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The natural vegetation of Canton Island,
an equatorial Pacific atoll

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INTRODUCTION

Canton Island (Lat. 2° 50'S., Long. 171° 38'W), a British-American condominium situated in the Phoenix Group, has gained in political and economic importance since 1939, largely because Pan-American Airways in that year established a permanent refueling station there, building a hotel on the south side of the island. In 1946 the United States Civil Aeronautics Administration set up a base on Canton. The island was occupied by United States military forces during the war years 1942-1945, when extensive construction and grading work was done. Before 1939 the island was uninhabited, being visited only infrequently by occasional guano diggers (Bryan 1942).

At the request of Mr. Garrison Costar, of the Civil Aeronautics Administration, a floristic and vegetational survey of Canton Island was conducted by Dr. Otto Degener and the author from July 11 to July 19, 1950. The island was revisited by the author in February 1951 and by Dr. Degener in April and May 1951. As a result of these surveys, recommendations were made leading to the introduction of many species of ornamental and otherwise useful plants. This paper is a report on the structure, distribution and ecology of the natural vegetation of Canton Island.

PHYSICAL ENVIRONMENT

Canton Island is a coral atoll approximately 21 miles in circumference (Fig. 1). The land surface is at no place wider than 3200 feet, and maximum elevation is about 20 feet above mean sea level. Local relief is slight, but a considerable proportion of the land surface is of sufficiently low elevation to be subject at high tide to the influence of a brackish water table. Such swales are occupied by a characteristic vegetation, as is discussed below. Along the ocean side of the northern portion of the island high dunes have formed, and the scanty vegetation of Triumfetta procumbens which occurs there has a distinctly xeric aspect.

The soil of Canton Island is derived from fragments of coral rock and calcareous sand deposited by waves and wind on a reef flat. Its texture is mostly rather coarse. In all places investigated a dark brown layer, from 7 to 15 inches thick, underlies the upper inch of sand or coral rock, or occurs at the surface of the ground. This dark layer, which contains a large proportion of guano, is believed to be of considerable significance in the development of the present vegetation of Canton Island.

During most of the year Canton Island is hot and humid, although actual precipitation is scanty. Mean annual rainfall is about 19 inches,

1/ The Rockefeller Foundation, Medellin, Colombia.

only the months March through August receiving over one inch of precipitation, on the average. Indeed, the months September through February constitute a well defined dry season, which attains its greatest intensity, on the average, in November. Extremely heavy precipitation has been reported in two years. In 1940, 70.60 inches of rainfall were recorded, while in the first eight months of 1941, 90.80 inches were reported. The records are to be interpreted with some caution, for there are indications that in at least one case data was incorrectly reported. It is undoubtedly true, however, that exceptionally heavy precipitation was received in those years, since Van Zwaluwenburg (1943) has shown by photographs the unusually luxuriant vegetation that developed in 1941, and stated that pools of standing water were of sufficient duration to allow insects with aquatic larvae to complete their life-cycles. Additional evidence for the great variability in annual rainfall on Canton can be derived from reliable records of only 8.46 inches total precipitation in 1947 and as much as 33.17 inches in 1948. It should also be emphasized that exceedingly heavy downpours often are followed by weeks of drought: thus the total precipitation of even a wet month may be received in two or three storms.

Very little variation in temperature occurs throughout the year. Mean annual temperature is about 84°F. The maximum recorded temperature for the three year period 1947-1949 was 98°F., the minimum 71°F. Relative humidity is constantly rather high, varying from a recorded minimum of 57 per cent to a maximum of 85 per cent. Average relative humidity at 1 p.m. is about 62 per cent. A very constant strong easterly wind is an outstanding feature of the Canton climate, and may affect the development of the natural vegetation. Planted ornamental trees and shrubs are commonly severely wind-clipped. Salt spray is undoubtedly a factor contributing to the stunting of the vegetation in some locations on Canton.

FLORA

The native flora of Canton Island is not rich, consisting of 14 species of vascular plants in as many genera. In addition, approximately 150 species have been introduced as ornamentals or adventive weeds. With only a few exceptions, the native flora is composed of wide-ranging Indo-Pacific strand plants, of which Scaevola frutescens may be cited as a typical example. The fruits or seeds of most of these species exhibit striking adaptations for floating.

The native vascular flora is largely confined to those parts of Canton Island which have not been subject to grading or other cultural operations. A weedy flora best characterized by the troublesome but short-lived sandbur, Cenchrus echinatus, dominates the semi-natural vegetation in the vicinity of the Pan-American Hotel, the Airlines Terminal, and the CAA Housing Areas during the wetter months of the year. It is a striking fact that this introduced flora has had very little tendency to invade the vegetation of those parts of the island which have not been subject to much human disturbance. Since this paper is concerned only with this "natural" vegetation, no further reference to the weed flora will be made.

NATURAL VEGETATION

The natural vegetation of Canton Island can be conveniently separated into three major types: communities dominated by trees, shrubs or herbs. All are relatively simple in composition and can easily be delineated on a map (Fig. 1). The results of planimeter measurements of the areas dominated by the plant communities recognized on Canton Island are presented in Table I.

TABLE I

Approximate areas included in the plant communities of Canton Island

Vegetation Type	:Per cent of :total land area:	:Per cent of land :area covered by :native vegetation :	:Approximate :area in acres
Cordia forest	: 0.29	: 0.81	: 8.3
Messerschmidia forest	: 1.05	: 2.92	: 30.0
Scaevola scrub	: 6.17	: 17.11	: 176.0
Suriana-Sesuvium flats:	88.58	: 23.80	: 244.9
Portulaca herbaceous community	: 19.96	: 55.37	: 569.6
Areas naturally bare	: 23.37	: ---	: 667.0
Disturbed areas	: 40.60	: ---	: 1,158.7
Total	: 100.02	: 100.01	: 2,854.5

The Cordia Forest--Well developed stands of Cordia subcordata exist today only on the south side of the island, less than one mile from Musick Light (Fig. 1). There two groves of trees flourish, covering about 3500 and 2700 square feet respectively. Other small groves of Cordia occur scattered around the island, but in those the trees are mostly leafless and in some cases actually dead.

The two groves of vigorous trees consist of pure stands of Cordia averaging about 19 feet in height; the tallest tree observed was 24 feet tall. Both forests are in reality nearly impenetrable thickets. Since Cordia on Canton Island reproduces chiefly by ground layering, the numerous shoots arising from decumbent branches make walking through the grove in a straight line virtually impossible. On the basis of a sample plot of approximately 400 square feet, in which 23 upright stems between 2 and 9 inches in diameter were counted, basal area was approximately 272 square feet and density about 2450 stems per acre. Average height to the first branch was only 29 inches, greatest length of clear bole being 75 inches. Light reaching the ground level in Cordia forest is rather diffuse; intensities as measured with a Weston photographic light meter inside the grove were only 5 to 10 per cent of those obtained outside. The ground is littered with dead branches, fruits, and a few leaves. Reproduction from seed within the grove is practically non-existent, but many Cordia seedlings which had recently germinated were observed near the periphery of the groves, most of them severely wilted. A small pit dug in the soil

inside the larger grove revealed a very dark sandy loam extending from the ground surface to a depth of about seven inches. Underlying the dark horizon was a layer of coarse sand which graded into fragments of coral rock and sand at a depth of 10 to 21 inches. The dark surface layer is interpreted as being composed chiefly of a mixture of guano and sand with addition of humus derived from rotting leaves and wood.

The Cordia groves are during the heat of the day a shelter for land hermit crabs (Cenobita perlatus). Large numbers of crabs may be found under fallen logs and branches and even climbing in the trees; two hermit crabs were discovered perched in a tree 69 inches above the ground. The crabs seem to do little damage to the trees. In some cases, however, young shoots have been stripped of bark and this mischief possibly may be attributed to the crabs.

A much more serious enemy of Cordia is the moth Achaea janata (L.) Caterpillars were abundant in both groves in July 1950, and it was observed that many shoots had been completely defoliated by these insects; nearly every leaf showed some damage. About 8 months later the author observed that the smaller of the two groves had been completely defoliated. Because of the depredations of this insect, it appears unlikely that Cordia subcordata will extend its range on Canton Island in the absence of control measures. This is unfortunate, since this tree is perhaps the most desirable species now known for purposes of afforestation. It is relatively large, has attractive flowers and foliage, and appears to be well adapted to the physical environment of Canton Island.

The Messerschmidia Forest.--Only one healthy, well developed stand of Messerschmidia argentea exists on Canton Island. This grove is situated a few hundred yards west of the principal airstrip, on the north side of the island. Another grove consisting of dead or dying trees was found southeast of the "fighter airstrip," and many isolated trees grow scattered about the island.

The healthy grove was studied in some detail. It was 158 feet long and from 35 to 51 feet wide; total area was about 7000 square feet, or 0.6 acre. The average height of the trees was about 15 feet, the largest tree in the grove being 19 feet tall. Like the Cordia forest, the Messerschmidia grove was in most places a tangle through which one proceeded only with difficulty. The trees branched at an average of 18 inches above the ground, and reproduction within the grove was apparently entirely by root suckers. A sample plot of 675 square feet was set out inside the grove, within which 18 living upright stems between two and eight inches in diameter were counted. The calculated density was therefore about 1160 stems and the basal area approximately 132 square feet per acre. Thus both in density of stems and basal area the figures for Messerschmidia forest were about one half those obtained in Cordia forest. The light intensity at ground level was correspondingly greater than in Cordia forest, being about 25 per cent of that outside the grove. Possibly because of the relatively high light intensity, a scattering of plants of Portulaca lutea, Boerhavia tetrandra, Setaria verticillata and Lepturus repens, all shade-intolerant plants, were established in the understory of the Messerschmidia grove. Soil profile studies revealed a

pattern similar to that in the Cordia grove. A dark sandy loam, presumably derived chiefly from coral sand, guano and leaf and branch litter overlay a light-colored sand, which contained fragments of coral rock.

Like the Cordia grove, the Messerschmidia forest is a favorite shelter during the warm daylight hours for large numbers of hermit crabs. No damage attributable to the crabs or to insects may be observed in the grove. It is believed that the crabs forage chiefly by night, but feeding habits are imperfectly known. One crab was observed to devour a flower of Portulaca lutea, however, and it is suspected that damage done to planted New Zealand spinach (Tetragonia tetragonioides) may be attributed to the crabs.

The Scaevola Scrub--On Canton Island Scaevola frutescens becomes a shrub ten feet tall and in some places nearly 50 feet in diameter. Reproduction proceeds radially from the oldest and tallest plant in the center of a clump, so that what may appear to be a single enormous bush may actually consist of many individuals belonging to several generations. Scaevola occurred in extensive, nearly pure stands at the southeast corner of Canton Island; other species occurring occasionally in the Scaevola scrub are Messerschmidia argentea, Sida fallax, Boerhavia tetrandra and Portulaca lutea.

In order to determine the approximate density of the Scaevola scrub, a sample plot of 625 square feet was laid out in a randomly selected area within the vegetation type. 12 Scaevola bushes were counted, the tallest eight feet high. This is a density of one bush per 52 square feet. Along a 1000-foot line transect, 115 bushes were counted, or one bush per 8.7 feet. The surface horizon of the soil is a stony sandy loam, containing considerable amounts of guano.

An interesting feature of this tract of Scaevola scrub is the enormous number of seabirds roosting and nesting in the shrubs. Frigate birds (Fregata minor palmerstoni) and red-footed boobies (Sula sula rubripes) predominate. In July many adults, young and eggs of both species were observed, but by February the boobies had largely disappeared. To estimate the number of birds roosting in a single bush, counts were made on the night of July 16 in the Scaevola scrub in the southeast corner of the island. Five bushes, each about 10 feet tall and ranging in area from 300 to 2000 square feet each were studied. As many as 45 birds were counted in a single bush; the average population for the five bushes studied was 34 birds per bush, that is roughly one bird per 30 square feet of bush. It appears not unlikely that the principal factor limiting the size of the Canton Island bird population is the absence of more such roosting and nesting sites. Indeed, at times the bushes are so crowded that frigate birds are forced to roost on the Sida fallax plants: these are spindly dwarf shrubs only about 10 to 12 inches high, and form a very insecure perch for a large bird. It is the opinion of the author that the large populations of roosting sea birds, which tend to congregate in relatively small areas, are of great significance in the development of the present natural vegetation of Canton Island.

The Suriana-Sesuvium Flats--Bordering extensive areas of tidal mudflats or covering small pockets of land influenced by the diurnal variation in the depth of the ground-water table is a plant community dominated by Sesuvium portulacastrum and Suriana maritima. The former is a fleshy decumbent herb, which occurs in striking bright green mats about 20 to 50 square feet in size. It usually occupies the centers of swales, or occurs near the high-tide level of mudflats of the sheltered lagoon side of the island. Suriana is a woody shrub, commonly about four feet tall, with fleshy yellow-green leaves. It characteristically borders the Sesuvium mats on the gently sloping edges of mudflats and swales. Large numbers of frigate birds are commonly observed in bushes of Suriana maritima.

The Portulaca Herbaceous Community--Portulaca lutea, together with Lepturus repens, Boerhavia tetrandra and Sida fallax dominates by far the largest area of natural vegetation on Canton Island. Portulaca lutea on Canton averages 6.5 inches in height and about 12 inches in lateral spread. It has a very fleshy taproot and main stem, up to one inch in diameter, and many branches radiating from the stem, each about 0.3 inches in diameter. Lepturus repens is a caespitose grass up to 19 inches in height (but averaging about 11.5 inches). It propagates itself at the periphery of clumps by ground-layering. The mats thus formed are occasionally quite extensive, the largest measured being 17.6 feet long and 9.3 feet wide, but covering only about 100 square feet. Generally, however, the clumps cover only about 1.25 square feet, the average diameter of the clumps being about 15 inches. Boerhavia tetrandra is a trailing vine with a large fleshy taproot up to 1.5 inches in diameter. Sida fallax, a dwarf shrub seldom over 12 inches tall on Canton Island, is a very common member of the community.

The Portulaca herbaceous community was studied quantitatively at two stations about nine miles apart. As is suggested by the data in Tables II and III, Portulaca is a consistent dominant in the community, while the frequency and cover degree of its associates are somewhat variable. In general it appears that the abundance of Sida and Boerhavia is correlated with a somewhat stony soil phase, while Lepturus is more prominent in areas of even-textured sand.

TABLE II

Frequency and Foliage Cover in the Portulaca Herbaceous Community. Data from five meter-square plots. Station I, about 10 miles by road from "Turning Basin."

Species	Frequency	Foliage Cover (Per cent)
<u>Portulaca lutea</u>	100	42
<u>Lepturus repens</u>	60	3
<u>Sida fallax</u>	40	2
<u>Boerhavia tetrandra</u>	20	5

Total

52

TABLE III

Frequency and Foliage Cover in the *Portulaca* Herbaceous Community. Data from 10 square-meter plots. Station II, about 19.5 miles by road from "Turning Basin."

Species	Frequency	Foliage Cover (Per cent)
<i>Portulaca lutea</i>	100	22
<i>Sida fallax</i>	100	18
<i>Boerhavia tetrandra</i>	100	15
Total		55

Beaches, Dunes and other naturally Bare Areas--About 23 per cent of the land surface of Canton Island has little or no natural vegetation cover. Such areas include beaches and other places subject to ocean wave action, and high dune. Triumfetta procumbens, a creeping perennial vine occurs occasionally on dunes on the north side of the island but its cover degree is very low. Ipomoea pes-caprae, which often is predominant in such situations in the Pacific is very rare on Canton Island. Only a single plant of this species was found in 1951, growing among rocks near fortifications erected in the war. It may have been planted by a soldier. Lepturus repens, reported by Christophersen (1937) to be characteristic of beach crests and shifting dunes on other Pacific equatorial islands, was not found in these sites on Canton.

DISCUSSION

The most striking features of the natural vegetation of Canton Island are the areal predominance of the *Portulaca* herbaceous community and the paucity of forest. This is perplexing in view of the fact that two native trees, Cordia subcordata and Messerschmidia argentea, are known in certain instances at least, to grow vigorously and to reproduce from seed. The forest communities thus formed tend to exclude the shade-intolerant herbaceous species of the *Portulaca* community. Moreover, the large shrub, Scaevola frutescens, is apparently invading the *Portulaca* herbaceous community about 9.5 miles by road from the "Turning Basin," on the north side of the island and possibly in other places. A relatively open stand of Scaevola might form a nurse crop favorable for the establishment of occasional seedlings of Cordia and Messerschmidia. Seedlings of Cordia soon wilt after germinating in the open herbaceous communities. It is quite possible that existing groves of Cordia and Messerschmidia may be traced to the successful establishment of single seedlings which by vegetative propagation have come to occupy their present areas. Thus it would appear that in the absence of disturbing factors the development of the natural vegetation of Canton Island might trend toward greater areal extent of forest and scrub, at the expense of the herbaceous communities.

It is evident, however, that such development is in process in only a few localities. Indeed, in most places the trend appears to be taking a different direction. Patches of native forest and scrub which are

situated more than one mile from human habitation are generally dead or dying. Extensive areas of Messerschmidia and Cordia forest about 10 miles by road from the "Turning Basin" are leafless and apparently dead. Counts of Scaevola bushes 16.5 miles from the "Turning Basin" revealed in a 1000-foot strip 35 vigorous plants, 40 dying plants and 40 dead ones. In a 625 square-foot plot, seven dead and five living bushes were counted.

Since healthy groves of Cordia and Messerschmidia exist on Canton Island possible climatic deterioration is not sufficient to explain the dying condition of most stands. No evidence has been found that the healthy stands owe their vigor to any possible cultural operations carried on within them. Instead, there is much evidence that a causal connection exists between the dead or dying condition of native forest and scrub in areas not affected by human activity and the enormous populations of fish-eating seabirds which roost and nest in the trees and shrubs. The arguments favoring such an hypothesis are listed briefly below:

1. Patches of native forest and scrub heavily populated with frigate birds and boobies invariably show high proportions of dying or dead trees and shrubs.

2. Patches of native forest and individual volunteer shrubs of Scaevola near human habitation and not visited by frigate birds and boobies are vigorous except when damaged by insects. Only Cordia exhibited noteworthy insect injury.

3. Soil profile studies in the Portulaca herbaceous community show beneath the surface inch of bleach sand a dark brown sandy loam to a depth of 15 inches. This dark layer is indistinguishable in the field from the guano soil at present developing under dying Messerschmidia, Cordia and Scaevola. The frigate birds and red-footed boobies at present visit only the forest and scrub, and other, smaller birds were observed only occasionally in the Portulaca community. It is suggested, therefore, that those areas in the Portulaca community exhibiting guano soil profiles were once covered with forest or scrub supporting large populations of roosting and nesting seabirds, at which time the guano was formed.

The mechanism by which birds might damage or destroy the native forest and scrub is not clear, although it appears likely that highly concentrated bird droppings might be as damaging to the trees and shrubs as would be excessive doses of nitrate and phosphate fertilizer. Stewart (1933) reported that roosting blackbirds severely injured a plantation of White Pine (Pinus strobus L.), and demonstrated that the concentration of soluble nitrates in the area of dying trees was enormously greater than in the unaffected area. The present author has conducted no experiments on the nature and properties of Canton Island guano soils. It is the experience of CAA personnel stationed on Canton, however, that ornamental plants potted in guano soil obtained from Canton Island forests grow much less vigorously than those potted in coral sand from the beach; these observations have been confirmed by the writer.

SUMMARY

1. Canton Island is a coral atoll situated at Lat. 2° S, Long. 171° W, in the Phoenix Group, Pacific Ocean. The total land area of the island is about 2,850 acres.
2. The climate is warm and humid, but rainfall is scanty and seasonal.
3. The native flora is scanty consisting chiefly of a few wide-ranging Indo-Pacific strand plants.
4. Natural vegetation consists of forests of Cordia subcordata and Messerschmidia argentea, scrub of Scaevola frutescens and Suriana maritima, and herbaceous communities dominated by Portulaca lutea. The last is much the most extensive type of natural vegetation on Canton Island.
5. Most native forest and scrub is in a dead or dying condition. It is suggested that the agents chiefly responsible for the death of native woody species are frigate birds, red-footed boobies and other fish-eating seabirds, which roost in enormous numbers in the forest and scrub. Observations are presented suggesting that certain areas presently covered by Portulaca and its associates formerly may have been dominated by forest or scrub. It is believed that in the absence of large populations of birds, native forest and scrub would tend to extend their present areas at the expense of herbaceous communities.

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