Integrated Coastal Management

Management is a process of modifying human behavior. Biophysical scientists can provide advice and predictions concerning factors such as levels of fishing pressure, siltation, and pollution. However, the management decisions must account for social, cultural, political, and economic considerations. Furthermore, almost all management interventions will have both positive and negative effects on various aspects of the ecosystem and the societies that impact it and depend upon it. For example, diverting fishers into forestry may lead to increased deforestation, siltation, and further reef degradation.

It is increasingly recognized that effective management is achieved only through approaches that integrate biophysical considerations with socioeconomic and related factors. Balanced stakeholder involvement is generally a prerequisite for compliance with management decisions. The field of integrated coastal management is rapidly evolving, as is the set of scientific paradigms on which it is based. To a large degree, the future of the world's coral reefs is directly linked to this evolution.

See also

Air–Sea Transfer: N_2O, NO, CH_4, CO. Autonomous Underwater Vehicles (AUVs). Beaches, Physical Processes affecting. Carbon Cycle. Carbon Dioxide (CO_2) Cycle. Cenozoic Climate – Oxygen Isotope Evidence. Cenozoic Oceans – Carbon Cycle Models. Coral Reef Fishes. Diversity of Marine Species. El Niño Southern Oscillation (ENSO). Eutrophication. Fish Feeding and Foraging. Geomorphology. History of Ocean Sciences. Lagoons. Macrobenthos. Mangroves. Manned Submersibles, Shallow Water. Nitrogen Cycle. Past Climate From Corals. Pelagic Biogeography. Remotely Operated Vehicles (ROVs). Rocky Shores. Sandy Beaches, Biology of. Satellite Oceanography, History and Introductory Concepts. Satellite Remote Sensing of Sea Surface Temperatures. Sea Level Change. Sea Level Variations Over Geologic Time. Ships. Storm Surges.

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CORAL REEF AND OTHER TROPICAL FISHERIES

V. Christensen, University of British Columbia, Vancouver, BC, Canada
D. Pauly, University of British Columbia, Vancouver, BC, Canada

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Introduction

Until recently studying and reporting on tropical fisheries tended to be done in the context of development aid projects initiated with the perception that the transfer of technology, management approaches, and scientific models to tropical countries would assist them in a way that would help to raise the standard of living and the food supply. Many of these aims have been achieved, although not necessarily through such North/South transfer but rather through local growth of the preexisting fisheries, and through access rights granted to distant water fleets of developed countries to operate in the waters of developing countries. These developments have turned tropical and reef fisheries from the marginal activities they were in the 1960s and 1970s to key players in international fisheries. Catches in tropical and subtropical fisheries presently exceed those in developed countries, as do exports from developing to developed countries – which dwarf exports in the opposite direction. In the process tropical fisheries have become globalized to a much further extent than other food commodities such as rice, for example, which is overwhelmingly consumed locally.

The experience gained in developing, managing, and studying developing country fisheries have in the process become part of the mainstream of fisheries research. Some of these findings are presented below to characterize trends in tropical and coral reef fisheries, which have paralleled or in some case preceded developments in higher latitude fisheries.

Coral Reef and Tropical Fisheries

Fisheries Development

Through the first half of the last century the tropical seas were only lightly exploited by humans, even if coastal areas were harvested on a small scale using sustainable methods and often with locally based regulation methods in place. However, during the inter-war period many colonial states tried to introduce more industrial fishing methods to increase productivity and food supply. In general, the early attempts were not particularly successful, an exception being the introduction of trawling in the South China Sea area by the Japanese in the late 1920s.

After the Second World War surplus engines and crafts allowed for an expansion of effort in many areas and the following decades saw the introduction of trawling in most of the coastal shelf areas of the tropics. Stagnating catches and signs of overfishing soon followed the expansion of trawling; an early example of this came from the Manila Bay in the Philippines where trawling was introduced shortly after the war, and where overfishing was apparent by the late 1950s.

The classical, well-documented case of how fisheries ‘development’ with the introduction of trawling quickly leads to stagnating catches in spite of continuing build-up of effort comes from the Gulf of Thailand. Here a development project in the early part of the 1960s initiated a demersal trawl fishery in hitherto unexploited parts of the Gulf. This led to a rapid build-up of commercial fisheries in the mid-1960s, and has often been hailed as a leading example of a successful development project. Fortunately, a stratified research survey series has been in place in the Gulf continuously since 1966 documenting the ecological changes brought about by the fisheries. Initially, the catches increased steadily with effort, but stagnated after a decade and since then they have remained at about the same level in spite of increasing effort. At first glance this may be indicative of a sustainable fishery – after all the catch level has been maintained for several decades. However, a closer look shows a different and unfortunately very typical picture.

As the fishing pressure increased, the longer-lived species rapidly declined, many by a factor of 10 or more within a decade. Sharks and the larger rays were among the first to disappear because of their low fecundity and long life spans, while the dominant group (by weight) in the ecosystem changed from ponyfishes to squids within a decade from the onset of the trawl fisheries. The average trophic level of the catches, as well as of the ecosystem resources in the Gulf, has decreased steadily as fishing pressure mounted. Hence, catch level may be maintained but what is being extracted is smaller and generally lower-value catches; the average fish is finger-sized. The groupers, snappers, and most other high-value species are gone, and the catches include some 40% of ‘trashfish’, i.e. small species and juveniles of larger, commercial species. The trashfish are being used to produce fish oil and meal mainly to supply a growing aquaculture industry.

The degradation of the Gulf of Thailand ecosystem as described is typical of what is happening to the fisheries of the world because of overexploitation, and is indicative of a process now generally being called ‘fishing down the food web’. This term recognizes how we change ecosystems by systematically eradicating the upper trophic levels, how we follow up by removing the more intermediate levels to end up catching squids, shrimps, and other organisms low in the food web. This may be considered an economically interesting alternative to the unexploited state given the high value of squids and shrimps, but a closer examination shows that it is a dangerous path, beset with increased risk of unwanted structural changes in the underlying ecosystems. The scientific and practical challenge lies in balancing the harvesting so as to maintain healthy ecosystems. Also, the path does not recognize the growing public concern for marine ecosystems – they may be largely out of sight but they are no longer out of mind.

The Ecosystem Perspective

Fisheries in temperate areas are often described in the form of their target, e.g. herring or cod fisheries. In tropical fisheries the taxonomic diversity, until recently not fully mastered by fish taxonomists (but see FishBase at www.fishbase.org), along with the unselective nature of the fishing gear used (e.g. lift-nets or trawls in shallow waters), result in a widely diverse catch, often comprising hundreds of species in a single haul. This precludes the notion of using single-species management procedures, which so far have dominated the management of temperate fisheries. From the onset, management in the tropics had to be based on the yields of aggregate of species of target groups (e.g. groupers), implicitly or explicitly taking account of their biological interactions. In contrast, in temperate waters managers have only recently fully realized the consequences of the non-selective nature of the gear used, and thus the ecological consequences of their impact through the food webs.

The trend in fisheries research in recent years has been toward incorporating an ecosystem perspective into the assessment and management of living aquatic resources. This is done in recognition both of the fact that there is biological interaction among the resources ('fish eat fish') and acceptance that exploitation has consequences not just for the exploited resource but for their predators, competitors, and prey as well. Of especial significance here is what may be termed 'charismatic' organisms, notably marine mammals, sea birds, and turtles. As the environmental movement has gained strength over the past decades it is becoming increasingly clear that there are more players to be recognized than the hunters and gatherers. Examples are the 'dolphin-free' tuna stamp now required to export tuna to the USA, and the turtle-excluding devices required for shrimp fisheries in order to maintain export markets.

Incorporating the ecosystem perspective into management has been an arduous task that has kept the fisheries research community challenged for decades. The pioneers in the field were E. Ursin working in the North Sea and T. Laevastu in the north-east Pacific back in the 1970s. Since then the major steps in the northern temperate areas have been focused on 'multispecies virtual population analysis' (MSVPA), based on single species assessment methodologies but incorporating biological interaction. Building directly on traditional assessment methodologies, MSVPA has had a wide support base in the fisheries assessment circles of the North, but it has not been widely used, partly because of a heavy price tag caused by its extensive data requirements, partly because it was designed to include only the commercial fish species, and partly because its ability to address ecosystem-level questions is limited.

In the tropics the development has taken a different route. A US fisheries scientist, J. Polovina, who had the task of developing an ecosystem model (Ecopath) for a Hawaiian reef system, was inspired by Laevastu's approach and developed a simple version of it incorporating all important functional groups of the ecosystem studied. The model required comparatively little information for parameterization and its ecological book-keeping system ensured that gross errors were likely to be recognized, hence providing a feedback to the biological sampling system. In the nearly two decades since it was first described, the Ecopath approach has been developed considerably by a growing team of scientists, and it has now reached a level where it is being used for ecosystem-based fisheries management in many countries. The approach (and the software that makes it operational, freely available from www.ecopath.org) is easy to adapt to new areas, as illustrated by the fact that it is being used in more than 100 countries in almost equal measures in temperate and tropical countries.

Fisheries Affect the Physical Environment

Many of traditional small-scale fisheries previously prevailing in the developing countries of the inter-tropical belt were benign, i.e. they did not modify the habitat in which the resources they used were embedded. The introduction of industrialized fishing methods and the modernization of local techniques both impacted local ecosystems very severely. Thus trawling in the narrow coastal shelf destroys structured habitats with sponges and soft coral to an extent that was not visible in the fisheries of the higher latitudes (where benthic habitats are also destroyed). Furthermore, coral reefs, which are important in the inter-tropical belt, are now exploited by extremely destructive methods such as dynamite and cyanide fishing; the latter usually to catch live large fish for restaurants or for the ornamental trade, both of which support valuable export sectors. Here again it is the visibility of the impacts that have subsequently led in the North to reassessment of the physical impact of fisheries on habitat. An example of this is the growing concern about how trawling impacts ecosystems; for instance, how heavy beam trawls have eradicated cold-water coral reef structures.

Globalization and Poverty Jointly Destroy Fisheries Resources

The bulk of the countries of the inter-tropical belt do not have the administrative structure that would make it possible to limit entry into fisheries. The result is that millions of landless farmers and other rural poor have become small-scale fishers in recent decades – the fisheries being the last resort for livelihood. These fishers have no tradition of restrained and community control of effort as they start to compete with more established fishers. Their lack of access to capital forces them to use cheap and often, unfortunately, destructive methods – most notably explosives and poisons (cyanide or insecticides).

Growing populations with a need for cheap fish provide an outlet for the low quality products that emerge from these activities, while a largely insatiable world market (notably Western Europe, USA, Japan, and China) absorbs the high quality products, especially expensive invertebrates such as shrimps and sea urchins. This massive uncontrolled inflow of effort leads to what has been called 'Malthusian overfishing', wherein extreme poverty reduces the cost of labor (usually a limiting factor in fisheries) to virtually nothing; thus making fishing 'profitable' even when productivity is very low. Adult fishers are often seen operating over an entire day to land only one pound of small fish per person. In such cases poverty and other nonfishers in the family subsidize the fishery.

Other subsidies impacting small-scale fisheries and leading to gross overexploitation are provided by development banks that continue to encourage increasing fishing effort, and the access rights that are negotiated by powerful developed countries for operating distant water fleets in the tropics, e.g. for trawling off west Africa by EU vessels or tuna fishing in the Indian and Pacific Oceans. Such developments, which have contributed to an enormous excess capacity in the developed world, have also contributed to making the subsidy issue more visible in developing countries, where attempts to address these problems have so far been stymied by shipbuilding and other powerful lobbies. There is, however, a growing realization of the need to reduce the overcapitalization, as perhaps best exemplified by the growing reluctance of development agencies to fund 'fisheries development' projects due to the recognized high failure rate of such projects.

Marine Protected Areas Are Part of the Solution

While the foregoing presented a number of problems, which appeared or became visible first in the inter-tropical belt and only later were seen as global problems, this section presents elements of solutions to the global ills, which also have appeared first in the developing world. One of these is marine protected areas (MPAs), first demonstrated in the Philippines to have the potential both to allow resources to regenerate/rebuild themselves and to increase the yield for fishers. Such marine protection implies permanent closure of a significant part of an area traditionally exploited by fisheries, 40% in the case of the island first studied by the pioneering team of Dr Angel Alcala in the Central Philippines. These closures allow the growth of animals, in this case especially groupers and snappers, which would otherwise be caught as juveniles. Their increased biomass and the high percentage of adults within the MPA lead to migration from the MPAs to the surrounding waters, and hence to increased catches in the surrounding areas, and as has been demonstrated, to larger overall catch.

As widely noted, MPAs are not a panacea; notably they require that fishing outside the MPAs must be regulated. Even more importantly the communities whose fishing grounds have been impacted by an MPA must accept the gamble that the MPA represents, and must indeed be the advocates and protectors of the MPA. This implies that they have accepted, through fruitful interaction with scientists or other communities that are patrons of an MPA, that their fishing impacts the resource, something still hotly denied by the less enlightened part of the fishing community in many countries. Further, the communities must be self-organized so that they can prevent defection, i.e. fishing within the MPAs for the resources that rapidly build up as the fishing pressure is released. Third, for the MPA to be set in place, the central government for the country in question must have relinquished enough power to the communities for them to be in a position to take pertinent decisions and see them implemented. Finally, for the MPA approach to work fishing communities must have accepted the notion that the immediate gains from exploiting a resource must be put in a longer-term context. Essentially the community must take a conservation-oriented standpoint, i.e. it must overcome the huge chasm which until now has separated fisheries from conservation.

Demanding as these requirements may seem, they have been met in many parts of the Philippines, the Caribbean, and other parts of the world – including New Zealand, a developed country. Given the difficulties in implementing other forms of effort reduction measures and the very destructive trends in the areas where MPAs are not implemented it is likely that the trend toward using MPAs as an integral part of sustainable fisheries management will continue. Indicative of this trend is the fact that in his last year of office US President Clinton signed an executive order calling for 'protection of existing MPAs and the establishment of new MPAs, as appropriate.'

See also

Ecosystem Effects of Fishing. Fisheries: Multispecies Dynamics. Fishery Management. Fishing Methods and Fishing Fleets. Marine Fishery Resources, Global State of. Network Analysis of Food Webs.

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CORAL REEF FISHES

M. A. Hixon, Oregon State University, Corvallis, OR, USA

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Diversity, Distribution, and Conservation

Coral-reef fishes comprise the most speciose assemblages of vertebrates on the Earth. The variety of shapes, sizes, colors, behavior, and ecology exhibited by reef fishes is amazing. Adult body sizes range from gobies (Gobiidae) less than 1 cm in length to tiger sharks (Carcharhinidae) reportedly over 9 m long. It has been estimated that about 30% of the some 15 000 described species of marine fishes inhabit coral reefs worldwide, and hundreds of species can coexist on the same reef. Taxonomically, reef fishes are dominated by about 30 families, mostly the perciform chaetodontoids (butterflyfish and angelfish families), labroids (damselfish, wrasse, and parrotfish families), gobioids (gobies), and acanthuroids (surgeonfishes).

The latitudinal distribution of reef fishes follows that of reef-building corals, which are usually limited to shallow tropical waters bounded by the 20°C isotherms (roughly between the latitudes of 30°N and S). The longitudinal center of diversity is the Indo-Australasian archipelago of the Indo-Pacific region. Local patterns of diversity are correlated with those of corals, which provide shelter and harbor prey. There is a high degree of endemism in reef fishes, especially on more isolated reefs, and many species (about 9%) have highly restricted geographical ranges.

The major human activities that threaten reef fishes include overfishing, especially by destructive fishing practices, and habitat destruction, including both local effects near human population centers and the ongoing global decline of reefs due to coral bleaching. Worldwide, about 31% of coral-reef fishes are now considered critically endangered and 24% threatened. The major solution for local conservation is 'no-take' marine protected areas, which have proven effective in replenishing depleted populations.

Fisheries

Where unexploited by humans, coral-reef fishes typically exhibit high standing stocks, the maximum being about $240\,t\,km^{-2}$ (about $24\,t\,C\,km^{-2}$). High standing crops reflect the high primary productivity of coral reefs, often exceeding $10^3\,gC\,m^{-2}\,y^{-1}$, much of which is consumed directly or indirectly by fishes. Correspondingly, reported fishery yields have reached $44\,t\,km^{-2}\,y^{-1}$, with an estimated global potential of $6M\,t\,y^{-1}$. These fisheries provide food, bait, and live fish for the aquarium and restaurant trades. However, the estimated maximum sustainable yield from shallow areas of actively growing coral reefs is