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The ecological setting of North Sea fisheries

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Abstract

Fisheries research has traditionally been largely concerned with direct interactions between fishing activities and individual fish stocks with a view of optimizing yields. This single species approach has been the basis for the common fisheries policy of the EEC aimed at managing fish stocks by means of catch quota. Although exploitation is undoubtedly a most important factor in the population dynamics of individual species, there are obvious natural links between different species which may affect their respective yields. Extensive recent studies of inter- and intraspecific predation have opened the gate to multispecies assessment, which allows partial evaluation of secondary effects of exploiting one species on the potential yields of others. As shown by the pioneering efforts of Andersen & Ursin (1977) to model the North Sea ecosystem, however, the situation is far more complex, because the dynamics of individual species may be intertwined through feed-back mechanisms between different groups of organisms in the food chain. This contribution is aimed at a qualitative discussion of the various ecological links between exploited fish stocks and the biotic and abiotic environment in the North Sea and of the effect that exploitation may have had on different components of the ecosystem.

Introduction

Archaeological evidence indicates that man has been an important fish consumer from early ages onwards and over wide geographical areas. Apparently, exploitation of natural fish resources does rarely lead to their extinction. Yields taken by marine fisheries have proved to be sustainable for centuries and problems appear to have arisen only fairly recently, when man in his eternal greed applied ever more sophisticated and powerful methods to catch the last fish alive. In the long run, this effort race is obviously harmful to both the fish and the fishery itself. However, even before the stocks cannot sustain any further increases in fishing pressure, fishing may induce considerable changes in the marine environment. The marine ecosystem appears to be an intricate system in which ultimately all components are somehow linked. The harder one fishes, the more the well balanced natural interactions will become disrupted.

In this contribution, I will first describe the nature of the various interactions between different types of human activities and the North Sea ecosystem. Then, because this symposium is concerned with the future, I will explore some trends that could be expected under different broadly defined options for management of the North Sea.

The interactions

Fish and fisheries

A direct effect of exploitation is that mortality in the fished population increases beyond the level produced by other top-predators present as well as by parasites and diseases. As a consequence, in adapting to the new situation the biomass of the fish stock will become reduced until there is again a balance between mortality and production. This type of primary interaction between a fishery and a fish stock has been the basis for modelling the dynamics of exploited fish species, culminating in the impressive studies by Beverton & Holt (1957) and Ricker (1958).

The central idea in this approach is that the yield of a particular fish stock can be optimized by modulating the fishing effort and the mesh size. Fishing effort is some measure of the chance that a fish will be caught, whereas the mesh size controls the minimum size of the fish brought on board. On the basis of time series of detailed information on the size and age composition of the commercial catches and on the effort applied to take the catches, it is possible to predict the effects of alternative exploitation regimes and to develop a management scheme accordingly.

An inherent assumption in this single species approach is that exploitation is the forcing function in the dynamics of a population and that all other factors affecting population processes can be regarded as subordinate. The latter should create at most some background noise on the observed trends in the population. This situation can only exist if the mortality caused by fisheries largely exceeds the mortality imposed by natural causes. However, in order to simplify an essentially highly complex system, this assumption does not appear to be unreasonable. If fisheries mortality is low relative to natural mortality, the models would not be particularly useful, but in those rare cases there would be little need for management anyhow.

Competition

Indirect effects of fishing are likely to become more pronounced at increasing levels of exploitation. Higher mortality and reduced biomass lead to more competition between human and non-human predators and consequently the latter are likely to suffer indirectly from fishing as well, if they have no access to alternative prey. This argument is for instance used by Gambell (1984) to restrict the Antarctic krill fishery in order not to impediment the restoration of the stocks of baleen whales. On the other hand, it can be argued that a reduction in population size would lead to less competition for food among the survivors, which therefore might respond favourably to exploitation by better growth. In addition, the prey species serving as food for the exploited species could be expected to increase in abundance.

Indirect effects may to some extent be taken into account within single species assessment as long as they refer to the species in question. Thus, density dependent population processes within the species can be incorporated in the models relatively easily. As regards side effects on other components, the problem is that these may ultimately be expected to cascade right through the entire food chain. Therefore, essentially different models are required to deal with many of the secondary effects of exploitation.

Interspecific predation among exploited species

One particular question of interest to managers relates to possible indirect effects of exploiting one species on the yield of other equally important species. For instance, adult cod feed on herring. Therefore, increasing effort in the cod fishery might reduce natural mortality on herring and increase its yield (Ursin, 1982; Sparre,1979). In recent years, multispecies models have been developed to analyse the effects of intra- and interspecific predation among exploited fish species in relation to variations in fishing effort directed to each of these species. These models (Helgason & Gislason, 1985; Pope, 1969) require, in addition to detailed catch statistics, reliable information on 'who eats who' (Daan ed., 1989).

In practice, the application is restricted to the fishable parts of the populations only and they are not suitable to evaluate the effects of species interaction during the recruitment phase. It has been shown that herring prey also on cod eggs, suggesting that direct feed backs operate within the system. However, we still hardly understand the causes of the large variations in year class strength in marine fish and the emerging recruitment patterns (Rothschild, 1986). Long-term recruitment effects due to species interaction remain unpredictable.

Although multispecies methods have not yet been widely accepted as a basis for fisheries management, the results have in some cases fundamentally changed our views on the effectiveness of particular management measures. For instance, single species assessment tends to indicate that significant gains in yield can often be obtained by increasing legal minimum mesh sizes. In contrast, multispecies assessment indicates that the gains for one species can be largely offset by losses to others due to increased predation rates (Anon., 1989).

Trophodynamics

Fisheries managers are primarily concerned with optimizing yields in weight and value. They show little interest in changes in the marine food chain due to overexploitation, unless these would in turn influence future yields. However, there is a growing public interest in the general well-being of the North Sea and environmentalists are more concerned about disruption of the ecosystem than about the commercial catches (Peet ed., 1986).

Macroscopic changes in the ecosystem have been well documented but the interpretation remains uncertain (Hempel ed., 1978; De Wolf ed., in press). This type of secondary effects is obviously much more difficult to tackle in modelling studies than the primary fisheries problems. Compared to the extensive detailed information available for intensively exploited fish stocks (Daan *et al.*, in press), relatively little is known about quantities, mortality and production rates of many other components of the marine food web. For instance, measurement of phytoplankton production is still surrounded by methodical uncertainty and the available estimates may be a factor of two too low (Gieskes & Kraaij, 1984). Biomass estimates of benthos are now becoming available from a comprehensive benthic mapping survey carried out in 1986 over the entire North Sea (Anon., 1986), but again production rates are virtually unknown.

It has been the virtue of two Danish scientists, Andersen & Ursin (1977), that they have tried to bridge the gap between fisheries assessment and fundamental ecology by constructing a complex quantitative North Sea ecosystem model, based on the best integrated knowledge available at that time. The main characteristic of this model is a closed energy budget. By taking full account of the internal amount of phosphorus in the different producer, consumer and decomposer compartments of the system, they were able to show that the collapse of the herring and mackerel stocks in the sixties caused by overexploitation could have released enough food for an upsurge in the stocks of industrial and gadoid species, which was in the same order of magnitude as required to explain the observed increases in yield in these species (Andersen & Ursin, 1978). In another version, the model showed that eutrophication of the North Sea by increased loads of phosphorus in river outflow did not contribute significantly to the overall phosphorus circulation in the North Sea (Ursin & Andersen, 1978) and therefore does not seem to be related to the observed changes in overall yield.

Such results can of course not be regarded as hard proof that pelagic stocks were replaced by gadoid and/or industrial fish stocks, particularly because important questions remain to be solved in respect of actual timing of the observed changes and the spatial discrepancies in distribution of the species involved (Daan, 1980). Nor do they prove that there are no significant local effects of eutrophication. They merely indicate that the data at hand are not in contradiction with such explanations.

Direct side effects of fishing

Apart from changes in trophodynamics, fisheries may also have direct side effects on other components within the system. Trawling gears, particularly beam trawls dragging several heavy chains through the top layer of the bottom, undoubtedly affect the mortality among the bottom fauna. In general, long-living and tender organisms could be expected to suffer most, whereas opportunistic short-lived or hardy species might remain unaffected or even take advantage (Reise, 1982), but it appears to be extremely difficult to prove such effects (Anon., 1988). Although tracks of otter boards can now be actually investigated by sidescanning techniques (Newton & Stefanon, 1975), the lack of suitable control areas where fishing is actually forbidden prevents a detailed evaluation of effects of trawling. The evidence for significant damage of fishing to the benthic communities is still open to scientific debate.

Damage by fishing might also turn into favourable feeding conditions by increased food availability to a variety of predators. This applies to fish, which may find a rich banquet of dead prey in the path of a net. Indeed, skippers of Dutch beam trawlers maintain that they stay on the same track for several days, because the catches of sole tend to increase gradually until the resource becomes exhausted. It has been shown that sole finds its food largely by olfactorial senses (De Groot, 1971) and the fish are supposedly attracted by the smell of decaying organisms. In a similar fashion, gulls and fulmars benefit from the fisheries, because discards provide a large and easy food supply. Fulmars have increased consistently from the thirties onwards and it has been suggested that this population increase is largely due to fishing practices (Furness, 1986).

Other human interference.

Fishing is not the only human activity affecting the marine environment. Pollution from rivers, refuse incineration, oil industry and shipping is sipping continuously into the system. Although the North Sea as a whole is still relatively clean compared to most fresh water systems and a far ranging harmful effect on the total system has not been documented so far, there are many problems of a local nature.

Experimental studies on the effect of contamination of harbour seals with PCB's have shown that concentrations at the level observed in the Waddensea have a negative effect on fertility (Reijnders, 1983) and the observed drop in reproduction rate has undoubtedly been a major factor governing the decline of this seal population. In 1988, the remaining population has been hit very hard by a virus infection and whether this infection is related to pollution remains to be proven. There is a strong suspicion, if not evidence, that high incidence levels of a variety of diseases in flatfish stocks are associated with local pollution loads (Dethlefsen, 1988; Vethaak, 1986). Sludge from oil drills has been found to disrupt the benthic fauna in the surroundings, but major deleterious biological effects occurred within 500 m from the platform (Davies *et al.*, 1984). The frequent occurrence of algal blooms in coastal areas has been related to eutrophication (Beukema, 1986). Often these blooms are just a nuisance causing foam on tourist beaches (Cadée & Veldhuis, 1988), but sometimes they can create large economic losses because they are poisonous. The examples of the *Chrysochromulina* bloom in the Kattegat in 1988 (Aksnes *et al.*, 1989) as well as the frequently returning Dinoflagellate blooms in areas of shellfish farming are well known (Kat,1989). The latter do present real hazards to human health because they may cause Diarrhetic and Paralytic Shellfish Poisoning.

In addition, dying off phytoplankton blooms are probably responsible for creating large areas of anoxia in the German Bight (Gerlach, 1984). Although fish can generally escape in time, dead benthic organisms have been reported to occur in large quantities in those areas.

The abiotic environment

Lastly, the abiotic environment fluctuates. Temperatures vary from year to year and so do the water movements and salinities due to climatological variations. They may even show long-term trends (Becker & Kohnke, 1978; Hill & Dickson, 1978). As a consequence the entire biotic environment also varies. Spring peaks in primary production depend critically on weather and temperature conditions. Zooplankton feeds on phytoplankton and the match-mismatch theory of Cushing (1967) suggests that survival of fish larvae depends heavily on the timing in the different production cycles. Thus the effects of environmental conditions climb upwards through the system to meet somewhere the effects of fishing cascading from the top end. Obviously, they must ultimately mingle into almost an inextricable ball. At present, it is impossible to separate natural and man induced effects in the changes observed at various levels of the food chain. This situation can only become worse, now that even climate has become affected by man's activities and sea temperature and level are expected to rise as a consequence of the green house effect (Rijkswaterstaat, 1989).

A perspective

The organizers have asked me to put the present developments of the North Sea ecosystem into some kind of perspective. Although futurology has become an accepted part of academic education in the Netherlands, this was long after my time at the university and I don't feel very much at ease in this field. A first reason is that we still don't understand essential features of historic trends (Hempel ed., 1978). Secondly, the future will depend at least to some extent on the political scope for management actions to stop and correct recent developments and I am not a politicologist. However, one way of tackling the future may be to ask oneself (1) what is likely to happen to the North Sea ecosystem when management remains largely as it has been in recent years, (2) could proper management action completely reverse the observed trends back to the virgin situation and (3) what management goal would be feasible in order to improve the marine environment. In addition (4), the green house effect will be discussed as something that appears to be inevitable.

Before addressing these options, I should make clear that my answers are not to be considered as scientific evidence that in reality things would happen as I propose under the given constraints. They are rather meant to evoke debate.

Doing nothing

Imagine the North Sea as we see it today. There are national and international agencies claiming that there is some kind of management and, surely, there is a tremendous number of regulations. Not only in fisheries, but also in the oil and shipping industry, in respect of pollution and to a lesser extent in the field of nature conservation. Still, there appears to be a severe lack of organizational power to enforce all these measures in such a way that the persisting trends are effectively halted.

Fisheries provide an excellent example in this respect. In 1983 an EEC fisheries policy has been adopted which was aimed at controlling the levels of fishing mortality by means of a quota system. A quick survey of the recent report of the Advisory Committee on Fisheries Management (ICES, 1989) shows that most stocks are even more overfished than they were back in 1983. The main result of the fisheries policy appears to have been a deterioration of the catch statistics impedimenting the provision of sound scientific advice for some time to come.

The struggle against pollution shows similar features. Eutrophication of the coastal waters has been indicated as a major problem already in the early seventies (Goldberg ed., 1973), but the worst cases of algal blooms occurred in recent years. If there is a causal relationship as claimed by many scientists, the situation has rather got worse than improved (Beukema, 1986). Although the importance of different pollutants changes continuously over time, there seems to have been no basic improvement in the total load of dangerous substances (Peet ed., 1986). Reports of oil spills from cleaning operations as well as accidents with cargo's appear frequently in the newspapers in spite of all regulations. And the seabed does not yield to an American Highway in the amount of beer cans and other garbage.

Altogether, there is a continuously increasing threat of various forms of marine life on all fronts. Even though this conclusion appears to be true in its generality, it does not mean that the North Sea is almost dead.

The response in the major fish stocks in the North Sea to overfishing has been a, in some cases dramatical, reduction in biomass. The decline of the herring and mackerel stocks provide classic examples (Hempel ed., 1978). The herring has recovered in recent years after the fishery had been closed for several years. This could be one of the few examples of an effective management measure in fisheries, although some scientists believe that the recruitment failure in the seventies was due to severe changes in the hydrography rather than to overfishing (Corten, 1986). In the demersal fish stocks, comprising gadoids and flatfish, the biomass increased in the sixties due to improved recruitment, but remained stable (plaice) or decreased steadily (cod, haddock, whiting and sole) afterwards as a consequence of increased fishing effort. For some of these species, the size of the spawning stock has reached an all time low level and the fishery is based almost exclusively on immature fish. At some stage, the numbers of adults can be expected to become a limiting factor to subsequent recruitment and, since we assume here that the fishery will not be managed effectively, my view is that for some of the larger species, in particular cod, haddock and sole, this stage will be reached within the near future. Because they are caught in mixed fisheries, which will probably continue to be profitable for quite a while even when these stocks have gone, these species may actually become virtually extinct.

Among the fish, several traditionally common species, ranging from greater weevers to blue tuna, have already become virtually extinct, even when they were not specifically sought after. Greater weevers were formerly caught in mixed fisheries and it seems quite possible that this species cannot stand heavy exploitation. If fishing effort increases even further, other species may follow and therefore, if anything, species diversity is likely to drop. On the other hand, scad has nowadays become an abundant summer migrant into the North Sea and the holes in the system may become filled by opportunistic species.

Taking away the larger fish from the system effectively reduces mortality on the small fish and therefore the industrial species might expand even further beyond the present level. This is good for the sea birds and the Danish industry and bad for the cetaceans which require larger prey. In this context, it is interesting to compare the size frequency distributions of research vessel catches in different areas (Pope & Knights, 1982; Pope *et al.*, 1988), which indicate that indeed the heavily exploited North Sea contains relatively more small fish and fewer large fish than less intensively exploited areas like the Faroe Bank and the Georges Bank.

The most likely effect of pollution on marine fish is a further increase in the number of diseased fish. When there are enough predators around, these would probably be removed by selective predation, but the mere absence of large predators may contribute to the high incidence levels observed.

Among other groups, there are some species which appear to have difficulties in sustaining life in the area for some reason or another. We don't have much quantitative information on the development of cetacean populations in the North Sea (Klinowska, 1986), but the populations of both harbour seals and harbour porpoises in the Dutch Waddensea have been severely reduced. In general, the top-predators in a system appear to be the most sensitive organisms to effects of pollution, because the dangerous substances accumulate in the food chain. Together with all the other hazards threatening marine mammals (drowning in fishing gear; oil spills), I expect that they will disappear in the long run altogether from the southern North Sea, if the pollution load is not drastically reduced below the present level. I am not so sure that the northern North Sea will ever become seriously affected by pollution, because the water mass is continuously renewed by Atlantic water and, unless the oceans become seriously contaminated, some kind of equilibrium can be expected to be maintained between the amount of pollutants that are entering the system mainly from river outflow and the amounts that are leaving through the Skagerak area.

Marine birds pose a rather different picture. Although the sandwich tern and eider populations in the Dutch Waddensea have suffered severely from chlorinated hydrocarbons during the sixties, the sea birds in general are doing very well. Herring gulls have increased in the Netherlands from 17000 breeding pairs in 1968 to 85000 in 1982 (De Wit & Spaans, 1984) and are increasingly considered as pests. Colonies of gannets and guillemots have expanded over most of this century up til the early eighties (Furness, 1986). Apparently, even though large numbers of oil victims may be found occasionally on the sea shores (Camphuysen 1986), as yet pollution does not seem to have a significant effect on population development. Some of these trends appear to be related to the overall increase in fishing effort. Discards supposedly play an important role in this respect, but the shift from a fish biomass dominated by old and large individuals unsuitable as food for birds to a biomass dominated by short-lived small species may have enhanced reproduction. Indeed food appears to be a major factor determining reproductive success in these species, as indicated by recent failures in the Shetlands bird colonies which coincide with poor recruitment to the local sandeel stocks (Furness & Monagan, 1989). Since the expectations for industrial species are favourable, the marine birds will probably thrive as long as pollution does not reach critical levels.

Bottom trawling will, if it has effects on the benthic fauna, most probably favour opportunistic short lived small species at the cost of long lived large species. This would widen the scope for small fish feeding on small benthos. Maybe, we will see some day an industrial fishery for solenette and gobies.

Further eutrophication of the North Sea will probably enhance primary production and phytoplankton blooms will be seen more regularly. The associated feature of anoxia in bottom waters kills off all benthic organisms which are not able to escape in time. This should also favour opportunistic benthos species and therefore work in the same direction as trawling.

In conclusion, I suggest that the Danish industrial fisheries have the best cards for the future if North Sea management remains as ineffective as it has been in the past, followed closely by the sea birds. The sight of a large cod will become a life time experience. The marine mammals will probably soon not need protection any more.

Doing the impossible

If we could scrap all fishing vessels, tow away the drilling platforms, replace tankers by pipe lines from the Middle East over the Alps and filter all PCB's from the water, would the North Sea then become as it was when sailed by the Vikings?

The answer is not necessarily yes. Some ecosystems have been so dramatically changed by man, that they will not return to the paradisaic situation without directed human interference. The Scottish Highlands were once covered with Scottish pine, but not a single seed can develop there now unless expensive measures are taken to drain the acid soil (?).

The North Sea is probably less influenced by man than the Scottish Highlands, but ecological theory acknowledges the possibility that ecosystems exhibit multiple steady states (May 1975) and that they do not return to some former equilibrium once they have shifted. In fact, when viewing life on earth on larger time scales, there is certainly no evidence that evolution makes loops. It may be equally unrealistic to expect that ecosystems would make loops. The marine ecosystem has become gradually adapted to the level of overfishing currently forced upon the North Sea, but how would a system know its way back?

The Dutch ministry of Transport and Public Works has set as its objective to reshape the quality of the ecosystem in the coastal areas to the situation that existed in the early thirties. At first glance this might seem a sensible approach, although there are some imminent problems. First of all, the situation at that time has not been very well described. Therefore, our managers, or rather their employees, have collected as much qualitative information about the occurrence of different species as they could and from these lists they have selected a small number of species which are to serve as guides in order to see whether they in the end will have reached their objectives. If there used to be porpoises and maybe a sturgeon now and again, they have to continue their efforts until the porpoises and one sturgeon are back again.

One can visualize an improvement in the water quality so that these animals could stay alive in Dutch coastal waters. However, in order to get them back they may have to put them in enclosures, because the life histories of these creatures are so complex that reintroduction in open sea areas are not likely to be effective. In addition, these administrators want the big cod back which means a reduction in the fishery, but at the same time there are many more small cod now than there were in the thirties, which means that they have to get rid of the juveniles by selective fishing.

The whole idea immediately leads to conflicting management actions and in my view is a rather unsensible approach. If we do not know exactly how a system works, and there is no hope that we will know this for a considerable time to come, it would seem better to restrict management objectives to clearly measurable and attainable goals. Trying to restore paradise is most likely to be a waste of money and time.

Doing one's best

The North Sea is a resource which serves a wide variety of functions or utilizations. In some respects it has to be considered as a renewable resource, in others as an unrenewable resource.

Among the renewable resource utilizations, shipping yields the perfect example. Any number of ships can be lined up and pass through the same water and still there is the same amount left. The same is true for fisheries, although here the restriction must be made that there is some limit as to the number of fish that can be taken to keep the resource renewable. In my view, the nature aspect of the North Sea can also be considered in terms of a renewable resource. People can enjoy nature and after nature has been enjoyed it is still there for others to enjoy. Although there is generally little economic return from a nature resource, one only has to consider books, films, public aquaria etc., or scientific research for that matter, to become convinced that marine nature and its derivatives represent at least some hard valuta. More importantly, however, a large pressure group wants an unspoilt North Sea containing every possible species that belongs there.

Using the North Sea as a refuse dump is clearly using it as an unrenewable resource. Sooner or later it will be filled up, if not literally than figuratively, because the sea will turn into a hazard to all human life around its edges. Oil industry as well as gravel extraction also belong to this category. There are limits to the total production and at some stage we have to face the bottom of the can. The difference here is that when the oil has been used up nobody has to worry anymore.

Given the multifunctionality of the North Sea, there are a large number of options for integrated management of these resources. The problem is to find a good compromise. Shipping is the easiest topic to deal with, because all problems resulting from interactions with other resource utilizations can be solved by safety regulations. In order to minimize chances for collisions among ships and between vessels and obstacles, the exclusive rights for shipping, fishing and drilling operations could be separated into geographically defined areas. Considering the large number of accidents where dangerous deck loads have been washed over the sides, there is also an apparent need for extending regulations for transport conditions of dangerous substances.

The oil industry does not necessarily interfere strongly with other users, but the hazards involved depend largely on the scale of the operations. The management options range from trying to get all the oil and gas out within as short a time period as possible to extending the production period by regulating the exploitation intensity. It is obvious that interference with other resource uitilizations will be smallest, when the latter option is pursued, while the cumulative returns to human society could remain the same.

The requirements for keeping the nature of the marine environment in tact as a resource for future generations are the most critical ones. Although nature is essentially resilient against disruptions, the resilience depends on the magnitude of the human impact. One important aspect is extinction. As soon as a component has been removed from the system, there is no guarantee that it can ever be introduced again and it is essentially lost to the resource. The best way to cope with this problem may be to set aside a nature reserve, a buffer area where interference from other resource utilizations is minimized. When in spite of all good intentions severe damage occurs somewhere else in the North Sea, the possibility is kept that these buffer zones take care of restoration. The fact that most organisms move freely over large areas within the North Sea would ensure those processes, although at the same time the interchange between water masses does make it difficult to ensure that these zones remain unaffected by processes taking place elsewhere.

Fisheries have traditionally been based on the principle of free access to all fishing grounds, but this principle has long been left. All types of regulations of these days interfere somehow with the individual freedom of a fisherman how and where to catch his fish. Fisheries management has nonetheless not been able to restrict overfishing on most fish species and it would seem worthwhile to try alternative methods. Direct effort control has in many respects clear advantages above the catch quota regime, but the national allocation of effort is problematic when different methods are employed. Nevertheless, management by catch quota should in my opinion be entirely abandoned and within EEC the emphasis should be directed to try and develop an effective effort control system in order to build up spawning stocks of large fish. In the mean time, area closures appear to be among the most effective measures that are presently taken. Although these have been so far based entirely on fisheries objectives, they could easily be combined with objectives from the viewpoint of nature conservation.

After the second world war, the mine fields in the German Bight prohibited fishing over a large area. Similarly, stoney bottoms were avoided by trawlers because gears were severely damaged. At present, the mines have gone and stones do not present much of a problem for many gears, which means that all reserves where fish could temporarily escape exploitation have effectively disappeared. From the fisheries perspective it would not be a bad idea to restore some of these reserves, because at this stage any type of protection seems better than no protection at all. And closed areas do not necessarily affect the total yield because fish are mobile enough to leave the area sooner or later, when they can be caught at a larger size. At the same time, areas of rich benthic communities could be saved from gear damage and nature reserves could also be scientifically interesting, because they would allow proper evaluation of side effects of fishing.

One of the inspiring thoughts behind multispecies assessment was that by fishing selectively for different species it might be possible to manage the species composition in such a way that the largest economic return would be obtained. Although this still appears to be true in principle, the scientific uncertainty about various processes, particularly recruitment mechanisms, would prohibit this approach unless fisheries managers would be prepared to face rather large risks. Moreover, the national politicians would have to agree on their priorities first. In my view, it is not realistic to assume that the Dutch and Danish ministers could ever agree on the relative importance of the beam trawl and the industrial fishery and therefore I do not see a bright future for sophisticated multispecies management. As a first step it would seem better to concentrate on effort reduction in order to stabilize the catch rates.

Pollution represents a type of resource utilization which for fundamental reasons cannot be brought into harmony with the use as a nature resource. It is a bad policy to wait until it is scientifically unambiguously proven that some substance is doing severe damage before forbidding to dump it, because by that time the damage will be done and the cure arrives too late. Moreover, by the very nature of oceanographic circulation anything released somewhere in the North Sea will spread virtually unrestrictedly over the oceans and any persistent substance may create problems far from the dumping area. And when a substance is not persistent and is claimed to be broken down by the system, it is always better to have it broken down before it is released into the environment.

Pollution can also not be combined with resource utilization for fisheries. The norms for contamination accepted in human food are generally well below the levels which affect population parameters of fish. Reports in the newspapers of mercury in fish have had in the past a marked influence on the market for fish products and this is probably a more important threat to the fisheries than via direct effects on the marine ecosystem. In so far, fisheries are more sensitive to pollution than the fish stocks themselves. The only way to reduce pollution loads on the system is by strengthening the regulations in the production process, not by setting norms for fish products.

In conclusion then, shipping, fishing, oil industry and nature could be maintained within the North Sea in future without too many problems if the different partners were prepared to compromise. A Doggerbank sanctuary shared by all coastal states might be a first step in this direction, but it will only survive if pollution is effectively overcome.

Green house effects

One of the processes that cannot be stopped anymore is the warming up of the world oceans and the rise of the waterlevel due to the green house effect. This aspect is receiving much attention in the Netherlands because it directly affects the safety of our population. The expectations for the rise in water level vary widely, but our ministry of Waterworks has accepted an average of 59 cm over the next century. Unless our government follows the option of strategical retreat on the higher grounds and thus would return a large nursery area to the North Sea plaice and sole, this will probably not be enough to change the North Sea ecosystem dramatically. It would add only approximately 1% to the total water volume and primary production would not gain at all because the depth of the photic zone rather than actual depth appears to be a limiting factor. There may still be secondary effects on the hydrography, although I am not aware of any predictions in this respect. If for instance circulation were increased due to larger transport through the English Channel and residence time decreased this might have a positive effect on water quality.

Increased temperatures are more likely to have an impact on the system, because several important boreal species like cod, haddock, plaice, herring and Norway pout approximate their southern limit in the North Sea, whereas lusitanian species like scad and whiting reach their northern limit. Some corresponding changes could be expected in the composition of the fish fauna, although this is not an easy matter. For sole, for instance, severe winters may cause a high mortality but they are also associated with extremely good year classes. Moreover, the hydrographical infrastructure of the North Sea, particularly in respect of stratification, depends to a large extent on the meteorology in our region. Therefore, the bottom temperature regime in the northern North Sea is probably more depending on the meteorological changes in western Europe associated with the global climatic change than with the expected temperature rise of the Gulf Stream.

In the southern part, however, a shift in dominance could be expected from boreal to lusitanian species and scad is marked as a winner in the time to come. More problems of anoxia in the shallow south-eastern part of the North Sea and maybe Adriatic conditions on our beaches belong also to the possibilities.

Conclusions

I hope I have made clear that there is considerable scientific uncertainty in respect of the quantitative effects of human activities on the North Sea ecosystem. Nevertheless, I am convinced that the resilience of the system is increasingly challenged and it would be over-optimistic to think that we can continue to abuse our environment without being punished later. The picture I have sketched of the future of the North Sea ecosystem on the basis of status quo conditions is certainly not very promising, but the sea will also not be a dead one. There is still time to improve the situation, if our societies would become convinced that some severe measures must be taken pretty soon to reduce our impact on the marine environment. Such measures would undoubtedly hit the industry hard, but the apparent short term losses will somehow turn into long-term gains.

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