Current Status and Prospects of Fishery Resources of the Indian Continental Shelf

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Introduction

Coastal fisheries are an important source of food, employment and foreign exchange. In India, the marine fish production increased by about six times in the last 50 years reaching about 3.2 million tonnes in 2008. It provides employment to about one million fishermen and earns foreign exchange of nearly Rs. 1,00,000 million. Most of the marine fish landings are from fishing operations in coastal shelf area, especially from the shallower region ranging from 5 to 100 m depth. In the last few years, the production from coastal fisheries is almost stagnant as these fisheries are adversely affected by a number of problems and issues, with serious consequences on the availability of fish and income to the fishers. As fisheries continue to be open access without any effective controls in place to limit the growth of fishing capacity and fishing effort or limit catches through a quota regime, the sector attracts more number of vessels and operators tend to invest more in technological improvements of fishing craft and gear.

Effective fisheries management measures need to be implemented for sustainable production. The general objectives of fisheries management are to achieve nutritional security, maintain sustainability of the resources, and ensure gainful employment and economic benefits. Consistent with sustainable coastal fisheries development as the overall goal, management entities should attempt to: (i) enhance coastal living resources, (ii) optimize economic realization, (iii) maintain distributional equity, (iv) achieve environmental integrity and (v) emphasize institutional effectiveness.

Issues in shelf fisheries

Excessive fishing effort

One of the major issues is the high level of fishing effort on coastal fish stocks, particularly in the near-shore traditional fishing grounds. Excessive fishing pressure in many coastal areas has resulted in stagnation and decline in the landings; decreased catch rates, incomes and resource rents; and intense competition and conflict among fishers. Conflicts among fishers using different types of fishing gear and different scales of fishing technology are pervasive in fisheries. These are especially common between small-scale fishers using boat seines, gillnets, hooks and lines, and trawlers that operate in near-shore waters targeting the same resources.

Inappropriate exploitation patterns

Inappropriate patterns of exploitation have led to erosion of benefits from the coastal resources. The use of trawls with small-meshed codends is a cause for concern from the point of view of growth overfishing, biodiversity loss and economic loss. It has been reported that the use of small-meshed trawl codends (about 20 mm) has led to losses up to 20% and 35% of yield and value, respectively (Silvestre and Pauly, 1998).

Post-harvest losses

In India, the large fleet of multi-day trawlers discards a substantial portion of the catch into the sea. This has attracted considerable attention over the last few years. Discarding takes place due to a number of factors such as multi-species nature of the resources, poor selectivity of the gear, use of small meshed codends, scarcity of space in fish hold, and poor market value of the landings. Apart from discards, the extent of physical losses due to spoilage of the landed fish and loss in value due to reduced quality are major concerns.

Habitat degradation

One of the factors that cause degradation of environment and depletion of fish stocks are the anthropogenic impacts other than that caused by fishing. The man-induced alteration of the physical, chemical and biological integrity of air, water, soil and other media is causing, in several cases, irreversible damage to the structure and function of ecosystems. Runoff from domestic, municipal and industrial wastewater discharges and agricultural fields, solid waste disposals, discharge from ships, oil spills from tankers and wells, are some of the major sources that cause deterioration of water quality, and damage to the aquatic ecosystems. Dams divert nutrient-rich water from entering into the sea, and obstruct the migratory path of some fishes. Pollutants such as trace metals and organochlorine pesticides enter the biological systems through food webs. Animals in higher trophic levels experience the effects of bioaccumulation and biomagnification of pollutants. Depending on the intensity, the interferences may affect the physiological processes of growth and reproduction of aquatic organisms, causing mass kills, biodiversity loss and displacement of species. There are several instances in which recruitment to the fishery is seriously affected causing reduction in fish catch and revenue returns.

Fisheries sustainability needs to be addressed in an integrated way by considering the issues of all the anthropogenic interferences such as increasing fishing intensity, damage to the physical, chemical and biological integrity of the ecosystems and climate change. As fisheries are impacted by the developmental needs of several other important prime sectors such as agriculture, industries and power generation, it is not possible to find solution to the issues from fisheries sector alone. For instance, issues such as water contamination, enforcement of standards for water discharge, maintaining the quality of river runoff, and reducing greenhouse gas emissions, have to be addressed by non-fisheries sectors.

Climate change

Another major perceived threat is from climate change. Emission of greenhouse gases from fossil fuel burning, industries, thermal power stations and several other anthropogenic activities has reached an alarming level of concentration. This is causing rise in water temperature, increase in salinity, sea level rise and acidification of water. It is feared that the oceans, which are carbon dioxide sink, may get saturated and may lose their carbon sequestration potential.

Most fish species have a fairly narrow range of optimum temperature related to their basic metabolism and availability of food organisms. Being poikilotherms, even a difference of 1°C or 0.1 unit of pH in seawater may affect their distribution and life processes. The more mobile species would be able to migrate to favourable areas over time, but less mobile and sedentary species may not be in a position to do so. Depending on the species, the area it occupies may expand, shrink or be relocated. This will induce increases, decreases and shifts in the distribution of marine fish, with some areas benefiting while others lose. From the recent investigations carried out by Indian Council of Agricultural Research, the following responses to climate change by different marine fish species are discernible in the Indian seas (Vivekanandan *et al.*, 2008): (i) extension of distributional boundary; (ii) shift in latitudinal distribution; (iii) change in abundance; (iv) shift or extension in depth of occurrence; and (v) phenological changes. Coral reefs may experience regular bleaching and become remnant in another 50 years.

Existing fishing regulations

Seasonal closure of fishing

The maritime state governments take year-to-year decision on the period and duration of closure of fishing operation by the mechanised vessels. Along the west coast, the ban is for 45 to 60 days during the southwest monsoon. Along the east coast, the ban is during April – May. The objective of seasonal closure is to reduce the annual fishing effort of mechanised vessels, particularly the effort of the trawlers during the spawning season of fishes, and thereby to replenish the stocks.

Demarcation of fishing areas for mechanised and artisanal sectors

In the context of persistent conflicts, most of the maritime state governments have delineated the areas of operation for the artisanal and mechanised vessels in the territorial waters, in their respective Marine Fishing Regulation Acts. In general, the mechanised vessels have been banned from operating in the inshore areas (extending to a distance of 5 to 10 km from the shore), which have been assigned exclusively to the artisanal vessels.

Regulation of mesh size

The purpose of controlling the mesh size, especially in the codend of the trawls, is to permit the escapement of juveniles hoping that their growth would largely compensate the loss and increase the exploitable biomass, which might be available to the fishery later. Minimum mesh sizes are often emphasized as essential by the scientists as there is general agreement that protection of young fish is necessary.

The codend mesh size of the trawls prevalent in India is uniformly very small (about 15 mm or even less). Most fishery scientists have suggested a minimum stretched mesh size of 35 mm. Regulation of codend mesh size is difficult to enforce.

For a fisheries management system to be effective, monitoring, control and surveillance (MCS) are necessary to enforce the regulations. This is one of the reasons why the fisheries management is considered to be very expensive. In several developed countries where fisheries management includes quotas, restrictive licenses, seasonal closures and gear limitations, surveillance is done on the shore and at the sea by using ships and aircraft. The entire surveillance system is able to sustain itself financially through licensing and fines or through redistribution of funds from other sources.

Prospective fishing regulations

Finding the existing fishing regulations inadequate to meet the increasing fishing intensity in the coastal waters, the government and non-government agencies have suggested various kinds of management measures for a sustainable fishery.

Limited entry

Fisheries conservation approach should involve rationalisation of capital investment on fishing. In order to avoid overcapitalisation and dissipation of economic rent, the number of vessels or aggregate gross tonnage and/or horsepower of fishing vessels operating in an area should form the basis upon which the number of licensed vessels has to be regulated. In determining the number of vessels to be licensed, the total capital investment has to be evaluated and distributed by the size-class of vessel.

Total allowable catch

The most common fisheries management method followed in many countries is to impose an upper limit on the total allowable catch (TAC). Setting an upper limit on how much can be caught, most fish stocks in the northeast Atlantic ocean are now controlled. This is a typical biological management measure designed to protect fish stocks. If adhered to, the TAC restrictions are well suited for conserving the fish stocks. Under this system, the fishery biologists recommend the TAC for each stock for the ensuing fishing season. These recommendations are usually based on the criterion that fishing mortality should be at the level that allows MSY or related criteria. Once the TAC is set, it is divided among vessels, depending upon the type and efficiency of the vessels.

A regulatory device called individual transferable quota (ITQ) is now being implemented in many countries. Under this device, the TAC quotas for each species and each vessel are transferable. The transferability ensures that the least efficient fishing vessels will not be used, as their quotas can be bought by the owners of more efficient vessels at a price that benefits both the buyer and the seller.

Access to fish resources must be limited by any of the restrictive methods though all of them have undesired side effects (Table 1).

Table 1: Methods of biological fisheries conservation

Methods	Desired effects	Undesired side effects
Restriction on fishing effort.	To relieve fishing pressure on the stock.	Fishers overcome restrictions by enhancing fishing efficiency; Fishing becomes expensive; Artisanal fishers affected.
Closed areas; Closed seasons; Minimum mesh size; Total allowable catch (TAC).	Protection of spawning stocks; Protection of juveniles; Increase in stock biomass; Decrease of fishing mortality; Rebuild of stocks	Fishing intensity increases outside closed areas and seasons; Instant decrease in catch not acceptable to fishers; Uniform minimum mesh size difficult in multi-species fishery; Overcapacity of fleets; Tendency to increase fishing efficiency.
Individual transferable quotas (ITQs).	Decrease of fishing mortality; Rebuild of stocks	Favours a few large companies

Ecosystem-based fisheries management

The ecosystem consideration of the effect of fishing is gaining importance. It is increasingly realized now that changes in ecosystems could be due to ecological and exploitation parameters either singly or in combination. Pauly *et al.* (1998) showed that landings from global fisheries have shifted from large piscivorous fishes to small invertebrates and planktivorous fishes, a process now called "fishing down marine food webs". Vivekanandan *et al.* (2005) reported fishing down marine food web in the Indian seas too at the rate of 0.04 per decade. The major concern about this trend is that fishing may cause large and valuable predatory fish to be replaced by other species lower down in the food web. This may not only affect the value of fisheries, but may cause significant problems in the structure and function of marine ecosystems (FAO, 2001). Considering this, ecosystem-based fisheries management has been recognized as a better management method compared to single species approach.

An ecosystem approach for management of fisheries facilitate (i) conservation of fisheries resources, protection of fish habitats, and allocation to fishers; (ii) a better understanding of the trophodynamics in an ecosystem, and also the impact of fishing gear selectivity on marine living resources; (iii) prevention of land-based sources of pollution that have an adverse impact on the ecosystem; (iv) protection of nursery grounds from destructive activities like construction and reclamation in coastal areas. Mangrove deforestation, destruction of coral reefs and the loss of marine biodiversity are the other vital issues that need to be dealt with seriously and effectively in the tropical waters.

The fisheries prevailing in about 150 marine ecosystems around the world have already been assessed based on ecosystem models. Developing the ecosystem approach would be ideal for a country like India, which is characterized by multi-species, multi-gear and multi-cultural in nature. However complex it might be, the ecosystem models need to be built up by knitting together all the relevant historic data, and involving in the process, the training and education of the fishermen towards the adoption of ecosystem approach to fishing.

No-fishing zones

If all forms of fishing in certain areas are banned altogether, the overall catch can be increased in a sustainable way. A plethora of studies have convincingly demonstrated that the creation of no-fishing reserves allows the rapid build-up of fish spawning stock biomass. The idea behind reserves is simple. If the fish are protected from fishing, they live longer, grow larger and produce an exponentially increasing number of eggs. It is observed that adult fishes tend to remain in the protected areas while their larvae help replenish adjacent fisheries. Overall levels of biomass per unit area can double in two years and quadruple in ten years of closure. However, there is no direct experience of reserves in India barring the marine sanctuaries in the fragile coastal zones to protect coral reefs and mangroves. Considering that the concept of no-fishing zone is a good strategic tool, fisheries managers in India should start working on the questions about how much of the fishing grounds should be placed in reserves, how many are needed, and where they should be located.

Adaptation and mitigation of fisheries to climate change

Considering the developmental needs of fisheries sector, the challenges posed by climate change calls for evolving an integrated Theme Plan with the involvement of all the stakeholders and may consist of the following approaches:

- Impact assessment of climate change on distribution and species diversity of fisheries resources;
- Assessment on production and economic value of commercially important fish in the changed scenario;
- Identify adaptive fishing and post-harvest practices to sustain production and quality;
- Evaluate sensitive biological processes such as growth, maturity and spawning and the adaptive capacity of important fish groups with reference to climate change;
- Identify genes for thermal tolerance;
- Identify new land use system for aquaculture;
- Identify new candidate species and develop breeding and grow-out techniques;
- Assess the changes in feed requirements for changed aquaculture practices;
- Investigations on potential fish diseases in the natural and farming systems;
- Investigations on diversity and dynamics of microbes in the water bodies;
- Assess demand-supply scenarios for fisheries at regular intervals;
- Develop regional contingency plans for weather-related risks to the fishing communities;
- Quantify GHG emissions from fisheries sector;
- Quantify the carbon sequestration potential of freshwater, brackishwater and marine ecosystems;
- Identify cost-effective opportunities for reducing GHG emission from fisheries sector;
- Establish Weather Watch Groups for fisheries sector;
- Evolve decision support systems;
- Develop a compendium on indigenous traditional knowledge in the fisheries sector and explore opportunities for its utilization;

- Intensify efforts to increase climate literacy among the stakeholders in fisheries sector.

Other options

Oceanic fishing

Despite the tremendous growth in marine fisheries from an artisanal, subsistence status to industrial fisheries, and the declaration of the EEZ with an area of 2.02 million km^2 in 1977, oceanic fishing by Indian entrepreneurs started only three years back. Conversion of medium range vessels (overall length: about 20 m) into tuna longliners has proved to be successful for catching the high-value yellowfin tuna. The annual catch by these vessels is around 25,000 t, most of which are exported as high-value products such as *sashimi* and loins. In addition to these vessels, Government of India has issued Letter of Permission to 72 tuna longliners to fish in the Indian EEZ.

Another major resource identified is the oceanic squids. The Arabian Sea is considered as one of the richest regions for the purpleback flying squid *Sthenoteuthis* (*Symplectoteuthis*) *oualaniensis*. The estimated stock size in the Arabian Sea is 0.9-1.6 million t (Zuyev *et al.,* 2002). These squids are pelagic animals living in the open ocean, usually beyond continental shelves (>200 m), and first appear over continental slopes at depths above 250-300 m. *S. oualaniensis* are shoaling animals in the open ocean and form shoals of up to 1000 individuals. They are attracted to light and undertake diurnal migrations rising to the epipelagic layer at night for feeding and descending up to 800-1200 m depth in the morning. The prospects for developing a new fishery for oceanic squids in the Arabian Sea either by hooks and lines or squid jigging are substantial, taking into account the relatively huge magnitude of the unexploited resource. In order to systematically carry out the utilization of an unexploited stock, information on its abundance in space and time, and an understanding of the life-history traits of the animal, with particular reference to the resilience of the stock to fishing pressure is essential. Production, processing, marketing and consumer preference are researchable issues in oceanic squid fisheries.

Artificial fish habitats (AFHs)

It has been widely recognized that installation of Artificial fish habitats (AFHs) is helpful in increasing fish production. When an AFH is installed, microorganisms grow on it. A large number of small animals and fishes feed on the microorganisms and larger individuals aggregate to feed on the smaller ones. The AFHs (i) attract and concentrate fishes and help in establishing an ecosystem; (ii) provide shelter for spawning populations, thereby serving as nurseries; (iii) enable the artisanal fishermen to fish near the shore without spending much time and energy to locate fish; (iv) increase catch rate by about 1.5 times compared to non-AFH areas; and (v) improve the income of the artisanal fisherfolk (Vivekanandan *et al.*, 2006).

Sea ranching

Sea ranching is one of the very few alternatives to increase coastal productivity and to conserve the resources. In sea ranching, selected species are bred, hatched and reared in hatcheries up to juvenile or fingerling stage and released, normally in bays, lagoons and protected ecosystems. This system is at present practiced on a modest scale in India.

Sea ranching is practiced very successfully in Japan where about 45 species are under sea ranching to supplement the natural stocks. This activity is subsidised by the government and implemented by sea ranching associations in collaboration with fisheries cooperative associations. Budget allocation is given to support programmes for activities associated with sea ranching, such as intermediate culture, tagging and fingerling release. The associations are wholly responsible for the sea ranching activities. Thus, this system combines private property management during the hatchery and rearing phases and common property management in capture fisheries at the time of recapture. For India, adoption of sea ranching technologies should be thoroughly examined for its applicability, considering the fishing situation prevalent here. The culture, norms and values as well as the system of implementation should be studied exhaustively before any action is initiated. Despite these factors and the high initial cost, it is worthwhile investing in sea ranching.

Application of remote sensing for locating potential fishing zones (PFZs)

Satellite observations of the sea have progressed immensely consequent upon India launching her own satellites. The quality, type and sheer quantity of data have increased manifolds and remote sensing can provide a significant part of the information needed to assess the potential yield of the fishing grounds and also assist in judicious exploitation, conservation and management of marine resources. Timely forecast of potential fishing grounds can help minimizing the fishing effort and thus save fuel and help schedule fishing operations. Satellite imageries provide continuous data on parameters such as sea surface temperature (SST), chlorophyll, sedimentation and coastal changes, covering most of the EEZ. These data have several applications including mapping potential fishing zones (PFZs) and fisheries forecast on a short term as well as long term basis.

The process of locating the PFZs by remote sensing is based mainly on two sources of data, *viz.* ocean colour and sea surface temperature. The colour change of the sea induced by the presence of primary producers (phytoplankton) or more precisely by the presence of photosynthetic pigments, is detectable from the space. By assigning colour tones to the oceanic waters, more pigmented and highly productive water could be distinguished from clear blue waters. By mapping the movements of waters of different colour intensities, the phytoplankton concentration or the magnitude of algal blooms could be deduced. Fish concentration depends on the algal organic carbon as it provides the basic food energy for the whole food web. From this relationship, the areas of high phytoplankton concentration are assessed as the PFZs. Data from infrared imageries have been used to estimate sea surface temperature. By mapping the movements of surface water masses of different temperatures, it is generally possible to sense fish abundance. The National Remote Sensing Agency (NRSA) at Hyderabad is regularly receiving the imageries from the Indian satellites. These imageries are used to derive the SST values for the Indian seas, which are further interpreted to identify the PFZs.

The greatest single advantage of satellite remote sensing over conventional observations is clearly its wide area coverage in very quick time. It is important that the capabilities of this technology are widely appreciated. Encouraging and supporting development of local facilities for receiving, processing and broadcasting the data are worthwhile.

Mariculture

Mariculture has the potential to augment production and incomes through coastal as well as open sea farming. The global aquaculture production has increased by about 25 times in the last 30 years against only seven times increase in capture fisheries production during the corresponding period (Gopakumar *et al.*, 2007). India has vast areas of suitable coastal waters, lagoons and bays which can be utilized for mariculture. Seed production and culture of marine finfishes has been expanding in the recent past in many parts of the world, but in India, it is only an emerging sector. The potential cultivable candidate finfishes are groupers, cobia, rabbit fish, sea bass, pompano, snappers and sea bream. Lack of availability of hatchery-produced seed on a commercial scale is the major bottleneck for large-scale marine finfish farming. The availability of seed from wild is often unpredictable, and hence, the development and standardization of seed production techniques for a few commercially important species is receiving research priority.

Farming in open sea cage farms is another area with great potential to increase production of high value edible finfish and shellfish. In recent years, open sea cage farming is expanding on a global basis. In India, the sea bass was farmed by CMFRI in cages with a diameter of 6 m and of depth 6 m, off Balasore near Orissa in a demonstration project. The cage was launched near Chaumukh beach in Balasore during January, 2009 and was stocked with 4357 Nos. of locally collected Asian seabass juveniles. After about six months, around 3200 kg sea bass was harvested indicating the potential. The cost of production per kg of sea bass worked out to Rs. 94.24/- against the value realization of Rs.189.89 per kg. The capital productivity measured through operating ratio worked out to be 0.80. These economic parameters indicate that this open sea cage farming of sea bass is economically viable (CMFRI, 2009).

In addition to development of hatchery techniques, the following policy interventions are required for developing mariculture in India (Gopakumar *et al.*, 2007):

- Leasing policies for open sea mariculture sites
- Notification of mariculture sites in the coastal areas
- Development of guidelines on precautionary principles for open sea mariculture
- Establishment of Sea Farmers Development Agency in maritime states and provision for subsidies for new entrants
- Policies on bringing exotic fast growing/disease resistant species for mariculture.

A focused research and development thrust with proper legislative and policy support in marine farming sector will pave the way for India to emerge as one of the major mariculture production countries in the world in the near future.

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