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ECOLOGICAL STUDIES OF SAURASHTRA COAST AND NEIGHBOURING ISLANDS—VI. AN APPROACH TO A CLASSIFICATION OF THE SAURASHTRA COASTLAND —A RESUME

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ABSTRACT

A geomorphic classification defined and delemitated by plant communities and edaphic features is outlined for the Saurashtra coast with discussion on diversity, zonal patterning and prevailing characteristics of habitats, plant communities, soils and phytogeography.

INTRODUCTION

Coastal landscape presents a varied array of landforms, flora and fauna. Their study has been of extensive interest to both geographers and ecologists. It is one of the projects on which some work has been carried out by the ecology unit of the Botanical Survey of India since 1960. The general physiographic account, phytosociological features (in part) and edaphic conditions followed by a description of some aspects of coastal ecosystems have been recently published (Rao *et al.* 1963, 1964a, b; 1966a, b; 1967). In the present resume a classification is proposed for the Saurashtra coast based on a combined knowledge of geomorphology, phytosociology and edaphic features.

STUDY AREA

The study was confined to the shores at Okha, Dwarka, Porbunder, Mangrol, Veraval, Somnath, Delvada and Diu island facing the Arabian sea; Okhamandal point, Beyt island, Armada, Salya, Jamnagar along the Gulf of Cutch; and Jafarabad, Mhuwa, Gopnath, Gogha, Piram island, Bhavanagar along the Gulf of Cambay. Despite this restriction, the descriptions and conclusions arrived so far appear fairly valid, in a broad sense, for the Saurashtra coastline.

COASTAL LANDSCAPE

Saurashtra coast is bounded by the Arabian sea along the south and south-west, the Gulf of Cutch along the north-west and by the Gulf of Cambay in the east. In all it has about 512 km long coastline. The coastline facing the Arabian sea from Okha to Diu island exhibits sandy beaches often intercepted by exposed rocky shores directly facing the sea. The long sea currents bring down sand which on deposition on the shores, is lifted by onshore winds. The waters in the gulf of Cambay are turbid all round the year and bring very little sand from the Arabian sea towards the western coast. The coastline within the gulf of Cambay and Cutch is not bordered by sandy shore/beach formation, but by distinct muddy flats, always under tidal effect often giving rise to mangroves and saline flats.

CLASSIFICATION

A classification is outlined incorporating physiographically active situations like beaches, dunes, marshes and cliffs, the corresponding vegetation and soil characteristics. The coastal areas in Saurashtra can be divided into three basic belts/subdivisions: the shore, the coastal and the arid/semi-arid subcoastal plain. Each belt includes distinct landforms and range of habitats. Along the coast there are three basic types of shores: sandy, rocky and muddy shore. Under each type, zones are recognised and in them the range of habitats are recognised in terms of plant communities (Fig. 1).

SANDY SHORE

A typical sandy shore exhibits two distinct zones, foreshore and backshore. The foreshore is further divisible into lower beach and upper beach. The backshore includes well organised landforms which can be broken up into habitats or topographic facets to study the distribution pattern of coastal plants. Where the coastline is not rocky or muddy the foreshore sandy strand extends inland depending upon the onshore winds. If the winds are severe, larger portion of the coast is brought under strand influence by shifting sand dunes and blow outs. The further inland extension of sandy shore

zoic coastal and subcoastal belts entirely depends on the onshore winds. Thus these belts are under the influence of onshore winds, shifting sand, storm water and salt spray and they in turn support a distinct adapted flora. In many sandy shores the line of junction between the zones is not great to

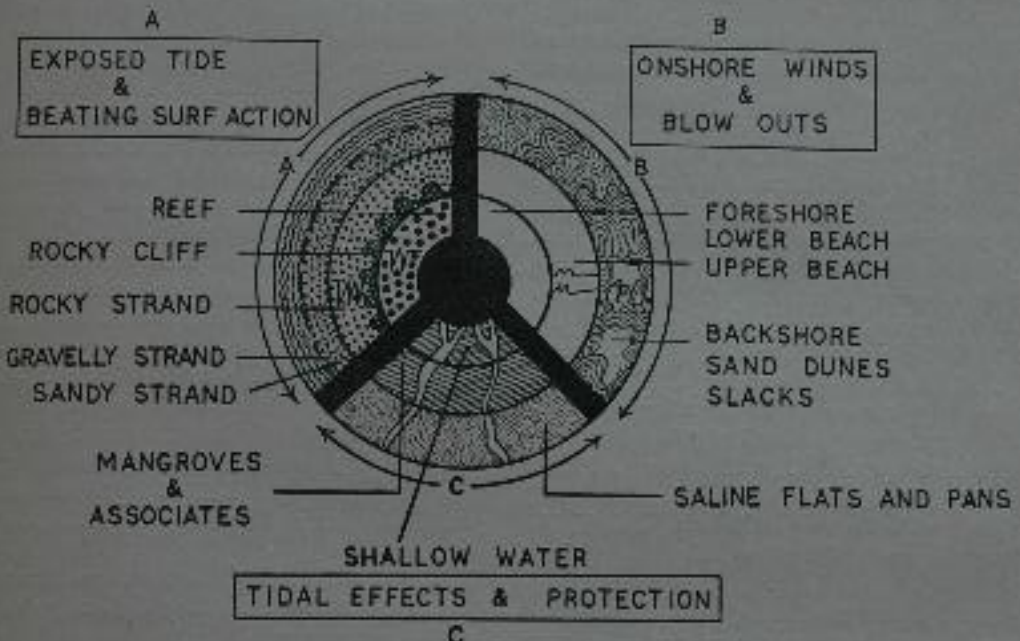

Fig. 1. A Chart to show successive belts of typical (A) Rocky, (B) Sandy and (C) Muddy coasts in Saurashtra.

effect appreciably the distribution of strand flora. However quantitative changes in salinity of soil does cause correlative changes in the pattern of distribution of strand flora (Table I).

TABLE I: *A typical sandy coastal situation in Saurashtra*

SHORE					COAST			ARID/SEMI-ARID SUB-COASTAL PLAIN
FORESHORE			BACKSHORE		EXTENSION OF BACKSHORE CONDITIONS			
Lower (Intertidal Area)	Upper	Drift Line	Sandy Bar & Bar Strand/Dune	Sand Dunes Habitat	Sandy flat extension	Slacks	Back Dune	
Yellow Reef Sandy	Moist sandy	Rich in organic matter	Sandy bars/ Dunelets	Dunelets		Saline or fresh water	*Aerva javanica*	Gravelly sandy or Lateritic
Algae or Marine angiosperms	No vegetation	*Sesuvium portulacastrum*	*Ipomoea pes-caprae* *Cyperus arenarius* *Launaea sarmentosa* *Polycarpaea corymbosa* *Halopeplis perfoliata* *Halopyrum mucronatum*			Mixed Flora	*Leptadenia pyrotechnica* *Aristida funiculata*	*Euphorbia nivalia* *Zizyphus mauritiana* or *Dichanthium indica* or Crops

SANDY STRAND FLORA

The pioneer plant is *Ipomoea pes-caprae* (L.) Sweet, a strand creeper of wide distribution all along the tropical coasts. This spreads rapidly on the elevated flat or steep beaches often forming a spreading mat. Closely following it especially on the upper beach, in the order of relative abundance, are *Cyperus arenarius* Retz., *Launaea sarmentosa* (Willd.) Alston, *Borreria articularis* (L. f.) F. N. Will. and *Boerhavia diffusa* L. Almost without exception the above species are also found growing in the varied habitats of the backshore. To the north especially near Dwarka, Okha sandy shores, *Asparagus dumosus* Baker forms an interesting localised strand plant often browsed by animals. To the south especially near Veraval and Mangrol shores, *Hydrophylax maritima* L. forms a pioneer strand plant. Another successful strand pioneer is *Halopyrum mucronatum* Stapf spreading considerably all along the sandy strand of Diu island. A rare and noteworthy sandy strand pioneer is *Psilostachys arenea* (Koen. ex Roxb.) Hook. f. often found in association with *Borreria articularis* (L. f.) F. N. Will. along the sandy shores bordering the gulf of Cambay.

The general pattern of distribution is one of scattered individuals or in tufts or hemispherical dome shaped suffruticose perennials. Majority of them are strand creepers forming dense or loose mats depending on edaphic gradients. They do not form a continuous vegetal cover but they are conspicuous wherever they are present. Most of them are of the perennial recurrent type and occur all over sandy shores. The floristic distribution pattern is zonal and the main cause is due to a gradient of salinity. The vegetal cover is represented by a few salt tolerant species. They develop succulent parts or other xeric features as adaptive features. Sometimes a few plants can grow well on sandy, muddy and saline drift lines, thus exhibiting plasticity for occurrence under varied conditions and a good example is *Sesuvium portulacastrum* L.

Soils are mainly deep, sandy to loamy sand in texture at the surface with moderately alkaline reaction, variable over 8 to 8.4 pH. Organic matter is low ranging from 0.25 to 0.64 P. C. Calcium carbonate is heterogeneous and variable over 13 to 92 P. C. of which higher percentages are recorded along the coast from Okha to Diu island. However, in areas away from the coast but covered with aeolian sea sand the organic matter is up to 2.28 P. C. Sodium chloride is 0.01 to 0.19 P. C. and total dissolved solids are 0.014 to 0.19 P. C. and it does not show any effect of sea water inundation or sprays. Such areas exhibit a mixed flora of strand and local plants.

ROCKY SHORE

A typical rocky shore in Saurashtra consists of a wave-cut exposed rocks directly facing the sea. In such cases the foreshore is free from sandy beach but invariably composed of limestone reef of considerable width followed by rock pools and fallen boulders of varied shape and size. This intertidal zone abounds in life especially algae and animals and is defined in terms of the distribution of organisms (Stephenson & Stephenson, 1949). However, the rocky shore above the supra littoral zone of Stephenson has received scanty attention. Except for the occurrence of *Exhalus acaroides* (L. f.) Rich. ex Steud. at certain shallow areas near Piram island, there is a general paucity of phanerogamic plants but such areas are rich in algal members. The study of intertidal zone is not within the scope of this paper.

The areas in and above the supra littoral zone is of ecological interest. They distinctly exhibit three distinct physiographic belts: Seaward rocky slope, summit rocky flats/rocky strand and landward rocky sandy strand (Table II).

Seaward rocky slope is barren and devoid of phanerogamic plants. Due to storm water or salt spray or offshore winds the rocks develop pot holes and crannies often filled up with sandy soil. Infrequently they are occupied with *Atriplex stocksii* Boiss., *Fagonia cretica* L., *Polycarpaea spicata* Wt. & Arn. and *Statice stocksii* Boiss. exhibiting scattered distribution and rarely forming definite communities.

Next, the summit areas of limited width, composed of weathered rocky flats with increased pot holes of varied size holding aeolian sand, constitute a rocky strand zone. This area supports *Aeluropus villosus* Cl., *Andrographis echioides* (L.) Nees, *Evolvulus hyssopifolius* (Willd.) Verd., *Fagonia cretica* L., *Heliotropium strigosum* Willd., *Kukxia ramosissima* (Wall.) Janchen, *Lindenbergia urticaefolia* Lehm., *Portulaca quadrifida* L., *Pavonia zeylanica* (Andr.) Chiov., *Pulicaria angustifolia* DC., *Sporobolus diander* (Retz.) Beauv., *Statice stocksii* Boiss. and *Tribulus procumbens* L. The general pattern of plant distribution is not zonal because of the limited plant niches and constant rock weathering. The plants

TABLE II : *A typical rocky coastal situation in Saurashtra*

SHORE			W A V E	COAST			SUB-COASTAL PLAIN			
FORESHORE		BACKSHORE					Arid		Semi-Arid	
Shallow Reef	Rock Pools	Fallen Boulders of varied size		Seaward Cliff with pot Holes	Summit Rocky flat; Rocky Strand	Rocky sandy strand	Alluvium Saline	Gypsophilous	Alluvium Saline	Lateritic
Algae or Marine angiosperms		Algae	C U T C O A S T L I N E	*Polycarpaea spicata*, *Statice stocksii*, *Kickxia ramosissima*, *Andrographis echioides*, *Lindenbergia urticaefolia*		*Capparis cartilaginea*, *Calotropis procera*, *Aerva lanata*, *Polycarpaea corymbosa*, *Indigofera cordifolia*, *Heylandia latebrosa*	*Acacia nilotica*	*Euphorbia nivulia*	*Hyphaene indica*, *Acacia nilotica*, *Butea monosperma*	Cotton, Millets

are small herbs or prostrate creepers or stunted suffruticose shrubs.

With increased accumulation of aeolian sand towards the inland the habitat changes into Rocky sandy strand. The nature and increase in proportion of fine soil fraction bring about different types of plants. Nearly 41 species are met with in this habitat. The flora is a mixture of coastal and inland plants and the interesting shrubby plants are *Aerva lanata* (L.) Juss., *Capparis cartilaginea* Decne., *Calotropis procera* R. Br., *Jatropha gossypifolia* L., *Ischaemum pauciflorum* Stocks and *Tephrosia purpurea* (L.) Pers. The ground layer is chiefly composed of *Alysicarpus monilifer* DC., *Convolvulus glomeratus* Chois., *Dipteracanthus patulus* (Jacq.) Nees, *Glinus oppositifolius* (L.) A. DC., *Heylandia latebrosa* (L.) DC., *Hibiscus micranthus* L. f., *Indigofera cordifolia* Heyne, *Polygala erioptera* DC., *Polycarpaea corymbosa* (L.) Lamk., *Taverniera cuneifolia* Arn. and other inland plants like *Blumea obliqua* (L.) Druce, *Heliotropium tuberculosum* Boiss., *Pulicaria foliolosa* DC. and *Sida ovata* Forsk.

Soils are mainly sandy to loamy sand and at times sandy clay. They are moderately alkaline in reaction, 7.8 to 8.1 pH. Organic matter is low, 0.43 to 0.72 P. C. Sodium chloride and total dissolved solids are 0.007 to 0.086 and 0.029 to 0.990 P. C. respectively and do not show direct sea influence. Calcium carbonate percentage ranges over 40 to 69 P. C.; however, lower counts of 23 and 25 P. C. are also met with. *Jatropha gossypifolia* shows an endurance to higher pH upto 8.5 and also contributes higher organic matter like *Tephrosia purpurea*.

MUDDY SHORE

Under this category falls such of the areas along the coastal belt, which are periodically flooded with tidal water. These are shallow, depressed or protected regions from open sea currents. Generally their formation is noticed near deltic sea boards, estuarine banks or creeks and back water tidal mud flats of the Gulf of Cutch and Cambay coast lines. A typical muddy shore under coastal tropics develops mangroves and other associated species and like sandy shores exhibits distinct zonation. The foreshore is a shallow water region always under tidal effects. With a gradual rise of the foreshore the muddy flats are partly exposed under low tide and completely submerged under high tide. This area becomes suitable for the germination of mangrove seedlings which ultimately results in a well knit formation of a mangrove thicket. Within it the vegetation can be divided into distinct subzones: lower, middle and upper. In the lower and middle subzones the dominant thicket forming plant with innumerable pneumatophores is *Avicennia marina* var. *acutissima* Stapf. This formation is extensive and biotically much disturbed. With the upwelling towards the landward side the ground is covered in the order of relative abundance with *Aeluropus lagopoides* Trin. ex Thw., *Atriplex stocksii* Boiss., *Salicornia brachiata* Roxb., *Suaeda fruticosa* Forsk. and *Urochondra setulosa* (Trin.) Hubbard. The zonal distribution in the middle and upper subzones is determined floristically and an analytical study of soils has revealed that edaphic factors exert quite a considerable influence in causing

zonation. Fringing the upper zone along moist muddy soil the leading plants are *Fimbristylis cymosa* R. Br., *Scirpus maritimus* L. and *Tamarix troupii* Hole. These plants grow in less saline situations. Sometimes the upper subzone changes imperceptively into an extensive saline flat supporting species of *Atriplex*, *Sesuvium* and *Suaeda* (Table III).

TABLE III : *A typical muddy coast in Saurashtra*

SHORE		COAST				SUB-COASTAL PLAIN	
		Mangrove (under protection)	Salt pans	Muddy flats	Saline flats	Arid or	Semi-arid plain
Shallow water under tidal influence	S I S N I G						
	C O A S T	*Avicennia marina* var. *acutissima*	nil	*Salicornia brachiata*	*Suaeda fruticosa*	Alluvial soil (Saline)	Lateritic Crops
				Urochondra setulosa	*Atriplex stocksii*	*Acacia nilotica* & *Euphorbia nivulia*	Cotton, Millets

Soils are sandy loam to silty loam with moderately alkaline reaction over 7.8 to 8.6 pH. Organic matter is higher and ranges from 1.41 to 2.85 P. C. Sodium chloride is 1 to 3.84 P. C. and total dissolved solids are 1.72 to 3.98 P. C. showing the intense residual effect of sea water on soils. Calcium carbonate varies from 7 to 21 P. C. and exceptionally higher content of 82 P. C. with *Urochondra setulosa* and 53 P. C. with *Avicennia marina* var. *acutissima* are typical, indicating the calcicolus nature of plants. Another noteworthy situation is the presence of salt pans. These are patches in the form of depressions found along the coastal belt and frequently flooded by tidal water. They are bereft of vegetal cover. But the typical circum-salt pan flora consists of *Aeluropus lagopoides* Trin. ex Thw., *Clerodendrum multiflorum* (Burm. f.) Kuze., *Cressa cretica* L., *Sporobolus virginicus* (L.) Kunth, *Suaeda nudiflora* Moq. and *Tylophora indica* L. Soils are heterogeneous from fine sand to silty loam but the reaction is mild to moderately alkaline with 7.6 to 8 pH. Organic matter is high and varies from 1.17 to 2.6 P. C. Sodium chloride is 0.88 to 0.94 P. C. and the total dissolved solids are 1.27 to 3.63 P. C. indicating effects of sea water. Calcium carbonate percentage ranges from 12 to 24.

SLACKS

Slacks are depressions in the varied habitats of coastal areas. They are found to occur in between sand dunes or depressions under tidal flow or beyond the coast line under the influence of storm water and can be classified into three intergrading classes: salt water, brackish water and fresh water slacks. All these are noticed along the gulf of Cutch and Cambay coasts. Salt water slacks are connected to the sea and shallow with raised moist circum-areas. They are either bare in the centre or develop *Avicennia* plants and along the landward muddy area, *Urochondra setulosa* is found in abundance. On the raised parts the flora is composed of *Biepharis sindica* Stocks, *Brachiaria ramosa* L., *Portulaca tuberosa* Roxb. and *Sporobolus marginatus* Hochst ex A. Rich. Brackish water slacks are formed in such depressions where there is intermingling of fresh water from streams and tidal waters of sea. The mixed flora is composed of *Alternanthera sessilis* R. Br., *Cymbopogon giduriba* (Hatn. ex Hook. f.) Haines, *Digitaria sanguinalis* (L.) Scop., *Eragrostis pilosa* (L.) P. Beauv., *Phyllanthus asperulatus* Hutch., *Portulaca quadrifida* L., *Tephrosia tenuis* Wall. Fresh water slacks are completely cut off from the sea by certain physiographic features despite their situations along the coast. The main source of water supply is from underground springs or by heavy precipitations. The flora is chiefly composed of fresh water aquatics like *Typha angustata* Bory & Chaub., *Potamogeton* spp. and *Vallisneria spiralis* L. Sometimes they dry up and expose a muddy bottom. Under such situations the plant cover consists of *Ammannia baccifera* L., *A. multiflora* Roxb., *Bergia*

capparis L., *Corchorus depressus* (L.) Stocks, *Cyperus mundtii* L., *Eclipta prostrata* (L.) L. and *Euphorbia hombaicensis* Sant. These constitute some characteristic plants of mud formation.

In general, in and around brakish and fresh water slacks there is an assemblage of mixed flora of coastal and inland types and they do not show patterns of distribution. The soils are heterogeneous and the texture vary from loamy sand to sandy clay loam with moderately alkaline reaction with pH varying from 7.8 to 8.3. Organic matter is high in dry muddy slacks and decreases in the peripheral regions from 1.56 and 4.69 to 0.26 P.C. Sodium chloride is 0.006 to .062 P.C. and the total dissolved solids are 0.047 to 0.11 P.C. in fresh water slacks. Calcium carbonate percentage is 40 to 70. Of all plants, *Portulaca quadrifida* L. endures highly calcareous soils.

COASTAL BELT

The region adjacent to coastline constitutes the coastal belt. The physiography of this area is influenced to a great extent by the nature of the shore. Physiographically active sandy shores and narbet, sometimes extend their influence beyond the coastline and simulate the sandy or muddy shore conditions. Under such situations the flora is repetitive but less pronounced. Generally the following plants are found growing in this habit: *Ipomea vicina* Cav., *Enicostema hyssopifolium* (Willd.) Verdc., *Jatropha gossypifolia* L., *Capparis decidua* (Forsk.) Edgew., *Calotropis procera* R. Br. and others. The pattern of floral distribution is not zonal probably due to edaphic and biotic influences. The flora is of degraded type and the soil is poor in nutritive status. Soils vary in depth and are fine sand to loamy sand in texture. They are mild or moderately alkaline in reaction with a pH variable from 7.6 to 8.6. Sodium chloride is .007 to .022 P.C. and total dissolved solids are around .311 P.C. Calcium carbonate is variable over a wide range of 1.3 to 37 P.C. depending upon the base material, and depth of soil. General profile studies at these sites indicate the gradual decrease of sodium chloride and total dissolved solids down the depth, though the texture improves.

ARID OR SEMI-ARID SUBCOASTAL PLAIN

This is the outermost inland area adjoining the coastal belt. The change from the coastal to subcoastal belt is gradual and imperceptible. Away from direct marine influence at certain places some mixed scrub forests are developed. Such a forest consists of *Acacia nilotica* L., *Commiphora wightii* (Arn.) Bhandari, *Grewia tenax* (Forsk.) Fiori, *G. villosa* Willd., *Lycium europaeum* L., *Maytenus emarginata* (Willd.) Ding Hou and *Salvadora persica* L. in the arid parts; while in semi-arid parts and particularly the sagittal belt from Kodinar-Delvada coast up to Una, the landscape is covered by *Hyphaene indica* Becc. stands. The other noteworthy shrubs of semi-arid areas are *Aerva javanica* L., *Butea monosperma* (Lamk.) Taub. and *Solanum surattense* Mattei. In the arid zone *Euphorbia nivalia* L. thickets form the dominant plant community sheltering many climbers and annuals.

Soils are fine sand to sandy loam with moderately alkaline reaction and the pH ranges from 7.8 to 8.4. Organic matter varies from 1.11 to 4.60 percent which is higher than in the sandy strands. Sodium chloride and total dissolved solids are low and do not show adverse effects of inundation or sprays. Calcium carbonate varies from 13 to 27 percent, indicating the calcareous nature of the soil.

DISCUSSION

In the light of the above findings the coastal landscape is discussed under the following categories: diversity, patterning and prevailing characteristics of habitats, plant communities, soils and phytogeography.

Physiographic diversity

Near the coastline there are two distinct areas: submersible and non-submersible. The former is identified with the intertidal area and the latter the terrestrial/maritime area adjoining the coastline. The study of the intertidal area does not fall under the scope of this investigation. Three belts are distinguished in the non-submersible area: backshore, coast and sub-coastal plain. By virtue of their nearness to the sea they are always under the influence of salt spray, or shore winds or exceptionally by storm water. Further, each belt is characterised by distinct type of flora and soil. It is seen that each belt changes imperceptibly into another especially along the muddy and sandy coasts. The ecotone line between the belts is not apparently sharp enough to affect appreciably the distribution of plants.

The physiography of the Saurashtra coast provides certain important information on the interrelationships of a group of plants occurring on a particular landform. In other words landforms

help to assort the plant communities on the basis of their habitat conditions as the index species. The second group of plants deviate a little from this principle and includes certain plants localised in and typical for a particular habitat but fails to reappear extensively on the same landform. Such plants are called localised because they have adapted selectively. It is unwise to say at this stage that they did not get a chance for their inward distribution or were incompetent to thrive under different habitats. The third group of indifferent species are those showing an extensive distribution range. Information on these specific plants and their amplitude is already pointed out.

Zonal patterning

The zonal approach as a basis for classification of marine littoral system is widely recognised. The studies of Stephenson *et al.* (1949) for rocky shores have been recognised and discussed by many workers. Similarly Hedgepath (1957) has projected a world wide zonation for sandy beaches comparable to the Stephensons' for rocky shores. Stephensons' work for rocky shores is definable in terms of distribution of organisms. The areas above supra-littoral zone under maritime influence is not worked out in the Stephensons' classifactory system. An attempt has been made in this direction by Johnson and Skutch (1928) in the temperate coast on a headland of Mt. Desert island. In the present study, it is recognised that areas above supra-littoral zone on the rocky coast tend to show distinct belts and each is recognised by its own flora. Similarly, here Hedgepath's classification for sandy beaches is defined in terms of plant communities. On the sandy shore the backshore is tenanted with distinct landforms, each displaying characteristic strand flora within its habitat. The zonal distribution of strand flora is a noteworthy feature. Muddy shore under protection in the coastal tropics becomes a marsh belt. Marsh vegetation in the broad sense under the tidal influence forms a distinct soil-vegetation unit and in tropics it becomes a mangrove belt. This is a distinct belt showing the distribution of adaptive flora in a zonal manner and the soil exhibits a salt gradation under each zone supported by pure stands of plant communities. The raised muddy flats/saline flats have within them a recognisable distinct flora. To fix the limits especially the upper limits of each belt on vegetation basis in the case of muddy, sandy and rocky shores would be difficult because many inland plants intermingle with the characteristic maritime plants. The zonal pattern of habitats of sandy and muddy coasts are of universal occurrence. But the present field data have revealed that in rocky shore the different belts beyond the supra-littoral zone do not exhibit vegetational zonation (Rao & Mukherjee, 1967). It may be possible to recognise in varied rocky belts soil vegetation units as distinct entities if catenary sequence is established.

Vegetational characteristics

The first recognisable part in any coast is psiere or a bare area. When the plant beginnings are noticed on bare rock or cliff, this constitutes a lithosere; if it is on bare sand, it is a psammosere and finally on a bare salty area it is a halosere. Psammosere is exemplified on the zones of upper foreshores, strand, strand/dune and dunes. This zone constitutes a well knit ecological series with well recognised distinct plant communities. The successfull colonist on a bare sand is *Ipomoea pes-caprae* either as a consocie or associe. The next series is constituted by a lithosere on the exposed rocks, closely followed by rock and gravelly strand with different types of plant covers. The third series physiognomically distinguishable as halosere consists of mangroves, muddy/saline flats and salt pans supporting perennial adaptive flora. Though succession of plant communities could not be studied, the present study of the coastal plants has revealed that significant changes from bare stage through the various stages to the development of a climax is evident (Table IV).

Edaphic conditions

Analyses of soil samples from a relatively wide area of similar habitats in which coastal plants grow under natural conditions has revealed that the coastal soils of Saurashtra are sandy, moderately alkaline, calcareous and poor in organic matter. The edaphic conditions change considerably in each belt. The lower reaches of sandy foreshore is too saline to support any flora. In the upper reaches the strand creepers are active sand binders and their caducous parts add to the humus content of the soil. Higher up, especially along the backshore, coastal and subcoastal areas there are a distinct change in the physical and chemical properties of the varied habitats. Subcoastal areas have more or less dense vegetation and are comparatively rich in humus. The rocky

TABLE IV : *Developmental Units under different shore conditions in Saurashtra*

	SANDY SHORE	ROCKY COAST		MUDDY SHORE
		Rock Strand	Rock Sand Strand	
A. Pioneer	*Ipomoea pes-caprae* *Cyperus arenarius* *Hydrophylax maritima* *Halopyrum mucronatum* *Psilostachys sericea*	*Polycarpaea spicata* *Atriplex stocksii* *Statice stocksii*	*Capparis cartilaginea* *Kickxia ramosissima* *Andrographis echioides* *Lindenbergia urticaefolia*	*Avicennia marina* var. *acutissima* *Urochondra setulosa* *Salicornia brachiata*
B. Developmental (Associes/Consocies)	*Ipomoea / Cyperus* *Hydrophylax/Cyperus* *Halopyrum/Ipomoea* *Psilostachys/Borreria* (Sometimes single dominants)	Do	*Statice/Andrographis* *Kickxia/Lindenbergia* *Enicostema/Kickxia* *Portulaca/Andrographis* *Statice/Polycarpaea* *Sericostoma/Lepidagathis*	*Avicennia/Salicornia* *Avicennia/Cressa* *Urochondra/Salicornia* *Atriplex/Cressa* *Suaeda/Urochondra* *Sporobolus/Cynodon*
C. Vegetational characteristics	Psammosere	Lithosere		Halosere

belts are subjected to weathering and poor in humus. The muddy or mangrove belt shows a medium fine textured soil with high total soluble salts and sodium chloride and a comparatively high content of organic matter. Such edaphic features are significantly related to the density of flora, sea water and winds.

From the above generalised habitat characteristics, valuable information on the individual soil plant relationship has been drawn. Among the strand flora *Ipomoea* and *Halopyrum*, the pioneering sandy strand species, show a higher degree of tolerance to salinity due to sodium chloride and a capacity to thrive well on extremely calcareous soils with moderate alkaline soil reaction and at times associated with species of *Cyperus*, *Hydrophylax* and *Psilostachys*. They are poor organic matter contributors. Salt marsh species are invariably salsuginous and do well under high sodium chloride content which accounts for nearly 75 to 100 P. C. of the total soluble salts. *Avicennia*, *Urochondra* and *Suaeda* species are maximum donors of organic matter and indicate a high amplitude to thrive well on a highly calcareous stratum, except *Suaeda*. *Aeluropus* and *Fimbristylis* are selective and grow well on medium fine textured silt-loam soils. *Salicornia* grows well on even 8·5 pH — a good salinity indicator. Within the rocky strands *Jatropha* species flourishes well on moderately alkaline sandy clay and contributes high organic matter. *Sericostoma*, *Enicostema* and *Fagonia* species do well on highly calcareous soils. Such investigations on soil plant relationship enrich our knowledge and open a new field for fixing minimal and maximal limits for a plant species.

Phytogeography

From the point of phytogeography the study and distribution of the plants of a region to find out their probable origin is of considerable interest. Climatically, the coast lying in the tropics hardly can be sub-divided into several parts. Unlike the temperate coast they do not show any marked seasonal change and the effect of the climate on shore life is almost negligible because of the all prevading influence of sea. The phanerogamic coastal flora of Saurashtra is a mixture of maritime and inland types. Some of them are extensively spread or may cover only a few square metres along the coast. The flora reveals that it is a mixture of Afro-arabian/western, and Indo-malayan elements with two apparently rare or endemic plants. The characteristic strand plants of western elements are represented by *Asparagus dumosus*, *Capparis cartilaginea*, *Launaea runcinata*, *Halopyrum mucronatum*, *Polycarpaea spicata* and *Statice stocksii*. Among the Indo-malayan elements of wide occurrence are *Ipomoea pes-caprae*, *Cyperus arenarius*, *C. conglomeratus*, *Borreria articularis* and *Hydrophylax maritima*. The other interesting plants are *Anaphalis cutchica* an endemic and an apparently localised rare plant *Psilostachys sericea* of limited distribution. In the interior, especially towards the north western sectors falling under arid climate the dominating community is mainly composed of *Euphorbia nivulia* thickets sheltering

number of climbers and herbaceous plants. Further down, near Kodinar, Delvada and Una sectors the landscape is dominated by *Hyphaene indica*. The other plants of distributional interest are *Sericostoma pauciflorum* and *Lepidagathis trinervis* occurring dominantly along the northern and western regions of the sub-coastal areas. They have a relatively limited distribution along the sub-coastal plain bordering the gulf of Cambay.

The collections of plants from the coast of Saurashtra have revealed the absence of certain Indo-malayan plants which are conspicuous and ubiquitous all along the Indo-malayan tropical coasts. The following species hitherto not reported from the coastal areas of Saurashtra are *Calophyllum inophyllum* L., *Heritiera littoralis* L., *Lumnitzera racemosa* Willd., *Cyperus pedunculatus* (R. Br.) Koen., *Scaevola taccada* (Gaertn.) Roxb., *Spinifex littoreus* (Burm. f.) Merr. But these plants are reported to occur in the western coast south of Bombay shore. However, their absence in the Saurashtra coast needs careful search and study.

SUMMARY

Physiographically the coastal areas in Saurashtra are divisible into three basic sub-divisions: the shore, the coastline and the arid or semi arid sub-coastal plain. Each sub-division includes distinct landforms, range of habitats and plant communities. The shore/beach is divisible into three basic types: sandy, rocky or muddy. Under each type, zones are recognised and in them the range of habitats is pointed out in terms of plant communities. The coastline is influenced by the nature of the shore. The active sandy shores and marshes sometimes extend their influence beyond the coast line and simulate the sandy or muddy shore conditions. When the coast line is rocky, the areas above supra littoral zone show distinct belts and each has a distinct flora. However, they do not exhibit vegetational zonation as in sandy and muddy coasts. Sub-coastal plain represents the outermost inland area adjoining the coastal line. The flora here resembles the hinterland.

The edaphic features are different and vary considerably under each physiographic subdivision and zone. They are also significantly related to the density of the flora. The soil-plant relationship reveals that plants grow and adjust over a reasonably flexible range unless warranted by extreme conditions like salt marshes and mangroves where the residual effects of salinity by sea water are persistent. Naturally under such conditions the composition of the flora is specialised and restricted.

The present resume tentatively suggests, that for a proper understanding of ecological studies a combined knowledge of geomorphic, phytosociologic (in part) and edaphic features would prove useful.

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