THE STRUCTURE AND FUNCTIONS OF THE SAND DUNE VEGETATION ALONG THE GOA COAST

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KASTURI N. DESAI
P.E.S. COLLEGE OF ARTS AND SCIENCE
FARMAGUDI, PONDA-GOA

RESEARCH GUIDE

DR. A. G. UNTAWALE
SCIENTIST
BIOLOGICAL OCEANOGRAPHY DIVISION
NATIONAL INSTITUTE OF OCEANOGRAPHY
DONA-PAULA, GOA 403 004

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This is to certify that the thesis entitled "THE STRUCTURE AND FUNCTIONS OF SAND DUNE VEGETATION ALONG THE GOA COAST", submitted by Mrs. Kasturi N. Desai, for the award of degree of Doctor of Philosophy in Botany, is based on the result of investigations carried out by her under my supervision. The thesis or part thereof has not been submitted for any other degree or diploma of any University.

AGUntawale 9/9/95

DONA PAULA

DR. A.G. UNTAWALE
RESEARCH GUIDE
SCIENTIST
BIOLOGICAL OCEANOGRAPHY DIVISION
N.I.O.
DONA PAULA, GOA

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A G Untawale 9/9/97

Dr. A.G. UNTAWALE)
RESEARCH GUIDE

(KASTURI DESAI)
CANDIDATE

DEDICATED

TO THE

MEMORY

OF

MY FATHER

LATE SHRI D.L.BHATTACHARJEE

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CHAPTER – I

INTRODUCTION

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1.1 INTRODUCTION

The word sand dune reflects the images of vast amount of shifting Sand, barren of plants and hostile to human habitation. Hot and dry winds shape and arrange the sand in geometric and artistic patterns described by the words such as barchen, transverse,star blow out dome strings, sheet, oblique and parabolic, (Wiedmann, 1984).

Sand dunes are generally of two types. The first type are the extremely dry interior deserts of continental land masses such as Sahara in Africa or Victoria desert in Australia.The other type known as the coastal sand dunes occur along the Atlantic and Pacific coasts of North America,along the Australian coast. In Asia the coastal dunes occur in Japan, India and several other countries.

1.2 SOURCES OF SAND

Principal sources of nearshore sediment for coastal areas are streams and rivers which transport sand directly to the ocean. Sand is also derived from the gradual wearing away and weathering of rock formation

and cliffs exposed on the shore. Shells, corals and other skeletal fragments provide sediments to some beaches especially those in the tropics (Anonymous, 1981).

1.3 SAND TRANSPORT AND DEPOSITION:

Sand particles are always in the process of movement, because of currents, waves and winds. The movement of sand up and down the coast is called long shore transport.

Coastal features, both natural and man made, can indicate the presence and direction of long shore transport. Obstacles in the path of longshore transport such as headlands,groynes and break-waters cause accretion on the updrift side resulting in the build up of sand on the beach. A similar amount of erosion occurs along the coast on the down drift side. Beach sand is also moved onshore and offshore by the action of waves, tides and currents. High energy storm waves erode sand from the beach. This sand is often deposited offshore as submerged sand bars. During the period of calm weather low energy waves move sand from offshore sources

and deposit it back on the beach to form a berm parallel to the shoreline. The berm or ridge of sand is formed on the upper part of the beach outside the reach of normal high tides by the swash of incoming waves. Storm waves can also deposit sand as berms at the peak of wave outside the reach of normal waves and tides (O'Keefe,1978).

Beach ridges consist of sand deposited by wave action. They can form as successive beach berms deposited on a seaward advancing shoreline. Grasses and other obstacles on the beach ridge trap sand blown up from the beach. The beach ridge is increased in width and height by accumulation of wind blown sand (O'Keefe,1978).

1.4 DUNE FORMATION

Dunes are composed of wind blown sand. Fore dunes are deposited immediately behind the beaches. Strong onshore winds erode dry sand from the steep face of the beach. This wind blown sand is deposited towards the top of the beach and a foredune is gradually formed. Foredunes are also normally formed where vegetation and other obstacles come on the way. On the upper part of

the beach it results in the deposition of wind blown sand. During periods of shoreline advancement, successive foredunes may develop to form a series of parallel dunes. Blowout parabolic dunes as well as mobile sand sheet complexes are initiated in foredunes,parallel dunes or beach ridge systems where strong onshore winds erode sand from unstable unvegetated areas (O'Keefe,1978) (Fig.1).

1.5 FORMATION AND FUNCTIONS OF FORE DUNES AND PARALLEL DUNES

Fore dunes are built up at the back of beaches on crests of berms and beach ridge where vegetation or other obstructions trap wind blown sand. They become higher and wider as sand accretion continues (Bird, 1972; Gale & Barr, 1977), (Plate 1).

Onshore winds of sufficient velocity move sand particles, erode sand from the dry part of the beach and transport it landward. Saltation is the main method by which sand is moved from the beaches by wind and is a process where by individual sand grains are carried away by the wind close to the surface in a series of

MATURE DUNES

PLATE - I

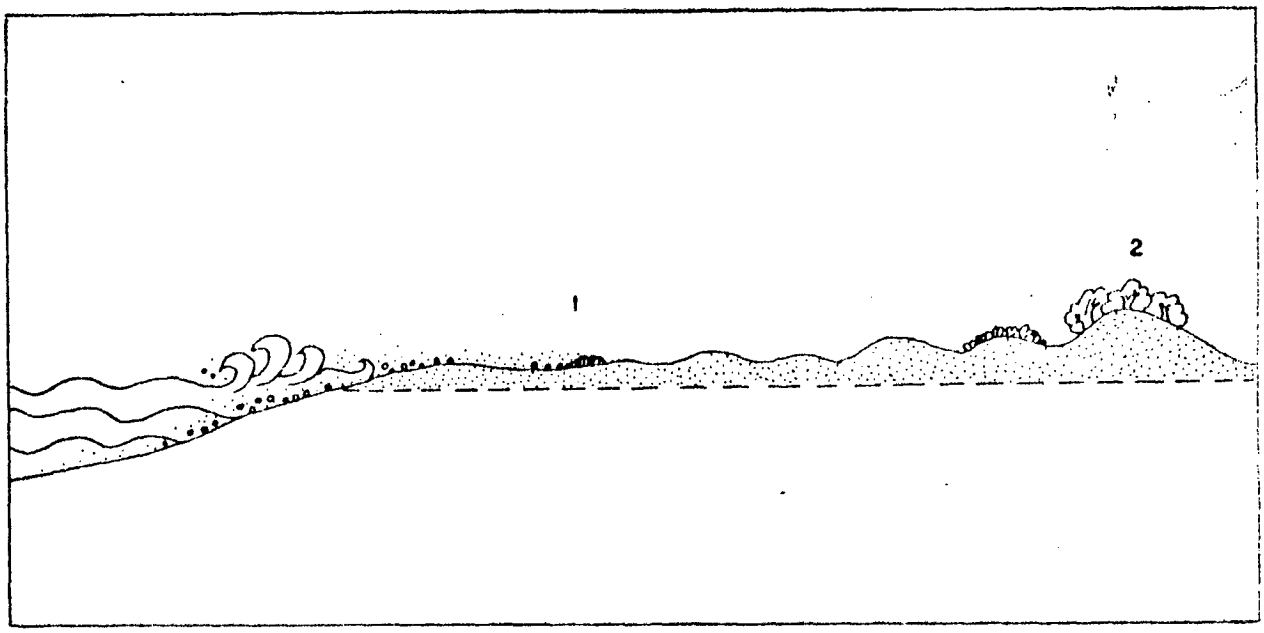

Fig. 1 Formation of a dune

1. Embryonic dune

2. Mature dune

short hops. Nearly all wind blown sand is moved by saltation.Wind action effectively sorts the original beach material. The small particles may be completely removed from the beach dune area while the largest particles remain. Sand grains removed from the beach by wind and deposited in dunes are essentially of one size(diameter ranges from 0.15mm to 0.30mm). Vegetation plays a dominant role in determining the size, shape and stability of foredunes.The aerial parts of vegetation obstruct the wind and absorb the wind energy. Wind velocity near vegetation is thus reduced below that needed for sand transport and hence the sand deposit around the vegetation. A characteristic of dune vegetation,particularly the grasses growing under these conditions, is its ability to produce upright stems and new roots in response to sand covering.If the plants do not continue to grow more rapidly than the rate of deposition, the arresting action of the plant ceases. Successive stages of plant growth and sand deposition result in an increase of width and height of the dunes (Bird,1972;Gale & Barr,1977).

During periods of shoreline advance, successive fore dunes may develop forming a series of dunes

parallel to the shore.The seaward margin of a foredune is termed as the margin of the foredune. As the new beach ridge develops, a low lying swale is formed between the developing ridge and the original foredunes. As the dune grasses colonize, the new beach ridge accumulates wind blown sand and a new foredune is built up. Stages in the successive formation of parallel dunes are seen (Bird, 1972; Gale & Barr, 1977).

Fore dunes act as barriers against the action of waves and tides,and are a source of sand for the beach during periods of erosion. They protect areas behind them from wave damage and salt water intrusion during storms.Vegetated foredunes are inherently flexible. If they are damaged by storm waves, the remaining vegetation traps sand blown from the beach and the dune is reformed, thus providing protection against future wave attack.Vegetated foredunes restrict wind, sand and salt spray intrusion into hind dune areas. The protective action of the foredunes allows the development of a more complex plant community on the hind dunes. Landward dunes parallell to foredunes are protective to a lesser degree. If they are well stabilized they serve as a second line of defence against water and wind erosion.

1.6 FUNCTIONS AND CHARACTERISTICS OF DUNE VEGETATION

Vegetation plays an important role in the formation and stabilization of coastal sand dunes.Pioneer plants trap and hold wind blown sand in the frontal dune and help to create condition which encourage the establishment and growth of other plant communities such as woodland, scrub heath and forest. All plants whether they are herbs,shrubs, or trees either growing singly or in groups have a role in the development of vegetation cover and together they bring about stabilization (Anonymous, 1981).

Wind blown sand trapped in the frontal dune by vegetation serve as a reservoir of sand for the beach during periods of wave erosion. In the absence of sand trapping dune vegetation,wind blown sand from the beach move inland and is lost to the beach\dune system. Wind erosion of the beach and unvegetated frontal dunes results in coastline recession (Anonymous, 1981). The above ground parts of dune plants act as obstruction, increase surface roughness,and cause reduction in the surface speed of sand carrying wind.

The reduction in wind movement results in the deposition of sand around the plants. *Spinifex littoreus* is the most successful sand trapping plant. It has the ability to grow through accumulation of wind blown sand. Cycles of sand deposition and plant growth results in dune formation.

The development of vegetation cover on newly formed dunes, if undisturbed, will create conditions which suit the colonization and growth of a wider range of plant species. The shade produced by plants keeps surface temperatures lower than that of bare sand and together with reduced wind movement help to lower the evaporation rate from the sand surface. Increasing vegetation cover further reduces wind movement which results in a lower rate of loss from plant leaves.Dead plant and leaf litter add humus to the sand (Anonymous, 1981).

The accumulation of humus results in improved moisture and nutrient holding capacity of developing dune soils. Thus with lower surface temperatures and increased moisture and nutrient content, the sand is able to support a great variety of plants. In this way the vegetation cover on the dune increases and movement of sand by wind is further decreased.

Pioneer plants make up the initial dune vegetation. They are found on the dune nearest to the sea where their survival depends on their ability to establish, grow and reproduce in order to colonise newly forming dunes. Pioneer plants must also tolerate salt spray, strong winds, sand blasts, and occasional washing away by sea water. Plants with these characteristics are ideally suited as agents for initial stabilization of dunes (Anonymous, 1981).

1.7 ORIGIN OF THE DUNES

There has been considerable debate on the origin of the fore dunes. Three primary modes of sand `beach ridge' genesis have been put forward by Davies (1957) and Mc Kenzie (1958). Two modes suggest a marine origin and one an aeolian origin. Davies (1957) proposed cut and fall hypothesis of sand 'beach ridge'formation in which a berm is built by calm weather waves (fill) and if not subsequently eroded (cut) becomes the nucleus for a beach ridge. Plants colonize the ridge trapping aerolian sand. After a certain time, a new berm may be built in front of the ridge and the process is repeated.

Davies (1957) suggested that swales were formed by the new berm being initially lower relative to the older beach ridge. According to Davies 'beach ridges' owed their alignment to the disposition of the berm nucleus which parallels the beach outline in plan.

A second mode of sand 'beach ridge' formation was put forth by Mc Kenzie (1958) who disagreed with Davies' (1957) hypothesis and stated that berms were not sufficiently stable to form the nucleus of the 'beach ridge'. In Mc Kenzie's view incipient fore dunes (newly developing foredunes or beach ridge) were formed where pioneer vegetation particularly *Spinifex hirsutus* grew seaward from a landward source trapping aeolian sand. He described the temporal development of this process in which a progression from ramp to terrace to terrace ridge fore dune morphologies occured as the beach was colonized by plant rhizomes and aeolian sand deposition took place.

Bird (1960,1963, 1965) originally agreed with Davies's hypothesis and disagreed with Mc Kenzie's and later (1969,1976) presented a modified version of the 'cut and fill' mode of ridge formation. In this, Bird described the scenario in which a fore dune forming on

top of a berm is scraped by storm waves. Subsequently waves built a new berm in front of and parallel to the trimmed foredune, separated from it by a low lying trough (Bird, 1976). Dune grasses colonise the berm first leaving the swale unvegetated and a new fore dune is formed. Bird (1976) stated that it was the effect of the cut which was responsible for the separation of dunes into parallel ridge and that in the absence of a cut, the foredune becomes broadened as a coastal terrace.

Whilst these three modes of beach ridge formation have been variously agreed to or modified by a number of workers (Thom, 1964,1965; Jennings, 1959; Jenkin, 1968; Hails, 1969; Wright, 1970; Davies, 1977, minimal evidence in the form of topographic or photographic survey has been presented to date to support the hypothesis outlined above.

In a study of beach, 'beach ridge' and foredune dynamics, Hesp (1982-83) recognised two major types of incipient fore dune initiation : Type I of those initiated by aeolian sand deposition within and in the lee of the discrete plants (especially annuals) and Type II those initiated by aeolian sand deposition within

laterally continuous plant communities (especially *Spinifex*). Aerial photograph studies by Hesp (1982-83)indicated that each incipient foredune was initiated by the growth of the annual *Cakile* germinating at the limit of spring tide swash on the beach shore (upper beach). Initially the *Cakile* plants individually trapped aeolian sand forming a broad hummocky terrace. This terrace was colonized by either *Spinifex longifolius* or *Tetragonia decumbens* and sometimes both spreading towards sea from the landward incipient foredune. These incipient foredunes gradually increase in size by aeolian sand deposition until progradation of the subarial beach allows a new discrete *Cakile* zone to become established. Over the time as the sand supply to each ridge is reduced due to seaward progradation and the formation of new ridges, pioneer species are replaced by intermediate and heath species in a well defined successional sequence (Ward, 1983). Studies by Hesp (1982,1983,1984) and Mc Kenzie (1958) provide evidence for an aeolian genesis of sand 'beach ridge' rather than marine (berm initiation or berm cutting) genesis (Davies, 1957; Bird, 1976). Hesp's observation indicated that the crests of berms are never successfully colonized by pioneer plant seedlings. This

was the case even under conditions of rapid beach progradation, the area of vegetation colonization consistently being restricted to the back- shore zone at or above the spring high tide line. These statements are strongly supported by international evidences (Salisbery, 1952; Olson, 1958).

Four major coastal dune complexes may be recognised in coastal South Africa. These are fore dunes, relict foredune plains, parabolic dunes and transgressive dune fields. Fore dunes are the foremost of primary vegetated dune ridges formed on the backshore of beaches by sand deposition within vegetation. This type corresponds to Davies' (1977) `impeded dune type' and Tinley's (1985) 'driftline embryo dune'. Foredunes may be classified into two types, incipient fore dunes and established fore dunes (Hesp, 1984).

Incipient fore dunes are the initial dunes formed by trapping of sand within pioneer plants. They may form a discrete mounds and drift dunes within discrete plants or clumps of plants (Hesp,1981) or as more continuous shore parallel ridges. The pioneer species which contribute to this dune formation in S.Africa are *Cladoraphis cyperoids, Tetrogonia decumbens, Arctotheca*

populiflora, Seaevola thunbergii and *Ipoemoea berasiliensis*. As incipient for dunes build higher and wider, they may eventually be colonized by intermediate and local climax species and hence become established fore dunes.

Where pioneer growth is pronounced and/or pioneer plants are more aggressive and the shore line is propagating, fore dunes may be successively formed over time to produce a series of shore parallel ridges. These relict fore dune plains which have been termed as 'beach ridge' in Australia are rare on South Africa coast and also in India.

Parabolic dunes sometimes called 'dune plume' (Boucher,1981) are 'U' shaped or upsiloidal dunes characterised by elongated trailing ridges which are terminated downwards in 'U' shaped ridges and sand sheets. Two sub-types are common, namely long-walled type or as suggested by Tinley (1985) Hairpin deflation type and other imbricate types. The former are generally elongated downward with marked deflation basins on the inside of the 'U'. They develop on the flat or near flat terrain where the rate of down wind migration is at a maximum. Imbricate types display an overlapping form

where the trailing ridges are usually short (Hesp & Pelham, 1984).

The fourth main type of coastal dune complex is transgressive dune field. This type corresponds to Davies' (1980) 'secondary dune' and Tinley's (1985)' Bare or Free Dune.' The transgressive dunefields comprise of moderate to large scale migrating bodies of sand which are predominantly vegetation free and on which variety of dune types may develop.

Krumbein and Slack (1956) have suggested 4 zones of sand shores namely (1) Near shore bottom (2) foreshore (3) backshore and (4) dunes. Champion and Seth (1968) have classified the dunes under 'littoral forest'. Rao and Sastry (1972) have classified the strand vegetation into (1) strand sand (2) sand rock (3) sand coral. The 'strand' has further been subdivided into (I) open pioneer zone or outer zone, (II) closed herbaceous zone, (III) middle mixed or bushy zone and (IV) inner woodland zone.

Chapman (1976) has divided the dunes into (i) embryonic dune, (ii) yellow dune and (iii) grey dune according to the growth of the dune with its vegetation.

Generally the pioneer zone of the sand dune area is covered by coarse sand as the finer sand particles are blown by the wind towards woodland zone.

The soil in pioneer zone has low water holding capacity and it is slightly alkaline to acidic.

1.8 CLASSIFICATION OF DUNE VEGETATION

Turner, Carr and Bird (1962) described 5 well defined zones of vegetation on dune ridge (Fig.2).

a) Zone-I: EMBRYONIC DUNE: On the seaward coast long sand ridges lie parallel to the ocean swell. This zone is nearest to the sea and is unvegetated. It is just above the high tide level with its steeper face inland. This is clearly formed by sand delivered to the beach by wave action. On its surface occur a few very small embryonic dunes of wind blown sand accumulated round the base of the plants. Other larger embryonic dunes occur along seaward side parallel to the foredunes, which are presumed to be built on an earlier berm. The dominant plants of the embryonic dunes on the Indian coast are *Ipomoea pes-caprae*.

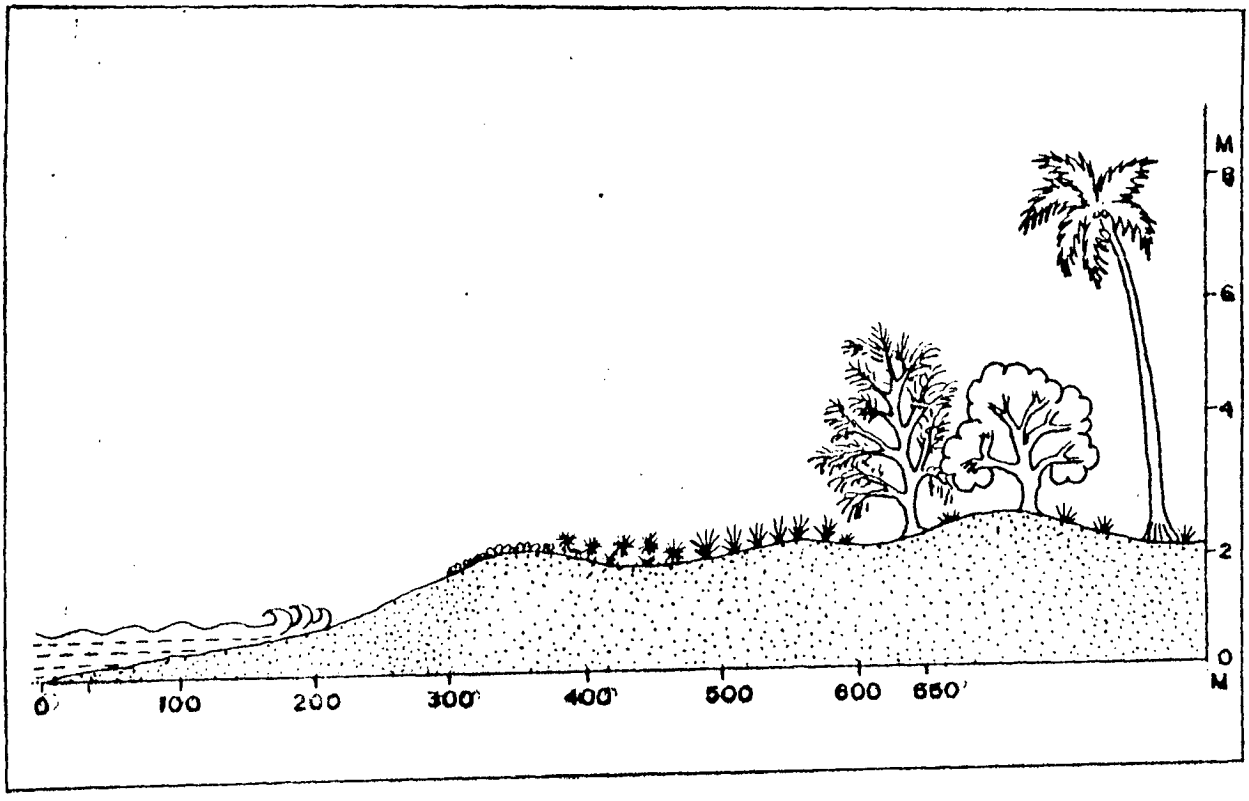

FIG. 2 GENERAL PROFILE OF A SAND DUNE

b) Zone-II: THE FORE DUNE: It runs parallel to the first beach ridge and is clearly formed on the earlier ridge by the coalescence of the embryonic dunes after further acceration of blown sand. The vegetation includes some species as zone I but is less open. *Spinifex littoreus*, a sand binding grass with creeping rhizome often advances to the embryonic dunes. This sand binder has efficient method of seed dispersal, the spiny globular fruiting heads being blown along the sand by the wind till they are caught in some obstruction and break up. Some herbs and shrubs, though not actually sand binders, are also included in this region from zone - III or other neighbouring salt marshes.

c) Zone-III:DUNE SCRUB or Stable dune Ridges: This is parallel to and close to the fore dune and forms the main part of the dune, which is little higher than the fore dunes but carries a close community of shrubs. On the Indian coast, *Casuarina equisetifolia* is often planted. Towards the seaward side it often adapts a more creeping habit though towards the inner land it grows fairly tall acting as a wind breaker. *Lantana camara, Vitex negundo, Clerodendron inerme* form part of

the natural vegetation here. The soil is slightly more mature than that of the earlier stages. There is a thin litter of dry leaves and the surface has pH 6.8. There is no mature soil profile.

d) **Zone-IV:SHRUB WOODLAND:** It is a long narrow sandy ridge running parallel and separated by mud flats with fringing salt marshes which are inundated at high tide.The vegetation on this part of the dune is often similar to the main inland. *Anacardium occidentale, Cocos nucifera, Pandanus tectorus* are some of the plants found in this region in India. The evidence that this region represents zone IV in the succession is provided partly by its position and height and partly by its soil characteristics and mainly by the major woody species of the dune scrub. These species occur both in zone III and zone V.

e) **Zone-V: THE DUNE WOODLAND:** It is made up of stable sand dunes. The vegetational community is closely similar to that found in the neighbouring coastal regions of the mainland on similar soils. The soil of the dune woodland is a very light quartz sand. There is some humus on the top.The surface layer has pH 4.5.

1.9 PURPOSE OF THE PRESENT STUDY

Goa, the smallest state of India is situated on the West coast with 120 Km. long coastline. The population is largely concentrated within the coastal talukas. Due to certain natural constraints like hilly terrain, dense forest, mining operations in the inner land development of human settlement is expanded on the coastal belt. The increased pressure on development should be balanced so as not to destroy the fragile ecosystem of the coastal belt. Moreover, the beaches of Goa are famous for their scenic beauty. The dimensions of tourism development on the beaches is surely affecting the dune system, and any further damage to this dune system will cause disaster by erosion or accretion of the coastal belt.The Karanzol beach profile map of 1905 and the map of 1985 prove that there is erosion taking place at the rate of 1 m. per year (Korgaonkar,1985). The coastal construction activity has resulted in damage of many buildings. To understand the dynamics of this region and to prevent any further damage, this study on the structure and functions of the sand dune vegetation along the Goa coast is taken up.

Different ecological parameters like temperature, wind speed (climatology),humidity,rainfall were observed. Study of sand size (granulometry),pH, vertical moisture content were noted .Monthly study of shore profile was taken up in one of the sample beaches of Goa, by name Varka situated in Salcette Taluka. The observation were well illustrated with the help of graphs and figures.

Aerial photographs of the beaches taken in 1973 and satellite pictures taken in 1988 were studied and compared by the actual survey of beaches during 1990-94. The structure and function of one of the sand binding plant *Spinifex littoreus* is studied in detail, as a case study of sand binding species.

The structure of the dunes and sandy beaches changes constantly because of their dynamic nature. As mentioned earlier,the moving sand dunes pose much danger by making the inland barren or extending deserts inwards. Hence, the dune vegetation plays an important role in minimizing the wind speed and also the movement of sand from the dune. Thus conservation and management of the dunes of Goa need immediate attention and hence the present relevant study is taken up.

CHAPTER – II

DISTRIBUTION

CONTENTS

2.1 INTRODUCTION

The coastal sand dunes like salt marshes result from the stabilization of transported sediment by vegetation. They are formed from wind blown sand rather than from water moved silt (Borden & Seed, 1985). The process of sand transport by wind was first studied in deserts but the same principles apply to beach sand also. When the surface wind is in excess of about 4.5 ms-, some sand particles are lifted from the sand surface, then they fall back setting other particles into motion so that these appear to jump from the sand surface, resulting in a process known as saltation.Sand leaving the surface may enter a higher air stream and thus be carried to greater distance before falling. However, presence of vegetation decreases air flow considerably. As a net result sand coming into the vicinity of pioneer growth is likely to settle and remain on the sediment surface. Embryonic dunes are formed provided upward and lateral grass growth can keep pace with deposition. Upward rate of 30 cmy- has been reported by Ranwell (1972).

Although the dune development is wind dependent, the earliest stage depends on tidal or climatically induced water level changes which enable to establish a streadline or drift. Blown out sand settles around this drift which contains debris of sea weeds, sea grasses or some animal matters. This debris allows water retention and supplies nutrients to the growing vegetation. The temperature fluctuation beneath the drift allows the salt tolerating seeds to germinate. The presence of drift line plants leads to further accumulation of sand, thus raising the beach level. Hence pioneer species can be established on the dune.

The grasses rapidly produce vertical and lateral roots and a rhizome system which binds the sand together.Reproduction is by seeds or from rhizome fragments. Some seeds like *Elymus* have a water soluble germination inhibitor,hence growth is not initiated in dry period. On germination a vertical seedling root is produced rapidly. This penetrates to deeper and moist sand layers. Lateral roots and then rhizomes are established which spread the plant outwards (Borden & Seed, 1985).

According to Swan (1979) coastal dunes are rare in equatorial regions. Principal factors conducive to dune

development are long dry seasons, strong onshore winds during the dry season, which are not found in the equatorial region.

2.2 LITERATURE SURVEY OF SAND DUNE VEGETATION OF THE WORLD

One of the oldest works on coastal dunes is by Woulter Van Dieren (1934) on how life reacts to stress and how dune building plants react to shape landscapes and protect long coasts.

Wiedmann (1984) reported about the sand dunes in the Atlantic and Pacific coasts of the North America. The environmental factors, classification of dunes, the plant communities and the wildlife habitats of the dunes have been well emphasized by him. Here the dunes are mostly broad, low sandy plains with generally slight relief. The wind force is not very conducive for the movement of the sand.

Terrel (1979), Cooper (1958, 1967) and Bird (1976) have contributed significantly to the studies of sand dune vegetation of the United States. A characteristic vegetation zonation occurs where succesive dune ridges

have been formed parallel to the shoreline. The zonation reflects the succession of the vegetation types from the pioneer colonizing species (typically grasses) on the fore dune through shrub species to a dune scrub with woodline or even heath on the older ridges. Extensive rearrangement of older parallel dune system has resulted in succession. The parabolic dunes carry younger soils and dune scrub vegetation whereas the undisturbed parellel ridges are covered by heath or woodland (Bird, 1961). The older parabolic dunes with acid soils are heath covered and more recent parallel dunes support a dense scrub (Parson,1966)

Eldred & Maun (1982), Maun (1989) reported the presence of sand dunes along the South Eastern shoreline of Lake Huron in Canada.

Grandos-Corona *et al* (1988) analyzed the changes in the vegetation of sand dunes of Donana National Park in the last four centuries. Until 1636 a Mediterranean forest dominated by *Quercus suber* was present. From 1636 to 1682 vegetation underwent profound changes with marked drop in trees and mature scrub. The vegetation was replaced by a pioneer scrub species. The climatic crisis around 1700 A.D. led to erosion of the sandy

soils which made the change irreversible. Live stock pressure also hampered natural forest regeneration until 1737,when *Pinus pinea* plantation started.From then onwards little change in vegetation is known to have occurred.

Seven coastal dune systems of Menorca Isle (Balearic islands) have been studied by Larrucea and Tebar (1990), to describe their vegetal zonation and to know the ecology of the main species. A zonation model related with the `distance to the sea' complex gradient has been proposed.

Kutiel *et al* (1980) studied the vegetation along the coastal plain of Israel. It extends 1-6 km. east of the Mediterranean coast. Eig (1939)and Zohary (1962) also studied the coastal vegetation along the Mediterranean coast.

Hesp *et al* (1989) reviewed the dune system on the African coast. They distinguished four principal coastal dunes: fore dunes, relict fore dune plains, parabolic dunes and transgressive dune fields. The evolution and morphology of each complex is briefly studied by them. Transgressive dune fields are the dominant dune

complexes. They are found on the high energy beaches experiencing high littoral drift and form two main types, tabular fields and buttress fields.Both tend to be dominated by transverse dunes.

Avis (1985) reported unconsolidated drifting sand dunes with sandy beaches in the coastline of South Africa. He assessed the stability by using the indigenous species for stabilizing mobile dunes in the Eastern Cape so that exotic species could be removed.

The coastal dunes in Europe including Dutch, German, Danish, French have been studied by Olson and Vanda Maarel (1989). They have introduced three types of coast with sand dunes as dominant feature.

By means of multivariate analysis and the relationship between vegetation and environment four vegetation groups are defined in Northern Spain by Onaindia *et al* (1991). These groups characterize different degrees of soil formation.

Maarel *et al* (1985) analyzed the vegetation on the coastal dunes in South West Netherlands, while Simpson and Mason (1984) reported the dune flora of Canterbury, and Babikir (1984) gave an account of the coastal sand

dune vegetation of Qatar. Classification and ordination of coastal sand dune vegetation along the gulf of Caribbean Sea of Mexico is given by Moreno- Casola et al (1986).

The United Arab Emirates has two coastlands, one towards the East and the other towards the West. The Western coastline extends along the Arabian Gulf while the Eastern coast runs along the Gulf of Oman. The South-West regions of the country comprise of extensive gravel plains with banks of aeolian sand piled up by the prevailing winds. Low towards the coast, these coastal banks increase until they form awesome dune barriers with slip (Western, 1989).

Gehu and Uslu (1989) studied the halophilous and psamophilous coastal vegetation of the Turkish straits area. Sand dunes were identified by phytosociological methods and their geographical distribution.

In the flora of Japan Ohwi (1953) and Lazarides (1980) reported the `Tropical Grasses of South East Asia'. Plants like *Spinifex* surely indicate the presence of coastal dunes.

According to the Beach Protection Authority of Queensland (1981), the coastline has been divided into three major regions; viz. (a) coastal sand masses of Southern Queensland, (b) coastal sand masses of Central Queensland, (c) coastal sand masses of Northern Queensland.

Important species of fore dune from various parts of the world have been studied and tabulated by Doing (1985). He suggested made a major division between tropical and temperate regions. The most extensive and complicated dune area occurs in the regions where disturbances of wind and fixation of dune by plant growth are equally strong. Coastal sand dunes of the world are shown in Fig. 3.

According to Silvester (1981), the sand at the back of a berm which has not suffered passage to sea for three years can promote vegetation. Thus,when the sand is blown from the berm it gets deposited on this zone due to reduction of wind speed.

Rao *et al* (1964,'71 '72 '74 and '75) under the Botanical Survey of India have worked extensively on the ecological studies of coastal and sand dune vegetation

FIG 3 : LEGENDS

1. United Arab Emirates
2. Japan Coast
3. Queensland Coastline (Australia)
4. Coastline of (a) Washington (b) Oregon (c) California (U.S.A.)
5. Victoria Coast
6. South Eastern Coast of Lake Huron in Canada
7. Coastal plains of Israel
8. African coast
9. South African Eastern Cape
10. Coastline of Dutch (Netherland) Germany, Denmark, France
11. Caribbean Sea, Gulf of Mexico, Canteburg
12. India

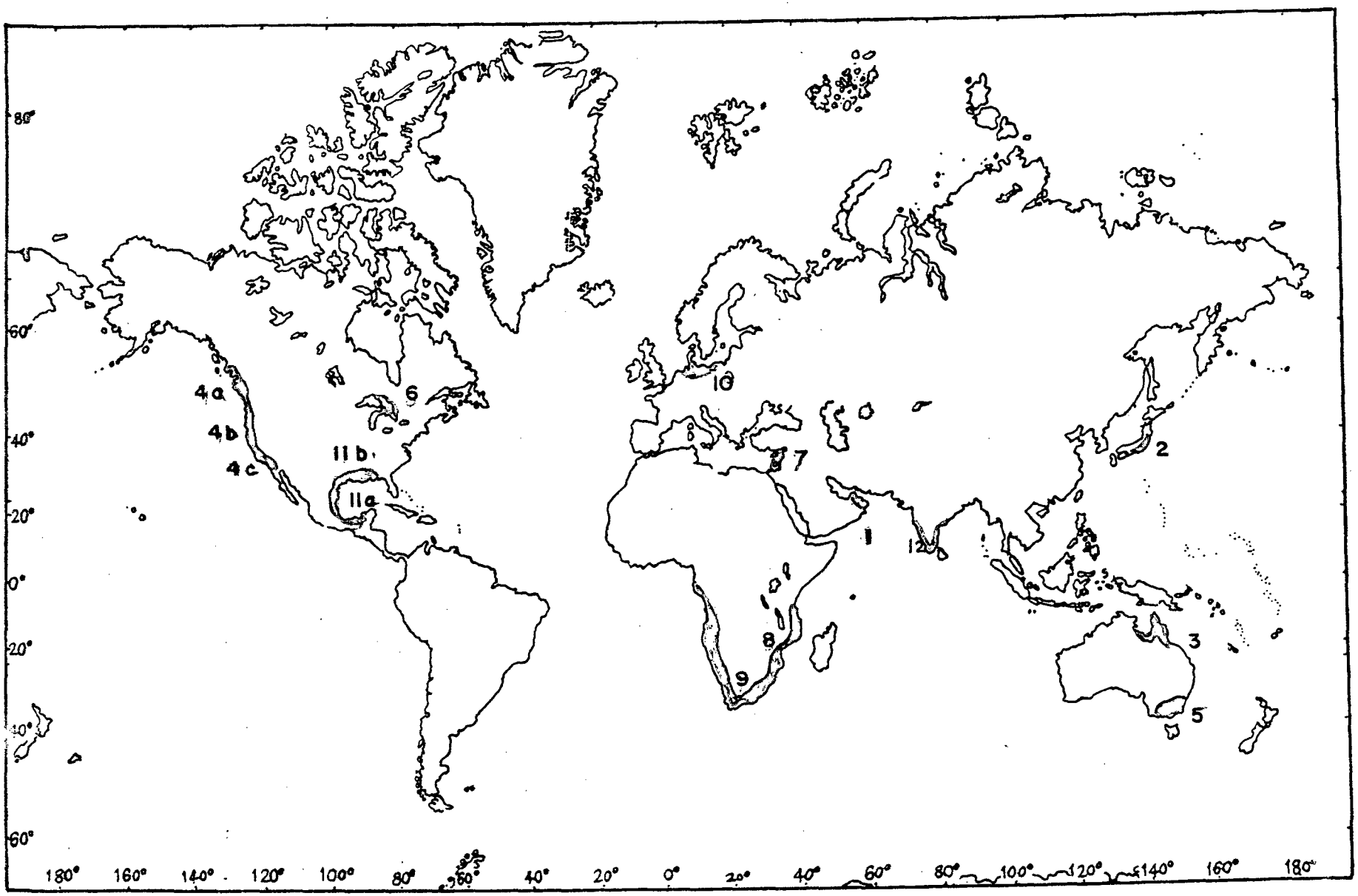

Fig. 3 World map showing sand dune vegetation

along the coasts of Saurashtra and the neighbouring islands, Tamil Nadu, Orissa and West Bengal.

Untawale (1980) gave a report of the sandy coasts of India (Fig.4). Sandy coasts have been reported in Gujarat (Kuchchh), Saurashtra and S. Gujarat which is limited between muddy and rocky shores. Sandy strips along rocky cliffs are also observed in Maharashtra. The sandy shore of Karnataka is of limited width while Kerala has extensive sandy beaches interspersed with coastal lagoons. They are often laterite or rock bound. Tamil Nadu has sand strips along the deltic shores and rock bound beaches. In Andhra Pradesh the sandy beaches are of limited width intercepted by river Godavari,Krishna and their tributaries. Konark, Puri in Orissa have extensive sand strips. The West Bengal coast is also limited. The coast of Andaman Islands has sand strips intercepted by bluffs, rocks or shingle along the coastline. Lakshadweep atolls have long stretches of coralline sandy beaches with unique vegetation.

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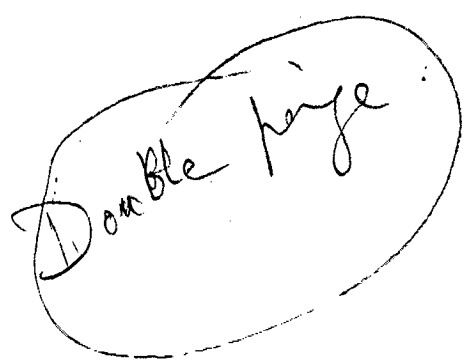


FIG 4 : LEGENDS

1. KUCHCHH
2. SAURASHTRA
3. MAHARASHTRA
4. GOA
5. KARNATAKA
6. KERALA
7. TAMIL NADU
8. ANDHRA PRADESH
9. ORISSA
10. WEST BENGAL

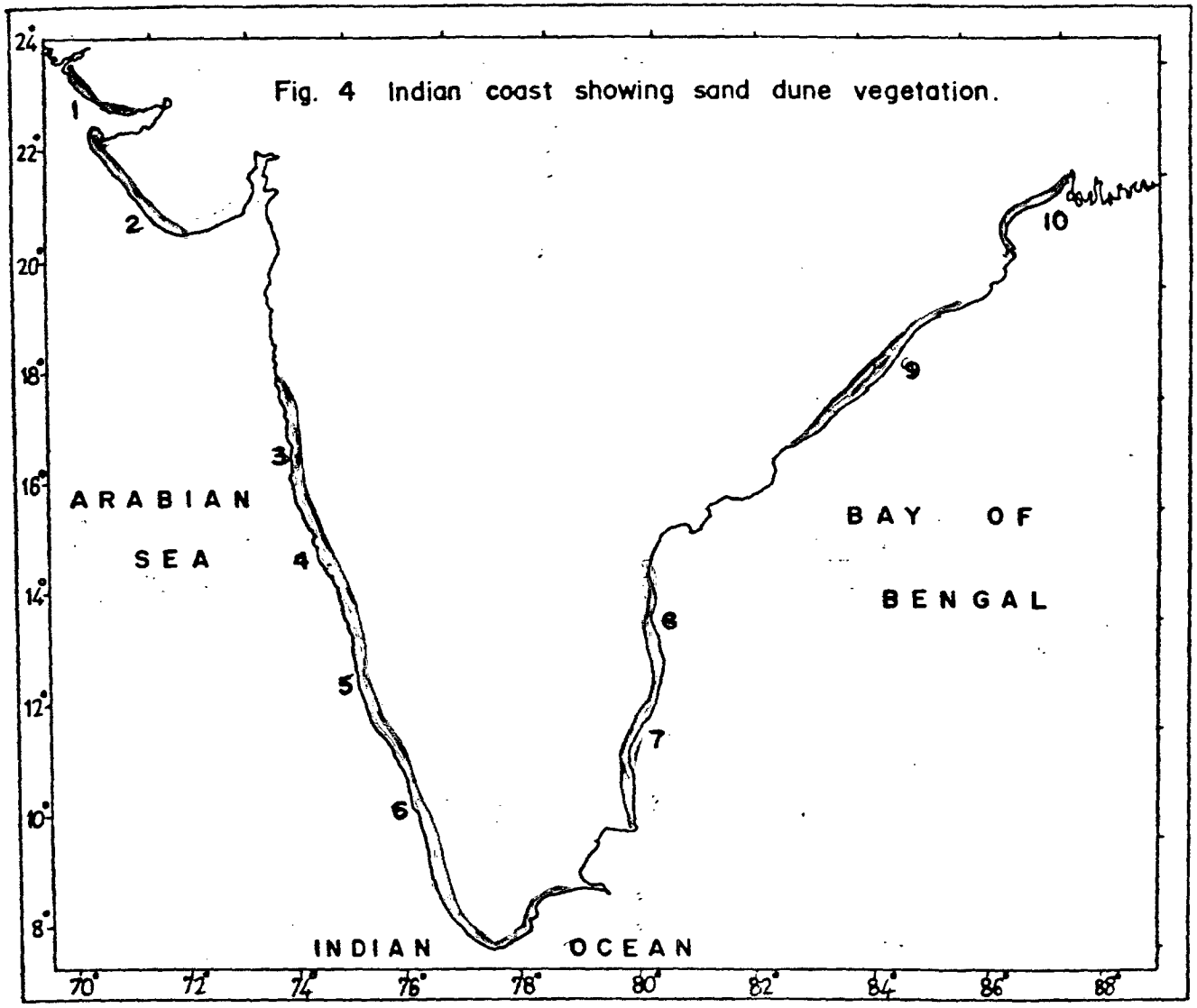


Fig. 4 Indian coast showing sand dune vegetation.

2.3 LOCATION OF THE PRESENT STUDY

The study was taken up in one of the smallest state of India, GOA, situated along the Central West coast of India lying in between Latitudes 15° 48' 00'' and 14° 43' 54''N and Longitude 74° 20'13'' to 73° 40'33''E. (Anonymous, 1979). The coastline of Goa is segmented as a result of seven rivers like Mandovi, Zuari,Chapora,Sal and others. Besides ,there are cliffs of Western Ghats, bays and creeks which intercept the coast (Ahmed, 1972). The coast is approximately 120 km.in length. The lengths of the sandy shores in Goa have been indicated in Table 1 (Dhargalkar, 1981),(Fig. 5). Nomenclature of the beaches has been followed as approved by the Survey of India and the names in the parenthesis are those approved by the Govt.

The detailed ecological study on the seasonal basis was taken up at Varka beach which is situated in the Salcette Taluka on the 20 kms. stretch between Kansavlim (Cansaulim) and Kalashi (Cavelossim). The most popular beach on its North is Benavlim (Benaulim) and on the South is Kalashi (Cavelossim). The total length of the beach is 4 kms. and the width is 600 mts. It is one of

TABLE - 1 : LENGTH OF SANDY SHORES OF GOA

Name of the sandy coast	Length in km
1. Terekhol	2.04
2. Keri	1.32
3. Harmal	4.32
4. Mandre to Morji	7.38
5. Chapora	1.5
6. Vagator	0.85
7. Anjuna	2.55
8. Baga	1.30
9. Kalangut to Sinquerim	5.75
10. Campal	0.45
11. Miramar to Karanzole	4.15
12. Dona Paula	0.65
13. Oshal, Kankire & Naveshi	2.20
14. Marmagao head	0.15
15. Baina	1.70
16. Binkade	0.45
17. Bogmol	0.70
18. Valsao	0.80
19. Kolva, Benavli, Varka,Betul	26.25
20. Betul Pt	0.6

(Table 1 contd.)

21.	Cabo de Rama	1.85
22.	Talpona	1.24
23.	Kankona island	1.55
24.	Galgibag	0.69
25.	Loliem Pt.	0.13
26.	Pollem	0.25
27.	St. Georges islands	0.55
	Total lengths in km	71.37
	% Sandy shores	59.47%

Source : Dhargalkar (1981)

FIG 5 : LEGENDS

1. KERI
2. HARMAL
3. MORJI
4. VAGATOR
5. KALANGUT
6. GASPAR DIAS
7. KARANZOLE
8. BAINA
9. KANSAVLIM
10. KOLVA
11. BENAVLIM
12. VARKA
13. KALASHI
14. BETUL
15. PALOLEM
16. LOLIEM

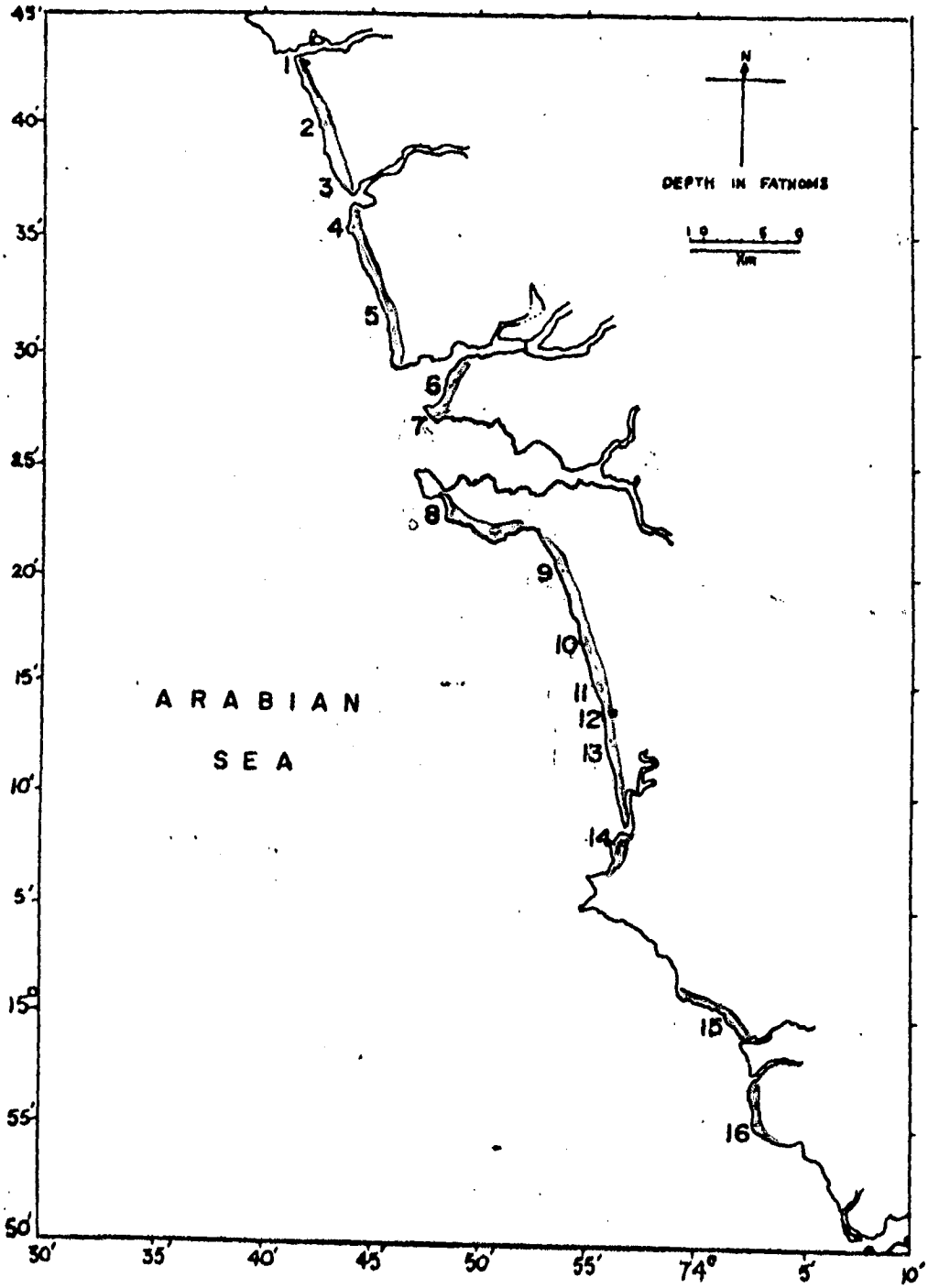


Fig. 5 Goa coast showing sand dune vegetation.

those beaches in Goa which have rich sand dune vegetation. Though, previously it had less pressure from tourism and urbinization, presently six hotel projects are proposed on the beach. (Personal communication: Town and Country Planning Department, Goa).

2.4 MATERIALS AND METHOD

The beaches on the coastline of Goa were surveyed for sandy shores and they were confirmed with earlier results. Plants growing on the sand dunes were collected from different beaches at different times of the year and herbaria were made of them which are kept in the Marine Biological Museum Cum Reference Centre of National Institute of Oceanography,Dona Paula, Goa. The presence of sand dune plants in three representative beaches in North, Central and South Goa have been tabulated.

At Varka, the frequency percentage of the most dominant species were calculated using the quadrate transect method. Three study areas were chosen 100 mts. apart in the different shore dune zones ie.

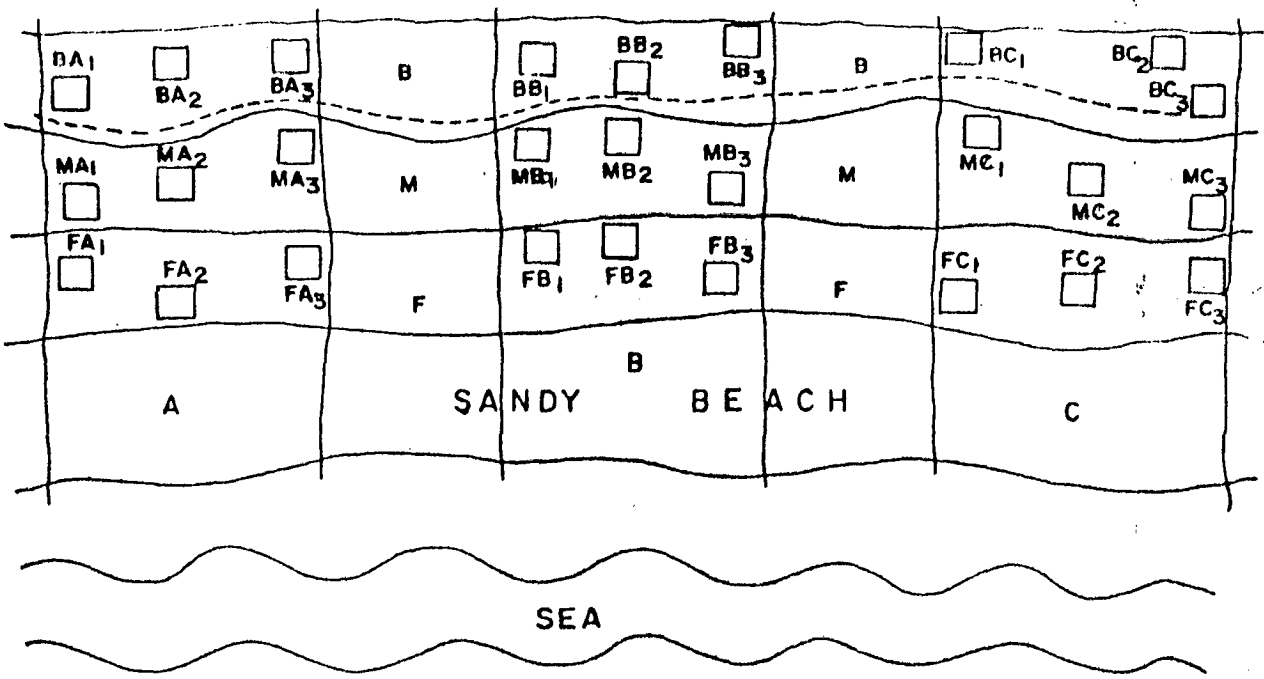
foreshore zone, mid shore zone and hind shore. At each zone three seperate quadrates were studied. In all 27 quadrates were studied (Fig 6) (Table 2-4) at random in three areas for statistical validity (Smith, 1966).

2.5 RESULTS AND DISCUSSION

As suggested by Olson and Maarel (1989) and Hesp *et al* (1989) four main types of dune systems could not be clearly recognized along the coast of Goa.

The primary dune system is about 250 mts. away from the high tide mark. It is marked by the presence of embryonic white dunes. Here,patches of *Ipomoea pes-caprae* are seen to be colonizing. The fore dune zone, however, was found to be covered by different species like *Cakile maritima, Atriplex cinercum* (Turner *et al*, 1968), *Convolvulus soldanella* and *Taneacetum donglasii* (Wiedmann, 1984) from Australia and the Pacific Coast.

Rao *et al* (1971) recognized communities of *Hydrophylax maritima* and *Ipomoea pes- caprae* growing on the Saurashtra coast. Along the Orissa coast Rao *et al* (1972) reported the growth of *Canavalia maritima, Cyperus arenarius, Ipomoea pes - caprae, Launea*



Why random?

Fig. 6 Random sampling by quadrates on different zones of the beach at Varka

LEGENDS: F - Foreshore M - Midshore B - Hindshore

A, B, C, – Three study areas

1 3 – Three quadrates in each area

TABLE - 2 : FORE SHORE DUNES QUADRATE STUDY AT SITE-VARKA

S.No.	Name of species	No. of individuals in diff. quadrats each of 1 sq.m.									Total No.of individuals	Density (pl/m^2)
		FA1	FA2	FA3	FB1	FB2	FB3	FC1	FC2	FC3		
1.	*Spinifex littoreus*	6	2	5	8	7	4	4	5	6	47	5.2
2.	*Ipomoea pes. caprae*	-	5	-	-	-	3	4	-	-	12	1.3

TABLE - 3 : MIDSHORE DUNES QUADRATE STUDY AT SITE - VARKA

S.No.	Name of species	MA1	MA2	MA3	MB1	MB2	MB3	MC1	MC2	MC3	Total No.of individuals	Density (pl/m^2)
1.	*Spinifex littoreus*, L.	8	9	7	12	15	10	13	12	9	95	10.5
2.	*Spermacoce stricta*, L.f	2	4	5	5	7	4	4	3	5	39	4.3
3.	*Cyperus arenarius*,Retz.	3	4	7	8	6	3	5	4	2	42	4.6
4.	*Launaea pinnatifida*,Cass.	4	4	3	3	6	5	3	4	3	35	3.8
5.	*Justicia simplex* Don.	2	3	4	2	2	3	3	2	1	22	2.4
6.	*Lactuca remotiflora*, D.G.	1	2	3	3	3	2	3	2	-	19	2.1
7.	*Eragrostis unioloides*Nees	1	1	2	3	3	2	3	2	1	18	2.0
8.	*Sporobolus virginicus*,Kunth	2	3	-	-	2	3	1	-	2	13	1.4
9.	*Vitex Negundo*, L.	-	-	4	-	-	-	-	-	-	4	0.4
10.	*Clerodendron inerme*,	-	-	3	-	-	-	-	-	-	3	0.3
11.	*Lantana camara Gaertn*	-	-	3	-	-	-	-	-	-	3	0.3
12.	*Pandanus tectorius*,Soland	-	-	-	5	6	-	-	-	-	11	1.2
13.	*Ageratum conyzoides*,L	-	2	4	5	6	-	4	3	-	24	2.6

TABLE 4 : BACK SHORE DUNE QUADRATE STUDY - SITE VARKA

S.No.	Name of species	BA1	BA2	BA3	BB1	BB2	BB3	BC1	BC2	BC3	Total No.of individuals	Density (pl/m^2)
1.	*Spinifex littoreus*,Merrill	2	-	-	4	6	-	-	3	5	20	2.2
2.	*Justicia simplex*,Don.	2	4	5	1	-	6	-	5	-	23	2.5
3.	*Crotalaria striata*,DC	-	1	2	-	-	3	2	1	-	9	1.0
4.	*Leea Sambucina*,Willd	-	2	-	-	-	1	2	-	-	5	0.5
5.	*Spermacoce stricta*,L.f.	2	-	-	1	3	-	-	-	4	10	1.1
6.	*Ageratum conyzoides*,L.	3	-	1	2	4	-	-	-	2	12	1.3
7.	*Cyperus arenarius*,Retz.	2	2	3	3	4	4	5	4	3	30	3.3

sarmentosa and Hydrophylax maritima. In the same paper they referred to the growth of *Ipomoea pes - caprae, Cyperus arenarius, Canavalia maritima, Launea sarmentosa, Sporobolus virginicus* and *Zoysia matrella* on the Andhra coast. On the West Bengal coast, the open pioneer zone is being covered with *Ipomoea pes-caprae, Launea sarmentosa, Dactyloctenium aegypticum* and *Cyperus arenarius* (Rao *et al*, 1974). The coast of Goa has the dominant flora of *Ipomoea pes - caprae* and *Spinifex littoreus* in this pioneer zone.

The `Parabola dune System' of Wiedmann (1984) is also referred to as 'Blowout dune system' by Olson and Maarel(1989). Here due to sufficient supply of sand and the effective wind speed, sand is blown and trapped by the plant cover resulting into the stabilized dunes. This zone is referred as closed Herbaceous zone by Rao *et al* (1972). On the Western coast, this zone was reported to be vegetated by *Halopyrum mucronatum, Borreria articularis, Lotus garcinii, Asparagus dumosus, Enicostema hyssopiflorum, Peplidium maritimum* and *Cassytha filiformis*. Along the Orissa coast the growth of *Euphorbia rosea, Geniospermum tenuiflorum,* and *Phyllanthus rotundifolius* was reported (Rao *et al*,

1974). While on the Andhra Pradesh coast the growth of *Spinifex littoreus, Goniogyne hirta, Perotis indica, Trachys muricata* and *Fimbristylis polytrichoides* was common. Along the West Bengal coast, Rao *et al* (1974) reported the growth of *Synostemon bacciforme, Borreria articularis, Brachiaria reptens, Elusine indica, Euphorbia thymifolia, Leucas lavandulaetolia, Narenga porphyrochoma, Rothia indica* and *Trianthema pentandra*. The dominant plants growing on the Goa coast are *Spinifex littoreus, Cyperus arenarius, Spermacoce stricta, Launea pinnatifida, Justicia simplex, Lactuca remotiflora, Ipomoea pes-caprae, Sporobolus virginicus, Clerodendron inerme* and other plants given in Tables 3 & 6. This region can be referred to as mid-dune region which forms the highest zone in the entire landscape and ends abruptly towards the hinterland. In different parts of the world, species like *Ammophila aranaria, Rubus caesius* are seen to stabilize this part. Another interesting feature of Goa coast was that at places naturally occurring depressions were observed. In Varka, fresh water hydrophytes like *Salvinia,Lemna* and *Eichornia* are found in the water trapped bodies.

'Migratory dune System' present in other parts of the world and reported by Cooper (1958); Wiedmann

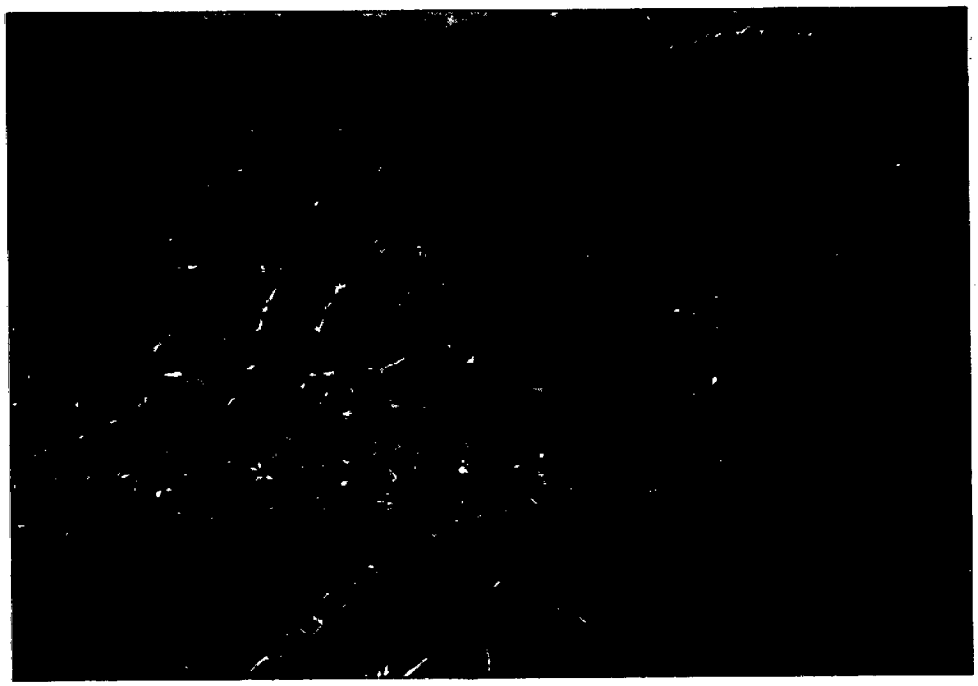
(1984); was not observed in Goa during the present studies. This may be due to the location of the coast (between 15° 48' 00" and 14° 43'54" latitude) where long dry season with strong onshore wind was not experienced. But near Varka, Benavlim and Kolva, towards much interior region along the road side huge dunes were observed suggesting that these dunes might have moved from the coastal region either when there was no vegetation cover on the beach or there must have been erratic behaviour of the wind in the past. Such dune system was not observed in any other talukas of Goa because in most places this area has been highly urbanized or cultivated with *Cocos nucifera, Casuarina equisetifolia* or covered with naturally growing trees like *Anacardium occidentale, Garcinia indica,* different species of *Ficus, Tamarindus indicus.* This area, although difficult to describe in terms of dune formations and dune landscape, can be called as back dune,which is often grey in colour. This dune system is also referred to as residual dune system.

Thus, it can be concluded that in Goa there exist mainly three types of dunes i.e. the white dune, yellow dune and grey dune.

A brief description of the beaches of Goa from North at Keri to south at Pollem follows. At Keri there is a successful plantation of *Casuarina equisetifolia* on the backshore while the foreshore has a good carpet growth of *Ipomoea pes-caprae*. But at Morji in the same taluka of Pernem the *Casuarina* plantation is too near the foreshore and mid- shore thus disturbing the natural vegetation with the result that the roots of these trees remain superficial and proper anchorage is not ensured resulting into uprooting of the trees (Plate 2).

Towards north at Mandre there was little natural vegetation of *Spinifex*, even *Casuarina* plantation was not very significant; however, good growth of *Pandanus* was found. Backshore has patches of Bamboo, *Anacardium occidentale*, and many mesophytes like *Leucas aspera* ,*Zizyphus rugosa*, *Z.jujuba* and *Crotalaria striata* .

On Harmal beach, lot of disturbance by human activities was observed. On the foreshore itself buildings and roads have been constructed. The beach was found to be totally devoid of vegetation. This region was also found to be prone to the erosion and if proper management care is not taken, the sea will



VEGETATION ON FOREDUNES

UPROOTED CASUARINA TREES

PLATE - II

encroach and damage the long sandy coast of 7 km. from Morji to Mandre.

The sandy shores from Chapora to Baga have few prominent dunes as this region is intercepted by rivers and cliffs. Moreover,with tourism developing as a major industry, there are number of hotels and restaurants on the beaches, which destroy the natural vegetation. The stretch between Kalangut` to Sinqueri in Bardez taluka has beautiful sandy shores but again the dune system is disturbed here by tourism activities.

The capital city of Panaji has sandy coast from Campal to Karanzol. Near Campal the buildings of Kala Academy and Youth hostel are too close to the shore, thus disturbing the dune system totally, with the result that there is erosion causing damage to the buildings. Uprooted *Casuarina* trees are also seen here. To protect the coast from erosion somewhere around 1934 a laterite wall was built on the shore.But this did not solve the problem, as in due course of time this wall was covered with sand, and erosion continued. Again, around 1974 a second wall was built which also has not served its purpose. What is important is not any

artificial construction on the shore but to maintain the natural vegetation in the specific zones.

The sandy shore of Gaspar Dias or Miramar is broad and is about 90-100 mts in length. At some places on Karanzol side the fore dune has thick carpet of *Ipomoea pes-caprae* in association with *Spinifex littoreus*, *Amaranthus spinosa*, *Boerhaavia diffusa*, *Crotalaria retusa* and *Zornia diphyla*, while on the Panaji side the fore dune vegetation is destroyed by plantation of *Casuarina*. This plantation would have been very successful in maintaining the fore and mid dune system if the plantation was taken up at the back shore. But the backdune is totally absent here due to urbanization.

Near Dona Paula the shore is intercepted by rocky cliffs and estuaries which sandwitch sometime the small sandy beaches. Oshal, Kankara, Naveshi do not have significant dunes as they have many cliffs; however, beyond the backshore zone paddy cultivation is taken up.

The sandy shore between Marmagao and Velsanv has many disruptions. This area has many industries and is heavily populated. Moreover, the Zuari estuary meets the Arabian sea in this area making it a highly dynamic zone.

The best of dunes in Goa were found on the stretch of Majorda, Kolva, Benavli, Varka, Betul and Kalashi, although, due to tourism industry dunes at several places in this part were found to be disturbed. At places the sea has already entered and erosion of the shore has taken place. Varka where the present study was taken up has well vegetated dunes. Here one can clearly see three different types of dunes: the fore or white dune, mid or yellow dune,and back or grey dune.

Towards South from Varka, till recently good dunes existed,but they are now under constant pressure as many 5-star hotels are coming up right on the beaches. These private hotels have encroached the fore dune areas and built their compound walls on the fore dune region, thus completely disturbing and destroying the dune vegetation. These constructions on the beaches will surely pose danger in near future.

Down South in Kankon Taluka the shore is again disrupted by river basins, cliffs and rocks.Dunes are found to certain extent at Agonda and Palolem. Galgibag has a very good shore but at many places the shore line is damaged. This is again because of the close plantation of *Casuarina equisetifolia* on the fore

shore. The trees are uprooted at many places, thus damaging the shore instead of protecting it. Loliem and Polem have little strips of sand on the shore. The village of Polem is almost on the shore.

It was observed that *Spinifex littoreus* was the most dominant species growing on Varka beach. The density and the frequency % of few of the dominant species growing on Varka was calculated by the formulae suggested by Raunkaier (1934) (Table 5). The other commonly occurring species found along the shores of Goa are *Ipomoea pes- caprae,* (Varka shore does not have a good distribution of this species) different species of *Cyperus, Spermacoce stricta, Sporobolus virginicus* etc. Table 6 gives the distribution of the dune flora on three different beaches of Goa i.e.,Morji, Miramar and Varka.

The dune vegetation is very important in shaping the coastal landscape. Some of the plants growing on the dunes are often considered to be only the members of weed flora but many of them are economically important (Table 7). Moreover, Untawale (1980) suggested that

TABLE - 5 : THE DENSITY AND FREQUENCY % OF FEW SPECIES GROWING ON VARKA BEACH

Name of species	Total No. of quadrats in which the spp occur	Total No. of quadrats studied	Total No. of individuals	Density* (pl/m^2)	Frequency** %
Spinifex littoreus Merrill	23	27	162	6.0	85.18
Justicia simplex, Don.	15	27	45	1.6	55.55
Spermacoce stricta, L.f.	13	27	49	1.8	48.00
Ageratum conyzoides, L	11	27	36	1.3	40.0
Cyperus arenarius, Retz.	18	27	54	2.0	66.0

* Density = $\frac{\text{Total No. of individuals}}{\text{Total No. of plots}}$

** Frequency % = $\frac{\text{Total No.of quadrats in which species occur}}{\text{Total No. of quadrats studied}} \times 100$

TABLE - 6 : SPECIES DISTRIBUTION OF SAND DUNE VEGETATION ALONG THE THREE MAIN BEACHES OF GOA

Sl.No.	Name of the species	Morjim	Miramar	Varka
1.	*Vitex Negundo*, Linn	+++	+	+++
2.	*Tephrosia purpurea*, Pers.	+	-	+
3.	*Fimbristylis sp*	-	-	-
4.	*Lactuca remotiflora*,DC.	-	-	++
5.	*Spermacoce stricta*	++	++	++
6.	*Triumfetta rhomboidea*,Jacq.	+	+	++
7.	*Cyperus arenarius*, Retz.	+	+	++
8.	*Cyperus* spp.	+	-	+
9.	*Ageratum conyzoides*,Linn.	+	+	+
10.	*Acrocephalus capitatus*,Bth.	+	-	+
11.	*Leucas aspera*,Spr.	+	+	+
12.	*Justicia simplex*,Don.	+	+	+
13.	*Leea sambucina*, Willd.	+	-	+
14.	*Crotalaria striata*, Dc.	-	-	-

+++ - Abundant

++ - Frequent

+ - Occasional

(Table-6 contd.)

15.	*A member of cucurbitaceae*	-	-	-
16.	*Fimbristylis* sp.	-	+	+
17.	*Abrus precatorius*,Linn	-	-	+
18.	*Spinifex littoreus*, Merrill	+++	+++	+++
19.	*Eragrostis unioloides*,Ness	-	-	++
20.	*A member of gramineae*	-	-	+
21.	*Cyperus* spp.	-	-	+
22.	*Cyperus* spp	-	-	+
23.	*Pedalium Murex*, Linn.	-	-	+
24.	*Lindernia ciliata*	+	-	+
25.	*A member of gramineae*	-	+	-
26.	*Panicum paludosum*,Rovb.	-	+	-
27.	*Fibristylis* spp.	-	+	-
28.	*Digitaria adscendens*,Henr.	-	+	-
29.	*Paspalidium flavidum*, Retz.	-	-	-
30.	*Sporobolus virginicus*, Kunth	-	+	-
31.	*Saccharum spontaneum*, Linn.	-	+	-
32.	*Dactyloctenium aegyptiacum*, Willd.	-	+	+
33.	*Launaea nudicaulis*, HK.f.	++	++	++
34.	*Ipomoea longiflora*, Br.	-	+	-

(Table-6 contd.)

35.	*Canavalia gladiata*, DC.	-	+	-
36.	*Avicennia marina*,Vierh.	-	+	-
37.	*Sesuvium portulacastrum*,Linn	-	++	-
38.	*Urginea indica*, Kunth.	+	+	-
39.	*Crotalaria retusa*, Linn.	-	+	+
40.	*Gomphrena decumbens globosa*, Linn	+	+	+
41.	*Phyllanthus reticulatus*, Poir	-	+	-
42.	*Zornia diphylla*,Pers.	-	+	+
43.	*Sida cordifolia*, Linn.	+	+	+
44.	*Acanthospermum hispidium*, DC	-	+	-
45.	*Ipomoea pes-caprae*, Linn.	+++	+++	+
46.	*Acanthus ilicifolius*, Linn.	-	+	+
47.	*Clerodendron inerme*,Goertn.	+	+	++
48.	*Opuntia* spp.	+	-	-
49.	*Dioscorea* spp.	-	-	++
50.	*Pandanus tectorius*, Soland.	+	-	++
51.	*Mimosa pudica*, Linn.	+	+	+
52.	*Duranta plumeri*, Jacq.	+	-	-
53.	*Anacardium occidentale*, Linn.	+	-	++
54.	*Physalis minima*,Linn.	+	-	+
55.	*Ficus* sp.	+	-	-

(Table-6 contd.)

Calotropis gigantea, Br.	+	+	+
Cassia Tora, Bak.	+	+	+
Casuarina equisetifolia Forst.	++	++	+
Hyphaene indica Becc	-	+	-

Cassia Tora
or Cassia tora ?

TABLE - 7 : ECONOMIC USE OF SAND DUNE PLANTS

Name of the species	Economic uses
1. *Ipomoea pes-caprae*	Sand binder used as stomachic and diuretic. External application for rheumatism. Seeds used for stomach ache and cramps.
2. *Ageratum conyzoides*	Used as nerve tonic, Decoction used in diarrhoea, dysentry, colic and other gastro intestinal ailments, leaves yield an essential oil used for flowering tobacco.
3. *Vitex Negundo*	Leaves used for tonic and vermifuge, smoked for relief in catarrh and headache. Leaves and roots possess tranquillizing effect. Young shoots employed for basketing.
4. *Lactuca remotiflora*	Used in chronic obstructiens of liver and bowels, as diuretics in calculous affection.
5. *Eragrostis unioloides*	Used as cattle and horse feed and as green manure
6. *Digitaria adscendens*	Used as fodder grass.
7. *Canavalia gladiata*	Green pods and beans used as a vegetable.
8. *Sesuvium portulacastrum*	Leaves and stem eaten as vegetable.
9. *Zornia diphylla*	Used as cattle fodder, also grown as cover crop for green manure.

(Table - 7 contd.)

10.	*Casuarina equisetifolia*	Used for fuel, house posts. bark used for dyeing and tanning, wind breakers and pond binders
11.	*Anacardium occidentale*	Kernel eaten, cashew apple used for preparation of wine. Oil used as varnish, ink, insulation coating wood. is used for packing case and boat building.

* Annonymous (1992)

sand dune areas could possibly be used for the cultivation of suitable crop plants which can tolerate maximum salinity. Traditionally, seasonal vegetables are cultivated near Varka shore and near Oshal, Kankara while at Karanzol paddy cultivation is taken up.

The dune vegetation either actively interacts with the wind blown sand or by its mere presence it passively interacts in protecting the shore from wind and water erosion. Thus, if dune management is properly undertaken the sea will not enter inland and cause damage. Moreover, if proper vegetation is maintained on the moving dunes, it would check the sand erosion. Hence, various aspects of dune vegetation studies have gained momentum throughout the world.

CHAPTER – III

MAPPING OF SAND DUNE VEGETATION

CONTENTS

3.1 INTRODUCTION

Sand dunes throughout the world have been recognized for their ecological significance. The dune vegetation helps in keeping the coastal land free from erosion and also prevents internal desertification. For effective management of the sand dune ecosystem basic information such as species composition, ecology, extent of land use and human intervention is required.

The territory of Goa, Lat. 15° 48'00"N to N 14° 43'54"; long. 74° 20'13"E to E 73° 40'33" (Anonymous, 1979) is midway along the Central west coast of India occupying a 120 km. long and 60 km. wide strip (in the widest area) between the Western Ghats and the Arabian sea.

The coast of Goa has beautiful stretches of sandy shores and beaches which attract large number of tourists from home and abroad, (Plate 3). A well planned development of the beaches is essential not only for the ecological importance of sand dune vegetation but also for an eco-friendly development of tourism and other industries, which will indeed be a contribution to the economy of the state.

GOA COAST WITH BEAUTIFUL
STRETCHES OF SANDY SHORES

WELL VEGETATED SANDY SHORES

PLATE - III

Wagle (1982) studied the coastal beaches of Goa along with its geo-morphological aspects. An attempt has been made here to study the spread of sand dune vegetation along Kolva and neighbouring coast in South Goa using the existing satellite images available at the National Institute Of Oceanography, Dona Paula, Goa. The aerial photographs and the satellite images of the Goa coast were further compared with the ground truth studies in this chapter.

3.2 GEO-MORPHOLOGICAL STUDY OF THE GOA COAST

An uncontrolled mosaic of photographs (1960 1:15,000 approx. and 1973 1:25,000 approx.) of the coastal area of Goa covering survey of India toposheets 48E\10, 14, 15,E\16,1\4,J\1 were prepared and studied. This was followed by a study under the mirror streoscope and the geo-morphic details were transferred on kodatrace and later compiled in a map (Wagle,1982) Fig.7.

Wagle (1982) studied the sand dunes of Goa coast by photo-element analysis such as tone, texture, shape, size, form, pattern and associated features. According

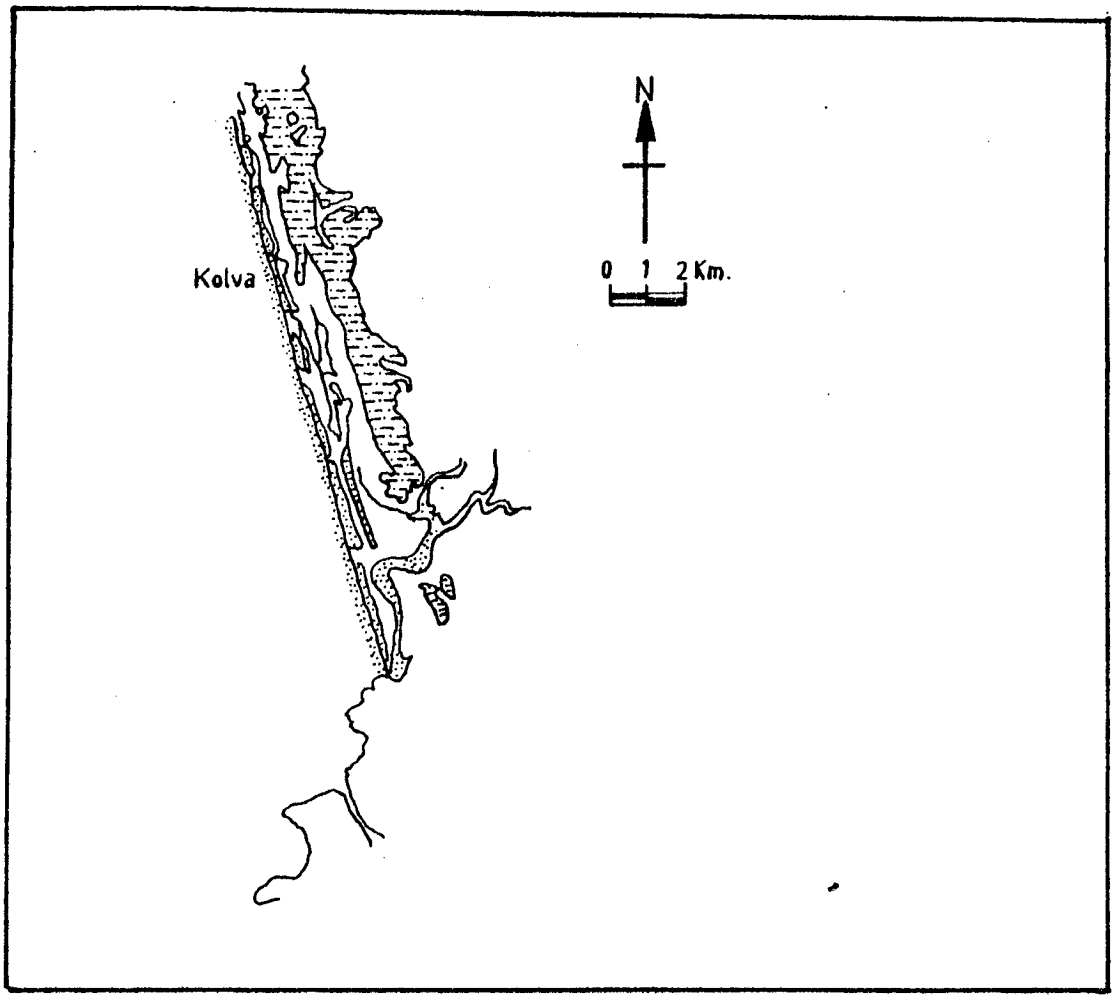


Fig. 7 Geomorphological map of south Goa coast Kolva and neighbouring beaches

to him a series of sand dunes occur parallel to the coast in many areas. Within these dunes a set of old and recent or active dunes can be distinguished. The recent or active sand dunes exhibit a very light tone in air photos. These are located close to the beaches and rise to a height of about 15 m. The dunes are generally devoid of vegetation or have only a thin veneer of vegetation. In the older dunes, landscape depicts a series of low ridges more or less parallel to the coast separated by swampy depression. The older dunes in the interior are usually stabilized by growth of thick vegetation. The dunes extend to about one or two kilometers inland and indicate the accretion of the shoreline.

3.3 MAPPING OF SAND DUNE VEGETATION FROM SATELLITE IMAGE

Photography from the ground or from aerial platform is a familiar and conventional form of remote sensing technique that has been extensively used since 1930s (Avery, 1966).Remote sensing has been used as a tool for study and management of Ecosystem (Odum,1967).

The sand dune vegetation along the Kolva and neighbouring coast of South Goa was studied with the available satellite images from National Institute of Oceanography at Dona Paula, Goa. The image is from the IRS-IA, the Indian Remote Sensing Satellite, taken on December 22,1988 (path no 29, row no 57) through the sensor called LISS-2 (the Linear Imaging and scanning System). The computer used is the mainframe micro VAX based ARIES Image Processing System.

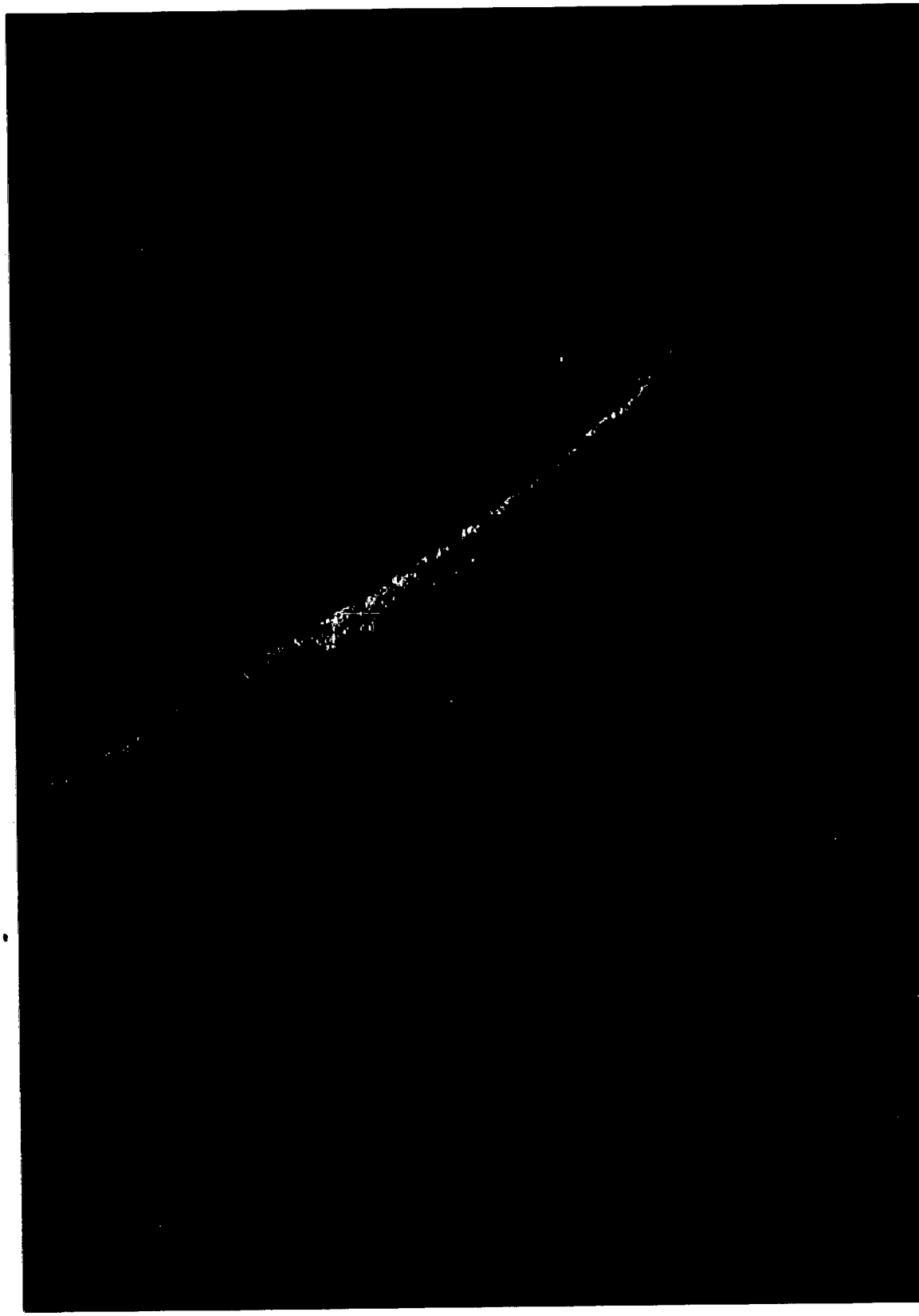
The method of mapping chosen here is known as the supervised classification, which is based on feeding to the computer prior information on location of known features of interest over a landscape at selected sites. The information needs to be available to the user through ground truth collection. This information needs to be accurate within the dimensions of pixel resolution of the image.

The image is first loaded on the TV monitor of the computer and the desired area is brought into focus by roaming the image. An area is marked on the image through the cursor (in the form of a loop), which encloses the given known feature at a selected site. The site as seen on the image is expected to be visited

by the user during the ground truth collection to confirm the existence of the given feature. In the present case, the feature was sand dune vegetation. The area enclosed in the loop is called as the training area.

The computer studied the training area and computed the statistical properties of the pixels such as the mean, the standard deviation etc., contained by the training area in various channels. Then the computer scanned the entire image to locate all the groups of pixels in the image wherever similar statistical properties existed and classified all such areas in a given colour code.

Plate 4 and 5 show part of the above mentioned image studied during this investigation. They show various parts of the coast line around Kolva in South Goa where sand dune vegetation was mapped. The sand dune vegetation is shown in blue colour while the unmapped part of the image is a false colour composite of two channels of the IRS viz., channel 4 and channel 3 loaded in red and green guns of TV monitor respectively.



SATELLITE IMAGE OF SAND DUNE VEGETATION
IN SOUTH GOA (SHOWN IN BLUE COLOURS)

PLATE - IV

SATELLITE IMAGE OF SAND DUNE VEGETATION
ALONG KOLVA COAST

PLATE - V

3.4 DISCUSSION

Ground truth collection between the period 1989 to 1994 showed that the new dunes or the so called fore dunes were sparsely vegetated with *Ipomoea pes-caprae* in most of the beaches. Some beaches like Morji, Miramar, Karanzol, Kansavlim, Majorda, Benavli, Varka, Kelashi, Agonda and Galgibag have natural thick growth of *Ipomoea pes-caprae* and *Spinifex littoreus*. On the hind dunes at many places like Keri, Morji, Kalangut, Baga, Miramar, Karanzol, Kansavlim, Galgibag plantation of *Casuarina eqisetifolia* has been taken up. The interior older dunes which showed thick vegetation through aerial photographs taken in 1973 have many constructions now. There has been a continuous pressure from tourism and hotel industries. The fragile sand dune ecosystem has deteriorated at many places recently. In the last two decades sand dune vegetation has been considerably reduced. However, presently efforts are being made to manage these resources on sustainable basis. Management plans for the conservation of the sand dunes have been prepared.

For the first time the sand dune vegetation has been studied through the satellite images. Spectral signatures for the species of sand dune vegetation, and the differences between the signatures will help in locating the signatures in the satellite image. Further study will help in locating the sand dune vegetation in any part of the world.

CHAPTER – IV

ECOLOGICAL OBSERVATIONS ON THE SAND DUNE VEGETATION

CONTENTS

4.1 INTRODUCTION

Coastal dune systems are dynamic natural features of vital economic and ecological importance. They function as flexible barriers to storm tides and waves (Wood house, 1982). The ability of dune vegetation for binding the sand is well known. The rapid increase in the desert area of the world has promoted intensive efforts to determine new and effective measures to stop or at least control the movement of the sand dunes (Untawale, 1980). Phytogeographical distribution of dune vegetation along the Indian coastline has received much attention from the beginning of this century. Champion and Seth (1968) have classified littoral and tidal forest of India. Rao and Sastry (1972) have done important work on the classification of coastal vegetation.

Burbour *et al* (1985) and Chapman (1976) have extensively reviewed the abiotic component of coastal sand dune. According to them the high temperature,wind speed, light intensity and potential evapotranspiration are of considerable significance. The sand is coarse with low level of inorganic nutrient content.As the

dunes succeed from embryonic dunes to woodland dunes, the increasing plant biomass results in higher humus content (Boerboom, 1963). With the increase in humus content of the soil the water holding capacity also increases. Nave (1983) suggested that the littoral dunes are formed under the action of winds,currents, tides, sedimentation processes and are fixed by vegetation. Dune erosion can be caused by geological processes, by meteorological factors and also by human activities. Different dune protection techniques like modifying dune profile, antiwind nets and phytostabilization techniques have been suggested as preventive methods.

Moreno (1982) suggested some environmental factors such as depth, fluctuation of ground water table, sand movements, aspects of steepness of slopes, temperature, humidity and some chemical as well as edaphic factors to study the floristic composition, structure and ecology of sand dune vegetation.

Untawale and Nair (1974) while studying the ecology of sand dune vegetation along the Miramar coast studied the climatological factors like rainfall,humidity, air temperature and wind speed as well as the edaphic factors, i.e., sand texture, pH,

humus content, soil temperature and the ground moisture.

The present study encompasses the phytogeographical distribution of the sand dune vegetation and the general morphology. The ecological observations were taken on the Varka beach, (Fig.5) Goa for eighteen months. On the basis of the ecological studies succession of the dune vegetation has been studied.

4.2 MATERIALS AND METHOD

To study the ecology of the sand dune vegetation along the coastline of Goa, initially all the beaches of Goa from Terekhol in Perne taluka (North) to Pollem in Kankon taluka (South) were visited. Photographs of the dunes and their vegetation were taken. For detailed ecological studies, Varka, a beach situated in Salcette taluka was chosen because it has rich sand dune vegetation and less disturbances from urbanization, tourism and human interference.

To study the edaphic factors of the coastline of Goa, granulometric experiments were performed. Sand from foreshore, midshore and backshore of four beaches - Morji, Harmal and Keri (all from Perne taluka) and Varka

(Salcette) were collected. The samples were weighed and oven dried. Then each of them were put in the sieve shaker of different size and the sand grain size was determined in terms of ϕ (phi) value, (Folk *et al*, 1957). Graphs are drawn to calculate the grain size. type of sand.

The organic matter content of the sand samples was calculated from fore, mid and hind shore of Varka beach.The sand from the three regions was collected and weight was taken in crucibles. The samples were then oven dried at 480 ^{o} to 500 ^{o}C till it burnt to ash.The weight of the ash was taken. The difference in weight was taken as the amount of organic matter present.

To study the moisture content sand samples from fore, mid and hind shore were collected at different levels at a difference of 20 cms. upto 1 metre. The samples were kept in an oven at 60^{o} C for 5 hours and then weighed. This procedure was repeated till a constant weight was obtained. The loss of weight accounted for the moisture content in the samples.

The pH of the sand was obtained by using pH paper. The sand samples from different levels and from

different shores were washed with distilled water and pH paper was dipped and dried. The colour of the paper was then compared with the standard colour range.

The dune temperature was taken with a celsius thermometer every month for eighteen months from May 1990 to October 1991. The temperatures taken were on the surface and at the depths of 5 cms. as well as 10 cms. Three diurnal temperatures i.e. during pre-monsoon (May), monsoon (August) and post-monsoon (November) were also noted. Graphs to show temperature fluctuation were drawn.

The climatological study included the wind speed atmospheric temperature, rainfall and humidity. The amount of rainfall and humidity percentage were obtained from the Meteorology Department Goa. Monthly wind speed was calculated from readings observed by field anemometer. Similarly,diurnal wind speed was calculated on three days during three seasons.

The profile map of Varka was drawn for all the eighteen months from May 1990 to October 1991.

Taking into account the various ecological

parameters the succession of the vegetation on the dunes was studied by field observation.

4.3 RESULTS AND DISCUSSIONS

4.3A GRANULOMETRY

The size of the sand grain was studied and expressed in terms of percentile (graphic) measures, following Folk and Ward (1957), as suggested by Veeraya (1978). Sand grains from Varka were compared with sand grains of three other beaches of Pedne taluka, Morji, Harmal and Keri.

The mid 0 (phi) value derived from the probability graph. This helped to analyze the type of sand in the respective beaches (Figs 8 to 11).

The grain size ranged from very fine to medium during the monsoon period. Inrman (1949), as referred by Veeraya(1978) suggested that sands of 2.5 0 are well sorted compared to sand with the size larger or smaller than 2.5 0. Thus,the sand from Varka backshore and Morji midshore were well sorted during the monsoon period.

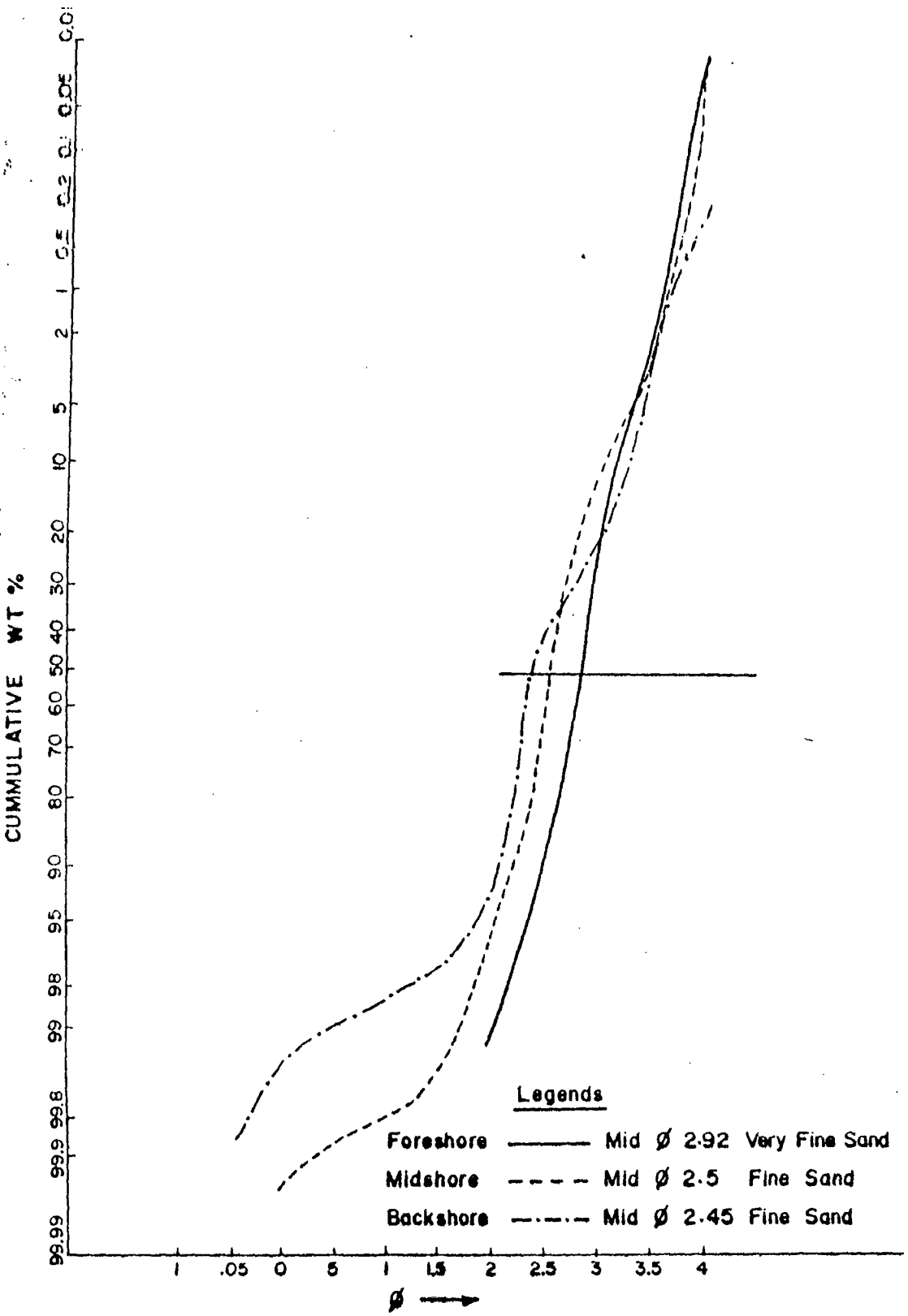


FIG. 8 SAND GRAIN SIZES : MORJI

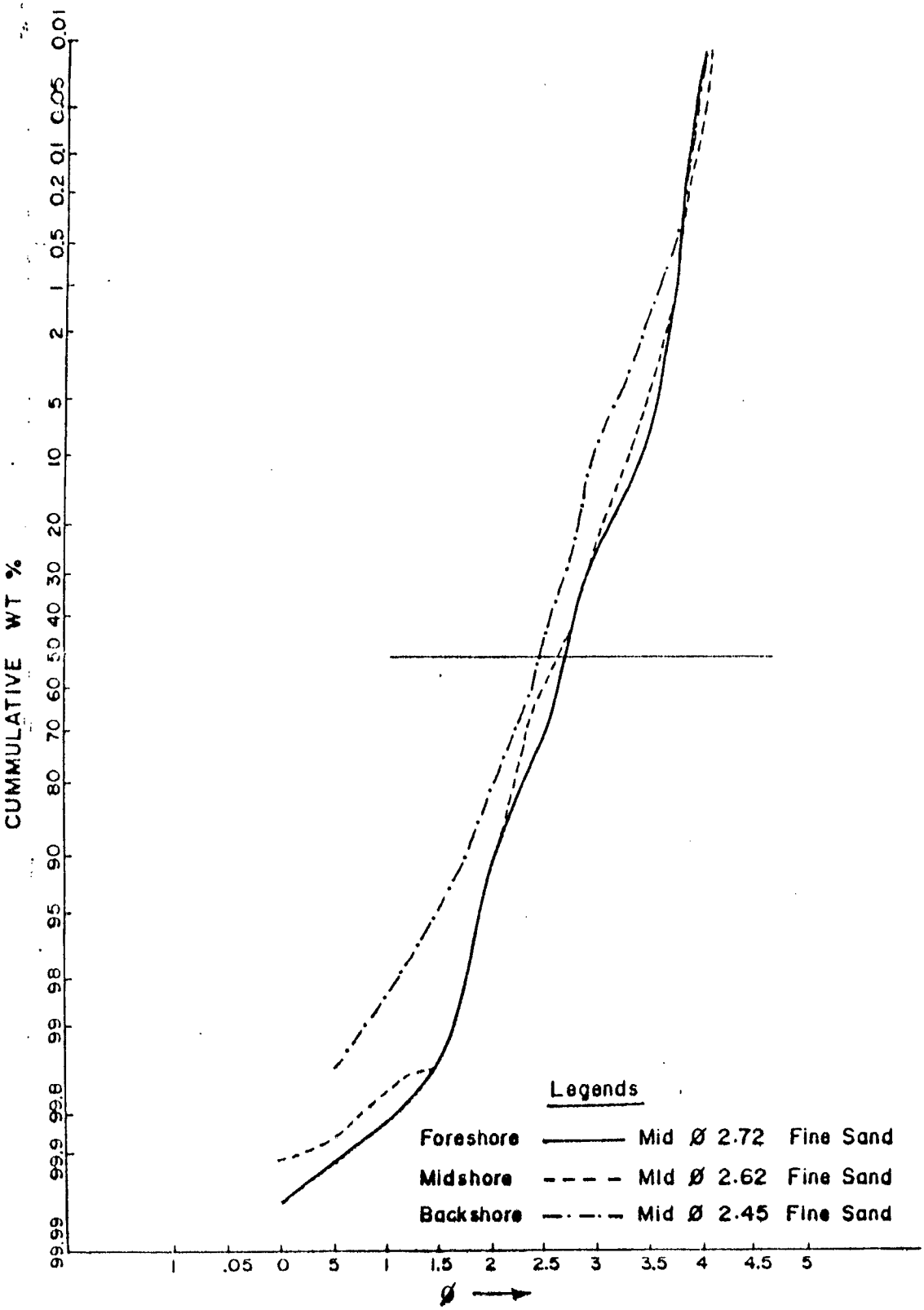


FIG. 9 SAND GRAIN SIZES : HARMAL

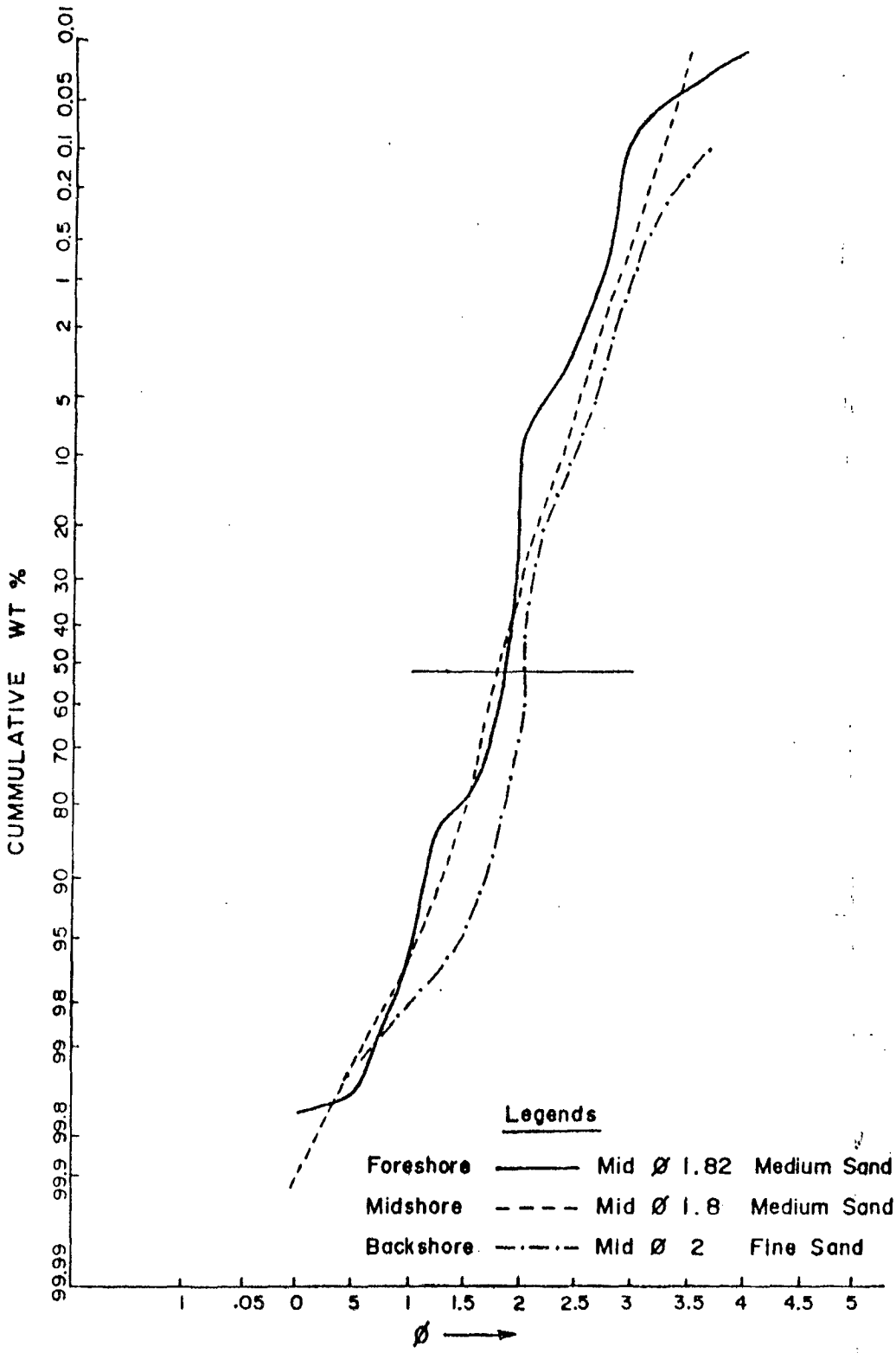


FIG. 10 SAND GRAIN SIZES : KERI

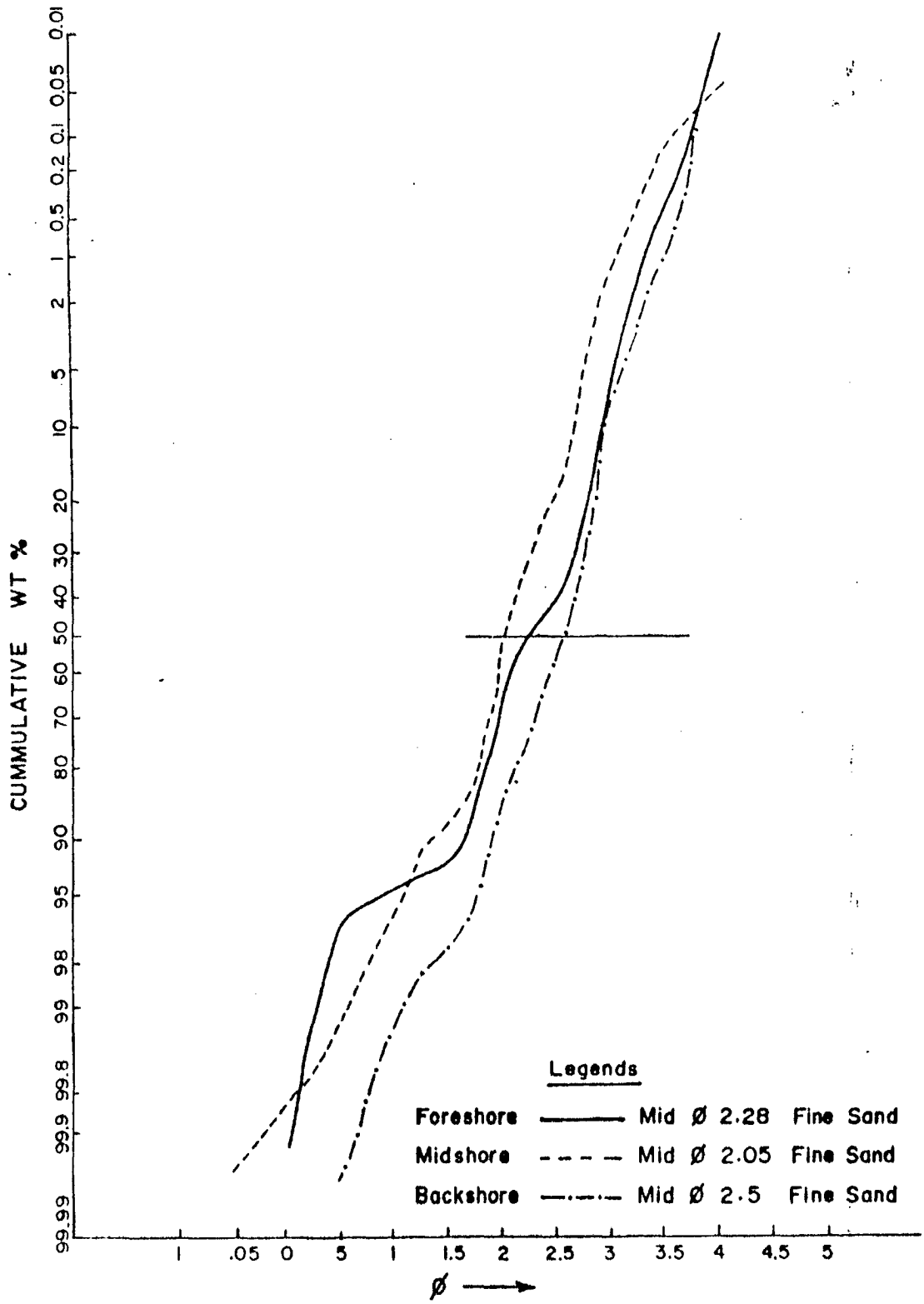


FIG. 11 SAND GRAIN SIZES : VARKA

Untawale (1980) studied the average diameter of the particle size of sands on Miramar Light House Point, Gaspar Dias and Karanzol, some beaches in Goa. His observations are given in Table 8. He studied the sand size according to method given by Krumbien and Pettijohn (1938) and his study was the comparison of sand particles in different seasons.

It was observed by Untawale (1974) that the sand remains almost unchanged through out the year in Karanzol except during the monsoon when it is finer. The Miramar and Gaspar Dias region have coarser sand through out the year.

According to Nybakken (1982) the life on sand beaches is governed by the wave action and it directly affects the particle size. which is a function of wave action. In the region of light waves, the particles are fine and heavy wave action leads to large particle size which forms gravel or shingle rather than sand. Hence,the particle size also differs from beach to beach. The water retention capacity and suitability for plants to penetrate, depend upon the sand size. Fine sand due to capillary action tends to hold much water.

TABLE 8 : AVERAGE SIZE OF SAND GRAINS (in mm) DURING VARIOUS SEASONS

Beach	Pre-monsoon	Monsoon	Postmonsoon
Miramar Light House	0.0250	0.230	0.220
Gaspar Dias	0.190	0.200	0.290
Karanzol	0.180	0.110	0.180

Source : Untawale and Nair (1974)

Coarse sand and gravel on the other hand allow the water to drain off faster. The occurrance and abundance of vegetation thus in turn depend upon the sand size. Wave induces the substrate movement. The fine sand is always in suspension and is churned and redeposited on the beach. The coarse sand moves only when the wave action is heavy. Thus, many beaches show gradation of particles from fine near the low water to coarser at high tide mark.

Thus the present study confirms the report by Nybakken (1982) as all the beaches studied have fine to medium grains and the wave action is also very low.

This study also confirms the findings of Cooper (1958) as well as Ritche and Mather (1969) who suggested that there is as much variation in either average or median particle size from site to site within a particular climatic region or even within a dune system as there is from one major climatic region to another.

Thus, the present study indicates that the sand in most of the beaches of Goa is capable of having good vegetation. Moreover, fine sand being light if not properly vegetated will be displaced by wind, so it is

essential that where natural vegetation is disturbed for some reason or the other, it has to be restored to prevent any disaster.

4.3B PROFILE

The beach profile of Varka was studied for 18 months from May 1990 to October 1991. This study being on a long stretch of comparatively undisturbed beach, the change in profile was clearly observed in different seasons across the shore i.e. from the sea ward to the hind dune region which may be 750-850 mts in distance. During the pre-monsoon and the post-monsoon periods when the wind was dry, it carried dry sand and settled towards the mid and hind dune regions. The dunes were quite prominent in pre-monsoon but during monsoon the sand got setteled down and the profile lowered (Figs. 12-14). Dwivedi *et al* (1973) as reported by Untawale (1974) suggested that the change in beach profile followed a definite sequence i.e. when one beach is in the process of building up the other one gets eroded. The latter summarized this by comparing the beach profile of Gaspar Dias, Light House beach and of Karanzol. Such comparison of profile study in the

FIG 12-14 : LEGENDS

Natural ?

Planted ?

1. *Ipomoea pes-caprae zone*
2. *Spirifex littoreus* zone
3. *Vitex Negundo* zone
4. *Anacardium occidentale zone*
5. *Cocos nucifera* zone.

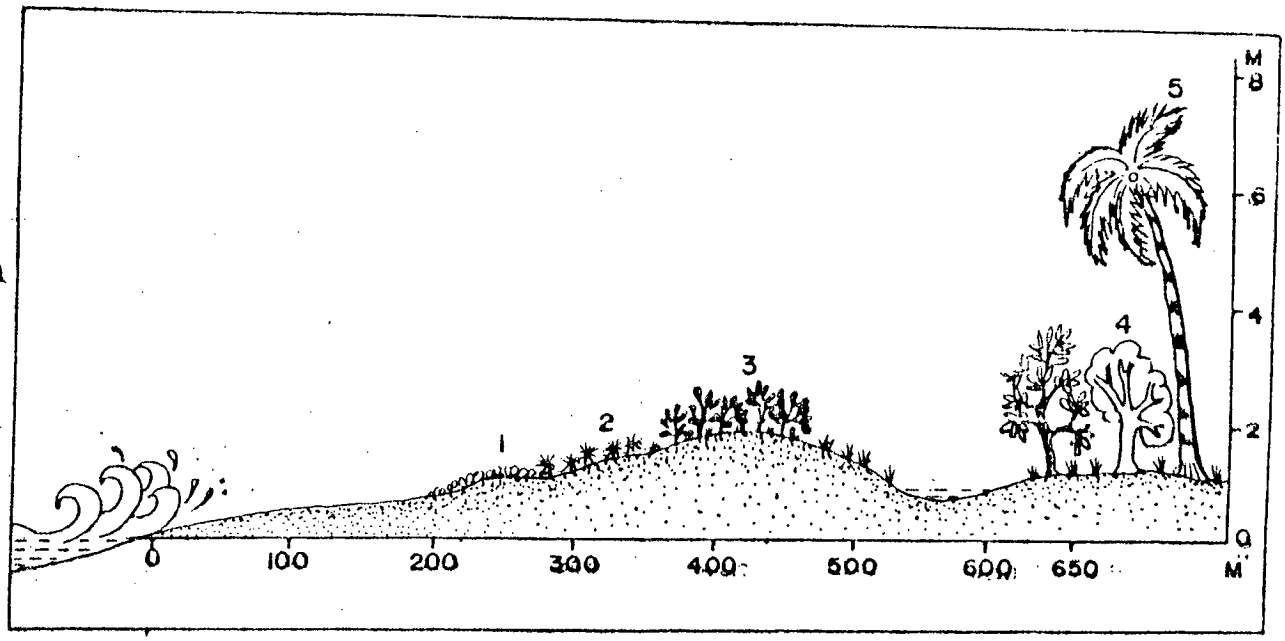


FIG. 12 PROFILE MAP OF VARKA BEACH PREMONSOON

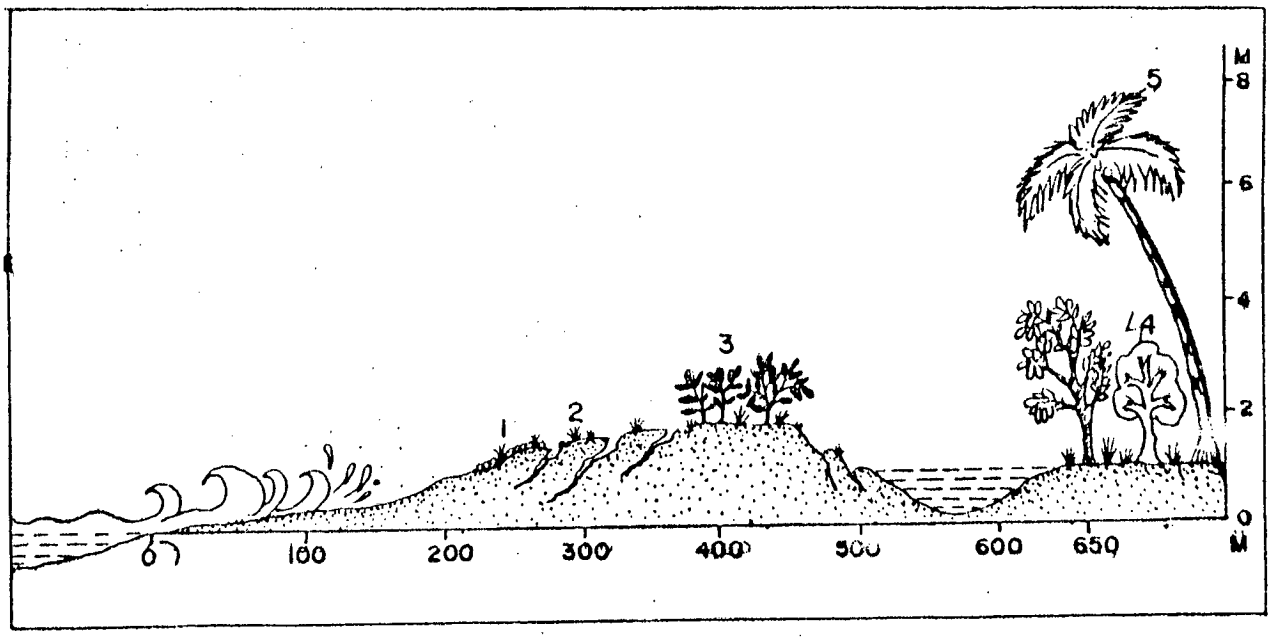


FIG. 13 PROFILE MAP OF VARKA BEACH MONSOON

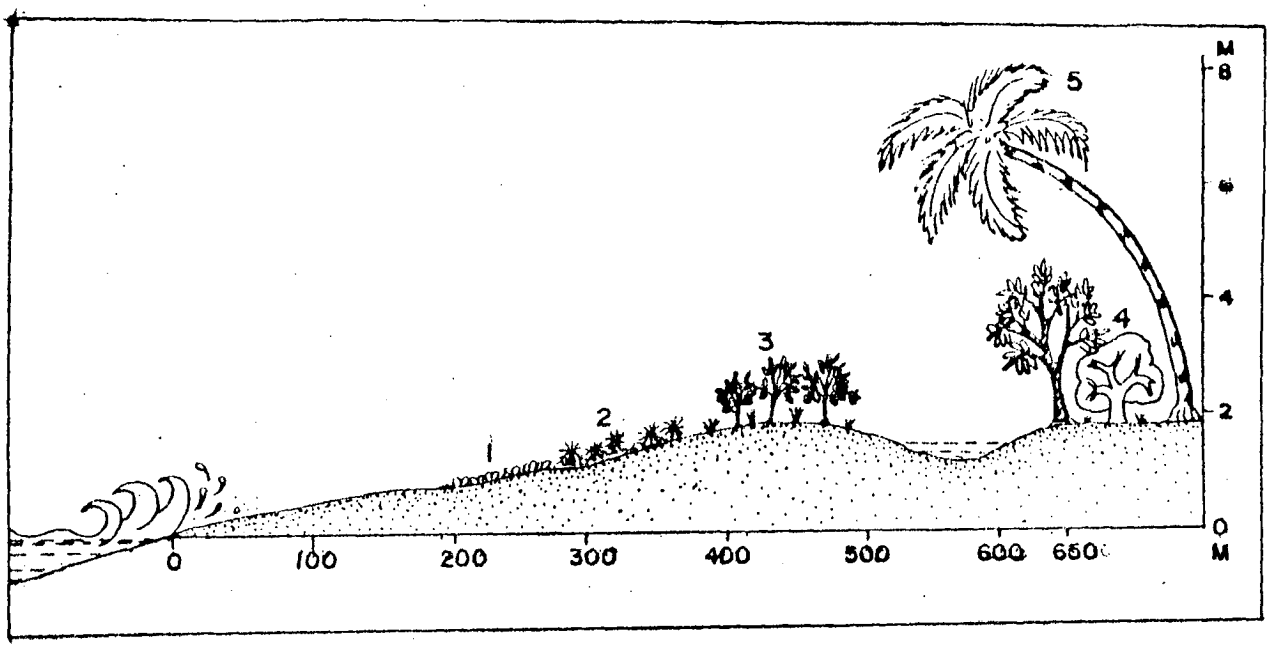


FIG. 14 PROFILE MAP OF VARKA BEACH POST MONSOON

adjoining beaches of Varka was not done as the condition of Benavli and Kolva towards North and Kalshi in the South is quite different from Varka. The other beaches were quite disturbed with temporary and permanent constructions on the dune region during the tourist season i.e. from October to May and hence, natural change in the profile of any of these beaches was not observed.

4.3C pH VALUE

The pH value ranged from pH 4 to pH 6. The soil was acidic and as it went deep in the hind dune the soil was found to be basic (Table 9). Acidity did not promote rich vegetation.Hence only few selected species like *Ipomoea* can survive on this soil. Towards the hind shore the soil was favourable to many mesophytic plants.

4.3D ORGANIC MATTER

Organic content of the soil was studied and was tabulated in Table 10. The organic content is low as 4.76 to 9.43%

TABLE 9 : pH VALUE OF SAND FROM DIFFERENT DEPTHS

Depth in cm	Fore dune	Mid dune	Mind dune
20	4	4	4
40	4	4.5	4.5
60	4	5	6
80	4	5	6
100	4	5	6

TABLE 10 : Organic Content of sand site Varka

	Initial wt of sand	Final wt of sand	%	Average % of organic matter
Fore dune	2.69	0.13	4.83	
	3.11	0.10	3.21	4.76%
	1.76	0.11	6.25	
Mid dune	2.08	0.11	5.28	
	1.59	0.16	6.29	5.47%
	2.48	0.12	4.84	
Hind dune	1.44	0.11	7.64	
	1.80	0.16	8.89	9.43%
	1.36	0.16	11.76	

4.3E MOISTURE CONTENT AND RAINFALL

The moisture content of the fore dune was much higher compared to that of mid dune and hind dune. The least being in the hind dune. The maximum moisture being at 1 mts. depth in the fore dune. The mid dune which has thick vegetation of dune plants held moisture in 20 cms. depth but later the moisture content went down. The hind dune had very sparse ground vegetation so evaporation was maximum, therefore surface moisture content was comparatively low. It had bigger trees and their moisture requirement was also high, therefore,the moisture content through out in the soil in different depths was low. The free water table was below 100cms.in the fore dune. This part of the beach was found affected by the tidal influnce as indicated by the profile studies at different points by Dwivedi *et al* (1973). The rain water generally percolated over the surface deposit. According to Willis *et al* (1959) the water formed a dome shaped structure several meters below. During the monsoon, the plants got water primarily from the rainfall and during the dry spell from the moisture present in the sand. Studies on the

dune communities showed that soil moisture was found upto depth of 60 cms. below the dune surface and then tend to fall off to more constant level (Salisbury 1952; Ranwell 1959). The light rainfall was absorbed and held near the surface by the presence of organic matter as observed by Olson-Sciffer (1909).

The humidity on the Goa coast was quite high. The highest being in the monsoon with 90% and during the non monsoon period the average was 75%.

The germination of seeds and the establishment of seedlings were found to be dependent on the rainfall and moisture present in the dune (Biswas and Rao, 1953). It was further observed during this study that monsoon period supports not only germination of seeds but the species like *Spinifex littoreus* and *Ipomoea pes-caprae* had elaborate vegetative growth and from each nodes of the plants young plantlets were seen to grow.

Yeaton (1988) studied the dunes from Atlantic coast to the base of Great escarpment of Africa. There was an inverse correlation between density of vegetation and the sand movement. The ultimate factors controlling the stabilization of these dunes and the dynamics of grasslands was the amount of rainfall which in turn

determined the establishment of new individuals from the seeds.The dune plants had a special adaptation to complete their life cycle within the moist season of the year.This study recorded a fairly good rainfall in Goa during the season. Untawale (1974) has listed 67 species of dune plants growing on the sand dunes of Goa, belonging to three different zones. These plants could form a very good cover to the coastal sand dunes and restrict the dune movement (Figs. 15-18).

4.3F WIND SPEED

According to Untawale (1974) the average wind speed during January to May arise from 11-14km\hr. However, during the monsoon the average wind direction is South Westerly with a velocity of 23km\hr. From October to December when North East wind starts, the speed remains about 9.5 to 10 km\hr.

Untawale (1980) summarized that wind is one of the most important factors in the dune system. It helps in the formation, movement and also destruction of the dunes. It decreases the surface moisture and the surface temperature. Increase in the wind speed enhances the

Fig 15 : Diurnal studies in sand dunes : Humidity

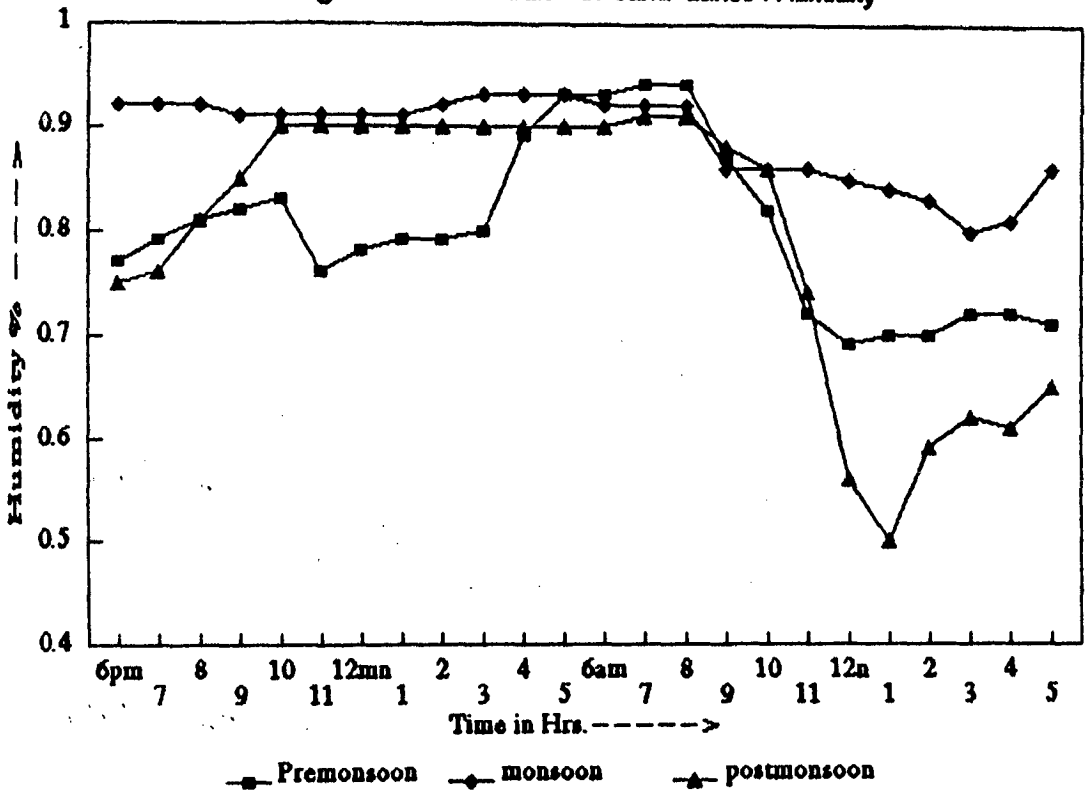


Fig.16: Moisture content in different depths on different zones

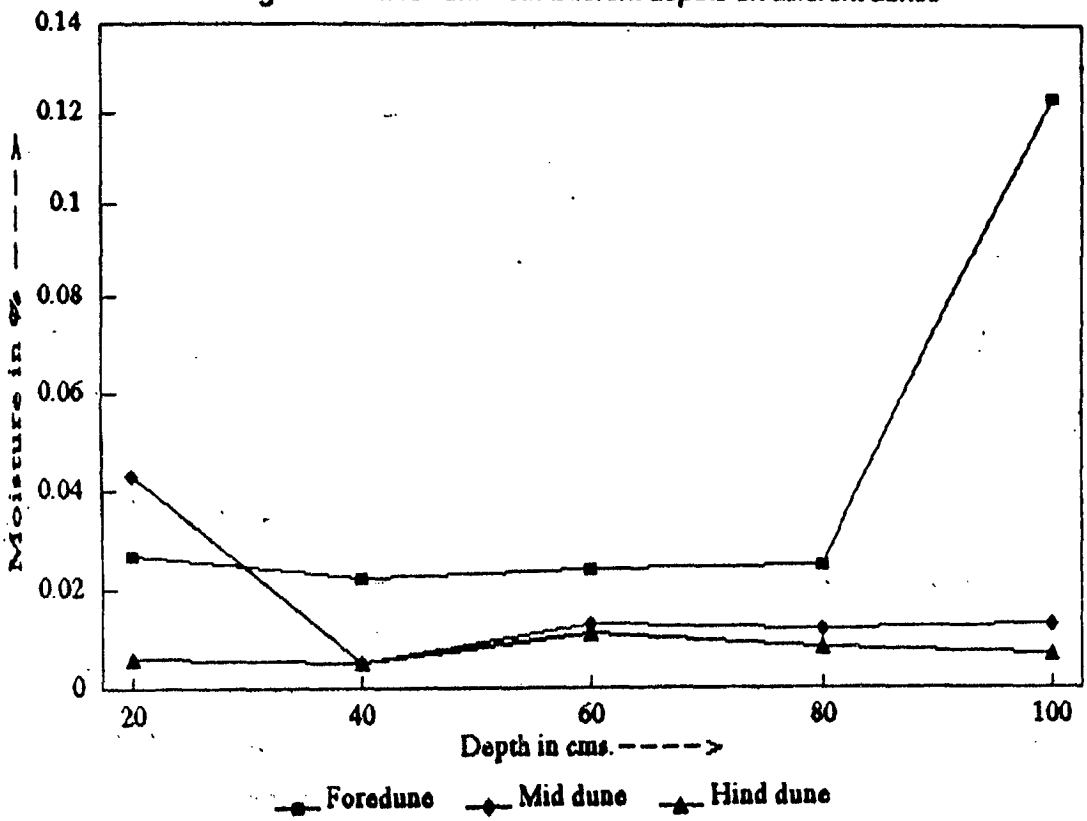
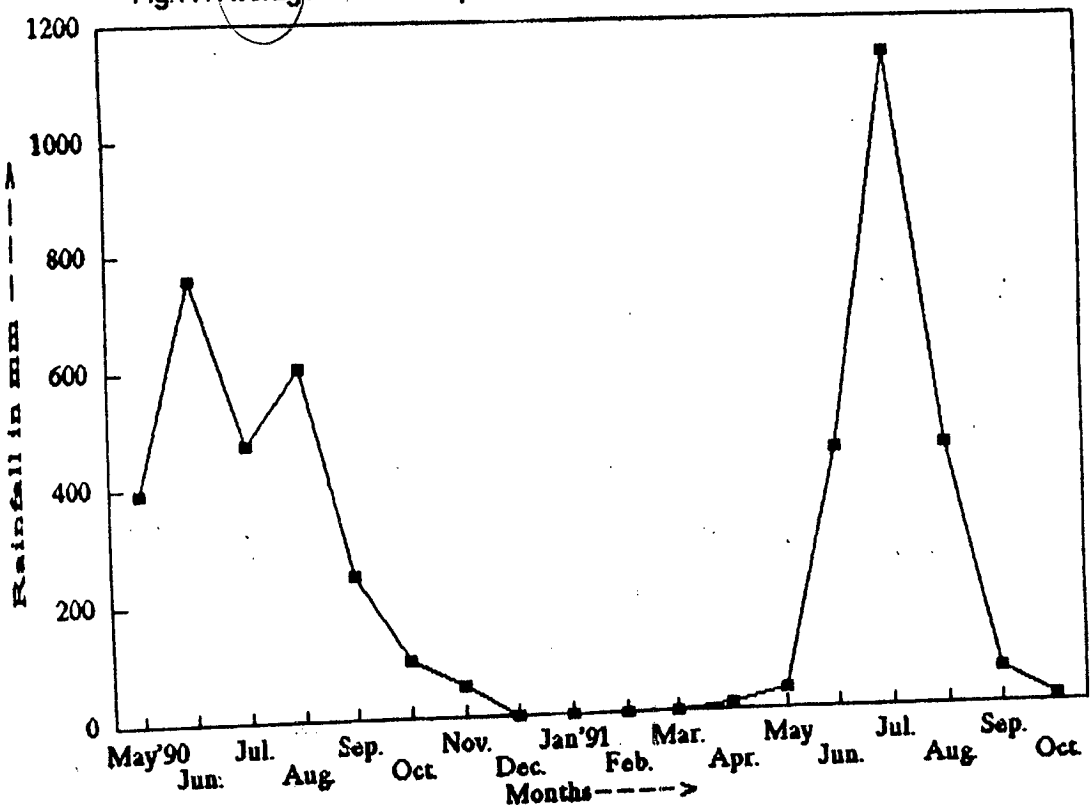
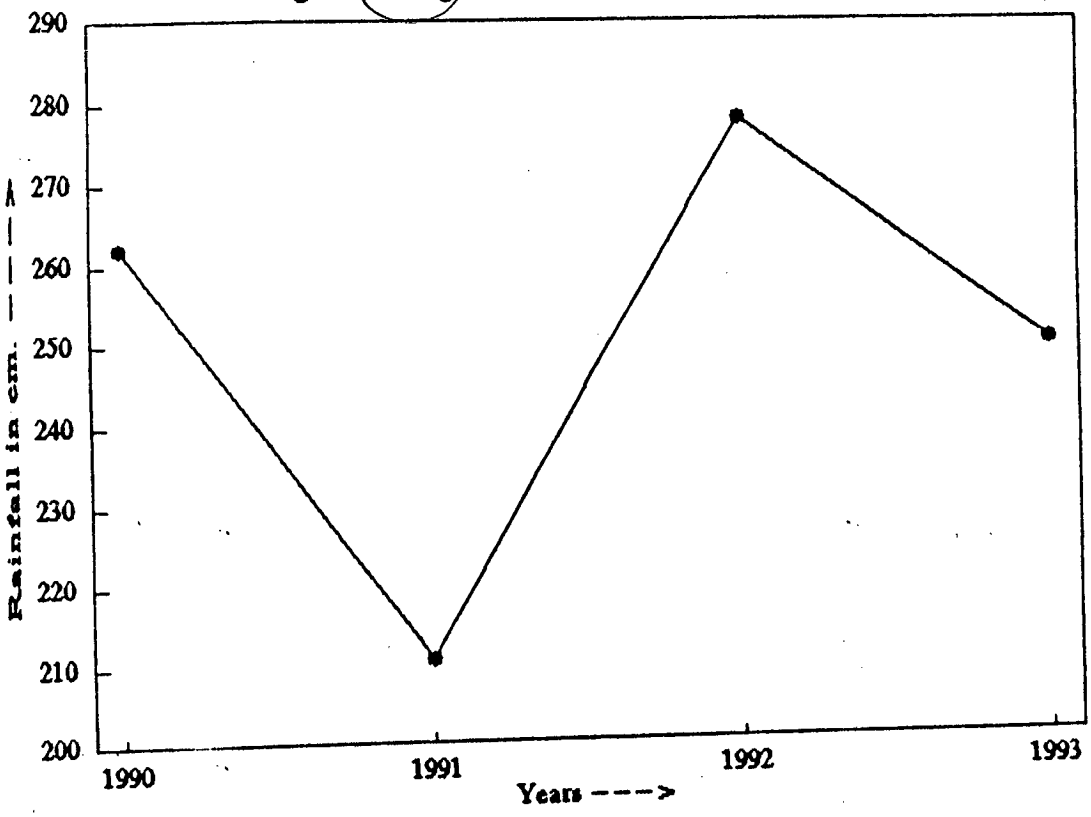


Fig.17: Average rainfall for a period of 18 months from May 1990 to Oct. 1991.



Total 9.

Fig.18 : Average Rainfall in Goa for 4 yrs. 1990–1993



transpiration rate in the dune plants. Cyclonic or stormy condition usually results in the destruction of dunes by dispersing dune vegetation and by changing the configuration of dunes.

In this study diurnal wind speed was recorded every month at 6 pm during three seasons and for 18 months. During monsoon the average wind speed being 14.5 km\hr, while in the pre-monsoon and post monsoon it is 7.1km\hr and 4.17 km\hr respectively in the year 1990. The average wind speed for 18 months from May 1990 to October 1991is 8.8 km\hr. Thus, comparing the two studies it shows that the wind speed is not constant for any season nor is it so for any month. The irregularities in the wind speed results in the change of dune structure and function. The Western coast of India rarely experiences cyclonic or stormy wind which also results in movement of the dunes inwards if not properly vegetated. The monsoon wind being laden with moisture do not infact contribute to much destruction to the dunes. But if trees like *Casuarina* are planted on the fore dune region instead of hind dune region they do not serve the purpose as wind breakers but are seen to be uprooted and pose danger to the fore dunes instead of protecting them (Figs.19-20).

Fig.19: Monthly cross-shore wind velocity in km/hr.

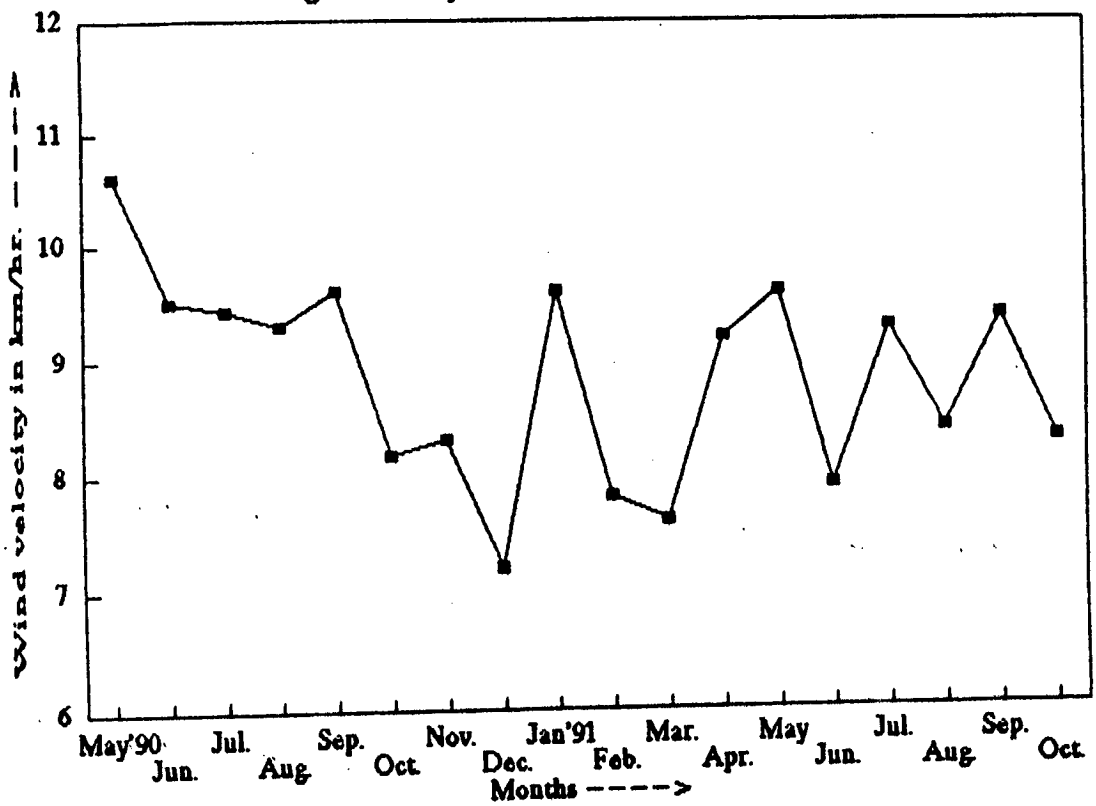
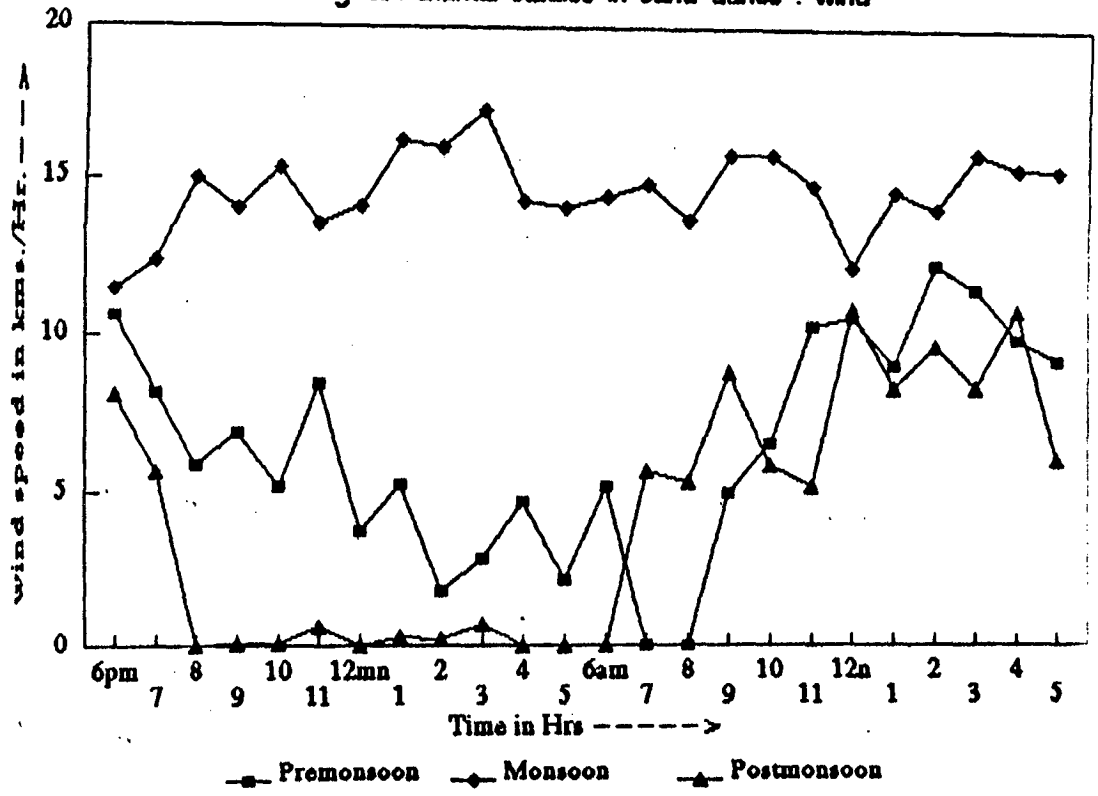


Fig. 20 : Diurnal studies in sand dunes : wind



4.3G TIDAL INFLUENCE

The inter tidal region of Varka beach has no vegetation. During the monsoon as a result of strong tidal waves, the beach gets eroded and along the waves seeds and fruits of many plants of the nearby shore like that of *Acanthus ilicifolius, Avecinia* spp. come and get temporarily established. Along with the tides, lot of waste materials like plastic bottles, polythene bags, tins got accumulated on the shore. No algal vegetation was seen here throughout the year on the beach as it is a total sandy beach.

4.3H TEMPERATURE

From May 1990 to October 1991 for 18 months atmospheric temperature and at dune surface, as well as temperatures at the depth of 5 cms. and 10 cms. was taken. The atmospheric temperature is between 24°C to 31°C, the highest being in the month of April. During the rainy season because of the moisture, the temperature was found to be maximum. The surface temperature was greatly influenced by the atmospheric temperature which was slightly more or same as the

atmospheric temperature. The temperature at 5 cms. depth was found to be usually more than the surface temperature differing by 1-2°C. While the temperature at the 10 cms was still higher, the maximum being 37°C in the month of April.

Diurnal studies of temperature in three different seasons at the surface, 5 cms. and 10 cms. depth and the atmospheric temperature showed that the maximum atmospheric temperature during pre monsoon period was 38°C while during monsoon it was 33°C and in post monsoon 37°C. The surface temperature was comparatively higher showing 42°C during the post monsoon season and the minimum being 23°C during the monsoon. The maximum temperature at 5 cms. level was 37°C in post monsoon while the minimum being 24°C in the monsoon. At the 10 cms. depth, the maximum temperature was 35°C at the pre monsoon and 24°C in the monsoon (Figs.21-25).

Thus, it is clear from the above observations that except for the monsoon i.e.only for 2-3 months, during most of the year the dune and the surrounding atmospheric temperature was very high. Ranwell (1972) stated that the annual plants of the sandy beaches tend to pass through the hot summer as seeds and then begin

Fig. 21: Monthly Temp. studies in sand dunes: Atm. Sur. 5 cm. & 10 cm. depths

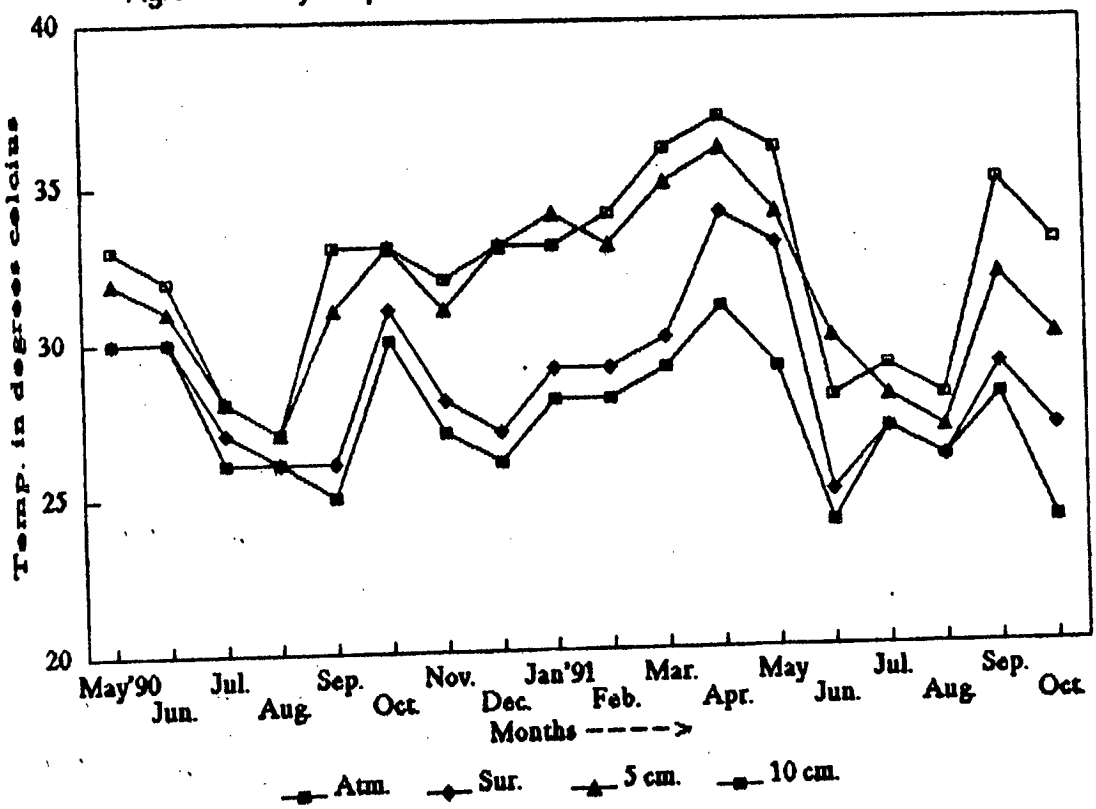


Fig. 22: Diurnal studies in sand dunes: Atmospheric Temperature

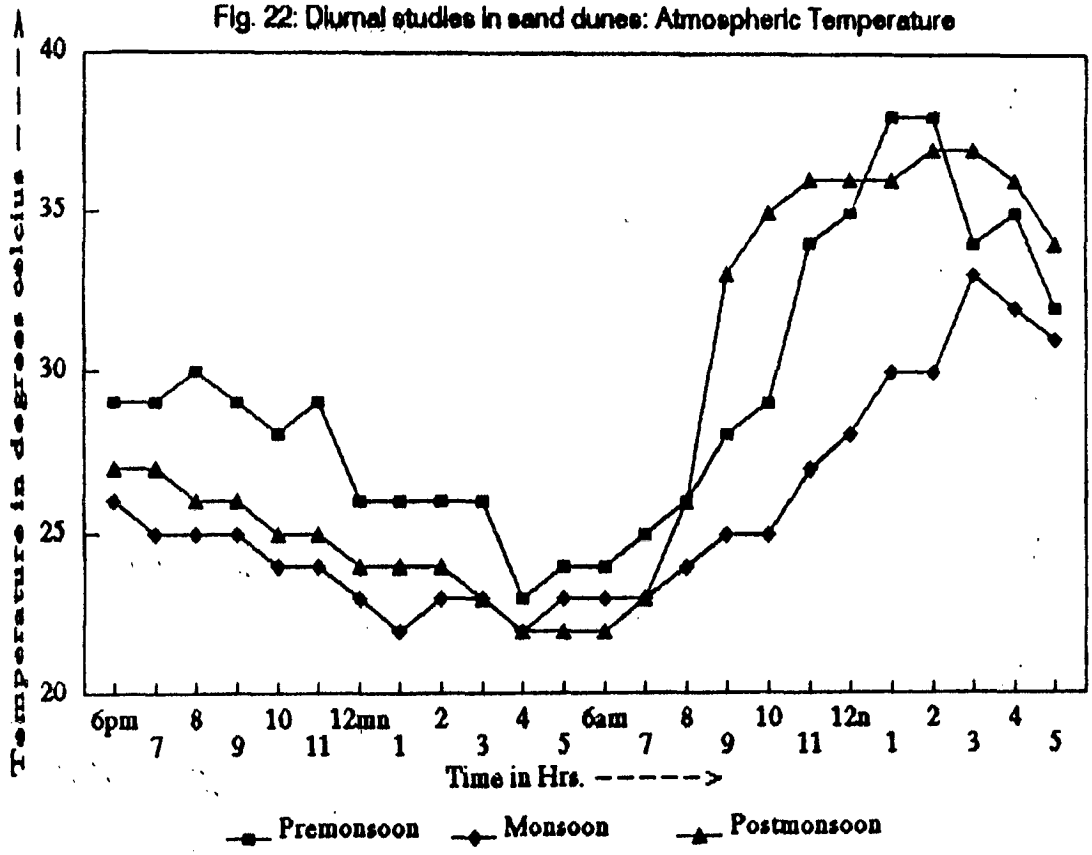


Fig. 23: Diurnal studies in sand dunes : Temperature (surface)

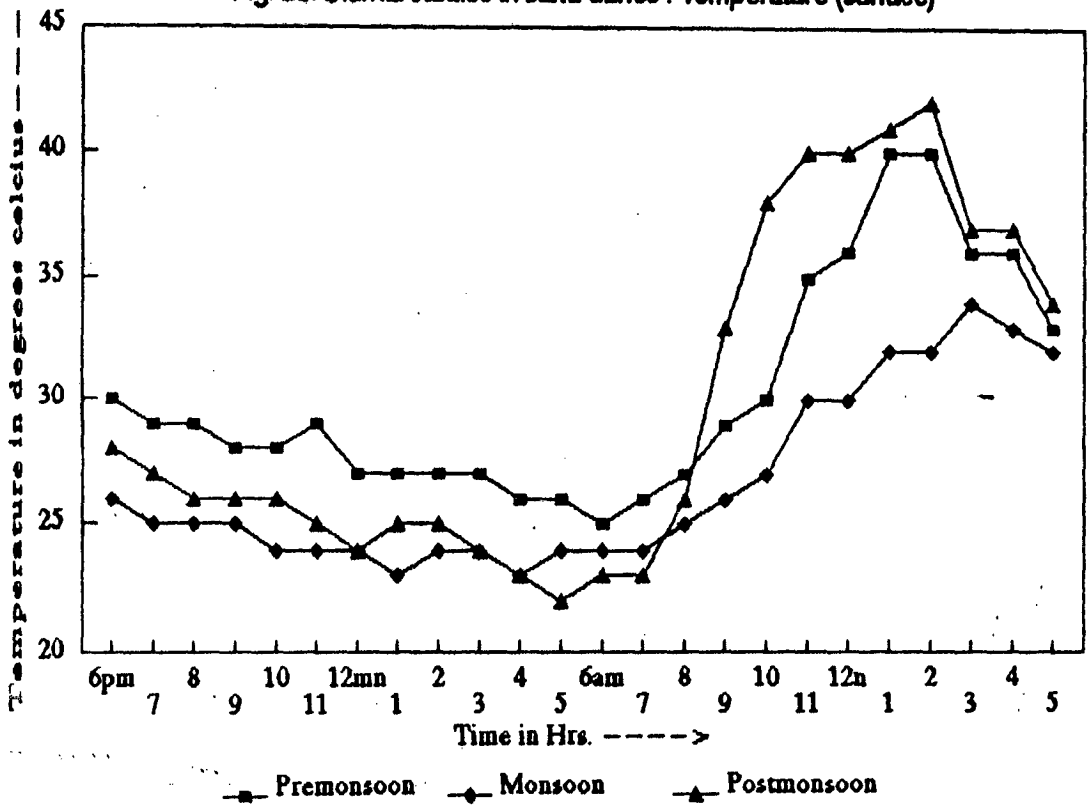


Fig.24 : Diurnal studies in sand dunes : Temperature at 5 cms.

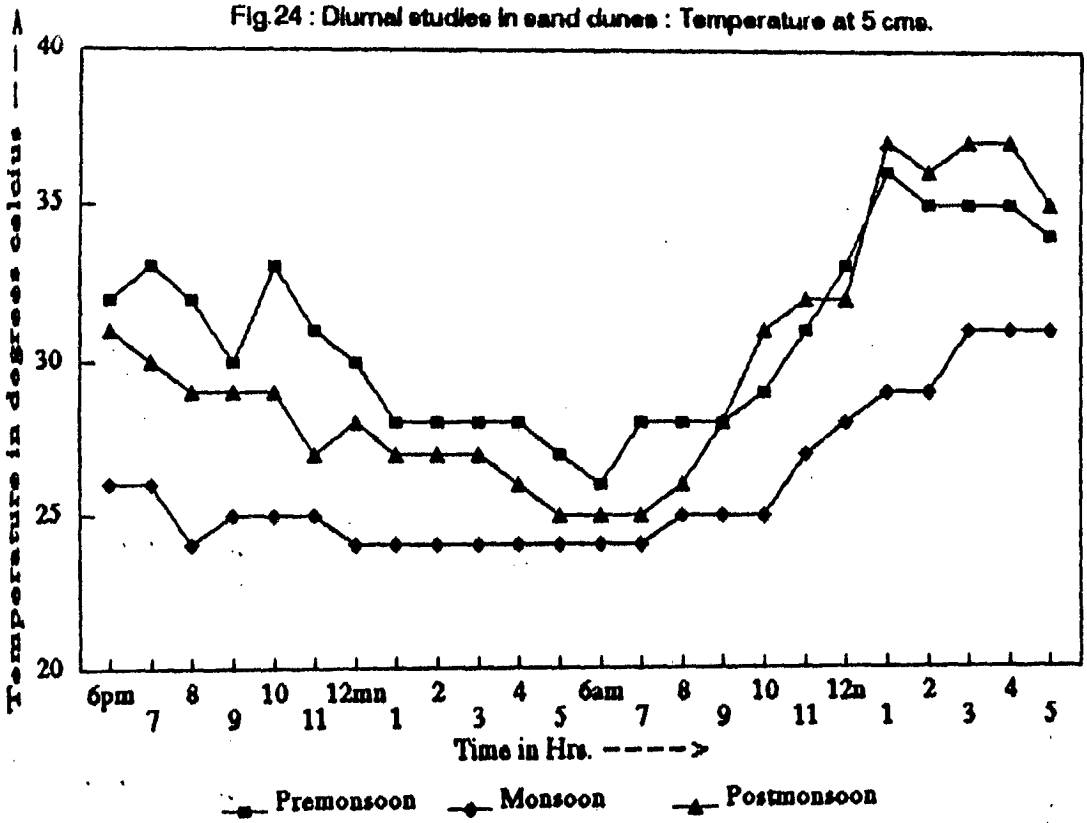
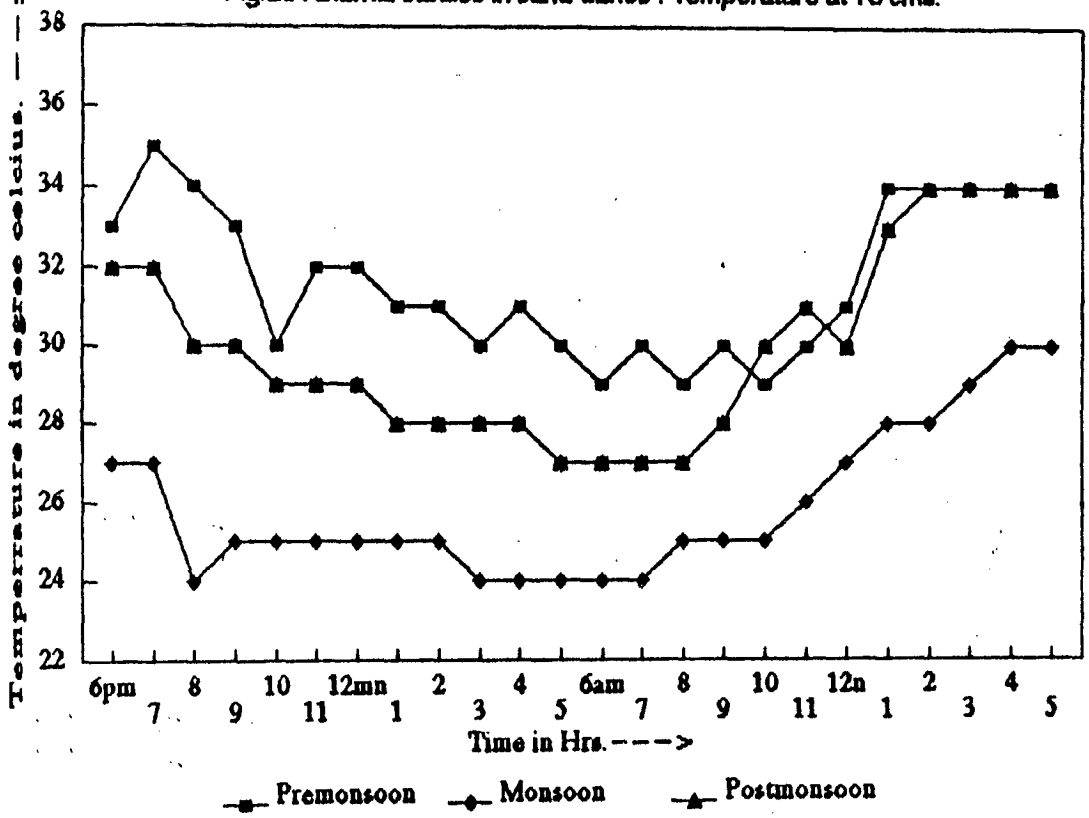


Fig.25 : Diurnal studies in sand dunes : Temperature at 10 cms.



to grow during the cooler months. In this hot condition only few plants like *Ipomea pes-caprae, Spinifex littoreus* can withstand the high temperature while many other plants that are seen to come up during the monsoon die of scorching heat on the sand dunes. It is also observed that the dune flora tend to keep the surface temperature low than the barren dunes. Sallisbury (1934) also observed similar differences in the temperature distribution.

4.3I SUCCESSION

Various attempts have been made to study the succession of sand dune vegetation. Van der Maarel *et al* (1985) stressed that the over all trend of succession in sand dune region is progressive with a strong increase in the area of tall shrub and woodlands. Retrogression also occurred partly as a result of disturbances such as fire, partly due to local death of a dominant woody species. According to them moisture and nutrient status were responsible for the different vegetation types.

Pammenter (1984) studied the sand dunes of East coast of Southern Africa and suggested that the sand

spray can be a major causative agent in the zonation of the vegetation. Plant succession may be controlled by the input of nutrients partly nitrogen into the system.

According to Turner *et al* (1968) sand dunes are rich in $CaCO_3$ which has been long ago dissolved and reprecipitated. The decaying plant material acts as a cementing agent on such dunes. Stability of the dunes depend upon the vegetation cover. In many of the Victoria dunes shoreline erosion has removed early stages of succession. Any disturbances to the vegetated cover lead to the blow out dunes which migrate inland forming sterile deserts.

According to Danin (1978) the increased environmental diversity and decreasing stress on plant life may be the main factors influencing species diversity during plant succession and during sand stabilization.

Levy (1990) also observed that vegetation can be affected by ocean side erosion accompanying salt spray.According to him succession can be progressive, retrogressive, chronic, patchy or cyclic.

According to Marson *et al* (1990) geo-morphic floristic variables were useful as general habitat indicators on coastal fore dune. Variables used in his study were vegetation cover, plant community structure and sand movement.

Mc. Lachlan *et al* (1987) quantified the biomass in a coastal dune slack. The vegetation zone exhibited a succession related to the movement of dune ridges. Moisture does not limit the vegetation but salt spray and the sand movement are the controlling factor.

Changes between 1950- 1980 on the Crataegus Betula dune in the Netherlands were studied by Mevlen *et al* (1985) by vegetation maps, air photograph and permanent plot observations. Woodland increase occur on places with ground water at or near the surface either because of natural or artificial ground change.

Watkinson and Davy (1985) reported that annuals represent a significiant component of vegetation of sand dunes. It is characterized by low water potential, marked spatial and temporal heterogenity and a zonation which within certain limits reflects successional change.

Guevara (1982) suggested that the process of succession, regeneration and reposition could be understood by studying the composition and structural changes exhibited in high levels of phenotopic flexibility growth in a range of environment. Adaptation is both by genetic and phenotopic flexibility. Plants from fore dune respond more than those from mature dunes.

Barren (1958) observes that in Honolulu the coastal forests have been replaced by coconut plantation because coastal areas are most accessible to European influnce and settlement.

Turner *et al* (1962) clearly defined the five stages in plant succession in the dune : (1) Embryonic dunes (2) Fore dunes (3) Dune scrub on stable dune ridge (4) Scrub wood and (5) Dune woodland.

The succession interaction on the coastal vegetation as given by Rico Gray *et al* (1987) is that the different communities form a gradient begining at the sea shore and progressing inland with the following sequence of dune vegetation; Pioneers, shrubs and low seasonal forest.

Kutiel *et al* (1980) studied the vegetation on the sandy soil near Caesarea,Israel. According to them the fixation of new blown sand starts with the establishment of the *Ammophila littorales-Cyperus conglomeratus* association which creates the germination site for *Artemisia monosperma*. Increased density of *A.monosperma* results in the accumulation of organic matter and fine grained material on the ground. The abundance of annuals further increased the percentage of organic matter and fine particles in the sand. The *Helianthemum stipulatum - Retama raetum* association represented an advanced stage of sand stabilization. The percentage of organic matter and fine particles was higher when compared to that of *Artemisietum monospermae*.

Since the succession takes place on sand this succession is called psammosere. Rao (1972) has grouped the dune vegetation according to its specialized characters

(1) Mat forming stranded creepers
(2) Diffusely branching, prostrate or erect strand herbs and hedges.
(3) Strand climbers
(4) Strand plants with perenating organs.

(5) Strand shrubs and trees.

(6) Strand stunted trees.

On the basis of these observation Rao (1972) was of the opinion that the dune vegetation of India is a mixture of Polynesian and Malaysian, Persio-Arabian/ Western type and a few indigenous species.

Considering Rao (1971), group of dune plants and the succession on Varka (Goa) beach shows the similar pattern.

The first blown sand is established by the growth of *Ipomoea pes-caprae* which has a creeping habit with a long tap root and creeping branches. Next on the line is a thick growth of *Spinifex littoreus* which has long rhizomes and roots are produced in regular intervals from the nodes.

Though strand climbers are not specially present, here, a few plants of *Dioscorea* were seen in certain areas among the *Clerodendron-Vitex-Lantana* region. These plants form a perennial boundary between the specialized dune plants towards the sea and the mesophytes on the land ward side.

Among the strand shrubs and trees in certain parts of the beach there is a thick growth of *Pandanus*. In other regions there is a clear depression where perennial water flows. Across the water body are different weed flora like *Leucus aspera, Crotolaria juncea, Calotropis gigantia,* and a number of plants belonging to families Rubiaceae, Asteraceae Poaceae and Cyperaceae. In this region coconut plantation is also seen. In some parts of this region cultivation of seasonal vegetable is taken up. Towards the South of the beach beyond the *Spinifex* region *Casuarina* plantation has been taken up which is at a primary stage. Beyond this *Casuarina* plantation natural growth of *Anacardium occidentale* is seen. Among the *Anacardium* climbers of *Abrus precatorius,* and several shrubs like *Calotropis gigantia, Crotolaria* and different members of Poaceae and Cyperaceae are seen.What is clear from the study of succession here is that the dune vegetation on the coast of Goa has not reached the climax stage and it is still on the growing phase. The reason for not having a climax forest is varying.One of the major causes may be the close proximity to the human habitation on the back shore region.

In Keri (Perne) where human habitation is not too near, a clear cut zonation of herbs, shrubs and trees is observed on the sandy beach.

On the Gaspar Dias beach or Miramar, Untawale (1980) reported a fairly good zonation. Disturbances of any kind at any stage of development hamper the succession. Thus, under normal condition the succession observed on the coastline of Goa is progressive.

CHAPTER – V

THE CASE STUDY OF SPINIFEX LITTOREUS

CONTENTS

5.1 INTRODUCTION

Sand dune vegetation has a significant role to play in the coastal regions. These species not only minimize the erosion, but also stabilize the dune region and increase the organic matter (Barson & Calder, 1981).

Spinifex sp. is one such grass which belongs to the family Poaceae (Gramineae). It has only one species *S. littoreus = (S. sqarrosus)* in India. This species functions as a pioneer species and grows in the 'foreshore zone' (or pioneer zone of the supratidal region, in association with *Ipomoea pes-caprae = (I.biloba)*.

Like most of the psamophytes S.littoreus also shows the ecological adaptations to grow in the extreme conditions and acts as a sand binder.

Taking into consideration an important role played by this particular species in the sand dune area, and also the paucity of scientific information,it was decided to thoroughly study various aspects of Spinifex littoreus to understand its structure and functions in a better way. Hence, the detailed account in the form of

case study of this species is given below:

5.2 TAXONOMY AND VARIATION

a) Classification Hooker (1875) classified this genus under Order Gramineae, Series Panicaceae and Tribe Paniceae. According to him there are four species, of which one i.e. *S. squarrosus* is Indian and three viz.are *S. dioceus Ham.* ex. Pritz; *Stipa littorea* Burm. and *Stipa spinifex* Australasian

Cooke (1906) placed the genus under Order Gramineae,Tribe Paniceae. This is in accordance with the suggestion of Stapf (1855). Gamble (1956) has also described the genus under family Gramineae.

Bor (1960) has slightly modified the classification and kept the genus under group Panicoideae and Tribe Paniceae of family Gramineae. However, Haines (1961) has grouped this species under the tribe Digitariastrae.

b) Name: *Spinifex squarrosus* Linn. is the synonym of *Spinifex littoreus* (Burm.f.) Merr.,Bor (1960); Biswas & Chowdhuri (1955); Rao & Sanware (1966). The allied genus with slight modifications are *Stipa spinifex L.ohwi*

(1953), *Spinifex hirsutus* (Anonymus,1981). Lazarides (1980) reported *Spinifex longifolia* R.Br. (1810:198) a. *S. littoreus var. longifoliius* (R.Br.).

5.3 DISTRIBUTION

This stout, rigid and bushy grass of *Spinifex* is well distributed on the sandy coasts of Burma, Ceylon, Java, China and India,(Hooker, 1875). Ohwi (1953) has also reported the genus in the Flora of Japan and mentioned its occurrence in Japan and Malaysia. The Beach Authority of Queensland has described *Spinifex hirsutus* as one of the major dune plants of Australia.

Lazarides (1980) reported the presence of this grass species in Taiwan besides India, Burma, Ceylon, Southern China, and Southern Japan. He also reported the allied species *Spinifex longifolius* from Indonesia and Papua New Guinea.

The Wealth of India has mentioned the occurrence of this grass on the sand dunes along the west coast from Gujarat to Konkan and on the eastern coast from West Bengal to Kanyakumari and in the Lakshadweep, Bor (1960); Biswas and Chowdhuri (1955); Rao and Sanware

(1966).

GOA REGION

Along the coast of Goa this grass grows extensively on all the sandy shores from Keri in the North to Pollem in the south. On some of the beaches like Morji, Miramar Varka, Kalashi and Galgibag the growth is extremely good.

5.4 RANGE OF HABITATS

a) Zone of occurrence

Sand dune vegetation or the strand flora is one of the unique coastal vegetations. It includes specialized plant community which grows on the sandy shore beyond the highest high tide level (Untawale, 1980). *Spiniifex littoreus* is one such common plant growing on this region. The plant is commonly found growing on the fore and mid shore dune region of the sandy shore, (Tables 2 and 3).

b) Substrate characteristics

The plant grows extensively on sandy shore where the sand is medium to fine between the range of 1.8-2.51

(Figs.8-11). The water holding capacity of the fine sand is more and this is made available to the plant by deep rooting system. It can absorb water from a depth of 60-70 cms. below the surface. The pH necessary for the growth of the plant varies from 4 to 5. The plant can also grow under low nutritional conditions. As such sand dune soils are generally low in the macronutrients but they appear to have adequate quantities of the micronutrients, (Chapman, 1976). The organic requirements of the plant are also very low, as the plant naturally grows on a low nutrition of 4.76 -5.47% of organic matter.

c) Climatic conditions :

The plant can withstand a maximum temperature of 38 C to 40 C and a minimum temperature of 20 to 23 C, (Fig. 21-23). The wind velocity on the shore is as high as 17 km\hr and the plant can withstand the stress of it (fIGS. 19-20).

d) Biomass, moisture, organic and inorganic content

The biomass contained in above ground and below ground parts of *Spinifex littoreus* were determined by

taking the wet weight of plants from ten quadrats. Plants from 1 m^2 each were removed along with the underground stolous and roots. The sand and the debris adhering to the parts of the plants were removed and wet weight of each of the plant part was taken. On the basis of wet weight Root/Shood Ratio was calculated. Further, moisture content of the components were obtained by drying the plant parts sesparately at 80°C for 48 hrs. till the constant weight. On the basis of dry weight also Root/Shoot Ratio was calculated. Further, the root and shoot materials were burried to ash at 800°C in muffels furnace to calculate the organic and inorganic content of the plant. The results are tabulated in Tables 11-13.

e) CHN Analysis

Stein, leaf and root of *S. Littoreus* were oven dried and ground separately to a fine powder in an electric mill. The materials were then analysed for carbon, hydrogen and nitrogen in Perkin Elmer CHN analyser using acctanilide as standard. Results were expressesd as %, H and N on dry weight basis.

It is observed that of all the components, nitrogen content is very low. The least being in the stem and

TABLE 11: Study of Biomass of *Spinifex littoreus* per m^2 and per ha.

Transacts of Sq.m. each	Underground biomass in gm	Above ground biomass in gm
A with 4 plants	1.98	242.20
B with 2 plants	0.46	89.24
C with 4 plants	1.20	141.18
D with 6 plants	2.75	382.68
E with 2 plants	0.38	91.10
F with 3 plants	0.39	98.38
G with 2 plants	0.17	105.28
H with 4 plants	0.94	91.89
I with 1 plant	0.25	78.90
J with 1 plant	0.18	59.46

Average underground/sq.m biomass 0.87 gm $\pm$ .829

Average above ground biomass = 138.031 $\pm$ 94.732

Underground biomass/ha 8.7 kg

Above ground biomass/ha 1380 kg

On the basis of wet weight Root/Shoot Ratio = .006

TABLE 12: Study of moisture content of *Spinifex littoreus* per m^2 and per ha.

Transacts of 1 sq.m.	Wet wt. in gms Under ground	Wet wt. in gms Above ground	Dry wt. in gms Under ground	Dry wt. in gms Above ground	Moisture Under ground
A with 4 plants	1.98	242.20	1.26	108.69	0.72
B with 2 plants	0.46	89.24	0.33	50.53	0.13
C with 4 plants	1.20	141.18	0.84	69.18	0.36
D with 6 plants	2.75	382.68	2.00	181.46	0.75
E with 2 plants	0.38	91.10	0.25	41.48	0.13
F with 3 plants	0.39	98.38	0.28	45.66	0.11
G with 2 plants	0.17	105.28	0.08	50.44	0.09
H with 4 plants	0.94	91.89	0.70	44.93	0.24
I with 1 plant	0.25	78.90	0.16	38.27	0.09
J with 1 plant	0.18	59.46	0.11	25.46	0.07

Average moisture content underground/sq.m 0.269 gm $\pm$ 0.247

Average moisture content underground/ha -2.7 kg

Average moisture content above ground/sq.m 72.431 $\pm$50.797

Average moisture content above ground/ha 724.3

On the basis of dry weight Root/Shoot Ratio 0.00916

TABLE 13 : Study of inorganic and organic matter content of *Spinifex littoreus*

Material	Wt of mat. before heating (in gm)	Inorganic matter/gm	Organic matter/gm
Stolon	5	0.024	0.976
Leaf	4.64	0.052	0.95
Root	0.14	0.142	0.86

the level of N is comparatively lighter in the roots. Olson (1958) recorded that the carbon to nitrogen ratio varies from 10:1 in young dune grassland soil to 20:1 in old forest dune soils. Since, the amount of N is so low in the soil, it is obvious that the content is low in the plant also. Haun et al (1989) also reported low N content in the dune soil. It is interesting to note that with such low N concentrations also the dune plants successfully grow. This adaptation to grow in low organic and nutrient soil is significant. The results of the analysis are given in Table 14.

5.5 EXTERNAL MORPHOLOGY

Hooker (1875) has described the genus *Spinifex* as stout rigid bushy dioecious grass. Leaves are long, rigid, involute.

Haines (1961) described the genus as a large glaucous fruticose grass forming bushes 0.60 - 1.20 m high. It has long underground or superficial stolons. Leaves 10-15 cm long, squarrose, recurved pungent, margins spinulose- serrulate; sheaths often imbricate

TABLE 14 : Carbon, Hydrogen and Nitrogen content and C:N Ratio

Component	Carbon %	Hydrogen %	Nitrogen %	C/N Molar element Ratio
Stolon	39.43	6.39	0.38	120.037
Leaves	33.79	5.22	0.60	65.875
Roots	42.33	6.16	1.04	47.597

inflated dry, striate hirsute at the mouth; ligule hirsute.

The present study deals with the morphological specialization of the plant to bind the sand and be a successful sand binder. The plant produces both aerial stems which are vertical and horizontal stolons. The horizontal stolon has effective sand binding ability being long with regular nodes and internodes. The nodes in turn produce long roots which initially run vertically and then obliquely below the sand. The maximum length of the root was found to be 62 cms. The roots in turn bear rootlets. Thus, the underground system successfully holds the sand. The detailed morphological study of 10 plants was done and their average has been tabulated (Table 15).

The leaves are produced in regular intervals from the nodes. They are in bunches, the outer leaves are older while the inner leaves are younger. The central core forms the solid growing point.

The reproductive bodies are in the form of male and female flowers produced separately on different plants. Thus, the plant is dioecious. According to Hooker (1875) male spikelets are two flowered; sub

TABLE 15 : Morphological studies of different parts of *Spinifex littoreus*

Morphological Characters	Average
1. Length of root (in cm)	38.5 ± 15.525
2. Length of Stem (in cm)	285.37 ± 150.074
3. Max. node length (in cm)	16.23 ± 6.382
4. Min node length (in cm)	7.4 ± 3.382
5. Length of leaf (in cm)	10.98 ± 4.855
6. Breadth of leaf (in cm)	0.03 ± 0.015
7. Length of spines (in μ)	175.38 ± 30.113
8. Length of sheathing leaf base	2.52 ± 0.726
9. Breadth of sheathing leaf base	0.810 ± 0.151
10. Area of Leaf (cm^2)	0.399 ± 0.293
11. Length of Trachied (μ)	777 ± 173.671
12. Breadth of Trachied (μ)	15.54 ± 5.437
13. Length of stem V.B. (μ)	206.46 ± 26.824
14. Breadth of Stem V.B. (μ)	296.37 ± 38.145
15. Length of Leaf V.B. (μ)	174.27 ± 23.832
16. Breadth of leaf V.B. (μ)	717.09 ± 219.05
17. Length of guard cells (μ)	22.88 ± 3.574
18. Breadth of guard cells (μ)	8.96 ± 1.68
19. Length of anther cells fls. (μ)	860.7 ± 297.33
20. Breadth of anther cells fls. (μ)	136.8 ± 46.043

(Table - 15 contd.)

21.	Length of anther cell fls. (μ)	1809.75 $\pm$ 563.846
22.	Length of anthers with Microspore mother cells (μ)	834.72 $\pm$ 213.212
23.	Size of pollen grains (μ)	27.75 $\pm$ 9.99
24.	Wt. of seeds (in gm)	0.00705 $\pm$ 0.00061
25.	Length of seed (mm)	4.3 $\pm$ 0.458
26.	Breadth of seed (mm)	2.4 $\pm$ 0.489

sessile, articulate on rigid peduncled spikes, which are collected in umbels surrounded by spatheous leafy bracts; glumes 4,membraneous, not awned; I & II empty; III & IV paleate, triandrous. Female spikelets collected in large globose heads of stellately spreading very long rigid rod like rachides surrounded by shorter subulate bracts , each spikelet is solitary and articulate at the very base of the rachis; lanceolate 2 flowered. Glumes I, II and III as in the male but longer; III paleate empty or triandrous; IV female, lodicules 2 large nerved styles long, free; stigma shortly feathery, grains free within the hardened glumes.

Cook (1906) described the male spikelets as 1-2 flowered, distichous, articulate on short pedicels; glumes 4; chartaceous; acute strongly nerved invol. glumes empty; lower floral glume paleate, empty or tri-androus, upper floral glume paleate, tri- androus, the palea of both floral glumes acuminate as long as glumes.Anthers linear. The famale spikelets are described by Cook (1906) as narrower than male erect lanceolate, 1 flowered, glumes acute or acuminate, strongly nerved, the lower involucre. glumes the longest; lower floral glume empty, upper floral glume

thin, dorsally compressed; palea linear, oblong, acuminate, lodicules 2, large, connate below; stigmas long panicillate, exerted at the top of the glume. Grain clavate tipped by the long rigid style, free within the hardened glume and palea.

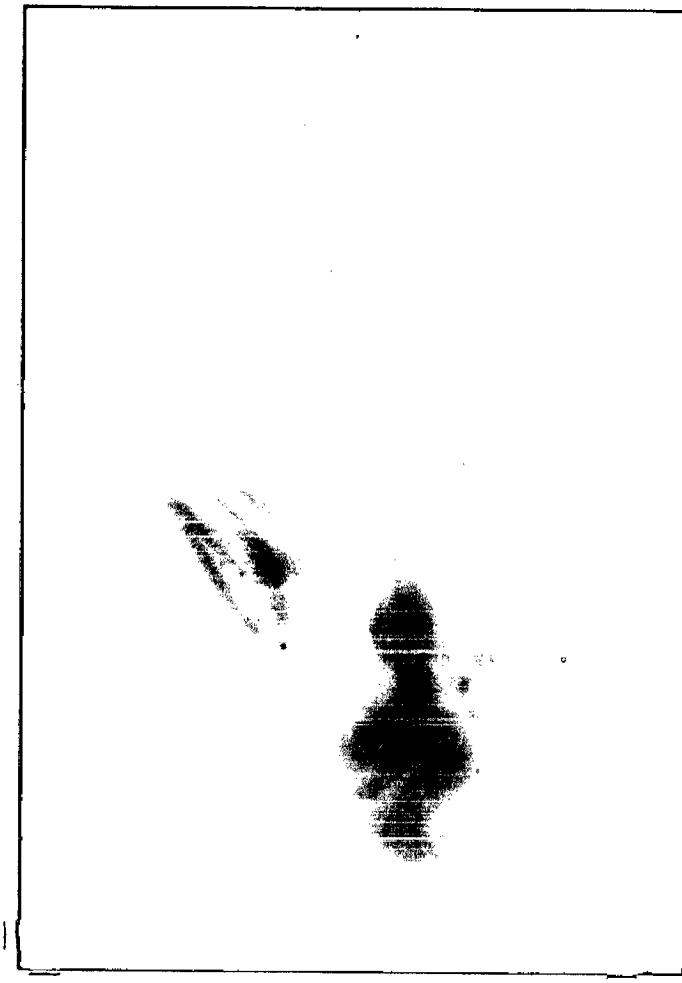
Gamble (1956) and Bor (1960) have given a similar description of the inflorescence but Gamble (1956) added that staminodes are sometimes present in the female floret.

Haines (1961) described the male umbel as sessile at the angles of a zig-zag rachies with pungent lanceolate bracts 1.8 - 3 cm long; spikes 5 - 7.5 cm long; with scabarous rachis produced at the tips into pungent spines resembling those of the female but short spikelets 1 cm. long glabrous, scaberulous, glume I) shortest about 5-6.35 mm. long, 7-9 nerved,II) similar but a little longer; III) lanceolate 5 nerved rigidly acuminate or sub arisate; IV) usually a little longer subarisate or cuspidately acuminate. Female spikelet 1 - 1.14 cm long partly sunk in the base of the needle like rachis which is supported by distichous bracts, some of which are similar to itself 7-15 cm. long others short flatter and 2.5 cm. long. Glumes and palea

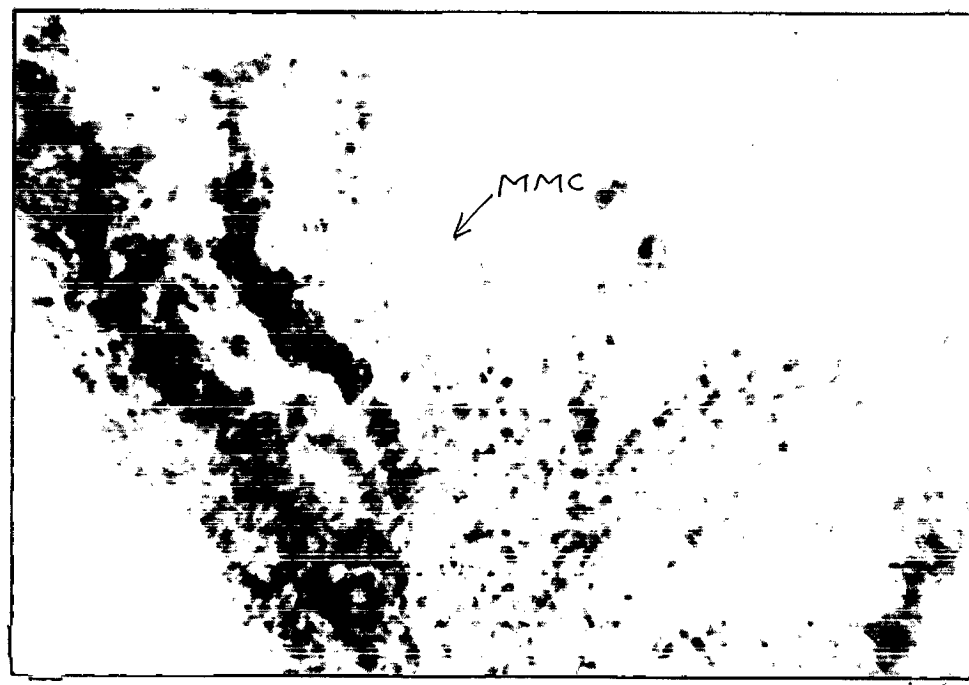
all lanceolate - acuminate, membranous,subequal, outer puberulous i) 11 nerved ii) 7-9 nerved; iii) 5 nerved, 2 sexual; palea 2 nerved lodicules quadrate, oblong, 2 nerved, style long with stigmas 1.9 cm. long.

Lazarides (1980) described the plant as dioecious, with bisexual and male spikelets in spiciform racemes on different individuals, the bisexual raceme reduced to 1 spikelet rarely 2, near the base of a long bristle like rachis, the male raceme with several spikelets. Florets 2;lower neuter or male and upper bisexual in the bisexual spikelet, both male in the male spikelet. Bisexual spikelets tardily disarticulating from its short pedicel. Rest of the description is similar to Haines (1961).

The present study confirms the works of the past authors and add that the female globose inflorescence have bisexual and female florets. The florets are initially either female or bisexual, (Plate 6). In the bisexual florets the anthers are distinctly bithecous and they develop upto the formation of micro spore mother cell stage, (Plate 6). As the florets grow the micro spore mother cells degenerate and the anthers become functionless. The male spikelets were also



BISEXUAL FLOWER OF
SPINIFEX LITTOREUS x 10



MMC : MICROSPORE MOTHER CELLS x 40

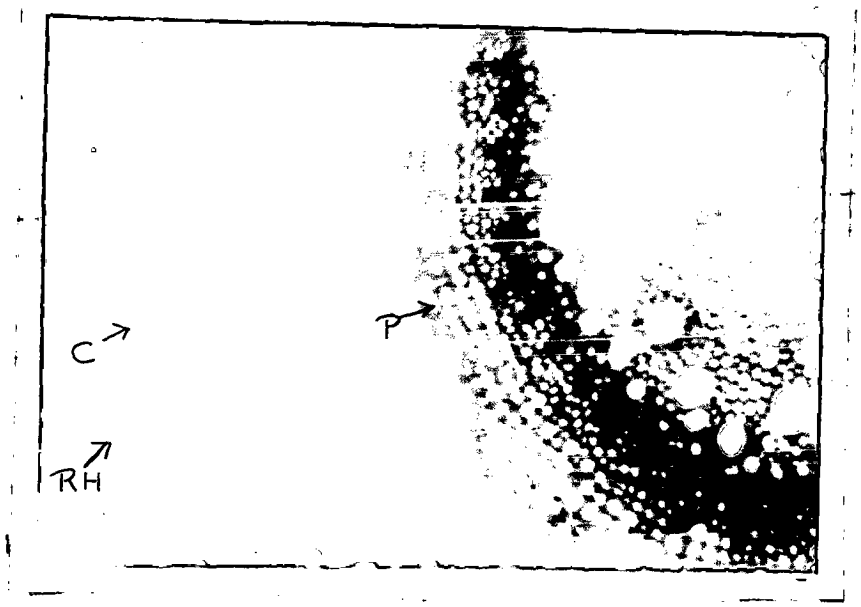
PLATE - VI

studied but they do not have rudiments of any ovary. Each male spikelet has two outer bracts enclosing 2 florets. Each male floret has 3 perianths enclosing 3 anthers. These anthers were longer as compared to the anthers of the bisexual florets and are bithecous. Presence of bisexual florets in the female inflorescence surely indicates that the plant has primitive evolutionary trends of being a bisexual flower.

The female florets are hypogynous with long style connate at the base and feathery stigma, with single ovule.

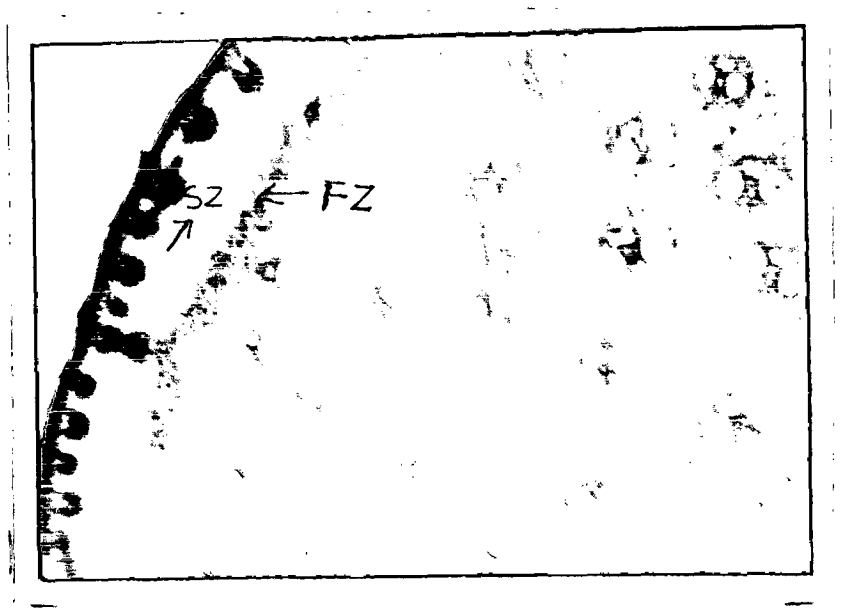
5.6 INTERNAL MORPHOLOGY

Anatomy : The transverse section of the root was studied, (Plate 7). The section showed single layered epidermis with thick cuticle and unicellular hair. The cortex was 12 - 14 cells thick, parenchymatous. A single layered endodermis with 4 layered pericycle was observed. The vascular bundle was polyarch with alternating xylem and phloem. The pith was parenchymatous and radiating.



RH : Root Hair, C : Thick Cuticle, P : Pericycle

T.S. OF ROOT x 40



S.Z : Sinous Zone, F.Z : Fibrous Zone

T.S. OF RHIZOME x 40

PLATE - VII

Metcalfe (1960) has reported about a secretion of an amorphous substance near the piliferous roots. It is non mucilagenous and is protective in function. According to the same author, root hairs are restricted to the roots near the surface of the sand. The present study confirms the presence of the secretion but does not agree with the restriction of the root hairs near the surface.

Metcalfe (1960) described an internal structure of the culm which is about 5 mm. in diameter. It revealed a depression on one side and a cavity at the centre. The epidermis was found to be subtended by 2 layers of fibres. The fibrous zone is bound on the inner side by a wide zone of rounded assimilatory cells approximately 10 cells wide. Assimilatory cells are bounded on the inner side by a second zone of fibres, 10 cells thick, the outer periphery of the zone being somewhat sinuous in the outline. Ground tissue on the inner side of the inner sclerenchymatous ring consisting of large thin walled cells with minute triangular intercellular spaces between them. Vascular bundles of the outer circle embedded in the inner sclerenchymatous ring. Remaining vascular bundles are scattered throughout the thin walled ground tissue. This study confirms the above

structure (Fig. 26) but does not agree with the presence of cavity at the centre.

Metcalfe (1960) gave the record of the internal structure of a rhizome of about 4 mm. in diameter. It is also slightly flattened on one side and is with solid centre. Epidermis is of small cells with very thick walls bounded on the inner side by a cortical zone about 10 -12 cells wide, followed by a sinous zone of thick walled fibres, with a circle of vascular bundles embedded in it, the portion of the fibrous zone between the vascular bundles being about 6 -10 cells wide. Inner ground tissue consisting of large, moderately thin walled cells with triangular inter cellular spaces between them. Large vascular bundles scattered throughout the inner ground tissue except at the centre of the rhizome. The present study confirms the above description (Plate 7) and further adds that the epidermis is followed by patches of sclerenchymatous cells. Associated with them on the outer side, are chlorenchymatous cells. At intervals there are two such associated group which touch the inner ring of sclerenchyma. These cholerenchyma - sclerenchyma patches are separated from each other by 3-4 parenchymatous

FIG 26 : LEGENDS

1. Epidermis
2. Parenehymatous cells
3. Selerenehymatous cells
4. Chlorenchymatous cells
5. Selerenchymatous ring
6. Cortex
7. Vascular Bundles
8. Solid pith

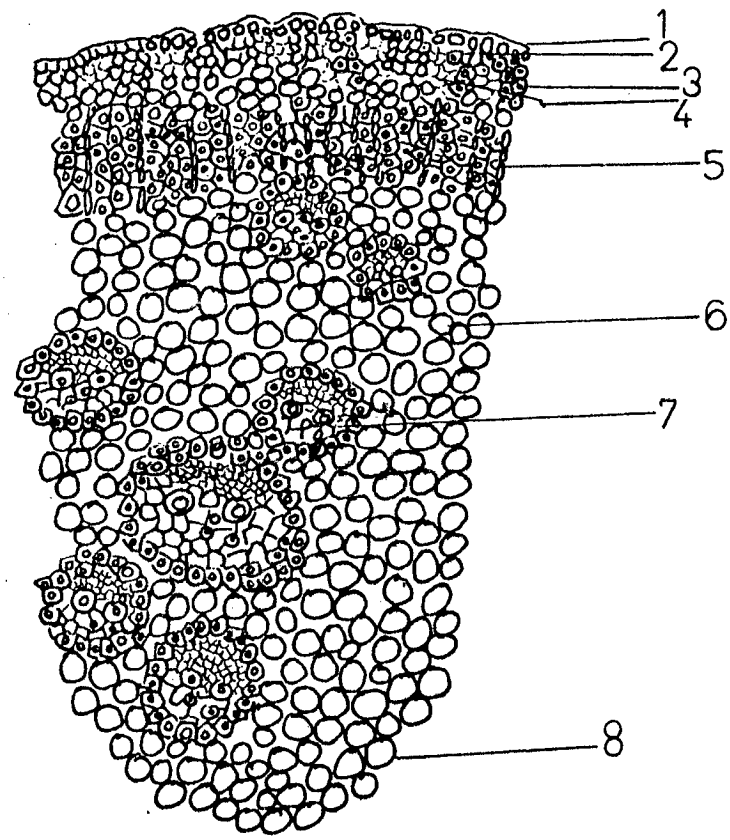


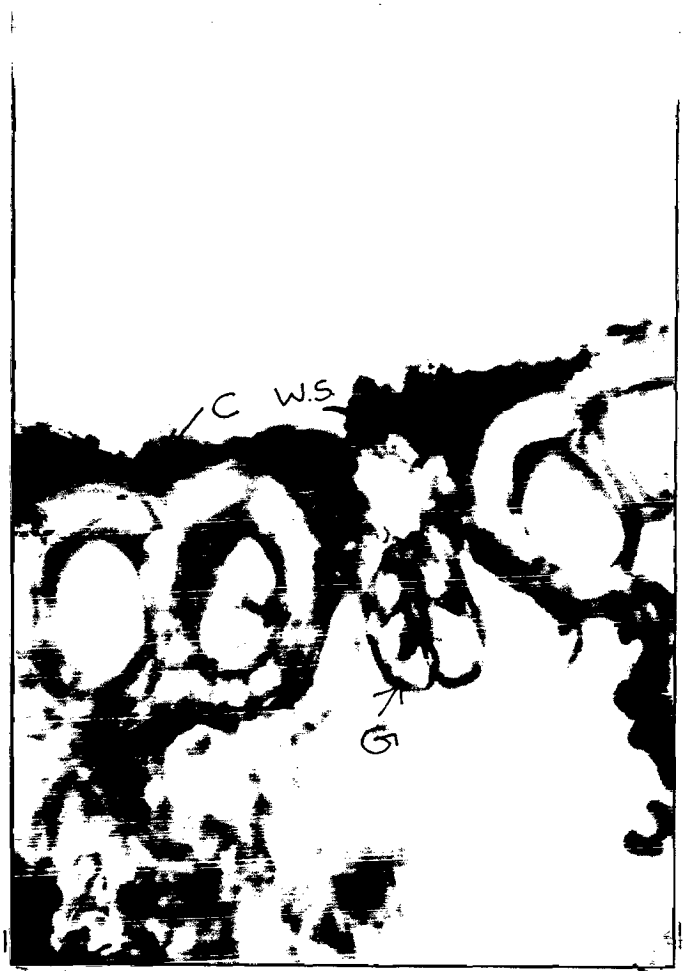
Fig. 26 T. S. of culm of Spinifex littoreus.

cells. Due to the presence of the inner sclerenchymatous ring, the ground tissue can be distinctly divided into outer and inner zone. The outer zone is specialized for photosynthesis and mechanical support while the inner zone is for translocation and storage. The presence of sclerenchymatous patch on the outer side and a continuous ring towards the inner side is justified because the plant is under constant pressure from strong winds and sand burial. This internal structure contributes to the sturdiness of the grass and thus help it to be a successful sand binder with low water evaporation.

Metcalfe (1960) has also described the internal structure of the leaf of *Spinifex hirsutus* Labill., which is quite different from that of the internal structure of *Spinifex littoreus* described in the present study, (Plate 8). The internal anatomy of S. littoreus shows the thick cuticle uneven and brown. The epidermis is made up of rectangular cells, covered with cuticle of varying thickness. The stomata are sunken in distinct furrows. They are guarded by thin walled oval guard cells, (Plate 8). The stomatal pore is blocked with certain waxy secretion to prevent excess of moisture loss. The sunken portion of the epidermis is

V.B. : Vascular Bundle, P : Photosynthetic Zone, S : Sclerenchymatous Cells

T.S. OF LEAF x 40



C : Cuticle, G : Guard Cells, W.S : Waxy Secretion

MAGNIFIED EPIDERMAL CELLS x 100

PLATE - VIII

continued to a passage which is surrounded by chloroplast, irregular in shape. This is the only photosynthetic zone and there is no palisade tissue. Next to the stomatal pit is a patch of thick walled sclerenchymatous cells 2-3 layered thick. Below it lie the vascular bundles which have a sclerenchymatous cap on the upper sides and the other three side are surrounded by single layered chlorenchymatous cells. In the vascular bundles the protoxylem is pointing towards the lower side. The lower epidermis is also single layered, with thick walled rectangular cells. The cuticle is comparatively less thick than the upper epidermis. There are no stomata on the lower surface. Between the upper and lower epidermis there are 14- 16 celled thick parenchymatous cells. The outer edge of the leaf shows distinct ridges and furrows. Since the sclerenchymatous patch at maturity push the vascular bundles down and the developing vascular bundles are found near the upper epidermis, vaascular bundles of different sizes are observed.

The anatomy of the leaf revealed that the plant must be growing under the stress conditions. The sunken stomata, waxy secretion, thick walled epidermis

covered with thick cuticle,significant sclerenchymatous patch make the plant suitable to grow in adverse conditions and restrict excessive loss of water through transpiration.

The dimensions of the guard cells,vascular bundles and the trachieds are given tabulated in Table 15.

5.7 REPRODUCTION

a) Cytology

According to Bor (1960) the chromosomes are very small and the chromosome number is 2n=18. This has been confirmed in the present study.

b) Sexual Reproduction

i) Palynological Studies: According to Nair (1966) Gramineae is grouped among Stenopalynous family. This study confirms the structure of the pollen grains described by Nair (1966). The pollen grains are with single pore surrounded by an annulus and surmounted by an operculum. The sizes of the pollen grains are given in Table 15.

The dimensions are in confirmation with Firbas (1949) and Woodhouse (1935) as quoted by Nair (1966), which evolve an artificial key for the grass pollen grains into cereal grass type wherein the size of the grain is above 35 μ upto 60 μ and the wild grass type size of the grains below 35 μ down to 20 μ .

The viability of the pollen grains was studied and the results has been given in Table 16. The viability of the pollen grains was found to be fairly good with 61.83% germination. The germination rate of the pollen grains was studied in different concentration of sucrose. The germination percentage was found to be 52.57% in 20% sucrose solution (Table 17).

ii) Pollination

The male florets are produced separately in male inflorescence on male plants. Bisexual florets are also seen in the female globose inflorescence,but they do not produce mature anthers, thus only the male florets are capable of producing viable pollen grains. The plant is apparently not visited by the insects and thus it is wind pollinated. In the mature female florets the stigma is well developed and this attracts the pollen grains

TABLE 16 : Viability of Pollen grains

Total No. of Pollen grains (under micro-scopic view)	Pollen grains showing the +ve test	% Viability	Average viability
7	7	100	
8	8	100	
9	6	66.66	
6	3	50	
5	1	20	61.86 ± 24.240
20	7	35	
10	5	50	
12	9	75	
12	7	58.33	
11	7	63.63	

TABLE 17 : Percentage germination of Pollen grains in different of sugar solution

Percentage of sugar solution	Total No. of Pollen grains	No. of germinating Pollen grains	No. of non germinating Pollen grains	% germination
	10	-	10	
	6	-	6	
	10	-	10	
	7	-	7	
CONTROL	6	-	6	0
	3	-	3	
	5	-	5	
	10	-	10	
	6	-	6	
	5	-	5	
	7	-	7	
	5	-	5	
	5	-	5	
	3	-	3	
	3	-	3	
10%	3	-	3	0
	5	-	5	

(Table 17 contd.)

	7	-	7	
	3	-	3	
	4	-	4	
	13	7	6	53.84
	8	4	4	50
	9	4	5	44.44
	5	4	1	80
20%	12	3	9	25
	12	6	6	50
	5	3	2	60
	7	4	3	57
	8	5	3	62.5
	7	3	4	42.85
	5	-	5	
	4	-	4	
	7	-	7	
	4	-	4	
	3	-	3	
30%	3	-	3	0
	3	-	3	
	3	-	3	
	3	-	3	
	7	-	7	

(Table 17 contd)

	4	-	4	
	4	-	4	
	7	-	7	
	3	-	3	
40%	5	-	5	0
	13	-	13	
	9	-	9	
	6	-	6	
	6	-	6	
	7	-	7	

from the male florets of male inflorescence from separate male plants. Hence, the plant is allogamous.

iii) Seed Production

Female globose inflorescence were studied to find out the number of seeds produced per female inflorescence and is given in Table 18. Few spikelets were found to be empty and mature seeds were produced only by the female florets having receptive stigma.

The seeds are caryopsis, oblong, free between indurated lemma and palea (Lazarides, 1980).

iv) Dispersal

The female inflorescence when sufficiently dry disarticulates itself from the plant and the dry rachides roll by itself enabling the globose inflorescence to roll on the dry beach and gradually disperse the seeds. According to Bor (1960) and Lazarides (1980) the sea also acts as the distributor of the seeds, as the infructescence is boyont and proceed to the sea, blown by wind and cross creeks.

TABLE 18 : No. of seeds produced per globose

Globose	No. of rachides	No. of spikelets	No. of seeds produced	% seed produced in one globose
1	20	80	10	12.5
2	23	85	15	17.64
3	24	100	14	14
4	25	100	20	20
5	22	83	12	14.45
6	20	90	18	20
7	18	82	13	15.85
8	25	87	15	17.24
9	24	80	14	17.5
10	23	92	19	20.65

Average seed produced ------> 16.983

$\pm$ 2.629

v) Seed statistics

The average size and weight of the seeds were studied in (Table 15). The seeds can be collected between January to May from the female inflorescence. In nature these seeds either remain within the inflorescence till the onset of the monsoon or are dispersed separately. The seeds were germinated under the laboratory conditions on wet blotting paper (Table 19; Plate 9). A brown secretion was observed around the seeds during germination. The percentage germination was 54%. Further, the seeds were tried for germination in polythene bags,under control,with organic fertilizer of cowdung and inorganic fertilizer of 'SAMPOORNA' containing NPK in the proportion of 19:19:19. (Table 20). The result was not satisfactory since the germination percentage was only 33% and that too under control. This low rate of germination may be because the seeds were collected immediately after their formation and tried for germination, and not allowing their normal dormancy period of 4-5 months under high temperature; and secondly addition of fertilizers changed the normal condition of the sand by increasing moisture content, lowering the temperature and raising the pH. Maximum germination of the seed can be ensured

TABLE 19 : Rate of germination of seeds in laboratory conditions

Total No. of seeds	No. of seeds germinated	% germination
20	11	55
20	13	65
20	10	50
20	11	55
20	09	45
20	12	60
20	11	55
20	10	50
20	08	40
20	09	45

Average seed germination 52%

$\pm$ 7.141

TABLE 20 : Germination of seeds in different conditions

	Total No. of seeds in each bag	No. of seeds germinated	% germination	Average germination
	10	3	30	
	10	4	40	
	10	3	30	
	10	4	40	
CONTROL	10	3	30	32
	10	3	30	
	10	2	20	
	10	3	30	
	10	3	30	
	10	4	40	
Sand 1 kg	10	2	20	
+	10	2	20	
Cowdung 2 gm	10	2	20	
	10	2	20	
	10	2	20	22
	10	4	40	
	10	3	30	
	10	2	20	
	10	2	20	
	10	1	10	

(Table 20 contd.)

Sand + Sampoorna	No. of seeds in each bag =10		0%	
Sand +	10	2	20	
Organic +	10	2	20	
Inorganic	10	3	30	
	10	1	10	
	10	3	30	20
	10	2	20	
	10	2	20	
	10	1	10	
	10	2	20	
	10	2	20	

if the entire inflorescence are adequately covered with sand (Anonymous,1981).

c) Vegetative Reproduction

The plant produces long stolons with nodes and internodes and each node is capable of producing roots which can separately grow as a new plant. During monsoon the horizontal growth of the plant is vigorous. It can be successfully grown with cuttings of 20- 40 cm long, (Anonymous,1981). Occasionally,due to high wind velocity the plants get uprooted and break into fragments. In favourable conditions these scattered fragments get established (Untawale,1980). Stem cuttings were grown in polythene bags and their rates of survival are shown in Table 21. The plants though survived, did not show significant growth as they needed wider area to produce horizontal stolons and their vertical growth was comparatively very low.

On the whole, vegetative reproduction was more successful than the sexual reproduction. Although, no special propagules were produced, the nodes of the plants served as the vegetative reproductive units.

TABLE 21 : Rate of survival of stem cuttings in different conditions

	Total No. of bags Each bag with 1 cutting	Survival Rate of plant	% Survival
CONTROL	10	6	60
Sand + Cowdung	10	4	40
Sand + Sampoorna	10	2	20
Sand + organic + inorganic	10	3	30

d) Phenology

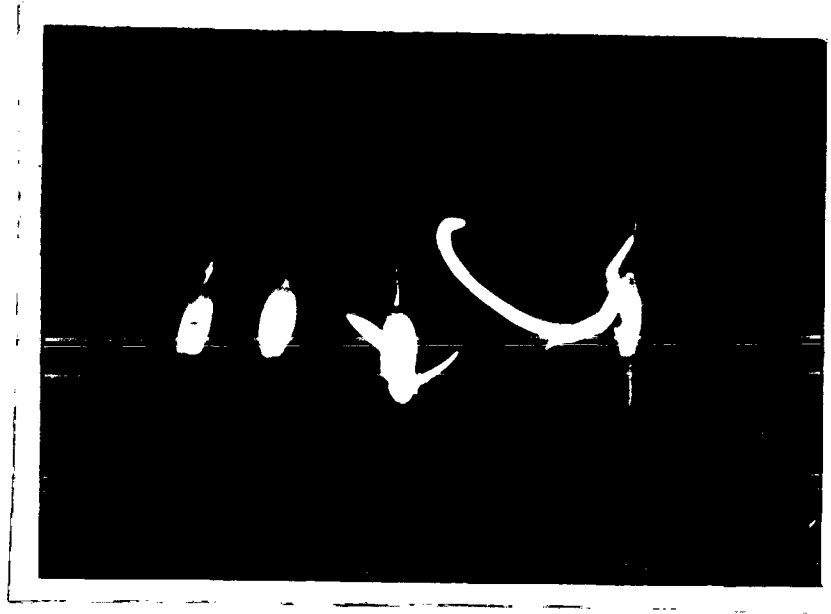
Growth of three plants was studied for eight months from October 1990 to June 1991 under natural conditions. Tags were tied at the last node and after one month, increase in length of the plant was noted (Table 22, Plate 9). The vegetative growth of the plants continued till the inflorescence appeared; and the vegetative growth was very good.

e) Life history of the plant

On the onset of the monsoon in June -July the seeds germinated giving rise to small seedlings. These seedlings grew for a year vegetatively and by the next year during September-October male and female inflorescence appeared separately on different plants, thus the plants were found to be dioecious. The pollen grains were ready for dispersal by late October or early November. The post monsoon season in the coastal area was dry with high temperature and strong wind. This was favourable for wind pollination. By January-February the seeds were ready on the plants. The Pre monsoon weather favoured the seed dispersal by disarticulating the ball like female inflorescence and rolling it on the

TABLE 22 : Growth of plants in cm during the period of one month

Plant	Growth of plants in successive months								
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Plant 1	Tags were	33	50	29	25	28.5	28	27	Plant covered by sand
Plant 2	put on the	20	13	13	23	23	30	28	7
Plant 3	last node	15	15	20	10	9	8	1	Appearance of inflorescence



SEED GERMINATION

GROWTH STUDIES

PLATE - IX

dry sandy beach. The seeds remained buried under the sand till the onset of the monsoon and with the onset of rains they germinated. Besides the sexual reproduction, the plant successfully propagate by vegetative propagation.

5.8 GEO-MORPHOLOGICAL INTERACTIONS

a) Response to Burial

The seeds are coated with thick testa and give out a peculiar secretion in brown colour which protects them from any injury. The plant is very sturdy and is very well adapted to sand burial. The long stolons are buried many times under the sand and again seen emerging out with a tuft of leaves. Usually the plant is not affected by tides. During monsoon lots of organic and inorganic debris gather on the shore and on the region of their growth, but this does not hamper the growth. The plant with all its special adaptation can grow on the embryonic dunes. The moving sand gets collected around the plant and slowly the dune is formed. This dune is further made stable by the long roots and the

stolons of the plant, thus the plant acts as an excellent sand binder.

5.9 INTERACTION WITH OTHER SPECIES

The other common sand binder seen to be associated with grow with *Spinifex sp.* is *Ipomoea pes- caprae,* few *Cyperus* species etc. (Table 4). Since, the plant is with spiny and rigid leaves, it is not grazed upon. No specific insects visit the plant and it is not infected by any disease or pest.

5.10 ECONOMIC IMPORTANCE

The plant as such is not of any economic importance (Anonymous, 1992), though fisherfolks sometimes use it as fuel. The plant with its morphological and anatomical adaptation is best suited for the coastal sand dunes. This plant as observed in the present study does not need any special care for its growth. Due to its adaptive features the plant is very important ecologically. It prevents the sand from moving inland, which results into the inland deserts. Desertification of land is one of the major problems faced by mankind

today. Thus, it is very important to preserve the natural growth of this and other sand dune plants. Since, the plant has no other economic value , it is often considered to be a weed flora and is always disturbed.

5.11 CONSERVATION AND MANAGEMENT

The plant is under constant pressure due to developmental activities, tourism and construction. It is, therefore, necessary not only to conserve the natural vegetation but also draw out managemental plans to conserve the plant successfully. A germ plasm bank through tissue culture technique could be started to prevent the permanent loss. Nurseries should also be maintained to propagate the plant on vacant sandy areas. Managemental programmes for protecting the sand dunes and the vegetation on them are separately outlined in the next chapter.

CHAPTER – VI

CONSERVATION AND MANAGEMENT OF THE SAND DUNE ECOSYSTEM

CONTENTS

6.1 INTRODUCTION

Sand dunes were perhaps among the earliest habitats for the primitive man. As land became scarce, dune system was levelled for housing, industries and for many other developmental needs. The disastrous results of the diminishing dunes were not known (Ranwell,1972).

The Wassenaar dunes near Hague were exploited since 1874, and afterwards, this has caused serious fall in ground water table, (Boerboom, 1960). Voo (1964) recorded that a fall in the water table even by 10 cms. can be fatal to plants and animals. Many moisture loving plants disappeared and plant communities dependent on high water table were almost destroyed when dunes were disturbed.

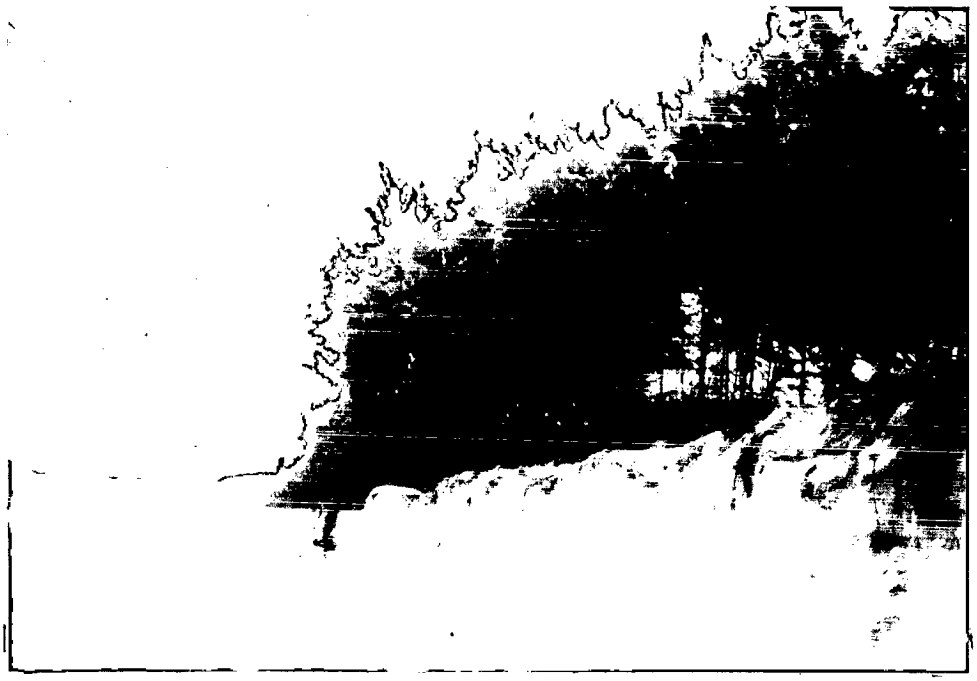
Clark (1977) observed that the dune systems act as a buffer to the force of stormy seas. As the dune is attacked by storm waves, eroded material is carried away and deposited off shore where it alters the shore profile. Accumulating sand decreases the off shore beach slope, thus making it more or less horizontal and thereby decreasing the friction of destructive waves. The dune system has the capacity to store sand and yield

it to the adjacent submerged land, thus protecting the shore land. Lower dunes have lesser but never the less significant effect. Storm resistance increases with the dune height. Thus, human interference by way of devegetating, eroding or lowering the dune, results in increased damage by storm. Bhimaya (1974) stressed the necessity for sand dune fixation. Naturally existing coastline dunes extend inward and pose danger to the shoreline. Moreover, if valuable installations are to be protected, it is extremely necessary to stabilize the frontal sand dunes (Plate 10).

6.2 CONSERVATION OF SAND DUNE VEGETATION

According to Untawale (1994) the herbaceous pioneer zone, shrubby midshore zone and backshore zone covered with trees form a natural sloping triangle in the coastal area which diverts the windflow upward, controlling the erosion. On the pioneer zone the herbs with creeping stolon grow. In the midshore zone herbs and shrubs with comparatively deeper root system are seen to be naturally growing. And,further on the backshore dune trees are found. This natural vegetational slope form a triangle with the herbs at the

ERODING COAST



ERODING COAST WITH CASUARINA

AT THE FORESHORE

PLATE - X

base and trees at the apex, (Fig.27). This natural growth of plants has to be maintained as they successfully utilize the ground water. Any change in the growth pattern will interfere with the dynamic system of sand dunes. All management programmes should be undertaken keeping in view this vegetational slope.

It is extremely essential to note that under no circumstances the foredune and its natural vegetation is disturbed. In fact no human interference in the form of preparing land for plantation or any other constructional activities should be allowed. In the midshore zone where natural vegetation like *Clerodendron inerme, Vitex negundo or Lantana camara* normally exist,plantation can be taken up without damaging the existing dune and its flora. At the back shore region soft wood trees like *Casuarina equisetifolia,* which act as wind breaker may be planted. Unless there is a rich ground flora on the fore and midshore zone, the backshore stabilization will not be successful.

Though, often sand dune flora is considered to be a weed flora, their conservation is essential as they are the only plants which can withstand adverse conditions of high wind velocity, shifting sand, salt spray as well

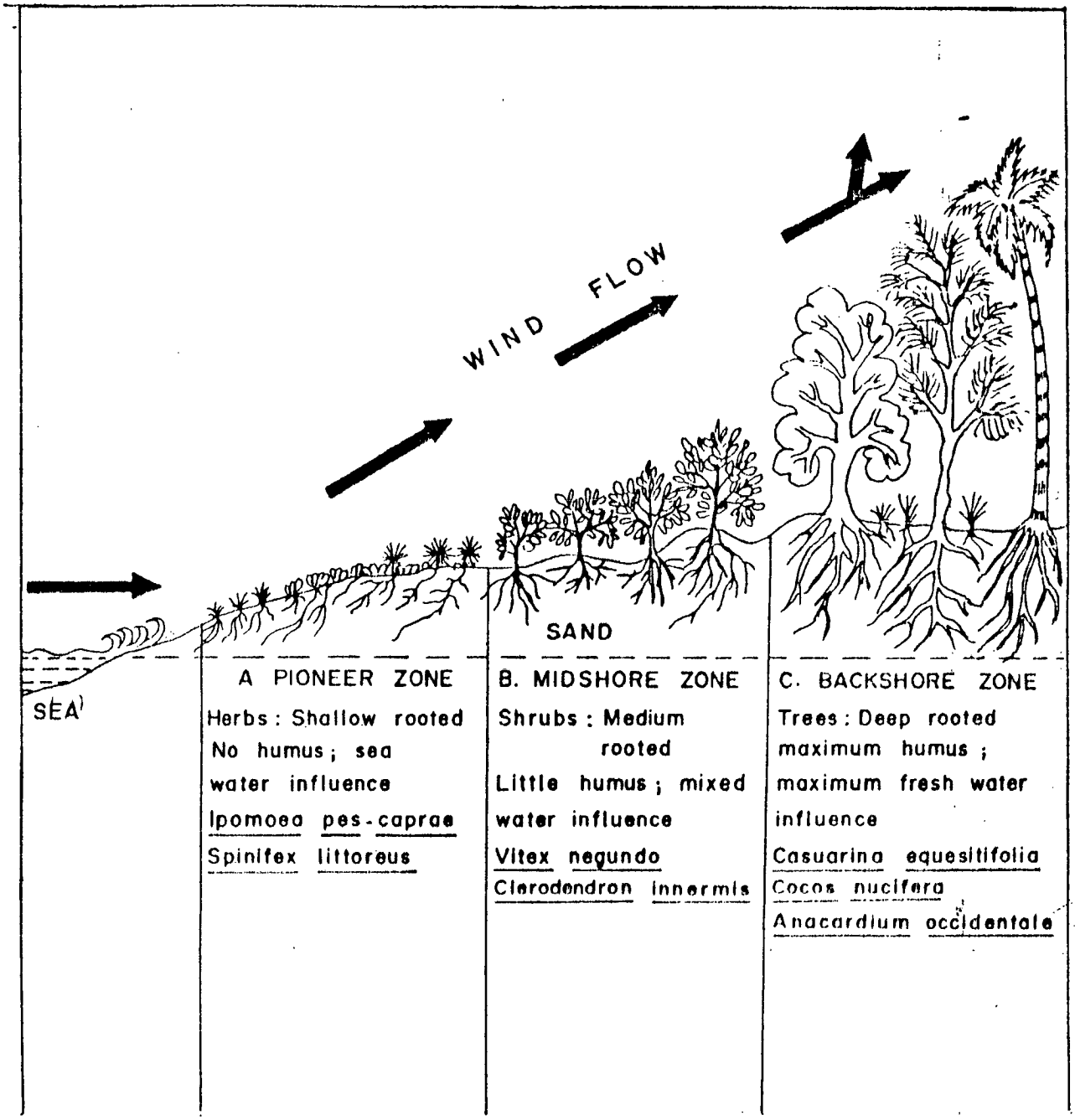


Fig. 27 Vegetation slope on the sand dunes

as less nutrients in the sandy soil. Eradication of total vegetation may lead to loss of important germplasm. Therefore, it is essential to establish germplasm banks of the dune flora through tissue culture technique. Ipomoea pes- caprae is successfully micropropogated in Murashige & Skoog's medium supplemented with neccessary nutrients (Kane et al, 1993) Also, salt tolerant varieties of various crop plants like Jowar, Bajra, barley, wheat, sugarcane and safflower (Narayana et al, 1964; Iyenger et al,1977;Kurian & Iyenger 1971; Kurian & Iyenger 1972;Iyenger &Abraham 1976;Iyenger et al 1977) should be introduced to protect the dunes.

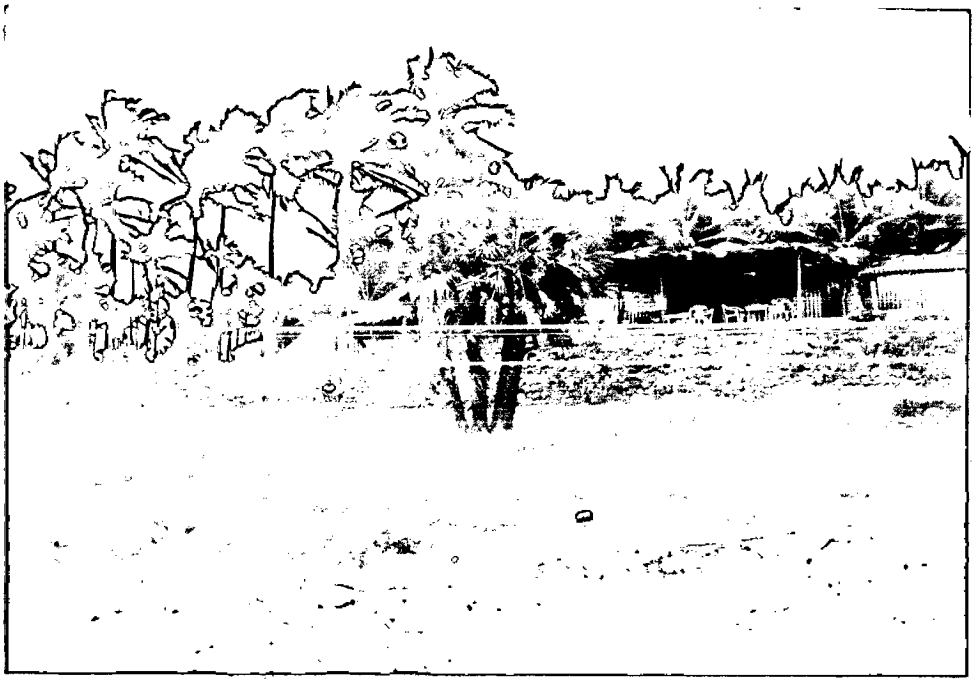
At present there have been no special efforts to grow sand dune plants or psamophytes. In order to conserve the sand dune ecosystem, it is first essential to stabilize the dunes and then restore the natural vegetation by special plantation programmes. This is possible only if dune plants are made available from nurseries. Forest Departments and private parties should be encouraged to start nurseries of sand dune plants.

6.3 MANAGEMENT OF SAND DUNE ECOSYSTEM

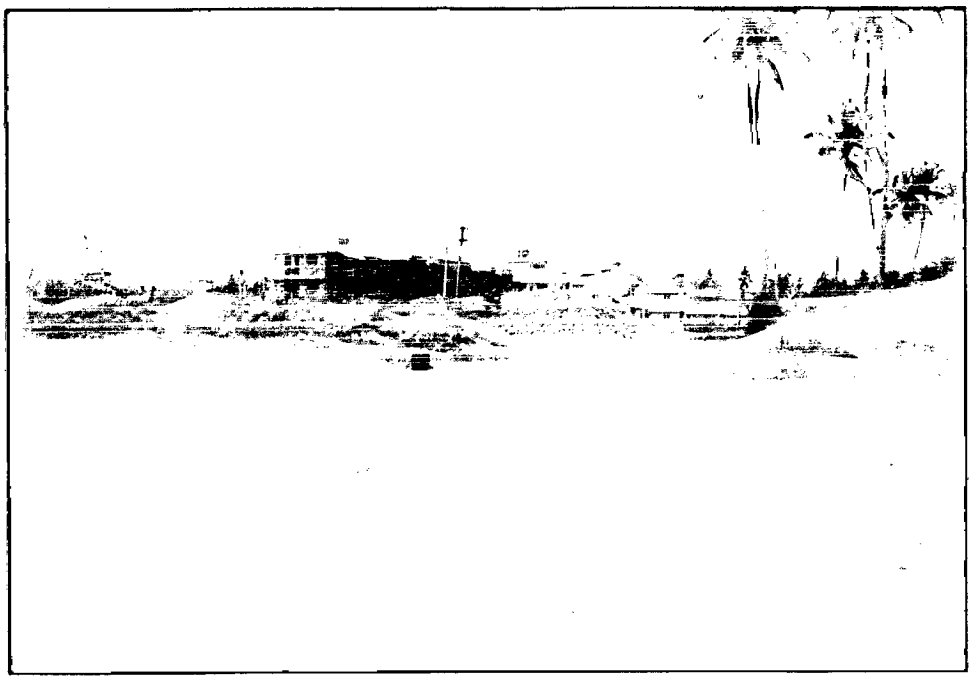
Management of coastal dune ecosystem has recently received attention in India. Taking into consideration the ever increasing pressure of development it has become essential to prepare the Coastal Land Use Plans and its management (Plate 11).

Clark (1977) while giving the outline of some policies, indicated that the vegetative cover is destroyed in coastal region by site preparations. The unstabilized sand is exposed to wind erosion, and the dunes become vulnerable to storm damage and also decrease their value as a storm buffer. Some of the preventive measures to protect sand dunes, as suggested by Chapman (1976) and Clark (1977) are given below:

1. Prohibit lowering of the dune crest to provide building sites.
2. Restrict construction to areas behind the dune line.
3. Prohibit all constructions on the dunes.
4. Where construction is permitted or already exists ensure replanting of devegetated area.



DEVELOPING HOTEL INDUSTRY



URBAN DEVELOPMENTAL PRESSURES
ON THE SAND DUNES

PLATE - XI

5. Provide technical assistance and a convenient source of beach grass plantings to property owners.
6. Prohibit all solid constructions on the beach.
7. If buildings are made the ground water level should not be allowed to reduce below a critical level otherwise stabilizing beach grass will be difficult and the dunes will be exposed to wind erosion and storm damage.
8. Access across the dunes should be restricted to stabilized pathways or roadways. All other routes should be blocked off.
9. Residential development should not prevent public access to the beach.
10. Public rights to way should be provided at frequent intervals.
11 Providing a cover to the sand initially artificially and then a closed vegetation proves successful.
12. Plants that can tolerate the adverse conditions of the dunes should only be tried for plantation.
13. Soft wood trees that need less attention for growth and improve the soil with their litter are suggested for plantation.

14. The movement of the sand should be stopped as near the source as possible.

15. There should be no gullies or embayment on the dunes as irregularities on the dunes affect the wind velocity. Smooth and regular sea frontage lessens the chance of erosion.

16. The initial fences must be located in relation to the prevailing wind on which depends the movement of the sand.

17. If the land is sinking in relation to the sea level, erosion will be continuous. So artificial dunes have to be built from time to time.

18. If the sand is not too mobile it can be stabilized by planting grass but if it is highly mobile it can be stabilized by brush fences at right angles to the sand movement.

19. In order to create or repair the fore dunes the dune produced should be with a wide base, low summit and relatively flat slope. The general method is to establish two fence rows about 2 mts. apart and 75 cms. high. When the sand reaches the top, two more fences, each a little to the sea ward side of the first pair are set up. When these are nearly covered plantation can be taken up. If the

dunes are still not high enough a third set of fences can be put up. The front of the dune is best planted in squares, while rows can be used on the leeward slope. Legumes are desirable plants to be introduced at an early stage because of the Nitrogen they add to the soil through the nitrifying bacteria in the root nodules. According to Ranwell (1972), dune systems are now recognized as a valuable and limited resource not only for wildlife but also as recreational land. Each country with dune resources clearly needs to develop a national plan for their protection and use. Such a plan would record the distribution and size of dune resources and designate those areas. Air photo monitoring may be required more frequently to detect changes in pathways patterns pointing to the need for closer access control or urgent restoration activities.

Coastal protection being primarily concerned with dune maintenance a regular intensive observation is needed on the entire dune system. In order to have proper access to the beach, pathways may be provided by rotational use. If the number of visitors visiting the

beach is less, then naturally vegetated pathways could be used; otherwise artificially surfaced paths have to be provided. A judicious management of the grass-shrub balance on the beach will accommodate more people within the dunes. To protect the natural vegetation it is essential to provide owners, planners and tourist, maps showing locations of sites where specific protection of flora\fauna or the dune itself is desirable (Ranwell 1972).

Now, that it is a well known fact that the dunes have to be protected,stabilized and revegetated, various methods have been worked out in different countries. The reports are as given below.

In Australia `The Beach Protection Authority of Queensland' has taken intensive programme to protect the frontal dunes. It has realized that the beach itself is tolerant to intensive recreational usage but the frontal dune is extremely fragile. Destruction of frontal dune vegetation is resulted from even moderately concentrated pedestrian usage. Once even a small patch of the frontal dune loses its vegetation, strong onshore winds can complete the destruction, initially by producing blowouts, then transverse mobile dunes and finally a

completely unstable dune system rapidly moving inland. Loss of sand from the frontal dune system by wind action accelerates the landward movement of the coastline. Natural recovery from damage is slow here because environmental conditions are unfavourable for the growth of plants here.

In order to protect the frontal dune vegetation, sensitive parts of the dune system can be fenced off and access to the beach is maintained. The tracks are conveniently placed in such a way that they are used by public and surfaced with gravel and installed with board and chain walkways or steps at the seaward end. These tracks are narrow. Vehicular access to beaches is also made such that vehicles do not cause damage to the frontal vegetation. Frontal dunes are stabilized by plantation. Primary sand colonizing plant like *Spinifex hirsutus* is either planted by sowing the entire inflorescence or nursery raised seedlings can be planted. Success have also been obtained by planting the runners of Spinifex or Ipomoea pes- caprae. After initial stabilization secondary stabilizers by shrubs like *Acacia, Lantana, Personia, Coelospermum* and trees like *Casuarina equisetifolia, Banksia integrifolia, Leptospermum laevigatum, Melaleuca quinquenervia, Acacia*

sophorae, Acacia leiocalyx and Acacia cyanophylla or Calophylum inophyllum as tertiary stabilizers are planted.

Since the coastal sand dunes have low levels of nutrients, they are usually deficient in nitrogen, phosphorus and potassium. According to the nutrient status of the sand nutrients are applied.

In some cases before plantation, stabilization of the sand surface is necessary. It may be done by plant material i.e., by placing complete layer of leafy parts of young trees or branches of trees or by spray of materials like Terolas (a bitumen emulsion) and Curasol A.C. (a polyvinyl acetate emulsion) on bare sand.

Sometimes dunes and the vegetation they support are damaged by cyclonic strong winds, droughts, fire or parasite attack. Apart from these natural causes man's activities like grazing, burning, development and foot and vehicular traffic result in damage or destruction of vegetated dunes. If the damage is by natural cause the repair of the damage is highly expensive. But, if it is damaged by human activities the repairing is feasible. Repairing programme can be undertaken by (1)

identifying the cause of the damage (2)investigating the possibility of removing or controlling the cause of the damage (3) determining the technical requirements (4) working out the time schedule (5) investigating sources of finance and finally (6) ensuring that the maintenance requirements are taken up periodically.

The re-establishment of frontal dunes involves the physical replacement of appropriate sand and stabilizing them by brush matting or by spray of materials. It should be remembered that any dune restoration programme is designed to be eroded during storm with inevitable losses of vegetation, walkways and fences. Further, a good restoration practice is to minimize maintenance commitment by providing vegetation which regenerates naturally and by using flexible or expendable structures which can accept storm attack or be replaced at minimum cost.

In New Zealand Wendelken (1974) observedrecords that before the European settlement in 1840 most of the coastal belt of New Zealand was stabilized by native grasses and shrubs. It was only in 1877 that the first Conservator of Forests drew attention to the possible dangers of shifting sands. It was only in 1903 that the

Government passed legislations to deal with the problem. Now, extensive afforestation programme is taken up after stabilizing the sand with plantation of *Ammophila arenaria* along with *Lupinus arboreus*. Chemical emulsion spray is also tried but it becomes a costly affair. Trees that could grow and form a dense wind break having useful wood are planted.

Besides producing usable wood from sand dune forest, management of coastal sand dune forest for recreational uses is becoming increasingly important.

Bhimaya (1974) presented a review of sand dune stabilization and afforestation in general in the different countries in the FAO\DANIDA Inter Regional Training Centre on heathland and sand dune afforestation in 1973.

In the Peoples' Republic of China, the coastal dunes occur in eastern and southern provinces. They do not create much problem in respect to stabilization and afforestation. Where a littoral vegetation exists planting with salt spray resistant species like *Casuarina equisetifolia* and *Pandanus odoratissima* is carried out directly while unstable dunes are first fixed by means of a seaward belt of sand and plants

like *Spinifex littoreus, Ricinus communis* are planted or sown with tree species. Where the effects of such dunes extend to the interior afforestation with timber species like *Pinus tabulaeformis and P. messoniana* is done after creating 50-100 mts. wide belts of salt resisting trees.

In Israel also the system of building fore dunes is followed. In severe cases two or more such fore dunes are built parallel to each other 50-100 mts. apart. These fore dunes are formed by planting sand accumulating species,fences or by brush barriers. They are formed 1-3 mts. high. The planting process starts from such fore dunes and generally *Ammophyla arenaria* is used. In between the fore dunes drilling of seed mixtures with tractors is done combined with water soluble butimin emulsions. Often wheat and barley are sown in alternate lines which protect the slow growing perennials and contribute some organic matter to the soil.

South Africa has problems of both, the coastal dunes and the inland dunes of the Kalahari. There were times when land resources were over used due to increase in tribal population and of the tribal and wild

animals. These were brought under control and thus not much was needed to be done in the inland dunes.

The usual technique of creating a littoral dune of 100 mts. from the high tide mark is adopted. Once the dune is formed it is planted over with grasses. When sea breeze does not blow freely Pyp-grass may be broadcasted and usually sown with seeds of *Acacia cyclops* and *A.saligna*. Under favourable conditions they will germinate in 2-3 weeks and cover up the whole area within a year. As the dune consolidates marram grass starts dying and trees are usually established. *Eucalyptus gomphocephala, Myoporum insular, Leptospermum laevigatum, Rhus crenata, Myrica cordifolia, Metalasia muricata* are planted. Since the seedlings of most of these plants are susceptible to wind damages usually they are established when marram grass stands to protect them.

In the United States of America sand dunes occupy about as much area as 1\10 of agricultural lands. Coastal dunes occur along the Pacific and Atlantic coasts and along the shores of the Great Lakes. The problem of moving coastal dunes was always faced in many parts of the coastal areas. Generally, the method of

creating artificial dunes across the wind direction is taken up where the problem is acute. Beach grasses like *Ammophila arenaria* form the base plantation and then shrubs like *Cytisus scoparius* and *Pinus contortus* are introduced in planting programmes. Fertilizers are applied where needed. And in order to stabilize the system brush matting or chemical spraying is done. Maun and Krajnyk (1989) have worked on stabilizing of Great Lake sand dunes.

In the erstwhile Union of Soviet Socialist Republics much of the moving sand dune problem seems to have been associated with inland dunes. Here, the moisture and the other conditions being favourable, the problems are brought under control by afforestation.

In Japan about 4% of the cultivated land is occupied by sand dunes. Presently this land is being utilized as advanced agricultural land. The crops cultivated on these lands are Diascoria batata, Allium bakeri, tulip, melons, grapes,tomatoes and cucumbers. Sprincler system of irrigation and drip irrigation are adopted to meet the water requirements of the crops (Iyenger,1977).

In India `The Great' Indian Desert' is expanding at the rate of 0.8 km\year as reported by Gupta (1971). Besides dunes in the desert and those on the banks of the rivers, the coastal sand dunes also pose danger to the country.

Vaishnav (1974) in giving the country statement on India in the report on heathland sand dune afforestation stressed that the sand dunes in the coastal region are exposed to strong winds and suffer shifting and re-shifting shortly after the recession of tidal waters when they become dry. Some of these dunes are as high as 20 mts. The states where the sand dune shifting problem is experienced on a considerable scale are Gujarat, Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. Rajasthan experiences problems of desert sand dunes. Adjoining Gujarat coastal dunes are to certain extent responsible for the growth of these desert dunes.

Along the coastal sand dunes where the rainfall is fairly high and the problem of salt laden winds is not too high nursery raised seedlings of *Casuarina equisetifolia* are planted at a spacing of 2.5 mts. In the areas where the problem of shifting sand excists,

sand immobilization work has been taken up by planting *Ipomoea pes-caprae, Aloe* and *Spinifex littoreus* before planting the tree species. In more refractory localities with looser sand and stronger winds the localities are cordoned off by erection of local grass and twigs in criss-cross fashion. In some places *Eucalyptus* and *Anacardium occidentale* are also planted. In East India especially in West Bengal, *Acacia auriculiformis* grows quite well.

In those localities where the problem of saline wind is experienced , the planting is deferred until late August and seedlings are watered for a season or two depending on the rainfall. In the regions having rainfall upto 700-800 mm. pure *Casuarina* is raised in protected pockets while in the stretches facing the sea, a live buffer of *Prosopis juliflora* is planted before *Casuarina*. In the regions where the rainfall is low, pure Prosopis juliflora is raised, though it is mostly preceded by immobilizing through plantation of *Ipomoea pes- caprae, Aloe* etc. In Tamil Nadu also *Casuarina* plantation is taken up regularly. Das (1974) gave a brief report on the afforestation measures taken up along the coastline of Orissa. Orissa has narrow sandy beach varying in width from 100-200 metres. This strip

is mainly planted with *Casuarina equisetifolia*, mixed with *Eucalyptus* species at some places. *Anacardium occidentale* and *Calophyllum inophyllum* are planted where some silt is present. The shifting dunes are planted with *Ipomoea pes-caprae* and *Spinifex cuttings*. Occasionally,a temporary palisade with palm leaves and live hedges of *Pandanus* are raised before the *Casuarina* plantation which protects the young seedlings from damage by wind blown sand. A strip of 50 mts. width is planted with *Casuarina* at a spacing of 1.5m x 1.5mts. This forms the wind break. The main plantations are raised two years later beyond this wind break, when it is about 3 mts. high. This strip is permanently maintained and is never cut though the main crop is felled at maturity. *Casuarina* has gained great popularity among the locals as it is a good fuel with high caloric value. Besides, improving the aesthetic beauty of the beaches of Orissa, *Casuarina* plantation has saved the famous Black Pagoda temple in Konark from sand burial. In the wake of regular cyclones, a scheme is proposed for raising an uninterrupted wind break of 1 km. width along the coast line. Vacated cultivated fields along the shore are being planted with species of *Eucalyptus, Anacardium, Trewia nudiflora, Barringtonia*

acutangula, Cocos nucifera, Calophyllum inophyllum, and a number of *Termenalia* and *Albezzia* species. Natural regeneration of tidal species is being encouraged.

Vaishnav (1974) suggested a list of indigenous and exotic plants that are suitable for growing on sand dunes in India ,(Tables 23-24).

Goa has a long coastal line with beautiful sandy shores. Nature has provided the shores with a natural defence against the attack of the forces of the sea mainly in the form of beaches. The first defence against the wave attack is the slopy nearshore bottom and the beach itself on which the waves break and dissipate their energy, setting a large quantity of material in motion. The sand dunes act as a second line of defence against the forces of the sea.

Goa being an important tourist spot, it is essential to maintain its beaches for aesthetic and recreational purposes.

In order to protect the shoreline several notifications and recommendations have been brought out from time to time. The Eco-Development Plan for Goa, (1981) in its preliminary report on coastal areas

TABLE 23: A list of early colonizers on sand dune

Shrubs	Grasses
1. *Calotropis procera*	1. *Panicum turgidum*
2. *Crotalaria burhia*	2. *Eleusine flagellifera*
3. *Aerua tomentosa*	3. *Spinifex spp.*
4. *Rhyinchosia minima*	4. *Fragrostis spp.*
5. *Leptadenis spartium*	5. *Saccharum spp.*
6. *Indigofera argentia*	
7. *Zizyphus rotunelifolia*	
8. *Ipomoea pes-caprae*	
9. *Calligonum polygonoides*	

Source : Vaishnav (1974)

TABLE 24 : List of plants (indigenous and exotic) useful for growing on the sand dunes

Indigenous	Exotic
1. *Prosopis spicigera*	1. *Prosopis juliflora*
2. *Delonis alata*	2. *Casuarina equisetifolia*
3. *Tamarix articulata*	3. *Acacia auriculiformis*
4. *Tecoma undulata*	4. *Ecacia tortolis*
5. *Salvadora oleoides*	
6. *Capparis aphylla*	
7. *Acacia jacquemontii*	
8. *Balanites roxburghii*	
9. *Cassia auriculata*	
10. *Anacardium occidentale*	
11. *Acacia senegal*	
12. *Aloe sp.*	

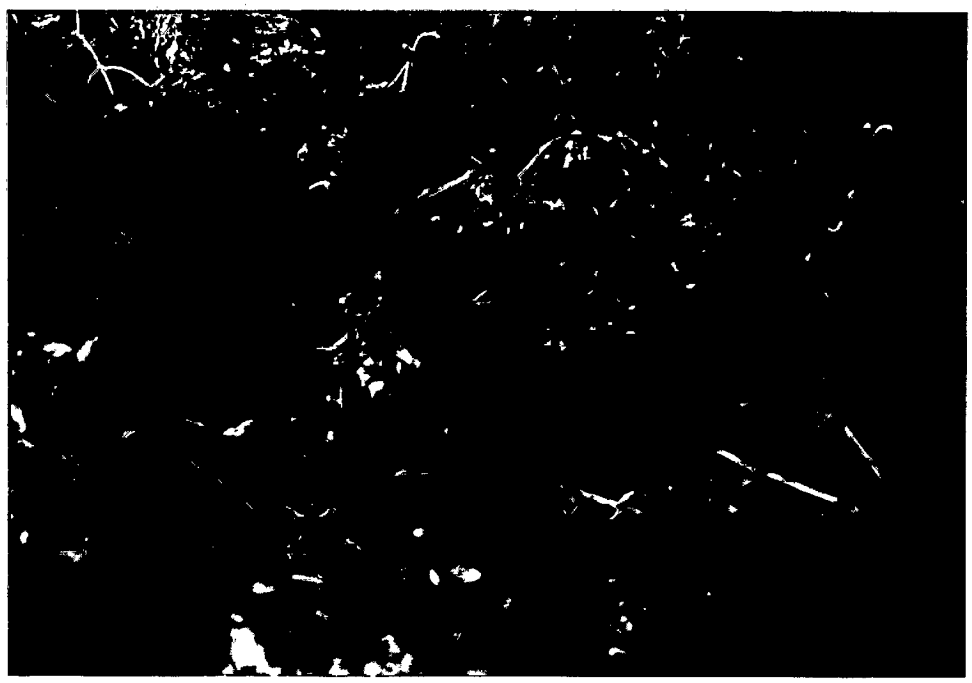
Source : Vaishnav (1974)

PREVENTIVE MEASURES - EXPENSIVE MANAGEMENT

SINKING PROTECTIVE WALL - WRONG MANAGEMENT

PLATE - XII

PREVENTIVE MEASURES - BREAK WALLS



PREVENTIVE MEASURES-LATERITE STONE

SUPPORTED BY NYLON NETTING

PLATE - XIII

suggested that a Preservation Line be marked so that all the development on the seaward side be controlled by established codes and ordinances. Development on the seaward side has to be duly considered after examining the actual purpose of the construction. Further, it has been notified that the sand dune belt immediately along the coastline is the most sensitive zone vulnerable to erosion. In order to protect this ecosystem there should be a ban on unauthorized construction activities and the dune end of the beaches should be stabilized with plantation of suitable trees like *Casuarina* and other shrubs and trees. They will have a binding effect on the sandy soil and will also protect the privacy of the beaches and enhance the scenic beauty.

While planning, designing and executing tourist complexes, ecological aspects of slope, stability, erosion control, vegetational cover and conservation of flora and fauna should be given key importance, so that the likely adverse effect of such construction can be prevented (Plates 12-13).

The notification released on 20\2\91 by Government of India clearly demarcated the Coastal Regulation

Zone(CRZ) on which no construction can be taken up. Text of the notification is given in the Appendix I.

6.4 NURSERIES FOR SAND DUNE VEGETATION

Nurseries are essential components of any large scale restoration or afforestation programme. The technology for this purpose is available freely. Nurseries also funtion as the store for the readymade seedlings which can be transplanted anywhere. Although the nurseries purely for the sand dune vegetations are not common in India, but some species like Casuarina etc. are commonly grown in the nurseries.

For setting up nurseries in the sand dune region, it is necessary to collect different data about the plant, soil, climate of the region. Some information is given below :

The seeds of *Casuarina* are sown in the mother bed. After 2 weeks the germinated seeds are transplanted in the field poly bags with 1:1:1 (cowdung, soil, sand) mixture. When the seedlings are about 30 cms.- 45 cms. long, which is usually after 6-9 months, the plantation

on the barren sand area are taken up. If the seedlings are transplanted from the poly bags at earlier stage they show stunted growth due to heavy wind speed on the shore and also due to the salt sprays which interfere with the physiology of the plant growth.

So far none of the nurseries have taken up plantation of *Spinifex* growing and this study suggest that *Spinifex* plantation can be taken up by cuttings or suckers instead of from seeds, as the germination rate of *Spinifex* seed is very low, (Table 20). Poly bags containing sand from the shore are to be taken and suckers from the plants naturally growing on the sea shore are to be planted. Care should be taken that no water logging takes place in the bags. No special organic or inorganic fertilizers are required. When the plant grows to about two nodes length, it can be transplanted on the fore shore zone (Table 21). Besides, growing in polythene bags cuttings can be also be grown successfully grown directly on sand beds.

6.5 STATUS OF SAND DUNE PLANTATION IN GOA

About 150 ha. of coastal land is planted with *Casuarina equisetifolia*. This plantation has started from 1965 onwards (Table 25). There has been no extensive plantation on this land because the sand dune area do not belong to anybody i.e., it is a `NO MAN'S LAND'. Since there is no authority over the ownership of the land and there exists no co-ordination between the Government Departments, the Forest Department cannot take up mass plantation. The ambiguity of the whole situation is that, though the Forest Department cannot use the land for plantation which is necessary to protect the shore, the Government leases out the same land for sand extraction. Moreover, the adjoining land is often sold out to the multinationals for hotel building, and they in due course of time encroach the `NO MAN'S LAND' and use it for their hotel purpose. The hotel owners are then forced to bow to the whims of tourism, whereby they prefer to have direct view of sea from the hotels rather than to have a thick protective green belt of *Casuarina*. Sometimes, local people also encroach upon the same land. At certain places in

TABLE 25 : Yearwise *Casuarina* plantation along the Goa coast

Year	Area under plantation (in ha)
1986-87	4.5
1987-88	19
1988-89	43
1989-90	-
1990-91	15
1991-92	10
1992-93	1

Source : (Personal communication with Goa Forest Department officials).

Salcette taluka on the request of the owners of these lands coconut plantation has been taken up by the Forest Department. On Kalangut beach barrier system plantation of Casuarina was taken up in three parallel rows. No attempt has been made so far in cashew plantation on Goa coast as is common in Andhra Pradesh and Tamil Nadu (Forest Department, Govt. of Goa)(Plate 14).

6.6 RECOMMENDATIONS

On studying the sand dune ecosystem along the Goa coast the following recommendations have been made to ensure proper conservation and maintenance of the coastal sand dunes and the vegetation thereon.

1) Strict enforcement of legal provisions of the Notification through proper publicity and due punishment if the rules are not rightly followed.
2) Rightful ownership of the sand dune area has to be established.
3) It should be made compulsory and mandatory for the users and owners of land adjoining Coastal Regulation Zone to grow and maintain local species of sand dune plants like *Spinifex* sp. and *Ipomoea*

STABILIZED DUNES WITH PIONEER VEGETATION

STABILIZED DUNES WITH CASUARINA PLANTATION

PLATE - XIV

sp. on the open area between 200 and 500 mts.

4) On the virgin beaches where land has not been sold for hotels\beach resorts, Government should immediately acquire such lands and develop 'DUNE PARKS' with proper live fencing and growing local species of sand dune plants.

5) Regular plantation programmes of sand dune plants like *Spinifex, Ipomoea,Clerodendron, Vitex, Lantana* and trees like *Casuarina, Anacardium* and *Pandanus* should be taken up by Government authorities and NGOs.

5) Importance of sand dune vegetation should be emphasized through various mass media to common man and also should be included in the curriculum of school\college texts.

6) The Forest Department and NGOs should maintain nursery of sand binding plants and make such plants available to those who are desirous of planting the same.

Though the High Tide Line rules are quite strict and will help in preserving the long coastline it is essential to note the following loopholes in them.

In calculating the FSI the area in No Development Zone is now allowed to be taken into account though no construction is allowed in the latter.

This will encourage the optimum possible construction on the area available under development zone, thereby putting pressure on the adjoining sandy coast and harming the dunes and their vegetation in the process.

6.7 CONCLUSION

Thus, with the implementation of above recommendations the coastline of Goa will not only be conserved from the ecological point of view but also from the aesthetic point. The protection of the beaches of Goa will surely enhance the scenic beauty and attract tourists from both home and abroad, thereby increasing the potentialities of tourism as an industry.

APPENDIX 1

The notification released on 20\2\91 by Government of India declares the following:

It has been declared that the coastal stretches which are influenced by tidal action in the land ward side upto 500 metres from the High Tide Line (HTL) and the land between the Low Tide Line(LTL) and HTL be referred to as Coastal Regulation Zone (CRZ). The High Tide Line is defined as the line upto which the highest high tide reaches at spring tide. According to the notification the following activities are declared as prohibited within the Coastal Regulation Zone.

1) Setting up of new industries and expansion of existing industries except directly related to water front or directly needing foreshore facilities.

2) Manufacture or handling or storage or disposal of hazardous substances as specified in the Notification of Government of India.

3) Setting up and expansion of fish processing units

including warehouse (excluding hatchery and natural fish drying) in permitted areas.

4) Setting up and expansion of units \mechanism for disposal of waste and effluents except facilities required for discharging treated effluents into the water course with approval under the Water Preservation and Control of Pollution Act 1974; and except for storm water drains.

5) Discharge of untreated wastes and effluents from industries, cities or towns and other human settlements. Schemes shall be implemented by concerned authorities for phasing out the existing practices if any, within a reasonable time period not exceeding three years from the date of this notification.

6) Dumping of city or town waste for the purpose of land filling or otherwise the existing practices if any, shall be phased out within a reasonable time not exceeding three years from the date of this Notification.

7) Land reclamation, building or disturbing the natural course of sea water with similar

obstruction, except those required for control of coastal erosion and maintenance or clearing of waterways,channels and ports and for prevention of sand bars and also except for tidal regulators, storm water drains and structures for preventions of salinity increase and for sweet water recharge.

8) Mining of sands, rocks and other substrata minerals except those rare materials not available outside the CRZ area.

9) Harvesting or drawl of ground water and construction of mechanism within 200 m. of HTL; in the 200 m to 500m. zone,it shall be permitted only when done manually through ordinary wells for drinking,horticulture, agricultural and fisheries.

10) Construction activities in ecological sensitive areas.

11) Any construction activity between HTL and LTL except facilities for carrying treated effluents and waste water discharge into the sea, facilities for carrying sea water for cooling purposes, oil, gas and similar pipelines.

12) Dressing or altering sand dunes, hills natural features including landscape changes for beautification, recreational and other such purposes.

However, the notification provides that permission from Ministry of Environment and Forest, Government of India is required for the following activities.

1) Construction activities relating to Defence requirements.

2) Operational construction for ports and harbours,light houses requiring water frontage.

3) All other activities exceeding rupees five crores.

4) Thermal power stations.

The coastal states and Union Territory administration had been asked to classify and prepare management plans for the CRZ areas. This Notification has also classified the Coastal Regulation Zone as follows:

For regulating developmental activities the coastal stretches within 500 metres of High Tide Line of the land ward side are classified into four categories.

Category-I or CRZ-I

Areas that are ecological sensitive and are rich in genetic diversity. Area between the Low Tide Line and the High Tide Line .

Category-II-CRZ-II

The areas that have already been developed upto or close to the shoreline.

Category-III- CRZ-III

Areas that are relatively undisturbed and those which do not belong to either category I &II. These include Coastal Zone in the rural area both developed and undeveloped.

Category-IV -CRZ-IV

Coastal stretches in the Andaman & Nicober, Lakshadweep and other smaller islands except those designated as CRZ-I,CRZ-II& CRZ-III.

According to the Notification the Norms for Regulation of Activities are given as below.

The development or construction activities in different categories of CRZ areas shall be regulated by the concerned authorities at the State \ Union Territory level in accordance to the following norms. CRZ-I No new construction shall be permitted within 500 mts. of High Tide Line. No construction activity will be permitted between Low Tide Line and High Tide Line except for carrying treated effluents and waste water discharges into the sea or for carrying sea water for cooling purposes.

CRZ-II(i) Building shall be permitted neither on the sea ward side of the existing road nor on sea ward side of the existing authorized structures. Buildings permitted on the land ward side of the existing authorized structures shall be subject to existing local Town & Country Planning Regulation including the existing norms of FSI\FAR.

(ii) Reconstruction of the authorized buildings to be permitted subject to the existing FSI\ FAR norms.

(iii) The design and construction of building shall be consistent with the surrounding land scape and local architectural style.

CRZ-III- The area upto 200 mts. from HTL is to be earmarked as `No Development Zone'. No construction shall be permitted within this zone except for repairs of existing authorized FSI. This zone may be permitted for the use of agriculture, horticulture gardens, pastures parks, forestry, salt manufacture from sea water.

(ii) Development of vacant plots between 200 and 500 mts. of HTL in designated areas of CRZ-III with prior approval of MEF permitted for construction of hotels\beach resorts for temporary occupation of tourist\visitors.

(iii) Construction and reconstruction of dwelling units between 200 - 500 mts. of the HTL is permitted as long as it is within the traditional uses like fishing villages. The dwelling units shall not cover more than 33% of the total plot size. The overall height of the construction shall not exceed 9 mts. and the construction shall not be more than two floors that is ground + one floor.

The Annexure II of the same Notification have laid down guidelines for development of beach resort\ hotels

in the designated area of CRZ III for temporary occupation of tourist and visitors.

The construction of beach resort\ hotels shall be with prior approval of MEF in the designated area of CRZ III.

(i) The project proponents shall not undertake any construction or fencing within 200 mts. in the landward side from the High Tide Line.

(ii) The total plot size shall not be less than 0.4 hectares and the total covered area on all floors shall not exceed 33 per cent of the plot size. The open area shall be suitably landscaped with appropriate vegetal cover.

(iii) The construction shall be consistent with the surrounding landscape and local architectural style.

(iv) The overall height of the construction shall not exceed 9 mts. or ground + one floor

(v) Ground water shall not be tapped within 200 mts. of the HTL; within 200 mts. and 500 mts.zone it can be tapped only with the concurrence of the Central\ State Ground Water Board.

(vi) Extraction of sand, leveling or digging of sandy stretches except for structural foundation of building, swimming pool shall not be permitted within 500 mts. of the High Tide Line.

(vii) The quality of treated effluents, solid wastes emissions and noise level etc. from the project must conform to the standards laid down by the competent authorities.

(viii) Necessary arrangements are to be made for the disposal of the effluents and solid wastes, such that no waste is discharged on the beach.

(ix) At least a gap of 20 mts. shall be provided between any two hotels\beach resorts to allow public to reach the beach. Such gaps shall not be less than 500 mts. apart.

(x) If forest land has to be converted for non - forest purposes clearances should be sought under the Forest (conservation) Act 1980.

(xi) Approval of State\Union Territory Tourism Department shall be sought.

(xii) In ecologically sensitive areas construction of beach resort\ hotels shall not be permitted.

This Notification is further amended and following changes\addition have been made by the same.

The High Tide Line is defined as the line on the land upto which the highest water line reaches during the spring and shall be demarcated uniformly in all parts of the country by the demarcating authority.

No construction can be taken up within 200 mts. in the land ward side from the High Tide Line and within the area between the Low Tide and High Tide Lines unless the Central Government permits taking into account geographical feature and overall coastal Zone Plans.

Further, the notification is amended by a draft amendment dated 11.11.93 following and following are the recommendation;

1a) Live fencing and barbed wire fencing with vegetative cover be allowed around private properties but this should in no way hamper public access to the beach.

1b) No flattening of sand dunes shall be carried out.

1c) No permanent structures for sports facilities shall

be permittted except construction of goal posts and lamp posts.

1d) Construction of basement may be allowed, subject to the condition that `No Objection' is obtained from State Ground Water Authority to the effect that such constriction will not adversely affect free flow of ground water in that area. State Ground Water Authority has to take into consideration the guidelines issued by Central Government before granting such `No objection' certificates.

1e) The Floor Space Index shall be calculated on the basis of the area of the entire plot.

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