

Strand plant communities of the Indian sub-continent

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Abstract. Strand plant-communities, other than the mangroves, composed of psammophytes, halophytes have been described along with bioclimatic, edaphic factors for the seven coastal biogeographic sub-divisions of the sub-continent.

Keywords. Strand plant communities; psammophytes; halophytes; bioclimatic factors; edaphic factors.

1. Introduction

Coastal landscapes of the Indian sub-continent comprises of an array of ecosystems.

The wet coastal ecosystem or the mangrove swamps and the dry coastal ecosystems or strand or beaches are recognised on sight based combined physiognomic and topographic criteria. That these studies are not only of great theoretical but also of practical interest has been recently shown by detailed reviews (Rao 1971; Rao and Sastry 1972, 1974 a, b; Blasco 1975, 1977).

Since the mangals or mangroves have already been studied (Chapman 1977), we will review in this article the strand or beach plant-communities (other than the mangals) composed of psammophytes, facultative halophytes or salt tolerant glycophytes and also mention briefly the potential terrestrial vegetation in the immediate vicinity of the strand.

At the very outset it may be mentioned that the environmental terms 'dry' and 'wet' as applied to the coastal ecosystems appear rather conflicting. Mangrove which in a strict sense of the term cannot be treated as a 'wet' ecosystem because of the physiological dryness of the habitat, however, has been included in the volume on Wet Coastal Ecosystems.

Dry and wet categories are distinguished on the basis of the general climatic features like annual average rainfall and length of the dry season. Thus on one hand lie very dry stations like Pasni, Karachi, Bhuj, Dwarka in the northern extremity of the west coast with rainfall less than 500 mm and dryness for 10 to 11 months of the year. In the southern part of the west coast, Kozhikode (Calicut) and Trivandrum represent very wet conditions with very high rainfall (exceeding 3000 mm) and with only 3-4 months of dryness.

However, such a climatic division is rendered ineffective in view of the overwhelming edaphic influence of sandy and salty milieux in the immediate vicinity of the sea, imparting floristic and physiognomic homogeneity to the plant communities of the maritime strand. It is true that the plant formations beyond the confines of the maritime influence show close relationship with the macro-climatic features.

The maritime strand is that strip of coast extending from just above mean high water to the end of the sandy relief. This area is characterised by a maritime climate, high exposure to salt spray and shifting sand dunes. They are lithologically different and can be categorised under calcareous and non-calcareous zones with significant plant indicators. Rao and Sastry (1972) have attempted an improvement on the informal strand ecosystem classifications of the past workers. They have recognised three major types, namely strand sand, strand rock and strand coral based on combined physiognomic and topographic criteria. Further, these have been subdivided on the basis of zonation, dominant species and substrate features. This has revealed apparent zonation in some sectors and disturbed mosaics in others specially at the woodland stage mostly due to anthropogenic influences such as agricultural practices (paddy cultivation), raising of plantations of *Casuarina*, coconut and cashewnut in climatically humid zones.

2. Biogeographic sub-divisions

The coastline of the Indian sub-continent which extends for more than 6000 km may be divided into the following sub-divisions according to the climatic and general floristic features. Geologically, the entire coastline may be broadly placed under recent alluvium.

(i) *Coastal tract of Pakistan, Kutch and north-western part of Kathiawar forming eastern extremity of the Saharo-Sindian region of Eig (1931)*. The climate as exemplified by the stations Karachi and Bhuj (figure 1) is arid with annual average rainfall of less than 500 mm and 9 to 11 months of dryness as per definition of Bagnouls and Gaussen (1953).

Natural vegetation in the sub-coastal plains is a thicket of *Prosopis cineraria* (L.) McBride-*Salvadora oleoides* Decne. type. The thicket aspect is given particularly by the bushes of *Euphorbia caducifolia* Haines which is the main species in the degraded areas where the soil is shallow and there are outcrops of rocks. It withstands the effect of salty winds.

(ii) *South-eastern Kathiawar and Gujarat north of the river Narmada may be included in the eastern half of the Sudano-Rajasthanian region of Meher-Homji (1965)*. The climate of this tract is semi-arid with rainfall of 500–600 mm and dryness of 8 months. Ombrothermic diagram of the station Veraval in figure 1 illustrates this type of climate.

Thickets of *Acacia* spp. and *Capparis decidua* (Forsk.) Pax are encountered in the areas beyond the strand. The branching palm, *Hyphaene dichotoma* (White.) Furtado is dominant in the Delvada-Kodinar sector.

(iii) *Konkan coastal strip extending from southern Gujarat up to Goa*.

Climate varies from dry (e.g. Surat) to subhumid (Bombay) to humid type (Ratnagiri, figure 1).

The dry or moist deciduous forests with teak (*Tectona grandis* L.f.) form the potential natural vegetation beyond the maritime influence.

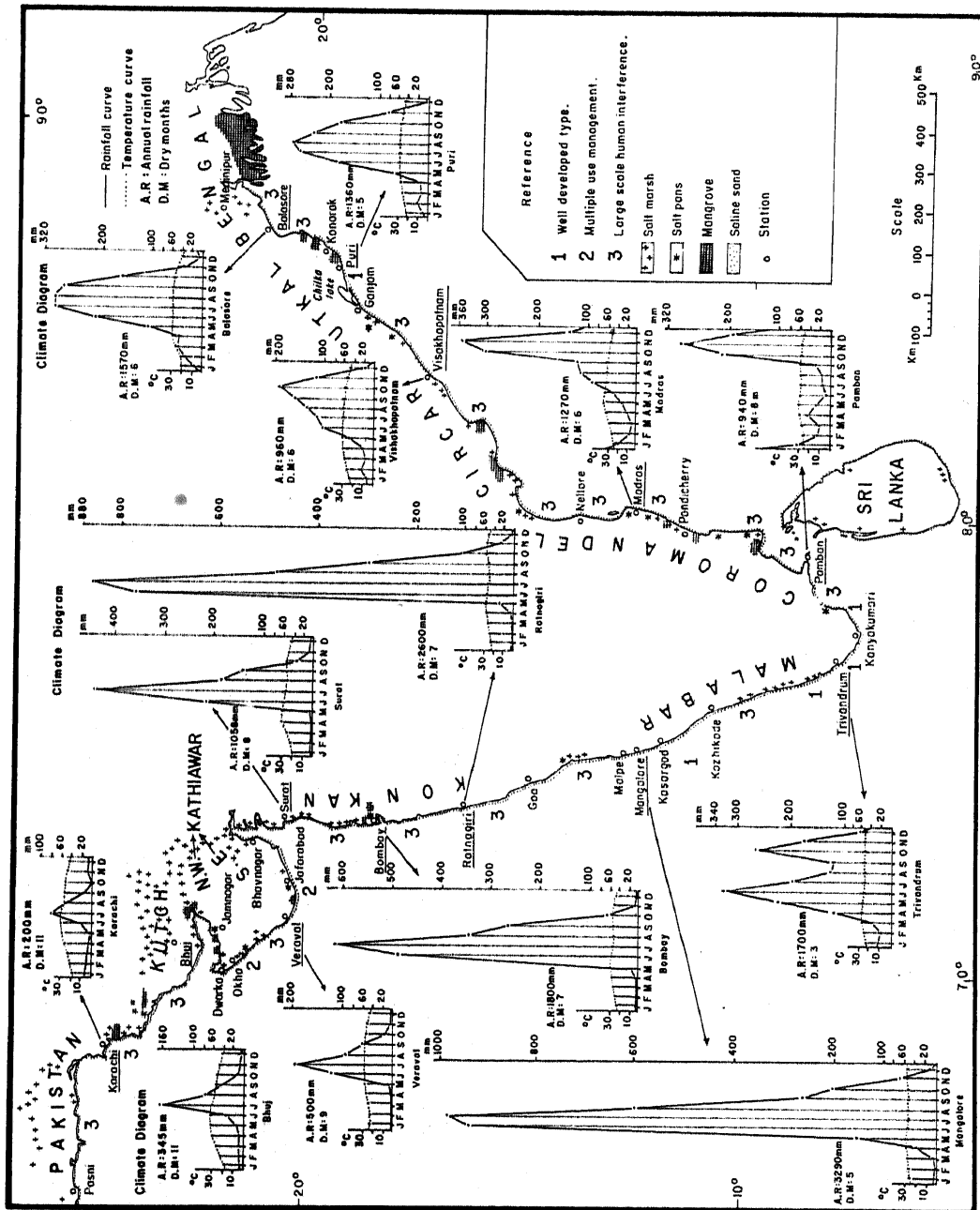


Figure 1. Coastal formations.

(iv) *Malabar region extending from Goa southwards up to Kanyakumari (Cape Comorin)*. The climate is humid (Mangalore) to perhumid (Kozhikode and Trivandrum, figure 1).

The areas beyond the limit of the coastal sands have the potentiality to bear evergreen forests but through human interference the original forests are much degraded in the coastal tract and much of the area is brought under cultivation.

(v) *Coromandel-Circar coastal plains of Tamil Nadu and Andhra Pradesh of the South-eastern part of India*, characterised by tropical dissymmetric regime of rains. South-west monsoon brings only light rains during June–September; heavy rains occur in October–November due to the depressions formed in the Bay of Bengal. Climate is dry (Pamban) to subhumid (Madras and Visakhapatnam, figure 1).

Potential vegetation of this tract is peculiar: dry evergreen forest (Champion 1936; Meher-Homji 1973, 1974; Blasco and Legris 1973; Sprangers and Balasubramanian, 1978; Werger and Sprangers 1982).

(vi) *The islands between India and Sri Lanka* though climatically similar to the Coromandel coast differ from the mainland in having coral sand and distinct vegetation (Rao *et al* 1963a, b).

(vii) *Utkal and Bengal coastal plains* The Utkal coast is the northern prolongation of the Circar region in Orissa state. It is formed of the Mahanadi delta and the coastal plains of Bhadrak, Balasore and Kunthi. The Chilka lake of Puri district which though only a few metres deep varies in size from 900–1200 km² and is alternately salty and fresh. The Medinipur coast marks the extension of the Utkal coast into Bengal.

The climate as exemplified by the stations of Puri and Balasore (figure 1) is humid.

The potential vegetation of the interior areas is typified by deciduous sal (*Shorea robusta* Gaertn.) forests. Along the sandy fringes, *Borassus flabellifer* L. and *Phoenix sylvestris* Roxb. are commonly met with.

Figure 1 shows the coastal habitats of the sub-continent. The strand sand type is dispersed on the sandy relief beyond the mean high tide limit. Zonation of the vegetation into an outer pioneer zone, a closed herbaceous zone, middle mixed or bushy zone and inner woodland zone can be made out (Rao and Sastry 1972).

The outer pioneer zone is characterised by the community of *Ipomoea pes-caprae* (L.) R. Br., *Spinifex littoreus* (Burm.f.) Merr., *Cyperus arenarius* Retz., *Canavalia maritima* (Aubl.) Thw. and *Launaea sarmentosa* (Willd.) Alston throughout the sub-continent.

3. Pakistan, Kutch, North-western Kathiawar

The coastal area may be divided into three sub-divisions: shore, coastal and sub-coastal plain (Rao and Aggarwal 1964).

(a) *Sandy strand flora*: The pioneer plant is *Ipomoea pes-caprae*, a strand creeper. Closely following it on the back shore in order of relative abundance are *Cyperus arenarius*, *Launaea sarmentosa*, *Borreria articularis* (L.f.) F. N. Will, and *Boerhavia diffusa* L. (figure 2).

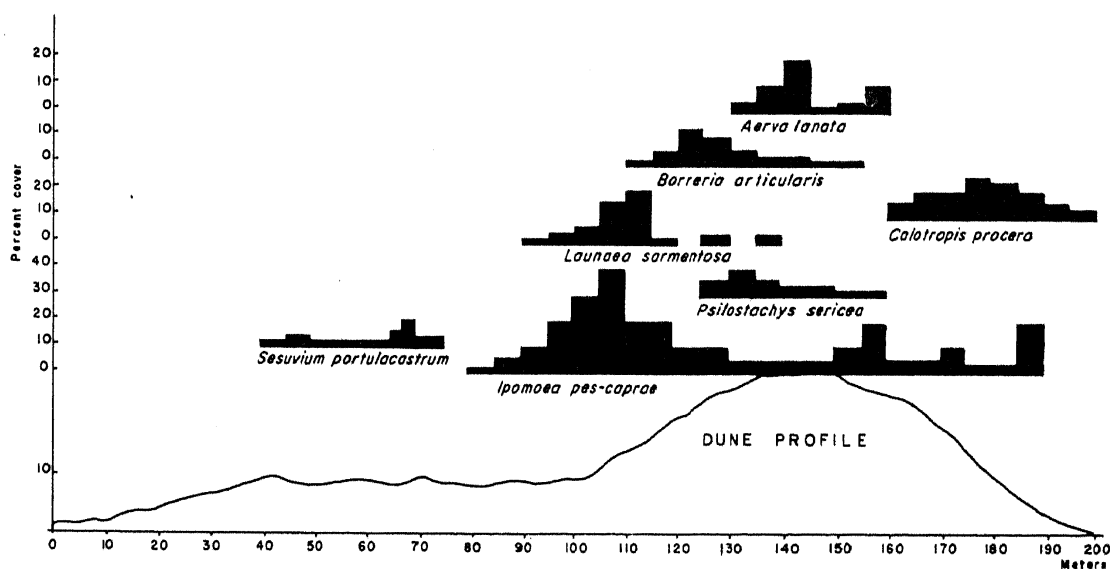


Figure 2. Percentage cover and zonal pattern of the strand/dune plants in a belt transect over a coastal strip, Kathiawar.

Near Dwarka and Okha, *Asparagus dumosus* Baker is a localised strand species.

Around Gharo village in the Indus delta (Pakistan), the sand and sand-dunes are covered with *Convolvulus scindicus* Stocks, *Leptadenia pyrotechnica* (Forsk.) Decne., *Launaea resedifolia* (L.) O. Ktze., *Aerva persica* (Burm.f.) Merrill and *Asparagus gharoensis* Blatter besides *Ipomoea pes-caprae*, *Launaea sarmentosa* and *Cyperus arenarius* (Blatter *et al* 1929).

Soils are sandy to sandy loamy in texture, moderately alkaline (pH 8–8.4), low in organic matter which ranges from 0.25–0.64%. Calcium carbonate ranges from 13–92%. Sodium chloride from 0.01–0.19% (Rao and Shanware 1967).

(b) The *rocky shore* is described under the second region of Southern Kathiawar-Gujarat north of the Narmada.

(c) *Muddy shore*: This includes shallow depressed areas periodically flooded by tidal waters. Such areas develop mangroves with *Avicennia marina* Vierh. var. *acutissima* Stapf & Moldenke. A little further inland appear *Salt marshes* with *Aeluropus lagopoides* (L.) Trin. ex Thw., *Atriplex stocksii* Boiss., *Salicornia brachiata* Roxb., *Suaeda fruticosa* Forsk., *Urochondra setulosa* (Trin.) Hubbard and *Sesuvium portulacastrum* L.

Fringing this zone along moist, less saline soils are *Fimbristylis cymosa* R. Br., *Scirpus maritimus* L. and *Tamarix troupii* Hole.

The Ranns of Kutch

A large area of Kutch, mostly the northern and western parts, is saline marshy; this is the Great Rann of Kutch. The Little Rann lies in the south-east. These are vast expanses of mud flats flooded by the sea during the monsoon.

They do not support any vegetation. However, some halophytic grasses are found at their margins: *Aeluropus lagopoides* (L.) Trin. ex Thw., *Sporobolus helvolus* (Trin.) Th.

Dur. et Schinz, *S. marginatus* Hochst., *S. coromandelianus* (Retz.) Kunth, *S. maderaspatanus* Bor, *Urochondra setulosa*, *Cynodon dactylon* (L.) Pers., *Crypsis schoenoides* (L.) Lamk., *Eriochloa procera* (Retz.) Hubb., *Eragrostis ciliaris* (L.) R. Br., *Cenchrus ciliaris* L., *Dactyloctenium aegyptium* (L.) P. Beauv. and *Chloris virgata* Sw.

In the saline areas bordering the Ranns, plantations of *Prosopis juliflora* DC. have been raised.

Salt pans

Some of the saline marshes are transformed into salt pans. The common circum salt-pan plants are *Aeluropus lagopoides* (L.) Trin. ex Thw., *Clerodendrum multiflorum* (Burm.f.) O. Ktze., *Cressa cretica* L., *Sporobolus virginicus* (L.) Kunth, *Suaeda nudiflora* Moq. and *Tylophora indica* L.

4. Southern Kathiawar-Gujarat north of the Narmada river

Sandy beaches and sand-dunes are covered with *Ipomoea pes-caprae*, (L.) R. Br., *Launaea sarmentosa* (Willd.) Alston, *Evolvulus alsinoides* L., *Convolvulus arvensis* L., *Boerhavia diffusa* L. Thus the sandy strand flora is more or less similar to the one described for the preceding region though the presence of *Hydrophylax maritima* L. f. a pioneer strand plant, *Halopyrum mucronatum* (L.) Stapf and *Psilostachys sericea* (Koen. ex Roxb.) Hook.f. is worthy of notice.

Spinifex littoreus and *Cyperus pedunculatus* (R. Br.) Kern which disappear in this territory reappear in Southern Gujarat.

Rocky shore

The foreshore is free from sand but it is composed of a lime-stone reef of considerable width. The pot holes and crannies developed in the rocks are filled up with sand and bear *Atriplex stocksii* Boiss., *Fagonia cretica* L., *Polycarpea spicata* Wt. and Arn. and *Limonium stocksii* (Boiss.) O. Ktze. on the slopes. More species are added towards the summit of the rocks: *Helichrysum cutchicum* (Cl.) Rolla et Desh., *Enicostema hyssopifolium* (Willd.) Verd., *Kickxia ramosissima* (Willd.) Janchen, *Lindenbergia urticaefolia* Lehm., *Portulaca quadrifida* L., *Pulicaria angustifolium* DC., *Sporobolus diander* (Retz.) Beauv., among others.

Further inland is encountered rocky sandy strand with mingling of coastal and inland plants like *Aerva lanata* (L.) Juss., *Capparis cartilaginea* Deone., *Tephrosia purpurea* (L.) Pers.

Soils are sandy to loamy sand and at times sandy clay with pH ranging from 7.8–8.1. Organic matter is low: 0.43–0.72%. Sodium chloride varies from 0.007–0.086% and calcium carbonate from 23–69%.

The branched palm *Hyphaene dichotoma* is encountered on the sandy coast near Diu, Delvadá and Kodinar sectors. Further southwards it occurs at Daman and Bombay. Thus the endemic occurrence of the species in the erstwhile Portugese territories is a feature worth noting. It may also be mentioned that *H. dichotoma* has close affinities with *H. thebaica* Mart. of Africa (Rao and Korlahalli 1969; Rolla 1963).

The presence of *Acacia planifrons* Wt. and Arn. in the vicinity of Porbandar is worth noting. It is also found after a long discontinuity in the semi-arid coastal areas of South

India, near Tuticorin and Pamban in Ramanathapuram, Tirunelveli districts. Morphologically, the species is closely allied to some African members of the genus *Acacia*, notably *A. tortilis* Hayne of north-east Africa and Aden.

The fact that there was an important trade in horses between Arabia, Africa and the Indian ports Porbandar and Tuticorin in the past may suggest that *A. planifrons* has been an accidental introduction in India, where over centuries it has emerged as a species only slightly distinct from the African members of the genus (Viart 1963; Meher-Homji 1970).

5. Konkan

The Konkan coast extends from South of the river Narmada to Goa. This coast is more or less cliffy. The northern part under riverine and tidal influence becomes muddy, otherwise the coast has jutting headlands and covered with a thick mantle of sand.

South of Daman there are marshy areas fringed with mangroves; raised grounds with less salinity bear saline pastures composed of *Aeluropus lagopoides*, *Fimbristylis junciformis* Vahl, *Paspalum vaginatum* Swartz. and *Sporobolus virginicus* (L.) Kunth.

Newly recorded occurrence is that of *Psilostachys sericea* on sands near Bombay. Near Marmagoa *Cyperus pedunculatus*, *Zoysia matrella*, and *Perotis indica* at Daman are the other interesting plants. *Calophyllum inophyllum* L. is absent along the Gujarat coast.

Satyanarayan (1958) has recognised the following seven strand associations along the Bombay coastline.

(i) *Ipomoetum pes-caprae*: *Ipomoea pes-caprae* forms the pioneer zone on sandy beaches and is the dominant plant of this association. Associated species are *Alysicarpus vaginalis* DC. and *Portulaca oleracea* Linn.

Behind the pioneer zone lies the mature community of *I. pes-caprae*. Among the companion species occur *Corchorus aestuans* Linn., *Tridax procumbens* Linn., *Phyllanthus fruternus* Web., *Borreria stricta* Schum., *Launaea sarmentosa*, *Boerhavia diffusa* Linn., *Indigofera cordifolia* Heyne, *Crotalaria retusa* Linn., *Dactyloctenium indicum* Boiss., *Leucas aspera* Spreng., *Opuntia elatior* Mill. *Urginea indica* Kunth is also recorded (Shah 1962). During monsoon *Chlorophytum tuberosum* Baker is a common plant on the sand.

Organic matter which is 0.05 % in pioneer zone increases to 0.16 % in the mature zone whereas the total soluble salts decrease from 2.32 % in the first zone to 1.24 % in the second.

Canavalia lineata DC., *C. ensiformis* DC. and *Sporobolus glaucifolius* Hochst. are other sea-shore plants. *Scaevola taccada* (Gaertn.) Roxb. has disappeared from Juhu beach but *Psilostachya sericea* is a new record for Bombay (Rao 1971).

(ii) *Spinificetum*: This association is restricted mostly to the island of Manori. It represents a stage higher than the pioneer *Ipomoea pes-caprae*. *Spinifex littoreus* is considered the characteristic exclusive species and *I. pes-caprae* the preferential species.

Among the companion species may be cited *Boerhavia diffusa* Linn., *Borreria stricta* Schum., *Cyperus rotundus* Linn., *Eragrostis ciliaris* Link., *Pedaliium murex* Linn., *Launaea sarmentosa* and *Canavalia lineata* DC.

Soils are coarse sandy in texture, low in moisture (0.57–0.76%) and organic matter (0.26–0.50%). Soil reaction is alkaline (pH 7.9–8.1) but compared to the preceding association total soluble salts are much less (0.08–0.14%).

Further inland this association is replaced by a shrub zone of *Pandanus tectorius* Soland.

(iii) *Pedaliatum muricae*: This association is confined to the island of Arnala. The dominant plant is *Pedaliium murex* Linn. which is also the characteristic exclusive species. *Perotis indica*, a typical sand strand grass, is considered as the characteristic preferential species. Companion species are *Borreria stricta*, *B. hispida* Schum., *Paspalum vaginatum* Sw., *Eragrostis ciliaris*, *Lindernia ciliata* Pennell and *Corchorus aestuans* Linn.

Higher moisture content, less alkaline reaction (pH 7–7.6), somewhat higher amounts of organic matter and predominantly fine sandy texture with higher amounts of clay distinguish the soils of this association from those of *Spinificetum*.

(iv) *Tephrosietum purpureae*: This herbaceous association marks a transition to the inland vegetation. The dominant species is *Tephrosia purpurea* Pers. The characteristic exclusive species is only one viz. *Eragrostis tremula* Hochst. Preferential species are *Alysicarpus vaginalis* var. *nummularifolius* Baker and *Sida veronicaefolia* Lam. The affinity with other psammophytic communities is indicated by species like *Perotis indica*, *Alysicarpus rugosus* DC., *Euphorbia hypericifolia* var. *parviflora* Hook., *Pedaliium murex* Linn., *Leucas aspera* Spr., *Rungia parviflora* var. *pectinata* and others.

Compared to the preceding association, the soils of *Tephrosietum* show an increase in silt, clay, moisture and organic matter and a somewhat lesser pH (6.5–6.8). Percentage of total soluble salts remains the same but change in soil texture leads to increased cation exchange capacity.

Further inland is a shrub zone dominated either by *Alangium salvifolium* (L. f.) Wang. or *Calycopteris floribunda* Lam.

Cyperetum rotundi, *Sesuvietum portulacastri* and *Aeluropetum repensi* are salt marsh communities.

(v) *Cyperus rotundus*: association sometimes forms the first zone behind the mangroves. It also occurs in rocky crevices where there is accumulation of soil particles. The characteristic preferential species are *Sporobolus glaucifolius* Hochst., *Fimbristylis polythricoides* Vahl and *F. ferruginea* Vahl.

Among companion species may be mentioned *Leucas aspera* Spreng., *Launaea sarmentosa*, *Paspalum vaginatum* Sw., *Rungia parviflora* var. *pectinata*, *Lindernia ciliata* Pennell, *Aerva lanata* Juss.

Soils are sandy, strongly alkaline (pH 8.1–8.6) but poor in moisture and organic matter. Soluble salt content is not too high (0.10–0.23%); where sea water bathes the vegetation at least 8 times a month, *Cyperus rotundus* makes room for *Fimbristylis ferruginea*.

(vi) *Sesuvietum portulacastri*: This community is as typical of tidal mud flats as *Ipomoea* is of sandy shores. It marks the beginning of the tidal zone. The dominant and characteristic species is *Sesuvium portulacastrum* Linn. Associated species are

Sporobolus virginicus Kunth., *S. glaucifolius* Hochst., *Paspalum vaginatum*, *Cressa cretica* Linn., *Vitis trifolia* Linn.

Silty loam in texture and strongly alkaline (pH 8.5–8.8), the soils are very rich in soluble salts (3.1–3.4%) which explains the paucity of the species.

(vii) *Aeluropetum*: This 'salt meadow' community comes up either in areas from where the mangroves dominated by *Avicennia* are cut down or in the mud flats as a pioneer or yet on "bunds" along the salt pans.

The dominant and exclusive species is *Aeluropus lagopoides* while the preferential species are: *Sesuvium portulacastrum*, *Sporobolus glaucifolius*, *S. virginicus*, *Suaeda maritima* Dum., *Suaeda nudiflora* Moq., *S. fruticosa* Forsk., *Clerodendrum inerme* Gaertn., *Paspalum vaginatum*, *Fimbristylis polythricoides*.

The association occurs both in places subject to tidal influence and those above the influence of tides.

With reference to the soils of the preceding *Sesuvium* community, the soils of *Aeluropetum* are less saline with total soluble salts ranging from 2.2–2.5%, mildly alkaline (pH 7.6–7.8), silty in texture and contain higher amounts of organic matter and moisture.

Succession

Ipomoea pes-caprae forms the pioneer stage of succession. This stage is succeeded by *Spinifictum* which in turn is replaced either by shrubby *Pandanus tectorius* or by *Pedaliium murex* if moisture and organic matter are higher and pH lesser. The next higher successional stage is that of *Tephrosietum purpurae* leading to the shrubby zone of *Alangium salvifolium* or *Calycopteris floribunda*.

6. Malabar region

Two examples may be given from this region: (i) Along the Malpe coast in the Udipi taluk of South Kanara district, Karnataka State, the pioneer zone of *sandy strand* is occupied by *Ipomoea pes-caprae* and *Cyperus pedunculatus*, which are found growing in pure or mixed stands with a sparse growth of *Oldenlandia herbacea* and *Launaea sarmentosa* (Arora and Aggarwal 1965) (figure 3).

Coarse sands from the pioneer zone are moderately alkaline. The organic matter content is very low. Dissolved solids and sodium chloride content range between 0.130–0.145% and 0.076–0.087% respectively.

Beyond the outer exposed beaches where the sand slope decreases to provide a stretch of fairly level ground, *Ipomoea spinifex* association dominates with *Crotalaria nana* Burm., *Polycarpaea corymbosa* (L.) Lamk., *Borreria hispida*, *Fimbristylis barbata* (Rottb.) Benth. and *Acrocephalus indicus* (Burm.) O. Ktze.

The main strand zone is occasionally interrupted by *Scaevola taccada* (Gaertn.) Roxb., *Pandanus tectorius*, *Clerodendrum inerme* Gaertn. and *Derris trifoliata* Lour.

Soils from the main strand zone are loamy to sandy with moderate alkalinity. Their organic matter content is higher but dissolved solids and sodium chloride contents are lower than the soils of the pioneer zone.

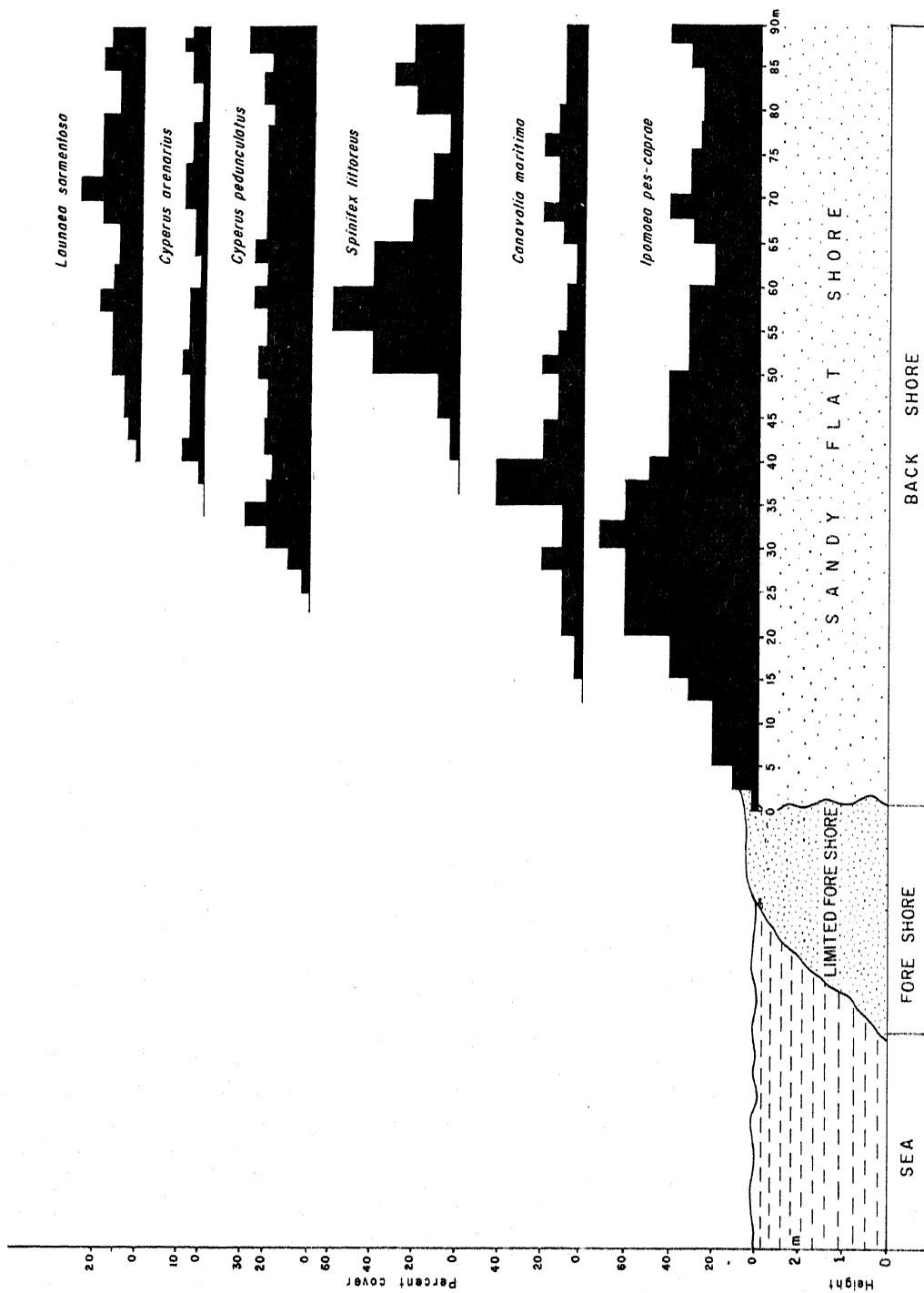


Figure 3. Percentage cover and zonal pattern in pioneer zone of Malabar coast.

Muddy shore under backwaters

Acanthus ilicifolius L. is the most common species covering muddy banks followed by thickets of *Clerodendrum inerme*, *Derris trifoliata* which in turn are followed by the mangroves.

Soils are loamy sand to sandy with mild alkalinity. Organic matter content, dissolved salts and sodium chloride are higher than in the preceding soils.

The transition from the herbaceous *Ipomoea pes-caprae* community to the littoral woodland or *Barringtonia speciosa* formation is not developed along the Malpe coast as the trees are cut down for growing coconut plantations. The belt of woody species may be split into two zones: one composed of *Scaevola taccada* and *Pandanus tectorius* generally growing on the seaward fringe and the other composed of tall species like *Barringtonia asiatica* (L.) Kurz, *Calophyllum inophyllum*, *Terminalia catappa* L., *Morinda citrifolia* L., *Hibiscus tiliaceus* L. (Arora and Aggarwal 1965).

Noteworthy strand plants of Karnataka part of Malabar region according to Rao (1971) are *Anotis carnosa*, *Crotalaria nana*, *Cyperus pedunculatus*, *Euphorbia atoto* Forst., *Indigofera aspalathoides* Vahl, *I. uniflora* Ham., *Ipomoea macrantha* Roem. & Schult. *Scaevola plumieri* occurs near Surthakal.

(i) The sandy vegetation of Veli (Trivandrum) is described by Thomas (1962).

Ipomoea pes-caprae and *I. repens* occur in great abundance along with *Launaea sarmentosa*, *Euphorbia rosea*, *Aerva lanata*, *Heliotropium scabrum* and *Zoysia matrella*.

Further inwards towards the land appears the community of *Catharanthus roseus* forming thick patches. Other common herbs on the sand are *Evolvulus alsinoides* L., *Rhynchelytrum repens* (Willd.) Hubb., *Cyanotis axillaris* R. & S., *Commelina nudiflora* L., *Polycarpha corymbosa* (L.) Lamk.

The Kerala part of the Malabar region is treated in detail by Rao (1978). The interesting plants of the area are *Lumnitzera racemosa* Willd. near Quilon, *Premna serratifolia* L. and a salt tolerant fern *Acrostichum aureum*.

7. Coromandel-Circar region

A phytosociological study carried out in the Pondicherry region showed that the coastal belt is characterised by the alliance of *Catharanthus roseus* (L.) G. Don (Marlange and Meher-Homji 1965). Under this alliance are grouped three associations.

(i) *Spinifex littoreus* association develops on the sea shore and on the new dunes.

This association has three characteristic species: *S. littoreus*, *Cyperus arenarius* and *Polycarpon loeflingae* Bth. & MK. f. The former is gregarious and dominates the association. *Catharanthus roseus* is the species of alliance common to all the associations of the coastal zone. Once a common species, it has been heavily exploited since 1971 for its use as a medicinal plant and is presently rare on the coastal sands.

Launaea sarmentosa (Willd.) Alston is the *species of alliance* between the communities of saline soil and those of sandy littoral.

The following species seem to be indicators of sandy texture; they are common to the communities of the littoral sands and of the ferrallitic sandy loam: *Canscora diffusa* R. Br., *Allmania nodiflora* R. Br. var. *procumbens* Hk. f., *Waltheria indica* L., *Perotis indica* O. Ktz., *Tephrosia purpurea* Pers., *Mollugo disticha* Ser., *Gisekia pharnaceoides* L.,

Bulbostylis barbata (Rottb.) Clarke, *Polycarpha corymbosa*, *Leucas suffruticosa* Benth.

(ii) On the older consolidated dunes, the association of *Spinifex* gives place to that of *Tephrosia purpurea* Pers. *Spinifex* and *Cyperus arenarius* disappear. *T. purpurea* becomes abundant and the general floristic composition remains the same as for the preceding association.

(iii) The association of *Catharanthus roseus* marks a more highly evolved stage of succession on the stabilised dunes. *Turnera ulmifolia* L. makes its appearance as a characteristic species of the association. Some more species of liaison of sandy littoral soils-ferrallitic sandy loam creep in: *Cleome aspera* Koen. ex DC., *Merremia tridentata* (L.) Hall. f., *Zornia gibbosa* Span., *Desmodium rottleri* Baker and *Evolvulus alsinoides* L.

Among the species of wider ecological amplitude which occur as companion species in this association, mention may be made of *Alysicarpus vaginalis* DC., *Euphorbia rosea* Retz., *Justicia prostrata* Gamb., and *Jatropha gossypifolia* L.

Saline soils: The association of *Suaeda nudiflora* occurs in the saline marshy zones in the Pondicherry region. The two exclusive species are *Suaeda nudiflora* Moq. and *S. monoica* Forsk. Among other characteristic species of this halophytic community mention may be made of *Cressa cretica* L., *Aeluropus lagopoides* and *Heliotropium curassavicum* L.

Launaea sarmentosa (Willd.) Alston and *Geniosporum tenuiflorum* (L.) Merr. are the two species common to the communities of saline marshes and coastal sands.

From Kanyakumari region, Nayar (1959) reports the following communities on the foreshore sand:

(a) *Spinifex littoreus*—*Cyperus arenarius* community, (b) *Ipomoea pes-caprae*—*Tephrosia purpurea* community, (c) *Calotropis*—*Cyperus* community.

Rao *et al* (1974) and Sebastine and Ellis (1967) have also listed the species from the Kanyakumari and the point Calimere coastal regions. The occurrence of *Myriostachys wightiana* HK. f. in the sandy saline flats around Point Calimere marks the Southern most limit of the species along the Indian coast (Rao 1971).

The Circar part of the Andhra Pradesh sandy coast is described by Sastry and Rao (1973).

8. The vegetation of the islands between India and Sri Lanka

This has been treated by Rao *et al* (1963a, b), Stoddart and Fosberg (1972), Sundararaj and Nagarajan (1964) and Srinivasan (1960).

The island areas are characterised by strand coral habitats. The coral strand is made up of weathered coral reef, foraminiferal sand and shell deposits. The vegetation of the pioneer zone is composed of *Pemphis acidula* Forst., *Suriana maritima* L., *Cordia subcordata* Lamk. and *Avicennia officinalis* L. The raised coral ridges support *Dodonaea viscosa* Jacq., *Halopyrum mucronatum* Stapf, *Excoecaria agallocha* L., *Thespesia populnea* Corr., *Lumnitzera racemosa* Willd. and *Scaevola* spp.

Newly recorded occurrence is of *Messerschmidia argentea* (L.f.) Johnst. on the back shore of Krusadi island.

Soils are coral sand with pH of 7.2–8.2, organic matter varies from 0.50–2.72%; calcium carbonate from 50–80% and total soluble salts from 0.17–1.25% (Rao *et al* 1963b).

Sri Lanka

The sands occupy a large extent along the low lying coast of the dry zone from where they may be blown to the interior as in the Mannar Peninsula.

Beyond the limit reached by the waves, on recently deposited unstable sands is encountered low creeping vegetation formed of *Ipomoea pes-caprae*, *Canavalia rosea* DC., *Spinifex littoreus* which one also finds on the dunes nearest to the coast as also *Scaevola plumieri*. The common companion species are *Hydrophylax maritima* L. f., *Synostemon bacciforme* (L.) Webster, *Launaea sarmentosa*, *Zoysia matrella* Merr., *Cyperus pedunculatus*.

Towards the interior, the sand becomes less saline and a little more fertile; the outer most zone is composed of *Tephrosia purpurea*, *Hedyotis corymbosa* Wall., *Phyllanthus debilis* Hook. f., *Crotalaria retusa* L. Var. *maritima*; the next zone of bushes comprises *Scaevola taccada*, *Clerodendrum inerme*, *Pemphis acidula*, and *Morinda citrifolia*. Finally there remain some remnants of a littoral forest now replaced by coconut plantations like *Calophyllum inophyllum*, *Terminalia catappa* L., *Thespesia populnea*, *Barringtonia asiatica* Kurz, *Hibiscus tiliaceus* L., *Pongamia pinnata* (L.) Pierre and *Pandanus tectorius* Sol.

Salt marshes

These are located along the margins of numerous lagoons which mark the coast of Sri Lanka, particularly in the zone of a long dry season where evaporation notably increases their salinity. In relation to this factor and the variable frequency of these being reached by the tides are differentiated zones characterised by closely adopted species, usually in pure populations.

In the salt marshes bordering Mundel lake, Chapman (1947) recognised the following zones.

- (i) Zone of *Cyperus haspan* L. and *Scirpus littoralis* Schrad.
- (ii) Association of *Zoysia matrella* Merr. with occasionally some small trees like *Avicennia intermedia* Griff. and *Heritiera littoralis* Dryand.
- (iii) Zone of *Suaeda monoica* Forsk. with some *Zoysia* and *Eleocharis setacea* (Retz.) R. Br.
- (iv) Zone of *Suaeda monoica* Forsk. without any other species except occasional *Zoysia* and *Arthrocnemum*.
- (v) A barren muddy zone with a fringe of blue-green algae here and there.
- (vi) A zone of *Halophila ovata* Grand.
- (vii) Mangrove zone dominated by *Avicennia intermedia*.

Salt pans

Species most resistant to salinity like *Salicornia* and *Suaeda* grow on their borders.

Halophilous pseudosteppes

Along the north-west coast of the island and to the south of the Jaffna lagoon occur black clayey soils with varied degrees of salinity; they bear a discontinuous grassy vegetation mixed with halophytes like *Tamarix gallica* L., *Suaeda* spp. as also some sparse trees like *Salvadora persica* L. and *Manilkara hexandra* (Roxb.) Dub.

There remain only a few patches in Sri Lanka. Most of these were cut down and drained for raising coconut plantations.

An excellent ecological study of a salt marsh of Sri Lanka located in the Gulf of Mannar is that of Pemadasa *et al* (1979). The authors recognised the following communities.

(a) *Suaeda*, (b) *Arthrocnemum* consociation, (c) Salt-marsh pastures, (d) Thorn Scrub, (e) Depressions.

9. The Utkal and Bengal Coast

An ecological study of the strand vegetation of the Utkal coast has been carried out by Rao and Mukherjee (1975). The strand flora situated on a raised sandy ridge from Balasore to Ganjam districts shows sufficient density towards inlands. The pioneers are *Canavalia maritima* (Aubl.) Thw., *Cyperus arenarius* Retz., *Fimbristylis junciformis* Kunth, *Launaea sarmentosa* and *Hydrophylax maritima* L. f. They are closely followed by *Euphorbia rosea* Retz., *Geniosporum tenuiflorum* (L.) Merr. and *Phyllanthus rotundifolius* Klein. The next set of strand builders are *Spinifex littoreus* (Burm. f.) Merr., *Borreria articularis*, *Ipomoea pes-caprae*, *Polycarpaea corymbosa*, *Portulaca tuberosa* Roxb. and *Perotis indica* (L.) O. Ktze. (figure 4).

The zonal pattern as stated above exhibits gradation in the substratum which is reflected in the variation of floristic composition.

Euphorbia rosea, *Geniosporum tenuiflorum* and *Hydrophylax maritima* encountered on the coastal sands of Utkal are not found further north of the Medinipur plain (Rao *et al* 1970); on the other hand, *Enicostema hyssopifolia* and *Aeluropus lagopoides* which are very common along the Indian coastline are not recorded from the Utkal coast (Rao 1971).

The fore-dunes in the vicinity of Digha have been described by Rao *et al* (1974). The newly recorded plants of Medinipur coast are *Aeluropus lagopoides*, *Cyperus esculentus* L., *Trianthema triquetra* Rottl., *Portulaca tuberosa* Roxb., *Gisekia pharnaceoides* L., *Rothia indica* (L.) Druce, *Spinifex littoreus* and *Syzygium ruscifolium* (Rao 1969).

10. Andaman and Nicobar islands

The strand vegetation occupies flat strips of limited length along the broken coast lines of these islands, varying from a few to several meters in width. In sheltered areas, dense strand vegetation is formed between the muddy flats and the interior. In some places shingles from weathered limestone cliffs or broken shells or corals constitute the beaches. The vegetation of the pioneer zone on the sandy relief is composed of *Ipomoea pes-caprae*, *Clitoria ternatea* L. and *Vigna lutea* Gray. The raised ridges in this area support *Scaevola taccada*, *Sophora tomentosa* L., *Erythrina indica* Lam. and



Figure 4. Percentage cover and zonal pattern in open pioneer-dune zone of Utkal coast near PURI.

Cynometra ramiflora L. The other notable trees are *Heritiera littoralis*, *Thespesia populnea*, *Ochrosia barbarila* Gmel., *Pongamia pinnata*, *Terminalia catapa* and *Calophyllum inophyllum*.

The coral strand relief, especially the raised consolidated ridges support *Cycas rumphii* Miq., *Scaevola taccada*, *Messerschmidia argentea* (L. f.) Johnst., *Caesalpinia crista* L. and *Manilkara littoralis* (Kurz) Dub. Along the coral sand the vegetation is composed of *Thuarea involuta* (G. Forst.) R. Br., *Cyperus pedunculatus*, *Scaevola taccada*, *Guettarda speciosa* L. and *Cycas rumphii*. The sandy areas in the Nicobar group of islands are composed of *Spinifex littoreus*, *Cyperus pedunculatus*, *Salomonina cantoniensis* Lour., *Euphorbia atoto* and *Wedelia biflora* DC.

11. Conclusions

Well developed stretches of the dry coastal ecosystems are rather rare in the sub-continent and only a few examples are available. One such stretch extends from Kozhikode to Kasargod along the Malabar coast where *Ipomoea-Canavalia* community forms a thick mantle on the sand as the area is not inhabited by the fishermen. Another example is the sandy bulge between Konarak and the mouth of the Chilka lake with the community of *Ipomoea-Hydrophylax* closely followed by *Spinifex-Geniosporum-Tephrosia*.

For the other areas of the sub-continent, the strand flora is considerably disturbed and altered by man. Under the multiple use management may be mentioned the Dwarka-Okha region of the north-west Kathiawar where gypsum is mined and sand is used for the manufacture of cement. Along the Malabar coast, shells are collected for various purposes and Thorium mineral is extracted.

Plantations of coconut almost throughout the entire coastline along with palmyra palm (*Borassus*), *Casuarina equisetifolia*, cashewnut (*Anacardium occidentale* L.) have considerably altered the original strand vegetation.

The non-calcareous beaches consist of fine grained sand and provide a good percolating field for the rain water. The good quality water stored at a depth of 5–10 m permits irrigation for agriculture and forest-nurseries.

Growing of crops like millets (*Pennisetum typhoides* (Burm.) Stapf et Hubb.), ground-nut (*Arachis hypogea* Willd.) with saline water irrigation in coastal tracts is still in an experimental stage at present.

The problem of shifting sand is noted in the Utkal coast, Coromandel coast, Malabar coast and in the Rameshwaram island. Active measures are needed to check the spread of the sand from invading the neighbouring cultivated land.

The growth-forms of the common strand plants are enumerated below after Rao (1971).

Growth-forms of common strand plants

(a) Mat-forming strand creepers.

Aeluropus lagopoides, *Canavalia maritima*, *Canavalia cathartica*, *Indigofera aspalathoides*, *Ipomoea pes-caprae*, *Launaea sarmentosa*, *Paspalum vaginatum*, *Perotis indica*, *Sesuvium portulacastrum*, *Sporobolus virginicus*, *Trachys muricata* (L.) Pers., *Zoysia matrella*.

(b) Diffusely branching prostrate/erect strand herbs and sedges

Allmania nodiflora Br., *Anotis carnosus* Hk. f., *Atriplex repens* Roth., *A. stocksii* Boiss., *Borreria articularis* (L. f.) F. N. Will., *B. stricta*, *Crotalaria nana*, *Enicostema hyssopifolium* (Willd.) Verdoon. *Euphorbia atoto*, *E. rosea*, *Geniosporum tenuiflorum* (L.) Merr., *Hydrophylax maritima*, *Polycarpaea corymbosa*, *P. spicata*, *Scaevola plumieri* (L.) Vahl.

(c) Strand climbers

Dalbergia spinosa Roxb., *Derris trifoliata*, *Flagellaria indica* L., *Ipomoea macrantha*, *Parsonia helicandra*.

(d) Strand plants with perennating organs

Asparagus dumosus, *Scilla hyacinthina* (Roth.) Macbr., *Urginea indica*.

(e) Strand scrubs

Acrostichum aureum (Strand fern), *Clerodendrum inerme*, *Dimorphocalyx glabellus* Thw., *Halopyrum mucronatum* Stapf, *Myriostachya wightiana* (Nees) HK. f., *Scaevola taccada*, *Syzygium ruscifolium* (Willd.) Sant. & Wagh, *Tamarix articulata* Vahl.

(f) Strand trees

Acacia planifrons W. & A., *Ardisia littoralis*, *Capparis cartilaginea* Decne., *Calophyllum inophyllum*, *Euphorbia caducifolia*, *Hyphaene dichotoma*, *Messerschmidia argentea* (coral sand), *Morinda citrifolia*, *Pandanus tectorius*, *Pemphis acidula* (coral sand), *Premna serratifolia* L., *Salvadora persica* L.

The mat-forming strand creepers may be suitably used for the fixation of the moving sand and mobile sand-dunes. Rao (1977) has proposed a list of useful species for the conservation of the sandy soils of the different biogeographic regions of the sub-continent based on the ecological amplitude of the coastal species.

It is interesting to note that the salt pans are confined to the zones with a relatively long dry season and are absent in the regions where the season of heavy rains exceeds 4 months.

References

- Arora R K and Aggarwal K R 1965 Observation on the vegetation of Malpe Coast and neighbouring islands. *J. Indian Bot. Soc.* **44** 314-325
- Bagnouls F and Gaussen H 1953 Saison sèche et indice xérothermique. *Documents pour les cartes des productions végétales* to. III, Vol. 1, art. 8, 47 p. Toulouse.
- Blasco F 1975 Les mangroves de l'Inde; *Inst. Fr. Pondichéry. Trav. Sec. Sci. Tech.* **14** 1-175
- Blasco F 1977 Outlines of ecology, botany and forestry of the mangals of the Indian subcontinent. in *Wet coastal ecosystems* (ed.) V J Chapman (Oxford: Elsevier) pp. 241-260
- Blasco F and Legris P 1973 Dry evergreen forest of Point Calimere and Marakkanam; *J. Bombay Nat. Hist. Soc.* **70** 279-294
- Blatter E, Mc Cann C and Sabnis T S 1929 *The flora of the Indus Delta* (Madras)
- Champion H G 1936 A preliminary survey of the forest types of India and Burma; *Indian For. Rec. (N.S.) Silv.* **1** 1-200

- Chapman V S 1947 The application of aerial photography as exemplified by the natural vegetation of Ceylon; *Indian For.* 73 287-314
- Chapman V S (ed.) 1977 *Wet coastal ecosystems* (Oxford: Elsevier)
- Eig A 1931 Les éléments et les groupes phytogéographiques auxiliaires dans la flore palestinienne. I Texte. II. Tableaux analytiques. *Repertorium specierum novarum regni vegetabilis*. Beihefte Band LXIII, 201 p. Dahlem bei Berlin.
- Marlange M and Meher-Homji V M 1965 A phytosociological study of the Pondicherry region. *J. Indian Bot. Soc.* 44 167-182
- Meher-Homji V M 1965 On the Sudano-Deccanian floral element; *J. Bombay Nat. Hist. Soc.* 62 15-18
- Meher-Homji V M 1970 Notes on some peculiar cases of phytogeographic distributions; *J. Bombay Nat. Hist. Soc.* 67 398-413
- Meher-Homji V M 1973 A phytosociological study of the *Albizia amara* Boiv. Community of India; *Phytocoenologia* 1 114-129
- Meher-Homji V M 1974 On the origin of the tropical dry evergreen forest of South India; *Int. J. Ecol. Environ. Sci.* 1 19-39
- Nayar M P 1959 The vegetation of Kanyakumari district; *Bull. bot. Surv. India* 1 122-126
- Pemadasa M A, Balasubramanian S, Wijewansa H G and Amarasinghe L 1979 The ecology of a salt marsh in Sri Lanka; *J. Ecol.* 67 41-63
- Rao T A 1969 The maritime strand flora along the Indian coast. A preliminary survey; *Proc. 56th Indian Sci. Congr.* III 432
- Rao T A 1971 Distributional resume on the maritime strand flora of India; *Bull. Bot. Surv. India* 13 192-202
- Rao T A 1977 Management of coastal sandy biomes in India. Seminar on Afforestation. Inst. Public Health Engineers, Calcutta.
- Rao T A 1978 On the coastal floristics and vegetation of the Malabar coast pertaining to Kerala State, India. The Madras Herbarium 125th Anniversary Souvenir Symp., p. 24.
- Rao T A and Aggarwal K R 1964 Ecological studies of Saurashtra coast and neighbouring islands: III. Okhamandal point to Diu Coastal areas. Symp. Problems Indian Arid Zone, Jodhpur, pp. 31-42
- Rao T A, Aggarwal K R and Mukherjee A K 1963a An ecological account of the vegetation of Rameswaram island; *Bull. Bot. Surv. India* 5 301-325
- Rao T A, Aggarwal K R and Mukherjee A K 1963b Ecological studies on the soil and vegetation of Krusadi group of islands in the Gulf of Mannar; *Bull. Bot. Surv. India* 5 141-148
- Rao T A and Korlahalli B C 1969 A note on the inflorescence of *Hyphaene indica* Becc; *J. Bombay Nat. Hist. Soc.* 66 235-236
- Rao T A and Mukherjee A K 1975 An ecological study on the strand vegetation of the Orissa coast; *Indian For.* 101 692-701
- Rao T A, Mukherjee A K and Banerjee L K 1970 Vascular plants of the coastal Midnapore district, W. Bengal; *Indian For.* 96 668-677
- Rao T A, Mukherjee A K and Banerjee L K 1974 A few unrecorded taxa for the flora of Kanyakumari shore (Cape Comorin), Tamil Nadu; *J. Bombay Nat. Hist. Soc.* 71 346-349
- Rao T A and Sastry A R K 1972 An ecological approach towards classification of coastal vegetation of India—I. Strand vegetation; *Indian For.* 98 594-607
- Rao T A and Sastry A R K 1974a An ecological approach towards classification of coastal vegetation of India. II. Estuarine border vegetation; *Indian For.* 100 439-452
- Rao T A and Sastry A R K 1974b An outline of the coastal vegetation of India; *Bull. Bot. Surv. India* 16 101-115
- Rao T A and Shanware P G 1967 Ecological studies of Saurashtra coast and neighbouring islands. VI. An approach to a classification of the Saurashtra coastland. A resume; *Bull. Bot. Surv. India* 9 240-248
- Rao T A, Shanware P G and Mukherjee A K 1974 Ecological studies on the coastal sand dunes and slacks in the vicinity of Digha, Midnapore district, W. Bengal; *Indian For.* 100 101-107
- Rolla S R 1963 *Hyphaene indica* Becc. along the west coast of India; *J. Bombay Nat. Hist. Soc.* 60 761-763
- Sastry A R K and Rao T A 1973 Studies on the flora and vegetation of coastal Andhra Pradesh, India; *Bull. Bot. Surv. India* 15 92-107
- Satyanarayan Y 1958 Ecological studies of Bombay coast line. I—Strand vegetation; *J. Biol. Sci.* 1 53-65
- Sebastine K M and Ellis J L 1967 A contribution to the vascular flora of Vedharanyam and Talignayar reserve forests, Tanjore district, Madras State; *Bull. Bot. Surv. India* 9 190-200
- Shah G L 1962 The vegetation along the seashores in Salsette Islands, Bombay; *Bull. Bot. Surv. India* 4 239-249

- Spratgers J T C M and Balasubramanian K 1978 A phytosociological analysis of the tropical dry semi-evergreen forest of Marakanam, South-Eastern India; *Trop. Ecol.* **19** 70-92
- Srinivasan K S 1960 Aspects of vegetation of Church Island off Tuticorin port in South India; *J. Bombay Nat. Hist. Soc.* **57** 348-353
- Stoddart D R and Fosberg F R 1972 South Indian sand cays. *Atoll Res. Bull.* **161** 1-16 Smithsonian Inst., Washington.
- Sundararaj D D and Nagarajan M 1964 The flora of Hare and Church Islands off Tuticorin; *J. Bombay Nat. Hist. Soc.* **61** 587-602
- Thomas K J 1962 A survey of the vegetation of Veli (Trivandrum) with special reference to ecological factors; *J. Indian Bot. Soc.* **41** 104-131
- Viart M 1963 Contribution à l'étude de l'action de l'homme sur la végétation dans le sud de l'Inde. Thèse d'Ingenieur Docteur, Faculté des Sciences, Toulouse, 259 p.
- Werger M J A and Sprangers J T C M 1982 Comparison of floristic and structural classification of vegetation; *Vegetation* **50** 175-183

