countries and political will. More generally, we emphasise that such changes must be considered carefully on a case-by-case basis – with full knowledge about the various fisheries and how they operate. It is not always clear that gear type X is better than gear type Y in every case – different gear types have different types of impacts, and if policy-makers want to impose such changes on fisheries, they must make informed, positive choices about what types of impact and fisheries are acceptable and what are not.

6.3 Conclusions to Part 3: Policy to support changes

6.3.1 General points

Suggesting policy change is difficult; it all too often results in increased regulation that further complicates the business of fishing without achieving positive results. Examining existing policy in detail is beyond the scope of this report - beyond the points we have made regarding the influence of regulation on fishing behaviour and its causal effect on environmental impacts. Nonetheless, the CFP reform provides an opportunity for decision-makers to examine existing policy and to strip away policy that results in unsustainable fishing behaviour. We have focussed on suggesting policy changes that bring fishermen into the decision-making process and support them in making changes to their fishing behaviour (the 'carrots'). There is clearly a need for policy to be backed up by legislation and enforcement (the 'sticks').

The preceding sections point to the complexity involved in weighing up decisions because of the number of factors involved. As mentioned previously, the diversity of fisheries depending on the local conditions means that generalised policy or regulatory changes are often not applicable or beneficial in all areas of Europe. Devolving responsibility for fisheries management decisions would allow a more customised fisheries management network to operate that is adapted to local conditions. Clearly there is a need for such systems to be monitored and regulated by national and European agencies, but giving local authorities and fishermen greater responsibility for what happens at the local level would likely improve the stewardship and management of the marine environment.

The number of factors relevant to the decision-making process is large and beyond the expertise of one person or authority, running the risk that decisions are based on an incomplete analysis of the factors at play. Furthermore, the information available to decision-makers may not be the most up-to-date or even correct. Decisions about policy should be based on a clear, transparent understanding of the relative merits and disadvantages of fishing, including impacts and the consequences of new measures. To enable transparent and equitable decision-making, the development of a decision-making framework would support policy-makers by structuring their deliberations and ensuring a consistent approach to fisheries management policy in all Member States with fishing fleets. If developed in conjunction with information repositories with data relating to the operational, economic and environmental aspects of fishing, decision-makers would be guided by a checklist of what information should be included in deliberations and where it can be found. The use of a transparent decision-making framework would also help guard against the demands of politics and the lobbying power of business interests overriding the concerns of the scientific community, small-scale fishermen and societal good. Ensuring the transparency of the system would furthermore provide the public, including fishermen, with insight into how the regulatory structure perceives the value of the marine environment and its associated goods and services and what influence outside interests have over the decision-making process.

6.3.2 Addressing specific hurdles

The largest policy area identified as a hurdle to change at present is the fisheries management system. Specifically, changes that we identify include:

- An end to micro-management and short-term tinkering by regulators towards more long-term and big-picture type management;

- A move away from management by TACs and quotas towards more flexible types of management – at least for multi-species and small-scale fisheries;

- More emphasis on spatial planning, zoning and closed areas (permanent and/or temporary);
- An end to discarding
- More local-scale management.

We note, however, that the type of management regime proposed will require i) excellent oversight and surveillance; ii) excellent scientific advice and iii) a real effort to address over-capacity.

Another important issue that we identify is the need for better engagement by policy-makers with the industry in general and with small-scale and coastal fishermen in particular – this is true both at EU level and in many cases at local level. Engagement is not only consultation – but real participation in management, and a real devolution of responsibility to the industry, within a robust management framework.

Other general policy changes we propose include i) increased transparency of the decision-making framework; ii) better information dissemination to support policy-making and to allow fishermen to adopt best practice; iii) a real end to subsidies that support unsustainable fisheries; iv) political will to address unacceptable practices and v) wider policy coherence where fisheries meet other sectors and the market.

6.3.3 Policy recommendations

We have also tried to create from the above discussion a list of more specific policy recommendations, which could be incorporated in the revised CFP or implemented by individual Member States:

- Development of a centralised information point containing a summary of European fisheries including, for each: categorisation of impacts (including carbon); spatial information relating to operations, habitats and impacts; measures of operational efficiency and regulatory efficiency set against defined EU-wide indicators, and; a tracking system for improvements over time;
- Switch perverse subsidies (including tax breaks for fuel) to time bound positive subsidies that incentivise change or uptake of new technology;
- Give the fishing industry more responsibility to engage with its members and to improve its operations. Engage with the industry as a key stakeholder when policy measures to reduce impacts of fishing are being discussed – particularly small-scale fishermen;
- Identify and remove regulatory or policy obstacles to change and innovation by fishermen;
- Ban or severely limit discarding – in association with other policy changes that will allow fisheries to operate better (e.g. much discarding arises from the current quota management system) and where necessary providing support in the development of new products and markets for previously discarded species;
- Consider support for 'good' fisheries – as long as they don't amount to subsidies to increase capacity;
- The system of taxation or access to the resource could be made dependent on the environmental impacts of the fishery in question;

- In policy for capacity reduction or in the attribution of 'rights' to fishermen, consider the implications for different fleets sectors in relation to their environmental impacts – carefully design of these policies can ensure that the most environmentally-friendly components of the fishing fleet are favoured (or at least, not disadvantaged);

- Consider spatial management to allow less damaging gears to co-exist with more damaging gears;

- Support the industry in improving the quality of its product and gaining more 'value added' per unit of catch;

- Increase funding for the implementation of EAF[27] and the adoption of the FAO Code of Conduct for Responsible Fishing. More than 12 years after international ratification of the Code of Conduct for Responsible Fishing, only 6 countries scored around 60% in compliance testing, none of which were EU Member States (Pitcher et al., 2008);

- Review and support the dissemination of best practice in reducing environmental impacts and carbon emissions;

- Ensure that EU actions are in line with EU policy on sustainability and environmental impacts of fisheries not only for fisheries in EU waters but also further afield.

6.4 Final remarks

Changes to Europe's marine ecosystems will become increasingly profound in the coming decades as a result of climate change. As fishing is the most significant direct human impact on these ecosystems, it is critical that this impact be well-managed to provide marine ecosystems with some space to adapt to changing conditions. The greatest threat is overfishing: it is broadly acknowledged that all Member States with commercial fleets suffer from overcapacity in some fisheries. Difficult decisions need to be made and acted upon by Member State governments and by the EU as the overarching regulator of European fishing. More than ever, it is important to balance the needs of marginal communities and societal good based on considerations of, inter alia:

- The true cost of fishing, including the cost to the taxpayer through indirect subsidies, greenhouse gas emissions and the environmental cost of deleterious fishing methods;

- The benefits of fishing;

- Our requirements for the future (e.g. food security, healthy ecosystems);

- The impact of reductions in fishing effort or of the implementation of alternatives;

- The impact on future generations of action and inaction; and

- National and international commitments.

Many of the factions engaged in the Common Fisheries Policy reform are perhaps not fully aware of the impact of their stance when placed in context of the 'bigger picture'. Making progress towards defining and agreeing a single, common goal would hopefully encourage all stakeholders to consider their positions and their approach to tackling what is a joint problem. It seems remarkable that there is a lack of common resolve to address unsustainable fishing and part of this must stem from a lack of common understanding. This point is laboured on somewhat in this report, because it seems to us that

27 Ecosystem Approach to Fisheries strives to "balance diverse societal objectives by taking into account the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions, and applying an integrated approach to fisheries within ecological meaningful boundaries" (FAO, 2002).

the lack of common direction is at the heart of the habitual inaction by politicians, the fishing industry and the public when faced with difficult issues around fisheries. We might even hope that peer pressure in the fishing industry itself might eventually lead to cost-effective policing of Europe's fisheries.

The fishing industry would do well to follow the example of the aviation industry by acknowledging its impact and making a broad commitment to achieve positive change by a defined date[28]. It is after all the industry itself that best knows the business: industry leaders should be publicly engaging with the remainder of the industry to fight for its future – by future we mean the productivity of the oceans that underpins the viability of all fishing businesses and which is fundamental to all fishermen across Europe. A significant problem with this is that the industry is very fragmented, with little dialogue at the industry level between sectors and Member States. A broader engagement of policy-makers with the industry could help facilitate dialogue within the industry as well.

The bluefin tuna fishery in the Mediterranean is a stark reminder of what happens when vested interests, shortsighted ambitions and greed are allowed to run their course. While there is a Catch-22 situation regarding the poor economic outlook of some European fisheries and the need to reduce effort to let stocks recover, it is clear that absorbing the unpleasant costs related to temporary cessations in fishing or reductions in effort would in the medium term (say 5 years) enable fisheries to operate with lower costs and better returns as CPUE increases. A rather unusual example of this principle in action can be observed in East Africa where Kenyan fishermen are catching fifty times their previous daily average as a result of the cessation of industrial fishing offshore, as the factory ships (some from the EU) are concerned about pirate activity originating from neighbouring Somalia[29].

To be fair to the industry, while recognising that there is resistance to change within numerous European fleets, the policy environment does not encourage engagement by the industry with regulators other than to defend their quota allocations. For example, the current CFP policy of allocating quota based on vessel track record does not encourage a vessel to catch less. The system does not adequately reward those who employ best practise measures[30], nor does it adequately punish those who repeatedly violate the law. Removing or redistributing quota away from irresponsible operators is nigh on impossible: one source (who wishes to remain anonymous) commented that the cost of likely legal battles would be greater than the value of the TAC.

Regulators are faced with the unenviable task of policing the fishing industry while safeguarding the ecological wellbeing of Europe's waters and the social fabric of coastal communities – probably an impossible task. However, it does seem that there is a tendency with European fisheries to over-regulate, stifling development and innovation while not producing the desired outcome (i.e. sustainability). Current regulations can incentivise a race to fish as much as each vessel can as quickly as possible, with negative consequences for the ecosystem and climate. In some cases, the existing rules may make a potentially sustainable fishery unviable: it is thus little surprise that fishermen are frequently observed dodging the law. Fishermen are fonts of knowledge whose expertise could be tapped into to develop regulatory structures that allow freedom for innovation and that could support scientific research into the state of fished stocks and the marine environment. Engaging scientists with the fishing industry and working towards defined, structured goals would support progress in the right direction and would enable cross-fertilisation between the two parties, which hopefully would result in quicker uptake of ideas. An example of positive collaboration is in the Netherlands, where the government's fisheries research vessel is given to the fishing industry for a few weeks each year to enable the industry to progress its objective of addressing the discard issue through reducing the volume of discards and increasing the survival rate of discards.

28 http://www.enviro.aero

29 http://www.channel4.com/news/articles/world/africa/the+aposbenefitapos+of+somaliaaposs+pirates/3399027

30 Market-based incentives such as the Marine Stewardship Council eco-label, play a valuable role, although the direct economic benefits to fishermen (e.g. through higher prices) are usually questionable, and enrolment in the scheme is more often due to fear of market loss than a presumption of gain.

Through comprehensive reform, the European fisheries sector could become a basis for economic growth and the source of sustainable livelihoods in many countries. It is possible that this can be achieved at the same time as increasing each Member State's natural capital in the form of fish stocks as well as other goods and services derived from the marine environment. This can only be achieved if fisheries operate sustainably. The window within which such change can be accomplished is becoming narrower with each passing month. The unpredictable consequences of climate change add urgency to the need to reduce or remove fishing impacts as it is imperative that biodiversity is afforded some degree of protection from direct anthropogenic impacts if the ecosystems are going to be able to adapt to rapid changes in environmental conditions.

The reform of the CFP should be viewed as an opportunity to develop a framework that will enable the continuation of livelihoods of those involved in the European fisheries sector and at the same time as the recovery of much-impacted marine ecosystems. It is high time that Europe's politicians made the link between sustainable fishing in a healthy marine environment and stable and secure coastal communities playing an important role in our food security.

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8 Annex A: Classification of gear types used in the EU

Classification of gear types used in the EU, with the number of vessels using each gear type, along with total tonnage and engine power.

Note that many vessels, particularly smaller inshore vessels, may use a variety of different gear types. The vessels in this list sum (more or less) to the total number of registered fishing vessels in the EU (between 85 000 and 88 000) so presumably the gear type allocated to each vessels is the main one in use.

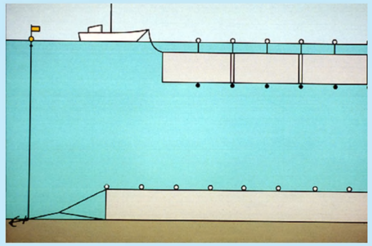
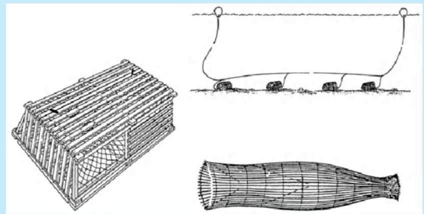
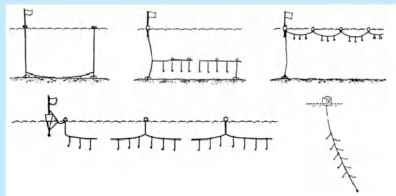
See http://ec.europa.eu/fisheries/fleetstatistics/index.cfm?lng=en.

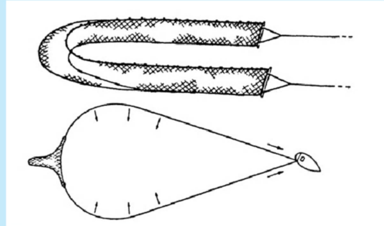
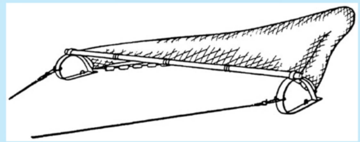
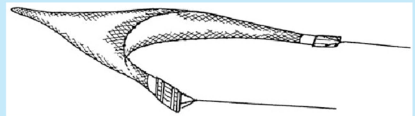
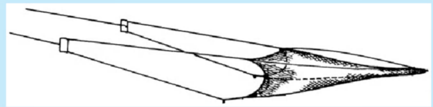
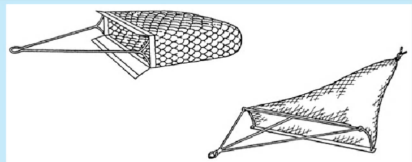
Gear group	Gear category	Fishing gear	Number of vessels	Total tonnage	Total engine power kW
Passive Gear	Gillnets and entangling nets	Set gillnets (anchored)	29 453	122 075	945 271
	Gillnets and entangling nets	Drift nets or drifting gillnets	952	10 343	60 504
	Gillnets and entangling nets	Encircling gillnets	61	150	2 403
	Gillnets and entangling nets	Trammel nets	10 005	27 368	273 710
	Gillnets and entangling nets	Combined gillnets-trammel nets	710	2 268	17 525
	Traps	Fish traps, crustacean pots, whelk pots, creels	9 461	37 952	579 752
	Hook and lines	Handlines and pole-lines (hand operated)	2 107	10 637	86 030
	Hook and lines	Handlines and pole-lines (mechanised)	417	1 352	11 853
	Hook and lines	Set longlines (demersal)	14 104	84 600	526 796
	Hook and lines	Drifting longlines (pelagic)	942	71 322	154 187
		TOTAL	**68 212**	**368 067**	**2 658 031**

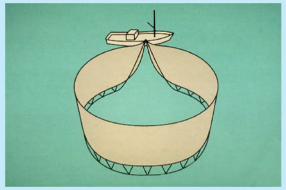
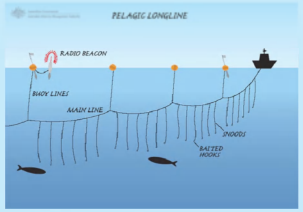
Gear group	Gear category	Fishing gear	Number of vessels	Total tonnage	Total engine power kW
Towed Gear	Seines	Beach seines	569	3 355	30 682
	Seines	Danish seines (demersal seine)	148	5 510	20 969
	Seines	Scottish seines (similar to above)	80	6 560	17 235
	Seines	Pair seines	5	850	2 294
	Trawls	Beam trawls	987	101 540	351 105
	Trawls	Bottom (demersal) otter trawls	8 518	695 144	2 090 229
	Trawls	Bottom (demersal) pair trawls	115	22 407	49 365
	Trawls	Midwater otter trawls	845	336 466	555 647
	Trawls	Midwater pair trawls	101	17 649	46 701
	Trawls	Otter twin trawls	148	12 804	41 209
	Dredges	Boat dredges	1 898	49 662	242 967
	Dredges	Hand dredges operating from a boat	100	1 400	5 104
	Dredges	Mechanised dredges including suction dredges	276	10 268	46 253
		TOTAL	**13 790**	**1 263 615**	**3 499 760**
Mobile Gear	Surrounding nets	Purse seines	3 524	228 866	643 348
	Surrounding nets	Without purse lines (lampara)	42	594	6 423
	Lift nets	Boat-operated lift nets	36	1 149	3 230
	Lift nets	Shore-operated stationary lift nets	1	2	6
	Hook and lines	Trolling lines	547	3 901	45 793
		TOTAL	**4 150**	**234 512**	**698 800**

9 Annex B: Operation of fishing gears and their main environmental impacts

Operation of fishing gears and their main environmental impacts. Information from Shifting Gears report and FAO gear fact sheets.

Gear	Operation	Impacts	
Passive gears			
Set gillnets	Nets that hang vertically In the water, with one edge weighted and anchored to remain in contact with the bottom. Multiple gillnets may be deployed together in a line.	Relatively unselective, except by mesh size. Anchors and weighted nets may cause localised habitat damage.	
Drifting gillnets	As above, but allowed to drift in the water column rather than anchored in one place. Often larger than set gillnets.	Unselective. Large animals such as cetaceans may become entangled. No habitat damage.	
Trammel nets (also known as tangle nets)	As set gillnets, but nets have two or three layers – usually two outer layers of large-mesh net sandwiching a finer mesh net.	Unselective by species and size. Large outer mesh may entrap large animals such as cetaceans.	
Traps	Pots of various sizes and shapes, nearly always baited. In some animals can enter and leave at will, but in most the animal enters and becomes trapped.	Selective by species and size, with most bycatch returned alive. Some but low habitat impacts. Most lost traps can continue to fish but regulations usually require a biodegradable panel to limit this.	
Handlines / pole and line	Lines with single or small number of hooks with bait or lure to attract fish.	Selective by size and species. Impacts very low.	
Demersal longlines	Lines anchored to bottom with multiple baited hooks on short side-lines.	Relatively selective but catches other species of predators that may be sensitive, including sharks, turtles and birds (during deployment and retrieval). Relatively fuel efficient.	

Gear	Operation	Impacts	
Towed gears			
Demersal seines	Net is deployed in a circle round the fish and then towed until the fish are caught in the cod end. May be called 'Danish' or 'Scottish' seine depending on method of deployment.	Relatively unselective except by mesh size. Low habitat impacts because no heavy parts in contact with bottom, and because towed more selectively than a trawl. More fuel efficient than other towed gears.	
Demersal beam trawls	Trawl net with the mouth kept open by a solid beam. Tickler chain in contact with the bottom. May be towed in pairs.	Unselective by size and species, with high habitat impacts due to heavy chain and beam. Fuel intensive.	
Demersal otter trawls	Trawl net with the mouth kept open by doors or otter boards. May have tickler chain or (more often) rockhopper discs in contact with bottom, as well as doors. May be much larger than a beam trawl. May be towed in pairs.	Unselective by size and species, with high habitat impacts due to heavy doors. Fuel intensive.	
Midwater trawls	Trawl net with the mouth kept open by doors or otter boards, but towed in midwater rather than on the bottom. May be towed in pairs.	Relatively unselective for pelagic species in principle (but catch may be quite monospecific due to fishing techniques). Relatively fuel intensive.	
Boat dredges	Solid metal frame with solid or flexible metal bag, Metal blade or prongs dig into the substrate to unearth infauna – usually bivalves. Multiple dredges may be deployed at once.	Unselective except by bag ring or gap size (but catch may be quite monospecific depending on area). Fuel intensive.	
Hand dredges	As above but operated by hand, either from shore or from a boat.	As above but lighter and covering a much smaller area.	
Mechanised / suction dredges	Hydraulic jet or suction pump is used to dig or wash out bivalves from the sediment. Used for mussels, cockles and clams.	As above, but may have very severe impacts on habitat in some areas (e.g. clam dredging in seagrass beds). Fuel intensive.	

Gear	Operation	Impacts	
Mobile gears			
Purse seines	Small-mesh net deployed in a circle round the school of fish and then cinched in by drawstrings at the bottom. Net deployment may be by fishing boat or by small boats launched from the fishing boat. Some purse seine fisheries use aircraft to spot fish schools, or aggregating devices (FAD) to attract them.	Selective by species (usually) but not by size. Catches can be very large. Can have impacts on species associated with the schools or the FADs – notably turtles and dolphins – however these can be reduced relatively easily. Fuel consumption depends on amount of travel to find fish rather than deployment of gear.	
Small seines	As above, but smaller and usually don't have drawstrings.	Relatively selective and low impact.	
Trolling lines (including towed pelagic longlines)	Single or multiple baited lines towed behind the vessel – lines can be several miles long with more than 2000 hooks.	Relatively selective but catches other species of predators that may be sensitive, including sharks, turtles and birds. Towed pelagic longlining seems to be quite fuel intensive.	

10 Annex C – Analysis of direct environmental impacts of fisheries

We found five de facto lists of impacts which provide an appropriate starting point: i) the Marine Stewardship Council (MSC) standard for sustainable fisheries[31]; ii) a European Parliament report (Franco 2007), iii) a survey of the environmental impacts of fishing gear carried out in SW England for the project Invest in Fish South West (Hoskins 2006), iv) a report of the Marine Conservation Biology Institute 'Shifting Gears' (Morgan and Chuanpagdee 2003) and v) a report by WWF Germany (Broeg 2008).

10.1 Impacts considered in the Marine Stewardship Council standard

The MSC standard effectively groups the direct environmental impacts of fisheries in six categories, as follows:

1. Impacts on the target species (MSC Principle 1)
2. Impacts on non-target commercial species which are retained (MSC Principle 2.1);
3. Impacts on species which are discarded (MSC Principle 2.2);
4. Impacts on protected species (MSC Principle 2.3);
5. Impacts on habitats (MSC Principle 2.4);
6. Impacts on ecosystems (MSC Principle 2.5).

Of these, the first five are straightforward but the sixth has always proved harder to interpret and evaluate in practice. The principle is to assess whether a fishery might have impacts on predators or prey, or cause changes in the trophic structure of the ecosystem such as trophic cascades. In practice assessing these types of interactions frequently requires more information on the ecosystem context of the fishery than is available. In addition, ecosystem impacts are usually a question of the target species rather than the fishing technique – fisheries on species with a low trophic level (such as herring or sandeels) which are important prey species for other fish, birds and marine mammals, are considered likely to have greater ecosystem impacts than fisheries for high trophic level species. It may be valid to question whether some fisheries for species which appear to have a keystone role in the marine ecosystem should exist at all – however, we consider this question separately in Outputs 2 and 3. Here we consider only impacts which can be addressed by changing fishing gear or techniques.

It is also questionable whether there is a real distinction between the first two impacts (target species vs. other commercial species retained by the fishery) and between impacts 3 and 4 (protected species vs. other discarded species). Here (as opposed to the context of an MSC assessment), there is no reason to distinguish between a specific target species and all the other species caught and sold by the fishery. Many EU fisheries are multi-species fisheries – in fact, very few are strictly single species.

It is also debatable whether it is useful in this context to distinguish between impacts on protected species and impacts on other species – particularly since in the marine ecosystem levels of protection are low. However, we acknowledge that impacts on some species (such as marine mammals and birds) are something of a special case as compared to other bycatch species, firstly because such impacts are often seen by the general public as more 'important' or 'worse' than impacts on less charismatic species; but secondly and more importantly because these populations are vulnerable to small amounts of additional mortality. In addition, the gear types that have impacts on these species may be different from those that have more general bycatch impacts. We therefore decided to retain the distinction.

31 See www.msc.org.

This reduces us to a list of four types of impact directly attributable to the gear and fishing technique:

1. Impact on target species
2. Impact on species which are discarded
3. Impacts on mammals, birds and other vulnerable species
4. Impact on habitats

10.2 Impacts considered in the European Parliament report

The European Parliament report (Franco 2007) uses a list of environmental impacts modified from Bjorndal (2002). It considers a larger number of impacts than the MSC, as listed below:

1. Size selectivity
2. Species selectivity
3. Bycatch mortality
4. Ghost fishing
5. Habitat impacts
6. Energy efficiency
7. Catch quality

We have chosen to consider energy efficiency separately below, under indirect (carbon) impacts.

Size and species selectivity are related, since in most cases the smaller are the animals than can be caught by the gear, the less selective is the gear[32]. Ghost fishing can be included as part of bycatch mortality (as it is in the MSC standard above).

Catch quality is interesting to include, because of course an objective of fisheries management should certainly be to maximise the amount of quality product obtained for a given fishing effort. However, it is not clear that catch quality is entirely or even primarily a question of the fishing gear used, but rather a question of how a particular gear is used in a given fishery or by a given fisherman. For example, this study ranks fisheries using the seine net high for product quality, and this is true in the case where it is used by small vessels to land high quality fresh tuna. However, in tropical tuna fisheries, large EU freezer-seiners land very poor quality product for canning, as compared to the Asian longliners (a much more selective gear by species and size) who land higher quality frozen whole tuna. Likewise, small trawls with short tow times may land high quality live product while large trawls with longer tows land much poorer quality product. With nets too, the quality of the product depends largely on the soak time rather than the net per se. With some crustacean pots, crabs or lobsters can enter and leave at will, so that even after a long soak time the catch is live; however other pots trap the animals inside so a long soak time may lead to poor quality product. Overall, we were not confident that ranking gear types by catch quality was straightforward, so we decided to leave this question aside (although we consider the issue more generally in one of the case studies in Output 2).

This leaves us with five impacts: size selectivity, species selectivity, bycatch mortality, ghost fishing and habitat impacts. Species selectivity and bycatch mortality are to some extent confounded – i.e. different ways of expressing the same concept of impacts on species unwanted in the catch. Ghost fishing can also be included in this category. So again, we resolve this list down to a list of three impacts – on the target species, other unwanted or bycatch species and habitats.

32 Except perhaps in the case of hook and line gear

10.3 Impacts considered in the SW England study

A survey exercise was carried out as part of the project 'Invest in Fish South West' (Hoskin 2006). The project developed a list of 19 fishing métiers relevant to SW England and asked respondents to score them against seven types of environmental impact, as follows:

1. Physical disturbance to the seabed & associated ecosystems
2. Bycatch mortality of large and/or charismatic animals (e.g. sea-birds, seals, porpoises, dolphins, basking sharks, etc.)
3. Bycatch mortality of unlandable commercial fishes (i.e. undersize or outside-quota)
4. Bycatch mortality of non-commercial fishes & invertebrates
5. Inputs of non-degrading litter
6. Inputs of organic wastes from catch processing
7. Losses of gear capable of ghost-fishing

This list raises similar issues: selectivity, bycatch, vulnerable species and habitat impacts, and also considers issues related to organic and inorganic pollution. These issues are peripheral for most fisheries, and are more a question of the operations of a particular fishing vessel than of the fishery or gear. We therefore decided to exclude these impacts.

10.4 Impacts considered by Shifting Gears study

The Shifting Gears study (Morgan and Chuanpagdee 2003) grouped impacts in two groups: bycatch impacts and habitat impacts – i.e. it did not consider the selectivity of the fishery on the target species (one or several) as an impact. This is logical since impacts on the target species is the whole purpose of fishing – it is not an unintended consequence in the sense of the other two types of impact. However, gears or fisheries which are unselective by target species – for example in catching a high proportion of small-sized individuals – may have significant impacts on the target population by fishing in a wasteful way. We need to consider the scope for change and improvement in these fisheries – i.e. we need to include selectivity for the target species as an impact in this context, while accepting that it may be less important than other impacts.

10.5 Impacts considered by WWF

The report by WWF Germany (Broeg 2008) include four types of impact in their analysis:

- Impacts on habitats and benthos;
- Impacts on mammals and seabirds;
- Impacts on target species; and
- Impacts on non-target species and juveniles.

These impacts are very similar to those we retained from the MSC standard (above).

11 Annex D – Analysis of relative carbon emissions of EU fisheries

11.1 Analysis of EU fisheries data

11.1.1 Use of engine kW as a proxy for fuel consumption

As outlined above, the advantage of using the EU fisheries database (see Annex A) for an analysis of carbon emissions by different fisheries is that it is comprehensive (i.e. covers all Members States and gear types). The disadvantage is that the measure of carbon emissions is very indirect – mean engine kW for a given fleet (country, gear type or country / gear type combination).

The size of an engine (in terms of its power output) is directly related to the amount of fuel it needs to cover a given distance, as a straightforward comparison of fuel efficiency in cars will tell you. Thus vessels with larger engines are a priori more likely to have higher total carbon emissions. However, engine size is not the only factor that determines fuel consumption: others include i) the design of the vessel (hull shape and weight); ii) the age of the engine (newer diesel engines are generally more efficient than older ones); iii) the type of engine (e.g. outboard petrol and inboard diesel engines are not comparable in any straightforward way – however outboard petrol engines are rare on fishing boats and restricted to the smallest vessels); iv) the speed; v) the fishing area (rough seas and high winds use more fuel) and vi) the gear type. Thus the use of mean engine power as a proxy for carbon emissions needs to be treated with considerable caution. Some of these factors are considered in relation to the results obtained below.

Having said all that, work by Tyedmers (2001) suggests that the correlation between engine power and fuel consumption is generally pretty good, assuming that each vessel spends a similar amount of time at sea. This is particularly true for correlations within particular fisheries, but also holds true more generally, as shown in Figure 3 below.

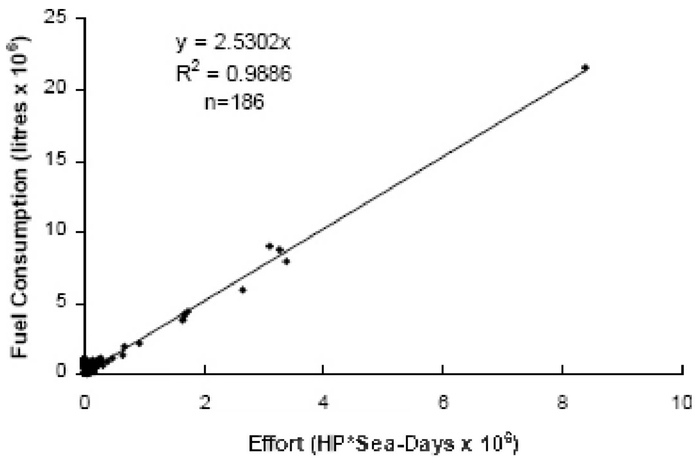


Figure 3: Fishing effort, measured as engine power (in this case HP rather than kW) multiplied by days at sea, correlated with fuel consumption (Tyedmers 2001).

11.1.2 Engine size of different types of vessel

The raw data for this analysis is given in summarised form in Annex A. From this data, we can calculate the mean engine power per vessel for each gear category and type (Figures 4 and 5).

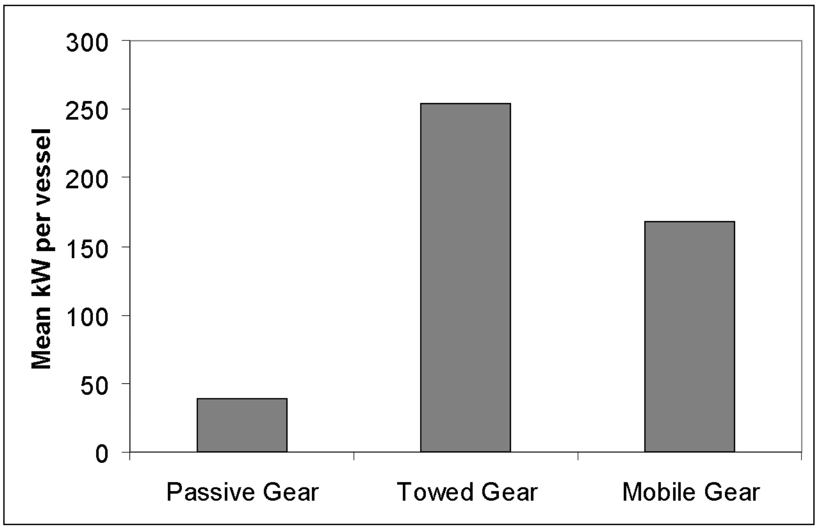


Figure 4: Mean kW per vessel for the three EU gear categories (data as given in Annex A - insufficient data available to calculate variance).

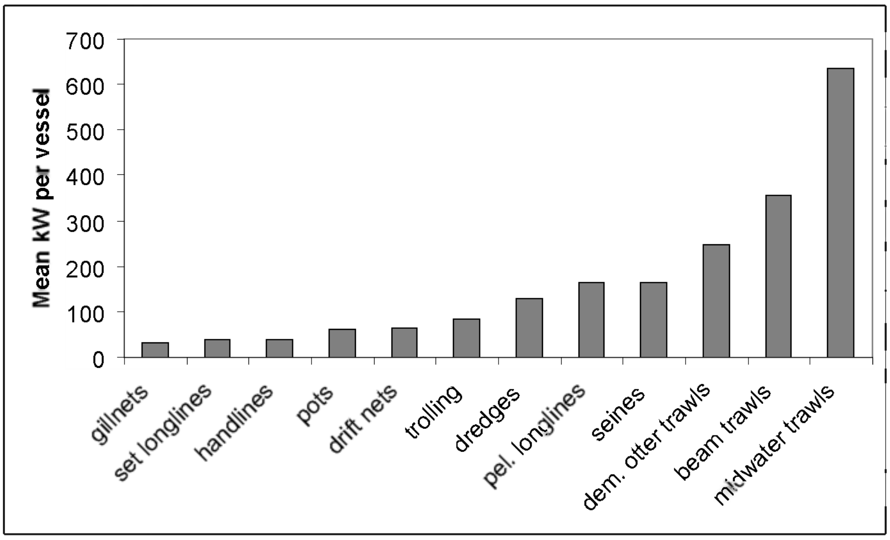


Figure 5: Mean engine power per vessel for each gear type (data as above).

As expected, towed gear requires the most powerful vessels, then mobile gear, then passive gear. The more powerful vessels are dominated by trawlers. Beam trawlers and in particular midwater trawlers seem to require a powerful engine for effective operation.

11.1.3 Analysis of catch per engine kW

If engine kW is a reasonable relative measure of carbon output, an analysis of the catch rate per engine kW ought, in principle, to provide a measure of the carbon 'efficiency' of the fishing fleet – i.e. how much fish (either in terms of volume or value) it can provide for a given amount of carbon emitted into the atmosphere. The analysis is somewhat crude but nonetheless throws up some interesting points.

Figure 6 shows the landings per kW engine power for each Member State, by weight (kgs per kW) and by value (€ per kW). The states are ranked by weight per kW from low to high.

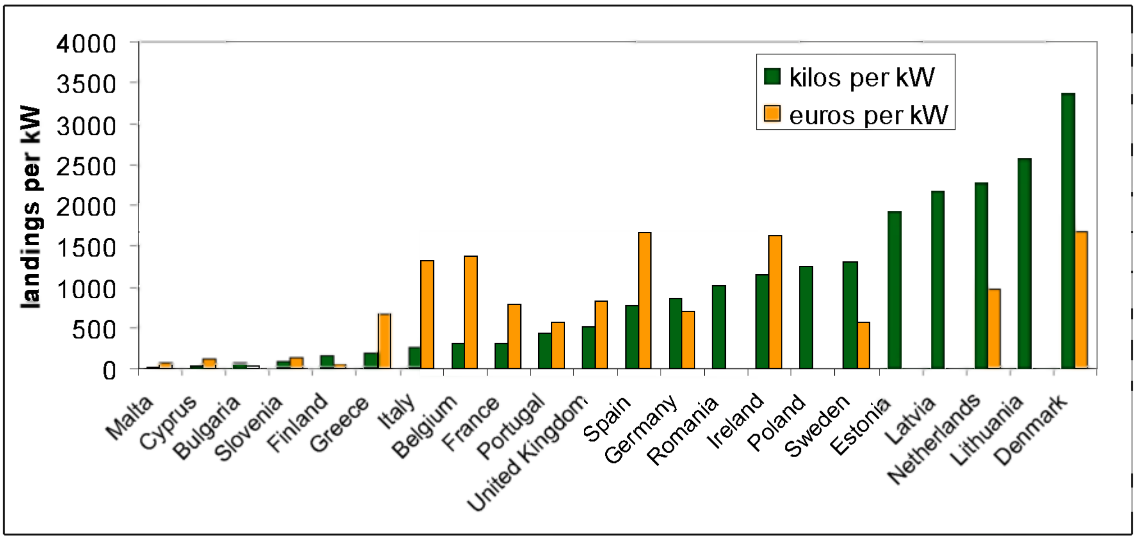


Figure 6: Catch volume and value per kW engine power of fishing fleet. Note that no data is available on value of landings for the newest Member States. Data from the European Commission (2008a).

It is clear that the 'carbon efficiency' – i.e. the effectiveness of the fishery per unit engine power – is not at all the same when considering volume as when considering value. In terms of volume of landings per engine size, the most 'efficient' countries (the Baltic states, the Netherlands and Denmark) are basically those where landings include a high proportion of small pelagic fisheries that deal in very large volumes – Baltic herring and sprats, Dutch sardines and sardinella and Danish sandeels[33].

This group includes the three countries with a high proportion of large vessels in the fleet (Lithuania, Belgium and the Netherlands) – and in fact as Figure 7 makes clear, there is (apart from Belgium as an outlier) a rough positive correlation between the mean vessel size in the fleet and the volume of landings per kW of engine power. As discussed above, this relationship is strongly driven by the nature of the target species and as such is not really a useful basis for drawing real conclusions about the relative efficiency (in terms of fuel use) of different fishing fleets.

33 Since 2000 the total allowable catch for North Sea sandeels has ranged between 400 000 and 1 000 000 tonnes, as compared to 40-150 000 tonnes for haddock, for example (data from ICES).

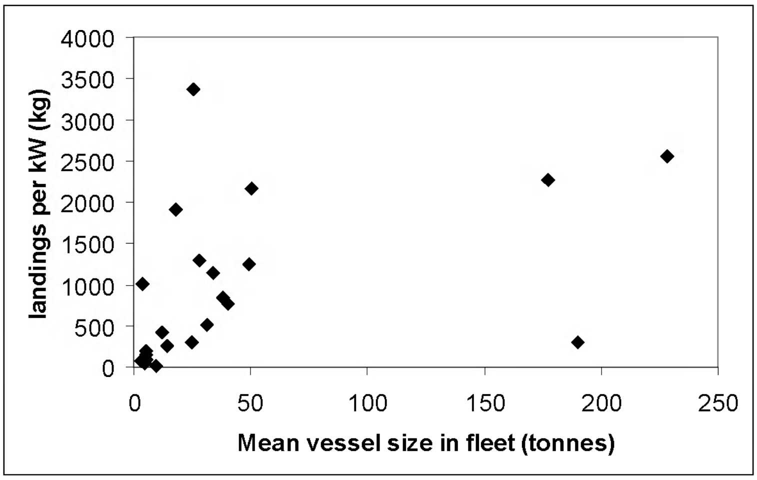


Figure 7: Volume of landings per kW as a function of the mean tonnage of vessels in the fishing fleet of each Member State. The three outliers are again (in order of landings per kW from low to high) Belgium, the Netherlands and Lithuania. Data from the European Commission (2008a).

Turning to unit value of catch (euros per kW), it is already clear that a different group of fishing fleets are 'efficient' in terms of unit value of catch per kW engine power. Figure 8 is Figure 6 above re-ranked by value instead of volume.

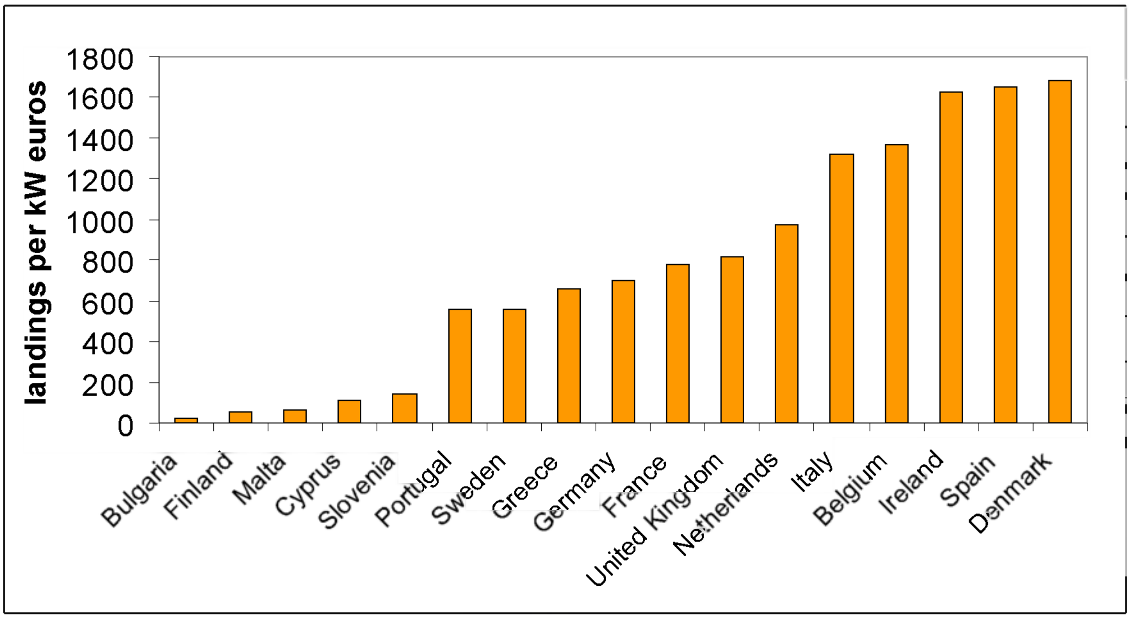


Figure 8: Value of landings per kW engine power for EU Member States. Note that no data is available on value of landings for the newest Member States. Data from the European Commission 2008a.

Figure 8, along with Figures 6 and 7 above rather strikingly divides the Member States into four groups. These groups, with their characteristics, are described in Table 10.

Table 10: Grouping of Member States by volume and value of catch per kW and characteristics of fleet (Note: this data not available for the newer Member States). Fleet characteristics from European Commission (2008a).

Group	Member States	Characteristics
1	Bulgaria, Finland, Malta, Cyprus, Slovenia	Small coastal vessels dominate fleet; many are artisanal vessels of traditional design. There may be a high proportion of part time fishermen (especially Finland). Low value species dominate the catch (except Malta).
2	Portugal, Sweden, Greece, Germany, France, UK	Typical coastal fishing nations: relatively large fishing fleets dominated by small commercial vessels (mainly <10m); wide mix of gears and species; plenty of good coastal habitat.
3	Italy, Ireland, Spain, Denmark	High value species important – tuna and molluscs. Spain and Italy have very large and diverse fleets and are major markets for wide range of seafood products. Denmark and Ireland: in this case the high value per kW appears to be driven mainly by important mussel fisheries.
4	Netherlands, Belgium	High value per kW driven by sole and shrimp fisheries

This analysis shows that fleets with a low value of landings per kW (i.e. 'inefficient' fleets) tend to be artisanal-type fleets – that mainly have a low volume of landings per kW as well. This may be because these fleets really operate inefficiently (from a carbon point of view) or may be because of other reasons: for example, i) much of the fleet may operate part-time or seasonally, or only work for a few hours a day instead of round the clock like most larger fishing vessels; ii) they may target low value species or do not get a high price for their catch in that particular market; or iii) they may have mainly outboard engines which are not comparable with the inboard diesel engines of larger vessels in terms of fuel consumption per kW.

In addition, it is again clear that there is a significant bias in the outcome by target species, but the reverse of the bias for volume catch per kW above. In this case, 'efficient' performers are biased towards those that target a high proportion of high value species such as flatfish, tuna, shrimp and molluscs. It is striking, for example, that the Dutch fleet performs relatively well in both analyses; this may be due to the two separate components of this fleet, with the high volume of landings per kW driven by the large midwater trawlers and the high value of landings per kW driven by the beam trawl fleet landing high value sole and shrimp.

Overall, while this analysis is relatively revealing in terms of characterising the different national fleets, it appears to be too general to draw conclusions about which national fleets are operating most efficiently from a carbon point of view: it depends on whether volume or value of catch is considered more important, and is confounded by differences in operation. In order to gain more insight, we have to make comparisons of like with like. This is the approach of most of the published studies presented in the next section.

11.2 Synthesis of published studies

11.2.1 General introduction

Although the assessment of carbon emissions is a relatively new area of study, at least in fisheries, there is a variety of information available from published studies which compare in some way different fisheries, different gears or different types of vessels for their carbon emissions per unit of catch. These studies include fisheries from both inside and outside the EU – we have considered both in this section for the purpose of drawing general conclusions.

As discussed above, it is very difficult to synthesise the data in these studies together into a more general integrated synthesis, because the studies use a wide variety of assumptions and units. We have had to discuss each study separately, and endeavour to draw general conclusions from them in a qualitative way at the end of the discussion.

11.2.2 Canadian study into global fisheries

The most comprehensive dataset we found was from a published study by Tyedmers (2001). This looks at the 'energy intensity' (fuel consumption per unit volume of catch) for over 40 fisheries worldwide (mainly from the North Atlantic and North America). This data set is summarised below in three ways: i) by gear category; ii) by gear type and iii) by target species (Figures 9, 10 and 11).

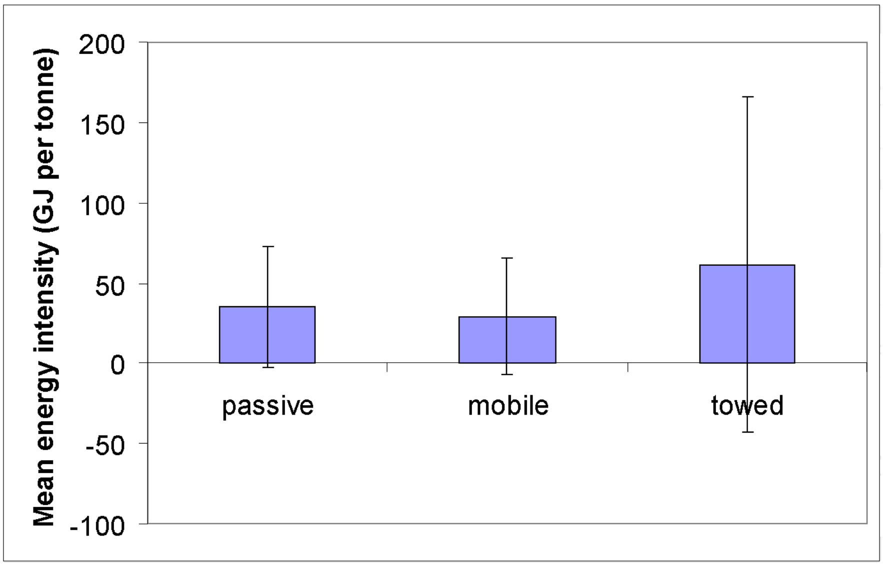


Figure 9: Mean energy intensity (fuel consumption per tonne of total landings) by gear category. Sample size for passive gears = 12, mobile = 12 and towed = 16.

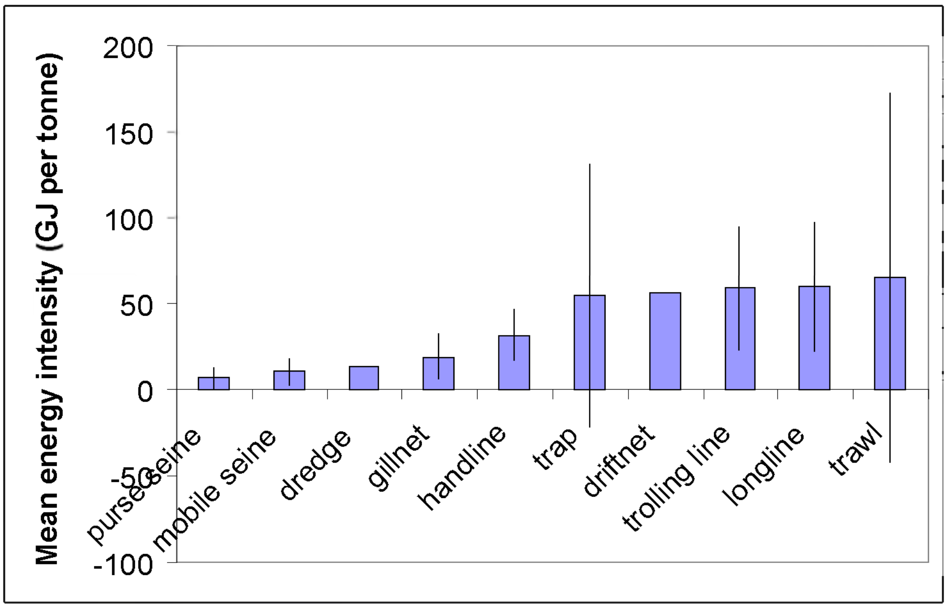


Figure 10: Mean energy intensity (fuel consumption per tonne of total landings) by gear type. Sample size: purse seine = 6, mobile seine = 2, dredge = 1, gillnet = 4, handline = 1, trap = 3, driftnet = 1, trolling line = 2, longline = 4 and trawl = 15.

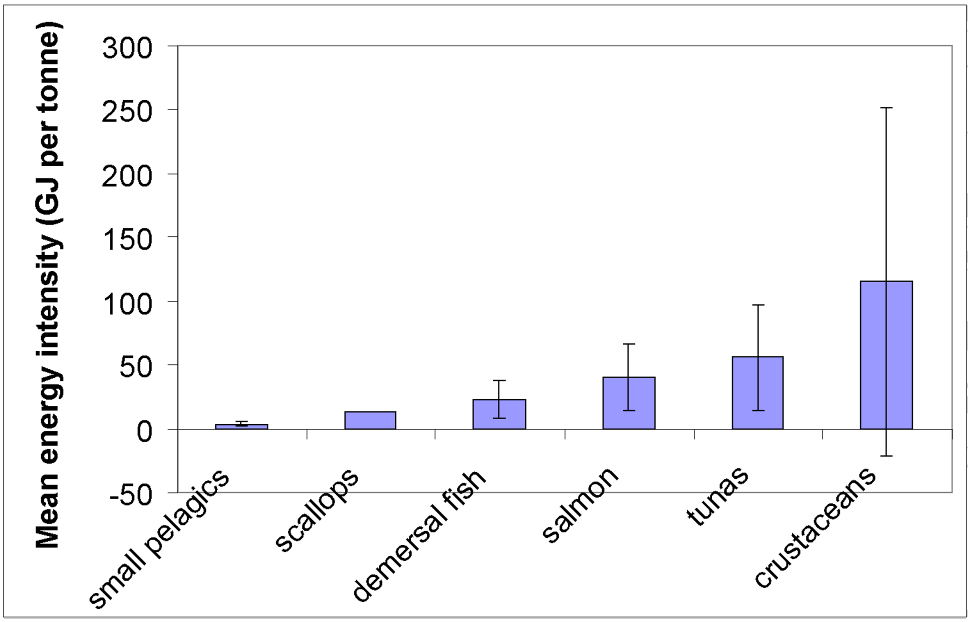


Figure 11: Mean energy intensity (fuel consumption per tonne of total landings) by target species. Sample size: small pelagics = 6, scallops = 1, demersal fish = 15, salmon = 6, tunas = 4, crustaceans = 8.

From Figure 9, we can see that, as expected, towed gears are the most energy intensive per unit volume of catch; however the variance in the data is high, suggesting that there may be significant exceptions.

Some light is shed on this by Figure 10: while trawl fisheries have the highest fuel consumption, the variance is again high – this might be partly because the data set does not distinguish between beam trawls and otter trawls. We note that the two fisheries in the dataset with by far the highest fuel consumption (>2000 litres of fuel per tonne) appear by their target species and nationality to be beam trawl fisheries, although this is not specified.

What is also striking from Figure 10 is that longline and trolling line fisheries also have high fuel consumption per unit catch (with lower variance than trawls, suggesting that this pattern is more consistent), and trap fisheries also do not perform well. Conversely, the single scallop dredge fishery in the dataset performed relatively well. This is probably because the longline and trolling fisheries considered in the study are offshore fisheries, while the scallop dredge fishery is an inshore fishery.

Breaking the data down by species (Figure 11), crustacean fisheries perform unexpectedly badly – but again with high variance. Tuna fisheries (longline and trolling line) also perform badly, while groundfish fisheries (including traditional trawl fisheries) perform better than expected.

The crustacean fisheries can be broken down further by gear (see Figure 12).

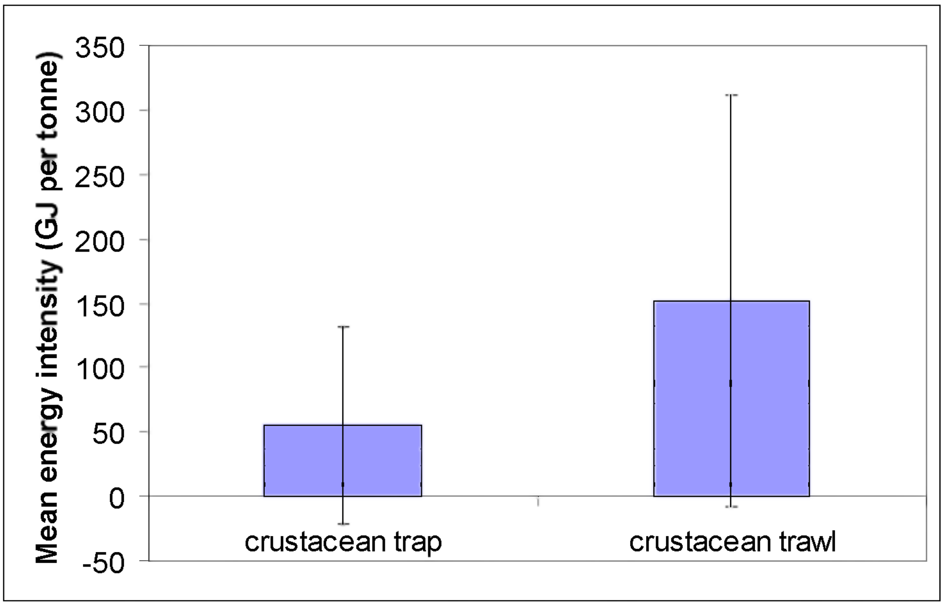


Figure 12: Mean energy intensity (fuel consumption per tonne of total landings) by gear type for crustacean fisheries. Sample size: trap = 3, trawl = 5.

- Icelandic fisheries

In the same paper (Tyedmers 2001) there is also a comparison of several Icelandic fisheries with different types of vessels and gears: two types of 'artisanal' vessel: small undecked and larger decked vessels, plus larger trawl vessels, with a variety of gears. The fuel consumption of these various fisheries in the 1980s and 1990s is shown in Figure 13.

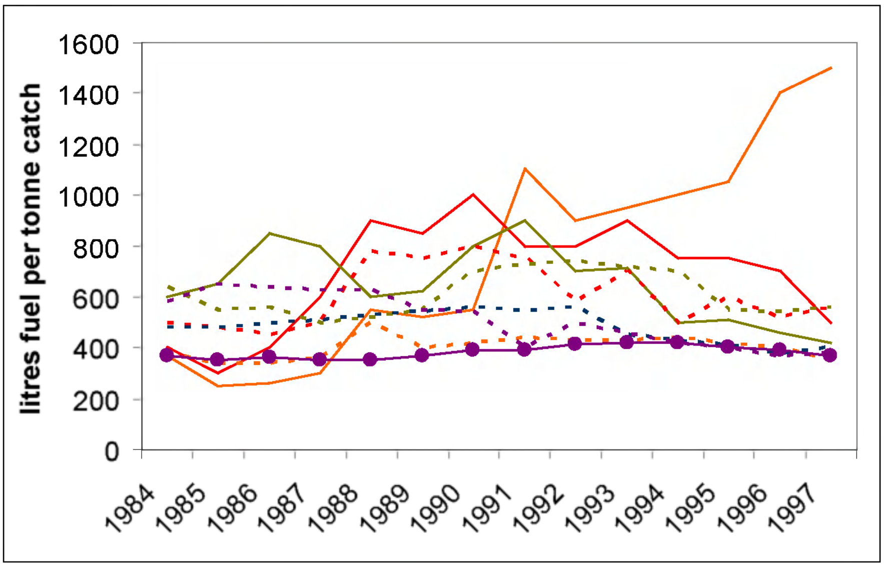


Figure 13: Fuel consumption per volume of catch for a variety of Icelandic fisheries. Solid lines = undecked vessels; dotted line = decked vessel; solid line with circles = trawler; orange = gillnet; red = handline; green = longline; blue = demersal seine; purple = bottom trawl.

From Figure 13 we note most strikingly that the smallest (undecked) vessels (solid lines without circles) surprisingly seem to perform generally worse than the larger vessels. Furthermore, the largest vessels (the trawlers – solid line with circles) in general perform best. It is not clear from this data why the undecked gillnetters in particular should have had such a dramatic increase in fuel consumption per unit catch in the 1990s, although it is probable that this group includes some vessels that are small but modern and fast with large engines (this has also been a trend in small coastal fisheries in other areas, particularly where coastal resources are depleted). We also do not know the situation since 1997. However, this data does show that smaller vessels are not necessarily better as regards fuel consumption per unit of catch – they may be the same or worse.

It is reasonable to assume (as discussed above) that all else being equal the total fuel consumption of a vessel is lower the smaller it is, so the difference must arise due to the much higher volume of catches by larger vessels, or by differences in engine power or some other technical issue. It may be that the undecked vessels focus on very high value species or products, so do not need to bring home a large amount of product on each trip to make a profit. However, it is also striking that the artisanal fleets in the analysis of EU data above also seemed to perform somewhat worse than the more commercial or industrial-type fleets.

11.2.3 Norwegian fisheries

Schau et al. (2009) analysed the fuel consumption per unit catch for various Norwegian fisheries. Their most important general conclusions are the following:

i) Fuel consumption tends to increase when fuel prices are low, but when prices increase fishermen can operate more efficiently;

ii) There is a strong correlation between low catch rates and high fuel consumption per unit catch – i.e. when management is poor and stocks are depleted, fishermen use more fuel for the same landings.

It is also possible to use the data in this paper to compare different gear types (Figure 14). In general, demersal trawls come off worst in terms of fuel consumption per unit catch. However, the different trawl fisheries are very different, with the gadoid trawl fisheries not all that much worse than the demersal seine or gillnet fisheries for the same species (although they are slightly worse) – and slightly better than the gadoid longline fishery. The worst fisheries by a large margin are the shrimp trawl fisheries – these are mainly deep and distant water fisheries. We notice again the very high variability in trap fisheries – some being fuel efficient and others very heavy on fuel consumption.

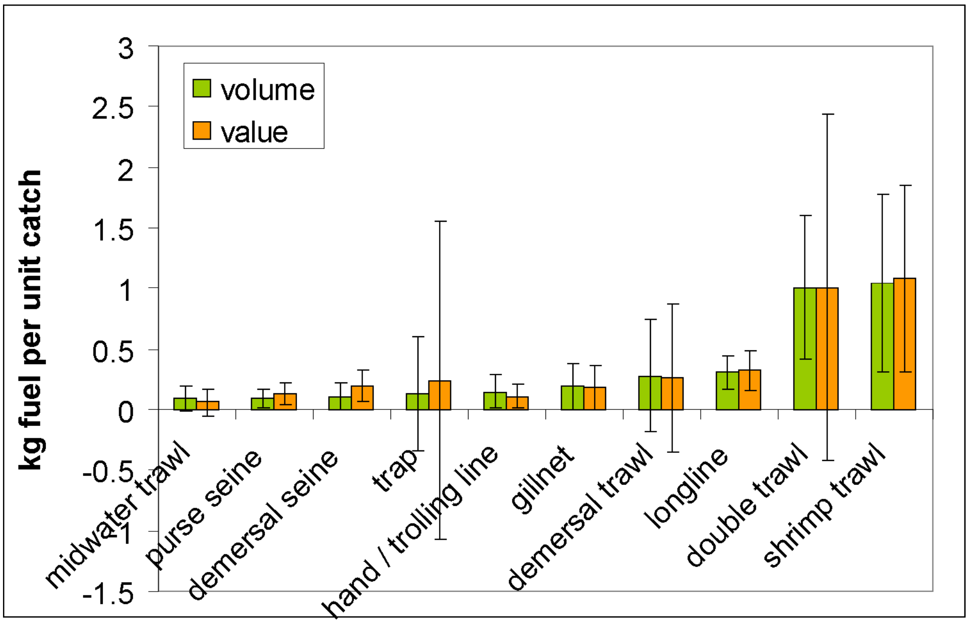


Figure 14: Comparison of fuel consumption per unit of catch for various gear types used in Norwegian fisheries. Demersal seines and trawls, handlines and gillnets target gadoids (cod and related species), midwater trawls and purse seines target small pelagics (herring and similar) and the double trawl, shrimp trawl and trap target crustaceans. Note that the 'volume vs. value' of catch comes from a modelling allocation of catch and is not directly comparable to direct measures of catch volume and value as above. Full details are given in Schau et al. 2009.

Figure 15 compares the fuel consumption per kg catch with the landed value of the catch. There is a positive correlation, which shows that fishermen can afford to spend more money on fuel per unit catch for high value species than for low value species, which have to be caught very efficiently to be profitable.

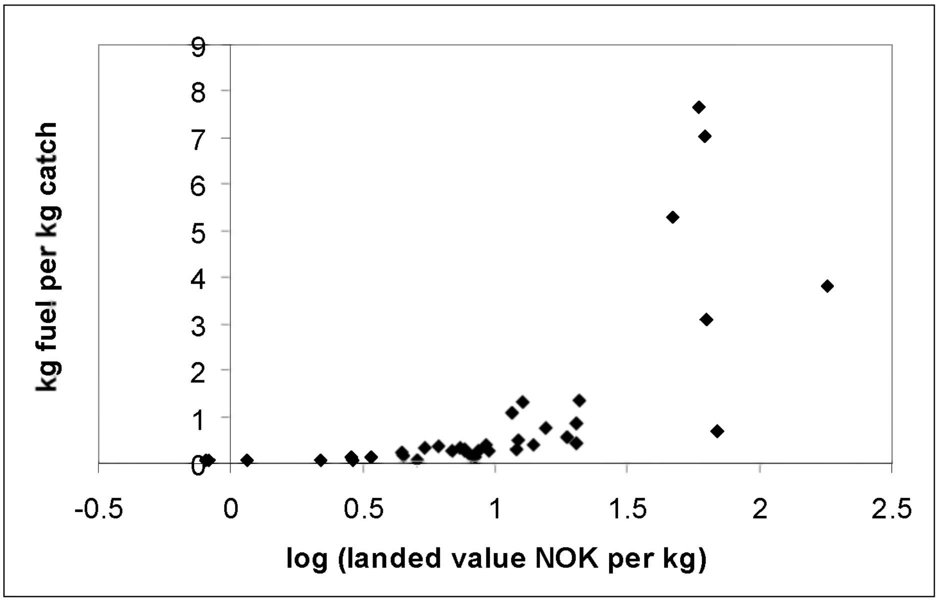


Figure 15: Percentage of revenues spent on fuel for various sectors of the Norwegian fishing fleets. Vessels arranged roughly according to mean size. Data from Schau et al. 2009.

11.2.4 EU study of fishing fleet fuel consumption

The EU have produced some data on fuel costs per unit of catch for various types of fishing vessel in several Member States (van Marlen et al. 2009, European Commission 2008b).

Table 11 below shows fuel consumption for a variety of EU fleets, both in terms of kg landings and as a percentage of income (van Marlen et al. 2009).

Table 11: Fuel consumption for various EU fishing fleets, per unit volume of catch and as a proportion of income. The most efficient fisheries are shown in green, and the least efficient in red. (Data from 2005-6, adapted from Marlen et al. 2009.)

Country	Gear	Length	Litres fuel / kg fish	Fuel cost as % income	Target spp.
Belgium	Beam trawl	12-24	3.1	33	sole
Belgium	Beam trawl	24-40	3.5	36	sole, plaice
Denmark	Demersal trawl / seine	12-24	0.2	12	sprat, cod, plaice
Denmark	Mixed passive gear	<12	0.3	5	cod
France	Demersal trawl / seine	12-24	1.9	20	monkfish, cuttlefish, *Nephrops*
France	Mixed passive gear	<12	3.4	5	mixed
Ireland	Demersal trawl / seine1	12-24	1.4	19	whiting, *Nephrops*
Ireland	Demersl trawl / seine	24-40	1.7	20	whiting, *Nephrops*
Ireland	Pelagic trawl / seine	24-40	0.2	8	herring, horse mackerel
Ireland	Pelagic trawl / seine	>40	0.1	12	blue whiting, mackerel, herring, horse mackerel
Italy	Demersal trawl / seine	24-40	4.4	28	shrimp, hake
Italy	Mixed passive gear	<12	1.7	11	mixed
Italy	Pelagic trawl / seine	24-40	0.3	11	anchovy
Italy	Beam trawl	24-40	3.2	21	sole, molluscs
Netherlands	Beam trawl	12-24	1.8	19	shrimp
Netherlands	Beam trawl	24-40	4.6	36	plaice, sole
Netherlands	Beam trawl	>40	3.8	39	plaice, sole
UK	Demersal trawl / seine	12-24	1.0	16	haddock, *Nephrops*
UK	Demersal trawl / seine	24-40	1.1	20	haddock
UK	Demersal trawl / seine	>40	1.4	29	cod, saithe
UK	Pelagic trawl / seine	>40	0.2	11	herring, mackerel, blue whiting
UK	Beam trawl	24-40	2.5	33	plaice, monkfish

Generally, there is good agreement between the two measures of fuel efficiency – i.e. that vessels that use a lot of fuel per unit of catch also spend a high proportion of their income on fuel. These fisheries include most of the beam trawl fisheries and several demersal trawl fisheries. The most efficient (and most profitable) fisheries are i) Danish and French small netters; ii) large Irish, Italian and British pelagic vessels.

Figure 16 shows the same data, plus data from other Member States (some not validated) amalgamated by gear type. Again, pelagic and passive gear fisheries perform well, while towed gears perform badly. This contrasts with Figure 4 above showing that this gear type is associated with the greatest engine power of any type of fishing vessels, across the EU as a whole. This probably relates to the fact that midwater trawls are designed to catch low value species in very large volumes; however, it may not be wise to assume that a large engine necessarily equates to inefficiency in terms of fuel costs per catch – at least not in every case.

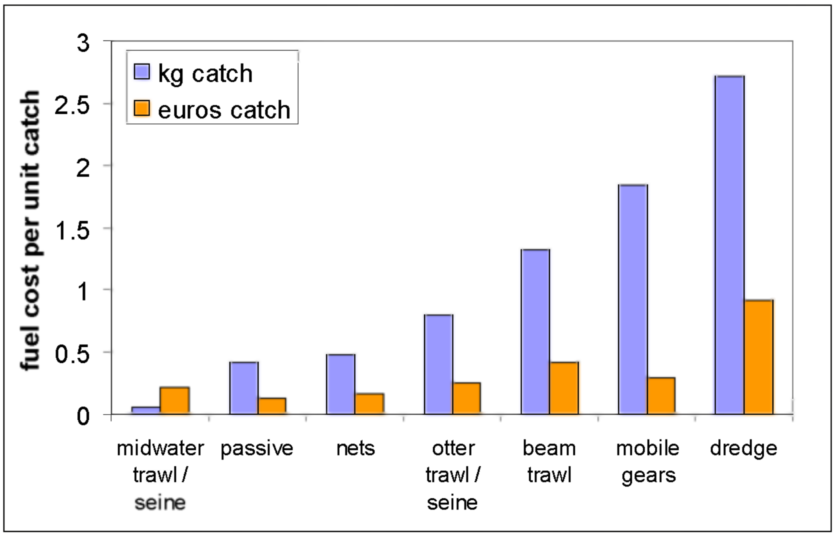


Figure 16: Fuel costs per unit of catch (volume in kg and value in €) for a variety of fisheries in 15 Member States of the EU (Belgium, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Lithuania, Netherlands, Poland, Sweden, UK). Note that the size of vessels may vary in each case, so the outcome is not simply an effect of the gear type alone. Data from European Commission 2008b.

In terms of vessel size, larger vessels appear to be less efficient than smaller vessels, but only up to a certain point – it is possible that the least efficient vessels are those in the 24-40 m size range, while the very large vessels >40 m are more efficient (Figure 17).

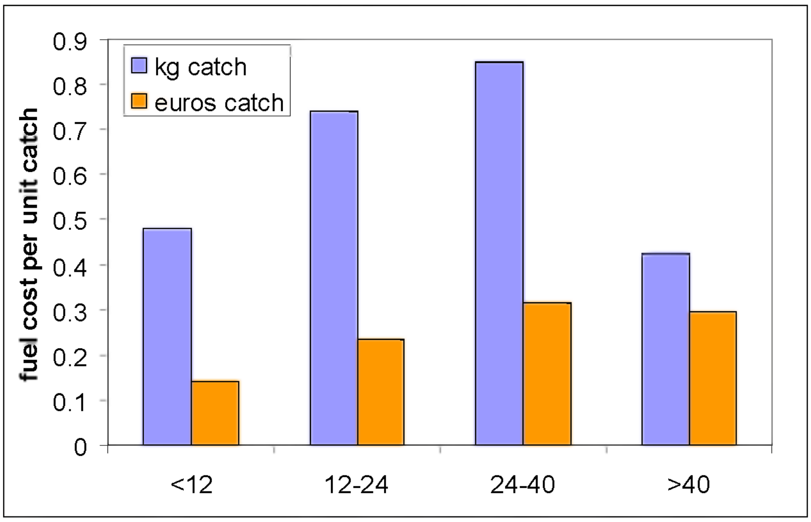


Figure 17: Fuel costs per unit catch (volume kg and value €) for EU fishing vessels of different sizes. Again, the gears, vessel types and target species are variable in each case, so this data has to be treated with caution. Data from European Commission 2008b.

To investigate this idea in more detail, we considered more comparable vessels which occur in the data across a range of sizes. Two gear types – midwater trawls and otter trawls – are represented in the data in three of the four size ranges (excluding the smallest) (Figure 18). From this it seems that the pattern above is driven mainly by demersal gears such as otter trawls, where fuel costs per unit catch dips sharply for the largest vessels compared to the medium-sized vessels. For midwater trawlers, however, the pattern is more of a consistent rise in costs with vessel size.

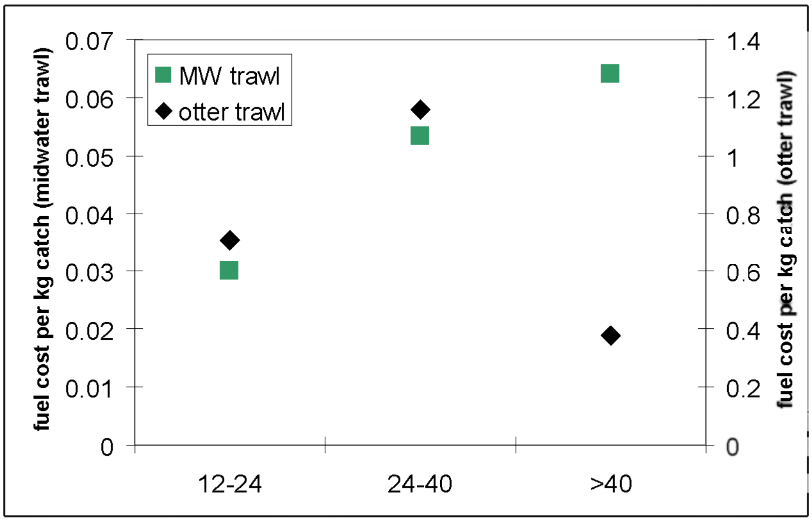


Figure 18: Fuel costs per kg catch for midwater trawlers and otter trawls across three of the four size ranges. Midwater (trawlers are on the left-hand x-axis, while otter trawlers are on the right hand x-axis (i.e. otter trawlers have greater fuel consumption for a given size). Data from European Commission 2008b.

It is also instructive to look at the pattern in fuel efficiency across different Member States (Figure 19). It is very variable indeed, with more than an order of magnitude different between the most and least efficient.

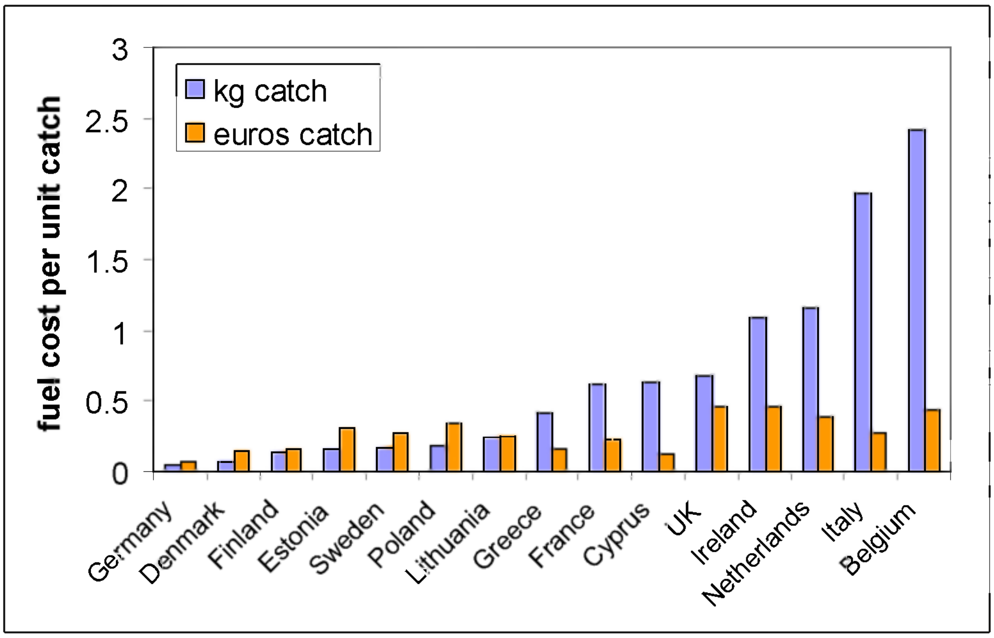


Figure 19: Fuel costs per unit catch for fishing vessels from different Member States – note that there are also differences in vessels, gear and target species so that comparisons must be made with care. Data from European Commission 2008b.

It is likely that much of this difference can be explained by differences in the vessels, gears and fisheries being compared in this rather incomplete data set – or by differences in the way the data are collected or interpreted. However, it is by no means clear that all differences can be explained this way. A more detailed comparison between two Member States with wildly differing fuel efficiency outcomes – France and Germany – is instructive.

For France, three types of fishing vessel were included in the analysis: i) midwater trawler / seiner >40m; ii) netter <12m and iii) otter trawler / seiner 12-24m. For Germany the fishing vessels were: i) midwater trawler / seiner >40m; ii) mobile gear 12-24m and iii) otter trawler / seiner 24-40m. Thus the vessel types were at least somewhat comparable even if the German vessels were on average somewhat larger. The data for fuel costs of each vessel type is given in Table 12.

Table 12: Fuel costs per unit catch for three types of German and French fishing vessel. Data from European Commission (2008b).

Country	Gear type	Vessel size	fuel cost/kg	fuel cost/€
France	midwater trawl / seine	>40	0.17	0.3
	Nets	<12	0.88	0.15
	otter trawl / seine	12-24	0.8	0.24
Germany	midwater trawl / seine	>40	0.005	0.01
	mobile gears	12-24	0.11	0.17
	otter trawl / seine	24-40	0.02	0.02

We do not know for sure the ultimate source of the data in Table 12, nor is it certain that the data from France and Germany are comparable. Nonetheless, the differences between the two fleets are striking. We can tentatively draw the following conclusions:

- For the large midwater trawler, the German vessels appear to be more efficient than the French vessels.
- For the otter trawlers / seiners, the German vessels are also more efficient than the French even though they are larger.
- French netters of <12m are similar in fuel costs per unit value of catch to the German vessels with mobile gear 12-24m – the German vessels are still more efficient in terms of fuel costs per unit volume of catch – despite being larger and using mobile instead of passive gear.

11.2.5 UK Seafish study

In the UK, Seafish is developing a tool for the analysis of the total carbon emissions associated with a variety of seafood products – from the fishing vessel leaving the quayside to the product on the supermarket shelf. Seafish are assessing emissions associated with fishing, transport and processing – here we consider only the fishing element. So far the project is in a pilot phase, and Figure 20 shows the relative carbon emissions from fishing of the nine fisheries considered so far.

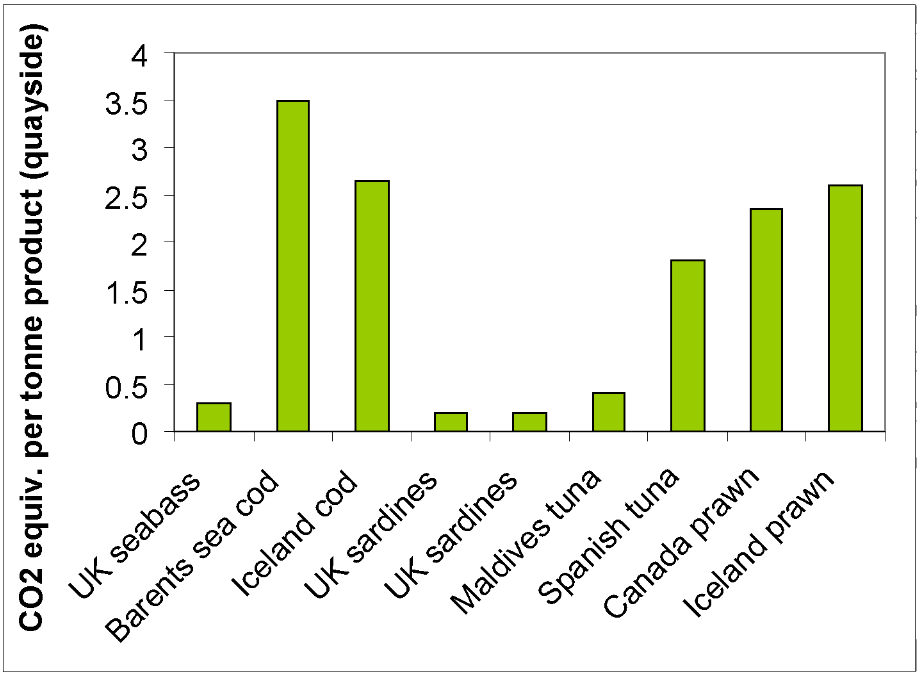


Figure 20: Fishing-associated carbon emissions for nine global fisheries. Data from Seafish (see www.seafish.org).

The nine fisheries can be classified as follows:

fishery	grounds	gear
UK seabass	inshore	handline
Barents sea cod	offshore	trawl
Iceland cod	mid	longline
UK sardines	inshore	ring net
UK sardines	inshore	ring net
Maldives tuna	mid	handline
Spanish tuna	offshore	purse seine
Canada prawn	inshore	trawl
Iceland prawn	mid	trawl

Figure 21 shows the fisheries divided i) by location of fishing grounds and ii) by gear type. The study suggests that offshore fisheries and fisheries using towed gear have higher emissions per volume of product than inshore fisheries and fisheries using passive or mobile gear. However, the sample size is small and the results are to some extent confounded with each other. Nonetheless, this result is interesting as part of a bigger picture.

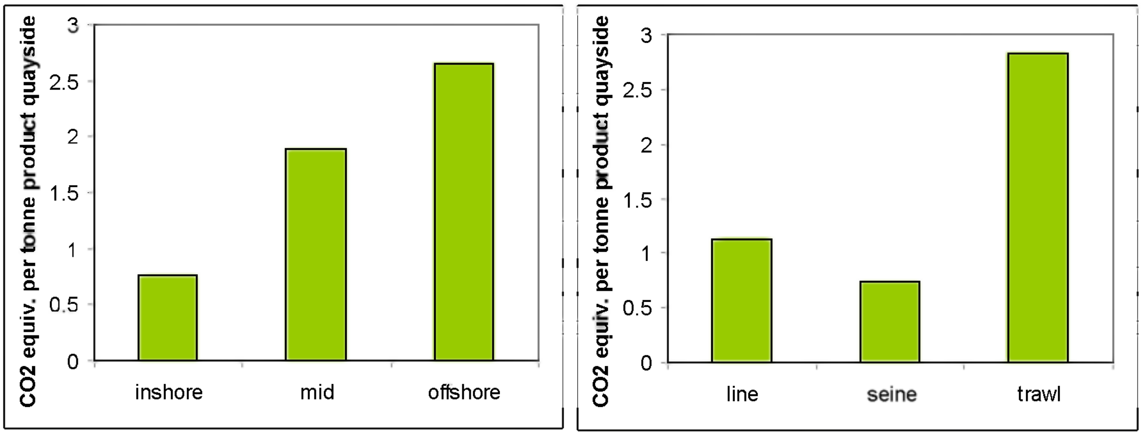


Figure 21: Carbon emissions per unit volume of product for the above fisheries, by fishing ground (left) and gear type (right)

11.2.6 Denmark fisheries study

Thrane and Nielsen (2003) collected data on catches and fuel consumption for various categories of Danish fisheries and compared them with the eventual value of the catch, including landed bycatch, to calculate CO2 emissions per unit volume of catch (Figure 22).

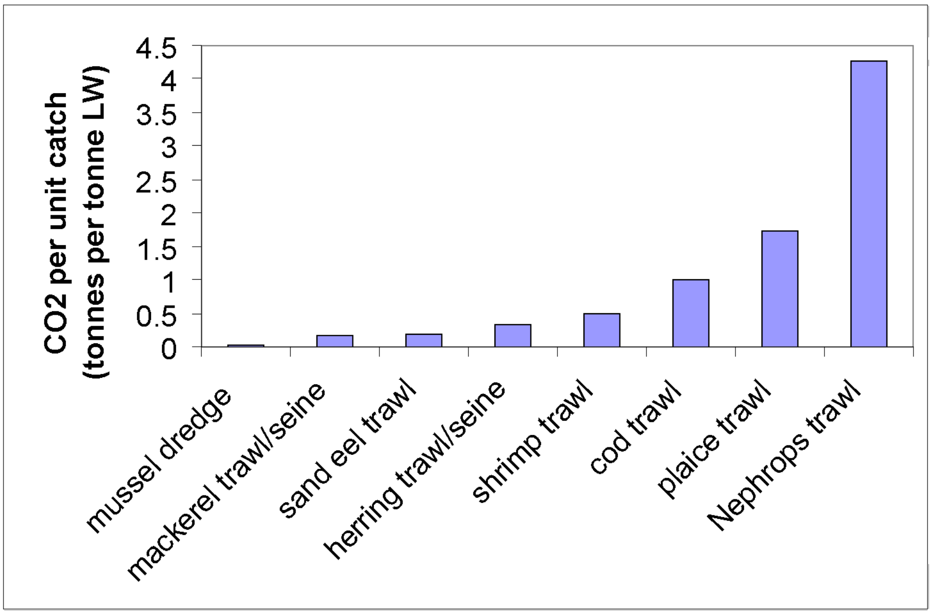
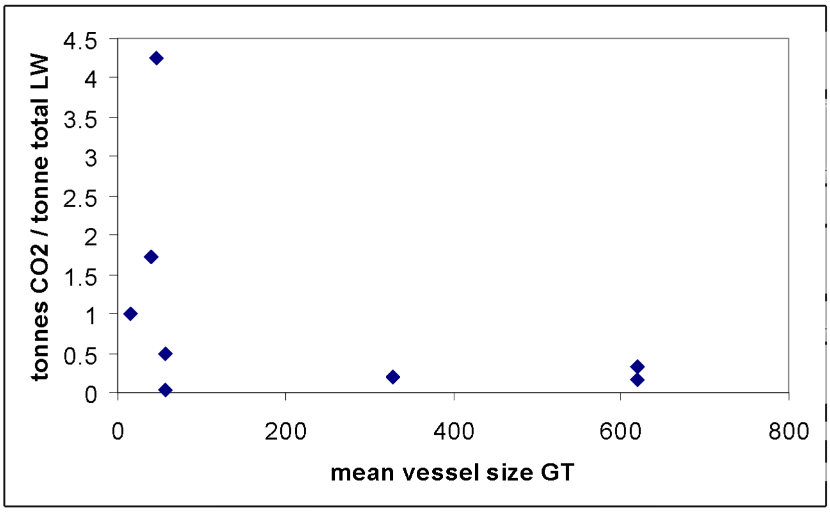


Figure 22: CO2 emissions per unit volume catch (live weight including landed by-catch) for a variety of Danish fisheries (data from Thrane and Nielsen 2003).

Apart from the mussel dredge fishery, these fisheries are all dominated by trawls, although the herring and mackerel fisheries also include some seining, and the cod and plaice fisheries some netting. There is thus no possibility of making comparisons by gear. However, the mean size of the vessels in each fishery is quite variable, as shown in Figure 23.



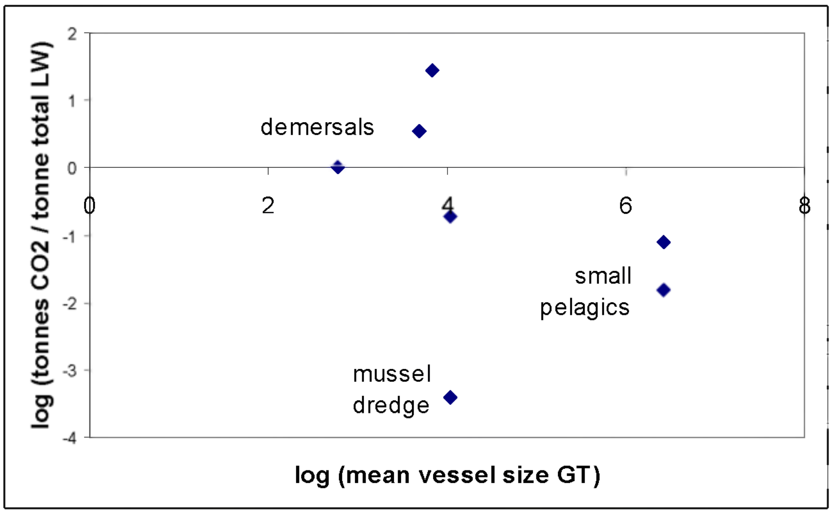


Figure 23: Carbon emissions in relation to mean vessel size in the fleet. The top graph is on a linear scale, while the bottom graph is on a log-log scale, showing up the different groups of vessels better.

Figure 23 shows that in this case, the vessel size is not strongly related to the carbon emissions per unit of catch – the fishing métier is more important, and the different métiers group together closely. The demersal vessels are the smallest but have the highest emissions per unit volume of total catch. The pelagic vessels have lower carbon emissions per unit volume of catch, despite being significantly larger. The mussels dredges (despite using a towed gear) are the most efficient in term of carbon emissions by a wide margin. This is all in agreement with the analysis of EU fleets above.

11.2.7 Study of French fisheries

Le Floc'h and Dangeard (in prep.) assessed the relative carbon emissions of different types of Breton fishing vessels, using data from an economic database of Breton fisheries. Catch, effort and fuel consumption data was available for 1830 vessels in various length categories and gear types.

The study gives figures for fuel consumption per unit volume of catch and also calculates carbon equivalents. For unit value of catch figures are only given for fuel consumption – however there is an almost perfect correlation between fuel consumption and carbon equivalents, so the fuel consumption data is given for both data sets for simplicity (Figure 24).

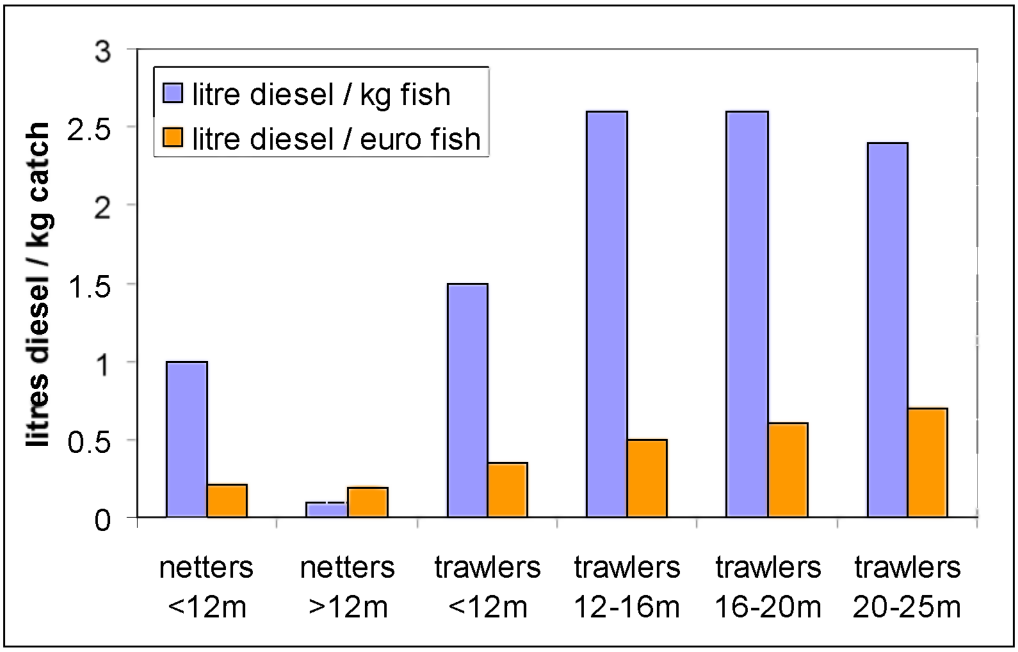


Figure 24: Fuel consumption per unit volume and value of catch for six types of Breton fishing vessel.

This study suggests that towed gear emits more carbon per unit volume or value of catch than passive gear. For the towed gear, there is also a suggestion that larger vessels are less efficient than smaller vessels, at least up to a certain size. However, this does not seem to be the case for the netters. This is because the netters >12m target mainly small pelagic species (sardine, anchovy and mackerel) – i.e. a high volume but low value fishery, while the smaller netters are more likely to be setting fixed gillnets for higher volume whitefish species (cod, hake, bass etc.). This explains why the larger netters do significantly better in terms of fuel consumption per volume landed, and again points up the difficulty of comparing like with like.

12 Annex E: Possible technical modifications to vessels, gear and fishing practices to reduce direct and carbon-related impacts.

The information presented here is taken from van Marlen et al. 2009 and FAO.

- Reduce speed to save fuel: Reducing speed is the easiest means of reducing fuel consumption. A 19.8m vessel operating a 540HP engine that reduces speed from 10 knots to 8 knots would reduce hourly fuel consumption by 70%. Over a distance of 100 nautical miles, this amounts to a saving of more than 600 litres of fuel and adds 2 ½ hours to the journey. This trend holds true for smaller vessels also: a 35 foot (10.6 metre) vessel on a 20-mile trip reducing speed from 9 knots to 8 knows would add 20 minutes to the journey time but save about 34 litres. In cost terms, assuming a per litre fuel cost of € 0.57 (£0.50), this would equate to a saving of almost € 20. Over a one-hour period, a fisherman would in essence be able to pay himself € 60 for an extra hour at sea. Installing a fuel monitor is a simple and cost-effective way of monitoring fuel consumption and by means of comparison with a fishing log can identify where savings can be made.

- Bow bulbs: These increase efficiency by creating a pressure field and resultant bow wave that is out of phase with the bow wave, significantly reducing resistance. Testing in Canada by the Department of Fisheries and Oceans suggests fuel efficiency can be improved by 15% by this means. Bow bulbs may also improve the stability of vessels, increasing work platform safety. However, improperly fitted bulbs can increase the pitching motion and they may not work well at all speeds. Steel retrofitted bulbs cost between € 30,000 to € 76,000 depending on vessel length and type.

- Propulsion and shafting: There are instances of vessels where propulsion systems have been chosen based on power and engine size without considering the propeller. Studies in Canada and USA suggest a significant number of vessels are operating with sub-optimal propulsion systems leading to declines in efficiency. Means of improving efficiency can be achieved by fitting a larger propeller where possible and redesigning the rudder system. Spade rudders, for example, can improve fuel efficiency by 3-6 %. Retrospective changes to the propulsion system are generally costly: € 35,000 has been quoted as the investment required to fit a controllable pitch propeller, new gearbox and modified drive shaft system.

- Hull and engine maintenance: Along with reducing speed, maintenance is the most economical means of increasing efficiency. For example, fouling on the hull has been demonstrated to increase fuel consumption by 7% over one month and by 44% over six months (Curtis et al., 2006). The effects of hull fouling are more pronounced at lower speeds, reducing benefits gained by speed reduction. External and squared-off (rather than faired) fittings create eddies that increase hull resistance leading to increased fuel consumption. Weight is also a consideration and should be reduced wherever possible, e.g., replacing existing fittings with lighter equivalents.

- Hull modifications: Lengthening the hull, bow, midships or stern can achieve significant improvements in fuel efficiency. These modifications require significant expenditure and would clearly only be worthwhile if a long operational life of a vessel is expected and if the business case makes financial sense. Nonetheless, saving can be substantial: simulations on an existing 65-foot (19.8 metre) vessel indicate that a decrease in immersed transom from 100% of amidships draught to a transom immersion of 10% could result in potential savings of 50% in required power at cruising speeds.

- Fishing gear efficiency: Each fishing vessel has a distinct energy consumption pattern based on the type of fishery, the vessel, gear setup and operational characteristics. Technological improvements can improve fuel efficiency for active gears because over 60% of all resistance comes from drag on netting while fishing. Reducing the amount of netting surface area, increased mesh sizes, hydrodynamic trawl doors, thinner twine, modern fibres and improved footgear all combine to reduce the drag of towed gear and lead to improved fuel consumption. Although a smaller netting surface area results in less swept area, the increase in efficiency enables vessels to cover a greater area for a smaller volume of fuel, maintaining productivity.

- New vessel considerations: When a vessel is commissioned there is an opportunity for the vessel owner to collaborate with a naval architect and the ship yard to develop an energy efficient vessel. New vessels can be designed with optimal length/beam ratios (longer vessels are more efficient), minimal transom immersion, small bow half-angles, stern shapes allowing for an efficient controllable pitch propeller, reduced windage above deck, bow bulbs, fuel efficient engines, low emission refrigeration systems, modular gear installation to enable easy conversion to target different species using different gears, etc.

- Improvements to refrigeration system: System components include the compressor, condenser, all line components and advanced electronic controllers to optimise the system. Natural refrigerants are by nature less aggressive and minimise the level of noise emanating from the refrigeration system as well as reducing the day-to-day wear and tear on the compressors and so extending its life span. Hydrocarbon refrigerants have a much reduced GWP (global warming potential) in comparison with more commonly used refrigerants. Energy savings and increased operating life are reported to have improved the economic performance of companies with hydrocarbon refrigeration systems (e.g., HAWCO ltd.)

- Increased gear selectivity: The use of larger mesh sizes, square mesh panels, rigid and flexible sorting grids and double codends (among other things), improves the selectivity of fishing gears reducing bycatch and discard levels and in some cases reducing fuel consumption. The most appropriate design for these selectivity devices depends a great deal on the specifics of the fishery – the target species, the species to be eliminated and the type of environment (e.g. Case Study 7 shows that one of these devices does not work well in weedy environments). These devices usually (but not always) result in some reduction in the catch of target species, making the fishery less efficient, so in many cases they should be regarded as an interim measure until the population in question can recover from overfishing – as in the example of the eliminator trawl to reduce cod bycatch (Case Study 1).

- Reducing drag by modifying gear: The drag of the gear through water accounts for about 80% of the total drag experienced by a fishing vessel during fishing (refer to case study 16). Any modifications that reduce the drag of the gear result in improved fuel consumption. For towed gears that contact with the seabed, modifications such as the SumWing beam trawl (see Case Study 6) result in significantly reduced drag and therefore fuel consumption, but also reduce the impact of the gear with the seabed resulting in significant environmental benefits as well. Other modifications include the use of wheeled shoes and electronic pulses rather than tickler chains on beam trawls, lighter meshes and increased mesh sizes, thinner net twine, pair trawling to remove the need for otter boards, etc.

- Reduced mortality of endangered species: The use of Turtle Excluder Devices, streamer lines and acoustic deterrents reduce the bycatch of unwanted species including marine turtles, seabirds and marine mammals. While this doesn't improve fuel consumption, it reduces the environmental impact of fishing on species that may be endangered or legally protected in some areas.