GREEN WALLS FOR KARNATAKA SEA COAST

(Honavar Forest Division - October 2010)

M. D. Subash Chandran,

G. R. Rao,

Prakash Mesta,

D.M. Vishnu

&

T.V. Ramachandra

Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560012

Email: cestvr@ces.iisc.ernet.in; energy@ces.iisc.ernet.in; mds@ces.iisc.ernet.in

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Chapter-1: BIO-SHIELDING OF THE COAST: AN INTRODUCTION

Sea shores the world over are characterized by deposits of sand or sand dunes wherever they are not bordered by rocky hills. The word 'beach' is used by most people to the sandy area that separates the sea from the land. The beach begins in the sand dunes above the high tide mark, the farthest point where the sand has been carried by wave action. It extends to the depth beyond which the wave action does not have sufficient force to move the sand particles. **Beaches and sand dunes represent flexible barriers which absorb wave energy during storms by moving and adjusting their shapes and position.** Sand dunes, however, cannot be viewed in isolation from other components of the coastal ecosystem. Sand dunes and beaches are interdependent that they have to be managed together. Sand dune management should be viewed within the overall context of **integrated coastal area management** (UNEP, 1998). From the point where the sand dunes are stabilized to a certain extent, the **backshore** region of the beach starts and extends down to a sudden change in slope, known as the **beach scrap (Figure 1-1).** The backshore generally contains one or more horizontal portions called **berms**. From the scrap the beach slopes seawards and is known as the f**oreshore.** The foreshore extends from the high water to the low water line, and may have continuous slope or a low tide terrace. Beyond the low tide level is the **offshore (Figure 1.2)**, which is submerged (Mukherjee, 1996).

Fig. 1.1: Stabilized beach backshore showing sudden change in slope, the beach scrap

Fig. 1.2: Backshore (with new mud road), foreshore (the inter-tidal region), from white sands to offshore, the permanently submerged part

The U.S. Environmental Protection Agency (1998) defines a beach as "the area of unconsolidated material, such as sand, pebbles, or rocks, that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves)."In other words, a beach is the sandy, pebbly or rocky shore of a body of water. The water body may be even a lake or estuary. Rocky coasts are very stable unlike the sandy one (**Figure 1.3**).

Fig. 1.3: Rocky coast of Apsarakonda, Honavar Forest Division

Erosion and accretion: Coastal **erosion** refers to the landward displacement of the shoreline caused by the forces of waves and currents. The sea can take away any unprotected shoreline especially the sandy beaches, if they are not supported behind by hilly terrain or if their vegetation is insufficient. Sandy beaches are dynamic sedimentary systems that naturally experience phases of erosion and accretion that operate over a range of time intervals. Frequent short term changes are seasonal erosion that mostly occurs in seasons when storms that generate erosional regimes are more frequent. Rapid erosion may also occur by high magnitude storms such as cyclones or low pressure systems. **Accretion** (deposit) of sand on beaches occurs during the more quite seasons when average swell waves deliver sediment back to the shoreline. Beach accretion is generally a much slower process than beach erosion. It may take several years for a beach to return to its original state after one major storm (Bhat, 2004).

Hegde, et al., (2009) have described erosion-accretion processes associated with the beaches towards the north and south of Sharavathi River in Honavar. Erosion takes place twice during the year, one during late May to early September (monsoon) and a minor phase during December to February. They also experience two periods of accretion, one during September to December (post-monsoon) and another during February to April. Northerly drift prevailing during the post-monsoon season favors spit growth across the river mouth from south to north, whereas the southerly drift during December to February is responsible for erosion of the portion of the beach to the north of the river mouth. The growth of a spit is at the expense of the beach to the north of the river mouth. Similar processes related to spit growth northward across the river mouths and retreat or narrowing of beaches to the immediate north of the river mouths were also observed towards the mouths of the rivers Venktapur and Gangavali in Honavar Forest Division. These processes cause narrowing of river mouths, spit growth across river mouths northwards, northward shift of river mouths as well as significant erosion of beaches to the north of these rivers (Nayak et al., 2006).

Causes of coastal erosion: Coastal erosion takes place due to the landward displacement of the shoreline caused by the forces of waves and currents. Due to its effect part of the shore gets invaded by the sea permanently or temporarily. Wave action carries away sand into the depth the ocean, or re-deposits the sand on another beach. Taking place through long time such loss of shoreline can be an irreparable loss. The factors that influence the coastal erosion are both natural and manmade.

Natural causes

- **Waves, currents and tides:** The sea never is calm most of the time. Winds passing over waters offshore or near-shore generate waves. Waters rise to varied heights as waves on absorbing energy from the winds. The waves, roll shore-wards, break on the shore releasing the turbulent energy that they gained from the winds. The wave energy is a function of the wave heights and wave periods. We often witness that obstructions with hard surfaces on the way of the waves, such as rocky shores or seawalls, or breakwaters resist the waves. Therefore when winds are strong waves rise high and move faster shorwards, dash on the hard surface and release the energy in splashes and sprays. On the other hand the porous sands of the beaches, on the way of the waves, provide a cushioning effect, absorb most of this violent energy so that the waves roll gently over the beach. The attraction of the moon and the sun elevates the water level that gradually raises the sea level from about one meter on some shores to several meters on some others depending on the geo-morphology and ocean characters. The movement of tides as well as rising and receding waves creates various kinds of water current systems that shift sediments on to the land as well as away from the land.
- **Winds, storms and cyclones::** Winds not only create waves but also shift dry sand from place to place on the sea beaches and in lands beyond. In sea beaches with scanty vegetation winds can be important causes of erosion. Storms and cyclones are high intensity winds, which when pass over the ocean contribute substantial energy to the surface water, which rise considerably and pound violently on the land for hours causing much erosion and irreparable damages along the shoreline.
- **Tsunamis:** These are unpredictable events caused by underwater earthquake, creating gigantic tidal waves, which while inflicting enormous loss of life and property may also permanently alter coastline morphology. The deadly Indian Ocean tsunami of December 2004 is still green in our memory.
- **Sea level rise:** The geological ages have witnessed the rise and fall of the sea levels several times. Since the last ice age sea level has risen by 110 meters. Today, due to global warming caused by increased input of greenhouse gases there has been a gradual rise in the sea level. Every millimeter of rise in the sea level can cause the sea swallowing about half meter of land.

Human impacts: Constructions close to the shore, sea walls, breakwaters, sand mining building of dams upstream in the rivers which affect normal flow of water and deposit of silt towards the confluence, as well as destruction of shore vegetation are notable human impacts that result in coastal erosion. Seawalls destroy eroding beaches first by reducing the size of the beach. As water moves in it eventually meets the wall, flooding the beach. The wave action causes the underlying sand to erode quickly, undermining the wall. Everything in front of the seawall gets eroded away and the waves start pounding on the wall itself destabilizing it. The pressure of water increases on adjoining beaches following construction of sea walls. Shoreline erosion in the northern regions of Chennai, Ennore, Visakhapatnam and Paradip ports has resulted due to construction of breakwaters of the respective port (Kumar et al., 2006). Mining of beach sands or tampering with the sand dunes in other ways, can lower the level of beaches and invite sea erosion. Dunes can be destroyed in places of unregulated tourism and where tourist resorts multiply. In beaches where wave energy is high it will be difficult to protect the coastline through dune formation. Coastal zones are variable and there is no simple solution to all coasts

Formation of dunes and dune fields:

- **Sand dunes** are narrow but important areas of sand that lie between the sea and the land. Dune-fields are formed above the beach as dry sand blows inland. The dunes may even extend several kilometers inland. Dunes form when there is an adequate sand supply and onshore winds of sufficient velocity to move the sand. As the dune builds, it becomes a major obstacle to the landward movement of windblown sand. Thus, the dune serves to conserve sand in close proximity to the beach system. When the wind encounters an obstacle its speed is reduced and the sand grains fall out under gravity, resulting in sand deposition. Sand will pile up on each side of an object resulting in a ridge parallel to the wind direction and streamlined by the wind. This type of dune is called the **shadow dune.** Eventually the object is likely to be buried again creating a smooth surface.

  Plants are good objects that cannot be easily buried by the moving sands. They try to come above the sand surface, compared to a lifeless object. Vegetation can grow above the sand surface. Many plants cannot survive the harsh environment of the sea shore.

Wind flow over a sandy surface can increase friction with the sand and therefore the wind speed will decrease closer to the surface. Wind transports sand in three different ways: Saltation, suspension and surface creep. About 75% of sand is moved by saltation. It is the process of sand grains being flicked up by the wind and carried forward a certain distance, before depositing on the surface. A minimum wind speed of 5 m/second is required to lift the sand grains and a minimum of 4.5 m/s required for keeping the grains suspended in the air, otherwise the sand grains drop down forming heaps. Finer particles suspended in the air cannot drop easily and are not significant in forming dunes. Winds also push the sand and make it creep on the beach surface. With increased vegetation the beach surface becomes rougher. Normally on a smooth beach the zone of zero wind speed is 0.002 to 1 cm in height. Dense vegetation can increase this height to 18 cm (Pethic, 1984)

- **Embryonic dunes or fore-dunes:** Individual plants or obstacles on the beach can act as centres for formation of dune embryos (**Figures 1.4 & 1.5**). As the dunes grow the plants grow taller to peep above the dune surface. These unconnected mounds of sand can reach one to two meters in height depending on the heights the species of plants can reach. Once the dunes have grown in height the other creeping plants such as Spinifex, Ipomoea can take over. These form a complete protective cover over the surface.

Fig. 1.4 (L): *Ipomoea pes-caprae* & Fig. 1.5 (R): *Cyperus maritima* colonizing the fore-dunes

Dunes promote more dunes: If there is ready supply of sand on the beach, more dunes may develop in front of the original. The dunes further back may be stabilized by plants, or blown inland if they fail to retain a good plant cover. Sand dunes are a sign of the ecological equilibrium between the powerful physical forces of the ocean and the land and they act as **nature's first line of defense** to prevent monsoon storm, waves and cyclonic surges. Sand dunes are not permanent formations. If they are not stabilized by vegetation they may vanish overnight. **Sand dune formation is a slow process; it may take decades. In order to form dunes there must be a large area of dry sand beach over which the winds can blow.** A sand dune belt performs multiple functions and is of immense value to the coastal population:

- Dunes are typical features of coastal stability,
- Dunes act as nature's first line of defense against sea erosion
- Sources of beach nourishment and protects coast from erosion and replenish the loss of sand dune to wave and current energies,
- Rich in genetic diversity (Flora and Fauna),
- Serves as an ideal place for recreation
- Dunes protect the hinterland from winds and other forces
- Economically, beach and dune systems are important for the tourism and represent an important sand resource for the construction industry. Silica sands are industrially important (McHarg, 1972; Arun et al., 1999). Highly radio-active sands containing thorium and monazite are found in Chavara beach of Kerala; the sand causes even genetic mutations in local people (Reinert, 2002).

Vegetational succession on sandy shores, progressing from herbs and creepers initially, ultimately results in the climax dominated by trees. Along the South Indian west coast the dominant trees on coastal sands in general are *Calophyllum inophyllum, Morinda citrifolia, Pongamia pinnata, Cocos nucifera* (cultivated), *Pandanus odoratissimus, Borassus flabellifer* (along Dakshina Kannada coast) etc. All perennial species of creepers, herbs, shrubs and trees that are adapted to grow in sandy places are referred to as **psammophytes.** Seasonal herbs that thrive on the sea shores during the rainy season depend on dilution of salinity by rain water for their growth, and hence they cannot be considered true psammophytes.

Threats from coastal erosion

Sand dunes have been mostly considered by humans as sand banks for building and industrial uses. Currents move away sand or soil from one place and might deposit them in another place. The eroded materials if carried away by waves and deposited in the sea bottom are practically lost to the sea shore. Increasing human pressure along the coast resulted in the conversion of expanses of sandy deposits into rice fields and coconut groves. To make rice fields the sand is dug and flat depressions are made. Often, traditionally, a high wall of sand is left between the high tide line and the human settlement in the interior of the shore. The ever increasing density of human population along the coastal zones, the increased conversion of ancient sand dunes into agricultural areas, and exploitation of sand deposits for construction activities elsewhere have made many shores vulnerable to sea erosion.

Sea erosion is a long term coastal hazard unlike the impact of tsunami or cyclones which have immediate impact on the shore. **Wave energy** is the primary cause of the shore erosion. 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. **Cyclonic storms** create powerful surge of sea waves that violently pound on the shoreline. **Tsunamis** are catastrophic events which create major coastal changes over a short period with unpredictable consequences. Sea level has risen nearly 110 meters since the last **ice age**. If the **global warming** events continue to happen, due to excessive release of **greenhouse gases**, the sea levels would increase faster submerging the low lying shorelines. Sea level has risen about 40 cm in the past century and is projected to rise another 60 cm in the next century. Average rise of sea level presently is in the order of 1.5 to 10 mm per year (varying from place to place). 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.

Human impacts in the form construction of sea walls, harbours and jetties and breakwaters can increase vulnerability of the unprotected coast elsewhere to erosion. Removal of beach sand and destruction of beach vegetation and mangroves and various other activities that reduce the height of the shore invite the wrath of the sea directly. Sand that is moved into deeper waters of the ocean from the land by the waves, tides and currents, as well as that is blown away from unprotected beaches is lost to the land.

The Indian mainland has about 5423 km of coastline of which nearly 43% are sandy beaches. At present about 23% of Indian coastline is affected by erosion. The west coast has high wave activity during the South West Monsoon and relatively calm sea conditions during the rest of the year. The east coast has significant wave activity during both the South West and North East Monsoons. The *State of the Environment Report and Action Plan-2003* of Karnataka states the length of coastline as 320 km. and 60 km of beach (19% of the total length of shoreline) as confronted with "appreciable or severe erosion". The erosion problems in Dakshina Kannada and Udupi districts are more severe than in Uttara Kannada, which has a greater proportion of rocky shores. About 28% of the total stretch of coastline in the DK-Udupi region is considered "critical" from the point of erosion, compared to 8% in Uttara Kannada. Coastal erosion and submergence of land have been reported at Ankola, Gokarna, Honavar, Bhatkal, Marvante, Malpe, Mulur, Mangalore etc. Total annual losses in Karnataka, in the form of loss of land and property, due to sea erosion are estimated to be about Rs.31.28 crore.

Coastal erosion: Engineering solutions: Engineering solutions to coastal erosion are structural measures. The following are briefly mentioned here:

- **Sea wall:** Seawall may be useful in protecting specific area of the shore from erosion and storm surges (**Figure 1.5**).

Fig. 1.5: Ineffective sea-wall : Udupi coast

- **Groins:** A groin is a strong low seawall built at right angle to the coast to reduce shoreline erosion. Groins can be effective in trapping sand and pebbles that are transported by long-shore

currents, especially towards the river mouths. Groins help in beach nourishment by trapping sediments (**Figure 1.6**).

Fig. 1.6: A groyne of rocks protruding into the sea

- **Off-shore breakwater**: Breakwater is a wall that breaks the impact of waves often constructed near harbours. The breakwaters by stopping the force of waves create relatively peaceful water in the zone protected by it. Breakwaters could be seen in Seabird Naval Base and Karwar harbor.

Drawbacks of engineering structures

Seawalls destroy eroding beaches first by reducing the size of the beach. As water moves in it eventually meets the wall, flooding the beach. The wave action causes the underlying sand to erode quickly, undermining the wall. Everything in front of the seawall gets eroded away and the waves start pounding on the wall itself destabilizing it. The pressure of water increases on adjoining beaches. Stabilization of the coastal zone through engineering structures protects the properties of relatively few people at a larger general expense to the public. Seawalls designed to protect the beach may eventually destroy it. The wave energy gets reflected off after striking the hard walls. Seawalls also get undermined from below or behind causing them to fail or collapse. Construction of groins is expensive and can as well mar the beauty of the coast. Severe downstream erosion may result due to littoral barrier effect of breakwaters. It is an expensive option and needs regular maintenance to avoid rapid breakdown due to constant pounding by waves.

Advantages of bio-shielding: Lowland sea coasts are fluctuating, dynamic boundaries between the sea and the land. From time immemorial humans living in coastal zones had realized the magnitude of problems that may be unleashed by the wrath of the sea by tampering with this dynamic zone beyond its automatic repairing capacity. They lived in most places adhering to certain safety norms and behind the protective shield of large mounds of shore sands stabilized by characteristic vegetation. In the recent times, due to mounting human pressures on the coastal zone in the form of mushrooming of townships and populated villages, expansion of agriculture and habitation to the brim of the sea, construction activities that took away bulk of the sand dunes, hacking of the shore vegetation for meeting fuel-wood and timber needs and a host of other detrimental activities, the proneness of the coasts to catastrophic erosion have mounted substantially. As incidents of sea erosion, storm surges and cyclones increased inflicting losses to lives and property, the remedies worked out expeditiously were in the form of expensive and ecologically ruinous and aesthetically displeasing sea walls and other artificial structures.

Ongoing investigations since last few decades undertaken in India and rest of the world, on protecting shores from erosion, using cheaper, eco-friendly, livelihood-supporting alternatives have converged mostly on rediscovering a remedy that revolves ultimately around the ancient wisdom of raising green walls between the land and the sea. Though the voices of concern on destruction of coastal vegetation and the depletion of dunes have been in the air for long they have been orchestrated well in the form of implementable action plans, aimed at bio-shielding of the coast, by M S Swaminathan Research Foundation, Chennai, following the deadly tsunami of December 24, 2004 that hit the east coast violently.

Coastal Regulation Zone Notification, 1991

On 19 February 1991, the Ministry of Environment and Forests issued a Notification called the **Coastal Regulation Zone (CRZ)** 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 was made applicable to the entire 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, for the first time, authorized the State Governments to declare from time to time as CRZ-I areas "areas likely to be inundated due to rise in sea level, consequent upon global warming" and "area between Low Tide Line and High Tide Line". These are among other ecologically sensitive areas of the coast such as mangroves, wild life areas, coral reefs, fish breeding areas etc. which are also to be treated as CRZ-I, requiring high priority coastal protection areas. The CRZ Notification, in modified form is, awaiting Government of India's approval.

Chapter-2: FLORISTIC COMPOSITION OF KARNATAKA SEA BEACHES

As our ultimate aim is raising green walls as a part of integrated coastal zone management, to benefit both humans and ecology, we need to familiarize with the sandy seashore plants of Karnataka. After surveying about 50 beaches in the coastal districts of Uttara Kannada, Udupi and Dakshina Kannada and representating all the taluks viz. Karwar, Ankola, Kumta, Honavar, Bhatkal, Kundapur, Udupi, Mulki and Mangalore a list of species has been chosen for re-vegetation of the beaches. The observations mainly are pertaining to the vegetation and its elements with special objective of short-listing plants suitable for re-vegetation of the sea beaches of Uttara Kannada, particularly of Honavar Forest Division (Annexure 1). As the beaches of Karnataka share more or less similar climatic conditions we have a wide range of species suitable for re-vegetation. The suitable species are listed below:

a. Sand binding creepers and spreading herbs

Ipomea-pes caprae (Figures 2.1)
Spinifex littoreus (Figure 2.2)
Launea sarmentosa
Hydrophylax maritima
Cyperus pedunculatus
Canavalia rosea (DK and Udupi) (Figure 2.3)
Sesuvium portulacastrum (Figure 2.4)
Glinus oppositifolius (Figure 2.5)
Cassytha filiformis (Figure 2.6)
Evolvulus alsinoides (Figure 2.7)
(Most of the above can be propagated by vegetative cuttings)

b. Erect herbs

Aerua lanata (Figure 2.8)
Boerhaavia diffusa
Borreria articularis
Dactyloctenium aegyptium
Pedalium murex
Crotalaria retusa (Figure 2.9)
Alternanthera sessilis (Figure 2.10)
Crotalaria verrucosa (Figure 2.11)
Urginea indica
Crinum asiaticm (Figure 2.12)

(Most are seasonal herbs that spring out naturally during the rainy season. Dissemination of seeds can enrich the beach ecosystem. As many have medicinal properties they are of value to the local population. *Urginea* and *Crinum* have underground bulbs and can be grown in dense patches towards the hind shore)

c. Shrubs

Scaveola taccada (mainly in DK and Udupi) (Figure 2.13)
Vitex trifolia (Figure 2.14)
Vitex negundo
Calotropis gigantea
Clerodendrum inerme (Figure 2.15)

d. Climbers

Derris trifoliata
Gloriosa superba (in the hind shore)
Coccinea indica (vegetable; hindshore, Dandibagh beach Karwar) (Figure 2.16)
Trichosanthes cucumerianus (wild snakegourd; mid and hind shore) (Figure 2.17)
Dioscorea bulbifera (hind shore)
Premna corymbosa

e. Trees

Calophyllum inophyllum (Figure 2.18)
Morinda citrifolia (Figure 2.19)
Pandanus odoratissimus (Figure 2.20)
Thespesia populnea (Figure 2.21)
Erythrina variegata
Ficus racemosa
Pongamia pinnata
Casuarina equisetifolia
Borassus flabellifer (palmyra palm- more in DK & Udupi; a couple of trees in Ramagindy) (Figure 2.22)

Fig. 2.1: *Ipomoea pes-caprae*

Fig. 2.2: *Spinifex littoreus*

Fig. 2.3: *Canavalia rosea*

Fig. 2.4: *Sesuvium portulacastrum*

Fig. 2.5: *Glinus oppositifolius*

Fig. 2.6: *Cassytha filiformis*

Fig. 2.7: *Evolvulus alsinoides*

Fig. 2.8: *Aerua lanata*

Fig. 2.9: *Crotalaria retusa*

Fig. 2.10: *Alternanthera sessilis*

Fig. 2.11: *Crotalaria verrucosa*

Fig. 2.12: *Crinum asiaticum*

Fig. 2.13: *Scaveola taccada*

Fig. 2.14: *Vitex trifolia*

Fig. 2.15: *Clerodendrum inerme*

Fig. 2.16: *Coccinia indica*

Fig 2.17: *Trichosanthes cucumerianus*

Fig. 2.18: *Calophyllum inophyllum*

Fig. 2.19: *Morinda citrifolia*

Fig. 2.20: *Pandanus odoratissimus* in Talamakki beach

Fig. 2.21: *Thespesia populnea*

Fig. 2.22: *Borassusflabellifer*

Chapter-3: BIO-SHIELDING THE COAST OF HONAVAR FOREST DIVISION

BEACH REHABILITATION METHODS

The Honavar Forest Division in the Kanara Circle has 97 km long coastline, covering the taluks of Kumta, Honavar and Bhatkal (see **Figures 3.1, 3.2 & 3.3**). Compared to Udupi and Dakshina Kannada the coastline is interrupted with hills and therefore rocky shores are many in between sandy beaches. There are several beautiful beaches in this Division. At present the beaches of Gokarna and Murudeshwar have become paradise for an ever growing tourist population. Many other picturesque beaches are slowly waking up to tourism. The notable beaches of the Division are Gangavali, Gokarna, Kudle, Om, Baad, Holangadde, Kumta, Handigon, Dhareshwar and Ramangindi of Kumta taluk, Haldipur, Kasarkod, Apsarakonda, Mugli, Manki and Talamakki of Honavar taluk and Bailur, Murudeshwar, Bengre, Jali, Haldin, Belke and Gorte of Bhatkal taluk.

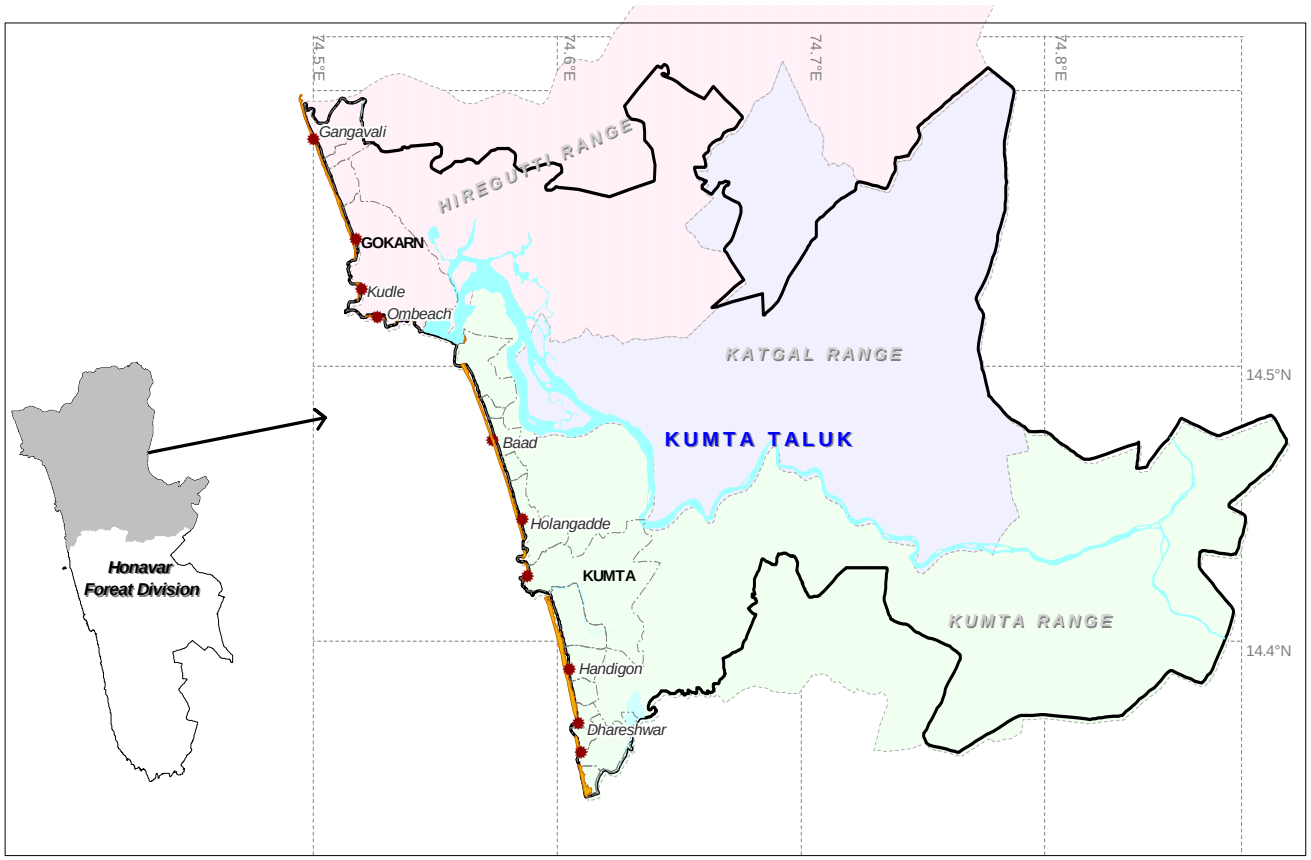

Fig. 3.1: Kumta taluk showing sea beaches

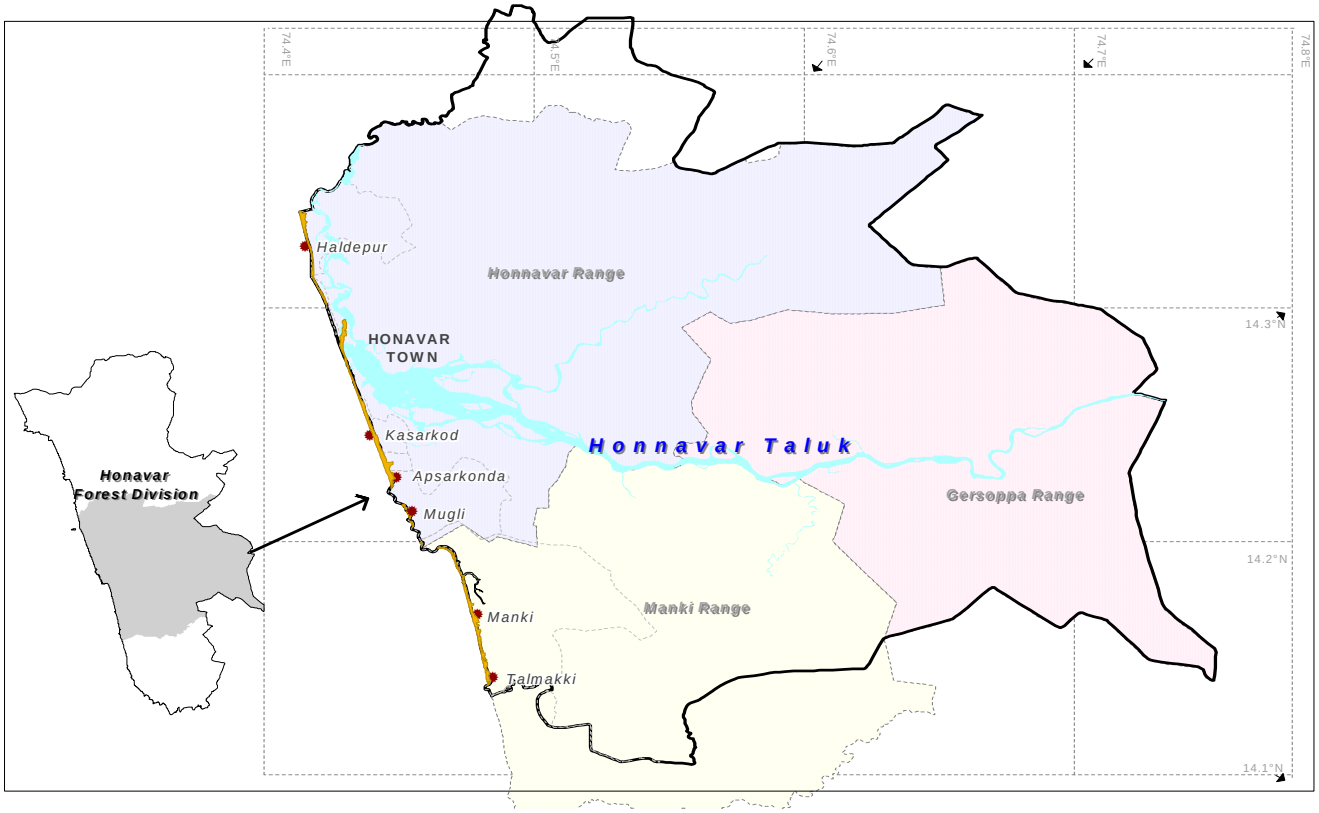

Figure 3.2: Honavar taluk showing beaches

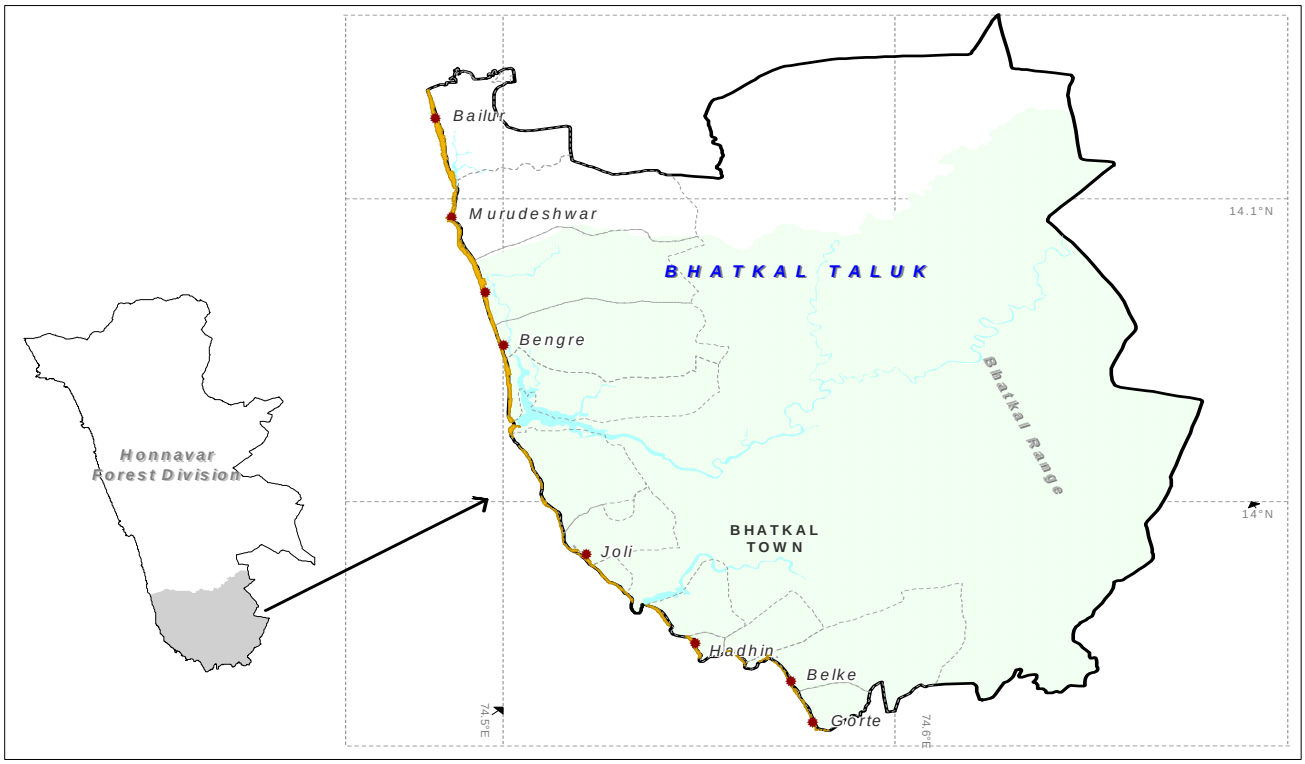

Figure 3.3: Bhatkal taluk showing beaches

The beaches which particularly requiring bio-shielding are those which are not bordered by background hills. Mention may be made of Gangavali, Gokarna, Baad, Holangadde, part of Kumta beach, Handigon, Dhareshwar, Haldipur, Kasarkod, part of Apsarakonda, Manki, Bailur, Murudeshwar, Bengre and Jali. These beaches are vulnerable to severe erosion from possible sea level rise, if steps are not taken today to raise high sand dunes on them stabilized by vegetation.

Methods of beach protection

For prevention and mitigation of sea erosion there are both **structural measures** and **non-structural measures** (Chapter-1 for more details). **Seawall** may be useful in protecting specific area from erosion and storm surges. However, adverse effects can be on the downstream side. **Off-shore breakwater** construction is carried out for shore protection and beach formation. Such breakwaters are constructed in the Arabian Sea in the Project Seabird Naval Base. The barriers like breakwaters are associated with severe downstream shore- erosion. It is also an expensive option and needs regular maintenance to avoid rapid breakdowns.

Vegetation cover is considered a **non-structural soft measure** to protect the shore from erosion. Stabilized sand dunes, natural safety barriers of beaches, are the contribution of **psammophytes**, at no cost to human economy. Plant roots are effective in stabilizing loose sand and protecting it from erosion by waves or wind. This report is devoted to the beach situation in Honavar Forest Division of Kanara Circle and to prescribe raising of appropriate vegetation cover, as a substitute for the artificial structures which are detrimental to the functioning of the beach as an ecosystem. The walls often interfere with natural plant succession along the beaches; they reduce the aesthetics of the coast and hamper the development of coastal tourism. The sea walls are expensive to build unlike the green walls of natural vegetation. The beaches might tend to subside in their levels due to the waves pounding on the rocks and returning vigorously as their turbulent energy is not absorbed by the stone walls (**Figure 3.4).** Moreover, the local community will be benefited from good vegetation on the sea beach due to various non-timber products and tourism potential. **Bio-shielding,** referring to raising of green walls using appropriate plant species, is a more recent term applied for shore protection with the help of vegetation. Bio-shielding serves the dual purpose of raising the sand dunes as well as increasing the protective cover of the vegetation. Not just the sea beaches but even the backshore has to be managed under integrated coastal management programme.

Fig. 3.4: A stone wall protected beach showing subsidence and lack of vegetation

Dune vegetation traps windblown sand and holds it on to the fore-dunes. The exposed dry sand is easily moved by high velocity winds and large volumes of sand can be rapidly shifted from one place to other. Shifting sands if deposited on herbaceous cover can smother it. But dune vegetation contains characteristic native species and has its own intrinsic biodiversity value. Beaches and dunes are important feeding, breeding and roosting grounds for sea turtles and shore birds.

Steps for protection and development of sand dunes and dune vegetation

- **Dune thatching** is a supporting measure for development of dune vegetation. It refers to covering of developing dunes with brushwood or twigs. It is a simple cost effective process. In our local situation this can be done with active co-operation from the local community, which should be aware of the importance of protecting the developing dunes with twigs or brushwood, so that they are not removed for fuel needs. This organic cover can last for one year and allow dune plants to develop on the sands. We can try experimentally coconut fronds and *Pandanus* leaves for the same purpose.

- **Fencing of sand dunes** is an effective practice to protect the developing vegetation. Fencing is done above the high tide limit. Fencing protects the developing dune vegetation, including beach plantations, from damage from people trampling as well as from trampling and browsing of plants by cattle. Dune fencing is done on the upper beach beyond the reach of the sea waves and tides. Dune fencing allows also the fore-dunes to develop towards the sea facing side. Fences also reduce wind speed across sand surface while allowing vegetation to develop un-impeded. Local community involvement will greatly help in success of the programme. Barbed wire fencing, though not itself promoting accumulation of sand, unlike the wood or bamboo stakes, is very effective protection measure. It is not advisable to fence beaches which are visited by sea turtles for laying eggs, as they get disturbed or even get entangled if the fencing is specially of barbed wire. In such beaches there is a practice of making parallel strips of wooden fencing vertically aligned to the sea shore, farthest from the water. Thin wooden strips fastened by wires are used for such fencing (**Figure 3.5)**. The fencing should not exceed five feet in height, and the length of any single stretch of fencing not to exceed 10 feet and leaving about seven feet gap between any two sections of parallel fencing. This type of fencing bordering the backshore of the sea allows sand to collect between strips and behind. Fencing can be parallel to the shore if it will not create regular movement of people into the beach, nor blocking the path of nesting turtles (**Figure 3.6).**

Fig. 3.5: Parallel wooden fencing vertical to the shore for sand dune development (popular in Europe)

Fig. 3.6: Beach fencing parallel to the shore for development of sand dunes

Species selection

For planting just above the high tide line, for the level portion of the sandy beach, the ideal plants are creeping, salinity and desiccation tolerant perennial species such as *Spinifex littoreus, Ipomoea pes-caprae, Hydrophylax maritima, Launea sarmentosa* and *Cyperus arenarius.* Occasional submergence by storm surges may not completely destroy these species which spring back to full life soon. Their stems creep along the sand surface and root at the nodes stabilizing the loose sands, and building up larger dunes. They are the forerunners of vegetational succession along the foreshore areas where the conditions are not ideal for others. Even if buried under shifting sands these plants will not perish, as they come up again on dune surface and spread by rooting at the nodes of their creeping stems which spread in all directions. They belong to the category of **prime sand-binders.** These species may be propagated during the rainy season by stem cuttings.

The mid-shore, where the perennial species enjoy greater security from flooding, is good for all the above species, where they continue to dominate. Additionally we also find the partial stem parasite, and yet another prime sand binder *Cassytha filiformis*, which forms wiry masses over the sand surface

attached to their host stems. *Lippia nodiflora, Canavalia rosea*, a leguminous creeper (common in the beaches of DK – Udupi region) are other prominent sand binders. It is a promising species that needs to be introduced into the Uttara Kannada beaches. The seeds of the legume can be collected and stored until the onset of the rainy season, when the seeds can be dibbled in the sand. Another leguminous species that spread on the mid-shore sand is *Derris trifoliata.* Spreading herbs suitable for the mid-shore are *Glinus oppositifolius* and *Sesuvium portulacastrum.* Shrubs like *Scaveola taccada, Datura metel, Calotropis gigantea, Clerodendrum inerme, Ixora coccinea,* etc. are good for this part of the beach. Among the climbers present are *Premna corymbosa* and *Vitis trifoliata* Numerous seasonal herbs such as *Pedalium murex* (a local medicine for kidney stone), *Alternanthera sessilis, Hedyotis corymbosa, Borreria articularis, Physalis minima, Vernonia cineria, Crotalaria verrucosa, C. retusa, Leucas aspera, Urginea indica, Crinum latifolium* are associated with this part. Among the trees that grow here are *Pandanus odoratissimus* which is remarkable for its sand-binding properties, having an entanglement of strong aerial roots that serve the purpose. We also find the palmyra palm *Borassus flabellifer,* the '*Noni*' tree *Morinda citrifolia, Zizyphus mauritiana, Casuarina equisetifolia, Calophyllum inophyllum* etc capable of surviving here.

The far part of the beach, the hind shore, has a variety of trees, shrubs, climbers and herbs. Characteristic of these sea-shore trees are *Pandanus odoratissimus, Calophyllum inophyllum, Borassus flabellifer, Cocos nucifera, Thespesia populnea, Erythrina variegata, Pongamia pinnata, Ficus racemosa, Morinda citrifolia, Zizyphus mauritiana, Casuarina equisetifolia* etc. Various shrubs, climbers and herbs of hinterlands can grow here according to the landscape elements associated with the beach system (such as hill, rice field, household garden etc.).

Use of Vetiver grass (Khas grass, Lavancha) or *Vetiveria zizanoides* is getting popular for dune stabilization. Vetiver grass could withstand very harsh climatic and soil conditions. Planting slips of this deep rooted grass in rows can effectively check erosion. The grass grows very fast, the leaves may dry up in summer but new tillers sprout from the base during rains.

(http://www.vetiver.org/KUW_WORKSHOP_papers/KUW_6TTV.pdf).

Vetiver grass, was first developed by the World Bank for soil and water conservation in India in the 1980s. Trees take several years to develop extensive and deep root systems necessary to anchor the soil on steep slopes to prevent landslides and reduce erosion, whereas vetiver grass, when properly established, can provide the same effect within 12 months. Vetiver technology is today getting popular in India as a very effective erosion control measure. Vetiver grass has massive, finely structured root system (**Figures 3.7-3.9)**. This massive root system that grows to few meters depth is very effective in preventing erosion by closely planting (Hengchaovanich, 1999). The dense stems of the grass can reduce run off water and trap sediment. It has high tolerance to pests, diseases and fire. It tolerates extremes of temperatures from -15^{o} to 55^{o}C. Its high tolerance of salinity makes it ideal candidate bio-shielding (Truong and Baker, 1998).. P Haridas of India Vetiver Network has successfully raised it in a beach resort near Chennai (personal communication).

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When planted as a single line, Vetiver forms a stiff, dense hedge that prevents erosion, forms natural terraces, increases soil moisture, and doesn't compete with companion crops. Once established,

Vetiver can withstand droughts, fire and floods, and will grow on highly acid or alkaline soils. It can reclaim mine dumps, stabilize road cuttings, embankments and river banks, is economical to propagate and install, and requires only labor and hand tools (VetiverSystems.com, August, 12, 2010).

Elaborating on the plan for beach protection Manjunatha Shetty, Assistant Conservator of Forests, Kundapur Forest Division stated: ""A green carpet of *Ipomoea biloba*, a creeper which grows at beaches and pins sand to the ground, will comprise the first tier. It will provide adequate cover to the beach wildlife…. The second tier will be made of Vetiver, an aromatic plant known for its thick network of roots and medicinal applications …. A thick cover of trees like *Casuarina*, *Calophyllum* and honge (*Pongamia pinnata*) will make up the third tier" (-ibid-).

Woody vegetation will serve as speed-breakers in coastal storms, cyclones and tsunami. They will also serve as carbon sinks, helping to enhance carbon sequestration and thereby mitigating global warming. While many species of plants are able to establish on sand or gravel beaches, the extreme conditions of desiccation, salinity and erosion allow few species to reach maturity and set seed. Severity of desiccation increases as particle size increases. On sandy beaches, successful vegetation establishment causes an increase in surface roughness, slowing both the wind and movement of sand, and resulting in the accumulation of sand in the form of coastal dunes. Vegetation cover increases with distance from the water's edge due to decreasing levels of erosive wind and water energy.

Management, planning and execution

Beaches and sand dunes represent flexible barriers which absorb wave energy during storms by moving and adjusting their shapes and position. The management of such ecosystems requires thorough planning and proper execution.

Selection of sites for sand dune rehabilitation depends on available funding and manpower. Initially all beaches are to be surveyed and those beaches alone should be selected which have very specific conditions suitable for formation of sand dunes. Such sites should have existing dunes or having history of dunes during the past 20 years. Dunes have suffered from pressures from humans such as development of agriculture, townships nearby, sand mining etc. Many of the beaches skirted by hills are

not much affected except perhaps by tourism. There is no point selecting for dune restoration beaches which are relatively in tact.

Minimum assessment of selected beaches: The following parameters are to be recorded:

- Site name
- Dune length, width and height: Dune length from map/imageries; dune width to measured at 50 m interval; the width of dry, sandy beach to be measured at 50 m interval; monthly measurement is desirable due to seasonal changes. Dune height (from few cm to meters) to be measured. Formation of new embryonic dunes to be noted
- Presence of parallel dune systems
- Dune vegetation; main species and coverage to be recorded at 50 m interval using appropriate sampling method
- Turtle nesting details: If turtle nesting exists the nesting season should be avoided for beach rehabilitation works
- History of beach and dune area

Rehabilitation methods

Sand trapping fences are useful. Fences are porous barriers that reduce wind velocity so that sand drops of wind stream near the fence. The fence should not block wind but only slow down it. Vertical wooden strips fastened by wire are ideal fences. Fences should have porosity of about 50%. Fences are to be made closer to the shore vegetation, above the dry sand bed, so that it is safe from frequent lashing by waves and tides. The fencing may be parallel to the shore or perpendicular to it in places of turtle nesting or depending on wind direction in the beach. As the cost of wood is high and pilferage from the site might happen, split bamboo may be used. In almost one years' time much of the fence might get buried in dune forming beaches. Another fence might be raised over the dune to trap more sand. The newly built dunes should be stabilized with vegetation. The species for planting should be chosen after due consultation with the experts to increase the degree of success. Organic manures may be judiciously applied as the beach sands are infertile. Surface mulch around the plants will help in retaining moisture

and in preventing erosion of loose sand during rains. Branches of trees such as of *Casuarina* placed flat on ground can help accumulation of sand. Planting should be done in the very beginning of wet season.

Co-management and awareness: As beaches are along the densely populated coastline local committees should be constituted for co-management. Periodical meetings with the community are very important. Involving local people in discussions and work will increase their level of awareness. Participation of local schools can increase the degree of success.

Post-project activities: Periodic measuring of sand deposit and spread of vegetation should be recorded

Beaches to be avoided

- Very badly eroded beaches
- Narrow beaches do not make good choice, as such beaches will be subjected to sea erosion during the rainy season

SOME IMPORTANT SPECIES FOR BIO-SHIELDING

When we consider the suitability of various species for bio-shielding of the coast, invariably we should consider the following for planting:

- ***Spinifex littoreus:*** Pale green, rigid and rough grass spreading along the sea shore sand and most tolerant of occasional submersion. Forms formidable patches tolerant of human intervention because of its rigidity and sharpness of leaf tips; also immune to grazing and trampling by cattle. Cuttings can be planted during rainy season. It is extensively planted in Tamil Nadu to control movement of sand.
- ***Ipomoea pes-caprae:*** A creeper widely distributed over the tropical and subtropical sandy places, such as sea shores river banks etc. A trailing vine along sand dunes. It roots at nodes, spreads rapidly and far from the base in all directions, very tolerant of salinity. Growing above the HTL the creeper forms large mats, stabilizing dunes. Branches may reach 10 m in length. Tap roots are long and deep sometimes reaching over a meter. Present throughout tropics and subtropics. Grows vegetatively from stem cuttings and also by seeds. Can resist salt spray and wave splash. It can recover from the high waves from cyclones. Survives heavy rains and

drought. The creeper adds to the attractiveness of beach by its large deep rose to purplish flowers. Cuttings can be planted during rainy season. Leaf extract is a traditional remedy for different types of inflammations including dermatitis and skin injuries caused by poisonous jelly fishes. The extract is said to have potency equal to that of aspirin. The extract has antispasmodic activity. It can be propagated by seeds as well as cuttings.

- ***Canavalia* spp:** This perennial legume is an extensive creeper and climber, a very effective sand-binder more found in Udupi-DK beaches. *Canavalia rosea* is common along open mid-shore sands; it is pan-tropical, but exclusive to coastal sands. whereas *C. cathartica* occurs along the tree line behind. *Canavalia* forms dense mats along the sand. It is an under-explored legume as human food; raw seeds of *Canavalia* possess 31-35% proteins and are rich in potassium, phosphorus, sodium and calcium. About 46 species of soil fungi are found associated with the roots of this species in different studies. The tender pods of *C. cathartica* are used as vegetable. Both species can withstand desiccation of the shore and increase soil fertility due to nitrogen fixation by root bacteria. In Padubidri and Sasihitlu the fisherfolks occasionally consume pods and ripe beans. The beans are soaked in water for long time for detoxification. The plants can be propagated by seeds.

- ***Pandanus* spp.** are shrubs to trees, often growing gregariously along the beaches. *P. odoratissimus* is commoner along the shores and borders of backwaters. *P. kaida* occurs along the bunds of coastal rice fields. *Pandanus* can grow on a wide variety of soils including on rocky beaches. It can withstand drought, strong winds and salt spray as well as occasional salt water inundation. The plants can resist moderate to severe cyclonic storms. In habit they are large shrubs to small trees. The species produces strong, aerial roots from the stem. These roots grow downward and anchor the plants firmly to the substratum. Flowers are fragrant and the fruit resembles pine-apple. The units of fruits are dispersed by ocean currents; seeds maintain their viability for months together. Seeds are also dispersed by birds and fruit bats; crabs also feed on the fruits. Pacific islands have several varieties of *Pandanus tectorius* with edible fruits. The natives carefully propagate the species by cuttings. Flavoured varieties of fruits in these islands are used for jams, jellies and juice. The Indian varieties have calcium oxalate crystals that cause irritation. Leaves are used for mats, baskets and hats. Mats are very good as floor mats and last for several years. Fragrant flowers are sold in the market and a perfume is also extracted from

the flowers. Along the coast it renders valuable ecosystem services. Apart from its value as a shore protector its fruits are eaten by birds, bats and crabs. The plant has a role in marine ecosystem and food chains. It provides shelter for birds. Honey bees forage on female flowers and fruits. Plant is progated from seeds as well as branch cuttings.

- ***Calophyllum inophyllum*:** Medium to large evergreen tree prominent along the coast with dark green shady foliage and fragrant flowers. The drupe is light yellow when ripe and carries single globular, oil rich seed within a hard endocarp. The tree grows in deep soil near sea as well as on pure sand. It is an efficient shore protector. Birds and bats feed on the fruit pulp and disperse the seeds, which are also water dispersed. Germination takes place in 50-55 days. Germination percentage is increased by removal of shell. The seeds yield oil; a tree yields about 22 kg of oil from its seeds. Oil is traditionally used for lighting; it is used for varnishing wood works since it contains 10-30% resin. Used as a lubricant; for tanning of leather; for applying on boats; for making soap, which has anti-fungal properties. Camphor-mixed oil applied for ringworm. Being anti-bacterial, useful for treating burns; also for ulcers and diseases of hooves of cattle. Kernel paste for painful joints; oil applied for rheumatism and gout; for scabies and skin disease. Oil cake is good organic manure; it also controls root nematodes. Timber is very useful. The tree renders considerable ecosystem services; its dense canopy is good habitat for birds and other animals.

  The University of Agricultural Sciences of GKVK, Bangalore, in its **Biofuel Park** at Hassan produces high quality **bio-diesel** from the seeds. Farmers' associations have been formed to plant, collect and process seeds of *Calophyllum, Pongamia,* neem, mahua etc. to produce bio-fuels. A fair price of Rs. 13-15/kg is paid to the seed collectors of *Calophyllum* which is becoming very popular with the farmers and poor landless persons who can at least gather seeds and sell and make their livelihood. The Biofuel Park, under the patronage of the **Biofuel Task Force of Karnataka** is organizing massive planting of the species widely in the State. The tree being ideal for the sea-shore should be planted in millions for not only the biofuel but also for its multiple uses and ecosystem services as well as a future source of income for the landless and unemployed.

- ***Borassus flabellifer:*** This tall palm, known as palmyra, is mainly found in DK and Udupi shores. It is very rare in Uttara Kannada; a couple of trees occur in Ramangindi beach and few along the

rocky shore of Apsarakonda. Male and female plants are different. Fruits are large drupes, which while tender produces sweet and juicy endocarp, much in demand during the summer months. Ripe drupes are heaped in one place and covered with soil. It takes 10-12 weeks for the seeds to germinate. The palm is very slow growing, but strong and sturdy. Close planting can beautify the sea-shore as well as serve as a defense against erosion. The male inflorescence is tapped for toddy from which palm sugar and sugar candy are produced. The sugar candy is popular for its soothing effects on cough. Leaves are used for weaving mats and various fancy items.

- ***Morinda citrifolia:*** A small tree along the coast, it is sparingly found in Karnataka. Flowers occur in heads and the multiple fruits reach 2.5 cm in diameter. The tree was formerly cultivated as a crop for the roots which yield a dye. The dye yield is maximum in 3-4 years old plants. Morindine is the coloring principle of the roots. Wood yields an yellow dye, which gives mordanted cotton, silk and wool red, purple and chocolate colours. Most parts of the plant are medicinal. It tolerates salinity and drought conditions and grow well on sandy beaches. It can attain a height of up to 20 feet and serve the dual purpose of preventing soil erosion and acting as a windbreaker. Normally stem cutting is used for propagation. The planting distance is about 15 feet apart. During the last decades Noni products, particularly the juice made from the fruit, has turned into a huge business! By planting Noni along the coastline the country can, apart from preventing soil erosion, capture a major chunk of the fast-growing Noni market. Noni starts yielding in 18 months and has a productive life span of around 40 years.

Notes on Olive Ridely turtle in Honavar Division

Olive Ridley is the only sea turtle that nests on the sea coast of Honavar Division. It is protected under Wildlife Protection Act and classified under Schedule-I. It is listed in IUCN Red List as **vulnerable.** Sea Turtle visiting the coast for nesting is prone to poaching and eggs laid by them are also exposed for various threats. They need to be protected from human beings, feral dogs, jackals and many other predators. Forest Department is working for the conservation of sea turtles since 1984. Earlier the turtles were recorded only from the sandy beaches of Jali village of Bhatkal. Later more beaches having potential for conservation of sea turtles have been identified and conservation programmes are under way through the involvement of a local NGO. Sea Turtle nesting season starts in the month of September. Six sea turtle potential beaches are identified for conservation.

(Ravi Pandit, personal communication)

Details regarding turtle hatcheries and associated matters in Honavar Forest Division are given in Table 3.1 below:

Sl. No.	Year	Hatchery	Eggs Collected	Hatchlings Released	No of Nests
1	2007-08	Apsarakonda	1048	593	
		Gangavali	1712	789	
		Dhareshwara	1559	800	
		Kadle	1802	907	
		Ramanagindi	163	48	
		TOTAL	**6284**	**3137**	
2	2008-09	Apsarakonda	228	92	2
		Gangavali	247	142	2
		Dhareshwara	3180	1158	30
		Haldipur	1840	769	17
		TOTAL	**5495**	**2161**	**51**
3	2009-10	Apsarakonda	341	170	3
		Hosahitlu(Manki)	897	537	10
		Kagal	278	270	3
		Haldipur	1005	463	11
		TOTAL	**2521**	**1440**	**27**

References

1. **Arun, A.B., Beena, K.R., Raviraja, N.S. and Sridhar, K.R.** 1999. Coastal sand dunes- a neglected ecosystem. *Current Science* 77(1); 19-21.
2. **Bhat, U G.** 2004. Coastal erosion and management. In: Nayak, V N (ed) *Proc. State Level Workshop on Biodiversity and Management of Coastal and Marine Ecosystems.* Deputy Commissioner, Uttara Kannada, Karwar, pp.95-102.
3. **Hegde, V.S., Shalini, G., Nayak, S.R., Rajawat, A.S., Surynarayana, A., Jaykumar, S., Koti, B.K., and Girish, G.K.** *2009*. Low-Scale Foreshore Morphodynamic Processes in the Vicinity of a Tropical Estuary at Honnavar, Central West Coast of India. *Journal of Coastal Research*: 25(2), pp. 305-314.

4. **Hengchaovanich, D**. 1999. Fifteen years of bioengineering in the wet tropics from A *(Acacia auriculiformis)* to V *(Vetiveria zizanioides). Proc. Ground and Water Bioengineering for Erosion Control and Slope Stabilization*, Manila, April 1999.
5. **Kumar, S.V., Pathak, K.C., Pednekar, P., Raju, N.S.N and Gowthaman, R**. 2006. Coastal processes along the Indian coastline. *Current Science,* 91(4), 530-536.
6. **McHarg, I**. 1972. *Civil Engg*., 42, 66-71.
7. **Mukherjee, B**. 1996. *Environmental Biology,* Tata-McGraw Hill Publising Co. Delhi
8. **Nayak, S.R., Hegde, V.S., Shalini, G. Rajawat, A.S., Girish, K.H., Jayakumar, S. and Suryanarayana, A.** 2010. Geomorphic processes in the vicinity of the Venkatapur River mouth, central west coast of India: implications for estuarine sedimentation. *Journal of Coastal Research*, 925-934.
9. **Pethic, J. 1984**. *An Intorduction to Coastal Geomorphology,* London.
10. **Rao, T.A. and Sherieff, A.N.** 2002. *Coastal Ecosystems of Karnataka State, India: II. Beaches (Psammophytes).* Karnataka Association for the Advancement of Science, Bangalore.
11. **Reinert, B.** 2002. Radioactive sand causes mutations in human DNA. *Genomes News Network*, Oct. 11, 2002.
12. **State of the Environment Report and Action Plan** – 2003. Department of Forest, Ecology and Environment, Government of Karnataka.
13. **Truong, P.N. and Baker, D.** 1998. Vetiver Grass System for Environmental Protection. *PRVN Tech. Bull*. No. 1998/1. ORDPB, Bangkok.
14. **United States Environmental Protection Agency,** 1998. Coastal Watershed Factsheets: The Beach and Your Coastal Watershed.
15. **United Nations Environment Programme & Caribbean Environment Programme**, 1998. *Manual forSand Dune Management in the Wider Caribbean*
16. **Van de Ven, TAM, Fryrear, TW and Spann, WN.** 1989. Vegetation characteristics and soil loss by wind. *Journal of soil and Water Conservation*, vol 44.
17. **VetiverSystems.com,** August 12, 2010. Vetiver's beach and coral saving green shield.

Annexure-1: VEGETATION OF THE SEA BEACHES OF HONAVAR FOREST DIVISION

Notes: 1: Baad beach; 2: Ramangindi; 3. Holegadde; 4. Haldipur; 5. Bailur; 6. Apsarakonda; 7. Talamakki; 8. Bengre

		BEACHES							
SPECIES	**FAMILY**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Acanthospermum hispidum	Asteraceae								P
Achyranthus aspera	Amaranthaceae	P							P
Acrocephalus hispidus	Scrophulariaceae				P		P		
Alstonia scholaris	Apocynaceae		P						
Alysicarpus moniliformis	Fabaceae								P
Anacardium occidentale	Anacardiaceae		P	P					
Aristolochia indica	Aristolochiaceae			P					
Odina wodier	Anacardiaceae		P						
Boerhaavia diffusa	Nyctaginaceae							P	P
Borassus flabellifer	Arecaceae		P	P					
Borreria articularis	Rubiaceae	P		P		P	P		P
Breynia	Euphorbiaceae					P			
Calophyllum inophyllum	Clusiaceae		P	P		P	P	P	P
Calotropis gigantea	Asclepiadaceae		P	P	P		P	P	P
Cassytha filiformis	Lauraceae							P	P
Casuarina equisetifolia	Casuarinaceae			P	P		P	P	P
Cerbera mangas	Apocynaceae		P			P	P	P	
Cereus peruvianus	Cactaceae	P							
Chromolaena odorata	Asteraceae			P					
Clerodendrum inerme	Verbenaceae		P	P		P	P	P	P
Coldenia procumbens	Boraginaceae							P	
Corchorus acutangulus	Tiliaceae						P		P
Crotalaria verrucosa	Fabaceae							P	P
Cynodon dactylon	Poaceae		P			P	P		
Cyperus arenarius	Cyperaceae		P					P	P
Cyperus compressus	Cyperaceae	P					P		
Cyperus difformis	Cyperaceae				P			P	
Cyperus malaccensis	Cyperaceae							P	
Cyperus maritima	Cyperaceae	P	P	P	P	P	P		
Dactyloctenium aegyptiacum	Poaceae	P		P	P	P			
Derris pinnata	Fabaceae					P			
Derris trifoliata	Fabaceae						P	P	
Desmodium trifloum	Fabaceae				P				

Dioscorea bulbifera	Dioscoreaceae						P		P
Echinocola colona	Poaceae				P		P		
Elephantopus scaber	Asteraceae		P						
Elaeocharis atropurpurea	Cyperaceae				P				
Emilia sonchifolia	Asteraceae		P				P		
Eragrostis amabilis	Poaceae			P			P		
Eriocaulon cinerea	Eriocaulaceae	P			P		P	P	
Eriocaulon xeranthemum	Eriocaulaceae			P					
Eriocaulon sp.	Eriocaulaceae		P				P	P	
Erythrina suberosa	Fabaceae					P			
Evolvulus alsinoides	Convolvulaceae			P			P		
Ficus racemosa	Moraceae		P						
Fimbristyls acuminata	Cyperaceae			P	P				
Fimbristylis argentea	Cyperaceae				P				
Fimbristylis polytrichoides	Cyperaceae						P		
Fimbristylis sp	Cyperaceae		P	P			P		
Fuirena ciliaris	Cyperaceae	P			P			P	
Flacourtia sepiaria	Flacourtiaceae							P	
Geissaspis cristata	Fabaceae				P		P		
Gloriosa superba	Liliaceae		P	P					
Hedyotis herbacea	Rubiaceae		P	P			P		
Heliotropium halicacabum	Boraginaceae							P	
Ipomoea calycina	Convolvulaceae						P		
Ipomoea pes-caprae	Convolvulaceae	P	P		P	P		P	P
Ixora coccinea	Rubiaceae						P	P	
Kirginalia reticulata	Euphorbiaceae						P		
Launaea sarmentosa	Asteraceae	P	P		P	P	P	P	P
Lippea nodiflora	Verbenaceae					P			
Leucas aspera	Lamiaceae	P	P	P	P	P	P	P	P
Lindernia ciliata	Scrophulariaceae				P		P		
Lindernia crustacea	Scrophulariaceae						P		
Lindernia oppositifolia	Scrophulariaceae				P				
Lindernia rotundifolia	Scrophulariaceae				P				
Lindernia sp.	Scrophulariaceae			P			P		
Mariscus pedunculatus	Cyperaceae				P				
Morinda citrifolia	Rubiaceae		P				P		
Mukia maderaspatna	Cucurbitaceae						P		
Murdannia spirata	Commelinaceae			P			P		
Murdannia versicolor	Commelinaceae		P						
Pandanus	Pandanaceae	P		P		P	P	P	P

Paspalidium sp	Poaceae		P				P		
Pedalium murex	Pedaliaceae							P	P
Physalis minima	Solanaceae						P		P
Picreus polystachyos	Cyperaceae	P	P		P	P	P		
Polycarpaea corymbyfolia	Caryophyllaceae						P		
Pongamia pinnata	Fabaceae		P						
Portulaca	Portulacaceae					P		P	
Rotala malampuzhensis	Lythraceae						P		
Saccharum spontaneum	Poaceae							P	
Sesamum orientale	Pedaliaceae							P	P
Shoenoplectus lateriflorus	Cyperaceae				P				
Shoenoplectus sp.	Cyperaceae						P		
Solanum xanthocarpum	Solanaceae							P	
Spinifex littoreus	Poaceae	P	P	P	P	P		P	P
Torrenia lindernioides	Scrophulariaceae						P		
Trichosanthes cucumeriana	Cucurbitaceae						P		
Urginea indica	Liliaceae		P	P			P	P	P
Utricularia sp.	Lentibulariaceae						P		
Vernonia cinerea	Asteraceae						P	P	
Vitex negundo	Verbenaceae		P						P
Vitex trifolia	Verbenaceae	P	P	P		P	P	P	
Waltheria indica	Sterculiaceae	P							
Xyris pauciflora	Xyridaceae				P		P		
Zizyphus mauritiana	Rhamnaceae	P							