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Fisheries research and management for the North Sea; The next hundred years

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Abstract

The type of management and research needed for the North Sea in the next hundred years will depend critically on developments in European society and the environment. It is possible to consider a number of extreme fates for the North Sea by extrapolating existing trends. These would include the North Sea as a basin-wide fish ranch or farm, as a huge marine park possibly with token fishermen as part of the system, as a tightly managed fishery or, as today, as a partially managed bunfight. Which of these fates overtakes it or how much of each occur is not easy to predict. Each will, however, require at least some element of management and hence appropriate types of knowledge to base the management on.

What might these requirements be and how might the fisheries scientists of the future approach them. From the last decades of fisheries science we can judge which problems have shown signs of yielding to investigations, for example some aspects of the multispecies problem, and which have proved intractable, for example the stock and recruitment problem. We can also extrapolate how our technical capabilities may extend, for example computer power, acoustic techniques, new mathematical methods and new research platforms. We can predict solutions to some of our problems but others we can perhaps predict will still be with our grandchildren.

Introduction *or* On Prediction and the Fate of Prophets

According to Niels Bohr, 'all prediction is difficult, particularly about the future'. G.K. Chesterton in the introductory chapter of his novel *The Napoleon of Notting Hill* explains the mechanism of this difficulty. He argues that the human race plays a game called 'Cheat the Prophet'. As he says 'The players listen very carefully and respectfully to all that the clever men have to say about what is to happen in the next generation. The players then wait until all the clever men are dead, and bury them nicely. They then go and do something else. That is all. For a race of simple tastes, however, it is great fun'.

The clear message of this wisdom is that only a fool or a knave would attempt to prophesy what the North Sea will look like in 100 years time and how the predicted fisheries might be managed. While I can claim excellent folly qualifications I have to confess to having flunked both pure and applied knavery in the 4th grade, consequently I need an alternative approach to prophesy. The only alternative seems to be to consider a series of scenarios sufficiently broad, so as to cover most eventualities short of Armageddon. The next section considers the biological foundations of this approach and the following section develops a factorial array of scenarios. The implications of some of these scenarios to the fisheries and their man-

agement is then considered in a rather extreme (science fictional) form. Finally some of the options for our future management of the North Sea are considered in the light of what we, or rather our great grandchildren may reasonably expect to know and what they probably will not be able to know.

The multispecies North Sea

Traditionally species management of fish species in the North Sea has been conducted on a single species basis. That is to say it was supposed that by a study of the life history parameters of a particular species it was possible to predict what would be the 'best' way of exploiting it in terms of the proportion of fish removed and the ages of fish on which exploitation was allowed.It is true that it was recognised, that where fishing fleets simultaneously exploited several species of fish, compromises would have to be reached between the 'best' ways of exploiting each species. This problem was called the technical interaction problem.

The attraction of arranging the management of fish on a single species basis is that it greatly simplifies the questions to be answered. Firstly the debate about the objectives of the management are confined to only those people with an interest in the catch of that species. Secondly the number of life history parameters to be estimated is small. Thirdly, and most importantly, the single species approach largely avoids the need for a detailed understanding of the processes by which young fish enter the fishery, the recruitment process. Providing the fishing levels do not reduce the spawning stock to the level where the numbers of young fish entering the fishery are reduced, it follows that the 'best' yield of a single species fishery can be calculated purely in terms of the average yield to be expected of an individual young fish entering the fishery (the yield per recruit). This feature of the single species approach to management is particularly useful since our understanding of the recruitment process is still very slight. We know that for many species recruitment fluctuates quite strongly from year to year and in a few cases, such as North Sea herring, we have some idea of how the numbers of young fish changes with spawning stock size. Moreover, even if we could understand what had caused fluctuations in recruitment in the past we would have little or no ability to predict it in future years except on a statistical average basis. This is because what drives the fluctuations are probably essentially unpredictable events such as weather.

All in all, then the single species approach to fisheries management appears to skirt round some of the more intractable problems of fisheries management and fisheries science. Unfortunately this enticingly simple approach is flawed because it assumes that fish species swim around in isolation and do not interact with one another. Andersen & Ursin (1977) argued that this comfortable assumption wasn't correct and that interactions between species had considerable effects on how the various species should be managed as a whole. The work of the ICES Multispecies working group confirmed these suspicions and set about providing multispecies management advice. The implications of this work are however less comfortable since: –

a) they show that the exploitation of one species will affect how another species should be exploited and thus widen the debate on the 'best' management of the

system. It also inevitably introduces economics into the question since the relative values of different species to different fishing fleets becomes part of the equation.

b) The model requires much more data and parameter estimates.

c) In making long-term predictions the absolute abundance of predators and prey species comes into the calculations and thus the recruitment process cannot be ignored in the calculation of future states of the system. It is, of course, possible to predict future scenarios under assumptions of average levels of recruitment but recruitment may well be subject to as yet undiscovered interactions which would perturb these average levels and perhaps overturn the predictions. Systematic climatic changes would of course have the same effect. The current situation then is one where we can suggest directions in which to steer the system but which will probably need mid-course corrections in the light of experience.

Despite all this it is possible to make some sensible empirical predictions about the future state of the North Sea based on the ideas of the conservative properties of size compositions. A recent paper by myself and colleagues at Lowestoft and Woods Hole compared and contrasted size compositions of all species of fish caught in the MAFF North Sea survey over the past 10 years with the combined size composition of fish caught on Georges Bank in the USA trawl survey which has been running since 1963. Some broad conclusions can be drawn from this work which seem to fit in with the conclusions of the ICES Multispecies Working Group. These are that the size composition at length is roughly loglinear over the size range 10 cm to 110 cm. That as fishing pressure increases on the larger fish the slope of the relationship changes so that there are corresponding more smaller fish. In the case of the Georges

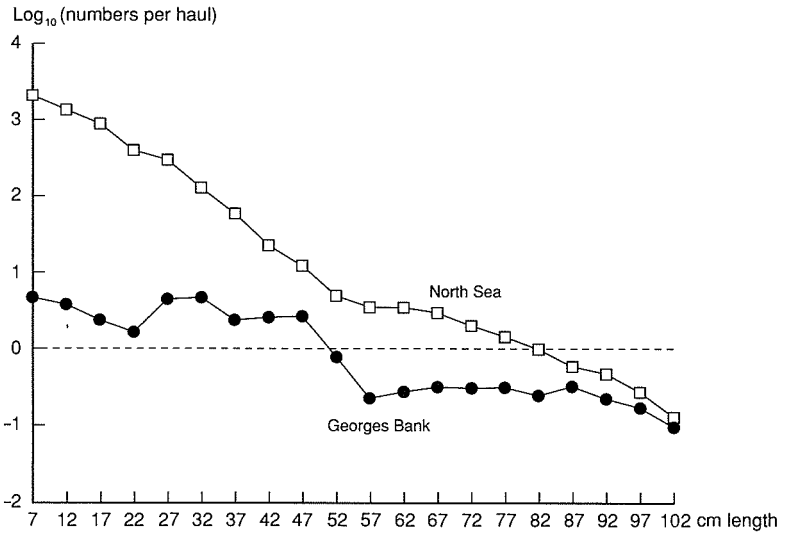

Fig. 1. Comparison of the total finfish catch at length per trawl haul on Georges Bank and in the North Sea.

Bank results there is also an indication that when only certain preferred species are fished from particular length groups then these tend to be replaced by those species which are only lightly fished. In the case of Georges Bank the commercially attractive species seem to have become progressively replaced by the unfished species of dogfish and skates and by silver hake (Figure 2). The virtue of these rules is they are not bound to a particular species assemblage as more detailed models are. Thus, while they present rather a simple picture they gives us some constraints to our imagination when we start thinking how the North Sea might look in a hundred years. In what follows, however outlandish the scenarios I develop may seem, they do try to hang on to these rules of how the North Sea might work in different circumstances.

Things that might change and how they might affect the North Sea fisheries

It is clear that in a hundred years things will change and that the North Sea of 2089 may not be like the North Sea of 1989 nor may the countries that use the sea be the same nor the world they interact with. What the changes will be however, is less clear so let us first consider some important factors which might change dramatically in the next 100 years and which must impact the system.

Firstly we should consider climate. Clearly 100 years is greater than the time scale hypothesized for significant 'greenhouse effect' changes so the North Sea might become warmer. Secondly, European populations might grow, stabilise or reduce in size. The economy of Europe might be richer or poorer in the next 100 years and the population might have more or less leisure to enjoy the wealth or endure the poverty.

Climate

If increased atmospheric concentrations of CO_2 and other greenhouse gases do cause global warming then we should regard it as inevitable that it will happen. Experience in fisheries gives a clear example that common property resources are difficult to manage and the atmosphere is perhaps the commonest resource of all. A few minutes reflections upon the difficulties of setting, let alone monitoring and enforcing CO_2 equivalent emission quotas should cure us of any optimism about the global communities ability to manage the problem. We can learn from the problems of multinational fisheries management that conservation of a resource does not impact all the players in the same way and that the balance of advantage to each country can be quite different. This makes international agreement on management policies difficult, while unilateral action only leaves scope for other players to increase their use of the resource.

All this is to say not that the greenhouse warming will occur but that if it does there will probably not be much that we can do about it beyond perhaps slowing down its effects. If it does occur then we can expect a warmer North Sea. Current predictions seem to favour atmospheric warming being more pronounced in winter than in summer but in the case of the sea this might translate into generally warmer seas. The effects of changes in winds is less clear so I will argue for a rather less windy North Sea.

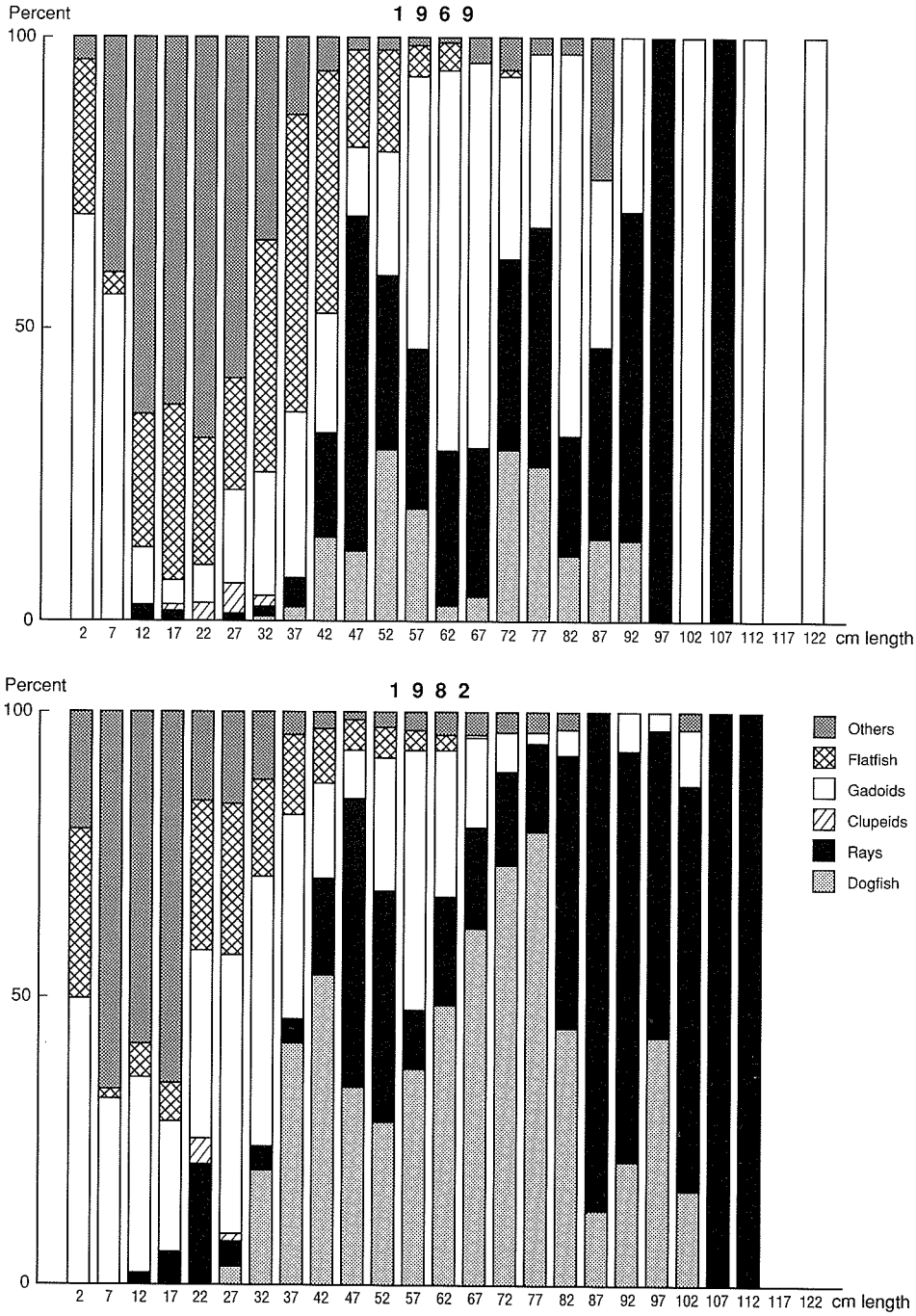

Fig. 2. A comparison between 1969 and 1982 of the percentage that various species groups form of the Georges Bank research trawl catch given by length group.

Economics factors

It is difficult to predict how the economy of Europe will change in the next 100 years. We can be sure that there will be changes but whether industry will have moved entirely to the Pacific rim leaving Northern Europe as a quiet non-industrial backwater or whether a common European market will generate an economic strength second to none on Earth remains very uncertain. Again we will reserve our judgement and consider scenarios for a richer or poorer Northern Europe.

Leisure

Whether Europe is richer or poorer or warmer or cooler we can imagine the population having more or less leisure in which to enjoy their wealth or endure their poverty. For example we can imagine a rich Europe so automated that the working week is reduced to a few days or we can imagine that richness is bought at the expense of hard work for long hours. Apart from these factors there are without doubt others which will impact the North Sea and its fisheries. Perhaps the most important will be the degree of technical advance. However, even these three factors allow us to consider 8 scenarios if we just consider the alternative options for each factor. Of these eight scenarios some seem recognisable as being similar to the situation in other parts of the world while others are terra incognito or as the old cartographers would have written 'here be dragons'.

Table 1 sets out various scenarios and what or where they remind me of. However, when it comes to the fuller development of these ideas, 'Art is long and time is fleeting', so this is confined to four of the scenarios (1, 4, 6 and 7) chosen to form

Table 1. The full factorial set of scenarios for a 2089 North Sea.

Scenario		Climate	Economy	Leisure	Current analogy	Dominant activity
A	1	Hotter	Richer	More	Florida	Sports fishing
	2	Same	Richer	More	Seattle	Commercial fishing + sports fishing
	3	Hotter	Poorer	More	West Africa	Artisinal fishing/foreign licencing
D	4	Same	Poorer	More	Terra incognito	Food production/waste dumping
	5	Hotter	Richer	Less	Terra incognito	Fish farming/quality artisinal fishing
C	6	Same	Richer	Less	Japan	Fish farming/ranching industrial fishing
B	7	Hotter	Poorer	Less	Terra incognito	Earning foreign exchange
	8	Same	Poorer	Less	Comecon	Commercial fishing/dumping waste

a latin square of the factors rather than as the full factorial design of eight. These scenarios of the North Sea foreign exchange earner, the North Sea fish farm and the North Sea larder are developed further below. They are all viewed from the perspective of a historian writing in about 2150 AD. They are revealed to us by the miracle of FUTUREFAX!

Scenario A: The North Sea as a playground

By the year 2050 the planet earth had warmed by 4.5 degrees Celsius and in the intermediate latitudes of the North Sea the temperature was considerable warmer and the seas calmer due to the northward migration of the wind belts and the attenuation of pressure differentials. The predominantly boreal species of the old North Sea had moved their distributions northward or become extinct and their place taken by more southerly species and by new species introduced or genetically adapted. The population of the Northern European Community (which succeed from the EC after a short civil war (the war of the Coconut milk subsidy) but was augmented by Scandinavia and all of Germany) was prosperous with its prosperity based upon the sale of intellectual rights. Manufacturing was for the most part done elsewhere and many of the population were leisured but technically able pleasure seekers.

The rise in temperature had brought about the predicted rises in sea level but with characteristic energy and vision the Northern Europeans had refused to sacrifice their low laying cities to the sea. This had been achieved in two stages. Firstly, to reduce tidal ranges by inducing interference patterns, parts of the Dogger Bank had been reclaimed as artificial islands. The development of genetically engineered coral and the concept of the floating reef made further massive sea defences feasible and eventually the southern North sea was enclosed along the line from the Flamborough Head to Horns Reef and from Dover to Calais. While justified on the overriding flood protection requirement this closure of the southern North Sea inadvertently produced one of the great playgrounds of the world. The sequence of events which lead to this were that

1. The lowered biological production of the North Sea coupled with a generally affluent population made commercial fishing a less attractive occupations for Europeans.
2. The warmer, clearer waters of the southern North Sea were becoming an increasing attraction to sport fishermen and to a series of other marine leisure industries (e.g. fish watching, wreck visits, submarine cruises). These interests in tandem with a rampant conservation lobby, which held that commercial fishing (particularly by trawl) created unacceptable effects on life in the sea, gradually succeeded in having legislation brought in to curb most commercial fishing activities. A few inshore fishermen did survive by potting and long lining coupled with working as longshore men for the extensive marinas but their presence had little effect on the North Sea stocks and they provided local colour rather than supplies of fish. Fish products were for the most part imported or synthesized.

By 2089 then the needs for fisheries science and fisheries management had changed very dramatically from the perceptions of the twentieth century. The main need was seen as providing an abundant and attractive variety of marine life. In particular there was a need to encourage the greatest possible numbers of the larger sizes of those species of interest to sport fishermen. (Large pelagics and sharks etc.) To do this it was necessary to introduce or adapt suitable species to create an ecosys-

tem adapted to the prevailing but still changing climatic situation of Northern Europe. This was only partially successful and the North Sea national park authority had to augment natural recruitment of some preferred species and also to develop control systems for undesirable species such as dogfish.

In short then the practical management of fishing was achieved by

1. Eliminating commercial fishing.
2. Tight gear restrictions on all remaining activities.
3. Expensive rod licences for sports fishermen.

These practical measures were underpinned by manipulations of the ecosystem to 'remould it nearer to the hearts desire' by both farming and stocking of desirable sport fish and by the partial control of undesirable species by a variety of techniques. Most prosaically this was done by delicensing fishing for these species or paying bounty for their capture. Other techniques, pheromone seduction of males away from spawning females, species specific pesticides, species specific diseases etc. were however increasingly adopted as being surer in their action.

Scientifically, the problems to be solved were

1. Problems of adopting and farming new species suitable for the system.
2. Development of biological control measures.
3. Ecosystem impact modelling to predict the new balances that would obtain with each introduction and the degree of control that might be implied. It was essential that these impacts should be reasonably understood before introductions were made rather than by observing consequences. This required an ability to predict the main life history parameters a species would have in the system from its observed physiology and behaviour. A further extensive field of scientific investigation was concerned with behavioural studies. These were not directed much at management problems, rather they provided an interpretation service for the tourist industry.

Scenario B:

The North Sea as a foreign exchange earner (or the Banana prawn republic)

Indeed the North Sea had warmed together with the rest of the world but the changing climate had served only to hasten the economic decline of Northern Europe already suffering from the movement of the earths economic centre of gravity to the Pacific rim. In the hard times suffered in late 21st century Europe there was much hard work and little leisure. The fauna of the North Sea had necessarily changed with the changes in climate leaving the North Sea less productive and with a preponderance of pelagic species. The military junta which was then controlling Northern Europe saw the North Sea as a means of earning hard currency (Chines Yuen, Federal Latin American Peso's) which were desperately needed for arms purchases. There was thus concentration upon tourism and upon export fisheries particularly shellfisheries. Shrimp fisheries augmented by artificial recruitment were particularly encouraged as being high earners and the resulting kill of juveniles of commercial fish species tended to depress still further the catch of the already de-

pressed commercial fisheries. The bycatch of young fish in the shrimp fishery was used primarily as food for fish farms producing some of the more sought after Asiatic species for sale on the far east market (snappers, sea breams etc.) and there was also production of exotic benthic species for the Chinese medicine market. The drowned remains of cities such as London provided artificial reef systems of interest to tourists and fishermen alike. Such off-shore fisheries as there were licensed to foreign off-shore fishermen for scarce foreign exchange.

The management requirements of this system were fairly minimal. The shrimp fishery was based upon an annual species and so was managed by suitable seasonal closures and by a landings levy to support the farming of young shrimp and other shellfish for release to the sea. We suspect that there was an element of graft associated with this arrangement since many farmers appeared to be related to the higher military. Drowned cities were recognised as sensitive ecosystems requiring gear restrictions (e.g. dynamite fishing was banned).

Off-shore foreign licences were limited to a fixed fishing effort level established on an ad hoc basis and sold to the highest bidder (or briber). Scientific inputs to the system were fairly minimal though Northern Europe supported one small laboratory and a research vessel which were supported by FAO funds.

Scenario C: The North Sea as a fish farm

The following quote is taken from the Financial Times review of the 21st century.

London 1st Jan 2100

'As one looks back over the past century one is struck by how few of the often predicted disasters occurred and yet how many of the positive predictions actually worked out. For example in the late 20th century there was wide spread fears of the 'greenhouse effect'. This was the name given to a predicted warming of the earths atmosphere consequent upon increased concentrations of CO_2 and other gases which it was believed could trap heat in the lower atmosphere. Viewed from our present perspective such fears were groundless, just another atavistic death wish like the earlier fear of Nuclear holocaust or the modern day fear of the ultimate moon virus. In retrospect such fears can be seen as the instinctive unease the human race has to its continuing success. Throughout the centuries there have always been those who called for us to repent while there was yet time but always there has proved to be much much more time than they allowed for.

Positive prediction have however more often been based upon closer understanding of the system and thus more likely to come true. Even so it seems probable that the continuing success of the single European market would have surprised even its creators. The unprecedented wealth it has brought to Europe is only exceeded by the moral improvement it has wrought in the working population with long and conscientious hours of work now seen as the measure of a man.'

In short then by the end of the 21st century Northern Europe was climatically much the same as a hundred years previously, the population was much wealthier than now but their wealth was based on outworking everyone else. The busy lifestyle of Northern Europe precluded many marine based leisure activities except

those that could be taken in fish restaurants. The North Sea was seen as a source of prime fish but it rapidly became apparent that it was more cost effective to rear these species in large sea cages, or in the case of salmon to ranch them. Competition with cage culture largely eliminated fishing except for deeper water industrial catches used for food inputs to the fish farms. The relative costs of producing a sole, turbot or cod by fishing were much higher than that of the cage raised animals that serious management of wild resources seemed unrewarding, though some limited numbers of wild fish were removed from Industrial Catches and sold at premium to speciality restaurants. The management of the North Sea became essentially akin to the management of land with cage anchorage areas being bought and sold like farm land. Active government based management was confined to monitoring that the organic and chemical outputs did not exceed limits specified for the site. This was achieved for the most part remotely using the so called spy in the cage. Since most installation were robot operated the monitoring service also had the right to randomly interrogate robot servers and as it was generally avowed 'no one has any use for a bent robot', compliance with these exacting water quality regulations were essentially complete. With respect to the industrial (fish food) fishery this was treated as though it were a single species. Management was through an industrial transferable quota system which had gradually transferred ownership to three fishing companies who managed the stocks to provide the maximum economic yield. While government quotas were set the companies themselves mutually agree measures to maximise profitable utilisation of the resource. The sciences bases of these industries were rather modest and mostly provided by and for the various companies. Most work was concerned with minimising the costs of the remote operation of fish cages and maximising production within the constraints of emission limits. The Government maintained disease diagnostic services and licensing services for chemotheroputants. A small government fisheries laboratory monitored the general abundance of the industrial fish be remote acoustic techniques but little else was needed.

Scenario D: The North Sea as a larder

In the year 2089 the climate of Northern Europe was sadly much as it has always been; cool, wet and overcast. The North Sea was also much as ever, dark, turbid and cool and productive. The Northern European economy was dark, turbid, cool and unproductive due to the move of advanced industry to the Pacific rim. Only basic dirty industries remained and there was much unemployment despite the centralised socialistic government, indeed there was even real malnutrition. The sea was therefore seen as 1) a useful extra source of food for the population and 2) a convenient dump for industrial wastes. The management of the North Sea was designed to maximise protein production regardless of species. The resulting catch was then processed into protein paste and reconstituted in various nutritious but uninviting formats. The practical management was arranged using effort limitation of a series of state owned fleets with different mesh and gear types. The objective being to create a fairly uniform fishing mortality of about 50% per year on all sizes of all species since this appeared to maximise protein production.

The science required to achieve this was relatively straightforward based upon

trawl and acoustic survey of size distributions on a quarterly basis. These served to apply corrections to the effort levels of fleets working on the various size and types of fish. Since the yield was considered only as a total and not by species these modifications could be fairly coarse and still meet the objective. Musing on the wonders of multispecies population dynamics developed in the late 20th century one can only sigh and say 'Sic transit gloria mundi'.

Discussion

The various scenarios develop disparate views of what the North Sea might look like in a hundred years time. However, despite the different solutions adopted for managing the North Sea under the different scenarios there is a unifying theme throughout. This is that in any circumstances we have to manage the system so as to create a species size spectrum in the North Sea which suits our purposes. However, given our uncertainties about the recruitment processes of fish we may have to manipulate the species mix in some way.

Under the playground scenario the managers had opted for a low exploitation system with lots of big fish and fewer small fish. They tried to manipulate the species distribution by a judicious manipulation of the species mix. They did this using hatcheries and by weeding out undesirable species. The foreign earnings scenarioists however went for a high exploitation rate with lots of small animals and few large animals. Again they tried to manipulate the species mix in their favour by hatching shrimps. When the North Sea fish farm strategy was adopted the Northern Europeans exploited the wild fish as a single species system for fish food but encouraged desired species by farming them directly. Under the 'larder scenario' the whole system was exploited for maximum protein yield, turned it into surimi and added flavour to taste. I suggest that this was done by exploiting all sizes fairly evenly but I am not sure this is in fact the best way of maximising protein yield. It might be done by an out and out fishery for small fish. But as Erik Ursin would have told me that might end you up with a size distribution of jelly fish.

Whatever our great grandchildren decide to do to the North Sea I expect they will be constrained by the North Sea system in similar ways to which the various scenarioists were in my examples. To manage it they will benefit if we understand the North Sea system in much better detail than we do now and if we also develop means to make the fish recruitment process more predictable. As for our grandchildren, I trust their ingenuity enough to suppose that they will bend the system to suit themselves even better than my scenarioists did. In any case I am sure they will 'Cheat the prophets'. Perhaps they will even make the CFP work.

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