Developing a Fisheries Ecosystem Plan for the North Sea.


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Abstract

The management tools required for the practical application of an ecosystem-based approach to environmental management is still under development as a management tool. If such new management schemes are to be workable and effective it is imperative that they focus on the key processes rather than attempt to address the huge number of potential variables which could be monitored or measured in an ecosystem.

The European Fisheries Ecosystem Plan (EFEP) aims to identify and examine the key processes required to introduce ecosystem-based management to the fished areas of the North Sea. The aim is to develop a framework which allows for sustainable fishing practices whilst protecting the ecosystem.

Integrating stakeholder perspectives into environmental management plans is integral to the ecosystem approach. The first phase of the EFEP has been to develop and initiate links with stakeholders and obtain their opinions on their preferred management regimes and their perception of ecosystem health. The second phase characterises the biological and physico-chemical environment of the North Sea to develop a conceptual model of ecosystem function. This model will form an important
tool in testing the effectiveness of different management regimes in protecting key ecosystem attributes.

Introduction

Fishing represents the largest anthropogenic impact on the marine ecosystem (Dayton et al., 1995). Traditional fisheries management schemes aim to optimise the catch of certain commercially important species usually without regard for the impact of fishing activity on the wider environment. However, the overfishing of target stocks and the concomitant effects on by-catch species and habitats, has resulted in changes to the structure and functioning of the ecosystem (Blaber et al., 2000) and forced attention towards management measures which will sustain the fishing of target species and reduce the deleterious effects on the wider ecosystem.

Inferring causal relationships between fishing and its effect on the environment is extremely difficult due to the complex nature of these systems. Not only may the relationships be indirect, but they may change in time and space. Additionally, large sets of historic data of un-fished areas do not exist and estimates of the impacts of fishing on the ecosystem cannot be measured directly and need to be assessed and estimated through a variety of approaches (Frid et al., 2001).

The impacts of fishing on the ecosystem relate to either the nature of the catches or the type of gear used (Hey, 1992). Fishing can affect ecosystem structure and function through at least four mechanisms: 1) the direct removal of species with different life histories may lead to shifts in the relative abundance of species with the community, independent of any change in species interaction; 2) the changes in the relative abundance of target and non-target species may lead to indirect effects mediated by changes in predator-prey relationships or competition; 3) gear effects on the sea bed may modify habitat which may influence the composition of the fauna; 4) discarding of fish and offal may increase the populations of scavenger species (Gislason, 2001). All four processes probably work in combination and all result in shifts in the relative abundance of various species in the community.

In the Rio Declaration of the UN Conference on Environment and Development (1992), it was agreed that, ‘states shall co-operate…to conserve, protect and restore the health and integrity of the Earth’s ecosystem’ and that ‘where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental
degradation’. Both the recognition that the ecosystem has been affected by anthropogenic activities and the adoption of the ‘precautionary principle’ has affected the development of environmental management plans in a radical move away from traditional measures. At the World Summit on Sustainable Development (2002), 189 countries acknowledged that three-quarters of the world’s fisheries are fished to their sustainable limits or beyond, and signed an agreement to allow fish stocks to return to, ‘levels that can produce the maximum sustainable yield, with the aim of achieving these goals for depleted stocks by 2015’. The methods by which this will be achieved are, as yet, uncertain, but there is a need to gain a greater understanding of how humans have affected the marine ecosystem and how management of these effects may encourage the return of large stocks of target species.

The ecosystem approach to the management of natural resources arose from the realisation that these resources operate in complex systems and are finite. The management of natural resources has focussed traditionally on maximising the rate of exploitation and only within the last century has some effort been made towards ensuring the exploitation rate did not exceed the rate of replenishment. Little or no attention was paid to the effect of exploitation on the wider environment and legislation regulating the exploitation of resources developed separately from that which conserves the natural environment.

Individual components of an ecosystem do not function, and therefore cannot be managed effectively, in isolation. The creation of a model which integrates the primary physico-chemical, biological and societal drivers of an ecosystem may be used to assess the effects of various management techniques and give some indication of the levels at which the sustainable exploitation of a resource is achievable without disrupting the functioning of an ecosystem. Crucial in this approach are the views and opinions of stakeholders. Their needs must be addressed if the management measures arising from this approach are to be implemented successfully. Consequently, the education of stakeholders and legislators is vital as not all the biological consequences of a given choice may be perceived by those whose choices may affect the performance of a system (Grant and Thompson, 1997). This new approach to management is currently under development as the coupling of environmental and socio-economic systems is not well understood and different theoretical and methodological approaches have developed (Grant and Thompson, 1997).
The effect of anthropogenic activities on the marine ecosystem is dependent upon the type of disturbance, the frequency of the disturbance and the ability of the ecosystem to recover (resilience). However, determining the extent of anthropogenic disturbance is problematic since no pristine ‘baseline’ marine habitats exist and historical data are sparse and may still be impacted by historical human activities (Frid et al., 2000). To further complicate any assessment, the two dominant anthropogenic effects within the marine environment, the rapid expansion and mechanisation of the fishing fleet (Rijnsdorp and Millner, 1996), and the introduction of chemical fertilisers in terrestrial areas which resulted in excess nutrients entering the marine system (Caddy, 2000; Rijnsdorp and Leeuwen, 1996), occurred simultaneously in the early to mid 20th century. The effects of the eutrophication and fishing activities on the marine environment may act synergistically.

The extent of an anthropogenic impact on the marine ecosystem is dependent upon the type of disturbance, the frequency of disturbance, the season, and the substrate type. Some studies show that disturbance by human activities has little effect in habitats where there are high levels of natural disturbance or where the biological community is constrained by regular disturbance. This will influence the way in which management targets are quantified as comparisons of pristine ‘natural’ states and those affected by man will require quantification. However, the effects of some anthropogenic activities are so pervasive that no pristine, or near pristine, areas exist, and all baseline measurements will have to be made on impacted systems. This will have implications on the later development of management strategies as the estimated baselines, and any changes to them, will be open to dispute from all interested parties.

This paper examines the effects of various fisheries management techniques on the functioning of the North Sea ecosystem with a view to ameliorating the effects of fishing.

Method

A list of management measures was compiled after interviews were conducted with stakeholders from the UK and the Netherlands. This list was condensed and five management techniques extracted: technical, effort, quota, closed areas and discard management.
The ecosystem components used to assess the effect of the management techniques were target populations, non-target populations and habitat modification. These components were identified after a review of the literature and discussion amongst the authors.

The components were divided into target and non-target species rather than target and by-catch species as the management measures to limit by-catch will be determined by the by-catch of target species not non-target species. The effects of management on habitat were separated into those which affect the physical habitat and those which affect the chemical environment as they have very different consequences despite their identical cause.

The effect of the various management measures on the ecosystem components was assessed and quantified after a review of the literature and discussion amongst the authors. Each technique was assessed by what is known to happen during a single fishing event. A management technique was given a score of 1 if it had an absolute positive effect, and a score of zero if it had an absolute negative effect. All other results were graded 0.5.

Results

1) The effect of management techniques on target species

*Technical measures*

Commercial fishing activities aim to maximise the catch of target species of the correct size and the gear is designed for this purpose. Changes to the mesh size was therefore given a score of 0.5 (Table 1), as it will not affect the catch of correctly sized target species but may afford some protection to the by-catch of undersized target species. The same score was given to the use of grid panels in the gear as they are not aimed at releasing correctly sized individuals of target species, but may provide some protection to the undersized juveniles. The size-selected removal of individuals from a population has three types of effect on population dynamics: direct effects on population density and on the mean size of individuals; short term environmental effects on growth and reproduction, mediated by phenotypic plasticity and density-dependent mechanisms; and long-term effects due to the selective pressure imposed by harvesting (Rochet, 1998). However, as the nets become blinded
by catch, their selectivity is reduced and mesh size will have little effect on the size of animal caught.

Table 1.
An assessment of the protection afforded by management techniques to three key ecosystem components: target species, non-target species and habitats.

<table>
<thead>
<tr>
<th>Management techniques</th>
<th>Effects on target population</th>
<th>Effects on non-target population</th>
<th>Habitat modification (direct)</th>
<th>Habitat modification (nutrient flux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TECHNICAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>♦ mesh size</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>♦ grid panels</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>♦ reduced penetration</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>♦ gear types</td>
<td>0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>EFFORT</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>QUOTA</td>
<td>1</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DISCARD MANAGEMENT</td>
<td>0.5</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CLOSED AREAS</td>
<td>(0.5) 1*</td>
<td>(0.5) 1*</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Key:
0  no protection
0.5 some protection
1  fully protected
1* fully protected in closed areas

Effort management

The management of fishing effort was given a score of 1 as target species are left undisturbed and fully protected if no fishing activity occurs.

Quota management

The introduction of quota limits was given a score of 1 as fishing disturbance will cease once the quota is filled. However, the way in which quotas are calculated and assigned is extremely complex and determined by both scientists and politicians (FRS, 2002). Most TACs (total allowable catches) are determined on an annual basis and include an assessment of historical trends in landings, spawning stock biomass, recruitment and fishing mortality rate, a description of the ‘state of the stock’ in relation to historical levels, the likely medium-term development of the stock using different rates of fishing mortality, and a short term forecast of spawning stock
biomass and catch (FRS, 2002). ICES has adopted the precautionary approach to fishery management and given the level of uncertainty in stock estimates there is a need to define the levels of biomass and fishing mortality rates which will trigger management action before stocks reach dangerously low levels. Problems may arise from the use of catch per unit effort (CPUE) as an index of stock density, as a corollary of this assumption is that catchability, the coefficient of proportionality between CPUE and stock density, is constant over time (Marchal et al., 2002). There is evidence that the catchability of commercial fleets has changed over the past decades, as catchability may include changes to fish accessibility and fishing power creeping.

**Discard management**

Discard limitation measures, such as real-time closures triggered by by-catch levels, will protect target species to some extent and were given a score of 0.5 as fishing activity must cease when discarding becomes too great. Again, this is important for undersized individuals of target species.

**Closed areas**

Closed areas may provide refugia for target species provided they occur over biologically relevant spatial and temporal scales. Provided the entire population of a target species is within the closed area, they are fully protected and this management technique was a score of 1. However, most target species are mobile and may move out of the closed area. In some cases, therefore, the closed area will only provide partial protection to the population and may be awarded a score of 0.5.

The protection of spawning and nursery grounds will benefit stocks and fisheries (Horwood, 2000). However, no-fishing zones cannot be considered as an effective alternative to other management regimes such as a reduction in effort (Horwood, 2000; Polunin and Wabnitz, 2001).

2) The effect of management techniques on non-target species

Fishing may have both direct and indirect effects on non-target populations. The direct effects include their capture in fishing gear and subsequent discarding or landing, or their disturbance, injury or death without capture after direct contact with the gear. The indirect effects of fishing on non-target species are primarily food chain
effects although other effects such as the smothering of epifaunal species by sediment re-suspended by the passing of a trawl, or a reduction in nutrient recycling due to a reduction in bioturbation may also occur. Fishing disturbance to species which produce biogenic structures may affect whole communities which are supported by the presence of these structures. Ghost fishing is believed to be an important factor affecting non-target populations. (Laist, 1996), estimated that the ghost fishing of some commercial stocks may equal 5-30% of the annual landings in the associated fishery.

Fishing techniques attempt to reduce the catch of non-target species. It has been estimated that of the total global catch of 100 million tonnes year⁻¹, approximately 27 million tonnes is discarded (Alverson et al., 1994) However, some level of by-catch is inevitable and attempts may only be made to limit this amount as gears tend to be size selective and not species selective. Compared to the information on target species, few records exist of the quantification and qualification of by-catch and little is known about the direct long term effects of fishing activity on non-target populations. However records of marine mammal and cetacean by-catch do exist. Between 1996 and 2000, >0.9% of the Harbour Seal population of the North Sea was caught as by-catch, between 1999-2000, >1.4% of the Grey Seal population was caught, and in 1995 >2.4% of the Harbour porpoise population was caught (ICES, 2001).

Technical measures

Technical measures were scored at 0.5 because although increases to mesh size and the introduction of grid panels will provide some protection, the fishing process is size selective and does not tend to be species selective. Some non-target species are extremely sensitive to fishing activity due to their fragile physiology and the stress of capture may cause serious injury or death.

Whilst alterations to the weight of the gear and reducing the gear penetration of the sea floor will protect deeper burrowing infauna, they do not provide protection for epifauna or shallow burrowing infauna, so both of these management techniques scored 0.5.
Effort management

A reduction in effort will offer only a limited amount of protection to non-target species as fishing activity will still occur for the target species. Effort management was awarded a score of 0.5. Also, a single fishing event may completely destroy a population of species which produce biogenic structures.

Quota measures

Changes to the quotas will not affect the amount of non-target species caught as they are calculated according to the stocks of target species. However, this may cause the early cessation of fishing activity, so the effect of quota management was awarded 0.5.

Discard management

Management of discarding was given a score of 0.5 as it will provide some measure of protection as it may result in a reduction of fishing effort and the closure of some areas to fishing.

Closed areas

Non-target species within the closed area are be fully protected and scored 1. However, as with mobile target species, once they venture outside of the closed area they are liable to the effects of fishing and in these cases closed areas were given a grade of 0.5, as it is still possible that they may protect populations through the provision of nursery and spawning grounds.

3) The effect of management techniques on habitats

The effect of fishing on habitats has never been considered in fisheries management and as a result there are very few quantitative data on how, and to what extent, changes in habitat structure have affected fisheries resources and contributed to the decline of fish stocks (Valdemarsen and Suuronen, 2001).

The disturbance of benthic habitats has direct implications for the fauna but also direct physico-chemical implications as disturbance to sub-surface layers will affect nutrient recycling and benthic-pelagic coupling as nutrients and other chemicals bound to the sediment particles will be released which will affect primary production in the water column. Further, the alteration of physical structures will change the
hydrology in localised areas which will affect the species composition of the communities that are supported by these habitats.

Technical measures
The effect of technical measures on habitats is dependent upon the substrate type and the mechanical strength of any protruding structures. Many gears are designed deliberately to disturb the sea floor. These types of gear are unlikely to affect those areas which encounter natural disturbance on a regular basis. However, in more sheltered areas, or those with fragile structures, any disturbance is likely to have a large impact and a reduction in tickler chains or the use of lighter gears will not mitigate the effect on the impact. Since changes in gear type and the reduced penetration of the sediment by gears will reduce the effects of fishing in some of the more resilient habitats, but not those which rarely encounter natural disturbance, this management measure has been graded 0.5.

Effort management
A reduction in effort will not affect the impact of fishing on either habitat modification nor nutrient flux as the passage of demersal and benthic gears over a habitat will immediately alter these components. Some habitats, such as *Lophelia* reefs, are extremely sensitive to fishing disturbance and will be destroyed by a single fishing event. Effort has been given a score of 0 as limiting effort will not provide any protection for habitats.

Quota management
No quota managements are likely to affect the habitats as the impacts of fishing will still occur. The protection afforded habitats by quota management has been graded 0.

Discard management
The management of discards will not provide protection to direct habitat modification as fishing activity will still occur. Discard management has a grade of 0 for its effect on habitat modification.
Closed areas

Closed areas with no fishing activity will fully protect habitats and have been given a score of 1.

Discussion

The creation of an ecosystem plan for the North Sea fisheries is vital for the future of North Sea fish stocks. The current management situation is not sustainable and the excessive exploitation of fish stocks over hundreds of years has resulted in irreparable damage to the ecosystem of the North Sea. Most of the target fish stocks are fished close to, or beyond, their safe biological limits and the managers of these stocks need realise that the threshold at which further management has any effect is getting closer.

The introduction of the ecosystem approach to the management of the North Sea fisheries is ambitious but necessary. The inclusion of stakeholder opinion and an awareness of the effects of fishing on the wider ecosystem is the next step towards a more responsible North Sea fishery. Education is a vital part of this approach as stakeholders and legislators need understand how their decisions affect the long-term health of the ecosystem. The major conflict for management occurs between the attempts to conserve the stocks and the desire for policy makers to satisfy the needs of the fishing community with respect to jobs and income (Mardle and Pascoe, 2002).

The term ecosystem approach is often used to refer to a multispecies approach. Although it is neither useful nor sensible to attempt to model the entire ecosystem, there is an urgent need to examine the effects of fishing beyond those that affect target species and appreciate that fishing may profoundly affect the physico-chemical environment and indirectly affect the food webs of fished areas. The lack of information regarding the wider effects of fishing is a handicap to the effective management of these areas.

Current knowledge of how the North Sea ecosystem functions, and how the fisheries have affected its processes, is patchy, as the majority of research has focused on the effects of fishing on target populations. Knowledge of which ecosystem processes are natural and which have been affected by anthropogenic activity further confuses possible management plans. The effects of fishing are pervasive, and research needs to be conducted to assess specifically the effects of fishing on the
ecosystem over a range of temporal and spatial scales. The use of models will assist with this research, but a variety of methods will need to be employed as few historical data exist, and many of the effects may need to be assessed indirectly as they will be difficult to separate from natural and other anthropogenic effects.

There is an urgent need for more information on how fishing affects the ecosystem of the North Sea. Although fishing activities are acknowledged to have altered the structure and functioning of the North Sea ecosystem (Gislason, 2001), direct causal evidence is difficult to obtain and in many areas, has never been investigated. More knowledge and detail of the key processes which occur within the North Sea are required for the effective introduction of an ecosystem plan. On a more short-term basis, the knowledge currently available may be used to greater effect if the management were able to react faster and were more flexible. The introduction of schemes such as the real time discard enclosures, which are capable of rapidly closing areas to fishing activity as a result of short term changes, are a positive step. Similarly, the adoption of the precautionary approach in the calculation of TACs has helped to promote a more responsible approach to fishing.

This paper has attempted to assess a few of the management options currently available and how effective they are likely to be on an ecosystem level. However, before these management plans are introduced, management must decide what it is trying to achieve. A reduction in effort or the introduction of quotas will protect target stocks but do nothing to protect habitats. Where stocks are managed by TACs, the creation of no-fishing zones must have clear aims, such as the protection of a nursery habitat, or they may simply divert fishing attention to other areas where similar amounts of fish are removed and the benefit to the population lost (Horwood, 2000).

Large stocks of target species no longer occur in the North Sea. All the stocks of round fish and flatfish species in the North Sea have been exposed to high levels of exploitation (ICES, 2002), and approximately one third of the fish biomass is removed each year (Gislason, 2001). The World Summit on Sustainable Development (2002) has recognised that urgent attention is required to conserve fish stocks and requires the support of governments, fisherman, communities and industry to move forward and develop radical new approaches to fisheries management.


