



**Centre for Aerospace & Defence Laws (CADL)
Directorate of Distance Education
NALSAR University of Law, Hyderabad**

Course Material

P.G. Diploma in GIS and Remote Sensing Laws

1.2.4. Coastal Zone Regulations and Management

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MODULE - I

INTRODUCTION TO COASTAL ZONE MANAGEMENT

Introduction:

Importance to Coastal Zone:

A large portion of the world's population has always inhabited coastal areas. Fertile coastal lowlands, abundant marine resources, water transportation, aesthetic beauty, and intrinsic values have long motivated coastal habitation.

The coastal zone includes both the area of land subject to marine influence and the area of subject to land influence. Coastal economics include commercial, recreational, and subsistence fisheries; ports and industrial facilities that rely on shipping; and tourism, agriculture and forestry dependent on the coastal climate. Coastal areas are a critical part of the economics of virtually all nations bordering the sea, particularly subsistence economics. Coastal habitats provide important areas for fish and wildlife, including many endangered species. They filter and process agricultural and industrial waste, and buffer inland areas against storm and wave damage.

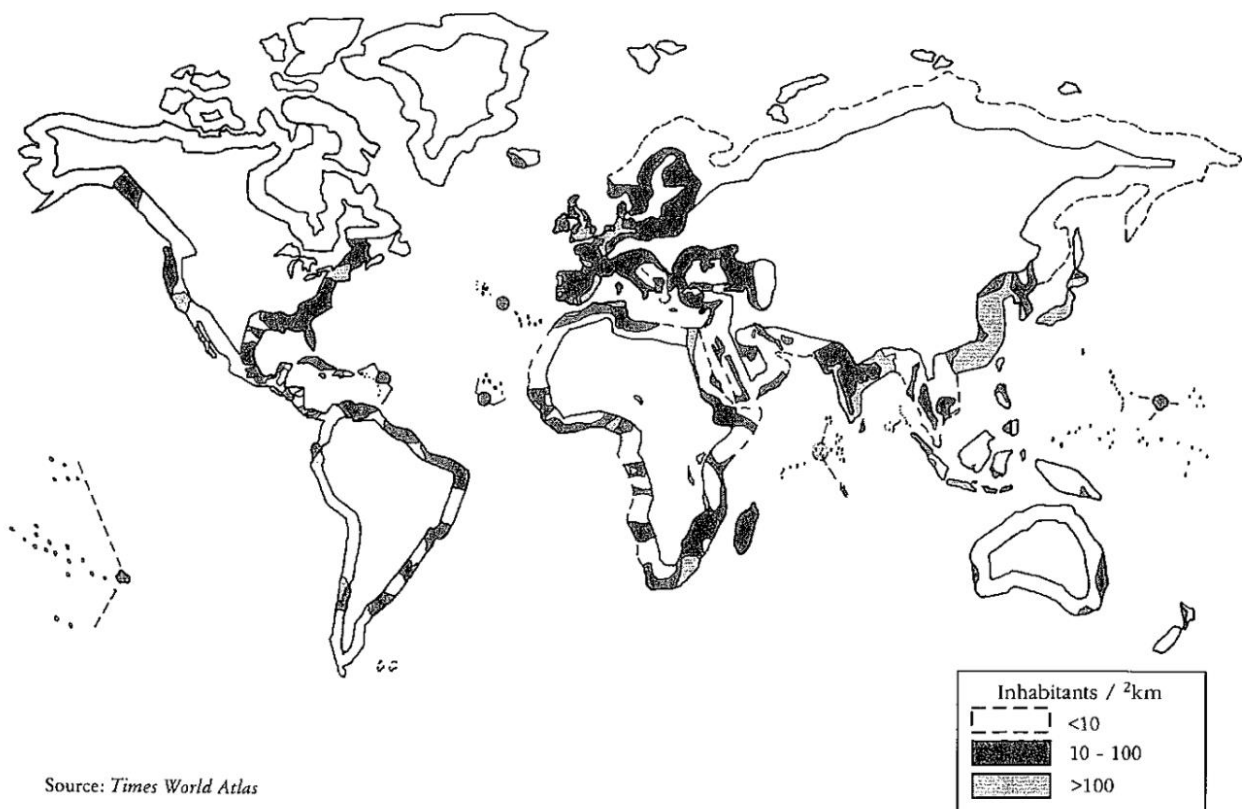


Fig. 1. Schematic world Map of population densities in Coastal Areas

Existing Problems:

Throughout the world, nations are facing a growing number of coastal problems as a result of development and increased population pressures. In many areas the functions and values normally associated with coastal areas are being degraded. Flooding, erosion, habitat loss and modification, structural damage, silting and shoaling, pollution, and over- exploitation of living resources, all have major public safety and economic consequences. Yet while these risks are substantial and

commonly recognized, the local benefits of using coastal resources outweigh the risks—sometimes significantly—and they continue to attract human activity and development to the coastal zone.

Shoreline alterations, mangrove and coral harvesting, dredge and fill activities, sand and gravel extraction, and disposal of wastes in the marine environment all result in changes to the natural character of the coast. Inland activities—particularly upstream of river deltas—can also have a significant impact on the coast. Construction of dams, diversion of river flows, and removal of ground water or hydrocarbons can result in coastal erosion, subsidence, and shifts in the fresh and salt water interface—so critical to the maintenance of coastal habitats and fisheries.

Obvious examples of the consequences of human activities include (1) the accelerated retreat of two Nile subdeltas following construction of the Aswan High Dam and loss of the sardine fishery; (2) the rapid loss of land in the Mississippi River delta due to subsidence, river levees, canals, and navigation channels; and (3) the exposure of valuable agricultural land in Malaysia to ocean waves as a result of uncontrolled mangrove harvesting.

If populations in coastal areas continue to grow, balancing environmental and development concerns will be increasingly difficult. Changes in climate and sea level will exacerbate many of these problems, particularly for small islands, deltas, and low coastal plains. High population density is therefore the most fundamental problem faced by coastal areas (Figure 1).

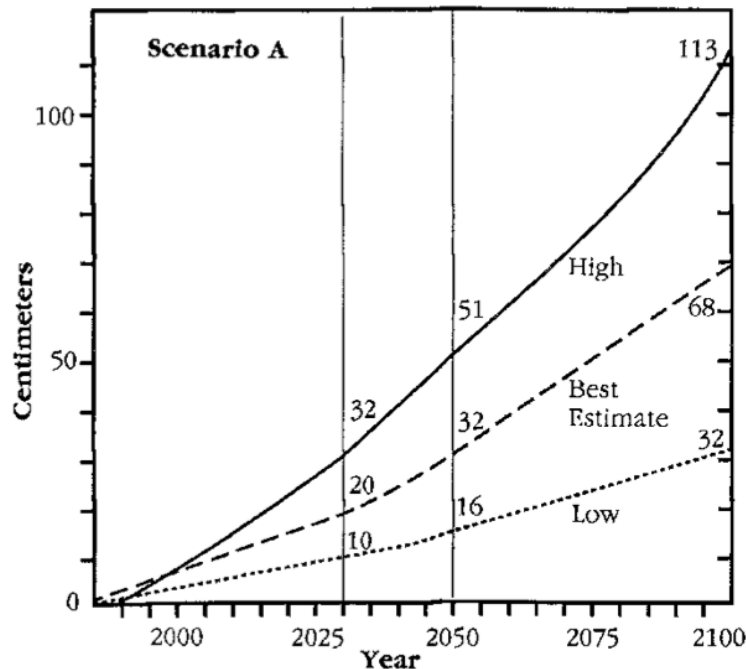
Global Climate Change:

An accelerated rise in global sea level is generally considered to be the most important impact of global climate change on coastal areas. The IPCC- Working Group I projects a rise in global sea level of 30 to 110 cm by the year 2100 (Figure 2), due principally to thermal expansion of the ocean and melting of small mountain glaciers. Such a rate of rise would be 3 to 10 times faster than the current rate. Even with actions to limit emissions, the IPCC-Working Group I concludes that there appears to be enough momentum in the global climate system for a rate of accelerated rise in sea level to be inevitable.

Sea level rise could increase flood-related deaths, damage to property and the environment, and cause some nations to lose territorial seas, and hence change the relative values of the coastal zone to society. This will inevitably lead to decisions regarding response options, for example, to retreat, accommodate or protect. A number of researchers have further suggested that extreme events may become more frequent as a result of climate change. For example, increased ocean temperatures may result in changes in the frequency, duration and intensity of tropical storms. Moreover, the effect of storm surges could be intensified by higher sea levels. Inundation of coastal areas is already common during tropical storms and any increases in the extent or frequency of inundation may render numerous heavily populated areas marginal or uninhabitable.

Because the global climate system is complex, our understanding of it may progress slowly. The existing system for monitoring global sea level cannot yet detect significant changes. Considerable uncertainties remain about the nature, timing, and magnitude of future sea level rise, and the local, national, and regional impacts of human-induced global climate changes.

**FIGURE 1.2 : Global Sea Level Rise,
1985–2100, for Policy Scenario A
(No Limitation of Greenhouse Gases)
IPCC-WGI, 1990**



ECOLOGICAL IMPACTS OF SEA LEVEL RISE

Working Group II suggests that a rise in sea level could:

- (1) increase shoreline erosion;
- (2) exacerbate coastal flooding;
- (3) inundate coastal wetlands and other lowlands;
- (4) increase the salinity of estuaries and aquifers;
- (5) alter tidal ranges in rivers and bays;
- (6) change the locations where rivers deposit sediment; and
- (7) drown coral reefs.

Estuaries, lagoons, deltas, marshes, mangroves, coral reefs, and seagrass beds are characterized by tidal influence, high turbidity (except coral reefs) and productivity, and a high degree of human activity. Their economic significance includes their importance for fisheries, agriculture, shipping, recreation, waste disposal, coastal protection, biological productivity, and diversity.

The direct effect of sea level rise in shallow coastal waters is an increase in water depth. Intertidal zones may be modified; mangroves and other coastal vegetation could be inundated and coral reefs

could be drowned. In turn, this may cause changes in bird life, fish spawning and nursery grounds, and fish and shellfish production. For example, coastal wetlands provide an important contribution to commercial and recreational fisheries, with an annual economic value of over \$10 billion in the United States alone. Equally important is the contribution of wetlands to commercial and subsistence fisheries in many coastal and island states. Table 4 lists the areas of coastal wetlands of "international importance" for major regions of the world.

In general, the effects on shallow coastal ecosystems are strongly determined by local conditions. A good understanding of the physical and biological processes and topography is required to forecast local impacts. But if the accumulation of sediments cannot keep pace with rising waters, or if inland expansion of wetlands and intertidal areas is not possible (because of infrastructure or a steeply rising coast), major impacts could occur.

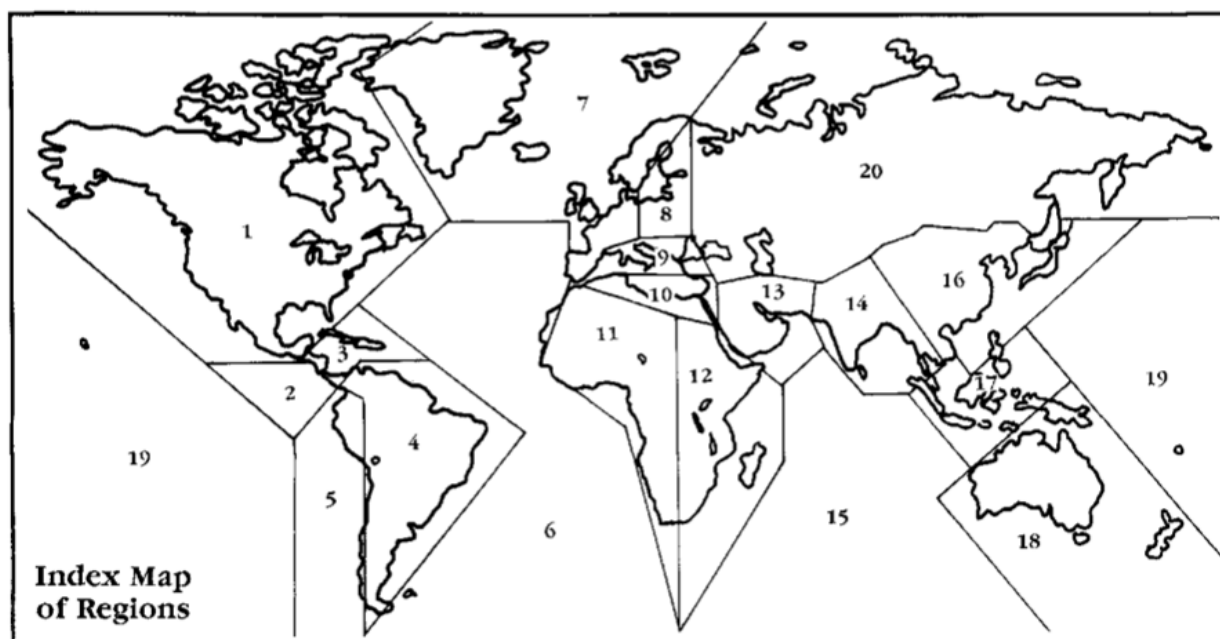
The estuarine response to rising sea level is likely to be characterized by a slow but continually adjusting environment. With a change in estuarine vegetation there could be an adjustment in the animal species living in and around the wetlands. Climate change may also provoke shifts in the hydrological regimes of coastal rivers and lead to increased discharge and sediment yields and, consequently, to increased turbidity. These changes, together with a rise in sea level, could modify the shape and location of banks and channels. If no protective structures are built, wetlands can migrate inland; however, a net loss of wetlands would still result.

TABLE 4: Areas of Coastal Wetlands* of International Importance in Sq km and As Percentage of Country Areas

REGION	AREA OF WETLANDS IN KM ²	WETLAND AS % OF TOTAL COUNTRY AREA
1. North America, excluding Canada and USA	32330	1.639
2. Central America	25319	0.882
3. Caribbean Islands	24452	9.431
4. South America Atlantic Ocean Coast	158260	1.132
5. South America Pacific Ocean Coast	12413	0.534
6. Atlantic Ocean Small Islands	400	3.287
7. North and West Europe	31515	0.713
8. Baltic Sea Coast	2123	0.176
9. Northern Mediterranean	6497	0.609
10. Southern Mediterranean	3941	0.095
11. Africa Atlantic Ocean Coast	44369	0.559
12. Africa Indian Ocean Coast	11755	0.161
13. Gulf States	1657	0.079
14. Asia Indian Ocean Coast	59530	1.196
15. Indian Ocean Small Islands		
16. South-East Asia	122595	3.424
17. East Asia	102074	0.999
18. Pacific Ocean Large Islands, excluding Australia and New Zealand	89500	19.385
19. Pacific Ocean Small Islands	—	—
20. USSR	4191	0.019
TOTALS	732921	0.846

Source: "A Global Survey of Coastal Wetlands, Their Functions and Threats in Relation to Adaptive Responses to Sea Level Rise." Paper by Dutch Delegation to IPCC-CZM Workshop, Perth, Australia, February 1990.

* Based on: Directories of Wetlands, issued by IUCN/UNEP (1980-90), 120 countries, excluding among others Australia, Canada, New Zealand, USA.



SOCIAL AND ECONOMIC IMPACTS OF SEA LEVEL RISE

Many developing countries have rapid rates of population growth, with large proportions of their populations inhabiting low-lying coastal areas. A one-meter rise in sea level could inundate 15 percent of Bangladesh, destroy rice fields and mariculture of the Mekong delta, and flood many populated atolls, including the Republic of Maldives, Cocos Island, Tokelau, Tuvalu, Kiribati, the Marshall Islands, and Torres Strait Islands. Shanghai and Lagos, the largest cities of China and

Nigeria, lie less than two meters above sea level, as does 20 percent of the population and farmland of Egypt.

Four highly populated developing countries, India, Bangladesh, Vietnam, and Egypt, are especially vulnerable to sea level rise because their low-lying coastal plains are already suffering the effects of flooding and coastal storms. Since 1960, India and Bangladesh have been struck by at least eight tropical cyclones, each of which killed more than 10,000 people. In late 1970, storm surges killed approximately 300,000 people in Bangladesh and reached over 150 kilometers inland. Eight to ten million people live within one meter of high tide in each of the unprotected river deltas of Bangladesh, Egypt, and Vietnam. Even more people in these countries would be threatened by increased intensity and frequency of storms.

Sea level rise could increase the severity of storm related flooding. The higher base for storm surges would be an important additional threat in areas where hurricanes, tropical cyclones and typhoons are frequent, particularly for islands in the Caribbean Sea, the southeastern United States, the tropical Pacific, and the Indian subcontinent. Had flood defenses not already been constructed, London , Hamburg, and much o f the Netherlands would already be threatened by winter storms.

Many small island states are also particularly vulnerable. This is reflected in their very high ratios of coastline length to land area. The most seriously threatened island states would be those consisting solely, or mostly, of atolls with little or no land more than a few meters above sea level. Tropical storms further increase their vulnerability and , while less in magnitude than those experienced by some of the world's densely populated deltas, on a proportional basis such storms can have a much more devastating impact on island nations.

Disruption could also be severe in industrialized countries as a result of the high value of buildings and infrastructure. River water levels could rise and affect related infrastructure, bridges, port structures, quays, and embankments. Higher water levels in the lower reaches of rivers and adjacent coastal waters may reduce natural drainage of adjacent land areas, which would damage roads, buildings, and agricultural land.

The potential impacts of sea level rise and climate change are varied and uncertain. Nevertheless, there is little doubt that adaptive responses will be necessary.

ADAPTIVE RESPONSES

The selection and timing of adaptive measures in response to sea level rise would depend on the physical, social, economic, political, and environmental characteristics of the affected areas. Although such measures could be implemented on case by case bases, growing population pressures and conflicting demands in many of the world's coastal areas favor implementation of comprehensive and systematic coastal management programs.

COASTAL MANAGEMENT

The three principal objectives of coastal management are to:

- (1) Avoid development in areas that are vulnerable to inundation;
- (2) Ensure that critical natural systems continue to function; and
- (3) Protect human lives, essential properties, and economic activities against the ravages of the seas.

Accordingly, such programmes should give full consideration to ecological, cultural, historic, and aesthetic values, and to the needs for human safety and economic development.

Coastal management programmes usually include governmental controls and private-sector incentives. Vulnerable areas are managed to minimize loss of life and property through such means as setback lines, limits on population densities, minimum building elevations, and coastal hazard insurance requirements. Resilient natural protective features, such as beaches, sand dunes, mangroves, wetlands, and coral reefs, are conserved and enhanced, which also maintains biological diversity, aesthetic values, and recreation.

Comprehensive plans for protecting existing economic activities help to ensure that defense measures are consistent with other coastal management objectives. Policies that specify which activities and development are permitted in new areas promote efficient private land use with the least risk of exposure to coastal hazards.

Successful coastal management programmes require public education to gain broad-based support, and public participation to ensure equal representation of interests.

Response strategies fall into three broad categories :

- **Retreat:** Abandonment of land and structures in vulnerable areas, and resettlement of inhabitants.
- **Accommodation:** Continued occupancy and use of vulnerable areas.
- **Protection:** Defense of vulnerable areas, especially population centers, economic activities, and natural resources.

RETREAT

Options for retreat include:

- 1) Preventing development in areas near the coast.
- 2) Allowing development to take place on the condition that it will be abandoned if necessary (planned phase out).
- 3) No direct government role other than through withdrawal of subsidies and provision of information about associated risks.

Governmental efforts to limit development generally involve land acquisition, land-use restrictions, prohibited reconstruction of property damaged by storms, and reductions of subsidies and incentives for development in vulnerable areas. Many nations have purchased large areas on the coast and designated them as nature reserves. Preventing development can reduce future expenditures for adaptation.

India, Sri Lanka, Tonga, Fiji, Mauritius, Australia, and the United States already require new buildings be set back from the sea. These regulations could be modified to consider the future impacts from a rising sea level, but most nations would require compensation for coastal property owners.

The second option gives the government a more limited role, in that it lays out the "rules of the game"—the eventual transgression of the sea. Investors are accustomed to evaluating uncertainty and can determine whether development should proceed, given the constraint. This approach can be implemented through (a) regulations that prohibit private construction of protective structures, or (b) conversion of land ownership to long-term or conditional leases that expire when the sea reaches a particular level or when the property owner dies.

The third option would be to depend on the workings of the private market. Productive crop and timber lands may be left to slowly and progressively deteriorate as a result of salt intrusion into the groundwater or by surface flooding. Wells and surface water exposed to saltwater intrusion would gradually be abandoned. Natural resources, such as mangroves, marshes, and coral reefs, would be left to their natural processes as sea level rises.

Under this option, governments could take the more limited role of ensuring that all participants in potentially vulnerable areas have full knowledge about the expected sea level rise and its associated uncertainties. Development would presumably not occur if developers, lenders, and insurers were not willing to accept the risks. However, if people continue to build in vulnerable areas, governments must be prepared to take the necessary actions to ensure public safety.

For small island states, retreat does not offer a broadly applicable alternative. There would be little or no land for resettlement, in addition to loss of heritage and cultural upheaval.

ACCOMMODATION

The strategy of accommodation, like that of retreat, requires advanced planning and acceptance that some coastal zone values could be lost. Many coastal structures, particularly residential and small commercial buildings, could be elevated on pilings for protection from floods. To counter surging water and high winds, building codes could specify minimum floor elevations and piling depths, as well as structural bracing. Drainage could be modified. Storm warning and preparedness plans could be instituted to protect the affected population from extreme events. Where saltwater damages agricultural lands and traditional crops, salt-tolerant crops may be a feasible alternative. Fundamental changes in land use may be desirable, such as the conversion of some agricultural lands to aqua-cultural uses.

Human activities that destroy the natural protection values of coastal resources can be prohibited. Perhaps the most important controls would be to prohibit filling wetlands, damming rivers, mining

coral and beach sands, and cutting mangroves. Undeveloped land with sufficient elevation and slope can be set aside to accommodate natural re-establishment of wetlands and mangroves. Within deltaic areas, natural processes can be maintained by diverting water and sediment. In response to salinity intrusion into groundwater aquifers, management controls can be implemented to regulate pumping and withdrawal practices.

Requiring private insurance coverage in vulnerable areas is an important method to compensate injuries and damages caused by natural disasters. It forces people to consider whether risks are worth taking and provides the necessary funds to repair damages and compensate victims.

PROTECTION

This strategy involves defensive measures and other activities to protect areas against inundation, tidal flooding, effects of waves on infrastructure, shore erosion, salinity intrusion and the loss of natural resources. The measures may be drawn from an array of "hard" and "soft" structural solutions. They can be applied alone or in combination, depending on the specific conditions of the site.

There is no single or generic "best solution," as each situation must be evaluated and treated on its particular merits. However, there are some basic steps in the selection of measures likely to produce the highest economic returns. First, those charged with planning, design or management responsibilities in the coastal zones should be cognizant of the potential for future sea level rise. Moreover, proposed plans should leave options open for the most appropriate future response. For example, many protection structures can be planned and designed with features that allow for future incremental additions that, if needed, could accommodate increased water levels and wave action. This can often be done without significant additional costs in the initial investment.

It should be noted that the capital costs associated with the "hard" set of options may prove a barrier to consideration of this option by developing countries and small island states.

Hard Structural Options

Dikes, Levees, and Flood walls are raised embankments or walls constructed for flood protection purposes. Depending on circumstances, internal drainage may be accomplished by gravity flow, tide gates, or pumping systems.

Seawalls, Revetments, and Bulkheads protect in land properties from the direct effects of waves and storm tides. Seawalls and heavy revetments (sloping armored surfaces) are constructed along open coast areas to defend areas against severe wave attack. Lighter revetments and bulkheads usually serve as secondary lines of defense along open coast areas, or as first lines of defense along more sheltered interior shores with low to moderate wave exposure.

Groins are structures placed perpendicular to the shoreline. They generally extend from the land into the near shore zone and trap sediment moving along the shore in order to widen the beach or prevent it from eroding.

Detached Breakwaters are robust structures placed offshore, usually parallel to the shoreline, for the purpose of dissipating the energy of incoming waves to reduce both erosion and damage from storms.

Raising Existing Defensive Structures may be facilitated through the incorporation of such a possibility in the initial design. Some dikes, levees, floodwalls, seawalls, revetments, and breakwaters can be easily raised and strengthened in the event of sea level rise or increased storm exposure.

Infrastructure Modifications may involve the elevation of piers, wharves, bridges, and road and rail beds; modifications to drainage systems; relocations of various facilities and the institution of flood-proofing measures.

Floodgates or Tidal Barriers, which are adjustable, dam-like structures, can be placed across estuaries to prevent the upstream flooding from storm tides. Such barriers are usually left open to avoid interfering with existing flows.

Saltwater Intrusion Barriers in surface water streams can consist of locks or dams that directly block upstream penetration of saline water. Dams upstream of a salt penetration zone may be operated so that water released from the reservoirs at appropriate times can act to minimize the upstream movement of salt water. Under certain conditions, underground barriers can be placed by open-cut or injection methods to prevent saline water intrusion in groundwater aquifers. Fresh groundwater lenses in coastal areas can be maintained by fresh water recharging techniques.

Soft Structural Options

Beach Filling and Subsequent Renourishment involves the placement of sandy material along the shore to establish and subsequently maintain a desired beach width and shoreline position to dissipate wave energy and enhance beaches, particularly for recreational and aesthetic purposes.

Dune Building, and/or the maintenance and preservation of existing dunes, in combination with adequate beach strands, provides an effective measure of protection to upland properties against the effects of storm tides and wave action.

Wetland/Mangrove Creation can be accomplished through the placement of fill material to appropriate elevations with subsequent plantations.

Other Possible Solutions may be found through increasing resilience and reducing vulnerability of coastal zone features that are under threat of degradation. Options include continued field research in the use of artificial seaweed, artificial reef creation, the rehabilitation of natural coral enhance growth, increasing coastal protection; instituting pollution controls, and preventing the harvesting of mangroves.

ENVIRONMENTAL IMPLICATIONS OF ADAPTIVE RESPONSES

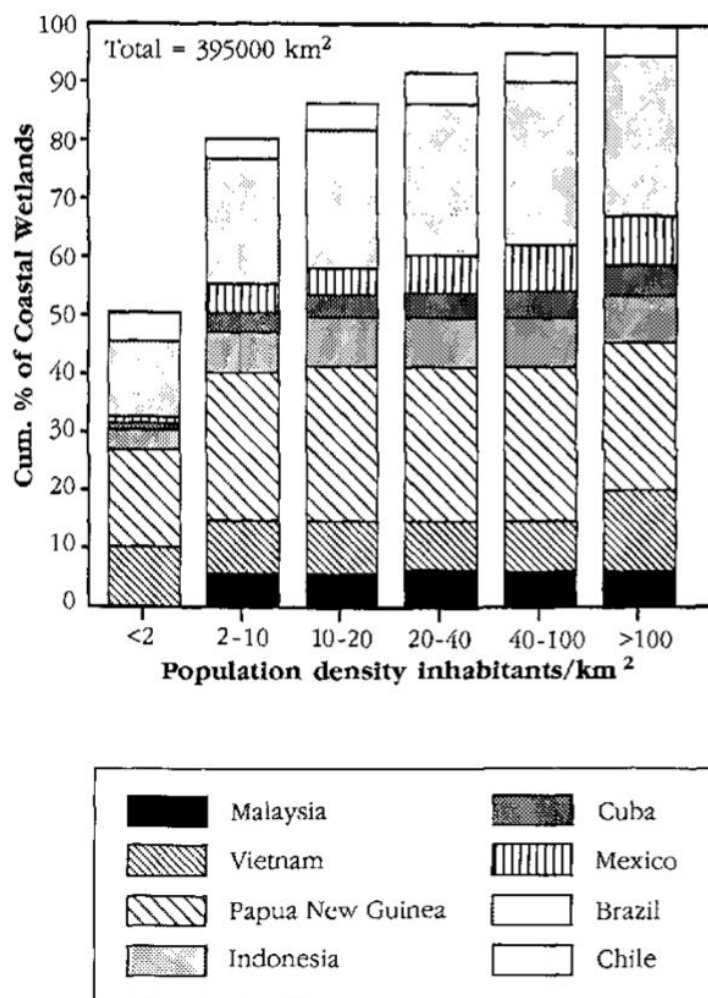
INTRODUCTION

Most coastal areas contain habitats that are important to fish, shellfish, sea turtles, sea birds, and marine mammals. These areas also have high recreational, cultural, and aesthetic values for many people. Working Group II concluded that a large net wetland loss would result as sea level rises, because the area onto which new wetlands might expand is less than the area of wetlands at risk.

RETREAT

Enabling wetlands to migrate inland is one possible motivation for a retreat strategy. Coastal wetlands can be found along most of the world's coastal margins, notably in the tropical and subtropical regions. From a global perspective, there is presently a large scale de facto retreat in process, given that most of the world's coastal wetlands border on land areas with low population densities and little major development (Fig. 3). Nevertheless, these areas may be developed in the future. Governments should focus attention on their wetland areas and, where appropriate, establish zones to which wetlands will be allowed to retreat using the measures outlined in the previous section. However, even a retreat cannot prevent a large net loss of coastal wetlands.

FIGURE 3: Cumulative Percentages of Major Coastal Wetlands and Their Population Densities



Developed nations with large land masses, such as the United States and Australia, have implemented retreat strategies along sections of their coasts in the interest of allowing coastal ecosystems, particularly tidal wetlands, to adjust to increased levels of the sea through a slow landward migration. By contrast, on small islands the lack of land for inland migration would restrict the applicability of this option; in the case of atolls, many ecosystems could be completely lost.

ACCOMMODATION

The implications of this option would be a compromise between retreat and protection. However, resource exploitation practices would change. For example, people may harvest mangrove wood for use as pilings to elevate houses. Flood control efforts might alter water flow patterns that could adversely affect the coastal environment.

PROTECTION

This strategy is most relevant for areas having relatively large populations and important infrastructure. These conditions inherently alter the environments. However, the structural measures related to a protection strategy can impose additional alterations not only to the immediate environment but also to the unaltered coastal ecosystems beyond the area of protection. Therefore, environmental impact assessments are particularly important when protective measures are under consideration.

Hard Structures

Along ocean coasts, seawalls constructed landward of the shorelines would have little immediate impact on the beach systems. However, an eroding shore would eventually reach the seawalls and result in a loss of the natural beach. This impact can be avoided by means of beach nourishment. Similarly, structures could block the inland migration of coastal wetlands. For example, in the United States, the loss from a one-meter rise would be 29-66 percent under the retreat option, but 50-82 percent if shores are protected with bulkheads.

Groins trap sediment moving along the shore. However, protection of one area is generally at the expense of increased erosion down drift from the protected area. Because these structures do not increase the total sediment available to beaches and barrier islands, their long-term impact is primarily a geographic shift of the erosion. Detached breakwaters often have similar effects, although they allow for nearshore habitat shifts in some cases, and often provide desirable fish habitats in much the same fashion as natural reefs.

Dams and saltwater intrusion barriers can protect water supplies and freshwater habitats. On the negative side, these structures can retain sediments that in turn can increase erosion of coastal headlands and impair the ability of deltaic wetlands to keep pace with sea level rise.

In deltaic areas, levees might be constructed along rivers to prevent flooding due to sea level rise. The resulting "channeling" of rivers could, in some cases, prevent annual river floods from providing sediment and nutrients necessary to enable deltas to keep pace with sea level rise and maintain the fertility of agricultural lands.

Soft Structures

Soft structures have a less severe impact than hard structures, since they usually consist of simulated natural features, such as beaches and wetlands. The most common “soft engineering” approach is beach nourishment, which involves dredging sand from back bays, navigation channels, or offshore, or excavating material from a land-based source and placing it on the beach. Because beach ecosystems are already adapted to annual erosion/accretion cycles, the placement of sand on the beach generally has little impact on beach ecosystems. By contrast, the dredging itself can seriously disrupt shallow water ecosystems and wetland habitats, both due to the direct effects of removing material and the resulting increase in turbidity.

ECONOMIC IMPLICATIONS

INTRODUCTION

The potential economic implications of responses to sea level and temperature rise over periods of fifty to one hundred years are extremely difficult to quantify. The variables to be considered include both the cost of the strategies themselves, and the effects of those costs on national economies. Thus far, only the cost of protecting against inundation and erosion has been estimated worldwide. Much more research needs to be done.

The cost of an adaptive response is site-specific. The nationwide impact of such costs will be greater on rural, subsistence economies, often found in coastal areas in developing countries. Losses of resources such as biologically productive wetland areas, and important mangrove stands and their products would compound such hardship. Reduction in the productivity of fisheries and the loss of land, resources, and jobs are a further consideration. Significant costs can also be associated with the establishment and operation of the institutional mechanisms necessary to implement retreat or accommodation strategies. Finally, and especially if structural response options are exercised, operation and maintenance costs are a factor.

A fundamental element in the decision-making process is a cost-benefit assessment to weigh the life-cycle costs and economic returns of the various alternatives. Not all of the important factors are totally quantifiable in monetary terms, however. This is particularly so for cultural, environmental, and social factors. Nevertheless, these non-quantifiable aspects must be evaluated and given due consideration in an equitable trade-off analysis in order to formulate and implement an acceptable adaptive response.

RETREAT

In densely populated and productive areas, retreat may prove to be the least economically viable response option because of nearly irretrievable losses involved, or, in the case of small islands, the lack of land on which people can resettle. Inundation of fertile coastal agricultural land and frequent flooding of industrial sites and urban centers would threaten the value of past investments and drastically limit future growth. In such cases, it is highly unlikely that the economic benefits of retreat would exceed the costs.

Large-scale resettlements could severely tax the planning, infrastructural, and distributive capabilities of most countries, especially for developing countries. In particular, small island nations would face the most serious economic implications of retreat. At its most extreme, it would involve resettlement of the populations of entire nations.

The slow (albeit increasing) rate of sea level rise permits appropriate planning and incremental implementation of retreat options, and this may reduce costs. However, in the case of arable lands, the inability to produce an adequate food supply may cause further national hardship through both unemployment and loss of exports.

ACCOMMODATION

Accommodation provides opportunities for inundated land to be used for new purposes. Thus, some compensatory economic benefits could be derived from accommodation or adaptation to inundation and flooding. For example, agricultural land may, in some instances, be found suitable for aquaculture; salt-resistant crops may be grown in areas previously dependent on freshwater. Nonetheless, considerable costs may be involved in the planning and restructuring of land use. The necessary expenditure may place significant stress on national budgets, especially in developing countries. In the case of an increase in extreme events induced by climate change, such as tropical storms, altered wave regimes, and storm-surge frequencies, significant expenditures would be involved in disaster planning and preventing loss of life. Responding to such events would require considerable national planning and might involve compensation.

PROTECTION

The economic benefits accruing from protection depend on the values of the land being protected. Benefit categories, as measured against taking no action include

- (a) prevention of physical damage to property as a result of waves and flooding;
- (b) prevention of loss of (economic) production and income;
- (c) prevention of land loss through erosion; and
- (d) the prevention of loss of natural resources (environmental and recreational).

Costs include capital, operation, and maintenance of the protective measures, as well as any cultural, environmental, and social changes that may result. For example, some hard structural protection works may cause beaches to disappear. For economies heavily dependent on tourism (e.g., Caribbean Islands) this may have serious adverse consequences. As previously stated, the non-quantifiable aspects of cultural, environmental, and social impacts must be considered when selecting any response strategy. Options may be restricted for some developing countries because of costs or lack of technology.

Cost Estimates for Protection

Although the potential economic developments in the next few decades are difficult to predict, an approximation of basic implementation costs is possible. Although any such calculations are only

rough approximations, they provide a useful first estimate and a guide for future data-collection efforts. Table 5 illustrates estimates based on a sea level rise scenario of one meter in 100 years, for 181 countries and territories with a marine coast. These estimates show that preventing inundation alone would cost, at a minimum, some U.S.\$500 billion (not discounted over time).

This value reflects only the marginal or added costs of protecting against the effects of a one meter rise in water level by the year 2100. It does not include any costs associated with basic coastal protection already in place or necessary to meet present coastal defense needs. The estimate does not include the value of the unprotected dry land or ecosystems that would be lost, nor does it consider the costs of responding to saltwater intrusion nor the impacts of increased storm frequency.

The annual cost of protection amounts to 0.037 percent of total Gross National Product (GNP). It is important to note, however, that the cost burden in terms of GNP is not uniform within the community of nations. For example, the small low-lying island nations of the world would have to commit a relatively high proportion of their GNP to protect against a one-meter rise in sea level. Specifically, the small island states in the Indian and Pacific Oceans would, respectively, have to commit 0.91 of 1 percent and 0.75 of 1 percent of GNP in the one-meter rise scenario. For some atoll islands the annual cost may be as much as 10-20 percent of their GNP.

SOCIAL AND CULTURAL IMPLICATIONS

INTRODUCTION

The social and cultural implications of adaptive response measures may affect hundreds of millions of people living in coastal zones, which have an average width of 50 kilometers. In some coastal areas, inhabitants are highly concentrated in a narrow coastal belt (e.g., Java, India, and China).

The lifestyles of many people are tied directly to the coast and its predominant local features. The coast also features strongly in the mythology of many cultures. Numerous places of particular cultural significance are situated on the coast, and many people in developed and developing nations view the sea, coasts, reefs, and beaches as central to their lives.

Social and cultural implications of adaptive options are likely to vary considerably from country to country and from site to site. Options that are socially and culturally beneficial in some situations may be less desirable in others. It is particularly important that the affected communities are consulted and participate in the decisions to adopt particular options. This is probably one of the best means available to identify the social and cultural implications for particular cases.

RETREAT

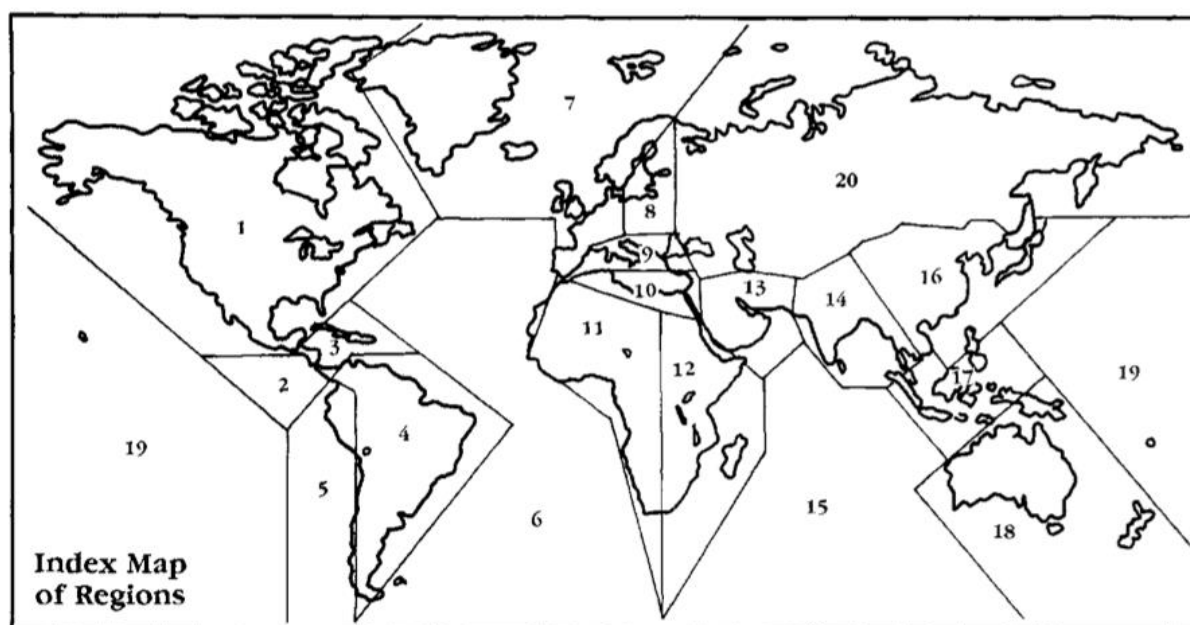
Retreat, as an option, may imply a partial, incremental process or a sudden large-scale event. In some circumstances, there may be a need to relocate inhabitants, or even entire communities, which could have major financial and social implications in developing countries. The loss of the traditional environment that normally sustains economies and cultures and provides for recreational needs, could severely disrupt family life and create social instability, with a resulting adverse impact on the entire community, especially on the young and the elderly. In addition, places of

great cultural significance, for example, burial grounds, historic places, or religious centers, could also be lost if retreat occurs.

TABLE 5: Estimate of Marginal Costs Involved in Protecting Countries Worldwide Against the Effects of a 1-Meter Sea Level Rise in 100 Years

REGION	TOTAL PROTECTION COSTS (BILLIONS U.S.\$)	STANDARD DEVIATION TOTAL COSTS (IN %)	TOTAL COSTS PER CAPITA (U.S.\$)	ANNUAL PROTECTION COSTS AS % OF GNP
1. North America	106.2	43	306	0.03
2. Central America	3.0	19	117	0.12
3. Caribbean Islands	11.1	17	360	0.20
4. South America Atlantic Ocean Coast	37.6	36	173	0.09
5. South America Pacific Ocean Coast	1.7	30	41	0.04
6. Atlantic Ocean Small Islands	0.2	28	333	0.12
7. North and West Europe	49.8	14	190	0.02
8. Baltic Sea Coast	28.9	23	429	0.07
9. Northern Mediterranean	21.0	23	167	0.04
10. Southern Mediterranean	13.5	16	87	0.06
11. Africa Atlantic Ocean Coast	22.8	11	99	0.17
12. Africa Indian Ocean Coast	17.4	27	98	0.17
13. Gulf States	9.1	17	115	0.02
14. Asia Indian Ocean Coast	35.9	26	34	0.14
15. Indian Ocean Small Islands	3.1	27	1333	0.91
16. South-East Asia	25.3	18	69	0.11
17. East Asia	37.6	56	38	0.02
18. Pacific Ocean Large Islands	35.0	23	1550	0.17
19. Pacific Ocean Small Islands	3.9	22	1809	0.75
20. USSR	25.0	36	89	0.01
TOTALS	488.1	12	103	0.04

Source: "Sea Level Rise: A Worldwide Cost Estimate of Basic Coastal Defense Measures." Paper by Dutch Delegation (Rijkswaterstaat/Delft, Hydraulics, Note No. H1068) to IPCC-CZM Workshop, Perth, Australia, February 1990.



All retreat options have been identified as having potentially significant implications both socially and culturally. This is particularly the case with abandonment and the resulting need to resettle whole populations. Even though migration is relatively common in some areas, for example, the South Pacific, there remains the need for social adjustment. Situations where an individual's or a

community's identity is closely associated with a particular piece of land or access to particular resources, as in most subsistence economies, can have implications that are difficult to resolve.

The greatest implications of retreat may lie in being denied access to the original coast. A well-planned retreat that provides for access to alternative resources could minimize some of these impacts. An associated issue is that of the social implications for the host people at the place of relocation. There exists a potential for conflict, and existing social services may be heavily taxed in the host area if relocation is not well-planned and managed. People may choose not to abandon even vulnerable coastal areas in anticipation of climate change impacts, if there is strong population pressure in adjacent areas.

ACCOMMODATION

The social and cultural implications of accommodation, while not as severe as those of retreat, may still be significant. A change in the economic activity of an area, for instance, from farming to aquaculture, will change lifestyles. Accommodating change may lead to living conditions being less desirable, for example, if properties are subject to periodic flooding, or if problems with sewage disposal occur. Public safety and health will thus be adversely affected by this option.

Accommodation is a more socially desirable option when applied in areas where there is a tradition of adapting to water, for instance, if people live in houses on stilts or in houseboats.

PROTECTION

Protection has fewer identified social and cultural implications. However, hard structures are likely to have less aesthetic value than the original environment, and access to the shore may also be restricted by some protective options. Beach losses could impair recreation, while loss of wetlands may affect fish stocks. If protective options involve non-local labor, there may be social and cultural friction which could lead to community disruption. Options that can be implemented by communities themselves are less likely to have social and cultural implications than those which require outside labor.

If the protection structures cause alteration to places of cultural significance, there could be opposition to their construction. The loss of any biological resources resulting from protection activities could also be of cultural significance. In some areas, for example, if a significant species is seriously threatened it may no longer be available for ritualistic or economic purposes.

LEGAL AND INSTITUTIONAL IMPLICATIONS

INTRODUCTION

Existing institutions and legal frameworks may be inadequate to plan and implement adaptive responses. New institutions and legal authorities may be needed in many coastal states. National legislation and institutions for coastal zone management can provide the needed planning. In addition, legal structures to require advance consideration of likely impacts—such as environmental impact review by those planning new projects—can encourage needed foresight.

One matter to consider is that virtually any adaptive option involves the use of "private" land. In some nations such use by individuals may be prohibited by law; in other states the government may not have authority to use the land without the consent of the landowner; and, in others, the government may have the authority to use private land, but only upon providing compensation to the land- owner.

An accelerated rate of increase in the global sea level also raises the possibility of legal issues pertaining to maritime boundaries and jurisdiction, and transboundary matters. These issues may require a review of existing international arbitration procedures. An example of the first issue would be if a nation loses maritime boundary base-points and therefore a legal claim to sea territory, or if beach nourishment measures are required in the vicinity of national borders. An example of the second issue would be if protective measures interrupt or impede the longshore sediment transport benefiting an adjoining coastal state. In the worst case, sea level rise may result in the total land loss of an island nation; the resulting legal implications are difficult to predict.

RETREAT AND ACCOMMODATION

The resettlement option could raise significant transboundary implications. The legal authority and institutional capability to manage or direct a relocation on a temporary or permanent basis must be clearly established. Authorities to facilitate and encourage relocation from vulnerable areas, and to subsequently deal with the use of abandoned lands may be needed. In extreme cases when individuals will not leave areas subject to great risk, authorities for condemnation of land and facilities may also be necessary.

Whether relocation is on a temporary or a permanent basis, accommodations for displaced inhabitants must be provided. In some coastal states, relocation could involve tens of millions of inhabitants. The relocation may be further complicated by the lack of land within small coastal or island states. If relocation outside such states is required, then the assistance of regional or international institutions may be needed.

The first option for both measures is to discourage growth in population, or additional development in vulnerable areas that would increase either the risks of losses or would increase the costs of later retreat to unacceptable levels. In order to implement this option, the coastal state must have the institutional facility for identifying vulnerable coastal zones. Many developing countries do not have the institutional structure and will require assistance to develop a national plan for management of coastal resources and coastal development. Alternatively, a state might choose to encourage private retreat and accommodation actions through non- regulatory measures, such as providing information to the affected population.

In addition to an institutional structure to plan and manage coastal development, legal authorities are needed to enforce restrictions or conditions on coastal development if a coastal or island state chooses to take an active regulatory role for implementing those strategies. Legal authorities may also be needed both to ensure the integrity of natural coastal protection systems and to avoid placing coastal populations and developments in jeopardy from sea level rise. For example, a coastal or island state may need new authority to restrict access or activities to certain areas in order to protect

natural systems (such as from the use of mangrove for firewood) as well as have the authority to restrict residential and commercial development (such as new settlements on deltas).

PROTECTION

An important implication of selecting an option to protect against sea level rise is liability for the failure of public protection structures. Structures to protect against sea level rise enable commercial, agri- cultural, and residential activities to continue in protected areas. Therefore, people and economic resources will be attracted to and concentrate in areas so protected. Should the structure fail, significant loss of life and property could result. Each type of structure is different, and each requires some type of maintenance in order to perform as de- signed. Where the entity responsible for maintenance is different from the entity that designed and/ or constructed the structure, it may be difficult to assess any liability for damage resulting from a failure of the structure. Some public or private entity within each nation, therefore, must have responsibility for maintenance of the physical integrity of these structures.

PRIORITIES FOR ADAPTIVE RESPONSES

INTRODUCTION

The projected rise in sea level warrants urgent policy responses in many coastal states, particularly those with populated coral atolls and deltas, or those with estuary-dependent fisheries. It is imperative that such actions focus on human safety and on sustainable development of coastal resources.

Even though sea level rise is predicted to be a relatively gradual phenomenon, adaptive strategies may require lead times in the order of 50 to 100 years, to tailor them to the unique physical, social, economic, environmental, and cultural considerations of a particular coastal area. Moreover, even though there may be no need to begin building dikes that are not needed for 50 years, it is appropriate to begin planning now to avoid actions that could increase vulnerability to the impacts of sea level rise. It will take 10 years to implement plans, in view of the time required for the necessary analyses, training the people, developing the plans and mobilizing public and political awareness and support. Therefore, the process should begin today.

Protection from coastal impacts of sea level rise and other impacts of global climate change include both capital investment in defense structures and maintenance costs. Moreover, if the sea continues to rise these structures may have to be augmented or replaced. Similarly, non-structural options to reduce vulnerability to impacts of sea level rise, such as land use planning, may require actions to implement and enforce them.

It is important to recognize that decisions today on planning for coastal development will greatly influence costs for later adaptation to impacts of sea level rise. Venice, Shanghai, New Orleans, and Lagos are all vulnerable because of decisions made 200-2,000 years ago. It is therefore necessary to establish some immediate priorities for planning and management of coastal resources, and for technical and financial assistance to developing countries to facilitate their planning.

There is a need to provide developing countries with the technical and financial assistance required to plan for coastal development in order to reduce vulnerability to impacts of sea level rise. There is also a need to estimate the future long-term funding requirements for developing countries that may be required if protection options are needed.

Finally, the success of strategies to limit climate change is a factor to be considered. Limitation measures will be likely to reduce the costs of adaptation to the coastal impacts of sea level rise; however, it is likely that some adaptation to sea level rise will be required regardless of the limitation strategies eventually implemented.

PRIORITIES FOR ADAPTATION

Science/Monitoring

There is still considerable uncertainty regarding sea level rise and other impacts of global climate change. This makes the selection of adaptation options extremely difficult. In particular, there is a lack of regional, national, and site-specific data that is needed to make decisions on adaptive options.

For example, a system to monitor, detect and predict sea level rise is needed to assist in determining the need for construction of protective structures or relocation of coastal inhabitants. There is also a need for information on other impacts, such as changes in tropical storms, in order to plan for natural emergencies.

Information

There is a great need to identify those areas that are most vulnerable to the impacts of sea level rise. The identification should concentrate on densely populated low-lying areas, deltas, and small atoll islands.

The need for clearinghouse arrangements to facilitate exchange of information and international data bases accessible to all nations has also been identified.

Development of models and assessment techniques to support coastal planning needs to be undertaken in order to provide decision makers insight into the complicated interactions and conflicting interests that are involved in coastal zone management. Equally important is the transfer to developing countries of existing coastal adaptation technologies and the provision of training in coastal zone management, engineering, and environmental monitoring. Such training might also include technology research centers, extension services, technology advisory committees, technology research and development, technology conferences, and pilot projects to enhance technology transfer.

Planning

Many priorities have been identified within the broad area of planning. These include:

- Emergency management planning to reduce vulnerability of inhabitants in areas exposed to extreme weather events.

- Coastal management planning to reduce impacts on development structures and on natural resources of the highest priority. Technical and financial assistance to developing countries may be required to develop and implement national plans for management of coastal development.

Education and Community Participation

Public education and education of decision makers regarding the impacts of sea level rise and the impacts of ongoing activities is essential, so that everyone understands the risks of development in coastal areas. The involvement of members of the local communities in selecting and implementing response options is also essential for the success of adaptive responses.

PRIORITIES FOR IMPLEMENTING ADAPTIVE OPTIONS IN DEVELOPING COUNTRIES

Retreat

Technical assistance to developing countries is required for timely planning for resettlement and emergency management pending resettlement. Financial assistance also may be needed to facilitate the resettlement. Assessments of potential relocation sites should be made to minimize dislocation difficulties such as linguistic diversity, cultural differences, and long-term viability.

Accommodation

Education, technical assistance, and training are required for developing countries so that their populations can understand the risks of development in coastal areas in order to reduce vulnerability to impacts of possible sea level rise.

Technical assistance on alternative activities—for example, mariculture agriculture—is required to mitigate the social, cultural, and economic implications of various options. Experience in this field exists in several developing countries and should be shared. The same holds true for alternatives to current coastal development activities. For example, using coastal areas for tourism rather than for industrial or residential activities, may also be a solution.

Protection

Protection options involving structures in most developing countries are likely to require external assistance. For example, the building of hard structures could require assistance such as transfer of skills and/or capital. There may also be a need for transfer of planning skills to support the choice of appropriate options.

CRITERIA FOR ALLOCATION OF RESOURCES

In addition to identifying priorities for adaptive responses it is also appropriate to identify the priorities that might be used to allocate resources. As the necessary resources vary considerably, depending on the adaptive option and the coastal area, allocation criteria must include consideration of both the options and the area.

A list of sample criteria are provided in Table 6. There is no intention to suggest that any one criteria should be pre-eminent. Some may be more significant in some situations while other criteria may be more important than others.

Table - 6: Criteria for allocation of resources

Related to the coastal Area
1. The contribution of current activities within the coastal area that contribute to its vulnerability to sea level rise; 2. The importance of the coastal area in terms of: • urgency of risk; • proportion of national land area; • population affected; • environmental importance; • economic importance; • social and cultural importance; and • regional importance. 3. The national ability to finance the response option; 4. The institutional and political ability to realize implementation.
RELATED TO THE ADAPTIVE RESPONSE OPTION
1. The cost of the option; 2. The effectiveness of the option; 3. Cost effectiveness; 4. The economic, environmental, social, cultural, legal, and institutional implications of the adaptive option; 5. The vulnerability of the option to the impacts of an accelerated sea level rise; 6. Performance under uncertainty; Equity.

MODULE - II

INTEGRATED COASTAL ZONE MANAGEMENT

Much of the World's coast has been carved since the end of the last glacial maximum when the global sea level was some 110 m below the present day base line. Deglaciation began some seventeen thousand years ago; leading to rapid sea-level rise that at times exceeded 30 mm/year. This dramatic inundation of the previously exposed shelfal regions largely ended some five to six thousand years ago when the sea level reached a relative still stand. Modern coastal morphologies date back to this period of relative eustatic stability. River deltas, where large maritime populace now resides, also began to be built out by rapid sediment accumulation after the cessation of marine transgression at this time. Currents, tidal and wave action, storm activity, as well as vertical movements of land have since sculpted the coastline as we see them today. These features, that remained relatively unaffected for much of early human history, first began to change with the advent of extensive agriculture in Asia and Europe that multiplied the sediment loads brought down to the coasts by rivers. More intensive human activities of the recent past, both on- and offshore, as well as in the hinterland, have dramatically influenced the coastal zone. Understanding the lithospheric, oceanographic, atmospheric and biological systems that control the morphological evolution of a coast over time and the anthropogenic influences that alter this natural progression forms the scientific basis and a necessary first step of managing a coastal zone for sustainable development.

The World community, through the venue of numerous international fora culminating in the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro has recognized the expediency of Integrated Coastal Zone Management (ICZM) for sustainable development. In developing maritime countries, where the resources of the coast may be crucial to the national economy, exploitation of these resources is often indiscriminate or ill planned, against a background of inadequate scientific knowledge, leading to rapid resource depletion and often irreversible environmental degradation. Uncoordinated management of some functions of the coast along sectorial lines can lead to detrimental impacts to other functions and services. Examples of deleterious impacts of haphazard exploitation of the coast abound in many developed and developing countries. Thus, an integrated, well-planned and sustainable use of all coastal resources, functions and services, based on both extant and longer-term scientific data, becomes an imperative. The creation of a management infrastructure for the coastal zone therefore by necessity has to cut across sectorial and functional lines, and incorporate administrative elements from various disparate functions and interests of many diverse stakeholders.

In 1994 an international workshop on ICZM was organized by the Intergovernmental Oceanographic Commission (IOC) of UNESCO in cooperation with the Ministry of Science and Technology of Pakistan with the support of UNDP and held in the coastal city of Karachi. The workshop evaluated the impact of socio-economic development of the coastal regions in developing countries, drafted guidelines for ICZM planning process suitable for the special needs of Pakistan and recommendations for national capacity building for management and sustainable development of the coast. A large number of papers on both institutional, scientific and technical aspects of coastal management, as well as case studies and experiences from various parts of the world were presented. The deliberations of the workshop are available in an IOC report (Workshop Report Series Number 114, UNESCO-IOC, 1995).

Integrated Coastal Zone Management for Developing Maritime Countries

This part explores the concept of integrated coastal zone management as it is evolving today, with special emphasis on its usefulness to maritime developing nations. The paper has two basic objectives, first, to describe the origins of the concept of integrated coastal zone planning and management and, especially, to layout the key developments relative to coastal management that took place at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, and secondly, to provide an account of the fundamentals of integrated coastal zone management (ICZM) as they might apply to developing nations.

To place the subject in the proper perspective it has to be realized that ICZM can be divided into two fundamentally different bodies of knowledge and understanding, both of which are critical to the development of an effective coastal management program. First, there has to be an understanding of the technical aspects of the coastal zone. These might include an understanding of: 1) the key physical processes at work (erosion, long shore drift, estuarine circulation, sediment flows, river delta behavior, etc.); 2) key biological processes (mangrove and wetlands ecology, variability in fish abundances, etc.); and 3) the fate and effects of various types of pollution found in the coastal zone (sewage outfalls, industrial effluents, agricultural and urban run-off, etc.).

Second, there has to be in existence a framework of organizational capability and an understanding of the institutional aspects of the coastal zone. For example, it must be understood: 1) which governmental agencies have what kinds of management and regulatory responsibilities in the coastal zone and how well are they performing? 2) what legal authority exists for management of the coastal zone and what new legal authorities might be needed? 3) what are the differing roles of the central government and the provincial and local governments concerning resource and environmental management? How are coastal and environmental policies set and enforced, etc.? What new policies may be needed?

In this paper the focus is largely on the institutional and policy side of ICZM. The emphasis will be to discuss both on the broad international context from which ICZM emerged, as well as, the conceptual framework for operationalizing ICZM in a given national setting. Given the importance of intergovernmental relationships - i.e., the relationships between central governments and local community levels - in virtually all developing nations, a discussion of the relative roles of the national government and the local governments in ICZM is also included. Experience shows that the federal-provincial-local governmental relationship is often the key to a well functioning ICZM program.

Early Efforts in Coastal Zone Management

In order to set the stage for the discussion of ICZM, it will be useful to briefly review some of the early efforts in coastal management. The first national coastal zone management program was implemented by the US in 1972. Legislation authorizing the program was enacted by the US Congress following the studies and recommendations of a high level commission (also called Stratton Commission) in 1969. The legislation authorized a system of financial grants to the 35 coastal states and territories in the US to encourage them to develop and implement management programs for their coastal zones consistent with general guidelines and standards contained in the

legislation. The fundamental offer to the coastal states by the legislation was that if the states developed and implemented coastal management programs which were judged to meet the standards contained in the legislation and which were binding on state and local actions, agencies of the federal government would also be required to act in a manner consistent with the coastal policies of approved state coastal management programs.

More than thirty years later the US program remains in effect with twenty nine states and territories (representing about 93 % of the US shoreline) now included in the program and with five of the six states still outside the program now in the process of completing coastal management programs for their coastal areas. The key to the near complete participation in the program are the incentives offered by the program - federal funding and "federal consistency". While the financial assistance has been necessary and helpful to the states, the promise of federal consistency has probably been even more important. For the first time, states are offered a mechanism to ensure that actions by the higher (national) level of government do not adversely affect their coastal zones and the resources they contain.

The US coastal management program represented a first attempt at integrated management. With respect to the four dimensions of ICZM discussed below, the US program was better designed to deal with integration of the spatial and intergovernmental dimensions than with the sectoral and interdisciplinary dimensions. In their initial form, state coastal management programs in the US tended to focus on land use decisions in a typically narrow coastal zone centered on the immediate land-water interface with relatively little attention paid to coastal water quality and living marine resources.

In 1990, an explicit legislative effort was made to broaden the sectoral concerns of the US coastal management program to include non-point source pollution as it affects coastal water quality. States are now completing management program elements to deal with this kind of pollution. While coastal management programs in the US do not deal directly with fisheries management issues, they are seen in some quarters as playing an increasingly important role in the protection and restoration of key fisheries habitats.

During the late 1970s and early 1980s, a growing number of nations initiated coastal management-related programs of one type or another. Sometimes these efforts were stimulated by national governments, sometimes by local communities wishing to deal with a specific problem (or opportunity), and sometimes donor agencies required a coastal management program as a condition for funding new facilities in the coastal zone. Typically, however, these efforts were sectoral in nature - they tended to address a single coastal problem (erosion, water pollution, resort development, port dredging, etc.). Over time it was discovered that the complexities and interconnections of coastal systems required a more integrated approach. By the mid-1980s, the term "integrated coastal zone management" was increasingly being used to describe what was now being seen as the appropriate way to manage the coastal zone. As the preparatory work for the UNCED began in 1990, it fully embraced the concept of ICZM (see below).

Prescriptions of the 1992 UNCED for ICZM and the Status of the Implementation of these Agreements: The UNCED was the culmination of a two and a half year of preparatory process. Early in that process, it was clear that ICZM would emerge as a concept of major importance.

Indeed, a number of UN organizations, especially the Food and Agriculture Organization (FAO) submitted papers highlighting the importance of ICZM. Ultimately, the need for an integrated approach to the ocean and coastal management became the first recommendation contained in the ocean and coastal chapter (chapter 17) of 'Agenda 21', the Action Plan that emerged from UNCED. The language used in chapter 17 relative to the need for an integrated approach is as follows:

Governance of ocean and coastal areas must be "integrated in content, and precautionary and anticipatory in ambit." Nations cannot rely solely on traditional approaches that govern one ocean use at a time but must also consider the effects of one resource or use on other resources, uses, and the environment.

Chapter 17 of Agenda 21 contains recommendations dealing with seven coastal and ocean issues areas. For completeness, each is described briefly below. ICZM is an important tool in at least 5 of the 7 issues:

1. ***Integrated management and sustainable development of coastal and marine areas, including exclusive economic zones:*** The recommendation encourages coastal states to commit themselves to integrated management and sustainable development of coastal areas and marine environments under their national jurisdiction..It calls for integrated policy and decision-making processes and provides a series of suggested actions that can assist coastal states in strengthening their efforts at integrated management. Recommendations include the adoption of measures to improve coastal human settlements, conserve and restore critical habitats, integrate existing sectoral programs, and maintain biodiversity and productivity of marine species and habitat.
2. ***Marine environmental protection:*** The recommendation emphasizes the importance of effectively dealing with land-based sources of marine pollution given the overwhelming contribution that such sources play to marine pollution. Specifically, the language calls for a global conference to be organized by the United Nations Environment Program (UNEP) to focus on the problem of land-based sources of marine pollution. (This conference was held in 1995 in Washington, DC. and some of the results are described below.)
3. ***High seas fisheries:*** Particularly emphasized in the recommendations are the problems of stocks that straddle marine boundaries between nations and straddle boundaries separating national jurisdictions from the high seas. The management problems associated with highly migratory stocks are also under- scored.A UN conference to resolve existing problems in these areas is called for. (Such a UN conference was held in the 1993-1995 period and a new binding international agreement to deal with these issues was approved.)
4. ***Fisheries under national jurisdiction:*** The recommendations call for nations to exert a higher level of stewardship in managing fisheries under national jurisdiction. The text highlights the fact that a substantial number of important fisheries under national jurisdictions are currently being overfished with deleterious impacts on stocks and, potentially, on the resources available for future generations.
5. ***Critical uncertainties (climate change):*** The recommendations call for states to commit themselves to improving the understanding of the ocean environment and its role in global

processes such as ozone depletion and greenhouse gas warming. Increased international cooperation is also called for with a view to strengthening national scientific and technological capabilities for analyzing, assessing and predicting global climate and environmental change. The recommendations also support the creation of the Global Ocean Observing System (GOOS) by IOC and cooperating nations.

6. *Strengthening international and regional cooperation and coordination:* The recommendation calls upon international organizations to take an integrated and multi-sectoral approach to marine issues and to promote more effective information exchange. The recommendation also discourages the use of unilateral trade sanctions as a method for achieving national environmental policies.

7. *Sustainable development of islands:* The recommendations highlight the special problems that small island developing nations face, especially related to climate change and the prospect of rising sea level. Such islands tend to be ecologically fragile and extremely vulnerable and tend to have a very limited resource base. A follow-up UN conference on the sustainable development of small island states (SIDS) was held in Barbados in April 1994 from which an Action Plan resulted.

Status of the Implementation of UNCED Agreements

As mentioned above, the UNCED has already triggered a number of activities in the seven issue areas listed above. In the area of integrated coastal management, the following actions have been taken:

- the World Coast Conference was held in the Netherlands in 1993 and issued a strong statement recommending that all coastal nations undertake integrated coastal management;
- the World Bank issued its Noordwijk guidelines for integrated coastal zone management in association with the World Coast Conference;
- UN agencies such as the IOC, UNEP, United Nations Development Program (UNDP), and the FAO have greatly increased their technical assistance, capacity-building, and training efforts in the area of integrated coastal and ocean management.

Also, as recommended at UNCED, a new institution was created by the General Assembly in December 1992 as a part of the UN Secretary General's office to monitor and oversee the implementation of the agreements reached at the Earth Summit. This institution, called the Commission on Sustainable Development (CSD), has met annually since 1993 to assess the progress of UNCED implementation and to highlight problems. The CSD is reviewing progress on selected, cross-cutting issues (financial aspects, poverty, etc.) and selected sectoral issues (fresh water, forest, oceans and coasts, etc.) each year. Progress on ocean and coastal issues was reviewed during the 1996 meeting of CSD.

As might be expected, the issue of financing the implementation of the UNCED recommendations continues to be a major concern, especially among developing nations. They firmly believe that "new and additional" financial resources must be made available to them by developed nations, who, after all, are largely responsible for creating many of the emerging environmental problems such as greenhouse gas warming and ozone depletion. Developed nations, on the other hand, would

prefer to see existing sources of funds (from bilateral and multilateral funding mechanisms) redirected to these new needs. Although the debate continues, the Global Environment Facility (GEF), a joint effort of the World Bank, UNDP, and UNEP, has emerged as a significant new funding source for UNCED-related implementation activities. A restructuring of GEF, which took place in 1994, created a new dual voting system which has given developing nations a greater voice in GEF policy and decision making.

The two international conventions opened for signature at Rio in 1992 quickly received the necessary ratifications and have "entered into force" - the Convention on Biological Diversity in December 1993 and the Convention on Climate Change in March 1994. The first meeting of the Conference of Parties of the Biological Diversity Convention took place in the Bahamas in November 1994 and the corresponding meeting for the Climate Change Convention occurred in Germany in March/April 1995. Meetings of the parties to both conventions continue on an annual basis as the implementation of these agreements takes place. Not unexpectedly, both conventions have some controversy associated with their implementation. In the case of the Biodiversity Convention, disagreements exist on the extent to which issues related to the distribution of benefits of biotechnology and issues related to biosafety concerns should be dealt with under the convention. Similarly, in the Climate Change Convention, a substantial gulf exists between nations that want to set (and enforce) real reductions in greenhouse gas emissions and those who wish to see additional hard evidence that man-induced climate change is really occurring before taking action. The 1995 assessment of the Intergovernmental Panel on Climate Change (IPCC), which was issued in early 1996 and reiterated the seriousness of the threat, may not help break this deadlock.

A number of UN organizations are reprogramming their resources to be able to respond to the recommendations coming out of UNCED. Most notably, UNDP, UNEP, and IOC all have (or are developing) significant efforts in research, education and training, and capacity building relative to integrated coastal and ocean management. These initiatives, if effectively coupled with the financial resources potentially available to developing nations from the GEF and other donors, could ultimately bring about a considerable advance in the extent to which ICZM is applied by coastal nations throughout the world.

Finally, as of 1996, ICZM appears to have become the tool of choice in at least five international coastal/ocean initiatives which had their roots in UNCED. These are:

- the management of coastal and ocean resources
- the Action Plan for Small Island Developing States
- the Program of Action for land-based activities affecting the marine environment
- dealing with sea level rise associated with climate change
- protection of coastal and marine biodiversity

What is Integrated Coastal Zone Management?

The Dimensions of ICZM

In the typical coastal management problem, it is necessary to "integrate" over several important dimensions. These include (1) the spatial dimension--i.e., the land-water interface; (2) the sectoral dimension (ie., consideration of all of the various sectoral activities that can interact in the coastal zone (fisheries, pollution, shoreline use, etc.; (3) the intergovernmental dimension (ie., the interplay between national, provincial, local government decision-making); and (4) the disciplinary dimension (ie., physical sciences, economics, law, etc.). These four dimensions are discussed in somewhat more detail below.

(1) ***The Spatial Dimension (land-water interface):*** Clearly, integration across the land-water boundary is basic to the concept of coastal management. The coastal zone area to be managed is usually defined in terms of both a shoreline area (the uses of which affect the coastal waters) and a water area (the uses and disturbances of which affect the shoreline). Understanding the effects which traverse the land-water boundary (in both directions) is of fundamental importance.

(2) ***The Intergovernmental Dimension:*** This important dimension encompasses the necessary integration of various levels of government into coastal management, especially between the national level and the provincial / local levels.

(3) ***The Intersectoral Dimension:*** It is becoming increasingly clear that the rational management of coastal resources requires that all activities affecting such resources (or the coastal environment in which they reside) come within the "reach" of the management program. For example, dredging to create a deeper harbor and/ or safer navigation channels can potentially affect habitats that are of critical importance to coastal fisheries. Hence, such dredging must be within the policy and regulatory purview of an integrated coastal management program.

(4) ***The Interdisciplinary Dimension:*** This dimension pertains to the need for a holistic approach to ICZM. It reflects the realization that coastal zone issues not only involve the use and protection of natural resources and the coastal environment, but that significant economic and social issues almost always exist as well. Decisions typically must balance economic, environmental, and social/ cultural concerns.

The Functions of ICZM

The integrated coastal management process typically involves half a dozen functions all of which are part of the responsibility of government relative to the ocean and coastal space and resources under its jurisdiction. The six functions are: area planning, harmonization, stewardship, protection of public safety, proprietorship, and development. Some of the kinds of activities that would be undertaken as a part of each of these functions are given below.

Area planning Function

- characterization studies of coastal and ocean environments and their uses; zoning for various types of uses;

- anticipation of and planning for future possible uses;
- careful regulation of new coastal development through consideration of carrying capacity, resource base, and other relevant factors.

Harmonization Function.

- studies of multiple uses and their interactions;
- methods of conflict resolution;
- mitigation for unavoidable adverse impacts.

Stewardship Function

- assessments of relative risks;
- establishment and enforcement of environmental quality standards;
- conduct of environmental assessments;
- protection and improvement of coastal water quality; reduction and eventual elimination of raw sewage and other untreated discharges;
- establishment and management of marine protected areas;
- conservation and restoration of coastal and marine environments particularly including productive coastal ecosystems such as mangroves, sea grass beds, wetlands, coral reefs.

Public Safety

- reduction of vulnerability to natural disasters and to globally-induced changes (climate change);
- regulation of development in high risk areas through such measures as establishment of setback lines" related to erosion rates and/or inundation zones;
- crafting of evacuation plans and other measures in case of coastal emergencies.

Proprietorship Function

- ensuring, through leases, fees, and rentals, a proper return to the public from the use of publicly-owned resources.

Developmental Function.

- encouragement, through economic incentives or other means, of appropriate and sustainable coastal-dependent enterprises.

Degrees of Policy Integration

One of the main challenges in putting in place an effective ICZM process pertains to the question of policy integration. Clearly, one of the key objectives of ICZM is for the governmental activities carried on in various sectors (fisheries, pollution control, coastal land use planning, industrial siting, etc.) and at various levels of government (national, provincial, local) to be guided by (and consistent with) a unified set of national coastal policies. How can this be achieved given the fragmentation that generally exists between the organizations in various sectors and between levels of government that are often act with considerable autonomy?

The following table illustrates five different degrees of policy integration that can exist.

Fragmentation	A situation characterized by the presence of independent units with little communication among them.
Communication	A forum exists for periodic communication/meeting among the independent units.
Coordination	Independent units take some actions to synchronize their work.
Harmonization	Independent units take actions to synchronize their work guided by a set of explicit policy goals and directions, generally set at a higher level of government.
Integration	More formal mechanisms exist to synchronize the work of various units who lose at least part of their independence as they respond to explicit policy goals and directions (often involving institutional reorganization).

Clearly, the goal in ICZM is to move down the list from the existing fragmented approach to the degree of integration necessary to achieve, on a nationwide basis, the adopted coastal goals of the country. Usually this means proceeding to a level of integration corresponding to the "harmonization" level. In most cases, full integration (the last level) is achievable only through a reorganization which often comes at an unacceptably high political price. Harmonization, however, can achieve most of the benefits of full integration without the high political costs provided that explicit policy goals are authoritatively set by a higher level of government, and an effective institutional mechanism (for example, an inter-ministerial council) is exists to monitor government agency compliance.

The Relative Roles of National and Local Governments in ICZM

One of the central problems in creating a workable ICZM process relates to the question of the relative roles of the national government and the provincial/local governments. While it is possible in concept to have an ICZM program operated entirely from the national governmental level, in practice, a collaboration and/or partnership between national government and the lower levels of government is usually necessary and desirable. This is because the lower levels of government-provincial, local, and/ or community-typically have important roles to play with respect to the use of the land (and sometimes the inshore water as well) and with regard to the siting and operation of facilities in the coastal zone.

Similarly, while coastal zone management can and sometimes does begin with initiatives and actions by local governments or communities, it is soon clear that the active support and cooperation by the national level of government is necessary to sustain the locally initiated effort. Only the national government level is able to ensure that all sectors support and act consistently with the policy goals of the coastal management program and usually it is the national government that has the financial resources necessary to underwrite such a program over the long term.

The type of capabilities that each level of government can usually "contribute" to the ICZM process are listed below:

National Government

- specialized sectoral data and expertise (fisheries, erosion, wetlands, environmental quality etc.);
- capacity to "harmonize" various sectoral activities;
- funding assistance;
- ties to relevant global and regional ocean and coastal programs.

Local Governments

- detailed understanding of "on the ground" problems and needs in the coastal zone;
- best understanding of constraints and limitations and possible solutions;
- best data and information concerning the local coastal zone;
- support of coastal user groups and of local communities.

In the initial stages of creating an ICZM program, it is useful to build understanding between the levels of government, that is, between the national level and the provincial/local level. This can be assisted by means of the following:

- identification of and pursuit of common interests;
- identification of unique expertise, experience and information that each level of government can bring to the process;
- selective use of outside experts selected jointly by the two levels of government;
- deferral of difficult issues until later in the ICZM formulation process.

Ultimately, the strongest ICZM program will be one that involves both levels of government (national and provincial/local) in a mutually beneficial partnership where the strengths, legitimate interests, and validity of concerns on both sides are recognized and where both partners are ensured of equality and equal standing in the relationship.

ICZM and Developing Nations

Many of the concepts embodied in ICZM are especially appropriate for the conditions found in most developing countries. Often, especially in small island developing states (SIDS), the coastal zones and their re- sources represent a major part of the resource base of the nation and as such, must be managed with the greatest of care. Sustainable use of coastal resources and coastal space over the long term is the overarching goal of ICZM. Hence, a well designed ICZM program can be of major importance to such developing coastal nations. Properly implemented, the program can help ensure that the environmental, economic, and social needs of the nation can be met in a balanced and sustainable manner.

Indeed, the argument can be more strongly put. Use of the traditional sectoral management of coastal resources can be very costly to a developing nation. In this approach, each sectoral activity is managed separately - land use by a land planning agency, coastal water quality by an environmental unit, fisheries by a fisheries agency, offshore oil and gas by a specialized agency, and so on. Typically, little or no coordination exists between these activities and little attention is paid to the adverse effects of one use on another. Degradation of valuable coastal ecosystems and the resources that they support can sometimes be the result. For example, inadequate attention to the sewerage generated by a sudden influx of new resort hotels was responsible for despoiling a previously pristine lagoon on the Island of Guam.

Understandably, developing nations may be concerned initially that an ICZM program will require large amounts of time, money, and expertise - all in short supply in most developing countries. However, this does not need to be the case. Programs can begin small first addressing the problems (and opportunities) in only one region of the coastal zone. As experience is gained, the initial pilot effort can be expanded (scaled up) to include other coastal regions or the entire coastal zone of the nation if that is appropriate. Similarly, the first ICZM effort does not need to be fully inclusive provided that the major issues in the region are comprehensively addressed. And, as mentioned earlier, assistance both technical and financial, is becoming available. Intergovernmental organizations such as the IaC, UNEP, UNDP, and the UN's Division of Ocean Affairs and Law of the Sea (DAILIES) are all beginning to provide education and training in ICZM as a part of a concerted international effort at capacity building in this field. Donor agencies such as the global environmental fund, the regional development banks, and nations acting bilaterally are also beginning to provide assistance to developing nations in ICZM.

In contrast to many developed nations, developing nations, in general, do not have deeply ingrained bureaucracies that jealously guard their missions and responsibilities (i.e., their "turf"). In the typical country case, the governance structure may still be in the formative stage with small and less entrenched administrative units. Hence, this is an ideal time for such nations to begin to put integrated resource management programs in place. The creation of an effective inter-ministerial coastal council, for example, may be easier at this stage than later when governmental entities become more set in their ways.

Thus, developing countries that are now beginning to consider strengthening their coastal management efforts have a splendid opportunity to adopt ICZM as the framework for their new management initiatives.

The Case of Pakistan: An Example

The October 1994 Workshop on ICZM in Karachi clearly indicated that ICZM is needed in Pakistan. A set of nationally important and urgent problems exist which can best be dealt with through an effective ICZM program. In fact, obtaining maximum long-term public benefits from Pakistan's important coastal zone and, at the same time, maximizing the benefits of the Indus River's irrigation and energy production activities can only be achieved through an effective ICZM program or its equivalent. The recent establishment of a Coastal Development Authority for Balochistan is a positive first step.

Initiation of ICZM in Pakistan can involve a series of steps. The first step of fundamental importance is to place a short but compelling document in the hands of the highest level of government which describes the urgency of the present coastal zone problems in Pakistan and shows how an ICZM program can effectively deal with such problems and issues.

Once the highest level of the national government sensitized to the need for ICZM, the second step is to prepare an ICZM plan for the nation. It would be best if the plan is prepared by an inter-ministerial team made up of representatives from all of the many government agencies presently dealing with coastal issues and activities affecting the coastal zone (including those related to the uses of the Indus River). In this way, a broader "ownership" in the ultimate ICZM plan will be secured.

Advice on the preparation of such a plan and on its content can be found in the guidelines on integrated coastal zone management issued by the World Bank in 1992 (the Noordwijk Guidelines). Such a plan will involve, at a minimum, an inventory of existing coastal problems and opportunities, the development of national coastal goals for Pakistan, such new and/ or strengthened management measures as may be needed, the creation of an institutional process for harmonization of the programs of various sectors and levels of government which affect or impact the coastal zone and its resources, a scheme for monitoring the achievement of the goals of the program, and a method of funding the program.

The third step is, of course, the actual implementation of the ICZM plan. Again, the World Bank guidelines offer some suggestions in this regard. Fundamentally, this stage involves the official actions by government that are necessary to put the plan into action (adopting such new legislation as may be required, putting in place new management measures that may be needed, the actual establishment of the inter-ministerial council (or other harmonizing mechanism), allocation of funds for the program, selection and training of staff, etc.). Once such implementing actions have been taken, the ICZM process can begin its operational phase. The final step should involve the creation and operation of a process to regularly monitor and assess the performance of the ICZM process to ensure that it remains an effective mechanism.

The information that emerged from the 1994 Workshop could be useful to officials in the drafting of the document that makes the compelling case for ICZM in Pakistan. Furthermore, when work actually begins on the formulation of an ICZM plan for the nation, the information assembled and presented at the Workshop should be of direct and immediate use. Ultimately, of course, the political will and motivation to develop and implement an effective program in ICZM will have to

come from the people, the leaders and the institutions of Pakistan itself. The Workshop has demonstrated that sufficient competence and expertise exists in the country to successfully embark upon such an undertaking. The work of the National Institute of Oceanography particularly stands out in this regard. As discussed above, outside resources likely can be identified which can assist the work at various stages. The World Bank, for example, and its offspring, the GEF have demonstrated a clear interest in ICZM. The IOC has a strong interest and an expanding capacity for providing technical and scientific assistance in the process of shaping an ICZM program as evidenced by its sponsorship of the 1994 workshop. UNEP and UNDP undoubtedly also can assist in such an effort.

That a program of ICZM is needed now in Pakistan is clear. Given the demonstrated competence of the local scientists in this area, with the encouragement of the local and federal governments, a successful program can and should be initiated.

Concluding Remarks

The Earth Summit strongly recommended that coastal nations begin to adopt more integrated approaches to the management of their coastal zones and the important resources that they contain. Developing nations especially should seriously consider the development and implementation of an ICZM program as an efficient way to move toward sustainable use and development of their valuable coastal resource base. A growing number of intergovernmental organizations and donor agencies appear to be ready to assist developing nations in mounting effective ICZM programs.

Participation of Local Authorities and Communities in Integrated Coastal Zone Management

There has been a global proliferation of Integrated Coastal Zone Management (ICZM) initiatives during the past twenty years. Many of these efforts are directed at the national or sub-national level and focus on the development of comprehensive legislation, national policy making and institutional reform. While these are essential components of integrated coastal planning and management, much of the work of ICZM takes place in coastal ecosystems, large and small, through broad working partnership arrangements. These partnerships are formed among national and provincial/state levels of government, the private sector, academic and research institutions" non-government organizations, local authorities and community groups. It is at the local level that national policy directions are translated into action and the essential working relationships in ICZM are put into practice through public involvement.

Yet involvement of the public must be approached in a thoughtful and meaningful manner. Government initiatives often involve the public only as recipients of information after the fact, or consultation about decisions that have already been taken. If ICZM initiatives are to be successful, they must be based on a joint planning and management arrangement, that involves local interests at all stages of the ICZM process - from conceptual development through implementation and program evaluation.

Implementation of ICZM programs must occur on at least three levels. These levels include: the development of national policy, legislation and standards; creation and implementation of state/provincial policies and plans; and the development of local and/or special area management

plans that have local focus and ownership and in which all stakeholders are actively involved. Ideally, there would be simultaneous development of these components at all levels in coastal nations. In practice, where national commitment to ICZM is perhaps still tentative, it may be advisable to first demonstrate that this integrated planning and management process can work through a small-scale application at the local level. Once the benefits of this approach can be demonstrated, the groundwork will have been prepared to push for the development of more integrated institutions and scaling up of programs at the provincial/state and national levels. A plan based on such an approach that has broad support is more likely to succeed and be sustained.

Introduction

ICZM has been recognized by nations and the international assistance agencies as an important tool for achieving sustainable development in coastal states and is considered to be the most appropriate process to address current and long-term coastal management issues. These issues include habitat loss, degradation of water quality, changes in hydrological cycles, depletion of coastal resources, and adaptation to sea-level rise and other impacts of global climate change (World Coast 2000, 1994).

The definition of ICZM most commonly used is: "a dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, social, cultural and institutional resources to achieve the conservation and sustainable multiple use of the coastal zone" (CAMP Network, 1989). Its purpose is to maximize the benefits provided by the coastal zone and to minimize the conflicts and harmful effects of activities upon each other, with the objective of balancing and optimizing environmental protection, public use and economic development.

Much of the emphasis in ICZM is focused on what we might call the "top end" of the management process, i.e., the efforts of governments to develop comprehensive legislation and national policy for the coastal zone and the design and implementation of institutional reforms. These are essential tasks as coastal areas in most countries are a morass of intersecting and overlapping jurisdictions, policies, interests and uses. Planning and management regimes in these critical coastal areas are traditionally sector-based (e.g. specific policies and programs for fisheries, transportation, ports, environmental protection, economic development, etc.), uncoordinated and lacking a common focus. The general populace has only been involved to the extent that it was seen as the beneficiary of the increased flow of resources. Concerted efforts to integrate these varied interests are required in any coastal management process.

Yet consideration must be given from the very beginning of the planning effort as to how these integrated policies and institutions will be put into practice on the ground. The basic principles of ICZM require a systems approach, i.e., planning and managing coastal ecosystems. Any coastal nation, large or small, will have a diversity of physical, biological and human characteristics within its coastal areas. Similarly, critical issues and priorities, as well as local needs, traditions of cooperation and management, will vary from one coastal ecosystem to another. Although national or regional policy and institutions will be required to provide a consistent framework and approach to their overall management, the actual planning and management regimes that are necessary to address small-scale ecosystem needs must be tailored to meet local conditions and realities. The considerations necessary to address local involvement are discussed in the following sections.

The Public Involvement Continuum

Since the 1960s there has been a marked shift towards the direct involvement of the general public in resource and environmental management. This involvement ranges from attempts to influence policy formulation at the highest political levels to taking responsibility for specific management activities at the local level. The involvement can be indirect, such as public hearings, or direct, such as beach clean-ups run by environmental advocacy groups. There is an increasing number of cooperative working relationships developing between government agencies and the public due, in part, to a growing desire and capacity of coastal stakeholders for a more participatory form of democracy and a maturing attitude by governments toward sharing responsibility for planning and management. A cynical view would attribute more weight to the recent financial difficulties faced by most governments as having caused resource management departments to enlist the assistance of the general public sooner than they might have otherwise been motivated to do so. Either way, the involvement of the public more directly in decision making is an active and evolving process.

The term 'public involvement' is, however, subject to varying interpretation. It is important to recognize the distinction between the terms commonly used and to realize that there is a continuum of involvement of the public in a meaningful way (Donaldson, 1994) (Fig. 1).

At one end of the continuum is the provision of public information, or education efforts by government agencies. This point on the continuum generally deals with decisions that have already been made and the public is merely being made aware of them after the fact. There is normally no request for comment from the public. The next step of enlightenment on this continuum involves requesting comments from the public on decisions that have already been made. This too, is merely seeking affirmation for something already decided. There is no onus on the proponent of a project or government agency to take public comment into account.

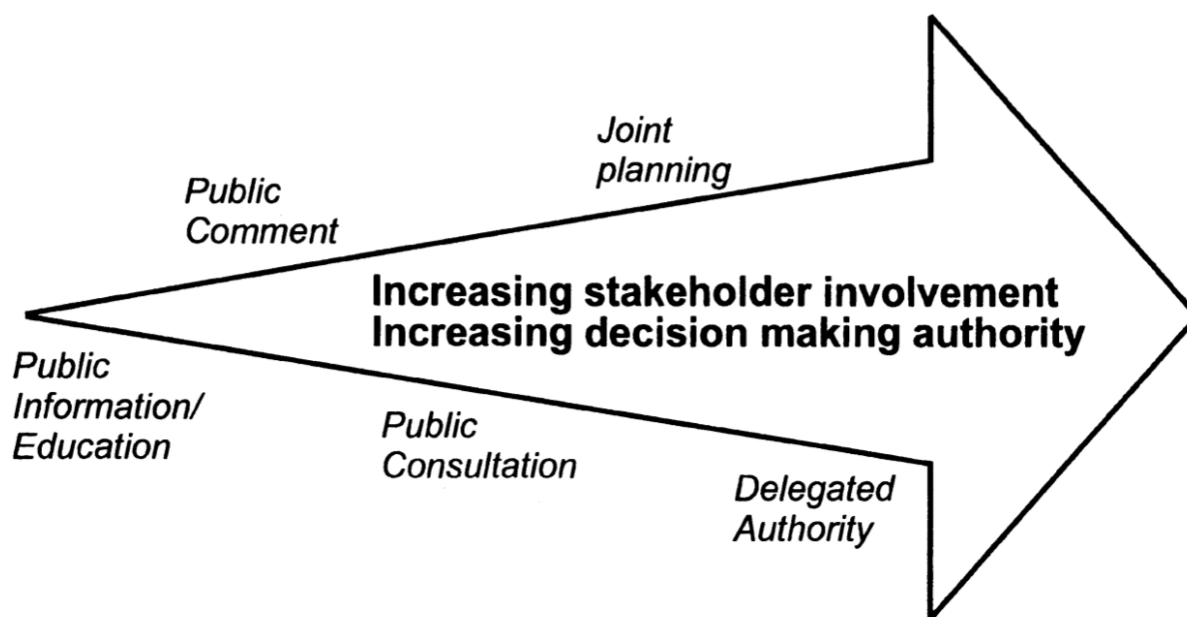


Fig. 1. The Continuum of Public Involvement in the ICZM Process

Public consultation is probably the level of public involvement that most are familiar with. A proponent of a project, plan or policy will seek input from the public through information meetings and formal public hearings. While an improvement on the above approaches, this type of consultation is by its nature confrontational. The proponent and supporters are in one camp, and the objectors in another. It is a reactive process in the sense that the public is asked to react to a proposal, often in such a manner that only criticism is possible. The public is not given the time to thoroughly discuss the proposal at any stage, nor given time to consider alternatives - all of this having been done by 'experts' prior to the consultation. A step beyond this type of consultation is the use of public advisory committees (the key word being advisory), but these too are not truly meaningful partnerships, or co-management arrangements.

In none of the above approaches does the public share in the responsibility or ownership of the proposed initiative since the need was not established by them, and the ongoing implementation may be totally out of their hands. There is, therefore, little incentive for the public to work for creative, alternative solutions - only to act as a critic. Typical public consultation processes often lead to adversarial situations resulting in lengthy approval timelines and little buy-in from the public.

The desired point on the public involvement continuum is Joint Planning. Commonly referred to as multi-stakeholder processes, these are by nature inclusive and recognize the rights of all interested and affected parties to be at the decision-making table with government. The process begins at the needs identification and conceptual stage of the effort, and provides a non-confrontational setting where all participants are at the same table, whether they agree initially or not. Joint planning allows for a full exchange of information which in turn assists informed decision making. The resulting decision reflects a wide range of interests and ideas, and results in a better understanding of the constraints and opportunities facing each stakeholder. The group becomes the proponent and champion of the project leading to greater ownership and responsibility. Successful implementation is therefore more likely. A further step, not advocated at this point largely because most governments likely are not ready to entertain it, is delegated authority. This means giving decision-making authority, and the ability to carry out those decisions, to a non-elected body. Joint planning should be the target for most ICZM efforts at this point.

There are many benefits to the joint planning (multistakeholder) process. It enhances the credibility and legitimacy of the effort through an open and accessible process; it minimizes adversarial situations; promotes consensus and conflict avoidance; is an educational process leading to informed decision making; and it develops beneficial and long-term relationships amongst all the stakeholders. These are key requirements in the ICZM process.

International Context

There have been a number of recent international events that have recognized and endorsed the central role of local authorities and communities in the ICZM process. Relevant documents include: The "Rio Declaration" and 'Agenda 21' (specifically Chapters 17, 18 & 28) of the UN Conference on Environment and Development (UNCED) held in Rio in 1992, the 1993 Lisbon Declaration on Implementation by Local Authorities of the Marine Chapter of Agenda 21, the 1992 OECD Council Recommendation on ICZM (OECD, 1992), the Report of the World Coast Conference in the

Netherlands in 1993 (IPCC, 1993), the Noordwijk Guidelines tabled by the World Bank (World Bank, 1993), the IOC Second International Conference on Oceanography in Lisbon in November, 1994 (IOC, 1994) and the Coastal Zone Canada Conference in Halifax in September, 1994 (Canada Coastal Zone Association, 1996). A selection of key statements from these important international events that support the active and meaningful involvement of local authorities and communities are highlighted below.

The 1992 Rio Conference stands as the most prominent event in terms of the advancement of guidance for planning and management of coastal and marine areas worldwide. The Conference produced a comprehensive action plan in Agenda 21 and the Rio Declaration on Environment and Development. The latter places particular emphasis on the role of local level authorities and communities in integrated coastal planning and management. This is highlighted in Principles 10 and 22:

"Environmental issues are best handled with the participation of all concerned citizens at the relevant level ... [and that] each individual shall have ... the opportunity to participate in decision-making processes"; and "Indigenous people and their communities, have a vital role in environmental management and development because of their knowledge and traditional practices. States should recognize and duly support their identity, culture and interests and enable their effective participation in the achievement of sustainable development."

Agenda 21 makes particular reference to the role of communities in ICZM in a number of sections, especially in its Chapters 17, 18 and 28. Relevant statements call for, inter alia:

"Providing access, as far as possible, for concerned individuals, groups and organizations to relevant information and opportunities for consultation and participation in planning and decision-making at appropriate levels"; "Ensuring capacity-building at the local level"; "Consulting on coastal and marine issues with local administrations, the business community, the academic sector, resource user groups and the general public"; and "Supporting pilot demonstration programs and projects in integrated coastal and marine management".

Chapter 18 in particular, is founded on the principle of subsidiarity- the delegation of management authority to the lowest appropriate level. This chapter calls upon governments to give 'full recognition to the role of local authorities'.

The OECD Council Recommendation on ICZM also recognizes the importance of local authorities and provides guidance for their involvement. It calls for, inter alia:

"Public education and participation in decision-making at an early stage of policy formulation and project assessment, and adoption of wider public participation procedures".

In May 1993 representatives of local authorities attending the Conference organized by the Advisory Committee on Protection of the Sea (ACOPS) and the Camara Municipal de Lisboa, developed and adopted the 'Lisbon Declaration on Implementation by Local Authorities of the

Marine Chapter of UNCED's Agenda 21'. The Lisbon Declaration recognizes a number of important principles inter alia:

"The vital role of local authorities must be recognized in developing and implementing such a strategy, since control of many of the sources of land-based marine pollution falls within their jurisdiction and competencies";

"The need to take cognizance of the principle of subsidiarity, which requires that actions best taken at national or local level, should be taken at that level".

The conference participants therefore recommended that Local Authorities should, inter alia:

"Seek to implement ICZM procedures and arrangements, pressing central government, where necessary to facilitate such implementation"; "Endeavor to ensure that their national Governments delegate to them, as appropriate, the legislative powers and financial resources necessary for them to take appropriate measures at the local level to combat the entry into the marine environment of pollutants deriving from land-based sources";

"Ensure that the necessary legislation is adopted at local levels to control or prevent, reduce or eliminate all sources of marine pollution that degrade the marine environment, especially coastal waters";

"Take into account the role that non-governmental organizations can play in enforcement, by seeking to ensure that they are appropriately involved at relevant stages of the legislative and enforcement procedures";

"Have regard to the need for maximum transparency in decision-taking, bearing in mind the importance of this for the enhancement both of public awareness and public involvement in the decision-making process".

The Intergovernmental Oceanographic Commission's Second International Conference on Oceanography in Lisbon in November, 1994 developed a 'shared vision' in which the oceans are used in a sustainable manner. The scientific experts in attendance emphasized the need for:

- 1) Strengthened communication and dialogue between scientists, decision-makers, managers and the public;
- 2) Cooperation at global, regional and local levels;
- 3) Using local knowledge; and
- 4) Better links between the marine sciences and society to enhance community involvement and awareness.

Another significant international event took place in September, 1994 in Halifax, Canada. Coastal Zone Canada '94 was organized with the theme of "Cooperation in the Coastal Zone" and explored, in depth, the role of local authorities and communities in ICZM. Over 700 participants from 52 nations, representing the full cross-section of stakeholders in the coastal zone, were in attendance. A Conference Statement and Call for Action highlights in particular, four key themes that stand out as

essential, and perhaps unique, for the continuing development of cooperation in the coastal zone. These include:

- 1) Empowering local communities through community-based management - that resources and activities should be managed in a manner which ensures meaningful stakeholder participation at the community level in decision making;
- 2) Strengthening coastal economies and dealing effectively with poverty - All levels of decision making consider the implications of proposed actions on local economies and take issues to the local level as a key part of the process;
- 3) Recognizing the rights and interests of Indigenous peoples - Establishing effective partnerships that recognize and incorporate Indigenous tenure, traditional ecological knowledge and resource management practices; and
- 4) Integrating traditional knowledge with conventional science - Establishing cooperative mechanisms and partnerships that enable the appropriate integration of science, policy, technology and traditional knowledge.

Captured within these important themes are the principles of: cooperation - the need to expand our understanding of cooperation as a process, and of the structures that make that process work; and empowerment - the need to provide all partners in the coastal zone with the knowledge, skills, information and other resources needed to play their full part in cooperative management processes.

The central role of local authorities and communities in ICZM is clearly recognized in these statements. The challenge now is to translate these international statements of policy into practical applications 'on the ground'. There are, however, a number of obstacles yet to be overcome. In particular, a fundamental shift in the attitudes of senior levels of government is required for them to truly embrace these principles and enter into meaningful partnership arrangements at the local level.

The Role of Local Authorities in ICZM

While UNCED's Agenda 21 provides a firm policy basis and strategic direction for the integrated planning and management of coastal areas, a weakness has been observed in the relationship between international environmental mandates and those who most often will be ultimately charged with their practical implementation - the local authorities of the world (Otto-Zimmermann, 1994). Local authorities play a central role as managers, regulators and investors in both development and environmental protection. Yet Agenda 21 does not fully reflect the importance of local governments in addressing the many issues found therein..

The importance of local authorities as partners in protection of the marine environment is demonstrated by the fact that, whenever national governments have established regional marine resources management programs, the final planning responsibility has ultimately been delegated to local authorities. These local authorities are the primary force in organizing and managing coastal settlements, and most of the significant coastal pollutants that find their way into the marine environment via sewerage and drainage systems are managed by municipal governments.

It must be recognized that local authorities have been instituting the next generation of control measures that affect the coastal zone. To take the example of land-based water pollution control, these measures include, inter alia:

- 1) Instituting freshwater conservation programs in order to reduce the volume of wastewater that is generated by a community;
- 2) Reducing the contamination of sewage and sewage sludge through regulatory and voluntary methods;
- 3) Engaging all sectors in remediation action planning;
- 4) Using land-use planning and development planning to link up locations in coastal areas for industries that produce hazardous waste with wastewater treatment infrastructure and to declare fragile landscapes along the coast to be natural reserves; and
- 5) Pressuring national governments to establish marine management and protection zones.

To ensure the effective involvement of local authorities and communities in the ICZM process, a number of principles must be recognized. First, the principle of subsidiarity should be followed. This is similar to empowerment and implies providing all partners in the coastal zone with the knowledge, skills, information and other resources needed to play their full part in cooperative management processes. It also implies that functions be decentralized, and responsibilities be followed with the provision of financial resources. Of importance at the international level, would be continued efforts to reform international donor and financing institutions to invest their resources to support joint local authority and community action.

Community-Based Coastal Management

One example of the community-based approach to coastal management can be seen in Canada's Atlantic Coastal Action Program (ACAP). In this program, coalitions of local stakeholders in 13 coastal ecosystems in Atlantic Canada, have taken the lead for the planning and management activities in their areas. The program is facilitated by the federal government (Environment Canada) but led and owned at the local level. All those affecting and/or affected by local decisions are involved in this process. The role of government in ACAP is reversed from the normal process - instead of the government departments being the lead agencies that sets policy and priorities, the communities assume this function and the government agencies respond to their identified needs.

ACAP is a prime example of the principle of 'subsidiarity' which involves the delegation of management responsibilities to the level of governance closest to the issues at hand. Referring back to our continuum of public involvement, this would bring us one, or perhaps two steps further along this path and into the realm of what are referred to as 'delegated authority' and 'self determination' (Donaldson, 1994).

Delegated authority means giving decision-making authority, and the ability to carry out those decisions, to a non-elected body. This approach requires true and lasting partnerships between all sectors of society based on trust, cooperation and responsibility. Self determination is a notion of how communities can become self-sufficient, more responsible for their activities, and more caring

for the ecosystem free from political interference. This can be seen through recent efforts in Canada and other nations toward Aboriginal self-government.

In Canada, and many other coastal nations, this joint management, or delegated authority approach, is seen as the wave of the future, as government resources continue to shrink and agencies cannot afford to 'go it alone'. It also reflects the growing desire and confidence of local interests to take a lead role and responsibility for their own futures. A much stronger and, given experience to date with ACAP at least, more effective partnership arrangement has been established and is demonstrating the strength and effectiveness of a lead role in ICZM for local authorities and communities.

Conclusions

As integrated planning and management regimes are proliferating in coastal nations around the world, there is a growing recognition of the need for and benefits of encouraging and supporting local applications of this practice. Such local applications are developing with the full involvement of, and often leadership by, local authorities and coastal communities. Truly integrated coastal planning and management approaches must involve partnerships among all stakeholders, from national levels of government to local authorities and coastal communities.

This partnership approach must, however, be a meaningful one with local interests. It involves going beyond the traditional consultation approaches. A joint planning and management approach is called for. Further, the principle of 'subsidiarity' or 'empowerment' - which implies the delegation of management authority to the level of governance closest to the issues at hand - must be considered seriously. The central role that local authorities play in managing coastal activities and the concept of the coastal community as a constituency are gaining increased recognition. The continuing evolution toward delegated authority and self determination for local interests in certain instances, is clearly underway.

This active role for local authorities and communities is enshrined in recent international policy statements and calls for national governments and international donor agencies to actively explore and support such arrangements. The challenge now, is to translate this high-level commitment into meaningful support to local institutions in the form of technical, financial and institutional resources.

A sound and diverse ICZM regime in a coastal nation would be comprised of planning and management activity on three levels. This would include national coastal policy, legislation and standards; provincial or state level policies and programs; and numerous small-scale, local management programs that focus on specific areas of the coast and which involve local authorities and individuals with an active and empowered role in planning and management for their section of the coast. This local-level application of ICZM approaches may be an advisable first step in nations where experience with ICZM is limited or non-existent, or where investment in a full-scale national program has not been secured. ICZM programs in such nations can evolve through a 'scaling-up' process.

By following such a course, coastal nations will be well positioned to manage their coastal resources and activities within a soundly developed and broadly supported process that has a high potential for success and sustainability.

MODULE - III

COASTAL ZONE REGULATION IN INDIA

Coastal zone management in India – present status and future needs

Introduction

The Indian coast is about 7500 km long and characterized by varied landforms and ecosystems. In the context of India, the coast is a place where geosphere, ocean, biosphere, and atmosphere interact. Mass and energy are continuously exchanged among these components and thus, such interactions created a unique ecosystem. In view of such exchanges, coastal regions are of remarkable biological productivity and diversity and hence, have become center of human activities. Coastal regions provide fish, shellfish, seaweeds, and host ports for trading and commerce. In addition, many biota are sources of fertilizer, drugs, cosmetics, and household products. Coastal wetlands also store and cycle nutrients, filter pollutants and help to protect the shoreline from erosion and storms. People are attracted to coasts because of their beauty, and thus, provide recreation and facilitate tourism. These products and services support human life and thus, impact the economy of a country and in turn its socio-economic conditions. Hence, we need to ensure robust health of coastal ecosystems through sustainable management, so that they continue to provide various goods and services for future generations, as well.

The information requirement for managing the coastal zone comprises up-to-date and comprehensive data on coastal habitats, ecosystems, landforms, shoreline conditions, water quality, living resources as well as impacts of natural hazards and anthropogenic activities on coastal environment. Remote sensing has greatly enhanced our knowledge on spatial pattern, extent, physical structure, and conditions of coastal habitats and on rates of changes in coastal landscape. Satellite remote sensing data for high spatial resolution (CARTOSAT, IRS LISS IV, and IKONOS), temporal resolution (OCEANSAT, OCEAN COLOUR MONITOR (OCM), MODIS, and SEAWiFS), multispectral (IRS LISS II, III, SPOT, LANDSAT MSS, and TM) and hyper-spectral (HYPERION) have been utilized to derive physical, geological, and ecological parameters. It is very important to understand the characteristics of each satellite data sets and spectral behavior of the targets, so that accurate information can be derived.

Coastal landforms and shoreline are the results of geomorphic processes such as erosion, sediment transport and deposition as well as sea level changes. Satellite data provided an excellent record of landforms and changes due to their repetitive nature. Such data also help us to understand changes occurring due to natural and anthropogenic activities. Coastal vulnerability maps showing likely areas to be inundated have been prepared for the entire coastline using both satellite and ground-based data. Coastal quality is an important parameter and monitored at 24 locations along the Indian coast.

Coastal ecosystems, such as mangroves and coral reefs, have been classified based on community- and geomorphology, respectively. The long length of records of satellite data allowed to effectively monitor such ecosystems and the changes were detected and mapped. However, such information on changes may not be sufficient to interpret as a climate signal.

The information on marine species is collected to understand ecosystem structure and function. In order to facilitate fishermen searching for fishing grounds efficiently, an advisory service for locating potential fishing zones has been provided.

The timely and accurate information provided by remote sensing and along with developments of GIS and GPS systems, has paved a way to develop an effective strategy for the selection of brackish water aquaculture sites, regulation zones, warning systems for hazards and ultimately sustainable management practices. In India, the application of remote sensing for the coastal environment has matured during the last 40 years, and been effectively used to manage the coast. A review of the same is presented in this part.

Coastal and marine habitats and biodiversity

The baseline information on coastal and marine habitats is vital. The first inventory of coastal habitats in India, with emphasis on coral reefs and mangroves, was carried out using IRS LISS II and LANDSAT TM data (1989–1991) at 1:250,000 and 1:50,000 scales. These maps show high tide line and low tide line (HTL and LTL) and landform/wet land features such as mudflats, beach, mangroves, coral reefs (as shown in Figure 1). Coastal land use maps showing HTL and LTL and land use features were also prepared at a scale of 1:25,000. The details of methodologies have been given by Nayak (1994a, 2009). The distinctive patterns of ecological and morphological zones of these two ecosystems were identified using IRS LISS III and Panchromatic (PAN) merged data. All the thematic maps related to coastal land use, wetland, mangroves, coral reefs, and shoreline changes have been organized in a GIS and Query Shell has been developed to create a data- base and generate output maps All these maps and outputs can be downloaded from www.vedas.sac.gov.in. The classification accuracy of these maps was 85% at 90% confidence level. In many regions, mangroves and coral reefs have degraded and as well as reclamation of lagoons and mudflats have been observed.

Coral reef, a keystone ecosystem of tropical region, is a highly productive area and exhibits distinctive ecological and geomorphological patterns. Such zones were mapped for all coral reef areas of the country. It was possible to identify types of reefs, characteristics of reef flats, lagoon, etc.. Submerged coral reef features were identified using OCEANSAT OCM and RESOURCESAT LISS III data. The extent of live corals was delineated only in a few cases. This is the limitation of these datasets. Hyperion hyper-spectral data in VNIR region are able to distinguish morphological features such as healthy (live) and degraded corals, reef flat, algal cover, algal ridges, sea grass, lagoon, knolls, and sandy areas. An approach, Coupled Ocean Atmosphere Radiative Transfer (COART) to correct for atmospheric and oceanic effects has been developed and applied to correct Hyperion data . Fusion of high spatial resolution images from IRS LISS IV, IKONOS, QUICK BIRD, etc. can further improve classification of coral reefs.

It was observed that coral reefs are generally in good condition, except those in the Gulf of Kachchh, Western India. This unique system is facing both natural and anthropogenic stress. The high suspended sediment load in the Gulf of Kachchh and anthropogenic activities have adversely affected coral reefs. The tsunami of 2004 destroyed almost 400 km² of coral reef areas and 130 km² of reef were covered with backwash in the Andaman and Nicobar Islands. However, it was observed that coral reefs have been recovering slowly and showing its resilience capacity.

Mesoscale processes such as cyclonic eddy can affect coral reefs. It is inferred based on model outputs that cyclonic eddy observed in South- west (SW) of Sumatra, though it generally enhances primary productivity, it can significantly damage corals through asphyxiation caused by massive phytoplankton blooms.

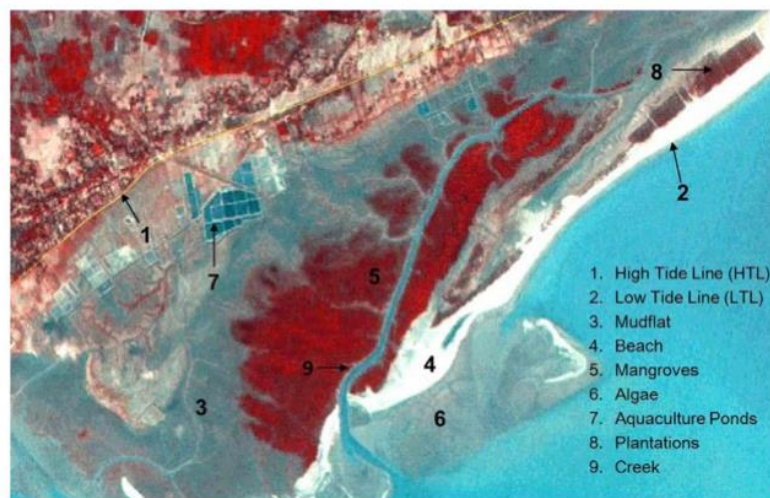


Figure 1. Various coastal landforms in East Coast of India (IRS LISS III and PAN merged Image of the Subarnrekha Estuary).

Incidences of coral bleaching have increased during the last two decades, especially in 1998 and 2010, due to warming of the sea. Coral reefs are made of many species of corals, each of which has a symbiotic relation- ship with algae living in their tissues. These algae supply vital nutrition to the host but are sensitive to environ- mental changes including increase in seawater temperature. However, we know that in the Persian Gulf, corals withstand high temperature, probably because of high thermal tolerance by algae. In view of increased warming of sea, corals may be quite different in the future. The associated loss of algae is known as coral bleaching. Hence, monitoring the health of order coral reefs is very vital. NOAA AVHRR Sea Surface Temperature (SST) data were used to identify cumulative temperature anomalies and thermal stress over coral reef regions. These two products were used to identify probable areas of bleaching (Mohanty et al. 2013). It was observed that soft corals such as *Acropora* are affected significantly, unlike hard corals such as *Porites*. Using this concept, Coral Bleaching Alert System (CBAS) has been introduced and regular bulletins are issued for coral reef areas (www.incois.gov.in).

The estimate for mangroves based on satellite data was 4460 km². The identification of dominant communities, viz. *Avicenna*, *Rhizophora*, *Ceriops*, *Heritiera*, *Excoecaria*, *Sonneratia*, *Xylocarpus*, etc. was accomplished using a combination of red, infrared, and middle-infrared bands of IRS 1C LISS III data. The community-wise classification of mangroves for the entire Indian coast was carried out. The mangrove area along the Indian coast has increased to 4956 km² (SAC 2011). The increase in mangrove extent was observed on the coasts of Maharashtra, Goa, Tamil Nadu, Orissa, and West Bengal, essentially due to conservation measures. The major decrease in mangroves was noticed on the Gujarat coast. In most cases the degradation in mangrove habitat was due to their conversion for agriculture, aquaculture or industrial use. Significant decrease in mangrove areas

(150 km²), on the Andaman and Nicobar Islands was due to the damage caused by the tsunami in 2004. Cyclones do damage mangroves and such damage is visible in NDVI images generated from OCEANSAT-1 OCM and IRS WIFs. It can also be observed in subsequent NDVI images that mangroves are very resilient and they recover within six months. A model for assessing the health of mangroves has been developed based on canopy cover, floral diversity, fragmentation and hydrological parameters and applied in the selected areas to assess the health of mangroves (SAC 2011). This model is yet to be applied for the coastline of the entire country.

The extent and condition of coral reefs and mangroves, mapped by using satellite data, is useful as an input to identify boundaries of the protected areas and biosphere reserves as well as to monitor them to detect changes, if any. About 128 marine protected areas have been identified, and monitored using IRS LISS III and IV data. It is demonstrated that the degradation of mangroves and coral reefs can be halted and the recovery of these ecosystems can take place by suitable conservation measures as observed in marine protected areas in the Gulf of Kachchh. The sustained conservation measures in the Gulf of Kachchh led to substantial increase in both density and extent of mangroves despite increased industrial activities (SAC 2011). However, degradation of these two key ecosystems was observed in many other protected areas.

The degradation of coastal habitats also results in loss of biodiversity. The information on biodiversity is very crucial, and is likely to be affected by anthropogenic activity and impact of global warming of sea. The impact of the loss of marine biodiversity on other processes needs to be understood. The detailed records of marine life and changes need to be meticulously recorded. The Indian Ocean Biogeographic Information System (IndOBIS) and Census of Marine Life programs have been launched to pool all the information, which made it available through a portal and internationally accepted data protocol. At present, IndOBIS has records of over 122,000 species, including new records of several species (www.indobis.org), for the Indian Ocean. The focus is on the understanding of the structure, function and vulnerability of ecosystems. We need to ensure a healthy ocean environment for the sustained benefit of our successive generations. Similar information systems for coastal areas need to be developed.

Brackish water aquaculture is one of major activities along most coastal regions of India. The selection of suitable sites is an important step towards efficient management and reducing environmental impacts. The coastal habitat data created for the entire coast were utilized to select the probable areas. Coastal habitat, drainage, transportation network, salinity, pH and other parameters were used to develop a criteria-based GIS model to prioritize sites.

Coastal processes and natural hazards

Geomorphic processes of erosion, sediment transport, deposition and sea level changes continuously modify the shoreline. The understanding of coastal processes is vital to plan effective coastal protection measures. It is also vulnerable to various natural hazards such as cyclones, storms, tsunamis which impact the coast. Multi-date high-resolution satellite data were used to detect long-term changes in shoreline and landforms. The information on shoreline changes along with near-shore water flow provide important insight into causes of shoreline changes. The shoreline-change maps using topographical maps (1966–1968) and satellite data of 1985–1989, 1990–1992, and 2004–2006 were prepared. The areas under erosion, deposition and relatively

stable areas were mapped (as shown in Figure 2). The construction of breakwaters and jetties for ports have increased erosion, generally in the direction of the long-shore currents as witnessed on the east coast of India. Similarly, the construction of dams on rivers also introduces erosion, immediately after commissioning of dams. It is observed that the coast stabilizes after few years. The role of sea level changes, neotectonics, and sediment transport was evaluated because they are shaping the present landforms in the Gulf of Khambhat, Western India. Shoreline change and land-form maps for the coastline of the entire country are now available (www.vedas.sac.gov.in).

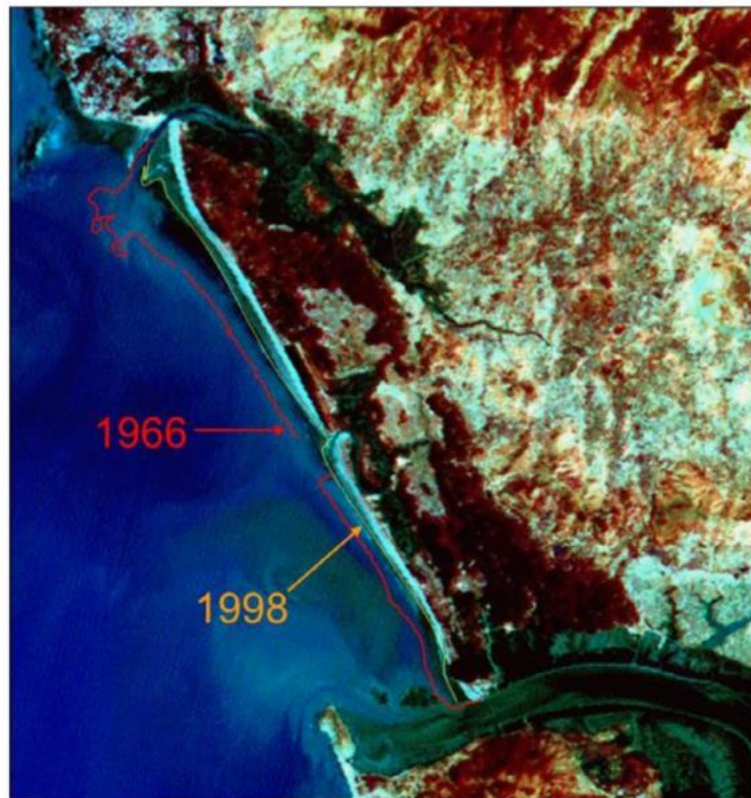


Figure 2. Erosion between 1966 and 1998 in IRS LISS III Image of the West Coast of India.

Geomorphic processes of erosion, sediment transport and deposition in the vicinity of river mouths on the West coast of India were studied by using satellite data as well as ground observations and sediment analysis. The sedimentation in the river mouth essentially takes place during pre-monsoon period (April–May), while beaches grow during post-monsoon (October– December) period. On the same coast, OCEANSAT-1 OCM data showed the northward and southward movement of suspended sediments along the coast during monsoon (June–September) and post-monsoon (October–December) period. The net suspended sediment movement towards estuarine mouths resulted in the formation of mudflats. In the same region, the presence of all types of spits, viz. paired, single and wing like, suggested that the role of sea level changes and tectonics along with long-shore currents in their formation. The presence of submerged bars is also very critical in formation of spits. The divergent spits are formed due to reversal in a long-shore drift and wave divergence which favor the movement of sediment in opposite directions.

An artificial mouth was created on the Chilika lagoon in 2000. Remote sensing data were effectively used to assess the impacts of such an artificial mouth on the Chilika lagoon in the East of India. The original 80 m-wide mouth was widened to 680 m over a period of time and erosion of the coast occurred. However, there was an improvement in tidal flux and mixing resulted in increased salinity levels and reduced weeds. This ultimately improved brackish water fishery in the lagoonal area. The repetitive satellite data proved to be quite useful in monitoring the impacts of engineering structures.

The coastal regions are regularly affected by cyclones and storm surges and occasionally by tsunamis. We must live with such hazards, and prepare ourselves to respond to hazards to save lives. It is essential to identify vulnerable areas, so that associated risks can be recognized and necessary mitigation measures can be taken up.

Coastal topography is one of the critical factors in defining vulnerability because its characteristics significantly affects the inundation due to storm surge or tsunami. The accurate information on topography improves the estimation of inundation. The evaluation of elevation data derived from CARTOSAT and Airborne Laser Terrain Mapper (ALTM) was carried out. It was observed that the elevation accuracies of CARTOSAT and ALTM are ± 2 m and ± 0.6 m, respectively. This inaccuracy affects the extent of inundation up to a certain extent. Considering the cost and time required for acquiring and analyzing ALTM data, its use may be restricted to urban areas. CARTOSAT data are quite suitable to be used in coastal regions.

Coastal vulnerability maps (cyclone, tsunami, and sea level rise) for the entire Indian coast, based on projected long-term rise in sea level, and climatological data on tidal range and wave height, coastal elevation and slope, long-term shoreline changes (rate of erosion and accretion) along with geomorphological setting have been produced. The vulnerability has been defined in terms of an index indicating likelihood of physical changes that may occur and the natural ability of coastal system to change environmental conditions. Such maps can provide base level information for coastal management. Vulnerability maps of the entire country have been prepared (www.incois.gov.in). In another project, a slightly different approach was used to prepare the multi-hazard and risk maps for part of the tsunami- affected area on the East coast of India.

Rising sea levels are already eroding shorelines, slowly drowning low-lying areas, and changing shoreline configuration of the coast. These changes in sea level coupled with high tides and waves and storm surges can cause excessive episodic flooding. Such flooding affects the ecosystems, settlements, and port operations, and ultimately the livelihood of coastal communities as well as leads to migration of local people to other areas. Human modification of the shoreline has altered currents and sediment delivery, resulting in the advancement of the coast in some areas and eroding beaches in others regions. We know that the evolution of coast depends on regional tectonics, sea level rise, vegetation, and wave activity. One view is that the slow rise in the sea level will advance the coasts while rapid rise will erode them. Recently, a distinct reversal of the Northern Indian Ocean (North of 5°S) sea-level decadal trend between 1993 and 2013 by using satellite and in situ observations, ocean analysis products and model simulations was reported. We need to model the impact of such changes in sea-level rise on coasts and islands. We should make people aware of the

changing environment and take adaptive and mitigation measures. Healthy mangrove and coral reef ecosystems can significantly mitigate the impact of sea-level rise on coastal areas.

Cyclones over the oceans trigger strong biological response and induce phytoplankton blooms. In the Bay of Bengal, cyclones are very frequent and cause lots of damage to infrastructure and life. The super cyclone which occurred during October 1999 in the Bay of Bengal, induced mesoscale phytoplankton bloom as evidenced from satellite data and persisted for over a month. It was observed that productivity increases substantially along the track of a cyclone. Such blooms were observed during subsequent cyclones as well. However, the magnitude of productivity varies during such events. Since phytoplankton plays a very significant role in the global carbon cycle, it is necessary to compute the uptake of carbon dioxide during such blooms.

A tsunami is a system of ocean waves formed as a result of large scale disturbances of the ocean floor. A state-of-the-art tsunami warning system has been designed around GIS and implemented after the devastating tsunami in December 2004. The system is capable of receiving and analyzing seismic and sea level, both on coast and deep sea, received from the Indian and global stations, in real time. It provides advisories about travel time, and run-up-height at 1800 coastal forecast points within 10 min to all concerned within India and the Indian Ocean Rim countries through web-based services. The performance of the tsunami warning system is as per design specifications (Kumar et al. 2012a, 2012b). The system has provided very useful advisories during last ten years. It is now recognized as the Regional Tsunami Service Provider for the Indian Ocean.

The prediction of cyclone tracks and landfall, 24 h before the event, has been improved to 140 km and 70 km, respectively. The assimilation of OSCAT data improved the location of the center and track predictions. The information on storm surges and associated inundation is very important for disaster management authorities. A simulation of both these aspects was carried out using the ADCIRC model. The simulated and observed surge heights matched well, but were underestimated. The extent of inundation matched reasonably well but an improved topographic model using CARTOSAT and ALTM data can further enhance the accuracy of delineation of inundation boundaries.

Water quality

Many national and regional monitoring programs exist for monitoring a variety of pollutants. In India, coastal water quality is being monitored for last 25 years at 24 priority sites. Various physical, chemical and microbiological parameters (total 54) for water and sediments are measured seasonally. Increased nutrient inputs to coastal waters due to rise in coastal population and agriculture intensification have been observed at many sites. This led to decreased levels of dissolved oxygen in coastal waters, although they are not at the alarming levels. This data helped to take mitigating action wherever pollution levels crossed threshold values. The data is available on www.incois.gov.in/portal/comaps/home.jsp.

Suspended sediments movement along with shore-line change information helps to understand relationships between sediment input, transport, and deposition. In tide-dominated areas, such as the Gulf of Khambhat and the Hooghly estuary, tides play very critical role in movements of sediments and fronts. OCEANSAT-1 Ocean Colour Monitor (OCM) provides extremely useful information on

decay of fronts, eddies, gyres, plumes, etc. Due to its high temporal resolution (as shown in Figure 3), OCM data were used to compute the advective velocity of surface currents and thus, to understand movement of sediments. Such information is very useful in modeling the path of waste effluents.

The frequency of Harmful Algal Blooms, resulting in mass mortality and morbidity of marine organisms, has increased significantly. In the North Arabian Sea, we have observed the shift from diatom to green dinoflagellates. The increase in extreme rainfall also increases river run-off, polluting coastal waters with more nitrogen and phosphorus, sediments and other contaminants. Increased direct monitoring of water quality parameters, coupled with satellite data, will improve our knowledge of health of coastal and ocean waters.

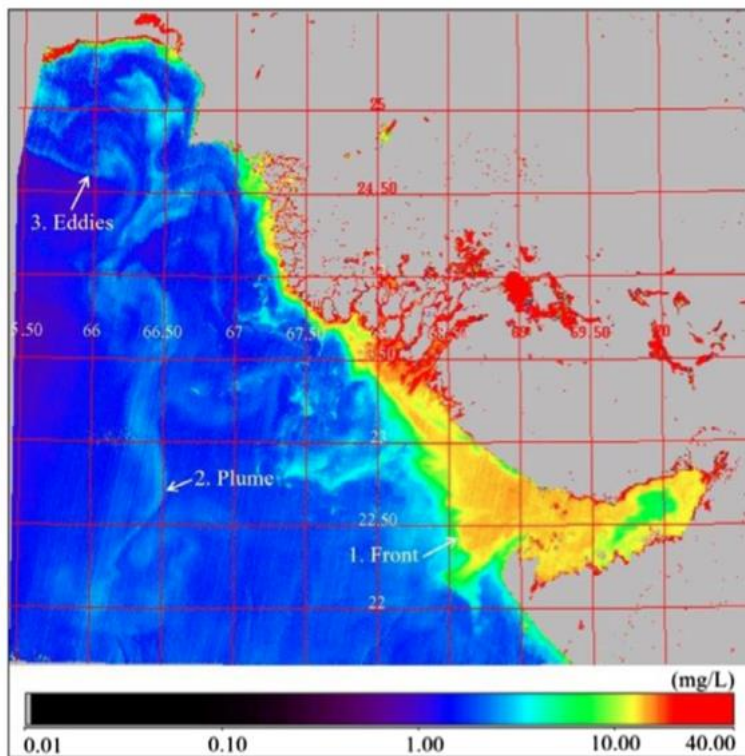


Figure 3. Suspended concentration in Oceansat-1 OCM Image of the North Coast of India.

Living resources

Marine fishery catch in India is about 3.5–4.0 million tonnes. Fishermen used to spend considerable time in locating fish schools and thus, cost-per-unit efforts were high. A satellite-based technique was developed to locate potential fishing grounds using NOAA AVHRR SST. This system was based on the detection of oceanographic features such as upwelling, divergent fronts, eddies, gyres, rings, meanders. Because the temperature variation in tropical waters is only about 3 °C, this technique was not very successful. During late 90s, the availability of satellite-derived chlorophyll information and its integration with SST further improved forecasts. A successful GIS-based fishery forecast system was developed by integrating chlorophyll, SST, surface currents and bathymetry. Daily advisories for more than 350 fishing harbors are being generated and disseminated through electronic boards at fishing harbors, web (www.incois.gov.in), and e-mails. At present, about 93% of fishermen are adopting these advisories, which direct fishermen to the productive areas and hence avoid exploitation of fishery in low to moderately productive areas. This technique helped fishermen to reduce catch-per-unit effort and hence brought economic benefits to fishermen.

Overfishing caused degradation of coastal and marine ecosystems, and destructive trawling techniques led to loss of nursery areas of commercial fishery in some regions. Hence, loss of coastal habitats affected the capacity of producing fish for human consumption. It was also discovered that populations of phytoplankton and copepods are also changing, threatening food supply of fishes as well as many marine mammals that in turn prey on fish. Such a shift can transform the biodiversity and functioning of marine ecosystems. There are many examples where changes in ocean climate contribute to shifts in abundances and seasonal cycles of variety of species. The increased availability of Sardines on the East coast and on the Maharashtra coast while reduced supply on the Kerala coast is an example. Annual stock assessments of fish are necessary to identify Maximum Sustainable Yield (MSY) for various commercially important species. This assessment will help to manage fishery for sustainable yield.

Summary and outlook

Coastal zone management depends on the information available on varied aspects of coastal habitats, coastal processes, natural hazards and their impacts, water quality, and living resources. The effective management practices depend on such knowledge and suitable response by concerned government agencies.

The loss of coastal habitat areas reduces key ecological services. Fish and shell fish stocks may decline and shoreline may be destabilized. The relationship between health of wetlands and fish stocks is generally linear. The ecological services are provided by wetlands, i.e. the wave attenuation service that protects coasts from storms and tsunamis. The relationship between this service and wetland area is non-linear. Such relationships have consequences for management and should be taken into account. Hence, the optimal land use option should include the integration of development and conservation activities and should be consistent with ecosystem-based coastal zone management goals.

The identification of areas suitable for brackish water aquaculture was accomplished based on coastal land- forms and land use derived from satellite images for the coastline of the entire country.

The movement of sediments along the coast, onshore–offshore sediment transport, impact of tides on sediment movement, and impact of engineering structures on sediment movement and areas under erosion and deposition, were studied using high temporal resolution satellite data. Based on this information, the alternative methods to restore beach such as beach nourishing and construction of an artificial reef are being attempted.

In order to preserve coastal ecosystems, the Government of India has declared areas between high and low tide lines (HTL, LTL) and 500 m from HTL as the Coastal Regulation Zone (CRZ) and prohibited or restricted construction and industrial activities. The accurate delineation of HTL and LTL is very critical. They have been delineated based on tonal discontinuity on satellite images. This regulation has undergone too many changes over last 25 years, mainly due to incorrect interpretation of HTL and conflicting laws of state and central governments. In view of this, it was suggested that such anomalies should be removed. CRZ regulation needs to focus on protecting ecologically sensitive areas, while urban and rural areas are governed by existing laws of state and central governments with few conditions. Local communities may be allowed to take up traditional aquaculture, ornamental fisheries, etc. In a separate report, it was also suggested to draw HTL using ALTM and high-resolution satellite data for the coastline of the entire country and use it as a construction setback line to draw boundaries of CRZ. However, these suggestions are yet to be implemented. Despite these limitations, this regulation has helped to conserve most of the protected areas, ensure livelihood security of fishermen, provide resilience to impacts of hazards and promote socio-economic development based on scientific principles.

The effects of anthropogenic activities on ecosystems have not been well-understood. We need to carry out predictive modeling, using existing climatic, coastal, and topographic data combined with ecological information, where historical data is available. We also know that the current climate impact models have been showing very large uncertainty. We need to improve the understanding of likely impact of anthropogenic activities on the coastal environment.

The advisory services for the cyclone and tsunami have been provided to all stakeholders. The response of the government to such events at the local, state and national levels has been exemplary. In the last century, a super cyclone struck the Orissa coast and more than 10,000 people died. During the last 10 years, loss of lives has been minimized because of the availability of accurate and timely information on track, landfall point, velocity of wind, storm surge, etc., the suitable response and actions of the government and the trust of local people in the forecast and government. The tsunami warning center has performed very well and there has been no false warning during the last 10 years. Such systems have definitely helped to reduce risk from these hazards. Though coral reef bleaching alert bulletins have been issued, it is not clear how one can respond to such an event. We need to address the issue of developing a response mechanism.

The sustainable management also depends on the nature of the social system, comprising political economic and industrial infrastructure and its linkages, with the knowledge about coastal systems as well as local communities. We have noted that economic growth and technological advancement during last two centuries have significantly affected our coastal environment and have also become major driver of influencing the earth system. The earth system processes, especially carbon cycle, ocean acidification, sea level changes, loss of biodiversity, and modern agriculture-induced

pollution of reactive nitrogen and phosphorous, have reached a level at which they can cause damage to the entire earth system. We need to model impacts of these processes and design adaptive and mitigation strategies for the sustainable development of the coastal zone. Geospatial information technology can contribute greatly to develop such models.

COASTAL ZONE REGULATIONS IN INDIA

The proposal of the Ministry of Environment and Forests (MoEF) to replace the Coastal Regulation Zone Notification (CRZ), 1991 with a Coastal Management Zone Notification (CMZ) after the review of implementation of CRZ by the Swaminathan Committee has evoked strong opposition from various stakeholders, especially the coastal communities. Fisher folk associations and organisations like the National Fishworkers Forum, Coastal Action Network, Indian Coastal Women Movement, National Union of Fishermen, South India Fishermen Welfare Association, Tamil nadu Fishermen Welfare Association, Tamil Nadu Pondy Fisher People Federation, Democratic Unorganised Workers Trade Union, Fish Marketers Association of Tamil Nadu and Kerala Swatantra Matsya Thozhilali Federation have vehemently opposed the proposal and have made submissions to the MoEF to withdraw the proposal. The Swaminathan Committee report has also been critiqued by civil society organisations working on coastal ecology and with communities. Despite the efforts to persuade the MoEF in not bringing out the CMZ Notification, the MoEF issued a draft in May 2008 proposing to phase out the CRZ Notification and implement the CMZ Notification.

In the context of this move by the MoEF, an analysis of the CRZ Notification, 1991, the Swaminathan Committee recommendations and the draft CMZ Notification has been made in order to substantiate the position to continue and strengthen the current regulation in the form of CRZ rather than substitute it with another. In this regard, a detailed comparison has been made to arrive at recommendations. The argument is further validated by taking the example of tourism as a development phenomenon that has affected the coast; hence the need to have stringent regulatory norms to curb adverse impacts on communities and ecosystems.

Coastal Regulation Zone Notification, 1991

The Indian coastal stretch of about 7,500 km is made up of diverse ecosystems - sand dunes, beaches, wetlands, mangroves, estuaries, backwater lagoons and coral reefs. Settlements of traditional people comprising about 10 million fisherfolk, are concentrated in these areas, as they mainly depend on coastal resources and seas for their survival. Several activities such as unregulated tourism, polluting industries, infrastructure, aquaculture, sand mining, construction of sea walls and rapid urbanization pose serious threats to the health of these ecosystems and to the lives and livelihoods of coastal communities. The tsunami of 2004 has shown that the coast is a naturally vulnerable area and that these activities have worsened the impacts on coastal people.

The Coastal Regulation Zone Notification, issued in 1991 using the provisions of the Environment (Protection) Act, 1986 is the most significant and specialized legislation regulating developmental activities along the coast. It recognized India's need to protect the interests of millions of her coastal people while ensuring their overall development, and protecting coastal ecology.

The CRZ Notification was introduced with three main principles:

- It is necessary to arrive at a balance between development needs and protection of natural resources;
- Certain activities are harmful for both coastal communities and their environment, and these should be prohibited or regulated;
- If coastal ecosystems are sustainably managed, then the livelihoods of millions will be protected and their survival guaranteed.

The CRZ Notification, 1991 covers the strip of coastal land abutting the sea all along India's coast and her islands. It extends 500 metres from the High Tide Line (HTL). In this narrow sensitive region, certain activities are regulated while other inappropriate ones are prohibited. The CRZ notification seeks to operationalise three objectives, which are very significant:

1. Siting or location of activities or operations

This is based on the understanding that coasts perform important functions for coastal communities and ecosystems. The coasts are important nesting and feeding grounds for several terrestrial and aquatic species. These coastal habitats also provide sustenance and livelihood opportunities to several coastal communities (both fishing and non-fishing communities). Rules for the siting of activities can ensure that the rights of traditional fishing and coastal communities over certain areas are not compromised to meet increasing development requirements such as the demands of the burgeoning tourism industry.

2. Restricting and permitting activities

The CRZ Notification defines the nature of activities that are to be regulated or restricted. It does not issue a blanket ban on all activities but lists activities that are restricted and those that are permitted.

3. Balancing development and protection needs

This objective is ingrained in the spirit of the CRZ, which recognises that different areas have different ecological sensitivities and therefore need varying levels or modes of protection. Thus, the protection afforded to CRZ I is designed to be more stringent than that accorded to CRZ II areas, where more activities are permitted.

With respect to Andaman & Nicobar Islands and Lakshadweep, the CRZ would be instrumental in deciding activities and developments because of their special status as oceanic island groups recognized by CRZ as Category IV. Moreover, environmental issues confronting these islands are more complex; it is critically important to address these.

What went wrong with the implementation of the Notification?

The implementation of this critical Notification was by and large ignored by many state governments. Vested interests from various lobbies such as the tourism and industrial lobby have

constantly sought to get rid of this Notification. The CRZ Notification has been amended twenty one times between 1994 and 2005, and each dilution has weakened provisions of the law.

Non-Demarcation of High Tide Line

S.O 1122(E) dated 29th December 1998 only gave the definition of the HTL and stated that it will be marked by an authority. It is surprising that 7 years after the Notification was issued, the central government did not specify which authority and did not provide guidelines for marking the HTL. Further, the High Tide Line (HTL) or the 500m/ 200m line from the HTL has not been demarcated in any coastal states, although attempts to put the 500m / 200m markers were made in states like Goa, Kerala. Thus categorically identifying the CRZ area and therefore identifying a violation has become difficult.

No progress on development of Coastal Zone Management Plans

Not a single coastal state or union territory has a fully approved Coastal Zone Management Plan (CZMP). This document is critical to the implementation of the law as it identifies the various CRZ areas and therefore the range of activities that can be permitted or prohibited. Without this in place, unregulated activities and developments are common on the coast. After the CRZ Notification, 1991 was issued; all the states were instructed to prepare and submit the CZMP within one year, i.e. by February 1992 to the MoEF for final approval. No states or UTs submitted the CZMP and the Supreme Court had to intervene thereby extending the date of submitting the CZMP to June 1996. All the states and UTs submitted their CZMPs in 1996, after which the MoEF reviewed them and wrote back to the states and UTs. The states and UTs were given comments on their respective CZMPs, which they had to incorporate, and in some cases rework maps, and re-submit to the MoEF for final approval. After this, it is not known which states have resubmitted their CZMP for final approvals from the MoEF and whether the MoEF has approved any one of them. Neither did the concerned authorities inform concerned stakeholders on the finalisation of the CZMPs and nor have the stakeholders been able to elicit a response from the concerned authorities on the status of CZMPs. Therefore, it is given to surmise that no coastal state or UT has a functional, approved CZMP.

Implications of amendments made to the CRZ Notification, 1991

Construction for petroleum storage to be allowed in CRZ II & III

S.O 730 (E) dated 4th August 2000 permitted storage of petroleum and its products thereby posing a threat to coastal environment. This also meant allowing construction in these areas including the No Development Zones (NDZ).

Exploration of oil and natural gas allowed

The amendment no. S.O 730 (E) dated 4th August 2000 gave a blanket allowance to oil and natural gas exploration, which could take place in CRZ areas. It could trigger off land acquisition process by government, following which there could be changes in land use. Mining in all CRZ areas has also been permitted by amendment no. S.O 329(E) dated 12th April 2001. While the need for such developmental activities is justified, it is equally important to ensure safeguards for environmental

protection to check adverse impacts arising from such activities, which the CRZ Notification has not specified clearly.

Land reclamation allowed

Amendment no. S.O 329(E) dated 12th April 2001 allowed reclamation of land for 'certain activities', which have not been defined. Reclamation for commercial purposes has been prohibited. Having undefined terms leaves the door open for interpretations wherein activities that adversely impact coastal ecosystems can find a way through.

Setting up of non-polluting industries in field of IT and other service industries in Special Economic Zones

Amendment no. S.O 550(E) dated 21st May 2002 opened up the CRZ areas for resource intensive and negatively impacting activities like IT and other service industries like tourism to come up in CRZ areas on the assumption that these are non- polluting. Further it legitimised the presence of SEZs in the CRZ areas.

Case Study: examples of non-implementation of CZR Notification, 1991 in Andaman and Nicobar Islands

Most of the area in the Union Territory of the Andaman & Nicobar Islands has been classified to come within CRZ-IV. This classification of CRZ- IV is unique to islands of Andaman & Nicobar and Lakshadweep, and it was specifically drafted taking into consideration the Islands' unusual, rare and fragile coastal ecosystems.

Wrongful categorisation of CRZ IV areas as CRZ II areas

In the Andaman & Nicobar Islands, the entire rural, revenue area is classified under CRZ-IV except for a small area, which is under CRZ-II. The coastal stretches of Port Blair, Bambooflat, Hut Bay, Mayabunder, Campbell Bay Headquarters and several other areas were proposed to be declassified as CRZ-II.

The CRZ Notification states that in some of the islands of Andaman & Nicobar Islands coastal areas may be classified as CRZ I, II or III based on the CZMP and on the approval of the MoEF. While the CZMP was submitted by the A&NI Administration for approval to the MoEF, in their letter dated 27th September 1996, the MoEF accorded only interim clearance to the CZMP. Further, one of the conditions laid out in the letter was that, for CRZ IV areas to be classified as CRZ II areas, a Committee had to be formed which would decide on this matter.

However, as noted by the Divisional Bench of the Calcutta High Court in its order dated 29.09.2003, the A&NI Administration and the Port Blair Municipal Council had converted certain CRZ IV areas into CRZ II areas in Port Blair. The Court noted that no documents were made available to prove that a Committee, as directed by the MoEF, was formed to look into the matter of reclassification of the CRZ IV areas into CRZ II areas and that these were made with approval from the MoEF. Despite this, Byelaw No. 15 of the Port Blair Municipal Council Building Byelaws, 1999 classifies coastal areas of Port Blair as CRZ II areas.

The court therefore concluded that decision of the A&NI Administration and the Port Blair Municipal Council to reclassify CRZ IV areas into CRZ II areas was “wholly unauthorised and ultra vires³ the CRZ Notification”.

No firm check on sand mining in the Andaman & Nicobar Islands

- Amendment no S.O.73 (E) dated 31st January 1997 stated that mining was permitted upto 31st March 1998 and not beyond. This means a prohibition exists on the extension of the deadline.
- After this there have been 10 extensions made to allow sand mining in A&N Islands to date.
- The Supreme Court (SC) ordered in May 2002 that extraction of sand shall be phased out at a minimum 20% per year on reducing balance basis to bring the sand mining to the level of 33% of the present level of mining within a maximum period of 5 years. The sand mining is to be brought down to 24,633 cubic metres by May 2007 as per the order.
- As per amendment S.O. 635 (E), 30th May 2003, sand mining was permitted up to 44,102 cu. m. for construction purposes on a case by case basis for the period 1st April, 2003 to 31st March, 2004 from sites selected, inter alia, based on the rate of replenishment or deposition of sand.
- This amendment took place after the submission of Shekhar Singh Committee report to the Supreme Court which stated “The extraction of sand should be phased out and no further extension should be granted after the current extension is over on 30 September, 2002”.

As per guidelines given in the CZMP of A&N Islands, minimum quantity of sand will be collected from identified eco safe pockets on a rotational basis; sands collected from coastal areas will be used after keeping the same in the open place for at least one full rainy season so that salt if any may be leached out; sand will not be collected from areas near mangrove patches, sand would generally not be collected during the monsoon to minimise disturbance to the coastal zone and landscape; coral sand will not be collected; stone dust from stone crushers and quarries will be utilised to reduce the use of sea sand; use of clay bricks will be encouraged, this would reduce the use of hollow blocks which need considerable quantity of sand; sand will not be collected from sanctuaries, national parks or other ecologically sensitive areas close to the breeding and spawning grounds of fish and other marine life. But, the methodology for sand extraction has not been specified beyond what currently exists. There is no information on the parameters, or permissible limits, or monitoring and assessing the final impacts of such an activity. If sand mining is to take place in the islands, considering its sensitivity, it does require further planning for proper implementation and enforcement of restrictions. Currently there is little enforcement and this has resulted in a severe impact on the ecology of these islands.

The Comptroller and Auditor General's report has implicated the MoEF for lack of implementation of CRZ Notification, 1991. It states that despite formation of various committees and the comprehensiveness of their reports to address specific issues, the amendments that MoEF had made to the CRZ Notification reflected a trend to allow commercial and industrial expansion in coastal areas. It states that “The Ministry of Environment and Forests did not enforce the Coastal

Regulation Zone Notification effectively resulting in extensive destruction in coastal areas due to industrial expansion”. That no coastal states have a CZMP has also been taken note of by the CAG.

Tourism and the CRZ Notification, 1991

Beaches have been prime tourist attractions the world over. In India, coastal areas have been targeted for tourism development to cash in on the large number of domestic and foreign tourists willing to make India's beaches their choice of a tourist destination. Coastal destination states like Goa, Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and Andaman Islands have witnessed significant tourist arrivals and consequent development of tourism infrastructure. Close proximity to the sea is most preferred in order to give the tourists the 'sun, sea and sand experience'. Any attempts to regulate tourism development in the coastal areas have either been met with resistance from the tourism industry or the industry has violated the regulations outright.

Reduction in the NDZ for Promotion of Tourism

The first amendment to the CRZ Notification was made because of pressure from the tourism lobby. The amendment was made by the MoEF vide notification no. S.O. 595(E) dated 18th Aug 1994 on recommendations of the Vohra Committee, which was constituted on 1st Jan 1992 and its report submitted on 31st Dec 1992. The issue dealt with was tourism. The reason for constituting the Vohra Committee was that there was a representation made by the hotel and tourism industry to the MoEF stating that the said Notification was very stringent and their operation was severely restricted by the CRZ. The tourism industry argued that fixing the NDZ at 200m from the HTL uniformly was unscientific. The tourism industry said it will be handicapped in competing with beach hotels of other countries, where no such restrictions exist. It further stated that the tourism industry would require only 25 to 30 Km of India's 6,000 odd Km of coastline, and hence relaxing the NDZ from 200m to 50m in the CRZ Notification, 1991 would not harm India's coastal ecosystems.

One of the recommendations of the Vohra Committee was reduction of distance of the NDZ in selected coastal stretches specifically for promoting tourism. The Ministry amended the CRZ Notification, 1991 on 18th Aug 1994, reducing the NDZ area all along tidal water bodies from 100 to 50 m (Swaminathan Committee Report - MoEF, 2005). The Amendment also permitted construction in NDZ thus giving expansive powers to the central government to permit such constructions on the landward side within 200m from the HTL according to its discretion. The SC quashed the amendments later terming the step that MoEF had taken as ultra vires and restored the NDZ from 50m to 100m in 1996.

The NDZ was eventually reduced to 50m only in the case of A&N Islands and Lakshadweep for tourism development through amendment, S.O.838 (E), 24th July 2003. This is against the directives of the SC, which were issued in 2002 based on Shekhar Singh Committee report, for not allowing tourism within 50m from the HTL. The relaxation was based on identification of areas in NDZ by the Integrated Coastal Zone Management Plan study conducted by the MoEF.

Rampant violations of the CRZ Notification by the tourism industry

The tourism industry has continued to violate CRZ norms throughout the nine coastal states and the five union territories, including the two island groups. Given below (in order of east to west; states and union territories) are indicative case studies media reports of violations in a few states, which have been brought to the notice of relevant Authorities as well as observations from the coastal areas where numerous tourism establishments, both old and new, continue to violate provisions of the CRZ Notification, 1991.

West Bengal

West Bengal to act against illegal hotels on the beach

Mandarmani, located about 180 km from Kolkata in East Midnapore district, has seen a spurt in tourism activity. The character of the Mandarmani beach has changed because of the illegal hotel industry that is operating in violation of the CRZ Notification.

Courts have upheld a verdict for a PIL filed by National Fishworkers' Forum and an NGO - DISHA in relation to violation of CRZ rules by the tourism industry. As per the judgement of the District Court, upheld by the Appellate Body and the High Court, the Pollution Control Board has asked for the demolition of more than 10 hotels (some with investment of above 10 crores) in the Midnapore area of West Bengal Coast. The hotels were displacing and taking over the fishing grounds of more than 10,000 fishermen in the region.

It has also been reported⁷ that the West Bengal government has moved in the Calcutta High Court against the unauthorised hotels and resorts that have come up on the sea beach at Mandarmani in violation of CRZ. In February 2007, the West Bengal Pollution Control Board (WBPCB) had issued an order directing them to demolish the hotels stating violation of the CRZ Notification, 1991. After the WBPCB order, the hotel owners moved the high court. Counsel for the hotel owners told the division bench of Chief Justice S.S Nijjar and Justice Pinaki Chandra Ghosh in Calcutta High Court that necessary permission for the hotels was obtained from the local administration (panchayats). The Calcutta High Court directed the state government to file an affidavit within two weeks. However, according to the WBPCB, the local administration along with state environment department officials went there repeatedly to demolish the construction but failed due to resistance from the local people.

The WBPCB would also take action against the local body if they have allowed the hotel industry to build permanent structures on the coast. The National Coastal Zone Management authority has already told the state government to take immediate action against the law violators at Mandarmani. However, the Division Bench of the Kolkata High Court gave an order maintaining status quo on the case in April 2007 and deferred the hearing to June 2007.

Andhra Pradesh

The Fisherman Youth Welfare Association, Visakhapatnam and District Fisherman Welfare Association through a petition brought to the notice of the High Court of Andhra Pradesh a gross violation of CRZ Notification, 1991. The petition accused Visakhapatnam Urban Development

Authority (VUDA) to have encouraged construction of a yacht yard on Rishikonda Beach, Visakhapatnam.

On 6th July 2007, the High Court of Andhra Pradesh on the above writ petitions ordered:

- VUDA and Vishakhapatnam District Collector to demolish all the constructions made in the entire coastal area in violation of CRZ Notification.
- To report back to the Court within two months about the removal of illegal structures near Rishikonda, which had come up in the name of a yacht yard, and to report the total CRZ violations along the coast of Visakhapatnam.
- Asked these authorities to send a report based on the action taken on demolition of the structures and removal of construction materials with photographs in two and half months time.
- Also asked the Principal Secretary, Department of Environment, Forests and Science & Technology to consider the feasibility of organizing workshops at least once a year for officers posted in the coastal districts to make them aware of the law relating to environment and ecology of coastal areas and to encourage them to take measures for protecting the same.

As a fall out of this Court Order, the Revenue department of Visakhapatnam District formed five teams to identify the CRZ violations along the coast of Visakhapatnam rural and urban areas. These teams have identified 300 constructions in violation of CRZ and given notices to the owners of the respective constructions as per the court order. They have also started demolishing the structures on the coast that had come up in the name of the yacht yard. These violations of CRZ also include tourism and recreation related activities that are put up for public use: Tenneti Amusement Park; concrete pavements, steps; a dais on Ramakrishna beach are some examples.

Tamil Nadu

The entire coastal stretch of Tamil Nadu is replete with tourism activity, starting with Pulicat Lake in Thiruvallur district in the north to Kanyakumari in the south. Construction of tourism establishments and related facilities are in close proximity of the coastline with no regard to CRZ norms.

South of Chennai, there are large beach areas that have been acquired by companies like VGP, and Buena Vista (Neelangarai) who have constructed an amusement park over a large area very close to the coast. There are many hotels and resorts along the coast, the prominent ones being The Taj Group's Fisherman's Cove. The Leela Group has acquired seven acres of prime land near the beach front in MRC Nagar for the purpose of starting a 20 storey five star deluxe hotel.

Mamallapuram is a well known tourist destination in Kancheepuram district. The department of tourism has constructed numerous wayside amenities along the East Coast Road (ECR), on the seaward side of the road very close to the coast. These include parks and picnic spots. There are many resorts that have come up close to the coastal areas in this district. Numerous hotels and restaurants have also come up on either side of the ECR and the trend seems to be increasing, making it difficult to keep track of numbers. Many of these constructions would sometimes be

within 200m when the ECR runs very close to the coastline. Some of the areas that have large tracts of coast under tourism are Jambodai where MGM resorts are located.

In Tarangampadi, Nagapattinam district, there is a governor's bungalow opposite to the Dutch fort that has been converted to a hotel by the Neemrana Group named Bungalow on the Beach. This structure is old and is very close to the coast. Extension activities of the hotel, like construction of a dormitory, have also been undertaken here. Velankanni is an important pilgrim tourist destination in the district. The number of tourists to Velankanni have been increasing steadily. The coastal stretch is very narrow and cannot accommodate the tourist inflow. The local authorities therefore decided to broaden this stretch by diverting the Upparu River from the Velankanni beach. Groynes were also laid near the estuaries. Nagapattinam also gets a sizable number of pilgrims to the mausoleum in Nagore. The combined activities of Nagore and Velankanni have prompted the establishment of many tourism related infrastructure in the coastal areas.

The rampant development of the tourism industry in Kanyakumari has left no space along the beach; the immediate stretches of land adjoining the sea towards the southern side have been completely occupied by the hotel industry. Amusement parks and water theme parks are the recent additions to attract domestic tourists. Baywatch is one such theme park which has planned its operation to cover about 4000 visitors a day. Sand dunes were levelled to have an elevated structure over it for a clear view of sunrise and sunset.

CRZ violations continue in Kanyakumari by the tourism industry as in the case where Coastal Regulation Zone norms were flouted by the developer of the beach front park and work was being carried out within 50m of the high tide line. Kanyakumari town panchayat leased out a prime beach front plot, 150m in length and 50m in width, adjacent to Kamarajar Memorial, to a private developer at Rs. 16,000 per annum to set up a recreation park. The developer levelled the red sand hills and erected grills and platforms, tampering with the geomorphology of the beach, a blatant violation of the stipulations of Coastal Regulation Zone. Kanyakumari Collector Jyothi Nirmala has ordered the immediate suspension of the development works at the Kanyakumari beach front, which were approved by the previous District Collector Mr. Devaraj Dev. The Collector also said that a complete reappraisal of the lease agreement between Kanyakumari town panchayat and the private developer would be done. In case if the violation of CRZ notification was found, the agreement would be scrapped.

HC notice on PIL

The Madurai Bench of the Madras High Court on 20th August 2008 issued a notice to the government on a public interest litigation petition filed by a scientist seeking to conserve the 40,000 year old fossilised coral reef in the coast off the famous tourist town of Kanyakumari and suspend all construction activities in the coastal area. Justice Elipe Dharmarao and Justice A Selvam directed the district collector to file his reply in a week's time. The Petitioner R S Lalmohan of Indian National Trust for Art and Cultural Heritage submitted that Kanyakumari town was a national heritage centre and the area came under Coastal Regulation Zone Notification (CRZ-I) and no construction should be taken up within 500 metres of the coast. He contended that the Executive officer of the Kanyakumari Town Panchayat, in the name of beautifying the coastal area, had leased it for three years from last year to one Chandran, who was running a hotel. Though the hotel owner

had been asked to maintain the park in the coastal area without making any permanent construction, he was using heavy machineries, bulldozers and excavators for scooping and dumping sand. They were also building platform adjoining the sea. This had already affected the geomorphology of the coast.

Kerala

5,753 unauthorised structures detected in State

As many as 5,753 unauthorised buildings constructed in violation of the Kerala Municipal Building Rules (KMBR) and the Coastal Regulation Zone (CRZ) norms have been identified by local self-government institutions across the State. As many as 309 cases are of CRZ violations, which have been identified at Kottukal, Vizhinjam (Kovalam beach), Poovar and Kappil panchayats in Trivandrum district, and 113 in Varkala [a much sought after beach tourism destination after Kovalam in Kerala].

Large scale flouting of building rules detected

“Kovalam, the internationally renowned tourism destination in Kerala, is undoubtedly one of the most glaring cases in point, of the damage that unplanned tourism can inflict on the environment. There are more than 150 resorts, shacks and restaurants within a single ward of the Panchayat. Almost all hotels and restaurants are located hardly ten metres from the sea in violation of the CRZ guidelines, indicating unplanned tourism development on the part of the government. The construction of hotels has drastically increased the rate of sea erosion with the sea ingress reaching up to five metres each year. In fact a proof of the blatant disregard for the environmental norms is the fact that hotels and restaurants are discharging their waste into open sewers that run parallel to the beach”.

In 2004, the Vigilance wing of the Local Self- Government Department has detected 1,500 cases of unauthorised constructions in the Vizhinjam panchayat. According to a preliminary report submitted to the Government, the panchayat committee has issued 'stop memo' in 104 cases. But no follow-up action has been taken on specific cases of violation of the Coastal Regulation Zone (CRZ) norms and the Kerala Municipal Building Rules. The report says that a hotel in Kovalam Beach Area -I has altered and reconstructed its old building without valid permit. The hotel functions out of a three-storey building. The panchayat committee had issued a 'stop memo' to the proprietor on September 17, 2003 (year), but no follow-up action was taken to either stop the construction or assess the tax on the basis of the new construction. The structure stands barely three metres from the high tide line, which is in violation of the building rules, CRZ and zoning regulations, the report says.

Karnataka

The Government of Karnataka has declared the entire coastal stretch comprising of three coastal districts of Uttara Kannada, Dakshina Kannada and Udupi as a special tourism zone as an outcome of the Coastal Investors' Meet held in 2003-04. While tourism establishments continue to come up in popular destinations like Gokarna and Murudeshwar in complete contravention of CRZ

Notification norms, with some buildings even in the inter-tidal zone, other areas are also being targeted for tourism development. However, no action is being taken by the government.

New resort raises head on Devbagh beach

A beach resort is being planned on the Devbagh beach in violation of CRZ. There is already a resort run by Jungle Lodges and Resorts near the spot where the Kali River meets the sea. The new resort is being built two kilometres away from the Devbagh beach on the stretch that leads to Majali. Small cottage-like structures have come up as part of the resort. A swimming pool is already under construction. CRZ Regional Director Vasanth Kumar said the issue of the resort has come to the notice of the department. Mr. Vasanth Kumar added that he had already gone to the spot and inspected the survey number and other documents available. A case of violation of rules is being registered, he said. Though there are stringent rules in Karnataka, they are being flouted blatantly.

Goa

Communities in Goa have been at the forefront in the fight against violations of the CRZ by the tourism industry. This has now taken a complex turn when small community based operators fear that the stand to protect the coast will be the principle on which they will be taken to task and the big hotels will go scot free.

In the Arossim coastal area in Cansaulim Panchayat one resort and two hotels have been proposed for construction. Of these, one resort Heritage Resort Pvt. Ltd. had commenced construction. The other hotels whose names have been advertised are Competent Group of Companies and Goa Inn Pvt. Ltd. These hotels have demarcated areas on the coast by fencing for construction. In the Utorda coastal area in Cansaulim Panchayat, Goa, one hotel called Hyatta has already been constructed. In an investigation undertaken jointly by Alternatives and Council for Social Justice and Peace, Goa and EQUATIONS, the following violations of the CRZ Notification were recorded:

Location of the hotels

- The Heritage Resort and all other hotels referred above are located within the 200 to 500 m from the High Tide Line (HTL) which is demarcated as No Development Zone (NDZ) according to CRZ Notification with reference to CRZ III (i) of the Notification.
- The Heritage Resort has constructed permanent construction beyond and within the 200 m from the HTL in violation of CRZ III (ii) of the Notification
- In the case of the Heritage Resort the construction is against the ambit of traditional rights and customary uses which is in violation of CRZ III (iii) of the Notification.

Restriction of public access

- The Heritage Resort and the aforesaid hotels have not left enough space for access to the beaches as prescribed in Annexure II 7 (1) (ix) of the CRZ Notification. Contrary to the prescribed 20 meters the space left for public access to the beach is less than 10 metres.

- The Heritage Resort and Hotel Hayatta was observed placing the Deck chairs for their guests on the NDZ and security guards were placed to drive away local people from traversing those areas, even for access to the coast.

Fencing

- The Heritage Resort and the Competent Groups of Companies have put up barbed wire fences with out any vegetative cover which is in violation of Annexure II 7 (1) (i) (ia) of the CRZ Notification.
- In case of Goa Inn Pvt Ltd they have fenced the property with wire mesh which is not prescribed under CRZ Notification and is thus violating Annexure II 7 (1) (i) (ia) of the CRZ Notification.
- In case of Hyatta Hotel they have fenced the property with a wooden fence which is also not prescribed under CRZ Notification and is thus violating Annexure II 7 (1) (i) (ia) of the CRZ Notification.

Pollution

- The Heritage Resort is discharging their solid wastes and the effluents directly into the sea without treatment thus violating Section 2 (v) and Annexure II 7 (1) (viii) of the CRZ Notification.

Flattening of sand dunes

- Flattening of sand dunes has been carried out for construction by the Heritage Resort and the Hyatta Hotel. The same has been done for putting up the fencing by the all the hotels and the Heritage Resort in violation of Sec 2(xiii) and Annexure II 7 (1) (i) (ib) of the CRZ Notification.

The investigation report has been used to file a Public Interest Litigation in the High Court of Goa for necessary action against the violators by the local groups.

Goa tough on CRZ violations

Tourism development has taken a huge toll on Goa's coastal environment with violations mounting by the day.

A few months ago the state government identified over 300 constructions that defied the ban on construction within 200 metres of the high tide line. A number of blatant violations of the CRZ (coastal regulation zone) on the tourist coast here will face the axe under a revived Goa Coastal Zone Management Authority, headed by Chief Secretary J P Singh. Mr. Singh, who took over as chief secretary is perhaps the first high ranking bureaucrat to take a stand to protect whatever is left of the coast here. Hundreds of illegalities have escaped being demolished in the past with the connivance of politicians. The authority has also ruled against beach shacks on turtle nesting sites like Galjibag beach in south Goa and Morjim in the north. Morjim beach attracts a large number of Russian tourists, many of whom have taken over the business of running shacks, illegally from locals.

Sea of trouble ahead? CRZ scanner on foreigners

The Goa Coastal Zone Management Authority (GCZMA) has discovered constructions by foreigners, especially Russians that have been built in violation of CRZ rules. Though the precise number is not known, government sources said that there are quite a number of constructions by foreigners in violation of CRZ. A majority of the violations are by Russians. In Morjim alone, there are more than ten constructions that have violated CRZ norms. Some of the major properties under the GCZMA scanner are: Artlitori Resort Pvt Ltd, Casa Blanca and La Valencia hotel, all in Morjim.

Coastal regulation zone violations rampant - Till date, 314 cases have been noted for action in Goa: Minister

Minister for Environment Wilfred de Souza disclosed in a written reply in the brief budget session of the Legislative Assembly that till date, 314 cases of CRZ violations have been “noted for appropriate action”. The famous beaches of Goa right from Calangute, Candolim, Baga, Anjuna, Wagator in North Goa to Bogmollo, Colva, Benaulim, parts of Cavellosim and Pallolem in South are racing to be another Baina (a beach in the port town of Mormugao which is notorious for blatant illegal constructions).

Maharashtra

Best kept secrets The 'green' greed

The more serious and conspicuous attempts to violate the notification have been recorded by vigilant groups all over the state. In Mumbai, a survey conducted under the auspices of the Indian National Trust for Art & Cultural Heritage (INTACH) and a number of other associations revealed that only one- third of the 34-kilometre waterfront from Colaba to Versova is available for public use. The CRZ notification has also been evoked by the local fisherfolk of Velaghar-Shiroda, in the Sindhudurg district, which was earmarked for tourism development by the Sharad Pawar government. The locals are presently contesting the land acquisition and eviction notices served by the Maharashtra Tourism Development Corporation (MTDC) on behalf of the Taj group of hotels, which plans to build a five- star hotel and beach resort with aqua-sports.

Andaman Islands

Tourism development in the Islands has largely occurred in contravention of the CRZ Notification, 1991. Tourism establishments that are beyond the prescribed limits of 200 or 500 metres from the high tide line are almost impossible to find and there are violations galore by tourism related activities in Port Blair, Wandoor, Havelock and Neil Island. All resorts in Havelock and on Neil Island, including the Dolphin Resort owned by Information, Publicity and Tourism Department (IP&T) which is a permanent structure are in violation of the CRZ Notification. In fact during high tide the sea water comes inside the premises of Dolphin Resort, over the sea wall that has been constructed. Dolphin Resort was inaugurated in 1993 by the then Lieutenant Governor Shri Vakkom Purushottam after the CRZ Notification, 1991 was issued. It is quite possible that this has been aggravated by the tsunami. However if the resort had complied with CRZ regulations, it is quite likely that such an extreme situation would not have arisen.

Corbyn's Cove south of Port Blair is popular with tourists and local people. To begin with, the Peerless Resort in Corbyn's Cove is located very close to the HTL. In addition to this, many permanent structures like a restaurant, washing and changing rooms for tourists have been built. The proximity of the entire setup is so close to the beach that sea sand accumulates on the road and in the premises of the resort, which needs to be cleared periodically. Again, as in the case above, this is about basic non-compliance to CRZ regulations in the first place. A slight subsidence has been recorded in South Andaman Island due to the earthquake of 26th December 2004. Locations like Corbyn's Cove have also been affected by the subsidence (or rise in sea level). Hence proximity of the resort to the beach has been further increased.

The road from Port Blair town to Corbyn's Cove, which is primarily used by tourists, has also been widened and the retaining sea wall has been rebuilt in 2007 to repair damages caused by the earthquake of December 2004. The CRZ allows bunding to facilitate permissible activities {section 2(viii)21} but also states that commercial purposes such as hotels are not permissible. A parking lot has also been constructed in 2007.

In Wandoor, there is a new restaurant that is being constructed just beside the road within a few metres of the HTL. There is a lot of waste-dumping on new Wandoor beach. The road is being widened and sea wall built in Chidiyatapu where the Department of Environment & Forests is constructing a biological park for tourists and other visitors.

Conclusions on the CRZ Notification, 1991

The CRZ Notification, 1991 was a positive legal response to the concerns raised from various groups, especially coastal communities and civil society organisations, for the protection of the coastal areas. The CRZ Notification provides a blanket restriction on all activities in a zone that is generally understood to be fragile. The prohibition of those activities categorised under thirteen types in section 2 of the Notification was a good step to begin with. There are positive sides to the CRZ Notification too, e.g. including rivers, creeks etc, up to the point where a minimum salinity level of 5 ppt is recorded in CRZ areas. It accepts developments prior to 1991 and attempts to minimize further damage in zones that have already had urban growth.

At the same time the CRZ Notification permits traditional inhabitants of coastal areas, namely the farmers and fisherfolk, to access and use coastal areas for their lives and livelihoods. They are permitted to construct dispensaries, schools, public rain shelters, community toilets, bridges, roads and provision of facilities for water supply, drainage, sewerage which are required for the local inhabitants. Also permitted is construction / reconstruction of dwelling units between 200 and 500 m of the HTL, as long as these are within the ambit of traditional rights and customary uses such as existing fishing villages and goathans in CRZ III, with the restrictions prescribed under the CRZ Notification.

The coastal community has traditional rights, which are in relation to traditional use like fishing and using the beaches to park boats, store nets and dry fish etc. these are rights that need to be continued. When the community also claim rights to do other activities like tourism, complications

arise and the current Notification does not nuance the different cases. The rights of the panchayats & urban local bodies are those accorded by the 73rd and 74th Amendment. These are not above rules like the CRZ Notification, 1991 which are formulated by taking into account on the basis of natural ecosystems and resources are common property resources. These need to be protected for the welfare of all people and not just one community. The panchayats & urban local bodies are given all the power to issue or cancel the licenses for any constructions happening within their jurisdictions. The coastal communities also have the legal right to approach court of law against any violations of CRZ or intrusion into their living and occupational spaces by industries.

The issue of the CRZ Notification, 1991 also set the precedence for involving the states and union territories in coastal conservation. However, because of lack of commitment of the state governments & union territories, the CRZ Notification has been rendered ineffective due to its poor implementation and led to continuous violations. While pressures from many vested interests have diluted the original Notification, a major role has been played by civil society organisations in enforcing the Notification inter alia through the public interest litigation route.

While there have been lapses in the implementation of the CRZ Notification, as has been described above, the tourism industry cannot be exonerated from not complying to the CRZ Notification, 1991. There is ample proof that activities like tourism have continued to expand in coastal areas in violation of the CRZ Notification, as is evident from the examples cited above. There is a need to deal with these violations sternly and decisively.

Swaminathan Committee Report, 2005

In July 2004 the MoEF constituted the Swaminathan Committee with the terms of reference to:

- I. Review the reports of various Committees appointed by the Ministry of Environment & Forests on coastal zone management, international practices and suggest the scientific principles for an integrated coastal zone management best suited for the country;
- II. Define and enlist various coastal and marine resources and recommend the methodology for their identification and the extent of safeguards required for conservation and protection;
- III. Revisit the CRZ, Notification, 1991 in the light of above and recommend necessary amendments to make the regulatory framework consistent with recommendations on (I) and (II) above and the Environment (Protection) Act, 1986

The Committee submitted its report in February 2005. The Swaminathan Committee report has been critiqued by associations, movements and networks of coastal community and civil society organisations like Coastal Action Network (Tamil Nadu), National Fishworkers Forum, as well as academic organisations like Ashoka Trust for Research on Ecology and Environment, and UN agencies like the United Nations Development Programme on its claims of being scientific and trying to infuse scientific aspects in coastal protection with state-of-the-art integrated coastal zone management processes. The lack of consultative processes with representatives of coastal communities and civil society organisations engaged with coastal issues while preparing the report has been the basis for widespread criticism of the report. Many groups and associations of the fishing community have rejected the report for its severe democratic deficit, apart from the short

shrift that the Report has given the coastal communities on their rights of control and access to coastal resources. Here we present an analysis of the Swaminathan Committee's recommendations and National Coastal Zone Management Action Plan.

Guiding principles of Swaminathan Committee recommendations

Before presenting its recommendations, the Swaminathan Committee presents 12 guiding principles for consideration when the recommendations are implemented. The guiding principles begin with stating that the integrated coastal zone management policy should take into consideration ecological, cultural, livelihood and national security (principle #1). They have, for the first time, suggested that the coastal zone also includes marine ecosystems on the seaward side of the coast to the extent of 12 nautical miles, including the seabed (principle #2). This is a positive move because land based activities have been found to affect marine ecosystems. By bringing marine areas into the fold of coastal regulation, protection of critical ecosystems like coral reefs could be ensured.

The guiding principles state regulation (principle #3), application of precautionary principle (principle #6, 9), public trust doctrine (principle #9) and principles of gender, social and intra & inter generational equity (principle #8). The principles also focus on conservation and sustainable development (principle #4, 5, 7, 10). While these principles are progressive, the way in which they are incorporated in the recommendations needs to be assessed.

The Integrated Coastal Zone Management (ICZM) policy that is being proposed does not include rights of coastal communities (principle #1). The role of local self governments to decide the kind of development and to have a say in matters in areas of their jurisdiction has been omitted in the decision making process and has been limited to education and social mobilisation only. The approach to coastal management omits traditional knowledge and practices wherever available as a potential source of conserving coastal ecosystems e.g. traditional methods of managing sand dunes, mangrove forests. It suggests stakeholders as parties in decision making and thus boundaries between those who are holders of rights and those who have a stake have been blurred (principle #8).

Protection of coastal areas from natural disasters has been restricted only to "bio-shields" (increasing vegetation cover through activities like plantations to act as barriers to strong winds, sea surges and wave action) with non-coastal, exotic species like casuarina, salicornia (principle #11). These interfere with and alter natural process of sand dune formations and growth of other endemic coastal vegetation. Further, such plantations are appropriated by forest departments thereby taking away the access and control of these areas from the community and local governing bodies. The scientific basis of such emphasis on bio-shields is also questionable as to whether this is being suggested based on impact assessment studies or not. Lessons from the tsunami are that protection by having bio-shields is not enough. The proposal to have bio-shields needs to be carefully thought through and areas where they can be put up need to be carefully identified through participatory processes. Bio-shields across the entire stretch of the coast are not an appropriate suggestion.

Recommendations of Swaminathan Committee

Terms of Reference #1:

Review the reports of various Committees appointed by the Ministry of Environment & Forests on coastal zone management, international practices and suggest the scientific principles for an integrated coastal zone management best suited for the country

The Swaminathan Committee has made recommendations under each Terms of Reference. The Committee's first ToR was to review reports of various other committees set up earlier by the MoEF and other international practices thereby suggesting scientific principles for an integrated coastal zone management system that would best suit the country. The Swaminathan Committee, after reviewing the earlier reports of the various committees, states that these were comprehensive and if it was not for the MoEF selectively choosing some and discarding the rest, the CRZ Notification would have been strengthened. The Committee also takes cognisance of civil society groups terming these selective choices of the MoEF as dilutions to the CRZ Notification (section 4.1.1.i).

The Committee suggests a holistic approach to tackle coastal problems and has suggested inclusion of the ocean and tidal water bodies along with coastal areas (section 4.1.1.ii). However, when it comes to regulation, the Committee has suggested a “pragmatic management” approach for protecting ecological systems (section 4.1.1.iii). Having said this, the Committee has not elaborated the relationship between management and regulation.

Later, it has recommended that regulatory frameworks and plans at area and region levels need to be ensured (section 4.1.1.vi). In this regard, strengthening the principles of the Coastal Regulation Zone has also been suggested complemented with policy mechanisms that would prevent further degradation of coastal zones. Likewise, the Committee has made many general recommendations that have the potential to ensure protection and conservation of coastal ecosystems if properly implemented.

The Committee states that coastal areas are common property resources. It acknowledges that collective and democratic initiatives are required at the level of local communities for preparation and implementation of ICZM (section 4.1.1.v). Such initiatives are also required at various levels of government – state and national but the Committee is silent about those. Decentralisation of decision making and management through devolution of powers and making available adequate resources to local self governments according to 73rd and 74th Constitutional Amendment for the sake of coastal regulation zone management has been made in the recommendations (section 4.1.1.vii, viii) and is omitted in the guiding principles.

The Committee suggests an integrated and inter- sectoral approach for environmentally and socially sustainable development vis-à-vis the ICZM. It states that the ICZM seeks to bring together users of coastal resources and relevant governmental agencies in order to achieve “eco-development”. Here, there is a lack of explanation as to who the coastal resource users are. Coastal communities are also users of coastal resources. They have traditional rights of access and use of coastal resources, notwithstanding that their rights are to be exercised in the broad framework of coastal

regulation²⁴. But “other” users such as tourism are resource intensive activities, which need and are known to occupy large amounts of resources like land, water. Further, there are instances when such activities have led to the displacement of coastal communities and denied their traditional rights. Therefore, bringing together two entirely different kinds of coastal resource users to achieve sustainable development needs a carefully thought through mechanism. There are doubts whether the proposed ICZM will be able to deliver this mechanism as the role of local self governments has been reduced to educating people on coastal management and only consulting them while undertaking activities on the coast. Therefore, if the right of people to decide has been taken away, processes like the ICZM would only be information sharing exercises where the project proponents and/ or the state, central level departments have already taken a decision.

Environmental and social impact assessments have been recommended as compulsory for any development activity along with provisions of a public review process, which is different from public hearing. Inclusion of social impact assessments is a progressive recommendation, and so is the suggestion for EIAs to account for social and economic costs that environmental degradation causes to local communities. Another positive aspect is for EIAs to take traditional as well as scientific knowledge into consideration (section 4.1.1.x).

The idea of having a public awareness programme prior to mandatory public hearing for projects is a progressive one (section 4.1.1.viii). It must, however, be kept in mind that public hearings as they are now being practiced is a mere formality because the Environmental Impact Assessment Notification, 2006 prescribes it, but the right of the community to decide has been denied in practice.

The Committee highlights the criticality of coordinating activities of government departments with jurisdiction in coastal areas (section 4.1.1.viii) and to ensure that there is no ambiguity in the allocation of responsibility and accountability (section 4.1.1.ix).

A particular exception seems to have been taken against aquaculture projects and a strict review of all such projects and their negative impacts has been recommended. Defence projects have been recommended to be subjected to impact assessment processes and conflict resolution mechanisms (section 4.1.1.xi). There seems to be no rationale for excluding defence projects from the ambit of public hearing.

Terms of Reference #2:

Define and enlist various coastal and marine resources and recommend the methodology for their identification and the extent of safeguards required for conservation and protection.

Conspicuous by its absence in this ToR is the task of defining & enlisting customary & traditional use of resources and recommending methodologies to identify and safeguarding them together with coastal and marine resources.

Under this ToR, the Committee has made many general recommendations pertaining to sustainable use of coastal resources. Biodiversity indexing and distinguishing between genuine community

needs and commercial interests has been identified (section 4.1.2.i). The coastal and marine resources that have been identified for protection, which have been recommended to be notified as ecologically sensitive areas, are all the various ecosystems and landforms (section 4.1.2.ii, iii). Identifying and protecting sites of archaeological importance has also been suggested (section 4.1.2.vi). While the Committee has identified the need to protect natural and cultural heritage of the coasts, safeguards to check increase in tourism activity need to be put in place because of tourism's tendency to target precisely protected areas of these kinds. The Committee does not make references to this effect in its recommendations.

Concerns about the suggested "bio-shield" programme (section 4.1.2.iv) have been mentioned above. However, activities with a proven track-record of environmental degradation – mining, chemical industries and other hazardous industries have been allowed with taxes and cesses instead of being located elsewhere and prohibited altogether in coastal areas (section 4.1.2.iv). The Committee seems to have resigned itself to the notion that coastal areas of "incomparable value" – a new term that is quite ambiguous as it has not been defined elsewhere - will be eventually developed and hence developers will have to take absolute liability and bear the burden of proving that their activities will not harm coastal ecosystems and communities (section 4.1.2.vii).

The Committee recommends that coastal policy and regulation should be guided by the principle of equity and through the participatory processes of fair, just and transparent environmental decision making (section 4.1.2.ix). Preparation of local level biodiversity and cultural heritage registers by the local community has been suggested (section 4.1.2.xiv). Enhancing the capacity of local self governments, educational institutions, civil society and relevant government departments to undertake environmental and biodiversity audits has been suggested (section 4.1.2.xv). However, the role of local self government institutions has been limited to consultation and involvement (section 4.1.2.vii) without recognising that they can disallow those activities that are prohibited in the CRZ Notification, and those that may not be in the interest of coastal communities even if permitted under the CRZ Notification.

Importance of conserving and rationalising use of freshwater, groundwater in coastal areas has been taken cognisance of (section 4.1.2.viii). References to relevant multilateral environmental agreements have been given for conservation and sustainable use of coastal resources and biodiversity (section 4.1.2.xi, xii, xiii).

Terms of Reference #3:

Revisit the CRZ, Notification, 1991 in the light of above and recommend necessary amendments to make the regulatory framework consistent with recommendations on (a) and (b) above and the Environment (Protection) Act, 1986

Where the CRZ Notification, 1991 is concerned, the Committee acknowledges need for transparency in current implementation of CRZ (section 4.1.3.i) and that the various amendments have been detrimental to the coastal areas and have distracted the original Notification from its objectives (section 4.1.3.ii, iii). Therefore, strengthening of CRZ Notification has been recommended keeping in mind the needs of coastal communities and conservation of the coast (section 4.1.3.ii).

A rewards package has been suggested for construction incorporating environment friendly technologies (section 4.1.3.vii). Where an all India Coordinated Research Project for Sustainable and Integrated Coastal Zone Management has been suggested (section 4.1.3.viii), a research programme would have been more appropriate for undertaking research as well as continuing the process of updating data and disseminating it.

The Committee has recommended doing away with demarcating the High Tide Line and adopting a natural boundary (section 4.1.3.ix). The reason for this being misuse by local authorities who implement some provisions of the CRZ Notification and deny essential activities on the coasts. However, it may not be a good idea to do away with demarcating the HTL as it gives a good reference point to gauge the interface between land and marine ecosystems. It is also useful to understand dynamics of climate change; sea level rise and natural phenomenon offsets like subsidence and uplift of land.

Other recommendations under this terms of reference are general, but may be helpful for conservation and regulation (section 4.1.3.x, xi, xii, xiii, xvi, xvii, xx) provided there is an organic link to other democratic processes and the opportunities for effective participation of public are given (section 4.1.3.xi). Setting up of Rural Knowledge Centres for capacity building of coastal communities has been suggested (section 4.1.3.x). Construction of new roads in CRZ areas has been suggested to be prohibited till ICZM Plans are put in place, except for providing access to the sea for fisher communities (section 4.1.3.xiii). Encouragement and support for the fisheries sector has been given (section 4.1.3.xix).

Coastal tourism and recreational facilities are to be promoted in potential areas identified after considering social issues, vulnerability and resources; awareness building for tourists needs to be undertaken. The criteria chosen by the Committee is inadequate given that tourism has serious environmental, social, economic and cultural impacts (section 4.1.3.xviii). While the Committee takes note of the threat of unplanned tourism development and its impact on coastal ecosystems, this recommendation is very open ended and may be used to open up more areas for tourism in the coastal areas. This is evident from the rampant growth of the tourism industry all along India's coastline including islands, which has grown in violation of the CRZ Notification, 1991 most of the time.

Recommendations for implementing National Coastal Management Programme

The recommendations of the Committee for a separate division in the Ministry of Environment and Forests to handle Coastal Zone Management and a National Board for Sustainable Coastal Zone Management are worth considering. The membership of the National Board for Sustainable Coastal Zone Management is also inclusive of a wide range of rights holders and stakeholders. The purpose of having representatives of the print and electronic media however raises a doubt. However, setting up of National and State/UT level Coastal Zone Management Authorities is redundant because such a structure exists today and could be incorporated as suggested in the organogram. Further, if coastal conservation and regulation is to be accorded the same priority as wildlife and forests, then the National Board for Sustainable Coastal Zone Management should be chaired by the Prime Minister. The Committee concludes the recommendations chapter by stating that existing regulations and institutional structures need to be strengthened.

National Coastal Zone Management Action Plan

The Committee has also suggested a National Coastal Zone Management Action Plan. The coastal zone is defined as the administrative boundary of a local self government, which may be useful in processes like regulation, preparation of management plans and so on, an ecological understanding of coastal areas would offer a better platform to permit or regulate certain activities. The area on the landward side influenced by wave action, extent of sand dunes and coastal vegetation, presence of coastal water bodies and so on are criteria that could have been adopted to define coastal zones.

There is not much change in the understanding of coastal zones except for the inclusion of the term proposed in the draft CMZ Notification. How impacting activities like tourism, industries, SEZs in these areas can be regulated is the key concern, which the Committee has not addressed rather leaves it to the ICZM Plan to decide. The CRZ Notification, 1991 gives a better description of classification of CRZ areas and permissible and prohibited activities.

The responsibility to identify and declare Ecologically Sensitive Areas (ESAs) should not rest only with MoEF, but it should be a participatory process involving both rights-holders and stakeholders. The suggestion to have a coastal policy and rules (hopefully to implement the Notification) is, however, valid.

Conclusions on the Swaminathan Committee Report

One of the points of critique of the Swaminathan Committee report has been the lack of consultations with various community organisations, fisherfolk associations and civil society organisations who are engaged on coastal issues. The Swaminathan Committee mentions in the beginning of chapter 4 that “Based on in-depth discussions and widespread consultations with the principal stakeholders, the Committee developed the following 12 basic guiding principles, which should govern future decisions on coastal zone management ...” However, this claim has been challenged by movements like the National Fishworkers Forum, who have gone ahead and pointed out the Swaminathan Committee has not practiced what it has preached. Further, the list of the “principal stakeholders” and minutes of the “widespread consultations” are nowhere available in the public realm. The constituencies agitating against the Swaminathan Committee report could then see the quality of the participatory process claimed by the Swaminathan Committee. Despite this critique, the MoEF or the Swaminathan Committee have not made any attempts to provide the details of these consultative processes.

Where the guiding principles state regulation (principle #3), application of precautionary principle (principle #6, 9), public trust doctrine (principle #9) and principles of gender, social and intra & inter generational equity (principle #8), they have also included the polluter pays principle. The polluter pays principle means that those who pollute should bear the costs of avoiding it or should compensate for it. While this is an internationally recognised component of international environmental law, there are inherent problems with this principle. Polluters would continue to pollute and pay whatever might be the costs, fines to the concerned authorities and compensation to people affected by the pollution. The multiple costs of long term environmental damage and harm to life will not be counted and the polluting activities will not be held accountable for it. People who are affected by environmental pollution will also not be compensated as has been the case in the

Bhopal Gas Tragedy. Industries are usually given subsidies and incentives by governments. When these industries pollute and pay for the pollution, it is in a way being financed by the taxpayers' money. The Indian Judiciary has acknowledged the polluter pays principle and given judgements based on it. But concerns remain on the criteria for fixing the costs that the polluter has to pay and that the principle would be left to various forms of interpretation.

Some of the recommendations of the Swaminathan Committee are useful and will help in strengthening the current CRZ Notification.

The positive aspects of the Swaminathan Committee recommendations, which need to be accepted, are:

- Inclusion of marine areas with the seabed within the coastal zone
- Strengthening of the CRZ Notification, 1991 and bringing transparency in the process of its implementation
- Formulating a coastal policy and rules.

Some recommendations are very general and often sound like analyses. Therefore they leave a lot of room for selective interpretation which will anyway happen by stakeholders. There is no value addition being made so suggest removing these sentences. The refrain of the ICZM resonates throughout the report without actually describing the content, structure and functioning of such a process although some basic guidelines have been given in the annexure. The way in which the recommendations have been structured also makes it difficult for the reader to make the necessary linkages; some are repetitive (e.g. heritage sites, biodiversity indexing and inventorisation of coastal bio-resources, polluter pays principle) and sometimes one issue has been dealt under different sections.

Where it falls short is on the actual role of local self governments despite references to 73rd and 74th Constitutional Amendments in the guiding principles, but the role to decide is not acknowledged in the recommendations. The right of the coastal community as per the Constitutional Amendment to decide on the type and pace of development is not acknowledged in the recommendations. The Committee fails to make the distinction rights- holders – the coastal community and local self governments – and other stakeholders. The rights- holders are those who are accorded rights as per Constitutional provisions to decide on the type and pace of development (at the local level). The suggestion to include stakeholders as parties in decision making is unacceptable and it leads to conflict of interest. There have been similar concerns raised by various , movements and networks of coastal community and civil society organisations, academic organisations and UN agencies who have critiqued the Swaminathan Committee Report.

The objective of the Committee to revisit the CRZ Notification, 1991 in order to provide appropriate amendments for strengthening it is reasonable. Therefore, it is surprising that the MoEF is proposing to replace the CRZ Notification thereby backtracking on its own objective of constituting the Swaminathan Committee and bringing out a new CMZ Notification.

Critique of the Draft Coastal Management Zone Notification, 2008

The Union Ministry of Environment and Forests officially posted the draft CMZ Notification in May 2008 vide notification no. S.O 1072 (E), which is a proposed replacement to the Coastal Regulation Zone Notification, 1991 and comments were invited within a 60 day period. In the words of MoEF, the present draft was necessary “perceiving the continuing difficulties posed by the Notification (namely the CRZ Notification) in its effective implementation for the sustainable development of coastal regions as well as conservation of coastal resources”.

Why the push for draft CMZ Notification?

The draft CMZ Notification comes at a juncture where both central and state governments are chasing economic growth through incentivising industry and deploying domestic and foreign private capital on a massive scale in new infrastructure and industrial developments. There is relentless drive for acquisition of land to facilitate the interest of the investors. In the process, all kinds of land; from agricultural land to forest, revenue land and common property resources are being targeted. The coast is no exception. For example, in Andhra Pradesh (AP) the State Government has come out with the Government Order (GO) 34, aimed at developing the coastal areas of AP right from Srikakulam to Nellore districts in an area covering kms, into a Coastal Industrial Corridor. The AP State Government is promoting it as a prestigious project that according to them would accelerate industrial growth in the state through the construction of industrial parks, theme parks, mega chemical complexes, amusement parks, pharma parks etc.

The 7,517 km coastline of the country from east to west in the southern peninsula is experiencing huge investments. Coastal lands are in high demand especially from the real estate developers, developers of SEZs and Entertainment hubs. The state-wise distribution of formally approved, in-principle approved and notified SEZ in the country posted in the SEZ portal of the Ministry of Commerce shows that the coastal states have the lion’s share of SEZs in the country. Out of the 513 formally approved SEZs in India²⁸, Gujarat has 45, Andhra Pradesh 94, Maharashtra 95, Karnataka 48, Tamil Nadu 60, Kerala 16 and even a tiny coastal union territory of Dadar & Nagar Haveli has 4.

According to a recent property development news report from Gujarat, Mandvi a coastal village of boat builders, will be developed as a “special entertainment zone” - the first major endeavour of the Gujarat government under its new tourism joint venture company set up with the Tourism Corporation of Gujarat Ltd (TCGL) and Infrastructure Lease and Finance Services. Mandvi beach will enjoy the privileges allowed to India’s SEZs. A 7 km stretch between Mandvi and Bhrabudi village, towards Mundra port, has patches of government and forest land, which will be put to use for developing the entertainment zone. Also, a 10 km stretch from Mandvi to Pingleshwar in the north shall be explored for the venture. According to news report says that a few months back the state Government has taken the decision to relax liquor norms and allow private parties to set up bars on Mandvi beach in Kutch. According to a senior official, “The TCGL has one lakh square metres of

land along the sea coast. The government team will see if more land can be made available, so that more than one private party can be asked to develop the area as it has one of the best sea beaches in the country.” The investor’s news from Kerala also showcases use of the coast for property developments, ports and IT Parks.

The planning of the central government to bring a change in the CRZ Notification is not new. Though not discussed or debated openly, the MoEF started working on a new draft way back in 2003. According to World Bank website³³ the government of India has entered into a loan agreement with World Bank on Integrated Coastal Zone Management. The objectives, according to the loan agreement, are to develop and implement an improved strategic and integrated management approach for India’s coastal zones to preserve the long-term productivity for continued sustainable development and economic growth. The four components are: (i) vulnerability and ecological mapping; (ii) institution building and strengthening at national level; (iii) development and implementation of state-level approaches; and (iv) project management. Implementation of this World Bank Project was initiated by MoEF well before MoEF officially acknowledged the drafting of the draft CMZ Notification.

Also, in the recent Planning Commission Document for Inclusive Growth, much emphasis has been given on the coast and coastal developments. A special section on Coastal Zone Management (in Chapter 9 - 9.1.59) of the Planning Commission Report talks about the CMZ Notification. Without going into the specifics of why CRZ Notification failed and how the draft CMZ Notification is a better option, it just states that the Swaminathan Committee prescribed that local circumstance and vulnerabilities should be the basis of coastal zone management and regulations. Interestingly, the Planning Commission document in its opening lines refers to the CRZ Notification as “the earlier Coastal Regulation Zone Notification ...” The Planning Commission is a pivotal planning body of the country. It is of concern that the Planning Commission refers CRZ Notification as an earlier notification while legally the CMZ Notification is still in the draft stage and according to MoEF is open for public consultation and debate.

Definitions

Coastal Zone: The definition includes the territorial water limits of 12 nautical miles including the seabed, as has been the demand of most the conservationists, activists and the coastal groups for many years now. It also includes inland water bodies influenced by tidal action – both the bed of the water-bodies as well as lands adjacent to such water bodies. However, it is not clear why the coastal zone extends up to the landward boundary of the local self- government / authority. E.g. the boundary of a coastal village panchayat may be quite far from the HTL or the coastal land affected by the sea. Bringing the entire panchayat within the CMZ framework to regulate activities would in this case be inappropriate. A more ecological definition of coastal zone, such as that land mass adjacent to the sea that is affected by the tide, current, wind and at the same time influences ecological processes of the sea, would help in identifying the environmental threats and thereby help regulate permissible activities and prohibit those that would impact the coastal ecosystems.

Integrated Coastal Zone Management (ICZM) and Plan (ICZMP):

The Draft CMZ Notification does not provide these details. Both the concepts need detailed explanations as to how they are going to be put in practice. The CRZ Notification, 1991 prescribed the CZMP and only gave broad suggestions that the CZMP should show categories of CRZ areas (CRZ – I, II, III, IV). This led to the states preparing status reports on current activities in the coastal areas and unilaterally deciding the CRZ category. Further, the HTL was also not marked. The CZMP should have ideally contained, which it did not contain, current activities, composition, constitution, process of functioning of the state CZMA, process of seeking, granting clearances and disciplinary, punitive action and its process against violators. Therefore, the absence of guidelines on preparing the CZMPs resulted in them being reduced to mere status reports. Similarly, no guidelines have been given for the ICZMP, which means that this document will be an updated status report of its predecessor.

Setback Line:

The concept of a Setback Line is not a new one. Even the NDZ prescribed in the CRZ Notification is nothing but some kind of a setback line. However the principle of the Setback Line in the CRZ Notification is completely different from the setback line proposed in draft CMZ Notification. The setback line under the CRZ Notification is intended to create a buffer zone to regulate activities like coastal tourism, mining and infrastructure development from impacting natural resources, which have a degrading effect on coastal ecosystems and impact coastal communities. The Setback Line in the draft CMZ Notification is more of a hazard line that according to the given definition is based on vulnerability to sea- level rise, flooding and shore line changes. That is the reason why it is not definite and will vary from place to place, even within a panchayat limit.

The definition of a setback line in the draft CMZ Notification says that it shall be based on the vulnerability of the coastal stretches to sea level rise, flooding and shoreline changes. Despite years of lobbying and advocacy by the civil society groups and scientists & researchers working on the biodiversity and ecology of the coast, the draft CMZ Notification does not acknowledge that infrastructure development, artificial landscaping and increased human interference due to tourism activities could also lead to devastation of the coast.

The High Tide Line (HTL) would be a better reference to demarcate coastal regulation zones if various coastal ecosystem components are incorporated into zones, e.g. the ecological boundary of sensitive areas may be the landward boundary of that particular coastal regulation zone if it is beyond 500m of the HTL, rather than being limited to 500m only. Therefore, the setback line would actually serve the function of a hazard or risk line. If this is overlaid on coastal regulation zones, it may provide a better perspective to take decisions on allowing or prohibiting activities.

Categorisation of coastal zone

The draft CMZ Notification is a clear dilution of earlier coastal regulation norms. categorisation of the coast into CMZ-I, CMZ-II, CMZ-III and CMZ-IV is the most crucial of all the activities suggested in the draft CMZ Notification. The management of various activities on the coast shall

depend on this categorisation. However, there is no provision in the draft CMZ Notification that calls for public participation or consultation in the entire activity of categorising the coast.

Coastal Management Zone I:

According to the draft CMZ Notification, CMZ-I will not be equivalent to CRZ-I. These zones shall no longer have statutory protection and non-interference as in case of CRZ-I. The proposed CMZ-I could allow activities like tourism in the eco-sensitive zones as long as they are included as part of the “Integrated Coastal Zone Management Plan”. As indicated in the critique by ATREE, unaccounted leverage given to the management authorities – in the present case to the State Coastal Zone Management Authorities (SCZMAs) - by introduction of words such as “ICZMPs prepared shall ensure proper protection and conservation of all ecological sensitive areas keeping in view the safety and livelihood needs of the local communities and essential development”. Nowhere are the phrases ‘livelihood needs of the local communities ’and ‘essential development ’explained. Thus, it has been left to the policy makers, in the present case the drafters of ICZMPs in respective states and Union Territories to decide what they perceive to be important for livelihood needs of the local communities and essential development. Anything from developing coastal tourism establishments to making of roads and rail links and ports in the coast; commercial activities such as SEZ development, industrial estates, mineral mining, man-made coastal protection structures and defence installations can be mooted as essential development and in support of livelihood needs of the local community. A comparison of the CRZ Notification in its original form to the draft CMZ Notification clearly points out that CMZ-I category has none of the protection and conservation ethos of CRZ-I. In its present format, it is a serious threat to the sensitive coastal ecosystem and communities. Thus the draft CMZ Notification gives a green signal for unbridled commercial activities along the coast.

Further, the list of areas that are demarcated as ecologically sensitive areas and thus categorized as Coastal Management Zone I (CMZ-I), is not a comprehensive list. The list does not include heritage sites, where activities like tourism could come in e.g. Mamallapuram, Tamil Nadu. The breeding grounds of fishes, reptiles other than turtles, amphibians and mammals that are part of the coastal ecosystem but that do not enjoy the status of protected areas under other laws like the Wild Life (Protection) Act, 1973 have not been included in the list.

Coastal Management Zone II:

CMZ-II in the draft CMZ Notification, which is equivalent to CRZ-II of the CRZ Notification, prescribes that coastal panchayats with more than 400 persons per square kilometres shall be declared as CMZ-II areas. This shall open up a whole lot of areas for various human activities which till date are protected as CRZ-III areas under the CRZ Notification, which will now get classified under CMZ- II thereby opening them to urbanisation and industrialisation. As per the prescribed limitation of activities in the CRZ-III areas, it brought a set of exclusive settlement rights to the fisherfolk and other local communities in the coast. A provision of CMZ-II has been strategically introduced keeping in mind that most of the coastal regions in India would fall under the category of CRZ-III. Under the present set up of the CRZ Notification, tourism and other industries which require waterfront and foreshore facilities can use CRZ-III areas with the permission and clearance from MoEF. The tourism industry has been lobbying with MoEF to do

way with the present set-up. As stated earlier, a number of violators of the CRZ Notification were taken to court and many of them were found to be guilty and their constructions face demolition orders. Therefore the proposal of CMZ-II seems very strategically made keeping in mind the interest of the industries like tourism, real estate so that no legal embargo can be enforced against such activities on the coast.

Similarly, the rationale for including heritage areas and notified archaeological sites under the Protected Monuments Act is unclear, as these areas should be under the first category due to their status as cultural heritage sites.

In line with the philosophy of draft CMZ Notification the permissible list of activities under “Areas of Particular Concern” given in Appendix III of the draft notification includes amongst others notified tourism areas, notified industrial estates, foreshore facilities for SEZs and green field airports, and expansion and modernisation of existing airports. These activities in the CMZ-II areas shall not require any Environmental Impact Assessment (EIA) or consultation with the local community. As pointed out by other researchers, the provision on green field airports as well as the matter on expansion of existing airports clearly reflects non-seriousness and non- commitment of the MoEF and central government towards conservation and protection of the coast. Such decisions are not only boosted by the aviation industry but also policy decisions like positioning and maintaining tourism development as a ‘National Priority Activity ’under the 10th Five Year Plan. The position has been reiterated in the 11th Five Year Plan. Planning Commission says that the Vision Document prepared by Ministry of Tourism envisages a target of 10 million international tourist arrivals by 2010. This target is proposed to be achieved through diversification of principal source market which includes improvement of infrastructure facilities like airports, roads and civic amenities. It also suggests that the infrastructure facilities at the airports would be developed to meet the rising air traffic requirements.

Coastal Management Zone III:

The Draft Notification declares CMZ-III as all other open areas including coastal seas but excluding areas classified as CMZ-I, CMZ-II and CMZ-IV. In relation to CMZIII, there is a need to carefully define it so as to include fisherfolk villages and that of other coastal communities who have been part of the ecosystem traditionally, and have been recognised by the CRZ Notification, 1991.

In CMZ-III areas the draft notification clearly states that water sports and recreation facilities shall be permitted on the seaward side of the setback line with the approval of the State or Union Territory Coastal Zone Management Authority. Green field airports and expansion and modernisation of existing airports are also permitted with EIA and Environmental Management Plan to be approved by MoEF. It is of concern that despite protests by local communities against exploitation of the coast through tourism expansion plans in states like Goa, Kerala and Andhra Pradesh, tourism continues to be promoted at the cost of the ecology as well as access to resources by the coastal communities.

National Board for Sustainable Coastal Zone Management

The constitution of the Board will be useful to provide the impetus for protection of coastal areas. If coastal areas are to be accorded the same level of protection as forests, wildlife then the suggested Board should have the Prime Minister as the Chairperson as in the National Wildlife Board. The list, although more inclusive than the National Coastal Zone Management Authority, is interesting to note as the MoEF has omitted Union Minister for Ocean Development and Representatives from Non- Governmental Organisations involved in activities related to coastal zone management, fishermen welfare and conservation of bio-resources and cultural heritage, as was recommended by the Swaminathan Committee, and has included the following:

Union minister-in-charge of ministry of earth sciences	Co-Chair
Secretary, ministry of environment and forest	Member Secretary
Experts (by name) in:	
Coastal Ecosystems	1
Marine biology	1
Maritime law	1
Meteorology	1
Disaster Management	1
Environmental Economics	1
Representative of the Ministry of Defence	1
Representative of the Ministry of Urban Development	1
Representative of the Ministry of Panchayati Raj	1
Representatives of community based organizations of the mainland coastal population	3
Representatives of coastal Rural District Panchayats	3
Representatives of coastal Urban Local Authorities	3

State/UT Coastal Zone Management Authorities

It is important to mention that the composition, functions and powers of the management authorities at the state and union territory level (State or Union Territory Coastal Zone Management Authority) are not defined. There is nothing in the draft CMZ Notification that gives a hope that draft CMZ Notification shall take care of the enforcement issues differently. There is no provision for strengthening the enforcement or powers for taking punitive actions against violators. Moreover, the draft CMZ Notification does not specify what will be done to punish those who have violated the CRZ Notification till date, once the draft CMZ Notification comes into operation.

The Draft Notification states that “The State/UT Environmental Appraisal Authorities (SEAA) set up under the provisions of the EIA Notification dated 14.09.2006, under the Environment (Protection) Act, 1986 shall also be the State/UT Coastal Zone Management Authorities”. The existing Coastal Zone Management Authorities cannot be done away with, as there is a more inclusive membership in the CZMAs as compared to the SEAAs. Environmental clearance procedures are also and hence overloading the SEAAs may not be advisable. CZMAs should continue to function with clearer and transparent procedures, and making them have a more democratic membership.

Management methodology

Notification of setback line: The draft Notification states that the setback line will be notified by the Central Government - MoEF alone cannot decide on the setback line. The notification of the setback line needs to be done in consultation with different users like fisherfolk in fishing villages, farmers in agricultural areas and inhabitants in housing localities. Participatory process with urban and rural local self government bodies need to be put in place at state / UT level for the purpose of demarcating the setback line. For this purpose, the state departments / CZMAs need to make the maps that will be prepared for marking the setback line available in local languages. These need to be discussed with the various constituencies and then finalised. The demarcation of the setback line also does not take into consideration important features like land use practices by the coastal communities.

Coastal Management Zone I: MoEF proposes to identify ecologically sensitive areas “...jointly with the concerned State Government / Union Territory Administration, with the technical assistance provided by one or more competent and established scientific research institutions specializing in coastal resources management, and notified by the Central Government”. Participation of local self governments needs to be ensured at the state government / UT level also. All activities cannot be only regulated in this category based on ICZMP, rather a list of prohibited activities needs to be made. The CRZ Notification, 1991 has a list for prohibited activities in CRZ-I areas which can be strengthened further.

Coastal Management Zone II: It is important to address violations of CRZ Notification, 1991 before the demarcation of areas as second category. A time frame to relocate or remove violations may be issued by the MoEF in consultation with state / UT level authorities. Further, resorting to coastal protection structures may not always be an option, which the Draft CMZ Notification wants. An appropriate method could be mapping of areas under the second category, which needs to be agreed upon by all concerned and then a call taken if coastal protection structures are required or not. It is not clear whether the ICZMP is required for this category of areas.

Coastal Management Zone III: The CRZ Notification, 1991 provided a better definition of this category of coastal regulation zone, which could be retained: CRZ-III covers areas that are relatively undisturbed and not falling under either CRZ I or II; up to 200m is NDZ; traditional rights of fisherman to build small structures is allowed. It is not clear whether the ICZMP is required for this category of areas.

Coastal Management Zone IV: Same as CRZ-IV.

Appendix – V: Activities Requiring Access to the Shorelines

As has been given in the Draft Notification, some activities like public toilets, beach tourism, discharge of effluent and sewage should not be allowed in close proximity to coastal areas.

Certain fundamental questions that remains unanswered:

If the MoEF feels that the CRZ Notification is not adequately taking care of the coast, they can amend the CRZ Notification to incorporate necessary provisions to bring back the CRZ Notification in its original spirit and form. Why is there a necessity to adopt a completely new draft?

It is important to point out that the present draft CMZ Notification calls for a major shift in the philosophy of coastal governance. The CRZ Notification was meant to be a regulatory mechanism with its core being conservation and preservation of the coast. The present draft CMZ Notification calls for management of the coast instead of regulating it. The title clearly refrains from using the term “regulation” and replaces it by “management”. It is a major paradigm shift that the draft CMZ Notification is trying to bring about in seeing how activities on our coasts need to be “managed” rather than be “regulated”. Literally as well as from a governance point of view, regulations brings in many restrictions which often are looked upon by industries like tourism, mining, port based industries as limitations and barriers. That was the exact case with CRZ Notification. The very fact that it prescribed a “No Development Zone” for a span of 500 meters in CRZ I and III areas and 200 meters in CRZ II areas in the coast hampered the business interest of many industries like the tourism industry, real state industry and infrastructure developers. These lobbies were always in the forefront of asking for amendments in the CRZ Notification in order to get a licence to grab, build upon and plunder the coast. The present draft CMZ Notification actually builds on the amendments that CRZ Notification has and thus calls for managing these activities instead of regulating them.

If the MoEF felt that there was a necessity of introducing a new framework, then why again in the form of a Notification when the need of the day is legislation for actual regulation and conservation of the coast?

Over the years there has been growing concern that the “Notification” character of the CRZ Notification makes it nebulous in nature. There has been a demand to convert the CRZ Notification into legislation. The MoEF argues that there is no difference between a notification that has been passed under legislation (in the present case the Environment Protection Act, 1986) and legislation per se. But legal experts have very clearly pointed out that a notification is conceived, drafted and brought into operation by the executives in the government, which to a large extent cannot be influenced by external agencies like the civil society. Legislation on the other hand calls for a debate in the Parliament and thus can be lobbied, advocated and influenced. For example: of the 21 amendments that were brought in CRZ Notification with the motive of diluting the regulatory framework, only 3 were put out for public comments before finalisation. In a governance structure like ours, we should not have a notification but proper regulatory mechanism through legislation for the coast. It actually reflects the complete impunity of the executives in the MoEF.

The preamble of the draft CMZ Notification says that “the Central Government proposes to bring into force a new framework for managing and regulating activities in the coastal and marine areas for conserving and protecting the coastal resources and coastal environment; and for ensuring protection of coast of coastal population and structures”. The question arises if it has been proven that the CRZ Notification is not adequately doing the same, what action has been taken by MoEF to see that CRZ Notification is effectively used? What have been those steps? Why have they failed?

It is a known fact that apart from diluting the CRZ Notification through numerous amendments, the MoEF has taken very few steps to ensure that the states compulsorily came out with their respective Coastal Zone Management Plans, appoint Coastal Zone Management Authorities and overhaul/penalise those state governments that failed in implementing the CRZ Notification. Moreover, numerous reports and analysis including the Swaminathan Committee Report have shown that the amendments to the CRZ Notification by the MoEF actually make implementation of the CRZ Notification problematic.

Concerns on scope of expansion of Tourism and related activities under the new draft Notification:

There are a number of people’s movements, environmentalists and civil society groups who have been working for many years, fighting a desperate battle against opening up of the coast to mindless, unplanned projects and consequent loss of livelihood of coastal communities. They have submitted their comments and concerns on the draft CMZ Notification and have also rejected it unanimously. We lend our voice of solidarity to those concerns and to the plight of coastal ecosystems and communities who are at the receiving end of this investment induced development. As we work specifically through research and advocacy on the impacts of tourism on communities (and tourism industry is one of the strong lobbies behind pushing ahead this new draft CMZ Notification) our critique of the draft CMZ Notification highlights the issues from the perspective of tourism and related expansions.

Looking back historically, it is important to remember that the first amendment of CRZ Notification relating to bringing down the “No Development Zone” from 100 meters to 50 meters (which was later quashed by the Supreme Court) along tidal water bodies was done by the MoEF under pressure from the tourism lobby. When the National Tourism Policy, 1992 proposed establishment of Special Tourism Areas (STAs) some of the identified locations were Bekal (Kerala), Sindhudurg (Maharashtra), Diu, Kancheepuram and Mamallapuram. Except for Kancheepuram all other locations were coastal regions.

In November 2006 the National Tourism Advisory Council (NTAC), a think-tank under the Ministry of Tourism & Culture (MoTC) meant to advise it on policy issues proposed establishing Special Tourism Zones (STZs) along the lines of Special Economic Zones (SEZs) to boost tourism and increase investment, employment and infrastructure in the country. The proposal specifically lays down that the STZs are to be located in tourist destinations, cities, along the coastline.

The recent Planning Commission Document (Volume III, Chapter no. 8.2 on Tourism) mentions that beach and coastal tourism on the beaches of Goa, Kerala, and North Karnataka may be considered for development due to easier accessibility of these places by air. It also mentions that

Kerala and the Andaman & Nicobar Islands have already been developed as international cruise tourism destinations. The objective very clearly lays down that the government is looking towards promoting and expanding beach and related coastal tourism.

The Federation of Hotel & Restaurant Associations of India (FHRAI) acknowledges that various efforts have been made by FHRAI to make the government review and eliminate obstacles posed by CRZ43 Notification. In the presentation made to the Government on the Draft CMZ Notification⁴⁴, the FHRAI includes the following recommendations:

- The word “temporary” with reference to permitted construction of structures for tourism in the CMZ III should be deleted. As RCC structures constitutes the various components of a beach resort. Moreover, even though the word “temporary” was used in CRZ Notification, the actual constructions that were carried out are of proper RCC buildings and not temporary by any definition. Inclusion of the term “temporary” would mean demolishing all these constructions which are already being used by tourism industry.
- All restrictions for resorts in CRZ III Areas should be removed, like height limitation of 9 mtrs, FAR and Ground Coverage Ratio (0.33% and 16.50% respectively) should be deleted.
- After the terms “Water-sports and recreation facilities” the words “swimming Pool, water bodies, boat club to house water sports equipment, changing rooms and spa/ health club” should be included so that in the NDZ areas i.e. on the sea ward side, of the setback line, these facilities are permitted to be set-up to make the guests of these resorts feel close to the beach.
- That the demarcation of the setback line along rivers, lakes etc should to 50mtrs or the parameter suggested in the draft CMZ Notification, which ever is less, This would help develop tourism along lakes and rivers in big ways.

These recommendations by the FHRAI reinforce our concerns that once the draft CMZ Notification is allowed to replace the CRZ Notification the tourism industry will use it to their advantage to further their goals of business options/ models and in the process ransack and exploit the coast⁴⁶. We shall then be left with the option of managing and not regulating these activities.

Conclusions on the draft CMZ Notification

The draft CMZ Notification fails in delivering a framework that will ensure adequate protection to ecologically fragile and sensitive ecosystems on the coast and facilitate community rights and livelihoods that are in harmony with the coastal ecosystem. In the process of changing the framework from being regulatory to management oriented, the prime aspects like conservation and preservation of the environment and socio-economic needs of the people and communities in the coast have been completely missed out. The scientific approach fails to bring in the much required practical and strong regulatory frameworks that are imperative to protect the coastal ecosystem in the country today.

It is surprising that the entire Draft CMZ Notification hardly dwells on regulation of coastal areas. The main problem of the CRZ Notification was that of non- implementation of the Notification

resulting in severe violations and no action being taken by the MoEF and the state governments with respect to such violations and non-compliance. A new draft Notification does not mean that the previous violations can be overlooked or pushed under the carpet. The present Draft does not make any effort to plug in the holes of the previous legislation. It is in fact more ambiguous than the CRZ Notification, 1991 on various processes pertaining to clearances and makes no mention of how violations will be dealt with. The Draft CMZ Notification excludes participation of state governments and of local self- governments and limits their responsibility to merely implementing decisions and policies laid down by the central government.

Coastal Regulation Zone Notification 2011: an evaluation

On February 19, 1991, the Ministry of Environment and Forests (“MOEF”) issued a notification under Section 3 of the Environment Protection Act of 1986, seeking to regulate development activity on India’s coastline. The approach adopted by the first notification was to define the ‘High Tide Line ’(“HTL”) and ‘Coastal Regulation Zone ’(“CRZ”) and thereafter specify the activities permitted and restricted in the vicinity of the CRZ. This regulated zone was further divided into four categories (CRZ I-IV) as per permitted land use.

There have been about 25 amendments to this notification between 1991 and 2009, some of which have been based on the directions of the Supreme Court. In May 2008, the MOEF brought out a new draft CRZ notification that evoked much criticism from all sections of stakeholders. Eventually this notification was allowed to lapse and the Ministry brought out a fresh notification in September 2010, which after much discussions and deliberations, was finally passed as Coastal Regulation Zone Notification 2011 on January 6, 2011.

The current notification has several new positive features:

- It widens the definition of CRZ to include the land area from HTL to 500 m on the landward side, as well as the land area between HTL to 100 m or width of the creek, whichever is less, on the landward side along tidal influenced water bodies connected to the sea. The CRZ also includes, for the first time, water area up to 12 nautical miles in the sea and the entire water area of a tidal water body such as creek, river, estuary without imposing any restrictions of fishing activities. Thus, the main change in the scope of regulation has been to expand the CRZ to include territorial waters as a protected zone. This may have been in response to the criticism that while the earlier CRZ notification regulated development on the coastal stretches, it did not per se deal with pollution of the sea in any direct terms.
- The concept of a ‘hazard line ’has been introduced. While the notification merely states that the hazard line will be demarcated by the MOEF through the Survey of India, by taking into account tides, waves, sea level rise and shoreline changes, this concept owes its introduction to the realisation of natural disasters such as tsunami and floods that may take place in this zone. In May 2010, the MOEF signed a Memorandum of Understanding with the Survey of India for undertaking this exercise over a period of four-and-a-half years, at an estimated cost of Rs 125 crore.

- The concept of classification of CRZ into four zones has continued in the 2011 notification with the following delineation:

1. CRZ I- ecologically sensitive areas such as mangroves, coral reefs, salt marshes, turtle nesting ground and the inter-tidal zone.
2. CRZ II- areas close to the shoreline, and which have been developed.
3. CRZ III- Coastal areas that are not substantially built up, including rural coastal areas.
4. CRZ IV- water area from LTL to the limit of territorial waters of India

CRZ IV has been changed from the 1991 notification, which covered coastal stretches in the islands of Andaman & Nicobar and Lakshwadeep. The MOEF has issued a separate notification titled Island Protection Zone 2011 in relation to these areas.

- A new category called areas requiring special consideration has been created which consists of (i) CRZ areas of Greater Mumbai, Kerala and Goa, and (ii) Critically vulnerable coastal areas such as Sunderbans.
- Clearances for obtaining CRZ approval have been made time-bound. Further, for the first time, post-clearance monitoring of projects has been introduced in the form of the requirement to submit half-yearly compliance reports, which are to be displayed on the Ministry's website.
- With respect to the list of prohibited activities, one of the most important changes has been that of expanding the list of exceptions to the rule prohibiting setting up of new industries and expansion of existing industries. While the earlier exception was limited to those activities which required access to the water front, four other exceptions have been now incorporated which include:
 1. Projects of Department of Atomic Energy;
 2. Facilities for generating non-conventional energy sources and desalination plans, except for CRZ-I zones on a case-by-case basis after doing an impact assessment study;
 3. Development of greenfield airport permitted only at Navi Mumbai; and
 4. Reconstruction, repair works of dwelling units of local communities including fishers in accordance with local town and country planning regulations.
- Another important aspect is the introduction of the Coastal Zone Management Plans, which will regulate coastal development activity and which are to be formulated by the State Governments or the administration of Union Territories.
- In Greater Mumbai, the redevelopment of approximately 146 existing slums in CRZ areas has been permitted, provided that the stake of the state government or its agencies in these projects is not less than 51%. Redevelopment and reconstruction of old, dilapidated, and unsafe buildings in the CRZ-II area has also been permitted. Also, the floor space index (FSI) or floor area ratio (FAR) prevailing in the Town and Country Planning Regulations as on the date of the project

being sanctioned, will apply. In order to ensure that the redevelopment of slums and dilapidated structures in Mumbai are done in the most transparent and accountable manner the Right to Information Act, 2005 will be applicable and auditing will be done by the office of the Comptroller and Auditor General (C&AG) of India.

- The 2011 Notification also lists out certain measures that have to be taken to prevent pollution in the coastal areas/coastal waters.

While the CRZ Notification 2011 has introduced several positive concepts seeking to protect the interest of the local traditional communities, it does have a few drawbacks namely:

- Although the no-development zone of 200 metres from the HTL is reduced to 100 metres, the provision has been made applicable to “traditional coastal communities, including fisher-folk”, thereby giving the chance for increased construction on the coast and higher pressure on coastal resources.
- Disallowing Special Economic Zone(“SEZ”) projects in the CRZ.
- There are no restrictions for expansion of housing for rural communities in CRZ III.

The CRZ Notification 2011 is a major step-up from the 1991 Notification and the MOEF has made special efforts to include specific provisions to benefit the fisher-folk community in all the coastal areas and address the shortcomings of the 1991 Notification such as time-bound clearances, enforcement measures, special provisions for specific coastal stretches etc. There is a significant change in the new notification but there is always need for further improvement.

Shailesh Nayak Committee Report on Coastal Regulation Zone

The Shailesh Nayak Committee was constituted in 2014 with the mandate of examining the issues of the coastal states and union territories of the country with respect to the Coastal Regulation Zone (CRZ) Notification, 2011.

The Central Government, with the intention of conserving and protecting the long coastal environment of India, issued the first Coastal Regulation Zone notification in 1991. This was subsequently revised in 2011. However, many coastal states and UTs expressed their disapproval of the 2011 rules stating that the revised norms would adversely affect their tourism.

- In order to examine the issues of the affected states and UTs, and also to examine inconsistencies and errors in the said notification, the Ministry of Environment and Forests (currently, the Ministry of Environment, Forests & Climate Change) constituted this 6-member committee chaired by the then Secretary of the Earth Sciences Ministry, Dr. Shailesh Nayak.
- The committee submitted its report in 2015 after consultations with all the states concerned.
- The committee recommended many relaxations to the norms that were established by the 2011 notification.

- It also recommended that many powers held by the central government with respect to the coastal areas be diluted.
- The recommendations suggested indicate that the committee wanted to provide a boost to the tourism, real estate and the port construction sectors.

Shailesh Nayak Committee Recommendations

Some of the major recommendations of the committee are discussed below.

- Reducing the ‘No Development Zone ’(NDZ) as specified in the CRZ.
 - For rural areas with a population density of over 2,161 persons/sq km, this NDZ should be 50m from the High Tide Line (HTL).
 - For other areas, the NDZ should be 200m from the HTL.
- Allowing housing infrastructure, slum development activities, ports, tourism, harbour and fisheries-related activities in the CRZs.
- Tourism development activities should be permitted in the NDZs.
- Devolving powers to the state and UT governments as well as the local governments for development and construction activities, except those that needed environmental clearance.
 - The central government’s role in coastal areas ought to be restricted to regulating environmentally-sensitive areas and environmental clearances.
- Allowing reclamations of the sea bed in CRZ IV areas (coastal stretches in the Andaman & Nicobar, Lakshadweep and small islands, except those designated as CRZ-I, CRZ-II or CRZ-III) for purposes of tourism, ports, harbour, bridges, national installations related to coastal security, etc.
- Ecologically sensitive areas (ESAs) in CRZ I should be identified and delineated.
 - CRZ I comprise ecologically sensitive regions such as mangroves, coral reefs, biosphere reserves, bird/turtle nesting grounds, etc.
 - States should prepare coastal zone management plans (CZMPs) for which the committee had provided guidelines.
 - All such ESAs should be notified under the Environment Protection Act, 1986 by the respective state/UT governments.

Importance of the CRZ Notification:

1. India has a long coastline of 7516 km, ranging from Gujarat to West Bengal, and two island archipelagos (Andaman Island and Lakshadweep).
2. Our coastal ecosystems provide protection from natural disasters such as floods and tsunamis to the 250 million people who live in our coastal areas.
3. Coastal waters provide a source of primary livelihood to 7 million households.
4. Our marine ecosystems are a treasure trove of biodiversity, which we are only beginning to discover and catalogue.

Thus, our coastline is both a precious natural resource and an important economic asset, and we need a robust progressive framework to regulate our coast.

Status of the Report:

The committee was formed in 2014 and its report was made available to the public only in June 2016 after intervention by CIC. While the ministry has not publically approved the findings of the report, the recommendations have been a source of several piecemeal but substantive amendments. For instance, upon request by the Municipal Corporation of Greater Mumbai to amend the CRZ regulation to allow for construction of a road, the notification was amended to allow “land reclamation for construction of coastal road”. So far the ministry has implemented 8 amendments on the basis of findings of the report.

Assessment of the Recommendations

Environmental Impact

1. Opening of seas for reclamation for projects in “public interest” can open a pandora’s box with respect to sustainable management of coasts. Overexploitation in the name of development can affect marine life and coastal ecosystem. For instance, while constructing road by Municipal Corporation of Greater Mumbai, the local population complained extensively of pollution
2. With the environmental clearance regime also relaxed especially for construction activity recently, if implemented, the Nayak committee recommendations could lead to a construction boom along the coast line.
3. Allowing construction activities so near to the coast will put the local population at greater risk from tsunamis etc. Allowing construction activities can also lead to depletion of mangroves, forests near coasts which act as the first line of defence in case of tsunamis, cyclones etc
4. Proposing new, lightly regulated tourism in “no development zones” is also an extraordinary measure. The proper course would be to identify specific areas for such activity, assess its environmental impact, demarcate the area under the State’s management plans, and fix responsibility for enforcement, particularly for pollution control.

Economic Impact

1. According to International Collective in Support of fisheries, any change in 2011 notification will directly impact 3200 marine fishing villages and 1.5 million people whose livelihood is dependent on fishing and allied activities
2. For instance, post construction of road by MCGM, the local fishermen complained that the ferry route to the proposed route pass through their fishing ground and adversely impact their livelihood.

Governance Impact

1. Transferring control of development in CRZII zone (built up cities and towns) from the environment department to state town planning authorities raises question over uniformity, efficacy and capacity of state town planning authorities.
2. The amendment to allow for same floor to surface area in coastal zone like in non coastal zone has not been accompanied by an the capacity of civic bodies, infrastructure and resources for sewage and waste disposal – demands for which will swell with taller buildings and more floors.

Secrecy Issues

1. The report itself has been shrouded in secrecy. The amendments to the CRZ notification are being done without consulting all stakeholders which belies the principles of democracy.
2. The report was made public only post the intervention by CIC, which should have been done in normal course.

Coastal Regulation Zone (CRZ) Notification 2018

The Union Cabinet has approved the Coastal Regulation Zone (CRZ) Notification, 2018 which were last reviewed and issued in 2011.

- CRZ Notification 2018 is based on the recommendations of Shailesh Nayak committee.
- The notification was released after a series of representations received by the Ministry of Environment, Forest & Climate Change (MoEFCC) from various Coastal States/UTs for a comprehensive review of the provisions of the CRZ Notification, 2011.

Salient Features of Notification 2018

- ***Floor Space Index Norms Eased:*** In CRZ, 2011 Notification, for CRZ-II (Urban) areas, Floor Space Index (FSI) was frozen as per 1991 Development Control Regulation (DCR) levels. In the CRZ, 2018 Notification, it has been decided to de-freeze the same and permits FSI for construction projects to enable redevelopment of these areas to meet the emerging needs.
- ***New Categories for densely populated rural areas:*** For CRZ-III (Rural) areas, two separate categories have now been stipulated as below:

- **CRZ-III A** - These are densely populated rural areas with a population density of 2161 per square kilometer as per 2011 Census.
 - Such areas will have a No Development Zone (NDZ) of 50 meters from the High Tide Line as against 200 meters from the High Tide Line stipulated in the CRZ Notification, 2011.
- **CRZ-III B** - Rural areas with a population density of below 2161 per square kilometer as per 2011 Census. Such areas shall continue to have an NDZ of 200 meters from the HTL.
- **Tourism infrastructure in coastal areas:** Temporary tourism facilities such as toilet blocks, change rooms, drinking water facilities etc. have now been permitted in Beaches. However, a minimum distance of 10 m from HTL should be maintained for setting up of such facilities.
- **CRZ Clearances streamlined:** Only such projects/activities, which are located in the CRZ-I (Ecologically Sensitive Areas) and CRZ IV (area covered between Low Tide Line and 12 Nautical Miles seaward) will be required to be cleared by Ministry of Environment, Forest and Climate Change. For, the CRZ-II (urban) or CRZ III (rural) areas, the CRZ clearance will be considered at the state level by the Coastal Zone Management Authority (CZMA).
- **No Development Zone (NDZ) of 20 meters for Islands:** For islands close to the mainland coast and for all Backwater Islands in the mainland, NDZ of 20 m has been stipulated.
 - Ecologically Sensitive Areas have been accorded special importance: Specific guidelines related to their conservation and management plans have been drawn up as a part of the CRZ Notification.
- **Pollution abatement:** In order to address pollution in Coastal areas treatment facilities have been made permissible activities in CRZ-I B area (the area between the Low tide line and High tide line) subject to necessary safeguards.
- **Defense and strategic projects** are exempted from regulations.

Benefits

- **Economic Growth:** The proposed CRZ Notification, 2018 will lead to enhanced activities in the coastal regions thereby promoting economic growth while also conserving the coastal regions.
- **Boost to Tourism and Employment:** It will result in significant employment generation and in better living standard and add value to the economy of India.
- **Boost to Conservation Efforts:** The new notification is expected to rejuvenate the coastal areas while reducing their vulnerabilities.

- **Boost to Housing:** De-freezing FSI Norms will add to creating additional opportunities for affordable housing. This will benefit not only the housing sector but the people looking for shelter.

Concerns

- The notification has simplified procedures for environmental clearances and will open up fragile intertidal areas to real estate agents adding up to the coastal degradation.
- The notification fails to address the concerns raised by the fishermen.

Coastal Regulation Zone (CRZ) norms, 2019

The Union Ministry of Environment, Forest and Climate Change has notified the 2019 Coastal Regulation Zone (CRZ) norms, replacing the existing CRZ norms of 2011.

1. The new CRZ norms have been issued under Section 3 of the Environment Protection Act, 1986.
2. The new CRZ norms aim to promote sustainable development based on scientific principles.

Objective of CRZ Regulations 2019:

1. To promote sustainable development based on scientific principles taking into account the natural hazards such as increasing sea levels due to global warming.
2. To conserve and protect the environment of coastal stretches and marine areas, besides livelihood security to the fisher communities and other local communities in the coastal area.

Salient Features of CRZ Regulations 2019:

Two separate categories for CRZ-III (Rural) areas:

1. **CRZ-III A:** The A category of CRZ-III areas are densely populated rural areas with a population density of 2161 per square kilometre as per 2011 Census. Such areas have a No Development Zone (NDZ) of 50 meters from the High Tide Line (HTL) as against 200 meters from the High Tide Line stipulated in the CRZ Notification, 2011.
2. **CRZ-III B** – The B category of CRZ-III rural areas have population density of below 2161 per square kilometre as per 2011 Census. Such areas have a No Development Zone of 200 meters from the HTL.

Floor Space Index Norms eased: As per CRZ, 2011 Notification, the Floor Space Index (FSI) or the Floor Area Ratio (FAR) had been frozen. As per the latest notification, the government has decided to de-freeze the Floor Space Index and permit FSI for construction projects.

Tourism infrastructure permitted in coastal areas: The new norms permit temporary tourism facilities such as shacks, toilet blocks, change rooms, drinking water facilities, etc. in Beaches.

Streamlining of CRZ Clearances: The procedure for CRZ clearances has been streamlined. Now, the only such projects which are located in the CRZ-I (Ecologically Sensitive Areas) and CRZ IV (area covered between Low Tide Line and 12 Nautical Miles seaward) will be dealt with for CRZ clearance by the Ministry. The powers for clearances with respect to CRZ-II and III have been delegated at the State level.

No Development Zone of 20 meters for all Islands: For islands close to the main land coast and for all Backwater Islands in the main land, No Development Zone of 20 meters has been stipulated in wake of space limitations and unique geography of such regions.

Pollution abatement: To address pollution in Coastal areas, the treatment facilities have been made permissible in CRZ-I B area subject to necessary safeguards.

Critically Vulnerable Coastal Areas (CVCA): Sundarban region of West Bengal and other ecologically sensitive areas identified as under Environment (Protection) Act, 1986 such as Gulf of Khambat and Gulf of Kutchh in Gujarat, Achra-Ratnagiri in Maharashtra, Karwar and Coondapur in Karnataka, Vembanad in Kerala, Gulf of Mannar in Tamil Nadu, Bhaitarkanika in Odisha and Krishna in Andhra Pradesh are treated as Critical Vulnerable Coastal Areas. These Critical Vulnerable Coastal Areas will be managed with the involvement of coastal communities including fisher folk.

Blue Flag Programme

The 'Blue Flag' beach is an 'eco-tourism model' and marks out beaches for providing tourists and beach-goers clean and hygienic bathing water, facilities/amenities, a safe and healthy environment, and involves sustainable development of the area.

The Environment Ministry has relaxed Coastal Regulation Zone (CRZ) rules that restrict construction near beaches to help States construct infrastructure and enable them to receive

'Blue Flag' certification.

- 13 beaches were selected by the Ministry for the certification.
- If a beach meets thirty-three criteria classified under four major heads, the certification is given.
 - Environmental Education And Information
 - Bathing Water Quality
 - Environmental Management Conservation
 - Safety And Services.

Blue Flag Beaches in India – 2021

In Dec 2020, eight Indian beaches held virtual and physical flag hoisting ('Blue Flag') ceremony attended by Union Environment Minister, State Ministers and officials. Among Asian nations, India is now the 4th country after South Korea, Japan and UAE with 'blue flag beaches'.

In Oct 2020, Eight Beaches in India were awarded the prestigious certification, namely:

- Golden Beach – Odisha
- Shivrajpur Beach – Gujarat
- Kappad Beach – Kerala
- Ghoghla Beach – Diu
- Radhanagar Beach – Andaman and Nicobar
- Kasarkod Beach – Karnataka
- Padubidri Beach – Karnataka
- Rushikonda Beach – Andhra Pradesh

The Blue Flag Certification is awarded by a non-profit organization called the Foundation for Environmental Education (FEE).

- To qualify for the Blue Flag certificate, a series of stringent requirements or criteria should be satisfied.
- The criteria are environmental, educational, access and safety related. There are a total of 33 criteria.
- The certification is awarded to beaches, marinas (which are small ports or harbours designed for pleasure yachts or boats) and sustainable boat tourism operators in FEE member countries.
- The Blue Flag is an eco-label and blue flag beaches should provide clean and hygienic bathing water, along with basic infrastructure for tourists.
- Operators of beaches or boating tourism that have been awarded the 'blue flag' are allowed to display the blue flag logo.
- This is awarded to local authorities or private operators only of the member countries.
- Blue Flag also advocates against inequality, disparity, unemployment, depletion of natural resources, health and environmental threats, pollution as well as general environmental degradation.

- The Blue Flag Programme originally started in France in 1985. It was presented to the FEE in 1987. It then became the European Blue Flag.
- In 2001, when South Africa became the first country outside of Europe to join the programme, the initiative changed its name to International Blue Flag.
 - At this time, the FEE acquired its current name, losing an 'E' since earlier it had European in its name.
- There are more than 4000 blue flag beaches worldwide with Spain leading the number of beaches per country with this certification.

About the Foundation for Environmental Education (FEE)

- The FEE is headquartered in Copenhagen, Denmark.
- It was founded in 1981 as the Foundation for Environmental Education in Europe (FEEE).
- Currently, it has 77 member countries.
- Its other programmes include:
 - Green Key
 - Eco Schools
 - Young Reporters for the Environment
 - Learning about Forests
 - Global Forest Fund

Blue Flag Mission

The mission of the Blue Flag Programme is described below:

1. Promoting and participating in environmental educational programmes for the users of marinas, beaches and boating operators.
2. Implementing efficient safety & environmental management systems.
3. Committing to collaborative action & partnerships in order to promote sustainable tourism development.
4. Monitoring environmental conditions in order to mitigate the impact of human activity at the marinas, beaches and boating operators.

Blue Flag Certification in India

In June 2018 it was reported that, Chandrabhaga beach on the Konark coast of Odisha is not only India's but also Asia's first beach to get the Blue Flag certification.

This project was initiated in 2017-2018 as a part of developing model beaches in each coastal UT or state in India. In 2019, the Ministry of Environment, Forest and Climate Change (MoEFCC) had identified 13 beaches in the country for blue flag certification, from which 8 were showcased. This required relaxing certain rules of the Coastal Regulation Zone notification, to enable certain construction activities on the beaches.

The pilot beaches are given in the table below:

Ghoghala beach (Diu)

Shivrajpur beach (Gujarat)

Bhogave (Maharashtra)

Padubidri and Kasarkod (Karnataka)

Kappad beach (Kerala)

Kovalam beach (Tamil Nadu)

Eden beach (Puducherry)

Rushikonda beach (Andhra Pradesh)

Miramar beach (Goa)

Golden beach (Odisha)

Radhanagar beach (Andaman & Nicobar Islands)

Bangaram beach (Lakshadweep)

Coastal Regulation Zone (CRZ) – Recent Developments related to Violations / Clearances

1. The construction of the livelihood support centre for fishermen by Kumbalam panchayat on the banks of Vembanad lake, Kerala is in the eye of the storm. People have approached Kerala Coastal Zone Management Authority (KCZMA) pointing out that the construction is in outright violation of the CRZ and Ramsar site norms.
2. Maharashtra has granted coastal regulation zone (CRZ) clearances to the National Highway Authority of India (NHAI) to cut 1,001 mangrove trees for the eight-lane Mumbai-Vadodara Expressway, which will pass through the Mumbai Metropolitan Region (MMR). The maximum mangrove losses would occur at Navghar and Vadiv villages in Palghar, falling under the Safale forest range. As per NHAI, they are ready for compensatory afforestation as much as 10 times the mangroves lost.
3. In a gross violation of environmental norms, tonnes of construction waste has been dumped in a notified turtle nesting area on Marina beach, Chennai. The area where the debris is being dumped falls under CRZ 1(A) of the Coastal Regulation Zone (CRZ) Notification, which is an ecologically sensitive area and activities like the dumping of construction waste are strictly prohibited. The concerned authorities had assured to rectify the problem.

MODULE - IV

MONITORING AND ENVIRONMENTAL ANALYSES

Role of Environmental Impact Assessment in Integrated Coastal Zone Management

There is a general agreement today that our planet is under stress due to changes brought about by man's activities (Brown et al., 1990, World Commission on Environment and Development, 1987). Before the industrial revolution, these anthropogenic stresses were largely of local nature, but with the advancements in technology and their application in improving the human condition, they have assumed regional and global dimensions. For example, it has been estimated that fluxes of carbon, nitrogen, phosphorus and sulphur induced by man's activities today are of the same magnitude as those associated with the natural global cycles of these elements. The far reaching environmental implications of the global issues such as global warming, depletion of stratospheric ozone, long range transportation of atmospheric pollution, reduction in biodiversity, and depletion of natural resources are also indisputable. It would, therefore, not be an exaggeration if we described man and his activities as a geological force which has not only modified the Earth but has fundamentally transformed it.

We live in an era of extremely complex interdependence between environment and economy and of conflicting interests on a global scale. An integration of various areas of science and learning, and more importantly, integration of conflicting social and economic systems and of ideas and values is a must today. We must deal with environmental issues in a "holistic" rather than a "reductionist" manner. Indeed, it is this need for integration that has given birth to the concept of "sustainable development" and subsequently to a variety of management approaches such as "Environmental Impact assessment" (EIA) and "Integrated Coastal Zone Management" (ICZM). These approaches by their very nature and definition are integrative and holistic, and aim at reconciling conflicting and diverging interests into a cohesive, but dynamic, system to direct human affairs. Under the existing political, economic and social conditions worldwide, however, the achievement of this goal may sound rather optimistic. Prudence, nevertheless, demands that for the long-term sustenance of the biosphere and for a balanced and harmonious coexistence of man and the nature, we guide our actions in light of the broad principles of sustainable development which form the basis of the integrated management approaches such as EIA and ICZM.

Since the ultimate goal of both the EIA process and ICZM is to ensure sustainable development, the purpose of this paper is to explore the role of EIA process in addressing the issues surrounding ICZM.

The Coastal Zone and its Importance

At the outset of this discussion, it is important to understand what we mean by the coastal zone and why it is important to accord a special treatment to its management? Although the coastal zone has been variously defined in recent years, for the purpose of discussion which follows, it would suffice that: the "coastal zone represents that part of the land affected by its proximity to the sea and that part of the ocean affected by its proximity to the land" (U.S. Commission on Marine Science, Engineering and Resources, 1969).

Therefore, the coastal zone can be a narrow area at the land-sea interface or it can extend from hundreds of kilometers inland to hundreds of kilometers offshore. Similarly, UNEP has

functionally defined the coastal zone as the area having significant effects in coastal and nearshore waters. In the management context, therefore, the physical boundaries of the coastal zone should not be fixed and should be issue-oriented.

The unique environmental conditions of the coastal ecosystems support a variety of productive and economically important habitats, such as coral reefs and mangrove forests. These ecosystems are governed by the coastal processes and fluxes, such as material and nutrient flows, and hydrodynamic regimes that keep them in dynamic equilibrium by performing a series of important functions (e.g., primary and secondary production, storage of materials such as sediments and organic carbon, filtration and cleansing of toxic materials, buffering to cope with coastal storm surges and winds). These functions are responsible for generating coastal resources in terms of both goods and services utilized by man (Fig. 1). Although these ecosystem functions are diverse, they are also interdependent and are collectively vital to the sustained productivity of the coastal resources.

In recent years, the dynamic equilibrium and productivity of the coastal ecosystems are being challenged by the increasing human activity, ranging from building dams and the discharge of industrial pollutants in coastal waters to the extensive and unsustainable utilization of renewable and non-renewable coastal resources. Thus, the disruption of coastal processes as the result of human activity and the unsustainable utilization of the coastal resources have threatened the coastal ecosystems. Both the assimilative capacity of the coastal ecosystems and the regenerative capacity of the renewable resources must therefore be taken into account in the resource management equation.

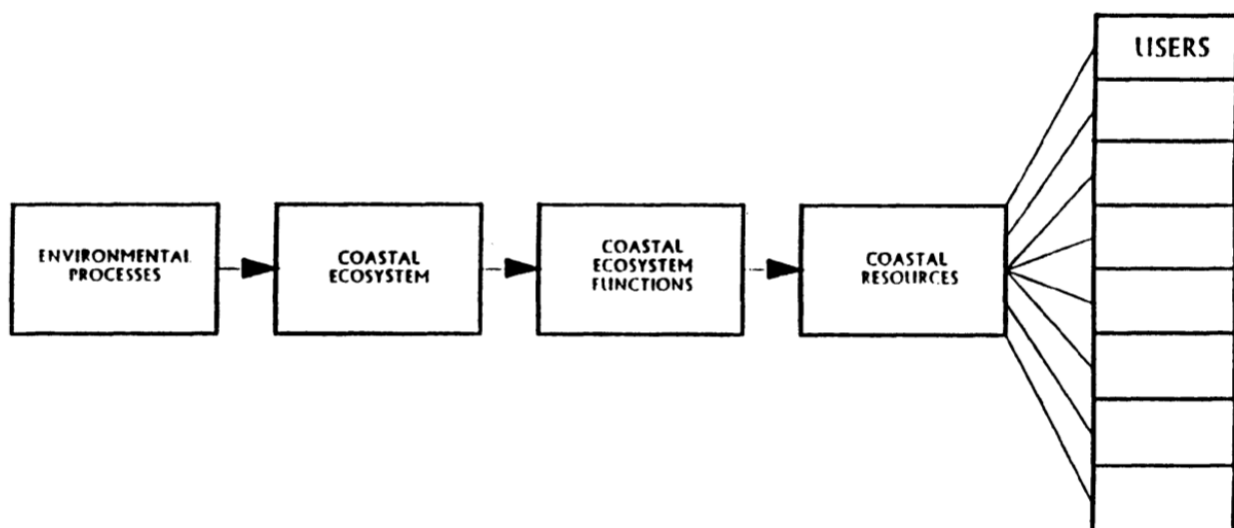


Fig. 1. The Coastal Ecosystem.

There are numerous causes for the devastating coastal resource depletion being suffered by many countries. The most critical causes are high rates of population growth in the coastal areas and economic distress exacerbated by dwindling resources. This situation will worsen as the coastal areas of the world come under increasing human pressures. For example, it has been estimated that by the year 2000, three billion people will be residing in urban areas and approximately 60% of this urban population will be concentrated in settlements located within 50 miles from the shorelines of

the continents. According to one estimate, the coastal urban population of the world will have increased by 380 million between 1980 and 2000 (WRI,1993). This magnitude of population growth and concentration of people in coastal areas is expected to significantly increase the already severe competition for coastal resources and the associated conflicts among different economic sectors. Since 80% of the marine pollution at the present time is from the land-based sources, the pollution stress on the coastal ecosystems will also increase. Despite these alarming statistics, very little is being done to counter these coastal trends as concluded in 'The State of the Marine Environment' by GESAMP (1990b):

"..we are concerned that too little is being done to correct or anticipate situations that call for action, that not enough consideration is being given to the consequences for the oceans of coastal development and that activities on land continue with little regard to their effects in coastal waters."

Chapter 17 (Protection of the Oceans) in Agenda 21 of the UN Conference on Environment and Development (UNCED, 1993) has also identified the unchecked coastal development as an important regional and global issue and has called for actions, including the promotion of EIAs for the prevention, reduction and control of degradation of the marine and coastal environment. Agenda 21 also recognized that many human activities often interact in their impact on the marine environment and only a fully integrated approach to managing these activities in an entire coastal zone can be effective.

Coastal Management Issues

The sustainable management of human activities in the coastal areas represents one of the most complex management challenges of our time. Generally, these issues (e.g., pollution, habitat destruction and resource depletion) are associated with: the fragmentation of jurisdictions, and the lack of biogeophysical understanding of the complex coastal ecosystems which limit prediction of impacts of developmental activities. Thus, the issues in coastal areas are both management and science oriented. This linkage necessitates that scientific investigation be integral to the administrative process. Several specific issues can be identified:

Fragmentation of Jurisdictions: One important issue in coastal zone management is that the administrative and legal institutions are fragmented along sectoral economic lines. It is not uncommon to find a several agencies at various levels of government (municipal, provincial or regional and national) responsible for some aspects of the coast. These sectoral agencies with interests in coastal resources are often reluctant to cooperate in integrated and coordinated policies because of the fear of losing their independent decision-making authority.

The coastal areas, therefore, suffer not only from the conflicting economic and management interests (e.g. mining, oil exploration, and fisheries), but also from the fact that the institutional arrangements treat the marine and terrestrial components of the coastal zone as separate entities, while in fact the two components are intrinsically linked and inter-dependent. To maintain the sustainability of the coastal environment co-ordination of these responsibilities, in the form of a

coastal planning and executive body or an inter-agency coordinating body, must be established to ensure the protection of legitimate sectoral interests.

Management Complexities: The management complexities generated by more diverse ecosystems and greater resource development opportunities in the coastal areas as compared to those found in purely terrestrial or purely marine environments are also a cause for the lack of cooperative and integrative planning in the coastal areas. A central authority for the management of the coast can reduce these management complexities and can foster common understanding of the strategic value of these areas.

Ignorance About the Strategic Value of Coastal Areas: There is a general ignorance among the policy-makers within sectors about the long-term strategic value of the coastal areas. Thus, the policy and planning decisions are often based on short-term economic and political gains. Interaction of various sectors under a central decision-making body would ensure that all sectors recognize this long-term strategic value.

Containment of the Increase in Human Population: One of the major causes of the deteriorating coastal areas worldwide is the rapid increase in population. In many places attempts to control anthropogenic stress on coastal ecosystems have been simply swamped by the increasing number of people who want to live and earn their living in coastal areas. This necessitates strict controls that restrict the increase in population in accordance with the ecological carrying capacity of the coastal region. Strict adherence to the EIA process to predict coastal developments that may accompany an increase in population must be the rule.

Lack of Integrated Information Base: The types of information (e.g., the coastal processes and fluxes, the structural and functional aspects of the coastal ecosystems, and inventories of coastal resources and habitats) necessary for developing a comprehensive view of the coastal areas are generally lacking. Since this synoptic view is essential for the prediction of impacts of human activities on coastal resources, it is important to link the administrative process with rigorous scientific investigation.

It is obvious that an integrated management approach is essential to ensure that efforts and energies of all sectors involved in coastal zone are channeled to achieve the common goal of sustainable (i.e., balanced and optimal) utilization of coastal resources, both in terms of marketable goods, such as fisheries, and services, such as navigation and recreation. In addition, the EIA process, as Originally envisaged in the 1969 National Environmental Policy Act, can play a significant role in the resolution of these issues.

Integrated Coastal Zone Management and its Objectives

ICZM is variously defined in recent literature, but generally it is understood as: a dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources to achieve the conservation and sustainable multiple use of the coastal zone" (Coastal Area Management and Planning Network, 1989).

The broad objectives of ICZM can be outlined as: 1) to increase benefits to be derived from resource or non-resource use of the coastal zone; 2) to minimize detrimental effects on the marine environment; and 3) to reduce conflict of use situations.

In order to achieve these objectives, however, it is imperative that we adopt certain principles that are consistent with the philosophy of sustainable development (World Commission on Environment and Development, 1987). The principles listed below are common to both ICZM and EIA.

Principles of Sustainable Development Common to ICZM and EIA Process: The following eight principles have emerged and crystallized since the publication of the report of the World Commission on Environment and Development (also known as the Brundtland Report) in 1987, and are both substantive and process-oriented. Collectively, these eight principles must form the basis of policies and management frameworks, such as ICZM. None of these principles can be compromised if sustainable development is the prime management goal:

- 1. Development is necessary for the satisfaction of basic needs such as water, food, jobs, sanitation and energy. These needs can, however, be met in the long term by conserving and enhancing the resource base. Thus, economic growth will have to be equitable in its impact on resources.*
- 2. Ecological integrity must be maintained within the limits of ecological carrying capacity. This principle encompasses the three goals of the World Conservation Strategy, that is the maintenance of essential ecological processes and life support systems, preservation of genetic diversity, and sustainable utilization of species and ecosystems. This principle also maintains that attention must be paid to the restoration of already degraded ecosystems.*
- 3. Equity and social justice must be applied in the per capita use of resources between nations and between generations. This is a major theme of the 1987 Brundtland Report and requires that decision-making take into account inter-generational consequences of actions on living standards, and fair distribution of power to ensure equitable access to resources by sectors and nations.*
- 4. While government regulations are necessary for the regulation of private and corporate sectors, public participation and involvement in decision making is necessary in promoting ecologically sound behavior.*
- 5. Approaches to sustainable development must be goal-seeking in a proactive and dynamic way. Objectives should be continually reviewed and adjusted to address the present and future needs.*
- 6. Approaches to sustainable development must take into account the spatial and temporal aspects of decision-making. For example, local actions can have regional and global implications and, therefore, they should be viewed in that context.*
- 7. Strategies for sustainable development must be adaptive. Management strategies must be adaptive through anticipatory and preventive approaches to risk management, and feedback mechanisms must be built into these strategies to facilitate dynamic and responsive management.*

8. Organizational approaches should be interactive. This principle emphasizes the need for promoting interdisciplinary and inter-sectoral collaboration for the synthesis of management strategies.

It is implicit in these principles that the concept of sustainable development is only an extension of the basic concept of sustainability such as the maximum sustainable yield in fisheries science, which allows the annual harvest to be equal to the annual increase in fish biomass. The goal, however, has been extended to include societal welfare, while maintaining the integrity of vital ecological processes and the ecological carrying capacity. Thus, the three goals of sustainable development, environmental, economic and social, are not only related, they also overlap with each other, generating conflicts which require compromise and resolution (Fig. 2). How can the sustainable development be achieved in a society that has divergent groups with conflicting interests when, for example, environmentalists want environmental systems sustained, consumers want consumption sustained, and workers want jobs sustained. Similarly, various sectors such as fisheries, mining and forestry want the activities of their sectors sustained in the interest of national economy.

Indeed, the challenge for scientists, economists and decision makers in the years to come is to develop a management framework that can deal with the conflicts inherent in the application of the concept of sustainable development in programs such as ICZM. In the interim, however, it appears that the entrenchment of a comprehensive EIA process with its related planning and assessment procedures into law, is probably the least painful entry point to translate the principles of sustainable development into a strategic and management framework.



Fig. 2. The Three Overlapping Goals of Sustainable Development - A Systems' Perspective (adapted from Sadler, 1990).

Environmental Impact Assessment and its Role in ICZM

EIA is a term applied to both a governmental process and an analytic method to assess the impact of policies, programs and development proposals on the biophysical and socio-economic environments.

Principle 17 of the Rio Declaration has explicitly acknowledged the practical contribution that EIA can make to informed decision making. Application of EIA is now generally accepted as a prerequisite to sustainable development and holistic environmental management.

Limitations of Environmental Assessment: Despite EIA's success in Canada, the US and some European countries, the currently practiced EIA process has certain limitations and needs reforms that would be more compatible with the principles of sustainable development:

- Despite its original intent EIA is generally not applied to policies and programs and is limited only to projects.
- EIA is applied to new but not existing projects or activities.
- The EIA analysis tends to be descriptive rather than predictive, partly because of the limitations placed on prediction by our lack understanding of the ecological processes and systems.
- The analysis are generally not supported by monitoring and follow up assessment..

- EIA is usually applied to large-scale projects such as hydroelectric dams and oil and gas exploration activities on public lands, and does not address the cumulative effects of small decisions which in time and space produce large-scale environmental impacts.
- The cumulative effects of human activities in both the temporal and spatial terms have generally been ignored. The concept of cumulative effect assessment is based on the premise that all ecosystems are connected and shared and respond to the cumulative impact of all stresses to which they are exposed. Cumulative effects have both spatial and temporal dimensions and can range from local and short-term to the global and long-term. Their complexity, both in terms of scientific analysis and in terms of administrative procedures, increases with the increase in temporal and spatial dimensions. The concept of cumulative effect assessment provides a perspective to deal with the causes of unsustainable development and must be incorporated in EIA.
- Rehabilitation of degraded ecosystems are usually not considered. In the assessment of projects to be sited in the degraded regions, EIA should have a retrospective view of the environmental change and should take into account plans for the redevelopment and rehabilitation of the degraded and damaged ecosystems.

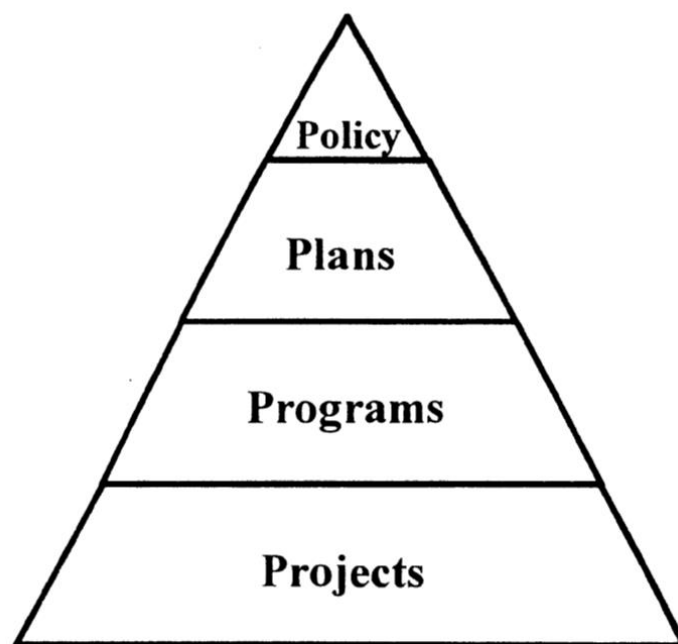


Fig. 3. Hierarchy of Planning Phases in Strategic Environmental Assessment.

Strategic Environmental Assessment: The limitations of EIA outlined above are directly or indirectly related to the fact that the relationship of EIA with policy making has been generally misunderstood, and the concept of Environmental Assessment (EA) is perceived as a process to deal with the environmental and socio-economic impacts of only the major developmental projects. With the coming in force of the U.S. National Environmental Policy Act (NEPA) in 1969, EA was meant to test, inform, and reorient federal decision making. Specifically, NEPA's Section 102(2)(c) makes explicit reference to "proposals for legislation and other Federal actions significantly affecting the environment. Similarly, Canada's Environmental Assessment and Review Process Guidelines Order requires that EA process be applied "as early as possible in the decision-making

process". In reality, for whatever reasons, this has not happened and with some exceptions, it has been largely project-oriented and has focused on "how" rather than "whether" or "where" development should take place.

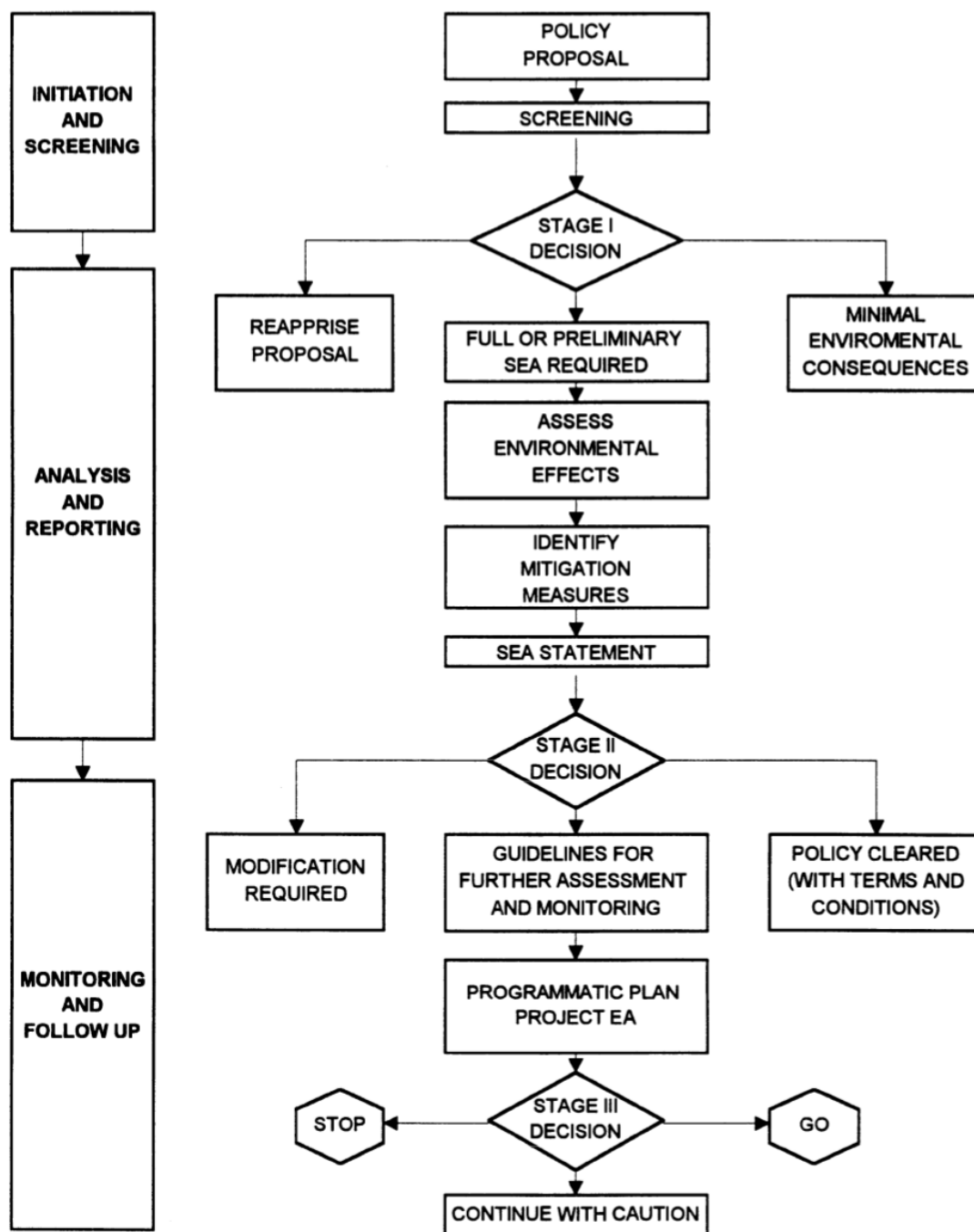


Fig. 4. A Flowchart showing the Application of Strategic Environmental Assessment (adapted from Sadler, 1994).

Originally, EIA was conceived as a comprehensive means of anticipating and preventing environmental and socio-economic problems associated with policies, plans and programs, as well as specific projects to counter the expensive traditional/React and try to cure" strategies. It can be defined as: "a formalized process which attempts to identify and predict the impacts of policies, legislative proposals, programs, projects and operational procedures on the biogeophysical environment and on human health and well-being. It also interprets and communicates information

about those impacts and investigates and proposes means for their management and remediation". The EIA process can be visualized as hierarchy of planning phases, a pyramid with the policy at the top and progressing downwards through programs to specific projects which form the base of the pyramid (Fig. 3). In the absence of this strategic framework, the project-oriented EIA will continue to prevail, as has been generally the case and the EIA process will continue to suffer from the lack of information which would otherwise be available to predict the costs and benefits of development proposals.

Concluding Remarks

The basic framework of Strategic Environmental Assessment (SEA) is similar to the project-oriented environmental assessment process and can easily be adopted if political will to base management decisions on the principles of sustainable development exists (Fig. 4).

The adoption of a systematic and phased approach to environmental planning or SEA as outlined in Figures 3 and 4, can play a significant role in ICZM, by providing a synoptic view of environmental assessment. SEA can address critical issues of coastal zone management by: 1) ensuring and facilitating intersectoral consultation and public participation; 2) improving planning and decision making by predicting impacts on the bio-physical and socio-economic environments, and ensuring that the environmental concerns are considered along with economic, financial and technological concerns in decision making; 3) providing the means for information necessary for the reliable prediction of impacts understandable by policy makers; 4) enabling governments to enforce decisions based on the results of the EIA process; 5) ensuring integrated approaches for assessing and evaluating the sustainability of developmental policies; and 6) facilitating consideration of cumulative and delayed impacts.

The adoption and strict implementation of SEA process, therefore, can be an impetus for the administrative change needed for the ICZM. Its most significant contribution could be the enhancement of interagency coordination and dissemination of information about the proposed actions (policies, programs, and projects) and their biophysical and socio-economic impacts.

Strategy for Monitoring the Environment in the Coastal Zone

Located between the open ocean and the terrestrial domain, the coastal regions of the world are characterized by intensive physical, biological and social interactions. In total, coastal areas comprise only 8 % of the world's surface area but they are extremely attractive for human settlement and social activity due to their wealth of natural resources and amenities. They are biologically highly productive, hubs of industrial infrastructure and economic growth, and highly desirable for tourism and recreation. It is this very attraction that has led to intense pressures on the diverse and valuable resources of the coastal regions; pressures that are likely to increase.

Just as today's population in coastal areas of the world is nearly the same as the entire global population in the 1950s, it is expected that in the coming 30 years coastal population will approximate the total global population today 5.5 billion people. The trend of increasing population densities in coastal areas is much more pronounced in Asian countries than elsewhere. Megacities, such as Calcutta, Bombay, Shanghai, Seoul, and Karachi are already burgeoning from population

growth. They are expected to become even bigger and be ranked among the top ten most populated cities in the world in the near future. Without a well-conceived strategy to respond to population growth and space requirements, accelerated loss of habitats (e.g., wetlands, mangroves, seagrasses), vulnerability to natural hazards (e.g., beach losses due to erosion and impoundment), and diminished economic potential (e.g., closure of recreational facilities, poor harvest of renewable resources, contaminated seafood, and loss of aesthetic value) are more likely to exacerbate. The present day collection of environmental problems and resource-use conflicts could coalesce into a series of national or regional crises within the foreseeable future. In recent years, the concept of Integrated Coastal Zone Management (ICZM) has been advanced in order to anticipate and resolve complex coastal management issues, ranging from resource conservation, to improved environmental quality and amenities, to strengthened economic vitality, to balanced human uses of the coastal zone. In essence, ICZM implies knowledge of the coastal environment, identification of policy issues and priorities; consideration of economics and legal issues relating to coastal resource use; and coordination of activities among layers (vertical structure) and branches (horizontal structure) of government (Fig. 1). The World Coast Conference '93 generated a framework for ICZM as follows: ICZM involves the comprehensive assessment, setting of objectives, planning and management of coastal ecosystems and resources, taking into account traditional, cultural and historical perspectives and conflicting interests and uses; it is a continuous and evolutionary process for achieving sustainable development (IPCC, 1994). To put in a simpler perspective, ICZM could be used to address the question: Can developing nations commercialize, industrialize, and become affluent consumers without ravaging their coastal and marine resources, grossly polluting their air and water, and endangering the health of their population?

This paper provides a framework, with a few illustrative examples from work done in the United States, for environmental monitoring in the context of ICZM. It is not intended as a blueprint for establishing a regional monitoring program in any particular country; rather, it provides a strategy to define the program's scope within which a suite of measurement activities should be designed and streamlined to address the environmental issues in question. Specific topics such as biological and chemical analytical techniques, quality assurance protocols, data management, and information dissemination procedures are not included herein for the sake of brevity; their details can be found elsewhere.

Significance of Environmental Monitoring

Environmental monitoring is viewed as an integral, and often the most critical, component of coastal resource management as it provides information that can be useful not only for the protection and rehabilitation of the natural environment and its valued resources but also evaluation of public policy mandates designed to abate the degradation of coastal environmental quality (NAS, 1990). In this context, monitoring programs must be comprehensive: they should include time-series measurements, field and laboratory experimentation, conceptual and analytical modeling, information synthesis, and reporting in usable formats. To be successful they must operate as a continuous, interactive and iterative process. In terms of their objectives, they must focus on specific environmental problems or issues to be addressed and practical management alternatives.

Cause-effect (or dose-response) relationships, natural variability, and uncertainty in measurements must be carefully considered in program design, site selection, and sampling frequency.

Purpose and Objectives

The primary purpose of regional environmental monitoring programs is to describe the condition of the natural environment and health of its biological resources. Their specific objectives may include: (1) To assess the magnitude and spatial extent of environmental degradation due to chemical contaminants and other anthropogenic sources; (2) To determine temporal trends in the levels of environmental degradation due to chemical contaminants and other anthropogenic sources; (3) To document incidence of pathological conditions, physiological dysfunction and biochemical abnormalities in sentinel organisms resulting from environmental degradation; (4) To formulate composite indices or sets of indicators that communicate information about the condition of the natural environment and are tractable toward public policy objectives.

Although research to increase the understanding of natural processes, cause-effect relationships between environment degradation and the health of biological resources, and cumulative impacts is not explicit in these objectives, it is required, perhaps more so in a sub-regional context, to interpret monitoring results in terms of specific management questions. In turn, this would improve the effectiveness of monitoring programs in an iterative sense over the long term.

Program Design

Environmental monitoring has been described as a first important step in "defining the extent and severity of pollution, evaluating environmental policies and actions, helping to estimate the risks and consequences of future actions, and detecting emerging problems before they become severe" (NAS, 1990). Inclusion of scientific construct, restatement of environmental issues as testable null hypotheses, and an objective field sampling protocol are key requisites for a credible monitoring program. Under circumstances where such is not the case, monitoring results and evaluative studies tend to become too broad to adequately respond to decision-making needs.

It is highly desirable to involve scientists and decision-makers in reaching a consensus on which resource management questions to address and what to monitor. There is often a risk that the monitoring program will be somewhat restrictive since management decisions are usually centered on "valued ecosystem components," and based on institutional constraints and short-term implications. For example, increased amounts of petroleum hydrocarbons in benthic sediment may be important only if it can be shown to originate from a particular industrial activity and linked to adverse effects on commercial species, species with recreational or subsistence value, and aesthetic factors within the time frame of that activity. Quite often, such programs lack operational definition of what an adverse effect might be and are of a short duration; as such, they are relegated to a highly unsatisfactory "survey and explain" monitoring approach. There may be situations or potential long-term effects that seem important enough to merit continued observations even in the absence of a reasonable causal mechanism. Many such situations - for example changes in the health or numbers of certain species, nature of sub-lethal or apparent cumulative effects, or inferred extent of susceptibility of biota to contaminant exposure - are diagnosed in "far-field monitoring"

programs. However, they are best studied in a coordinated program of research and monitoring, and in a localized context.

In the US, the Environmental Monitoring and Assessment Program (EMAP) of the Environmental Protection Agency (EPA) and the Mussel Watch project of the National Oceanic and Atmospheric Administration (NOAA) are two examples of such "far-field" monitoring programs. They tend to forego intensive, site-specific monitoring data for use in local or subregional management of coastal resources in return for reliable data on regional or nation-wide changes and temporal trends in environmental quality. On a zero-sum basis, it is obvious that seasonal monitoring would result in a four-fold reduction in the area coverage and monthly sampling would result in an order of magnitude reduction in sampling sites.

More frequent and detailed monitoring, in terms of parameters, at a number of "sentinel sites" is often presented as an alternative to regional extensive monitoring. Such an approach would be suitable if the widely isolated "sentinel sites" were representative of coastal ecosystems at risk from environmental degradation; if not, monitoring data would only be useful for determining temporal trends at individual sites. Considering the sensitivity and vulnerability of different coastal systems and a complex matrix of poorly defined stresses on those ecosystems, it would be difficult, if not impossible, to infer regional conditions from "sentinel sites" alone.

The dual-purpose of environmental monitoring - defining the status and temporal trends in environmental quality nationwide or in a broad spatial context, and providing data to address specific coastal resource management needs in a regional or local context - necessitate a tiered structure for the monitoring program. According to such a structure, a national monitoring network would consist of sparsely distributed stations encompassing the entire study area i.e., territorial coastal region or some other entity, and would be expected to continue indefinitely. Its sampling sites would be selected for long-term trend assessment of few common parameters of environmental quality and coastal ecosystem health. A number of intensive, regional monitoring programs would be embedded within the national network and expected to be finite in duration. Regional monitoring programs, to be implemented as a joint national or Federal effort with state or provincial government and designed with contributions from a variety of stakeholders, would be tailored to support specific environmental and ecosystem management needs in the region. The program would include specific hypotheses (and test them using scientific data from field and laboratory experiments) relating to specific cause-effect relationships between valued coastal resources and environmental degradation or habitat alteration. Data and results from the intensive, regional monitoring programs would be presented as information synthesis reports, integrating monitoring data with those from environmental assessment and research programs in the region, describing sources of environmental pollution and ecosystem degradation, and evaluating the impact of government programs to maintain or enhance coastal environmental quality or ecosystem health.

Combining and coordinating field sampling, data analysis and interpretation of results on key environmental attributes and ecosystem parameters - which operate on different spatial scales and temporal frequencies - will also result in a continuum of observations that is essential to achieving a comprehensive and holistic understanding of regional environments and ecosystems. Using a hierarchical scheme in the designs of national and regional monitoring programs, particular

emphasis will be placed on areas, of marine populations and other resources under greatest stress from chemical contaminants, nutrient over-enrichment, degradation of habitats, unusual plankton blooms, biotoxic events, and other stresses to ecosystem health and environmental quality. This will facilitate: 1) formulation of specific hypotheses for elucidating cause-effect relationships, and for developing appropriate study design; 2) preparation of interpretive reports that will identify the factors affecting ambient environmental quality, contaminant loading in the benthic environment and biota, and the health and quality of living coastal ecosystems; and 3) recommendation for management actions or other measures to restore degraded environmental quality and ecosystems. An overall coordinated approach (establishing a nationwide monitoring program, emphasizing regional environmental and ecosystem management issues, and providing for a continuum of observations using a consistent system of measurements) has also been advocated by the National Research Council (NAS, 1990).

Such a tiered structure may be quite appropriate for a monitoring program in developing countries. If we take the case of Pakistan as an example, a sparse network of permanent monitoring sites could be set by the Federal government over its territorial domain. Intensive, regional monitoring programs could be set up, based on identified resources management issues and cooperatively with provincial governments and non-government entities. Off the Pakistan coast, different physiographic segments of the coastline also have markedly different major environmental concerns: Indus River Delta (curtailed freshwater flow from Indus River depleting mangrove cover and associated ecosystems; contaminant load from the expansive watershed of the river; deterioration of shrimp aquaculture sites; and impaired biological productivity), Karachi coast (ever-increasing pressures on coastal resources due to rapid population growth; massive and largely uncontrolled pollution from municipal, medical and industrial sources causing degraded habitats, diminished aesthetic values, and risks to human health; and preemption of coastal sites due to expanding industrial and maritime infrastructure), Lasbela coast (nascent shellfish fishery; recreational use of beaches; and impending coastal development), and the relatively pristine Makran coast (tectonic vertical movements following earthquakes, sea-level change; marine biodiversity; fisheries economy; planned expansion of maritime facilities; and possible development of mineral resources).

Sampling Regimes

Once a decision has been made on the overall monitoring strategy, special consideration should be given to field sampling, analytical techniques, quality assurance and data management aspects of the program. Sampling in certain large-scale monitoring programs, such as the US Mussel Watch project, is essentially based on intuition and accumulated knowledge. The selected sites are away from waste discharge points or other "hot spots" and some coincide with a previous monitoring efforts that sampled bivalves along the US coast. Sites selection in Environmental Monitoring and Assessment Program of the US Environmental Protection Agency is based on hierarchical sampling within spatially identifiable sampling units, 40 km² hexagons centered on the points of a systematic triangular grid, superimposed over the area of interest. Site selection in sediment toxicity assessment surveys, conducted as part of the NOAA's National Status and Trends Program, is based on stratified-random block design. In this scheme, blocks or zones are selected on the basis of physiographic and sedimentological features and information on the extent of environmental

degradation, and samples sites are chosen on a random basis. The merits and limitations of non-probability sampling as well as systematic, stratified, and two-phased sampling have been amply discussed in a number of reviews. Also important in sampling considerations is the concept of the power of the statistical test [power = $1-b$, where b is the chance of missing a change that has actually occurred], i.e., the probability with which a change of a particular magnitude would be detected. Inclusion of the power of the test parameter in deriving an optimal sampling design also has practical significance since this would incorporate technical and management (including cost) considerations in a statistical framework. It allows estimation of the number of samples (and, thereby resources) that would be needed, for example, to detect a 10 or 50 %change in contaminant loading with a 80% power of detecting such a change.

Contaminants of Interest

Literally hundreds of chemical contaminants and other substances reach the coastal waters by way of atmospheric deposition, freshwater runoff, industrial effluents, and municipal discharges. Many of them are known to accumulate in various tissues of biota, several are known to cause adverse biological effects in humans and wildlife ranging from reproductive impairment, physiological dysfunction, biochemical aberrations, and behavioral changes. Organochlorine compounds are noteworthy in this regard due to their variety and persistence in the environment, and their demonstrated harmful effects on biota. Nearly 15,000 chlorine-containing compounds are currently produced for use in pesticides, herbicides, fungicides, pharmaceuticals, disinfectants, and many consumer products. Some are produced as by-products during polyvinyl chloride (PVC) manufacturing or bleaching in the paper and pulp industry. More than 5,000 formulations have been listed under the general category of pesticides. These formulations, made from 650 or so active ingredients, include insecticides, herbicides, fungicides, nematocides, rodenticides, and other biocides or repellents. It is estimated that 1 to 2 billion pounds, depending on classes of compounds presumed to be "pesticides," was used in the US annually. The total amount of 35 commonly used pesticides used in coastal drainage areas in the conterminous US in 1987 was estimated at 30 million pounds. Data on worldwide use of pesticides are generally unavailable or unreliable; they can be estimated by assuming that pesticide use in the US is about one-third of the total world use. In other estimates, pesticide use in the US is assumed to be one-half of the world's total. Since most pesticides are biochemically very active, they pose significant threat to non-target organisms, including humans. It is estimated that, on the whole, known costs of environmental contamination, loss of fish and wildlife, and human health hazards, and other ancillary losses due to pesticide use add up to \$8 billion per year.

Box 1. Organic Contaminants and Major Trace Elements that have recently been measured as a part of NOAA's National Status and Trends Program.

Chlorinated Pesticides	Polycyclic aromatic Hydrocarbons	Benzo(e)pyrene
2,4'-DDD	<u>2-ring</u>	Perylene
4,4'-DDD	Biphenyl	Dibenz(a,h)anthracene
2,4'-DDE	Naphthalene	Benzo(b)fluoranthene
4,4'-DDE	1-Methylnaphthalene	Benzo(k)fluoranthene
2,4'-DDT	2-Methylnaphthalene	<u>6-ring</u>
4,4'-DDT	2,6-Dimethylnaphthalene	Benzo(ghi)perylene
Aldrin	1, 6, 7-trimethylnaphthalene	Indeno(1,2,3-cd)pyrene
Dieldrin	C1-C4 naphthalenes	Major elements
Alpha-chlordane	<u>3-ring</u>	Aluminum
Cis-nonachlor	Fluorene	Iron
Trans-nonachlor	Phenanthrene	Manganese
Oxychlordane	1-Methylphenanthrene	Silicon
Heptachlor	Anthracene	Trace elements
Heptachlor epoxide	Acenaphthene	Antimony
Lindane (gamma-HCH)	Acenaphthylene	Arsenic
Alpha-HCH	Dibenzothiophene	Cadmium
Hexachlorobenzene	C1-C2 Fluorenes	Chromium
Mirex	C1-C4 Phenanthrenes	Copper
Endrin	C1-C3 Dibenzothiophene	Lead
Endosulfan I	<u>4-ring</u>	Mercury
Endosulfan II	Fluoranthene	Nickel
Chlorpyrifos	Pyrene	elenium
Polychlorinated Biphenyls	Benz(a)anthracene	Silver
Congeners PCB-8,18, 28, 44, 52, 66,101, 105, 118, 128, 138, 153, 179, 180, 187, 195, 206, 209	Chrysene	Tin
Mono-, Di, Tri-butyltin	C1-C4 Chrysene	Zinc
	<u>5-ring</u>	Related parameters
	Benzo(a)pyrene	Grain Size
		Total Organic Carbon
		Lipid

Dozens of petroleum hydrocarbons and associated non-hydrocarbon contaminants, as well as non-petrogenic hydrocarbons, are ubiquitous in the coastal and marine environments of the world, including the Arctic and the Antarctic. It was estimated a total of 3.2 million metric tons of petroleum is discharged or accidentally released into the world's ocean annually (NRC, 1985). This estimate, with a range of 1.7 to 8.8 million metric tons, includes inputs from various sources such as offshore production, marine transportation and shipping, municipal and industrial effluents, atmospheric transport, coastal and river runoff, and natural sources. Coastal contamination from a wide variety and globally-used industrial chemicals, such as polychlorinated biphenyls and organotin compounds, is even more difficult to estimate.

Most countries or regional authorities formalize lists of chemical contaminants or other pollutants for remedial activities of the coastal environmental resources, often in accordance with their environmental quality statutes. The lists are generally derived in consideration of the environmental persistence, toxicity, and bioaccumulation potential in the ecosystem. Such listings become known as "priority pollutant list," "black and gray lists," or "red list." Concentrations of eighty (80) different chemical compounds, isomers and elements (Box 1) in bottom sediments and bivalves are measured on a routine basis in coastal regions of the US as part of the National Status and Trends Program. Several low molecular weight, volatile or highly water-soluble chemical contaminants are not measured on a routine basis. Also not included in the nation-wide monitoring are certain "contemporary" pesticides, such as atrazine, methyl-parathion, and carbaryl. Such chemicals could be included in region-specific, more intensive studies that are designed to address regional or sub-regional coastal resource management issues.

Box 2. Advantages of Bivalves as Sentinel Organisms for Marine Environmental Quality Monitoring (adapted from Farrington, et al., 1983)

1. *Wide Distribution:* Bivalves, notably mussels, are geographically widely distributed, minimizing problems inherent in comparing data from markedly different species.
2. *Bioaccumulation:* Bivalves can accumulate contaminants in their body tissues in concentration 2-5 orders of magnitude higher than in the surrounding medium.
3. *Metabolic Transformation:* Bivalves seem to have lesser propensity for metabolizing contaminants than, for example, fish or crustaceans.
4. *Repetitive Sampling:* Being sedentary and having stable populations, bivalves are amenable to repeated sampling to determine temporal trends in concentration of contaminants
5. *Portability:* Bivalves can be transplanted and maintained at sites where they do not occur naturally thereby allowing greatly expanded study area
6. *Commercial Value:* Bivalves are commercially harvested as food in many areas of the world; as such, tissue contaminant data are of interest from both environmental and public health perspectives.

Program Components

Mussel Watch: Mussel Watch programs are credited for providing uniform and comparable sets of data on marine pollution (Box 2). The first such program in the US evolved following recommendations of the National Academy of Sciences in 1975. The program collected and analyzed samples from 62 sites on the east and west coast of the US during the period 1976-78. The program was adapted in 1977 for use in water quality surveillance and monitoring efforts of the

State of California, although in recent years greater emphasis has been placed on assessment of sediment toxicity, in situ changes in benthic biological community structure, and occurrence of pollution indicator species (SCCWRP, 1995). The French Mussel Watch program has maintained a network of sites since 1979 to describe the quality of the marine environment around its coast.

The use of mussels, or other bivalves, in assessing the extent of chemical contamination of coastal water in other parts of the world has been endorsed as the International Mussel Watch Program under the sponsorship of the Intergovernmental Oceanographic Commission, the United Nations Environmental Program's Ocean and Coastal Areas Program, and the US National Oceanic and Atmospheric Administration. Its initial phase was recently concluded with sampling at 76 sites in the central and South America and the wider Caribbean area (IMWP, 1995). The next phase of the program will be in the Asian-Pacific region. The International Mussel Watch Project has been valuable in terms of capacity building in host countries, comparison of data between regions, and collective awareness of the condition of coastal resources.

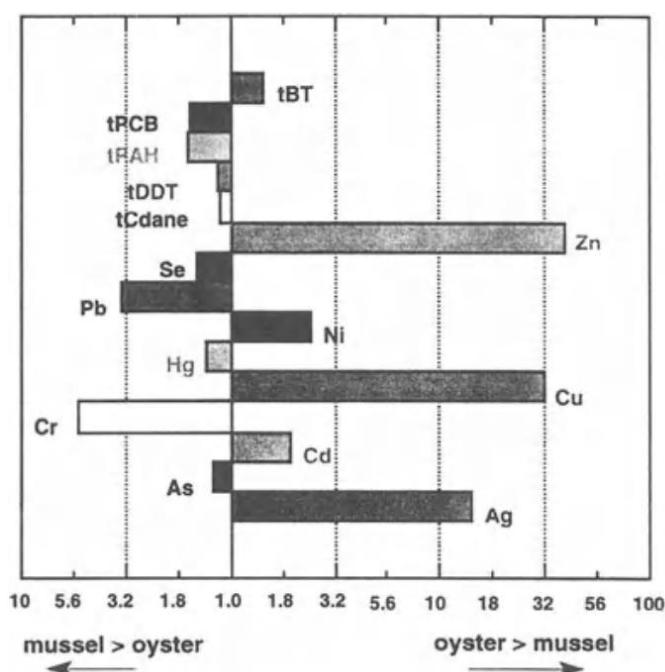


Fig. 1. Factors by which contaminant concentrations in mussels differed from those in oysters at a site in Long Island Sound in 1989 (O'Conner *et al.*, 1994).

Since 1986, Mussel Watch has remained a major component of the National Status and Trends Program that is managed by NOAA. Along the coasts of the US, seven different bivalve species are sampled: the blue mussel or bay mussel *Mytilus edulis* on the East Coast from Maine to New Jersey, the American oyster *Crassostrea virginica* on the East Coast south of Delaware Bay and in the Gulf of Mexico; the blue mussel *Mytilus edulis* and the California mussel *Mytilus californianus* on the West Coast, the oyster *Ostrea sanvicensis* in Hawaii, the mangrove oyster *Crassostrea rhizophorae* in Puerto Rico, the zebra mussel *Dreissena polymorpha* at site in the Great Lakes, and the smooth-edged jewel box clam *Chama sinuos* at a site in Florida Keys.

The paradigm of comparability of Mussel Watch data among regions is compromised by the fact that no single species is present everywhere even though the blue mussel *Mytilus edulis* is very

widely distributed in the northern hemisphere. Clearly, there are differences in patterns of bioaccumulation of contaminants between mussels and oysters. Oysters are known to accumulate zinc in detoxified form in very high concentrations and mussels are believed to excrete or otherwise eliminate much of the accumulated zinc. In a study of mussels (*Mytilus edulis*) and oysters (*Crassostrea virginica*) collected at a single site, oysters showed much larger accumulation - exceeding a factor of 10 - of silver, copper and zinc (Fig. 1). On the other hand, mussels showed greater tendency to concentrate chromium and lead, and most of the organic contaminants tested (total PCBs, total PAHs, total DDT, total chlordane).

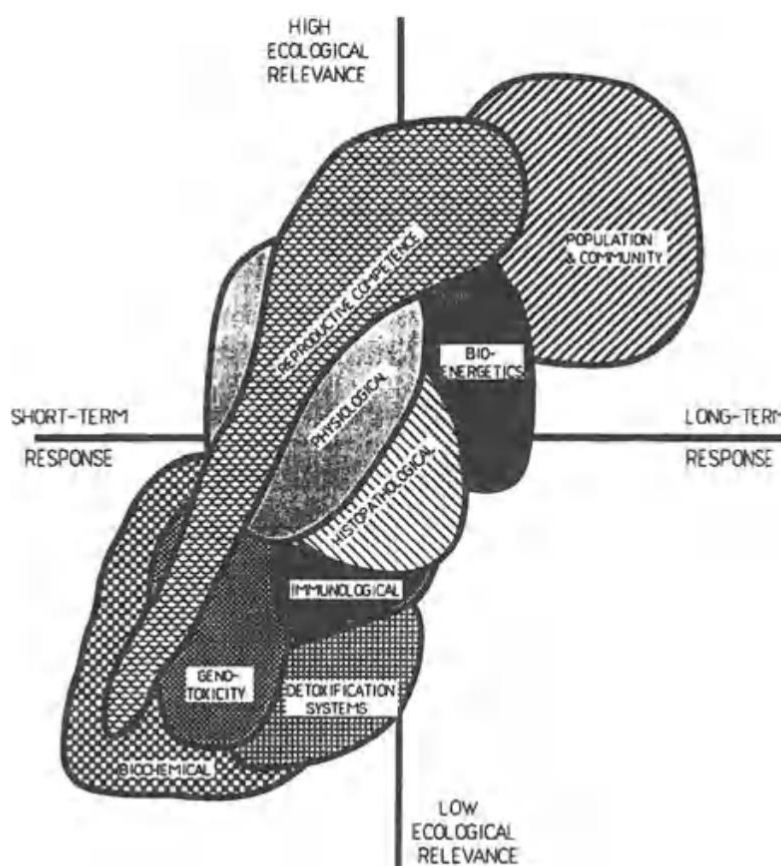


Fig. 2. Scales of biological effects of contaminants and their relevance to environmental assessment (after Wolfe, 1992).

There are inter-species differences in bioaccumulation as well. For example, it was pointed out that the lack of differentiation between *M. edulis* from two similar species, *M. galloprovincialis* and *M. trossolus*, would lead to misinterpretation of data; it was shown that *M. trossolus* accumulated significantly higher concentration of many elements than did *M. edulis*. Confusion on systematic characterization of the genus *Mytilus* complicates the issue further. Given such large differences among taxa, even at the species level, and other factors that particularly affect metal accumulation in invertebrates, it is not reasonable to expect a narrow band of contaminant concentration that could be described as a background level. Considerable attention must be placed on the species being sampled and its patterns of bioaccumulation of contaminants,

notably toxic metals. Rainbow (1993) has concluded that assessment of the significance of metal concentration can only be made intraspecifically.

Box 3. Stages in the Assessment of Biological Effects of Chemical Contaminants

Biotransformation, detoxification, and tissue distribution.

Indices of xenobiotic exposure (e.g., metabolites in bile).

Indices of early response (e.g., DNA adducts).

Observable effects:

Individuals (e.g., pathological conditions, mortality);

Populations (e.g., significant population gains or losses);

Communities (e.g., altered species richness and connectance; impaired resilience).

Restoration and recovery.

Environmental and ecosystem monitoring.

Assessment of Biological Effects

Reflecting the hierarchical and concentric organization of biological systems, effects of chemical contaminants may occur at all levels of biological organization, from cells to ecosystems. Effects on biological populations, communities and ecosystems, either direct or indirect through habitat degradation, seem to have more relevance in terms of environmental management and protection of resources (Fig. 2). Such effects are difficult to ascertain, in part due to problems in distinguishing between natural and anthropogenic causes, and in part due to a lack of comprehensive design of monitoring and assessment studies. It can be Reasonably argued that widespread mortality and population-level effects manifest themselves long after biochemical dysfunction, physiological abnormalities, growth impairment, and ecologically important changes have occurred as a result of environmental degradation. In fact, the reciprocal objectives of increased understanding (toward the molecular or cellular level) or increased relevance (toward the population or ecosystem level) form a core issue in the assessment of biological effects of chemical contaminants.

Even in areas where there is only one major point sources of environmental contamination, for example, crude oil loading and transportation in Port Valdez, Alaska, none of the laboratory-derived biological effects of petroleum hydrocarbons (for example, impaired growth, behavior and energetics in several species) was observable in feral populations. In the laboratory, such effects occurred at much lower concentrations of petroleum hydrocarbons in water than the highest values found in the port. Does this mean that a more focused and concerted effort could have revealed such effects in the field, or that the nature of laboratory experiments is inherently too simplistic for validation of results in the field? Such questions continue to lead to circuitous arguments about the applicability of laboratory data to environmental management.

It is also instructive to outline various stages signifying the onset and progression of adverse biological effects of chemical contaminants (Box 3), some of which may be reversible. Depending on the nature and severity of the environmental issue at hand and the desired endpoints (or, more often, the "institutional culture") of different resource management agencies, the process can be started or halted at any stage. The full spectrum of these stages is seldom, if ever, included in programs designed to manage environmental quality and conserve biological resources. A comprehensive effort would require a long-term commitment of intellectual, financial and material resources, and may be most effective if carried out in the context of inter-disciplinary and multi-institutional program designed to address regional resource management needs.

As a start, regional biomonitoring is typically based on three lines of measurements: sediment toxicity, biomarkers of contaminant exposure and effects, and in situ biological changes. These types of measurements, coupled with information on the sources of contaminants and their transport mechanisms, can be designed to integrate the chemical and biological components of environmental assessment.

Evidence from Sediment Toxicity: Surficial sediments in coastal and estuarine waters act both as sinks and sources of contaminants. As in other areas, coastal sediments are formed by the settlement of particles and colloids except that their composition is greatly affected by varying pH and redox potential as well as the amount of contaminants associated with freshwater runoff. Less polar organic compounds and many toxic elements are accommodated on the particles, ultimately leading to their accumulation on the sea floor. Often the concentration of contaminants associated with sediments is orders of magnitude higher than in the water above.

Animals associated with the sea bottom, benthic and demersal fauna, can be exposed to a variety of contaminants by direct contact with sediment, pore water (interstitial water), the nepheloid layer at the water-sediment boundary, or via ingestion of particles. The bioavailability of contaminants and their bioaccumulation potential are greatly influenced by physical conditions in the external environment and vary from species to species. Assessment of biological effects of contaminated sediments is therefore based on standardized toxicity experiments on specific test species, organelles, or plasmids with known organizational structure or responses to xenobiotic exposure. Their desirable features are standardized procedures, controlled test conditions, reproducibility of results, and comparability of data between regions and treatments.

Typically, a battery of sediment tests is used: one based on whole sediment, second on porewater, and third on extracted contaminants. The following three tests have been widely applied.

Amphipod Toxicity: The acute toxicity test with adult amphipods has been used widely following standardized American Society for Testing and Materials (ASTM) protocol (ASTM, 1992). Amphipods are generally abundant, wide-spread in their distribution, and ecologically important. The test species are selected on the basis of their abundance in the area; for example, *Ampelisca abdita*, a tube dwelling amphipod, is abundant on the East Coast of the US, whereas *Rhepoxynius abronius*, a burrowing amphipod, is common on the West Coast. In essence, a batch of animals is exposed to test sediments for 10 days in a static, aerated and temperature-controlled chamber with continuous lighting. Incidence of mortality in reference to experimental controls is the primary response criterion. Mean amphipod survival in the control tests is expected to be at least 90%.

Porewater Toxicity: This test is designed to determine fertilization success in the sea urchin *Arbacia punctulata* (or some other suitable species) following exposure to porewater of sediment samples collected from different sites. Adult male and female sea urchins are stimulated to spawn and their gametes collected. The test involves exposing a known quantity of sperms in 5 ml of the test solution (100%, and several dilutions of extracted porewater) for 30 minutes, followed by the addition of ca. 2,000 eggs. After allowing for 30-minute fertilization period, an aliquot of eggs is examined microscopically for fertilization success. The formation of fertilization membrane is the experimental endpoint.

Microtox Test: This test is based on the attenuation of luminescence in the bacterium *Photobacterium phosphoreum* due to contaminant-induced disruption of cellular metabolism. When optimally grown, this organism diverts 10% of its energy to a metabolic pathway that converts chemical energy into light. The reduction in light production in test organisms is calculated in comparison with experimental controls. The reduction in light production and the substrate concentration at which a 50% reduction in luminescence occurred (EC50) are calculated. In bioeffect assessment surveys, most tests are conducted on organic (dichloromethane) extracts from whole sediments with a series of dilutions. Larger gamma values (ratio of light lost to the light remaining) and smaller EC50 values would indicate increasing toxicity.

Evidence From Biomarkers: In broad terms, "biomarker" is described as a measure of a living system's inability to cope with stress and, as such, it is synonymous with the term "bioindicator" that is often used in ecological literature (Oenkins and Sanders, 1992). Examples of such an inability could be individual mortality, as measured in laboratory toxicity testing; altered pattern of biological production or species succession, as it is sometimes caused by eutrophication; or population decline, generally related to depleted food resources, habitat degradation, or excessive removal of year classes. More often, however, the term "biomarker" is used to describe suborganismic response at the histological, physiological or biochemical levels.

Biomarkers, as a measure of contaminant exposure or effect, have the advantages that they respond only to the biologically available contaminants and that they record the biological response much more rapidly than, for example, at the population or community level. Virtually every biomarker used in ecotoxicology is an application or adaptation of measures used in medical or clinical sciences. However, when applied to the coastal and marine fauna, including sentinel species for which a fair amount of data is available, interpretation of biomarker data is impeded by a general lack of understanding of fundamental biochemical and physiological processes that persists to date. There is little information on the homeostatic range of most biomarkers under which an organism can continue to function normally for a short period of time when exposed to external stressors, whether the stress is natural, e.g., food availability, or anthropogenic, e.g., chemical contaminants or a specific xenobiotic substance in the environment. Recent scientific reviews provide detailed descriptions of various biomarkers and assess their relevance in environmental management.

A large variety of measures has been described as biomarkers of environmental stress in coastal and estuarine areas of the US. Many of them have been applied to or developed under studies sponsored by the National Status and Trends Program (Box 4). Not all of the listed biomarkers were studied in comparable detail; some were used on an exploratory basis and not used widely, and some were measured to provide ancillary information to relate a particular biomarker to endogenous factors.

For example, impairment of defense capabilities (immune system) in oysters due to contaminant exposure was studied as a factor to elucidate parasite burden.

Box 4. Examples of biomarkers in fish and bivalves that have been studied as part of the National Status and Trends Program.

Wellness and Condition of the Animal

Atrophied organs and connective tissue

(occurrence of edema, cellular sloughing, necrosis)

Condition Index

Glycogen depletion in hepatocytes

Hepatosomatic Index

Length-weight relationship

Serum Contents (glucose, albumen, cholesterol)

Altered Enzyme Response

Acetyl-cholinesterase

P450 and monooxygenases

Phase II enzymes (e.g., glutathione S-transferase)

Cellular Integrity and Cytogenetic Damage

DNA adducts

DNA unwinding

Lipofuscin

Lysosomal stability

Micronuclei

Declined Immune System Response

Antibody levels

Hemocyte density and mobility

Lymphocyte blastogenesis

Macrophage function

Phagocytic index

Serum lysozyme

Impaired Reproductive Potential

Egg mass

Fecundity

Gonadosomatic index

Gonadotropins

Steroids (plasma estradiol, testosterone)

Yolk proteins (vitellogenin)

Other Indicators of Contaminants Exposure and Metabolic Response

Contaminant accumulation in tissues

Fluorescent aromatic compounds

Metallothionein induction

Multi-xenobiotic resistance proteins (MXRs)

PCBs in liver

Stress proteins

Parasitic Infection

Cestodes

Protists (e.g., *Perkinsus marinus*)

Trematodes

Incidence of Disease

Black gill disease

Cutaneous melanophore hyperplasia

Fin rot

Lens cataracts

Neoplasia in liver, kidney and gonads

Non-neoplastic lesions

Pre-neoplastic lesions

Shell disease

Skeletal abnormalities

Spleen lesions (lymphoid and myeloid necrosis)

It is evident from the literature, that considerable progress has been made in the elucidation of initial metabolic response to environmental contamination and development of biomarkers that indicate certain adverse biological response in animals exposed to chemical contaminants. However, the study of biomarkers remains a nascent field of research; there is a myriad of contaminants that cause a wide range of effects on the sub-cellular, cellular and organismic levels. Quite often, search for an answer results in the unmasking of more questions. The present state of knowledge can be illustrated by the following two cases: one dealing with contaminant effects on the reproductive potential and the other with the presence of DNA adducts. The test animals in

these illustrative examples are fish since much more is known about their physiology and cytochemistry than about bivalves.

Reproductive Potential: In one of the very few detailed and comparative studies of bioeffects, English sole from sites contaminated with polycyclic aromatic hydrocarbons (PAHs) in Puget Sound, Washington showed impaired gonadal development and lower plasma estradiol concentration, but winter flounder, collected from PAH contaminated sites in Boston Harbor, Massachusetts, showed no clear negative effect on gonadal recrudescence, gonadosomatic index, plasma estradiol concentration, or fecundity. This apparent discrepancy in observations could be due to winter flounder's lower sensitivity to chemical, stimulatory effect of certain contaminants in Boston Harbor, or seasonal migration pattern of winter flounder to offshore, presumably less contaminated, waters during early *vitellogenesis*. Such dissimilar responses in closely related species to similar contaminant exposure complicate interpretation of results, and underscore the need to consider natural history and behavioral aspects of the test species as well.

DNA Adducts: The presence of specific adducts - meaning an addition product - that are formed by covalent binding between a chemical species and cellular DNA, is generally regarded as a key diagnostic end-point of biological effects of chemical contaminants. However, on occasions, it has been shown that incidence of DNA-adducts in several species of fish, including marine fish, was similar in specimens collected from polluted and non-polluted waters. Such apparent discrepancy in response in the fundamental biological molecule is difficult to explain. It could be due to the presence of other "pollutants" that are known to mediate the formation of adducts, such as benzo(e)pyrene, or endogenous factors, such as hormonal and nutritional status of the animal. Nonetheless, the weight of scientific evidence clearly points to a number of chemical contaminants, some of which occur widely in the coastal and marine environments, as the most likely source of DNA adducts.

Still, biomarkers remain an attractive means to assess the health of the coastal resources since bioaccumulation per se has little relevance to biological effects. Newly formulated pesticides and some industrial chemicals, even though they are highly toxic, do not persist in the environment or biological tissues for a long time. Their adverse biological effects can only be determined by sensitive and reliable biomarkers.

Evidence from in situ Changes in Biological Populations & Communities

Population Changes: There are numerous, well-known cases where excessive harvesting of fish and wildlife species for commercial purposes decimated discrete stocks or entire populations. There are only a few instances where a precipitous and persistent population decline in coastal and marine species has been ascribed to chemical contaminants. Oil spills are generally associated with mass mortalities in fish and wildlife, and perhaps long- term ecological damage. Examples of mortality associated with oil spills include widespread losses of littoral fauna, fish and wildlife from the Torrey Canyon oil spill and dispersant application (Bourne, 1968; Southward and Southward, 1978), and an estimated one million dead heart urchins (*Echinocardium sp.*) and losses of other biological resources from the Amoco Cadiz oil spill (NOAA, 1978). Thousands of sea otters,

seabirds and other animals were observed or presumed to have died following the Exxon Valdez oil spill. Some mortality in affected sea otters and other rescued animals could have been due to stress caused by the human handling of animals in clean-up cages and pens. In general, populations affected by oil spills can and do recover in the absence of continued and cumulative stresses. For a few oil spills, for example the Ekofisk well blow-out in the North Sea in 1977, there is little documentation of wide-spread mortalities or other adverse biological effects, although presence of petroleum hydrocarbons in some biota and tainting of fish were noted in the immediate vicinity of the accident (Mackie, Hardy, and Whittle, 1978). Following account is to exemplify cases where chemical contaminants have been associated, at least in part, with population decline of a valued species.

Striped Bass: Long-term decline in the population of striped bass *Morone saxatilis* in the San Francisco Bay-Delta has been related to reduced fecundity and increased larval mortality due to petroleum hydrocarbons, DDT, PCBs, and toxic metals. Secondary effects of environmental stress, reduced immunocompetence and high parasitic infestations - preponderance of cestode-induced lesions - may also have played a significant role in larval and adult survival. Unlike most other fish species, striped bass is more vulnerable to sub-lethal effects of pollution due to its longer life span, feeding at higher trophic levels, and its predominantly estuarine and coastal habitats. However, it is difficult to separate pollution-induced effects on the population from those resulting from habitat degradation and salinity changes associated with freshwater diversion that have occurred over the past several decades. Population of striped bass has also declined on the East Coast of the US, due to a combination of over-harvesting, habitat loss, and chemical contaminants. Viable sport fishery for this species exists but concern about contaminant load in fish caught from several bays in the region limits human consumption of this and other fish species (HEP, 1995).

Oysters: Commercial harvest of the eastern oyster *Crassostrea virginica* from Chesapeake Bay has steadily declined in recent years in many parts of the world. In the state of Maryland, USA the 1994-95 harvest of 160,000 bushels was about 15% of the harvest only 10 years ago, and in Delaware Bay, the commercial oyster catch is virtually non-existent (unpublished data, NOAA, Chesapeake Bay Program Office, Annapolis, Maryland). This decline has been attributed to the widespread presence of two protozoan parasites, known as Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*), that damage oyster tissues, excessive harvesting of the resource, and environmental pollution. It is speculated that increased Dermo infection results from depressed immune system that may be a contaminant-induced effect. In addition, reduced fecundity, coupled with increased larval mortality, caused by a variety of chemical contaminants, including organotin compounds, pesticides, and petroleum hydrocarbons, may accentuate downward cycle of oyster stocks in the region. It should be noted that the Chesapeake Bay watershed receives the highest pesticide application in the US, and tributyltin concentration in the bay's waters, even though much reduced in recent years, approach or exceed State water quality standards in several areas of the bay; in marinas, the tributyltin concentration may be an order of magnitude higher (unpublished data, NOAA Chesapeake Program Office, Annapolis, Maryland).

Coastal Birds: Marine and coastal birds, and perhaps marine mammals as well, are vulnerable to population declines resulting from significant loss and reproductive impairment of individuals that may be caused by chemical contaminants. The near collapse of the brown pelican population off

southern California and major population declines in other regions, for example, off the coasts of Louisiana and Texas, were due to eggshell thinning, and the resulting hatching failures, that were caused by exposure to DDT. Extremely low concentration of DDE in brown pelican eggs, 3 ug/g, has been associated with reproductive failures. In the case of peregrine falcon, which also suffered population decline in several regions of the US due to DDT exposure, it is the accumulation of the DDT metabolites across a complex food chain, that resulted in reproductive failures. Being a top predator, the animals were subjected to higher concentrations of organochlorine and other contaminants in their prey. Reproductive impairment in this species was associated with considerably higher levels of DDE, 30 ug/g, than in brown pelican. Experimental exposure to lead during early developmental stages of coastal birds in the New York Bight has shown behavioral and morphological abnormalities, including reduced feeding abilities, reduced fledgling size, and impaired growth, that can easily compromise the animal's fitness and survival. A decline in population of common tern in the region since 1989 is coincident with increased levels of lead in the coastal waters of the bight.

Often the relative abundance of a commonly occurring species is chosen to distinguish between contaminated and uncontaminated sites. For example, the population density of the red brittle star *Amphiodia urtica* in the vicinity of municipal wastewater outfalls off southern California is nearly zero; In relatively uncontaminated areas of the region, its population is quite high, approaching 2,000 animals per sq. meter. This suggests that the species is responding to changed sediment texture and environmental quality in the vicinity of the outfalls. However, laboratory experiments showed no evidence of growth impairment or reduced reproductive potential in the species when adult specimens were exposed to sediment from the outfalls (SCCWRP, 1995). It could be that such effects are most pronounced during larval settlement and early developmental stages but this has not been tested.

Conversely, the increased abundance of certain species that can utilize enriched organic matter and tolerate low levels of dissolved oxygen has been used as an indicator of impaired habitats. The abundance of *Capitella capitata*, a deposit-feeding polychaete worm of cosmopolitan distribution is a common example. The reproductive strategy of the species is such that it can exploit various kinds of disturbed environments and increase its population size rapidly. To afford additional competitive advantage, the species is known to consist of sibling species (e.g., *C. capitata capitata*, *C. capitata ovincola*, *C. capitata tripartita*) as well as several genotypes (Warren, 1976). This inherent genetic adaptability allows one of the sibling species or genotypes to occupy and flourish in an abandoned niche, such as polluted area devoid of sensitive species. The increased abundance of the species has been well documented in areas affected by municipal wastewater discharges, pulp and paper mill effluents, and in some areas affected by petroleum hydrocarbons, including oil spills.

Biological Community Changes

Considerable attention has been placed in recent years on possible effects of contaminants on biological communities or ecosystems. This is predicated on the belief, that a significant change in the structure of the ecosystem (composition of its components) or in its function (the way ecological processes interact) may adversely affect the ecosystem's intrinsic and beneficial qualities, including its productivity and sustenance of desirable species. The effect of chemical contaminants on the

biological community structure and regional ecosystems is much more difficult to assess even though there is ample and convincing evidence for that to happen.

Such a change has been well-demonstrated in the case of fisheries where changes in the biomass yields and species composition have occurred due to significant changes in hydrographic conditions or excessive harvest of a particular species. For example, decline in the inflow of warm Atlantic Ocean water to the Barents Sea is believed to have caused the collapse of traditional fisheries (based on cod, haddock and herring) and much increased biomass of euphausiids that is economically much under-utilized. On the continental shelf off the northeastern US, a marked decline in the biomass of gadoid and other commercially valued fishes due to overfishing appears to have been compensated by an increase in the biomass of sandlance and elasmobranch fishes (dogfish and skates) that are commercially much less desirable. The overall biological productivity of the region probably did not change. These changes are believed to have been caused by over harvesting of species and decadal-type climatic changes, and perhaps only minimally due to chemical contamination.

In a carefully designed and coordinated study of changes in the structure of biological community along a pollution (petroleum hydrocarbons and copper) gradient, water depth was found to be the overriding factor controlling community structure and it may have masked pollution effects, if any. In deed, the most obvious sign of stress was at sites that are subject to seasonal anoxic conditions. Parallel studies, based on mesocosm experiments, showed that there were differences in the abundance of certain taxa; copepods showed decreasing diversity with increasing concentration of contaminants. This was a result of disproportionate increase in the abundance of certain species rather than due to selective mortalities. Nematodes, on the other hand, were virtually unaffected. Such studies demonstrate the usefulness of certain taxa, in this case copepods, in discriminating between polluted and clean sites but also point out that certain stress measures and objective analytical techniques do not reveal clear cut differences between treatment levels.

In recent years, attempts have been made to develop indices based on structural and functional properties of benthic assemblages. A "benthic index of estuarine quality" was developed for estuaries in the mid- Atlantic states (the Virginian Province) as part of US Environmental Protection Agency's Environmental Monitoring and Assessment Program. For the estuarine areas tested, the index distinguished between test and reference sites on the basis of five variables: proportion of expected number of species [as a function of salinity], number of amphipods, % of total abundance as bivalves, number of capitellids, and average mass per individual polychaete. The index values showed that between 16 and 30 % of the estuarine areas in the Virginian Province had benthic resources that were degraded, compared to regional reference sites.

Environmental Indicators

The potential role of indicators in assessing the state of the environment was underscored in the US National Environmental Policy Act (Train, 1972) and in recommendations by the National Academy of Sciences (NAS, 1975). More recently, the United Nations Conference on Environment and Development, held in Rio de Janeiro; Brazil in 1992 (Agenda 21, Chapter 40) specifically called for the use of indicators in decision- making in light of sustainable development of resources and to evaluate performance of public policy mandates or international accords dealing with the

environment. It is conceivable that environmental indicators could become invaluable for comparing environmental conditions among different localities and over time, enforcing regulatory standards, allocating resources, and informing the public about the environmental conditions and the performance of public programs.

Box 5. Examples of Coastal Environmental Indicators

Measurements on Individuals and Populations

Body burden of chemicals in various tissues
 Biochemical effects / physiological dysfunction
 Carcinogenesis
 Teratogenesis
 Susceptibility to disease
 Population abundance, biomass
 Population age structure
 Number of breeding pairs
 Geographical range of population
 Migratory corridor of population

Measurements on Communities and Ecosystems

Species richness
 Diversity measures
 Changes in biotic size spectrum
 Microbial (prokaryote, eurykaryote) community composition
 Relative biomass of sensitive or tolerant species
 Measures of stability, yield, persistence and resistance

Measurements of Environmental Quality

Dissolved oxygen content

Sediment contamination concentration
 Sediment toxicity
 Sediment *Clostridium* spores
 Marine debris and floatables
 Water clarity
 Submerged aquatic vegetation, seagrass, and mangrove cover
 Sediment organic matter / mephitic conditions

Measurements of Human Use

Commercial fisheries
 Beach / shellfish closures
 Recreation and tourism
 Drinking and industrial use water supply
 Shipping and transportation
 Aesthetics

Measurements of Human Health

Incidence of disease
 Medical costs
 Native subsistence lifestyles

Several water quality indicators have been developed since the first such effort to quantitatively rate different bodies of water in terms of pollution and present the composite index values in a readily interpretable color-coded scheme. It is worth noting that Horton's Water Quality Index, which was derived from weighted sum of eight variables, did not consider toxic substances. The author believed that "under no circumstances streams should contain substances that are injurious to human, animal or aquatic life." Most environmental indicators deal with air quality issues or freshwater ecosystems. As a general observation, air quality indices are more consistent in their composition and easier to interpret than are water quality indices. This is due to more uniform national standards (for example, National Ambient Air Quality Standards in the US), much larger reference data, more uniform measurement techniques, and delineation of wide geographic regions or "basins" facing similar air pollution problems. A few coastal "environmental quality" indices were developed in the US in the early 1980s as a result of a court decision to evaluate whether ocean dumping of sewage sludge caused "unreasonable degradation" of human health, welfare and

amenities in the context of all relevant environmental, social and economic factors as noted in the Marine Protection, Research, and Sanctuaries Act.

Box 5 provides examples of a variety of indicators that have been (or can be used) in assessing the condition of the coastal environment, status of resource use patterns, and extent of environmental and human health effects. These and other indicators developed to date have successfully explored certain aspects of the complexity of the natural environment and anthropogenically altered state of some of its components. Their use in coastal environmental management has been hampered first by their sheer number and variety, making it difficult to convey a concise message to decision-makers and the public, and second by the fact that they do not explicitly incorporate ecological changes in relation to human-induced changes.

In recent years, attempts have been made to aggregate water quality and biological measurements in a quantifiable framework to derive integrated measures of coastal ecosystem health. Examples include Index of Biotic Integrity, Ecosystem Distress Syndrome, Sediment Quality Triad (Chapman et al., 1987), and, as noted earlier, Benthic Index. In general, these indices are outcomes of fragmented, but very worthwhile, attempts to define the condition of the environment on a posteriori basis. They sometimes lack foundation in ecological principles, although that is not necessarily viewed as a shortcoming. Considerable refinement, including derivation of objective, quantitative measures, and concerted efforts are needed to assure their intended use, i.e., more informed and objective assessment of impacts of anthropogenic changes in the coastal environment and ecosystems.

The pressure-state-response framework has been adapted by the Organisation for Economic Cooperation and Development (OECD) for formulating or categorizing environmental indicators to guide work on environmental management, including performance evaluation of environmental policies. The framework is based on a concept of causality: human activities exert pressure on the environment and its resources that could affect the environmental quality and aspects of quantity and quality of natural resources [or "state" of the environment], requiring societal response through regulatory or policy changes [or "response"]. For example, in the case of environmentally persistent organochlorines in coastal waters, it can be surmised that indicators of "pressure" would include the manufacture, use and discharge (or release) of organochlorines; indicators of "state" would include body burden of organochlorines, physiological dysfunction, incidence of histopathology, prevalence of genotoxicity in animals; and indicators of "response" would include development and use of new chemicals or agricultural and pest control practices, clean-up of degraded environments, more effective pollution control or remedial measures, and public education and awareness campaign. Similar sets of indicators can be formulated to assess and control effects of eutrophication, excessive harvest of species, petroleum pollution, and the like.

The framework is also meant to stimulate development of a core set of "aggregated indicators" or the so-called Environmental Indices, thereby giving priority to development of a limited set for international use. These aggregated indicators, in turn, are designed so that they can be further aggregated, and form a basis for collecting and reporting data within nations and for national reporting of progress at international fora, for example, the United Nations Commission on Sustainable Development. Examples of Environmental Indices are: Net Resource Depletion,

Composite Pollution, Ecosystem Risk, and Human Welfare Impact. Each of these is made up of 4-6 sub-component indicators; for example, the "Indicator of Composite Pollution" could be based on emission of ozone-degrading gases, emissions of greenhouse gases, emission of acidifying gases, emissions of substances that cause eutrophication, emission of toxic substances, and solid waste returned to environment.

Benefits of an Effective Monitoring Program

In terms of real estate values, business developments, natural resources and recreational opportunities, the coastal regions of the world are by far the most lucrative environment. It is estimated that vacationers alone spend \$1.9 trillion annually worldwide, most of it in cities and resorts on the coast (Weber, 1994). In the US, recreational boating alone accounts for \$10 to 17 billion expenditures annually (US Bureau of Census, 1995). In 1994, the ex-vessel price of coastal and marine fisheries resources in the US was \$3.8 billion, with a value-added contribution of \$20 billion to the economy (NMFS, 1995). The total amount of consumer expenditures relating to commercially harvested coastal and marine fisheries was \$39 billion (NMFS, 1995). This total reflects final retail value of seafood products and food service outlets, plus secondary wholesale and processing of secondary products.

On the other hand, nearly \$37 billion was spent in 1992 in the US for abatement of water pollution: \$25 billion by businesses and industry, and \$12 billion by the government (US Bureau of Census, 1995). Another \$741 million was spent to comply with water pollution regulations and monitoring - about 2% of the total pollution-related expenditures - and \$320 million on R&D. Assuming that 33 % (±10 %) of the total water pollution regulation and monitoring costs were for coastal waters, these costs could have ranged between \$170 million and \$319 million. As a perspective, it should be noted that the total economic cost of the Amoco Cadiz oil spill was estimated at \$190 to 290 million (NOAA, 1983). For Exxon Valdez spill in 1989 clean-up and restoration costs and punitive damages are likely to exceed several billion dollars.

The overall cost of water pollution abatement and control has generally increased each year despite societal intent, as reflected in legislation and myriad of environmental regulations. The total, in constant 1987 dollars, has increased from \$27 billion in 1980 to \$33 billion in 1992 (US Bureau of Census, 1995). In contrast, similar costs to curtail air pollution from automobiles has decreased in recent years: from \$20 billion in 1986 to \$12 billion in 1992 (US Bureau of Census, 1995). This could be, at least in part, due to more effective monitoring and indices to gauge the extent, severity and sources of air pollution. It can be surprising that a modest (say, \$10 to 15 million per year), but well-designed, monitoring program with due consideration of ICZM - even if it resulted in only 1% reduction of pollution abatement and control costs - would mean a tremendous net savings to businesses, industry and the tax payer. In addition to obvious savings, a number of other tangible and intangible benefits could accrue from such a program: sustainable fisheries resources, increased economic vitality, improved quality of coastal environments and appreciation of aesthetic values, development of environmental technology applications, stronger linkages at different levels of government, and involvement of different stakeholders in the conservation of coastal resources.

Conclusions

Legislative mandates in many industrialized and developing countries and recent international accords, notably Agenda 21 of the United Nations Conference on Environment and Development (Rio de Janeiro; 1992) have highlighted concerns about the condition of the coastal environment and sustainable use of coastal resources. ICZM offers a framework for anticipating and resolving wide ranging and complex coastal management issues. The framework includes long-term monitoring whose purpose should be to provide information on the nature of changes in the environment, condition of coastal ecosystems and biotic resources, and measures to evaluate success of programs that are designed to improve coastal environmental quality and ecosystem health. Monitoring programs without linkage to resource management scenarios have little relevance to formulation, analysis and evaluation of resource management strategies, and may in fact contribute to misguided pollution control measures with their corollary, but unnecessary, cost to society.

The dual-purpose of environmental monitoring - defining the status and temporal trends in environmental quality, and providing data to address specific coastal resource management needs - necessitate a tiered structure of the monitoring program. This structure would be based on: 1) a sparsely distributed network of stations over a broad spatial extent, and 2) embedded within the network, intensive monitoring programs in designated regions that would be tailored to support specific coastal resource management needs. The latter component would include specific hypotheses relating to cause-effect relationships between valued coastal resources or amenities and environmental degradation, identification of sources of environmental contamination, and models of pollution transport and fate within the ecosystem. In this context, monitoring and research are seen as complementary efforts: for example, knowledge of change or trends in environmental quality or biomass of a valued species, including knowledge of known or putative causes, would be a prerequisite for an improved management strategy for the resource.

It is also imperative that environmental monitoring programs explicitly include meaningful biological measures of contaminant exposure, contaminant-induced adverse biological effects, and susceptibility of biota to environmental degradation. Measurement of body burden of contaminants in sentinel species or in species noted for commercial, aesthetic or ecological value has little significance to ICZM. It has been shown that very high bioaccumulation of certain "toxic metals," for example, zinc approaching the range in soft tissues of some barnacle species, has no obvious adverse biological consequences. On the other hand, exceedingly low concentrations of certain compounds, for example 0.064 $\mu\text{g/kg}$ of dioxin in diet of test animals, are believed to disrupt endocrine system of animals and may arguably have long-term consequences at the population level. Development of coastal environmental indicators should also be part of the overall strategy. Such indicators, best described as parsimonious descriptors of several environmental measures, should be based, at a minimum, on the pattern of human use of coastal and marine resources, condition of the coastal environment, and the health of its ecosystems.

The multi-faceted strategy, as outlined herein, transcends institutional boundaries and, to an extent, traditional ecological acumen. It does promote flexibility in design and region-specific solutions to resource management problems. To the author's knowledge, such a strategy has not yet been

implemented anywhere, although some of its aspects are highlighted in recent US legislation (Title V of the Marine Protection, Research, and Sanctuaries Act), recommendations of the National Research Council (NAS, 1990), and conclusions of an inter-governmental task force on environmental quality monitoring in the US (ITFM, 1995). Without significant institutional changes and investment of resources, both intellectual and material, the present trend of curtailing or eliminating long-term monitoring program will continue, particularly so in industrialized countries.

Capacity Building for Integrated Coastal Zone Management in Countries of South Asia

The five maritime countries of the South Asian region, Bangladesh, India, Maldives, Pakistan and Sri Lanka, share a complex legacy of social, cultural and environmental realities that characterize the historical and geographical identity of the subcontinent. The coastal areas of these countries have a number of shared natural resources, and many similar environmental and developmental problems. Different perceptions of the importance of the coastal zone exist in the South Asian countries, but the awareness of the special nature of the coastal zone seems to be growing in the region. The countries are increasingly recognizing the ecological and economic significance of their coastal areas and the problems associated with the development of coastal resources.

The region's countries have undertaken a few coastal zone management initiatives and are at different stages of formulation and development of national coastal environmental planning systems. A limited number of bilateral and multilateral assistance programs and projects have supported national efforts in the preparation of policy review studies, the formulation and development of national planning instruments and the execution of pilot projects.

Under the momentum generated by the United Nations Conference on Environment and Development (UNCED) held in 1992, capacity building is increasingly seen as a crucial factor to achieve the integration of environmental perspectives in the development process. This represents a particular challenge for coastal zone management in the South Asian region.

A fundamental thrust in this endeavor is the development of adequate national initiatives to support national policies and priorities for the specific environmental and developmental conditions and needs of each country. The issue also has a regional component, and regional co-operation activities may assist the countries in identifying common areas of concern, developing a better understanding of environmental and development problems and strengthening institutional capacities through cooperative actions.

This paper reviews the literature and some of the experiences in coastal resource development and management in the South Asian region. It also discusses the issue of capacity building and the opportunities as well the requirements for technical cooperation.

Coastal Zone Management Issues in South Asian Countries

Coastal and nearshore areas are often subject to high number of conflicts in the utilization of resources, severe impacts of natural hazards and often bear the heaviest burden of externalities arising out of the economic development. Coastal zone problems are easily aggravated by the higher rate of economic development, which is often geographically concentrated in coastal areas. Coastal natural resources are particularly fragile and show extensive effects due to high population

pressures and accelerated urban growth. Coastal resource planning requires considerable technical and management capabilities and institutional means, within a context generally characterized by a highly fragmented planning system.

South Asian maritime countries are no exception to this common situation. Box 1 shows selected environmental indicators of the coastal areas of the South Asian countries . In a regional scenario characterized by mass poverty, underdevelopment and environmental degradation, the socio-economic characteristics of coastal areas present a range of conditions between two extremes: few areas facing noticeable economic development (due to urbanization and industrialization processes); and backward and depressed areas, sparsely populated and lacking in resources. Within this range, the economic importance of coastal productive activities cannot be underestimated. In the former case the coastal economy clearly plays a crucial role in the development of the national economy. In the latter, low-level productive activities sustain the livelihood of local populations according to traditional practices, highly dependent upon the natural resource base.

Four basic aspects of environmental management of coastal resources can be schematically identified in the environment and development context of South Asia. First, there is a need to manage pressures exerted by population and economic dynamics and to ensure the long term and balanced conservation of the coastal resource base. The protection of the integrity of coastal ecosystems is necessary to secure the preservation of life support systems, with particular regard to those primary productive activities on which large strata of the population base their sustenance. Growing economic demand and unbalanced exploitation patterns often disrupt the complexity of coastal ecosystems, limit development opportunities, give rise to externalities and may impair equity and efficiency in the allocation of resources.

Secondly, due to population growth and poverty that characterize the region, the maritime South Asian countries face the challenge of identifying and pursuing new and additional development opportunities. They need to develop coastal resources to meet the basic requirements of coastal populations and the growing demands of the national economy. While the productive potential of traditional sectors such as agriculture and fisheries should be expanded, additional economic benefits are expected from the exploitation of offshore resources.

The economic growth of marine and coastal areas requires the development of an adequate infrastructure base for tourism, transport, industry and housing. This issue is likely to become of increasing importance for coastal environmental management in the region.

A fourth fundamental issue of coastal zone management in the region is the need to prevent and mitigate disastrous natural calamities, which frequently occur in coastal areas.

Ensuring Long-term and Balanced Conservation of Coastal Resources and Life-Support Systems

Fisheries and agriculture are the main economic activities in the coastal areas in the South Asian region. These countries, except for India and the tuna fishing sector in Maldives, rely mostly on artisanal fisheries and the exploitation of nearshore fish stocks. These stocks are generally considered overexploited, particularly in Pakistan, Sri Lanka and India. However, the considerable

information gaps which still surround the assessment of fisheries resources (catch and effort data, biological data and information on migration patterns) represents a major constraint for sectoral planning (FAG, 1993). Nearshore stock depletion is caused by the size of the overall fishing effort, as well as the utilization of indiscriminate fishing methods. The yield of important fisheries, such as penaeid shrimps, is affected by fleet mechanization and the increase in effort of trawl fishery. Nearshore wild shrimp stocks are also threatened by the capture fisheries supporting coastal aquaculture and the destruction of stocks that accompanies push net fishing.

Threats to those habitats, such as mangroves swamps, which are necessary for the life cycle of economically important species, may also aggravate the impacts due to direct exploitation of fish stock. In Sri Lanka and Bangladesh artisanal fisheries rely particularly on sensitive brackish water bodies (estuaries and lagoons) which may be affected by land reclamation and the planning of river catchments.

Water is possibly the most crucial resource at stake in the coastal areas of the region. This concern is multifaceted: it involves the management of conflicting claims exerted by competing economic activities in the coastal zones (e.g.; fish farming vs. rice farming); the drought affecting extensive coastal areas in Pakistan; and the planning of inland water resources, which has very complex implications in the Indian subcontinent.

Paddy cultivation is the main source of staple food throughout the region and coastal areas are often endowed with valuable agricultural land. Such land is increasingly reclaimed for the development of other productive activities, housing and urban infrastructures. Similar patterns of land reclamation also affect coastal forested areas and are often based on a limited assessment of land suitability.

The countries of the region are home to some of the most magnificent ecosystems of the world and of utmost importance for the conservation of biodiversity, such as the mangrove forests of the Sundarbans in Bangladesh and of the Indus delta in Pakistan and coral reefs in India, Sri Lanka and Maldives. Environmentally sound management of such eco-systems is essential to ensure the preservation of the highly interdependent and complex natural resource base of coastal productive activities. The establishment of reserves may provide benefits in terms of alternative sources of income (i.e., eco-tourism). However, the long term conservation of ecosystems structures and development potentialities represents the main challenge for coastal area management. The collection of wood and minor forestry products has an important role for sustaining coastal populations of the region. Mangrove forests provide biomass for fuel wood and fodder, maintain the productivity of coastal waters and shelter the coastline. However, population pressure and unsustainable exploitation may inflict serious environmental degradation and fragmentation to coastal forests. Although significant examples of sustainable management practices exist, concerns over damages to the extensive mangrove forests in Bangladesh, Pakistan and India and significant areas in Sri Lanka are widely reported. Logging has exceeded sustainable levels also in the Maldives and the country has become importer of timber.

Coral and sand mining are important coastal environmental management issues in Maldives and Sri Lanka. The burning of coral is the main source of lime for the construction industry and the coral based lime industry represents a major economic activity in certain areas of Sri Lanka. Coral mining

has disastrous implications for the conservation of coastal geomorphology and prevention of storm induced erosion and flooding. Attempts at controlling the industry with regulation have had limited impacts. There is a need to identify alternative economic activities for the concerned labor force and alternative sources of construction material.

Coastal erosion problems are well known along the South-West coast of Sri Lanka and the east coast of India. Erosion problems are aggravated by concurring phenomena such as coral mining and the indiscriminate development of the shoreline. However, their causal factor mainly relies on the complex dynamics of the coastal systems that respond to natural forces and human induced impacts. In areas most affected by erosion problems, planning agencies increasingly recognize that shoreline management should not be narrowly constrained in a local perspective, i.e., to tackle the above mentioned problems of coral and sand mining or shore- line developments. A broader management framework is necessary to deal with coastal erosion: the definition of the planning boundaries of the coastal zone would often require the inclusion of river catchments. Such a wider demarcation of the coastal zone could allow a more efficient formulation of integrated land-use and water-use plans for coastal ecosystems and habitat management.

The capacity of coastal waters to act as a waste sink is considered often impaired, and environmental degradation due to dumping of industrial and domestic wastes and biocides, is widespread in the coastal waters of the region. Most industrial wastes produced are not treated before their disposal into water bodies. Treatment facilities for domestic waste- water are also rarely available. Hot spots of marine pollution are re- ported around all major coastal industrial centers, such as high concentrations of heavy metals in the waters of the Thane creek of Bombay coast (Ministry of Environment and Forests, India, 1993). The problem of industrial pollution control is compounded by the small average size of industrial units, firms' technical constraints and lack of institutional resources to monitor and enforce compliance with standards. Additional factors affecting the control of industrial sources of pollution are the pace of industrial expansion, which may counter the development of control capabilities; and the social and employment implications of enforcing strict discipline of compliance, such as through the closing of facilities.

Extensive maritime transport of oil from the Gulf takes place along the route crossing the Arabian Sea, passing the southern tip of Sri Lanka, crossing the southern Bay of Bengal through the Malacca Strait. This oil transport is also cause of concern for marine pollution. The intense transport taking place along the route toward the Far East and Japan, makes the Indian Ocean extremely vulnerable to oil pollution due to accidents and routine tanker operations. While the sighting of oil at sea and along the beaches is common along the route (ESCAP, 1992) the countries of the region have limited capabilities for pollution monitoring and contingency planning for emergencies.

Development of Productive Activities

Population pressure is a common feature of coastal areas of the region, except for Pakistan, where population density is low outside the metropolitan area of Karachi. Enhancing the economic productivity of coastal areas is a compelling need for all countries of the region. There is a need tboth to expand food production capacities in face of demographic growth and to meet basic needs of local communities by increasing income and generating employment.

Rural development remains the central issue of coastal area management in the region. Rural development in coastal zones has to face the challenge of ensuring the preservation of the natural resource base of the livelihood of local population, in a context of multiple use allocation. The expansion of food supply capacities is bound to the identification, testing and promotion of solutions for resource use conflicts among different productive activities (fish farming, rice farming, salt production) over allocation of land, water and resources for development of necessary infrastructures.

Coastal aquaculture production is expanding and the sector has still untapped potential for growth in the eyes of the governments of the region. The governments support the growth of the industry to boost protein supply in the diet of local population, to generate employment, to ensure welfare of local communities and for export earnings. The sector is booming in India, where about 70,000 hectares are estimated to be under shrimp farming (FAO, 1994), and is also Significant in Bangladesh and Sri Lanka. Due to the high capital investment and operating costs of intensive farms, the sector's growth does not necessarily benefit local populations. Cropping patterns may include seasonal alternation of shrimp culture and paddy or salt production, such as in Bangladesh. But the spreading of intensive fish farming plants gives rise to increasing problems which have been widely experienced in other Asian countries, particularly in South East Asia. The issue is two fold: on one hand, the tremendous growth of coastal aquaculture can cause extensive impacts and modifications in coastal ecosystems. Fish farmers compete for agricultural land and fresh water supply with other coastal productive activities. Besides these conflicts, the expansion of the profitable shrimp farming industry brings along the associated problems of mangrove forest depletion, salinization (with effects on the livelihood of rice farmers), the depletion of natural seed resources, extraction of groundwater and disposal of organic effluents, drugs and chemicals. On the other hand, fish farming operations can be disrupted by several natural and man induced phenomena, including river catchment management, domestic sewage discharge, cyclones, salinity and temperature fluctuations, weed infestation, heavy sedimentation, soil acidity, etc. The lack of an adequate regulatory system affects the growth of the industry in the South Asian region and raises concerns, particularly for the necessary multiple use of coastal resources. The further development of coastal zone planning systems in the countries of the region will probably face as major issue the management of coastal aquaculture development.

Opportunities for growth in the fisheries sector and alternative sources of livelihood for coastal fisherfolks are expected from the development of capacities for exploitation of offshore fish stocks, based on expansion of capacities of the commercial fishing industry. Therefore, the technological development of the fishing fleet and fish processing facilities, as well as the creation and expansion of adequate credit policies for the sector are fundamental requirements for these countries. The issue is widely recognized. In India, where the government has undertaken a number of programs to assist small scale fishermen toward the extension of their range of operation by upgrading fleet capacities. In Maldives fish canning has been recently introduced based on an intentional policy shift to increase the value of the products for exports (Ministry of Planning, Maldives, 1994).

The potential for development of offshore resources includes the exploitation of mineral deposits, particularly along the coast of Sri Lanka and India. India extracts natural gas off the Andaman and Nicobar Islands and the sea basin of Godavari and Kaveri. India's offshore petroleum extraction

from the Bombay High and off the coasts of Mahanadi and Hoogli amounts to about 60% of the country's crude oil production. Offshore potential for oil deposits in Sri Lanka, Bangladesh and Pakistan has been poorly investigated. The Indian Ocean basin is also rich in polymetallic nodules, not yet exploited for lack of technological capabilities.

Development of Infrastructures

A number of large urban centers are located along the coast of the five countries, from Chittagong and Khulna in Bangladesh, to Bombay, Calcutta, Cochin, Madras, Visakhapatnam in India, Karachi in Pakistan and Colombo in Sri Lanka. Major industrial and maritime transport infra- structures are often located in proximity to or within coastal urban centers.

Demographic growth and needs for economic development confirm that the trend of expansion of the coastal centers is bound to stay. Although the largest part of the South Asian population still lives in rural settlements, the growth of urban centers is expected to play a fundamental role in the uplifting of economic and social conditions in the region, along with the urbanization process experienced in other Asian countries. The contribution of India's urban sector to net domestic product rose from 29 % in 1950-51 to 41 % by 1980-91; and it is likely to be over 60 % by 2001 {World Resources Institute, 1993-94}. Thus the process of urbanization, which is facilitated in coastal areas, will be an issue of increasing importance in the context of coastal zone management in the region.

Urban infrastructures, such as sewerage and water supply, are limited. A considerable proportion of urban population throughout the region are squatters. In Karachi, Pakistan the squatters are estimated at 38 % of the total population and growing at twice the rate of the population of the city {Govt. of Pakistan, 1991}. The lack of urban infrastructures causes tremendous environmental problems in the major centers. The unavailability of services also affects coastal rural areas, where the lack of proper housing is often a major problem for local communities, compounded by problems of encroachment on agricultural and forest lands and near brackish water bodies.

The development of industrial and transport infrastructures in coastal areas is a first consideration for the governments, along with the establishment of special development and economic zones, increasingly seen as incentive to private investment. India invested US\$ 620 million in port development projects over the period 1988 -1992, most of which was spent on the Jawaharal Nehru port project in Bombay; and a wide range of development and modernization projects are being undertaken in the other main ports (ESCAP, 1994a). The projected annual growth rate of port container throughput between 1993 and 2000, aggregated for the South Asian region, has been estimated at 9.3 % {1.46 times the estimated world growth projection}, with an estimated investment requirement of about 4 billion dollars over the same period {ESCAP, 1994b}.

The tourism sector {reviewed in ESCAP, 1994c} is expected to grow considerably in the region over the next few years. This growth will be at a different pace in different areas, controlled by uncertainties introduced by local political climate, lack of adequate infrastructures and services. Aggregate figures of tourist arrivals to the South Asian region indicate an increment over the previous year of 2.0 and 7.6% in 1991 and 1992, respectively. The World Tourism Organization has forecasted an average annual growth of international arrivals in the region at 7.15% between 1995

and 2000. The countries of the region need to achieve a sustained minimum growth over the coming years to attract the necessary capital for investment projects. Therefore, the governments of the region are actively supporting and promoting the growth of the industry. These optimistic prospects for the region are strengthened by the current efforts to improve international communications and to open up the local economies. In 1992 India had about 44,000 authorized hotel rooms and forecasts indicated a need for doubling of that number by 1996. Investments are being encouraged through economic incentives. Beach resorts are the main destination for international tourists, particularly in India (Goa), Maldives and Sri Lanka, where coastal locations attracts foreign visitors, thanks to their relatively natural conditions. Coastal resorts may, therefore, bear great pressure from the growth of tourism industry.

Response to Natural Calamities and their Prevention

The region is notoriously prone to natural disasters. Bangladesh has a long record of floods; the east coast of India, particularly in the state of Andhra Pradesh, and the coast of Bangladesh, bordering the Bay of Bengal, are regularly hit by storm surges associated with tropical cyclones. In 1991 a cyclone killed over 130,000 people in Bangladesh's Chittagong area. About 38 severe cyclones have been reported in the coastal zone of Bangladesh between 1872 and 1992, a frequency of about one severe cyclone in three years (Topping et al., 1993, see also B.D. Haq, this vol., Milliman, this vol.). The risks associated with such natural calamities call for adequate physical planning of coastal areas, development of necessary forecasting and emergency relief capabilities and the construction of shelters for local population. However, coastal resources of affected areas remain exposed to the possibility of colossal damages, bringing destruction and destitution to hundred of thousands of poor coastal dwellers.

The toll of natural calamities of the region also includes the occurrence of droughts, which affect the coast of Pakistan and particularly the province of Balochistan. Shortage of water supply impair human uses for agriculture production and domestic and industrial supply. Over-exploitation of water resources may damage the ecological balance of coastal wetlands and frequently induces salinity intrusion with disastrous consequences for coastal ecosystems.

An additional threat to coastal zones is due to the vulnerability of low-lying coastal areas to accelerated sea-level rise induced by global warming. Although the risks associated with global warming induced phenomena are still surrounded by considerable uncertainties, a sound long term planning of coastal areas should be based on the assessment of potential implications caused by accelerated sea level rise, in terms of vulnerability to flooding and impacts of extreme events. Increasing awareness on the issue has prompted a number of studies on vulnerability assessment of coastal areas. Such studies advocate improving monitoring of climatic and environmental trends in the region through cooperative programs and formulating long term coastal zone strategies on sound vulnerability assessment. Crucial issues to be addressed include phenomena of land subsidence, trends of river sediment supply, impairment of natural defenses (i.e., mangrove forests), location of key infrastructures and cost appraisal for potential response measures. A particular concern is raised on the possible increase in frequency and intensity of cyclones induced by climate change. This concern needs to be addressed through further research and upgrading of forecasting capabilities.

Coastal Zone Management Systems in South Asia

The planning systems of the five maritime South Asian countries, Bangladesh, India, Maldives, Pakistan and Sri Lanka, present great differences in planning objectives, policies, instruments and institutional frameworks. Box 2 summarizes the current availability of strategic studies, legislative and national planning instruments and special area management plans for coastal areas.

Bangladesh: No comprehensive coastal zone management plan has been approved by the government. ESCAP assisted in the preparation of a coastal environmental management plan for Bangladesh in 1988 (ESCAP, 1988). The study reviewed major environmental and development planning issues. The government formulated in 1992 a Concept Plan for Integrated Coastal Protection and an ICZM Strategy was produced in 1993 with assistance from UNDP. It includes recommendations for the formulation of public policies, the establishment of inter-agency coordination mechanisms, the development of planning instruments based on land suitability analysis and the implementation of pilot studies at the local level. A large scale mangrove reforestation program has been carried out by the Forest Department since 1966 and considerably expanded with World Bank support since 1980. The program aimed primarily at the protection and stabilization of coastal areas for mitigation of natural hazards. The program has also produced significant impacts and implications for the planning and socio-economic development of the coastal areas of the country, which may have a bearing on the future formulation of ICZM initiatives.

India: In India the Environment (Protection) Act 1986 deals with all matters relating to protection and preservation of environment, including the coastal zone (Ministry of Environment and Forests, 1993-94). The Ministry of Environment and Forests issued in 1991 a Notification on Coastal Regulation Zones. This notification imposes regulations on the setting up and expansion of industries, hotels and other activities: it lists prohibited activities and states conditions and regulations for permissible ones. The notification also requests the coastal states to prepare Coastal Zone Management Plans in accordance with given guidelines on the classification of the "Coastal Regulations Zones" and to specific guidelines for the development of tourism infrastructures in undisturbed areas. These Plans are currently at various stages of preparation by the state governments and review by the Ministry of Environment and Forests. The Ministry of Environment and Forests reported in 1993 that the coastal zone management Plans had been finalized in the Union Territories of Pondicherry and Daman and draft plans for the States of Goa, Tamil Nadu, Kerala and Union Territories of Andaman & Nicobar and Lakshadweep were under consideration by the Ministry. The coastal zone management plans, once approved, would be part of the local statutes to the effect of enforcement of the provisions of the Notification on Coastal Zone Regulation. The basic planning unit in the country is constituted by the District; administrative jurisdictions at state level are complex and may vary from state to state. The state government of Andhra Pradesh was the first to establish, in 1985, a Shore Development Authority with a clear mandate for coastal zone management. An Island Development Authority was set up in 1986 under the Planning Commission for Development Planning of Small Islands, to issue guidelines on natural resource management for Andaman & Nicobar and Lakshadweep islands. The implementation of the above mentioned Notification would place considerable challenge for state and local administrative structures to fully meet the requirements for coordinated management of

coastal developments and multiple use planning, with particular regard to the encouraged development of growing sectors such as tourism. Amendments to the Notification are being considered by the Ministry of Environment and Forests to review the distance criterion from high tide line for locations of hotels and resorts in coastal areas. (Also see earlier module)

The Maldives: In Maldives, coastal environmental management clearly means overall environment and development planning of the archipelago. The responsibility for formal planning in the government of Maldives belongs to the Ministry of Planning, Human Resources and Environment (MPHRE). The coordination of planning interventions is ensured through the National Commission for the Protection of Environment; the Commission has its secretariat in the Environment Section of the Ministry and has representation from all government departments dealing with the environment. Environmental protection and management are pursued under the umbrella legislation "Environmental Protection and Preservation Act, 1993". This Act provides extensive authority and regulatory power to MPHRE on development projects (through requirements for environmental impact assessment), formulation of planning guidelines, the management of protected areas and the enforcement of regulatory provisions. Line Ministries have also promulgated a number of regulatory guidelines in sectors such as logging, tourism, waste management, housing, etc. In particular the fisheries sector is controlled through regulations issued by the Ministry of Fisheries and Agriculture under the purview of the Fisheries Law of the Maldives. In 1989 a National Environmental Action Plan was formulated to support the assessment of environmental conditions, the development and application of management instruments, the formulation of legislative provisions and the strengthening of necessary institutional capabilities.

Pakistan: In Pakistan the seaward coastal zone up to 12 nm from the coastline is under the jurisdiction of the two provinces of Sindh and Balochistan. Provincial governments have responsibility for legislation and enforcement for sectors such as fisheries, forestry, etc. However, the Federal government is responsible for the protection of the environment and the conservation of natural resources. The Federal government has also responsibility for the Exclusive Economic Zone. The umbrella legislation in the environmental field is the Environmental Protection Ordinance 1983, which has provisions for mandatory environmental impact assessment. Sectoral legislative instruments for fisheries, pollution control and forestry are also available. The complex distribution of responsibilities among Federal government bodies, provincial governments and local agencies of the Federal government would require an effective coordination mechanism to address coastal problems and resource management issues. No legislative framework existed for the formulation of planning instruments in the coastal areas, until the recent establishment of the Coastal Authority for Sindh. The preparation of a coastal environmental management plan for the entire coast of the country has been prepared with the support of ESCAP to assess issues and problems of coastal areas, but no integrated management plan has been actually implemented. A few environmental management projects affecting coastal areas have been developed. The World Conservation Union (IUCN) has an established record of projects in the coastal areas of the country, focusing on the sustainable management of mangroves in the Indus Delta (the Korangi Ecosystem Project). A Coastal Recreation Development Plan has been prepared for Karachi by the Karachi Development Authority.

Sri Lanka: Sri Lanka has a comprehensive and well established legislative, institutional and management framework for coastal area planning. The planning system has been developed through the undertaking of pioneering studies, such as the Coastal Environmental Management Plan for the Southwest Coast (CEMP) (ESCAP, 1985) prepared by the Central Environment Agency with support from ESCAP in 1985. An Accelerated Strategy for the Development of Coastal Resources in the Southern Province has been prepared in 1988. The Coast Conservation Act, No; 57 of 1981 and its amendment in 1988 established the Coast Conservation Department (CCD). CCD applies a permit procedure for all activities coming within its area of authority, as well as environmental impact assessment regulations for development projects in coastal areas. Through inter-agency coordination mechanisms, the CCD can interact with the numerous national, regional and local organizations involved in planning activities affecting the coastal zone. The fundamental planning instrument is represented by the Coastal Zone Management Plan (CZMP) (Sri Lanka Coastal Conservation Dept., 1990), prepared by the CCD. The Plan addresses three main coastal problems only: coastal erosion, the management of coastal habitats and the loss and degradation of archaeological, historical and cultural sites and recreational and scenic areas. The plan is an operational working document that sets planning and management principles, on which CCD's regulatory system and coordinating mechanisms are based. The CZMP sets defined management objectives and policies for each problem, in the context of its nature and causes. A specific Master Plan for Coastal Erosion Management was also prepared in 1986 (Sri Lanka Coast Conservation Dept., 1986). In view of the due revision of the CZMP, a strategic study has been prepared, based on the evaluation of experiences from the implementation of the CZMP. This new strategy calls for a substantial broadening of the geographical boundaries and planning scope for coastal zone management. In particular it advocates the widening of the scope of CZMP to include the whole socio-economic context of environmental problems, to address the environmental degradation caused by economic development activities and to achieve higher benefits through improved resources management. The study report suggests changes such as: a more comprehensive approach not limited to single agency and sectoral approaches to coastal resources; a revision of the emphasis given to regulation; integrated strategies for water quality management, habitat degradation, natural resource use by people and institutional weaknesses; broadening the geographic definition of coastal zone; participation by local and provincial officials and coastal communities in the formulation of plans and strategies. Valuable experiences in the preparation and execution of special area management plans on coastal areas are also available, such as the Muthurajawela-Negombo Lagoon Master Plan (Greater Colombo Economic Commission, 1991) and the Special Area Management Planning (SAMP) for Rekawa Lagoon area and the Hikkaduwa Marine Sanctuary.

Box 2.. Summary of Coastal Zone Management Instruments in the South Asian Countries.

Strategic Analysis and Planning Studies		Legal Instruments for Intersectoral / Integrated Planning of Coastal Areas	Planning Agencies with Responsibility for ICZM	Statutory Management Plans	Special Area Management Plans
Bangladesh		Coastal Environmental Management Plan, ESCAP, 1988 Concept Plan for Integrated Coastal Protection, 1992 Feasibility Study: Integrated Coastal Zone Management for Bangladesh, 1993. Report on Coastal Zone Management in Bangladesh, ESCAP, 1993 [1]	..	..	..
India		Report on Coastal Zone Management in India, ESCAP, 1993 [2]	Notification F.No.1811/5/87-HSMD on Coastal Regulatory Zones, Ministry of Environment and Forests, 1991 (under the 1986 Environment Protection Act)	Ministry of Environment and Forests Governments of State or Union Territory (Urban Development Offices or Town Planning Offices)	Coastal Zone Management Plans under preparation by Coastal States and Union Territories
Maldives		Report on Coastal Zone Management in Maldives, ESCAP, 1993 [3]	Environmental Protection and Preservation Act, 1993	Ministry of Planning, Human Resources and Environment (1989) National Commission for the Protection of the Environment (1989)	National Environment Action Plan, 1989
Pakistan		Coastal Environmental Management Plan, ESCAP (1993) Report on Coastal Zone Management in Pakistan, ESCAP, 1993 [4]	Sindh Coastal Authority Act, 1994	Coastal Authority for Sindh (1994)	Karachi Coastal Recreation Development Plan 1990-2000 (1990) Korangi Ecosystem Project (IUCN) (1992)
Sri Lanka		Coastal Environmental Management Plan for the South West Coast, 1988 Accelerated Strategy for the Development of Coastal Resources in the Southern Province, 1988 Coastal 2000: Recommendation for a Resource Management Strategy for Sri Lanka Coastal Region, 1992 Report on Coastal Zone Management in Sri Lanka, ESCAP, 1993 [5]	Coast Conservation Act 1981 EIA Regulations on Project Approving Agencies, 1993 EIA Regulations on Projects or Undertakings Wholly or Partially Outside the Coastal Zone Defined in the Coast Conservation Act of 1981, 1993	Coast Conservation Department (1981) Central Environmental Authority	Muthrajawela - Negombo Lagoon Master Plan, 1991 SAMP for Rekawa Lagoon Area and Hikkaduwa Marine Sanctuary, 1990 Colombo Metropolitan Environmental Improvement Programme (in preparation)

[1] Nishat (1993) [2] Parasada Rao (1993) [3] Shihab (1993) [4] Haq and Rizvi (1993) [5] Samarakoon (1993)

The promotion of ICZM is increasingly being advocated as a fundamental goal of many environmental resource management projects and plans throughout the world. Agenda 21 includes among its objectives the commitment by coastal states to integrated management and sustainable development of the coastal areas and marine environment under their jurisdiction (Agenda 21, 1992). A growing number of development agencies and research institutions are adopting ICZM concepts and objectives in their programs. They generally assert that the notions and tools of ICZM may support the integration of environmental considerations in development planning of coastal areas. A number of ICZM projects have been designed and a few innovative and successful ICZM experiences have taken place, mainly at local level. International development agencies have produced a few ICZM guidelines and management tools based on the lessons learned from early experiences.

Despite this fervor, the tangible implementation of ICZM plans and the application of guidelines can be considered generally still very limited. The concrete execution of the ICZM plans has to face a reality of complicated coastal environmental and development problems, intricate political and planning factors at local and national level and the tangle of the many conflicting and mutable interests at stake. This complex mix of factors affects the real impact of coastal zone management programs and moreover make unreliable any attempt to produce recipes of general value. ICZM practitioners are increasingly perceiving the need for a deeper assessment of the reasons of successes and failures of earlier experiences. New initiatives should be more closely built on precise evaluations of available lessons and experiences and assessment of local factors and requirements.

ICZM is indeed more a process than a defined planning system. This process should aim at producing a progressive coordination of sectoral planning instruments and harmonization of development activities to ensure long term sustainable management and exploitation of the coastal resources. This would require an effective integration of physical and economic planning, both in terms of planning instruments (Le., resource management plans, investment development policies, siting policies, etc.) and governance structure (Le., technical capabilities and human resources of administrative institutions, vertical and horizontal jurisdictions of government, interest groups, etc.).

In South Asian countries this process would require considerable institution building efforts. The national programs, initiatives and policies outlined in the previous section, indicate that in these countries there is a growing awareness of the special nature of coastal environmental issues and the peculiar planning requirements generated by coastal developments. Nevertheless, the range of objectives and scope of national coastal policies and plans epitomizes the diversity of perceptions and priorities among the countries of the region.

The promotion of ICZM should aim at achieving strong commitment from the central government, which is an essential factor to ensure the long term success of any program. Some of the ICZM initiatives supported by bilateral and multilateral development agencies throughout the world, have not achieved their desired long term objectives. They have often come short of expectations in the phase of execution. ICZM programs frequently advocate progressive innovations of the system and culture of planning. These are positive long term objectives which need to be pursued by consistent and sustained efforts. On one hand, there is need to increase awareness among different government levels and stakeholders of the benefits achievable through ICZM. Awareness raising should be

based on effective communication and the demonstration of tangible results. On the other hand, ICZM programs should be integrated in the national physical and development planning system of the recipient country. Only this integration would secure the institutional and financial commitment necessary for the long term sustainability of the ICZM initiatives.

This requirement is particularly acute in the case of developing countries, such as the South Asian countries. In these countries the scope of ICZM initiatives cannot be limited to natural resource management. This narrow definition of ICZM would undermine its significance and impact. ICZM initiatives should primarily pursue practical and effective development targets for the benefit of local stakeholders. They should provide a sustainable and pragmatic framework for development activities.

This condition has considerable implications in a national perspective. Even the impact of successful ICZM projects executed in this region and elsewhere are often confined to limited areas within limited economic and social scope. A primary reason is because coastal zone management efforts have often developed without substantial integration with the driving forces of the national development process.

To prevent these limitations, ICZM should be built within a defined national strategy for the coastal area. The strategy should recognize in a comprehensive perspective development needs, potentialities and constraints of the coastal region. The development perspective of the coastal zone would therefore assume the status of a long term strategy with the involvement and backing of highest policy and planning levels.

All the countries of the region have carried out or are undertaking with variable approaches the formulation of comprehensive development and environmental management strategies for the coastal zone. All these national strategies encourage, although to different extent, multiple use objectives, intersectoral and interdisciplinary coordination, interdisciplinary approach in planning and the promotion of participation of local communities and local government in the planning process. These processes should be further sustained. They should also be supported toward their translation into effective planning instruments, based on sound scientific assessment and appraisal of socio-economic conditions.

Sri Lanka's experience in coastal zone management provides interesting lessons on the progressive evolution of a national coastal development policy, which may provide useful and practical lessons to the development of ICZM programs in South Asia as well as in other regions. Sri Lanka developed a national framework for coastal zone management initially focused on a few priority problems. The initial preparation of the CZMP was carried out by identifying the environmental and development issues of the coastal zone through extensive consultation with planning agencies, the academia and non-governmental organizations. The enactment of legislation for coastal zone management promoted the formulation of planning instruments by the Coast Conservation Department. The Department had a clear mandate for interagency coordination and experienced and skillful staff. Bilateral and multilateral assistance programs provided support to the preparation of the coastal management plan and to its implementation. CCD's primary responsibilities were coastal zone planning, policy and research coordination; administration of permit procedures for the regulation of coastal developments; and the construction and maintenance of shoreline protection

works. As mentioned in the previous section, the national coastal zone management process has now completed a first cycle and is going through a review process. The "Coastal 2000 Report" evaluates the lessons learned with the first generation CZMP and indicates a number of crucial requirements for the further development of coastal zone planning in the country. These requirements include the need to decentralize the management program; involve the public sector in implementation; develop special area management plans in locations of ecological and economic significance; strengthen research and monitoring on major resource management issues; enhance institutional and human capacities; promote public awareness and education.

The experience of Sri Lanka clearly shows that the development of coastal zone management is a complex process of cyclical nature. Successive planning cycles allow to broaden progressively the CZMP's objectives, priorities and the scope of generated interventions and instruments. Through this cyclical process the integration of environmental and development planning objectives in the ICZM system can be pursued progressively.

A few additional points deserve special consideration. The development and implementation of zoning systems for coastal land and regulatory systems for coastal developments generally represent a fundamental target for ICZM. Nevertheless it has been experienced a number of times that command and control systems for coastal resources management do not suffice in solving problems of multiple use conflicts. ICZM planning experiences in Sri Lanka, as well as sectoral plans (i.e. for coastal aquaculture) in other countries, have proved that regulatory systems should be supported by adequate economic incentives. Furthermore, environmental management policies should be meaningfully integrated with investment promotion policies.

ICZM experiences have also underscored that the involvement of the community at large, and particularly of the population directly affected by the planning measures, is a critical factor for their success. Public consultation should go hand in hand with inter-agency coordination and should be promoted and sustained by adequate and recognized opportunities for communication, discussion and review (see also Hildebrand, this volume). The planning process should ensure the participation of local administrators, the business sector, the academia, rural communities and the general public. This is necessary to tackle in an effective manner complex conflicts among resource users. Participatory processes need to support ICZM both at formulation and implementation stages. Well conceived plans may still have a very limited impact in the field due to lack of support from stakeholders. Therefore, they should strive to avail of the involvement and consensus of stakeholders as the necessary driving force behind the progressive development of area based management processes.

In the South Asian region, Sri Lanka has some documented and significant record of participatory processes in ICZM. It should be considered that favorable local conditions have contributed to the success of such pioneering experiences. However, these considerations may not necessarily hinder the application of similar experiences and approaches to coastal areas of other countries of the region, with due regard to local factors and requirements. Moreover, significant records of participatory rural development activities are already available in the region although not developed in the context of ICZM. These experiences may offer interesting lessons for the promotion of ICZM, through the application of local successful approach to the peculiar problems of coastal

areas. It should also be noticed that in countries where coastal zone management is still at early stage, ICZM is often promoted by groups mainly composed by scientists and environmental planners. Therefore, in these countries a cross fertilization of ideas and experiences with experts and planners of rural development should be encouraged and may yield interesting results.

The promotion of ICZM should be sustained by the development of necessary capacities in terms of human resources and institutional means. Planning offices and environmental management agencies are too often poorly equipped with the capabilities necessary to carry out proper environmental assessment activities (coastal resources monitoring, preparation of coastal environmental profiles and databases, rural appraisal surveys), to formulate management instruments (i.e., development of zoning and management plans, guidelines for major coastal development activities, involvement of various stakeholder including local communities in the plan formulation process) and to ensure enforcement (application of coastal development regulatory systems, application of pollution control systems, long term monitoring, education and public awareness campaigns, dissemination of planning reports, implementation of development projects related to ICZM plans).

To meet these capacity-building requirements, long term training and institution development programs are required. Only long term programs could address the complexity of ICZM training, provide practical training experiences, and obviate at personnel turnover, frequently experienced in developing countries' administrations. It is therefore necessary to base capacity building efforts on clear institutional commitments and adequate resources to ensure their sustainability. Human resource development and institution strengthening programs should be included as integral component of planning programs and projects. This approach would provide opportunities for field experiences and on-the-job training of personnel and also contribute feedback and support to the planning projects themselves.

Capacity Building for ICZM in South Asia

Based on the review of issues, planning systems and available experiences and lessons learned in the region, a few ideas are addressed here for further analysis toward the elaboration of ICZM initiatives. A number of interrelated issues seem to deserve particular attention in the regional context.

Awareness Raising: The effective promotion and application of ICZM is affected by a number of factors, which include both national decision-making and the availability of necessary capacities. The development of a required legal and institutional framework for ICZM is a national undertaking determined by national policy priorities and decision making conditions. The benefits to be pursued and possibly achieved through the promotion of an ICZM process should be brought to the attention of policy makers as well as to all stakeholders. Additional awareness raising efforts may promote the development of an ICZM framework at national and local level. All societal groups should therefore be involved in the planning process through public workshops, dissemination of information via media and educational material and community-level workshops.

Developmental Objectives: ICZM should not be limited to the formulation of sound resource management instruments. Its main thrust should be the identification and promotion of development opportunities for the coastal populations. ICZM should aim at improving the quality of life of

coastal dwellers by improving housing conditions, food supply, availability of drinking water, raising and diversifying income, expanding education and public services and providing opportunities for autonomous determination of development objectives.

Demonstration Projects: Effective capacities in ICZM can be conveniently built through the execution of demonstration projects in ICZM. These projects often involve a limited area, where a coastal zone management plan is designed and executed over a limited time-span. Such demonstration or pilot projects often generate important benefits in terms of improved technical and management capabilities. These experiences can facilitate the gradual acquisition of institutional experience in the management of multidisciplinary and intersectoral planning processes, the building of local professional capacities, the raising of awareness and understanding of ICZM processes and benefits in the local communities, the government and private sectors. Interesting experiences of special area management are available in the South Asian region. These efforts have been supported by various government agencies, non governmental organizations and development agencies. Some of them have encouraged participatory process through consultations, training, workshops and participation in project activities. Through these steps, special area management plans may improve the perception within the community, private and government sectors of coastal environments and resources, coastal conservation and development, as well as the process and benefits of coastal management planning. These initiatives constitute a form of laboratory test for the development of appropriate institutional mechanisms required by the interconnections among coastal systems. However, the number of pilot projects in ICZM is still very limited in the region and mainly confined to Sri Lanka. The region may benefit from additional support to demonstration activities. In the long term, pilot ICZM projects may be expected to act as model and provide examples of the process and benefits of coastal management planning. In a national perspective, a successfully implemented project for selected demonstration area will stimulate interest among other coastal communities and governmental agencies, and possibly generate a momentum and thus contribute to the process of designing coastal zone management plans for the entire coast (where they do not exist yet) through replication.

MODULE - V

GIS FOR COASTAL ZONE MANAGEMENT

Coastal Spatial Data Infrastructure

INTRODUCTION

The term Spatial Data Infrastructure (SDI) is now in common use in countries around the world, although definitions for the term differ quite considerably. The stated objectives of SDI initiatives vary as much as do the definitions, legal mandates, types of organisation responsible for specifying and implementing SDI and actual progress achieved in creating national and regional SDIs.

One complication in specifying any SDI is the nature of spatial information, i.e. information with an important location attribute, often said to represent 80% of all information held, especially at government level. The visionaries and designers of SDI must accommodate the widely varying information needs of highly diverse disciplines and sectors of society, business and government. Health epidemiologists are seldom interested in the same spatial data as geological surveyors, air traffic controllers or coastal zone managers. Yet an important overlap in jurisdiction and information needs may arise, e.g. when a potential health epidemic is generated by toxic chemical concentrations in marine fauna later consumed by area residents. Then knowledge of the coastal zone flora and fauna, hydrography, tidal states, nearby land use practices of industry and agriculture and transport routes, fishing practices and zones all become intertwined. The complex relationships between different types of spatial information are one reason that countries take different routes to specify their SDI, ranging from visions to strategies to goals to detailed content (data and standards) and implementation plans (rules and regulations).

We all recognize that the coastal zone is a difficult geographical area to manage due to temporal issues (tides and seasons) and the overlapping of physical geography and hydrography (offshore, near shore, shoreline, inshore), of jurisdictions, legal mandates and remits of government agencies and the often competing needs of stakeholders. Typically, many different local, national and regional government agencies are responsible for different aspects of the same physical areas and uses of the coastal zone, e.g. fisheries, environment, agriculture, transport (inland and marine), urban planning and cadastre, national mapping agency and the hydrographic service.

Conflict resolution in this complex piece of real estate called the “coast” is sometimes used as justification for special attention for the coast within NSDI initiatives. As Bartlett (2000) expresses it: “Given the diversity of interest groups, stakeholders, managerial authorities and administrative structures that converge at the shore, conflicts are almost inevitable between and among coastal users, managers, developers and the wider public, as well as between human society and the natural environment.”

Because of such complex physical and institutional relationships, it is not possible to develop a coastal SDI (CSDI) in isolation from the broader National SDI (NSDI) for a nation or Regional SDI (RSDI). CSDI will necessarily be a subset of a more comprehensive NSDI because the coastal zone covers multiple physical and institutional spaces included in the generic NSDI. For that reason, it is important that people and agencies with specific knowledge and experience of the coastal zone and marine offshore areas and information requirements be an integral part of the NSDI and RSDI planning process.

CSDI WITHIN NATIONAL, REGIONAL AND GLOBAL SDI

Few nations have specified separate SDI components for individual sectors such as the coastal zone. In the USA, a Coastal NSDI vision exists based on four goals that relate to the USA NSDI (NOAA, 2001). Practical implementation work is undertaken by the National Oceanic and Atmospheric Administration (NOAA) and the Federal Geographic Data Committee (FGDC).

Canada has proposed a Marine Geospatial Data Infrastructure initiative (MGDI) within the national Canadian Geospatial Data Infrastructure (CGDI). MGDI is seen as an extension to the CGDI in response to “the need for a comprehensive, integrated and common infrastructure of marine data and information ... accessible to all stakeholders.”

Regional SDI Initiatives

At regional level, the INSPIRE project (Infrastructure for Spatial Information in Europe) recognizes hydrographic data as one of its “selected topographic themes” for data content for a Regional SDI for Europe (INSPIRE, 2002). More detailed data requirements are presented in the European Commission’s Water Framework Directive (European Commission, 2000), which underpins the need for INPSIRE. These two European regional projects are discussed more fully in a later section as they have legal mandates from a recognized regional government body—the European Commission—and have developed detailed descriptions of spatial data requirements, including marine and coastal zone data.

Work on specification for an Asia-Pacific SDI (APSDI) began in 1994 with formation of the Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) under the auspices of the UN Regional Cartographic Conferences (UNRCC). The APSDI model stresses institutional frameworks, technical standards, fundamental datasets and an access network (PCGIAP, 1998).

A new initiative started in 2000 for a Regional SDI for the Americas (PC- IDEA), but it is too new to have achieved anything more than creating a basic project organisational framework at this stage.

Global SDI Initiatives

Global level SDI initiatives include the Global Map Project (ISCGM, 2001), which began in 1996, the Global Spatial Data Infrastructure (GSDI) Association, which began as a series of international conferences in 1996, and the Digital Earth initiative sponsored by the US government (Evans, 2001). These initiatives intend to build on existing national and/or regional SDI work and existing data resources (primarily remote sensing imagery). They typically mention shoreline data, boundary data (including marine, ocean, inland waters) and references to cadastre that may or may not include marine cadastral data. GSDI and the Global Map project are discussed more fully later.

Of more immediate interest—and importance—to coastal and marine managers and researchers is the work of the Intergovernmental Oceanographic Commission (IOC) International Oceanographic Data and Information Exchange (IODE) working group mentioned later and described in some detail by Longhorn (2002).

CSDI IN THE US

The US NSDI initiative began formally in April 1994 with a presidential Executive Order (Clinton, 1994) in response to a national performance review of federal government. One of the main elements of the US NSDI is the creation, harmonisation and promulgation of technical standards by which all federal spatial information can be recorded, metadata being of highest importance so that existing spatial data resources can be identified, accessed and used. This major task fell to the Federal Geographic Data Committee (FGDC), which was created in 1990. Responsibilities with regard to NSDI implementation for all federal agencies in the US was set out in the revised OMB Circular A-16 in 2002 (OMB, 2002).

In the US, the Coastal SDI vision is based on four goals relating to the NSDI (NOAA, 2001). The US CSDI initiative is led by the Coastal Services Centre of NOAA (National Oceanic and Atmospheric Administration). The main goals of the US CSDI are:

- that the coastal management community should understand and embrace the vision, concepts and benefits of the NSDI,
- spatial coastal and marine framework data should be readily available to the coastal management community,
- technologies to facilitate discovery, collection, description, access and preservation of spatial data should be widely available to the coastal management community, and
- NOAA should help develop and implement spatial data applications to meet the needs of the coastal and marine communities.

Note the emphasis on support for coastal resources management, a role assumed by NOAA under the 1972 Coastal Zone Management Act, as opposed to NOAA's historical focus and initial primary mission of ensuring safety of navigation.

The main elements of CSDI that NOAA promote are bathymetry, shoreline identification and marine cadastre, although other types of data are under review for attention as a formal part of CSDI, e.g. coastal imagery, marine navigation, tidal benchmarks and benthic habitats (Lockwood and Fowler, 2001). Development of technical standards to support the CSDI is undertaken by the FGDC's Marine and Coastal Spatial Data Subcommittee, under chairmanship of NOAA/CSC (FGDC, 2002). The committee's primary mission is to develop and promote the Marine and Coastal NSDI so that "current and accurate geospatial coastal and ocean data will be readily available to contribute locally, nationally, and globally to economic growth, environmental quality and stability, and social progress" (NOAA, 2003). In 2000, this committee assumed the remit of the FGDC Bathymetric and Nautical Charting Data Subcommittee, formed in 1993.

Bathymetric data is treated as a sub-layer of the Elevation layer data in the NSDI Framework. Marine cadastre is being examined within both the FGDC Marine Boundary Working Group (MBWG) which includes members of the FGDC Cadastral Subcommittee. The MBWG was formed in 2001 to address issues relating to the legal and technical aspects of marine boundaries, with the

goal to alleviate cross-agency problems concerning marine boundaries, plus provide outreach, standards development, partnerships and other data development critical to the NSDI. A major product of the MBWG work to date is the FGDC's Shoreline Metadata Profile (FGDC, 1998).

Two further standards nearing completion for the CSDI are the National Hydrography Data Content Standard for Inland and Coastal Waterways (FGDC, 2000a) and Accuracy Standards for Nautical Charting Hydrographic Surveys (FGDC, 2000b).

The US CSDI initiative should help identify the basic reference data required to achieve goals for national programs such as those stated in the Clean Water Action Plan - Coastal Research and Monitoring Strategy, which represents "the first effort to integrate coastal monitoring and research activities on a national scale to provide thorough, cross-cutting assessments of the health of the nation's coastal resources" (CRMSW, 2000). These goals include:

- Improving monitoring programs for integration at national level
- Integrating interagency research efforts
- Conducting national and regional coastal assessments, and
- Improving data management.

Interestingly, a report from the US Commission on Ocean Policy found a tight connection between inland systems for development and agriculture to areas traditionally designated as coastal. "The coastal zone is not a narrow band. It's the whole country" (US CoOP, 2002). Regarding data collection and sharing, the US Ocean Policy report further found that "there is no marine equivalent to the networks of meteorological observation stations distributed on land on all continents. Ocean observation efforts are limited temporally and spatially." This leads to the conclusion that "there is a need for a better and more comprehensive way to link the work of different disciplines in a manner that offers a more integrated understanding of the marine environment and the processes that control it... there is a need for standardized practices and procedures" (US CoOP, 2002). These findings reinforce the premise that CSDI cannot and should not be developed in isolation from the broader NSDI of a nation or region. Actions like the Clean Water Action Plan mentioned earlier provide important input into the political process for securing added support for creating a CSDI.

CSDI IN CANADA

In Canada, the NSDI is called the Canadian Geospatial Data Infrastructure (CGDI) with the snappier, market-oriented title GeoConnections. From its beginning, the CGDI recognized that "governments have a responsibility to make geospatial information available ... for developing a knowledge economy in response to the needs of citizens, industry and communities in support of economic, social and environmental well-being". Marine navigation and charting for pollution control, coastal zone management and environmental monitoring were considered important applications to be fostered under CGDI. The CGDI has five technical and policy thrusts: access, data framework, standards, partnerships and creating a supportive policy environment. The CGDI vision is "to enable timely access to geo-info data holdings and services in support of policy,

decision-making and economic development through a co- operative interconnected infrastructure of government, private sector and academia participants. From the outset, CGDI planners realized that “institutional issues will likely eclipse technology as an impediment to CGDI development and implementation”.

Within the framework of the CGDI, the Marine Geospatial Data Infrastructure (MGDI) is being developed in Canada, “to enable simple, third party access to data and information that will facilitate more effective decision-making” for anyone involved in coastal zone management. MGDI is described as comprising data and information products, enabling technologies as well as network linkages, standards and institutional policies. The concept for an MGDI-like information network was first proposed in 1988 as the “Inland waters, Coastal and Ocean Information Network (ICOIN)”.

In support of the five main elements of GeoConnections (the CGDI), a Marine Advisory Committee was created in 1999 at the time of publication of a draft concept report for the MGDI (CCMC, 1999). The committee’s remit is to ensure the full functionality of the CGDI in providing service to all marine stakeholders. To aid in this, a Marine Advisory Network has been set up to act as the physical focal point for stakeholder outreach and consultation.

The MGDI recognizes the need for common standards permitting data to be used seamlessly across disciplines and systems. Because of the principally land- based focus of most NSDI developments, MGDI also recognizes that standards that apply perfectly well to land-based applications and data are sometimes incompatible with the marine world. It is also understood that simply making spatial data available across the Internet does not always provide solutions to specific problems. Data is not information and information is not knowledge. MGDI also recognizes that data pricing and related policy issues dealing with intellectual copyright will be crucial to the success of both CGDI and MDGI and that, while these potential barriers may not fall easily, they are not insurmountable. The needs of users and potential stakeholders were identified more completely in an extensive requirements analysis study in 2001 (DFO, 2001).

The MGDI architecture includes:

- A common spatial data model
- An integrated process and data modelling environment
- A common spatial language and data exchange format
- Methods for managing, querying and delivering data with integrity, and
- Open source productivity tools ensuring access for all.

Progress in implementing the MGDI as a coherent system has been slower than anticipated, due mainly to two things that affect nearly all such initiatives known to this author, i.e. lack of resources (especially any new or extra resources) and institutional barriers inherent in government whether local or national. Note that even the Presidential Executive Order creating the USA NSDI did not

offer any new money, rather all work to achieve the NSDI had to be conducted from within existing budgets.

CSDI ELEMENTS IN REGIONAL SDI

Regional SDI (RSDI) initiatives have started in Europe (INSPIRE), Asia-Pacific (PCGIAP) and the Americas (PC-IDEA). These projects all intend to build on National SDIs located within their geographic regions. Unfortunately, since few NSDIs have reached an advanced degree of completion—and many have not yet even been specified or received legal mandates—it is still early to see how coastal and marine SDI requirements will be accommodated within the RSDI envelopes. The Permanent Committee for SDI for the Americas (CP-IDEA/PC-IDEA) was only formed early in 2000 under the auspices of the UN Regional Cartographic Conference. This new initiative has yet to produce any substantial documents relating to how SDI will be coordinated across the nations of Central and South America. Initially it is focusing on institutional strengthening, metadata, access policies, outreach and similar issues to those being pursued by PCGIAP and within the global GSDI Association.

INSPIRE—Infrastructure for Spatial Information in Europe

INSPIRE recognizes hydrographic data as one of its selected topographic themes for data content for the proposed Regional SDI for Europe (INSPIRE, 2002). Hydrography is defined as “surface water features such as lakes and ponds, streams and rivers, canals, oceans and shorelines.” During the many years that European SDI consultations progressed from the GI2000 initiative (1995–1999) through ETeMII (European Territorial Management Information Infrastructure 1999–2001) to INSPIRE (2001–present), reference to specific themes for spatial data content in the proposed SDI specification was initially resisted. After much debate, the hydrographic component (including coastal zones) was included, along with only two other “topographic themes” - transport and height. Hydrography is defined in INSPIRE as “surface water features such as lakes and ponds, streams and rivers, canals, oceans and shorelines.” The “height” topographic theme includes “contour data showing heights by isolines, and including with the same data set spot heights, high and low water lines, breaklines and bathymetry” (INSPIRE, 2002). At the end of the consultation period, INSPIRE was extended to cover a wide range of coastal and marine data components, including “bathymetry, coastline, hydrography, surface water bodies, water catchments, oceans and seas, oceanographic spatial features, sea regions, aquaculture facilities, polluted areas and more (INSPIRE, 2003).

European Water Framework Directive

The EU Water Framework Directive (European Commission, 2000) represents the culmination of five years of consultation and negotiations for implementing a harmonized and integrated water policy for all European Union Member States (now 15, soon to be 25). The WFD places quite detailed—and some say onerous— monitoring and reporting requirements for the status of surface water in four regimes: rivers, lakes, coastal waters and transitional waters (estuaries and similar bodies of water which are partly saline but strongly influenced by freshwater flows).

The data relating to coastal and transitional waters required in order for EU Member States to report to the European Commission on water condition include: detailed location (boundary) information,

various biological data for aquatic flora and benthic fauna, hydromorphological data including depth variations, tidal regimes, transparency, thermal conditions, oxygenation conditions, salinity, nutrient conditions and pollution.

In order to do this reporting, a very detailed GIS specification has been produced (European Communities, 2002). For coastal waters, the data to be captured include shape, name, various identifying codes, type of water body, status of the water body (artificial, heavily modified), salinity typology, depth typology, tidal typology, and more. The specification document is nearly 170 pages long—a far cry from the “hydrography” or “marine boundary” terms found in isolation, without further explanation, in other regional and all global SDI specifications. In fact, one worries if the European government authorities and their national oceanographic and coastal research institutions will be able to provide data at the level of detail required within the timeframe set by the Directive, which comes into force in December 2003.

The WFD Directive has been used by various Directorates General at the European Commission to justify the INSPIRE European Regional SDI initiative, on the basis that much harmonised, integrated and interoperable basic reference data will be required if WFD reporting requirements are to be met at least cost. It remains to be seen if the level of detail already specified in the INSPIRE working documents will in fact be sufficient to help fulfil that requirement.

Asia-Pacific Regional SDI (APSDI)

In the Asia-Pacific SDI (APSDI), what are termed “fundamental datasets” are only presented in the most general terms and with no detail. The discussion on what data should be included in the APSDI began in 1998 and has yet to reach a conclusion. Due to the large number of participants—55 nations across Asia and the Pacific are members—and very limited development resources, we should not expect the situation to change any time soon in regard to formal data specification. At the most recent meeting of the Working Group on Fundamental Data held in April 2002, the working group recommendations included (PCGIAP, 2002):

- The contents of the Asia-Pacific Regional Fundamental Dataset shall be defined, and further, the technical specifications of the Asia-Pacific Regional Fundamental Dataset shall be developed, with the Global Mapping Specifications and Administrative Boundary Pilot Project Specifications, as reference.
- For the first version of the Asia-Pacific Regional Fundamental Dataset, the vector data shall be no less accurate than 1:1 million in map scale, and the raster data shall be no less than 1KM in ground resolution.

At a 2001 meeting of the PCGIAP Working Group on Cadastre, an item was recommended for the work plan covering “identification of broad types of marine cadastres in use throughout the world as they become established” (PCGIAP, 2001). Unfortunately, the meeting also noted “concern about the apparent direction of the Cadastre WG in majoring in activities on marine cadastre, boundaries being a very sensitive issue in PCGIAP.”

One surmises that little practical progress has been achieved in more detailed data specification in nearly six years of work and that the small scale of the data will be of minimal use to local coastal managers or researchers. Also, political issues may limit the degree of actual detail that will be agreed within the very broadly based group.

CSDI AT GLOBAL LEVEL

At the global level, the not-for-profit Global Spatial Data Infrastructure (GSDI) Association primarily offers a forum for discussion and exchange of experiences, especially in relation to creating SDI at national level. The GSDI's 'SDI Cookbook' (GSDI, 2001) does not specify what types of data nations should have in their SDI, but rather it concentrates on general, though still important, matters such as metadata creation, access policy and other administrative and institutional issues. In a general listing of the types of data that should be considered for including in a National SDI, the cookbook does mention cadastre and hydrography. No further details are given and there is no working group specifically targeting marine or coastal data requirements. A more thorough review of how coastal zone information is related to the GSDI can be found in Longhorn (2003b).

The Global Map specification (ISCGM, 2000) makes reference only to "coastline/shoreline" and "ocean/sea" boundary data, "ferry routes" under a "transportation" heading and edges of "islands" and "inland water" under "drainage (hydrography)." The remainder of the specification is devoted to identifying existing public domain data sources (all at scales of 1:1 million or smaller), data models for vector and raster data, precision and accuracy and metadata issues. The primary data sources listed are VMAP Level 0 from the US National Imagery and Mapping Agency (NIMA), the Global 30 Arc Second Elevation Data Set (GTOPO30) and Global Land Cover Characteristics Database, both available from the US Geological Survey and other sources. These resources have been available in the public domain for some years now, and include only small scale data, some of which are rather old compared to the time frames of interest for much coastal management and research work. For these reasons, there is little new in the Global Map project that would excite coastal managers and researchers.

What approximates a useful global marine SDI does exist for oceanographic data due to long established information management and data exchange programmes of the Intergovernmental Oceanographic Commission (IOC) (Longhorn, 2002). At its most recent meeting in June 2002, the IODE working group considered including coastal data in its remit, only to have the possibility removed from its future agenda by refusal or reluctance of the governments of some important developing country members to permit ready access to coastal zone data for national security and economic reasons.

PRINCIPAL COMPONENTS FOR CSDI

Having reviewed the few formal coastal SDI initiatives that exist, all at national level, it appears that a CSDI mainly comprises: data sources, standards, enabling technologies and institutional policies. Work in relation to the first two components needs to be carried out with a specific marine or coastal focus, which is sometimes missing from generic SDI initiatives. The latter two aspects

apply to the wider requirements of any information infrastructure, not just that of coastal SDI or even for spatial data alone.

Basic Reference Data for the CSDI

The presence or absence of basic reference spatial data (also sometimes called ‘framework ’data) in National, Regional and Global SDI implementations that relate to the needs of a viable coastal SDI are shown in table 1.1. As one might suspect, the most common are bathymetry, shoreline and boundary data. For most Regional and Global SDI initiatives, there is not sufficient detail in specification of data elements to determine whether or not the needs of coastal and marine resource managers and researchers will be met (with the exception of INSPIRE/WFD). Since the basic data will be collected at national level, this might not appear to be a serious problem at the moment. Yet when data exchange is required for research purposes, resolving boundary disputes or to satisfy a nation’s responsibilities regarding various international data exchange conventions, then the absence of regional and global agreement on SDI contents and access issues will become noticed.

A ‘yes ’indicates that the component in the left-hand column is formally listed as an important data component in the definition of spatial data infrastructure at national, regional or global level. The number of ‘no ’and ‘maybe ’entries is disquieting. Fortunately, the ‘nos ’appear mainly in regional or global initiatives while ‘maybes ’indicate that detailed user requirements or specifications have been identified and published, along with existing data sources that might provide this data. However, no firm decisions have been made as to how or if this data will be included within the higher-level NSDI or not.

Table 1.1 Coastal SDI components in national, regional and global SDIs

SDI Component	USA	Canada	INSPIRE- WFD	APSDI	GlobalMap
bathymetry	yes	yes	yes	maybe	maybe
shoreline	yes	yes	yes	yes	yes
marine cadastre	yes	yes	no	yes	maybe
coastal imagery	maybe	maybe	yes	no	no
marine navigation	maybe	yes	maybe	no	maybe
tidal benchmarks	maybe	maybe	yes	no	no
benthic habitats	maybe	maybe	yes-WFD	no	no

CSDI Is More Than Data

Other components of an SDI mentioned in most SDI descriptions cover: metadata creation and standards, technical guidance (including standards) on spatial precision, accuracy and data formats (both raster and vector), data access policies (some of which are more liberal than others) and intellectual property guidance.

Standards issues in the spatial data world are now much better addressed than a mere five years ago due to the extensive work of the International Standards Organization's Technical Committee 211 (TC/211) on Geographic Information/Geomatics which is creating "a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth" comprising some 40 new GI- related standards (ISO, 2002). In parallel with ISO, the global reach and uptake of the GIS interoperability work of the Open GIS Consortium, Inc., and OGC Europe, Ltd., is providing a clear way forward in regard to integrating GI applications and data sources, especially using the Web as the service delivery machinery (OGC, 2002).

Other important standards developments relating to coastal and marine data include the S-57 (Special Publication No. 57) cartographic standard developed for and maintained by the International Hydrographic Organisation (IHO) and International Hydrographic Bureau (IHB) in Monaco (IHO, 1996). This standard is used for collection and exchange of hydrographic data among national Hydrographic offices globally. It is also very important for marine navigation as applied to the new Electronic Chart Display and Information Systems (ECDIS) now being introduced throughout the maritime industry. S-57 comprises a hydrographic data model, an object

catalogue and an electronic nautical chart (ENC) product specification that are standard for ECDIS data.

Various shoreline and boundary data metadata standards have been developed at national level, as mentioned previously for the USA within the FGDC shoreline metadata working group. Looking to the future, two projects are underway that aim to specify a globally agreed standard for marineXML, a marine-specific implementation of the eXtensible Markup Language (XML) now used widely on the Internet for conveying semantic content of information as opposed to only the display specifications provided by HTML (Hypertext Markup Language). MarineXML is described as “an interoperability framework for global ocean observation systems” (ICES, 2003) which will encompass coastal zone elements as well. The development work on marineXML is undertaken by the European Union, via a part-funded project in the EU’s Framework RTD programme (IOC, 2003a) in conjunction with the Intergovernmental Oceanographic Commission’s Committee on International Oceanographic Data and Information Exchange (IODE) based at UNESCO headquarters in Paris (IOC, 2003b). National initiatives on creating marineXML specifications are also underway, for example in Australia and the USA.

More serious barriers remain in regard to harmonised data access policies and exploitation rights for spatial information, particularly that collected by public sector agencies. The European Union is trying to address this problem at a regional level via a new Directive setting out an agreed EU-wide framework for access to and exploitation of public sector information (European Commission, 2002). Similar initiatives are under discussion, in consultation or being implemented in both developed and developing nations across the globe. The impact that these initiatives will have on the coastal zone (and larger research) community cannot be underestimated. Even in countries with strong “freedom of information” cultures, such as the USA, some public sector marine information is not disclosed due to fear of liability actions against the data providers (Lockwood and Fowler, 2001). With intellectual property (IP) legislation in a state of flux across the globe while attempts are made to accommodate the prior IP regime and existing international IP conventions to the digital world, resolving many of the non-technical data-related problems is far easier than the institutional ones.

CONCLUSIONS

The CZM community should be aware that their input, based on knowledge and experience of the coastal zone, is imperative during specification of SDI initiatives, whether at national, regional or global level. What we can conclude from the above examination of various types of spatial data infrastructures that are under development—national, regional and global—is that, at regional and global level, the emphasis is virtually all on process, standards, metadata and institutional issues, and rarely on data specifications for the content of an SDI. Thus, for the most part, these initiatives will almost certainly never have a separate strong coastal or marine focus. The only exception at Regional SDI level is that of INSPIRE, justified partly by the legal data reporting requirements of the European Water Framework Directive, the latter of which focuses very heavily and in great detail on coastal and near-shore waters. As more such regional (non-European) environmentally focused initiatives evolve, we can expect a similar emphasis on the need to arise for wider access to and use of coastal and marine spatial data in regard to environmental monitoring.

At the global level, some of the most important work in regard to major elements of what comprise an SDI has been implemented within major international environmental monitoring and research programmes, such as those of IOC, the World Meteorological Organization (WMO), International Geosphere- Biosphere Program (IGBP) and others.

At national level, where one tends to find more detail in specification of the SDI and a more advanced state of actual implementation of elements of SDI, there is evidence that only the more obvious data needs are being considered, e.g. shoreline, hydrography/bathymetry and (sometimes) cadastre/boundaries. Yet other important elements such as habitat and navigation do not fit well within the primarily land-focused sections of NSDI specifications. This may be due partly to the absence of coastal zone/marine professionals on the SDI development teams or for other reasons, e.g. a national decision that the SDI should focus on only the most basic 'reference data' that is considered commonly needed to underpin broadly based economic activities and governance.

Finally, one should not forget that spatial data is only one facet of an SDI implementation. Important institutional, jurisdictional, data policy and standards/interoperability issues also figure high on the agenda. These appear to be the principal focal points for most regional and global SDI initiatives, rather than detailed basic reference data specifications.

A Comparative Study of Shoreline Mapping Techniques

INTRODUCTION

The shoreline is a unique and complex feature and has been recognized as such by the International Geographic Data Committee (IGDC), which designates it as one of 27 key distinct features on the earth's surface. A shoreline is defined as the line of contact between land and a body of water. Although it is easy to define, the shoreline is difficult to capture because of the natural variability of water levels. An accepted method of capturing this line of interface is to determine the tide-coordinated shoreline, which is the shoreline extracted from a specific tide water level. NOAA uses Mean Lower Low Water (MLLW) and Mean High Water (MHW) in this way to map shorelines that can be georeferenced. Both the MLLW and MHW are calculated from averages over a period of 18.6 lunar years.

Like the shoreline, shoreline mapping techniques are changing and being improved upon. At present, photogrammetric techniques are employed to map the tide-coordinated shoreline from aerial photographs that are taken when the water level reaches the desired level. Aerial photographs taken at these water levels are more expensive to obtain than remote sensing (RS) imagery. With the development of remote sensing technology, satellites can capture high-resolution imagery with the capability of producing stereo imagery: one such source is the IKONOS satellite images. The question is: is it possible to use RS imagery to map the shoreline so that we can reduce the costs and improve mapping efficiency and accuracy?

During our study we extracted shorelines from aerial photos, simulated and actual IKONOS imagery, and the intersection between a Coastal Terrain Model (CTM) and the water level. We estimated the accuracies of these shorelines and analyzed the potential of these techniques for practical shoreline mapping by comparing the extracted dataset with the shorelines from the United

States Geological Survey (USGS) topological maps and National Oceanic and Atmospheric Administration (NOAA) nautical charts.

SHORELINE EXTRACTION

To evaluate the new shoreline mapping techniques it is necessary to compare the results with a current shoreline product. In our study, the shoreline extracted from the tide-coordinated aerial photos was used as the reference shoreline and the other shorelines were compared with it to assess their relative accuracies. Shorelines from USGS Digital Line Graphs (DLG) and a NOAA Nautical Chart were digitized to facilitate the evaluation of the new results. The extraction methods used are discussed in the following sections.

Shoreline from aerial photos

A shoreline was digitized from tide-coordinated aerial orthophotos. This product was chosen as the baseline in our analysis due to its high accuracy. The aerial photos were commissioned by NOAA in 1997 when the water surface reached the specified level (MLLW). The photo scale is about 1:20,000 and the pixel size is about 0.6 meters on the ground. This shoreline is tide-coordinated to the mean lower low water level. A Global Positioning System (GPS) survey was carried out in 2000 to obtain control points for the bundle adjustment. Eight control points were used in the adjustment. The Root Mean Square (RMS) numbers indicate a good precision in this adjustment: 0.106, 0.107 and 0.073 meters in the X, Y and Z directions, respectively. Based on the bundle adjustment results, Digital Terrain Models (DTMs) and orthophotos were generated in sequence. Then, the orthophoto mosaic was created with a resolution of 1 meter. The shoreline was digitized manually from this orthophoto mosaic. The task was accomplished using ERDAS software.

Shorelines from simulated and actual IKONOS images

IKONOS imagery has two resolutions, 1-meter panchromatic and 4-meter multispectral. We first obtained 4-meter multispectral geo-referenced imagery for our project. The stereo 1-meter images were still pending when we produced the shorelines in this paper. To study the potential of 1-meter stereo imagery in shoreline mapping, we simulated the imaging procedure and obtained the simulated IKONOS 1-meter stereo imagery using rational functions (RFs). The shoreline extracted from aerial orthophotos was used for back-projecting to the simulated IKONOS raw backward- and forward-looking images. The resulting shorelines on IKONOS raw images show that RFs work very well. This indicates that we can use RFs to extract high accuracy 3-D shorelines from real IKONOS 1-meter imagery provided that we can find well-matched conjugate points on raw IKONOS images along the shorelines. To improve the accuracy of 4-meter IKONOS real data, 8 control points were used to perform planar polynomial geo-correction. The RMS in the X and Y directions are 1.048 meters and 1.1028 meters respectively. A shoreline was extracted from the refined IKONOS image.

Shoreline from the intersection between a CTM and the water level

This idea comes from the definition of a shoreline as the contact or intersection line between the water level and the land. We tried to obtain the land model and water surface model (WSM) and then compute the intersection line of these two models. This method is intuitive to people's

perception of shoreline (See the profile in Figure 3.1 and the colour insert following page 164). The CTM depicts the elevation and bathymetry in the coastal area. The water surface model is obtained from the Great Lakes Forecasting System at The Ohio State University (OSU). To extract the shoreline, these two models were overlaid and the WSM was subtracted from the CTM to get an output layer. Theoretically, the shoreline should be the line with the zero value in the output layer. In practice, the zero pixels do not form a line due to random errors in these two data models introduced from data acquisition and sampling. We chose a small value range for the study and obtained a shoreline strip. We then took one side edge of the strip as the shoreline for our study. We employed this method because the strip is very thin and it is very small compared to the error of the CTM.

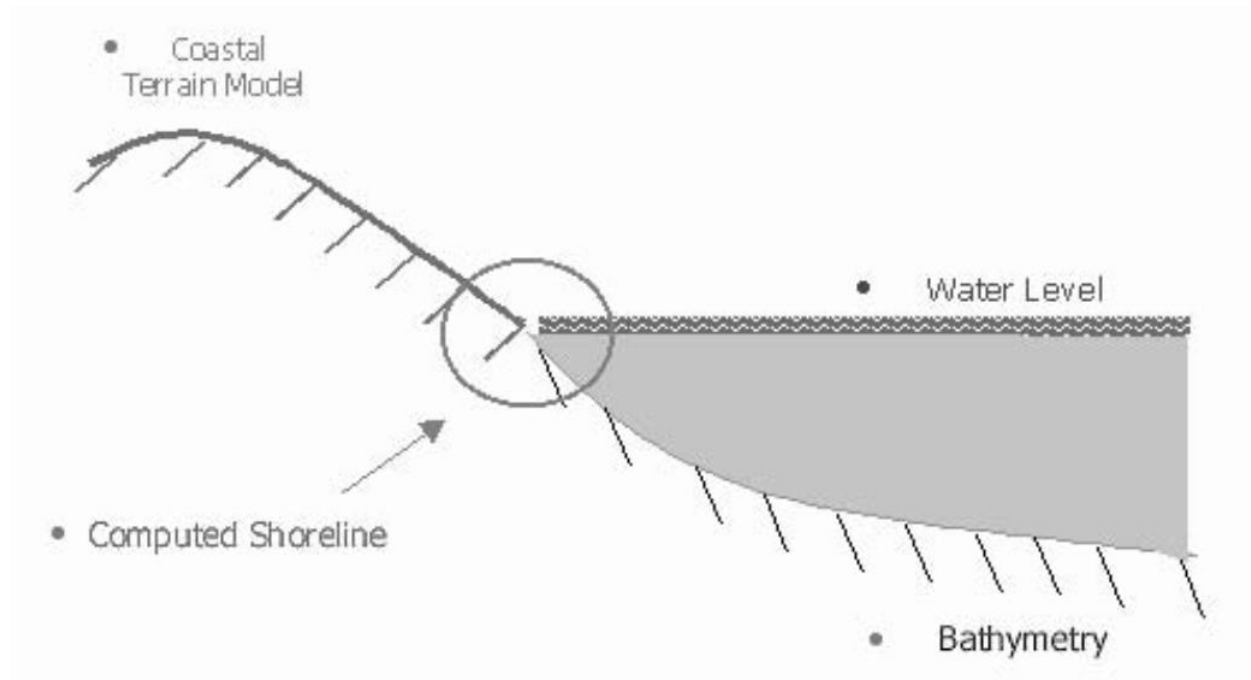


Figure 3.1 Generation of Digital Shorelines

Shorelines from other sources

Besides the above shorelines, four other shorelines were used for the analysis in our study. Among them, two digital shorelines were provided by the Ohio Department of Natural Resources (ODNR), the third one was extracted from a USGS DLG and the fourth one was digitized from a NOAA Nautical Chart.

ESTIMATION OF THE ACCURACY OF THE SHORELINES

The accuracy of these shorelines was analyzed in our study by considering the data sources and the extraction methods. More extensive work will be done in the future to further investigate this important issue.

From the bundle adjustment and conjugate point matching, the DTM standard deviation derived from the aerial photographs is estimated to be 2.1m in X and Y coordinates. Considering the error introduced by resampling from the aerial photos of a 0.6m resolution, the 1-meter orthophoto has an estimated standard deviation of about 2.1m. The identification error of the shoreline from the orthophoto may introduce 1.5 pixels, that is 1.5m, considering those situations where the water and land separation is very hard to define. Therefore, the shoreline from the aerial orthophoto has an estimated standard deviation of about 2.6m if we apply a simple model of error propagation.

The accuracy of the shoreline derived from 1-meter simulated IKONOS imagery should be about 2-4m (Zhou and Li, 2000), considering the fact that the accuracy of 3D ground points reaches 2-3m with GCPs and the accuracy of identifying and locating conjugate shoreline points is about 1.5 pixels (1-2m). The 4-meter IKONOS images have an accuracy of 23.6m (http://www.computamaps.com/ikonos_tech.html). After polynomial georectification using 8 GPS control points, the difference between the GPS and computed coordinates at the control points is about 6m. An optimistic estimation of the shoreline accuracy derived from the 4-meter IKONOS images in this specific case is about 8.5m.

Table .1 Estimated accuracy of the shorelines derived from various sources

Shoreline	Estimated standard deviation
T-sheet	2.5m to 20m depending on scale
USGS DLG	12m (1:24,000)
ODNR map	6m (1:12,000)
Orthophoto	2.6 meters
CTM and water level	2m-13m dep. on CTM quality
IKONOS 1-meter simulated image	2-4 meters
IKONOS 4-meter image	8.5 meters

The accuracy of the shoreline derived from a CTM and the water level is affected by the accuracy of the CTM and the accuracy of the water level. The CTM comes from the DTM generated in turn from the aerial photos and the bathymetry. The DTM has an accuracy of 2.1m and the bathymetry has an estimated accuracy of 40m. When we merged these two data sets, we select the DTM grid points in the overlapping area. If there is gap between the two data sets, we interpolate the elevations using weights of 2/3 from DTM and 1/3 from bathymetry where the standard deviation of the CTM is about 13.4m. Overall the accuracy of the CTM is from 2.1m to 13.4m for the area where the water surface model intersects with the CTM. The water level data is accurate to several centimeters. Taking 5 degrees to be the coastal slope in worse cases and 5cm the water level error, we can estimate the horizontal accuracy of the intersected shoreline caused by the water level error to be about 0.6m. Therefore, the final accuracy of the digital shoreline is about 13.4m with the CTM contributing the greatest source of error.

The NOAA T-sheets have large and medium scales: from 1:5,000 to 1:40,000. Taking 0.5 mm on the map as error source, the accuracy of the digitized shoreline from the T-sheet is about 2.5m to 20m. The shoreline digitized from the USGS DLG (1:24,000) should have an accuracy of within 12m. The ODNR map scale is 1:12,000. Again, using 0.5mm as the shoreline digitizing error, the estimated error of the shoreline is about 6m.

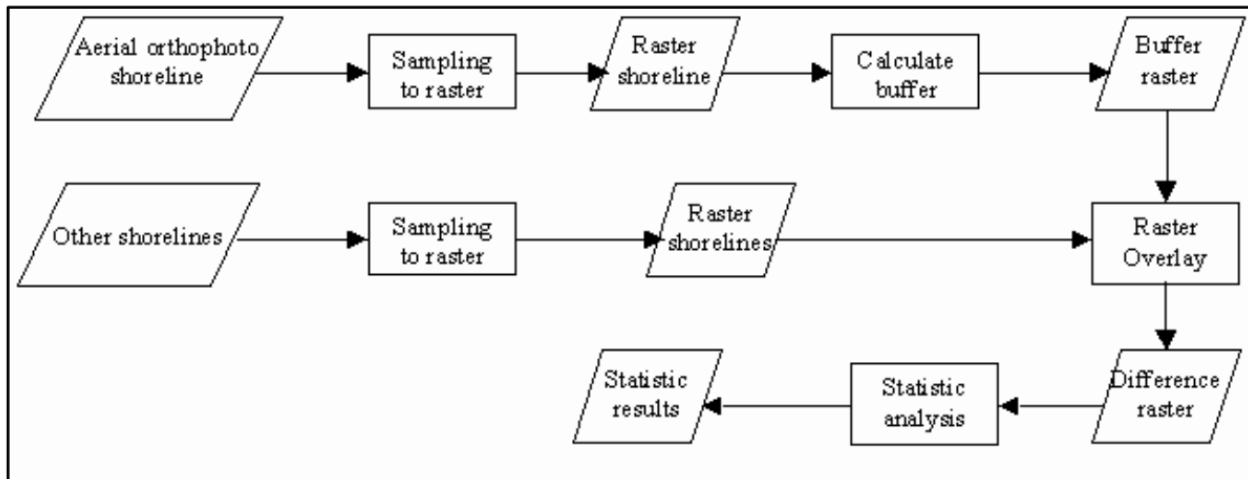


Figure .2 Difference Analysis Procedure

DIFFERENCE AND SHORELINE CHANGE ANALYSIS

The shorelines were acquired at different times and differences can be seen in the results (Table1). There are two possible interpretations of the shoreline differences. One is that the shoreline indeed changed in the real world. The other possibility is that the differences were introduced as shoreline mapping errors.

Table .2 Statistics of the differences between derived shorelines and the reference shoreline

	Points used	Avg. Dif. (pixel)	Avg. Dif. (m)	Max. Dif. (pixel)	Max. Dif. (m)	RMS (pixel)	RMS (m)
Shoreline from 4-m IKONOS images	6652	4.02	10.04	16	40.0	4.91	12.27
Digital shoreline	4590	2.34	5.84	9	22.5	2.74	6.84

From our analysis of the accuracies above, the shoreline from the aerial orthophotos has the highest accuracy, and so we used it as the baseline for the difference analysis. The analysis was performed in raster format because of the efficiency of this method. The first task was to convert the vector shorelines into raster shorelines. The resulting pixel size was 2.5 meters. The procedure is outlined in Figure .2.

This analysis involved comparing every point on the test shorelines with the reference shoreline, which was derived from the aerial orthophoto, in a perpendicular direction toward the reference shoreline. In the buffer zone of the reference shoreline we created pixels whose value represented the distance of each pixel to the reference shoreline. By overlaying other raster shorelines with the buffer image we were able to discern and quantify differences between the shorelines and the reference shoreline. For example, for the shoreline from the simulated IKONOS images, each point on the shoreline has a value of the shortest distance to the reference shoreline. Finally, we calculated some statistic indicators including RMS of the differences for the shorelines derived from the 4-m IKONOS images and the digital models (table .2).

The accuracies of the shorelines derived from the 4-meter IKONOS images and the aerial orthophoto are 8.5m and 2.6m respectively; as a result, the estimated accuracy of the difference between them should be 8.9m, which is smaller than the RMS value 12.27m in table 3.2. This may indicate the actual shoreline change during the period from July 1997 when the aerial photos for the reference shoreline were taken to October 2000 when the 4-meter IKONOS images were taken. In addition, the IKONOS shoreline is an instantaneous shoreline, instead of a tide-coordinated shoreline. The water level in October was 0.2-0.3 meters lower than in July creating artificial shoreline accretion. We are developing methods that correct instantaneous shorelines to tide-coordinated shorelines and then compare them. For the digital shoreline from the CTM and WSM intersection, the RMS value 6.842m in table 3.2 is smaller than the worse case shoreline error of 13m in table 3.1. The difference can be introduced by two different factors. One is the seasonal water level difference, which can introduce a large difference in a flat area like Sheldon Marsh. Another factor is the difference between the accuracies of DTM and bathymetry in CTM. If the DTM covers the coastal surface up to the MLLW or better (this is the case in our research), the water surface model intersects with the DTM portion of the CTM and results in smaller errors; otherwise, the shoreline would be intersected by the water surface model, and the bathymetric part or the interpolated part of the CTM produces large errors.

Observing the differences between the reference shoreline and earlier shorelines from the maps, they may represent the shoreline changes (erosion) that occurred in long time periods. The earliest shoreline in our study is the shoreline from 1973 ODNr map, 24 years before the aerial photos for the reference shoreline were taken in 1997.

CONCLUSIONS

From the analysis above, we can draw several conclusions. First, we determined that the method for generation of digital shorelines from CTM and WSM can be used in mapping instantaneous shorelines. The generated shorelines can meet the accuracy requirement for certain user communities. Additionally, this work shows that high-resolution satellite imagery, such as IKONOS imagery, has the potential to become a tool in shoreline mapping and coastal change detection, and that it may reduce mapping costs. Finally, our study confirms that to detect coastal changes, tide-coordinated shorelines must be derived from the instantaneous shorelines so that the amount of shoreline change can be estimated objectively.

New Directions for Coastal and Marine Monitoring: Web Mapping and Mobile Application Technologies

THE VALUE OF COASTAL AND MARINE RESOURCES

Coastal and marine areas are ever increasing in value to the welfare of nations. These areas provide natural, social and economic functions that contribute to increased quality of life. The oceans are instrumental in determining climate that beneficially affects all life on Earth. Other natural functions include habitat for endangered species, species breeding and resting areas, water treatment, groundwater recharge and flood attenuation. Some social and economic functions include tourism, commercial and recreational fishing, oil and gas development, and construction.

It is clear that coastal and marine areas are of vital importance to human life. Yet human terrestrial and marine activities have proven to have destructive effects on these areas. According to Canada's National Program of Action (CNPA) (2000) the major threats to the health, productivity and biodiversity of the marine environment result from human activity in the coastal areas and further inland. Approximately 80 percent of marine area contamination results from land-based activities such as municipal, industrial and agricultural waste and run-off, in addition to the deposition of atmospheric contaminants resulting from human industrial activities (CNPA, 2000).

There is a need for a wider dissemination of knowledge relevant to the importance of coastal and marine areas to the world's well-being, and a re- evaluation of societies' attitudes towards these spaces. Good coastal and marine governance (e.g. information dissemination, management, monitoring, etc.) is therefore a key factor in the sustainable use of these environments and will require an integrated, coordinated and equitable approach. If governance is about decision-making and steering, then up-to-date, accurate, complete, usable information (which feeds into the acquisition of knowledge) is indispensable to governance. This is especially critical in the information age of rapid changes, interconnectivity, and globalization that have brought more information to more people making them acutely aware of the unsustainable nature of current social, economic and political use of marine and coastal spaces.

Where informed decisions have to be made using real-time information there is a need for architecture that quickly disseminates information affecting coastal and marine resources. Accurate, up-to-date, complete and useful spatial information (on many levels) regarding the resources that currently exist, the nature of the environment within which those resources exist, as well as on the users of those resources is always a requirement for effective monitoring of coastal and marine areas. Information on (but not limited to) living and non-living resources, bathymetry, spatial extents (boundaries), shoreline changes, marine contaminants, seabed characteristics, water quality, and property rights all contribute to the sustainable development and good governance of coastal and marine resources.

Web Mapping and CMM Networks

There are several Coastal and Marine Monitoring (CMM) networks in the world. Most of them are involved in obtaining real-time quantitative indicators that impact on coastal and marine health such as water temperature, water level and meteorological conditions (wind speed and direction,

temperature, barometric pressure), together with qualitative indicators such as visual images of the beach and nearshore. Others are involved in collecting quantitative and qualitative indicators of coastal environmental quality. The networks involve government, academic and environmental NGO institutions. They consist of huge repositories containing databases of archival and current material. They vary in scope - from local to regional to national and international networks. Their results are provided in synchronous and asynchronous fashion but increasingly, electronic means of communication are being used to provide information needed by the various interest groups.

The World Wide Web has had a tremendous effect on the way businesses communicate. Large amounts of information can be made available quickly and conveniently to anyone with Internet access and a web browser. The ability to distribute and view spatial information has quickly shifted from a desktop application (fat client) to a browser-based architecture (thin client). This latter architecture is referred to as thin client since the user only needs a web browser to access services and information on the web. With particular reference to spatial information, there has traditionally been the question of accessing the volumes of information, especially if it resides in several different geographical locations. The web lets a data provider make spatial information available to a wider audience. The data provider can therefore provide a virtually centralised repository of resources without having to change the physical location of the data. This prevents any problems that might arise from maintaining or updating duplicate data sources, such as limited space or corrupt data. The web therefore makes it easy to provide the most up to date spatial data.

It is therefore common practice to go to one of several websites dedicated to CMM and download (or interact with) information about a specific geographical location that one is interested in. Whether it is the “Enviromapper for Watersheds” interactive mapping application that provides an index of watershed indicators for US aquatic resources, or the “Scorecard” mapping application, which maps toxic chemicals released from facilities, institutions like the Environmental Protection Agency in the USA are increasingly providing these CMM indicators through their websites (United States, 2003). The US Department of Commerce’s National Oceans and Atmospheric Administration (NOAA) and the Canadian Department of Fisheries and Oceans (DFO) provide a variety of information on their websites on oil and chemical spills, tides, marine weather, and fisheries. This information is superimposed on maps to give a geographical context to the information. The superimposition of information on maps – and the provision of such information on the web, together with limited GIS functionality – is what is referred to as web mapping, webGIS or interactive mapping.

Web Mapping Technologies

The emergence of web-GIS technologies is providing the catalyst for easier collaboration, integration and cooperation among organizations with a stake in good governance and sustainable development. This is done by providing an environment for data sharing and integration over the Internet, sometimes without organizations having to make any major changes to the structure and formats of the data they maintain. The full range of analytical capabilities available in most contemporary desktop GIS however is not available on the web browser (or WebGIS client) since they are built on the thin-client concept. To include more functionalities at the client end would

seem to defeat the concept of the low cost and convenience of utilizing only a web browser to access spatial data.

Traditional mapping issues still pose challenges to web mapping. Some of these new technologies support different data formats (e.g. ESRI shape files, CARIS, MapInfo files etc.), projections, scales, datums, etc., with conversions and visualization being done "on the fly." Certain web-GIS technologies now facilitate the transmission, integration, visualization and analysis of spatial information stored in geographically dispersed locations. A user with permission to access the geographically dispersed data sets need only have access to a web browser in order to view, query, and analyse the data sets. In some instances however, some webGIS can only deal with data residing on one server.

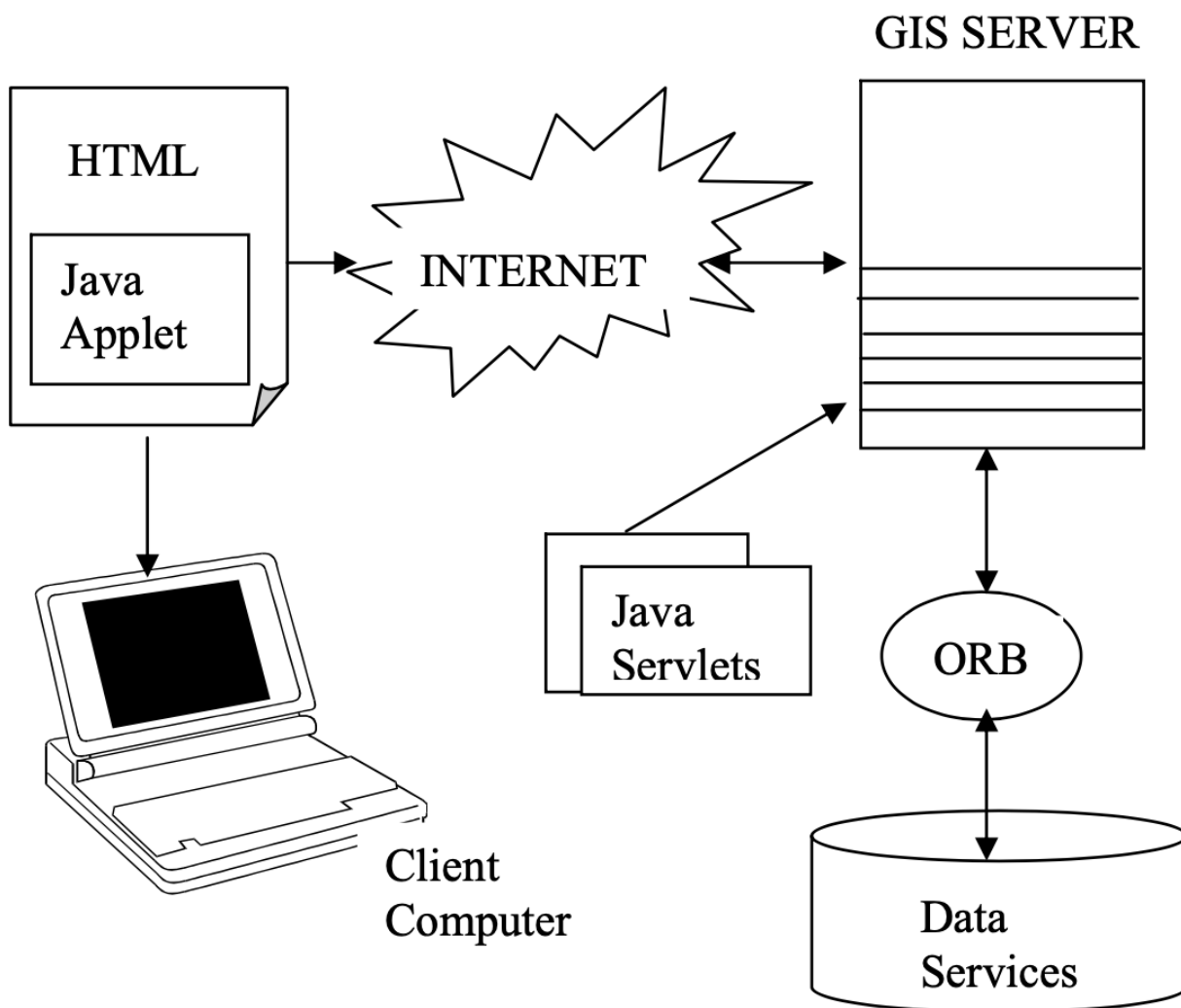


Figure 6.1 CARIS Spatial Fusion Architecture (from the CARIS Spatial Fusion Administrators Guide)

A Web Mapping Example - CARIS Spatial FusionTM

Let us briefly describe a web-mapping technology in order to explain the underlying architecture. CARIS Spatial FusionTM is a "web-mapping" technology that lets users integrate distributed data sources using a web browser. It is an Internet-based technology whose primary function is

accessing, visualizing, and analysing heterogeneous, distributed data sources (Fitzgerald, 2000, Webmapper.com, 2000). Spatial Fusion™ combines the speed, convenience and simplicity of the Internet with the ability to read multiple data sources in their native format. Earlier versions of Spatial Fusion™ consisted of a customized Java client and a number of Fusion Data Services. On the server side, Spatial Fusion™ was made up of the following components (CARIS, 1999, Fitzgerald, 2000):

- A Web Server: One must already be running on the network.
- The Orbix™ Runtime needs to be installed on every machine that hosts a Fusion Data Service. The Orbix™ Runtime lets the Spatial Fusion™ applet and the Data Services communicate across the Internet.
- Catalog Service: This service lists all of the available Fusion Data Services.
- Fusion Data Services: These services must be registered with the OrbixWeb™ Implementation Repository. Each service has an accompanying configuration file that contains the name used to register the service with the daemon and the location of the data source.
- Configuration Utilities: CARIS MapSmith™ and CARIS dbMaps™ are provided to help customize the display of CARIS, Oracle 8i Spatial, or Shapefile data.

Recent changes in Spatial Fusion™ Version 3.0 have removed the Orbix runtime component and replaced it with TAO ORB - an open source implementation of an Object Resource Broker using Common Object Request Broker Architecture (CORBA). In Spatial Fusion™, the Object Request Broker (ORB) is the broker for information from the java servlets to various data services. The servlet container is Tomcat developed by the Apache Software foundation to manage and invoke servlets when requested. The normal setup is to have a web server such as Microsoft Internet Information Services (IIS) configured to connect to Tomcat. When an action is performed, the Spatial Fusion™ applet sends a request to a servlet, which is handled by the Jakarta Tomcat Servlet container. The request is then sent by the servlet to the data services through the ORB (CARIS, 2003).

As far as the user is concerned, they simply download the Spatial Fusion™ applet from a web server. At that point, a user can easily open data from any fusion service they have access to, providing them with a secure and fully scalable environment (CARIS, 1999, Webmapper.com, 2000). In addition, CARIS Spatial Fusion Developer™ lets users customize the client, so that specialized applets can be rapidly built in a drag and drop environment, giving the ability to tailor applets for specific users (Fitzgerald, 2000). Thin client web mapping applications such as Spatial Fusion™ have traditionally depended on “wired” infrastructure because large amounts of spatial information have to be sent from the server to the client. The need to have information provided on mobile devices such as PDAs and cell phones is however driving information dissemination towards a wireless infrastructure. But would there be a need for wireless access to CMM networks? Is the general public ready to embrace this technology? In the following section we address these questions.

RE-ENGINEERING MARINE MONITORING NETWORKS

There exists in every jurisdiction a public policy issue associated with information collection (McLaughlin, 1991). This issue is related to the notion of providing ready and efficient access to information about resources, and rights associated with them, to all members of the community. The public is defining itself as an individual property owner – the property being the marine commons and its resources – and is realigning itself to be a primary decision maker. Most people are therefore interested in how resources are being utilized and whether resource use is being policed effectively.

Coastal and marine monitoring networks fulfill the role of providing information effectively. But they are also builders of communities of interest i.e. a forum where participants are able to interact on a specific topic. These online communities are valuable as they are increasingly providing forums for like minded individuals to participate in the decision-making process. With more citizens being involved in advocacy efforts and words like “stewardship of resources” increasingly being used to rally the general public into participation in the decision-making process, provision of information about the space that citizens inhabit is becoming critical.

Sociologists have traditionally viewed this kind of participation as social capital – a relationship that can blur social inequality and enhance transactions that lead to capital accumulation and social growth. We are seeing the public being involved in a culture of participation, through these networks, although this is concentrated on citizen access to information. What is needed is the enhancement of citizen participation, to citizen-based leadership: where the citizens pro-actively seek information (and are able to receive it as it happens) rather than react to information that they come across. This is where wireless access to information becomes important.

Wireless Access to Information

Developments in Internet-enabled spatial data integration and analysis tools are now allowing decision-makers the opportunity to have access in real-time (or near real-time) to spatial information. The public is becoming more technologically “savvy” and is using newly available devices to access various kinds of information. What one finds online is also now available on mobile devices – and with evolving wireless technology we are seeing web-enabled mobile devices being used to integrate and retrieve geographic data as it is collected. Additionally, it makes sense for companies to focus on wireless Internet services given projections for future growth: the Yankee Group predicts that there will be more than one billion mobile devices worldwide by 2003. Some estimate that half of those will be web-enabled.

This is not a new trend. Increasingly, we now have various types of information being sent to us via our mobile devices – allowing us to remain informed about various topics that we are interested in. Take the example of access to information about entertainment or restaurant locations, based on one’s geographical location, delivered to a mobile phone. This represents a relatively new trend referred to as Location Based Services (LBS).

Location Based Services – The Driving Force

When this paper was written in 2001, the author had been following the evolution of killer applications in mobile mapping technologies – location based services (LBS). In addition to maps and directions, LBS allows customers to locate branches, service centres, stores or any points of interest near their home. A business can use LBS to locate its customers, manage its supply chain, and to implement its business rules. In fact, recently Microsoft has joined with AT&T Wireless to provide location-based services. LBS are now the driving force in wireless mapping applications.

In the coming years, Location Based Services (LBS) are expected to play a defining role in driving not only the mobile Internet but also mobile commerce as well. Location based services find the geographical location of a mobile device and provide services based on that location. LBS applications automatically identify subscribers' locations from the wireless networks and combine this with other information to obtain maps and driving directions, perform proximity searches and find places and points of interest. Although there has been a slow rollout of LBS, Konish (2002) indicates that the slow economy is forcing wireless carriers to look for revenue-bearing services. Inevitably these are being found in making wireless devices location aware and providing location based services. Many LBS applications are already available especially in the field of asset tracking and fleet management. Other applications include automatic vehicle location and tracking, sale and marketing automation, consumer travel services, wireless call centre tracking, and location-based billing.

Providing Web Mapping to Mobile Devices

LBS can be provided in several different ways – from simple text messages providing a list of options e.g. restaurant names and locations – to a full webcentric interaction with the LBS service – involving GPS locations superimposed over interactive maps. This latter option is accomplished by using a dedicated protocol, the Wireless Application Protocol (WAP), which enables a mobile device to behave like a micro browser. The Wireless Application Protocol (WAP) is an open, global specification that empowers users of wireless devices to easily access and interact with information and services themselves. This information is available through a data portal that allows the user to access services in a manner similar to that found on the Internet. The protocol however has certain limitations to it – for example, it only allows the use of sequential menus for users to browse for information. However, WAP is continually evolving to encompass greater functionality.

The Wireless Application Protocol incorporates a relatively simple micro- browser into the mobile phone. As such, WAP's requirement for only limited resources on the mobile phone makes it suitable for thin clients and early smart phones. WAP is designed to add value-added services by putting the intelligence in the WAP servers whilst adding just a micro-browser to the mobile phones themselves. Microbrowser-based services and applications reside temporarily on servers, not permanently in phones. The Wireless Application Protocol is designed for use with anyone's standard such as Code Division Multiple Access (CDMA), Global System for Mobiles (GSM), or Universal Mobile Telephone System (UMTS) and is aimed at turning a mass-market mobile phone into a "network- based smart phone".

Wireless terminals incorporate a Handheld Device Markup Language (HDML) microbrowser that uses the Handheld Device Transport Protocol (HDTP). HDML is a version of the standard HyperText Markup Language (HTML) Internet protocol that is specifically designed for effective and cost-effective information transfer across mobile networks themselves. This protocol is used to link a mobile device terminal to a server that is connected to the Internet (or Intranet) where the information resides. The content at the site is tagged with HDML tags that can be easily read and converted by the microbrowser in the handheld device themselves.

A user with a WAP-compliant phone uses the in-built micro-browser to make a request for information or service. This request is passed to a WAP Gateway that then retrieves the information from an Internet server either in standard HTML format or preferably directly prepared for wireless terminals using Wireless Markup Language (WML) themselves. In this paper, WML and HDML are used interchangeably. If the content being retrieved is in HTML format, a filter in the Wireless Application Protocol Server may try to translate it into WML. The requested information is then sent from the WAP Gateway to the WAP client, using whatever mobile network bearer service is available.

Extending the Trend to CMM Networks

N'gang'a et al. (2001) provided a possible scenario that utilized the technological components mentioned in the preceding sections of this article. A summary of the scenario that had previously been proposed is as follows:

1. A marine event involving coastal or marine environments occurs. This event could be a oil-carrying tanker being involved in an accident, or as diverse as enforcement against banned activities or the enhancement of safety of navigation;
2. The event is detected by remote sensing means or by visual observation. These event sources are important as they establish how the event will enter into the marine event information circle. The marine event information circle is a term that has been coined by the author to represent the flow of information from the event source to the interested group;
3. If the event is detected by visual observation, the observer has the option of using a VHF radio to communicate with someone who has access to a web-mapping server (e.g. a Spatial FusionTM data server). Alternatively, the user can use other means of event dissemination such as the mobile phone and Internet connectivity. The term "event content" refers to the information that is recorded regarding the event. In this work, this information is the location and the nature of the event;
4. The event is then registered with the event server, which in this case is analogous to a Spatial FusionTM Data server. In particular, the data needs to be configured so that it can be accessed using the fusion services. An event coordinator (or moderator) must exist in the marine environment information circle to serve this purpose;
5. Transmission of information updated with the marine event is then accomplished using electronic means. An email list of a registered interest group can be used to contact the users of the marine environment information circle, or the information can be relayed to a website that the general user can access. Alternatively if there is a WAP server, the information can be relayed (with additional

functionality) to members of the registered interest group who are within geographic proximity of the event. These options allow the event server to provide alternative value-added services.

6. Information dissemination is accomplished using the wireless application protocol and existing GSM networks. In the near future GSM combined with GPRS or the third generation UMTS networks can be used for broadband access to marine events.

Once the information is served up to a user group, decisions can be made regarding implications of the marine event on existing policies, activities, or populations within (or adjacent to) the marine environment. Informed decisions are therefore made with available information about the nature and location of marine events.

What about Bandwidth Issues?

Spatial data involves the transmission of geometric as well as attribute information. It can therefore be argued that a substantial amount of data must be transmitted which implies that a large bandwidth must be available. There is a general consensus in the wireless industry that in the near future bandwidth will no longer be a problem especially when the third generation of mobile phone network becomes available.

We now are connected using the Global System for Mobiles (GSM) wireless network that provides data rates of 9.6 Kbytes/s. An ancillary service on the GSM network is the General Packet Radio Service (GPRS), which provides compression technology that improves data transmission rates to 100 Kbytes/s (Mobile Lifestreams, 2000; Villalobos, 2000). In the near future, the Universal Mobile Telephone System (UMTS) will provide 2 Mbytes/s (. This will definitely change the way we use both wireless and Internet technologies.

Third-generation wireless communication (3G) such as UMTS will definitely play an important role in web based spatial visualisation in the near future. It is forecast that the mobile phone will become a portable terminal where the Internet, video and audio will be supported in a multimedia environment. Therefore, it is expected that the WAP will adapt to the potential offered by this technology. There have been arguments that the WAP protocol is not a protocol for the future due to its graphical limitations and access speed; however, the protocol is still evolving and advances in technology and application are expected to eventually address these concerns.

The solution simply requires data connectivity from devices. The amount of data passed over the wireless network for the LBS applications is quite small and doesn't require the higher bandwidth allowed by 2.5G and 3G networks.

Some Examples

While there are several web mapping software that exist, only recently has the provision of web mapping services begun to move to mainstream mobile devices. Some of these products include

- AutoDesk's MapGuide and Onsite – Onsite enables viewing of digital design data on Microsoft Windows CE-based handheld computing device.

- ESRI's ArcIMS and ArcPad – ArcPad provides database access, mapping, GIS, and global positioning system (GPS) integration to users out in the field via handheld and mobile devices.
- MapInfo's MapExtend and MapExtreme - MapInfo® MapXtend® is a developer tool for creating location-based applications running on wireless handheld devices.
- Microsoft Map Point Webservice – The MapPoint Web Service is the Microsoft® platform for location-based services (LBS) and can be used by mobile applications.

In Canada there are several researchers already working successfully on the kind of approach outlined in this paper. Canadian researchers Nickerson et al. (2003) have already provided a general-purpose architecture for real-time web access to mobile geospatial operations. The research demonstrated that their three- tier architecture, using Wireless Application protocol (WAP), along with eXtensible Markup Language (XML) tags embedded in a Uniform Resource Locator request, provided a sound basis for decision support of real time geospatial operations. Real time field activities were viewed by web users globally as well as stored in (and retrieved from) an online central server and database.

In Ng'ang'a et al., (2000) the authors had drawn attention to some advances in web mapping location-based services such as the automatic vehicle locator (AVL) application used at the city of Fredericton Police department². This was part of the Wireless Public Safety Decision Support System (WPSDSS) for the city of Fredericton (Lunn, 2001). The application uses a cellular digital packet data wireless data network to transmit information about the location and status of police vehicles. The information is overlaid onto the City's GIS mapping layers and orthophoto imagery. While the application does not display information on mobile devices (like cell phones or PDAs), it is just a matter of time before it does.

On the CMM front in Canada, Fisheries and Oceans Canada, Environment Canada, the Defence Department, Transport Canada and the Canadian Space Agency are already collaborating on a program called Integrated Satellite Targeting of Polluters (I-STOP), to use a satellite operated by Radarsat International to identify ocean slicks.

Canada's Radarsat satellite will be used to provide all weather, day/night images of the Earth's surface and give officials an indication of suspicious activity in a vast area that couldn't easily be covered by any other means, such as aircraft. The technology is only being used on the East Coast for now. If it proves successful, it could also be used on the Pacific coast. The Calgary Herald

Table 4.2 Area measurements for successional-young grassland at Kenfig NNR, taken from the classified CASI images.

Section	Area of Section (m ²)	Area of successional-young grassland (m ²)	%
Southern	1,771,276	201,248	11.3
Northern	2,706,684	782,120	28.8
Whole site	4,477,960	983,368	21.9

(2002) reported that the first hit came nine days into the project when the satellite spotted a spill off Newfoundland's south coast, near one of the province's most valued marine bird reserves. A plane was sent to the area off Cape St. Mary's and the ship was ordered back to port, where its operators now face charges under the Migratory Birds Act for allegedly creating a 116-kilometre-long, 200-metre-wide slick. While WAP technology is not being used in this program, one can see that soon enough there will be a situation where individuals interested in coastal and marine monitoring will have information delivered about this fragile ecosystems health to their mobile devices.

The Use of GIS to Enhance Communications of Cultural and Natural Resources and Contamination

INTRODUCTION

Five Pribilof Islands, volcanic in origin and remotely located in the Bering Sea, are home to Aleuts and the breeding grounds to 70% of the world's northern fur seal population and numerous seabird species. The once uninhabited islands were first occupied by the Russians in 1786 and later became controlled by the U.S. Government. At the time of the Russian incursions into the Aleutian Islands, some have estimated the Aleut population at 15,000-18,000. First Russia and then the U.S. relied on the forced labour of Aleuts relocated to the Pribilof Islands from the Aleutian Islands chain to harvest sea otters, fur seals, and arctic fox. From their first arrival and through much of the 20th century, Unangan (people) or Pribilof Aleut people relied on the islands 'and Bering Sea's natural resources, including fur seals, sea lions, whales, arctic fox, walrus, sea bird species, and a variety of plants for customary traditional purposes and subsistence. Even today natural resources are vital to the survival interests of Unangan on the Pribilofs. Unangan of St. Paul and St. George Islands are the world's single largest ethnic Aleut community whose world population approximates 3,200 individuals. Fur seal, endangered Steller sea lion, introduced reindeer, halibut, crab and other marine invertebrate species, and plants, such as crowberry, continue to play a significant role in customary traditional practices, economic development, and the maintenance of cultural and ecological harmony.

Settlement terms under the Alaska Native Claims Settlement Act (ANCSA) of 1971 required the National Oceanic and Atmospheric Administration (NOAA), as the most recent of the former federal land managing agencies for these islands, to transfer more than 95% of the land area to the local Aleuts. A 1976 Memorandum of Understanding and a 1984 Transfer of Property Agreement (TOPA) incorporated the details of the property transfer between NOAA and various local entities. The settlement and subsequent legislations including the Pribilof Islands Environmental Restoration Act of 1995 and the Pribilof Islands Transition Act of 2000 required NOAA to restore the islands ' environmental integrity compromised by U.S. Government activities supporting its commercial fur sealing enterprise. Environmental concerns included numerous releases of petroleum fuel products associated with the disposal of used oil, overfilling of storage tanks, corrosion of storage tanks, pipelines, and barrels, as well as landfills for household wastes, construction and demolition debris, scrap metal and junked vehicles, boats, barges, and aircraft. In addition, military activities during World War II contributed to soil and groundwater contamination. More than ninety sites on the two inhabited islands, St. George and St. Paul, required evaluation and potential restoration in order to complete the land transfer. The islands 'remoteness, approximately 2,200 statute miles from

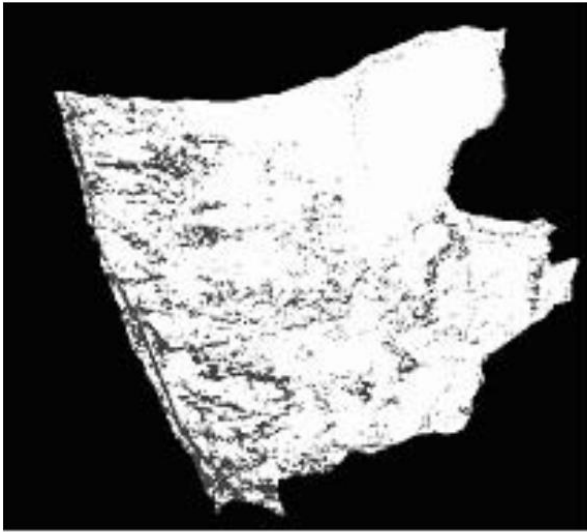


Figure 4.8a Areas classified as successional-young grassland in the southern section

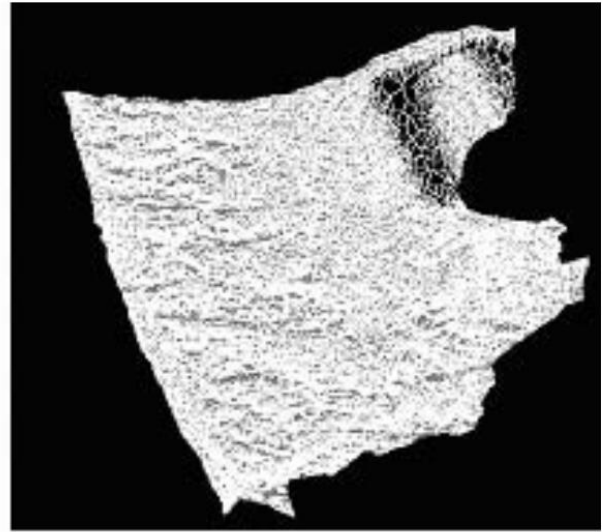


Figure 4.8b Areas with a south-facing aspect

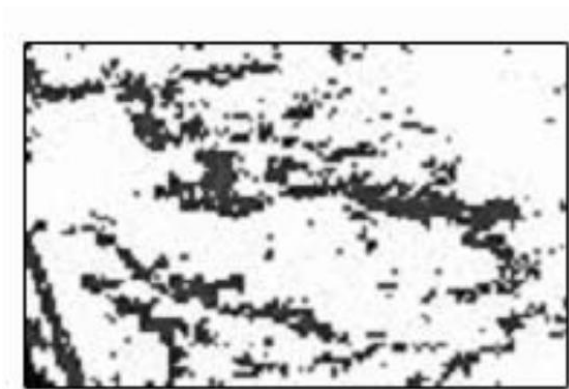


Figure 4.8c Areas classified as successional-young grassland in the south-western part of the southern section

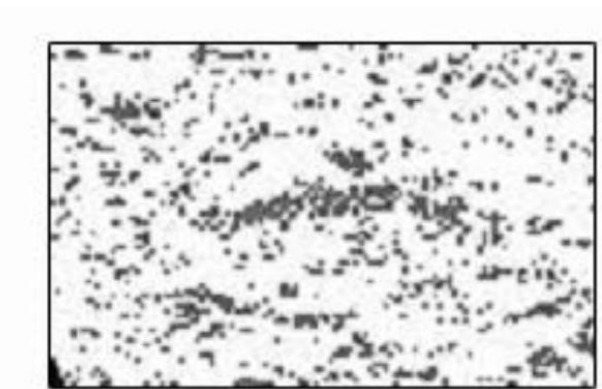


Figure 4.8d Areas with a south-facing aspect

NOAA's base of operations in Seattle, Washington requires a minimum of eight hours in travel time. Weather extremes involving fog, snow, and wind frequently cause flight cancellation. Improving communications through such multimedia technologies as Internet, GIS, and video were identified early as absolutely critical to the restoration project's success.

In the context of public land transfer to private sector entities and the restoration of lands and structures located within a National Historic Landmark and District, the National Historic Preservation Act (NHPA) further mandates NOAA to mitigate for these actions. Mitigation efforts at a minimum will provide a historical legacy associated with the federal ownership period for the benefit of future generations. The legacy is expected to include a book, video documentaries, and a detailed Geographic Information Systems (GIS) project. This chapter focuses on the GIS project. The NOAA Pribilof Islands Environmental Restoration Project Office (PPO) entered into collaboration with the St. Paul Tribal Government's Ecosystem Conservation Office to build a GIS project that included not only extant conditions, but also traditional cultural and natural resource features. This chapter presents an ongoing project that began in 1999, the conclusion of which is not expected for several more years.

GIS APPLICATION

The environmental restoration project began nearly two decades ago. Numerous written reports included site locations and analytical results from hundreds of soil samples. Unfortunately, site boundaries and sample point locations have not been easy to recover because of poor referencing and a relatively monotonous environment that becomes overgrown with waist high vegetation or eroded by violent winds. A decision was made at the outset to map all features using differential global positioning systems (DGPS) and a GIS. This approach would allow the relocation of sites and sampling points in years distant if necessary, as well as aid in other efforts, such as defining the vertical and horizontal extent of contamination, and the calculation of volumes of soils requiring excavation. The PPO also recognized the importance of mapping historical, natural, and cultural resource features, such as gravesites, to aid the communities in their future management of the islands, and subsequently to comply with the NHPA and the Coastal Zone Management Act.

Alaska's high latitudes and the islands' remoteness challenge GIS application. Normally available geo-referenced base maps, such as topographic quadrangles and nautical navigation charts, are scarce, small scale, or nonexistent. Early project acquisition and prosecution of DGPS data acquired with Trimble Pro XRS and corrected with post processing layered over existing electronic versions of nautical charts revealed positional errors requiring exhaustive research to rectify.

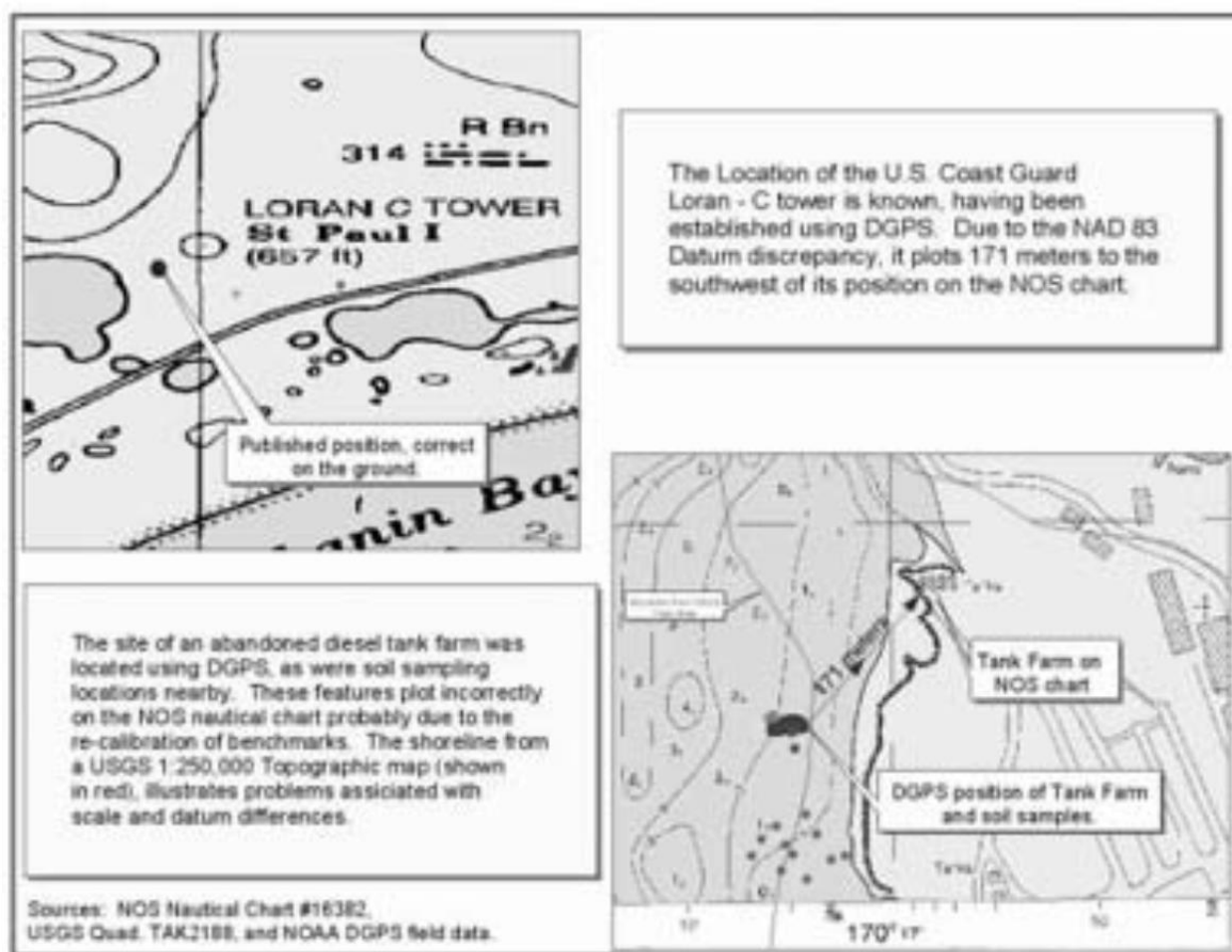


Figure 13.1 Errors in previous mapping projects.

The project resurveyed the two principal islands, St. Paul and St. George, to first order following National Geodetic Survey protocols. The results revealed a transcriptional error in an earlier version of the cartographic process that translated into an approximate 180-meter error (Figure 13.1). New benchmarks were installed on the islands, and NOAA/NOS issued new nautical navigation charts in March 2001. The chart scale, however, was still too small (1:50,000) for practical use. The NOAA project entered into a cost share collaboration with the US Geological Survey to provide Digital Elevation Models (DEMs) at 1:24,000 scale, topographic quadrangles at 1:25,000 scale with 10-meter contour intervals, and Digital Ortho Quarter Quads (DOQQ's) at 1:12,000 scale using pre-existing (1993) colour aerial photography. In an effort to acquire recent high-resolution imagery, NOAA contracted with a satellite vendor to provide 1-meter panchromatic and 4-meter multi-spectral imagery. The PPO is considering the application of interferometric synthetic aperture radar (IFSAR) imagery of the islands for use in establishing hydrographic controls to further improve island charting and to monitor long-term Aeolian erosion processes that have a potential to impact current restoration efforts. These products, when combined with historical maps and project data, will provide a comprehensive view of the islands and their changes over time.

The Pribilof Islands GIS mapping project uses ESRI's ArcView version 3.2. Federal Geographic Data Committee compliant metadata allows rapid data searches. The project focuses on several coverages and features (Table 13.1). As noted above, base maps include NOAA navigational charts as well as airphoto- and satellite-derived DEMs. Historical maps acquired from various sources including libraries and published reports dating back to the late 1800's provide a reference for changes occurring over more than a century. Changes of interest include fur seal, sea lion, and walrus rookery and haul out locations, as well as building and off-road trail locations. The maps are scanned at 1200 dpi and overlaid on registered and rectified base maps. The PPO uses Trimble Total Station RTK (real time kinematic) 5700 DGPS survey equipment to provide real time horizontal spatial accuracy of ± 1 cm and vertical accuracy of ± 2 cm. Acquired data is used for contouring and creation of 3-D models of landfill activities, excavations, contaminated soil stockpile volumes, and potentially for plotting seabird nests on cliff faces combined with laser spotting technology.

Table 13.1 Pribilof Islands GIS coverages and features

Coverage	Features
Geographic	Islands and land masses
Geologic	Soils, stratigraphy
Chemical	Soil and water
Demographic	Buildings, roads, debris sites; historic and current video and still images
Topographic	Cinder cones, landfill relief, DGPS ground surveys, aerial and satellite imagery
Biological (fauna and flora)	Fauna, flora, rookeries, haul outs, migration patterns, historic and current video and still images
Oceanographic	Bathymetry, currents, ice pack
Archaeological	Habitations, burial sites, historic and current video and still images

The authors' previous experience with marine GIS projects (e.g. Lindsay et al., 1999; Butman and Lindsay, 2000) revealed the robustness of ArcView GIS. Using hotlinks the GIS project is enabled to include multimedia features, such as still, raster (laser line scan), and video imagery and sound recordings. The PPO uses Canon XL-1 digital and Panasonic 720p High Definition (HD) electronic media cameras and digital still cameras to document field activities. HD is down-converted to standard definition. Standard Def and digital videotape postproduction relies on MacIntosh G4 editing suites with Final Cut Pro software and DVD Studio Pro authoring software. Real GIS data are imported into a Hewlett Packard X4000 with XSI animation software to create textured, lighted, and animated production quality 3D models for viewer friendly but scientifically accurate renditions of real data. Historical video on Betacam and VHS tapes are converted to digital format using the same hardware and software. The GIS project itself and video mini-documentaries are placed onto DVD (digital video disk) using super drives. (Please note that any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.)

ENVIRONMENTAL RESTORATION

The U.S. Government initiated environmental restoration activities on the Pribilof Islands in 1983 following the final decision to transfer island lands from the public to the private sector. Former operations managers, residents, and historical reports aided in the identification of contaminant and debris sites. From a mapping perspective the primary emphasis of the environmental restoration activities on the Pribilof Islands has been on the locations of land features, boundaries, and the acquisition of soil and water chemical contaminants data. Demographic land feature focus has been on ownership, including federal land tracts and parcels targeted for transfer under the ANSCA and TOPA, topography, cultural uses associated with waste disposal practices, debris and contaminated waste site boundaries, building locations, utility locations (water, electrical, fuel transfer, cable, telephone and television lines), and grave site locations. Pribilof Islands' soil and groundwater chemistry has typically been evaluated at sites where spills or releases of petroleum products were suspected or known to have occurred, such as landfills and building sites.

A significant commercial infrastructure was built on St. George and St. Paul Islands to harvest and cure northern fur seal skins between 1872 and 1984. Numerous buildings were constructed for brine and salt curing, barrel making, skin packing, and seal by-product production, such as oil and animal meal. Other structures included electrical generation plants, gasoline stations, a radio station, fuel storage and transfer, commercial store, storage and utility buildings, a school, health clinic, quarries, and roads. As the value of the harvesting grew, so did the sophistication of the infrastructure and the use of petroleum based fuels for electrical generation and motorized vehicles. Storage tanks of various sizes ranging from about 500 gallons to 200,000 gallons and fuel lines serviced the islands' energy needs. Until about 1970, these tanks were filled from 55-gallon barrels brought ashore by bidarrahs, a native rowing craft with Russian influenced origins that were covered by sea-lion skins, and eventually by fuel barges with floating transfer lines.

Environmental restoration efforts prior to 1999 lacked either resolve and/or management experienced in restoration; consequently their efforts resulted in restoration of readily visible debris that included six thousand tons of surface debris, thousands of barrels either empty or containing used oil, and some underground storage tanks. Contaminated soils, groundwater, and landfills were

left virtually untouched. In addition, initial efforts relied on conventional surveying and mapping techniques that archived features on paper maps without providing adequate geo-references. Subsequent field activities failed to recover site boundaries and soil sampling points. Short field seasons punctuated by years of inactivity resulted in as many as four characterizations at some sites in this treeless and knee-high grass environment in part due to the lack of geo-referencing and unique visual cues such as building foundations, stressed vegetation, soil staining, or surface debris. In an effort to capture these data, the PPO scanned existing paper maps, periodic air photos dating back to 1948, geo-referencing these when possible, and including them in the GIS project along with textual and tabular information. Since 1999, the PPO has relied on DGPS survey systems to log data points and vectors, to catalogue site features, and to relocate sites and sampling points. For the first time Pribilof Islands data was entered into a GIS were spontaneously created in the field office for planning and discussion purposes. Subsequent maps demonstrated the extent of soil and groundwater contamination, and served to increase the efficiencies of removal action decisions.

For example, diesel fuel contaminated sites are first verified by laboratory soil chemical analyses. Using GIS created maps depicting analytical results, and site historical and current features as guides, a removal or excavation is initiated within the bounds defined about these analytical results. These analyses seldom define within several meters the horizontal and vertical extent of contamination. Therefore, following initial excavation of contaminated soils, the project relies on thin layer chromatography (TLC) soil screening to verify whether remaining soils have diesel fuel contamination. The project has determined that field applied TLC based on standards offers a high probability (>95%) of accuracy within a sliding scale (e.g. 0-100 mg/kg, 100-250 mg/kg). TLC samples and their horizontal and vertical positions can be collected, processed, and the results entered into a GIS within approximately two hours. The sample results are overlaid onto registered and rectified historical air photo(s) depicting the historical structures, such as buildings, fuel tanks and fuel lines linked as sources of the contamination but long since dismantled. The composite photomap allows the cleanup team to substantiate the TLC results in context with the extent of the excavation and likely sources. If the map depicts a sample result with likely low levels of contamination, and no historical source was within close proximity to the spot, the cleanup team has received greater certainty about stopping further excavation. When excavation is considered complete, additional soil samples are taken for fixed laboratory analysis. The photomaps created during these field exercises can be displayed on laptop computer screens, printed on photographic papers, projected onto walls and plasma screens, and transmitted via Internet to far off locations.

High resolution (sub-meter scale) topographic maps of quarries and mineral stockpiles are created with the DGPS and GIS. On the islands, the project is required to purchase sand, scoria, and rock for use as backfill in excavations of contaminated soils, making haul-roads over the tundra, and capping landfills. Owners of the mineral rights require the purchaser to conduct pre- and post-surveys of the quarries to first approve and then verify quantities removed to establish a cost or royalty. The projects survey grade GPS in combination with the GIS are used to create the survey maps.

As mentioned above, the driving force behind the environmental restoration is the land transfer from the American government to local entities. These lands in the form of lots, parcels, and tracts were initially surveyed more than two decades ago using traditional surveying techniques by a

separate federal agency. The available plats are in paper form and they are not easily applied in discussions involving numerous individuals and multiple issues that may involve structures, and contamination of soil and groundwater. In addition some shoreline changes have occurred since the original surveys. The project scanned and registered best fits of these plats and entered them into the GIS project for use as overlays with air and satellite photos. These enhanced maps from the original plats, hotlinked to still or video imagery, greatly improved communications between on- and off- island officials.

NATURAL RESOURCE NAMING CONVENTIONS

On and around the Pribilof Islands, marine mammals and seabirds dominate the environment. Only three terrestrial mammals are indigenous to the Pribilofs; they include the arctic fox, the black-footed lemming on St. George, and the Pribilof shrew on St. Paul. While English naming is the predominant convention followed today, some Unangan elders still refer to various species and/or their life stages in either Unangam tunuu (our people's language) or Aleut language, or Russian. For example, the arctic fox is called aygagux in Unangam tunuu. Fur seals are identified by sex and life stage in one or more languages. GIS mapping features can incorporate the various naming conventions applied to these species as appropriate.

LOCATION NAMES

Present Pribilof Islands location names are also a mixture of Unangam tunuu, Russian, and English. For example on St. Paul Island, Lukanin Bay and beach, also spelled Lukannon, was named after the promyshlenik [fur hunter] who along with another, Kaiekov, killed 5000 sea otters during the first year of occupation in that area. Zolotoi Beach is literally interpreted as "Golden Sands" (Martin, 1960). Other present-day place names demonstrate American influence. On St. Paul, Hutchinson Hill acquired its name after Hayward Hutchinson, the first American to secure the commercial rights to the islands' fur seals.

The northern fur seal is the most intensively studied mammal on the islands. Records and maps of rookery locations, and haul out areas date back to the Russian period. Henry W. Elliot and others (cf. Elliot, 1881; Townsend, 1896; Osgood et al., 1915) provided some of the earliest American rookery and haul out area maps. Rookery names as with other points of interest varied over time. For example, today's Northeast Point rookery on St. Paul was known during the Russian period as Novastoshnah Rookery while in Unangam tunuu it is Chaxax.

During NOAA's restoration activities the Aleut community expressed desire for greater recognition for their contribution to the islands' history. Although the literature is not devoid of Unangam tunuu place names, such names are uncommon on maps. Leaders on both islands had already begun to ascribe Unangam tunuu (Aleut place names) but official maps were wanting. NOAA enlisted the assistance of the U.S. Geological Survey (USGS) to procure digital aerial mosaics of the islands for the construction of base maps and the first large scale (1:25,000) topographic relief maps of the islands. These maps were released as a publication in March 2003. NOAA and USGS encouraged the local residents to document Unangam tunuu on these topographic maps and the USGS worked to secure their official status by having the place names reviewed and accepted as Geographic Names by the Alaska Historical Commission.

POPULATION DISTRIBUTIONS

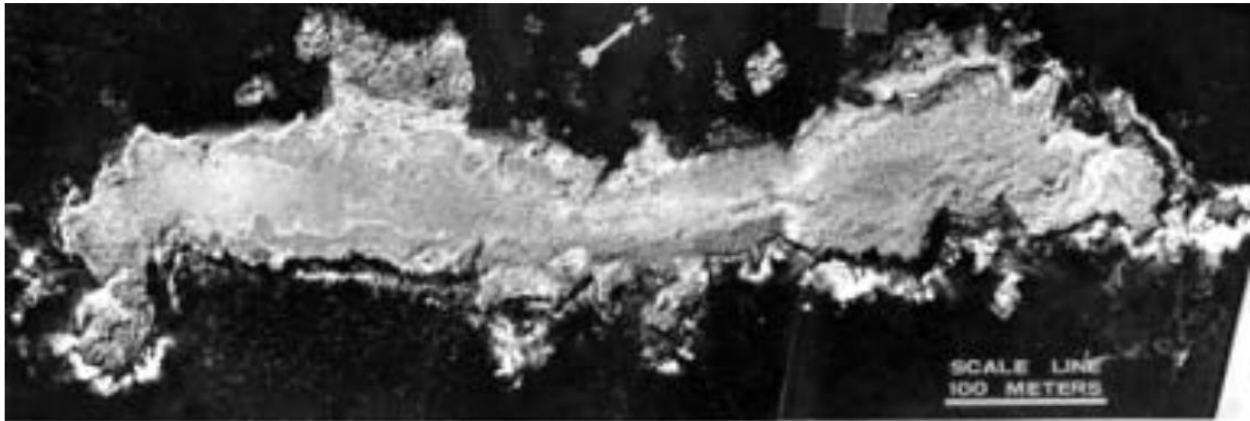


Figure 13.2 1948 aerial survey of Walrus Island.

While the Russian discoverers, beginning with the navigator Captain Gerassim Pribylov, may have recorded various marine mammal population statistics, locating such records will require more concerted efforts than we have so far undertaken. But early American records clearly indicate that many of the aforementioned species at least once flourished on the islands.

Pack ice is said to influence the comings and goings of a variety of species, but most notably, walrus, arctic fox, and polar bear. Mastodon bones and molars have been recovered from lava tubes on the islands, suggesting either arrival via land bridge or pack ice. Purportedly in 1835, long lasting pack ice around St. Paul prevented haul out by pregnant fur seals, which resulted in the loss of both females and potential pups (Martin 1960). The pack ice in the early 1960's is reported by locals to have brought a polar bear to St. Paul, as well as several other times in the past. During 2000, pack ice was responsible for the occurrence of 6 to 7 arctic foxes on Walrus Island, a significant seabird rookery. These foxes are largely responsible for depopulating sea bird colonies, especially murre, on this small rocky island. Presently, NOAA has pack ice distributions in GIS format dating back to 1972. Ice pack incursions about the Pribilofs are being included in the GIS Project. More detailed information can be obtained through a weblink to NOAA's National Environment Satellite Data and Information Service's National Ice Center (www.natice.noaa.gov).

As noted elsewhere, fur seals received the attention of both the Russians and the Americans. Official duties of government agencies from both countries included mapping rookeries and haul out areas and maintaining various population statistics. With the passage of time, the influence of humans and the alteration of habitat has resulted in rookeries being modified or lost. For example, Webster's Point and the Salt Lagoon Rookeries are no more. GIS layering of historical areas is useful for the study of such changes, and the project also takes into account location names as ascribed over time within and between cultures.

The NOAA National Marine Mammal Lab has accumulated numerous aerial photographs of seal rookeries on St. Paul. The PPO scanned, registered, and rectified images from 1948, 1967, and the 1980's and included them in the GIS project.

Elliott noted (1875) only "a few sea-lions" bred on Walrus Island, although thousands could be seen among the fur seals at Northeast Point on St. Paul. Osgood et al. (1915) reported only two breeding rookeries: one of these was at Sea Lion Neck on St. Paul and the other near Garden Cove on St.

George. But they also noted major haul out areas on all five Pribilof Islands. An aerial survey in 1948 found 1,258 adult sea lions on Walrus Island, but the resolution was insufficient to determine the number of pups if any. The aerial photos have been registered and rectified for inclusion into the GIS project. During a rare visit to Walrus Island in 2000, our contingent observed 109 sea lions of which 11 were pups. During the same period fewer than 10 sea lions were observed on Otter Island. Today, despite the significantly reduced numbers, Walrus Island is the major sea lion rookery in the Pribilofs. Eleven species of seabirds nest on the Pribilof Islands. The red-legged kittiwake, as one example, occurs only in the Bering Sea and it has major rookeries on the Pribilofs. Only one shore bird, the rock sandpiper, breeds on the Pribilofs. The U.S. Fish & Wildlife Service monitors seabird nesting on the islands, but no electronic maps are available to date.

CULTURE AND SUBSISTENCE

Veltre and Veltre (1981) undertook the first focused comprehensive evaluation of the subsistence natural resources on the Pribilofs, although much of their work was acquired from historical documents dating back to the 1800's. They point out that the sealing industry "had significant ramifications on subsistence in the Pribilofs." Table 13.3 provides a listing of some representative natural resources on or about the Pribilof Islands and the customary traditional uses of each.

Two species have been virtually eliminated from the Pribilof Islands, the Pacific walrus and the sea otter. Neither animal apparently played much of a subsistence role on the Pribilof Islands in part because of their demise by the promyshleniks who sought the valuable ivory and pelts, respectively. Their historical haul out areas are included in the GIS project.

A third species, the Steller sea lion, is close to extinction on the Pribilof Islands as discussed above. Scans of historical maps depicting sea lion rookeries and haul out areas are layered onto the GIS project and verified observations of sea lions on shore will be logged into the project. Today, the sub-adult male sea lion constitutes a subsistence resource and is hunted primarily from the shore. Some hunting does occur on the water at St. George Island, however. Sea lion are hunted for their meat, blubber, internal organs, and fore flipper, although in earlier years the animal provided several customary traditional uses (Table 13.2). Historically, the dried flesh and hides of sea lions along with fur seals has long been a staple on the Pribilofs. The sea lion provided essential meat and clothing, as well as covering for the bidarra.

The northern fur seal continues to play a major subsistence role on the Pribilof Islands with several hundred being killed on St. Paul and St. George each year. Until recently, the U.S. Government allowed a subsistence take of 2,500 young bachelor males to be harvested each year. Today, the Tribal Governments on each island and the NOAA National Marine Fisheries Service (NMFS) are co-managing the subsistence harvest of fur seal. Locations authorized for subsistence sealing by year and favourite hunting areas are being included in the GIS project. Several recent seal midden locations are being mapped as well.

Links from the GIS maps are used to display more detailed information on the food subsistence value offered by the northern fur seal. A link from the map to a photograph (Scheffer 1948) that laid out the various body parts provides even more detailed information (Figure 13.3).

Today, as in the past, many seabirds have customary traditional uses. Millions of seabirds flock to the islands each year for breeding. Henry W. Elliott was the first American on the Pribilof Islands that accounted for their natural history and cultural subsistence through prolific writings extending over 20 years. He noted that large flocks of chuchiigix (*Aethia pusilla*) arrived in the spring and were harvested by Unangan with hand scoop nets. Chuchiigix, known as the least auklet, make nests in crevices among boulders. Chuchiigix are still hunted today by using a long bamboo pole to strike the small birds out of the sky (bamboo often washes up on the shores of the islands). Veltre and Veltre (1981) point out that this is one of the few species that can be hunted by children. Elliott (1881) reported that least auklets were replaced in late July by large flocks of red-legged turnstones that were also eaten by Unangan. Unlike the chuchiigix, the turnstones bred elsewhere, but they stopped on the Pribilofs to feed on the “flesh flies and their eggs, which swarm over the killing grounds.” The killing grounds are not nearly as extensive as they once were, but whether the abundance of turnstones on the islands was affected is not known.

Table 13. 2 Species list using either Aleut or English name found on or about the Pribilof Islands and their customary traditional use. Egg

Subsistence Resource	Customary Traditional Use
<i>qawax</i>	Hides: baidarkas and bidarrahs (skin boats) Intestines: waterproof garments Throats: boot tops Fore-flipper palms: boot soles Stomachs: oil containers Whiskers: traded to Chinese Sinews from back: “thread” for sewing Gall bladder: healing sores Carcass, liver, lungs, lard: food (Elliott, 1881)
<i>itxayan</i>	Carcass: food
<i>aygagux</i>	Skin: sold for it fur value
<i>kagayax</i>	Eggs: food Carcass: food
<i>chuchiigix</i>	Carcass: food
<i>sikiita</i>	Skins and feathers: parkas Eggs: food Carcass: food
<i>saquudax</i>	Plant stem: food
<i>qayux</i>	Berries: food
<i>Salmonberry</i>	Berries: food
<i>aguganax</i>	Roe: food
<i>waygix</i>	<i>Body: food</i>

gathering was a major annual activity on the Pribilofs, although it is much less so now. Primary egg

gathering areas included the steep rocky bluffs and the tabletop flat Walrus Island. According to Elliott, the primary egg- gathering season on Walrus Island was June-July (Elliott 1875). Historical egg gathering locations are included in the GIS project.

The Pribilof Islands are treeless, except for a low-to-the-ground-willow species. Several plant species afforded both cultural and subsistence value. For example, Elliot (1875) commented that only two berry plants, *Empetrum nigrum* and *Rubus chamemorus*, are readily harvested by the Aleuts during the end of August and first week in September. These species are still much sought after and often families spend summer afternoons harvesting the berries. Saquudax (wild celery) seemed to have had more importance in the past than it does now. A silent 1930's black and white film archived in the Oregon Historical Society shows Aleut children harvesting saquudax and demonstrating how it is eaten. A digitized version can be viewed via a hotlink when the distribution plots for the plant are active in the GIS project.

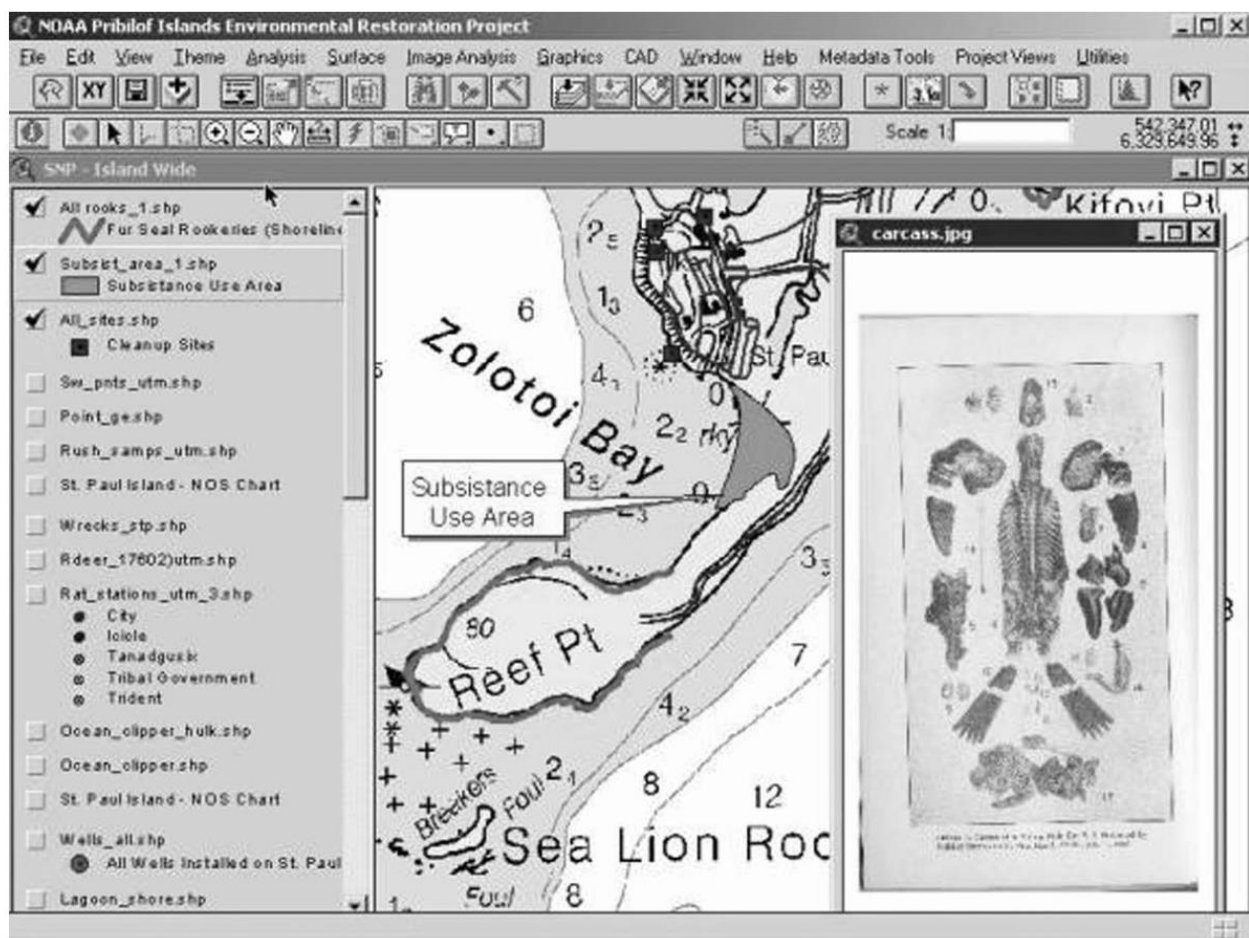


Figure 13.3 Example of hyperlinked media accessible from within the GIS: body parts and subsistence values of a northern fur seal.

Heretofore, little documentation logged by the U.S. Government, Aleut community, or Russian Orthodox Church is known to exist as to the burial of deceased islanders. Some gravesites are marked, while many are known only orally and most are not recalled at all. As a community service and as part of the interest in historical documentation, NOAA received permission from the local churches to develop a GIS project of the cemeteries. Using a survey grade GPS, more than 700

gravesites on St. Paul and St. George Islands were entered into the GIS project. Digital images of each location along with individual statistics (individual names and photo, birth and death dates, and short biographical sketches as available) are linked to the geographic locations. Printed hard copy maps were provided for use by the local churches and municipalities. Using DVD authoring software, the GIS project enhanced with animation and Aleut choir music was transcribed onto a DVD. NOAA provided the respective DVDs to the local church councils. In turn, the St. Paul Island council is relying on the Tribal Government for long-term maintenance of the GIS project. Recently, the Russian Orthodox Church Diocese of Alaska began promoting this GIS application throughout the Diocese.

LONG TERM NATURAL RESOURCE MANAGEMENT

Currently, Tribal Government of St. Paul's Ecosystem Conservation Office (ECO) is using GIS in combination with traditional ecological knowledge for use in environmental and resource management. Due to the increased human interactions with the Pribilofs 'Bering Sea environment, the need to monitor and record these interactions and their impacts on St. Paul and neighbouring islands has become vital. Monitoring of commercial and customary traditional activities, the island ecosystem (i.e. numerous plant and animal species, lands, and environmental changes), in addition to ecological disaster prevention planning are essential in safeguarding customary traditional practices and for protecting and conserving the health of the islands. Critical response planning to prepare the community to effect immediate responses to future ecological perturbations is also vital as competition increases between traditional and commercial interests for the dwindling Bering Sea fishery resources.

The impacts associated with regional oil spills, off-road all terrain vehicle trailbreaking, and commercial fishing along with knowledge about decreasing populations of northern fur seals, Steller sea lions, and various seabird species serve to highlight a need for a balanced harmony between the subsistence users and other interests. Harmonious relations can be achieved through communication, planning, negotiation, and mutual work towards an understanding and respect for differences among groups. To this end, ECO has worked on ongoing development of Tanalix Amgignax (Island Sentinel/Guard) Program in coordination with the Pribilof Islands Stewardship Program, PPO, NMFS, and USFWS. This program includes the following elements:

- Promote "caretaking" and stewardship of the Pribilof Islands 'many life systems.
- Provide a central forum that actively deals with environmental issues.
- Monitor activities that have potential adverse implications on this area of the Bering Sea environment.
- Promote a proactive position on behalf of all life systems indigenous to the Pribilof Islands Bering Sea area for immediate monitoring.
- Exercise the Aleuts 'inherent right to be responsible for the islands 'environment.

- Share caretakership concerns and activities with others, expecting visitors to be on their “best behavior” while visiting St. Paul Island and the surrounding sea.
- Promote environmental and cultural awareness.

Some specific *Tanalix Amgignax* activities that also involve GIS include: preventing rats from coming to the island by actively setting and maintaining rat traps in and around the harbour area and sanitary landfill; monitoring the islands 'shoreline and interior for natural process impacts (weather and wildlife) and disturbances, such as vegetative changes by overgrazing reindeer, shoreline erosion, and derelict fishing gear (i.e. nets, buoys, line, etc.) that wash up on shore; removal of fishing gear from around fur seals 'necks; and sharing the importance of taking care of the Bering Sea environment with the community and visitors alike. Rat trapping locations are entered into the GIS project. If and when any rats are captured this information will be similarly logged into the project. GIS mapping of derelict fishing gear not only provides information to managers for directing shoreline cleaning up efforts, but also documents the periodicity of cleanup efforts along shorelines, the relative quantities and types of debris recovered, and identifies areas where oceanographic conditions work to focus debris. *Tanalix Amgignax* Program is a prime example of the use of GIS in bringing together traditional ecological knowledge and “western science.” NOAA 's contribution to the ECO GIS project will foster the dialogue among the many interests that the *Tanalix Amgignax* Program seeks to bring together.

CONCLUSIONS

GIS application in the Pribilof Island Environmental Restoration Project afforded insights and opportunities not contemplated at the outset of the project. The use of DGPS technology to simply map contaminated and debris site locations, and sampling points led to numerous significant contributions. One of the more routine contributions involved using JPEG and TIFF files cut from the GIS project to make maps for documents on topics such as site investigations, corrective action plans, corrective action reports, and requests to oversight regulators for no further action. Among other significant contributions came new nautical charts with improved near-shore confidence by local fishers in GPS navigation systems; map overlays of historical northern fur seal and sea lion rookeries for comparison with current and ever changing population and environmental conditions; estimates of shoreline erosion rates; improved control management of shoreline marine debris; near real time mapping of contaminant excavations allowing for on the ground decisions; sub-meter scale topographic maps to assist engineers in landfill closeout design and calculating royalty payments from sand and scoria (used as excavation backfill and capping solid wastes) mining; improved communications among officials who lacked on-island experience yet hold responsibility for land transfers following cleanup; and sorting through conflicting boundary descriptions arising from a variety of official documents over an approximate 25-year period.

A collaborative spirit between the government and Aleut entities grew out of training opportunities provided by NOAA in DGPS and GIS, access to NOAA DGPS equipment for ECO Projects, and contributions of GIS software to the City of St. Paul and ECO. Subsequent collaborative geo-spatial projects further improved overall communications. DGPS and GIS enabled local Aleuts to express

their own cultural heritage by applying Aleut location names to the first ever large- scale topographic quadrangles of the islands. In terms of community relations, the most significant contribution afforded by DGPS and GIS came from the mapping of the islands 'gravesites. Unwittingly, this single DGPS/GIS exercise offered up as a community service in context with a federal mandate to preserve historical information provided the strongest bond and trust between the islands 'Aleut population and U.S. Government agents.

Acquisition of precision geo-spatial data in real time is one of many challenges in the higher latitudes. Geodetic control points, such as those offered by Continuously Operating Reference Stations (CORS), are far and few between in America. Alternatively, one can, as done in this project, survey in a base station to provide short-range control. For long-term applications base stations must be maintained against vandalism, climatic events, and curious animals such as foxes that chew through cables. Repeater stations serve to overcome multipath interference such as caused by hilly terrain and buildings. Once these obstacles are overcome, real-time DGPS in combination with GIS provide the investigator with tremendous power to work multiple field situations near real time as well as providing for long-term documentation.

GIS Applications In Coastal Management: A View from the Developing World

INTRODUCTION

Geographic Information Systems have revolutionised the way spatial data/information is acquired, stored, managed, and displayed. In the past the acquisition of spatial data was done mainly with analogue theodolite and levels, and the recording and storage of these data were done in analogue manner. Data management was a very cumbersome exercise and the display was in the form of paper maps. Recent developments in information and digital technologies, communication and satellite technology, and improved computing speed and computer hard disk space, have impacted tremendously the way spatial data is acquired, stored, managed, and displayed. The development has created a revolution in spatial information technology in a way never experienced before. Today, virtually every human activity is spatial. Some schools of thought stipulate that in countries such as the United States and the United Kingdom as much as 75- 80% of all the activities is spatial. There is correlation between geospatial information technology development and economic development. Developed countries of the world are associated with high spatial information technology development. Conversely, poor economic development is associated with low spatial information technology development as witnessed in developing countries of the world.

The development of Geographic Information Systems and associated technologies has created and is still creating employment opportunities all over the world. It has also led to changes of curricula of training institutions, and new training opportunities are being created. Transfer, sharing access to and development of spatial data standards have become major issues. We now discuss spatial data infrastructure as a major requirement for development, as has long been done with regards to other infrastructures such as roads, rail and waterways, electricity, and water supplies.

Geographic information has been employed in several fields such as management of disasters, vehicle tracking systems, forestry, utilities management, oil exploration, environmental

management, health management, census, and mineral resources development, governance (EIS Africa, 2002) and – the focus of this paper – coastal management.

Coastal Areas

The coast is an area that witnesses a substantial amount of physical and economic activities. It is a zone of great significance in the sense that intense agriculture, business and recreational activities take place here. Settlements have been established in these areas and international trade and communication originated in the coastal fringes. The coastal zone houses about two thirds of the world's population and this percentage is expected to increase to 75% by the year 2020 (UNEP, 1992). Most of the important cities of the world, such as Alexandria, Lagos, London, Rotterdam, Shanghai, Tokyo and Venice, are located within the coastal environment, while two thirds of the world's cities having a population of over 2.5 million are within the coastal zone. The coastal environment is very rich in both living and non-living resources. For example, a lot of crude oil and gas exploration and exploitation take place with the coast.

Wetlands are known to be a very productive ecosystem. Most of these wetlands are located in the coastal areas. They are the sanctuaries to many global endangered species and also can assist in dampening the effect of flooding from normal sea flooding, storm surges and sea level rise. Fishes that are caught in the upwelling zone of the Canary Island coast are hatched within the mangrove ecosystem of the Niger Delta and later migrate to the upwelling area. Similar relationships are found in most of the world's major fishing waters.

The coast is therefore a very important zone. Having discussed the importance of the coastal areas, it is now necessary to define the 'coastal zone.' Bird (1967; 1985 & 1993) defines the coast as a zone of varying width including the shore and extending the crest of cliff, the head of a tidal estuary, or the solid ground that lies behind the coastal lagoon, dunes and swamps. Komar (1976) on the other hand defines the coastal zone to include the littoral zone and extending further inland to include the sea cliffs, any marine terraces, dune fields and so on; the seaward limit is limitless. For most studies the coastal zone refers to that zone that is affected by what happens on the sea and on land. The coast is therefore very important for the existence of human life.

Integrated Coastal Area Management

Integrated Coastal Areas Management is defined as a dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural and institutional resources to achieve the conservation and sustainable use of the coastal area (Coastal Area Management and Planning Network, 1989). Planning for sustainable resource management is based on weighing priorities, translating these priorities into policies and finally defining goals, identifying responsibilities for each step and establishing a time frame for action and review. There is no one 'right' way to manage coastal areas. However the design of a coastal management programme or policy for a nation or a region should take into consideration the legal instrument for the implementation of the program as well as the instrumental frame work for policy implementation (Emovon, 1991).

In order to practice effective coastal management, planners need to understand the way the natural environment and human activities are interconnected to form a system. Key aspects of the system include the following information themes:

- i. Biological: This includes type and extent of ecosystem, primary productivity, specie diversity and abundance, nursery grounds and life cycles;
- ii. Physical: This includes topography, geology, temperature, salinity, nutrients, tides, sea level and current, meteorology, sediment types and distribution, flooding and erosion/ accretion;
- iii. Socio-economic: This includes human population distribution and growth, economic activities and land use;
- iv. Legal and Institutional: Land tenure system, resource use rights, relevant laws and regulations, responsible agencies and availability of financial and human resources (Borrego, 1994).

Each of these activities is greatly influenced by activities within and beyond the coastal zone. It is for this reason that the resolution of conflicts in the use of coastal resources requires a broad perspective on the environmental process and interaction among human activities.

THE GUINEA CURRENT LARGE MARINE ECOSYSTEM PROJECT

The Concept of Large Marine Ecosystem Project

Large Marine Ecosystems are regions of the ocean space encompassing coastal areas from river basins and estuaries to the seaward boundaries of the continental shelves, and the outer margins of the world's current system. These marine regions are considered in terms of their ecological unity based on their distributive bathymetry, hydrographic, productivity, and trophic linkages (Sherman et al., 1993; UNIDO, 2002). The world's 64 LMEs are the most productive ecosystems, and together produce 95% of marine fishery biomass yields. It is also in the LMEs that most of the global ocean pollution, fisheries over-exploitation and coastal habitat alteration take place.

The LME ocean management approach focuses on the sustainable development of the ocean resources and requires a paradigm shift from a small spatial scale to a larger one and from a short-term to a long-term perspective. It requires countries bordering the LME to set priorities on how to tackle their common transboundary issues. Since the early 1990s, the developing countries have approached the Global Environment Facility (GEF), the United Nations Industrial Development Organisation (UNIDO) and other United Nation implementing agencies for technical and scientific assistance in restoring and protecting their coastal and marine ecosystem. GEF agreed to provide guidance and funding in addressing these issues within the framework of sustainable development. It recommended the use of the Large Marine Ecosystem (LME) concept and their contributing freshwater basins as the geographic focus for addressing the issues (UNIDO, 2002).

The Guinea Current Large Marine Ecosystem Project Implementation

The Guinea Current Large Marine Ecosystem Project is funded by the Global Environment Facility (GEF) and managed by the United Nations Industrial Development Organisation (UNIDO). The phase I of this project was started in 1995 and ended in 1999 with the countries of Cameroon,

Nigeria, Benin Republic, Togo, Ghana and Côte d'Ivoire participating. Apart from GEF and UNIDO, some form of scientific and technical support came from the United Nations Education and Scientific Cultural Organisation (UNESCO), other UN agencies, and the US National Oceanic and Atmospheric Administration (NOAA). The participating countries provided in country support in the form of logistics such as provision of offices and transportation vehicles. The execution of the project was in form of modules. The modules that were covered in the project included Integrated Coastal Areas Management (ICAM), Geographic Information System (GIS), Mangroves, Industrial Pollution, Policy Issues, Fisheries, Coastal Erosion, Plankton and other pollution. The structure made provision for a National Project Director in each of the participating countries and a National Expert for each of the modules. All the national experts were reporting to an International Expert who co-ordinated each of the modules. The project had a Project Coordinator who was based in Abidjan, Côte d'Ivoire. The office of the Project Coordinator also served as the Secretariat for the project. In each of the participating countries, there was a Focal Point Agency and Focal Point Institution.

In Nigeria, the now-defunct Federal Environmental Protection Agency was the focal point agency, while the Nigerian Institute for Oceanography and Marine Research was the focal point institution. There were other participating institutions such as the University of Lagos. In the other participating countries, the focal point agency was the Ministry of Environment. Efforts were made in the project to collaborate with relevant institutions.

The second phase of the project is bringing in an additional 10 countries. These include Guinea Bissau, Guinea, Sierra Leone, Liberia, Congo Brazzaville, Democratic Republic of Congo and Angola. These countries, in addition to the original six, are in partnership activities for sustainable development of the Guinea Current Large Marine Ecosystem (GCLME). The addition of these to the original six countries meant that the full extent of the Gulf of Guinea Current Large Marine Ecosystem is covered. This stage of the project will commence in January 2004 (UNIDO, 2002).

All participating countries are making contributions to a Transboundary Diagnosis Programme (TAD) and a Strategic Action Programme (SAP) for the project (UNIDO, 2002).

The ICAM Module

The essence of the Guinea Current Large Marine Ecosystem project is the sustainable management of the living resources of the Gulf of Guinea region. The region was experiencing a serious environmental stress due to urbanisation, pollution from industries and domestic wastes, population explosion, oil spillage, deforestation, erosion, and over-fishing. The fish stocks were depleting at a fast rate and the socio-economic lives of the inhabitants are adversely affected. The lagoons that dot the coast from Côte d'Ivoire to Nigeria had become heavily polluted. Most of the problems highlighted above are transboundary in nature. There was therefore a need to reverse the situation and address these problems from a regional perspective rather than from a national perspective.

Under the module, an experienced ICAM professional prepared guidelines for implementation of ICAM in the countries. The National Experts prepared a country profile for each of the six participating countries in the first phase. The country profile is a baseline of the situation in each of the participating country's coastal area. The information used in preparing the country profile was

obtained from existing literature and from relevant institutions. This was followed by a three-day workshop where stakeholders discussed the profile and made recommendations where necessary. A final copy of the country profile was made after effecting the necessary corrections from stakeholders.

An outcome of the workshop was the setting of the National Integrated Coastal Area Committee for each of the participating countries. Another success of the workshop and activities of the Guinea Current LME phase 1 is the creation of awareness on the importance of Integrated Coastal Area Management: prior to the Guinea Current LME project, there was no National ICAM Committee in any of the six participating countries.

As part of the efforts to assess the health of the Guinea Current LME, a fish trawl survey was carried out from Côte d'Ivoire to Cameroon. Results from the survey confirmed the fear that the fish stock, together with the plankton, was being depleted.

Application of GIS to The Project

As was the case in the Integrated Coastal Area Management Module, there was a National Expert for the GIS Module in each of the participating countries in phase I of the project. The author served in this position for Nigeria. The project started in 1995 but the National experts were engaged in 1997 for a two-year period. The contract was on part time basis.

The major goal of the GIS application in the project was to use GIS as an information and decision support system. Decision-makers are not always in a position to read all the volumes of materials that are passed to them. The graphic displays that are provided by GIS will invariably reduce the time that would have been spent in reading several volumes of materials, and assist in taking decisions that affect a project quickly. For example, it is easy to visualise the way a mangrove ecosystem of a region is changing over time through graphical displays.

Capacity Building for the GIS Module

The project provided for National Experts to attend Training workshops and conferences. A Project Expert Committee Workshop was organised by the Project Coordinator's office in Abidjan in April 1997 for all the National GIS Experts. This workshop touched on GIS application in the project and in particular the issue of metadata. Since the project is regional in nature the issue of harmonisation of different mapping datums in the region was discussed extensively. The National Experts provided information on institutions using GIS in the different participating countries. It was also a forum for experts to get to know each other. Another GIS Expert meeting took place in Abidjan between 29-30 September 1998 to deliberate on issues affecting the project.

SIMM Coast Workshop

SIMM is an acronym for sustainable integrated management and so SIMM Coast stands for sustainable integrated management of Coast. This workshop was organised by Prof. McGlade, formerly of the Centre for Marine Research, University of Plymouth, United Kingdom. It was essentially on the application of artificial intelligence in integrated coastal management. All the GIS National Experts were sponsored by UNIDO to participate in the workshop. This workshop took

place at the Food and Agricultural Organisation office in Accra, Ghana between July 30th and 31st, 1998.

The Accra Declaration

The first meeting of the Ministerial Committee of the Gulf of Guinea Large Marine Ecosystem (GOG-LME) Project took place in Accra, Ghana, on 9th and 10th of July, 1998. Five Ministers with responsibility for the Environment respectively in Benin, Cameroon, Côte d'Ivoire, Ghana and Togo and the Director General/Chief Executive of the Federal Environmental Protection Agency of Nigeria attended the meeting.

After the deliberations of the ministers, which were based on extensive and substantive preparations, the Committee of Ministers adopted the Accra Declaration on Environmentally Sustainable Development of the Large Marine Ecosystem of the Gulf of Guinea. Part of the decision reached was that efforts shall be made to initiate, encourage and work synergistically with current and/or programmed national and international programmes on integrated coastal zone management in the region. The national concerns of flooding, and pollution caused by hydrocarbons, toxic chemical products, fisheries productivity and over-exploitation and, above all, coastal erosion, call for the special attention of donors. Also, data and information networking between the GOG-LME countries should be improved. National and Regional databases on the coastal and marine environment should be established using the Geographical Information System (GIS) to support decision-making, to be available to all users.

Results from the Phase I of the GCLME Project

As part of the success story of the GCLME project, guidelines for integrated coastal areas management and planning have been developed for Benin, Cameroon, Côte d'Ivoire, Ghana, Nigeria and Togo. Country coastal profiles were similarly developed and major issues and options for national and regional actions were identified.

The Gulf of Guinea Large Marine Ecosystem (GOG/LME) project has organised and facilitated a series of activities that have enabled each country to take the appropriate steps toward the adoption of Integrated Coastal Areas Management Plans, including strengthening legal and policy frameworks. In addition, these plans and policies are available for incorporation into National Environmental Action Plans. ICAM has proven to be the most effective way to involve the grassroots stakeholders in a meaningful way and could be the cornerstone for the GOG/LME potential Phase II Project.

Indications that member countries will embrace and make this effort sustainable are beginning to appear. First, National Steering Committees have been established by legal instruments. Second, the individuals who are participating in the programme range from top Ministry officials to citizens in NGOs and CBOs, indicating the existence of multilevel support.

An important parallel development with the effort to put National ICAM Plans in place has been the process of establishment of information management and decision-making systems such as Geographic Information Systems (GIS) at both the national and regional levels. ArcView 3.1 GIS

software was chosen as the GIS platform for the project. It is hoped that in the second phase of the project, ArcGIS 8.3 will be the platform.

OTHER COASTAL AREAS PROJECTS IN AFRICA

Niger Delta Environmental Survey

The Niger Delta is an environmentally sensitive and fragile region owing to its peculiar natural physical setting and its distinctive ecological features and functions which over the years have drawn the attention of conservationists especially on the need for sustainable development and the protection of its biodiversity (NDES, 1997). Considerable changes are occurring in the ecological environment and in the socio-economic setting of the Niger Delta as a result of both natural and another anthropogenic transformations that include: upstream dam construction, coastal zone modification, urbanisation, deforestation, agriculture, fishing, industrial development, population pressure, and crude oil exploration and exploitation. The Niger Delta is therefore under increasing pressure from rapidly deteriorating ecological and economic conditions, social dislocation and tension in communities, problems that are not being addressed by current policy and behaviour patterns.

It is for this reason that the Niger Delta Environmental Survey (NDES) was set up. The NDES, in concert with communities and other stakeholders, undertook a comprehensive survey of the Niger Delta. It established the causes of ecological and socio-economic changes over time and induced corrective actions by encouraging relevant stakeholders to address specific environmental and related economic problems aimed at improving the quality of life of the people and achieving sustainable development in the region. Part of the objectives of the survey was to generate data and information on the Niger Delta including the establishment of a Geographic Information System (GIS). The data and information can be used in formulating strategies and plans for effective natural resource management towards the sustainable use of resources, in order to protect the environment and the livelihood of peoples of the region (NDES, 1997).

Analogue maps of the Niger Delta at scale of 1/25,000 were digitised and updated with remotely sensed images. The map information is now in a GIS environment, and is used in decision-making for the planning and management of the Niger Delta.

Secretariat for Eastern African Coastal Area Management (SEACAM) Project

SEACAM means secretariat for Eastern African Coastal Areas Management. It was set up in August, 1997 in Maputo, Mozambique, with the purpose of accelerating the implementation of integrated coastal zone management in the region as put forth in the Arusha Resolution of 1993 and Seychelles statement of 1996 on ICZM. The Secretariat is hosted by the Ministry of Environmental Affairs for Mozambique.

The objective was to assist Eastern African Countries to implement ICZM following up the Arusha resolution and the Seychelles statement on capacity building and information dissemination. It was supported by the Government of Finland, Danish International Development Assistance (DANCED), the World Bank and UNESCO. A number of other donors provide important support to select activities that match their programme areas.

In 1996, the Western Indian Ocean Marine Science Association organised an expert and practitioners workshop in Tanga, Tanzania on integrated coastal area management, which provided an input into the second ministerial policy conference on integrated coastal and zone management in Eastern Africa and Island States held in Seychelles, October, 1996. It is not certain whether GIS was used in this project.

Lake Victoria Environmental Management Project

For decades, East African scientists, policy makers, stakeholders and others around the world noted the escalating environmental degradation of Lake Victoria, which is an international water body. It was observed that increased population is a major contributing factor. The total population of the riparian communities currently stands at 30 million.

As a result of the degradation the riparian countries to Lake Victoria, which are Kenya, Tanzania and Uganda, initiated discussions immediately after the United Nations Conference on Environment and Development (UNCED) to broaden regional cooperation in environmental and social issues affecting Lake Victoria Basin. This led to the signing of a triplicate agreement in 1994. The project attracted financial support from the International Development Association (IDA) and Global Environmental Trust Fund (GEF) to the tune of US \$70.00 million. The participating countries agreed to contribute \$7.2M as counterpart funds. Apart from other achievements of the project, mapping of the present land use/land cover and soil erosion hazard in the Lake basin is almost completed. Data on pollution loading are being collected from selected micro-catchments and provide useful information on soil nutrients and water losses. Human capacity is being developed. An important component of the project is community participation in the preparation and implementation of the project. It is not clear whether GIS was used as an information management tool but it is obvious that there was mapping which could, if still in analogue format, be converted to digital format and managed in a GIS environment.

Information Technology for Coastal Zone Management of the Nile Delta

This is an initiative for development and implementation of an integrated coastal analysis and monitoring system. A workshop was organised between 7 – 10 April 2003 aimed at addressing issues such as coastal erosion, pollution, monitoring and fisheries management. It will serve as a model for information system implementation in the developing world context, where the need for operational coastal management is often great but for which information infrastructure and knowledge base are frequently lacking.

Eastern African Coastal Resource Maps Project

The Eastern African Coastal and Marine Environment Resources Database and the Atlas was founded within the framework of the 1985 UNEP brokered Eastern African Action Plan for the protection, management and development of the Marine Environment of the Eastern African Region (EAF). The countries of Comoros, La Réunion, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia and Tanzania participated in the project.

The project was initiated in 1993 by the Ocean and Coastal Area Programme Activity Centre (OCA/PAC) in co-operation with the Global Activity Centre (GRID/PAC-Nairobi). The project was

scheduled to run for five years. The first phase of the project only focused on Kenya while Phase II and III (1995-1996) concentrated on Comoros, Mozambique, Seychelles and Tanzania. Phase III and IV (1996-1997) concentrated on Madagascar, Mauritius, La Réunion and Somalia. Phase V is intended to round up all activities at the National Level.

The production of the digital database led to wiser use of resources and helped reduce wastage of non-renewable resources. The main objective of the project is to collect existing information on coastal resources of the region and to summarise the same in country map sheets managed in a GIS environment (Okemwa, 1995).

Scientists from the participating countries took part in the collaboration of the information and the development of the database. Information in the database covers parameters including but not limited to climate, hydrology, oceanography, coastal types, geomorphology, geology, tourist infrastructure, important ecosystems such as mangroves systems, wetlands, estuaries, rangelands and mineral resources.

The maps will be useful in studying the vulnerability of the coastline and indeed as a versatile tool in making strategic intervention in cases of oil spills.

CONCLUSIONS

Various coastal management projects in Africa have been discussed above. It is observed that most of these projects were conceptualised and executed by the developed countries, mainly European countries, while the African scientists only played supportive roles. Two projects in the opinion of the author stand out as clear exceptions to this situation. These are the Guinea Current Large Marine Ecosystem project and the Niger Delta Environmental Survey.

As earlier stated, the Guinea Current Large Marine Ecosystem project is funded by the Global Environment Facility and managed by the United Nations Industrial Development Organisation. Initially, the project was conceptualised by the governments of Nigeria, Ghana, Togo, Cameroon, Benin and Côte d'Ivoire. It was later realised that there was a need to include all the countries bordering the Guinea Current and this increased the number of participating countries to sixteen.

The other project, the Niger Delta Environmental Survey, was conceptualised by the oil prospecting companies in Nigeria. Its mission statement is: "In concert with communities and other stakeholders to undertake a comprehensive environmental survey of the Niger Delta, establish the causes of ecological and socio-economic changes over time and induce corrective action by encouraging relevant stakeholders to environmental and related socio-economic problems identified in the survey to improve the quality of life of the people and achieve sustainable development in the region" (Niger Delta Environmental Survey, 1996). Incidentally, these two projects are in Nigeria.

There is therefore a need to involve the African scientists and researchers from the conceptualisation stage of projects on the Continent. This is believed to be more beneficial to these countries and their scientists, particularly in the area of capacity building.

MODULE - VI

REMOTE SENSING FOR COASTAL ZONE MANAGEMENT

Remote Sensing of Coastal Environments: An Overview

INTRODUCTION

Coastal zone, as defined by the Coastal Institute of the University of Rhode Island, includes areas of continental shelves, islands, or partially enclosed seas, estuaries, bays, lagoons, beaches, and terrestrial and aquatic ecosystems within watersheds that drain into coastal waters. The coastal zone is the most dynamic interface between land and sea and represents the most challenging frontier between human civilization and environmental conservation. Worldwide, over 38% of human population lives in the coastal zones. In the United States, about 53% of the human population lives in the coastal counties. An increasing proportion of the global population lives within the coastal zones of all major continents that require increasing attention to agricultural, industrial, and other human-related effects on coastal habitats and water quality and their impacts on ecological dynamics, ecosystem health, and biological diversity.

Coastal environments contain a wide range of natural habitats such as sand dunes, barrier islands, tidal wetlands and marshes, mangrove forests, coral reefs, and sub-merged aquatic vegetation that provide foods, shelters, and breeding grounds for terrestrial and marine species. Coastal habitats also provide irreplaceable services such as filtering pollutants and retaining nutrients, maintaining water quality, protecting shoreline, and absorbing flood waters. As coastal habitats are facing intensified natural and anthropogenic disturbances by direct impacts such as hurricane, tsunami, harmful algae bloom, and cumulative and secondary impacts such as climate change, sea level rise, oil spill, and urban development, inventory and monitoring of coastal environments become one of the most challenging tasks of the society in resource management and humanity administration. Remote sensing science and technologies that involve space-borne and airborne sensor systems in data acquisition and observation have profoundly changed the practice in monitoring and understanding of the dynamics of coastal environments.

Coarser spatial resolution remote sensing data have been used for broader scale coastal studies. For example, high concentrations of suspended particulate matter in coastal waters directly affect water column and benthic processes such as phytoplankton productivity productivity of submerged aquatic vegetation, nutrient dynamics and the transport of pollutants. Although there has been considerable effort toward using remotely sensed images to provide synoptic maps of suspended particulate matter, there are limited routine applications of this technology due in part to the low spatial resolution and long revisit period. Miller and McKee (2004) examined the utility of moderate-resolution imaging spectroradiometer (MODIS) 250 m data, with integration of in situ measurements, for analyzing complex coastal waters in the Northern Gulf of Mexico, and mapped the concentration of total suspended matter. The study demonstrates that MODIS near daily coverage of medium-resolution data is useful for examining the transport and fate of materials in coastal environments, particularly smaller bodies of water such as bays and estuaries.

The Sea-viewing Wide Field-of-view Sensor (SeaWiFS) system acquires radiance data from the Earth in eight spectral bands with a maximum spatial resolution of 1 km at nadir. The Global 9 km² spatial resolution Level 3 data provide daily, 8-day, monthly, and annual standard data products.

Acker et al. (2008) employed monthly chlorophyll a data from the 8-year SeaWiFS mission and data from MODIS to analyze the spatial pattern of chlorophyll concentrations and seasonal cycle. The data indicate that large coral reef complexes may be sources of either nutrients or chlorophyll-rich detritus and sediment, enhancing chlorophyll a concentration in waters adjacent to the reefs. Lohrenz et al. (2008) reported a retrospective analysis of nutrients and phytoplankton productivity in the Mississippi River plume, in which long-term patterns in riverine nutrient flux in the lower Mississippi River were examined in relationship to spatial and temporal patterns in surface nutrient concentrations, chlorophyll, and primary productivity.

AVHRR data have long been used in the study of coastal waters. Now the CoastWatch Program at the National Oceanic and Atmospheric Administration (NOAA) produces multiple regional daily daytime sea surface temperature images for the United States derived from AVHRR. NASA's remote sensing assets have been used to address coastal issues, such as land-use and land-cover change (LCLUC) detection, harmful algal bloom forecasting, regional sediment management, monitoring coastal forest conditions, and coastal line assessment and synthesis.

Landsat type of remote sensing data has been used in coastal applications for decades. The multispectral capabilities of the data allow observation and measurement of bio-physical characteristics of coastal habitats, and the multitemporal capabilities allow tracking of changes in these characteristics over time. Landsat and SPOT imageries have been applied in inventory mapping, change detection, and management of mangrove forests through visual interpretation, vegetation index, classification, band ratio, and to map seagrass coverage, among others. As archived Landsat images have been made available at no cost to user communities since early 2009, coastal applications can take advantage of this type of data.

Remote sensing has been identified as one of the primary data sources to produce land-cover maps that indicate landscape patterns and human development processes. Development of standardized and regional land-cover information is in demand for enabling resource managers to coordinate the planning of shared resources, facilitating an ecosystem approach to coastal environmental issues. The NOAA's Coastal Change Analysis Program (C-CAP), for example, is a nationally standardized database of LCLUC information for the coastal regions of the United States. Developed using Landsat remote sensing imagery, C-CAP products inventory coastal intertidal areas, wetlands, and adjacent uplands with the goal of monitoring those habitats by updating the land-cover maps every 5 years. The C-CAP protocol recommended that shorter time periods may be necessary in regions undergoing rapid economic development or affected by catastrophic events.

Although Landsat and SPOT types of multispectral and medium spatial resolution remote sensing data have been broadly applied to address a variety of coastal issues, the complexity of coastal constituents imposes significant challenges in application of remote sensing technologies due to the dynamic spatial and temporal nature of coastal habitats. Recent development in active remote sensing, such as LiDAR (light detection and ranging) and interferometric synthetic aperture radar (InSAR) technologies, and in optical remote sensing, such as hyperspectral and high spatial resolution sensors, bring new types of data and enhanced capacities in the study of coastal environment. LiDAR and InSAR are very effective in coastal studies from three-dimensional (3D) habitat mapping to morphological change analysis. Hyperspectral remote sensing employs hundreds

of narrow and contiguous spectral bandwidths in data collection to enhance the capacity in identification of coastal habitats. Space-borne and airborne high spatial resolution remote sensing data, in meter and submeter levels, provide refined spatial details for mapping the coastal landscape and seascape. Remote sensing is well known for its unique role in the study of dynamics of coastal landscape and land-cover/land-use change caused by natural and anthropogenic forces. On the other hand, field survey and in situ observations are essential to identify coastal habitats through remote sensing. Almost every remote sensing exercise will require field survey to define habitats, to calibrate remote sensing imagery, and to evaluate the accuracy of remote sensing outputs. With GPS-guided positioning and field spectral measurements becoming routine operation, challenges remain for incorporation of in situ measurements with remote sensing observations for quantitative analyses of coastal habitats.

ACTIVE REMOTE SENSING

Active remote sensors are radars and LiDAR systems that transmit electromagnetic pulses with a specific wavelength (λ) and measure the time of return (translated to distance) of the signal reflected from a target. LiDAR systems generally transmit pulses at a wavelength around the visible domain ($\lambda \sim$ nanometers), whereas radar pulses are in the microwave domain ($\lambda \sim$ centimeters). LiDAR and InSAR are among the new developments in active remote sensing that are the topics that have attracted particular interest in coastal-related studies.

Active radar sensors are well known for their all-weather and day-and-night imaging capabilities, which are effective for mapping coastal habitats over cloud-prone tropical and subtropical regions. The SAR backscattering signal is composed of intensity and phase components. The intensity component of the signal is sensitive to terrain slope, surface roughness, and dielectric constant. Studies have demonstrated that SAR intensity images can map and monitor forested and nonforested wetlands occupying a range of coastal and inland settings. SAR intensity data have been used to monitor floods and dry conditions, temporal variations in the hydrological conditions of wetlands, including classification of wetland vegetation at various geographic settings. When the phase components of two SAR images of the same area acquired from similar vantage points at different times are combined through InSAR processing, an interferogram can be constructed to depict range changes between the radar and the ground, and can be further processed with a digital elevation model (DEM) to produce an image with centimeter to subcentimeter vertical precision under favorable conditions. InSAR has been extensively utilized to study ground surface deformation associated with volcanic, earthquake, landslide, and land subsidence processes. Alsdorf et al. (2000, 2001) found that interferometric analysis of L-band (wave-length = 24 cm), Shuttle Imaging Radar-C (SIR-C) and Japanese Earth Resources Satellite (JERS-1) SAR imagery can yield centimeter-scale measurements of water-level changes throughout inundated floodplain vegetation. Wdowinski et al. (2004) applied L-band JERS-1 images to map water-level changes over the Everglades in Florida.

LiDAR technology includes small- and large-footprint laser scanners. LiDAR has shown promising results for assessing tree heights, forest biomass, and volume, in particular the coastal habitats. Due to the rapid laser firing, LiDAR pulses can penetrate vegetation cover, which makes LiDAR technology well suited to measure topography in coastal salt marsh areas. Airborne LiDAR data

have been tested for identifying coral colonies on patch reefs. A recent study compared the capability and accuracy of LiDAR and InSAR for the detection and measurement of individual tree heights and forest plot heights.

HYPERSPECTRAL REMOTE SENSING

Hyperspectral technology brings new insights about remote sensing of the coastal environments. Hyperion sensor on board of EO-1 satellite, launched in November 2000, is a representative space-borne hyperspectral system. This grating imaging spectrometer collects data in 30-m ground sample distance over a 7.5-km swath and provides 10-nm (sampling interval) contiguous 220 spectral bands of the solar reflected spectrum from 400 to 2500 nm. Airborne visible infrared imaging spectrometer (AVIRIS) is a representative airborne hyperspectral sensor system. The AVIRIS whiskbroom scanner collects data in the same spectral interval and range as the Hyperion system but with 20 m spatial resolution. Hyperspectral remote sensing has advantages in coastal wetlands characterization due to its large number of narrow, contiguous spectral bands as well as high horizontal resolution from airborne platforms. It has been used to map habitat heterogeneity (Artigas and Yang, 2004), to determine plant cover distribution in salt marshes (Li et al., 2005; Belluco et al., 2006), to map spread of invasive plant species (Rosso et al., 2006), and to map spatial pattern of tree species abundances (Anderson et al., 2007). Hyperspectral images have been used to separate vigor types by detecting slight differences in coloration due to stress factors, infestation, or displacement by invading species (Artigas and Yang, 2005). Expert system approach has been tested for processing hyperspectral remote sensing data for salt marsh mapping (Schmidt et al., 2004).

HIGH SPATIAL RESOLUTION REMOTE SENSING

High spatial resolution remote sensing imagery data provide much needed spatial details and variations at submeter level for mapping dynamic coastal habitats. For example, besides changing in areas, degradations of mangrove forests due to changing environment and selective harvesting have significant effects on ecosystem integrity and functions. Accurate and effective mapping of mangrove forests is essential for monitoring change in spatial distribution and species composition. Advancement of high spatial resolution multispectral remote sensing data makes such an inventory and monitoring possible (Wulder et al., 2004). Mumby and Edwards (2002) improved thematic mapping accuracy of habitats by incorporation of texture information with high spatial resolution IKONOS satellite data. Wang et al. (2004a) developed an integrated pixel-based and object-based method for improved classification of mangrove forests using IKONOS data. Wang et al. (2004b) compared the performance of QuickBird and IKONOS satellite images for mapping mangrove species and demonstrated the advancement of high spatial space-borne remote sensing in mangrove forest identification. High spatial resolution satellite multispectral and airborne digital remote sensing data have been employed to evaluate benthic habitats (Su et al., 2006; Deepak et al., 2006; Lathrop et al., 2006; Wang et al., 2008).

EFFECTS OF LCLUC

LCLUC is an interdisciplinary scientific theme that includes to perform repeated inventories of landscape change from space; to develop scientific understanding and models necessary to simulate

the processes taking place; to evaluate consequences of observed and predicted changes; and to further understand consequences on environmental goods and services and management of natural resources. The study of the LCLUC is critical to improve our understanding of human interaction with the environment, and provides a scientific foundation for sustainability, vulnerability, and resilience of land systems and their use. This is even true in coastal zones where land and water are constantly affected by natural and anthropogenic forces. An emerging area of increased emphasis in physical oceanography studies is the research on the coastal ocean. As identified by NASA's Research Opportunities in Space and Earth Sciences in 2008 that many of the practical problems with respect to human interaction with the ocean lie within the coastal seas. Deforestation and loss of topsoil can affect the amount of sediment deposited in rivers and streams, which empty into coastal regions, and eventually to the open ocean. Treatment of agricultural crops and changes in land-cover and land-use practices can also lead to chemical constituents being added to waters of rivers, lakes, and oceans.

Change detection has often been discussed in the literature (Mouat et al., 1993; Lambin and Strahler, 1993; Roberts et al., 1998; Mas, 1999; Hayes and Sader, 2001; Rogan et al., 2002; Woodcock and Ozdogan, 2004; Rhemtulla et al., 2007; Wilkinson, et al., 2008).

Hurd et al. summarizes a study in Chapter 17 about land-cover change analysis of the Connecticut coast. The coastal area of Connecticut is diverse, but is under significant pressure from both anthropogenic and natural forces. For example, Connecticut's two largest populated cities, Bridgeport and New Haven, are located within this region. Once thriving industrial centers, these cities represent some of the most intensively developed areas of the state. Several towns along the western coast comprise the "Gold Coast" of Connecticut, wealthy suburbs of New York City, which provide their own unique form of housing, commercial development, and open space patterns. Also, the two largest casinos in the United States, Foxwoods and Mohegan Sun, in addition to Pfizer Pharmaceutical's new Global Research and Development headquarters are located in the eastern region, all recently contributing to significant housing growth and related impacts on the coastal landscape of Connecticut. This chapter describes the development of the Connecticut's Changing Landscape (CCL) land-cover dataset, and how these data were used in two projects, the Coastal Area land Cover Analysis Project (CALCAP) and the Coastal Riparian Buffers Analysis Project to assess the land-cover condition of coastal Connecticut.

Monitoring Coastal Environments Using Remote Sensing and GIS

INTRODUCTION

This paper concerns the monitoring of the marine and coastal environment in South Wales using state-of-the-art survey techniques and a geographic information system (GIS). One of the most important natural resources in South Wales is its marine aggregate. This resource is vital to the regional economy in that it provides the building industry with that most essential of raw materials, sand and gravel. However there are growing concerns as to the possible effects of the commercial extraction of aggregate on the coastal and marine environment, and a number of environmental monitoring procedures are in place to detect changes. These range from traditional beach profile surveys to state-of-the-art airborne remote sensing techniques. The National Assembly for Wales has pioneered the use of airborne LiDAR (Light Detection and Ranging) for the acquisition of

highly detailed topographical data on beaches, and CASI (Compact Airborne Spectrographic Imager), for the determination of the state of the vegetation along part of the coastline. LiDAR is capable of accurately detecting changes in beach levels. The procedure began in 1998 and will continue until at least 2003, giving an unprecedented insight into coastal changes over time.

Another remote sensing technique has also been deployed. Close-range photogrammetry has been used to determine the degree of retreat of unstable sea-cliffs. All the data collected is used to populate a GIS. Data acquired in this way is compared with that from various monitoring procedures carried out previously (aerial photography and beach profiles). A number of advanced techniques have been developed in parallel to the GIS for the interpretation, analysis and visualization of the data. A number of invaluable lessons have been learned.

Apart from the site-specific monitoring procedures, other strategic data sets such as the macro-fauna community distribution, modelled parameters, etc., have also been acquired from a number of sources. Amongst these parameters, the most important of all is the sediment environment. It defines the fuzzy geographical boundaries in which distinctive hydrodynamic regimes operate. A summary on the resources and constraints is generated for each of the sediment environments. These resources and constraints summaries together with the GIS form the basis of a decision-support system for assisting the formation of policy for the management of the marine resource. The findings will shape future decisions about the sustainable use of the marine resource in South Wales.

BACKGROUND

The marine and coastal environment is important to Wales. About 75% of the length of the country is coastal, allowing the waters of the Irish Sea and the Bristol Channel to lap its shores (Figure 4.1 and the colour insert following page 164). South Wales lies adjacent to the Bristol Channel, a body of water largely unaltered in its current dimensions since its beginnings as a marine transgression in the early Holocene. (The Holocene, or post-glacial epoch, covers the period from the end of the Pleistocene about 10,000 years ago to the present day). Here the coastal areas are not only characterized by a number of urban and industrial centres, such as Newport, the capital city Cardiff, Bridgend, Port Talbot and Swansea, but also by many cherished areas of special landscape and nature conservation interest, such as: the Gwent Levels; the Kenfig National Nature Reserve and candidate Special Area of Conservation (cSAC) designated under the European Habitats Directive; the Gower Area of Outstanding Natural Beauty (AONB) – the first to be designated in the United Kingdom; and the Glamorgan Heritage Coast (Figure 4.2 and colour insert). Together, and for different reasons, these coastal areas attract thousands of visitors every year, providing employment opportunities for some of the local population. One of the unseen resources of the Bristol Channel, however, contributes to the local economy in a different way – by yielding high quality building sand for local industry, an essential prerequisite for many forms of economic activity.

Whilst this economic activity brings undoubted prosperity to South Wales and neighbouring regions in mid Wales and South-West England, many people perceive changes to their familiar coastlines, and in particular, to the sandy beaches. There are growing concerns as to the possible effects of the extraction of marine sand from the Bristol Channel, and not everyone thinks the removal of this resource is acceptable or sustainable.

Generally, in Welsh waters, the extraction of sand from the marine environment by dredging is licensed by the Crown Estate. (The Crown Estate Commission is the representative of the Crown, which, in the UK, constitutes the owner of the seabed out to a 12-mile territorial limit). However, the decision on whether a production license should be granted essentially rests with the Environment Minister at the National Assembly for Wales – a devolved and autonomous arm of central Government that came into being in 1999. With its inception has come a desire to increase outside involvement in policy-making and administration, and to increase transparency and accountability in deciding major issues. The challenge for the Assembly's civil servants is to continue to provide objective advice to Ministers in an ever-evolving social, economic, environmental, cultural and political context. This advice must be based on facts and scientific evidence, together with the specialist and professional judgement of the officers involved. All of the dredging licenses granted in recent years have stringent environmental monitoring conditions attached. It is the scientific data from these monitoring procedures that form the basis of sound advice.



Figure 4.1 Wales and its surrounding areas.

This paper discusses the introduction of a Geographic Information System (GIS) into part of the National Assembly for Wales for the analyses of the monitoring data. It highlights the technique's influence on the monitoring procedures and the way it has helped reshape the environmental

monitoring requirements in relation to dredging licenses. By way of illustration, a number of the state-of-the-art procedures currently deployed are examined.

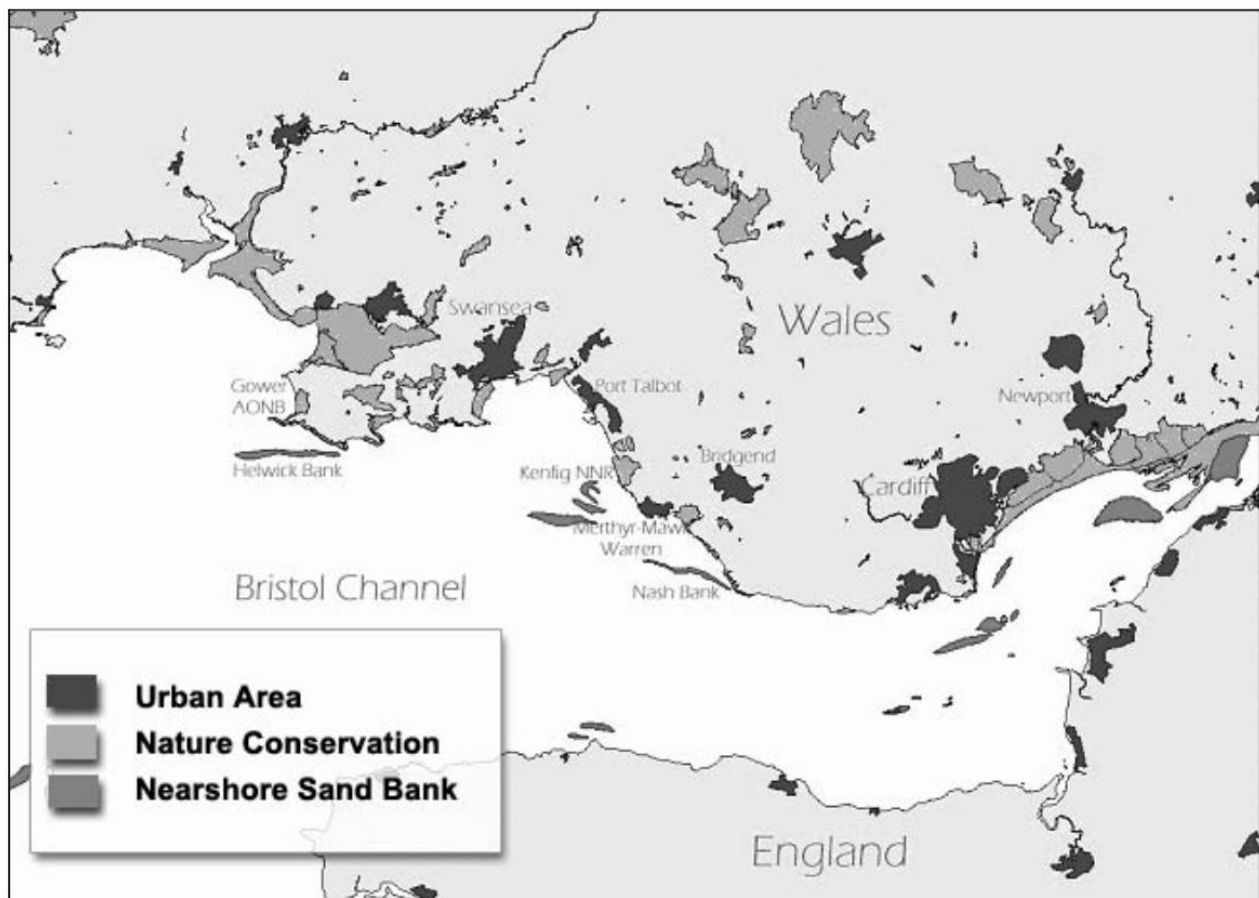


Figure 4.2 South Wales and the Bristol Channel

DATA ANALYSES USING GEOGRAPHIC INFORMATION SYSTEMS

The benefits of modern computerized GIS have been well documented by others, for example, Clark et al., 1991 and Maguire, 1991. GIS was first introduced to the former Welsh Office (now the National Assembly for Wales) in early 1997 for analysis of the monitoring data acquired in respect of the dredging license at Nash Bank. A prototype was developed using ESRI's (Environmental Systems Research Institute Inc.) ArcView GIS. The benefits of the technique over the traditional paper-based reporting were immediately apparent. It:

- provided a stable platform for the integration of disparate data from different sources;
- allowed a large quantity of data to be stored and processed;
- provided a seamless geographical database overcoming the restrictions of traditional map/chart boundaries;
- provided facilities for sophisticated analysis and cross-examination of data; and
- provided advanced facilities for the display and visualization of data to a wider audience.

After a period of evaluation, the technology was adopted for operational use. It would play a key role in re-shaping the environmental monitoring procedures. GIS highlighted the weaknesses of some of the established procedures in terms of both the quality and coverage of the data. The capability of GIS in handling spatial data, in particular, has also presented new opportunities for the introduction and subsequent adaptation of more efficient and cost-effective procedures. The following sections discuss some of these new and innovative environmental monitoring techniques. They are: the assessment of cliff instability using close-range photogrammetry; repeated topographical surveys using Light Detection and Ranging (LiDAR); and habitat mapping of sensitive sites of nature conservation interest using Compact Airborne Spectrographic Imager (CASI).

Assessment of Cliff Instability Using Close-Range Photogrammetry

The Nash Bank lies in the Bristol Channel very close to part of the Glamorgan Heritage Coast. The sandbank contains about 200 million tonnes of material and is a relic feature of the last (or “Devensian”) glaciation. The bank is formed ostensibly from pre-existing glacial and glacio-fluvial deposits subsequently moulded by advancing seas. At low water its eastern end is often exposed above the surface of the sea, and it resides, at its nearest point, only 300 metres from the shore. Its physical orientation and proximity to this area of sensitive coastline means that it acts as a “barrier” to incoming waves, and is therefore an important structure in terms of coast protection. Physical processes such as the movement of sediment in, on and around the feature, as well as human activities, are altering the shape of this sandbank. One way of measuring the “vulnerability” of the nearby coastline to such changes is by careful scientific examination of instability in the highly unstable Blue Lias cliffs that predominate. Extremely accurate measurements of the geometry of a representative 800-metre section of this geologically special part of the Glamorgan Heritage Coast, and including part of the Southerndown Coast Site of Special Scientific Interest (SSSI), have been undertaken since 1997 using close-range photogrammetry. Its application in this context is unique in the United Kingdom.

Annual surveys have been undertaken in August of each year between 1997 and 2000. A further one took place in February 2001.

Close-Range Photogrammetry: The Technique

Close-range photogrammetry operates on the same principle as aerial photography. It produces highly detailed geometric data of three-dimensional structures. Data capture involves the use of a specialist metric camera oriented horizontally on a tripod, and usually mounted on top of a theodolite. The lenses are calibrated and their distortion characteristics considered for subsequent data processing. The technique is also known as terrestrial photogrammetry. Both aerial and close-range photogrammetry have been described in detail in Wolf (1985).

Close-range photogrammetry involves photographing the features or structures being surveyed using the metric camera in a known orientation from two positions. The camera positions and their orientation can be established by “traditional” surveying methods, such as using visual intersection combined with theodolite measured distances from known control points. Alternatively, a number of control points can be set up in the area being surveyed and subsequently included in the

photogrammetric survey. These control points are used to compute the position and orientation of the two camera positions.

Data is derived from the photographic images by simulating the relative orientation of the two camera positions, and processing involves the generation of a three-dimensional stereo model representing the geometry of the structure. It is relatively labour-intensive because the orientation of the two camera positions is not always parallel, and this means additional computational requirements. However, the generation of the 3D geometric model has been helped by advances in automatic image matching techniques in the past decade.

Close-range photogrammetry has been used widely for surveying architectural structures worldwide. Its main advantage is that it can survey the physical dimension of any structure that does not lend itself readily to traditional surveying techniques. It has also been used extensively by traffic accident investigators for collecting data from the scenes of accidents where a very limited period is available for data capture. It is therefore a technique which is characterized by a short set up time, data capture by relatively straightforward photographic means and an ability to survey structures and features which are difficult to examine by any other means.

The intention was twofold: to (a), “test” the technique in the “real-world” of unpredictable environmental change, and (b), establish accurate rates of retreat which could be looked at against historical records. The technique is well suited to the task for several reasons. First, it allows data capture by photographic means without the need to get too close to the area being surveyed – an important consideration given the inherent instability of the Blue Lias cliffs! Also, because the Bristol Channel has the second highest tidal range in the world, only limited periods of time are available for data capture. The technique allows surveyors to record data very quickly around mean low water. Finally, the photographic images captured can be manipulated and rectified to provide a geometrically- correct picture called an orthoimage. An orthoimage is a distortion-free map-like image of an original photographic record. It is produced by rectifying the original photographic image using geometric data derived subsequently. It provides a definitive visual record of the conditions of the cliff at the time of the survey.

In addition, the distortion-free orthoimages of the study area can be displayed in the GIS environment where they can be used to help make accurate quantitative measurements, while the map-like orthoimages can be used in conjunction with the 3D geometry derived earlier in the process to produce a realistic representation of the cliffs using advanced computer visualisation techniques such as Virtual Reality.

The combined use of orthoimages and 3D geometric models in a GIS environment has provided a robust platform for analysis of changes to the cliffs. Quantitative contours are interpolated at 0.5 metre and 1-metre intervals using information derived from the geometric data sets. These contours, representing the degrees of change, are displayed on the rectified orthoimage. This innovative visualisation technique allows quantitative measurements of yearly change to be related directly to the cliff face and its geology. This may be vital in guiding interpretative analysis of why change occurs and in attempting to understand whether or not rates of recession are increasing.

An example will help illustrate the techniques. A large rock fall occurred in the winter of 2000-01. Figure 4.4 illustrates the extent and magnitude of the event (in the middle right of the picture) from an oblique angle.

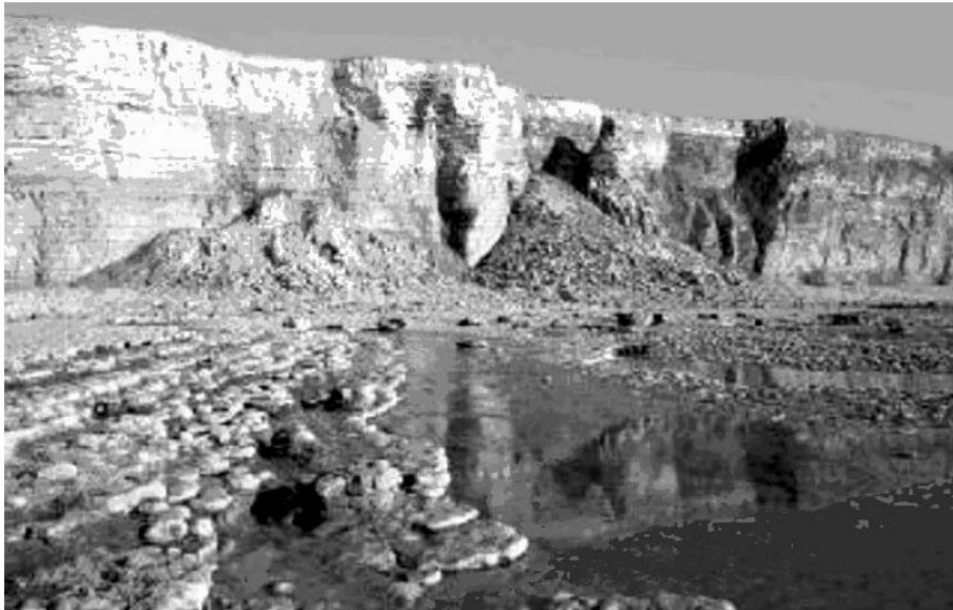


Figure 4.4 The Large rock-fall of winter 2000-01. The cliffs are comprised of Blue Lias rocks and are about 65 metres high. In the foreground is part of a wave-cut platform in the same formation that has been developing for about 7,000 years.



Figure 4.5 Data for a 200-metre stretch of coastline north-west of Cwm Bach

A geometric representation of this event can be displayed and visualised in a couple of interesting ways. Firstly, the interpolated surface can be colour-coded in relation to distance between the viewer and the cliffs. Figure 4.5 shows the data for a 200-metre wide area centred on the fall. Darker shades represent features further away from the observer.

Secondly, the changes brought about by the fall between surveys can be colour-coded to illustrate the changes to the cliffs, and interpolated surfaces may be produced using the GIS. Changes at the sampling positions are shaded in reds and blues, depending on the nature of the change recorded. Data collected in February 2001 was compared with that for the summer of 2000.

The fairly large area of the cliffs represented by deeper reds “failed,” causing materials to be deposited as a “classic” debris fan at the base (in deeper blues). The thin area in blue towards the right of the failure represents an “advance.” This is, in reality, a rock column which has become

detached from the main body of the cliff, and which has been left as a freestanding pillar with a considerable void behind (see Figure 4.4). Future movements will be interesting to monitor!

Topographical Survey Using Light Detection and Ranging

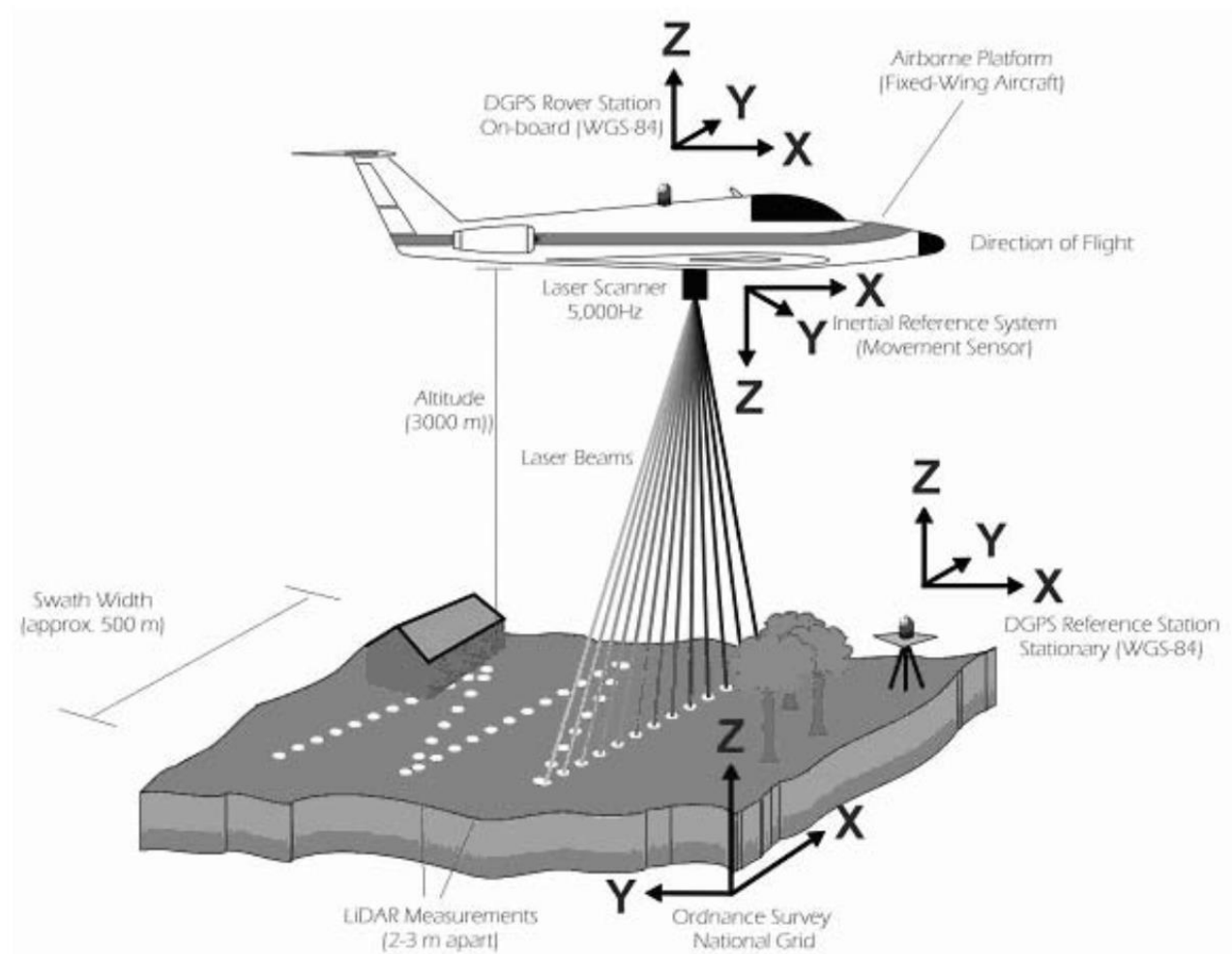


Figure 4.6 A systematic diagram of the three components of airborne LiDAR.

Light Detection and Ranging (LiDAR) is a modern airborne remote sensing technique for surveying topography. It operates on the same basic principle as traditional Radio Detection and Ranging (RADAR), but uses laser as the detection medium. It accurately measures the distance between the instrument and its surrounding environment, and consists of three components: a laser-scanning device, an on-board Differential Global Positioning System (DGPS), and an Inertial Reference System (IRS).

The laser-scanning device is used for the measurement of the distance between the instrument and the topography being surveyed. It emits laser pulses in perpendicular directions to the flight path. By measuring the time required for the laser pulse to return, the distance between the instrument and the topography can be accurately determined. At the same time, an on-board DGPS communicates with navigation satellites and a stationary ground reference station. It gives the positions of the airborne platform, usually a fixed-wing aircraft, in relation to the earth's surface. The last component of the system is the IRS. This is essentially a motion sensor, and detects minute movements of the aircraft in terms of its yaw, pitch and roll (i.e. movements about its three axes). It

corrects the orientation of the laser pulses that can become distorted because of aircraft movement. When the three components work in unison, the surveyed topography is recorded very accurately. Routine field validations of the technique by the Environment Agency have indicated an accuracy of better than 15 cm generally. Ground resolution of data is directly dependent on flying height and speed of the surveying aircraft, as well as the scanning rate of the laser pulses. For example, when flying at 70 knots at an altitude of 3,000 feet LiDAR, with a 5,000 Hz scanning rate, can acquire topographical data with a ground resolution of about 2.5 to 3.5 metres. At the time of writing, the Environment Agency has plans to operate a newer version of LiDAR with a scanning rate of 33,000 Hz. The new instrument should produce topographical data with a 0.5 metre ground resolution! Figure 4.6 shows the three main components of airborne LiDAR.

In South Wales, the coastline is diverse, characterized as it is by bays, inlets, estuaries, beaches, rocky-shores, high cliffs, sand dunes, near-shore sand banks and mud flats. Traditional monitoring on some of the beaches using linear profiles has provided some limited data. In addition, accurate identification of ground features from aerial photographs has been difficult and is relatively expensive. LiDAR, however, has provided a high-value and cost-effective solution. Its capability in capturing very detailed topographical data, without the need to physically visit most of the locations being surveyed, makes it well suited for environmental monitoring purposes, especially for inter-tidal zones where it can survey a large area within a short space of time. One of the few restrictions for the deployment of LiDAR is the tidal window.

LiDAR was first available in the UK in early 1998. The National Assembly for Wales has long realized the potential of the technique and has pioneered its use in Wales. As early as March 1998, in relation to dredging at Helwick Bank, the National Assembly for Wales decided to include the technique as one of the environmental monitoring requirements to measure change along the coastline. As such, the procedure would be deployed annually to monitor levels of key beaches in South Gower. This will continue until at least June 2003. This requirement is believed to be the first of its kind in the UK, and highlights the fact that the analyses of the highly accurate topographical data over time is innovative and pioneering.

To complement these activities, in early 1999, a collaborative project called the “Glamorgan Coastal Monitoring Initiative” was launched by the Welsh Office. This was designed to further embrace the potential of this airborne remote sensing technique, and to marry the data to high-resolution habitat information derived from the Compact Airborne Spectrographic Imager (CASI). This is discussed in the following section.

LiDAR produces extensive data sets. In Kenfig National Nature Reserve (NNR), for example, over 30 million data points have been collected under the Glamorgan Coastal Monitoring Initiative. A number of custom-built computer programs have been written to reduce the data files to more manageable sizes. The data sets have been transferred to an ArcView GIS for interpolation and further analysis. Some important derivatives, such as slope and aspect, have also been computed.

Habitat Mapping Using Compact Airborne Spectrographic Imager (CASI)

Compact Airborne Spectrographic Imager (CASI) is a state-of-the-art remote sensing instrument for measuring radiation reflectances in the electro-magnetic spectrum. The classification of CASI data

can produce a “map” by positively identifying the radiation reflectances of different “objects.” In the case of habitat mapping, CASI can “see” a clear boundary between different types of vegetation as long as they emit different levels of radiation – the so-called spectral signature. Habitat mapping using CASI involves three components: an airborne survey using CASI; a simultaneous ground-truthing exercise; and image classification to produce the habitat map. The data acquisition stage is characterized by an airborne survey using CASI. The ideal timing for the airborne survey is around midday. This is the time when the sun’s angle is at its highest, casting minimum shadow and giving the most accurate representation of radiation reflectance. While the CASI survey is being carried out, a team of specialists undertakes a ground-truthing exercise to determine the ecology of selected locations within the study area. The ecological parameters are measured using traditional methods such as 1m x 1m quadrats with the aid of modern DGPS for accurate determination of position. The exercise provides important information to allow the airborne CASI data to be cross-referenced with known vegetation types. The last stage is the classification of CASI data in conjunction with the ground-truthing information to generate a map of the vegetation types. This classified map is subsequently interpreted to form the basis for a habitat map.

CASI has been used as an integral part of the “Glamorgan Coastal Monitoring Initiative.” The main objective has been to provide a benchmark survey for Kenfig NNR which together with Merthyr Mawr Warren makes up the European Union’s candidate Special Area of Conservation (cSAC). Both sites are of national and international importance. For example, Kenfig NNR holds over 40% of UK’s population of the rare fen orchid (*Liparis loeselii*), whilst Merthyr- Mawr Warren is the second highest mobile sand dune system in Europe.

Kenfig has many other features of conservation interest. The successional- young stages of dune development, in particular, are species-rich, with more than 40 plant species usually found in a 1m x 1m quadrat. These habitats have been prioritised for management and monitoring purposes under the current European Habitat Directive. However, there are growing concerns that the over-stabilization of the mobile sand dunes at Kenfig NNR is threatening the biodiversity of the cSAC.

For discussion purpose, Kenfig NNR has been divided into two broad areas: a southern and northern section (Figure 4.7). The southern section is mostly dominated by mature dune vegetation, whereas successional-young seral stages are more prominent in the north of the site. The boundary is situated where one starts to grade into the other.

The area Figure for the successional-young grassland has been calculated by carrying out a pixel count for the habitat type based on a pixel size of 2 x 2m (Table 4.2). The area measurement for the whole site has been calculated in the same way.

Table 4.1 The classified values, the classifications and their corresponding display colours in plate 4.6, the classified habitat map of Kenfig NNR.

Category	Classification	Colour
1	water	dirty green
2	bare sand	yellow
3	scrub	dark green
4	<i>Phragmites</i>	red
5	<i>Calluna</i>	light green
6	<i>Pteridium</i>	pale blue
7	successionally-young grassland	blue
8	orchid-rich slack	purple
9	successionally-young slack	light brown
10	tall rank grassland	light blue
11	embryo dune slack	pale blue

Preliminary results show that successionally-young grassland not only covers a much greater area in the Northern Section (which might have been expected because it is considerably larger than the Southern Section), but also occupies a much larger percentage of the area than in the South. This evidence confirms observations that the dunes in the southern part of Kenfig are generally in an advanced state of stabilisation, while this is less so in the northern part of the site where successionally-young grassland is relatively well distributed.

Evidence from the joint analysis of topography and habitat classification in the southern section provides interesting comparison. A high proportion of the areas classified as successionally-young grassland occur close to the top of south-facing slopes. Figures 4.8a and b show the areas classified as successionally-young grassland in the Southern Section, juxtaposed with those showing a south-facing slope. There is also some correlation between the successionally-young grassland and aspect, and this is particularly evident in the south-western part of the section. Figures 4.8c and d are illustrative.



Figure 4.7 Kenfig NNR divided. The section in darker grey represents the ecologically older and more mature southern region of the Reserve. The northern area is depicted in pale grey.

THE NEXT FRONTIER – MARINE AGGREGATE RESOURCE MANAGEMENT AND PLANNING SYSTEM (MARMPs)

Data collected from these innovative monitoring procedures helps to shed light on some of the plethora of natural processes causing change to the coastal environment. It also helps to expose the implications of some human activities. The data sets are used to populate a GIS. This provides a technical tool to underpin an embryonic decision-support system which will be used for the management and planning of the marine aggregate resource in South Wales to ensure it is only extracted in a sustainable way.

This system, entitled the “Marine Aggregate Resource Management and Planning System (MARMPs),” will operate using data and information on three layers: the site-specific monitoring data sets acquired in relation to the dredging licences, including those relating to bathymetry, 3D cliff analysis and topographical beach data; the regional data from the Glamorgan Coastal Monitoring Initiative, including data from both the LiDAR topographical survey and CASI habitat mapping survey; and the broad-scale and comprehensive strategic data sets derived from the “Bristol Channel Marine Aggregates: Resources and Constraints” project. This research, completed in August 2000, examined the available marine aggregate resources, and the technical, economic, environmental and cultural constraints operating to deter extraction. Two of the many significant outcomes of this work were, firstly, the delivery of an abstractive GIS database with about 100 data themes for the Bristol Channel and, secondly, the derivation of sediment environments representing sub-areas of the physical system that are considered to exhibit similarities across various components of the sediment regime. Together, these will help form the basis for future strategic policy and decision-making.

MARMPs will adopt a multi-criteria approach to aid decision-making at a more local level. In the Bristol Channel, a complicated number of conflicting objectives co-exist, for example, the

economic demand for marine aggregate and possible environment impact. MARMPS will define the relationship between these by quantifying them in commensurate terms. In doing so, the conflicting objectives will be summarized and “optimised.” The decision-makers will also take part by defining, in their own way, the relative importance of these conflicting objectives, and a weighting mechanism will be applied to take account of these views. Clearly, the weighting may change over time. MARMPS, when completed, will be the first system of its kind in the United Kingdom. It will be operational, designed to tackle real world issues. It will assist decision-makers in reconciling the conflicting interests of different users in the coastal zone.

It is not within the scope of this paper to discuss MARMPS in extended detail. However, the availability of good quality data sets is essential to the success of the development of the system. The National Assembly for Wales will continue to strive to acquire data sets that are robust and meaningful. Continual monitoring of the coastal and marine environment is key to an understanding of the mechanisms of coastal change.

But MARMPS is not just about data collection. There are, for example, a number of identifiable interfaces: the relationship between the coastal and the marine environment; the interaction between various bodies and organizations who have a common interest in the coastal zone; and the need to find lines of communication between science and the general public. The most important interface is, however, the one that brings about an understanding of the strengths and limitations of the natural environment and the formulation of a complementary sustainable policy to ensure wise use of its resources. The outcomes from this interface will, of course, have socio-economic implications.

The development of MARMPS is the latest in an ever-increasing list of new ways of collecting, analysing and using data and information by the newly devolved National Assembly for Wales — the introduction of GIS; routine deployment of LiDAR to monitor coastal change; habitat mapping using CASI; and 3D geometric monitoring of cliff instability. MARMPS will no doubt assist decision-makers at the National Assembly for Wales in making better informed and evidence-based decisions on the future sustainable use of our coastal heritage for many generations to come.

FORMOSAT-2 Images in Mapping of South Asia Tsunami Disaster

INTRODUCTION

Natural disasters are considered to be destined, but nowadays limited prevention and reduction approaches can be adopted due to a great deal of coordination. An efficient action of disaster mitigation and rescue relies on timely and effective information about hazard areas. Unfortunately, natural disasters are often widespread and the devastated areas are sometimes unreachable so that an overall on-site investigation becomes difficult or even impossible. With the rapid technology development of space platform and digital imagery, remote sensing data have been broadly applied to monitoring the Earth's surface in the last decades, such as agriculture monitoring, environmental change, and water pollution assessment. Several studies applying remote sensing to natural hazard investigation and management were reviewed thereafter. Landsat5 TM images were applied to identify the neotectonic features of the September 7, 1999 Athens earthquake. Gupta and Joshi and Lin et al. used remote sensing and geographic information system (GIS) techniques in assessing

landslides and debris flows. The U.S. National Oceanic and Atmospheric Administration monitors droughts on a large area by developing an Advanced Very High Resolution Radiometer (AVHRR)–based Vegetation Condition Index (VCI) derived from the Normalized Difference Vegetation Index (NDVI) and the Temperature Condition Index (TCI) derived from the AVHRR-measured radiances. SPOT satellite images were used to analyze the NDVI for comparison and evaluation of the vegetation recovery rates before and after the Chi-Chi Earthquake. Aerial photographs and SPOT satellite images were coupled to assess the damage level and potential risk of collapsed spots on the Tsao-Ling land- slide caused by the Chi-Chi Earthquake. A synthetic probability map of the Tsao-Ling landslide reoccurrence was produced that provided efficient information for planning emergency response and making a rehabilitation strategy. Also, automated classifications were developed and applied to SPOT satellite images for the recognition of landslide hazards. The integration of GIS, remote sensing, and global positioning system (GPS) can provide a low-cost and rapid methodology of disaster management as well as critical information for decision support by emergency managers and the disaster response community. A decision support system (DSS) for open mining areas during the formulation of a restoration plan was developed by using thematic maps derived from observation data from Earth.

Satellite images have several advantages for hazard monitoring, such as digital data beneficial for processing; large area coverage; and routine, repetitive, continuous, and economical image acquisition. Compared with aerial photography, however, satellite images have a lower spatial resolution that limits their applications in urban areas. With the launching of IKONOS-1 in 1999 and QUICKBIRD in 2001, a new era of commercial satellite imaging with high spatial resolution was begun by offering resolutions of 1 and 0.6 m panchromatic images as well as 4 and 2.44 m multispectral images, respectively. The land cover map derived from IKONOS satellite images was used as input for the flood simulation model LISFLOOD-FP to produce a Manning roughness factor map of inundated areas. Intensity-Hue- Saturation (IHS) was used to integrate hyperspectral and radar data into a single image of an urban area by image fusion that provided rich information necessary for assessment and mitigation of hazards in urban disaster management. High- resolution digital elevation models (e.g., from InSAR, Lidar, and digital photogrammetry) and image spectroscopy (e.g., using ASTER, MODIS, and Hyperion) are believed to significantly contribute to hazard management of natural disasters, such as earthquakes, volcanos, floods, landslides, and coastal inundations.

However, high spatial resolution images do not fulfill the demand of a complete disaster management. A better temporal resolution (revisit capability) is desirable during hazard response and recovery due to their emphasis on “real-time” information about a disaster area. In this chapter, a civilian satellite with both high spatial and temporal resolutions, FORMOSAT-2, was employed for remote monitoring of the severe coastal disasters from the tsunami-devastated areas of the Sumatra catastrophe. FORMOSAT-2 offers images with a high spatial resolution of 2 m panchromatic and 8 m multispectral as well as a high temporal resolution of 1 day. FORMOSAT-2’s superior temporal frequency of remote sensing data acquisitions makes it possible to apply satellite images to response and recovery of disaster management.

DISASTER MONITORING USING SATELLITE IMAGES

Hazard management involves four phases in a cycle, which should consist of mitigation, preparedness, response, and recovery. Remote sensing has been playing a key role in disaster mitigation activities, including assessing risk and reducing potential effects of disasters. Spatial and temporal anomalies of the Earth's emitted radiation in the thermal infrared (TIR) spectral range measured from a satellite were analyzed for monitoring a seismically active region. Geospatial information products derived from remote sensing data are addressing the operational requirements of the hazard DSS, which is helpful in risk assessments, mitigation planning, disaster assessment, and response prioritization for policy makers, emergency managers, and responders. Various useful information, such as land use, land cover, infrastructures, human settlements, topography, vegetation recovery index, morphology, and geology for risk analysis, and hazard maps can be extracted from remote sensing data. Preparedness consists of planning actions in a disaster and trying to increase available rescue resources. The information about risk analysis extracted from high spatial resolution satellite imagery can be introduced into GIS to establish a disaster-relief database for preparedness. Response relates to all possible emergency activities immediately following a disaster occurrence. When a disaster occurrence passes away, short-term and long-term recovery continues until all life-support systems are back to normal. The recovery rate of an ecosystem can be successfully estimated by comparing satellite images before and after a disaster.

TABLE 12.1
FORMOSAT-2 Remote Sensing Instrument Specifications

Payload	Remote Sensing Instrument (RSI)
	Imager of Sprites and Upper Atmospheric Lightning (ISUAL)
Weight	742 kg (with payload and fuel)
Shape	Hexahedron, height 2.4 m, outer diameter about 1.6 m
Orbit	891 km, sun-synchronous, passes over Taiwan Strait each day
Panchromatic (PAN)	0.45–0.90 μm
Multispectrum (MS)	0.45–0.52 μm blue; 0.52–0.60 μm green; 0.63–0.69 μm red; 0.76–0.90 μm NIR
Ground sampling distance (GSD)	2 m for black and white images; 8 m for color images
Swath	24 km
Mission life	5 years
Launch date	May 21, 2004 (Taipei Time)

Among these four phases of hazard management, satellite imagery provides limited support during the short period of disaster response due to its deficient temporal resolution for instant reactions immediately following a disaster. However, the response phase is the most critical portion of the disaster cycle because it provides emergency assistance to victims of an event and reduces the likelihood of secondary damage. Thus, routine, repetitive, and continuous observations of the Earth's surface from high temporal resolution satellite imagery are very useful for acquiring rapid assessments to take rapid and effective action in the disaster response phase. The application of satellite images to disaster response includes several steps, including orbit determination, image acquisition, data preparation, image processing, image interpretation, and decision supports for

disaster response. Through the analysis process, high temporal satellite imagery can efficiently assist authorities in making disaster response decisions and further recovery plans. In the phase of recovery, routine, repetitive, and continuous observations of the Earth's surface from operational satellites with high temporal resolution imagery are useful in assessing hazard impact and making recovery plans. Also, satellite images are suitable for a long-term assessment of environment and ecosystem recovery.

FORMOSAT-2 SATELLITE

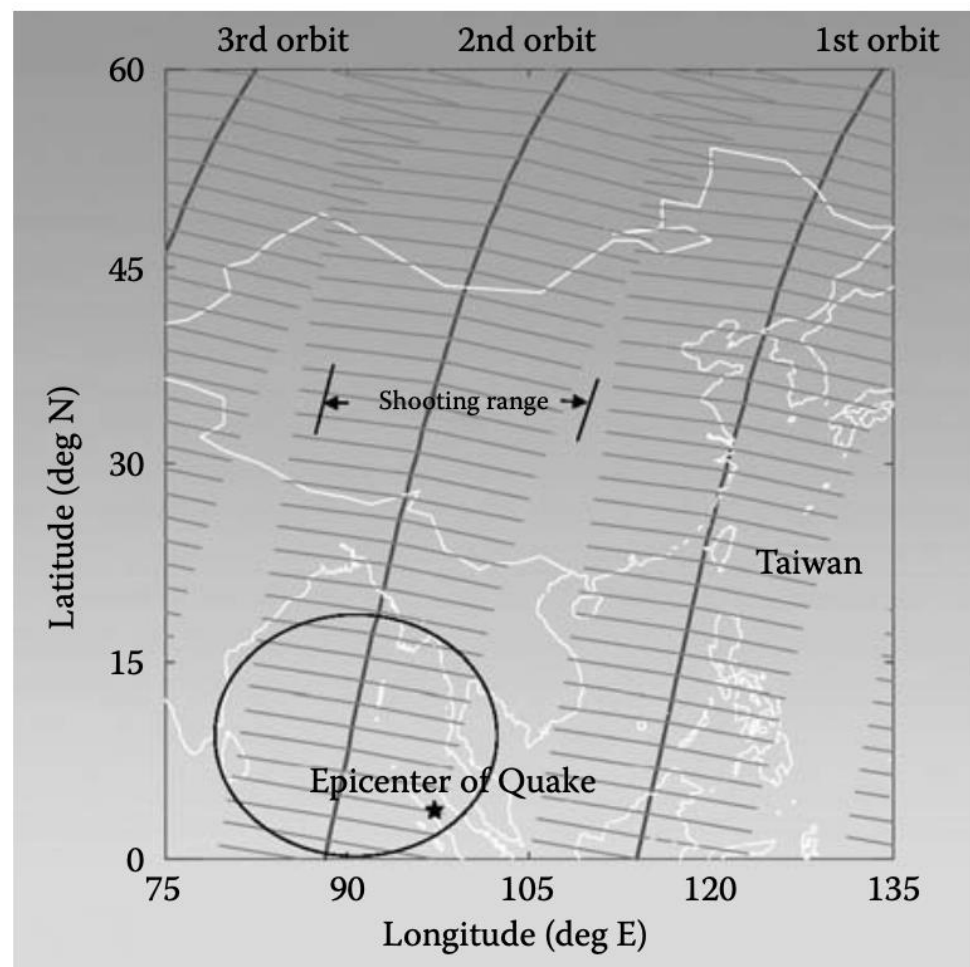


FIGURE 12.1 FORMOSAT-2 orbits covering the Asia area.

As other developed countries in the world, Taiwan faces dynamic changes of land use due to a rapid economic growth and a frequent attack of natural disasters such as earthquakes and typhoons. In the aftermath, the need for timely remote sensing data to monitor and assess damage becomes urgent. Thus, in 1991 the National Space Organization (NSPO) was founded by the National Science Council (NSC) as a governmental agency to execute the national space program. Currently, two satellites are operated by the NSPO to collect remote sensing data. One of them, FORMOSAT-2, takes land images for fulfilling Taiwan civilians' needs by providing black and white images with the resolution of 2 m and color images of 8 m resolution (Table 12.1). Also, an imager on board FORMOSAT-2 observes upper atmospheric lightning for the first time from a satellite.

FORMOSAT-2 was successfully launched on May 21, 2004 (Taipei Time), and acquired the first image at 9:39 a.m. on June 4. To provide timely and low-cost image data, FORMOSAT-2 can daily monitor the environment and resources throughout the Taiwan main island, the offshore remote islands, Taiwan Strait, the surrounding ocean, and other regions under international cooperation. FORMOSAT-2 is expected to have many useful applications, such as agriculture and forestry predictions, natural disaster evaluations, land usage analyses, environmental monitoring, coastal search and rescue, and academic research and extension education. Especially for natural disaster evaluations, FORMOSAT-2 images are valuable for assessing damages through applying for tasking orders possibly within 1 day if weather allows. The conditions of flood-submerged fields, landslides, debris flows, and the structural integrity of hillsides also may be assessed. A couple of significant contributions by FORMOSAT-2 in monitoring and evaluating natural disasters in Taiwan include the flooding and debris flows brought by Typhoons Midully and Aere in summer 2004.

FORMOSAT-2 IMAGES OF SOUTH ASIA TSUNAMI

On December 26, 2004, a 9.0-Mw earthquake was caused by the release of stresses accumulated as the Burma tectonic plate overrode the India tectonic plate. Data from 60 GPSs in Southeast Asia were collected to identify the crustal deformation caused by the Sumatra earthquake. This great earthquake generated a rupture expending at a speed of about 2.5 km/s toward the north-northwest and extending 1200–1300 km along the Andaman trough. Subsequently, the significant movement of the seafloor resulted in a tsunami, or seismic sea wave, which struck the coastal regions of Sumatra, Thailand, Sri Lanka, southern India, and most South Asia areas. Over 170,000 people were reported dead or missing due to the tsunami unleashed by the quake.

TABLE 12.2
Process Timetable of FORMOSAT-2 Imagery

Sequence	Time Needed
Order	2 h
Scheduling	2 h
Imaging	2–24 h
Acquisition	2 h
Processing	2 h
Distribution	2 h
Total	12–34 h

For an instant response to the natural disaster, catastrophic images were acquired in 2 days by an emergency orbit scheduling. Passing over South Asia on its second orbit satellite as shown in Figure 12.1, FORMOSAT-2 was one of the first remote sensing satellites to successfully take images of Phuket Island and Banda Aceh, two heavily hit areas, within 2 days after the disaster, as

listed in Table 12.2. Those images were processed and provided to aid rescuers working in those areas through channels of the Department of Foreign Affairs and research centers of Taiwan. Meanwhile, FORMOSAT-2 continued imaging up to an additional month for those seriously hit areas, including the west coast of Thailand, Sumatra of Indonesia, the eastern coast of India, Sri Lanka, and Andaman and Nicobar Islands. Highly-efficient data propagation increases the benefits from remote sensing data sharing and dissemination; therefore, the NSPO established a window through the Internet for the public access to FORMOSAT-2 image database. Several images of devastated regions were analyzed in this chapter as Figure 12.2. A standard level-II product of FORMOSAT-2 has been through image system geometric and radiometric correction. For a better visual interpretation, fusion images were produced by using a multiplicative algorithm on 2 m panchromatic images of high spatial resolution and 8 m multispectral images of high spectral resolution. The fusion images provide rich information necessary for hazard assessment and mitigation.

Furthermore, for hypertemporal image analysis, three requirements must be met: (1) univariate at each temporal image; (2) precise coregistration; and (3) radiometric consistency. Ground control points (GCPs) and local reference maps could facilitate advanced georectification if necessary. Supremely, radiometric correction is the major process affecting image analysis of multiple-date satellite images. These multitemporal images were radiometrically corrected by first using the pseudoinvariant feature (PIF) method to locate possible dark and bright objects (the same buildings, roads, and water pixels on both images) and then processing the radiometric control set (RCS) method on the selected pixels to find out the correlation coefficients between images for each band of the multispectral images. Under the assumption that at least some pixels have the same average surface reflectance among images acquired at different dates, the RCS method examines the band-to-band scattergrams in which the pixels have little or no variation between the dates of image acquisition. The radiometric methods were employed to correct the digital numbers (DNs) on the December 31 image based on the December 28 image for Phuket Island in this research. The radiometric rectification equations of the December 31 image were acquired through linear regression as follows:

$$DN_{band1'} = 1.2116 DN_{band1} - 26.873; \quad R^2 = 0.917, \quad (12.1)$$

$$DN_{band2'} = 1.2165 DN_{band2} - 18.395; \quad R^2 = 0.958, \quad (12.2)$$

$$DN_{band3'} = 1.1664 DN_{band3} - 8.5458; \quad R^2 = 0.964, \quad (12.3)$$

$$DN_{band4'} = 1.2462 DN_{band4} - 17.781; \quad R^2 = 0.972. \quad (12.4)$$

The high correlation coefficients of regression results show a significant confidence in the radiometric correction.

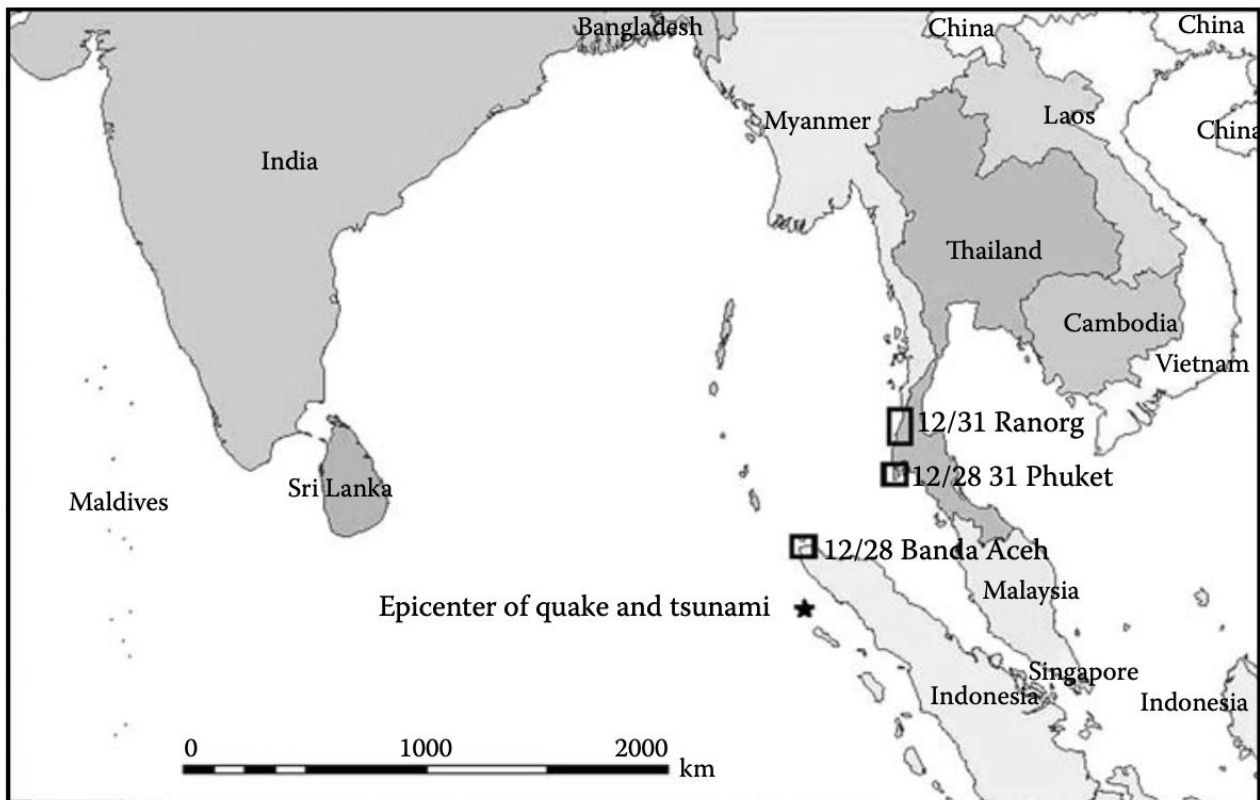


FIGURE 12.2 Illustrated study areas attacked by the Sumatra earthquake and tsunami.

IMAGE PROCESS AND INTERPRETATION

After being corrected for geometry and postprocessed, the FORMOSAT-2 image is suitable for constructing about 1:24,000 scale maps in true or false color that can be analyzed for monitoring the disaster damages. The extent and localization of the tsunami damages were analyzed through either visual interpretation of the fusion images or digital analysis on multispectral FORMOSAT-2 images, including haze reduction, feature extraction, image classification, contrast enhancement, and band ratio analysis. To provide the promised information to help cope with the tsunami catastrophe, several important discovery and analysis results were addressed in the subset images of interest, which are useful for disaster region positioning, damage level assessment, rescue planning, and environmental impact evaluation (Figures 12.3 through 12.5).

The extent and localization of the damage were estimated by digital analysis of the differences between the struck and nonstruck areas. The VI (vegetation index) and NDVI were analyzed for revealing the extent of the intruded area by the tsunami. Near-infrared (NIR) reflectance intensity is related to mostly vegetation conditions and inversely to water content. Destroyed vegetation and high water content caused by the tsunami reduced NIR reflectance intensity in the inundated terrains. Immersed areas after the tsunami reflect weaker NIR than non-struck areas. Moreover, the scooped terrain by the tsunami flood wave increases red reflectance intensity. Thus, the VI or NDVI analysis is helpful for interpreting the boundary between the struck and nonstruck areas.

Figure 12.3 shows the destruction of Ranong, in the western part of Thailand along the Andaman Sea. Figure 12.3a1 is the false-color NIR fusion imagery of Khao Lak revealing the destructions by

the tsunami, where there is a portion of Khao Lak—Ram Lu National Park. The long-term impact upon the ecological environment must be noticed in the future. Figure 12.3a2 is the NDVI analysis of the original multispectral images. A distinguishable difference of NDVI values between the struck and nonstruck areas along the coastline illustrates the extent of the tsunami inundation, resulting in a negative NDVI value. Also, the indentation eroded by the tsunami in the coastline becomes more evident in the NDVI map. Figure 12.3b shows the overwhelmed wooden houses in the vacationland in Thap Lamu, Ranong. Mud and clay brought by the flood wave covered most of the vacationland so that the traffic network was interrupted.

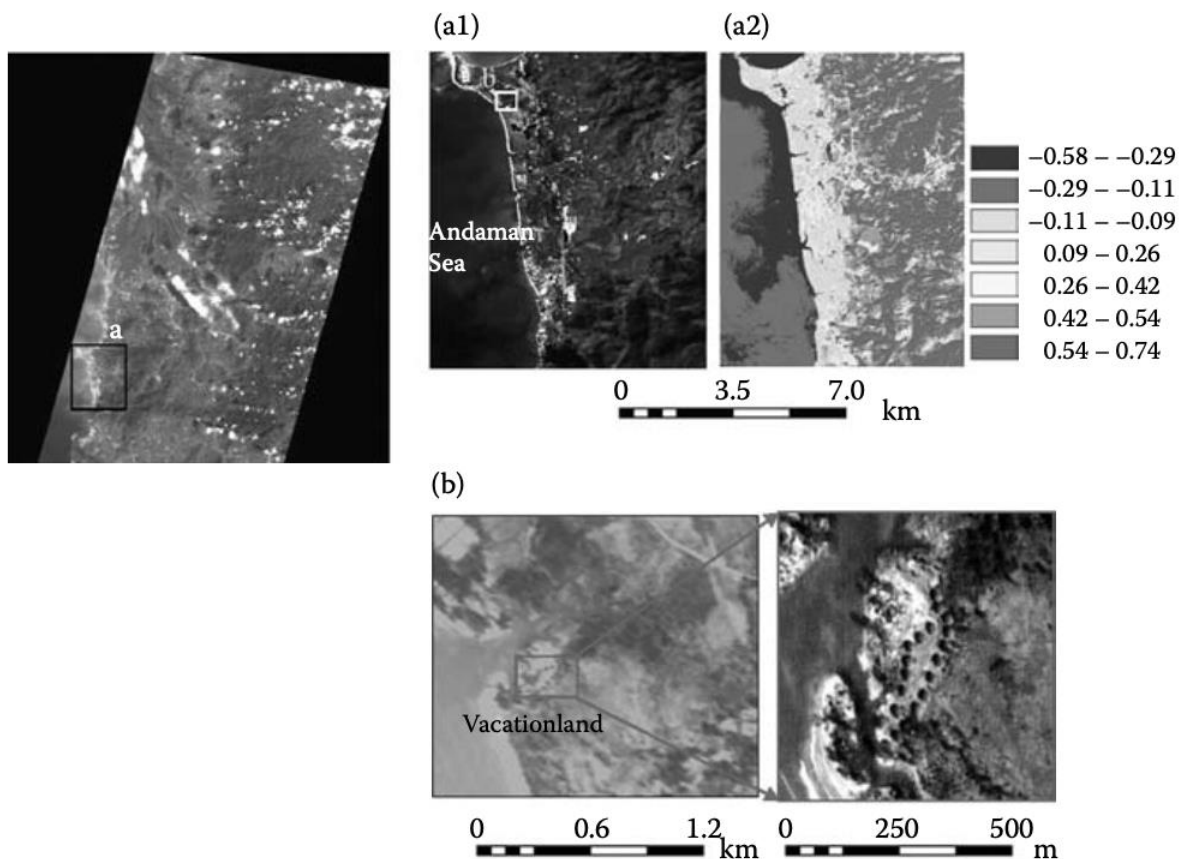


FIGURE 12.3 Destruction of Ranong, in the western part of Thailand along the Andaman Sea. (a1) Devastated area of Khao Lak, (a2) NDVI analysis helpful for distinguishing the extent of the tsunami destruction, and (b) overwhelmed wooden houses in the vacationland in Thap Lamu, Ranong.

With many hotels and golf courses built in the neighborhood of the beach area, Thailand's Phuket is a world-famous resort island and were severely devastated in this disaster. Traffic facilities, such as roads, bridges, and airports, affect the efficiency of disaster relief. Important traffic infrastructures, such as the Sarasin Bridge connecting Phuket Island and mainland Thailand in Figure 12.4a and the Phuket International Airport for international aid in Figure 12.4b, were undamaged and usable for emergency rescue and recovery. An international airlift was still allowed to ferry critical aid and medicine to Phuket and also to take surviving travelers home. Figure 12.4c1 shows that Bang Thao, one of the coastal towns in the western Phuket Island, had only minor destruction after the tsunami. The clinic and clubs were safe to provide medical aids and disaster shelters. The main road, Scenic Coastal Drive, was not destroyed by the floodwaters. Moreover, to improve the visual

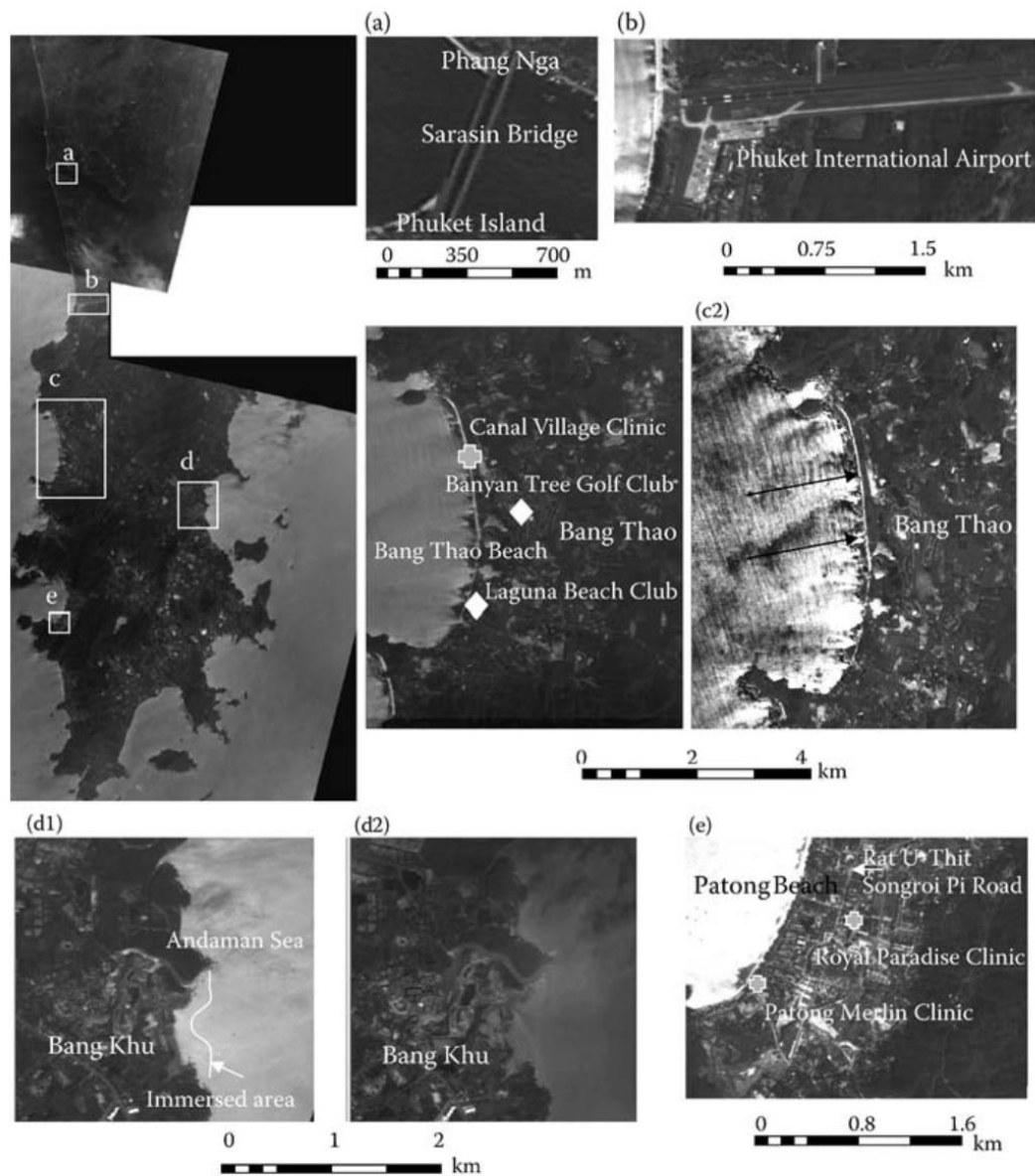


FIGURE 12.4 Post-tsunami Phuket island images. (a) The Sarasin Bridge connecting Phuket Island and mainland Thailand. (b) The Phuket International Airport used for receiving international aid. (c1) Bang Thao resort. (c2) The enhanced image with magnified waterfront areas; the attacking direction of the tsunami is shown by arrows. (d1) Infrared (IR) fusion image of Bang Khu on December 28. (d2) IR fusion image of Bang Khu on December 31. (e) The fusion image of Paton.

appearance of waves, contrast enhancement was conducted on the extracted water body from the

panchromatic imagery. Through histogram analysis and linear stretch, the waterfront was magnified. In this recreation beach area, the wave condition usually is calm inside the fiord and the wave front is parallel to and the wave direction perpendicular to the shoreline due to the dragging effect on the seabed and coastal terrain. The unusual wave height and pattern in the Ban Thao beach indicates the attacking direction of the tsunami, shown by red arrows in Figure 12.4c2. Figure 12.4d1 and d2 are the false-color NIR fusion images of Bang Khu in the eastern coast of Phuket which were taken on December 28 and 31, respectively. Comparing these two radiometrically corrected images, we discovered that flooding vanished in the coast region and the submerged land reappeared on December 31. Figure 12.4e is the fusion images of Patong, which is a famous international resort town. The west side of Patong by Rat U-Thit Songroi Pi Road, where many scenic spots and quality hotels were located, was drastically slashed by the tsunami. There were two clinics providing medical aid in Patong were; Patong Merlin Clinic was struck by the tsunami and the Royal Paradise Clinic was safe to take care of the wounded people in the catastrophe.

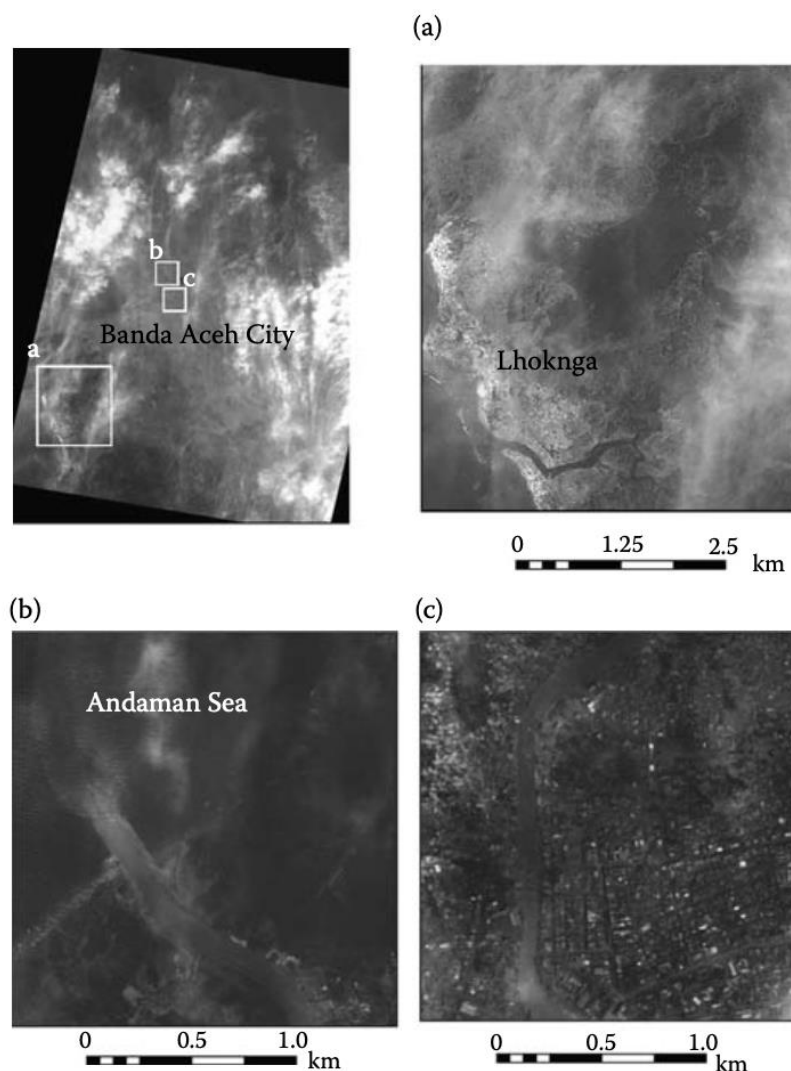


FIGURE 12.5 Worst-hit region—Aceh province. (a) Struck and flooded Lhoknga. (b) Polluted water of one tributary of the Aceh River with high suspended solids and wastes toward the Andaman Sea. (c) Badly destroyed traffic infrastructures and buildings in the downtown area of Banda Aceh city.

Through haze reduction (by using a 3×3 high-frequency kernel) and Gaussian contrast adjustment on the FORMOSAT-2 image of December 28, the authorities and public were able to get a better glimpse of the devastated west coast of Indonesia's Sumatra Island—nearest the epicenter of the massive quake and tsunami. Many coastal areas of the northwestern Sumatra were badly hit by the quake-driven walls of massive water. Aceh province in particular suffered extensive damage and loss of life in this catastrophe. Figure 12.5a shows that the Lhoknga area was severely struck and flooded by the tsunami. The tsunami swashed up to about 3–4 km inland and destroyed the forests and farmland in the coast regions. More analyses of the tsunami effects in Banda Aceh, including inundation distance, shoreline erosion, and coseismic subsidence can also be found in Borrero's investigation report [34]. Figure 12.5b shows that one of the Aceh River tributaries crossing the downtown area toward the Andaman Sea was polluted by salty seawater, mud flow, and wastes. Thus, the invaded city was expected to be severely afflicted with the problems of water resources and environmental pollution. Pure water shortages and overwhelmed aquatic ecosystems need to be paid attention to during hazard recovery. Figure 12.5c is zoom-in subset showing the badly destroyed traffic infrastructures and buildings in the downtown area of Banda Aceh city. The city was flooded and blanketed with mud and rubble after the quake and tsunami, which increased the difficulty of emergency rescue and recovery.

CONCLUSIONS

Although satellite remote sensing has been advocated for monitoring terrain changes for a long time, satellite images with a high temporal resolution represent indeed a major progress in coastal disaster monitoring. FORMOSAT-2 can efficiently contribute timely information for disaster response and recovery due to its high spatial and temporal resolutions. Especially for an instant response to a natural disaster, FORMOSAT-2 images can be acquired in at most 2 days through an emergency order. In this application, FORMOSAT-2 proved to be a useful source in the monitoring of the severe Sumatra earthquake and tsunami disaster. Through digital image processes, some results of image analysis and interpretation were useful for instant response and rescue and were helpful for disaster recovery. The FORMOSAT-2 fusion images provide rich information necessary for disaster assessment and mitigation. FORMOSAT-2 imagery, especially fusion imagery, of December 28 and 29, 2004, clearly revealed the extension of flooding and widespread devastation to the coastal cities and surrounding areas. Evidently, the contribution of FORMOSAT-2 in providing the most up-to-date images available on hand can be appreciated. More advanced image processes can be executed based on the acquisition of local geographic and environmental information in order to prepare a sound and comprehensive recovery plan and indemnities distribution for those disaster areas. Remote sensing has been playing a key role in disaster mitigation and damage assessment nowadays and will flourish in disaster management as more advanced remote sensing satellites begin operations in the near future.

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