
HUMAN INTERFERENCE ALONG THE COAST OF GOA

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ABSTRACT

Till the 1970's the goan coast was largely pristine and unsullied, as most coastal activities were located away from and behind sand dunes. A distinct harmony prevailed between man and Nature. During the last two decades or so, the promotion of tourism, increase in population and construction activities have created a heavy demand for resources resulting in congestion on coasts, increase in density of constructions and pressures on infrastructure. We note large scale conversions of dune belts leading to indelible alterations of coastal landscape, in general, and dune ecosystems, in particular. Lack of implementation and enforcement of legislations has led to blatant violations of CRZ laws and uncontrolled growth along certain sectors of the coast. Major impacts are seen in the form of damage to dune vegetation, permanent elimination of coastal sand dunes and (localized) beach erosion. Major impacting factors are constructions on dune belts, mining of dune sands and roads along sandy areas. Excessive pumping of ground water has induced salt water ingress, although seasonal in nature. Other human impacts such as beach shacks and recreation appear to be less harmful. Building activity has now gradually invaded coastal hill slopes some of which are already degraded. Maintaining of appropriate free spaces and compulsory set back lines, together with a stringent enforcement of CRZ legislation are imperative so as to preserve the remaining shreds of the coastal environment.

INTRODUCTION

The coastal zone of Goa had been exclusively used for agriculture, farming, shell fishing, traditional fishing and low key recreation (Dume, 1986). Goans of yesteryears used the shoreline for fishing by using hand-cast and hand-pulled nets; traditional fishing was the main economic activity of coastal populations. They never occupied dunes or beaches. The only identifiable structures along the shore were a few cabins and thatched huts that housed sea going canoes, some of which can still be seen today. The large plain areas behind the dune belts were used for farming and paddy cultivation, activities which are common at certain places even at present. Recreation was restricted to a few beaches only.

Although little was scientifically known those days, our forefathers had somehow grasped the sanctity of Nature, the sand dune ecology for example (Lobo, 1988). Till the 1970's, there was no evidence wherein sand dunes were razed to build houses. Ancestral mansions, roads, traditional villages, and any major activity such as paddy cultivation were all located at safe places away from and behind the dunes. Although obscured by modern development, this type of age old planning can still be identified. Such places landward of dune belts thus remained as areas of peace and tranquillity. The coastal zone environment was largely pristine, well preserved. Therefore, such a setup could be cited as a unique example of the harmony that prevailed between man and Nature (Lobo, 1988; Mascarenhas, 1990; Alvares, 1993; Mascarenhas et al., 1997).

Human pressures on the beach - dune systems started during the 1970's when tourism was declared a potential revenue earner for Goa, a place that was projected as a major tourist destination. During 1971 - 1991 period, almost 80% of the urban growth was, and still is, concentrated in the coastal talukas (D'Souza et al., 1988; Wilson, 1997). Moreover, during the last decade, a large number of people chose to move towards the coast as can now be observed at Caranzalem or Dona Paula, for example. Since then, there has been a dramatic growth and a proliferation of innumerable coastal resorts, residential flats, dwellings, small restaurants, roads and beach shacks along and across the sand dune belts. Several coastal areas have thus changed from virtual wilderness in 1970's to haphazardly developed stretches, full of concrete buildings and related structures, in less than 20 years (Mascarenhas, 1997; Sawkar et al., 1998). Several shore fronts have been built in such a manner that they bear little resemblance to the coast that formerly existed. All these activities resulted in haphazard growth and overcrowding of coastal regions that we see today.

Therefore, the advent of tourism and population increase, coupled with building activity and modern societal demands, have resulted in large scale changes in the geological and ecological setup and indelibly altered ecosystems, land use patterns and the coastal zone landscape (Lobo, 1988; Alvares, 1993; Mascarenhas, 1997; Mascarenhas et al., 1997; Narayan, 1997; Sawkar et al., 1998; Mascarenhas and Sawkar, 1998; Rosario, 1998). Considering that the open sea front of Goa is being built up at a very fast pace, it is not known in what way the heavy developmental activities are affecting the sandy areas, in general, and the dunes, in particular. Therefore, this study is aimed at understanding the influence of man along the coastal strip including areas around estuaries. The purpose of this chapter is to identify issues of conflict, highlight various anthropogenic impacts during the last two decades and delineate areas of concern along the open coastline of Goa.

COASTAL ECOSYSTEMS OF GOA

The open sea front of Goa is characterized by a combination of beaches, rocky shores and headlands (wooded or bare) which protrude into the sea. These promontories are composed of basaltic or metamorphic formations capped by laterite and intruded by basic igneous dykes. Linear sandy beaches are located between promontories; sandy pockets are often found at the base of coastal hill slopes. The width of the beaches varies between 50 and 180 meters. Of the 105 km long coast, more than 70 km comprise sandy beaches, all backed by several rows of 1 to 10 m high sand dunes which extend almost half a kilometer or more before merging with the hinterland coastal plain.

Five key coastal stretches are characterized by conspicuous sand dune complexes as follows (Mascarenhas, 1997).

1. Querim - Morjim sector with pristine beaches and turtle nesting sites (Anonymous, 1997a), including three creeks lined by mangroves and located behind sand dunes;
2. Chapora - Sinqerim belt;
3. Caranzalem - Miramar (Mandovi estuary), the most prominent dune belt within the estuaries of Goa;
4. Velsao - Mobor linear stretch being the longest strip of the most exquisite dune system of the entire coastal zone of Goa, and

5. Talpona - Galgibaga strip, presently a pristine area. In addition, the coastal stretches also consist of several sandy areas and secluded coves backed by cliffs, rocky shores, headlands or promontories and wooded or bare hill slopes. Some uninhabited islands with an appreciable forest cover are found off Goa.

From north to south, the coastal zone of Goa is traversed by seven major dynamic estuarine rivers and four minor river systems. The Combarjua canal is the only connection between two such major rivers. Most of the major rivers which cut across hinterland formations originate in the western Ghats, across the border (Alvares, 1993). All the rivers are lined by dense mangroves, except at places. Several islands and shoals inhabited by thick mangroves are found within the rivers, the Choraao island being the most prolific. The tidal effect can be felt more than 40 km in the hinterland.

Throughout the course of these rivers, one can find an intricate network of creeks and backwaters scattered all over the coastal zone. A luxuriant growth of mangroves (some of which are degraded) and associated swamps can be observed in most water bodies. The most prominent and extensive backwaters with mangroves are located east of the capital city of Panjim.

The coastal plain of Goa varies in width. In the northern part, it extends to about 35 km, virtually to the base of the western Ghats, whereas it is about 20 km wide in the central part. In the southern part, the coastal plain is less prominent, identified only adjacent to the two rivers; this sector is mostly occupied by evergreen forests.

In general, the coastal plains comprise an intricate system of wetlands, tidal marshes and cultivated paddy fields, all intersected by canals inland lakes, bays, lagoons and creeks. All the rivers and the extensive backwaters in the hinterland are governed by regular tides, which raise or lower water levels by 2 or 3 meters daily. The prominent lowlands found adjacent to most of the rivers are locally known as "khazan lands", a term which denotes land reclaimed by gradual filling of the shallow seas. Most of these lowlands are almost at and even below sea level.

METHODOLOGY

Issues discussed in this chapter form a part of a larger study being conducted over the past two years; this work is still continuing. Extensive field checks have been regularly carried out along the entire coastal zone of Goa; more than 200 sites (including backwaters) were inspected and surveyed, and detailed physical data and ground truth

observations have been collected with which the areas of concern can be identified. Various types of geological samples of different landforms including dune sands were also collected. The photography of natural features of various coastal ecosystems has been undertaken to justify their ecological importance and their intrinsic value, and also to depict the present coastal scenarios. Violations of coastal zone environmental regulations have been noted where they exist; this exercise mostly consists of identifying man-made structures in wrong places along the coastal tracts. Existing toposheets and recent satellite imageries were also referred to; these specific details are being published elsewhere.

Various official and other reports, published and unpublished, have been made use of for comparison with our data. Discussions with respective officials, planners, bureaucrats, scientists, politicians, senior citizens and natives or locals concerned with coastal issues are of immense use from the point of view of problems and conflicts, planning and management and also in reconstructing past scenarios for a comparison with the changes observed at present.

PROBLEMS AND CONFLICTS

Since 1982, there have been a number of official reports on various aspects of coastal issues, policy matters regarding coastal activities, land use and tourism. The Master Plan for Tourism development (Anonymous, 1987) describes infrastructural problems and classifies the development into tourism development areas, tourism resort areas and village tourism areas. The Regional Plan for Goa (D'Souza et al., 1988), a more comprehensive document, highlights detailed town and country planning policies, aims at rationalisation of disparities in development, discusses integrated rural development, environmental conservation and measures for the improvement in the quality of life.

Although these documents were published in public interest, they are not readily available for public reference, and unfortunately, all environmental plans have been shelved. All these documents have therefore turned into an exercise in futility (Anonymous, 1998b). Moreover, the government brought an amendment empowering itself to modify the Regional Plan whenever required; this plan is now obsolete. Thus, a sincere attempt to advocate sustainable development has been ruined.

In Goa, human pressures on the coasts are being felt since the early 1970's when the revenue potential of tourism was identified. The first starbed beached resort was set

up at Sinquerim in 1974, the second at Dona Paula in 1982 and another in Majorda in 1984. Since then there has been a dramatic growth and a proliferation of innumerable edifices such as coastal hotels and resorts, residential flats, dwellings, small restaurants, beachside bars, roads and beach shacks along and across the coastal zone, but most of which are located on sandy areas as dunes. Some of the surveys indicate that the growth is uncontrolled (Sawkar et al., 1998; Chari, 1998; Mascarenhas and Sawkar, 1998) and as such several coastal areas are overcrowded (Wilson, 1997). This growth resulted in an undesirable over urbanization of coastal regions with an associated loss of biodiversity and deterioration in the quality of life.

Since there is a heavy competition over limited coastal space and resources with a consequent rise of land prices, the coastal space utilisation has now turned into a delicate issue mostly because of various types of conflicts on different topics (Alvares, 1993; Anonymous, 1995). Discordant views are being regularly expressed between real estate developers, builders, planners, policy makers, bureaucrats and politicians who insist on shore front "development" under the banner of demands, and environmental scientists and NGO's who insist on basic ecological and environmental principles. Therefore, there is a vertical split with perceptible differences of opinion when coastal zone issues are to be tackled.

The builders lobby, real estate developers and resort owners are the leading players in the present construction activity. Consequently, the weaker sections of the society, for example, are being pushed away from their traditional lands and even professions as traditional fishermen lose space for their age-old fishing activities. Considering charges of corruption against government department officials and innumerable infringements, which are going unchecked in the coastal zone, the builder - politician nexus is suspected.

With various such problems in view, and since uncontrolled development had started along the coastal zone of the country, the Ministry of Environment and Forests (MoEF), New Delhi, enacted a legislation called the Coastal Zone Regulation (CRZ) Notification (Anonymous, 1991) issued under the Environment Protection Act of 1986. The main purpose of this notification, which lists various rules and guidelines, was to control and minimize environmental damage to coastal stretches including estuaries and backwaters. No Development Zones (NDZ) which had to be measured from the High Tide Line (HTL) were notified for beaches, rivers and backwaters. Accordingly, all coastal states of India were bound to formulate coastal zone management (CZM) plans

classifying coastal stretches as coastal regulation zones, based on the nature of existing ecosystems and/or development. The CZM plans (Anonymous, 1996a) prepared by the state of Goa were rejected (Anonymous, 1996b) as the document contained some flaws. In the meantime, flagrant misuse of coastal spaces on a national scale forced some environment conscious citizens to file a public interest litigation based on which the Supreme Court of India validated the CRZ Notification on 25 April 1996. In June 1996, The MoEF requested the National Institute of Oceanography, Goa, for information on the eco-sensitive areas of coastal Goa. After a detailed survey, all related data were submitted to the MoEF, in August 1996, in the form of an unpublished report (Anonymous, 1996d). The final approval of the plans, with certain modifications to be incorporated, was issued in September 1996 (Anonymous, 1996e). This is the prevailing law, which governs developmental activities along the coasts, rivers and backwaters of Goa.

Despite clear legislations in place, it is observed that a large number of structures presently found in sandy areas close to the beach tantamount to blatant violations of CRZ regulations. Many constructions have been stopped by the courts (Anonymous, 1997c; Anonymous, 1998a), some judicial cases are pending, some structures were demolished but were subsequently rebuilt in the same place. Different types of infringements in the coastal zone and their legal implications have been documented elsewhere (Alvares, 1993). Recently, based on site visits (state government committee) in 1996, more than 20 luxury hotels and resorts were issued show cause notices for violating CRZ regulations, a fact admitted by the state legislative assembly.

Therefore, following complaints from citizens and NGO's, the first writ petition was filed in 1988 and have continued since then. Courts have intervened in coastal matters for a variety of reasons as, in some cases, constructions started before obtaining requisite clearances. Letters from concerned individuals have been converted into writ petitions. Similarly, courts have ordered hotels to remove all structures within 200 m area, including houses, rooms, wells, roads, fences. The state government was also ordered not to allow constructions within 200 m from HTL (Anonymous, 1996c). Courts have also ruled that disturbing sand dunes threatens coastal ecology and hence sand mining leases had to cancelled. Stay orders have been imposed in several cases, the latest being a resort in Baga and a construction in Utorda (Anonymous, 1997,c; Anonymous, 1998,a).

The CRZ legislation was apparently hurt the powerful builders lobby, resort owners and influential members of the government some of whom had already acquired

large tracts of prime coastal lands (Anonymous, 1997b; Anonymous, 1997d). Thus, the CRZ Notification was sought to be criticised and misinterpreted to suit vested interests, as such defeating the very purpose for which it was enacted. The outcome is what we see today (Figure 12.1): an unprecedented and haphazard growth of coastal structures with consequent alterations of the face of the coast.

HUMAN INTERFERENCES

Reference to ancient documents, maps and planning literature, supplemented by discussions with concerned individuals offer valuable information about the past. The effects of development on the coast can be assessed by comparing the coastal configuration and topography prior to major human occupation with conditions that exist today; this approach has been attempted wherever possible. In Goa, to our knowledge, only isolated data on human intervention on the coast is available, and as such, we do not have comprehensive details about the present scenario along the entire coast. Major factors responsible for coastal degradation are described in the sections to follow.

1. Impact of construction activities on sand dune fields

Since the 1970's, heavy construction activities and associated infrastructure requirements of the tourism industry have led to uncontrolled and haphazard growth of many coastal stretches as several coastal belts are overbuilt. The northern Baga-Candolim strip is a classic example as, at many points there is no proper public access to the beach. Here, the entire coast has turned into a continuous row of hotels and resorts (Figure 12.1). It is therefore obvious that these coastal areas have crossed a saturation point (Mascarenhas et al., 1997; Sawkar et al., 1998; Rosario, 1998). Whereas Colva and the Cavelossim-Mobor areas of central Goa will meet the same fate in a short time, Palolem in the south will follow very soon.

Compared to all coastal geomorphic features, sand dunes have borne the maximum brunt and have suffered the greatest from indiscriminate anthropogenic pressures (Lobo, 1988; Mascarenhas, 1990, 1996a & b). Large scale conversion of dune belts has taken place, and thus, the functions of a dune ecosystem virtually changed to a residential area. These effects are identified wherever man-made structures have encroached on dune fields (Figures 12.2 and 12.3). These impacts can be observed along most of the sandy coast of Goa, particularly from Baga to Mobor including the two major estuaries in between.

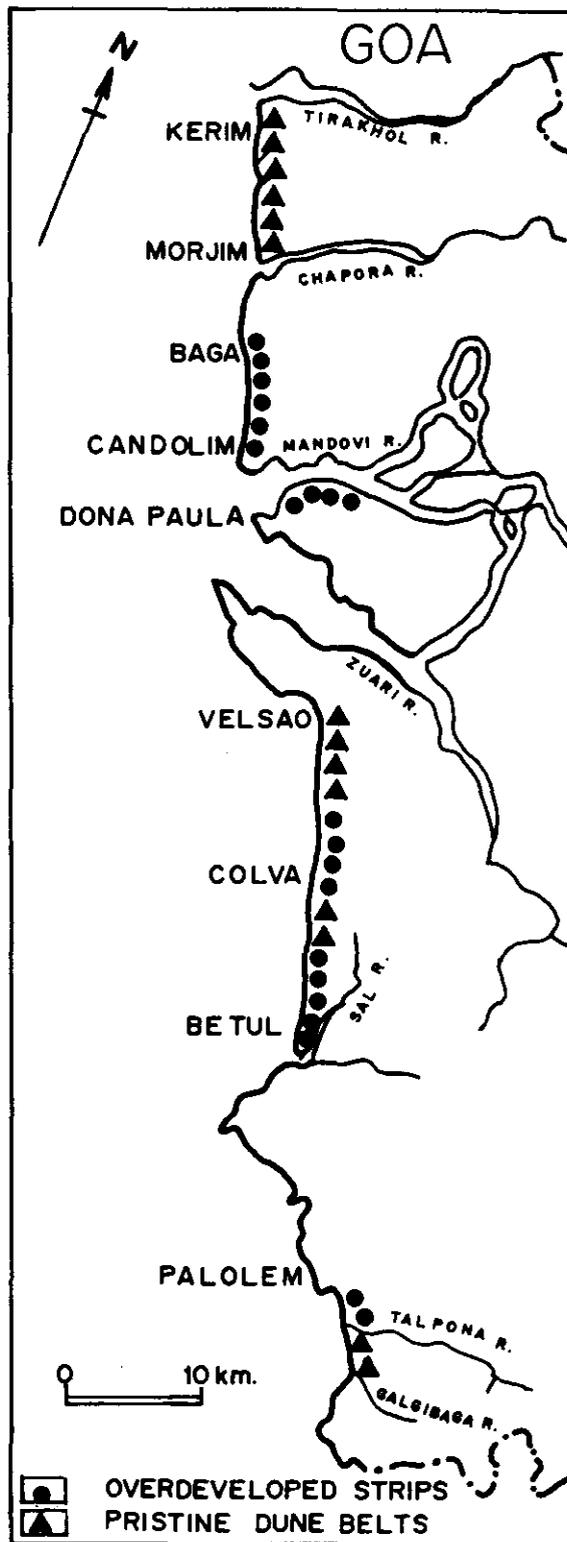


Figure 12.1: Map showing coastal strips which are overbuilt and areas where pristine dune belts can still be found.



Figure 12.2: A resort which was being built on the dunes at Baga, less than 50 m from HTL. Being a violation of CRZ, the project was stopped by the courts (Photo: August, 1996).



Figure 12.3: Residential dwellings at Miramar being built on a dune complex that was completely levelled; the former dune system is now a residential area (Photo: May, 1992).

Our studies along all dune belts of coastal Goa clearly show that high dunes have been razed, levelled, flattened or simply removed so as to make place for hotels, resorts or other structures. Large dune areas are thus found obliterated and damaged due to human intervention. All these anthropogenic activities have resulted in irreversible alterations to the dune systems as removal of large volumes of sand has created a negative sand budget, which in turn has affected their stability. Many parts of the coastal zone have changed from virtual wilderness to areas where buildings are mushrooming, and as such, many of the coastal stretches bear little resemblance to the primitive shore that existed before.

Several structures have been identified on the beach - dunes along the HTL, the most prominent being a resort at Miramar and many other smaller ones at Anjuna and Palolem. Excavations and removal of dune sand close to the beach have created deficiencies in the volume of sand. All these sites are precisely the ones where significant erosion has been noted. Although the erosive processes are localized at the moment (except at Miramar), it is found that these hard structures which are in direct contact with marine water are mainly responsible for shoreline erosion, as clearly observed at Palolem. Pertinent details are discussed in later sections.

2. Impact of dune sand extraction

Dune sand deposits have been under constant pressure for various reasons such as:

- (a) the common man uses sand (on a low scale) as cement mixture for houses and homes,
- (b) industrialists and builders plunder sand which is used as a raw material for a variety of construction purposes,
- (c) all coastal resorts and hotels located in sandy areas find sand as a readily available resource, and
- (d) levelled dunes can be converted into plots for further development.

Permission was required to mine sand during the erstwhile Portuguese regime. After liberation in 1961, sand mining leases were granted to private parties for as long as 20 years (Alvares, 1993). Even during the late 1980's, there were sand mining sites at Anjuna, Baga, Candolim, Arossim, Benaullim, Cavelossim and Mobor. As a result, thousands of tones of sand were extracted and even exported outside the state (Alvares,

1993). Following protests from people and expert advice from the scientific community, in 1983, the state government issued orders cancelling all leases. Nevertheless, sand extraction continued unhindered till 1988 when the courts intervened decisively forbidding sand mining. Our observations however show that clandestine sand extraction still continues (Figure 12.4).

The dune sand extraction has shown many impacts in the form of danger signals (Lobo, 1988; Anonymous, 1997e). Saline water entered paddy fields in the hinterland at Mobar; fruit bearing trees were destroyed. In 1977, a dune which was removed left a scarp/gap through which storm winds blew tonnes of sand onto the hinterland paddy fields affecting paddy output and fruit trees which were scorched by salt air (Alvares, 1993). At Varca, large amount of sand from dunes over a wide area were plundered by contractors to supply sand for constructions that made the area flat and featureless. In 1977 and 1978, disturbances of dune systems resulted in a storm surge in Mobar, and attack by storm waves and inundation in Majorda, Betalbatim, Varca, Carmona, Cavellossim (Lobo, 1988). The elimination of dunes has lead to levelled areas, which are later converted into plots. Thus, dune sand extraction has shown disturbances in the form of erosion and salt water invasion inland as such anthropogenic activities work against the sound ecological principles of the coastal zone, the dune systems in particular.

3. Effects of roads on sand dunes

Access roads are seen at many places along the coast, being more concentrated on the dunes of Baga - Sinquerim sector, the rest being found in the south. Roads over the dune belts have lead to obliteration of dune topography (Mascarenhas, 1996,a), removal of sand, levelling of dunes, desecration of dune vegetation which acts as sand binders, all of which generate loose and free sand resulting in its excessive mobility. In all cases therefore, such roads are covered, sometimes in totality, by a layer of sand; this is a recurring process. Such a phenomenon is very evident wherever roads occupy former dune fields, and very conspicuous at Calangute and particularly the parking lot in Colva. In fact, each and every approach road to the beaches is covered with a layer of sand.

The Miramar circle, which was built about more than 100 years ago, can be cited as a human failure. During windy days in summer, large quantities of dry sand are blown inland. The beach, which is excessively frequented, is devoid of dune vegetation, and therefore, bare in most of the areas. The result is that the Miramar round-about and the radiating roads are covered by sand for most part of the year, creating dangerous road

conditions for traffic. Imbalance in the sand budget has rendered sand mobile, and comes to occupy its rightful place: the circle, now located on former sand dunes.

The new coastal road to Dona Paula will meet the same fate. A major part of the road is laid on dune sands. It is already evident, at least at two places, that sand is attacking the road where small accumulations of sand are noticed, although on a low scale. If remedial measures are not taken, it is obvious that this problem will aggravate further and the road (as in other areas discussed above) may be drowned in sand, thus creating hazards to drivers in general and motorists in particular.

4. Impact of beach shacks

Beach shacks comprise simple huts, made of bamboo and coconut tree leaves, are of a purely temporary nature. In the past, there were few of them but at the moment, the ever increasing competition has resulted in their proliferation as almost 220 shacks (and numerous unauthorised ones) have been granted licences for about 60 km of beach length (D'Mello, 1997). Strictly speaking, since a sandy beach falls under CRZ-I category, even a temporary stall such a shack cannot be allowed on the beach according to the CRZ notification. However, since shacks are seasonal and form the livelihood of hundreds of unemployed individuals, it appears that the beach shacks have come to stay.

The profile of a sandy beach keeps changing and adjusting itself towards an equilibrium, as a beach generally restores itself. Therefore, beach shacks, which come and go are not expected to induce any large-scale damaging effects from the environmental point of view. However, their rising numbers have resulted in severe crowding which is gradually leading to over exploitation of limited beach space. As they are frequented by a large number of people, shacks generate huge quantities of garbage, which unintentionally mixes with sand, and hence litter large areas, and invariably finds its way into the estuaries.

Shacks are bound to occupy only the upper part of beaches; but many of them are seen beyond these limits. The adjacent sand dunes are thus invaded, as seen in Candolim-Calangute belt. This is where ecological degradation takes place as dune vegetation is uprooted and cleared to make place for them, an environmental damage that can be significant and sometimes irreversible. This is also because sand dunes are flattened and as such lose their intrinsic value. Therefore, beach shacks, although simple in design, have not only flattened dunes and added litter onto the beach, but have their own share towards coastal degradation.

5. Influence of recreation on dunes

Activities of pleasure seekers and picnickers are not restricted to a particular area, but can be observed almost along the entire coast particularly where sandy stretches as the dunes are found. Two dune areas, in Baga and in Candolim, are regularly used as a football ground by the villagers and also tourists. Although these recreational activities may not be termed as harmful to the dune environment, it does create ecological degradation in areas which are most sought and frequented. Driving on the beach which is an illegal activity is often noticed, parking of vehicles on dunes (Figure 12.5), play fields on dunes, continuous movement by pedestrians and cyclists are factors which destroy dune vegetation, flatten dunes, induce shifting of sand and renders the sand mobile, thus affecting the stability of sand dunes.

6. State of dune vegetation

The status, importance, uses, types, ecological aspects and management implications of dune vegetation have been studied earlier (Desai, 1995). Dune vegetation, an integral part of the dune ecosystem, plays a crucial role as the vegetal cover acts as an effective sand binder and hence promotes the stability of dunes by reducing erosive processes. Dune vegetation is vulnerable to human interference due to its fragility. Our observations have revealed that sand dune vegetation is in various stages of degradation in different parts of coastal stretches. The maximum damage appears to be along the Baga-Candolim strip.

There are innumerable anthropogenic factors which are responsible for the destruction of dune vegetation: real estate owners who prepare plots for buildings, hotels or resorts clear all dune vegetation; roads are laid over levelled dunes thus eliminating the vegetal cover; beach shacks and various other recreational activities have shown similar effects as dunes are rendered bare. Nevertheless, there are several isolated tracts along the coast where sand dune vegetation is still found in its pristine form as in the northernmost coastal strip of Goa.

7. Litter on beaches

Litter found in sandy areas is attributed to various sources. With the ever increasing pressure on the coastal belt, and as more people are moving towards the coast, our beaches are getting dirtier. The Baga-Candolim stretch, Miramar, Colva and even Benaulim can easily be singled out. For instance, the annual sea food festival held at Miramar produces heaps of garbage, a part of which gets mixed with the sand. It was



Figure 12.4: A huge sand dune near Miramar has been mined and sand used for constructions in the vicinity; a building now stands in the place of the dune (Photo: May, 1992).

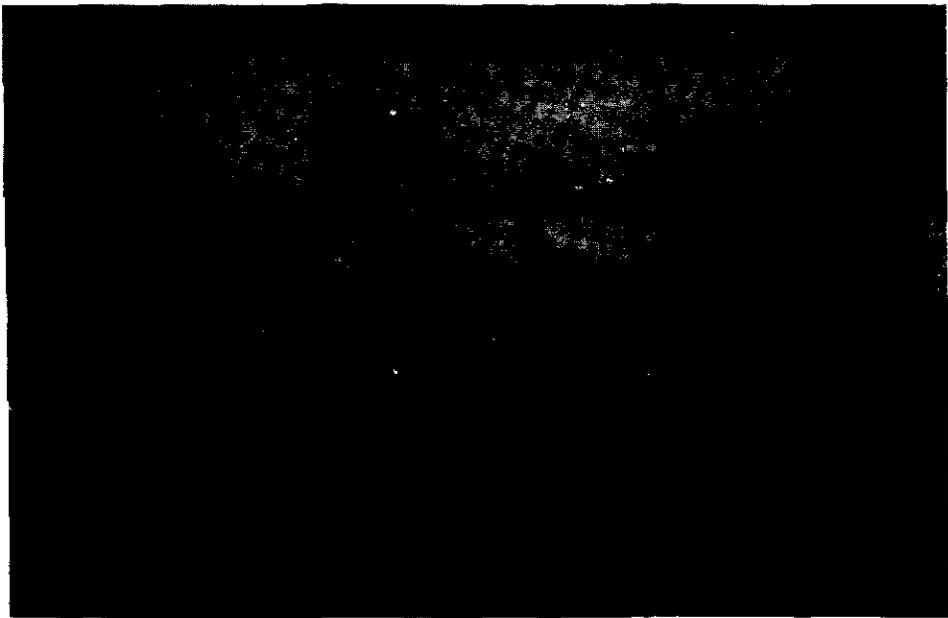


Figure 12.5: A large area on the dunes being used for parking all types of vehicles at Candolim. The dunes are now flat, bare and devoid of vegetation (Photo: January, 1998)

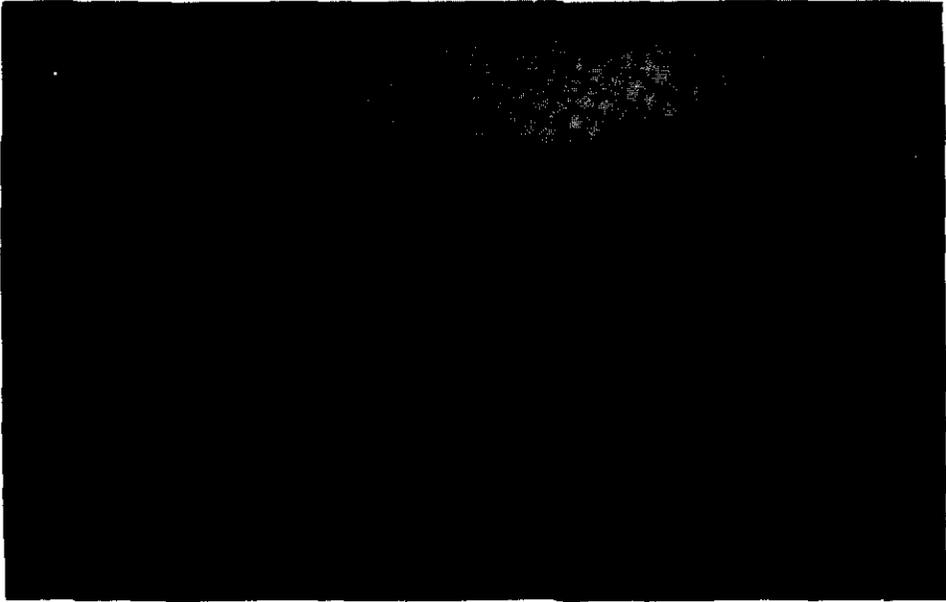


Figure 12.6: Brutal cutting of a hill slope for road widening for the bridge approach roads at Betim; over the years, the loose mud has deposited in the Mandovi river creating shoals at places (Photo: December, 1997).



Figure 12.7: A site of vigorous erosion where the original beach at Campal has vanished. A resort is being built at a place prone to erosion (Photo: January, 1998).

noticed that a large pit in the dunes at Calangute is used to dispose garbage by the public at large. At Colva, the prominent creek is used as a dumping site for all types of waste by stall owners in the vicinity. Hotels in south Goa produce large dumps of non-biodegradable garbage which along with sewage is discharged in the river Sal. Interestingly, large rafts of plastic waste were found floating in the river Sal; a close look revealed plastic items (and even seals) dumped by starred hotels and not by the locals.

Litter scattered along the coast ultimately finds its way into the rivers or the sea and is subsequently thrown back on the beach as can be observed along most beaches during the post monsoon period. According to newspaper reports, the Navy identified large rafts of plastics floating in the sea off Goa. Therefore, irresponsible disposal of garbage in the coastal zone has resulted in a progressive build up of plastic waste in our estuaries.

8. Salt water ingress

Till a decade ago, there were no complaints of salt-water intrusion into coastal aquifers. Problems started in recent years when a large number of bore wells with powerful pumps were installed within the 200 m limit, notably by the builders, the hotel industry and also by private parties (Alvares, 1993). It is to be noted that the pumping of underground fresh water in the dune belts is forbidden by CRZ regulations particularly within 200 m from HTL. Beyond this limit, permission of competent authorities is needed. Despite this, several infringements are reported, as large number of cases were detected beyond 200 m where borewells are regularly used to draw water particularly by the hotel industry (Alvares, 1993). In some coastal places, water is openly sold by private parties to hotels for use in their swimming pools. Thus, this ban is routinely violated. Since domestic water supply is grossly inadequate to meet the rising demands of hotels for their lavish use, no action is taken on builders and hotel owners for tapping underground water for consumption.

This kind of unchecked exploitation of ground water has resulted in lowering the groundwater table and seepage of saline water into fresh water wells. In 1992, several wells of Mobor peninsula were invaded by salt water (for details see Alvares, 1993). Coastal aquifers in north Goa have been affected by ground water fluctuations and seasonal increases in salinity, as wells near the sea shore show influence of salt water encroachment as it is hydraulically connected to coastal water table; therefore ground water quality is deteriorating (Chachadi and Kalavampara, 1995).

The outcome of deliberate tampering with coastal aquifers under dune systems is distinctly demonstrated in south Goa. A resort located between the sea and the river excavated a huge dune area to be converted into an artificial sweet water lagoon without a proper assessment and despite repeated warnings against this adventure. To their dismay, saline water trickled, attacked and filled the artificial lake and today we only find a salt water lagoon. Such an unwanted human interference with the dune system is a clear example of salt water ingress into a former fresh water aquifer.

9. Human activity on coastal hill tops and slopes

The coastal strip of Goa also consists of evergreen hills and promontories with wooded or bare hill slopes which often intersect beaches and jut into the sea. Forests along hill slopes offer an intrinsic natural beauty and also contribute towards slope stability. Coastal hill slopes which control erosion and also recharge aquifers are integral parts of the coastal zone ecosystems.

Of late, we find lot of building activity on plateaux and coastal hill slopes. Frenzied development can be observed along the hill slopes of Dona Paula-Bambolim stretch, along the river Zuari as well as within the Mandovi estuary, on the banks and slopes opposite the city of Panjim. A large number of constructions have gradually taken over and encroached the coastal hill slopes, some of which have almost reached the water line, whereas others, perched on the edge of the plateau have constructed steps of concrete which lead to the water. In addition, hill slopes at many other places within estuaries have been brutally sliced for widening of roads as in Betim (Figure 12.6) and laying of railway tracks as in Cortalim, Talpona and Galgibaga.

The environmental impacts of such actions can be manifolded. Human activity along hill slopes has lead to mud flows into the rivers resulting in heavy siltation at places. This is clearly evident on either side of the railway track at Talpona estuary. Construction activities are not only spoiling coastal aesthetics but also gradually leading to the degradation, deforestation and concretisation of coastal hill slopes. Shoals and mud flats which are promptly colonised by mangroves within rivers are a direct consequence of negative impacts due to interference of man along these slopes. Coastal hill slopes, particularly the wooded ones which recharge aquifers and arrest erosion, need to be protected from any development whatsoever.

10. CRZ violations

Infringements in the CRZ is a burning problem in Goa, despite clear rules and guidelines. The notification has been deliberately misinterpreted to suit individual interests. The result is seen in the form of blatant large scale violations of CRZ regulations observed along the open sea front as well as along the rivers and backwaters. The sanctity of this unique regulation is therefore at stake due to the following activities:

Buildings and constructions: Based on our field observations, it is clear that there are numerous irregularities along coastal sandy stretches. The setback lines as stipulated in the notification have been conveniently set aside (Anonymous, 1997c; Anonymous, 1997d). There are many such cases in the Baga-Candolim sector; the Calangute panchayat has been hauled up for the maximum number of environmental violations (Anonymous, 1996c). Miramar-Campal area also deserves mention (Figure 12.7). During the last few years, south Goa dune belts are under assault. The Mobor peninsula which was once declared as a green cover area, has witnessed a frenzied proliferation of resorts which have violated almost all rules stipulated in the environmental guidelines (Alvares, 1993; Anonymous, 1997b). Our observations show that the latest negative developments are in Palolem where a number of small buildings have mushroomed close to the beach, even on the HTL. A concrete ramp to facilitate vehicles on the beach is probably an unprecedented infringement along the beaches of Goa.

Sand extraction: Although prohibited by law, unscientific clandestine dune sand extraction which has gone unchecked is rampant at several sites along the sandy coasts (Anonymous, 1997e). A large dune near Miramar was almost completely mined as recently as 1992 (Figure 12.4).

Bore wells: Since piped water supply is often irregular and does not meet the existing demand, many real estate owners, the hotel promoters in particular, resort to unfair practice of ground water tapping by sinking bore wells (Alvares, 1993). Although several defaulters have been booked, many such cases go unnoticed and clandestine operations such as selling ground water continue unabated.

Roads: In some cases, ancient paths used by beach users are slowly being converted into roads some of which are already tarred, whereas others are incomplete and/or stopped by legal means.

Fences/public access: Several promoters of hotels and resorts have put up fences in the no development zone, sometimes up to the HTL. Existing law does not allow

fences or walls within the 200 m zone and yet they are frequently seen, at Calangute for example. Courts had to intervene in some cases so as to restore public access to the beaches. Several resorts in north and south Goa and a luxury hotel in Dona Paula can be cited as examples.

DISCUSSION

The relationship between human activities and coastal changes and evolution is not fully understood (Nordstrom, 1994a and 1994b). There appears to be a lack of scientific interest in the evolution of developed coasts because geomorphologists do not study human altered coastal systems, but mostly deal with landscape evolution at larger time scales. Nevertheless, there are several reports on the effects of man made structures on the coastal zone ecosystems world wide. We can also find field oriented studies on the effects of buildings, dwellings and roads on the adjacent coastal beach-dune systems as well as impacts of tourism and allied activities on the coastal morphology. The present study mostly aimed at coastal sand dune ecosystems is therefore one such initiative in this direction.

The anthropogenic impacts discussed above clearly indicate that construction of resorts and buildings, dune sand mining and roads on sandy strips are the three major factors responsible for the large scale degradation of coastal sandy strips. In addition, flagrant violations of prevailing legislations have complicated matters further as changing coastal configuration has remained unchecked. The consequent result is the elimination of coastal sand dunes; this is the single largest irreversible impact that is being faced at present.

Impacts such as the marine salt water ingress which is seasonally showing up in coastal aquifers is attributed to excessive ground water withdrawal; although somewhat under control, this effect could lead to alarming problems if these trends continue. In comparison, all the remaining man-made effects related to beach-dune systems can be termed to be minimal as, in most cases, these impacts can be fully reversed.

The main prerequisites for the formation of sand dunes are wind, sand and vegetation - three elements with complex and dynamic interactions (Carter, 1988). Wind plays the most important role; its direction, frequency, duration and speed are to be considered as only winds with a speed greater than 16 km/hour can lift, displace and transport fine dry sand (Paskoff, 1994). This is more so along low gradient beaches

particularly when they are sub-aerially exposed at low tides, and when strong winds blow perpendicular to a particular coast. Vegetation behind the beaches also play a key role as these objects act as wind breakers which force wind to drop sand along its path; vegetation thus traps and stabilises moving sand (Carter, 1988; Paskoff, 1994).

The first step in the formation of a dune is a berm which is an accumulation of sand brought up by the waves on the beach at a point just above the highest high tide. The berm swells due to the eolian import of sand. Thus, these small sand mounds which form, finally develop into a continuous chain of sand dunes. These eolian bedforms can be symmetrical, several meters in height and can differ from place to place. Their dimension depend on the degree of evolution and the aptitude of vegetation to trap and retain sand. The destruction of sand dunes in Goa is almost exclusively anthropogenic (Figures 12.2, 12.3, 12.4 and 12.5). This can be clearly observed in Baga-Candolim where resorts and hotels are dense, Miramar-Caranzalem, and Betalbatim-Mobor, but more particularly at Cavelossim. Although they had remained free from human intervention, they are now too frequented subsequent to the promotion of coastal tourism. They have thus suffered greatly from the assaults of tourism and other related activities which have spread over coastal spaces during the last two decades or so. Their existence is therefore in peril: destabilisation due to the degradation of their vegetation which is sensitive to the human presence, flattening due to sand extraction, or their destruction and elimination due to the creation of plots by the sea side. Their disappearance is total where sand is being extracted for construction activities, and also where dunes have been simply levelled and flattened to erect buildings and resorts.

Similarly, the destruction of dune vegetation (Figure 12.5) is crucial as sand binders appear to be exclusively anthropogenic and attributed to several factors discussed above. In several areas, the frequent visits of picnickers, tourists, revellers, vehicles, cycles have rapidly degraded sand dune vegetation which is particularly sensible to human interference. Native plant species are prevented from colonising because of the preference for the lawn grass and exotic shrubs for landscaping. Real estate developers and owners of resorts have replaced natural vegetation with gravel, cemented paths, or simply maintained an unvegetated barren surface which is used for other purposes such as parking (Figure 12.5). Natural dune vegetation can only be seen on existing stretches which have so far remained free from development.

Littoral sand dunes which constitute spaces of recreation complementary to the beaches behind which they are located, are edifices of extreme fragility and are essential for the sedimentary and ecological equilibrium of coastal environments (Carter, 1988). Their

destruction can sometimes be attributed to natural causes. If the vegetation is destroyed by prolonged dry periods, or other reasons, they are destabilised as they are laid bare. If subsequently, a dune is cut by high waves leaving an escarpment, the latter is capable of increasing wind speed manifold. Wind then opens cavities through which free sand is liberated and bombarded inland thus attacking populations and buildings located along its path.

Coastal dunes show a dynamic natural behaviour which has to be understood, respected and not contradicted, as is often being done, by anthropogenic influences (Paskoff, 1994). Dunes cannot simply follow a pattern which is not naturally theirs. Thus their intrinsic value is lost (Nordstrom, 1990), and as a result, consequences are noticed on the beaches with which they are associated (Carter, 1988). A sand dune belt has multiple functions and hence of immense value to coastal populations as mentioned below.

- i. The beach-dune environment is a highly organized system, features of coastal stability, the result of a delicately balanced ecological equilibrium between the forces of the ocean and loose coastal sediments,
- ii. The dune environment is classified as edifices of extreme fragility, sensitive and vulnerable due to its propensity for changes under even slight environmental stress,
- iii. Sand dune chains, as high as 10 m in Goa, are categorized as Nature's line of defence as they arrest blowing sand, deflect wind upwards, assist in the retention of fresh water and protect the hinterland from attack by waves,
- iv. Coastal sand dunes serve as "sand banks" (Paskoff, 1994), are sources of beach nourishment and also neutralize and dissipate wave and current energy in the coastal zone and maintain the sedimentary and dynamic equilibrium of the dune-beach ecosystem,
- v. Dune vegetation acts as sand binders and preclude loose sand from advancing inland and thus menacing coastal populations,
- vi. Dunes protect the hinterland from winds and other forces and hence make the zones behind dunes as areas of peace and tranquillity,
- vii. Sand dunes of Goa are about 5000 years old (Sriram and Prasad, 1988) but can be as old as 6400 years (Kale and Rajaguru, 1983) and

- viii. The predicted sea level rise is bound to inundate coastal areas with a profound effect on the coastal zone; dunes stand guard against any sea level rise as they will act as Nature's wall of defence. Therefore, these geomorphic edifices have to be preserved at all costs.

It must be mentioned that sand dune ecosystems were not included within the ambit of CRZ-I in the original notification. Since sand dunes are sensitive and fragile geomorphic features that are vulnerable to even small environmental stress, and since they act as Nature's line of defense against the forces of the ocean, a case was made for sand dunes fields as CRZ-I (Anonymous, 1996d; Mascarenhas, 1996b). This was following the request made by the Ministry of Environment and Forests (in June 1996), to the National Institute of Oceanography, Goa, to identify areas which are ecologically sensitive. Accordingly, a report was submitted to them in August 1996 (Anonymous, 1996d). Based on this report, and considering the ecological importance and immense use of sand dunes to society, the Ministry of Environment and Forests declared and classified the sand dunes belts under the CRZ-I category. Subsequently, in September 1996, the Ministry issued separate orders (Anonymous, 1996e) categorically directing that sand dunes are to be independently included under CRZ-I, a parameter that had to be incorporated in the coastal zone management plans of Goa. Therefore, in coastal areas characterized by sand dunes, no new constructions are permitted up to 500 m from HTL.

The damage and destruction of dunes, irrespective of the agents responsible, pose various consequences for the coastal environment (Miossec, 1988; Nordstrom and Gares, 1990). Disrobing a sand dune results in the formation of free sand which is rendered mobile; sand therefore keeps shifting (Figures 12.4 and 12.5). Along the coast of Goa, the transfer of sand landward far into the hinterland is a common phenomenon observed particularly during windy days at several places; the Baga-Candolim sector is one such example. The risks of inundation are increased when sand is removed on a large scale. Excessive pumping of fresh water leads to salt water ingress and contamination of coastal aquifers as identified at Candolim (Chachadi and Kalavampara, 1995). Elimination of dunes also induce erosion, as beaches are starved of the requisite sand budget (discussed below). All these factors adversely affect coastal equilibrium and hence its stability.

Research has revealed that recreation can have adverse effects on dunes (Vogt, 1979). Coastal buildings alter wind flow around them, reduce the velocity on the lee; *structures built on dunes induce localised deposition and cause local increase in the height of the dunes and reduce the inland migration of the dunes.* Even a moderate

development on dune belts strongly affect sediment transfers (Nordstrom and McCluskey, 1985). Buildings also change the location of accretion and scour on beaches and dunes. Large buildings cause a reversal of regional wind flow; wind blown sand accumulates against buildings, houses, boardwalks and roads creating a diverse dune scape, distinctly different from the one created under natural conditions (Nordstrom and Jackson, 1993; Nordstrom, 1994b). Sand accumulation on the roads can be seen at Miramar. In our case, the major drawback is that the human intervention on the sand dunes of Goa has never been quantified, an exercise which requires immediate attention.

Since sand dunes are eolian bedforms which are dynamic and mobile, they should be allowed and be able to evolve freely and naturally in form and space. Research has shown that dunes in certain areas have displaced and migrated naturally by tens of meters towards the sea as well as away from it as compared to their primitive location. This has been ascertained by successive aerial pictures (Psuty, 1988; Paskoff, 1994). Since a natural sand dune is in a natural equilibrium with the beach, if the beach retreats the dune should be able to do likewise (retreat) so as to assure its role as a sand reservoir in order to maintain the equilibrium between the dune-beach ecosystem. Since a majority of beaches are in a process of retreating due to a slow rise in sea levels, the dunes should also retreat landward by rolling on themselves. Such a mobility and flexibility of sand dune are rarely considered. For this, ample space is necessary and is to be reserved for migration and sand dunes should be at liberty to do so. The present style of development as observed along the sandy stretches of Goa, therefore, works against the natural behaviour of sand dunes. That was precisely the reason why our ancestors never occupied sand dunes, built houses and roads away from beaches and always lived behind sand dunes, a system that can still be observed along the entire west coast of India. Their wisdom to maintain a perfect coastal equilibrium cannot be questioned.

Erosion of beaches and dunes has been observed at several places along the open sea front and within estuaries. This phenomenon, although localised, is significant at Arambol, Anjuna, Majorda and Colva. A proper scientific proof pending, these events are attributed to annual changes that a beach undergoes as these areas regenerate themselves during the post monsoon period, as has been observed by the author over the last few years. Sea erosion is however most pronounced at Velsao and Agonda as evidenced by a large number of tall uprooted trees (Mascarenhas, 1996b). These are areas of periodic intense wave energy and heavy erosive tendency. These are instances of natural erosion.

Near Verem in the Mandovi estuary, the existing small sandy beaches are gradually disappearing. This is attributed to a series of walls erected recently, mostly by hotels. Similarly at Palolem, many hard structures have been built along the beach. This human intervention has resulted in shoreline changes, wherein the sea is advancing landward as observed over the last two years. A remarkable erosive activity is proved by breaches in concrete embankments and uprooted trees; marks left on these walls show a lowering of the level of the beach indicating that a large volume of sand has been washed away. The erosive activity at Palolem, attributed to human action, is definitely and undoubtedly irreversible.

The most alarming erosive processes are seen along the Miramar-Campal sector (Figure 12.7). The entire stretch which constituted a dune belt with a thick vegetal cover as late as the 1950's has now ceased to perform the functions of a beach dune-ecosystem. The dune complex no longer exists; buildings have come up in its place. A stone embankment was erected during the last decade; but erosion continues with full vigour as hardly any sand can be seen along this structure. The lighthouse which was once on the shore is now found in water and is hence under threat as it faces an imminent collapse. This is an example where the planners got the taste of their own medicine as the stone wall keeps collapsing. This is because hard structures increase the turbulence of waves resulting in the removal of sand (Kraus, 1988; Frihy et al., 1996); the beach at Campal has therefore disappeared. Despite the fact that the shoreline is prone to erosion, a huge hotel complex is now under construction on a dune at Miramar, precisely at a place where it should not have been (Figure 12.7). This is a classic example of a human blunder.

The coastal hill slopes and even promontories are unfortunately not covered by the CRZ Notification, although plateaus are ideal for future development. However, wherever buildings are coming up, leaving a reasonable setback from the edge of the cliff or hill slope is imperative, be it from the safety or environmental points of view. But in reality, this rule is not observed. The hill slopes are being invaded with impunity. If this trend is not reversed, constructions along coastal hill slopes are bound to assume alarming proportions in future.

Along western India including Goa, the rise in the eustatic sea level over the past decades is estimated to be 1 to 1.5 mm/year, based on tide gauge records along the west coast (Subrahmanya, 1996). Although a nominal rise in sea level will not affect population and structures at higher altitudes, it will have a profound influence on flat beaches, estuaries and lowlands. Such an effect may be less severe on the sandy beaches

of Goa as most of them have an appreciable gradient and, as such, the dunes are situated at a significantly higher level, beyond the reach of normal sea waves. However, in the event of a (predicted) one meter rise in global sea levels during the next century, the erosive capacity and storminess of the seas will increase manifold (Haq and Milliman, 1996). Such a scenario will eventually invade and erode beaches, the flat ones in particular, as large volumes of sand are expected to be washed away by stormy waters. Beach erosion is induced by rising seas which shifts wave action to progressively higher levels, leading to extensive and rapid erosion. This will in turn influence and modify the sand dune systems (Carter, 1988) as a large part of beaches may disappear. Therefore, these precautions ought to have been included in the coastal zone management plans as rows of beach resorts are located along the coastal belt. This important criteria is however conveniently omitted.

This is what brings us to the question of setback lines. Considering the fragility and mobility of sand dunes, it is imperative that NDZs be strictly enforced. Buildings should be located behind sand dunes. Free spaces are also needed along the edges of coastal plateaux which are ideal for future development. Similarly, in the event of a predicted sea level rise, the most cost-effective long term solution is to set aside land for future marine transgressions. Hence the imperative need for reasonable set back lines.

CONCLUSIONS

- Laxity in implementing and enforcing legislations has resulted in unauthorised structures and uncontrolled growth along the coastal zone. Blatant large scale violations of CRZ regulations are observed along the sandy stretches of Goa. Some structures are seen even along the HTL.
- Our study reveals that (a) construction of resorts and buildings on dunes, (b) mining of dune sands and (c) roads on sandy strips, are the three major factors which are responsible for the coastal degradation.
- Sand dunes have borne the maximum brunt and have suffered the greatest from indiscriminate anthropogenic pressures which mostly include haphazard construction activities. Pristine dune belts do however exist.
- Localised coastal erosion is observed wherever hard structures interfere with sea water. Such man-made problems are generally irreversible.

Mandatory setback lines are imperative. Sand dunes are landforms essential for coastal stability, they are ecologically sensitive, they are sometimes mobile and hence shifting in nature; the threat of an impending sea level rise will make dunes act as Nature's line of defense. These factors collectively demand that coastal dune systems be compulsorily designated as no development zones.

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