2. Fisheries: taking stock

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Fisheries have had to deal with uncertainties — with attempts made to manage them — for centuries. The topic is therefore doubly challenging as, while the underlying precautionary principle is the same as for pollutants, the practical approach to implementation is necessarily very different.

'Late lessons' is certainly an appropriate topic for marine capture fisheries. Awareness of events such as those described here — from the Middle Ages, through to 19th century Scottish fisheries, the mid-20th century Californian sardine fishery crash and the collapse of Canadian northern cod stocks in the 1990s — provide a sometimes gloomy awareness of history repeating itself. But there are also positive things to learn from the past. The need for an explicitly precautionary approach has been increasingly recognised in the last decade. In areas such as the North Atlantic, the principal problem now is finding a means to allow fishers to turn theory into practice, against the backdrop of short-term economic pressures.

2.1. Early warnings

The relationships between precautionary attitudes, cultural perspectives, technological ability, and risks and benefits, are complex. In a sense there is nothing new in varying degrees of precautionary management, and warnings of the risk of overexploitation. There is some evidence that certain Native North American communities may have died out because they overexploited marine resources. Others, however, circumscribed their catches by rights and taboo, re-enforced by knowledge of fish ecology. They maintained substantial catches for centuries, for example of salmon, in contrast to the commercial fishers who displaced them and extinguished the stocks (McEvoy, 1986).

In medieval Europe people were also aware that fish could be overexploited. An early call for precautionary action comes from 1376–77 (March, 1953). A petition was presented to the English parliament calling for the prohibition of a net 'of so small a mesh, no manner of fish, however small, entering within it can pass out and is compelled to remain therein and be taken... by means of which instrument the fishermen aforesaid take so great an abundance of small fish aforesaid, that they know not what to do with them, but feed and fatten pigs with them, to the great damage of the whole commons of the kingdom, and the destruction of the fisheries in like places, for which they pray remedy.' The response to this assertion was to set up a commission 'by qualified persons to inquire and certify on the truth of this allegation, and thereon let right be done'. Between then and the late 19th century there were numerous attempts in England (as elsewhere) to regulate fishing by still familiar means (such as, in 1716, a minimum mesh size, a ban on circumvention by placing one net within another and minimum fish landing sizes).

2.2. 19th century British fisheries

In the 19th century British fisheries, as elsewhere, grew rapidly. Uncertainty about the consequences for the valuable herring fishery, and the expansion of trawling for other species (recently unearthed by a 'lay' Wick inhabitant, historian Ian Sutherland (Sutherland, n.d.)) provoked, among other events, a series of official enquiries between 1866 and 1893 (Report, 1866; Report, 1885).

2.2.1. Scottish herring fishery

Many marine fish species markedly fluctuate in abundance as a result of natural causes. In this, herring and its relatives, such as sardine, can show extreme changes over tens of years. Given this context, it took a long time for it to be accepted that fisheries could exacerbate such natural cycles. In 1865 the prescient James Bertram (Bertram, 1865, pp. 277–282) documented inshore Scottish herring catches between 1818 and 1863, when the area of drift nets carried per boat grew from 4 500 to 16 800 square yards, yet the catch fell from 125 to 82 crans (barrels). Such figures spoke too plainly to him to 'expend further argument'. He wrote 'I have always been slow to believe in the inexhaustibility of the shoals, and can easily imagine that overfishing, which some people pooh-pooh so glibly, could easily be possible... As it is, I fear the great Wick fishery must come some day to an end. When (it) first began the

fisherman could carry in a creel on his back the nets he required; now he requires a cart and a good strong horse.'

Subsequent action or inaction
Bertram's words proved prophetic. Yet several decades later Thomas Huxley, President of the Royal Society and Inspector of Fisheries (no fool, yet now infamous for his comment that 'marine fisheries are inexhaustible' (Huxley, 1883)), could still maintain for British herring in general 'nothing to show, so far as I am aware, that, taking an average of years, they were ever either more or less numerous than they are at present' (Huxley, 1881), while in 1893 a parliamentary committee also saw 'no indication of any falling off in the numbers of herrings to be found off our coast'. Presumably landings were equated with stock size, without allowing for increasing effort, area covered and length of season.

In the 1890s the German Heincke established, contrary to general belief, that herring existed as isolated races, implying management at this level. But by then the innermost shoals of Wick and the Moray Firth were gone. The fishing moved further offshore and, overall, North Sea herring landings fluctuated without trend during the first half of the 20th century. This was not so much due to lessons learned and action taken, but to turmoil in the continental European markets that restrained the technological potential of the new motorised drifters. When an 'industrial' fishery for fishmeal and oil subsequently developed in the second half of the 20th century, both the new technology and the necessary safety margins were underestimated. This brought the North Sea herring to the brink of collapse by the 1970s, forcing a moratorium on the fishery. The stocks did recover, and the industrial fishery upon herring was subsequently restricted when fishing reopened; nevertheless the pressure from 'human consumption' fisheries remained so great that, by the mid-1990s, further emergency measures had to be imposed, until once more the stocks recovered. Although we appear to have learned enough by the late 1990s to stave off total collapse, it was hardly a model of effective management.

2.2.2. The advent of steam trawlers
Another major development of the late 19th century was steam-powered trawling for 'demersal' fish (such as cod, haddock, whiting and flatfish). This allowed access to areas too dangerous or inaccessible for sail or oar (a natural equivalent of modern 'no-take' zones), and increased the ability to drag and haul nets, resulting in much bigger catches. Trawling divided scientists and fishers alike. The principal complaints were that trawling destroyed spawn on the seabed; caught immature fish; resulted in wastage through damaged fish; interfered with other fishers; and that trawlermen — mobile outsiders — depleted the traditional grounds of others. Interestingly, in 1883 trawlermen based in Yarmouth themselves voluntarily agreed not to work certain offshore grounds at certain seasons to avoid catching immature fish, although this was undermined by other trawlermen and abandoned.

Subsequent action or inaction
In 1865 Bertram raised such accusations against trawling, although he also thought it was, used wisely, the best tool for certain fisheries (Bertram, 1865, p. 308). By 1883 another parliamentary enquiry had commissioned research which concluded that the immature catch from trawling was insignificant (less than by traditional multiple hook and line 'long-lining'); that most fish caught were undamaged for sale and that, of the commercial species, only herring spawn lay on the seabed, and even here it was questionable whether injury would occur. But regarding the effects of trawling within the most accessible inshore waters, McIntosh — the research's author — stated that these 'could very easily be trawled out' and that the suspension of trawling 'would be a very valuable experiment. It would set at rest all sorts of notions, and it is upon safe lines, and does no harm to anyone'. This was supported by Scottish fisheries officers, other scientists, some trawlermen, and evidence from neighbouring countries and the United States. However the enquiry concluded that, although fishers tended to blame each other for any decline, natural fluctuations 'largely influence the supply of fish'. They could not justify prohibition unless experimental evidence 'decisively settled' the issue, because of the loss of valuable catches.

This was controversial. In Scotland (only), despite the enquiry, a political decision was made to ban trawling in inshore waters, including the Moray and other firths. This continued until the 1920s when fishers, under pressure from the failing herring market and searching for alternatives, started dragging their 'seine' nets, effectively using

these as a trawl. The initially large landings of codfish and flatfish suggested that the previous policy had successfully nurtured stocks.

2.2.3. Costs and benefits

It is possible to give some qualitative statements about the immediate costs and benefits of actions taken in the 19th century regarding British herring fishing and trawling (MacGarvin and Jones, 2000). Scottish towns such as Wick, heavily dependent on local herring fisheries, went into decline. The centralisation that accompanied trawling contributed to an increase in the prosperity of larger centres, such as Fraserburgh, Peterhead and Aberdeen, at the expense of smaller communities. The same expansion was true of the home ports of widely ranging trawler fleets south of the border, such as Grimsby, Hull, Newlyn, Fleetwood and Swansea.

Over the longer term, the 19th century set in train events that can be traced through to the present day. Concentrating on Scotland, landings and boat tonnage (including both the herring and dermersal fleet) stayed remarkably constant between 1898 and 1998, at ca. 333 000 tonnes and 109 000 tonnes respectively (Scottish Office, 1898 to present). But the number of boats fell from 11 536 to 2 661, and the number of fishers from 36 161 to 7 771. Sail and oar boats fell from 11 383 to nil, and fossil fuel use increased enormously. Prosperity fluctuated widely, but overall was not maintained. By the late 1990s the average net profit on capital invested for the Scottish demersal fleet was just 0.1 % per annum, according to the 2001 European Commission Fisheries Green Paper (European Commission, 2001b).

One can question just what had been gained by this investment in technology. But on the benefits side, one change has been a marked fall in deaths at sea (although fishing remains dangerous). In the good years, it may also have provided some individuals with a means of acquiring significant capital in a relatively remote area with few economic opportunities. This could then be invested in other activities, or elsewhere, resulting in higher returns. In such circumstances there is no particular interest in maintaining a sustainable fishery. But for others (probably the majority) it was and is a way of life, with a deeply ingrained wish to maintain this for future generations, and a sense of being forced down a track whose direction they do not control.

The changing catch composition for Scotland was broadly similar to that for the North Sea as a whole during this period of over a century. First, overall in the North Sea, herring caught for human consumption become less important. Demersal catches increased and then declined in turn, being supplanted by 'industrial' catches (initially for herring, sprats and mackerel, and later for species such as sand-eels) which grew explosively from the 1950s. These peaked, for the North Sea as a whole, in the 1970s with 2.2 of the 3.5 million tonne total catch. This reflects a global pattern of 'fishing down the food web' (Pauly *et al.,* 1998), proceeding from (potentially) high-value species to industrial stocks lower in the food web, and of lower unit value. One can surmise that the vast removal of biomass by the fisheries will have also had an impact on other species, but comprehensive data are scarce.

2.3. Californian sardine fishery 1920s to 1942

By the 1920s both exploitation strategies and scientific and managerial arrangements were beginning to take their current form. In this the Californian sardine fishery was precocious. The fish were originally canned for human consumption, but similar market conditions to those faced by the British herring fishers meant that their reduction to fishmeal and oil became far more important, driving the economics.

At this time there were no catch limits. Californian state scientists, involved in overseeing the fishery, were by the mid-1920s emphasising what was clearly precautionary action: 'Unnecessary drain upon the supply should be avoided until research has shown that it is possible to detect overfishing in time' (McEvoy, 1986, pp. 160–161). It was the function of government 'not only to aid in the greatest possible use, but to ensure its continuance because it is the only agency uniting all factions and successive generations' (McEvoy, 1986, p. 159). As in Scotland decades earlier, the catch was no longer increasing in proportion to the increasing effort; the average age of the fish was falling, and ships had to travel further and fish longer — classic signs of overfishing. A limit was recommended. While there were uncertainties the State Fisheries Laboratory concluded that the growing intensity of the

fishery was 'fact enough to make us sure that we are headed for destruction and a great loss'.

2.3.1. Subsequent action or inaction

The federal authority, the United States Bureau of Fisheries, took a different view. While acknowledging that the evidence of depletion was strong, there was 'no clear-cut or convincing evidence that will satisfy everyone' that the sardines were overexploited. Its view was 'to us conservation means wise use. We do not believe in hoarding our fisheries resources'. Rather, 'We believe very firmly that restrictions that are unnecessary hamper or restrict legitimate business enterprise' (McEvoy, 1986, pp. 162–166).

The fishers were divided. Those disadvantaged by the developments saw depletion as inevitable. Those behind the expansion saw a plot to 'impoverish one of the few successful enterprises in the Depression'; that any changes could be attributed to environmental fluctuations, and that in any case sardines were so fecund they would soon grow back. To simply discount their testimony that the sardines were abundant was 'brutal... medieval scholasticism'.

The dispute rumbled on unresolved until, in 1939, the new Californian Governor replaced the state experts with 'emergency' appointees, and the tone of the reports changed from 'unmistakable' signs of depletion and an 'imperative' need to reduce the catches (1938) to 'no reason to be concerned' (1942). It was then agreed to increase the catch (to 'assist the war-effort'), but in that year the sardine stock collapsed. It only began to show signs of a recovery in the mid-1980s (San Diego Natural History Museum, 2000).

2.3.2. Costs and benefits

There are similar imponderables regarding the impact on other species as for the British fisheries. Regarding the economics, the rate of return on processing fishmeal and oil prior to the collapse was extraordinary, with many plants in the 1930s recovering the entire investment in one season (McEvoy, 1986, p. 145).

So far as the processing companies such as Starkist and Van Camp were concerned, it could be argued that they had followed an optimum economic strategy, effectively 'mining' the fish in a seller's market as quickly as possible, and then shifting equipment and operations down to South America, with heavy involvement in opening the Peruvian anchoveta fishery, whose exploitation followed the Californian model, and which collapsed in the early 1970s (McEvoy, 1986, p. 155).

2.4. Newfoundland cod

Soon after the Californian experience, managers turned to increasingly complex mathematics in the attempt to squeeze more from the limited information on stock sizes, and the effect of fishing intensity. This was assisted by ever increasing computational powers. By the 1970s there was optimism that past mistakes could be avoided.

No more was this so than for the Newfoundland 'northern cod' stock. This, historically the largest cod stock in the world, had been exploited by European fishers since the 16th century (DFO, 2000). However, fishing intensity grew dramatically in the 1960s with a peak catch of 800 000 tonnes in 1968, after which it dropped well below those actually authorised by the international regulatory body. This, the International Commission for the Northwest Atlantic Fishery, ICNAF, was regarded by many Canadians as ineffective (O'Reilly Hinds, 1995), a consideration also true of its successor, the Northwest Atlantic Fisheries Organization, NAFO (Day, 1995).

In the late 1970s, using the then novel UN Convention on the Law of the Sea, Canada extended its jurisdiction from 12 to 200 nautical miles, one intention being to bring much of this stock under its control. Its goal was to impose what many would even now consider as precautionary measures, setting 'deliberately conservative' restrictions on catches, aiming to limit these to ca. 20 % of the stock, with the intention of rebuilding. The Department of Fisheries and Ocean's calculations indicated that this was happening, and offshore catches by Canadian trawlers increased. In 1988 the Department of Fisheries and Oceans (DFO) claimed a 'five fold increase in Northern Cod since 1976', and it was held in wide regard as an example of how cautious, science-driven, management could turn around a seemingly hopeless situation.

2.4.1. Subsequent action or inaction

The only dissenting group were inshore fishers, who (unlike those offshore) had generally not upgraded their technology, and who could not reconcile their falling catches with this supposed increase. Their protests disregarded, they commissioned what became the Keats Report, published in 1986. Keats highlighted the DFO's own (downplayed) retrospective analyses that indicated consistent and severe underestimation of the fishing pressure on the stock since the imposition of Canadian control, with 'the result that we have consistently taken from 1.5–3 times the (20 % of stock) catch since 1977' (Keats *et al.*, 1986). The DFO dismissed this 'as biased pseudoscience written to support a political agenda' (Finlayson, 1994). Keats nevertheless gained media attention, forcing the commissioning, by the federal fisheries minister, of an official report.

This 1988 Alverson Report had authority, in official eyes, because it was prepared by fisheries scientists. In the body of the report they concluded that the stock had increased since 1977, although after 1982 it increased 'probably only very slowly'. But they too stated that the 'fishing mortality actually exerted has been considerably in excess of target mortality' because of the 'consistent overestimation of the current stock size'. The problem was that, for any year, some five subsequent years' data were required before the estimated fishing mortality and biomass estimates for the original year 'effectively converged to the correct answer'. The shorter this period the more it simply reflected the assumed level of fishing mortality. This is a critical flaw where a stock becomes so depleted that it depends on the last few years' breeding success (now commonplace for many stocks). Moreover, if a stock goes through a period of sharp decline, the method instils a false sense of assurance. Alverson demonstrated how sensitive conclusions about stock size were to the wide range of fishing mortality estimates that might be implied by the data. However in the executive summary this was turned on its head, it being stating that the DFO calculations of fishing mortality fell 'within the range of estimates supported by the data', albeit at the lower end.

The DFO had responsibility for the management of the release of the Alverson Report. Publicly Alverson noted that 'it's rather amazing that we are as close to each other as we are'. The DFO in its response emphasised that 'the difference in numbers overall was about 4 to 5 percent... the conclusions... are quite similar (with respect to stock size and cause of the decline in inshore fisheries)... the credibility of DFO science was not questioned'. Privately the Alverson team were less sanguine and there was an internal reappraisal of DFO methodology. The 1989 assessment assumed that fishing mortality was higher, concluded that the stock was not growing, and recommended that the offshore catch be virtually halved.

This reappraisal was seen as an admission that the DFO had got it wrong all along. This caused serious problems for the administration, as they depended on the 'science' touchstone as an arbiter to conflicting claims to resources. Now the offshore fishers were complaining bitterly that there was no evidence that stocks had fallen. The fisheries minister called a new enquiry, the 1990 Harris Report, this time fully independent of DFO control. Harris also concluded that, prior to 1989, fishing mortality was probably more than double that intended, and the stock little more than half the assumed size, with the result that the stock had been fished at levels that pointed towards commercial extinction — a conclusion widely reported by the media.

The Harris Report cautiously concluded that the revised DFO 1989 assessment was a better approximation of reality. But also, over many pages, it pointed to major issues, not easily resolved, at every conceivable level. 'We acted in substantial ignorance of the animals in which we were principally interested and in almost total ignorance of the dynamics of the ecosystems in which they existed.' 'We continued for too long to wear rose tinted glasses and to interpret all data in the manner best calculated to support and confirm the model of growth upon which our hearts had been set.' What were (and often still are) 'believed to be the best available management theory, data and assessment methodologies will legitimately support claims of stock status ranging from sustainable growth to dangerous decline', (Harris, 1990).

2.4.2. Costs and benefits

Harris estimated that the total allowable catch, TAC, would have be reduced from 235 000 tonnes in 1989 to ca. 125 000 in 1990 to bring this into line with the goal of no

more that 20 % stock removal, but that this 'would precipitate social and economic repercussions of a particularly drastic nature'. Instead Harris suggested a TAC of 190 000 tonnes (ca. 30 % removal), although cautioning that 'this may contribute to further decline'. Yet this was done, at a loss of CAD 26 million (ca. EUR 21 million) of landings, CAD 66.6 million (EUR 53 million) processed product and the equivalent of some 1 000 jobs. Similar limits were set for 1991–92. But during the 1992 fishing season it became apparent that there was little left to catch. The situation was far worse than even the most pessimistic projections. An emergency moratorium was imposed in July 1992, initially for two years. But the stock failed to rebound, and it was not until 1999 that an inshore fishery of just 9 000 tonnes was permitted. The financial cost during the 1990s, including lost sales, unemployment benefit and financial assistance, was in excess of several billion Canadian dollars (MacGarvin, 2001a).

Somewhat depressingly, the 2000 DFO assessment concluded that 1999 catch was already in excess of the 20 % reference level, something 'unacceptable under a precautionary approach', and that the stock remained so weak that even an index fishery (i.e. to monitor the state of the stock) 'may be associated with an increased risk of the inshore (stock) declining and the offshore not recovering'.

The 2000 DFO assessment also makes it clear just how little is understood about this most studied stock — why it collapsed, why it has failed to recover, what proportion are being taken by predators and other fishing activities — and of the poor status of capelin, small fish that are important prey for the northern cod. Even the linkage between inshore stocks and those offshore — the source of the original controversy — is now open to question. There is also growing awareness that the 'stock' is made up of more or less discrete local populations (cf. Heincke's conclusions about herring in the 19th century), and this has considerable implications for recovery programmes (Kent Smedbol and Wroblewski, 2000). On the positive side the assessments are freely available and the uncertainties clearly set out; attempts are being made to incorporate 'lay' assessments of stock strength made by fishers (DFO, 2000); a constructive debate has been initiated concerning the future of the fisheries (Atlantic Fisheries Policy Review, 2000); and management methods, such as no-take zones, that are not so dependent on the accuracy or theory of stock assessments are being evaluated (Guénette *et al.,* 2000).

2.4.3. The human dimension

As described so far, the demise of the northern cod is already a remarkable event, one that challenges the likely success of precautionary approaches, still advocated, based on setting a limit on calculated fishing mortality as part of an intensive reliance on stock modelling and prediction (see below). Yet there is more. *Fishing for truth* (Finlayson, 1994), a remarkable sociological study completed just before the final collapse, contains many illuminating interviews with key participants, detailing the human dimension.

According to the views quoted there, DFO scientists warned of the uncertainties at an early stage of Canadian management, but in the event not loudly enough (ibid., p. 136). Pleas then that the information demanded (for long-term forecasts) was impossible to provide were overridden, and they apparently took seriously the threat that if they did not do the job, then economists would do it for them (ibid., p. 135). There was a double pressure to downplay the uncertainty; on one side the politicians pleaded for constancy and certainty to aid them resolve disputes (ibid., pp. 132–133, p. 142). The scientists — believing that, given a range of estimates, the highest catch would always be taken — also tended towards lower (and they believed precautious) estimates, and with a greater assertion of precision than their internal assessments suggested (ibid., p. 141). Ultimately this public overemphasis of confidence hoist them on their own petard, when even their most pessimistic view turned out to be based on underestimates of the historic level of fishing mortality.

Moreover the scientists were aware of wider shortcomings regarding biological and physical parameters (ibid.), fundamental sampling problems (ibid., pp. 73–74), and the often dubious nature of scientific advice hammered out each year for the many stocks in a few weeks of intensive meetings (ibid., p. 79). Harris likened fisheries science to the Ptolemaic model of the solar system (which placed Earth at the centre of the universe) where, when observations did not fit the theory, an additional layer of complexity was added, rather than questioning the basic theory (ibid., p. 69). This accorded with

strong criticism, at that time, from related but separate disciplines, such as theoretical ecology (Peters, 1991).

However none of this happened because the participants were stupid, careless or lacking in intent to restore the stock. It was a systems failure that prevented fishers, scientists and politicians from responding to existing information or extracting themselves from the situation.

2.5. Precaution becomes explicit

By the early 1990s precaution had become explicit, due both to disasters such as northern cod, and to its increasing prominence in other fields. The most significant global development was the negotiation of two related documents in 1995: the UN FAO Code of Conduct for Responsible Fisheries (FAO, 1995) and the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks (UN, 1995).

The FAO Code applies a 'precautionary approach' to fisheries. The adoption of this terminology initially arose from a nervousness amongst the fishing industry and managers that the precautionary 'principle' was a concept captured by environmental NGOs, which might unjustifiably be used as a weapon to substantially reduce or even halt fishing. Their use of 'approach' is therefore probably best seen as an initial statement about ownership of the process, rather than any close analysis, or fundamental difference of outcome, arising from this choice of terminology. However, as described in the opening paragraph, there are advantages in maintaining a distinction between a universally applicable principle and the detailed approach to implementation, which will differ from field to field, although this was not a distinction made by those who negotiated the Code.

Precaution in the Code covers uncertainties relating to individual stocks, other affected species, and environmental and socio-economic conditions. However, the aspect emphasised is the mechanism for taking account of uncertainties in stock assessment models, namely to determine 'stock-specific target reference points (i.e. the 'positive' goal of optimum stock size), and at the same time, the action to be taken if they are exceeded' and 'limit reference points (the negative goal of the lowest acceptable stock size), and at the same time, the action to be taken if they are exceeded; when a limit reference point is approached measures should be taken to ensure that it will not be exceeded'. The explicit reference to targets, limits and predetermination were novel developments.

The UN agreement provides details, notably that 'the fishing mortality rate that generates maximum sustainable yield (MSY) should be regarded as a minimum standard for limit reference points (i.e. the 'negative' goal)'. It is a minimum because the old concept of MSY (yet a widely used method of calculation) is known to overestimate sustainable yields. The implications are profound, because many stocks are depleted well beyond formal MSY. It continues, 'For stocks which are not overfished, fisheries management strategies shall ensure that fishing mortality does not exceed that which corresponds to maximum sustainable yield, and that the biomass does not fall below a predefined threshold'. For overfished stocks 'the biomass which would produce maximum sustainable yield can serve as a rebuilding target'. The possible contradiction here may well be the result of a negotiated compromise — it can be a mistake to try to interpret such documents as the product of a single consistent mind.

Nevertheless, overall the UN agreement and, indirectly, the FAO code emphasise precaution at the level of maximising long-term yields.

2.5.1. Subsequent action or inaction

US federal guidelines (Restrepo *et al.,* 1998) recognise that stocks should be managed in a manner consistent with the UN agreement and FAO code ([3]). The Canadian position (Richards and Schnute, 2000) is that stocks must be equal to or greater than, and fishing mortality less than, that resulting from MSY; or for equivalent proxies to be used where MSY is inappropriate or inapplicable.

Unlike the United States and Canada, fisheries responsibilities within the seas under EU Member State control are split.

(3) The US position and technical guidance is of interest beyond fisheries. It requires the implementation of protective measures 'even in the absence of scientific certainty that stocks are being exploited'. Prior to this approach there was a 'perceived... inability to implement timely conservation measures without scientific proof of overfishing. Thus, the precautionary approach is essentially a reversal of the 'burden of proof'.'

The International Council for the Exploration of the Sea — ICES — is responsible for technical advice, but the responsibility for management, including the setting of targets, resides with the European Commission and Member States. This causes complications. Currently ICES advice centres around B_{lim} (biomass lower limit) and a larger 'precautionary approach' target stock size, B_{pa}, at least according to interpretations arising from within the FAO (Garcia, 2000). Two equivalent levels of fishing mortality believed to achieve these reference points are also used: F_{lim} and F_{pa}. B_{lim} is set not to MSY but to a level where, if depleted further, a stock 'is in immediate danger of collapse' (Garcia, 2000, p. 22). B_{pa} is set inconsistently, depending on the state of the stock. For those in a poor state, such as North Sea cod, haddock and plaice, it is set at or close to the minimum biologically acceptable level (MBAL), below which there is judged to be unacceptable risk that it could reach B_{lim}. Unfortunately many stocks are judged by ICES to be below B_{pa}, even close to B_{lim} (cf. ICES advice on North Sea cod in 2000 (ACFM ICES, 2000a)). This emphasis and interpretation of reference points has been seen as conflicting with the FAO/UN approach, resulting in peer-group criticism from within the FAO (Garcia, 2000, p. 23), the United States (Restrepo *et al.,* 1998, p. 24) and Canada (Richards and Schnute, 2000, p. 7). In effect the earlier management regime (a goal of maintaining stocks above MBAL) often remained unchanged, although the language has been given a precautionary gloss.

ICES may concur, noting that this use of limit reference points 'is a needlessly restricted interpretation of a concept' and — obliquely — that 'the adoption of precautionary reference points requires discussion with fisheries management agencies' (ACFM ICES, 2000b, p. 55). This illustrates the tensions that arise from split responsibility. ICES itself does not refer to B_{pa} as a 'target' reference point, but as a 'buffer' or a 'precautionary reference point' (ACFM ICES, 2000b, p. 2), presumably because setting a 'target' is seen as impinging on the responsibilities of the Commission and Member States. The 1995 criticism by the Commission's Scientific, Technical and Economic Committee (European Commission, 1995) of a management system 'at ease with crisis management or an unwillingness or inability to state specifically a more positive goal aimed at enhancing the productivity of fisheries in either a biological, economic or social sense' still appears valid. As yet Member States appear unwilling, or unable, to fund the short-term investment involved in restoring stocks to optimal levels. The European Commission 2000 communication on the application of the precautionary principle (European Commission, 2000) argues that the reason why ICES does not refer to MSY is twofold: namely that for 'a number of stocks' the conditions whereby sustainable yields can be obtained are 'difficult, if not impossible' to define, and that fishing pressure on many EU stocks is 'well above that which would correspond to the maximising of yield'. A likely response is that establishing maximum yields is no more or less certain than establishing the level at which stocks will collapse, while high fishing pressure is the reason why the code is necessary, not a reason why it should not be applied.

The relationship between EU policy and the FAO code and UN agreement certainly has the potential to become a highly contentious issue. However the Commission 2001 Green Paper on the future of the Common Fisheries Policy (European Commission, 2001a), while general in scope, contains a frank identification of the problems as well providing a constructive basis for discussing the way forward. Concentrating on the future rather than dwelling overmuch on the past may be the most constructive way forward.

Turning back to the code and agreement in general, one problem remains unchanged: the quality of the data. For Canadian northern cod the underestimation of a vital statistic, fishing mortality, was a key factor. Yet a retrospective analysis in 1999 of fishing mortality rates of major North Sea stocks for which the best data were available (cod, haddock, whiting, plaice and sole) found the same fundamental problems (van Beek and Pastoors, 1999; ACFM ICES, 1999, p.12). For cod, haddock and whiting mortality was much higher than originally stated, for plaice there was no correlation, and for sole there was a possible negative correlation. This too noted that underestimating fishing mortality is associated with an overestimate of stock size. Moreover this problem had been identified as early as 1977. The parallels are startling. One conclusion drawn is that Northeast Atlantic cod can survive higher levels of mortality that the northern cod, but this seems to be based on the circular

argument that they have not yet crashed. Northern cod also survived periods of intense fishing pressure beyond that prevalent at the time of the crash.

Indeed the goal that the Canadians adopted after taking over control of northern cod management was identical to that now advocated under the precautionary approach: to severely curtail fishing effort and to build up the stock to a level above that predicted for optimum economic yields. Yet still it crashed. So it is legitimate to ask whether the change — as yet — is sufficient.

2.6. The ecosystem approach

Another criticism of the UN/FAO approach is that while it nominally requires precaution at the ecosystem level, the practical emphasis remains on single stock management. Moreover, one's value judgement might be to target precaution not at avoiding stock collapses (cf. ICES/EU), or even ensuring that stocks are maintained above MSY (UN/FAO), but at preventing adverse effects on other species dependent on the fish. Greenpeace was an early advocate of this in its 1994 precautionary approach (Earl, 1994), although since then others have also argued that catches, in order to be sustainable, should be reduced the same order of magnitude as other predators (Fowler, 1999). There is thus no one 'correct' precautionary approach; it depends on the objectives set (MacGarvin, 2001b). Even between different fisheries in the same area, judgements will necessarily differ as to the costs and benefits, and the acceptable risks, of different elements of a precautionary response, dependent on how these impinge on activities and interests.

Indeed, stocks cannot be treated in isolation from one another, because many of them are major predators on each other (Swain *et al.*, 2000). Fishing one stock has implications for the others. An attempt is sometimes made to allow for this in the single species models, but it falls far short of the evident complexity. Indeed the gulf between the disciplines of fisheries science and theoretical or community ecology is remarkable. In the early 1990s prominent ecologists commented that fisheries management was, for example, a field 'so accustomed to inaccuracy in its basic models that striking differences between model and observation are scarcely noted... Nevertheless fisheries biologists fit data to models that are clearly inaccurate and make decisions on that basis'.

Nevertheless there are signs of change, with a new emphasis by regulators on the need to adopt an 'ecosystem approach'. Notably in the United States (Ecosystems Principles Advisory Panel, 1998) but also within ICES's Advisory Committee on the Marine Environment (ACME ICES, 2000) and in Canada (Murphy and O'Boyle, 2000) there is an increasing involvement of theoretical and community ecologists and concepts. The US report (Ecosystems Principles Advisory Panel, 1998) notes the role of chaotic population dynamics that may make systems fundamentally unpredictable. Indeed an earlier study of interactions between fish species on the Canadian Grand Banks suggests that the more realism that is incorporated into the models, the more unpredictable become the effects of a change in any one species — in effect the system may work as a gigantic random number generator (Gomes, 1993).

However, the US report also emphasises that we do know that ecosystems have limits which, when exceeded, can result in irreversible changes; that diversity is important; that systems operate at multiple scales; and that boundaries, to the great inconvenience of managers, are indistinct. 'There is simply not enough money, time or talent to develop a synthetic and completely informed view of how fisheries operate in an ecosystem context. There will always be unmeasured entities, random effects, and substantial uncertainties, but these are not acceptable excuses to delay implementing an ecosystem-based management strategy.' Similar conclusions have been drawn by European experts (Daan, 1998). For example, we have been unable to fill a crucial gap identified as long ago as 1914 (Hjort, 1914): that of being able to predict, from the number of eggs laid, the number of fish that will subsequently mature to appear in the stocks. However, according to the US approach, we know enough about ecosystem functioning to do a better job of management than in the past. Whilst in 1919 a Californian fisheries regulator required that 'proof that seeks to change the ways of commerce and sport must be overwhelming' (Thompson, 1919), now the burden of proof is on fisheries to take account of uncertainty regarding ecosystem effects. At an operational level stakeholder involvement is essential. What might be called a 'second

generation' precautionary approach, less centred on stock assessment models (even with their precautionary attempts to incorporate error), and including error-resilient concepts such as no-take zones, appears to be producing results for finfish and shellfish on the US Georges Bank (Murawski *et al.,* 2000).

The Canadian approach in particular highlights the active involvement of fishers, and the stock assessments now attempt to incorporate their knowledge (for example, DFO, 2000), while in northern Europe considerable attention has been devoted to the policy implications of ecosystem management (Norwegian Ministry of the Environment, 1997; Nordic Council of Ministers, 1998). While at an early stage, and as yet without overall consensus, taken together they provide the elements of a new approach, incorporating precaution, which has considerable potential if implemented.

2.7. Late lessons

Fisheries provide a rich seam of lessons regarding the precautionary approach, of wider interest than to fisheries alone. These include:

- the distinction between the precautionary principle and precautionary approaches (logical distinction between a simple 'principle' and differing practical implementation in different fields; also a 'political' distinction as in the FAO Code);
- appropriate levels of proof (19th century Scottish fishery, 1920s Californian state scientists, 1990s US ecosystem approach);
- distinguishing between uncertainty and ignorance (Harris Report, uncertainties attached to estimates, ignorance regarding ecology);
- unrealistic expectations (or incredible claims) as to the 'soundness' of scientific conclusions (specifically northern cod, but a general feature);
- drawing upon historical knowledge (Heincke's importance of sub-stocks, Scottish natural no-take zones, success of areas protected from trawling);
- not brushing 'blind spots' under the carpet (Harris Report, rose-tinted spectacles);
- avoiding dominance by any one discipline or sub-discipline (the general dominance of stock modellers);
- accounting for 'real-world' conditions (underestimation of real fishing mortality and technologies);
- taking full account of the pros and cons of any one approach (stock assessment *vs.* wider approaches);
- using lay knowledge (Native American, Scottish 19th century fishers, Canadian inshore fishers);
- taking account of wider social perspectives, acknowledging the importance of value judgements and evaluating all the options available (different interpretations of precautionary approach);
- avoiding reliance on ever more elaborate models to explain away predictive failures (Harris, Ptolemaic astronomers and analytical fisheries science);
- dealing with institutional obstacles and regulatory independence (reluctance to address fundamental economic issues, blurred independence of technical advisers and policy-makers from Californian sardines to present);
- maintaining due humility ('biased pseudoscience' 1986 response of DFO to criticism).

Positive changes of attitude are occurring. The question is whether they are happening fast enough to stave off further collapses. While there will be some interest groups who see it as in their interest to pursue a short-term strategy, the need for precaution is generally not something that should need to be laboured within the fishing industry. Not cutting stocks so 'close to the bone' not only takes us into areas of greater certainty regarding the maintenance of stocks, but will also greatly increase the economic returns (Whitmarsh *et al.,* 2000). The problem is that the natural capital has been run down so far that industry in many cases cannot absorb the short-term hit necessary to rebuild the stocks. Interest groups need to redirect their attention from arguing with each other and instead learn the language of, and engage with, the economic ministries who — not surprisingly given the history of inappropriate subsidy — have a highly jaundiced view of the merits of investing in recovery programmes.

Fisheries: early warnings and actions Table 2.1.

Source: EEA

Early fisheries in the UK	
1376–77	Setting up a committee is the answer of the English parliament to a call for precautionary actions in fishing by controlling the mesh of the nets
1866–93	Following uncertainty about the consequences of fisheries growth official enquiries take place, but no action is taken
Sardine fisheries in California	
Mid-1920s	Californian sardine fisheries scientists call for precaution and research
1942	Continuous inaction leads to the collapse of the sardine stock (signs of recovery only in mid-1980s)
Northern cod fisheries in Canada	
Late 1970s	Canada starts managing the northern cod fisheries up to 200 nautical miles, claiming it is doing so precautiously
1986	Keats Report commissioned by inshore fishers indicates severe underestimation of the fishing pressure
1988	Alverson Report, prepared by fishery scientists, states that consistent overestimation of the stock size leads to overfishing
1989	A new government assessment recommends that the offshore catch should be halved
1990	A new independent assessment, the Harris Report, confirms overfishing
1992	The stock collapses and a moratorium is imposed
1999	Restart of the northern cod fisheries at low levels, but dissidents state it is not low enough
General fisheries	
1990s	The ecosystem approach slowly settles in fisheries management procedures
1995	FAO Code of Conduct for Responsible Fisheries and the UN Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks are negotiated and published
2001	European Commission Green Paper on the future of the Common Fisheries Policy
2001	Positive changes are occurring, but are they happening fast enough to avoid further collapses?

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