Coastal and Sea Erosion

1) What is Coastal /Sea erosion?

Every land mass on Earth has miles of coast at the interface between the hydrosphere and the lithosphere. Natural forces such as wind, waves and currents are constantly shaping the coastal regions. The combined energy of these forces moves land materials.

The landward displacement of the shoreline caused by the forces of waves and currents is termed as ***coastal erosion***. It is the loss of sub-aerial landmass into a sea or lake due to natural processes such as waves, winds and tides, or even due to human interference. While the effects of waves, currents, tides and wind are primary natural factors that influence the coast the other aspects eroding the coastline include: the sand sources and sinks, changes in relative sea level, geomorphological characteristics of the shore and sand, etc. other anthropological effects that trigger beach erosion are: construction of artificial structures, mining of beach sand, offshore dredging, or building of dams or rivers.

2) Causes of Erosion?

Coastal erosion occurs when wind, waves and long shore currents move sand from the shore and deposits it somewhere else. The sand can be moved to another beach, to the deeper ocean bottom, into an ocean trench or onto the landside of a dune. The removal of sand from the sand-sharing system results in permanent changes in beach shape and structure. The impact of the event is not seen immediately as in the case of tsunami or storm surge. But it is equally important when we consider loss of property. It generally takes months or years to note the impact of erosion; therefore, this is generally classified as a ***"long term coastal hazard".***

Glossary of Terms

- **Coastline** – is the interface between the ocean and the land - dynamic morphological entity
- **Erosion** – is the wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation
- **Wave** - A ridge, deformation, or undulation of the surface of a liquid (sea water)
- **Littoral drift** - The movement of sediment along-shore

Major Causes of Coastal Erosion are

I. Natural Causes

1. Action of Waves: Waves. Waves are generated by offshore and near-shore winds, which blow over the sea surface and transfer their energy to the water surface. As they move towards the shore, waves break and the turbulent energy released stirs up and moves the sediments deposited on the seabed. The wave energy is a function of the wave heights and the wave periods.

2. Winds: Winds acts not just as a generator of waves but also as a factor of the landwards move of dunes (Aeolian erosion).

3. Tides: Tides results in water elevation to the attraction of water masses by the moon and the sun. During high tides, the energy of the breaking waves is released higher on the foreshore or the cliff base (cliff undercutting). Macro-tidal coasts (i.e. coasts along which the tidal range exceeds 4 meters), all along the Atlantic sea (e.g. Vale do Lobo in Portugal), are more sensitive to tide-induced water elevation than micro-tidal coasts (i.e. tidal range below 1 meter).

4. Near-shore currents: Sediments scoured from the seabed are transported away from their original location by currents. In turn the transport of (coarse) sediments defines the boundary of coastal sediment cells, i.e. relatively self-contained system within which (coarse) sediments stay. Currents are generated by the action of tides (ebb and flood currents), waves breaking at an oblique angle with the shore (long-shore currents), and the backwash of waves on the foreshore (rip currents). All these currents contribute to coastal erosion processes.

5. Storms. Storms result in raised water levels (known as storm surge) and highly energetic waves induced by extreme winds (Cyclones). Combined with high tides, storms may result in catastrophic damages such as along the east coast of India (Orissa Super Cyclone, 1999). Beside damages to coastal infrastructure, storms cause beaches and dunes to retreat of tenths of meters in a few hours, or may considerably undermine cliff stability.

6. Catastrophic events

In addition to the daily, slow sculpting of the coast, other events like tsunamis which result in major coastal changes over very short time periods. These are referred to as catastrophic events because of the extensive damage that is caused and the unpredictable nature of the event.

7. **Slope processes.** The term "slope processes" encompasses a wide range of land-sea interactions which eventually result in the collapse, slippage, or topple of coastal cliff blocks. These processes involve on the one hand terrestrial processes such as rainfall and water

8. **Vertical land movements (compaction).** Vertical land movement – including isostatic rebound, tectonic movement, or sediment settlement – may have either a positive or negative impact on coastline evolution. If most of northern Europe has benefited in the past from a land uplift (e.g. Baltic sea, Ireland, Northern UK)

9. Sea Level Rise

Sea level has risen about 40 cm in the past century and is projected to rise another 60 cm in the next century. Sea level has risen nearly 110 meters since the last ice age. Due to global warming, average rise of sea level is of the order of 1.5 to 10 mm per year. It has been observed that sea level rise of 1 mm per year could cause a recession of shoreline in the order of about 0.5 m per year.

II. Anthropogenic Causes

Human influence, particularly urbanisation and economic activities, in the coastal zone has turned coastal erosion from a natural phenomenon into a problem of growing intensity. Anthropological effects that trigger beach erosion are: construction of artificial structures, mining of beach sand, offshore dredging, or building of dams or rivers. Human intervention can alter these natural processes through the following actions**:**

- dredging of tidal entrances
- construction of harbours in near shore
- construction of groins and jetties
- River water regulation works
- hardening of shorelines with seawalls or revetments
- construction of sediment-trapping upland dams
- beach nourishment
- Destruction of mangroves and other natural buffers
- Mining or water extraction

3) Factors that influencing the coast are

- **Sand sources and sinks:** Beach material can vary in size from very fine sand (0.005 cm) to small pebbles (1.5 cm). Sand is brought to the shore from the continental shelf, rivers and eroding cliffs, sand dunes, as well as from other beaches through the action of long shore currents.
- Sinks for the sand include continental shelf accumulations of sand that are in water at depths greater than 30 meters (100 feet) and sand that is carried into deep ocean canyons. This sand is below the "reach" of the waves and cannot be moved and returned to the beach. In addition, sand that is blown inland is also lost from the beach.
- **Rising sea level: To** assess the scope of changes in sea level, scientists have developed methods to interpret the geologic record left by prehistoric events.

Other factors that influence sea level include:

- Size of polar ice caps and valley glaciers which change the amount of water available for oceans and seas
- Expansion and contraction of ocean volume due to changes resulting from plate tectonics
- Rising and sinking of coasts due to plate tectonic changes
- Warming of ocean water which leads to increased volume for the same amount of water
- Increase in total water available in the ocean due to human activities which release groundwater and make it part of the surface water system

Some beach erosion factors:

- Effects of human impact, such as construction of artificial structures, mining of beach sand, offshore dredging, or building of dams or rivers.
- Loss of sediment offshore, onshore, alongshore and by attrition.
- Reduction in sediment supply due to deceleration cliff erosion.
- Reduction in sediment supply from the sea floor.
- Increased storminess in coastal areas or changes in angle of wave approach.
- Increase in beach saturation due to a higher water table or increased precipitation

Table 1: Natural Factors Affecting Shoreline Changes and their effects:

FACTOR	EFFECT	TIME SCALE	COMMENTS
Sediment supply (source and sinks	Accretion/ Erosion	Decades to Millennia	Natural supply from inland or shore face and inner shelf sources can contribute to shoreline stability or accretion
Sea Level Rise	Erosion	Centuries to Millennia	Relative sea level rise
Sea Level Change	Erosion	Months to years	Causes poorly understood
Storm surge	Erosion	Hours to days	Very critical to erosion magnitude
Large wave height	Erosion	Hours to months	Individual storms or seasonal effects
Short wave period	Erosion	Hours to months	Individual storms or seasonal effects
Waves of small steepness	Accretion	Hours to months	Summer conditions
Alongshore currents	Accretion, no change, or erosion	Hours to millennia	Discontinuities (up-drift/down-drift) and nodal points
Rip currents	Erosion	Hours to months	Narrow seaward-flowing, near-bottom currents may transport significant quantities of sediment during coastal storms.
Underflow	Erosion	Hours to days	Seaward-flowing, near-bottom currents may transport significant quantities of sediment during coastal storms.
Inlet presence	Net erosion; high instability	Years to centuries	Inlet-adjacent shorelines tend to be unstable because of fluctuations or migrations inlet position; net effect of inlets is erosional owing to sand storage in tidal shoals.
Over wash	Erosional	Hours to days	High tides and waves cause

			sand transport over barrier beaches
Wind	Erosional	Hours to centuries	Sand blown inland from beach
Subsidence, Compaction	Erosion	Years to millennia	Natural or human-induced withdrawal of subsurface fluids
Subsidence, Tectonic	Erosion/Accretion	Instantaneous, centuries to millennia	Earthquakes; Elevation or subsidence of plates

Physical characteristics and in vulnerability to erosion

Physical Diversity: Coastal shorelines differ markedly in physical characteristics and in vulnerability to erosion. Erosion rate over time at a given point along the shoreline depends on factors such as:

- direction of littoral drift
- inlet dynamics
- sand supply
- short- and long-term climate fluctuations
- gradient of submerged ocean or lake bottom
- relative mean sea level
- human actions affecting shoreline processes

Erosion Process:

Waves start by attacking the main points of weakness in the rock such as the joints and any faults that there may be in the rock. The point of weakness is increased until it becomes a cave. The waves continue to attack the cave, which finally results in an arch being formed through the headland. The arch is then attacked by both coastal and sub - aerial erosion and finally the roof of the arch falls into the sea. This then leaves behind a stack, which is then slowly eroded down to become a stump.

Low outcrop of rock formed by the erosion of a coastal stack. Unlike a stack, which is exposed at all times, a stump is exposed only at low tide. Eventually it is worn away completely.

The easiest way of describing the overall effect of coastal erosion is that, if left unchecked, all the coastlines would be, low wave cut platforms. Most erosion takes place around high tide and will be carried out in one of three ways. The first is Hydraulic erosion which has an effect of a small explosive charge. The sudden impact of a wave on to the cliff face forces air into any cracks that they might be or along the bedding planes, compressing the air briefly then releasing the pressure. the changes in pressure causes the cracks to widen and go further into the cliff, material breaks away and washed out of the cliff by following waves. The material washed away becomes means for further erosion. The debris is washed against the base of the cliff in a process known as corrosion and acts in a grinding motion. In this process, not only does erosion take place at the foot of the cliff but the sediment itself is worn down and rounded in a process known as attrition. The third type of erosion is chemical, particularly in limestone and chalk cliffs where chemicals within the sea water attack the rocks eroding the weaker sections and gradually causing the cliff to collapse.

Coastal lands may experience long-term erosion under some conditions. For instance, if sea level is rising, the beach may eventually migrate landward or drown. This causes coastal land behind the beach to erode. Also, if the amount of sand from the seaward side is reduced, a beach will erode the land behind it to maintain a constant sand supply. This creates a condition called coastal erosion.

Beaches on eroding coasts undergo seasonal profile adjustments, but they slowly shift their position landward as the land erodes. Hardening a shoreline can interfere with necessary profile adjustments because the dune can no longer share its sand with the beach. As a retreating beach encounters a seawall or revetment it can no longer draw upon a landward sand supply and it begins to erode.

Erosion Rate: Erosion rates vary over time and space. These variations occur in response to many factors. Among them are:soil slope and composition

- erodibility of material
- nearshore seabed shoals and slopes
- storm wave energy and duration
- precipitation
- ground water and soil conditions
- ice cover
- shoreline orientation
- beach composition, width and slope
- shore protection structures

It has been observed that sea level rise of 1 mm per year could cause a recession of shoreline in the order of about 0.5 m per year.

4) Effects of Coastal Erosion

Coastal erosion, or coastal instability, threatens property and businesses and puts people living near cliffs and shorelines at risk. The great concentration of national resources in coastal zones makes it imperative that coastal change is well understood.

1) Coastal Erosion in India

The Indian coastline is about 7517 km, about 5423 km along the mainland and 2094 km the Andaman and Nicobar, and Lakshadweep Islands . The coastline comprises of headlands, promontories, rocky shores, sandy spits, barrier beaches, open beaches, embayment, estuaries, inlets, bays, marshy land and offshore islands. According to the naval hydrographic charts, the Indian mainland consists of nearly 43% sandy beaches, 11% rocky coast with cliffs and 46% mud flats and marshy coast. Oscillation of the shoreline along the Indian coast is seasonal. Some of the beaches regain their original profiles by March/April. Fifty per cent of the beaches that do not regain their original shape over an annual cycle undergo net erosion. Shoreline erosion in the northern regions of Chennai, Ennore, Visakhapatnam and Paradip ports has resulted due to construction of breakwaters of the respective port. At present, about 23% of shoreline along the Indian main land is affected by erosion.

State	Sandy beach (%)	Rocky coast (%)	Muddy flats (%)	Marshy coast (%)	Total length* (km)	Length of coast affected by erosion** (km)
Gujarat	28	21	29	22	1214.7	36.4
Maharashtra	17	37	46	–	652.6	263.0
Goa	44	21	35	–	151.0	10.5
Karnataka	75	11	14	–	280.0	249.6
Kerala	80	5	15	–	569.7	480.0
Tamil Nadu	57	5	38	–	906.9	36.2
Andhra Pradesh	38	3	52	7	973.7	9.2
Orissa	57	–	33	10	476.4	107.6
West Bengal	–	–	51	49	157.5	49.0
Daman and Diu					9.5	–
Pondicherry					30.6	6.4
Total mainland	43	11	36	10	5422.6	1247.9
Lakshadweep					132.0	132.0
Andaman and Nicobar					1962.0	–
Total					7516.6	1379.9

*According to the Naval Hydrographic Office.
**Information collected from respective states.

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Types of coastal erosion in Maritime states of India

As per National Hydrographic Office, Dehra Dun, the Indian sub-continent has a long coastline, extending to a length of about 7516.60 kms including Daman, Diu, Lakshadweep and Andaman & Nicobar Island. Almost all the maritime States/UTs are facing coastal erosion problem in various magnitudes. About 1450 km of coastline has been reported to be affected by sea erosion, out of which about 700 km of coastline has been reasonably protected by construction of seawalls, groins, etc, and 750 km is yet to be protected.

7) State profile

As per a survey conducted by the Ocean Engineering Division of National Institute of Oceanography, Goa, India about 23 per cent of India's mainland coastline of 5423 kms is getting affected by erosion. As much as 1248 km of the shoreline is getting eroded all along the coast with 480 km of the 569 km shoreline of Kerala is being affected by the phenomenon. In Karnataka, the erosion was marked over 249.6 km out of the state's total coastline of 280 km with the problem relatively more severe in south Kannada and Udupi coasts where about 28 per cent of the total stretch is critical. Again, the coastal erosion is marked over 263 km of the 652.6 km shoreline of Maharashtra while 107.6 km out of 476.4 km of Orissa's coastline has already been affected. Shoreline erosion in the northern regions of Chennai, Ennore, Visakhapatnam and Paradip ports has resulted due to construction of breakwaters of the respective port.

Rivers have been identified as the major sources of sediments along the Indian coast among which the Ganges and Brahmaputra contributed a major share of suspended sediments to the Bay of Bengal and the Indus to the Arabian Sea. The continental shelf along the country's east coast is narrow whereas along the west coast, the width of the shelf varies from about 340 km in the north to less than about 60 km in the south.

The west coast of India experiences high wave activity during the southwest monsoon with relatively calm sea conditions prevailing during the rest of the year. On the other hand, in the east coast, wave activity is significant both during southwest and northeast monsoons. Extreme wave conditions occurred under severe tropical cyclones which are frequent in the Bay of Bengal during the northeast monsoon period.

Along Gujarat coast, shoreline erosion is observed at Ghoga, Bhagwa, Dumas, Kaniar, Kolak and Umbergaon, and sediment deposition leading to the formation of sand spits at the estuarine mouths of the Tapti, Narmada, Dhadar,Mahe, Sabarmati, Kim, Purna and Ambika.

Erosion has been observed at Versoa, Mumbai; near Kelva fishing port, north of Mumbai and at Rajapuri, Vashi and Malvan along the **Maharashtra coast.** Along **Goa coast**, erosion is noticed at Anjuna, Talpona and Betalbatim.

Erosion of Versov Caost , Maharashtra where houses washed out

The **Andaman and Nicobar** consists of about 265 islands, most of which are composed of rocks like fossiliferous marine petroliferous beds, conglomerates, sandstone and limestone. Land subsidence of 0.8 metre to 1.3 metre has occurred at the Andaman and Nicobar islands due to December 26, 2004 tsunami and has resulted in shoreline erosion in some of the islands.

The **Lakshadweep,** is an archipelago of coral islands in the Arabian sea consists of 36 islands, 12 atolls, three reefs and five submerged coral banks. Coastal erosion in all these islands had been taken up in all the inhabited islands and a total length of 40 km had been protected so far, the report said.

Erosion along the beaches near river mouths has been commonly noticed along **Karnataka coast**. Coastal erosion and submergence of land have been reported at Ankola, Bhatkal, Malpe, Mulur, Mangalore, Honnavar, Maravante and Gokarn in Karnataka. About 60 km of beach (19% of the total lengthof shoreline) is affected by erosion. The problem is relatively more severe in Dakshina Kannada and Udupi coasts, where about 28% of the total stretch is critical. In Uttara Kannada region, about 8% of the coast is subjected to severe erosion.

Along **Tamil Nadu** coast, the erosion rate observed at Poompuhar, Tarangampadi, Nagapattinam, Mandapam, Manapadu, Ovari, Kanyakumari, Pallam, Manavalakurichi and Kolachel is about 0.15, 0.65, 1.8, 0.11, 0.25, 1.1,0.86, 1.74, 0.60 and 1.2 m/yr respectively. The maximum rate of erosion along Tamil Nadu coast is about 6.6 m/yr near Royapuram, between Chennai and Ennore port10. The accretion rate at Cuddalore, Point Calimere, Ammapattinam, Kilakarai, Rameswaram, Tiruchendur, Manakudi and Muttam is observed to be about 2.98, 3.4, 0.72, 0.29,0.06, 0.33, 0.57 and 0.17 m/yr respectively.

Andhra Pradesh coast has frequently been affected by cyclones and inundated by storm surges. Erosion is noticed at Uppada, Visakhapatnam and Bhimunipatnam.

Erosion is noticed at Gopalpur, Paradip and Satbhaya in **Orissa**. Growth of long sand spits at Chilka lake indicates the movement of littoral sediment and subsequent deposition.

BEACH EROSION AT KONARK, ORISSA

Major length of **the West Bengal** coast is represented by the Sundarban region of the Ganges mouth with shoals,sand spits, mud flats and tidal swamps. Beach erosion is noticed at Digha, Bankiput and Gangasagar regions of the West Bengal coast. In Kerala, about 360 km long coastline is exposed to erosion.

EROSION AT KAPPAKKAL BEACH (PAYYANAKKAL) AT CALICUT, KERALA

Damages due to Sea Erosion

States	Land lost		Residential/ Industrial/ Office Buildings		Crops		Other losses (Plantation, public utilities, cattle, village road, boats, etc.)		Total annual Losses (Rs. Crores)
	Quantity (Ha.)	Amount (Rs. Crores)	Quantity (no.)	Amount (Rs. Crores)	Quantity (Ha.)	Amount (Rs. Crores)	Quantity	Amount (Rs. Crores)	
Karnataka	67.48	3.485	2294	25.882	---	0.3109	---	1.602	31.28
Maharashtra	66.20	12.85	34	0.363	10.73	0.552	---	30.258	44.023
Orissa	89.55	2.24	3000	75	---	49.00	---	17.50	143.74
Tamilnadu	67.55	46.453	209	6.162	271	0.906	---	7.163	60.684
West Bengal	102	12.50	28.373	9.07	74124	23.38	---	34.11	79.06
Pondicherry	---	---	---	---	---	---	---	---	9.60
Total	**392.78**	**77.528**	**33910**	**116.477**	**74405.7**	**74.149**	**---**	**90.633**	**368.387**

7) *Preventive and Mitigation measures*

- **STRUCTURAL MEASURES**
  - Through construction of SEA WALL / REVETMENT
  - GROYNES

– OFF-SHORE BREAKWATER

- **NON-STRUCTURAL / SOFT MEASURES**

  – ARTIFICIAL NOURISHMENT OF BEACHES
  – VEGETATION COVER
  – SAND BYPASSING AT TIDAL INLETS

The remedial measures should be selected after proper investigation and model studies. It must be ensured that protection measures do not shift erosion problem from one site to some other site. The measures to control erosion include non-structural and structural or their combination.

Structural measures used for coastal erosion prevention are as follows:

- Sea wall/ Revetment: Seawall may be useful in case of protection of specific area from erosion and storm surges. Adverse effect is experienced on downstream side.

- Groynes: Groynes may be adopted to stop or decrease shoreline recession and for beach formation. However, extremely adverse effects are observed on downstream side and groynes should be avoided unless their main purpose is to keep a beach at one particular position at the cost of adjoining areas.

- Off-shore breakwater : These may be adopted for shore protection and beach formation. Severe downstream erosion may result due to littoral barrier effect. It is an expensive option and needs regular maintenance to avoid rapid breakdown of breakwater.

Soft-structural measures generally adopted to reduce/prevent coastal erosion are:

- Artificial nourishment of beaches : Beach nourishment may be adopted for protection and beach development. Combination of nourishment of beaches with seawall/groynes will create beach in front of protected area and eliminate leeside erosion.

- Vegetation cover such as mangrove and Palm plantation : Vegetation cover can restrict sand movement and erosion.

- Sand bypassing at tidal inlets : Severe erosion problem has been experienced due to construction of jetties and/or dredged channels. This problem can be solved by bypassing of material from the updrift side of inlet to the downdrift side.

Out of these measures, the techno-economically viable and site-specific suitable measure should be adopted. Combination of the above measures may give optimum results with least adverse effect on down drift.

8) *Coastal Erosion Management: Techniques and Approaches*

In order to provide a comprehensive guide to the options available for the management of coastal erosion all principle coast protection and erosion management techniques are covered. It must be recognised, however, that finely all of these can be damaging to the natural environment, to a greater or lesser degree, in inappropriate situations. The inclusion of any particular approach herein does not, therefore, indicate that it is, necessarily, environmentally sensitive, nor are universally appropriate as a means of managing erosion. Rather, the summaries highlight and encourage the pursuit of good practice, from an environmental perspective, which ever approach is deemed necessary by the circumstances concerned.

The various approaches to management of coastal erosion in beach and dunes are as follows**:**

1. ADAPTIVE MANAGEMENT

Appropriate locations	Locations with low value, life expired or moveable backshore assets
Effectiveness	Short term loss of assets, but highly sustainable over medium to long term
Benefits	Allows natural processes to continue with possible strategic benefits spread over adjacent areas. No ongoing management costs.
Problems	Backshore assets are lost or moved, often causing conflict due to differing perceptions of values

General description:

Many cases of dune erosion may be best managed by not interfering with the natural processes, but instead accepting that erosion will occur and adapting backshore management accordingly. This approach will involve relocation and monitoring costs, but these may be much lower than the cost of protection. Adaptive management should be considered at all sites before considering any of the other options set out in this guide.

Function

Adapting to erosion, or the potential for erosion, by moving, replacing or demolishing structures or other assets that are at risk will avoid the need for interference with coastal processes. Better still is the initial control of any form of development along the shoreline dunes, though in many instances it will be too late to adopt this preventative approach.

Clear felling of forestry along an eroding coastline.

2 DUNE GRASS PLANTING

Appropriate locations	Above normal limit of wave run-up at any location with available blown sand. Unlikely to succeed where erosion is severe.
Effectiveness	Enhancement to natural dune recovery. Reservoir of sand held in planted foredunes will provide a buffer to resist storm erosion.
Benefits	Compliments natural system. Can be used to improve other management options. Potentially self sustaining.
Problems	Normally requires dune fencing or thatching to achieve success. May be completely lost to storm erosion.

General description

Vegetation encourages dune growth by trapping and stabilizing blown sand. Transplanting marram grass (*Ammophila arenaria*) to the face of eroded dunes will enhance the natural development of yellow dunes above the limit of direct wave attack. Sand couchgrass (*Elymus farctus*) or lyme grass (*Leymus arenarius*) can be transplanted to encourage the growth of new foredunes along the toe of existing dunes, as these species are tolerant to occasional inundation by seawater. These natural dune grasses act to reduce wind speeds across the surface, thereby trapping and holding sand. They grow both vertically and horizontally as the sand accumulates. Marram grass is particularly effective as it positively thrives on growing dunes, and is perhaps the easiest to transplant.

Dune stabilisation using marram and lyme grass transplants.

Function

Transplanting vegetation will not prevent erosion, but it will accelerate natural recovery after storm damage creating a reservoir of sand within the foredunes that will make the dunes better able to withstand the next period of erosion. Additional works are often necessary to increase the potential for success. Thatching and beach recycling will assist in the accretion of sand, will provide minor protection from waves and will reduce damage due to trampling. Once grasses are well established they may well become self-sustaining, although any storm erosion damage will need to be rapidly made good.

3 DUNE THATCHING

Appropriate locations	Above normal limit of wave run-up at any location with available blown sand. Unlikely to succeed where erosion is severe.
Effectiveness	Enhancement to natural dune recovery. Modest resistance to storm erosion. Enhanced by vegetation transplanting.
Benefits	Minimal impact on natural system. Materials are all natural, degradable and low cost.
Problems	Without maintenance thatching will last no more than 1 year. Materials are often used to build bonfires.

General description

Thatching of exposed dunes faces or blowouts using waste cuttings from forestry management, or other low cost materials, is a traditional way of stabilising sand, reducing trampling and protecting vegetation. Materials are low cost if locally available and no machinery or skilled labour is required to achieve success, but continual maintenance is important. The approach is normally carried out with dune grass planting to encourage dune stability. Thatching materials are often removed for bonfires by beach users.

Thatching and brushwood fencing along an eroded dune face.

Function

Well laid thatch will encourage dune recovery and will resist some erosion, but cannot prevent erosion where wave attack is frequent and damaging. The thatch reduces surface wind speeds, encouraging deposition of blown sand. Success depends on the amount of blown sand, the frequency of wave attack and the availability of vegetation. Transplanting dune grasses after thatching will enhance dune recovery and longer term stability. Continual maintenance and replenishment of cuttings is required.

4 DUNE FENCING

Appropriate locations	Above normal limit of wave run-up at any location with available blown sand. Unlikely to succeed where erosion is severe.
Effectiveness	Enhancement to natural dune recovery. Limited resistance to storm erosion. Enhanced by vegetation transplanting.
Benefits	Minimal impact on natural system. Can be used to control public access and to improve other systems.
Problems	Damaged fences and accumulated debris can be unsightly. Fences need regular maintenance and have a maximum life of about 5 years depending on material, frequency of storm wave damage and vandalism.

General description

Construction of semi-permeable fences along the seaward face of dunes will encourage the deposition of wind blown sand, reduce trampling and protect existing or transplanted vegetation. A variety of fencing materials can be used successfully to enhance natural recovery. Fencing can also be used in conjunction with other management schemes to encourage dune stabilisation and reduce environmental impacts.

Dune fencing along upper beach.

Function

Sand fences cannot prevent erosion where wave attack is both frequent and damaging, but they will encourage foredune growth and resist some erosion. Fences reduce wind speed across the sand surface and encourage foredune deposition. They also act as a modest barrier to wave attack, reducing the erosion potential of waves near the limit of uprush.

Success depends on the void to solid ratio of the fence, the availability of blown sand, the frequency of wave attack at the fence and the amount of vegetation available to stabilise the accumulated sand. Success will be enhanced by a programme of dune grass transplanting, thatching and beach recycling/regrading to establish new foredunes. Fencing and associated works can be used to enhance the appearance and effectiveness of other erosion defences. Rock, timber or gabion structures can provide a fixed line of defence, but are incongruous along a natural dune coast: partial burial by recycled or sand accreted by fencing and grasses will create a more natural dune environment.

5 BEACH RECYCLING AND REPROFILING

Appropriate locations	All locations, including those with limited blown sand for natural recovery.
Effectiveness	Short term defence against erosion, and enhancement of natural recovery. Moderate resistance to single storms. Enhanced by fencing and vegetation transplanting, and can be successfully used to bury hard defences.
Benefits	Accelerates natural recovery of fore dunes and provides short

	term defence against single severe storms.
Problems	Removes material from other sites, possibly transferring erosion or environmental damage to a different frontage. May introduce beach debris, non-indigenous sediment and/or vegetation, potentially damaging local ecology.

General description

Recycling is the mechanical shifting of sand, shingle or even boulders from an area of accretion to an area of erosion. Normally recycling would be undertaken at a local level, with sediment being taken from an accreting ridge, the lower beach or an estuary bar, and transported a short distance to an eroding dune face or a blow out. Alternatively the donor area may be to landward if sand is blown onto roads or other areas where it is not wanted and from where it can be recovered.

Reprofiling is an alternative term, usually referring to the direct transfer of material from the lower to the upper beach or, occasionally, the transfer of sand down the dune face from crest to toe.

Recycling sand or shingle can be undertaken to repair minor erosion problems such as blowouts, or it can be used to rebuild long lengths of upper beach. Use of boulders is usually restricted to relocating small numbers up the beach face to provide temporary armouring of a short length of dune face suffering minor erosion.

Reprofiled dune face following storm erosion. Sand taken from inter-tidal bar formed after storm event.

Function

Recycling provides an artificial buffer between the dune face and the erosive forces of the sea. Where erosion is active this buffer provides a short-term defence of the dunes, possibly only lasting through a single storm. Where the beach is stable or recovering, recycling accelerates the development of new foredunes. The success of this approach will be enhanced if combined with vegetation transplanting and dune thatching or fencing .

Recycling can also be used to enhance the coastal landscape by burying hard defences (sand bags, rock, gabions or timber), with the understanding that those defences may become re-exposed and active during storms. This will only be successful if the defences are high on the beach face - structures within the normally active foreshore zone will not be successfully buried as waves will rapidly remove the recycled material.

6: SAND BAG STRUCTURES

Appropriate locations	Low to moderate energy sandy shorelines requiring lower cost, temporary defence.
Effectiveness	Provides short term fixed line of defence. Less than 5 year life. Burial may extend life.
Benefits	Low cost, low skill approach using local materials that are returned to the beach when the defences no longer required.
Problems	Sand bags subject to vandalism and rapid deterioration due to wave action, sunlight and public pressure. Bags are effectively impermeable and do not absorb wave energy, so beach scour may accelerate.

General description

Sand bags of various sizes and lengths can be used to form temporary reefs, breakwaters, groynes, headlands or revetments on sand beaches. Sturdy geotextile bags are filled in-situ with local beach sand and therefore have a relatively low cost.

Function

Sand bag structures can be placed without the need for costly equipment or skilled labour. They can be used to form any form of shoreline structure but will have a short life expectancy due to lack of resistance to physical damage (wave borne debris impacts or vandalism) and the effects of UV sunlight. They are potentially most useful as a buried revetment under the dune face, where they will form a final line of protection after the overlaying sand has been eroded by storm waves. An alternative use is to form temporary headlands to protect backshore assets while other, longer term, options are planned and implemented.

7 BEACH NOURISHMENT

Appropriate locations	High value amenity beaches. Shorelines suffering erosion due to updrift construction works or channel dredging. Mixed sand/gravel beaches with moderate to high value backshore assets.

Effectiveness	Short to medium term reduction in erosion. Enhancement to natural recovery. 1 to 10 year life before first major recharge.
Benefits	Erosion protection without hard structures. Natural beach processes retained. Recreational value of beach enhanced.
Problems	Appropriate materials may be unavailable or expensive. Dissimilar imported material may alter geomorphology or ecology. Sand may be blown inland causing a nuisance.

General description

Beach nourishment (also known as beach recharging) involves the importing of sand or gravel to make good losses due to erosion. If the source of material is local and related by coastal processes to the eroding area then this approach is known as recycling .Nourishment schemes can vary from a few truckloads to repair a blow out or other small eroded area up to multi-million pound schemes requiring sea delivery of sand dredged from the seabed.

Function

The imported material may be placed on the intertidal foreshore where it will help to protect the dunes by increasing wave energy dissipation across the beach. Alternatively the material may be placed directly at the dune face to form an artificial foredune.

Nourishment with sand is normally only appropriate to high value amenity beaches or small pocket beaches. The sand is quickly redistributed alongshore and offshore by waves, currents and winds, so large volumes and continuing top ups are required to achieve a lasting benefit. In areas with existing mixed sand/gravel beaches a gravel nourishment can be cost effective. The gravel tends to form a narrow storm ridge along the toe of the dunes from where it is redistributed alongshore by wave action at high tide only.

The success of a nourishment scheme will be enhanced by vegetation transplanting and fencing or thatching some instances the nourishment may also benefit from the construction of groynes, reefs, breakwaters or sills that will reduce longshore transport losses. Where high value assets are to be protected, the nourishment scheme may be backed by a fixed line of defence such as a gabion or rock revetment, possibly buried by the nourishment.

8: GABION REVETMENTS

Appropriate locations	Sandy beach sites suffering periodic moderate to severe erosion where backshore assets are at risk. Useful for estuary bank protection.
Effectiveness	Well placed gabions provide reasonable fixed defences, but have a limited life of 5-10 years due to deterioration of the baskets.
Benefits	Useful solution where armour rock is considered inappropriate

	or too costly. Various forms available. Can be buried by sand and vegetation. Permeable face absorbs wave energy and encourages upper beach stability.
Problems	Limited life, leading to unsightly and hazardous wire baskets along beach and the release of non-indigenous cobbles to the beach system. Wire affected by saltwater, vandalism and abrasion by trampling or gravel beach impacts.

General description

Gabions are wire mesh baskets filled with cobbles or crushed rock. They are filled insitu, often with locally available material and therefore have a relatively low capital cost. Because they are flexible and porous they can absorb some wave and wind energy, thereby reducing the scour problems associated with impermeable sea defences such as concrete seawalls. Gabions can be placed as sloping "mattresses" or as near vertical cubic baskets. The latter are intended for bank or cliff stabilisation and are not normally suitable for use in shoreline situations.

Gabion revetments (foregound) are generally preferred to gabion walls (background) in coastal environments being less reflective of wave energy and more stable. Blown sand is also better able to accumulate on revetments, potentially softening their appearance.

Function

The purpose of a gabion revetment is to provide short term (5-10 years) protection from backshore erosion by absorbing wave energy along the dune face. Their application is restricted to the upper part of sandy beaches, since they are not sufficiently durable to withstand regular direct wave action. They should not be installed on shingle beaches because wear and tear will rapidly cause damage to the baskets. As they are porous structures they will tend to trap wind blown sand and allow the growth of vegetation under favourable conditions.

This only applies to sloping structures: steep walls of cubic baskets will not attract sand or allow dune vegetation regrowth.
Gabions provide a short term alternative to rock armour structures in areas where large rocks are not available at an acceptable cost, or where long term protection is not appropriate.

9 ARTIFICIAL HEADLANDS

Appropriate locations	Rapidly eroding dunes with important backshore assets at discrete intervals along the shore.
Effectiveness	Good temporary or long term protection for protected length. Allows natural processes to continue elsewhere. Can be used with other low cost methods. Unlimited structure life for rock headlands.
Benefits	Provides local protection with minimum disturbance to dune system as a whole. Can be modified or removed at later date.
Problems	Visually intrusive. Do not control erosion along the whole frontage. Structures may interfere with longshore transport, particularly on sand-gravel beaches, and may require periodic extension or relocation landward to avoid outflanking.

General description
Artificial headlands are rock structures built along the toe of eroding dunes to protect strategic points, allowing natural processes to continue along the remaining frontage. This is significantly cheaper than protecting a whole frontage and can provide temporary or long term protection to specific assets at risk. Temporary headlands can be formed of gabions or sand bags, but life expectancy will normally be between 1 and 5 years.

Rock headland protecting a golf course tee.

Function

Artificial headlands stabilise discrete lengths of the dune face while allowing the intervening stretches to erode naturally, forming an increasingly embayed shoreline. As the shoreline becomes more indented so the wave energy will be dissipated over a longer frontage and ultimately a more stable plan shape can develop. Stability will depend on the length and spacing of the headlands. Short structures with long gaps will provide local protection but may not allow a stable planshape to develop. If ongoing erosion is severe the headlands may need to be extended or relocated to prevent outflanking or structural failure, although they will continue to provide some protection as nearshore breakwaters The embayments between headlands will not become independent units as sand will be transported by wind, waves and currents along the lower foreshore to seaward of the structures. If gravel is present the headlands may restrict longshore movement along the upper beach; this can be useful to control losses if renourishment or recycling is undertaken.

10 ARTIFICIAL REEFS

Appropriate locations	Exposed dunes of high ecological and landscape value.
Effectiveness	Causes lee side accretion, but least effective during storm surge conditions. Unlimited structure life.
Benefits	Natural processes are only partly disrupted, allowing dunes to stabilise. Rocks create new intertidal habitat.
Problems	May cause navigation hazard. Visually intrusive at low tide. Disrupt amenity use of beach.

General description

Artificial reefs are shore parallel rock mound structures set part way down the beach face. They may be long single structures or form a series of reefs extending for some distance alongshore. They are distinguished from Nearshore Breakwaters by being submerged for at least part of the tidal cycle, and are therefore less intrusive on the coastal landscape, have less impact on upper beach longshore processes and add a new intertidal habitat to sandy foreshores.

Function

Reefs dissipate part of the incident wave energy before it reaches the dune face, protecting the upper beach from erosion and encouraging deposition. Long structures (sills) reduce wave energy over an extended frontage, resulting in a more stable upper beach and dune face. Shorter, segmented reefs protect short lengths of the shore, allowing erosion to continue elsewhere. The result is an embayed shoreline with upper beach deposits (salients) forming behind the reefs.

Salients will allow new foredunes to develop, but this accretion may be at the expense of continued erosion elsewhere. Recycling or nourishment, followed by fencing, thatching and transplanting may address this problem, and will enhance the rate of dune-beach recovery. Reefs have less impact on upper beach transport processes than nearshore breakwaters, and can be used on open beaches. In particular, tombolos will not form behind low level reefs, but can form with higher breakwaters; tombolos would significantly disrupt longshore drift, potentially causing downdrift erosion.
Reefs are of little use within estuaries where currents, rather than waves, are the main erosive force.

11 NEARSHORE BREAKWATERS

Appropriate locations	High value frontages with low rates of longshore transport, and weak near shore tidal currents.
Effectiveness	Cause lee side accretion and erosion behind gaps. Offers good protection within enclosed bays, but potentially damaging to open coasts.
Benefits	Dunes not directly disturbed, increases area of dry upper beach, may allow new fore dunes to stabilise. Unlimited structure life.
Problems	Visually intrusive, alter upper beach morphology, may cause fine sediment, seaweed or debris to accumulate along upper beach. Can cause locally strong currents and may be a hazard to beach users.

General description

Nearshore breakwaters are segmented, shore parallel structures built along the upper beach at approximately high water mark. They are normally built of rock, but can be formed of concrete armour units. At maximum tide levels their crests are still visible, but they may be separated from the shoreline. The gaps allow some wave energy to reach the upper beach and even the dune face.
These structures are distinguished from Artificial Reefs that are built further down the foreshore and are submerged at high tide.

Nearshore breakwaters on the upper foreshore in the Dornoch Firth, shortly after construction.

The same breakwaters as illustrated above, seven years after construction. Note relative stability of backshore.

Function

Breakwaters reduce the energy of waves reaching the shoreline, but do not completely isolate dunes from the natural beach processes. The structures act as a direct barrier to waves, but at very high water levels they allow some overtopping. The gaps between segmented structures allow some wave energy to reach the upper beach and dune face, but this is dissipated by refraction and diffraction. Erosion may continue in the lee of the gaps leading to formation of an embayed shoreline as sand moves into the shelter of the structures.

Sand build up in the lee of the structures (salients) may grow seawards sufficiently to connect with the structure, forming a "tombolo". If the salient is stable, new foredunes may develop. Recycling or nourishment followed by fencing, thatching and transplanting may be used to accelerate formation of stable salients and dunes.

Breakwaters can have a strong influence on longshore drift and should not normally be used on long expanses of open coast or within estuaries if strong wave or tidally induced currents are present. Breakwaters can cause downdrift erosion or result in dangerous conditions for beach users.

12 GROYNES

Appropriate locations	High value frontages influenced by strong long shore processes (wave induced or tidal currents) where nourishment or recycling are undertaken. Best on shingle beaches or within estuaries.
Effectiveness	Good on exposed shorelines with a natural shingle upper beach. Can also be useful in estuaries to deflect flows. Unlimited structure life for rock groynes.
Benefits	Encourages upper beach stability and reduces maintenance commitment for recycling or nourishment.
Problems	Disrupts natural processes and public access along upper beach. Likely to cause downdrift erosion if beach is not managed.

General description

Groynes are cross-shore structures designed to reduce longshore transport on open beaches or to deflect nearshore currents within an estuary. On an open beach they are normally built as a series to influence a long section of shoreline that has been nourished or is managed by recycling. In an estuary they may be single structures.

Rock is often favoured as the construction material, but timber or gabions can be used for temporary structures of varying life expectancies (timber: 10-25 years, gabions: 1-5 years). Groynes are often used in combination with revetments to provide a high level of erosion protection.

Recently built rock groyne at estuary mouth, constructed in association with beach renourishment of adjacent foreshore.

Function

Groynes reduce longshore transport by trapping beach material and causing the beach orientation to change relative to the dominant wave directions. They mainly influence bedload transport and are most effective on shingle or gravel beaches. Sand is carried in temporary suspension during higher energy wave or current conditions and will therefore tend to be carried over or around any cross-shore structures. Groynes can also be used successfully in estuaries to alter nearshore tidal flow patterns.

Rock groynes have the advantages of simple construction, long-term durability and ability to absorb some wave energy due to their semi-permeable nature. Wooden groynes are less durable and tend to reflect, rather than absorb energy. Gabions can be useful as temporary groynes but have a short life expectancy.

Groynes along a duned beach must have at least a short "T" section of revetment at their landward end to prevent outflanking during storm events. The revetment will be less obtrusive if it is normally buried by the foredunes.

Beach recycling or nourishment is normally required to maximise the effectiveness of groynes. On their own, they will cause downdrift erosion as beach material is held within the groyne bays.

13 BEACH DRAINAGE

Appropriate locations	Low tidal range sand beach sites with a high amenity value, low to moderate wave energy
Effectiveness	Increases upper beach width and therefore dune stability, variable life expectancy.
Benefits	Non-intrusive technique resulting in wider, drier beach
Problems	Storm erosion of beach is likely to damage the system

General description

Beach drains comprise perforated land drain pipes buried below the upper beach surface, and connected to a pump and discharge. The concept is based on the principle that sand will tend to accrete if the beach surface is permeable due to an artificially lowered water table. The system is largely buried and therefore has no visual impact.

Function

Mild upper beach and dune erosion can be controlled by beach drains. The system actively lowers the water table in the swash zone, thereby enhancing the wave absorption capacity of the beach, reducing sand fluidisation and encouraging sand deposition. The deposited sand forms an upper beach berm

that protects the dune face during storm events that might otherwise cause erosion.
Benefits are greatest on micro-tidal (<2m range), high value amenity beaches where landscape issues preclude the use of other management approaches. Important backshore assets should not rely on drainage systems for erosion protection during storms, even as a temporary measure.

14: ROCK REVETMENTS

Appropriate locations	Sites suffering severe and ongoing erosion where important and extensive backshore assets are at risk.
Effectiveness	Good long-term protection. Can be extended or modified to allow for future shoreline change. Unlimited structure life.
Benefits	Low risk option for important backshore assets. Permeable face absorbs wave energy and encourages upper beach stability.
Problems	Strong landscape impact. Can alter dune system permanently as sand tends not to build up over the rocks if beach erosion continues.

General description
Rock revetments may be used to control erosion by armouring the dune face. They dissipate the energy of storm waves and prevent further recession of the backshore if well designed and maintained. Revetments may be carefully engineered structures protecting long lengths of shoreline, or roughly placed rip-rap protecting short sections of severely eroded dunes.

Major rock armour revetment in front of dune system.
Though offering long-term security, the landscape impact and damage to habitat are considerable.

Function
Rock revetments are widely used in areas with important backshore assets subject to severe and ongoing erosion where it is not cost effective or environmentally acceptable to provide full protection using seawalls he function

of permeable revetments is to reduce the erosive power of the waves by means of wave energy dissipation in the interstices of the revetment.

Permeable revetments can also be built from gabions timber) or concrete armour units. Concrete units are normally too costly for use as dune protection, but may be appropriate where high value back shore assets must be protected and armour rock is difficult to obtain. They are often considered to be more unattractive than rock.

Revetments may not prevent on going shoreline recession unless they are maintained, and, if necessary, extended. If the foreshore continues to erode, the rock revetment may slump down, becoming less effective as a defence structure, but will not fail completely. Repairs and extensions may be necessary to provide continued backshore protection at the design standard.

15 TIMBER REVETMENTS

Appropriate locations	High value sites suffering modest and periodic erosion.
Effectiveness	Provide good protection if only occasionally exposed to waves. 5-30 year life.
Benefits	Normally acceptable to the public. Less expensive than seawalls or rock revetments
Problems	Limited life, particularly where exposed to wave action. Visually intrusive. Alters beach-dune processes as sand interchange is disrupted.

General description

Timber revetments can range from substantial, impermeable breastwork to temporary permeable upper beach wave barriers. The former is a final line of dune erosion protection, while the latter serves to partially dissipate wave energy before it reaches the dune face.

Timber breastwork functioning successfully within an estuary.

Function

Timber revetments have been widely used in the UK for coast protection where the costs or impacts of a seawall may have been unacceptable. Construction flexibility allows timber revetments to serve various purposes. They can provide a partial barrier to wave energy when built as a permeable "fence" along the upper beach. Alternatively they can form a final wave protection wall when built as an impermeable vertical breastwork along the dune face.

Temporary structures can be built relatively cheaply of pressure treated softwood but more substantial structures are usually built of imported hardwood. Concerns over the sustainability of hardwood sources have increased material costs considerably, making it unlikely that large scale timber defences will be used in the future. Timber is now only likely to be viable for smaller schemes in relatively low energy areas. On an open beach exposed to large storm waves, hardwood structures will be abraded, giving a life expectancy of only 15-20 years. Within estuaries or on low energy beaches the timber may last 25-30 years before abrasion and wood boring invertebrates cause significant damage. Softwood structures are likely to have a life of only 5-10 years.

16 IMPERMEABLE REVETMENTS AND SEAWALLS

Appropriate locations	Exposed frontages with extensive and high value backshore assets.
Effectiveness	Provides good medium term protection, but continued erosion will cause long term failure (30-50 year life expectancy).
Benefits	Fixed line of defences allowing development up to shoreline. Allows amenity facilities along backshore and easy access to beach.
Problems	Continued erosion may cause undermining and structural failure. Complete disruption of natural beach-dune processes.

General description

Impermeable revetments are continuous sloping defence structures of concrete or stone blockwork, asphalt or mass concrete. Revetments are built along the dune face, preferably above the run-up limit of waves under normal conditions. Where frequent wave attack is anticipated, the revetment may be topped by a vertical or recurved wall to reduce overtopping.

Seawalls are near vertical structures of concrete, masonry or sheet piles, designed to withstand severe wave attack. Their use was popular in the past but they are now normally considered to be costly, detrimental to the stability of beaches and unsuitable for erosion management along a dune shoreline.

Function

Rock faced concrete revetment with sheet piled toe and rock armour apron.
The rock armour was placed after beach lowering exposed the toe of the revetment. The good medium term protection of such structures has to be balanced against considerable landscape impact and habitat damage.

Impermeable revetments provide a fixed line of defence for frontages with high value backshore assets. They are intended to withstand storm wave attack over a life expectancy of 30 to 50 years. Amenity facilities such as promenades, slipways and beach access steps can be built into the revetment.

Revetments will severely disrupt natural beach-dune interactions, and should not be used on frontages valued for natural heritage. Ongoing beach erosion may result in undermining of the revetment toe, leading eventually to structural failure or the need for repairs and extensions.

Concrete and stone seawall.
In common with many other fixed structures the natural interchange of sand between beach and dunes is prevented with the consequent loss of transitional habitats.

17 NOVEL COAST PROTECTION METHODS

Dumping of rubble is unsightly, poses a health hazard and does little to impede natural shoreline recession.

There are a number of coast protection techniques that are of marginal use for dune protection. They are either unproven or inappropriate. These include the following:

- Open revetments or breastwork
- Artificial seaweed
- Seaweed planting
- Bubble barriers
- Alternative breakwaters
- Sunken vessels
- Tyre revetments
- Interlinked concrete block mattresses
- Bitumen spraying

Open revetments, sills or breastwork

Large rocks, concrete tank traps or timber “soldiers” (vertical piles) placed at discrete intervals in a line or as an open array along the mid to upper beach will have a limited influence on cross-shore wave energy. During mild conditions they may have a positive impact on upper beach and dune stability, but their impact during storms may be negligible. As the units are brought closer together to form a tight array they begin to act as a standard permeable headland, breakwater, reef or revetment and become increasingly effective at damping wave energy. To achieve storm protection a void to solid ratio of 0.3 – 0.5 would be required, preferably with a cross-shore width of at least two units (e.g. 2 rows of touching rocks). A properly designed structure would also have the advantage of greater stability of individual elements (i.e. single rocks or concrete units on the beach are less stable than rocks forming a structure).

Artificial seaweed

There have been several attempts at placing artificial seaweed mats in the nearshore zone in an effort to decrease wave energy by the process of frictional drag. The field trials have generally been inconclusive as regards wave energy

attenuation. The most successful trials have been in areas of very low wave conditions, low tide range and relatively constant tidal current flows, when some sedimentation was found to take place.
On open coast sites there have been major problems with the installation of the systems and the synthetic seaweed fronds have shown very little durability even under modest wave attack. The synthetic seaweed has tended to flatten under wave action, thereby having minimal impact upon waves approaching the coast.
Field trials in the United Kingdom have been unsuccessful and the experiments were abandoned in all cases, due to the material being ripped away from the anchorage points.
In the Netherlands experiments were more successful with synthetic seaweed being placed in relatively deep water, where sedimentation up to 0.35m took place soon after installation, although this would result in only a very minor decrease in shoreline wave conditions.
The cost of the artificial seaweed is low but the costs and frequency of maintenance works make this option not worth pursuing in an exposed coastal environment, where it would be subject to severe wave conditions and would become damaged rapidly.

Bubble barriers
The principle behind the bubble barrier technique is the creation of a continuous curtain of bubbles rising from the seabed to dampen wave energy. The concept was developed with the aim of stilling wave energy at the mouths of harbours, where it would be possible to create suitable conditions over a short distance. The installation costs of such techniques are high, and the maintenance problems are likely to be difficult.
The bubble barrier technique is inappropriate for an open coast location where the costs of installation over hundreds of metres or greater would be considerable. The technique is still very much in an experimental stage with respect to shore protection.

Alternative breakwaters
A considerable amount of research has been carried out on the potential performance of various types of breakwater including:

- Layered plate frameworks
- Floating breakwaters
- Perforated caissons

These techniques involve the attenuation of wave energy by means other than providing a direct barrier. The numerous designs that have been tested or built are usually specific to a particular wave environment, and are usually aimed at vessel protection over relatively short distance. Design, construction and management costs are high. None have been shown to be practical as far as dune protection is concerned.

9) National initiatives (special programmes, committees, commission set up)

COASTAL EROSION MANAGEMENT: INITIATIVES BY GOVT. OF INDIA

Action taken by Government of India

In order to assist maritime States/UTs in protection of vulnerable coastal areas from sea erosion, there are two schemes namely (i) Centrally Sponsored Scheme (transferred to State Sector since April 2005) currently under implementation during X Plan by providing central assistance to maritime States for protection of critical stretches from sea-erosion and (ii) National Coastal Protection Project (NCPP) for protection of coastal areas of maritime States/UTs from sea erosion is under formulation with a view to explore possibilities of funding through external resources or other domestic resources.

I. Centrally sponsored scheme (CSS)
II. National coastal protection project (NCPP)
III. Coastal protection & development advisory committee (CPDAC)
IV. Technical assistance (TA) program financed by Asian Development Bank (ADB)
V. Preparation of execution manual
VI. Updating of design manual
VII. Exploration of soft structural measures
VIII. Preparation of coastal atlas
IX. Proposals for XI five year plan

(I) Centrally Sponsored Scheme

To tide over the immediate fund constraint faced by the states in completing anti-sea erosion measures on the critical reaches, a Centrally Sponsored Scheme, "Critical anti erosion works in coastal and other than Ganga basin States", estimated to cost Rs. 20.64 crores, is under implementation during X Plan. The scheme has now been transferred to State Sector. Out of estimated cost of Rs. 20.64 crores, Central share is Rs. 15.98 crores and State share is Rs. 4.66 crores. The central assistance is in form of Grant-in-aid to States restricted to 75% of the total cost of scheme. Central grant of Rs. 8.52 crores has been released to coastal States/UT till February 2006 under the scheme.

(II) National Coastal Protection Project

The National Coastal Protection Project for protection of coastal areas of maritime States/UTs from sea erosion is under formulation with a view to explore possibilities of funding through external resources or other domestic resources. The proposals of coastal states of Karnataka, Kerala, Maharashtra, Orissa, Tamilnadu, West Bengal and UT of Pondicherry have been found acceptable for inclusion in the National Coastal Protection Project, while; the compliance to CWC comments is awaited from the coastal states of Andhra Pradesh, Goa and Gujarat. U.T. of Lakshadweep has been requested to reformulate proposal of Lakshadweep for inclusion in the NCPP in the light of recommendations/discussion held during site visit of Lakshadweep Islands by a team of CWC/CWPRS officers in January 2006. The UT of Andaman & Nicobar Islands has not submitted any proposal so far.

(III) Coastal Protection & Development Advisory Committee (CPDAC)

Considering the vast potential of the development in the protected coastal zone and the pressure of population in the densely populated areas in the coastal zone, the Beach Erosion Board, constituted in the year 1966, was renamed as "Coastal Protection and Development Advisory Committee" (CPDAC) vide MoWR Resolution No.15/2/91-BM dated the 17th April, 1995 with its secretariat in the Central Water Commission to identify and develop the various resource potential available behind the protected areas. CPDAC is a high level body of experts in the field of coastal engineering, which is regularly approached by the maritime States and other concerned organizations for specific advice on the problems of coastal erosion. CPDAC provides a common platform to all maritime States/UTs to discuss and solve their coastal erosion problems. CPDAC is headed by Member (RM), CWC with C.E. (P&D), CWC, as its Member-Secretary and the representatives of coastal States and the related Central departments as its members. The CPDAC has so far held 9 meetings. 9th meeting of the CPDAC was held at Port Blair (A&N Islands) during 23rd-25th January 2006. 10th meeting of CPDAC was held in October 2006 in Andhra Pradesh. **(ANNEXUE-I)**

STATUS OF COASTAL PROTECTION WORKS IN MARITIME STATES

(Length in km)

Sl. No.	Description	Andhra Pradesh	Goa	Gujarat	Karnataka	Kerala	Maha-rashtra	Orissa	Tamil Nadu	West Bengal	A&N Islands	Laksha-dweep	Pondi-cherry	Total
1.	Total coastal length	973.7	160.5+	1214.7	280.0	569.7	652.6	476.4	906.9	157.5	1962.0	132.0	30.6	7516.6#
2.	Total length of coastline affected by sea erosion	9.19	10.50	36.40	249.56	478	263	107.55	36.15	125	--	132.0@	6.40	1453.75$
3.	Total length of coastline protected up to VIII plan	0.49	3.00	4.00^	55.77 upto Oct 2004	386.20 upto Mar 05	127	10.00	8.20	80.80 upto Mar 05	--	44.43 upto Jan 2002	6.40	726.29$
4.	Total length of coastline yet to be protected	8.70	7.50	32.4	193.79	91.80	136	97.55	27.95	58.70	--	87.57	6.40**	748.36$
5.	Expenditure incurred up to VIII Plan (Rs. in crore)	0.025 Upto June 98	0.96	0.99	57.26 upto Oct 2004	288.49 upto Mar 05	12.58	1.25	12.40	28.02	--	--	2.23	404.205
6.	Total length of protection works proposed/considered for inclusion in NCPP (a) New-Beach	2.615 --- 6.00	7.50 1.50 4.00	45.19 --- ---	49.875 17.605 ---	52.065 59.448 ---	72.36 --- ---	89.55 --- ---	13.824 --- ---	10.75 --- 36.50	Proposal awaited	72.57 --- ---	--- 6.40 ---	416.299 84.953 46.50

7.	Protection Works (b) Reformation-Beach Protection Works (c) New-Tidal bank/River bank protection works in tidal reaches (d) Reformation-Tidal bank / river bank protection works Estimated cost of NCPP proposal (Rs. in crore)	43 35.65	3.00 55.00	--- 174.30	--- 135.95!	--- 216.96!	--- 193.801!	--- 304.517!	--- 167.692!	--- 256.23!	---	--- 142.307	--- 25.50!	46.00 1707.907

As per National Hydrographic Office, Dehradun + includes coastal length of Daman & Diu also excluding A&N Islands

** Reformation work only @ As per Lakshadweep NCPP proposal.

^ Anticipated achievement upto IX Plan

! Proposal has been considered for inclusion in the NCPP

10. COASTAL REGULATION ZONE NOTIFICATION

INDIA'S POLICY FOR PROTECTING THE COASTAL ENVIRONMENT FOR SUSTAINABLE USE

In recent years, the country's coastal stretches have become a pressure point for indiscriminate and unsustainable development pressures. The coastal zone - the land which extends from the beginning of the coastal plain to the beginning of the continental shelf - occupies only a marginal portion of the country's territory yet it is home to a disproportionately large section of the population. And the numbers are ever on the increase. It is not only the powerful scenic beauty that this eco-region has to offer which drives people to crowd themselves in these narrow stretches, but the fact that the coastal regions are extremely productive lands hosting nearly a quarter of the earth's primary plant production, the world's major spawning grounds and fish nurseries and also some of the most fertile agricultural lands.

In addition to farming and fishing - the two major coastal industries - there are several development interests which also show a marked preference for the coastal region. Industries wish to be located there for easy access to the sea for discharge of effluents; thermal power plants, for easy access to the enormous quantities of cooling water they need; tourism promoters want to use the beaches for raising hotels; middle- and upper-class citizens wish to have residential bungalows located there. There are also activities for which foreshore facilities are essential: for example, ports, harbours, jetties, wharves and quays. All these new development pressures are in addition to demands already being made by existing coastal inhabitants. The concentration of development activities on such a scale, in fact, threatens to destabilise the very resources that provide the possibilities of living in the coastal belt. The increased economic activities in the region over the past three to four decades have led to the depletion of marine life due to overfishing in coastal waters, the levelling of sand dunes (nature's first line of defence to protect the hinterland from the ravages of the ocean), the destruction of hundreds of acres of mangrove forests and coral reefs, and the ingress of saline water into adjacent freshwater aquifers. In addition, pollutants and toxins galore are emptied daily into the coastal waters as the authorities find it a cheap and easy way to get rid of town and industrial wastes. In India, these pressures would have led to a sharp decline in both the aesthetic and the ecosystem values of such areas and would also have impinged negatively on traditionally sustainable economic activities carried out by fishermen and toddy tappers. It is also widely known that tourism development in several other parts of the world has led to closure of beaches to the local population as the tourism promoters have increasingly privatised these hitherto public resources.

Cramming such areas with large numbers of buildings for tourists has also reduced their tourism value, dissuading people from visiting.

The CRZ Notification issued in 199 1 by the Ministry of Environment and Forests seeks to tackle some of these issues and to place any further proposed development within India's vast coastal stretches within a controlled framework.

The Ministry of Environment and Forests, Government of India, has created a statutory innovation in the form of a legal notification for the protection and planned development of coastal areas, including the reservation of areas in coastal zones set aside as No- Development Zones. The notification actually crystallises a fairly firm policy that had extended over a decade to protect coastal areas from unplanned and indiscriminate human activities. ***On 19 February 1991,*** the Ministry of Environment and Forests issued an elaborate notification called the Coastal Regulation Zone (CRZ) Notification which sought to regulate human activities in the area of 500 m from the High Tide Line (HTL) along the coastal stretches of the country. The CRZ Notification came into immediate effect on the same day and was made applicable to the entire 6,000 km coastal belt of India and, in addition, to riverine stretches affected by tidal action. The objective of the CRZ Notification is to protect the coastal areas from becoming degraded due to unplanned and/or excessive development which results in pollution and the eventual destruction of this highly prized, fragile and irreplaceable natural resource. The Notification is a unique piece of statutory regulation and other countries that seek to also regulate activities in their coastal areas for environmental reasons may benefit from studying India's experiences.

DESCRIPTION OF THE PRACTICE/INNOVATIVE EXPERIENCE AND ITS MAIN FEATURES

The statutory innovation is today referred to as the CRZ Notification. ***It was issued under the powers given to the Central Government under the Environment Protection Act 1986.***

The Environment Protection Act itself is a comprehensive piece of legislation which has become today the basis of environmental law in the country and an enormously powerful legal tool for environmental protection. The CRZ Notification was issued on 19 February 1991 and is decidedly one of the most controversial and significant statutes to be issued under empowering clauses of the EPA. Under the CRZ Notification, the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (in the landward side) up to 500 m from the High Tide Line (HTL), and the land between the Low Tide Line (LTL) and the HTL, were identified as the Coastal Regulation Zone (CRZ). Areas identified as CRZ would henceforth receive special and individual protection. The Notification forthwith imposed several restrictions on the setting up and expansion of industries, operations and processes in these areas.

Among the activities that are today prohibited outright in CRZ. Areas are the following:

(a) setting up of new industries and expansion of existing ones;
(b) manufacture, handling, storage or disposal of hazardous substances;
(c) discharge of untreated waste and effluents from industries, cities, towns and other human settlements;
(d) land reclamation, bunding or disturbing the natural course of sea water;
(e) mining of sand, rocks and other substrata minerals:
(f) drawing of groundwater, using mechanical means; and
(g) dressing or altering of sand dunes, hills and other natural features, including landscape changes, for beautification, recreation, etc.

All activities other than those expressly prohibited are sought to be strictly regulated in the CRZ and henceforth require the prior approval of the Government of India (especially if the investment exceeds five crores (50 million) of rupees). The Government itself, moreover, cannot grant approvals for projects in contravention of any of the restrictions imposed on coastal areas by the CRZ Notification.

For purposes of proper planning and management of the coastal areas, the CRZ Notification classifies coastal areas into four zones depending on the intensity of protection that these areas require and also considering the extent of development that has already taken place in such areas. The four zones are as follows:

(a) **CRZ I:** Comprises those areas that are most fragile and consequently in need of absolute protection from any form of development. The zone therefore comprises areas which are ecologically sensitive and vulnerable, such as mangroves, coral reefs, national parks, marine parks, sanctuaries, spawning grounds of fish and other marine life, areas rich in genetic diversity, areas of outstanding natural beauty, historical and heritage areas, areas likely to be inundated due to global warming and the foreshore area which lies between the LTL and the HTL. In this zone, for obvious reasons, no development whatsoever is permitted by the statute.

(b) **CRZ II:** Comprises areas that have already been developed up to or close to the shore line. All cities and other well-populated areas which are substantially built up and have roads and other infrastructural facilities such as water supply and sewerage mains would fall into this zone. In these areas, development is permitted only on the landward side of existing buildings or roads -the general idea being that since it is not economically and politically feasible to reverse the development that has already taken place, the least one can do is to prevent further damage by restricting development to areas behind those that have already been developed. Since, by and large, in most of the coastal metropolises high-rise buildings already exist up to the waterfront, and paved roads and footpaths cover the rest of the open areas, not much additional development can actually take place in new areas or areas not yet touched by development except in areas where construction already exists. (c) CRZ III Includes those areas that are relatively undisturbed and which do not fall under either CRZ I or CRZ II. This includes largely rural areas and also areas in legally designated urban areas which are not substantially built up.

(c) **CRZ III zones:** the area up to 200 m from the HTL is a No-Development Zone and no construction/development is permitted in this stretch. Between 200 m-500 m, a concession has been made for the foreign-exchange earning potential of the tourism industry and therefore hotels for tourism purposes are permitted, provided they comply with certain conditions. Among the conditions listed are the following:

(i) the hotel or resort buildings will not have more than two floors (ground plus one upper floor) and the total height of construction will not exceed 9 m up to the highest ridge of the roof;

(ii) groundwater will not be tapped by mechanical means in the area up to 500 m from the HTL;

(iii) there will be no extraction of sand or leveling of the sand dunes;

(iv) the floor space index will not exceed **33%;**

(v) any green fencing or barbed-wire fencing that is put up within 200 m of the HTL **will** not hamper public access to the beach; and

(vi) the construction will be consistent with the surrounding landscape and local architectural style.

Recognizing that the beach areas are an important arena **of** economic activity for the coastal communities comprising fisher folk, and recognizing also that beach areas form a valued recreational area for the vast majority of common folk, the Environment Ministry also gave much weightage to the question of public access to the beach. The law therefore stipulates that "to allow public access to the beach at least a gap of 20 m width shall be provided between any two hotels/beach resorts and in no case shall gaps be less than 500 m apart." This implies that: (i) hotels adjacent to each other must have an access for the public to the beach between them, and (ii) if the beachfront property owned by a hotel is a very large one, there must be a public access which cuts through the property every half a kilometre.

(d) CRZ IV: The zone comprises the coastal stretches of the Andaman and Nicobar Islands, Lakswadeep and other small islands. These eco-fragile regions have been treated as separate entities and special protection status has been accorded to them as a consequence. Under the Notification, the coastal states **of** the Indian union have been directed to prepare Coastal Zone Management Plans (CZMPs) which will identify the CRZ areas in each state, classify them into zones in accordance with the Notification and also indicate the scope of development planned or proposed therein. The different CZMPs of the various coastal states were prepared under the specific direction of the Indian Supreme Court in 1996 and were also approved in the same year by the Ministry of Environment and Forests. They now control or provide the framework for the sustainable development of India's coastal areas.

The CRZ Notification of 199 1 was in fact the culmination of a decade long period of intense activity on the part of the Government of India to protect the coastal areas from being ravaged and destroyed by the forces of unplanned development. Thus, the coastal areas first received executive protection way back in 1981 when the then Prime Minister Mrs. Indira Gandhi – a world-renowned figure known for the environmental causes she championed - addressed a brief letter to the chief ministers of all the coastal states in India directing them to ensure that the coastal zone up to 500 m from the HTL was kept free from development activities of all kinds. This straightforward and simple communication - though technically bereft of legal sanction as it did not emanate from Parliament - was nonetheless widely respected as a diktat issuing from the ruling head of government and consequently observed and obeyed. The period from 198 1 to 199 1 saw guidelines being issued in line with the policy as well as some modifications and changes in the implementation of the same guidelines. During this period, there was also intense activity on the part of NGOs to lobby the government to give the policy legal backing.

Eventually, when the Central Government decided to come up with legal protection, several NGOs were associated with the preparation of the Notification. The draft notification was next gazetted for objections. After these were all considered, the necessary changes were effected in the draft notification. Finally, in February 1991, the CRZ Notification became the new statute applicable to all coastal areas, protecting this natural resource for the present and future generations of this country.

DESCRIPTION OF THE INSTITUTION RESPONSIBLE AND ITS ORGANISATIONAL ASPECTS

The Ministry of Environment and Forests, which is the institution responsible for drafting and issuing the CRZ Notification, was set up by the Government of India in the early 1980s. It is a normal government ministry headed by a Minister with independent charge. (Prior to that, it functioned as a department.) Since 1981, the Ministry's scientists had been working on a set of guidelines for the protection and development of coastal areas. Several meetings were organized by the Ministry with experts, NGOs and environmentalists to expand the fund of knowledge and expertise available in the Ministry on the coastal ecosystems. Finally, a set of detailed guidelines was drawn up and published in the form of a booklet and circulated to all coastal states. Thereafter, the Ministry has continued to administer the Notification. Since the Ministry is subject to intense political pressures, it has been forced at times to try and water down the coastal regulations. However, such efforts have not been successful in the past due to the vigilance exercised by NGOs.

PROBLEMS OR OBSTACLES ENCOUNTERED AND HOW THEY WERE OVERCOME

There have been several problems encountered in the entire exercise of enforcing the CRZ Notification. Most of these have resulted from pressures exerted by vested interests and development bodies who would like to have greater liberty in utilising the resources of the coastal areas for their own short-term private objectives. The tourism lobby was the most vocal of the lot and did everything in its power to sabotage the Notification once it was issued, either by flouting it openly **or** by undermining it surreptitiously. Thus, violations of the law cropped up almost immediately after the statute was notified. Disputes were raised by resort developers about the location of the HTL, constructions were surreptitiously raised in the 200 m No-Development Zone, groundwater was illegally tapped by digging bore and tube wells, and resort owners attempted to enclose the open spaces in the No-Development Zone with fencing or walls. It was at this juncture that Indian environment NGOs promptly stepped in. They first registered their protest against such violations with the government and when they found that that was not enough, they approached the courts. Writ petitions were filed in the courts challenging the violations of the CRZ Notification as being violative not only of the EPA but also of Art. 21 of the Indian Constitution (Art. 21 enshrines the right to life: the Supreme Court of India has taken the stand that Art. 21 now includes the right to a safe, clean and healthy environment. Thus, all courts in the country are bound to take cognisance of environment offences.).

Responding positively and often swiftly to these writ petitions filed in the public interest, the judiciary made several observations which served to strengthen the CRZ Notification. It held, for example, that the No-Development coastal zone was absolute and sacrosanct and no development whatsoever could be permitted therein. In some cases, it ordered the immediate removal of illegal structures constructed in the No-Development Zone. In others, it halted construction work midway when it was shown that the construction activity was destroying the sand dunes. The courts were equally severe when instances of illegal tapping of groundwater in the coastal areas by five-star luxury-resort owners were brought to their notice: they ordered the immediate closure of such illegal wells. The issue of public access to the beach also found favour with the courts and they were quick to protect the public interest by ordering the removal of unauthorized walls and fencing, thus reopening the traditional pathways. The result of the fight put up by the environment NGOs and public-spirited citizens to save and protect the coastal areas and the positive response of the judiciary drove home the message that the law would be strictly enforced and violators strictly dealt with. The judicial orders also served to give the CRZ Notification all the judicial sanction it required. Faced with this situation, the tourism and development lobby did the next best thing. It prevailed upon the Environment Ministry to modify and relax the CRZ Notification. This was done by the Environment Ministry in August 1994; an amendment Notification was issued under which some of the more stringent conditions of the original 1991 Notification were relaxed. However, most of these modifications - the principal objective of which was to ensure that the **CRZ** Notification became a worthless statute – were struck down by the Supreme Court and the original provisions restored. Another obstacle to implementation of the CRZ Notification was the attitude of the state governments, which resented interference by the federal government in what they saw as their territorial fiefdoms. Some of them also tried to back CRZ violators by applying their own interpretations on the CRZ Notification. For example, the state of Goa demarcated the HTL based on maritime data which resulted in the HTL being marked far closer to the sea than was permissible. Naturally, if the coastal zone shifted 40 to 50 m closer to the sea, there would be obvious advantages for developers and industrialists. The Goa government also attempted to demarcate practically the whole of Goa as CRZ **II** (the zone which allows maximum development) and to exclude the riverine areas from the purview of the CRZ Notification. State governments were also lackadaisical in the preparation of the Coastal Zone Management Plans and delayed them as far as they could. It was only with the intervention of the Supreme Court that all the coastal states prepared their CZMPs by 1996.

Once again, it was the NGOs which played an important role in ensuring that the CZMPs were prepared strictly in accordance with the Notification and would not turn out to be mere pieces of paper incapable of really protecting the coastal areas. On becoming aware that mischief was afoot in the process of finalising the CZMPs in some states, environment NGOs launched a fierce counter-attack. They prepared their own CZMPs with detailed explanations and sent them to the Environment Ministry, which was in charge of approving CZMPs, **so** that the Ministry would be well prepared to evaluate the CZMPs submitted by the coastal states. The Central Government thereafter was forced to send its own team of experts to countercheck the CZMPs produced by the states. Thus, the

perpetration of a fraud on the public was prevented and the objectives of the CRZ Notification maintained. It is thus the vigilance of environment NGOs and concerned citizens which has forced the authorities to enforce the CRZ Notification and the statutory coastal management plans. However, the main problem in the implementation of the Notification still remains -namely the lack of political will on the part of the coastal states. Pressures continue to be exerted on the Central Government **to** consider yet another round of amendments to the CRZ Notification on grounds of economic development and because the Notification is alleged to be causing hardship to the common people. The protagonists of this move have sought to play on the feelings of ordinary people, particularly the fishing community, by depicting the CRZ Notification as an anti-people law in as much as it restricts development in the coastal areas. This is actually not true because the CRZ Notification specifically permits the traditional inhabitants ***of*** the area, namely the farmers and fisherfolk, to construct or renovate their dwellings within the CRZ while restricting outsiders from doing **so.** For a while, people were swayed by such canards and showed signs of resisting the CRZ Notification. But not anymore. Uneducated and generally marginalised, they have seen how big business, industrial development and tourism have displaced them from their traditional occupations without giving them alternative sources of employment. The traditional
fishing communities all along the west and east coasts of India have now rallied solidly behind the CRZ Notification.

EFFECTS OF THE PRACTICE/INNOVATIVE EXPERIENCE

The CRZ Notification has turned the coastal areas into a major battleground, with those who see them as an arena for unlimited opportunity on one side and those who argue for restraint in the interests of ultimate survival and protection of the region on the other. However, the necessity of implementing the Notification underlined recently by a comprehensive Supreme Court judgement has led to enhanced appreciation of the coastal environment, coastal ecosystem values and longterm sustainable development practices.

The large-scale pressure groups and lobbies that had hoped to impose themselves in CRZ areas in the 1980s have now found themselves largely restrained due to the limitations set by the Notification. Town planning authorities have been forced to think of alternative measures to dispose of coastal town wastes since the CRZ Notification has declared it illegal for the authorities to continue to use the oceans as dumping grounds for untreated wastes and effluents from industries, towns or cities and other human settlements. Shrimp aquaculture (prawn farming) in the coastal areas has also suffered a setback, with the Supreme Court declaring intensive and semi-intensive forms of prawn farming contrary to the Notification. This form of aquaculture, besides displacing the traditional rice/shrimp rotating aquaculture practiced by the local farming community, had also begun to pose a serious threat to the environment due to coastal pollution as effluents from the aquaculture farms were being discharged directly into coastal waters without any treatment. Chemicals and antibiotics injected into the feed to produce high yields of shrimp eventually find their way into the fragile coastal belt, threatening other fragile forms of marine life. Even the pressure to raise large-scale residential complexes has declined with the restriction that only those from the traditional coastal village communities can construct residential houses and that too after obtaining the required permissions. The 200 m zone (from the HTL) has continued to remain largely a No-Development Zone and this has resulted in many of the coastal areas being maintained in their original natural state. This itself is an attraction for tourists who have long tried to escape from the concrete jungles of their own countries. More importantly, it is protective of traditional livelihoods like fishing and toddy-tapping. Thus, in contrast to tourism development in countries like Spain or Malaysia, the coastal areas in India and their specific ecological endowments have been left largely intact and in their wild and natural state. India has conceded that nature also has its own right to be.

POSSIBILITY AND SCOPE OF TRANSFERRING TO OTHER COMMUNITIES OR COUNTRIES

Several aspects of the CRZ Notification and its features could be utilized by other statutory authorities in other coastal countries for implementation under their own statutory laws. The CRZ Notification should be studied by the Environment Departments of other countries in the South. It will certainly be **a** useful model for them, even if they do not need to copy all its features in planning for the sustainable development of their own coastal areas.

OTHER COMMENTS

Literature on the CRZ Notification is easily available in India in printed form. An excellent compilation is available from The Goa Foundation, Above Mapusa Clinic, Mapusa 403 507, Goa, India. The book contains the CRZ Notification, the Supreme Court judgement upholding it and the approved **CZMPs** of all the coastal states in India.

11. Research – past and current

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