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Stability and the objectives of fisheries management: the scientific background

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Abstract

Everyone would like more stability in fisheries, but it is difficult to achieve because of the very large fluctuations of recruitment to most fish stocks. Maximum stability would be achieved with no fishing, when the stocks would be large, and contain many yearclasses. Even so, there would be quite a lot of variation in the longer term, entirely due to natural causes.

In many cases we are at the opposite extreme for many stocks in the Northeast Atlantic, with very high fishing rates and stocks that depend on only one or two yearclasses. This both emphasises the fluctuations, and makes it much more difficult to make accurate catch forecasts. If fishing effort is kept constant, the catch, and therefore the Total Allowable Catch (TAC), will vary from year to year, just because of recruitment variations. For lightly exploited stocks it would be possible to keep the TAC constant, and let the stock take the strain. However, this would mean that fishing effort would have to vary from year to year - the TAC would sometimes be taken early in the year, and at other times could not be taken with the usual level of fishing effort. This is also a very risky strategy on a highly exploited stock, and could lead to stock collapse. The fundamental problem is that it is impossible to have both constant catch and constant effort at the same time. A substantial reduction of fishing intensity (around 40%) would certainly help improve stability, but the ideal is unattainable.

The profitability of fishing depends on the catch-rate, which depends strongly on the stock size for most demersal stocks. To maximise profitability would, like maximising stability, mean reducing fishing effort to zero, to give the biggest possible stock. This is not likely to be an acceptable objective. Total yields can be maximised by fishing at a moderate level, so that the death rate from fishing is not more than about double that from natural causes. Maximum Economic Yields (MEY's), after deducting the costs of fishing, would be attained at a somewhat lower level of fishing intensity.

In practice, individual fishermen can still be fishing profitably when total fishing intensity is much higher. Market forces tend to drive fishing effort up to levels well beyond those which would be considered desirable. This is the 'tragedy of the commons', translated to the sea. These natural economic forces may in fact drive levels of exploitation up to the point where the stocks collapse. Sustainability, too, requires moderate levels of fishing. Thus profitability, productivity, and sustainability all require fishing effort to be restrained.

Catching and discarding small, immature fish makes matters quite a lot worse. Eliminating this wasteful process would be the single most effective conservation measure that could be taken for stocks such as North Sea haddock, where it is a major problem.

Finally, it is important to recognise that the benefits of reducing fishing effort - larger stocks, higher yields, improved stability, and higher profitability - can only be maintained if the fishing effort is kept down indefinitely. The reductions required are permanent: the effort cannot be allowed to increase again, and no more fishing boats will be needed, even when the stocks have been rebuilt. The price of profitability is eternal regulation.

STABILITY

Everybody agrees that stability in fisheries would be a Good Thing. Fish processors would like constant supplies, and the fishermen would like constant catches (or possibly constant earnings) so that they can plan their investments in new boats, and not get caught out on the loan repayments. The administrators would like the same TACs from year to year so that they could just use last year's deal again this year, without re-negotiating everything, and the scientists would like the stocks to stay put for a while so that they could have a better chance of figuring out what's really going on.

Unfortunately, nobody has told the fish what they're supposed to do, and most of the stocks in the North Atlantic fluctuate enormously, mostly because the number of young fish recruiting to the stocks each year is very variable indeed. This is because only a tiny fraction of one percent of the eggs spawned each year survive the first year of life. Any slight change in that enormous death rate means a big change in the final numbers of survivors. The fluctuations are believed to be due to subtle changes in the weather and currents at certain times of the year. They don't seem to have much to do with how many bigger fish there are to produce the little ones, or indeed to eat them up. They certainly aren't due to anything very obvious, or someone would have figured it out long ago. There are still a lot of people trying to find out what causes these fluctuations, but don't hold your breath while you're waiting for the answer.

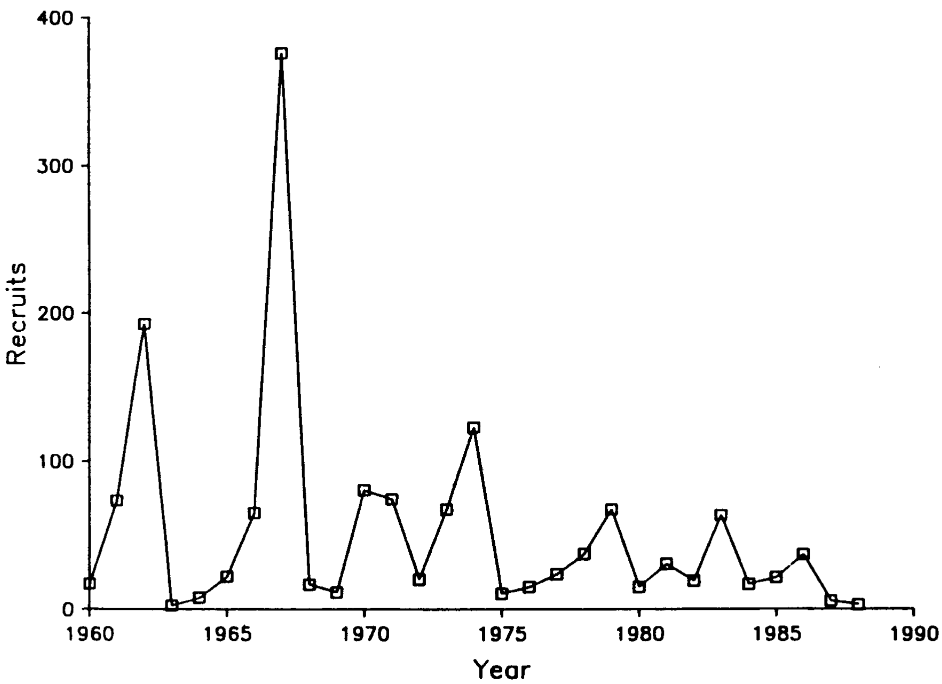

Figure 1. North Sea haddock: recruitment

You can see the sort of thing which happens in Figure 1. This shows the number of young haddock recruiting to the North Sea stock from 1960 up to 1988. The number varies wildly from year to year; quite often it's more than double, or less than half, the average, and every now and then there's a real ringer - the enormous 1967 yearclass, for example, or the tiny one of 1987 - the smallest on record, the one that's led to the scarcity of haddock in the North Sea right now. Haddock stocks often exhibit more variation than most other stocks, but the Northeast Arctic cod provides another example (Figure 2). Here there are also big fluctuations in recruitment, but they seem to be a bit more systematic. The number of young fish seems to go in cycles, with a period of 6 or 7 years. We don't know the reasons for this cyclic behaviour, but it certainly seems to be there. In both cases there also seem to be some long-term changes, with good recruitment before 1975, and not so good since then.

Now, what are the consequences of these variations of recruitment?

First, they mean that the stock size varies - and if the death rate of the fish is high, so that there are few older fish, then the stock size may vary a lot. This is just like putting money in the bank; if you pay in highly variable amounts each month, but take out and spend half of what is there every month, you wouldn't expect your total balance to stay constant. If, on the other hand, you only take out 10% each month, you will accumulate something like a year's worth of money. And with a nice big balance like that, you wouldn't notice the effects of the variability of the monthly amounts nearly so much.

Exactly the same is true for fish stocks - except that fish usually take a few years to grow up and join the fishable stock, so there's a time lag involved.

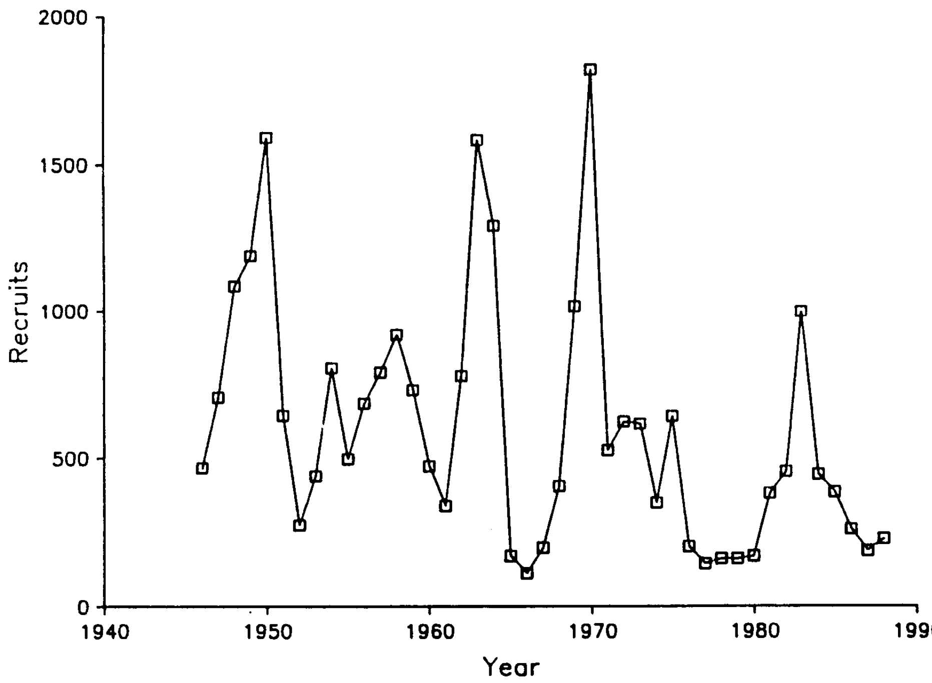

Figure 2. Northeast Arctic cod: recruitment

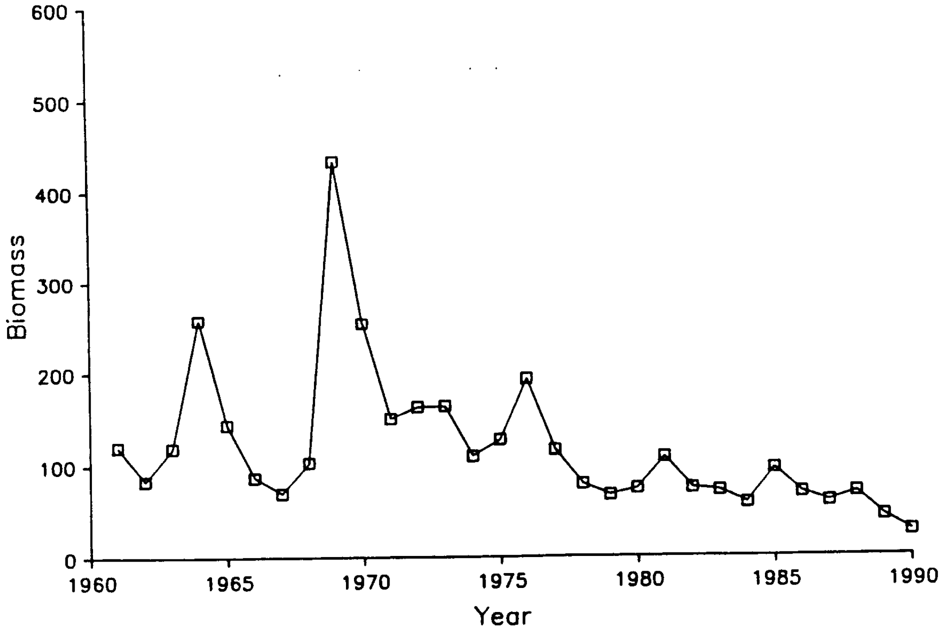

Figure 3. North Sea haddock : stock size at 30% fishing rate

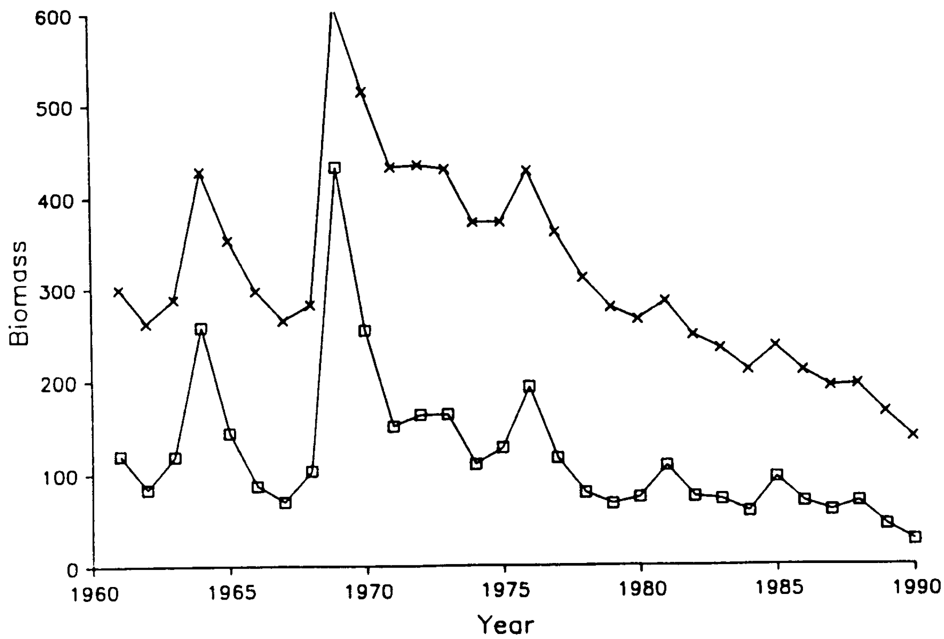

Figure 4. North Sea haddock: stock size
Upper line - no fishing; lower line - fishing rate = 30%

Figure 3 shows what the fishable stock of haddock would have been with a moderate death rate from fishing of 30% per year over the period 1961-1990, based on the recruitment figures you saw before. You can see that it varies quite a lot - not so much as the recruitment, because even with this death rate there are still several yearclasses contributing to the stock at any time. But it's a long way from being constant.

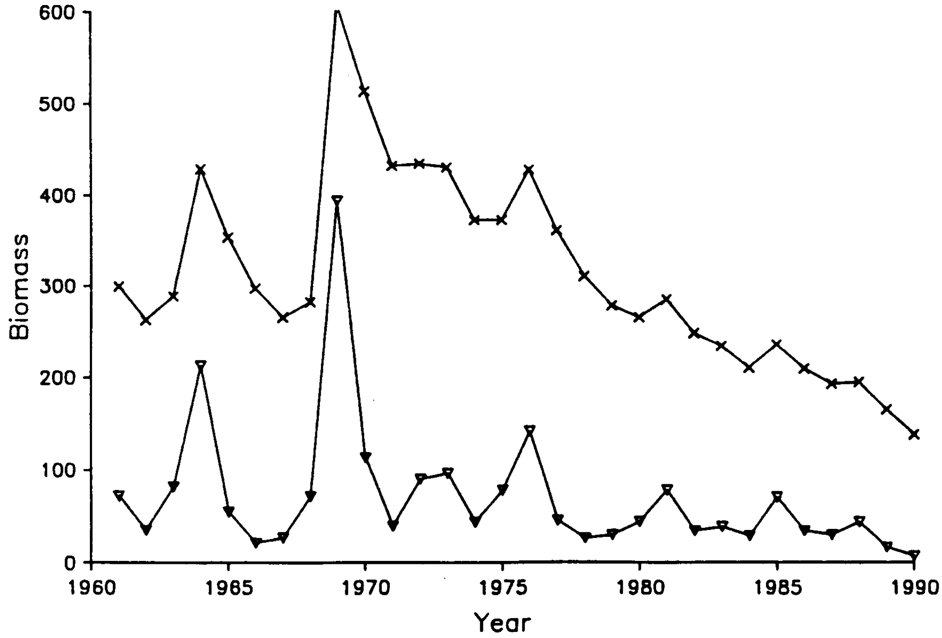

Figure 5. North Sea haddock : stock size
Upper line - no fishing; lower line - fishing rate = 70%

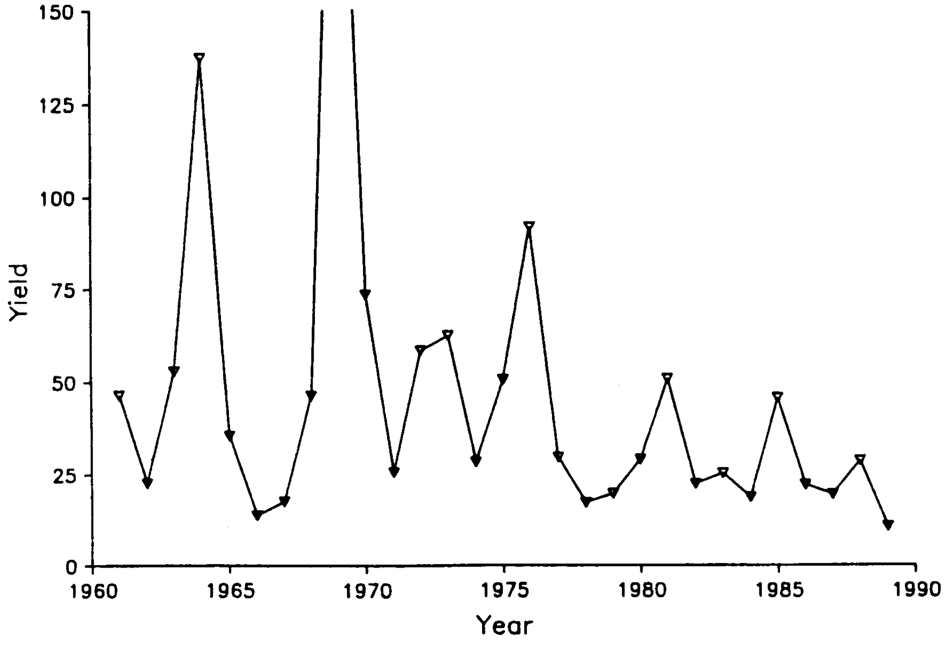

Figure 6. North Sea haddock: yield at 70% fishing rate

With a lower death rate, you would have a much bigger stock, and much smaller fluctuations. If you really wanted maximum stability for the stock, the best you could achieve, **with no fishing at all,** so that deaths are due to natural causes only, is shown in Figure 4.

It's still quite variable over long periods, though the year to year fluctuations are quite small - and that's with no fishing. The first picture for a 30% death rate is closer to the real situation - in fact recently the death rate has been even higher than that, near 70%, and the effect on the stock is shown in Figure 5. The fluctuations are severe, and the stock crashes to very small levels in bad years - just because the death rate is so high.

Well - so what if the stock size does fluctuate? That's tough for the fish, but should we care? Unfortunately, yes, for demersal (bottom-living) fish at any rate. The fisherman's catch rate, in boxes per tow or whatever, is roughly proportional to the stock size. So a variable stock means variable catch rates, and that means variable earnings, with good years and bad years - a situation with which any fisherman will be only too familiar. This was always the situation, long before TACs were implemented under the Common Fisheries Policy, and it will stay that way.

Let's see what this means for catches and TACs. Figure 6 shows what the catch would have been over the last 30 years if we'd fished at the current very high rate for the whole time. This is also what the TACs would have been if we'd had them that far back, assuming we'd adopted a constant effort strategy. You can see that it's very much boom and bust, with big variations from one year to the next. With a fairly low level of fishing, taking 30% of the stock each year, the TACs would be as shown in Figure 7 - lower in the boom years (when there could well be marketing problems anyway), a bit better in the bad years (though you can't buck the long-term trend for long), but not crashing up and down nearly so violently.

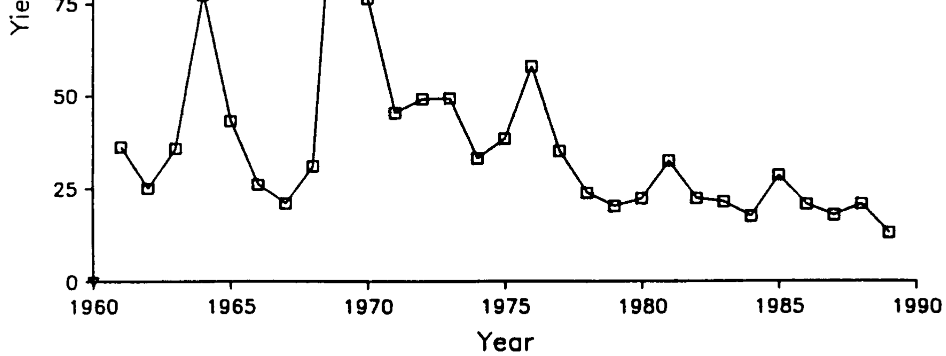

Figure 7. North Sea haddock: yield at 30% fishing rate

Unfortunately, that level of fishing corresponds to a massive 75% cut in fishing effort, and would be very difficult and very painful to achieve, even if spread over many years. More realistically, we can see what would happen with a 40% cut in effort - still painful, but probably achievable over two or three years, given the will to do it. This would lead to TACs like those of Figure 8. Here the good years are a bit better, and the bad ones no worse. It's a useful improvement on the present position, anyway, even though this year (1989) would still be the worst on record. Two really poor yearclasses in a row is still enough to cause a lot of trouble. At the end of the day, everything still depends on the recruitment, and that's something we still can't forecast before it happens, let alone control. We can only observe it in our surveys as soon as we can, and base our forecasts and advice on those estimates.

This is the main cause of varying catches, and varying TACs. It's not due to mistakes by scientists, or by politicians - though there are a few of those, of course. The main cause is simply mother nature, aided and abetted by all of us - scientists, politicians, administrators and fishermen - because between us we've let the fishing pressure get too high, and made the situation worse.

Well - suppose we could get the fishing pressure down a bit. That would reduce the fluctuations, but they'd still be there - still big enough to give us TACs that varied up and down by something like 30% or 40% each year, even if fishing effort were held constant. Do you want catches that are more stable than that, from year to year? If so, there are only two ways - reduce the fishing pressure even further - and that means fewer fishermen and fewer boats - and keep it that way. Or vary the fishing effort, with short seasons or fewer

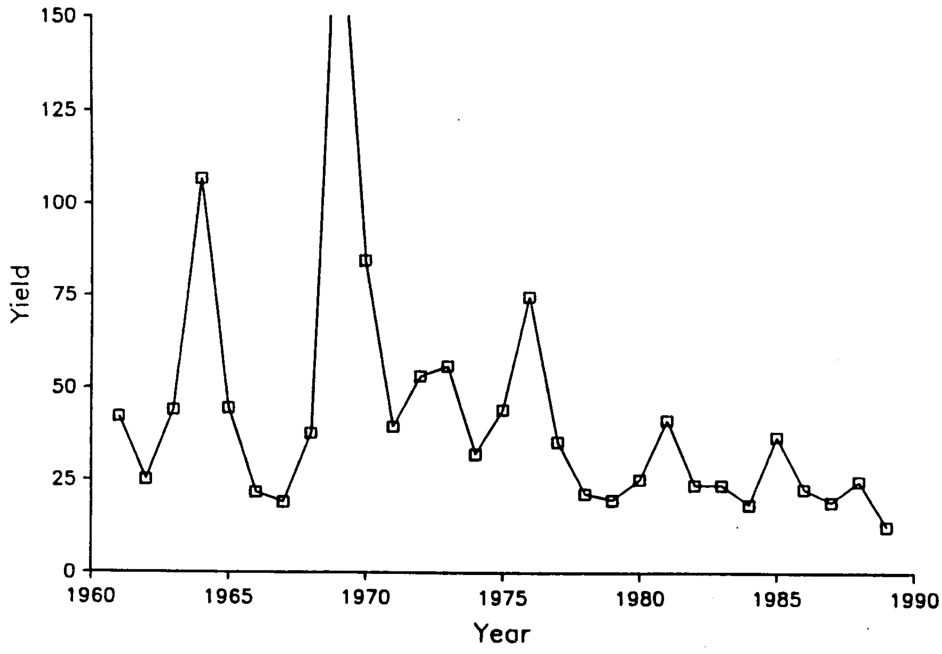

Figure 8. North Sea haddock: yield at 50% fishing rate

trips in one year and more in the next. That's certainly possible, but be warned - the changes of effort needed are big - even bigger than the variations of catch if you keep the fishing effort constant. And you'll be fishing flat out to try to take the quotas in a bad year, and forced to tie up in port when the stock is high and the fishing is good. That's what constant catches and constant TACs mean in reality. If you really want that, the managers can arrange it - but I don't really think you do. I think you want constant catches and constant effort - and you can't have that. It's not on offer: not because the scientists and politicians and managers don't care, but because mother nature doesn't work that way.

In fact we've recently done some fancy sums in collaboration with some control engineers at Oxford University, to see what you would have to do if you really wanted to minimise variations of **both** catch and effort at the same time. The answer's pretty obvious when you think about it. If the stock is in good shape, with low fishing pressure, you can reduce fishing effort when you get good recruitment, and still get better catches. When recruitment is poor, you have to increase the fishing effort to try to keep the catches up, in an attempt to 'fill in the troughs' in the bad years. That means you let the stock take the strain - you fish it down even further when it's depressed. That's obviously a pretty dangerous strategy, and in fact is only viable when the fishing pressure is low. When it's high - and it's very high for most stocks in the Northeast Atlantic - it turns out that the best you can do is to keep fishing effort constant, and hope for the best. And that's pretty much the basis on which most TACs have been set for the last few years. If we could get the fishing pressure down - especially on young immature fish - by a significant amount - something like a 30% reduction as a minimum, then we'd have more room for manoeuvre. Until then, there's no point in trying to be clever - we just have to try to reduce fishing effort, ride with the natural fluctuations, and hope for the best. If we have to ride this roller-coaster, we should at least make sure we've got the brakes on.

OBJECTIVES

Stability is one possible objective for fisheries management, and as we've seen, it's going to be pretty difficult to achieve. But there are lots of other possible objectives, and it's worth seeing what they all mean when we come to think about management.

First, of course, comes **money**. The profitability of a fishing trip depends on how much you catch, and that depends on how many fish there are in the sea. We can calculate how many fish there will be of fishable size, from a yearclass of a given size, for various levels of total fishing pressure, and this is shown in Figure 9.

Not surprisingly, the stock size goes down as the fishing pressure goes up. The fish are killed off quicker, so they aren't around so long. That means we have a simple answer. If you want to maximise the profitability of fishing, you should reduce the total amount of fishing to the lowest possible level. That means the last fisherman has no competitors - so he does fine!

But it's pretty obvious that that's not a sensible objective. Why should one man stay in business making fat profits when the rest are forced out? The supply of fish to the market from that last boat would be pretty small too. There's another possible objective - fish supplies. How should we maximise those? We can calculate that too - that's shown in Figure 10.

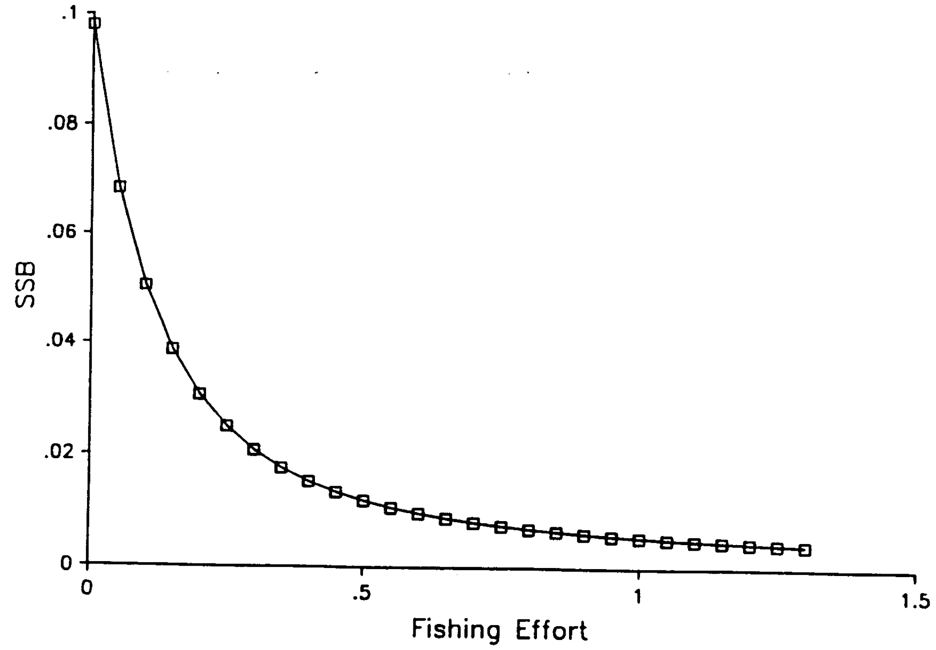

Figure 9. North Sea haddock : spawning biomass per recruit

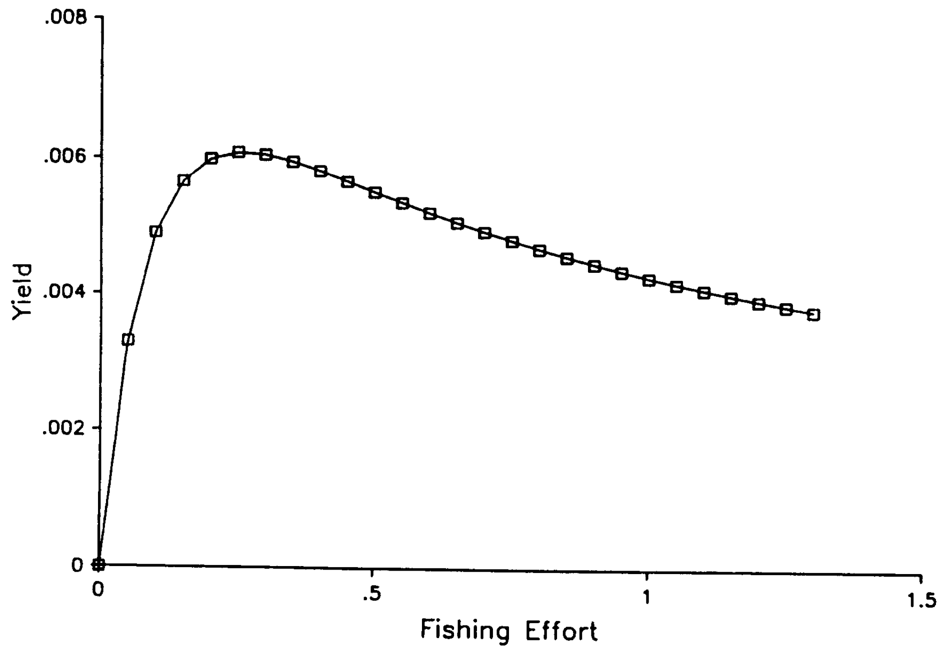

Figure 10. North Sea haddock: yield per recruit

As you increase fishing effort from zero, at first the catches go up in proportion. But pretty soon you get to a state of diminishing returns - the curve starts to level off. And pretty soon after that, it <u>does</u> level off, so you get <u>no more</u> fish from the increased effort. You're just sharing out the same catch between more boats. If you still increase fishing effort beyond this point, you actually get less fish from increased effort.

Not just diminishing returns - we've all heard about those - these are negative returns. So, if you want maximum fish yield, you only want moderate fishing pressure. In practice, you don't usually want the fishing mortality to be more than about double the natural mortality (typically about 20% per year). This level of fishing, that would give a maximum yield from a given level of recruitment, is described by a number called F_{max} that you'll often see in the tables of catch options that ICES* working groups and ACFM+ provide. It's a possible target level for management, but by no means the only one. In fact the curve is often quite flat-topped, so you get more-or-less the same yield over a wide range of fishing effort. That means there's no point in fishing very hard.

However, increased fishing effort means increased costs - more boats, more men, more fuel. Obviously, when you start getting negative returns (reduced gross earnings) in total, you've gone too far. But if you take account of the costs, it's obvious you should stop increasing fishing effort before you reach that point. With the help of a friendly economist, you can calculate that too. The point of Maximum Economic Yield (MEY) always corresponds to less fishing effort than maximum landings or maximum earnings. How much less depends on the balance of costs and earnings. If you can't find a friendly economist (quite likely these days), you can calculate something called $F_{0.1}$ which is a substitute for MEY. It's quite popular as an objective of management in some parts of the world (e.g. Canada), and invariably corresponds to low values of fishing mortality: usually roughly equal to the level of natural mortality, and certainly less than $F_{max.}$

From the point of view of an individual fisherman, however, this isn't the main point. He usually cares about his own profits, not those of fishermen as a whole. At a low total level of fishing mortality his profitability would probably be very high. In fact, an individual fisherman may still be fishing profitably when the fishing pressure is way above this MEY (or $F_{0.1}$) level. It may indeed still be high when fishing pressure is way above the level for maximum total earnings, and well into the region of negative returns.

This happens, and this is why fishing pressure has increased on so many stocks, and continues to increase while the scientists continue to say that it's much too high. In an unregulated fishery this means that more and more fishermen fish harder and harder, and drive the stock down to the point where fishing becomes unprofitable, and the stock may collapse. This is the 'tragedy of the commons' applied to the sea, and it's been repeated over and over again, all around the world. It's not that anyone is doing anything wrong or unreasonable. It's just the natural effect of market forces operating. For many industries the operation of market forces leads to many benefits, and is generally a Good Thing. But unrestrained market forces cause serious problems for fisheries, because these are based on a finite, and fragile, renewable resource. The combination of unrestrained market forces and the basic biological facts of life is almost invariably disastrous in this case. This natural interplay between the biological and economic facts of life has indeed led us to the present position, where most fisheries in the Northeast Atlantic (not just cod and haddock in the North Sea) are fished at levels of intensity way above those indicated by the F_{max} and $F_{0.1}$ reference points, with yields less than the maximum obtainable, and stock sizes only a fraction of what they could be.

**The International Council for the Exploration of the Sea*
+The Advisory Committee on Fisheries Management

What about the fragility of the resource? Fish stocks do collapse. North Sea herring, Atlanto-Scandian herring, North Sea mackerel, Georges Bank haddock ... the list is quite long, even close to home. So sustainability of fish stocks, and the catches which they can yield, is another potential objective for management. The processes leading to stock collapse are poorly understood. The big natural fluctuations correspond to excessive noise, and we have trouble finding the signal in amongst that noise. We know that zero stock means zero recruitment, but usually have difficulty deciding just how low a stock has to be driven before the risk of recruitment failure becomes serious. But there's no doubt that in most cases, to be reasonably sure of sustainability means aiming for a fishing mortality that's quite low - certainly no more than another reference point called F_{med}. Above that level of fishing mortality the risks of collapse start getting serious - higher than 50 : 50 in the long run. Below it, collapse shouldn't be too much of a worry, though nothing can be guaranteed in the natural world.

Finally, what about employment? In the last decade unemployment has been a serious problem throughout Europe and North America, and creating jobs has often been an over-riding objective. For fisheries this means increased fishing effort, obviously. It's a pity that this is the opposite of most of the other things I have considered.

To summarise, there are two possible objectives that would argue for high fishing effort: employment, and individual earnings in the short-term. All the other possible objectives we have mentioned - maximum total landings, maximum total earnings, high stability, sustainability (low risk of collapse), profitability, high stock size - all these indicate low, or at most very moderate, levels of fishing effort. There is a genuine conflict, and the whole question is very complicated, and it really doesn't help to pretend that there is a simple answer. There isn't. Somebody, somewhere, has to figure out which of these objectives is most important. Then we can try to manage in the appropriate way. We really need a constructive dialogue between fishermen, scientists and managers, and up to now that's been pretty difficult to achieve.

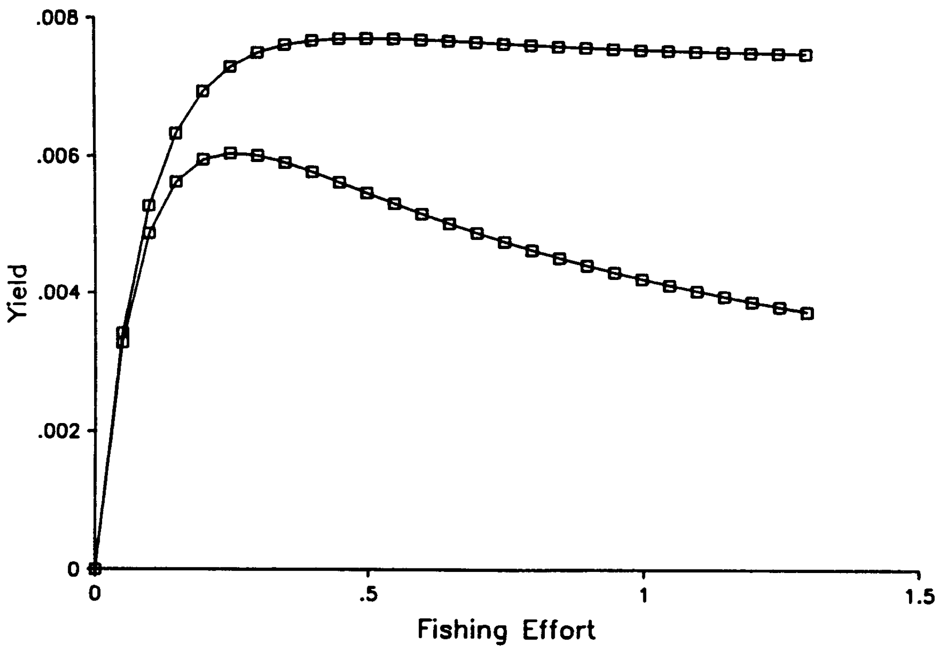

Figure 11. North Sea haddock: yield per recruit
upper line - no discards
lower line - with discards

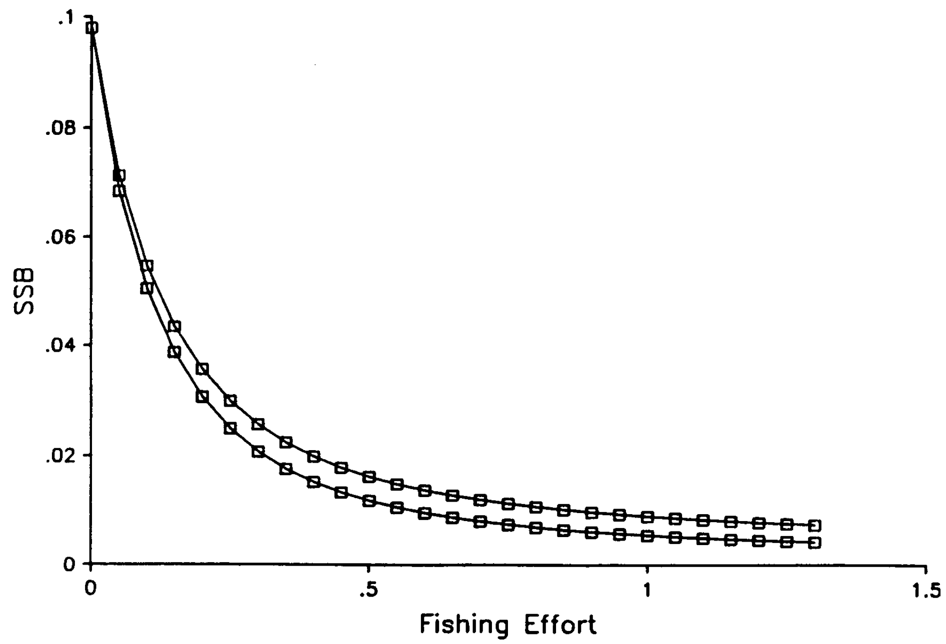

Figure 12. North Sea haddock: spawning biomass per recruit
upper line - no discards
lower line - with discards

Before leaving the subject of objectives - what about discarding of small fish? I'm sure everyone realises that catching, killing and discarding young fish is very bad for the stock, and for the future of the fisheries that depend on it. It's a particularly serious problem for the North Sea haddock stock too. Just how serious can be seen from Figure 11, which shows how much extra yield could be obtained (upper line) if it were possible to eliminate the extra deaths of young fish entirely. One could almost double the yield at present levels of fishing intensity. Figure 12 shows the effect on the spawning stock size. This doesn't look so impressive at first sight, but it does still represent almost a doubling of the present depressed stock size, for the same level of recruitment. Of course it would be very difficult to eliminate discards entirely, but there's no doubt that a lot could be done by using more appropriate fishing gear, and avoiding times and places where the young fish congregate. A major reduction of discards would be the single most rapidly effective conservation measure that could be applied for this stock.

There is one other thing which is often misunderstood, that ought to be mentioned. Suppose we accept that fishing effort ought to be reduced, say by 30% as a minimum, to increase the stock size, improve profitability and stability and so on. For how long does the effort have to be kept down, before it can be increased again? There is an unpleasant answer to this question: the answer is, for ever. If the effort is kept down for a few years, the benefits should begin to appear. The fisheries will become more profitable, and everyone will want to increase his effort, maybe get another boat, or one for his son. But if this is allowed to happen, the effort will increase, and after a couple of years things will be back where they started. The uncomfortable truth is that maintaining healthy fish stocks means permanent restriction of fishing effort, to a level less than market forces would allow. It's not just one spoonful of bitter medicine that has to be swallowed. It's more like a rigorous diet that has to be followed for the rest of your life. Thomas Jefferson said that the price of liberty is eternal vigilance. For fisheries, we could say that the price of profitability is eternal regulation. That may be an unwelcome conclusion, but I'm afraid it seems to be true.

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