

ENVIRONMENTAL IMPACT ASSESSMENT – A MANAGEMENT TOOL FOR CONSERVATION OF LARGE MARINE ECOSYSTEMS

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A B S T R A C T

Coastal development includes a variety of activities which will have significant impact on marine ecosystem especially in the shallow nearshore areas. The stress relevant to coastal zone emerge from hinterland activities, urban development and waste disposal, sea transport and exploitation of living and non-living resources. Mitigation actions to reduce stress on marine ecosystem especially the living resources of the coastal waters are required to ensure long term sustainability of biomass yields and conservation of natural resources. The problem has become crucial and the only alternative is the implementation of Environmental Impact Assessment (EIA) to evolve environmental management strategies for optimum use of a given coastal area without disturbing the natural equilibrium of the ecosystem. EIA is a management tool which identifies, predicts, interprets and communicates the potential impacts a proposed project may have on the environment and find ways to reduce the adverse impacts. It is not sufficient to introduce this procedure for a specific activity, but is important to establish the carrying capacity of the coastal segment in order to implement an effective and planned coastal zone management programme. This requires planned investigation and establishment of adequate baseline covering relevant physical, chemical and biological parameters at the coastal stretch selected for the EIA. It is necessary to evaluate the changes, if any, from the predicted assessment through periodic post-monitoring of the development to confirm the validity of the predicted assessment.

Overfishing is a direct threat to the marine resource as well as to the sustainable yield by altering the food web by removal of selected populations that constitutes a significant part of the ecosystem. Though a set of negative aspects of fishing have been developed, an operational definition of marine environmental quality for fishing activity is yet to be formulated within a rational framework. There is growing concern about the environmental implications of aquaculture development. The environmental impact of marine fish farming depends very much on species, culture method, stocking density, feed type, hydrography of the site and husbandry practices. Marine fish culture can be a sustainable

development, provided pollution loading generated by fish farms are kept well below the carrying capacity of the coastal system. Effects can be reduced by careful site selection and adopting standard methodologies including integrated culture. It is recommended that any attempt to combat marine pollution should be governed by strict enforcement and tougher sanctions for non-compliance.

Introduction

Growing human settlement on the coastal fringe of continents is the single most important pressure on coastal marine ecosystem. Consequent activities result in changes in the structure and community dynamics of marine ecosystems leading to habitat loss, increasing pollution levels and effects of excessive fishing mortality. It is true that overfishing has caused enormous quantity of biomass flips, wherein a dominant species rapidly drops to a low level to be succeeded by another species generating cascading effects among other components of the ecosystem. Also biomass yields are being influenced by multiple, but different, driving forces in marine ecosystems, a major one being effect of environmental perturbations and pollution on living marine resources. Mitigating actions to reduce stress on living resources in the oceans are required to ensure the long-term sustainability of biomass yields (Sherman, 1993). Or conservation is the wise way to preserve the natural resources.

A Large Marine Ecosystem (LME) can be defined as an extensive area in the ocean usually greater than 200,000 km² with unique hydrographic regimes, submarine topography and tropically linked populations (Sherman and Alexander, 1986). The biomass constituting 95% of the annual yield of marine fisheries is caught within the geographic limits of 49 LMEs (Sherman, 1993). In India LMEs producing an annual biomass yield of 2.1% of world's marine catch are Arabian Sea and Bay of Bengal.

India has a large coastal zone associated with our coastline of over 7000 km. The total number of industries along the coast is about 308 while aquaculture farms amount to 138. A total of about 1.35 million cubic metres of liquid effluent and about 34,500 tonnes of solid waste (Table 1) are generated by these coastal industries every day (CPCB, 1996).

Table 1 : Coastal industries (large and medium) and waste generation

	East coast	West coast	TOTAL
Industries	75	233	308
Aquaculture farms	138	-	138
Industrial effluent (in million m ³ /d)	0.50	0.85	1.35
Aquaculture farm waste (in million m ³ /d)	2.37	-	2.37
Industrial solid waste generation (tpd)	19,834	14,642	34,476

Source : CPCB, 1996

Sources of stress

The coastal zone in general is influenced by a variety of stresses. Sources of stress in the coastal region can be categorized under six headings (GESAMP, 1990).

1. Coastal Development

Coastal development includes a great diversity of activities, ranging from the construction of ports/harbours, industrial installations, sea defence and development of tourist/recreational facilities. This will result in movement of large number of people to the coast. Today three quarters of the world's cities with more than 4 million people are located along coasts.

2. Hinterland activities

Developments at the edge of the sea or far inland can be damaging and three general types of activities relevant to this context are manipulation of hydrological cycles, felling of forests and coastal agriculture. Construction of dams/barriers for power generation, flood control, or irrigation can reduce the flow of water to the sea, alter the salinity regimes and ecology of estuaries and change the erosion characteristics of the coast. Felling of forests lead to soil erosion inland resulting in increased transport of sediment to the coast.

3. Urban development waste disposal

The increased human settlement along the coasts results in much greater input of waste water composed of untreated sewage and industrial effluents. The sewage presents a public health risk as it contains human pathogens. Industrial

effluents containing diverse constituents as metals, oil and synthetic compounds will lead to deterioration of environmental quality.

The problem of nutrient input is mainly due to enhancement in the levels of nitrogen and phosphorus due to waste water discharge, input from agriculture and from intensive stock rearing. Along some coastal areas marked increase in nutrients leads to unusual algal blooms, deoxygenation of water and fish kills.

Thermal and nuclear power plants discharge unutilized heat into the cooling water source. This leads to thermal stratification, inhibition of photosynthetic activity and changes in the activities of aquatic fauna.

4. Sea transport

Pollution due to ship traffic is one of the primary source of oil pollution. Normal ship operations are responsible for 70% of the oil entering the sea from marine transportation (Collins, 1964). In addition, major accidents can have a catastrophic local effect and severe long term consequences.

5. Exploitation of non-living resources

The major exploited non-living resources are oil and gas which in some places being exploited upto the edge of the continental shelf. Oil and gas platforms adversely affect seabed within a radius of 2-3 km². Other items exploited are metal rich minerals, sand/gravel, polymetallic nodules, phosphorites etc. Though not a major activity, sea is also used as a renewable energy source in developing thermal, tidal or wave energy.

6. Exploitation of living resources

Over-fishing is an example of exploitation of living resources. Besides, the direct threat it poses to the resource, there are problems of alterations of the natural food web by removal of selected populations from an ecosystem. Fishing gear can cause direct damage to the seabed and its fauna. A more recent issue is associated with expansion of mariculture and the threat the activity presents through waste input and restriction of access to other users of the sea. Construction of coastal ponds for culture of fish and prawns lead to measurable annual losses of habitat. Connected with expanding shrimp farming activity harvesting of wild specimens using very fine mesh nets that produce an enormous bycatch of other juveniles. In India, thousands of acres of mangroves have been reclaimed for shrimp culture. These wetlands act as a buffer between the hinterland and the offshore ecosystems.

Most of the problems in the sea due to man's activities will come under one of the above six items. However, about 80% of marine pollution derives from land based sources. At present, people are conscious of the impact of pollution as it will adversely affect the marine ecosystem and degrade man's economy and recreational facilities. The problem has become crucial and the only alternative is the implementation of Environmental Impact Assessment concepts to evolve environmental management strategies for optimum use of a given coastal area without disturbing the natural equilibrium of the ecosystem (GESAMP, 1986). EIA is a management tool which identifies, predicts, interprets and communicates the potential impacts that a proposed project or plan may have on the environment and finds ways to reduce the adverse impacts.

Environmental impact assessment (EIA)

Objectives of EIA

1. To formulate environmental management plan.
2. To identify beneficial and adverse environmental impacts and to suggest the required mitigation actions.
3. To identify appropriate monitoring strategies to track impacts and provide an early warning system.
4. To aid selection of the optimum alternative.

Approach to EIA

There are 7 major steps for the effective execution of an EIA programme.

1. Preliminary activities

This includes site characteristics for the project, assessment of the suitability of the site, review of existing laws, regulations and ordinance which are applicable to the project.

2. Impact identification

On the basis of general project proposal an exhaustive list of all impacts can be drawn up. The most efficient means of developing check list of impacts is by the study of other EIAs on similar projects and through available literature.

3. Baseline study

This investigation is to obtain bench mark information prior to a development for future comparison and assessment. The baseline studies should cover major components of the marine environment i.e. seawater, sediment and biota. As majority of marine environmental parameters vary in space and time, a seasonal survey at pre-determined locations is required to evolve a dependable baseline. Existing developments in the coastal zone and their likely cumulative impacts on marine ecology should also be considered.

The data collection involved the following :

Coastal dynamics : Tides, currents, circulation, stratification, rate of water exchange, flushing rate etc.

Water quality : Temperature, salinity, pH, suspended solids, dissolved oxygen, nitrate, nitrite, ammonium, phosphate, trace metals, petroleum hydrocarbons, phenols, pathogenic bacteria etc.

Sediment quality : Texture, nitrogen, phosphorus, trace metals, petroleum hydrocarbons etc.

Biological characteristics : Primary productivity, secondary productivity, macrobenthos, fishery potential, breeding grounds, intertidal flora and fauna. The attempt should be to describe habitat type, representative communities, prey-predator relationships and the key species present.

4. Impact evaluation

The quantification of impacts is the most difficult and controversial aspect of EIA. Though it is necessary to quantify impact, the present knowledge does not permit quantification of major impacts on the marine sector. Hence, it is inevitable to assess impacts qualitatively wherever quantification is not feasible.

5. Resource of EIA

For successful EIA studies, the most essential requirements are establishment of a qualified experienced multi-disciplinary team, access to EIA techniques, analytical facilities, financial/institutional support and monitoring and enforcement powers.

6. Mitigation measures

Though it is not possible to eliminate an adverse environmental impact altogether, it is often feasible to reduce its intensity. Such mitigation measures may require modification in the design or efficient management practices as per laid down protocols.

7. Assessment

This involves the selection of optimum alternative from the different worked-out schemes. For this evaluation, environmental loss/gain should be combined with economic cost/benefit to evolve a full picture of each project alternative.

8. Marine environment management plan

Assessment of impacts of a project on marine ecosystem is often qualitative and also evaluations are made presuming that the operational phase of the project will be based on present protocols. Due to uncertainties involved in impact evaluation, project operations, human negligence etc. the predictions may differ from actual situation. Therefore, it is essential to formulate a well designed environment management plan that should include the following two components namely contingency plan and monitoring plan.

Contingency plan should deal with the steps to be taken in case of an emergency arises. The contingency plan should be in sufficient details and should include information on equipment required, their storage, transport to the accident site, manpower and training etc.

Monitoring programme should be comprehensive to cover the parameters which are likely to be influenced and assess accurately to identify trends of variations beyond the natural variabilities. For this it is necessary to develop a baseline marine environmental quality criteria for the region.

Case studies of EIA

Success of a project implementation based on EIA can be assessed only through post project monitoring studies and comparison of the data with that of pre-outfall studies. It is worth quoting a few examples.

1. Maharashtra Gas Cracker Complex (MGCC) of Indian Petrochemicals Corporation Limited (IPCL) established at Nagothane on the western bank of Amba estuary utilize associate gas from Bombay High as a feed stock and went into commercial production during March 1990. The treated waste to the specifications laid down by Maharashtra Pollution Control Board is being released near Mankule (Lat.18° 45.37"N and Long72° 59.13"E) through subsurface outfall in the estuary of Amba region, about 26 km downstream of the plant. The maximum volume permitted to be released in the estuary as per MPCB consent is 14,760 m³/d industrial and 7640 m³/d domestic wastewater.

The location of release of the wastewater was selected on the basis of detailed studies carried out by the National Institute of Oceanography (NIO, 1987) during 1986 with respect to relevant EIA parameters. Subsequent to the operation of the plant, NIO has been periodically monitoring the estuary since 1990 at the instance of IPCL and 13 reports were submitted (NIO, 1998). Monitoring is being done at the wastewater location and 6 other locations in a 40 km segment of the estuary.

The overall assessment suggests that the water quality, sediment quality and biological characteristics are comparable to the baseline criteria and gross changes in ecology have not occurred (Table 2). It has also been observed that

Table 2 : Selected biological parameters in December at the discharge point (Mankule) during 1986-1997

Parameter	1986	1990	1993	1995	1996	1997
Chlorophyll a (mg/m ³)	1.1	3.2	2.4	2.3	1.2	2.8
Phaeophytin (mg/m ³)	5.5	1.1	1.4	2.0	0.7	1.6
Phytoplankton cell count (no x 10 ³ /l)	-	-	-	238	38	61
No. of phytoplankton genera (no)	-	-	-	14	4	6
Zooplankton biomass (ml/100 m ³)	43.4	21.6	10.7	28.2	13.0	15.1
Zooplankton population (no x 10 ³ /100m ³)	-	13.2	11.4	5.2	51.8	30.4
Total number of zooplankton groups (no)	-	11	14	11	11	12
Macrobenthic biomass (g/ m ² ; wet wt)	1.0	5.0	6.8	1.3	1.6	3.4
Macrobenthic population (no/ m ²)	120	101	6953	475	621	900
Total number of macrobenthos (no)	3	2	4	3	3	4

Source : NIO, 1987; 1998

catch rate and species composition of fish also did not indicate any significant change (Table 3).

Table 3 : Trawl catch data at the discharge point (Mankule) during 1990-1997

Year	Catch rate ()	No. of species			Major groups
		Fishes	Prawns	Others	
Jan 1990	14.9	8	4	-	Croaker, Anchovy, Bombil, Prawn
Dec 1990	8.0	6	4	2	Croaker, Anchovy, Cat fish, Lobster
Dec 1995	18.0	7	3	3	Croaker, Anchovy, Dori, Crab
Dec 1996	17.6	6	3	2	Croaker, Anchovy, Koth, Lobster
Dec 1997	12.4	6	2	2	Koth, Eel, Anchovy, Croaker, Crab

Source : NIO, 1998

2. Response of larval fishes to sewage disposal

Fish larvae are extremely sensitive to pollutions. Studies in the coastal waters off Sydney (Australia) indicated that sewage plumes from outfalls at the land-sea interface exposed large population of fish larvae to waste (Gray *et.al.*, 1996). Increased levels of larval mortality could have significant effects on levels of recruitment and in the dynamics of populations of fish. Concerns have therefore been expressed that coastal sewage disposal may affect larval survival and subsequent year-class strength of recreationally and commercially important species of fish.

Hence Sydney's three major shoreline sewage outfalls were decommissioned in 1990/91 and replaced by three deeper outfalls which now discharge sewage from a linear array of diffusers spanning 500-800 m of the seafloor in 60-80 m depth located about 2-4 km offshore. Studies by sampling of the larvae from the outfall showed that some larvae from deeper waters were displaced upwards by rising plumes. However, no predictable positive or negative numerical response of larva to outfalls were evident. Further field based studies are required to track larvae through plumes to assess changes in numbers and condition of larvae.

Impact of pollution on fishery

Anthropogenic perturbations affect fisheries in different ways. In general, protection of any living marine resources can be accomplished only by maintaining the stability/equilibrium between trophic levels. Imbalance in productivity at lower levels namely primary productivity, secondary productivity and benthic productivity can interfere with the fishery potential of an ecosystem as many fishes directly feed on plankton and benthos. Although fishes are able to swim away from polluted areas the larval stages being planktonic drift with tides and currents. The offshore industrial/sewage outfall can often adversely influence the larval stages of fishes. Long-shore currents can transport large numbers of larvae through plumes that can potentially affect the health of the larvae leading to deformities of notochord, eye and head (Kigsford *et.al.*, 1996). Fish and shrimp nursery ground are often placed in shallow estuarine or coastal areas where pollution exerts its major effects. Uncontrolled and poorly planned dredging/reclamation activities tend to aggravate the environmental problems for the nursery ground and the environment as a whole.

Mangroves support small scale fisheries producing nearly one million tonnes of crabs, shrimps, molluscs and fishes annually which contributes 1.1% to the world's total fish catch. Destruction and degradation of the mangroves have already caused fall in fishery resources and coastal erosion. As mangroves also serve as prime breeding/nursery ground for many economically important species of fish and shrimp it is necessary to conserve this natural wealth. The sensible solution to conserve them are through mangroves afforestation. Connected with all coastal development it should be kept mandatory to plant and regenerate the lost vegetation.

Petroleum hydrocarbons in a marine environment can cause wide variety of short and long-term effects in fishes depending on their bio-availability and persistence and the ability of organism to metabolise them. Fish often shows avoidance reaction even at low concentration of oil in water. Moreover, the fish possess an enzyme system which can deal with petroleum hydrocarbons in tissues. Hence, fish kills due to oil pollution are rare. No conspicuous decline in fisheries of accidental oil spill areas are observed, though some changes in the composition of catch and total population are reported. Large spills in enclosed areas can make the habitat unsuitable for fishing and render the fish commercially unacceptable due to tainting. However, the greatest threat of oil pollution is to benthic fish and spawning/breeding grounds of fish. Concentration over 1 mg/litre of petroleum in water can cause lethal effects on fish eggs and larvae. However, such concentrations are unlikely to occur or persists in the marine environment except immediately after the spill.

Impact of fish culture on environment

There is growing concern about the environmental implications of aquaculture development comprising the adverse effects of aquaculture operations on the environment as well as the consequences of increasing aquatic pollution affecting feasibility and sustainable development. The environmental impact of marine fish-farming depends very much on species, culture method, stocking density, feed type, hydrography of the site and husbandry practices. In general some 85% of phosphorus, 80-88% of carbon and 52-95% of nitrogen input into a marine fish culture system as feed may be lost into the environment as waste (Wu, 1995). Problem caused by high organic and nutrient loadings conflict with other uses of the coastal zone. The use of chemicals and the introduction of pathogens and new genetic strains have also raised environmental concerns.

Effluent standards for land based fish farms have been well established (Alabuster, 1982). It is much more difficult to set effluent standards and control effluent quality in open-water cage farming systems.

Results of various studies show that some 23% of C, 21% of N and 53% of P of feed input into the culture system is getting accumulated in the bottom sediment affecting significantly an area confined within 1 km of the farm. This can lead to high sediment oxygen demand, anoxic sediment, production of toxic gases and a decrease in benthic diversity. To prevent unacceptable changes to the environment an EIA should be undertaken to predict significant potential impacts and monitoring (once production has begun) to detect and evaluate the scale of impact.

Principles of monitoring

Any environmental assessment and monitoring effort should be related to the scale of perceived impact of a given aquaculture operation. To optimize resources, the level of monitoring (number of variables and frequency of monitoring) should be related to the size of the operation and the sensitivity of the receiving water body (GESAMP, 1996). Main features to be considered while designing monitoring programmes to detect the effects of aquaculture wastes are listed below.

1. *Environmental capacity* : Environmental capacity is a property of the environment and its ability to accommodate a particular activity or rate of activity without unacceptable impact. In the case of aquaculture the environmental capacity is the rate at which nutrients are added without

triggering eutrophication, the rate of organic flux to the benthos without adverse impact to natural benthic process or the rate of dissolved oxygen depletion that can be accommodated without mortality of the indigenous biota.

2. *Environmental quality standards* : The coastal aquaculture monitoring programmes specify the variables to be measured like dissolved oxygen, ammonium, infaunal species richness without defining a threshold of impact beyond which mitigation is necessary. Monitoring is most effective and the environment best protected, if environmental quality standard are established and monitoring is designed to verify compliance with these standards.
3. *Baseline studies* : This reference data can be used to (1) design an appropriate monitoring programme including the location of sampling and reference stations (2) establish conditions of the local ecosystem against which future changes can be compared.
4. *Reference station* : Ecosystems are dynamic with considerable natural, temporal variability in physical, chemical and biological properties. Hence while quantifying ecological changes if any, change attributable to natural variability would be falsely identified as a consequence of culture. Reference sites may only be 50 m from the aquaculture facility or may be more than one km away when there is large-scale aquaculture development.
5. *Delegation of monitoring responsibility* : Monitoring to protect the natural environment is to be performed by staff of a regulatory authority or a trained person employed by the farmer as per the regulatory authority which should include occasional checking by the regulatory agency.
6. *Detecting ecological change* : A monitoring programme requires to detect a small change and will require more replicates and more precise measurements than would be required to detect a large impact. Hence an essential consideration in the design of a monitoring programme is therefore the power of the sampling regime to provide data which allows detection of change. It is necessary to suggest how many samples are needed to detect a change at a certain power.
7. *Flexibility in monitoring intensity* : Intensity of monitoring should depend upon the size of the culture facility and the sensitivity of the

receiving waters. Flexibility in design of monitoring programmes and scaling of monitoring requirements to farm size and site sensitivity can be decided when programmes are developed on a case to case basis between the culturist and regulatory body.

8. *Monitoring effluents versus receiving waters* : The purpose of monitoring is to determine compliance with standards/conditions laid down under discharge licences. It is also necessary to monitor the receiving water to ensure that effluent standards adequately protect the receiving waters.
9. *Developing aquaculture-specific guide lines for ecological monitoring* : Monitoring is not being undertaken in the majority of current coastal aquaculture practices. It is recommended that farm managers, regulators, scientists and administrators should work together to develop specific guidelines for ecological monitoring of aquaculture waste.

Suggestions and conclusions

1. All activities inland need to be examined at the initial planning stage for potential effect along the coast. It is not sufficient to introduce this procedure for specific individual activity, but to be effective, planning should be done to establish the carrying capacity of the coastal stretch or the river system under consideration.
2. Identify the characteristics of the coastal strip in each LME, noting the presence of potential pollution sources.
3. Undertake long term ecosystem monitoring to develop a sound scientific data base.
4. There is need for improving research associated with monitoring the overall effects of fisheries, leading to a better knowledge of both effects and recovery process associated with overfishing and biomass removal from marine ecosystems.
5. Mesh size regulation should be kept under continuous review. Procedure for the closing of fishing grounds with a high incidence of young fish must be made more effective.
6. Ban on certain gear types and temporary ban on fishing in sensitive areas.

7. Though a set of negative aspects of fishing have been developed an operational definition of marine environmental quality for fishing activity has yet to be emerged within a common rational framework.
8. Marine fish culture can be a sustainable development, provided pollution loading generated by fish farms are kept well below the carrying capacity of the water body.
9. Regular EIA of water and sediment quality should be carried out to ensure culture activities are environmentally sustainable.
10. Finally any admirable initiative to combat marine pollution will be ineffective without better methods of enforcement and tougher sanctions for non-compliance.

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