ICES Journal of Marine Science, 57: 761–765. 2000
doi:10.1006/jmsc.2000.0721, available online at http://www.idealibrary.com on IDEAL®

Viewpoint

Effects of fisheries on marine ecosystems: a conservationist's perspective

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Agardy, T. 2000. Effects of fisheries on marine ecosystems: a conservationist's perspective. – ICES Journal of Marine Science, 57: 761–765.

There are ample data that suggest fisheries exploitation affects not only target stocks but also communities of organisms, ecological processes, and even entire ecosystems. Conservationists, and the non-governmental organizations they represent, consider such impacts a cause for concern, because the loss of biodiversity that can result is largely irreversible. Those of us who view conservation of biodiversity as paramount need good scientific information to inform our decisions on advocacy, public awareness-raising, and support to field and policy projects. In light of what seems to be global, serial mismanagement of commercial fisheries, conservation groups advocate a number of measures to supplement – not replace – conventional fisheries management regimes. First, better information is needed on the true, ecosystem-wide impacts of fisheries activity, particularly where new fisheries are being launched, major gear modifications are taking place, and/or major expansion of fishing effort is occurring. Second, there must be a paradigm shift in the way evidence of impact is gathered, so that the burden of proof and the resources spent on trying to establish that proof are not the sole responsibility of conservationists. Third, greater use must be made of marine-protected areas as a tool to strengthen management and to provide control sites to further scientific understanding and promote adaptive management.

Key words: biodiversity, by-catch, habitat, marine protected area, reserve.

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Impacts on ecosystems and biodiversity

Marine ecosystems, and the substantial biodiversity they support, are threatened the world over (NRC, 1995). As downstream recipients of degrading impacts caused by poor land-use practices and simultaneously under increasing pressure to supply natural resources and space to accommodate human needs, the world's coastal zones and shallow seas are affected both directly and indirectly. Multiple and cumulative threats have already caused the loss of both species and genetically unique stocks of organisms and have undermined the functioning of many marine systems (Dayton *et al*., in press). Conservationists, and the non-governmental organizations (NGOs) they represent, are concerned that unless we change our attitudes towards use of the seas, a marine biodiversity crisis looms.

If a common conservationist or NGO perspective can be said to exist, it is that the conservation of biodiversity should take precedence over maximizing marine fisheries yields. Though this may appear an ethical argument, its justification is in fact a scientific one. The loss of biodiversity, whether at the level of genes and species (alpha diversity), or ecological communities (beta diversity), is irreversible and represents potentially huge opportunity costs in the future. Our common agenda is thus preserving biological diversity – or, more specifically, preventing activities that cause irreversible impacts to ecosystems. This is seen in contrast to fisheries organizations that commonly aim to maximize the production of commodities or the economic efficiency of their activities.

The drive to exploit living marine resources stems from an increasing reliance on fisheries-derived protein to feed burgeoning human populations, livestock, and cultivated aquatic organisms (NRC, 1995). This growing demand is exacerbated by poor agricultural practices that reduce the potential of terrestrial sources to meet these protein needs. Overexploitation stems not merely

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from need but from the tragedy of the global commons – that is, the inability of governments to adequately regulate use of common property resources (Hardin, 1966). Commercial fishing, whether large-scale industrial fisheries or small-scale operations, commonly overexploits stocks, in some cases collectively causing trophic mining (Pauly *et al*., 1998). Though the list of marine endangered and threatened species pales in comparison to that of terrestrial and freshwater systems, marine biodiversity is being lost at an alarming rate as genetically unique populations of marine organisms are extirpated (Dayton *et al*., 1995; Vermeij, 1993). Even for cosmopolitan species, this reduction in genetic diversity is damaging (Jennings and Kaiser, 1998).

Serial mismanagement of fisheries extends beyond the effects of overexploitation to include exploitation methods that compromise marine biodiversity. Fishing methods commonly used to catch highly valued species selectively affect many other species – not only unutilized finfish, but also sea turtles, sea birds, and porpoises (Dayton *et al*., 1995). These incidentally caught and wasted species, some of which are already endangered, may constitute a higher percentage of catch than the target species – in some cases, nearly 30 times more by weight. Surface long-lining contributes to the mortality of thousands of seabirds annually, while mid-water long-lining has been implicated in the dramatic population decline of the leatherback turtle and shrimp trawling has severely reduced populations of other sea turtle species (NRC, 1995). Habitat alteration, as exemplified by bottom trawling that rakes the benthos, kills epibenthic plants and animals, and interrupts key ecological processes, is also problematic (Auster, 1998).

To understand the extent of the fisheries crisis, how selective removal of target species affects ecosystem health and productivity must be appraised. By concentrating harvest on top predators (e.g. mako shark, billfish, bluefin tuna), fishing practices dramatically affect biological communities by causing cascading effects down food webs that decrease diversity or productivity. Removal of such apex predators need not be at industrial scales to result in these effects, because many of these species are naturally rare or patchily distributed. Even recreational fisheries that target these species can affect wider marine biodiversity.

Decreases in the abundance of valuable species high in the food chain have caused fishers to target less valuable resources at lower trophic levels (Pauly *et al*., 1998). Because of their lower value, they are fished with increased intensity – such that entire trophic levels can be affected. Decline in abundance of primary consumers removes important forage species for organisms higher in the food web, again with cascading effects (Dayton *et al*., 1995; Jennings and Kaiser, 1998). Such altered ecosystems may have impaired function and be unable to replenish lost resources.

When these ecological impacts caused by fisheries are coupled to general environmental degradation, such as eutrophication of coastal waters, toxic pollution, or global climate change, the capacity of marine systems to support sustainable fisheries is reduced (Costanza *et al*., 1993). Even more importantly, when essential habitat is lost, as in the conversion of wetlands or nursery areas for coastal development, the critical threshold levels inevitably move down (Dayton *et al*., in press). The paradox is that marine ecosystems are increasingly less able to support demand, even as demand continues to increase.

What NGOs advocate in response

Conservation NGOs are increasingly addressing global problems in fisheries management, and most attempt to base their projects and advocacy on the best available scientific information. They sometimes undertake in-house scientific research, predictive modelling, and meta-analysis. However, in most cases, NGOs are recipients of scientific information and act as liaisons between the scientific community, decision-makers, and the public.

To be maximally effective in addressing global marine biodiversity concerns, conservationists consider several facets of sustainability: (1) the levels of resource removal that can be realized without adverse impact on the ecosystem given the particular environmental condition of the ecosystem at time of harvest; (2) the least invasive means by which desired harvest levels can be taken, such that habitat impacts and by-catch are minimized; and (3) the most appropriate stocks for large-scale harvest, i.e. stocks that are not the sole representatives of a deme or particular genetic structure and those that do not play a critically important ecological role or are redundant.

Conservationists are also concerned that, in determining what constitutes sustainable levels, methods of exploitation, and target species, changing environmental conditions and contexts are taken into account. For instance, resource removal that may have minimal impacts on ecosystem function and overall biodiversity under relatively pristine conditions could potentially have devastating effects in ecosystems already stressed by pollution, eutrophication, and alterations to primary or ecologically linked habitats.

In general the NGO response to fisheries-induced loss of marine biodiversity is to synthesize existing information, communicate it and advocate change in policy and regulations. In addition, we feel there is a need to go beyond fisheries-by-fisheries management reform to include at least two additional issues: (a) shifting the burden of proof when evaluating fishing impacts on ecosystems; and (b) establishing strictly protected marine reserves to further our understanding and protect species, habitats, and ecological processes.

Shifting the burden of proof has received recent attention in the fisheries management community (Dayton, 1998), but there remain misconceptions. Conservationists believe the current situation is illogical and intractable. As new fisheries are developed, evaluating prospective impacts becomes the tacit responsibility of environmental interests, who must contract and fund scientists to undertake appropriate studies. This is in sharp contrast to other regulated development sectors, in which environmental impact assessment is the responsibility of the development interests. In the latter case the burden of proof, showing no likely impact or acceptable levels of impact, rests on those who will profit from development. Therefore, most of the conservation community advocates shifting this burden of proof in evaluating the prospective impacts of new fisheries, expanding fisheries, or new technologies – and for regulators to permit such fisheries development only when proof of no likely impact exists.

Marine protected areas

Marine protected areas (MPAs) are increasingly being selected from the portfolio of options available to managers, largely because conventional measures to manage fisheries and conserve marine ecosystems have repeatedly failed (Agardy, 1994). This failure entered the realm of public consciousness as the signs of mismanagement began to affect consumers as well as fishers. Limiting fisheries management to controls on quantity of effort or catch ignores the potentially significant impact that fisheries activities have on ecosystems and their function. The use of spatial and temporal regulations, as made possible by area closures, ensures that the benefits of management are extended beyond just the target stock to wider segments of ecosystems. Thus, fully protected areas, when used in conjunction with other forms of regulation, can move management away from largely ineffective species-by-species fisheries management to more ecosystem-based conservation.

MPAs are fundamentally different from terrestrial protected areas, though whether these differences are in kind or degree is debatable. An important factor underlying these differences is the nebulous nature of boundaries in the fluid environment of the sea, making it difficult to attach boundary conditions to marine ecological processes and threats to those processes. While this is also true for inland freshwater systems, terrestrial ecosystems commonly have discernible outer bounds and distinct thermal regimes that delimit biotic communities. To a far greater extent than on land, it is impossible to "fence in" living marine resources or the critical ecological processes that support them, just as it is impossible to "fence out" the degradation of ocean environments caused by land-based sources of pollution, changes in hydrology, or ecological disruptions occurring in areas adjacent or linked to a protected area. Long-distance dispersal and the vastness of linkages between critical habitats in coastal and marine ecosystems requires comprehensive management of all their parts (Caddy and Sharp, 1986; Costanza *et al*., 1993).

The open nature of coastal and ocean areas exists as a spectrum ranging from relatively fixed systems to highly dynamic and complex systems. Coral reef ecosystems, for instance, harbour organisms that are largely confined in their movements to the specific habitats of reef, surrounding soft or hard benthos, and coastal wetlands (Hatcher *et al*., 1989). Their structural framework is fixed in place and can be mapped, much as a tropical forest provides a relatively fixed framework for the interactions within the forest community. The functional links between the water column in reef areas and the benthos are strong, so one can treat the marine organisms together with reef structures. In contrast, temperate open ocean systems such as estuarine/gulf/banks complexes are highly dynamic and in no way fixed. Here living marine resources move in space and time according to largely non-deterministic patterns that are controlled by physics (de Groot, 1992). The ecology of the water column is not strongly linked to that of the benthos, and physical reference points cannot easily be mapped. This wide array of system types thus presents a challenge to conservationists and resource managers, requiring that MPA measures be appropriate to the system in question (Agardy, 1997).

Because identification of critical areas, public education, and enforcement is more easily achieved in coral reefs and other relatively fixed ecosystems, work on MPAs has proliferated in these systems (Quinn and Botsford, 1993). That is not to say, however, that MPAs in temperate and boreal systems are infeasible, nor should it suggest that their potential benefits are fewer in non-tropical systems (Dayton *et al*., in press). It merely suggests that random application of terrestrial models to marine environment may not result in a viable means of protecting resources and their underlying ecology. New paradigms are needed – and the newest developments reflect both acknowledgment of fundamental differences between marine and terrestrial systems, and existence of new information and planning technologies that can optimize MPA design.

Clear evidence exists that MPAs can be designed to help make fisheries and coastal management more effective. In the last 5 years, new, rigorous, and defensible evidence has emerged to show that MPAs do indeed improve fish yields while conserving biological diversity more generally (Jennings and Kaiser, 1998). These benefits have included increased fish stock size inside the reserve as well as spillover effects to surrounding areas in the Caribbean (Roberts, 1995b; Roberts and Polunin, 1991), Philippines (Russ and Alcala 1996, 1997), and in numerous other areas (Bohnsack, 1996; Dugan and Davis, 1993; McClanahan and Kaunda-Arara, 1996). The ideal situation seems to be the establishment of closed areas within the context of a larger multiple-use protected area such as a coastal biosphere reserve, marine sanctuary, or other large-scale MPA.

Area closures that are designated specifically to protect "seed banks" or sources of recruits are becoming more common (Roberts, 1995a; Russ and Alcala, 1996). The link between certain coastal areas and maintenance of marine fisheries resources has been clearly established. Although recruitment dynamics are often complex and seemingly unpredictable (Fogarty *et al*., 1991), dispersal pathways for recruits can be sometimes readily identified. The important biological processes that support fisheries yield include spawning, migratory pathways, feeding, settlement, and concentrated feeding (de Groot, 1992). Such critical ecological processes in nearshore ecosystems are often concentrated in areas that can be easily identified by physical parameters such as reef formations, extensive shallow areas, certain types of coastal wetlands, continental shelf breaks, and frontal systems.

An additional role for MPAs is to serve as control sites for scientific research and experimentation, especially to foment true adaptive management in which controls on use serve as experiments to test management effectiveness. Without control areas and rigorous hypothesis testing, management cannot be truly adaptive. Unfortunately, many managers and the public at large tend to think that any management that is revised over time or is flexible is adaptive management. Without the science behind it, such flexibility is in essence only bet-hedging.

Although the usefulness of closed areas and harvest refugia is being increasingly documented as resource managers turn to this option, there are undeniable constraints to its broad applicability (Russ and Alcala, 1998; Allison *et al*., 1998). Limited scientific knowledge on population replacement rates, dynamics, recruitment patterns, and impacts of fishing pressure on ecosystem function have all been used as excuses hindering establishment of no-take reserves. The stochastic nature of many marine systems also undermines the usefulness of this approach, particularly if closed areas are treated as static and immutable entities instead of as flexible management measures. Social constraints also may limit their applicability. The fishing industry is notoriously hard to regulate, precluding the acceptance of any new, potentially effective management tool. Closures having a scientific basis may be viewed by the fishing community as exclusionary practices that are somehow rooted in social discrimination. This predisposes user groups to reject the idea of MPAs even before they have the chance to discover exactly why and how these would be beneficial to them.

However, if carefully planned and grounded in good scientific understanding of ecosystem dynamics, MPA designations can be an effective tool to complement other fisheries regulations. The prospect of increased management and enforcement that their implementation entails will not be readily embraced by most fishing communities, but only until their effectiveness in maintaining and even increasing catch is demonstrated. Managers will have to be responsive to changes in scientific information, in the status of the resources, and in management needs to make MPAs optimally effective. This will require adopting management techniques that allow refinement based on periodic reassessment of zone boundaries, regulations and overall extent.

Conclusion

From the conservationists' perspective, the solution is not to shut down fisheries but rather to modify the type of management, and use public awareness to help raise political will for taking responsibility for the conservation of marine systems. Coupling current consumer awareness and purchasing power with strong and effective management could indeed alleviate pressure on many marine species and allow their subsequent recovery. Critical to this effort would be real willingness among governmental agencies and decision-makers to protect areas needed for spawning, feeding, and migration through marine reserves, as well as entering into enforceable international agreements to protect shared or common resources. This means not only discussing and defining essential fish habitat, as has been done in the reauthorization of the U.S. Magnuson Fisheries Conservation and Management Act, but actually biting the bullet and setting aside strictly enforced MPAs. Without decision-makers taking more responsibility for fisheries management and habitat protection, fisheries and marine biodiversity will be permanently compromised.

Acknowledgements

Special thanks are extended to Mike Sinclair for his genuine interest in unconventional perspectives and his commitment to broadening participation in ICES deliberations.

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