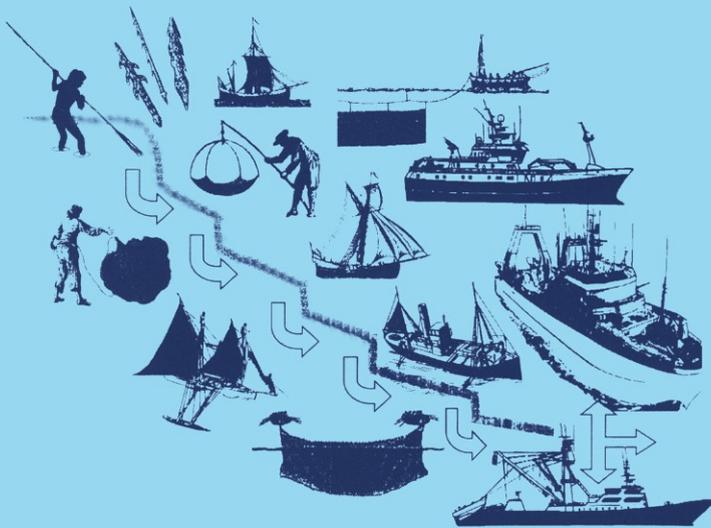


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Reinventing Fisheries Management



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Rebuilding ecosystems, not sustainability, as the proper goal of fishery management

Tony J. Pitcher and Daniel Pauly

ABSTRACT

We propose that rebuilding ecosystems, and not sustainability *per se*, should be the goal of fishery management. Sustainability is a deceptive goal because human harvesting of fish leads to a progressive simplification of ecosystems in favour of smaller, high-turnover, lower-trophic-level fish species that are adapted to withstand disturbance and habitat degradation. Present fisheries management seems unable to reverse this trend for several reasons. Because of this effect on the ecosystem, sustainable harvests are generally incapable of ever being defined using single species-population dynamics, yet almost all fishery science has been long engaged in trying to do this. Even if our science and management were capable of sustaining exploitation at a defined ecosystem structure, we argue that this is the wrong goal. Aquatic systems are likely capable of producing large harvests of high-production, low-trophic-level species, perhaps much in excess of current global fishery yields of around 100 million tonnes per year, yet such exploitation would shift their structure and nature in a way, and lead to products, that would be unacceptable to many. Primal

systems, defined as those existing before humans used large-scale harvesting, are generally characterized by an abundance of large top-predator species. An approach to the primal abundance of such systems may have an increasingly higher economic value than present systems in an era where demand is outstripping supply. Therefore, we argue that management that moves aquatic systems in the direction of their primal states and abundance should be rewarded, and that this rebuilding and restoration of ecosystems should be the overarching goal of the new fisheries management.

24.1 INTRODUCTION

Sustainability is widely regarded as a desirable and proper goal of fishery management. The concept is unquestioned and deeply embedded within many disciplines that address fisheries issues (for example, Richards and Schnute, Chapter 30, Rice, Chapter 14, Charles, Chapter 6, and Sutton, Chapter 8, all in this volume, and Botsford *et al.*, 1997), even though it may be relatively new for some areas (McGuire, Chapter 18, and Jentoft, Chapter 12, both this volume). In this chapter we propose that, whatever its present degree of acceptance, sustainability is the wrong goal for fishery management. Moreover, we argue that success in implementing this goal, as currently understood in our discipline, is not only likely to reduce the biodiversity of the oceans, but will also seriously compromise future economic options for human wealth based on the harvest of aquatic resources. Our analysis suggests that the most effective goal for fisheries management is the rebuilding of natural ecosystems.

Much quantitative fishery research is judged by a sustainability criterion, assessment methods are defined and tested in terms of how well they address long-term sustainability, and the success of management measures is judged by reference to sustainability. For a long time, maximum sustainable yield (MSY) ruled supreme as the objective of fishery management (see contributions in Roedel, 1975) and despite its often-heralded demise (Larkin, 1977; Barber, 1988), sustainability is universally employed to delineate the many population criteria that have proliferated to complement or replace it (Smith, 1993, Smith *et al.*, 1993; Drummond and Symes, 1996). So deeply embedded is the concept of sustainability that when Ludwig *et al.* (1993) claimed that fishery management has failed, annoying many of their colleagues (the late Ray Beverton told us that the paper had 'done a great deal of harm'), they defined failure in terms of sustainability, in that no fishery, according to their analysis, has ever been sustainable.

Several mechanisms, some biological, the others socio-economic, jointly contribute to push exploited marine ecosystems toward states dominated by high-turnover, low-trophic-level species. To halt and reverse this trend, an understanding and resolution of both ecological and human factors is critical to success. Hence the proposed goal of rebuilding aquatic ecosystems is inherently interdisciplinary. Although the ecosystem concept was integral to the ideas of pioneers of fisheries science (Hardy, 1956; Skjoldal *et al.*, 1993) it was forgotten early in the era of domination of single-species population dynamics. Moreover, attempts to reinstate ecosystem management have lacked clear quantifiable goals (Larkin, 1996) and so a practical rebuilding goal would form part of a truly 'reinvented' fisheries management. Furthermore, if we look at the management practices of indigenous and aboriginal peoples (Johannes, 1987; Johannes *et al.*, 1993), we see that this goal is being revisited rather than reinvented.

24.2 ECOLOGICAL FACTORS

Harvesting alters ecosystem structure in ways that are only just beginning to be understood. We argue that long-term heavy commercial harvesting, that may well meet the most rigorous sustainability criteria, is likely to shift the ecosystem to high-turnover species with low trophic levels. Ludwig *et al.*'s (1993) argument that no fishery management has ever worked has the corollary that heavy commercial fishing (in many large fisheries over 80% of the fish are caught each year) alters systems irreversibly.

The dominant biological mechanism underlying species shifts is relatively well understood, and results from large, long-lived fishes, which also have low natural mortality rates (Pauly, 1980), being affected more strongly by a given rate of fishing mortality than smaller fishes that are part of the same community.

A second shift-inducing biological mechanism is habitat degradation caused by various fishing gears, especially bottom trawls. Here, the effect is through the elimination of the bottom structure, such as 'oyster reefs' and sponge beds (Young and Glaister, 1993; Pauly *et al.*, 1996) created, often over hundreds of years, by the sessile planktivores and detritivores upon which long-lived large benthic fish rely to complement their diet of small pelagic fishes. The destruction of these structures by trawls, besides depriving benthic fishes of habitats and prey, also has the effect of redirecting carbon flows toward the pelagic system, thereby adding to the effects of anthropogenic nutrient inputs.

Thirdly, these fluxes, and the fishery-induced reduction of predatory pressure by benthic fish, may then lead to an increase of small pelagic fish and squids which become available for exploitation, thus in part masking

the decline of the demersal group (see contributions in Pauly and Murphy, 1982, and in Daan and Sissenwine, 1991). In the Gulf of Thailand, off Hong Kong, and other areas of the South China Sea, extremely heavy trawl pressure has resulted in a shift from valuable demersal table fish such as croakers, groupers and snappers (*Sciaenidae*, *Epinephelinae*, *Lutjanidae*) to a fishery dominated by small pelagics used for animal food, and invertebrates such as jellyfish and squids (Beddington and May, 1982; Boonyubol and Pramokchutina, 1984; Pitcher *et al.*, 1998).

These mechanisms may lead, through a positive feedback loop, to a fourth biological mechanism: harvesting small pelagic fish species at lower trophic levels reduces the availability of food for higher trophic levels, which then decline further, releasing more prey for capture by a fishery that finds its targets even lower down the food web, a process now occurring throughout the world (Fig. 24.1). The overall effect of harvesting aquatic ecosystems is summarized in Fig. 24.2, which plots a suitable index of biodiversity (such as abundance, biomass, species richness) against time, which may be extended to the left to the first known human fisheries – deer antlers carved into fish spears used to harvest giant river catfish some 85 000 years ago in what is now the Republic of Congo

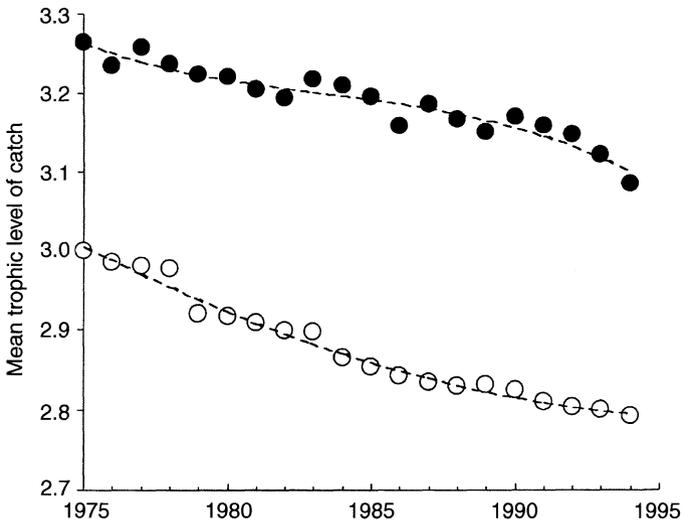


Fig. 24.1 Decline of the mean trophic level of fish and invertebrates caught by global marine (solid circles) and inland (open circles) fisheries, 1975–1994 (Pauly *et al.*, 1998). Cubic trend lines have been added to the two series. Figure is based on the FAO catch statistics and trophic level estimates included in FishBase 97 (Froese and Pauly, 1997).

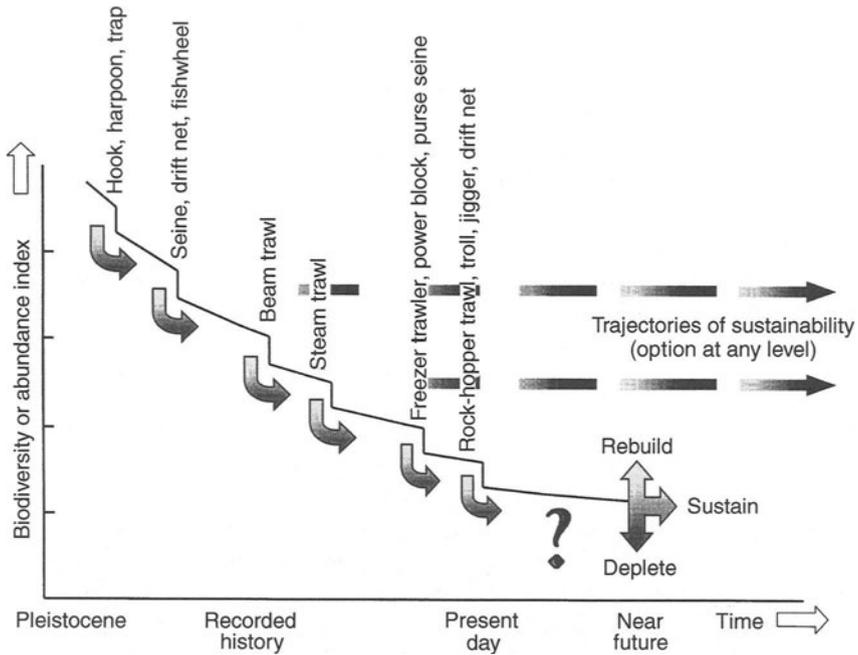


Fig. 24.2. Schematic representation of the loss of biodiversity in aquatic ecosystems since prehistory. Vertical axis represents abundance, biomass of top predators, a suitable diversity index or an ecosystem breadth measure. Horizontal axis is time. Stepped downward line represents serial depletion of the resources as new fishing technologies (some of the principal fishing gear inventions are indicated) are invented by humans. Horizontal arrows show sustainability which, in theory, may be pursued at any level if management instruments are capable. Future options are indicated by the three-way arrow.

(Yellen *et al.*, 1995). Successive stages in the development of human fishing are shown from left to right; historically the stages are congruent with major enhancements to fishing technology such as the development of the seine and cotton drift nets, beam trawl, steam trawls, freezer trawlers, power-block driven and drum purse seines, rock-hopper trawls, high-technology trollers for Pacific salmon, squid and tuna hook-and-line jiggers and nylon drift nets. Downward arrows indicate major depletion events as new technologies are rapidly deployed. A fascinating historical example of the spread of driftnet technology for catching herring in Scotland in the early 1800s is graphically described in the novel *The Silver Darlings* by Neil Gunn (1941).

At first sight, sustainability appears to be an option if management techniques can achieve this goal. Some fishery scientists think that this can be done (Beverton, 1998; many chapters in this volume), while others, notably Ludwig *et al.* (1993) and Parrish (1995), are pessimistic.

There is some evidence supporting the optimists and some supporting the pessimists. The latter might argue that fishing selects species with life history parameters that allow population persistence in the face of high mortality; this ecological argument is hard to counter. But optimists may contend that technical measures to allow for uncertainty provide risk-averse, fully precautionary management, and could allow us to maintain populations in the long term. Pessimists point to the growing series of collapses, which does not inspire great confidence. Moreover, fresh factors that should have been taken into account are revealed after each new collapse. The most recent example is the critical need for spatial analysis of abundance during depletion (Hutchings, 1996; Walters and Maguire, 1996; Pitcher, 1997), where only a short while ago, the majority in fishery science regarded such information as of only academic interest with no place in a stock assessment that pooled all other information. Again, contrary to the assumptions built into the majority of current stock assessments, there is now evidence of risk of recruitment failure at low-to-moderate biomass levels (Mertz and Myers, 1996; Myers and Barrowman, 1996) and analyses suggesting that truly sustainable rates cannot be anywhere near the 70–80% exploitation rates often encountered today.

The optimists can point to some recent papers (Mace, 1997) that, while deploring collapses, have cheerfully reported increases in some fished populations, and have hailed this as encouraging evidence of the potential success of present management science. Moreover, there is a current myth, based on pelagic fish such as herring, that, with the exception of skate in the Irish Sea (Brander, 1981), marine fisheries by humans have never brought about species extinction and are never likely to do so (Mace, 1997). But as exploited systems shift down Fig. 24.2, increases in species with life histories favoured by harvest are inevitable – Table 24.1 lists several such examples. For instance, it is likely that enormous populations of pollock, *Theragra chalcogramma*, in the North Pacific may be a direct result of exploitation and extinction of marine mammals since the 1700s. The huge expansion of trawl fishery in the 1980s, aimed at harvesting this resource, may have exacerbated the situation. Moreover, in the Bering Sea there are worrying reports of a vast increase in numbers of jellyfish (Brodeur *et al.*, 1996), a symptom of a shifting food web and decreasing trophic level known also from the South China Sea (Saeger, 1993), amplified to disaster level in the Black Sea (Shushkina and Vinogradov, 1991). Finally, supporting the pessimists, it often comes as a surprise to fishery scientists that living organisms, including fish, evolve in response to

Table 24.1 Some examples of documented shifts toward smaller, higher-turnover species in exploited multispecies fish communities

Fishing grounds/stock (period)	Remarks	Source(s)
Gulf of Thailand demersal stocks, 1960 to 1980s	Overall biomass reduced by 90%; residual biomass dominated by 'trash fish'	Boonyubol and Pramokchutina (1984)
Philippine Shelf small pelagics, 1950 to 1980s	Gradual replacement of sardine-like fishes by anchovies	Dalzell and Pauly (1990)
Carigara Bay, Samar, Philippines, all fish, 1970 to 1990	Fish replaced by jellyfish, now an export item	Saeger (1993)
Black Sea	Small pelagics and jellyfish replace large table fish	Shushkina and Vinogradov (1991)
North Sea	Halibut and small sharks extinct; cod and haddock threatened; demersal omnivores and small pelagics favoured	Rijnsdorp <i>et al.</i> (1996)
Humboldt, Current, Chile	Large hake depleted, small pelagics favoured	Aguayo (1995 and pers. comm.)
North Pacific	First marine mammal depletions, followed by huge trawl fisheries; pollock favoured	Trites (pers. comm.)*
South China Sea, Hong Kong	Croakers and groupers almost extinct; small pelagics bulk of fishery	Pitcher <i>et al.</i> (1998)

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selective mortality, a process recently shown to be remarkably fast, even in vertebrates (Houde and Endler, 1990; Wiener, 1994). Astonishingly little effort has been made to trace such effects in fisheries (Policansky, 1993), but they may be much more widespread than previously thought. An example may be the halving of the size of mature chinook and pink salmon (*Oncorhynchus tshawytscha* and *O. gorbuscha*: McAllister *et al.*, 1992). In the semelparous salmon, early maturity means less time at risk of being caught and therefore higher fitness. These species have been intensively managed for over 80 years using the best that single-species quantitative science can offer, and yet chinook are in decline, something

that has, not surprisingly, been blamed on environmental change (Beamish *et al.* 1995).

These considerations suggest to the pessimists, notably Parrish (1995), that the ultimate fate of all exploited aquatic ecosystems is analogous to the heavily depleted and unregulated fisheries of the South China Sea – dependent on jellyfish (which is now harvested), prawns, squids, small fast-growing pelagics, and little else. But whether or not sustainability is truly achievable using management based on single-species stock assessment actually proves to be irrelevant to our main argument.

24.3 SOCIO-ECONOMIC FACTORS

Two main socio-economic mechanisms contribute to species shifts. The first of these is increasing prices, both for traditional high-value species and for former 'trash' species. Astoundingly, bluefin tuna, *Thynnus thynnus* were discarded as trash fish in Danish waters until the 1930s (Pauly, 1995), as were Atlantic halibut, *Hippoglossus hippoglossus*, in the New England fishery until 1825 (Cushing, 1988). Such price increases are effective in masking the economic consequences of fishing at lower trophic levels, i.e. of catching what were previously low-value fish e.g. mackerel in Britain, (Lockwood, 1988), or jellyfish in the Gulf of Thailand (Soonthonvipat, 1976) or in the Philippines (Saeger, 1993).

The second mechanism, embodied in the scenarios represented in Fig. 24.2, is psychological, and more insidious. This is the 'shifting baseline syndrome of fisheries' (Pauly, 1995), wherein successive generations of fisheries scientists lose sight of the state of the resource during periods preceding their careers. Earlier accounts of high abundance (e.g. in Mowat, 1984, or MacIntyre *et al.*, 1995) are perceived as irrelevant anecdotes, though they pertain to a sensitive phase of the early fisheries, when a relatively small level of effort sufficed for a major reduction of resource biomass.

In fact, we show below how both of these mechanisms offer a means for resolving the problem.

24.4 METHODOLOGY

Is it practical to try to manage systems to rebuild? Do we have tools that enable us to assess the status of exploited aquatic ecosystems and to evaluate options for management? We think that the answers are 'Yes' and accordingly this section reviews five sets of techniques that may allow a rebuilding goal and determine how it might be evaluated.

1. Role of population dynamics

Reviewing what we can do with single-species population dynamics and what we cannot illustrates the limitations of even the best quantitative science. Paradoxically, the insufficiency of population dynamics is an important part of our argument, but the tools developed for population dynamics must be an essential part of any new methodology. Stated explicitly, detailed information on growth, mortality and recruitment schedules and their associated errors and uncertainties are all essential, i.e. the 'stuff' we teach, learn and elaborate in today's fisheries science is all necessary, but not sufficient for the ecosystem approach we advocate.

Likewise, management targets for particular species can as easily be defined as part of a system-rebuilding strategy as they are for single-species management. Such targets, fully bounded by risk evaluations, are structured in terms of spawning stock biomass, age structure, recruitment risks, effort or fishing mortality, although targets expressed directly in terms of catch quotas are probably not so wise (Walters and Pearse, 1996).

2. Role of ecosystem modelling

There are many recent developments in trophic models of aquatic ecosystems. Such modelling can now be performed more rapidly and rigorously than ever before (see contributions in Christensen and Pauly, 1993; Pauly and Christensen, 1995), providing a basis for viable and practical simulation models that have real predictive power (Walters *et al.*, 1997).

This was made possible by the development of Ecopath (Polovina, 1984; Christensen and Pauly, 1992), for construction of mass-balance models of ecosystems, based mainly on diet composition, food consumption rates, biomass, and mortality estimates, i.e. on information available for most commercial species, and easy to generalize to other species. The flux estimates obtained through this approach, though typically representative of an 'average' situation, are extremely useful for stock assessment purposes, e.g. to assess the relative impact of predation vs. fisheries, or to estimate the biomass of groups that cannot be sampled straightforwardly, such as oceanic squids (see contributions in Pauly and Christensen, 1996).

Such biomass values may sometimes be more reliable than estimates from independent surveys, although survey data can be used to tune biomass values in the model. One problem is that Ecopath estimates represent 'averages', inappropriate for ecosystems that are used as 'way stations' for migratory resources such as herring, salmon or tuna. Doubtless we may be accused here of setting up a new goal without the quantitative tools being yet in place. We suggest that more research effort should be

put into honing tools for ecosystem management, such as Ecopath, rather than making old single-species tools ever more elaborate.

This new emphasis is particularly justified in that once an ecosystem has been described using Ecopath, its behaviour can be studied using Ecosim, the dynamic version of Ecopath (Walters *et al.*, 1997). Although still under development and far from perfected, this generic modelling software allows the validation and evaluation of alternative harvesting strategies on different parts of the system. It has recently been used, for the first time, for comparing the behaviour of different upwelling ecosystems (Mackinson *et al.* 1997), and the relation between stability and detritus recycling in marine ecosystems (Vasconcellos *et al.* 1998), while various applications to specific ecosystems are forthcoming.

In these applications, Ecosim is used to show the trajectories of various sectors of the resource when one of them is subjected to greater or lesser levels of harvest. A set of scenarios can be used to plot likely rebuilding strategies. At present, single-species dynamics would then be employed to investigate recommended harvest levels in detail; eventually, Ecosim, or some of its likely successors, should be used instead.

3. Role of fisheries management measures

Standard fishery management devices such as minimum size regulations, restriction of gear types, restriction of effort and catch (Pitcher and Hart, 1982 for a list) have an important role. But these devices have been termed 'band-aids' to be applied after the damage is done (Walters, 1995). Unless accompanied by draconian fishing regulations (such as the notorious '1-hour opening' of some Pacific fisheries), these devices are unlikely to contribute toward a rebuilding goal.

Marine reserves are critical (Bohnsack, 1993, 1996). This is not only because of their value in countering uncertainty (Clark, 1996), but also because they provide resilience against overexploitation (Guenette *et al.*, 1998) by allowing natural systems to regenerate (Ballentine, 1991) and act as a reservoir of large high-value species, precisely the objectives of the new goal put forward here.

4. Role of traditional environmental knowledge (TEK)

Historical records and indigenous knowledge can help tune the rebuilding models and define management objectives. The value of historical records of abundance and species composition is high. For instance, in the North Sea, there has been a call for 'data archeology' (Daan *et al.*, 1996) with which to try to evaluate major changes in the ecosystem. For example, a comparison of data from the 1990s with those from the early years of the

Table 24.2 Some costs and benefits in fish resources of depleting, sustaining and rebuilding ecosystem management strategies

Strategy	Product value	Total resource value	Harvest cost	Enforcement cost	Monitoring cost	Processing cost	Employment in sector
Depletion	Low	Stable	Low	Low	High	High	High
Sustaining	Medium	Rising	High	High	High	Medium	Low
Rebuilding	High	Fast rising	Low	Low	Low	Low	Low

20th century revealed shifts to lower species diversity, smaller fish and higher evenness in the demersal community (Rijnsdorp *et al.*, 1996). Finding ways to harness even older data from the 1800s and earlier (Cushing, 1988) may be valuable in evaluating the societal options for the nations around the North Sea that have been foregone by an unthinking industrialization of fisheries.

If we look at the management goals of indigenous and aboriginal peoples, we see that a goal related directly to primal abundance strikes an immediate chord (Haggan, Chapter 2, and Harris, Chapter 20, both this volume). Moreover, traditional environmental knowledge (TEK) can, through the cultural shadow cast by past abundances, help with the construction, tuning and validation of our scientific models of natural ecosystems. Present work is seeking ways of combining quantitative and qualitative information so that, together, the models and traditional knowledge can be used to describe the state of past natural systems

5. Role of socio-economics

In this section we compare the relative economic and social values of three scenarios: depletion, sustaining and rebuilding (Table 24.2).

The depletion scenario

If the pessimists are correct, the likely outcome of present-day management is depletion and ratcheting down the trophic levels, i.e. a continuation of the trends in Figs 24.1 and 24.2. In this scenario, the unit value of seafood products declines, although larger harvests, lower costs and higher demand may enable profits to be maintained. In the medium to long term, processing costs will rise as products for human consumption are created out of inauspicious species (such as myctophids or krill) and this may

create industrial employment and market opportunities in the food industry. This scenario has low enforcement costs, but high monitoring costs as small pelagic and midwater organisms that are difficult to sample quantitatively would come to dominate the system. Fishing vessels and gear would have to change as their target size and location shifts, but the catching power of the world's fleet will likely stay the same, i.e. remain excessive. In many ways this scenario is the logical, and some will say, most likely, extension of the recent history of the world's fisheries.

The sustainability scenario

If optimists are correct and we are able to perfect management for sustainability in the face of the ecological and evolutionary mechanisms outlined above, then the present harvest regime will continue. In many ways, this scenario would be a dream come true for most fisheries scientists. But what is likely to happen? For the next century, product and resource values will likely rise with the inevitable further growth in the human population and, it is to be hoped, increasing living standards. Profits would be less than they might be, however, because of high harvest, enforcement and monitoring costs in a sustained fishery. There will likely be a panoply of strictly enforced management regulations: bycatch and discard regulations and limitations on fishing gear, closed areas and seasons, catch monitoring devices such as port inspection and onboard observers. Direct employment will likely be reduced as high technology is harnessed to reduce costs. The catching power of vessels will likely increase from this pressure, although strict regulation (or the market power of transferable harvest rights) would ensure that the total number fell. Given a stable catch, the economic efficiencies of large scale would ensure that the processing and harvesting industry became concentrated in fewer and fewer hands. Although they will try to appear to do so, governments will hence be hard pressed to reduce subsidies to fishing and to coastal communities. Clearly this scenario has major economic benefits that are much preferable to depletion. It also holds out the prospect of rewarding employment for the many fisheries scientists who will be needed to keep the adaptive management engines turning (Bundy, Chapter 26, this volume).

The rebuilding scenario

In what ways is a rebuilding strategy better than the sustainability scenario? The principal benefit in a world of increasing demand will be high prices for traditional large table fish. Indirect benefits will be increased opportunities for recreational fishing as top predators recover. Hence the

total value of the resource will rise quickly for at least the medium term. Harvest costs will be low, as allowable catches will be easily made from an abundant resource. In most cases there will be no need for new technology to increase catching power, but technological solutions to provide highly selective harvest will be fostered. Enforcement costs, at least for a management system that includes large no-take reserves (Sumaila, Chapter 23, this volume), and uses the social power of local communities, should be relatively low. Monitoring costs should also be low as they can concentrate on simple indicators of rising abundance, for example using acoustics and range extension records. Because of the high product value, processing will be largely confined to traditional freezing, but distribution costs could be high for fresh fish (e.g. air freight). The only down side might be the employment, which would likely be relatively low in a small but valuable seafood industry.

24.5 CONCLUSIONS

Clearly, some of this crystal ball gazing may be flawed. But we suggest that rebuilding is likely to have the highest economic value of these three scenarios, and because of the high product values, it is the least likely to be prejudiced by high discount rates or inelastic seafood demand. An additional benefit is that the countries with 'rebuilt' fisheries resources would be able to meet the commitments implied in the various biodiversity conventions they have signed. Extrapolation of present practices will not allow for this.

In a major review of the issues facing world fisheries, Mace (1997) considers that sustainability has not been achieved in the past because we have adopted an inappropriate set of ground rules. She argues that once we successfully abandon these, true sustainability will be achievable using the instruments of modern fisheries management, such as the development of effective institutions to implement risk-averse management and the precautionary principle, set up workable access rights, a reduction of fleet capacity, and an environmentally friendly expansion of aquaculture. She presents a cogent analysis, with which we do not disagree, of the continued legacy of the inexhaustibility paradigm, a belief in the status quo, fishing as a birthright, and blaming the wrong scapegoats (such as MSY or the environment) for failure. But we disagree when Mace represents the maxim that 'recognizing the problem is half the solution' as not applying to fisheries. She considers that we have enough science, tools and insight to know what needs to be done. She comes closer to our vision when she argues that we need true environmental sustainability rather than single-species sustainability, but we contend that

the outcomes she would like to see would become more probable with the rebuilding of fish stocks as the management goal.

Is the rebuilding of functioning, diverse systems, a concept valued in the culture of many aboriginal peoples but virtually absent from contemporary resource management, a realistic goal? Well, it's not so strange. We humans have just done it with large whale populations (Swartz, pers. comm., quoted in Mace, 1997) and, in the terrestrial environment, schemes are being attempted with prairie grassland and grazing bison (Callenbach, 1995). For terrestrial habitats, it has been argued that even to sustain natural habitats, some rebuilding must be done to offset natural destruction caused by wind, fire, and damage owing to the vicinity of unnatural ecosystems (Sinclair *et al.*, 1995; Arcese and Sinclair, 1997).

In summary, the suggested procedure is first to build an ecosystem model of a present ecosystem and explore the likely depletion pathway for the near future, using simulation software such as Ecosim and ecological and life history information on species likely to go extinct (Parrish, 1995). The second step is to construct mass-balance models of past systems using historical records and TEK. Both the inclusion of species and past abundance can be validated by TEK and historical documents. For example, inputting the likely number of humpback whales known to have occurred 100 years ago in the Strait of Georgia, British Columbia, into an Ecopath model also including the groups still occurring in that system will, upon rerunning the model, force a solution with much larger biomass of herring, krill and other humpback prey species. Thirdly, a socio-economic evaluation of an alternative rebuilt system can be compared with the value of the status quo and with the value of the depletion strategy. Note that in nearshore tropical habitats, an economic balance between rebuilding and sustaining will likely be found, because some species – prawn, squids – that are favoured as depletion occurs have high economic value. An important advantage is that an economic evaluation based on an ecosystem model can evaluate these options objectively, prior to their entering the political 'allocation' arena.

Some forms of habitat destruction other than trawling mentioned above, such as accumulation of debris and changes in flow reducing oxygen in river gravels for spawning salmon, or the loss of mangroves that provide nursery areas for many tropical species, may not result directly from fishing gear, but from other human activities, especially logging (Marchak, 1995). Conventional goals for fisheries management treat these influences at best as separate issues, to be solved separately from the standard population management. At worst, such issues form no part of any quantitative evaluation. In contrast, the rebuilding goal and its supporting methodology would have to explicitly take these factors into account.

There are some other advantages that come along with the adoption of an ecosystem view. For example, trade-offs between species are seen as a political issue in single-species management, and are often regarded in terms of 'allocation' between competing parts of the fishery sector. In contrast, all interacting species are included in a multispecies resource evaluation which is part of ecosystem-based management. Bioeconomic evaluation automatically includes harvest options for fish at different trophic levels. Indeed, maximizing economic and social returns is integral to the whole procedure.

Rebuilding implies some form of pre-existing structure. Although ecosystems are always in a state of flux, especially over geological time, what we refer to here is the state that obtained before the gross and rapid depletion caused by human fishing, as illustrated in Fig. 24.2. So the former state we rebuild towards is the species mix and levels of abundance of the system before significant human fisheries began. In some parts of the world this would be thousands of years BP, in others as little as 50 years BP. Of course, we would not necessarily wish to, nor be able to, restore things to their Pleistocene levels. We easily forget that we are living through one of the largest rapid mass extinctions in the history of the planet: all of them caused by ourselves. The normal fluxes of ecology have been so totally overwhelmed by human intervention, and in aquatic ecology our responses have been so ineffectual, that remedial action requires a drastic shift in attitude and concepts. How far we should go in this direction, and how much we should rebuild to counter continuing losses, are issues of detail that will be discussed in a future publication.

Unlike some sectors of the 'green' movement, we are not advocating a return to the Pleistocene (Fig. 24.2), which is clearly unrealistic. However, given the trend in Fig. 24.1, the more fisheries move down the slope on Fig. 24.2, the more valuable the seafood harvest in those jurisdictions that have the good sense and the courage to adopt rebuilding as a goal. If adopted, a rebuilding goal for resource management will encourage consultation and consent and will directly harness traditional knowledge and history to a societal goal.

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