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VEGETATION AND ENVIRONMENT ON THE BARBADOS COAST

By ROLAND E. RANDALL

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INTRODUCTION

Barbados, with a total area of 445 km^2, is the easternmost island in the Caribbean, at about 13°N and 59°W (Fig. 1). The greater part of the island is covered by Pleistocene reef limestone (Senn 1946) but older sedimentary rocks are exposed in the Scotland District (Trechmann 1925). The tropical, oceanic climate has been described by Skeete (1963). Barbados lies within the belt of the north-east trade winds which blow fairly constantly with a mean velocity of 16·8 km/h. Average annual temperatures vary between 24° C and 28° C with daily variation usually less than 3° C. Rainfall, 75% of which falls between June and mid-December, is extremely variable but averages 160 cm. Daily sunshine is least in October with 7·3 h rising to 8·8 h in April. Humidity is usually between 71% and 76% throughout the year. The island is not within the normal hurricane belt and has been hit only once this century (Dinger 1962).

Several climatic parameters vary considerably around the coast, influencing the type of vegetation. Average rainfall for coastal stations is shown on Fig. 1. The north and south of the island have approximately 110 cm/year and the central parts of the east and west coasts have over 135 cm. This difference in precipitation is further emphasized by evaporation. Data were collected at the fifteen coastal locations shown on Fig. 1 between May and September 1967. During this period Windward stations averaged 9·1 mm evaporation/day and Leeward stations 5·8 mm (Randall 1968b). Both evaporation and salinity are directly affected by wind speed (Randall 1968a). At 1 m above ground level this averaged 150% more on the Windward than the Leeward coast. These differences result in the north and south coasts being the driest and most saline and xeric scrubland is found on the cliff-tops (Fig. 4). Conversely the central part of the Leeward coast is the wettest and least saline and a coastal forest formation results (Fig. 5).

Barbados is heavily populated and fully cultivated with only areas such as the coastal fringe and bare rock exposures not planted. The soils of the island have been described by Vernon & Carroll (1966) and Randall (1969).

The greatest variation in coastal soils is that between those of the Scotland District which have a siliceous sand base, and those of the rest of the island which are based on coral sand. This difference restricts the distribution of certain plants. Of even greater importance to the vegetation is the amount of silt and clay present in the soil. Where there are beaches, silt and clay content are very low, the rooting medium is mobile and psammophytes are present (Fig. 6); where there are cliffs, greater quantities of the finer fractions occur and different communities are found (Fig. 4).

In the present paper, gradients of the vegetation and environment at selected locations around the island are described and examined to discover relationships between environmental variations and changes in the coastal vegetation. There are large-scale, circum-

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coastal ranges of species and small-scale ranges down individual beach profiles orthogonal to the shore. The former presumably are related to gross climatic gradients and regional contrasts in the island soils and the latter reflect the variety of local environments. Species that exemplify the circum-coastal ranges are *Swietenia mahagoni* which is limited to the Leeward coasts, and *Chrysobalanus icaco* which does not occur off the

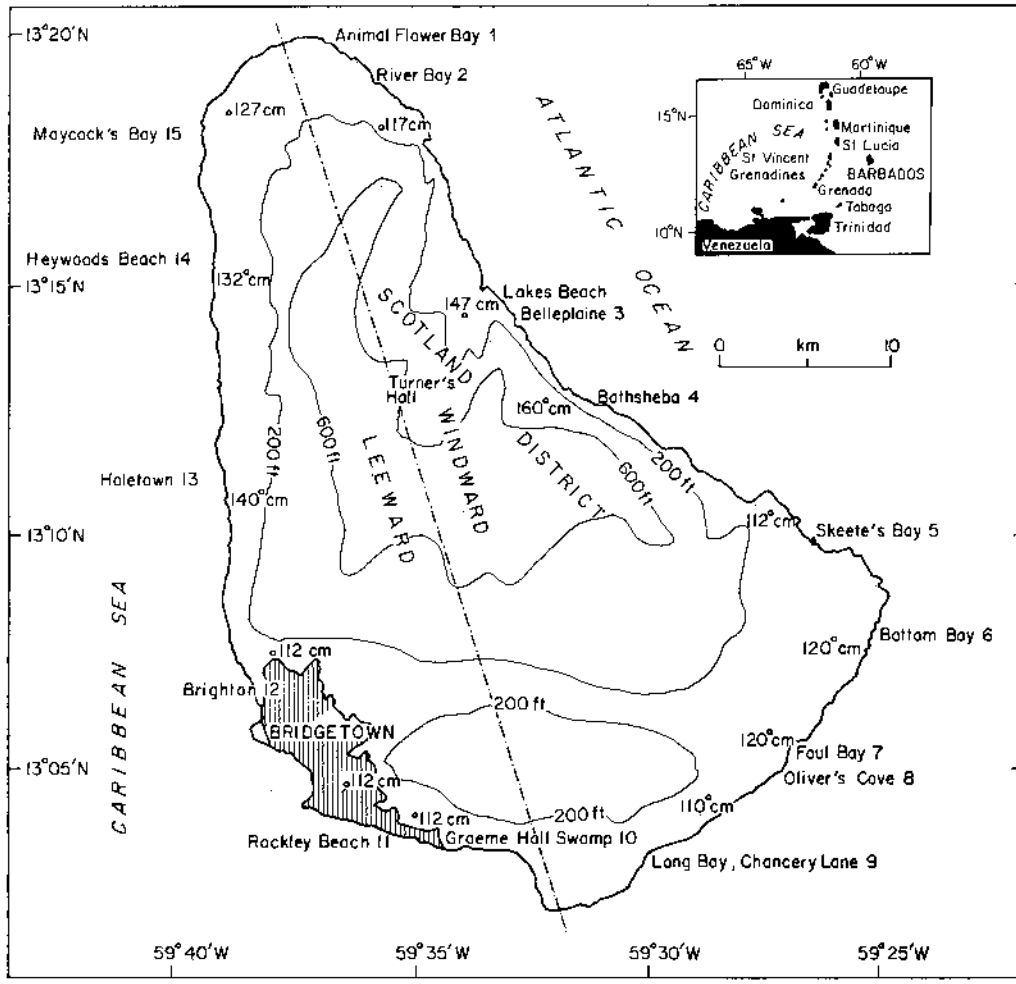

FIG. 1. Location map of Barbados showing the position of the fifteen sampling sites and average rainfall (cm) at coastal stations.

siliceous soils. Examples of orthogonal ranges are *Euphorbia mesembrianthemifolia* which is not found inland of mobile sand and *Andropogon intermedius* var. *acidulus* which is rarely present on the strand.

A flora of Barbados has been compiled recently by Gooding, Loveless & Proctor (1965) but there are limited ecological data. Beard's monograph (1949) includes a short discussion of the vegetation; Hardy (1934) gives a brief ecological study of the island, and there is also an historical treatment of the vegetation by Watts (1966). Studies were made by Gooding (1944) of Turner's Hall Woods and by Allan (1957) of Barbadian grasses.

Gooding (1947) has published the only article directly concerned with the coast: in this he examines the sand dunes of the west and south.

The coastline of the island, which according to McLean (1965) is 95 km long, is not greatly indented. It comprises 34 km of coral cliffs, 32 km of coral sand beach, 11 km of silica sand beach, 11 km of older sedimentary cliffs and 7 km of sea defences. Tidal

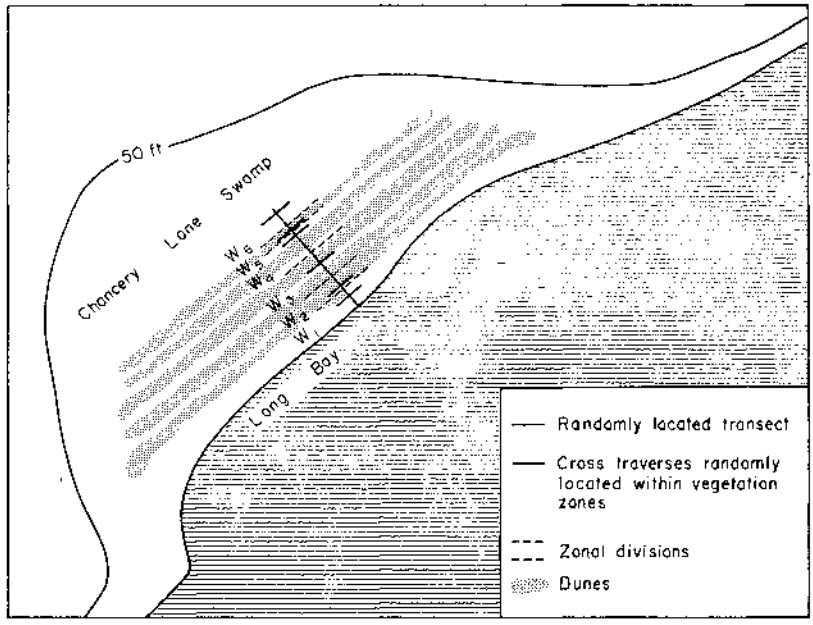

FIG. 2. A plan of the sample area at Chancery Lane, Long Bay, showing transect, traverses and zonal boundaries. Not to scale.

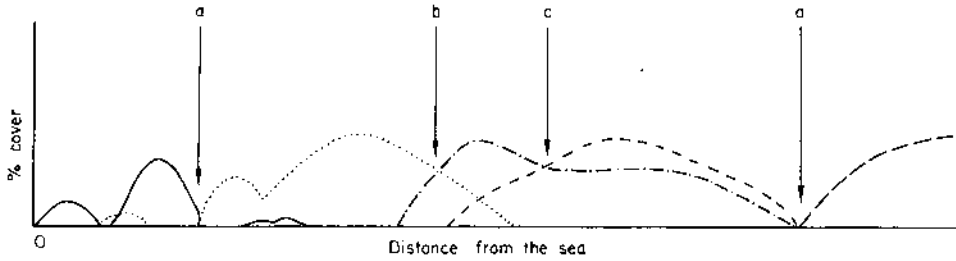

FIG. 3. Hypothetical example of zone recognition by means of superimposition of cover percentage histograms. Species: ——, 1; . . . . . , 2; — · — · —, 3; — — —, 4; – – –, 5. Boundary determined by a, change in species, b, change in density and species and c, change in density but not species.

range is about 1 m. Wave amplitude is considerably greater on the east coast than the west (Lewis 1960), and at the time of storm swells (Donn & McGinness 1959; Randall 1968b) great changes result in both the vegetation and physical environment.

METHODS

After a preliminary survey of all beaches on the island, fifteen were selected (Fig. 1) to illustrate major environmental factors. At each beach vascular plants were collected and

identified using the nomenclature of Gooding *et al.* (1965) and pedologic and climatic data were obtained. Soils were analysed for pH, salinity, carbon, calcium carbonate, moisture and grain-size (Randall 1969). Rainfall, evaporation, ground-surface and aerial salt, and wind data were collected over a 5-month period. Vegetation and environmental factors were sampled in contiguous quadrats along transects located at each beach by the use of random numbers. Transects began at estimated high water mark and ran inland orthogonal to the shoreline as far as the nearest cultivated land or road. This modification of gradient analysis (Whittaker 1967) has been used frequently in coastal studies (Poggie 1963; Sauer 1961, 1967a, b; Thom 1967). Reconnaissance work showed that little extra information was gained from more than one transect per beach but that small cross traverses, centred on the single transects and randomly located within zones based on the transect data, provide a suitable measure of transverse homogeneity within the data. Fig. 2 shows a plan of the sample area at Long Bay, Chancery Lane.

Recognition of zones

Histograms of cover percentage of the commoner species in each quadrat along the beach transects were plotted, then superimposed (Randall 1968b). A simplified, hypothetical example of this method of recognition is illustrated in Fig. 3. These histograms indicate that although no two species have identical distributions, 'community types' (Whittaker 1967), or zones having dominant species can be recognized. The histograms demonstrate that similar groups of sequential zones are present in three ecosystems of the island's coasts. Thus, a maximum of four zones occurs in coastal cliff ecosystems, seven on Windward beaches and dunes (whether silica or coral sand) and five on Leeward beaches. The widest zones usually are found on coastal cliffs and the narrowest on Leeward beaches. Where the zonal sequence is incomplete, this results from the influence of major environmental variables as in the case where a road crosses the upper part of the littoral. The reality of these zones is substantiated by data from the cross traverses and visual examination of the beaches. Although none of the beaches has an environment sufficiently similar to possess the same complement of species, many species repeatedly recur, reflecting external influences by their positions on the transects. Since both coastal cliff and beach may occur in the same transect on the Windward coast, in some circumstances only a partial sequence of zones may be developed in each ecosystem (see Fig. 7). In the descriptions following, cliff zones are prefixed with the letter 'C', Leeward beach zones with 'L' and Windward beach zones with 'W'.

THE VEGETATION

The coastal cliff ecosystem

Coastal cliffs are present only on the Windward coast of Barbados. Their vegetation was examined at Animal Flower Bay, River Bay, Skeete's Bay, Bottom Bay and Oliver's Cave (Fig. 1).

(a) *Type transect at Oliver's Cave*

Fig. 4 is a transect through coastal cliff vegetation at Oliver's Cave. This location is in the dry south-east of Barbados. The cliff faces south, rather than north-east, thus avoiding the most severe effects of the trade winds. The transect has been divided into four zones. The most seaward of these zones (C_1) is dominated by *Sesuvium portulacastrum**

* Nomenclature of species follows that by Gooding *et al.* (1965).

but also contains *Sporobolus virginicus*. A second zone (C_2) is demarcated where *S. virginicus* becomes dominant and *Sesuvium portulacastrum* dies out. Further inland (zone C_3) an increasing number of species are present, including *Egletes prostrata* and *Pectis humifusa*. In locations with extremely shallow soil *Strumpfia maritima* occurs. A

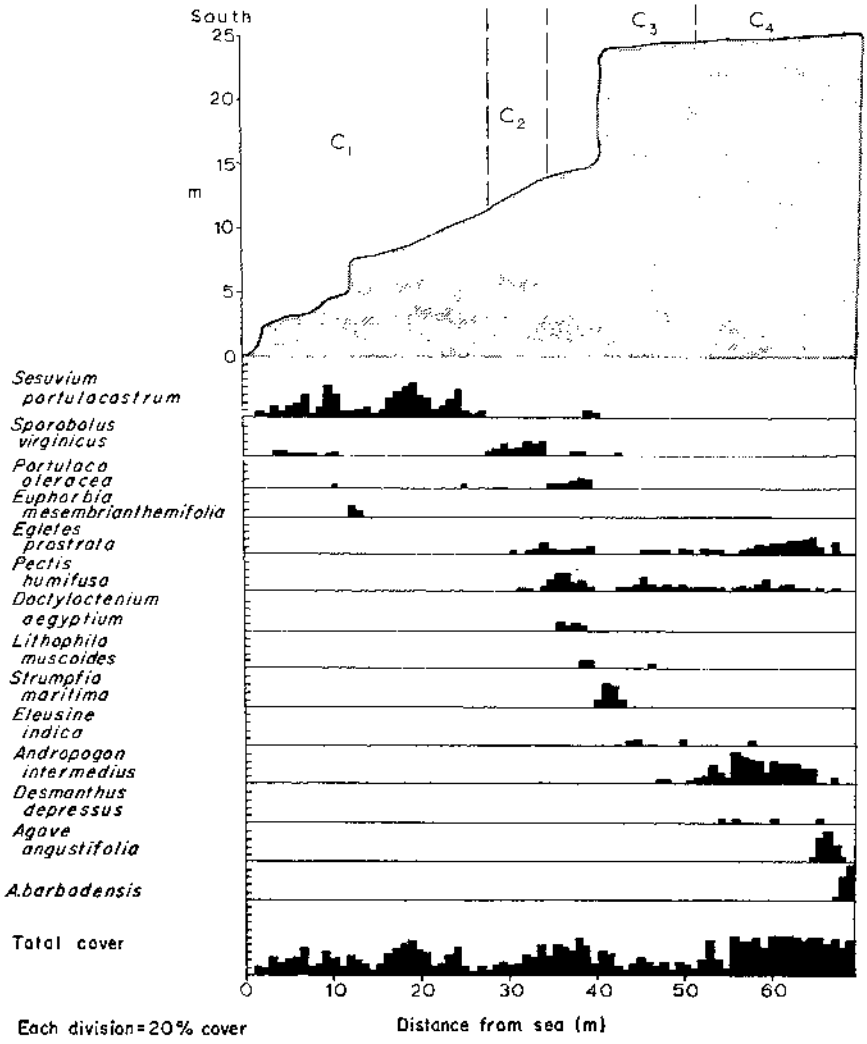

FIG. 4. Type transect at Oliver's Cave—an example of a coastal cliff location. In this and succeeding transects, zones located by the superimposition of cover values are plotted. Cover is graduated in 5% intervals estimated from vertical examination: hence a maximum of 100% cover.

fourth zone (C_4) is found adjacent to cultivated land where *Andropogon intermedius* var. *acidulus* dominates but *Agave angustifolia* and *A. barbadensis* are also present.

(b) *Other coastal cliff locations*

Four similar zones are found at Animal Flower Bay. Here the cliff falls sheer to the sea and all zones are developed on the cliff-top. This location faces north-east directly into

the trade winds and is consequently more severe. The zones are wider, stretching over 300 m instead of 80 m as at Oliver's Cave. The same species dominate the zones but a total of eighteen species is present. At River Bay, Skeete's Bay and Bottom Bay partial sequences occur. The transect from Bottom Bay (Fig. 7) contains the two inland zones (C_3 and C_4) of the cliff ecosystem.

The Leeward beach ecosystem

The Leeward coast of Barbados has the least adverse environment of the littoral. Vegetation of the sandy beach type was examined at Rockley Beach, Brighton Beach,

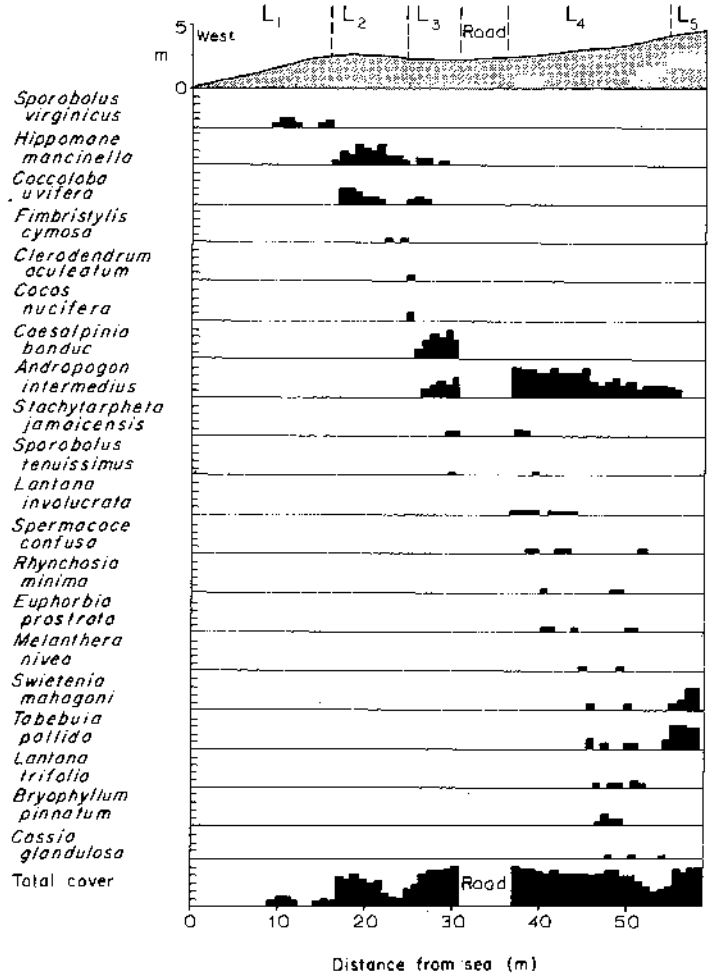

FIG. 5. Type transect at Maycock's Bay—an example of a Leeward beach location. Each division = 20% cover.

Holetown, Heywood's Beach and Maycock's Bay (Fig. 1). Mangrove swamp, such as at Graeme Hall, occurs at restricted locations on the Leeward coast.

(a) *Type transect at Maycock's Bay*

Fig. 5 shows a transect through Leeward beach vegetation at Maycock's Bay. The

five zones are much narrower than on cliffs, totalling only 60 m in width. The first two zones (L_1 and L_2) are developed on mobile sand. The seaward zone (L_1) has only a sparse cover of *Sporobolus virginicus*. The second (L_2) zone is dominated by *Hippomane mancinella* but in places *Coccoloba uvifera* grows as a small tree and occasional specimens of *Fimbristylis cymosa* occur in the understorey. Zone L_3 contains *Caesalpinia bonduc* with *Andropogon intermedius* var. *acidulus*. The fourth zone (L_4) has thirteen species but is dominated by *A. intermedius* as is the fourth zone of the cliff ecosystem. Zone L_5 is the coastal forest of *Swietenia mahagoni* and *Tabebuia pallida*.

(b) *Other Leeward beach locations*

The above complement of zones does not occur in full at the other Leeward beach sites examined. Zone L_5 has been removed at all the southern beaches to make way for human habitation. At Rockley Beach and Brighton, *Ipomoea pes-caprae* is present in most zones, especially L_4, but is rare further north. *Stachytarpheta jamaicensis* is also more common at the southern sites.

The Windward beach ecosystem

Many Windward beaches of Barbados possess dunes and hence have great topographic variation over short distances, and more zones result. Windward beach vegetation was

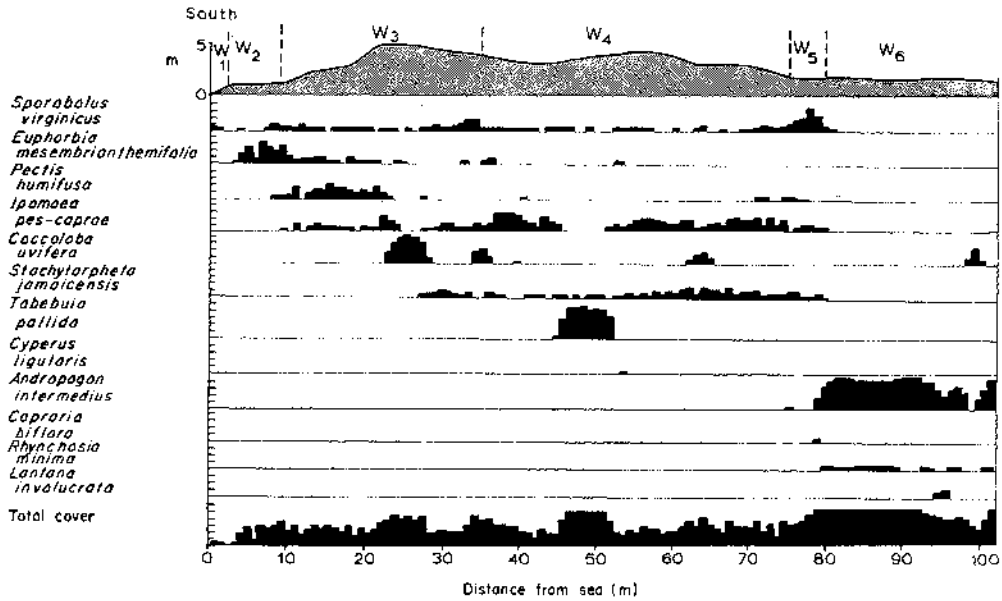

FIG. 6. Type transect at Chancery Lane, Long Bay—an example of a Windward beach location. Each division = 20% cover.

examined at Lakes Beach Belleplaine, Bathsheba, Skeete's Bay, Bottom Bay, Foul Bay and Long Bay, Chancery Lane (Fig. 1).

(a) *Type transect at Long Bay, Chancery Lane*

Fig. 6 illustrates the vegetation along a south-facing Windward beach transect at Long Bay, Chancery Lane. As on the Leeward coast, the most seaward zone (W_1) contains only *Sporobolus virginicus*. Zone W_2 is dominated by *Euphorbia mesembrianthemifolia*.

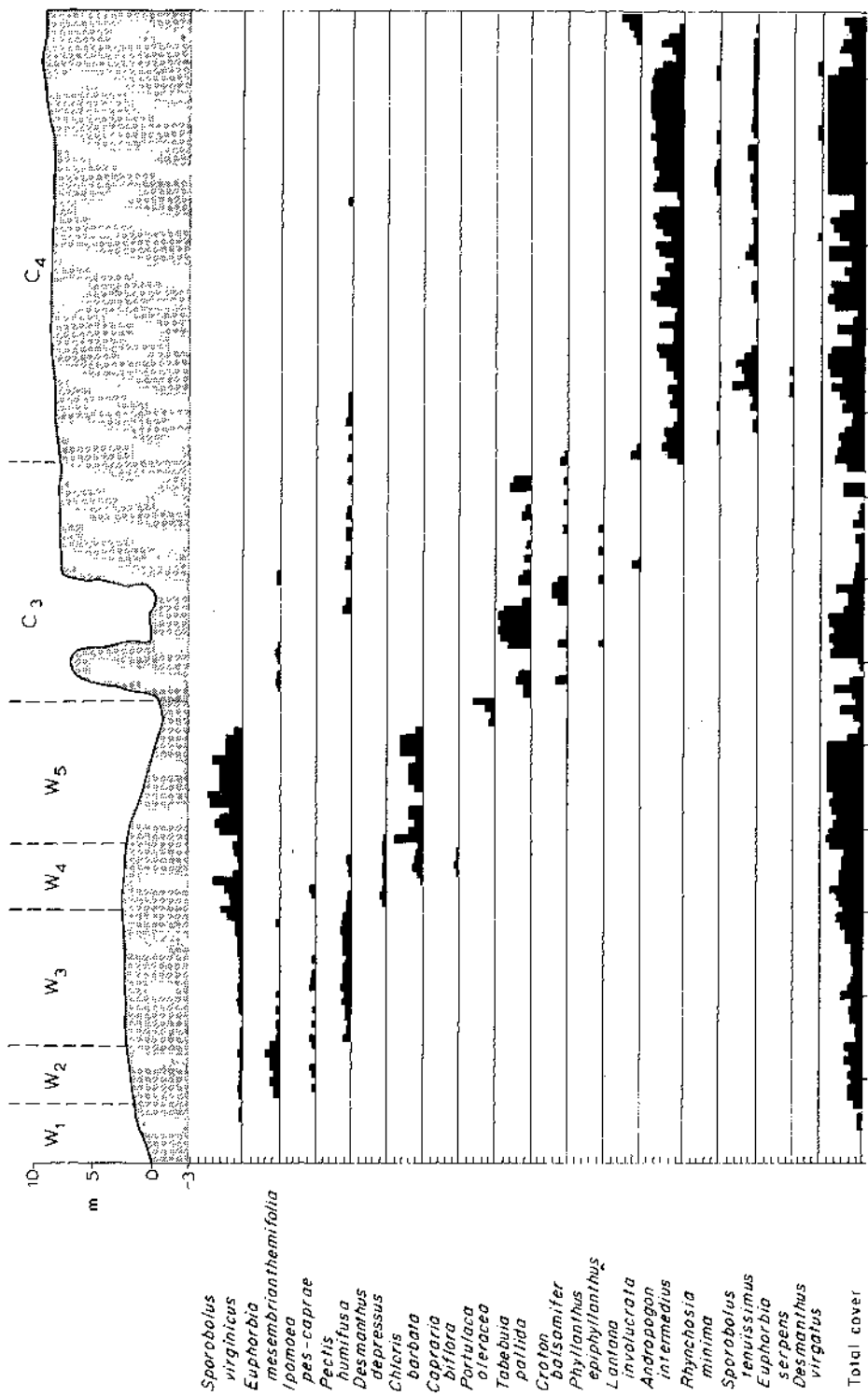

FIG. 7. Type transect at Bottom Bay. This shows the partial sequences that result when two coastal environments are juxtaposed. Each division = 20% cover.

Zone W_3 has three co-dominant species: *E. mesembrianthemifolia*, *Ipomoea pes-caprae* and *Pectis humifusa*. The zone includes the crest of the major foredune on which a dense cover of *Coccoloba uvifera* is found. A fourth zone (W_4) is dominated by *Ipomoea pes-caprae* with *Sporobolus virginicus*, *Stachytarpheta jamaicensis*, and occasional bushes of *Tabebuia pallida* also present. In zone W_5 *Sporobolus virginicus* becomes dominant again. At this location the dunes back onto a drained swamp covered by a sward of *Andropogon intermedius* var. *acidulus*.

(b) *Transect at Bottom Bay*

Fig. 7 shows a transect where coastal cliff and Windward beach are adjacent, and an incomplete sequence of zones within each ecosystem results. The seaward zones are similar to those at Long Bay, Chancery Lane. However, zone W_5 is both lower in elevation and more sheltered at Bottom Bay and a semi-stable grass sward of *Chloris barbata* and *Sporobolus virginicus* has developed. The rocky nature of zone C_3 results in *Tabebuia pallida* dominating but *Pectis humifusa* is also present. The landward zone has the same dominant, *Andropogon intermedius* var. *acidulus*, as other C_4 locations.

(c) *Other Windward beach locations*

Lakes Beach Belleplaine and Bathsheba are within the siliceous sand area, and consequently possess some different species. At both sites *Philoxerus vermicularis* dominates in zone W_2 and *Chrysobalanus icaco* is present in similar locations to *Coccoloba uvifera*. *Stachytarpheta jamaicensis* is not present east of Long Bay, and is replaced in zone W_4 by *Canavalia maritima* and also on siliceous sands by *Stenotaphrum secundatum*. At Lakes Beach Belleplaine and at Foul Bay, zones W_6 and W_7 are fully developed. In W_6 *Lantana involucrata*, *Croton balsamifer* and other species present in zone C_3 of coastal cliffs occur. In zone W_7 *Hippomane mancinella* and *Coccoloba uvifera* dominate as in zone L_2 of the Leeward beach ecosystem.

DISTRIBUTION OF SPECIES WITHIN ECOSYSTEMS AND ZONES

One hundred plant species were recorded growing on the Barbados littoral. Thirty-eight occurred at only one beach, forty-two were present at two to four beaches and twenty were present at more than four of the fifteen beaches sampled. If the species are examined by grouping them within the three ecosystems—coastal cliffs, Windward beaches and Leeward beaches—fifty-eight species are found to be limited to one or other of the three, thirty-four occur within two but not the third while eight are common to all three (Table 1).

On the cliffs twelve unique species were recorded. These are found predominantly in inland pastures but around the coast are limited to cliffs because they are favoured by the better developed soils present in the rear zones. Another group are those species which occur in dry, rocky habitats. Some of these may be limited to the rear zones of coastal cliffs, others may be seen widely inland. Two groups of species are restricted to the Windward beach zones: the psammophytes of the dunes, and those plants limited to siliceous sand soils. The Leeward beaches have the greatest number of unique species since their inner littoral zones are the least exposed of those studied. Nearly a quarter of the species are found only in mangrove swamps and the remainder are either tolerant inland weeds that can compete within the inner littoral, or garden escapes and deliberately planted species. No species are limited to the Leeward foreshore of the island.

Table 1. *Occurrence of species by gross environmental divisions*

Species	Coastal cliffs*	Windward beaches*	Leeward beaches*
Abrus precatorius	.	.	+
Agave angustifolia	+	.	.
A. barbadensis	+	+	.
Andropogon intermedius var. *acidulus*	+	+	+
Argemone mexicana	.	.	+
Avicennia schauerana	.	.	+
Bontia daphnoides	.	+	.
Bryophyllum pinnatum	.	+	+
Caesalpinia bonduc	.	+	+
Calotropis procera	.	+	.
Canavalia maritima	.	+	.
Capraria biflora	+	+	+
Cassia glandulosa var. *swartzii*	.	.	+
Casuarina equisetifolia	+	+	+
Catharanthus roseus	.	.	+
Cenchrus echinatus	+	.	+
Cephalocereus barbadensis	+	.	.
Chloris barbata	.	+	+
C. petraea	.	+	+
C. radiata	.	.	+
Chrysobalanus icaco	.	+	.
Clerodendrum aculeatum	+	.	+
Coccoloba uvifera	+	+	+
Cocos nucifera	.	+	+
Conocarpus erectus	.	.	+
Conyza canadensis	.	.	+
Corchorus aestutans	.	+	.
Cordia obliqua	.	.	+
C. sebestena	.	.	+
Croton balsamifer	+	+	.
C. lobatus	+	.	.
Cynodon dactylon	+	+	.
Cyperus ligularis	.	+	.
C. rotundus	.	.	+
C. sphacelatus	.	.	+
Dactyloctenium aegyptium	+	.	.
Delonix regia	.	.	+
Desmanthus depressus	+	+	.
D. virgatus	+	.	.
Echinochloa colonum	.	+	.
Egletes prostrata	+	+	.
Eleocharis mutata	.	.	+
Eleusine indica	+	+	.
Emilia coccinea	.	.	+
Eragrostis ciliaris	+	+	.
Euphorbia mesembrianthemifolia	+	+	.
E. prostrata	+	.	+
E. serpens	+	+	+
Ficus citrifolia	.	+	.
Fimbristylis cymosa	.	+	+
Heliotropium curassavicum	+	+	.
Hippomane mancinella	.	+	+
Hymenocallis caribaea	.	+	.
Hyptis pectinata	.	+	.
Ipomoea pes-caprae	+	+	+
I. tuba	+	.	.
Jacquinia arborea	+	.	.

Table 1 (*continued*)

Species	Coastal cliffs*	Windward beaches*	Leeward beaches*
Jasminium fluminense	.	.	+
Jatropha gossypifolia	+	.	+
Lantana involucrata	+	.	+
L. trifolia	+	.	+
Leonotis nepetifolia	.	.	+
Leucaena leucocephala	.	.	+
Lippia strigulosa	.	+	.
Lithophila muscoides	+	+	.
Mallotonia gnaphalodes	.	+	.
Melanthera nivea	.	.	+
Opuntia dillenii	+	.	.
Pandanus utilis	+	.	.
Paspalum vaginatum	.	.	+
Pectis humifusa	+	+	.
Philoxerus vermicularis	.	+	.
Phyllanthus epiphyllanthus	+	.	.
P. fraternus	.	.	+
Portulaca oleracea	+	+	.
Rhizophora mangle	.	.	+
Rhynchosia minima	+	.	+
Ruellia tuberosa	+	.	.
Ruppia maritima	.	.	+
Sansevieria metallica	.	.	+
Scoparia dulcis	.	.	+
Sesuvium portulacastrum	+	+	.
Spermacoce confusa	.	.	+
S. tenuior	+	.	+
Sporobolus pyramidatus	.	.	+
S. tenuissimus	+	.	+
S. virginicus	+	+	+
Stachytarpheta jamaicensis	.	+	+
Stenotaphrum secundatum	.	+	.
Strumpfia maritima	+	.	.
Stylosanthes hamata	+	.	+
Swietenia mahagoni	.	.	+
Tabebuia pallida	+	+	+
Tecoma stans	.	+	.
Tephrosia wallichii	.	+	+
Terminalia catappa	.	.	+
Thespesia populnea	.	.	+
Vigna vexillata	+	.	+
Wedelia trilobata	.	+	+

* Six locations studied.

Although species occurring on both cliffs and Windward beaches can in part be explained by geographic coincidence, there are also those plants that can tolerate an extremely harsh environment: the pioneers of the foreshore or overhanging rocks. These species contrast with those limited to cliffs and Leeward beaches, which occur in the inner littoral where a reasonable soil cover and low salinity are found. A small group of species, primarily psammophytes, occurs in both beach ecosystems but not on cliffs. Lastly there are species found within all three ecosystems. These are all extremely tolerant but vary widely in habitat. *Sporobolus virginicus* is everywhere found in foreward zones but *Andropogon intermedius* var. *acidulus* is limited to the rear zones. Different forms of *Coccoloba uvifera* and *Tabebuia pallida* occur in different habitats: both are found as trees on the Leeward coast but may grow as tiny shrubs on cliff faces.

Table 2 shows the distribution of the 100 species recorded within the zonal series.

Table 2. *Occurrence of species by zonal divisions*

Species	C_1	$C_2W_1L_1$	W_2	W_3	W_4	W_5	C_3W_6	W_7L_2	L_3	C_4L_4	L_5	Mangrove swamp
Abrus precatorius	.	.	.	.	.	.	.	.	.	+	.	.
Agave angustifolia	.	.	.	.	.	.	.	.	.	+	.	.
A. barbadensis	.	.	.	.	.	.	+	.	.	+	.	.
Andropogon intermedius var. *acidulus*	.	.	.	.	.	.	+	.	+	+	+	.
Argemone mexicana	.	.	.	.	.	.	.	.	.	+	.	+
Avicennia schauerana	.	.	.	.	.	.	.	.	.	.	.	+
Bontia daphnoides	.	.	.	.	+	.	.	.	.	.	.	.
Bryophyllum pinnatum	.	.	.	.	.	.	+	.	.	.	+	.
Caesalpinia bonduc	.	.	.	.	.	.	+	.	+	.	.	.
Calotropis procera	.	.	.	+	.	+	.	.	.	.	.	.
Canavalia maritima	.	.	.	+	+	.	.	.	.	.	.	.
Capraria biflora	.	.	.	.	.	.	+	.	.	+	.	.
Cassia glandulosa var. *swartzii*	.	.	.	.	.	.	.	.	.	+	.	.
Casuarina equisetifolia	.	.	.	.	.	.	+	.	.	+	.	.
Catharanthus roseus	.	.	.	.	.	.	.	.	.	+	.	.
Cenchrus echinatus	.	.	.	.	.	.	.	.	.	+	.	.
Cephalocereus barbadensis	.	.	.	.	.	.	.	.	.	+	.	.
Chloris barbata	.	.	.	.	+	+	+	.	.	+	.	.
C. petraea	.	.	.	.	+	.	.	.	.	+	.	.
C. radiata	.	.	.	.	.	.	.	.	.	+	.	.
Chrysobalanus icaco	.	.	+	+	.	+	.	.	.	.	.	.
Clerodendrum aculeatum	.	.	.	.	.	.	+	.	+	.	.	.
Coccoloba uvifera	.	.	.	+	.	+	+	+	+	+	.	.
Cocos nucifera	.	.	.	.	.	.	+	+	+	.	.	.
Conocarpus erectus	.	.	.	.	.	.	.	.	.	.	.	+
Conyza canadensis	.	.	.	.	.	.	.	.	.	+	.	.
Corchorus aestutans	.	.	.	.	.	+	+	.	.	.	.	.
Cordia obliqua	.	.	.	.	.	.	.	.	.	+	.	.
C. sebestena	.	.	.	.	.	.	.	.	+	+	.	.
Croton balsamifer	.	.	.	.	.	.	+	.	.	+	.	.
C. lobatus	.	.	.	.	.	.	.	.	.	+	.	.
Cynodon dactylon	.	.	.	.	.	.	+	.	.	.	.	.
Cyperus ligularis	.	.	.	.	+	+	.	.	.	.	.	.
C. rotundus	.	.	.	.	.	.	.	.	.	+	.	.
C. sphacelatus	.	.	.	.	.	.	.	.	+	+	.	.

Dactyloctenium aegyptium	.	.	.	.	.	.	+	.	.	.	.	.
Delonix regia	.	.	.	.	.	.	.	.	.	+	+	.
Desmanthus depressus	.	.	.	.	+	.	+	.	.	+	.	.
D. virgatus	.	.	.	.	.	.	.	.	.	+	.	.
Echinochloa colonum	.	.	.	.	.	+	.	.	.	.	.	.
Egletes prostrata	.	+	.	.	.	+	+	.	.	.	.	.
Eleocharis mutata	.	.	.	.	.	.	.	.	.	.	.	+
Eleusine indica	.	.	.	.	.	.	+	.	.	+	.	.
Emilia coccinea	.	.	.	.	.	.	.	.	.	+	.	.
Eragrostis ciliaris	.	.	.	.	.	.	+	.	.	+	.	.
Euphorbia mesembrianthemifolia	+	+	+	+	.	.	.	.	.	.	.	.
E. prostrata	.	.	.	.	.	.	+	.	.	+	.	.
E. serpens	.	.	.	.	.	+	+	.	.	+	.	.
Ficus citrifolia	.	.	.	.	.	.	+	.	.	.	.	.
Fimbristylis cymosa	.	.	.	.	.	.	.	+	+	+	+	.
Heliotropium curassavicum	.	.	.	.	+	.	+	.	.	.	.	.
Hippomane mancinella	.	.	.	.	.	.	.	+	+	+	.	.
Hymenocallis caribaea	.	.	.	.	.	+	.	.	.	.	.	.
Hyptis pectinata	.	.	.	.	+	+	.	.	.	.	.	.
Ipomoea pes-caprae	.	.	+	+	+	+	+	.	+	+	.	.
I. tuba	.	.	.	.	.	.	.	.	.	+	.	.
Jacquinia arborea	.	.	.	.	.	.	.	.	.	+	.	.
Jasminium fluminense	.	.	.	.	.	.	.	.	.	+	+	.
Jatropha gossypifolia	.	.	.	.	.	.	+	.	.	+	.	.
Lantana involucrata	.	.	.	.	.	.	+	.	.	+	.	.
L. trifolia	.	.	.	.	.	.	.	.	.	+	.	.
Leonotis nepetifolia	.	.	.	.	.	.	.	+	.	+	.	.
Leucaena leucocephala	.	.	.	.	.	.	.	.	.	+	.	.
Lippia strigulosa	.	.	.	.	.	+	.	.	.	.	.	.
Lithophila muscoides	.	.	.	.	.	.	+	.	.	.	.	.
Mallotonia gnaphalodes	.	.	+	.	.	.	.	.	.	.	.	.
Melanthera nivea	.	.	.	.	.	.	.	.	.	+	.	.
Opuntia dillenii	.	.	.	.	.	.	+	.	.	.	.	.
Pandanus utilis	.	.	.	.	.	.	.	.	.	+	.	.
Paspalum vaginatum	.	.	.	.	.	.	.	.	.	.	.	+
Pectis humifusa	+	+	+	+	+	+	+	.	.	+	.	.
Philoxerus vermicularis	.	.	+	.	.	.	.	.	.	.	.	.
Phyllanthus epiphyllanthus	.	.	.	.	.	.	+	.	.	+	.	.

Table 2 (*continued*)

Species	C_1	$C_2W_1L_1$	W_2	W_3	W_4	W_5	C_3W_6	W_7L_2	L_3	C_4L_4	L_5	Mangrove swamp
Phyllanthus fraternus	.	.	.	.	.	.	.	.	.	+	.	.
Portulaca oleracea	+	+	.	.	.	+	.	.	.	.	.	.
Rhizophora mangle	.	.	.	.	.	.	.	.	.	.	.	+
Rhynchosia minima	.	.	.	.	.	.	+	.	.	+	.	.
Ruellia tuberosa	.	.	.	.	.	.	.	.	.	+	.	.
Ruppia maritima	.	.	.	.	.	.	.	.	.	.	.	+
Sansevieria metallica	.	.	.	.	.	.	.	.	.	+	.	.
Scoparia dulcis	.	.	.	.	.	.	.	.	.	+	.	.
Sesuvium portulacastrum	+	+	.	.	.	.	.	.	.	.	.	.
Spermacoce confusa	.	.	.	.	.	.	.	.	.	+	.	.
S. tenuior	.	.	.	.	.	.	.	.	.	+	.	.
Sporobolus pyramidatus	.	.	.	.	.	.	.	.	+	+	.	.
S. tenuissimus	.	.	.	.	.	.	.	.	.	+	.	.
S. virginicus	+	+	+	+	+	+	+	.	.	.	.	.
Stachytarpheta jamaicensis	.	.	.	+	+	.	.	+	.	+	+	.
Stenotaphrum secundatum	.	.	.	.	+	+	.	.	.	.	.	.
Strumpfia maritima	.	.	.	.	.	.	+	.	.	.	.	.
Stylosanthes hamata	.	.	.	.	.	.	.	.	.	+	.	.
Swietenia mahagoni	.	.	.	.	.	.	.	+	.	+	+	.
Tabebuia pallida	.	.	.	.	+	.	+	+	+	+	+	.
Tecoma stans	.	.	.	.	.	+	.	.	.	.	.	.
Tephrosia wallichii	.	.	.	.	.	.	+	.	.	+	.	.
Terminalia catappa	.	.	.	.	.	.	.	.	.	+	.	.
Thespesia populnea	.	.	.	.	.	.	.	.	.	+	.	+
Vigna vexillata	.	.	.	.	.	.	.	.	.	+	.	.
Wedelia trilobata	.	.	.	.	.	+	.	.	.	.	.	.

Zones placed in order of decreasing maritime influence from left to right. Dominants in each zone indicated in bold type.
C, Coastal cliffs; W, Windward beaches; L, Leeward beaches.

Table 3. *Generalized averages of some environmental data within zones*

Zone	Coastal cliffs				Windward beaches and dunes							Leeward beaches				
	C_1	C_2	C_3	C_4	W_1	W_2	W_3	W_4	W_5	W_6	W_7	L_1	L_2	L_3	L_4	L_5
Aerial salt (μmho/cm/24 h)*	4000	3500	1000	400	3750	3500	3000	2500	1000	500	250	250	150	150	100	80
Ground surface salt (μmho/cm/24 h)†	1500	1100	300	250	550	500	600	1000	500	800	250	150	100	80	75	50
Soil salt (μmho/cm/6 g sample)‡	10000	7000	700	250	450	400	150	450	180	150	100	200	175	150	150	125
Clay (%) (hydrometer)	20·0	25·0	30·0	30·0	0·1	0·1	0·1	5·0	0·5	0·5	5·0	0·1	5·0	15·0	20·0	25·0
Organic matter (%) (wet combustion × 1·72)	1·25	2·50	3·00	3·80	0·01	0·03	0·07	0·30	0·50	0·50	1·00	0·05	1·00	2·00	3·50	3·50
$CaCO_3$ (%) (Collins' calcimeter)	35	6	5	5	10§ 98¶	10 98	10 98	12 98	12 98	15 85	15 35	90	80	45	16	10
pH (electrode)	7·8	7·6	7·5	7·1	8·0	8·0	8·0	7·9	7·9	7·8	7·8	7·9	7·8	7·6	7·6	7·4

* Collected on 1000 cm² towels and conductance measured in 300 ml H_2O.
† Collected on 250 cm² towels and conductance measured in 75 ml H_2O.
‡ Shaken for 1 h in 50 ml H_2O.
§ Scotland coast.
¶ Coralline coast.

Certain zones from different ecosystems have a similar complement of species and have been classed together. Generally the number of species present in each zone increases with distance away from the sea. The absence of this trend in zones W_7 and L_2 is due to the dominance of *Hippomane mancinella* which exudes a toxic secretion fatal to all but a few hardy species. Similarly L_3 is dominated by *Caesalpinia bonduc* which grows so densely that few other species can compete. Zone L_5 represents the coastal forest in which almost all species except *Tabebuia pallida* and *Swietenia mahagoni* are shaded out. Another trend is an increase in cover and height with distance inland. The most seaward zones have mat and trailing species, the intermediate zones have grasses and low shrubs and the zones abutting inland vegetation have tall shrubs and trees.

Few species are limited to only one zone (Table 2), and there is enough floristic continuity between adjacent zones in the field to show that all are part of a larger unit, the littoral. A quite abrupt increase in number and type of species is found between zones W_5 and W_6C_3 representing the division between 'outpost' and 'inner littoral' species (Sauer 1961).

DISTRIBUTION OF ENVIRONMENTAL VARIABLES

Table 3 shows a generalization of some environmental parameters within the zones of the three ecosystems. Although certain zones from different ecosystems could be grouped together on the basis of similar floras (Table 2), these show distinct differences in environmental parameters such as salinity. Nevertheless the environmental parameters show progressive changes through the floristic zonal sequences such as decreasing salinity and increasing clay content with distance inland (Table 3). Anomalies to these trends occur on the Windward coast dunes where salt both within the soil and on the ground surface, and clay contents, are higher in the lee of foredunes and vary directly with height on rear dunes (Randall 1968a, b). The trend of the calcium carbonate content, which generally decreases going inland, is reversed in some siliceous sand areas (Randall 1969).

Since these environmental parameters are graded along a continuum they do not show discontinuity at floristic zone divisions. Nevertheless many of them vary so rapidly that the parameters in the core areas of adjacent zones may be extremely different. Vegetation and environment gradients of this type are useful indications of the causes of species behaviour but should not be interpreted in a direct cause/effect manner.

The reason that similar vegetation is found in areas with different environmental parameters is that a similar net effect may be produced by the interaction of the various parameters. The environmental gradients described are better thought of as expressions of environment complexes rather than single factors directly affecting behaviour of single species.

In coastal cliff soils large quantities of clay are found which can retain the salt particles. It will be seen that zones C_1 and C_2 are more saline than pioneer zones elsewhere (Table 3). However, the fallout of salt particles from the air decreases rapidly with distance inland and there is a concomitant amelioration of the habitat in this ecosystem. Since the zones shown in Table 2 are placed in order of decreasing maritime influence, zones C_2 and C_3 are not adjacent. On Windward beaches, where soil particles are large and the clay content small, little salt is trapped in the soil. Thus with distance inland salt content becomes insignificant as a vegetation control. But the grain-size of soil particles does not change rapidly as distance from the sea increases. Since this parameter affects the content of both soil-moisture and organic matter content, it becomes the more important factor

in vegetation distribution. On Leeward coasts adverse qualities of both soil and salt place L_1 with other zones of harsh environment. Since zones L_3–L_5 have few adverse factors they occur as the least harsh zones of the littoral.

COMPARISON WITH OTHER TROPICAL AREAS

There are few published sources concerning other tropical coastal areas with which these data can be compared. Gooding's work (1947) is limited to the sand dune areas of Barbados and extensive building in the interim period has changed several of his sites beyond recognition. However, Gooding's ecological divisions of the dunes do not seem to apply at the present time and it is apparent that such divisions cannot truly be made on the basis of one major species but rather on groups of species, gradually evolving and declining spatially. None of the studies by Sauer (1959, 1967b) or Poggie (1963), in other tropical areas, attempts to relate the location of vegetation to environmental data. The most interesting comparison is with the work of Sauer (1961) in Mauritius. He concludes that the coastal vegetation forms two groups 'divided by unlike tolerances of the sea as a habitat factor'. Unfortunately his environmental data are not quantified and cannot be directly compared. Nevertheless it seems that where somewhat similar conditions to those of Barbados prevail, a similar situation results in the littoral vegetation.

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SUMMARY

Vegetation on selected beaches around Barbados is described by means of transects of contiguous quadrats orthogonal to the shore. By means of the technique of superimposing histograms of the data on each species along each transect, three series of zones have been distinguished within the vegetation. A maximum of four zones occurs in coastal cliff ecosystems, five on Leeward beaches and seven on Windward beaches and dunes. In these three ecosystems similar zonal series recur, though where coastal cliffs are found at the same location as Windward beaches, two partial series are present. Some species are limited to certain zones within the three ecosystems by reason of aridity, ground and air salinity, sand petrology, soil development and soil grain-size. A few tolerant species are found in all three ecosystems and some zones from different ecosystems have a similar complement of species. The number of species present and total biomass generally increase with distance from the sea. Environmental parameters are not divisible into zonal series but do show rapid progressive changes with distance inland. The occurrence of similar vegetation in widely different habitats can be ascribed to the interaction of the various environmental factors within the different ecosystems.

REFERENCES

Allan, J. A. (1957). The grasses of Barbados. *Colon. Res. Publs*, **23.**
Beard, J. S. (1949). The natural vegetation of the Windward and Leeward Islands. *Oxf. For. Mem.* **21.**

Dinger, J. E. (1962). Spectra of ocean waves and microseisms as related to storms at sea. *Rep. U.S. nav. Res. Lab.* 5084.

Donn, W. L. & McGinness, W. T. (1959). Barbados storm swell. *J. geophys. Res.* **64,** 2341–9.

Gooding, E. G. B. (1944). Turner's Hall Wood, Barbados. *Caribb. Forester*, **5,** 153–70.

Gooding, E. G. B. (1947). Observations on the sand-dunes of Barbados, British West Indies. *J. Ecol.* **34,** 111–25.

Gooding, E. G. B., Loveless, A. R. & Proctor, G. R. (1965). *Flora of Barbados.* London.

Hardy, F. (1934). *Some Aspects of the Flora of Barbados.* Barbados Advocate.

Lewis, J. B. (1960). The coral reefs and coral communities of Barbados, W.I. *Can. J. Zool.* **38,** 1133–45.

McLean, R. (1965). *Mechanical and biological erosion of beachrock in Barbados.* Ph.D. thesis, McGill University.

Poggie, J. J. (1963). Coastal pioneer plants and habitat in the Tampico region, Mexico. *La St. Univ. cstl Stud. Ser.* **6.**

Randall, R. E. (1968a). Measurements of aerial salt on the coast of Barbados. *McGill Univ. Publs (Clim. Bull.)*, **3,** 23–35.

Randall, R. E. (1968b). *Vegetation zones and environment on the Barbados coast.* M.Sc. thesis, McGill University.

Randall, R. E. (1969). The coastal soils of Barbados. *J. Barbados Mus.* **33,** 25–7.

Sauer, J. D. (1959). Coastal pioneer plants of the Caribbean and Gulf of Mexico. *Unpubl. Rep., Project N. R.* 388–047, Geog. Branch, O.N.R.

Sauer, J. D. (1961). Coastal plant geography of Mauritius. *La St. Univ. cstl Stud. Ser.* **5.**

Sauer, J. D. (1967a). *Plants and Man on the Seychelles Coast.* Madison, Wisconsin.

Sauer, J. D. (1967b). Geographic reconnaissance of seashore vegetation along the Mexican Gulf coast. *Tech. Rep. cstl Stud. Inst. La St. Univ.* 1–59.

Senn, A. (1946). Geologic investigations of the ground-water resources of Barbados. *Rep. Br. Un. Oil Co.* 1–110.

Skeete, C. C. (1963). A description of the weather of the island of Barbados. *Unpubl. Rep. Woods Hole oceanogr. Instn*, 63–19, pp. 1–284.

Thom, B. G. (1967). Mangrove ecology and deltaic geomorphology in Tabasco, Mexico. *J. Ecol.* **55,** 301–43.

Trechmann, C. T. (1925). The Scotland beds of Barbados. *Geol. Mag.* **62,** 481–504.

Vernon, K. C. & Carroll, D. M. (1966). *Soil and Land-use Surveys.* No. 18. *Barbados.* Trinidad.

Watts, D. (1966). Man's influence on the vegetation of Barbados, 1627–1800. *Occ. Pap. Univ. Hull (Geog.)*, **4,** 1–96.

Whittaker, R. H. (1967). Gradient analysis of vegetation. *Biol. Rev.* **42,** 207–64.

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