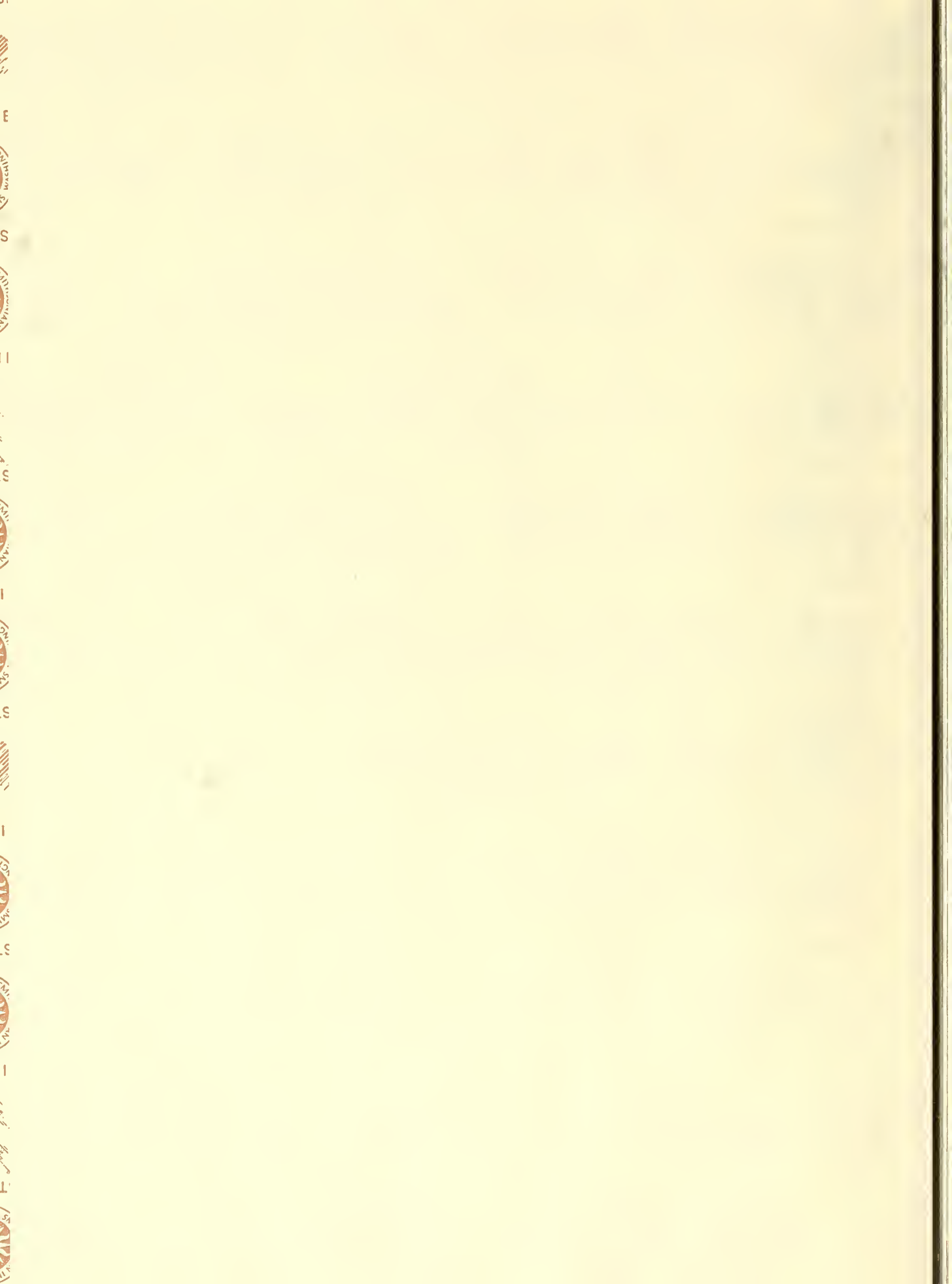
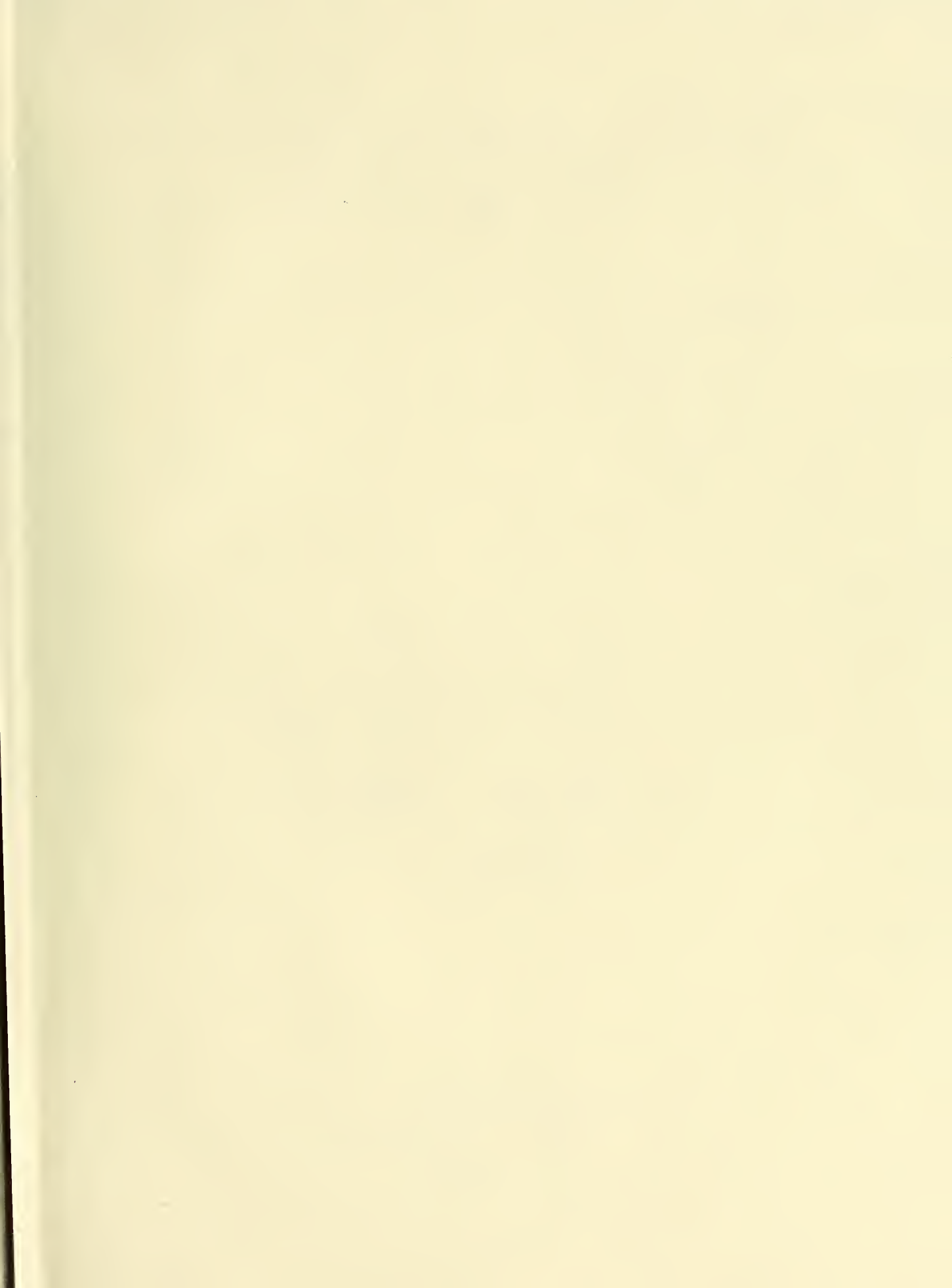










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BIRD AND DENIS ISLANDS, SEYCHELLES

by D. R. Stoddart and F. R. Fosberg

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BIRD AND DENIS ISLANDS, SEYCHELLES

by D. R. Stoddart and F. R. Fosberg

1. Geography and ecology of Bird Island, Seychelles

INTRODUCTION

Bird Island is one of two small coral islands on the northern margin of the Seychelles Bank, western Indian Ocean. It is situated in latitude 3°43'S and longitude 55°13'E, 98 km northnorthwest of Mahe, the main granitic island of the Seychelles (Figure 1). J.C.F. Fryer spent one week there in 1908 and later contributed the basic account of the island (Fryer 1910). Subsequently it has been the subject of brief visits by geologists, botanists and zoologists (Table 1), but no comprehensive account of the island appeared until the recent major paper by Feare (1979), based on observations during a year's residence during a study of the Sooty Tern colony.

The purpose of the present paper is to present information on the terrestrial botany of the island, and to call attention to some early sources on its natural history (notably the visit by H.M.S. Alert in 1882) not mentioned by Feare. Detailed information given by Feare, especially on the birds, will not be repeated here, and the reader is referred to his paper for a more comprehensive account.

MORPHOLOGY AND STRUCTURE

The island is 1800 m long and a maximum of 830 m wide (Figure 2); Coppinger (1885) gives dimensions only half as great, but both Horsburgh (1809) and Fryer (1910) give approximately similar figures. Figure 2 is based on a compass traverse map made in March 1976, with additional detail from air photographs, and yields an area of 82.5 ha. No elevations have been determined on the island, but the maximum height is unlikely to be more than 4 m above mean sea level. Tidal range at springs is 1.2 m and at neaps 0.9 m.

Bird consists entirely of reef-derived carbonate sands and fine gravels, with small quantities of drift pumice. Beaches are wide and extensive around the entire coast, except for some erosion and cliffing at the southern point. In March 1976 there was a broad unvegetated spit, composed of several beach ridges, at the northeast end of the island, but this is probably a largely seasonal phenomenon and varies

Table 1. Scientific studies at Bird Island

<u>Date</u>	<u>Visitor</u>	<u>Subject</u>	<u>Publication</u>
1771 August	Lt W. Robinson Lt D. Thomas, <i>Eagle</i>	Charting	Dalrymple 1780
1808	<i>Hirondelle</i>	Wrecked	Froberville 1848
1822	F. Moresby	Survey	Moresby 1842
1882 4 March	R.W. Coppinger H.M.S. <i>Alert</i>	General collecting	Coppinger 1885; Bowdler Sharpe 1884 Hemsley 1885 Admiralty Chart
1891	Lt C.H. Simpson Lt F.M. Leake H.M.S. <i>Stork</i>	Charting	
1908 24 July - 1 August	J.C.F. Fryer	General survey and collecting	Fryer 1908, 1910
1935?	D. Vesey-FitzGerald	Birds	Vesey-FitzGerald 1941
1952 27 Sept	E.S. Brown	Insects	Mattingly and Brown 1955
1955	M. Ridley, R. Percy	Birds	Ridley and Percy 1957
1960 14-15 September	C.J. Piggott B.H. Baker	Coconuts Geology	Piggott 1968, 1969 Baker 1963
1962 March	C. Jeffrey	Botany	Jeffrey 1962
1963 4 Nov.	R. Bailey	Birds	Bailey (1967)
1969 ?	F.L. Lambrecht	Insects	Lambrecht 1971
1970 14 July	J. Procter	Botany	Procter 1970
1972 June, August-November 1973 May-October 1974 July	C.J. Feare	Birds, general ecology	Feare 1973a, 1973b, 1975, 1976a, 1976b, 1976c, 1979 Feare and High 1977
1976 25-27 March	D.R. Stoddart	Botany, general ecology	This paper
1977	L.G. Nikiforov et al.	Geology and sediments	Nikiforov et al. 1978

in location with the monsoons from the northeast to the northwest sides (cf. the trace of the 1960 shore from air photographs in Figure 2). Piggott (1968, 53) concluded from the existence of this spit that the island was increasing in size, but this seems unlikely.

The beaches face a reef flat 300 m wide, which dries at low springs, on the southeast side, but the western beaches overlook deeper water. Table 2 gives characteristics of beach and berm sediment samples from sites around the coast, based on sieving at 0.25 ϕ intervals, and Figure 3 gives cumulative curves and sample locations. The beach samples (from mid-beach) are generally rather coarser than the beach crest samples, though this is only at all pronounced on the leeward coast. All the samples lie in the coarse to medium sand size range, are well to moderately well sorted, exhibit little skewness, and are platykurtic to mesokurtic.

Nikiforov et al. (1978, 46-61) measured the height of beach ridges at the northeast point reaching successively 2-3, 3.1 and 3.4 m from sea to the vegetated island surface (datum not stated). Holes were drilled in the second and third of these units to depths of 6.75 m; subsurface sediment samples were mainly coarse-grained and poorly sorted calcareous sands with shell and mollusc fragments. The centre of the island was also drilled to a depth of 5.2 m below the surface; the sediments were unsorted carbonate materials with near-surface cementation. Nikiforov et al. (1978, 53) interpret this cemented layer as an ancient beachrock, dated at 2500-2700 years B.P., but from their description it appears to be a phosphate rock.

Phosphate rock covers much of the central part of Bird Island. Figure 2 shows the distribution of this material according to Baker (1963, 46-48) and Piggott (1968). The phosphorite has maximum thicknesses of 1-2 m, and wells in it penetrate to the water table at depths of 1.5-2 m. The rock is brown and speckled, well-cemented and dense at the surface but crumbly below. The upper surface is intricate and fractured, with many loose blocks, while the lower limit of the rock is characteristically broadly lobate and irregular. A sample of the phosphorite has been analysed by T.P. Scoffin, who finds P_2O_5 28.2% and CaO 52.7%. He comments: "The rock is extensively phosphatized and grains are hard to identify. There are some unaltered coral grains but most grains are completely or partially replaced. Those that are partly replaced have undergone centripetal phosphatization at their rims. There is a dense brown phosphatic fine grained or amorphous crust on the grains. This crust is not banded. One grain shows unaltered carbonate cement needles in skeletal chambers. There are bladed grains showing undulose extinction which may be broken pieces of an earlier phosphate cement." The surface guano overlying the cemented material has been largely removed for export. Piggott (1968, 39) describes the soil overlying the phosphorites as Jemo Series, in contrast to the Shioya Series of the rest of the island.

Table 2. Characteristics of Bird Island beach sands

Sample	Location	Position	ϕ mean	ϕ median	σ I	Sk I	K G
1	West Bay	Beach	1.44	1.40	0.78	0.05	0.83
2		Berm	0.78	0.81	0.62	-0.04	1.04
3	Northeast Bay	Beach	1.56	1.46	0.79	0.10	0.85
4		Berm	1.25	1.15	0.69	0.16	1.00
5	Southeast Bay	Beach	1.31	1.21	0.48	0.20	1.08
6		Berm	1.68	1.72	0.50	-0.08	0.96
7	Southwest Point	Beach	0.92	0.83	0.60	0.19	1.10
8		Berm	0.93	0.92	0.48	0.06	1.02
9	Northeast Point	Beach	1.59	1.08	0.60	0.77	1.04
10		Berm	1.37	1.34	0.67	0.05	1.11
11	Northwest coast	Beach	1.55	1.40	0.73	0.18	0.88
12		Berm	0.89	0.92	0.78	-0.04	1.08

CLIMATE

Bird Island falls within the general Seychelles régime of an extended period of dry Southeast Trade winds from April to November, and a wet season of northwesterly winds and calms during December to March. Rainfall records are available only for 1961 and 1962, totalling 2358 and 1589 mm respectively; the monthly figures show considerable variation between the two years (Table 3). The incidence of rainfall in 1961-62 was very similar to that of Denis Island (Table 5), though with marked divergences in December 1961 to February 1962. Feare (1979) also measured rainfall, recording 703 mm between 15 August and 5 November 1972.

Table 3. Monthly rainfall at Bird Island, 1961-1962 (mm)

<u>Year</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>
1961	364.7	366.5	142.0	73.1	1.5	1.3	30.2	164.1	319.0	226.3
1962	216.9	224.8	21.8	182.1	212.8	35.6	29.5	133.1	270.0	20.8
	<u>Nov</u>	<u>Dec</u>	<u>Year</u>							
1961	469.1	200.1	2358.1							
1962	112.3	128.5	1588.5							
	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>
Mean	290.8	295.6	81.9	127.6	107.1	18.4	29.8	148.6	294.5	123.5
	<u>Nov</u>	<u>Dec</u>	<u>Year</u>							
Mean	290.7	164.3	1973.3							

Source: Stoddart (1971)

VEGETATION

Horsburgh (1809, 126), in the first description available, says that Bird Island "is very low, with small bushes on it", and all later nineteenth century accounts are broadly similar. "Le seul végétal qui pousse sur cette terre désolée, est le veloutier [*Scaevola taccada*]", comments Froberville (1848, 99). Moresby (1942, 12) found it "a small sandy island with a few shrubs on it" in about 1822, and Pelly (1865, 231) puts it in the class of "low sandy islands, sprinkled with scrubby brushwood". In 1882 Coppinger (1885, 211) supplied more detail during the visit of H.M.S. *Alert*. He found a "dense thicket of bushes, which forms a fringe around the margin of the island" (presumably mainly *Scaevola taccada*); a central area with "scrubby grass ... [and] several introduced plants gone wild"; and "two or perhaps three *Casuarina*".

By the time of Fryer's visit in 1908 there was still a narrow marginal belt of *Scaevola* and *Tournefortia argentea* bushes about 10 m wide; a bare area with practically no vegetation, comprising the Sooty Tern colony; rough ground on the phosphate rock, with herbs and grasses; and a small coconut plantation extending east to west across the centre of the island. The composition of the herbaceous ground cover was not recorded, though Fryer's collections included *Cassytha filiformis*, *Ipomoea pes-caprae* and *Tribulus cistoides*; *Boerhavia repens* and

Portulaca oleracea were probably also widespread. A few years before Fryer's visit, a visiting magistrate in 1903 had enumerated 6000 coconuts, mostly young, with "a few filaos" [*Casuarina*] and three acres (1.2 ha) of maize (Seychelles Archives, C/SS/74(1), 139). In spite of this general impression of a virtually treeless landscape, however, it is worth noting that in 1908 Fryer recorded both *Calophyllum inophyllum* and *Terminalia catappa*, together with *Hernandia sonora* and *Morinda citrifolia*, neither of which have been seen since (though the *Morinda* is very probably present).

Nevertheless, it is clear that the vegetation today differs greatly from that of the period before 1908. The whole island is now covered with coconut woodland, managed as a plantation, with peripheral tall *Casuarina* and a littoral hedge of *Scaevola taccada*. Feare (1979) distinguished seven physiographic and vegetational units, broadly congruent with the following:

1. Littoral hedge, dominated almost exclusively by *Scaevola taccada* and extending almost continuously along the west and southeast coasts. The hedge is about 5 m tall and 10-25 m wide. Its inner margin is often marked by trees of *Guettarda speciosa*, and along the southeast shore it is fronted for about 200 m by a low zone of *Suriana maritima* (Plate 1).
2. Littoral woodland of *Thespesia populnea*, found on the northeast coast where the shore is aggrading and where, as Feare (1979) states, the phosphatic sandstones outcrop. *Pisonia grandis* and *Cordia subcordata* are also present in this unit (Plate 2), but are rare. *Thespesia* is also found on the cliffed eroding shore at the south point.
3. *Casuarina* woodland. This has been planted as a windbreak inside the *Scaevola* hedge, especially in the southwest and eastern parts of the island and around the settlement. Many of the trees are 25-30 m tall, but in recent years many have been felled for use in construction.
4. Coconut woodland. A tall closed woodland of coconut palms, with a ground cover which varies with substrate. On sand the surface is occupied by grasses, *Lippia* and other low herbs; on phosphatic sandstone by tall *Kalanchoe pinnata*, *Nephrolepis* and *Carica papaya* as well as a diverse low herbaceous flora. Small gardens are scattered through the plantations. Weeds such as *Achyranthes aspera* and *Phyllanthus casticum* are ubiquitous. In 1962, according to Piggott (1968, 41) the plantations yielded 40 tons of copra per annum, with 10-40 nuts per tree.
5. *Tournefortia* parkland (Plates 3 and 4). In the northwest part of the island, where the Sooty Terns nest, there is an open area of *Boerhavia repens* and *Portulaca oleracea*, dominated by mature trees of *Tournefortia argentea* and occasional shrubs of *Scaevola* and *Suriana*.

The *Tournefortia* trees are 4-5 m tall. The vegetation of this area is now managed to promote the breeding of the terns (Feare 1976).

6. Pioneer herbaceous vegetation (Plates 5, 6 and 7). This is extensive in the northeast bay and on the northeast spit. It is dominated by *Ipomoea pes-caprae*, grasses and sedges, and small shrubs of *Scaevola* and *Suriana*. Terns also nest here, though in lower densities.

7. Airstrip herbaceous vegetation, with a low mat of *Lippia nodiflora* and other herbs and grasses (Plate 8).

8. Settlement, with a diverse collection of introduced weeds and decorative plants (including *Tabebuia heterophylla*, massive *Ficus benghalensis*, and *Calophyllum inophyllum*), and crop plants. Many of these were introduced at an early date. Coppinger (1885) recorded coconuts, *Casuarina*, cotton, sugarcane, papaya, yam and gourd in 1882; Fryer (1910) added maize and tobacco in 1908. Conversely plants such as *Catharanthus roseus* were not recorded until 1962, and *Stachytarpheta jamaicensis* and *Ricinus communis* not until 1970, though presumably introduced considerably earlier.

The extent of the phosphorite on Bird Island raises questions about the possible former extent of *Pisonia grandis* woodland, in view of Fosberg's hypothesis of the role of acid *Pisonia* humus in the precipitation of phosphate cement. *Pisonia* is now rare on Bird (only a single tree was seen in 1976), but Feare (1979) drew attention to the existence of litter and humus beneath *Scaevola*, *Tournefortia*, *Suriana* and *Cyperus*, suggesting that these may substitute for *Pisonia* in the phosphate reaction. Collections were made of litter from beneath eight species of trees and shrubs in 1976, and pH was measured over a 27 day period in the laboratory. pH levels were stable during this period, and averaged as follows:

<i>Scaevola</i>	5.3	<i>Casuarina</i>	6.4
<i>Guettarda</i>	5.7	<i>Tournefortia</i>	6.6
<i>Suriana</i>	6.0	<i>Pisonia</i>	6.9
<i>Thespesia</i>	6.3	<i>Cordia</i>	7.2

None of these dry-season litter samples resembled the deep humus found under *Pisonia* woodland elsewhere, however, and it is unlikely that such high pH levels would lead to phosphate precipitation. These measurements do not, of course, resolve the question of the former existence of *Pisonia* woodland on Bird Island; but if it ever did exist it had clearly disappeared before 1882.

FLORA

The flora of Bird Island, excluding sea-grasses, totals 101 species, about half introduced. Of these, 43 were recorded by Coppinger or Fryer in or before 1908; Jeffrey recorded 7 in 1961-62, Procter 37 in 1970, Feare 55 in 1972-74, and the present study 62. The flora includes sixteen tree species, but of these probably only *Pisonia*, *Thespesia*, *Cordia*, *Tournefortia* and *Guettarda* are native, and some of these may have colonised naturally since the transformation of the island in the early twentieth century. Shrubs are represented only by *Scaevola* and *Suriana*, both indigenous. It should be noted that both Fryer (1908, 1910) and Summerhayes (1931) misidentified *Suriana* as *Pemphis acidula*, as did Procter (1970); *Pemphis* is not found on the islands of the Seychelles Bank, nor indeed is it found in the western Indian Ocean islands north of St Joseph Atoll. Christensen's (1912) record for Bird of *Acrostichum aureum* is almost certainly a locality error, since *A. speciosum* is found on Denis Island and is not otherwise recorded for Bird Island; and the same is clearly true for *Typha javanica*, recorded for Bird by Summerhayes (1931).

INVERTEBRATES

Feare (1979) has recorded the presence during his stay on Bird Island of land crabs, Myriapoda, Insecta and Arachnida. In addition, Fryer made collections of insects and some other groups in 1908. Table 4 keys the subsequent literature of insect determinations from Bird. Only Lepidoptera, Coleoptera and Orthoptera are at all well represented. However, the records of Diptera have been extended by studies of the mosquitoes by Mattingly and Brown (1955) and Lambrecht (1971). *Aedes albopictus*, *A. albocephalus* and *Culex pipiens* are all biters and from time to time abundant. In addition, from Fryer's collections, Budde-Lund (1912) records a terrestrial isopod, Hirst (1911) five species of spider, and Hirst (1913) a scorpion.

REPTILES

Feare (1979) records nesting by Green and Hawksbill turtles. It is worth noting that Dalrymple's chart of 1780, based on the *Eagle* survey in 1771, is annotated "many turtle". There is now no means of knowing either the size of the former nesting population or the scale of the decline in numbers. Fryer also collected the two common geckos, *Hemidactylus frenatus* and *Phelsuma madagascariensis* (Boulenger 1911); Feare (1979) suggests that the former may have been introduced. Fryer did not collect the common skink *Mabuia sechellensis*.

MAMMALS

Bird Island was formerly known as Ile aux Vaches marines, though

Table 4. Key to the literature on insects collected at Bird Island

<u>Family</u>	<u>Number of species</u>	<u>Source</u>
Orthoptera	9	Bolivar 1912, 1924
Dermaptera	1	Burr 1910
Odonata	1	Campion 1913
Hemiptera	9	Distant 1913
Neuroptera	1	Needham 1913
Lepidoptera	11	Meyrick 1911; Fryer 1912
Coleoptera	13	Champion 1914, 1917; Gebien 1922; Scott 1912, 1913; Sicard 1912
Hymenoptera	1	Forel 1912
Diptera	7	Lamb 1912; Mattingly and Brown 1955; Lambrecht 1971

in his paper Feare (1979) makes no mention of the former existence of marine mammals there. Horsburgh (1809, 126-127) refers to "Sea Cows, or Bird Island", and comments that "When this island was explored by the Eagle Cruizer, from Bombay, in 1771, many sea-lions (probably Manutees or large seals) were seen on the beach"; Dalrymple's chart of 1780, from the same survey, is annotated "many Seals". Moresby (1842) calls the island Ile aux Vaches. Froberville (1848, 99) paraphrasing an account dating from the wreck of the *Hirondelle* in 1808, states: "Les vaches marines se trainent souvent sur les dunes pour y dormir au soleil, et, dans cet état, on peut les entendre souffler de bien loin: cet animal est peu redoutable malgré sa taille énorme et ses dents menaçantes; nos matelots en assommèrent plusieurs pendant notre séjour, mais nous n'en faisons pas beaucoup de cas, la chair n'en étant pas supportable; une seule tortue nous faisait plus de plaisir lorsque nous parvenions à la surprendre". Fryer (1910, 15) commented that "there is no doubt the island was the haunt of the species of dugong known as Vache marine, which unfortunately has long ceased to exist". No such animal was recorded by the *Alert* in 1882, or since that time. In discussing these and other records, I have concluded that the records referred to seals of unknown species rather than to dugongs (Stoddart 1972).

BIRDS

Early accounts agree on the great size of the bird populations. In 1771 the *Eagle* found "birds innumerable" (Horsburgh 1809, 127). The first collections and observations on birds were made by Coppinger in 1882; subsequently Fryer made observations in 1908 which were utilised by Feare (1979).

Coppinger (1885, 212) specifically states that there were "no land birds" at the time of his visit. Given the sparse vegetation and his familiarity with land birds of the Seychelles islands, it is unlikely that he would have failed to record them had they been present. By the time of Fryer's visit the Madagascar Fody *Foudia madagascariensis* and the Ground Dove *Geopelia striata* had been introduced. Coppinger mentions "multitudes of white egrets" and collected two males of *Bubulcus ibis* (Bowdler Sharpe 1884), the first record of this presumably native species; Feare (1979) had taken Fryer's reference to a "white heron" as the first mention of this species. The Mynah *Acridotheres tristis* was first recorded by Feare (1979), and the date of its introduction after Fryer's visit is not known.

Of the seabirds, Coppinger in 1882 found the ground "everywhere excavated by burrows of petrels", and collected a male *Puffinus pacificus* (Bowdler Sharpe 1884, as *P. chlororhynchus*); he also stated that "many gannets are breeding on the island". Fryer found boobies "breeding in small colonies at the edge of the goelette Sooty Tern colony". He names the species *Sula piscator* (= *S. sula*?), as does Gadow (1907), who comments that "The guano of Bird Island, Seychelles, was principally formed by a great colony of this species". In the 1930s Vesey-FitzGerald (1941) found both nesting Masked Boobies *Sula dactylatra* and immature Red-footed Boobies *S. sula*. To further complicate matters, Coppinger (1885, 213) refers to "a large brown bird" which was probably a Brown Booby *Sula leucogaster*. According to Feare (1979), all three species are occasionally seen today. There must remain some doubt as to which were present and breeding in the nineteenth century, though the absence of trees suggests that only the ground-nesting Masked and Brown Boobies could have been numerous.

Other early seabird and shorebird records are of less interest. Coppinger (1885) mentions "a great flock of frigate birds", and terns in "great numbers"; he collected a Brown Noddy *Anous stolidus* (Bowdler Sharpe 1884). Fryer (1910) also mentions the noddies nesting in *Scaevola* and *Tournefortia*, and refers also to a "large grey tern" and a gull. Of migrants, Coppinger mentions "great flocks of turnstones and curlews" (Bowdler Sharpe 1884 cites skins of the former) and "a few oyster catchers". Fryer lists turnstone, plover, curlew, sanderling, whimbrel and stilt, as well as the moorhen *Gallinula chloropus*, all of which are listed by Feare (1979).

Nothing is to be added to Feare's (1976) account of the Sooty Tern colony. He suggests that this numbered over 1,000,000 pairs in 1907.

By the mid 1930s, with habitat change and interference, it had declined to 65,000 pairs (Vesey-FitzGerald 1941) and by 1955 to 18,000 pairs (Ridley and Percy 1966). Thereafter it recovered to 120,000 pairs in 1966 (Ridley and Percy 1966) and to 395,000 pairs occupying 11.7 ha by 1973 (Feare 1976). Feare estimated that during his study the birds laid some 300,000 eggs during the period 8-17 June.

In addition to the comprehensive list of vagrants and migrants recorded by Feare (1979), there are subsequent records by Feare and High (1977) and by Turner and Forbes-Watson (1976).

HISTORY

The early history of Bird Island is virtually unknown. The *Eagle* called there and charted the island in 1771. The *Hirondelle*, a French privateer with 180 people on board, was wrecked there in 1808. "They proved water by sinking a pit in the sand, remain'd there 22 days until they constructed a raft, on which a part arrived at Mahe" (Moresby 1842). Thereafter, apart from Moresby's own visit in 1822, there is no information before the visit of H.M.S. *Alert* sixty years later.

Feare (1979) has outlined the major changes in the ecology of the island brought about by guano mining and the introduction of the coconut. The former began in 1895: before that, in 1882, Coppinger (1885, 211) found only two negroes salting fish and birds. By early February 1896 385 tons of guano had been removed, and by early April 500 tons (Seychelles Archives B/44.195, 233). During 1900-1905 a total of 17,000 tons was exported, and the resource was apparently exhausted by 1906 (Baker 1963). The population at this time (1903) numbered 42 men, 17 women and 31 children (Seychelles Archives C/SS/74(1), 139); subsequently it declined to a total of 12 in 1931, but then increased as the plantations were established, to 25 in 1947 and 49 in 1960.

The plantations had the effect of drastically reducing the area available for nesting seabirds, and during the general disturbance introductions included rats, mice, donkeys, pigs, goats, cats and dogs. A new phase was opened in 1971-73 by the clearing of the airstrips and the opening of tourist accommodation, but this increased accessibility has coincided with a new ecological awareness on the part of the owners and in a considerable intensification of scientific studies.

ACKNOWLEDGEMENT

We thank M. Guy and Mme Marie-France Savy for their generous help on Bird Island in 1976.

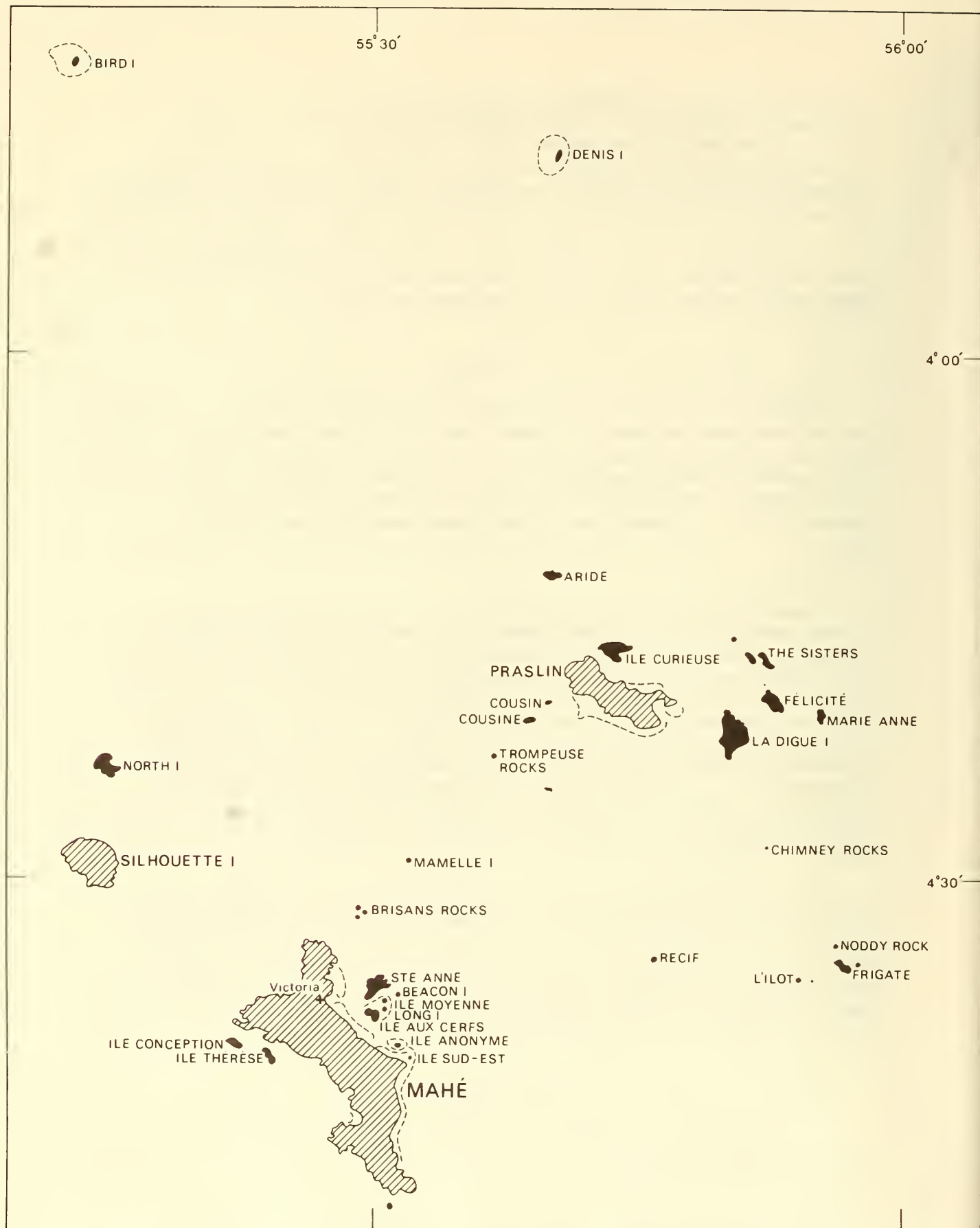


Fig. 1. The Seychelles Bank

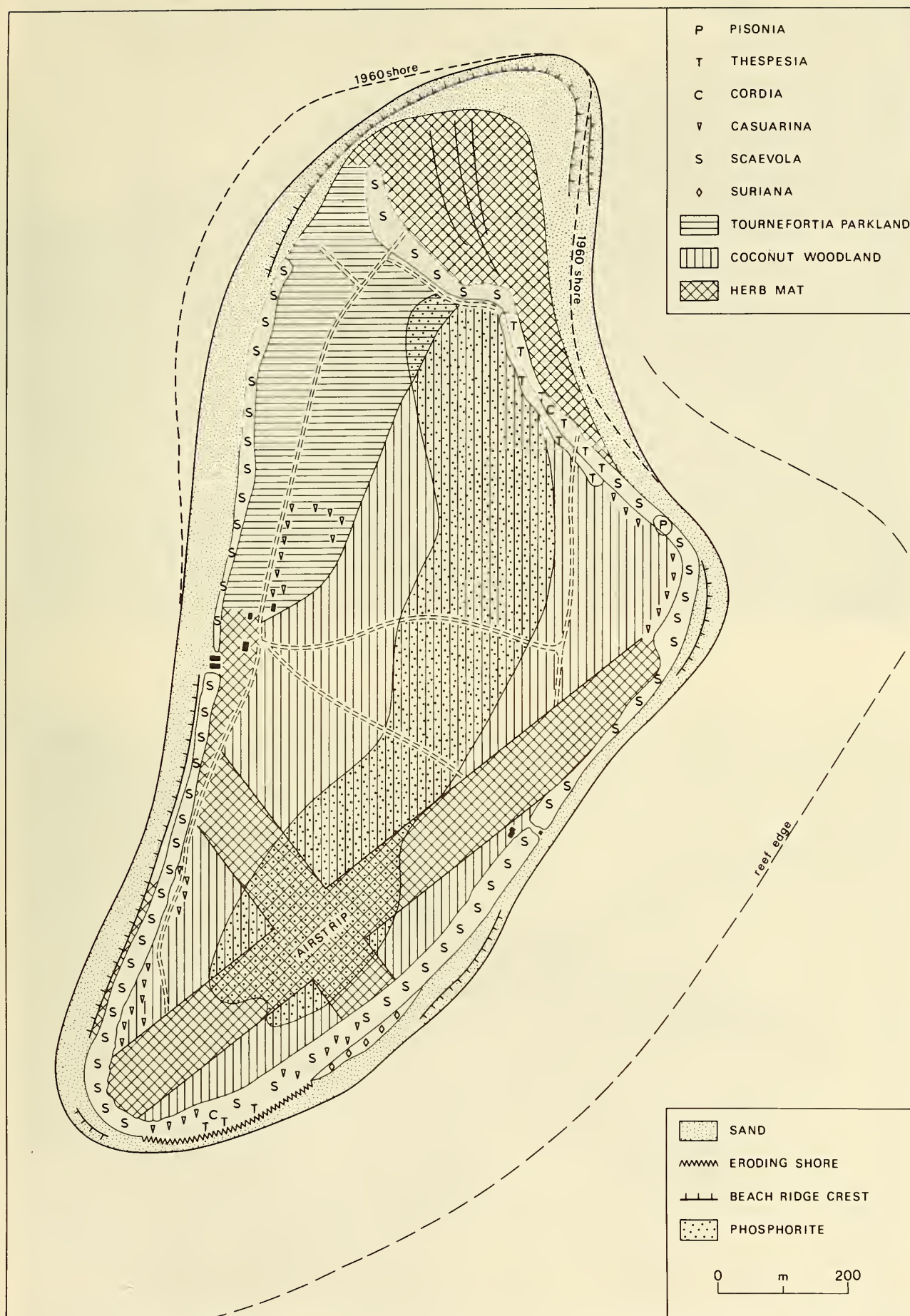


Fig. 2. Bird Island in 1976

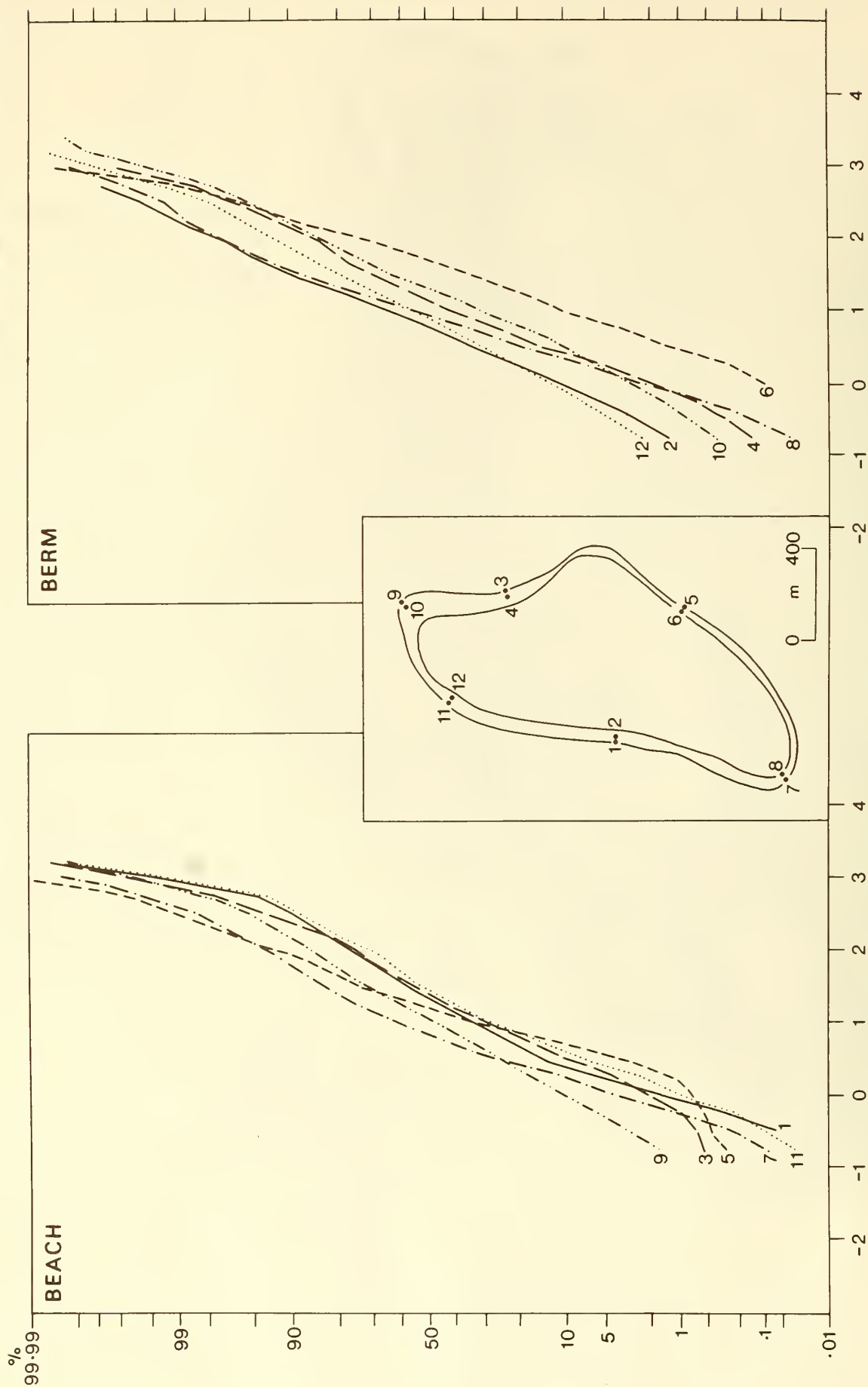


Fig. 3. Beach sediment at Bird Island



Pl. 1. Bird Island: *Suriana* zone on the northeast shore



Pl. 2. Bird Island: *Pisonia* and *Cordia* woodland with *Suriana* on the northeast shore



Pl. 3. Bird Island: *Tournefortia* parkland in the northeast



Pl. 4. Bird Island: tree-like *Tournefortia* in the northeast



Pl. 5. Bird Island: pioneer sedges and *Scaevola* on the east shore



Pl. 6. Bird Island: pioneer *Ipomoea pes-caprae* on the east shore



Pl. 7. Bird Island: pioneer sedges, *Scaevola* and *Tournefortia* on the northeast shore



Pl. 8. Bird Island: airstrip from the southeast

2. Plants recorded from Bird Island

POLYPODIACEAE

Acrostichum aureum L.

Fryer, in Christensen (1912) [in error for Denis Island?]

Nephrolepis biserrata (Sw.) Schott

Procter 4040 (Mahe); Fryer, in Christensen (1912); Gardiner, in Christensen (1912); Feare, sight.

Nephrolepis multiflora (Roxb.) Jarrett

Stoddart 7110 (US).

Polypodium scolopendria Burm.f.

Fryer, s.n. (K); Fryer, in Christensen (1912) (as *P. phymatodes*)

[TYPHACEAE]

[*Typha javanica* Schnizl ex Rohrb.

Fryer, in Summerhayes (1931) (in error for Denis Island?)]

POTAMOGETONACEAE

Thalassodendron ciliatum (Forsk.) d. Hart.

Cymodocea ciliata (Forsk.) Ehrenb. ex Aschers.

Stoddart 7123 (US); Fryer, sight (1910) (as *Cymodocea*).

GRAMINEAE

**Cynodon dactylon* (L.) Pers.

Stoddart 7112 (US); Procter, sight.

**Dactyloctenium aegyptium* (L.) Willd.

Stoddart 7072 (US); Procter, sight; Feare, sight.

**Digitaria horizontalis* Willd.

Procter 4049 (MAHE).

**Eleusine indica* (L.) Gaertn.

Procter 4049 (MAHE); Coppinger, in Hemsley (1885); Feare, sight.

Enteropogon monostachyum K. Schum. ex Engl.

Procter, sight.

Enteropogon sechellenis (Barker) Dur. and Schinz

Stoddart 7064 (US), 7091 (US); Procter, sight.

Eragrostis subaequiglumis Renv.

Procter 4044 (MAHE); Stoddart 7074 (US).

**Eragrostis tenella* (L.) Beauv. ex R. and S. var. *tenella*

Piggott, s.n. (K); Stoddart 7081 (US); Procter, sight.

Eragrostis tenella var. *insularis* Hubb.

Vesey-FitzGerald 5656 (K).

Lepturus repens (Forst.) R.Br.

Fryer, sight, in Summerhayes (1931).

**Panicum repens* L.

Fryer, sight, in Summerhayes (1931) [locality as "Ile aux Vaches"].

Pennisetum polystachion (L.) Schult.

Fryer, no number, in Summerhayes (1931).

**Saccharum officinarum* L.

Coppinger, sight (1885).

Sporobolus virginicus (L.) Kunth

Fryer, no number, in Summerhayes (1931); Procter, sight.

Stenotaphrum micranthum (Desv.) Hubb.

Stenotaphrum subulatum Trin.

Procter 4041 (MAHE); Stoddart 7073 (US), 7129 (US); Feare, sight.

**Zea mays* L.

Fryer, sight (1910).

CYPERACEAE

Cyperus sp.

Stoddart 7120 (US).

Cyperus conglomeratus Rottb.

Procter 4037 (MAHE) (as *C. pachyrhiza*); Stoddart 7071 (US); Feare, sight (as *C. pachyrhiza*).

Cyperus dubius Rottb.

Mariscus dubius (Rottb.)

Fryer 26 (K) (as *Mariscus dregeanus*); Procter 4038 (MAHE); Feare, sight.

Cyperus ligularis L.

Mariscus ligularis (L.) Hutchinson

Fryer 25 (K) (as *Mariscus rufus*); Jeffrey 1201 (MAHE) (mislabelled: this specimen is from Denis Island); Stoddart 7087 (US).

PALMAE

**Cocos nucifera* L.

Coppinger, sight (1885); Fryer, sight (1910); Piggott, sight (1969); Procter, sight; Feare, sight; Stoddart, sight.

ARACEAE

**Alocasia macrorrhiza* (L.) Schott.

Stoddart 7109 (US).

Colocasia esculenta (L.) Schott.

Stoddart 7118 (US).

LILIACEAE sensu latissimo

**Agave rigida* Northrop var. *sisalana* Perr. ex Engelm.

Agave sisalana Perr.

Feare, sight; Stoddart, sight.

**Crinum* sp.?

Stoddart 7116 (US).

MUSACEAE

**Musa sapientum* L.

Feare, sight; Stoddart, sight.

MARANTACEAE

**Maranta arundinacea* L.

Fryer, sight, in Summerhayes (1931); Procter, sight.

CASUARINACEAE

Casuarina equisetifolia L.

Stoddart 7107 (US), 7133 (US); Coppinger, sight (1885); Fryer, sight (1910); Piggott, sight (1969); Procter, sight; Feare, sight.

MORACEAE

**Artocarpus altilis* (Park.) Fosb.

Stoddart, sight (juvenile).

Ficus sp.

Stoddart 7098 (US); Feare, sight.

**Ficus benghalensis* L.

Stoddart 7097 (US).

Ficus nautarum Baker

Fryer, no number, in Summerhayes (1931); Procter, sight.

AMARANTHACEAE

Achyranthes aspera L.

Procter, sight.

Achyranthes aspera cf. var. *fruticosa* Boerl.

E.S. Brown in 1952-1953 (BM).

Achyranthes aspera cf. var. *velutina* (H. and S.) Townsend

Stoddart 7079 (US); Feare, sight.

**Amaranthus dubius* Mart. ex Thell.

Stoddart 7103 (US), 7127 (US).

**Amaranthus caudatus* L.

Fryer, no number, in Summerhayes (1931).

**Amaranthus cleraceus* L.

Feare, sight.

NYCTAGINACEAE

Boerhavia diffusa L. (sensu lato) (prob. = *B. repens* L.)

Fryer 32 (K).

Boerhavia repens L. var.

Procter 4043 (MAHE) (var. *maris-indica* Fosb.); Stoddart 7083 (US); Feare, sight.

**Bougainvillea glabra* Choisy
Stoddart 7102 (US).

**Mirabilis jalapa* L.
Stoddart 7094 (US), 7111 (US); Feare, sight.

Pisonia grandis R. Br.
Stoddart 7080 (US); Feare, sight.

PORTULACACEAE

Portulaca oleracea L. var. *granulato-stellulata* v. Poelln.
Stoddart 7088 (US); Coppinger, in Hemsley (1885); Procter, sight;
 Feare, sight.

LAURACEAE

Cassytha filiformis L.
Stoddart 7077 (US); Fryer, sight (1910); Procter, sight; Feare,
 sight.

HERNANDIACEAE

Hernandia sonora L.
Hernandia peltata Meissn.
Hernandia nymphaeaeifolia (Presl) Kubitzki
 Fryer, sight (1910) (as *H. peltata*).

CAPPARIDACEAE

**Cleome viscosa* L.
 Feare, sight.

**Cleome gynandra* L.
Gynandropsis gynandra (L.) Briq.
Procter 4046 (MAHE); Feare, sight.

MORINGACEAE

**Moringa oleifera* Lam.
Stoddart 7122 (US); Feare, sight.

CRASSULACEAE

**Kalanchoe pinnata* (Lam.) Pers.

Stoddart 7084 (US); Procter, sight; Feare, sight.

LEGUMINOSAE

Caesalpinia bonduc (L.) Roxb.

Caesalpinia bonducella (L.) Flem.

Fryer 7 (K).

Cassia occidentalis L.

Procter, sight; Feare, sight.

Sesbania sericea (Willd.) Link

Stoddart 7105 (US); Coppinger, in Hemsley (1885) (as *S. aculeata* Pers.).

ZYGOPHYLLACEAE

Tribulus cistoides L.

Stoddart 7130 (US); Fryer, sight (1910); Procter, sight (as *Tribulus* sp.); Feare, sight.

SURIANACEAE

Suriana maritima L.

Stoddart 7069 (US); Coppinger, in Hemsley (1885); Feare, sight.

EUPHORBIACEAE

Acalypha indica L.

Fryer 27 (K); Procter 4045 (MAHE); Stoddart 7082 (US); Feare, sight.

**Euphorbia cyathophora* Murr.

Fryer, no number, in Summerhayes (1931) (as *E. heterophylla* L.).

**Euphorbia hirta* L.

Stoddart 7114 (US); Procter, sight; Feare, sight.

Euphorbia prostrata Ait.

Procter, sight; Feare, sight.

**Pedilanthus tithymaloides* (L.) Poit.

Stoddart 7117 (US).

**Phyllanthus amarus* Schum.

Stoddart 7125 (US).

Phyllanthus casticum Willem.

Stoddart 7089 (US), 7113 (US); Piggott, sight (1969); Feare, sight.

Phyllanthus maderaspatanus L.

Stoddart 7062 (US).

**Ricinus communis* L.

Stoddart 7063 (US); Procter, sight; Feare, sight.

SAPINDACEAE

**Cardiospermum halicacabum* L.

Fryer 24 (K).

MALVACEAE

**Abutilon indicum* (L.) Sweet

Stoddart 7106 (US), 7121 (US); Coppinger, in Hemsley (1885); Procter, sight (as *Abutilon mauritianum*); Feare, sight.

**Gossypium hirsutum* L.

Stoddart 7104 (US); Coppinger, sight (1885); Procter, sight (as *Gossypium purpurascens*); Feare, sight.

**Malvastrum coromandelianum* (L.) Garcke

Procter, sight; Feare, sight.

**Sida acuta* Burm. f.

Feare, sight.

Sida parvifolia DC.

Stoddart 7124 (US).

Thespesia populnea (L.) Sol. ex Correa

Stoddart 7076 (US); Feare, sight.

GUTTIFERAE

Calophyllum inophyllum L.

Fryer 17 (K); Stoddart 7099 (US) (var. *takamaka* Fosb.); Feare, sight.

TURNERACEAE

**Turnera ulmifolia* L.

Stoddart 7067 (US); Procter, sight; Feare, sight.

PASSIFLORACEAE

**Passiflora suberosa* L.

Stoddart 7090 (US); Fryer, no number, in Summerhayes (1931);
Procter, sight; Feare, sight.

CARICACEAE

**Carica papaya* L.

Stoddart 7085 (US); Coppinger, sight (1885); Fryer, sight (1910);
Piggott, sight (1969); Procter, sight; Feare, sight.

CUCURBITACEAE

**Cucurbita* sp.

Stoddart 7108 (US).

**Cucurbita* cf. *maxima* Duchesne

Stoddart 7134 (US).

**Cucurbita moschata* Duchesne

Procter, sight; Feare, sight.

[LYTHRACEAE]

[*Pemphis acidula* Forst.

Fryer, sight, in Summerhayes (1931); Procter, sight (both in error
for *Suriana maritima* L.)]

COMBRETACEAE

Terminalia catappa L.

Fryer 16 (K).

APOCYNACEAE

**Catharanthus roseus* (L.) G. Don

Vinca rosea L.

Lochnera rosea (L.) Spach

Fryer 29 (K) (as *Lochnera rosea*); Stoddart 7086 (US), 7101 (US);
Piggott, sight (1969); Feare, sight.

**Plumeria* sp.

Stoddart, sight (juvenile).

CONVOLVULACEAE

**Ipomoea batatas* (L.) Lam.

Fryer, no number, in Summerhayes (1931).

Ipomoea macrantha R. and S.

Ipomoea tuba (Schlecht.) G. Don

Stoddart 7093 (US); Fryer, sight (1910); Feare, sight.

Ipomoea pes-caprae (L.) R. Br.

Stoddart 7075 (US) (var. *brasiliensis* (L.) v. Ooststr.); Fryer, sight (1910); Procter, sight; Feare, sight.

BORAGINACEAE

Cordia subcordata Lam.

Stoddart 7078 (US); Feare, sight.

Tournefortia argentea L.f.

Messerschmidia argentea (L.f.) Johnst.

Stoddart 7068 (US); Coppinger, in Hemsley (1885); Fryer, sight (1910); Procter, sight; Feare, sight.

VERBENACEAE

Lippia nodiflora (L.) Michx.

Phyla nodiflora (L.) Greene

Fryer 31 (K); Procter 4042 (MAHE); Stoddart 7066 (US); Feare, sight.

Stachytarpheta jamaicensis (L.) Vahl

Stoddart 7065 (US); Procter, sight; Feare, sight.

LABIATAE

**Plectanthurus* sp.

Stoddart 7115 (US).

SOLANACEAE

**Capsicum minimum* Roxb. (= *C. frutescens* L.?)

Feare, sight.

**Datura metel* L.

Stoddart 7095 (US); Procter, sight; Feare, sight.

**Nicotiana tabacum* L.

Fryer, sight (1910).

**Solanum melongena* L.

Feare, sight.

Solanum nigrum L. (s.l.)

Stoddart 7126 (US); Feare, sight

SCROPHULARIACEAE

Striga asiatica (L.) O. Ktze.

Fryer 33 (K).

BIGNONIACEAE

**Tabebuia heterophylla* (L.) Hemsl.

Stoddart 7096 (US), 7100 (US); Feare, sight (as *Tabebuia rosea*).

ACANTHACEAE

Asystasia multiflora Kl.?

Stoddart 7119 (US).

**Asystasia gangetica* (L.) T. Anders. (= *Asystasia multiflora* Kl.?)

Procter, sight; Feare, sight.

RUBIACEAE

Guettarda speciosa L.

Stoddart 7092 (US), 7132 (US); Feare, sight.

Morinda citrifolia L.

Fryer 4 (K).

GOODENIACEAE

Scaevola taccada (Gaertn.) Roxb.

Stoddart 7070 (US); Fryer, sight (1910) (as *Scaevola koenigii*); Piggott, sight (1969); Procter, sight (as *Scaevola frutescens*); Feare, sight.

COMPOSITAE

Vernonia cinerea (L.) Less.

Stoddart 7061 (US); Fryer, no number, in Summerhayes (1931);
Procter, sight; Feare, sight.

SOURCES

Coppinger collection: listed by Hemsley (1885), pp. 16-17; additional
sight records in Coppinger (1885).

Fryer collection: Fryer's paper on Bird Island (1910) and his
manuscript diary; enumerations of flowering plants in Summerhayes
(1931) and of ferns in Christensen (1912).

Procter collections: Department of Agriculture, Mahe, and enumeration
of collections and sight records in 'List of plants recorded on
Bird Island on 14 July 1970', typescript.

Jeffrey collection: Department of Agriculture, Mahe.

Feare records: sight records cited in Feare (1979).

Stoddart collection: determinations by F.R. Fosberg.

A few miscellaneous collections in herbaria indicated.

Species marked * are judged to be introduced.

Some of the sight records may well be misidentifications.

3. Geography and ecology of Denis Island, Seychelles

INTRODUCTION

Denis Island is located on the northern margin of the Seychelles Bank in latitude 3°48'S. and longitude 55°40'E., 89 km northnortheast of Mahe and 52 km east of Bird Island. It is 2000 m long, has a maximum width in the north of 1380 m, and has a total area of 120 ha (48 per cent larger than Bird Island) (Figure 4).

The island was discovered by and named after Denis de Trobriand, in command of the *Etoile*, in August 1773, but the first full account resulted from the visit of J.C.F. Fryer in August 1908 (Fryer 1910). Subsequently the island was visited by B.H. Baker, C. Jeffrey and C.J. Piggott in the early 1960s (Table 5), but the only connected account of the natural history of Denis remains that of Fryer. The present paper is based on a visit on 10-11 December 1977; it brings together the existing literature, including unpublished material in the Seychelles Archives, and also provides an account of the vegetation and flora.

MORPHOLOGY AND STRUCTURE

Denis is an island formed entirely of carbonate sands which have been extensively phosphatised. The beaches are narrow and apparently stable; there are no pronounced spits or beach ridges, as at Bird Island, and no storm deposits. The average surface elevation is probably only about 2.5 m, rising to 3.5 m in the north and northeast, though no instrumental determinations have been made. About 80 per cent of the surface area is occupied by phosphate rock, totalling about 95 ha, and this reaches the coast to form irregular cliffs about 2 m high at the southwest corner (Muraille Bon Dieu) (Plates 9 and 10) and at the pronounced indentation on the east coast (Sans Tache). As on Bird Island, the upper surface of the phosphate rock is blocky and irregular, with many loose fragments. The lower surface of cementation is irregular and lobate, forming pillars and inlets in the cliffs (Plate 11; also illustrated by Fryer 1910, Plate 2). This morphology is identical to that of similar rocks at Raine Island, Great Barrier Reef, where the lower surface is also exposed in cliffs.

Table 5. Scientific studies at Denis Island

<u>Date</u>	<u>Visitor</u>	<u>Subject</u>	<u>Publication</u>
1775 12 Aug.	D. de Trobriand <u>Etirole</u>	Discovery	De Trobriand, in Fauvel 1909
1906 29-31 March	W.F. Stephens	Phosphate	Stephens 1906a, 1906b
1908 2-8 August	J.C.F. Fryer	General survey and collecting	Fryer 1910
1927	J. Hornell	Collecting	Burleigh 1979
1952	E.S. Brown	Insects	Mattingly and Brown 1955
1960 Sept	C.J. Piggott B.H. Baker	Coconuts Geology	Piggott 1968, 1969 Baker 1963
1962 March	C. Jeffrey	Botany	Jeffrey 1962
1969?	F.L. Lambrecht	Insects	Lambrecht 1971
1977 10-11 December	D.R. Stoddart	Botany General ecology	This paper

According to Piggott (1968, 55), the phosphate rock is more than 1.2 m thick in the northeast but thinner elsewhere. Baker (1963, 41-46) describes a double horizon of cementation in the northeast, in the following section: 5-46 cm: phosphate rock, 30-90 cm: unconsolidated sand, 18-30 cm: phosphate rock. According to Baker the phosphate rock is thicker in the centre of the island, where it forms a single horizon. The cemented material is overlain by guano, much of which has been removed for export. Piggott (1969, 63) terms the superficial material a Jemo Series soil, in contrast to the Shioya Series of the rest of the island, and Baker (1963) gives total P_2O_5 content of guano samples of 31.5, 28.2 and 7.8 per cent.

Towards the eastern side of the island there are elongate water-filled depressions about 1 m below the general surface level. It is not known whether these are natural or whether they result from guano-digging operations earlier this century. They contain fresh water and hydromorphic soils, which are unusual on western Indian Ocean coral islands. Piggott (1969, 63) gives the following profile:

0-13 cm Black clay loam with coarse soft crumb structure, containing about 10 per cent P_2O_5 and 20 per cent organic matter.

- 13-38 cm Brown phosphatic sandstone; very dark in the upper part but getting pale below; the sand being fairly coarse.
- 38-46 cm Coarse white sand, with the watertable at 46 cm.

In addition to the phosphate rock, beachrock outcrops extensively along the southeast shore, where it was noted by Fryer in 1908. Remnants of beachrock indicate this beach was formerly longer, but the coast itself seems to be a stable one. Beachrock also outcrops intermittently along the shore of the west bay. Tidal movement of sand suggests that the beachrock is much more extensive than the outcrops at any time suggest.

As at Bird Island, surface reef is only extensive along the eastern side of the island. The shoal on which Denis stands is very much smaller than that of Bird, and the surrounding surface of the Seychelles Bank is 55-75 m deep.

CLIMATE

Rainfall records were maintained at Denis Island from 1951 to 1962 (Table 6, Figure 5). The mean annual rainfall over 12 years was 1730 mm, with extremes ranging from 1176 to 2643 mm. In the two years (1961-62) for which records were also kept at Bird Island, the Denis Island rainfall was substantially greater (12 per cent greater in 1961, a wet year, and 19 per cent greater in 1962, an average year). It is interesting that the pattern of wet and dry years at Denis during 1951-1962 closely resembles that at D'Arros in the northern Amirantes (Stoddart, Coe and Fosberg 1979), suggesting a general regional control of rainfall variability. December and January are the wettest months and July much the driest. All months show considerable variation in rainfall totals from year to year, but Denis does not experience the prolonged dry seasons and severe droughts which occur on coral islands in the southern Seychelles.

VEGETATION

De Trobriand in 1773 described the vegetation of Denis Island as follows: "quelques parties de l'isle sont coupées par des espèces de prairies dont l'herbe parait très bonne quelques autres petites portions sont d'une terre assez sèche mêlée de sable: environ la moitié de la surface de l'isle est couverte d'assez gros arbres mais dont le bois m'a semblé être trop gros et trop spongieux pour être propre à la construction des vaisseaux" (in Fauvel 1909, 47). These trees may well have been *Pisonia grandis*. Fryer (1910, 19) unfortunately concluded that "the vegetation is of no interest, being all secondary in character and dependent on the coconut cultivation to which its whole surface is devoted". He did, however, distinguish a littoral hedge of *Scaevola*, *Tournefortia* and *Suriana* (wrongly identified by both him and Summerhayes (1931, 278) as *Pemphis acidula*), with *Hibiscus tiliaceus*. Trees

Table 6. Monthly and annual rainfall records at Denis Island

<u>Year</u>	<u>Jan</u>	<u>Feb</u>	<u>Mar</u>	<u>Apr</u>	<u>May</u>	<u>Jun</u>	<u>Jul</u>	<u>Aug</u>	<u>Sep</u>	<u>Oct</u>	<u>Nov</u>	<u>Dec</u>	<u>Year</u>
1951	253.7	70.6	162.8	54.9	161.5	0	0	142.2	91.4	247.1	0	307.3	1491.5
1952	281.2	139.9	121.9	105.4	40.6	140.9	52.8	133.1	57.4	17.3	128.5	207.0	1426.2
1953	221.0	190.5	299.5	75.4	66.8	72.6	76.2	82.6	111.0	109.2	230.1	333.0	1867.9
1954	300.0	0	57.2	12.2	120.6	106.7	86.9	150.4	34.3	7.9	100.6	199.6	1176.3
1955	541.3	243.6	120.1	129.8	11.9	0	0	79.2	241.0	42.4	53.6	274.8	1737.9
1956	210.0	190.2	158.2	97.8	147.3	0	0	85.6	104.6	49.8	99.3	169.2	1312.2
1957	350.3	75.7	287.8	67.8	124.2	60.2	36.1	13.5	64.8	356.1	248.9	496.1	2181.3
1958	104.6	120.9	89.2	158.7	277.9	638.0	24.1	35.8	63.2	50.0	167.9	112.3	1841.7
1959	322.6	71.4	184.9	129.3	61.2	23.9	22.9	99.8	97.3	109.2	181.9	325.6	1630.0
1960	134.6	227.8	15.2	200.2	93.7	95.7	38.1	45.7	66.8	355.1	9.9	274.1	1557.0
1961	419.9	430.8	205.5	78.2	0	27.7	64.3	259.8	319.3	222.2	292.3	196.8	2643.9
1962	429.5	344.7	5.6	118.1	202.9	84.1	20.8	112.5	265.9	120.6	97.0	91.4	1893.1
Mean	297.4	175.5	142.3	102.3	109.1	104.2	35.2	103.3	126.4	140.6	134.2	248.9	1729.5

Source: Stoddart (1971).

mentioned by him included *Casuarina*, *Calophyllum*, *Hernandia*, *Ficus* and *Pisonia*. He also noted the existence of *Typha*; a large fern (probably *Acrostichum* rather than the *Asplenium* he mentions); and *Catharanthus*, as well as bananas and vanilla. Piggott (1969, 59-65) also remarks on the number of large trees in the east and centre of the island (*Calophyllum*, *Hernandia*, *Pisonia*, *Ficus*, *Terminalia*), and found both *Catharanthus* and *Cassytha* to be widespread.

Based on the visit in 1977 and the map and collections then made, the following vegetation units may be distinguished;

1. Littoral hedge, dominated by *Scaevola taccada* but also with *Tournefortia argentea* and *Suriana maritima*, often much covered with *Cassytha filiformis*. On its landward side both *Guettarda speciosa* and *Hibiscus tiliaceus* are common, and in places, especially on the west and southeast sides, *Scaevola* is replaced by *Guettarda*. The littoral hedge on the west side is narrower, less continuous and more diverse, and in places (on the slightly eroding northeast shore and where the phosphate rock outcrops) it is entirely lacking.
2. *Casuarina* woodland. *Casuarina equisetifolia* is extensively planted as a windbreak along the greater part of the coastline (Plate 10), forming a zone 20-100 m wide, often with the trees set out in regular rows. Many are tall and old and some are being removed for timber.
3. Coconut woodland. This covers the entire centre of the island, and many of the trees are about 80 years old. When the plantation was begun on a commercial scale is not known, but it was probably about 1890. By 1903 there were 20,000 trees yielding 50,000 nuts per month (Seychelles Archives C/SS/74(1), 139), and by 1906 the yield was 60,000 nuts per month (Stephens 1906a). Piggott (1969) found the plantation well managed, in spite of the age of the trees and the effects of Rhinoceros Beetle and coccids, and he commented on the high quality of the copra in spite of the poor quality of the nuts. The plantations are still scattered with broadleaf trees - massive *Barringtonia* and *Calophyllum* and smaller *Tabebuia*, *Morinda*, *Terminalia* and *Pisonia*. The fern *Polypodium* and *Kalanchoe* form extensive and dense ground cover on the phosphate areas; *Catharanthus* and other weedy plants are widespread. Piles of coconut husks are covered with the fern *Nephrolepis*.
4. Marsh vegetation. The inland freshwater marshes support tall and impenetrable stands of the fern *Acrostichum speciosum* and the bulrush *Typha javanica* (Plate 12). The latter is rare on coral islands; it is common on high islands in the Seychelles, notably on Praslin and Curieuse, which are the closest high islands to Denis. *Alocasia macrorrhiza* is cultivated in these marshes.

FLORA

Fryer in 1908 recorded a total of 29 species of plants (Fryer 1908, 1910; Summerhayes 1931); 17 species collected by Jeffrey in 1962 are in the Department of Agriculture Herbarium, Mahe; and the 1977 visit yielded 72 species. With occasional archival records the known flora stands at 91 species, rather less than that of Bird Island, but undoubtedly more remain to be recorded. It is apparent that many species were introduced at Denis at an earlier date than at Bird Island. *Casuarina*, *Terminalia*, lime and pumpkin were recorded by the visiting magistrate as early as 1903 (Seychelles Archives C/SS/74(1), 139), and in 1908 Fryer (1908, 1910; Summerhayes 1931) recorded vanilla, banana, cotton, *Datura metel*, *Capsicum frutescens* and *Solanum nigrum*, as well as *Kalanchoe* and *Stachytarpheta*. The *Agave*, *Carica* and *Ricinus* found in 1977 must also have been introduced at an early stage.

INVERTEBRATES

With the exception of the mosquitoes, recently collected by Mattingly and Brown (1955) and Lambrecht (1971), knowledge of the insect fauna of Denis Island derives entirely from the collections of Fryer in 1908. The known fauna of about 60 species is dominated, as at Bird Island, by Coleoptera, Lepidoptera and Diptera. The literature on Fryer's collections is keyed in Table 7. In addition, Hirst (1911) records four species of spiders, and Hirst (1913) a scorpion, all collected by Fryer.

REPTILES

When De Trobriand discovered Denis in 1773 he recorded it as "généralement couverte de tortües de terre et de mer" (in Fauvel 1909, 47). By 1908 Fryer (1910, 19) found only "a few introduced specimens" of the Giant Land Tortoise *Geochelone gigantea*, and he commented that turtles had become "very scarce"; turtle tracks were seen in 1977 on the western beach, but there is no means of estimating the size of either the past or the present population. Apart from De Trobriand's description, there is no further eye-witness account of the Giant Land Tortoise on Denis Island. In 1927, however, James Hornell collected fossil tortoise eggs, presumably from phosphorites, on Denis. These have now been radiocarbon dated by Burleigh (1979), and yielded an age of 1308 ± 85 years B.P., or in calendar terms approximately 680 ± 100 A.D. These eggs confirm De Trobriand's account of the existence of tortoises on Denis Island, and the date, which predates the human occupation of the Seychelles, establishes that they must have colonised the island naturally and not been introduced.

Fryer also collected the skink *Mabuia sechellensis* and the gecko *Phelsuma madagascariensis*, according to Boulenger (1911); by implication (Fryer 1910, 19) he also collected the gecko *Hemidactylus frenatus*.

Table 7. Key to the literature on insects collected at Denis Island

<u>Family</u>	<u>Number of species</u>	<u>Source</u>
Orthoptera	9	Bolivar 1912, 1924
Dermaptera	1	Burr 1910
Odonata	1	Campion 1913
Hemiptera	9	Distant 1913
Neuroptera	1	Needham 1913
Lepidoptera	12	Meyrick 1911; Fryer 1912
Coleoptera	11	Arrow 1922; Champion 1914; Gebien 1922; Maulik 1931; Scott 1912; Sicard 1912; Fleutiaux 1923
Hymenoptera	4	Cockerell 1912; Forel 1912; Meade-Waldo 1912
Diptera	14	Edwards 1912; Lamb 1912, 1914, 1922; Lambrecht 1971; Mattingly and Brown 1955; Stein 1910; Theobald 1912; Bezzi 1923

MAMMALS

In 1773 De Trobriand also mentioned the presence of "vaches marines" on Denis Island (Fauvel 1909, 47). There is no other mention of these animals on the island, other than Fryer's (1910, 19) comment that "the dugongs are extinct". As with the similar but more extensive records at Bird Island, it is probable that these animals were seals rather than dugongs (Stoddart 1972, 215).

BIRDS

De Trobriand in 1773 found the island covered with birds, "dont plusieurs espèces inconnues à ceux de nous qui avons faits des campagnes rares. Ces oiseaux étaient si peu accoutumés à voir des hommes que nous en avons pris une très grande quantité dans les arbres et que nous en avons tué autant que nous avons voulu avec des batons"; he also speaks of "la prodigieuse quantité d'oiseaux de toutes espèces" (in Fauvel 1909, 47).

The island lacks the enormous Sooty Tern colony of Bird Island, and also the colony of Wedge-tailed Shearwaters. The two most abundant seabirds, especially in the *Casuarina*, are the White Tern *Gygis alba* and the Brown Noddy *Anous stolidus*. Fryer (1910) recorded the former as common but did not mention the latter. The Crested Tern *Thalasseus bergii* was also seen in 1977.

Fryer (1908, 1910) recorded the Souimanga Sunbird *Nectarinia sovimanga* (as *Cinnyris*) in 1908, and this is the only native landbird. All the other land birds are introduced. They include: Barred Ground Dove *Geopelia striata*, introduced prior to Fryer's visit in 1908; Mynah *Acridotheres tristis*, not mentioned by Fryer, and, as at Bird, a more recent colonist; Madagascar Fody *Foudia madagascariensis*, introduced to Mahe in 1879 and to Praslin in 1904, but already "common" on Denis in 1908; Turtledove *Streptopelia picturata*, also present in 1908; Moorhen *Gallinula chloropus*, "extremely common" in the marshy areas in 1908 and also in 1977; and escaped *Gallus* in 1908.

Migrants include Turnstone *Arenaria interpres*, common in 1977, and Whimbrel *Numenius phaeopus*, collected in 1908 and seen in 1977.

There are no records of Tropicbirds, Boobies and Frigatebirds, and they certainly do not nest. The absence of attention to the birds of Denis by previous workers on Seychelles birds is remarkable; there are no records for the island given by Vesey-FitzGerald (1940, 1941), Gaymer et al. (1969), Loustau-Lalanne (1962, 1963), or Betts (1940).

HISTORY

At the time of its discovery in 1773, Denis was uninhabited and there was no trace of any human occupation. The island was leased on 31 December 1815 to Captain Lesage (Unienville 1838, III), presumably for fishing and turtling, but nothing at all is known of this period in its history. It presumably became permanently occupied, and in about 1880 a 40 ft high lighthouse tower was erected. This collapsed on 10 December 1881. An iron tripod was then built to hold the light, but this rusted badly, and a stone light was proposed to replace it in 1890. The light was rebuilt in August 1893 but Fryer (1908) found it "somewhat primitive". The present cast-iron braced tower was built in July 1908-September 1910 (Seychelles Archives: B/38, 434, 472; B/39, 168; B/41, 262; B/42, 22, 289, 304, 319, 406; B/43, 337, 365; B/48, 172, 205; B/50, 37). In 1903 the population consisted of 27 men, 7 women and 2 children (Seychelles Archives C/SS/74(1), 139).

In 1906 W.F. Stephen made the first report on the guano deposits, which he found to be more extensive than at Bird Island but untouched. He estimated (1906a) that over half the island was covered with guano, giving a total reserve of 25,000-30,000 tons. He took 30 samples, and later analyses (1960b) gave phosphoric acid contents for the guano of 26.2, 31.3, 30.6 and 29.7 per cent, and of the underlying rock 27.3, 24.5, 20.2, 19.0 and 20.7 per cent. Serious digging did not start

until 1929, however. Between 1929 and 1941 a total of 16,195 tons were exported, mostly in the period 1929-1934 (Baker 1963). After the guano digging ended, coconut palms were rapidly planted over the whole island. Donkeys, pigs and poultry had been introduced by the early 1960s (Piggott 1969).

It is difficult to give any precise idea of the ecological history of Denis Island, since it, like Bird, has clearly undergone profound changes in recent centuries. The amount of phosphate rock must indicate the existence of large seabird colonies within the past five thousand years. These may have been tree-nesting species such as the Red-footed Booby, if the island had *Pisonia* woodland on it, or ground-nesting species such as the Masked and Brown Boobies, if it were largely bare. The former existence of a large tortoise colony, which would require adequate shade, and the presence of many broad-leaf trees in the coconut woodland, as well as De Trobriand's account in 1773, suggest that the island, unlike Bird, was wooded, and that vegetation was not suppressed by ground-nesting birds in the numbers of the Bird Island Sooty Terns. The occurrence of woodland would also account for the existence of a native sunbird and the early introduction of other landbirds. Presumably the native seabirds must have been largely destroyed during the fishing, turtling and coconut growing of the nineteenth century, and the tortoise itself probably became extinct at a very early date. The very extensive guano digging and coconut planting fifty years ago would have completed the ecological transformation.

An airstrip was cut by the owners of the island in 1975-76, and a small tourist hotel opened in 1978. This should give the opportunity for more detailed scientific observations in the future.

ACKNOWLEDGEMENT

We thank M. Pierre Burckardt for making it possible to work on Denis Island in 1977.

4. Plants recorded from Denis Island

POLYPODIACEAE

Acrostichum speciosum Willd.

Stoddart 8109 (US).

Asplenium sp.?

Fryer (1910) (but Christensen 1912 records no ferns).

Nephrolepis cf. *hirsutula* (Forst.f.) Presl

Stoddart 8083 (US).

Polypodium scolopendria Burm.f.

Stoddart 8097 (US).

TYPHACEAE

Typha javanica Schnizl ex Rohrb.

Jeffrey 1209 (MAHE); Stoddart 8143 (US); Fryer (1908) (as *Typha*);
Fryer (1910) (as *Typha angustata*); Summerhayes (1931) (incorrectly
cited as from Bird Island).

POTAMOGETONACEAE

Thalassodendron ciliatum (Forsk.) d. Hart.

Fryer (1910) (as *Cymodocea*).

GRAMINEAE

**Cenchrus echinatus* L.

Jeffrey 1202 (MAHE); Stoddart 8140 (US).

Dactyloctenium ctenoides (Steud.) Bosser

Stoddart 8098 (US).

**Eragrostis ciliaris* (L.) R.Br.

Jeffrey 1199 (MAHE).

**Eragrostis tenella* (L.) Beauv. var. *tenella*

Stoddart 8104 (US).

Eragrostis tenella (L.) Beauv. var. *insularis* Hubb.

Stoddart 8139 (US).

**Eleusine indica* (L.) Gaertn.

Stoddart 8082 (US).

Enteropogon monostachyos (Vahl) S. and E.

Jeffrey 1200 (MAHE) (= *E. sechellensis* (Baker) Dur. and Schinz?)

Enteropogon sechellensis (Baker) Dur. and Schinz.

Stoddart 8087 (US).

**Panicum maximum* Jacq.

Stoddart 8134 (US).

**Pennisetum polystachion* (L.) Schult.

Stoddart 8102 (US), 8108 (US).

Sporobolus virginicus (L.) Kunth.

Stoddart 8150 (US).

Stenotaphrum dimidiatum (L.) Brong.

Stoddart 8094 (US).

Stenotaphrum micranthum (Des.) C.E. Hubb.

Jeffrey 1208 (MAHE).

**Tricholaena rosea* Nees

Rhynchelytrum repens (Willd.) C.E. Hubb.

Stoddart 8101 (US).

CYPERACEAE

Cyperus conglomeratus Rottb.

Cyperus pachyrrhizus Nees ex Boeckl.

Pycneus odoratus (L.) Urban

Jeffrey 1205 (MAHE) (as var. *effusus* (Rottb.) Kuk.); Stoddart 8099 (US); Summerhayes (1931) (as *Pycneus odoratus* and as *C. pachyrrhizus*)

Cyperus dubius Rottb.

Stoddart 8122 (US).

Cyperus ligularis L.

Jeffrey 1201 (MAHE) (mislabelled as from Bird Island); Stoddart 8112 (US), 8144 (US).

**Cyperus rotundus* L.

Stoddart 8142 (US).

Fimbristylis cymosa R.Br.

Stoddart 8121 (US).

PALMAE

**Cocos nucifera* L.

Fryer (1908, 1910), sight; Piggott (1969), sight; Stoddart, sight.

ARACEAE

**Alocasia macrorrhiza* (L.) Schott

Stoddart 8110 (US).

LILIACEAE

**Agave rigida* Northrop var. *sisalana* Perr. ex Engelm.

Agave sisalana Perr.

Stoddart, sight.

**Crinum* sp.

Stoddart, sight.

MUSACEAE

**Musa sapientum* L.

Stoddart, sight.

CASUARINACEAE

**Casuarina equisetifolia* L.

Fryer (1910), sight; Piggott (1969), sight; Stoddart 8085 (US).

MORACEAE

Ficus sp.

Fryer (1908), sight (as 'banyan'), (1910), sight; Piggott (1969), sight.

- **Ficus benghalensis* L.
Stoddart 8141 (US).

AMARANTHACEAE

- **Achyranthes aspera* L. var.?
Jeffrey 1210 (MAHE).
 **Achyranthes aspera* L. cf. var. *aspera*
Stoddart 8086 (US).
 **Amaranthus* cf. *dubius* Mart. ex Thell.
Stoddart 8105 (US).

NYCTAGINACEAE

- Boerhavia repens* L.
Jeffrey 1206 (MAHE) (as *Boerhavia coccinea* Mill., but probably
 this species); Stoddart 8093 (US).
Pisonia grandis R.Br.
 Fryer (1908), sight (as 'Mapou'), (1910), sight (as *Pisonia*
calpidia); Piggott (1969), sight; Stoddart 8148 (US).

PORTULACACEAE

- Portulaca oleracea* L. var. *granulato-stellulata* v. Poelln.
Stoddart 8092 (US).

LAURACEAE

- Cassytha filiformis* L.
 Piggott (1969), sight (as *Cassytha*); Stoddart, sight.

HERNANDIACEAE

- Hernandia sonora* L.
 Fryer (1908) sight (as 'Bois blanc'), (1910), sight (as
Hernandia peltata); Piggott (1969), sight (as *Hernandia peltata*).

MORINGACEAE

- **Moringa oleifera* Lam.
Stoddart 8135 (US).

CRASSULACEAE

**Kalanchoe pinnata* (Lam.) Pers.

Stoddart 8114 (US); Fryer, no number, in Summerhayes (1931) (as *Bryophyllum pinnatum* Kunz:).

LEGUMINOSAE

**Canavalia gladiata* DC.

Fryer, no number, in Summerhayes (1931).

**Cassia occidentalis* L.

Stoddart 8106 (US), 8136 (US).

**Crotalaria verrucosa* L.

Stoddart 8111 (US).

ZYGOPHYLLACEAE

**Tribulus terrestris* L.

Fryer, no number, in Summerhayes (1931).

RUTACEAE

**Citrus aurantiifolia* (Christm.) Swingle

Noted by Visiting Magistrate in 1903 (Seychelles Archives).

SURIANACEAE

Suriana maritima L.

Jeffrey 1207 (MAHE) (mislabelled *Pemphis acidula* Forst.); Stoddart 8138 (US); Fryer (1910), sight (as *Pemphis acidula*); Piggott (1969), sight; Fryer, no number, in Summerhayes (1931) (as *Pemphis acidula*).

EUPHORBIACEAE

**Acalypha indica* L.

Fryer, no number, in Summerhayes (1931).

**Euphorbia cyathophora* Murr.

Euphorbia heterophylla L.

Jeffrey 1204 (MAHE) (as *Euphorbia heterophylla* L.); Stoddart 8090 (US).

**Euphorbia hirta* L.

Fryer, no number, in Summerhayes (1931); Stoddart 8084 (US).

Euphorbia microphylla Heyne ex Roth.

Fryer, no number, in Summerhayes (1931).

**Euphorbia prostrata* Ait.

Fryer, no number, in Summerhayes (1931).

**Pedilanthus tithymaloides* (L.) Poit.

Stoddart 8151 (US).

Phyllanthus maderaspatensis L.

Jeffrey 1198 (MAHE); Fryer, no number, in Summerhayes (1931).

**Ricinus communis* L.

Stoddart 8125 (US).

MALVACEAE

**Abutilon indicum* (L.) Sweet

Stoddart 8116 (US); Fryer, no number, in Summerhayes (1931).

**Gossypium hirsutum* L.

Gossypium maxicanum Tod.

Fryer, no number, in Summerhayes (1931).

Hibiscus tiliaceus (L.) L.

Stoddart 8118 (US); Fryer (1908), sight (as 'Bois du var'), (1910), sight; Fryer, no number, in Summerhayes (1931).

**Sida acuta* Burm.f.

Stoddart 8128 (US).

Sida parvifolia DC.

Jeffrey 1203 (MAHE); Stoddart 8088 (US).

Thespesia populnea (L.) Sol. ex Correa?

Stoddart 8113 (US).

GUTTIFERAE

Calophyllum inophyllum L. var. (probably all var. *takamaka* Fosb.)

Stoddart 8115 (US), 8119 (US); Fryer (1908), sight (as 'Takamaka'), (1910), sight; Piggott (1969), sight.

TURNERACEAE

**Turnera ulmifolia* L.

Stoddart 8130 (US).

PASSIFLORACEAE

- **Passiflora suberosa* L.?
Stoddart 8146 (US).

CARICACEAE

- **Carica papaya* L.
Stoddart 8149 (US).

CUCURBITACEAE

- **Cucurbita* cf. *maxima* Duchesne
 Stoddart, sight.
- Melothria maderaspatana* Cogn.
 Fryer, no number, in Summerhayes (1931).

[LYTHRACEAE]

- [*Pemphis acidula* Forst.
 Fryer (1910), sight (in error for *Suriana maritima* L.);
 Summerhayes (1931) reporting Fryer's sight record.]

COMBRETACEAE

- Terminalia catappa* L.
Stoddart 8126 (US); Piggott (1969), sight.

BARRINGTONIACEAE

- Barringtonia asiatica* (L.) Kurz.
Stoddart 8147 (not retained).

APOCYNACEAE

- **Catharanthus roseus* (L.) G. Don
Stoddart 8124 (US), 8131 (US); Fryer (1910), sight (as *Vinca rosea*); Piggott (1969), sight (as *Catharanthus*).

CONVOLVULACEAE

- Ipomoea* sp.
 Fryer (1910), sight.

**Ipomoea coccinea* L.

Jeffrey 1211 (MAHE).

Ipomoea macrantha R. and S.

Stoddart 8152 (US).

**Ipomoea obscura* (L.) Ker-Gawl

Stoddart 8145 (US).

Ipomoea pes-caprae (L.) R.Br. ssp. *brasiliensis* (L.) v. Ooststr.

Stoddart 8120 (US).

BORAGINACEAE

Cordia subcordata Lam.

Stoddart 8096 (US), 8117 (US).

Tournefortia argentea L.f.

Stoddart 8107 (US); Fryer (1908), sight (as 'Boistabac'), (1910), sight (as *Tournefortia*); Fryer, no number, in Summerhayes (1931); Piggott (1969), sight (as *Tournefortia*).

VERBENACEAE

**Lippia nodiflora* (L.) Michx.

Stoddart 8123 (US).

**Stachytarpheta jamaicensis* (L.) Vahl

Stoddart 8129 (US); Fryer, no number, in Summerhayes (1931).

SOLANACEAE

**Capsicum frutescens* L.

Fryer, no number, in Summerhayes (1931).

**Datura metel* L.

Fryer, no number, in Summerhayes (1931).

Solanum nigrum L. var. *americanum* (Mill.) O.E. Schulz

Stoddart 8103 (US).

SCROPHULARIACEAE

Striga asiatica L.

Stoddart 8089 (US).

BIGNONIACEAE

- **Tabebuia heterophylla* (L.) Hemsl.
Stoddart 8133 (US).

ACANTHACEAE

- Asystasia bojeriana* Nees
Stoddart 8127 (US).

RUBIACEAE

- Guettarda speciosa* L.
Stoddart 8091 (US).

- Morinda citrifolia* L.
Stoddart 8095 (US).

- Spermacoce repens* (DC.) Fosb. and Powell
Stoddart 8093 (US).

GOODENIACEAE

- Scaevola taccada* (Gaertn.) Roxb.
Stoddart 8137 (not retained); Fryer (1908), sight (as 'Bois
 veloutier').

COMPOSITAE

- Vernonia cinerea* (L.) Less. var. *parviflora* DC.
Stoddart 8132 (US).

- Synedrella nodiflora* (L.) Gaertn.
Stoddart 8100 (US).

SOURCES

Fryer collections and observations: Fryer's paper on Denis Island
 (1910) and his manuscript diary (1908); enumerations of flowering
 plants in Summerhayes (1931).

Piggott observations: Piggott (1969).

Jeffrey collections: Department of Agriculture, Mahe.

Stoddart collections: determinations by F.R. Fosberg.

Species marked * are judged to be introduced.

Some of the sight records may well be misidentifications.

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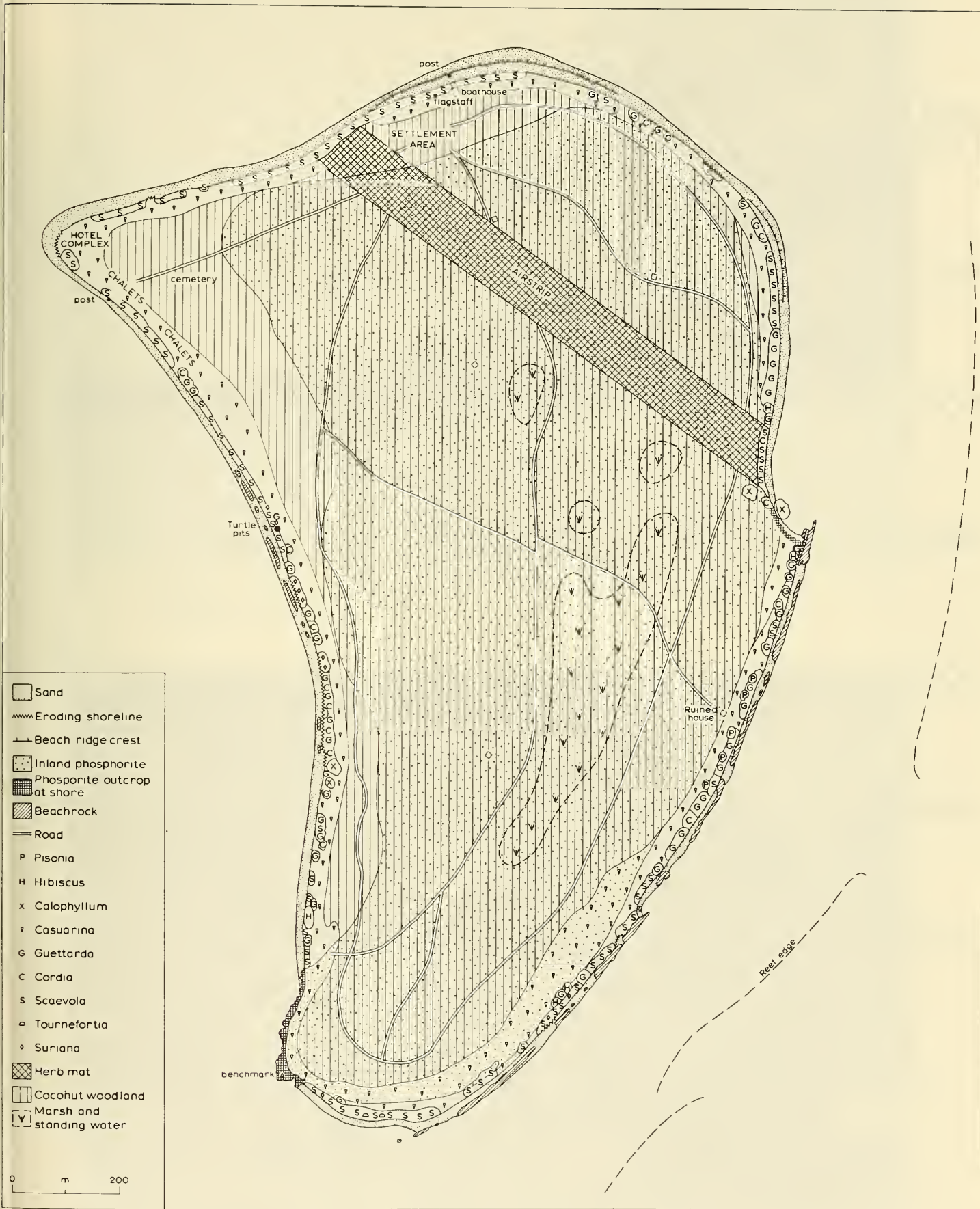


Fig. 4. Denis Island in 1977

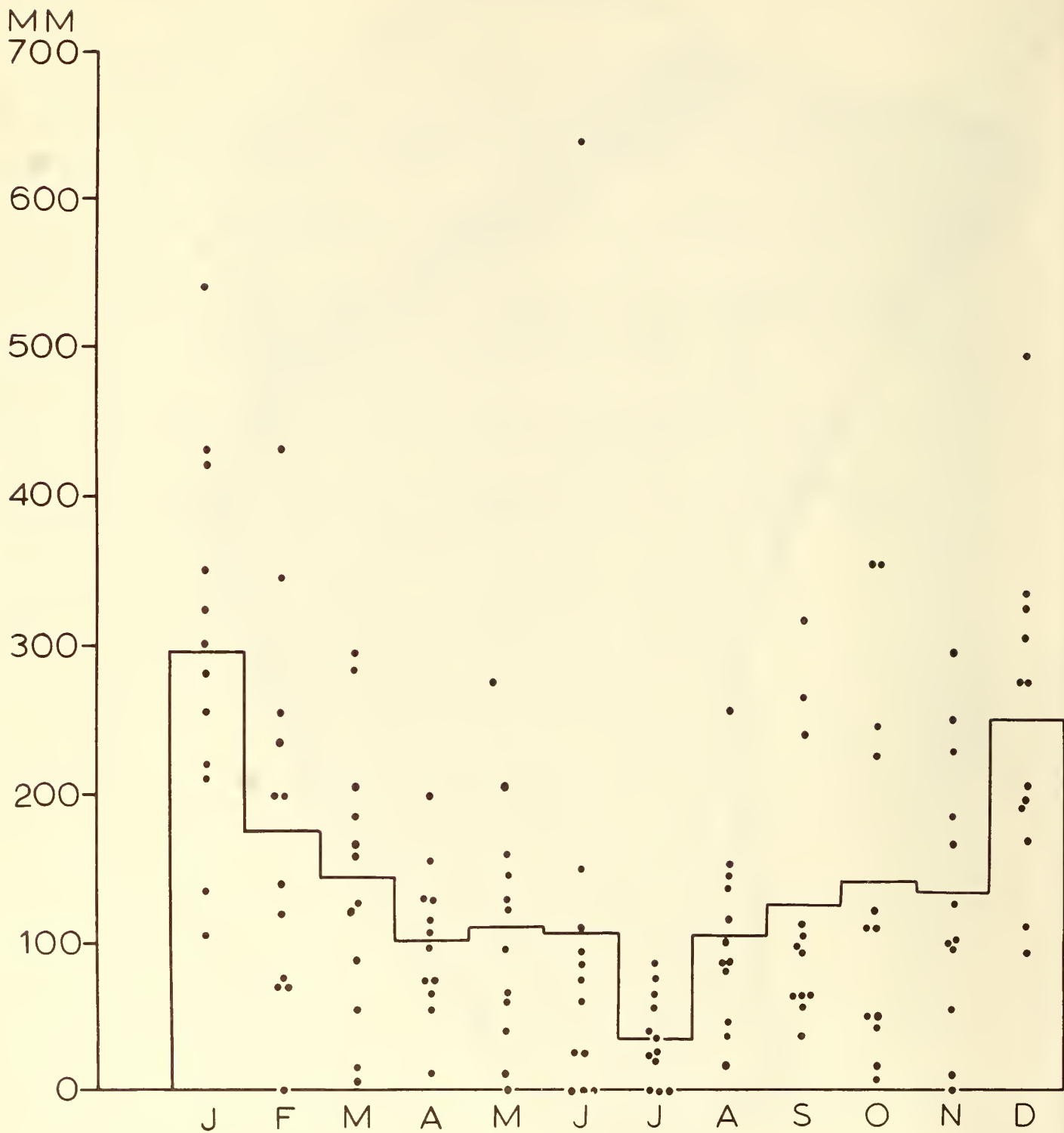


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**TOPOGRAPHIC AND FLORISTIC CHANGE, DRY
TORTUGAS, FLORIDA, 1904-1977**

by D. R. Stoddart and F. R. Fosberg

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TOPOGRAPHIC AND FLORISTIC CHANGE, DRY TORTUGAS, FLORIDA, 1904-1977

by D. R. Stoddart¹ and F. R. Fosberg²

ABSTRACT

Topographic and floristic surveys of the Dry Tortugas keys in 1904, 1915 and 1937 have been used in discussions of the changing relationships between area and floristic diversity on small islands over time, and of the processes of colonization and extinction. It is shown that earlier topographic surveys are in general too unreliable to be so used. A list of Dry Tortugas plants, including all published records as well as new collections made in 1962 and 1977, is presented, together with maps of the keys made in 1977. The total flora of about 130 species includes at least 35 native species, including 5 species of sea-grasses and 4 species of mangroves. Introduced species are largely confined to the two largest islands, and the floras of the smaller keys are dominated by a small number of native species.

INTRODUCTION

The Dry Tortugas Bank (Figure 1) lies at 24°40' N, 82°50' W, 110 km west of Key West, Florida and 165 km north of the nearest point of Cuba. It has a maximum NE-SW dimension of about 18 km, and is 5-8 km wide. As outlined by the 60 ft (18.3 m) isobath, the Bank covers almost exactly 100 sq km. Reef shoals in the centre and eastern part of the Bank rise to less than 6 ft (1.8 m) and have a total area of 245 ha, or only 2.5 per cent of the total Bank area. These shoals have historically supported eleven sand keys, of which three disappeared between 1775 and 1875 and a further three during the present century. The total land area of the eight keys existing in 1900 was about 50 ha; of this, two islands (Loggerhead and Garden Keys) comprised some 70 per cent.

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The reefs and keys of the Dry Tortugas have considerable historical interest. Here Agassiz (1888) first mapped the distribution of coral communities on any extensive reef tract (though his map, showing extensive areas of the now absent *Acropora palmata*, was perhaps somewhat conjectural); here too the presence of the Tortugas Laboratory of the Carnegie Institution led to a long series of research studies published between 1908 and 1942. The reefs have been studied by Vaughan (1914), Brooks (1962) and Jindrich (1972), the latter emphasising the role of hurricanes in controlling community succession and sediment accumulation. More recently, Shinn *et al.* (1977) have shown from shallow borings that the topographic highs on the Bank are Holocene reef constructions at least 8 m thick which have accreted at rates of 1.9-4.5 m/1000 yr.

The keys themselves have been the subject of a series of topographic, geological and botanical studies. Detailed accounts of individual islands are available at intervals over more than 70 years, and this presents an opportunity to study changes in a way not possible for most other reef islands in the world. Indeed, Millspaugh (1907, 1911), who published the results of O.E. Lansing's first surveys in 1904, stated that "the principal value of the survey lies ... in the historical record of the present flora". The main studies available are as follows:

1904, March 19-22	O.E. Lansing, Jr., reported by Millspaugh (1907)
1915, July; 1916	H.H.M. Bowman (1918)
1926, June	W.R. Taylor (1926, 1928); algae and sea-grasses
1931, June-July;	G. Tandy, land plants; no publication
1933, August	and collections not seen
1937, 1938	Davis (1940, 1942)
1962, August	F.R. Fosberg
1977, May-June	D.R. Stoddart

The most important of the earlier studies are those of Millspaugh, Bowman and Davis. In addition a great deal of incidental topographic and botanical information is contained in extensive studies of the Dry Tortugas sooty tern colonies, notably by Stevenson (1938), Sprunt (1948, 1950, 1962-63), Robertson (1964), and Dinsmore (1972). Robertson in particular makes a major attempt to collate all previous information, published and unpublished, on the topographic development and nomenclature of the keys, and his results have been used in the present paper.

Given this data base, it is not surprising that MacArthur and Wilson (1968), 51-55) used the Dry Tortugas as one of their two examples (the other being Kapingamarangi Atoll) of the relationship between floristic diversity and area on small islands. MacArthur and Wilson used plant diversity levels in 1904 and 1916 (the Lansing and Bowman surveys) to calculate extinction rates during this period, and related these to island areas derived from Bowman's surveys.

Plant collections were made by the present authors on the Dry Tortugas keys in 1962 and 1977, and the islands were mapped by pace-and-compass methods in 1977. Comparison of the 1977 maps with earlier maps shows beyond doubt that the maps published by Millspaugh are thoroughly unreliable, and indeed none of his maps possesses any scale at all. Even worse, the scales of maps published by Bowman in 1918 are variable and misleading: the scales of each of his maps are given only in captions, and it is clear that the printer has differentially reduced the figures without a corresponding correction in the cited scale. The island areas derived from Bowman's maps by MacArthur and Wilson are thus wrong. Davis's (1942) maps, in contrast, are meticulous, but unfortunately he maps only Bush, Garden, Loggerhead and Long Keys.

In view of this situation, and especially of the theoretical discussions already based on the Dry Tortugas data, this paper does two things. First, we present maps of the keys in 1977, compare them with previous maps, and attempt to provide reasonable estimates of size and area at the times of the successive surveys. In this section the earlier work of Robertson (1964) is of outstanding importance. Second, we list the plant collections made in 1962 and 1977 and collate the previous records given by Millspaugh, Bowman and Davis. This collation is based only on literature records; no herbarium material from the earlier surveys has been examined; nor have we seen any lists or collections from Tandy's surveys in 1931 and 1933. These data are then used to provide revised floristic lists for each island at the time of each survey. Finally, the usefulness of these revised data for the kind of analysis carried out by MacArthur and Wilson is discussed.

ENVIRONMENT

Rainfall recording at Key West began in 1832; the long term annual mean is 961 mm, with extremes of 1770 mm (1870) and 520 mm (1838). There is a dry season from December to April, with an average of less than 50 mm rainfall per month, a secondary rainfall peak of 105 mm in June, and the main wet season from August to October. September is the wettest month with 165 mm. Hurricanes are frequent between August and December and may bring heavy rainfall as well as high winds and seas; the highest individual monthly rainfall recorded is 533 mm in November 1954. Mean daily temperature ranges from 21.3°C in January to 29.1°C in August; cold spells of several days, with temperatures exceptionally approaching 0°C, may occur during 'northers'

in the dry season. Prevailing winds are easterly, and so are currents (Vaughan 1935), so that the fauna and flora of the Keys are probably mainly derived from the Florida Keys and mainland. The Dry Tortugas are almost tideless: range at springs (MHHW to MLLW) is only 0.2 m.

DESCRIPTIONS OF THE KEYS

Bird Key

Bird Key, the Booby Key of Gault (1790), was located 1.3 km southwest of Garden Key; it disappeared in 1935. Audubon (1835, 263-269) visited it (and called it Bird Key) in May 1832, when it was occupied by a party from Havana collecting tern and noddy eggs.

Robertson (1964) quotes a survey by Tatnall and Gednery in 1829 which gave an area of 4 acres 2 roods 20 poles, equal to 18,210 m², and an estimate by Scott in 1890 of about 8 acres, or 32,400 m². Millspaugh (1907) gave dimensions of 500 x 250 ft (= 153 x 76 m), derived from Lansing's map of 19 March 1904, and if this is used to scale the map the resulting area is 6,440 m². Bowman's (1918) map, at its cited scale of 1:6340, yields an area of 47,695 m²; MacArthur and Wilson (1968) derive an area of 13,935 m² from Bowman's account; while correcting Bowman's scale to 1:2717 by reference to his text, where he gives dimensions of 500 x 300 ft (= 152 x 92 m), yields an area of 9,375 m². Watson (1908), however, gave dimensions of 400 x 300 yds (= 366 x 274 m). Table 1 summarises dimension and area estimates for the island, and Figure 2 gives the maps by Lansing and Bowman at the same scale and orientation: it is clearly impossible to estimate the size of the island with any confidence from these conflicting data.

Wurdemann (1861) in 1857 described a scrub of *Suriana* 7-8 ft (2.1-2.4 m) high, with some *Opuntia*. Lansing found a 'dense growth of *Suriana maritima*', with a marginal zone of herbs and shrubs, especially on the eastern side (Millspaugh 1907, 233). Watson (1908, 192) also mentioned the *Suriana* cover, as well as *Opuntia*. Much of the *Suriana* was killed by a hurricane on 15-17 October 1910, after which Bowman (1918) described *Euphorbia mesembrianthemifolia* as dominant, with extensive *Portulaca* and *Opuntia*. The vegetation was stripped in another storm on 10-11 September 1919 (Robertson 1964, 8, 60-61), and the key itself was destroyed by a hurricane variously dated as 1933, 1935 and 1938. By 1934 it was no more than a sandbar. In January 1940 it was a sandbar 40 ft (12 m) long and 2 ft (0.6 m) high (Robertson 1964, 9); it was not seen in 1977.

Table 2 lists the plant species recorded by Lansing on 19 March 1904 and by Bowman in 1915-1916. The total flora of 15 species includes only one certain introduction, *Cocos nucifera*, which was probably planted between the two surveys. Bartsch (1919, 470) mentions "a few ornamental shrubs near the buildings". but there is no record of their identity.

Apart from the noddies and sooty terns, Robertson (1964, 25) records that pigs were taken to the island from Long Key in July 1865.

Bush Key (Plates 1-5)

Bush Key, immediately east of Garden Key, has had a varied topographic history. It does not appear at all in Gault's (1790) survey of 1773-75, but according to Bartsch (1919) it was vegetated at the time of Audubon's visit in 1832. Robertson (1964) quotes the Tatnall and Gednery survey of 1829 as yielding an area of 5 acres 3 roods 22 poles, or 23,270 sq m. Robertson summarises the subsequent history as follows: a sizeable island by the 1850s; hurricane damage ca 1870; a sandbank in 1889; not mentioned as a separate island in 1890; used as a source for dredged sand for fill at Garden Key in 1901-5. The island was stated to be awash in Millspaugh's (1907) account of Lansing's 1904 survey.

Bowman (1918) prepared the first map in 1915-16 (Figure 3), in a composite map of Bush and Long Keys, said to be on a scale of 1:6340. Bush was given dimensions of 583 x 342 m, and was said to have shrubs on it 12 years old. However, Bartsch (1919, 469) said in 1917 that all vegetation had 'long since' been swept away, and that the island was 'barren'; it is, however, possible that he was really describing Long Key rather than Bush. It is clearly difficult to relate Bowman's map to the present topography of the key, or even to Davis's map of 1937-38; Davis (1942, 187) indeed states that Bowman's map is wrongly oriented by 90°, but even reorientation does not make identification easier.

Davis's map is the first reliable one, giving an area of 115,900 m². Davis (1942, 188) shows three small ponds at the western end of the key, said to have resulted from dredging in 1905, to have been cut off from the sea since about 1919, and to have been infilled during the next decade as the eastern spit gradually extended towards Long Key. He noted (1940, 377) a 'young swamp of *Laguncularia*' around one of these ponds, together with recently established *Avicennia* and *Rhizophora*. Many *Rhizophora* seedlings also drifted ashore here during dispersal experiments in 1937-38 (Davis 1940, 373). In 1942 bombing practice led to a fire 'that burned all vegetation' (Robertson 1964, 35). In 1946 Sprunt (1948, 6) found a 'remarkable spread' of vegetation. There was an eastern pond with *Laguncularia*, *Rhizophora* and some *Suriana*, and a western pond with *Opuntia*, *Salicornia* and *Tournefortia* on its margins; *Salicornia* and *Tournefortia* covered large areas of the key.

In 1962 Fosberg found a dense thicket of *Laguncularia* with a few *Rhizophora* in the main depression; a second small pond covered with *Rhizophora* 4-5 m tall; and much of the island occupied by *Suriana* scrub 2 m tall and by *Opuntia*, with scattered *Sesuvium*, *Sporobolus* and *Uniola*. Areas at the western end used by the sooty terns were almost bare of vegetation. In 1977 the island was much narrower than in 1937. The location of *Conocarpus* and *Laguncularia* thicket indicates that the narrowing has been by erosion along both north and south shores. The

main change in the vegetation has been the development of *Avicennia* woodland within the eastern spit. Dinsmore (1972, 131-132) gives an accurate brief account of the vegetation.

Table 4 lists the plants recorded in 1915-16, 1937, 1962 and 1977. Of the total of 28 species, 25 are native, in spite of the very large number of introductions on the adjacent Garden Key. *Casuarina*, the only certain introduced species, was first recorded in 1977, and could have dispersed naturally from Garden Key.

East Key (Plates 5-8)

East Key was charted by Gauld (1790) in 1773-75. Tatnall and Gednery in 1829 give an area of 12 acres or 48,600 m² (Robertson 1964). The key was said to be eroded during the nineteenth century, but Agassiz's (1888) chart shows the island as one of the largest in the group, with a length of about 500 m and a pronounced NW-SE orientation. Scott in 1890 gave an area of 18 acres or 72,800 m². Lansing mapped it on 21 March 1904, when it was 'a mere sand bank about 280 x 50 feet in area' (Millspaugh 1907, 224-225). Using these dimensions to scale his map gives an area of 2170 m²; if, however, the measurements were really in yards rather than feet the area would be 6500 m². Bowman's (1918) map at its stated scale of 1:6340 yields an area of 115,610 m²; MacArthur and Wilson (1968) estimate the area from Bowman's survey at 111,480 m²; but if Bowman's dimensions of 540 x 250 m are used to rescale the map to 1:5512 the area becomes 87,220 m². Other estimates are given in Table 5. Unfortunately the island was not mapped by Davis. Its area in 1977 was 27,145 m², and its orientation had altered to NE-SW. The sediments of the key have been studied by O'Neill (1976). The variation in size alone of the maps of the island shown in Figure 5 strongly suggests that gross errors have entered the earlier records.

Robertson (1964, 12) quotes Holder's (1892) observation in 1860 that the vegetation comprised 'a dense stand of bay cedar bushes [*Suriana*] and numerous mangroves'; records in 1875 mention it 'partly covered with a growth of cedar', in 1889 as having 'a few bushes on it', and in 1890 as 'covered in parts with stunted bushes'. According to Lansing in 1904 "the vegetation consists principally of *Cenchrus* and *Euphorbia* with a sprinkling of *Uniola* at the southern end; two isolated patches of *Sesuvium* near the centre of the islet; and a few other species scattered without definite association" (Millspaugh 1907, 225): Lansing records *Scaevola*, *Iva* and *Tournefortia*, but not *Suriana*. In 1915-16 Bowman (1918) found the key "almost entirely covered with vegetation", with "large well-grown bushes", but again he does not record *Suriana*. Bartsch (1919, 469) describes "a dense growth of Bermuda grass [meaning *Uniola*?] on the flattened, upper portion, with a scattered growth of *Scaevola* bushes and other plants". Davis (1942) mentions a thicket of *Suriana* on the highest ridge, together with *Ipomoea*, *Sesuvium* and *Cenchrus*. In 1946 Sprunt (1948, 17) found that "Sea-oats (*Uniola*) or sea-lavender (*Tournefortia*) and some bay cedar (*Suriana*) are the principal growths, and there is a

great deal of the goat's-foot vine (*Ipomoea pes-caprae*) running along the beach". Robertson (1964, 13) in about 1960 found "sizeable bushes of bay cedar [*Suriana*], sea lavender (*Tournefortia gnaphalodes*), and *Scaevola plumieri*". In 1977 the island was dominated by open *Uniola* grassland with *Scaevola*, *Suriana*, *Iva*, *Tournefortia* and herbs.

Table 6 shows the plants recorded from East Key by Lansing, Bowman, Davis and Stoddart. All ten species are native. *Suriana*, not recorded by Lansing and Bowman, was certainly present in the nineteenth century, and *Ipomoea pes-caprae*, also not recorded by them, may have simply been overlooked. The only mangrove records for East Key are the *Rhizophora* seedlings which drifted there in 1937 and 1938 during Davis's dispersal experiments (Davis 1940, 373).

Garden Key

Garden Key, the Bush Key of Gault's (1790) survey of 1773-75, has been enormously altered by the construction of Fort Jefferson, said to be the largest brick construction in the western hemisphere, during 1846-1864. The original sand key, on which a lighthouse was built in 1825, was estimated at 7.5 acres (30,350 m²) by Tatnall and Gednery in 1829, and at 8.8 acres (35,610 m²) by Bache in 1845 (Robertson 1964). The total area of the Fort, including the moat, is 64,400 m², and the area within the walls 34,000 m². The Fort was abandoned in 1875; the island was used as a coaling station by the U.S. Navy in 1901-1905, when its areas was increased and modified by dredging in the channel to the east and on the site of Bush Key; and it was again abandoned in 1910 and once more in 1925. It was declared a National Monument in 1935.

The island was mapped by Lansing on 22 March 1904 (Millspaugh 1907, 228-231), by Vaughan (1918), by Bowman (1918), and, in greatest detail, by Davis (1942). Fort Jefferson itself provides a common scale to all these maps. By calculation Lansing's map is at 1:3680; Bowman's is said to be at 1:6340 but is actually at 1:4900; and Davis's is at 1:4646. Comparison of the maps (Figure 7) shows that Bowman's is clearly inaccurate (e.g. in the relative location of the coaling sheds), and that as a result his map overestimates the total area of the island by about 50 per cent.

Millspaugh (1907, 228-231) and Bowman (1918, 125-128) map the vegetation outside the Fort and describe that inside; Davis (1942, 184-187) gives the most detailed account and distribution map. The island was not remapped in 1977. In addition to the main sources, Bartsch (1919, 469-470) gives a brief note on the vegetation. Table 8 lists over 100 species of plants recorded from Garden Key. Of these only 24 are native, and all of the native species were recorded by Millspaugh and by Bowman.

Loggerhead Key (Plate 9)

Loggerhead or Turtle Key (of Gault 1790) is the westernmost of the group. A lighthouse 50 m high was built on it in 1856-1860. The island was the site of the Tortugas Laboratory for more than thirty years (only the foundations now remain); and it is permanently inhabited. Maps are available for 1904, 1915-16, 1937-38 and 1977 (Figure 8). These show variability in length, which is undoubtedly seasonal, and also a general decrease in width. Both types of change are traced by relict beachrock distributions. Loggerhead Key is the only island in the group to possess actively forming beachrock. This was noted by Agassiz (1888, 67), but characteristically misinterpreted as the equivalent of the last interglacial limestones of the Florida Keys. More recent studies of the Loggerhead Key beachrocks are those of Field (1919, 1920), Ginsburg (1953) and Multer (1971).

The vegetation has changed greatly over the last century. Initially, ca 1840, according to Bowman (1918, 120), the island was covered with 'a large stand of old white buttonwood trees, *Conocarpus erectus* L.' These were either cut down or burned by residents. By the time of Lansing's visit in 1904 the centre of the island was covered by a 2 m tall scrub of *Suriana*. Bowman (1918, 121) found *Suriana* dominant, supplemented by an *Opuntia* association. Bartsch (1919, 470) also briefly describes this vegetation. Today the island is dominated by a tall woodland of *Casuarina*, originally introduced by the director of the Tortugas Laboratory ca 1910. *Casuarina* seedlings were growing all over the island by the time of Davis's survey in 1937-38, though *Suriana* was still dominant. It is also interesting that many of the *Rhizophora* seedlings released up to 65 km east of the Dry Tortugas by Davis in 1937 and 1938 arrived on the east beach at Loggerhead Key (Davis 1940, 371-377).

Both Millspaugh (1904, 235) and Bowman (1918, 121) found the key remarkably free from common weeds. Table 10 lists plants recorded from the island. Of the total of 57 species, 19 are native. Fifteen of the 24 definitely introduced species were recorded before 1916.

Long Key (Plate 10)

Long Key, the Rocky Key of Gault (1790), was first mapped by Bowman (1918, 129): it was described as awash and without vegetation by Lansing in 1904. The difficulties of interpreting Bowman's map (Figure 3) have already been discussed in the account of Bush Key. Bartsch (1919, 469) mentioned scattered *Scaevola* and grasses on the southern end of the island, which otherwise was a simple boulder ridge. Davis (1940, 381-382, plate 12; 1942, 189-190) was responsible for planting mangrove seedlings: a few in 1937, 4100 in 1938, 575 in 1940. 2500 were alive in February 1942. Additional seedlings also drifted ashore here during dispersal experiments (Davis 1940, 373). In 1940 also there were 25 *Avicennia* bushes, four of which were more than 60 cm tall. Other plants mentioned by Davis were the mangrove

associates *Batis*, *Salicornia* and *Sesuvium*. Since Davis's survey the key has reduced in area by about 80 per cent.

By 1962 Fosberg found a considerable low scrub of *Avicennia* and much *Salicornia* on the leeward side, with mats of *Sesuvium*, and small numbers of *Rhizophora* up to 1 m tall. In 1977 Stoddart found a woodland of *Rhizophora* and *Avicennia* 4.5 m tall on the west side of the beach ridge, with strand shrubs and herbs on the seaward side.

Table 12 documents the plant species recorded from Long Key. Fifteen of the 16 species recorded are native; *Casuarina* is the only introduced species, recorded as a seedling 50 cm tall.

Middle Key

Middle Key, the Bird Key of Gault (1790), is the smallest of the vegetated islands of the group. It lacked vegetation in 1875 (Robertson 1964). Agassiz's map (1888) shows it to be about 140 m long. In March 1904 Lansing found it awash, with no vegetation. Bowman (1918, 131) described it as an oval patch of sand 80 x 50 ft (24 x 15 m), with an area of 194 m², with clumps of dead *Cakile*. Bowman's map, said to be at 1:6340, is actually at 1:520, and this yields an area of 370 m². Davis (1942) described it as 75 ft (23 m) long in 1937, with *Cakile*, *Iva* and *Euphorbia*. In July 1938 it was intertidal, and in 1940 and 1942 non-existent. Fosberg in 1962 described it as a crescent-shaped sand bar with no vegetation, and it remained the same in 1977.

Table 13 lists the plant records from Middle Key: all three recorded species are native.

North Key

This was charted by Gault (1790) in 1773-75. It was a sandbar in 1860, and had disappeared by 1875 (Robertson 1964, 16). According to Bartsch (1919, 492-493) it may have been the island of a few acres in area named Booby Island by Audubon in 1832.

Northeast Key

This was charted as Sandy Key by Gault (1790) in 1773-75. In the 1850s it possessed a tern colony, but had disappeared by 1875 (Robertson 1964, 16). It was not seen in 1977.

Sand Key (Plate 11)

Lansing mapped Sand Key (or Hospital Key) (the Middle Key of Gault 1790) on 21 March 1904, when it was a small oval island (Figure 10) of only 80 x 50 ft (24 x 15 m), though possibly these measurements should be in yards (= 73 x 46 m): on Agassiz's (1888) chart the island is about 160 m long. Bowman (1918) described it as measuring 90 x 45 ft (27 x 14 m) and mapped it at a scale said to be 1:6340 but actually 1:460. The true area at both surveys, assuming the dimensions in feet

to be correct, was about 225 m² (Table 14). The flora was confined to few scattered herbaceous species; there were no plants on it at all at the time of Bartsch's (1919, 469) survey. In 1938 Davis gave dimensions of 110 x 70 ft (34 x 21 m) but did not map it. It had a sparse vegetation, but *Rhizophora* seedlings which drifted there in 1937-38 failed to become established (Davis 1940, 373). It was unvegetated in 1946 (Sprunt 1948). Fosberg noted 'a patch of bushes and a patch of grass' in 1962. Robertson (1964, 14) described it as "always a small, shifting sandbar with little vegetation ... no permanent plant cover has been established". In 1977 it was much larger than in the past, but again unvegetated (Figure 10).

A hospital was built on the key in the 1870s, and became derelict and ruined at an unknown data. Broken blocks of masonry were noted on the key by Bowman in 1938, Davis in 1938, and again in 1977. Davis also noted relict beachrock, which is extensive in shallow water south of the key.

Table 15 lists plants recorded from the key: all eight species are native.

Southwest Key

This was charted by Gauld (1790) in 1773-75; it had disappeared by 1875 (Robertson 1964, 16).

FLORA

The flora comprises 35 native or probably native species (including five species of sea-grasses and 4 species of mangroves); at least 73 introduced species; and 23 species of uncertain status; giving a total of 131 species. This compares with 25 species (20 native) at Alacran Reef, Gulf of Mexico; 16 species (15 native) at the Morant Cays, 11 species (6 native) at the Pedro Cays, and 63 species at Glover's Reef, all in the Caribbean Sea. It is striking that the smaller Dry Tortugas islands, other than Garden and Loggerhead Keys, are dominated by native species, and that a very small number of native species occur on most of the islands. These include *Cenchrus incertus*, *Uniola paniculata*, *Cyperus planifolius*, *Sesuvium portulacastrum*, *Cakile lanceolata*, *Suriana maritima*, *Euphorbia mesembrianthemifolia*, *Ipomoea pes-caprae*, *Tournefortia gnaphalodes*, *Scaevola plumieri* and *Iva imbricata*, all present on at least five islands. The other two-thirds of the native species are more patchily distributed (Table 16).

The native flora is characteristic of small Caribbean/West Indian coral islands, but with some distinctive additions and several omissions. The five native grasses include the tall and distinctive sea-oats *Uniola paniculata*. This species extends along the coast of Florida, round the Gulf of Mexico into Tabasco, through the Bahamas, and along the north coast of Cuba (Yates 1966), but it is otherwise absent from the Caribbean strand flora. The other grasses are

widespread strand species. The single sedge (*Cyperus planifolius*) is also a widespread reef-island species.

The shrubs are dominated by *Suriana maritima* (also extensive at Alacran); *Tournefortia gnaphalodes*, a widespread Caribbean beach shrub; *Scaevola plumieri*, common in the northeastern and eastern Caribbean; and *Iva imbricata*, a variable plant of the tropical and subtropical Atlantic coast of North America but not otherwise found on Caribbean coral islands. *Borrchia arborescens*, which extends through the Florida Keys to the Marquesas, and is also extensive in Cuba and the Bahamas, as well as further south (Semple 1978), is curiously absent from the Dry Tortugas.

The herbaceous flora includes common reef island species of *Portulaca*, *Sesuvium*, *Cakile*, *Euphorbia*, and the vines *Ipomoea macrantha*, *Ipomoea pes-caprae* and *Canavalia rosea*. *Cassytha filiformis* is notably absent. On some islands with suitable substrate conditions there is a mangrove community (*Conocarpus*, *Laguncularia*, *Rhizophora*, *Avicennia*) with associated *Batis maritima*, *Atriplex pentandra*, *Salicornia bigelovii*, *Alternanthera maritima* and *Philoxerus vermicularis*, but the mangroves are much less extensive than in the nearby Marquesas and may be a recent development (Bowman 1918, 115, describes mangroves as 'entirely lacking').

There is no indubitably native tree species, though the status of *Cordia sebestena*, *Bursera simaruba*, *Coccoloba uvifera* and *Thespesia populnea* is open to question. All are common Caribbean coral island species.

VEGETATION

Both Bowman (1918, 115) and Davis (1942) have described vegetation units from the Dry Tortugas. Bowman distinguished a *Uniola* grass community (with *Cakile*, *Cenchrus*, *Sesuvium*, *Tournefortia*, *Ipomoea* and *Scaevola*); a *Suriana* scrub community (with *Canavalia*); an *Opuntia* community (with *Paspalum*, *Ipomoea macrantha*, *Ipomoea pes-caprae*, and *Melanthera aspera*); and a *Euphorbia* [*Chamaesyce*] community with *Iva imbricata* and *Cyperus planifolius*. Davis's categories were broader and described in terms of topographic units common to the Florida Keys as a whole. They included:

- (a) Strand-beach Associates (*Sesuvium*, *Cakile*, *Ipomoea*, *Sporobolus*, *Uniola*, *Euphorbia*, *Tournefortia*).
- (b) Strand-dune Associates (*Uniola*, *Euphorbia*, *Hymenocallis*, *Tournefortia*, *Suriana*).
- (c) Strand-scrub Associates (dominated by *Suriana*, with *Caesalpinia*, *Solanum* and *Opuntia*).

In addition he describes an *Opuntia* Associates, a *Euphorbia* [*Chamaesyce*] Associates, an *Agave* Associates, and a *Laguncularia* Associates. He comments on the absence of mangrove communities, except around the ponds on Bush Key.

These categories remain useful for describing vegetation units on the keys, but an additional unit of *Casuarina* woodland must be added for the tall woodland which has grown up on Loggerhead Key since 1940.

CONCLUSION

It will be apparent from this paper that the uncertainty over past estimates of dimension and area of the Dry Tortugas keys is too great for acceptable estimates to be derived from the surveys made in 1904 and 1915-16. This results from a combination of surveying error, printer's error, and natural change in the islands themselves. Only Davis's surveys in 1937-38 of Bush, Garden, Loggerhead and Long Keys meet required standards of reliability. Since there is also much evidence of considerable topographic changes in the islands themselves, it is not acceptable in analyses of area-diversity relationships to standardise island area on the basis of any one survey, however reliable it may be.

Second, we do not believe that the plant species records from the earlier surveys can be made to bear inferences of colonisation or extinction between the surveys, except for those islands such as Bird, Middle and Sand Keys which underwent catastrophic destruction during cyclones and were then recolonised. On the larger islands inadvertent non-recording is at least as plausible an explanation as colonisation or extinction. Indeed, apart from the cyclone-damaged islands, where floristic change resulted from massive substrate disturbance, we are impressed by the stability of the native floras over time. The fact that on all of the islands the total number of native species recorded has increased between 1904 and 1977 we interpret as simply the result of collecting intensity rather than any true increase in the number of native species present.

This is not to deny that processes of the kind envisaged by MacArthur and Wilson (1968) may operate on small reef islands, but rather to say that the data from the Dry Tortugas are not of sufficient quality to support their theoretical speculations. Furthermore, we feel it highly likely that more species remain to be recorded on the keys, and that such new records should not themselves be inferred to be new arrivals.

The data considered in this paper are summarised in tabular form in Table 17 (numbers of all species, of native species, of introduced species, and of species of uncertain status, recorded for each island at the time of each survey) and in Table 18 (the area, total number of species, and number of native species for each island at each survey). Table 19 revises MacArthur and Wilson's (1968) Table 5, which sets out data on presumed extinctions between 1904 and 1916. Finally, Figure 11 uses the 1977 island areas and the total recorded number of species for each island (other than Garden and Loggerhead Keys) to give a visual impression of the relationship between species number and island area both for the Dry Tortugas and for other Gulf of Mexico and Caribbean

groups of reef islands. In addition to a rather diffuse area control, Figure 11 also shows that wet islands close to continental areas (such as Glover's Reef) have higher species numbers than more remote and drier islands such as the Pedro and Morant Cays, with the Dry Tortugas in an intermediate position. These relationships have been analysed further by Stoddart and Fosberg (in press).

The problems examined here are not, of course, unique to the Dry Tortugas. It is worth recalling that Millspaugh (1899) was also responsible for a series of early maps and species records for the islands of Alacran Reef, Gulf of Mexico. These islands were remapped by Folk (1967) in 1960, and the flora restudied by Bonet and Rzedowski (1962) and Fosberg (1962) in 1961. Table 20 summarises the Alacran data from these surveys. Island areas derived from Folk's maps vary from 1.4 to 6 times the areas measured in 1899, the average increase being about four times; Folk (1967, 415, 343) used these apparent increases in a detailed commentary on stages of island evolution. Similarly Fosberg (1962, 4) commented on the 'profound changes' which had occurred since Millspaugh's visit. In view of the ambiguities demonstrated in the Dry Tortugas data, it would perhaps be wise to be sceptical of the Alacran — and indeed other early — records which purport to indicate massive changes over short periods of time.

The temptation to use such data in support of general theory is considerable, but we need to remember that such theory is no better than the data by which it is supported.

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PLANTS RECORDED FROM THE DRY TORTUGAS KEYS

This list derives mainly from the published records of Millspaugh (1907), Bowman (1918) and Davis (1942), together with determinations by F.R. Fosberg of collections made by the authors in 1962 and 1977. Species marked N are judged to be native; those marked I to be introduced; and those marked ? are of uncertain status.

PANDANACEAE

I *Pandanus tectorius* Park.

Garden Key: Fosberg sight record in 1962.

ZOSTERACEAE

N *Halodule wrightii* Aschers. (sensu lato)

Garden Key: Fosberg 43018 (US).

Bird Key: W.R. Taylor, 7 June 1926 (MICH) (den Hartog 1970, as *H. beaudettei* (den Hartog) den Hartog).

Long Key: W.R. Taylor, 25 June 1926 (MICH) (den Hartog 1970, as *H. beaudettei* (den Hartog) den Hartog).

N *Syringodium filiforme* Kütz.

Garden Key: Fosberg 43013 (US).

Loggerhead Key: W.R. Taylor, 19 June 1926 (MICH) (den Hartog 1970).

HYDROCHARITACEAE

N *Halophila decipiens* Ostenfeld

Dredged, 15 fathoms, H.H.M. Bowman, July 1915 (MICH);
10 fathoms, Tandy 1111 (BM), Tandy 1254 (BM); 18-20 fathoms,
Tandy 1570 (BM) (all citations from den Hartog 1970).

N *Halophila engelmanni* Aschers.

Dredged, 18-20 fathoms, Tandy 1569 (BM), Tandy 1599 (BM) (den Hartog 1970).

N *Thalassia testudinum* Banks ex König

Bird Key: Tandy 1068 (BM) (den Hartog 1970).

'Long Bush Key': Tandy 1264 (BM) (den Hartog 1970).

GRAMINEAE

I *Brachiaria* sp.

Garden Key: Fosberg 43021 (US).

- ? *Cenchrus echinatus* L.
 Garden Key: Millspaugh 1907; Davis 1942; Fosberg 43059 (US).
 Loggerhead Key: Bowman 1918; Stoddart 8056 (US).
- ? *Cenchrus myosuroides* H.B.K.
 Loggerhead Key: Fosberg 43041 (US).
- N *Cenchrus incertus* M.A. Curtis
 Bird Key: Millspaugh 1907 (as *C. tribuloides*); Bowman 1918.
 Bush Key: Bowman 1918.
 East Key: Millspaugh 1907 (as *C. tribuloides*); Bowman 1918;
 Davis 1942; Stoddart 8033 (US).
 Garden Key: Millspaugh 1907 (as *C. tribuloides*); Fosberg 42983, 42990, 43060 (US).
 Loggerhead Key: Bowman 1918; Fosberg 43045 (US).
- I *Cynodon dactylon* (L.) Pers.
 Garden Key: Bowman 1918 (as *Capriola dactylon*); Davis 1942;
Fosberg 42996 (US).
- I *Digitaria horizontalis* Willd.
 Garden Key: Fosberg 42981 (US).
- ? *Digitaria sanguinalis* (L.) Scop.
 Garden Key: Millspaugh 1907 (as *Syntherisma fimbriatum*);
 Bowman 1918 (as *Syntherisma marginatum*); Davis 1942;
Fosberg 42985 (US).
- I *Eragrostis ciliaris* (L.) R.Br.
 Garden Key: Fosberg 43017 (US).
- ? *Eragrostis prolifera* (Sw.) Steud.
 Garden Key: Fosberg 43019 (US); Stoddart 8065 (US).
 Loggerhead Key: Stoddart 8052 (US).
- I *Eragrostis tenella* (L.) Beauv. ex. R. & S.
 Garden Key: Davis 1942.
 Loggerhead Key: Fosberg 43032 (US).
- N *Eustachys petraea* (Sw.) Desv.
 Bush Key: Davis 1942 (as *Chloris*).
 Garden Key: Millspaugh 1907; Davis 1942 (as *Chloris*);
Fosberg 43056 (US).
 Loggerhead Key: Fosberg 43051 (US); Stoddart 8058 (US).
- I *Panicum maximum* Jacq.
 Loggerhead Key: Fosberg 43047 (US).
- ? *Paspalum caespitosum* Fleugge
 Garden Key: Bowman 1918; Davis 1942.
 Loggerhead Key: Bowman 1918.

N *Paspalum distichum* L.

Bird Key: Millspaugh 1907.

Garden Key: Millspaugh 1907.

? *Sporobolus domingensis* (Trin.) Kunth

Garden Key: Davis 1942.

? *Sporobolus purpurascens* (Sw.) Hamilt.

Garden Key: Millspaugh 1907.

N *Sporobolus virginicus* (L.) KunthBush Key: Davis 1942; Fosberg 43000 (US); Stoddart 8004 (US).

Garden Key: Bowman 1918; Davis 1942.

Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Fosberg 43029 (US).Long Key: Stoddart 8029 (US).I *Stenotaphrum secundatum* (Walt.) O. Ktze.

Garden Key: Fosberg sight record in 1962.

N *Uniola paniculata* L.

Bird Key: Millspaugh 1907; Bowman 1918.

Bush Key: Bowman 1918; Davis 1942; Fosberg sight record in
1962; Stoddart 8001 (US).East Key: Millspaugh 1907; Bowman 1918; Stoddart 8031 (US).

Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942.

Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Fosberg 43038 (US); Stoddart 8048 (US).

Sand Key: Millspaugh 1907; Davis 1942.

CYPERACEAE

N *Cyperus planifolius* L.C. Rich.Bird Key: Millspaugh 1907 (as *C. brunneus*).Bush Key: Fosberg 42999 (US); Stoddart 8018 (US).Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942 (as
C. brunneus); Fosberg 42982, 43054, 43055 (US).Loggerhead Key: Bowman 1918 (as *C. brunneus*); Fosberg 43033 (US); Stoddart 8053 (US).Long Key: Bowman 1918 (as *C. brunneus*).

PALMAE

I *Cocos nucifera* L.

Bird Key: Bowman 1918.

Garden Key: Fosberg sight record in 1962; Stoddart sight
record in 1977.Loggerhead Key: Bowman 1918; Davis 1942; Stoddart sight
record in 1977.I *Phoenix canariensis* Hort ex Chabaud.

Garden Key: Bowman 1918; Davis 1942.

I *Phoenix dactylifera* L.

Garden Key: Bowman 1918; Davis 1942; Fosberg sight record in 1962.

I *Pritchardia* sp.

Garden Key: Fosberg sight record in 1962.

I *Washingtonia filifera* (Lindl.) Wendl.

Garden Key: Fosberg sight record in 1962.

COMMELINACEAE

I *Rhoeo spathacea* (Sw.) Stearn

Garden Key: Fosberg sight record in 1962.

LILIACEAE

I *Agave decipiens* Baker

Garden Key: Bowman 1918.

I *Agave americana* L.

Garden Key: Davis 1942.

Loggerhead Key: Davis 1942.

I *Agave rigida* Mill.

Loggerhead Key: Bowman 1918.

I *Agave* sp.

Loggerhead Key: Fosberg sight record in 1962; Stoddart sight record in 1977.

I *Aloe barbadensis* Mill.

Garden Key: Fosberg sight record in 1962.

Loggerhead Key: Bowman 1918; Davis 1942 (both as *Aloe*).

I *Asparagus sprengeri* Regel

Loggerhead Key: Bowman 1918.

Without locality: Davis 1942 Table 7.

? *Hymenocallis latifolia* (Mill.) Roem.

Bird Key: Bowman 1918 (as *H. caymanensis* Herb.).

Garden Key: Millspaugh 1907 (as *H. caribaea* (L.) Herb.);

Bowman 1918 (as *H. caymanensis* Herb.); Davis 1942 (as *H. caymanensis* Herb.).

Loggerhead Key: Millspaugh 1907 (as *H. caribaea* (L.) Herb.);

Bowman 1918 (as *H. caymanensis* Herb.); Davis 1942 (as *H. caymanensis* Herb.); Fosberg 43050 (US); Stoddart sight record in 1977.

I *Hymenocallis littoralis* (Jacq.) Salisb.

Garden Key: Fosberg sight record in 1962.

I *Yucca aloifolia* L.

Loggerhead Key: Bowman 1918; Davis 1942.

MUSACEAE

I *Musa sapientum* L.

Garden Key: Fosberg sight record in 1962.

CASUARINACEAE

I *Casuarina equisetifolia* L.Bush Key: Stoddart 8008 (US).

Garden Key: Davis 1942.

Loggerhead Key: Bowman 1918; Davis 1942; Stoddart 8050 (US).Long Key: Fosberg 43005 (US).

MORACEAE

I *Ficus carica* L.

Without locality: Davis 1942 Table 7.

I *Ficus hispida* L.f.

Loggerhead Key: Bowman 1918; Davis 1942.

I *Ficus palmata* Forsk.?Loggerhead Key: Fosberg 43048 (US).

POLYGONACEAE

? *Coccoloba uvifera* L.Garden Key: Bowman 1918; Davis 1942; Fosberg sight record in 1962; Stoddart 8062 (US).Loggerhead Key: Bowman 1918; Stoddart 8041 (US).

BATIDACEAE

N *Batis maritima* L.

Bush Key: Stoddart sight record in 1977.

Long Key: Davis 1942.

CHENOPODIACEAE

- N *Atriplex pentandra* (Jacq.) Standl.
 Bush Key: Bowman 1918 (as *A. cristata*); Stoddart 8019 (US).
 Garden Key: Millspaugh 1907; Bowman 1918 (both as
A. cristata); Stoddart 8081? (US).
 Long Key: Bowman 1918 (as *A. cristata*); Fosberg 43004 (US);
Stoddart 8021 (US).
 Without locality: Davis 1942 Table 7 (as *A. cristata*).
- N *Salicornia bigelovii* Torr.
 Long Key: Davis 1942; Fosberg 43007 (US); Stoddart 8026 (US).

AMARANTHACEAE

- N *Alternanthera maritima* J. St. Hil.
 Bush Key: Bowman 1918; Davis 1942.
 Garden Key: Bowman 1918.
 Long Key: Bowman 1918.
- ? *Alternanthera philoxeroides* (Mart.) Griseb.
 Bush Key: Stoddart 8009 (US).
- I *Amaranthus viridis* L.
 Garden Key: Millspaugh 1907.
- I *Amaranthus* sp.
 Without locality: Davis 1942 Table 7.
- N? *Philoxerus vermicularis* (L.) Beauv.
 Bush Key: Fosberg 42975 (US).
 Garden Key: Millspaugh 1907 (as *Lithophila vermicularis*).
 Without locality: Davis 1942 Table 7 (as *Lithophila*
vermicularis).

NYCTAGINACEAE

- ? *Boerhavia coccinea* Mill.
 Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942
 (all as *B. viscosa*); Fosberg 43061 (US).
 Loggerhead Key: Bowman 1918; Davis 1942 (both as *B. viscosa*);
Stoddart 8055? (US); Fosberg 43035 (US).
 Without locality: Davis 1942 Table 7.
- I *Bougainvillea glabra* Choisy
 Garden Key: Fosberg sight record in 1962.

PORTULACACEAE

N *Portulaca oleracea* L.

Bird Key: Millspaugh 1907; Bowman 1918.

Garden Key: Millspaugh 1907; Bowman 1918; Fosberg 43008, 43009 (US); Stoddart 8073 (US).

Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942.

AIZOACEAE

N *Sesuvium portulacastrum* (L.) L.

Bird Key: Millspaugh 1907; Bowman 1918.

Bush Key: Bowman 1918; Davis 1942; Fosberg sight record in 1962; Stoddart 8011 (US).

East Key: Millspaugh 1907; Bowman 1918; Davis 1942; Stoddart 8032 (US).

Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942.

Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942; Fosberg sight record in 1962.

Long Key: Bowman 1918; Davis 1942; Fosberg sight record in 1962; Stoddart 8029 (US).

Sand Key: Millspaugh 1907.

PAPAVERACEAE

I *Argemone mexicana* f. *leiocarpa* (Greene) G.B. Ownbey

Garden Key: Millspaugh 1907 (as *Argemone leiocarpa*).

N *Cakile lanceolata* (Willd.) O.E. Schulz

Bird Key: Millspaugh 1907 (as *C. fusiformis*); Bowman 1918.

Bush Key: Bowman 1918; Stoddart 8002 (US).

East Key: Millspaugh 1907 (as *C. fusiformis*); Bowman 1918; Stoddart 8035 (US).

Garden Key: Millspaugh 1907 (as *C. fusiformis*); Bowman 1918; Stoddart 8080 (US).

Loggerhead Key: Millspaugh 1907 (as *C. fusiformis*); Bowman 1918.

Middle Key: Bowman 1918; Davis 1942.

Sand Key: Bowman 1918.

CRUCIFERAE

I *Lepidium virginicum* L.

Garden Key: Bowman 1918; Fosberg 43025 (US).

LEGUMINOSAE

I *Abrus precatorius* L.

Garden Key: Fosberg sight record in 1962.

- ? *Caesalpinia bonduc* (L.) Roxb.
 Garden Key: Bowman 1918 (as *Guilandina crista*).
 Loggerhead Key: Millspaugh 1907 (as *Caesalpinia crista*);
Stoddart 8059 (US).
- I *Caesalpinia pulcherrima* (L.) Sw.
 Garden Key: Fosberg sight record in 1962.
- I? *Caesalpinia* sp.
 Loggerhead Key: Fosberg 43042 (US).
- I *Cajanus cajan* (L.) Millsp.
 Garden Key: Bowman 1918 (as *Cajanus cajan*).
 Without locality: Davis 1942 Table 7.
- N *Canavalia rosea* (Sw.) DC.
 Garden Key: Millspaugh 1907 (as *C. obtusifolia*); Bowman 1918;
 Davis 1942 (both as *C. lineata*); Fosberg 43057 (US);
Stoddart 8063 (US).
 Loggerhead Key: Millspaugh 1907 (as *C. obtusifolia*); Bowman
 1918; Davis 1942 (both as *C. lineata*); Fosberg sight
 record in 1942.
- I *Ceratonia siliqua* L.
 Garden Key: Fosberg 43064 (US, POM).
- I *Crotalaria pallida* Ait.
 Garden Key: Stoddart 8078 (US).
- I *Delonix regia* (Boij.) Raf.
 Garden Key: Fosberg sight record in 1962; Stoddart 8070 (US).
- ? *Desmanthus depressus* H. & B.
 Garden Key: Fosberg 43011 (US).
- I *Desmodium incanum* (Gmel.) Schinz
 Garden Key: Fosberg 43067 (US).
- I *Rhynchosia minimum* (L.) DC.
 Without locality: Davis 1942 Table 7 (as *Dolicholus minimus*).
- I *Rhynchosia parviflorus* DC.
 Garden Key: Bowman 1918 (as *Dolicholus parviflorus*).
- I *Sesbania* sp.
 Garden Key: Millspaugh 1907 (as *S. sericea*); Bowman 1918 (as
Glottidium vescarium); Davis 1942 (as *S. macrocarpa*).
- I *Tamarindus indica* L.
 Garden Key: Bowman 1918; Davis 1942; Fosberg sight record in
 1962.

ZYGOPHYLLACEAE

? *Tribulus cistoides* L.

Loggerhead Key: Millspaugh 1907.

RUTACEAE

I *Citrus aurantiifolius* (Christm.) Swingle

Garden Key: Fosberg sight record in 1962.

SURIANACEAE

N *Suriana maritima* L.

Bird Key: Millspaugh 1907; Bowman 1918.

Bush Key: Bowman 1918; Davis 1942; Fosberg sight record in 1962; Stoddart 8020 (US).

East Key: Davis 1942; Stoddart 8037 (US).

Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942; Stoddart 8071 (US).

Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942; Stoddart 8051 (US).

Long Key: Bowman 1918; Fosberg 43006 (US); Stoddart 8023 (US).

BURSERACEAE

? *Bursera simaruba* (L.) Sarg.

Garden Key: Bowman 1918; Davis 1942 (both as *Elaphrium simaruba*); Fosberg sight record in 1962.

Loggerhead Key: Fosberg 43027 (US).

EUPHORBIACEAE

I *Breynia disticha* (J.R. & G. Forst.)

Garden Key: Fosberg sight record in 1962.

I *Codiaeum variegatum* (L.) Blume

Garden Key: Fosberg sight record in 1962.

? *Euphorbia adenoptera* Bert.

Garden Key: Millspaugh 1907.

? *Euphorbia blodgettii* Engelm. ex Hitchc.

Garden Key: Fosberg 42980, 42995 (US).

I *Euphorbia glomerifera* (Millsp.) Wheeler

Garden Key: Bowman 1918 (as *Chamaesyce hypericifolia*);

Fosberg 42994 (US), 43062 (US, POM).

? *Euphorbia heterophylla* L.

Poinsettia pinetorum Small

Euphorbia havanensis Willd.

Bush Key: Stoddart 8005 (US).

Garden Key: Millspaugh 1907 (as *E. havanensis*); Davis 1942
(as *Poinsettia cyathophora*); Fosberg 42989 (US);
Stoddart 8075 (US).

Loggerhead Key: Bowman 1918 (as *Poinsettia pinetorum*); Davis
1942 (as *Poinsettia cyathophora*); Fosberg 43046 (US);
Stoddart 8054 (US).

Some of these seem intermediate between this species and
Euphorbia cyathophora Murr.

I *Euphorbia hirta* L.

Garden Key: Fosberg 43015 (US).

Loggerhead Key: Fosberg 43031 (US).

N *Euphorbia mesembrianthemifolia* Jacq.

Chamaesyca buxifolia in Bowman 1918.

Euphorbia buxifolia in Millspaugh 1907, Davis 1942.

Bird Key: Millspaugh 1907; Bowman 1918.

Bush Key: Bowman 1918; Davis 1942; Fosberg 42976 (US);
Stoddart 8012 (US).

East Key: Millspaugh 1907; Bowman 1918; Stoddart 8034 (US).

Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942.

Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Fosberg sight record in 1962; Stoddart 8045 (US).

Long Key: Bowman 1918; Fosberg sight record in 1962;
Stoddart 8022 (US).

Middle Key: Davis 1942.

Sand Key: Millspaugh 1907; Davis 1942.

I *Euphorbia prostrata* Ait.

Garden Key: Fosberg 42991 (US).

Loggerhead Key: Fosberg 43030 (US).

I *Pedilanthus tithymaloides* (L.) Poit.

Garden Key: Fosberg sight record in 1962.

Loggerhead Key: Bowman 1918.

Without locality: Davis 1942 Table 7 (as *Tithymalus smallii*
(Millsp.) Small).

I *Phyllanthus amarus* Schum. & Thonn.

Garden Key: Fosberg 43014 (US).

I *Ricinus communis* L.

Garden Key: Bowman 1918.

MALVACEAE

- I *Hibiscus rosa-sinensis* L.
Garden Key: Fosberg sight record in 1962.
Loggerhead Key: Bowman 1918.
- I *Malvaviscus arborea* Cav.
Garden Key: Fosberg sight record in 1962.
- I *Sida acuta* Burm. f.
Garden Key: Millspaugh 1907; Bowman 1918 (both as *Sida carpinifolia*); Fosberg 43016 (US).
- I *Sida procumbens* Sw.
Garden Key: Millspaugh 1907 (as *Sida diffusa*); Bowman 1918;
Fosberg 43012 (US).
- I *Thespesia populnea* (L.) Solander ex Correa
Garden Key: Bowman 1918; Davis 1942; Fosberg sight record
in 1962; Stoddart 8068 (US).
Loggerhead Key: Bowman 1918; Davis 1942; Stoddart 8042 (US).

STERCULIACEAE

- I *Waltheria indica* L.
Garden Key: Fosberg 43068 (US).

CARICACEAE

- I *Carica papaya* L.
Loggerhead Key: Millspaugh 1907 (as *Papaya*); Bowman 1918.

CACTACEAE

- N *Opuntia dillenii* (Ker.) Haw.
Bird Key: Millspaugh 1907; Bowman 1918.
Bush Key: Davis 1942; Fosberg sight record in 1962;
Stoddart sight record in 1977.
Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942.
Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Stoddart sight record in 1977.

LYTHRACEAE

- I *Lawsonia inermis* L.
Garden Key: Fosberg 43065 (US).

COMBRETACEAE

N *Conocarpus erectus* L.

Bush Key: Davis 1940, 1942; Fosberg sight record in 1962;
Stoddart 8015 (US).

Garden Key: Bowman 1918; Davis 1942; Fosberg 42992, 42993
(US); Stoddart 8066, 8067 (US).

N *Laguncularia racemosa* (L.) Gaertn. f.

Bush Key: Davis 1940, 1942 (as *Laguncularia*); Fosberg sight
record in 1962; Stoddart 8007, 8016 (US).

Long Key: Fosberg 43001 (US).

I *Terminalia catappa* L.

Garden Key: Bowman 1918 (as *Terminalia*); Fosberg sight record
in 1962.

MYRTACEAE

I *Psidium guajava* L.

Garden Key: Bowman 1918; Davis 1942; Fosberg 43069 (US).

RHIZOPHORACEAE

N *Rhizophora mangle* L.

Bush Key: Bowman 1918; Davis 1940, 1942; Fosberg 42977 (US);
Stoddart 8014 (US).

East Key: Davis 1940 (drift seedlings).

Garden Key: Bowman 1918; Davis 1940 (drift seedlings).

Loggerhead Key: Davis 1940 (drift seedlings).

Long Key: Bowman 1918; Davis 1940, 1942; Fosberg 43002 (US);
Stoddart 8027 (US).

Sand Key: Davis 1940 (drift seedlings).

ARALIACEAE

I *Polyscias guilfoylei* (Cogn. & March.) Bailey

Garden Key: Fosberg sight record in 1962.

GENTIANACEAE

? *Eustoma exaltatum* (L.) G. Don

Garden Key: Fosberg 42979 (US).

APOCYNACEAE

I *Catharanthus roseus* (L.) G. Don

Garden Key: Fosberg sight record in 1962.

Loggerhead Key: Bowman 1918 (as *Vinca roseus*); Fosberg
sight record in 1962.

I *Nerium oleander* L.

Garden Key: Bowman 1918; Davis 1942 (both as *Oleander*);
 Fosberg sight record in 1962.
 Loggerhead Key: Bowman 1918.

I *Ochrosia elliptica* Labill.

Garden Key: Stoddart 8064 (US, POM).

I *Thevetia peruviana* (Pers.) Schum.

Loggerhead Key: Bowman 1918 (as *Cerbera thevetia*).

ASCLEPIADACEAE

I *Cryptostegia grandiflora* R. Br.

Garden Key: Fosberg sight record in 1962.

CONVOLVULACEAE

N *Ipomoea macrantha* R. & S.

Bush Key: Stoddart 8017 (US).
 Garden Key: Bowman 1918 (as *Calonyction tuba*);
Stoddart 8079 (US).
 Loggerhead Key: Millspaugh 1907 (as *Calonyction album*);
 Bowman 1918; Davis 1942 (both as *Calonyction tuba*);
Fosberg 43052 (US).
 Long Key: Stoddart 8025 (US).

N *Ipomoea pes-caprae* (L.) R. Br. subsp. *brasiliensis* (L.) v. Ooststr.

Bush Key: Bowman 1918; Davis 1942.
 East Key: Davis 1942; Stoddart 8038 (US).
 Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Stoddart 8074 (US).
 Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Fosberg 43044 (US); Stoddart 8043 (US).
 Long Key: Fosberg 43003 (US).
 Sand Key: Millspaugh 1907.

BORAGINACEAE

I *Cordia sebestena* L.

Garden Key: Bowman 1918; Fosberg sight record in 1962;
Stoddart 8069 (US).
 Loggerhead Key: Millspaugh 1907; Bowman 1918 (as *Sebesten*
sebestina); Fosberg sight record in 1962; Stoddart 8044
 (US).

N *Heliotropium curassavicum* L.

Garden Key: Millspaugh 1907; Fosberg 43066 (US).
 Without locality: Davis 1942 Table 7.

I *Heliotropium angiospermum* Murray

Garden Key: Fosberg 43024 (US).

N *Tournefortia gnaphalodes* (L.) Kunth

- Bird Key: Millspaugh 1907; Bowman 1918.
 Bush Key: Bowman 1918; Davis 1942; Stoddart 8003 (US).
 East Key: Millspaugh 1907; Bowman 1918; Stoddart 8040 (US).
 Garden Key: Millspaugh 1907; Bowman 1918; Stoddart 8066 (US).
 Loggerhead Key: Millspaugh 1907; Bowman 1918; Davis 1942;
Fosberg 43043 (US); Stoddart 8049 (US).
 Long Key: Bowman 1918; Stoddart 8024 (US).
 Sand Key: Davis 1942.

VERBENACEAE

N *Avicennia germinans* (L.) L.

- Bush Key: Davis 1940; Fosberg 42998 (US); Stoddart 8013 (US).
 Garden Key: Bowman 1918 (as *A. nitida*); Davis 1940, 1942;
Fosberg 43058 (US).
 Long Key: Davis 1942 (as *A. nitida*); Fosberg sight record in
 1962; Stoddart 8030 (US).

? *Lippia nodiflora* (L.) Michx.

- Garden Key: Bowman 1918 (as *Phyla nodiflora*); Fosberg 43010,
43020 (US).
 Without locality: Davis 1942 Table 7.

I *Stachytarpheta jamaicensis* (L.) Vahl

- Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942 (all as
Valerianoides jamaicense); Fosberg 42997 (US);
Stoddart 8077 (US).
 Loggerhead Key: Stoddart 8046 (US).

LABIATAE

? *Salvia serotina* L.

- Loggerhead Key: Millspaugh 1907; Bowman 1918; Fosberg 43026
 (US).
 Without locality: Davis 1942 Table 7.

SOLANACEAE

N? *Solanum bahamense* L.

- Bush Key: Fosberg 42974 (US).
 Loggerhead Key: Fosberg 43034 (US).

SCROPHULARIACEAE

? *Capraria biflora* L.

- Garden Key: Millspaugh 1907 (as *C. saxifragifolia*);
Fosberg 43023 (US).
 Loggerhead Key: Millspaugh 1907; Bowman 1918; Fosberg 43028
 (US).
 Without locality: Davis 1942 Table 7.

GOODENIACEAE

N *Scaevola plumieri* (L.) Vahl

Bird Key: Millspaugh 1907; Bowman 1918.

Bush Key: Bowman 1918; Fosberg 42978 (US); Stoddart 8006 (US).

East Key: Millspaugh 1907; Bowman 1918; Stoddart 8039 (US).

Garden Key: Bowman 1918; Stoddart 8072 (US).

Loggerhead Key: Millspaugh 1907; Bowman 1918; Fosberg 43053 (US); Stoddart 8047 (US).

Sand Key: Bowman 1918.

COMPOSITAE

? *Ambrosia hispida* Pursh

Loggerhead Key: Fosberg 43039 (US).

I *Bidens alba* (L.) DC.

Garden Key: Millspaugh 1907; Bowman 1918 (both as *B. leucantha*); Fosberg 42987 (US).

Loggerhead Key: Davis 1942 (as *B. leucantha*); Stoddart 8060 (US).

I *Conyza canadensis* (L.) Cronquist

Garden Key: Bowman 1918; Davis 1942 (both as *Leptilon canadense*); Fosberg 42984 (US).

Loggerhead Key: Fosberg sight record in 1962.

I *Gaillardia pulchella* Foug.?

Garden Key: Fosberg 43022 (US).

N *Iva imbricata* Walt.

Bird Key: Bowman 1918.

Bush Key: Bowman 1918.

East Key: Millspaugh 1907; Bowman 1918; Stoddart 8036 (US).

Garden Key: Millspaugh 1907; Bowman 1918; Davis 1942.

Loggerhead Key: Millspaugh 1907; Fosberg 43040 (US); Stoddart 8052 (US).

Middle Key: Davis 1942.

Sand Key: Millspaugh 1907; Bowman 1918.

N *Melanthera aspera* var. *glabriuscula* (O. Ktze.) Parks.

Bush Key: Stoddart 8010 (US).

Garden Key: Millspaugh 1907 (as *M. nivea*); Bowman 1918; Davis 1942 (both as *M. brevifolia*); Fosberg 42986 (US); Stoddart 8076 (US).

Loggerhead Key: Millspaugh 1907 (as *M. nivea*); Bowman 1918 (as *M. brevifolia*); Fosberg sight record in 1962; Stoddart 8061 (US).

I *Sonchus oleraceus* L.

Garden Key: Millspaugh 1907; Bowman 1918; Fosberg 42988 (US).

Without locality: Davis 1942 Table 7.

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Table 1. Dimensions and area of Bird Key

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Millspaugh 1907, 233	500 x 250 ft	153 x 76 m
Watson 1908, 191	400 x 300 yds	366 x 274 m
Bowman 1918	500 x 300 ft	152 x 92 m
AREA		
Tatnall and Gednery 1829	4 ac 2 roods 20 poles	18,210 m ²
Scott 1904, 278	ca 8 ac	ca 32,400 m ²
Millspaugh 1907	from map	6,440 m ²
Watson and Lashley 1915, 35	ca 6,000 sq yds	ca 5,017 m ²
Lashley 1915, 61	less than 5 ac	less than 20,200 m ²
Pearson in 1915	8 ac	32,400 m ²
Ashe and Lowe in 1918	ca 6 ac	ca 24,300 m ²
England 1928, 14	less than 5 ac	less than 20,200 m ²
Bowman 1918	from map at given scale	47,695 m ²
	from map by MacArthur and Wilson 1968	13,935 m ²
	from map, corrected scale	9,375 m ²

Source: records in Robertson (1964) and papers cited

Table 2. Plants recorded from Bird Key

	<u>Status</u>	<u>1904</u>	<u>1915</u>
<i>Cenchrus incertus</i>	N	x	x
<i>Paspalum distichum</i>	N	x	-
<i>Uniola paniculata</i>	N	x	x
<i>Cyperus planifolius</i>	N	x	-
<i>Cocos nucifera</i>	I	-	x
<i>Hymenocallis latifolia</i>	?	-	x
<i>Portulaca oleracea</i>	N	x	x
<i>Sesuvium portulacastrum</i>	N	x	x
<i>Cakile lanceolata</i>	N	x	x
<i>Suriana maritima</i>	N	x	x
<i>Euphorbia mesembrianthemifolia</i>	N	x	x
<i>Opuntia dillenii</i>	N	x	x
<i>Tournefortia gnaphalodes</i>	N	x	x
<i>Scaevola plumieri</i>	N	x	x
<i>Iva imbricata</i>	N	-	x

	<u>Total</u>	<u>1904</u>	<u>1915</u>
Number of species	15	12	13
Native species	13	12	11
Introduced species	1	0	1
Uncertain status	1	0	1

N: native

I: introduced

?: uncertain status

Table 3. Dimensions and area of Bush Key

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Bowman 1918	from map	583 x 342 m
Davis 1942	from map	976 x 333 m
Stoddart in 1977	from map	880 x 207 m
AREA		
Tatnall and Gednery 1829	5 ac 3 roods 22 poles	23,270 m ²
Davis 1942	19 ac	115,900 m ²
Sprunt 1948	110,000 sq yds	91,960 m ²
Robertson 1964, 12	20 ac	80,900 m ²
Stoddart in 1977	from map	81,330 m ²

Source: records in Robertson (1964) and papers cited

Table 4. Plants recorded from Bush Key

	<u>Status</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
<i>Cenchrus incertus</i>	N	x	-	-	-
<i>Eustachys petraea</i>	N	-	x	-	-
<i>Sporobolus virginicus</i>	N	-	x	x	x
<i>Uniola paniculata</i>	N	x	x	x	x
<i>Cyperus planifolius</i>	N	-	-	x	x
<i>Casuarina equisetifolia</i>	I	-	-	-	x
<i>Batis maritima</i>	N	-	-	-	x
<i>Atriplex pentendra</i>	N	x	-	-	x
<i>Alternanthera maritima</i>	N	x	x	-	-
<i>Alternanthera philoxeroides</i>	?	-	-	-	x
<i>Philoxerus vermicularis</i>	N?	-	-	x	-
<i>Sesuvium portulacastrum</i>	N	x	x	x	x
<i>Cakile lanceolata</i>	N	x	-	-	x
<i>Suriana maritima</i>	N	x	x	x	x
<i>Euphorbia heterophylla</i>	?	-	-	-	x
<i>Euphorbia mesembrianthemifolia</i>	N	x	x	x	x
<i>Opuntia dillenii</i>	N	-	x	x	x
<i>Conocarpus erectus</i>	N	-	x	x	x
<i>Laguncularia racemosa</i>	N	-	x	x	x
<i>Rhizophora mangle</i>	N	x	x	x	x
<i>Ipomoea macrantha</i>	N	-	-	-	x
<i>Ipomoea pes-caprae</i>	N	x	x	-	-
<i>Tournefortia gnaphalodes</i>	N	x	x	-	x
<i>Avicennia germinans</i>	N	-	-	x	x
<i>Solanum bahamense</i>	N?	-	-	x	-
<i>Scaevola plumieri</i>	N	x	-	x	x
<i>Iva imbricata</i>	N	x	-	-	-
<i>Melanthera aspera</i>	N	-	-	-	x

	<u>Total</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
Number of species	28	13	13	14	21
Native species	25	13	13	14	18
Introduced species	1	0	0	0	1
Uncertain status	2	0	0	0	2

N: Native

I: introduced

?: uncertain status

Table 5. Dimensions and area of East Key

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Agassiz 1888	from chart	500 m long
Millspaugh 1907	280 x 50 ft	85 x 15 m
Bowman 1918	1/3 mile long, 1/6 mile broad	ca 540 x 250m
Davis 1942	1200 x 600 ft	366 x 188 m
Stoddart in 1977	from map	345 x 103 m
AREA		
Tatnall and Gednery 1829	12 ac	48,600 m ²
Scott 1904 (in 1890)	18 ac	72,800 m ²
Millspaugh 1907	from map (dimensions in ft)	2,170 m ²
	from map (dimensions in yds)	6,500 m ²
Bowman 1918	from map at given scale	115,610 m ²
	from map estimated by MacArthur and Wilson 1968	111,480 m ²
	from map, corrected scale	87,220 m ²
Sprunt 1948	85,000 sq yds	71,070 m ²
Stoddart in 1977	from map	27,145 m ²

Source: records in Robertson (1964) and papers cited

Table 6. Plants recorded from East Key

	<u>Status</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1977</u>
<i>Cenchrus incertus</i>	N	x	x	x	x
<i>Uniola paniculata</i>	N	x	x	-	x
<i>Sesuvium portulacastrum</i>	N	x	x	x	x
<i>Cakile lanceolata</i>	N	x	x	-	x
<i>Suriana maritima</i>	N	-	-	x	x
<i>Euphorbia mesembrianthemifolia</i>	N	x	x	-	x
<i>Ipomoea pes-caprae</i>	N	-	-	x	x
<i>Tournefortia gnaphalodes</i>	N	x	x	-	x
<i>Scaevola plumieri</i>	N	x	x	-	x
<i>Iva imbricata</i>	N	x	x	-	x

	<u>Total</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1977</u>
Number of species	10	8	8	4	10
Native species	10	8	8	4	10
Introduced species	0	0	0	0	0
Uncertain status	0	0	0	0	0

N: native

I: introduced

?: uncertain status

This tables does not include the strand records of *Rhizophora mangle* resulting from Davis's (1940) drift experiments in 1937 and 1938.

Table 7. Dimensions and area of Garden Kay

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Millspaugh 1907	from map	515 x 310 m
Vaughan 1918	from map	541 x 319 m
Bowman 1918	from map	720 x 360 m
Davis 1942	from map	590 x 320 m
AREA		
Tatnall and Gednery 1829	7.5 ac	30,350 m ²
Bache in 1845	8.8 ac	35,610 m ²
Millspaugh 1907	from map	92,880 m ²
Vaughan 1918	from map	*96,550 m ²
Bowman 1918	from map	150,540 m ²
Davis 1942	from map	112,420 m ²

Source: records in Robertson (1964) and papers cited

*with the separate sandbar to the northwest the area is 101,200 m²

Table 8. Plants recorded from Garden Kay

	Status	1904	1915	1937	1962	1977
<i>Pandanus tectorius</i>	I	-	-	-	x	-
<i>Brachiaria</i> sp.	I	-	-	-	x	-
<i>Cenchrus echinatus</i>	?	x	-	x	x	-
<i>Cenchrus incertus</i>	N	x	-	-	x	-
<i>Cynodon dactylon</i>	I	-	x	x	x	-
<i>Digitaria horizontalis</i>	I	-	-	-	x	-
<i>Digitaria sanguinalis</i>	?	x	x	x	x	-
<i>Eragrostis ciliaris</i>	I	-	-	-	x	-
<i>Eragrostis prolifera</i>	?	-	-	-	x	x
<i>Eragrostis tenella</i>	I	-	-	x	-	-
<i>Eustachys petraea</i>	N	x	-	x	x	-
<i>Paspalum caespitosum</i>	?	-	x	x	-	-
<i>Paspalum distichum</i>	N	x	-	-	-	-
<i>Sporobolus domingensis</i>	?	-	-	x	-	-
<i>Sporobolus purpurascens</i>	?	x	-	-	-	-
<i>Sporobolus virginicus</i>	N	-	x	x	-	-
<i>Stenotaphrum secundatum</i>	I	-	-	-	x	-
<i>Uniola paniculata</i>	N	x	x	x	-	-
<i>Cyperus planifolius</i>	N	x	x	x	x	-
<i>Cocos nucifera</i>	I	-	-	-	x	x
<i>Phoenix canariensis</i>	I	-	x	x	-	-
<i>Phoenix dactylifera</i>	I	-	x	x	x	-
<i>Pritchardia</i> sp.	I	-	-	-	x	-
<i>Washingtonia filifera</i>	I	-	-	-	x	-
<i>Rhoeo spathacea</i>	I	-	-	-	x	-
<i>Agave decipiens</i>	I	-	x	-	-	-
<i>Agave americana</i>	I	-	-	x	-	-
<i>Aloe barbadensis</i>	I	-	-	-	x	-
<i>Hymenocallis latifolia</i>	?	x	x	x	-	-
<i>Hymenocallis littoralis</i>	I	-	-	-	x	-
<i>Musa sapientum</i>	I	-	-	-	x	-
<i>Casuarina equisetifolia</i>	I	-	-	x	-	-
<i>Coccoloba uvifera</i>	?	-	x	x	x	x
<i>Atriplex pentandra</i>	N	x	x	-	-	x
<i>Alternanthera maritima</i>	N	-	x	-	-	-
<i>Amaranthus viridis</i>	I	x	-	-	-	-
<i>Philoxerus vermicularis</i>	N?	x	-	-	-	-
<i>Boerhavia coccinea</i>	?	x	x	x	x	-
<i>Bougainvillea glabra</i>	I	-	-	-	x	-
<i>Portulaca oleracea</i>	N	x	x	-	x	x

Table 8 cont.

	<u>Status</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
<i>Sesuvium portulacastrum</i>	N	x	x	x	-	-
<i>Argemone mexicana</i>	I	x	-	-	-	-
<i>Cakile lanceolata</i>	N	x	x	-	-	x
<i>Lepidium virginicum</i>	I	-	x	-	x	-
<i>Abrus precatorius</i>	I	-	-	-	x	-
<i>Caesalpinia bonduc</i>	?	-	x	-	-	-
<i>Caesalpinia pulcherrima</i>	I	-	-	-	x	-
<i>Cajanus cajan</i>	I	-	x	-	-	-
<i>Canavalia rosea</i>	N	x	x	x	x	x
<i>Ceratonia siliqua</i>	I	-	-	-	x	-
<i>Crotalaria pallida</i>	I	-	-	-	-	x
<i>Delonix regia</i>	I	-	-	-	x	x
<i>Desmanthus depressus</i>	?	-	-	-	x	-
<i>Desmodium incanum</i>	I	-	-	-	x	-
<i>Rhynchosia parviflorus</i>	I	-	x	-	-	-
<i>Sesbania</i> sp.	I	x	x	x	-	-
<i>Tamarindus indica</i>	I	-	x	x	x	-
<i>Citrus aurantiifolius</i>	I	-	-	-	x	-
<i>Suriana maritima</i>	N	x	x	x	-	x
<i>Bursera simaruba</i>	?	-	x	x	x	-
<i>Breynia disticha</i>	I	-	-	-	x	-
<i>Codiaeum variegatum</i>	I	-	-	-	x	-
<i>Euphorbia adenoptera</i>	?	x	-	-	-	-
<i>Euphorbia blodgettii</i>	?	-	-	-	x	-
<i>Euphorbia glomerifera</i>	I	-	x	-	x	-
<i>Euphorbia heterophylla</i>	?	x	-	x	x	x
<i>Euphorbia hirta</i>	I	-	-	-	x	-
<i>Euphorbia mesembrianthemifolia</i>	N	x	x	x	-	-
<i>Euphorbia prostrata</i>	I	-	-	-	x	-
<i>Pedilanthus tithymaloides</i>	I	-	-	-	x	-
<i>Phyllanthus amarus</i>	I	-	-	-	x	-
<i>Ricinus communis</i>	I	-	x	-	-	-
<i>Hibiscus rosa-sinensis</i>	I	-	-	-	x	-
<i>Malvaviscus arborea</i>	I	-	-	-	x	-
<i>Sida acuta</i>	I	x	x	-	x	-
<i>Sida procumbens</i>	I	x	x	-	x	-
<i>Thespesia populnea</i>	I	-	x	x	x	x
<i>Waltheria indica</i>	I	-	-	-	x	-
<i>Opuntia dillenii</i>	N	x	x	x	-	-
<i>Lawsonia inermis</i>	I	-	-	-	x	-

Table 8 cont.

	<u>Status</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
<i>Conocarpus erectus</i>	N	-	x	x	x	x
<i>Terminalia catappa</i>	I	-	x	-	x	-
<i>Psidium guajava</i>	I	-	x	x	x	-
<i>Rhizophora mangle</i>	N	-	x	-	-	-
<i>Polyscias guilfoylei</i>	I	-	-	-	x	-
<i>Eustoma exaltatum</i>	I	-	-	-	x	-
<i>Catharanthus roseus</i>	I	-	-	-	x	-
<i>Nerium oleander</i>	I	-	x	x	x	-
<i>Ochrosia elliptica</i>	I	-	-	-	-	x
<i>Cryptostegia grandiflora</i>	I	-	-	-	x	-
<i>Ipomoea macrantha</i>	N	-	x	-	-	x
<i>Ipomoea pes-caprae</i>	N	x	x	x	-	x
<i>Cordia sebestena</i>	I	-	x	-	x	x
<i>Heliotropium curassavicum</i>	N	x	-	-	x	-
<i>Heliotropium angiospermum</i>	I	-	-	-	x	-
<i>Tournefortia gnaphalodes</i>	N	x	x	-	-	x
<i>Avicennia germinans</i>	N	-	x	x	x	-
<i>Lippia nodiflora</i>	?	-	x	-	x	-
<i>Stachytarpheta jamaicensis</i>	I	x	x	x	x	x
<i>Capraria biflora</i>	?	x	-	-	x	-
<i>Scaevola plumieri</i>	N	-	x	-	-	x
<i>Bidens alba</i>	I	x	x	-	x	-
<i>Conyza canadensis</i>	I	-	x	x	x	-
<i>Gaillardia pulchella</i>	I	-	-	-	x	-
<i>Iva imbricata</i>	N	x	x	x	-	-
<i>Melanthera nivea</i>	N	x	x	x	x	x
<i>Sonchus oleraceus</i>	I	x	x	-	x	-

	<u>Total</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
Number of species	107	35	51	36	71	21
Native species	26	19	21	14	9	11
Introduced species	64	8	22	13	51	7
Uncertain status	17	8	8	9	11	3

N: native

I: introduced

?: uncertain status

Table 9. Dimensions and area of Loggerhead Key

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Agassiz 1888	from chart	1140 x 190 m
Millspaugh 1907	3/4 x 1/8 mile	1210 x 200 m
Bowman 1918	from map	1635 x 353 m
Davis 1942	4500 x 600 ft	1380 x 208 m
Stoddart in 1977	from map	1280 x 243 m
AREA		
Tatnall and Gednery 1829	ca 30 ac	121,400 m ²
Millspaugh 1907	from map	242,300 m ²
Bowman 1918	from map at given scale	473,840 m ²
	from map estimated by MacArthur and Wilson 1968	195,090 m ²
	from map, corrected scale	278,665 m ²
Davis 1942	from map	209,920 m ²
Robertson 1964, 14	ca 30 ac	ca 121,400 m ²
Stoddart in 1977	from map	227,700 m ²

Source: records in Robertson (1964) and papers cited

Table 10. Plants recorded from Loggerhead Key

	Status	1904	1915	1937	1962	1977
<i>Cenchrus echinatus</i>	?	-	x	-	-	x
<i>Cenchrus myosoroides</i>	?	-	-	-	x	-
<i>Cenchrus incertus</i>	N	-	x	-	x	-
<i>Eragrostis prolifera</i>	?	-	-	-	-	x
<i>Eragrostis tenella</i>	I	-	-	-	x	-
<i>Eustachys petraea</i>	N	-	-	-	x	x
<i>Panicum maximum</i>	I	-	-	-	x	-
<i>Paspalum caespitosum</i>	?	-	x	-	-	-
<i>Sporobolus virginicus</i>	N	x	x	x	x	-
<i>Uniola paniculata</i>	N	x	x	x	x	x
<i>Cyperus planifolius</i>	N	-	x	-	x	x
<i>Cocos nucifera</i>	I	-	x	x	-	x
<i>Agave americana</i>	I	-	-	x	-	-
<i>Agave rigida</i>	I	-	x	-	-	-
<i>Aloe barbadensis</i>	I	-	x	x	-	-
<i>Asparagus sprengeri</i>	I	-	x	-	-	-
<i>Hymenocallis latifolia</i>	?	x	x	x	x	x
<i>Yucca aloifolia</i>	I	-	x	x	-	-
<i>Casuarina equisetifolia</i>	I	-	x	x	-	x
<i>Ficus hispida</i>	I	-	x	x	-	-
<i>Ficus palmata</i>	I	-	-	-	x	-
<i>Coccoloba uvifera</i>	?	-	x	-	-	x
<i>Boerhavia coccinea</i>	?	-	x	x	x	x
<i>Portulaca oleracea</i>	N	x	x	x	-	-
<i>Sesuvium portulacastrum</i>	N	x	x	x	x	-
<i>Cakile lanceolata</i>	N	x	x	-	-	-
<i>Caesalpinia bonduc</i>	?	x	-	-	x	x
<i>Canavalia rosea</i>	N	x	x	x	x	-
<i>Tribulus cistoides</i>	?	x	-	-	-	-
<i>Suriana maritima</i>	N	x	x	x	-	x
<i>Bursera simaruba</i>	?	-	-	-	x	-
<i>Euphorbia heterophylla</i>	?	-	x	x	x	x
<i>Euphorbia hirta</i>	I	-	-	-	x	-
<i>Euphorbia mesembrianthemifolia</i>	N	x	x	x	x	x
<i>Euphorbia prostrata</i>	I	-	-	-	x	-
<i>Pedilanthus tithymaloides</i>	I	-	x	-	-	-

Table 10 cont.

	<u>Status</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
<i>Hibiscus rosa-sinensis</i>	I	-	x	-	-	-
<i>Thespesia populnea</i>	I	-	x	x	-	x
<i>Carica papaya</i>	I	x	x	-	-	-
<i>Opuntia dillenii</i>	N	x	x	x	-	x
<i>Catharanthus roseus</i>	I	-	x	-	x	-
<i>Nerium oleander</i>	I	-	x	-	-	-
<i>Thevetia peruviana</i>	I	-	x	-	-	-
<i>Ipomoea macrantha</i>	N	x	x	x	x	-
<i>Ipomoea pes-caprae</i>	N	x	x	x	x	x
<i>Cordia sebestena</i>	I	x	x	-	x	x
<i>Tournefortia gnaphalodes</i>	N	x	x	x	x	x
<i>Stachytarpheta jamaicensis</i>	I	-	-	-	-	x
<i>Salvia serotina</i>	?	x	x	-	x	-
<i>Solanum bahamense</i>	N?	-	-	-	x	-
<i>Capraria biflora</i>	?	x	x	-	x	-
<i>Scaevola plumieri</i>	N	x	x	-	x	x
<i>Ambrosia hispida</i>	?	-	-	-	x	-
<i>Bidens alba</i>	I	-	-	x	-	x
<i>Conyza canadensis</i>	I	-	-	-	x	-
<i>Iva imbricata</i>	N	x	-	-	x	x
<i>Melanthera aspera</i>	N	x	x	-	x	x
	<u>Total</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
Number of species	57	22	39	22	32	24
Native species	19	15	16	11	15	11
Introduced species	24	2	15	8	8	6
Uncertain status	14	5	8	3	9	7

N: native

I: introduced

?: uncertain status

This table does not include the strand records of *Rhizophora mangle* resulting from Davis's (1940) drift experiments in 1937 and 1938.

Table 11. Dimensions and area of Long Key

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Davis 1942	from map	512 x 178 m
Stoddart in 1977	from map	224 x 73 m
AREA		
Davis 1942	from map	47,300 m ²
Stoddart in 1977	from map	8,120 m ²

Source: papers cited

Table 12. Plants recorded from Long Key

	<u>Status</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
<i>Sporobolus virginicus</i>	N	-	-	-	x
<i>Cyperus planifolius</i>	N	x	-	-	-
<i>Casuarina equisetifolia</i>	I	-	-	x	-
<i>Batis maritima</i>	N	-	x	-	-
<i>Atriplex pentandra</i>	N	x	-	x	x
<i>Salicornia bigelovii</i>	N	-	x	x	x
<i>Alternanthera maritima</i>	N	x	-	-	-
<i>Sesuvium portulacastrum</i>	N	x	x	x	x
<i>Suriana maritima</i>	N	x	-	x	x
<i>Euphorbia mesembrianthemifolia</i>	N	x	-	x	x
<i>Laguncularia racemosa</i>	N	-	-	x	-
<i>Rhizophora mangle</i>	N	x	x	x	x
<i>Ipomoea macrantha</i>	N	-	-	-	x
<i>Ipomoea pes-caprae</i>	N	-	-	x	-
<i>Tournefortia gnaphalodes</i>	N	x	-	-	x
<i>Avicennia germinans</i>	N	-	x	x	x
	<u>Total</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>
Number of species	16	8	5	10	10
Native species	15	8	5	9	10
Introduced species	1	0	0	1	0
Uncertain status	0	0	0	0	0
N: native	I: introduced	?: uncertain status			

Table 13. Plants recorded from Middle Key

	<u>Status</u>	<u>1915</u>	<u>1937</u>
<i>Cakile lanceolata</i>	N	x	x
<i>Euphorbia mesembrianthemifolia</i>	N	-	x
<i>Iva imbricata</i>	N	-	x

	<u>Total</u>	<u>1915</u>	<u>1937</u>
Number of species	3	1	3
Native species	3	1	3
Introduced species	0	0	0
Uncertain status	0	0	0

N: native

I: introduced

?: uncertain status

Table 14. Dimensions and area of Sand Key

<u>Source</u>	<u>Original estimate</u>	<u>Metric equivalent</u>
DIMENSIONS		
Agassiz 1888	from chart	160 m long
Millspaugh 1907	80 x 50 ft	24 x 15 m
Bowman 1918	from chart	27 x 14 m
Davis 1942	110 x 70 ft	34 x 21 m
Stoddart in 1977	from map	113 x 42 m
AREA		
Millspaugh 1907	from map	228 m ²
Bowman 1918	from map at given scale	41,733 m ²
	from map estimated by MacArthur and Wilson 1968	3,344 m ²
	from map, corrected scale	222 m ²
Stoddart in 1977	from map	3,512 m ²

Source: papers cited

Table 15. Plants recorded from Sand Key

	<u>Status</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>
<i>Uniola paniculata</i>	N	x	-	x
<i>Sesuvium portulacastrum</i>	N	x	-	-
<i>Cakile lanceolata</i>	N	-	x	-
<i>Euphorbia mesembrianthemifolia</i>	N	x	-	x
<i>Ipomoea pes-caprae</i>	N	x	-	-
<i>Tournefortia gnaphalodes</i>	N	-	-	x
<i>Scaevola plumieri</i>	N	-	x	-
<i>Iva imbricata</i>	N	x	x	-

	<u>Total</u>	<u>1904</u>	<u>1915</u>	<u>1937</u>
Number of species	8	5	3	3
Native species	8	5	3	3
Introduced species	0	0	0	0
Uncertain status	0	0	0	0

N: native

I: introduced

?: uncertain status

This tables does not include the strand records of *Rhizophora mangle* resulting from Davis's (1940) drift experiments in 1937 and 1938.

Table 16. Distribution of native plants (excluding sea-grasses) on Dry Tortugas keys

	Bird	Bush	East	Garden	Loggerhead	Long	Middle	Sand
<i>Cenchrus incertus</i>	x	x	x	x	x	-	-	-
<i>Eustachys petraea</i>	-	x	-	x	x	-	-	-
<i>Paspalum distichum</i>	x	-	-	x	-	-	-	-
<i>Sporobolus virginicus</i>	-	x	-	x	x	x	-	-
<i>Uniola paniculata</i>	x	x	x	x	x	-	-	x
<i>Cyperus planifolius</i>	x	x	-	x	x	x	-	-
<i>Batis maritima</i>	-	x	-	-	-	x	-	-
<i>Atriplex pentandra</i>	-	x	-	x	-	x	-	-
<i>Salicornia bigelovii</i>	-	-	-	-	-	x	-	-
<i>Alternanthera maritima</i>	-	x	-	x	-	x	-	-
<i>Philoxerus</i>	-	x	-	x	-	-	-	-
<i>vermicularis</i>								
<i>Portulaca oleracea</i>	x	-	-	x	x	-	-	-
<i>Sesuvium</i>	x	x	x	x	x	x	-	x
<i>portulacastrum</i>								
<i>Cakile lanceolata</i>	x	x	x	x	x	-	x	x
<i>Canavalia rosea</i>	-	-	-	x	x	-	-	-
<i>Suriana maritima</i>	x	x	x	x	x	x	-	-
<i>Euphorbia</i>	x	x	x	x	x	x	x	x
<i>mesembrianthemifolia</i>								
<i>Opuntia dillenii</i>	x	x	-	x	x	-	-	-
<i>Conocarpus erectus</i>	-	x	-	x	-	-	-	-
<i>Laguncularia racemosa</i>	-	x	-	-	-	x	-	-
<i>Rhizophora mangle</i>	-	x	-	x	-	x	-	-
<i>Ipomoea macrantha</i>	-	x	-	x	x	x	-	-
<i>Ipomoea pes-caprae</i>	-	x	x	x	x	x	-	x
<i>Heliotropium</i>	-	-	-	x	-	-	-	-
<i>curassavicum</i>								
<i>Tournefortia</i>	x	x	x	x	x	x	-	x
<i>gnaphalodes</i>								
<i>Avicennia germinans</i>	-	x	-	x	-	x	-	-
<i>Solanum behamense</i>	-	x	-	-	x	-	-	-
<i>Scaevola plumieri</i>	x	x	x	x	x	-	-	x
<i>Iva imbricata</i>	x	x	x	x	x	-	x	x
<i>Melanthera aspera</i>	-	x	-	x	x	-	-	-

Table 17. Numbers of species in different categories recorded from the Dry Tortugas keys

	<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1962</u>	<u>1977</u>	<u>Total</u>
TOTAL NUMBER OF SPECIES						
Bird	12	13	-	-	-	15
Bush	1	13	13	14	21	28
East	8	8	4	0	10	10
Garden	35	51	36	71	21	107
Loggerhead	22	38	22	32	24	56
Long	-	8	5	10	10	16
Middle	-	1	3	-	-	3
Sand	5	3	3	-	-	8
NUMBER OF NATIVE SPECIES						
Bird	12	11	-	-	-	13
Bush	1	13	13	14	18	25
East	8	8	4	0	10	10
Garden	19	21	14	9	11	26
Loggerhead	15	16	11	15	11	19
Long	-	8	5	9	10	15
Middle	-	1	3	-	-	3
Sand	5	3	3	-	-	8
NUMBER OF INTRODUCED SPECIES						
Bird	0	1	-	-	-	1
Bush	0	0	0	0	1	1
East	0	0	0	0	0	0
Garden	8	22	13	51	7	64
Loggerhead	2	14	8	8	6	23
Long	-	0	0	1	0	1
Middle	-	0	0	-	-	0
Sand	0	0	0	-	-	0
NUMBER OF SPECIES OF UNCERTAIN STATUS						
Bird	0	1	-	-	-	1
Bush	0	0	0	0	2	2
East	0	0	0	0	0	0
Garden	8	8	9	11	3	17
Loggerhead	5	8	3	9	7	14
Long	-	0	0	0	0	0
Middle	-	0	0	-	-	0
Sand	0	0	0	-	-	0

Table 18. Summary of area and plant species numbers for Dry Tortugas keys

		<u>1904</u>	<u>1915</u>	<u>1937</u>	<u>1977</u>	<u>Total</u>
Bird	Area sq m	6,440	9,375	-	-	
	Total no. species	12	13	-	-	15
	No. native species	12	11	-	-	13
Bush	Area sq m	-	-	115,900	81,330	
	Total no. species	13	13	14	21	28
	No. native species	13	13	14	18	25
East	Area sq m	6,500*	87,220*	-	27,145	
	Total no. species	8	8	4	10	10
	No. native species	8	8	4	10	10
Garden	Area sq m	92,880	150,540*	112,420	-	
	Total no. species	35	51	36	21	107
	No. native species	19	21	14	11	26
Loggerhead	Area sq m	242,300	278,700*	209,900	227,700	
	Total no. species	22	39	22	24	57
	No. native species	15	16	11	11	19
Long	Area sq m	-	-	47,300	8,120	
	Total no. species	0	8	5	10	16
	No. native species	0	8	5	10	15
Middle	Area sq m	0	194	-	0	
	Total no. species	0	1	3	0	3
	No. native species	0	1	3	0	3
Sand	Area sq m	228*	222*	-	3,512	
	Total no. species	5	3	3	0	8
	No. native species	5	3	3	0	8

*area considered unreliable

Table 19. 'Extinction' of plant species on Dry Torugas keys, 1904-1916

This table is a revision of Table 5 in MacArthur and Wilson (1968), p. 52; their original figures are given in brackets.

	Total number of species in 1904	Number of species present in 1904 but absent in 1916	Estimated per cent of all species extinct during 1904-1916	Number of local species in 1904	Number of local species present in 1904 but absent in 1916	Estimated per cent of local species extinct during 1904-1916
Bird	12 (12)	2 (1)	17 (8)	12 (6)	2 (1)	17 (17)
East	8 (8)	0 (0)	0 (0)	8 (3)	0 (0)	0 (0)
Garden	35 (35)	12 (6)	34 (17)	19 (24)	5 (6)	26 (25)
Loggerhead	22 (21)	3 (1)	14 (5)	15 (12)	1 (1)	7 (8)
Middle	0 (1)	0 (1)	- (100)	-	-	-
Sand	5 (5)	4 (5)	80 (100)	5 (-)	4 (-)	80 (-)

Table 20. Species-area data for Alacran Reef

	Area in 1899 based on maps in Millspaugh (1916), ha	Area in 1960 calculated by Folk (1967), ha	Ratio of 1960:1899 areas	Number of species in 1899, from Millspaugh (1916)	Number of species ca 1960, from Bonet and Rzedowski (1962)	Number of species in 1960, from Fosberg (1962)*	Total number of species recorded
Perez	5.37	19.83	3.69	17	17	16	24
Desertora	2.04	12.55	6.15	5	7	13	14
Pajaros	1.55	4.45	2.87	10	12	11	14
Chica	0.95	1.29	1.36	6	7	7	9
West Desterrada	-	6.67	-	-	-	7	7
East Desterrada	-	7.69	-	-	-	5	5
Desaparecida	-	0.4	-	-	-	0	0

*excluding cultivated pot-plants



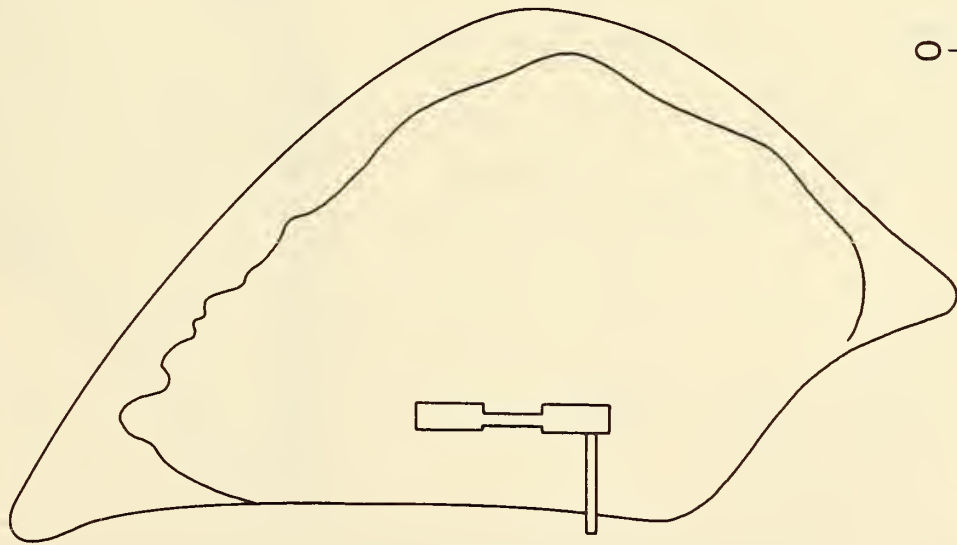
feet	fathoms	meters
6	1	1.8
18	3	5.5
60	10	18.3

contours in feet

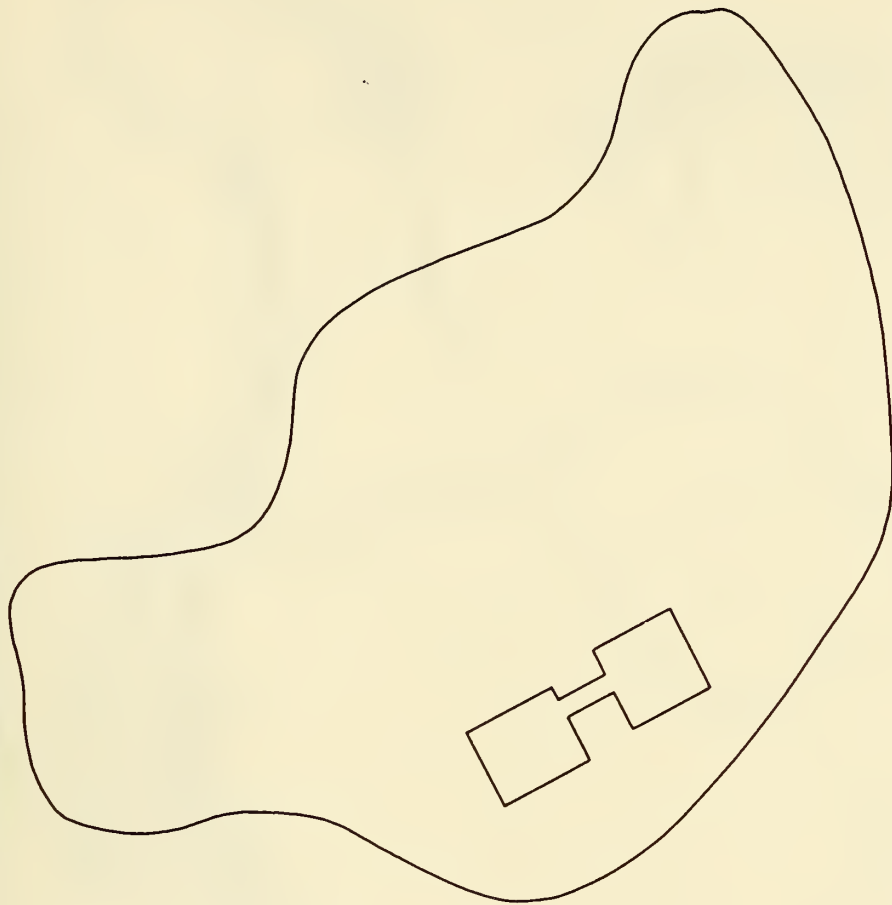
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BIRD KEY

LANSING 1904



BOWMAN 1915-16



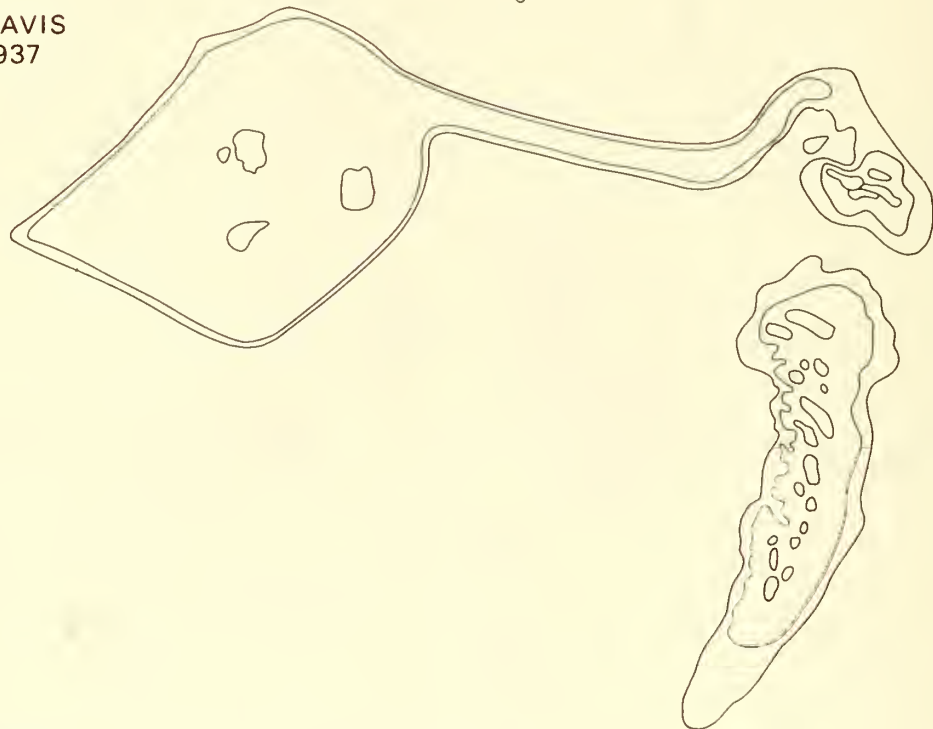
0 m 50

Figure 2. Bird Key in 1904 and 1915-16 (Millspaugh 1907, Bowman 1918).

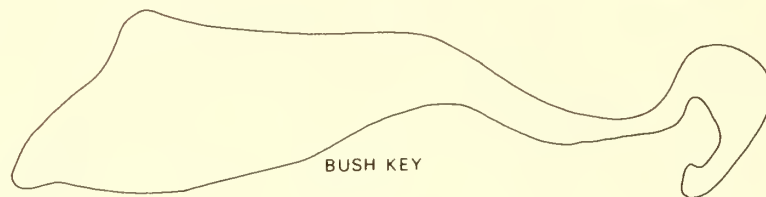
BOWMAN
1915-16



DAVIS
1937



1977



BUSH KEY



LONG KEY

0 m 300

Figure 3. Bush Key and Long Key in 1915-16, 1937 and 1977 (Bowman 1918, Davis 1942, and Stoddart in 1977).

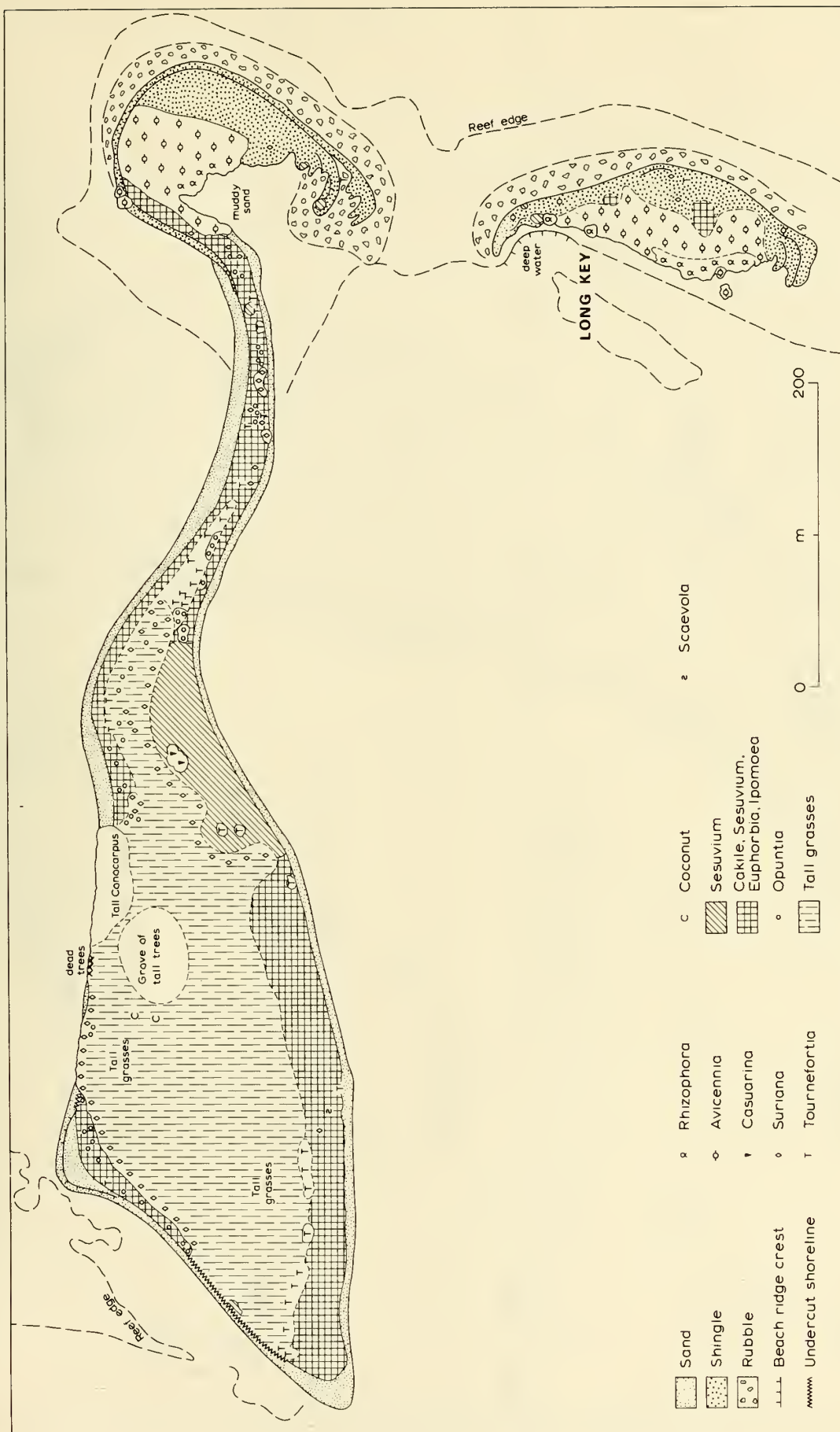


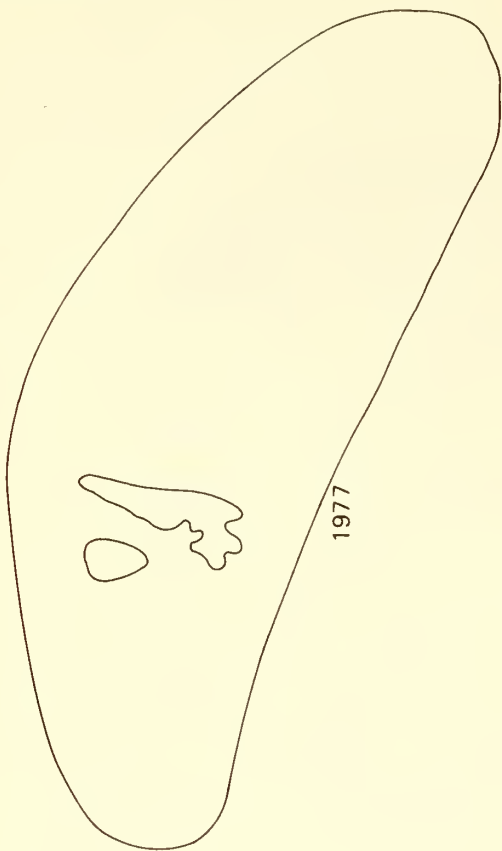
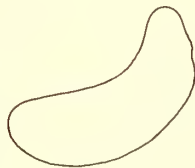
Figure 4. Bush and Long Keys in 1977.

SAND KEY

LANSING
1904



BOWMAN
1915-16



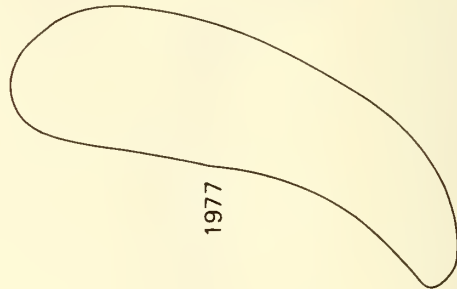
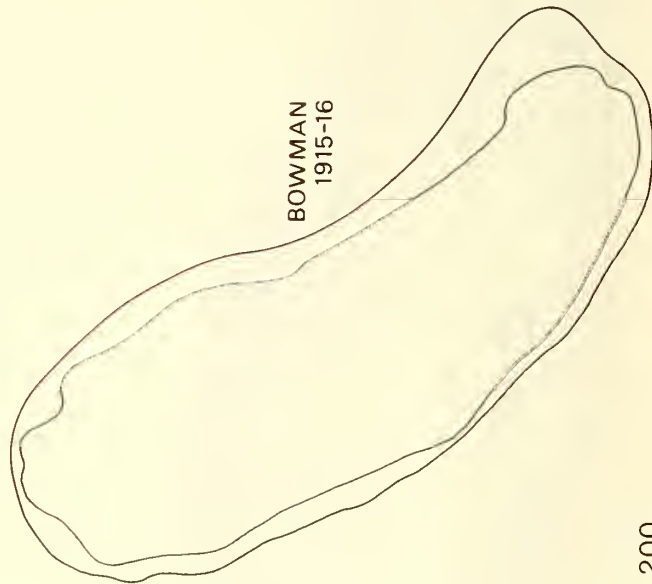
0 m 25

EAST KEY

LANSING
1904



BOWMAN
1915-16



0 m 200

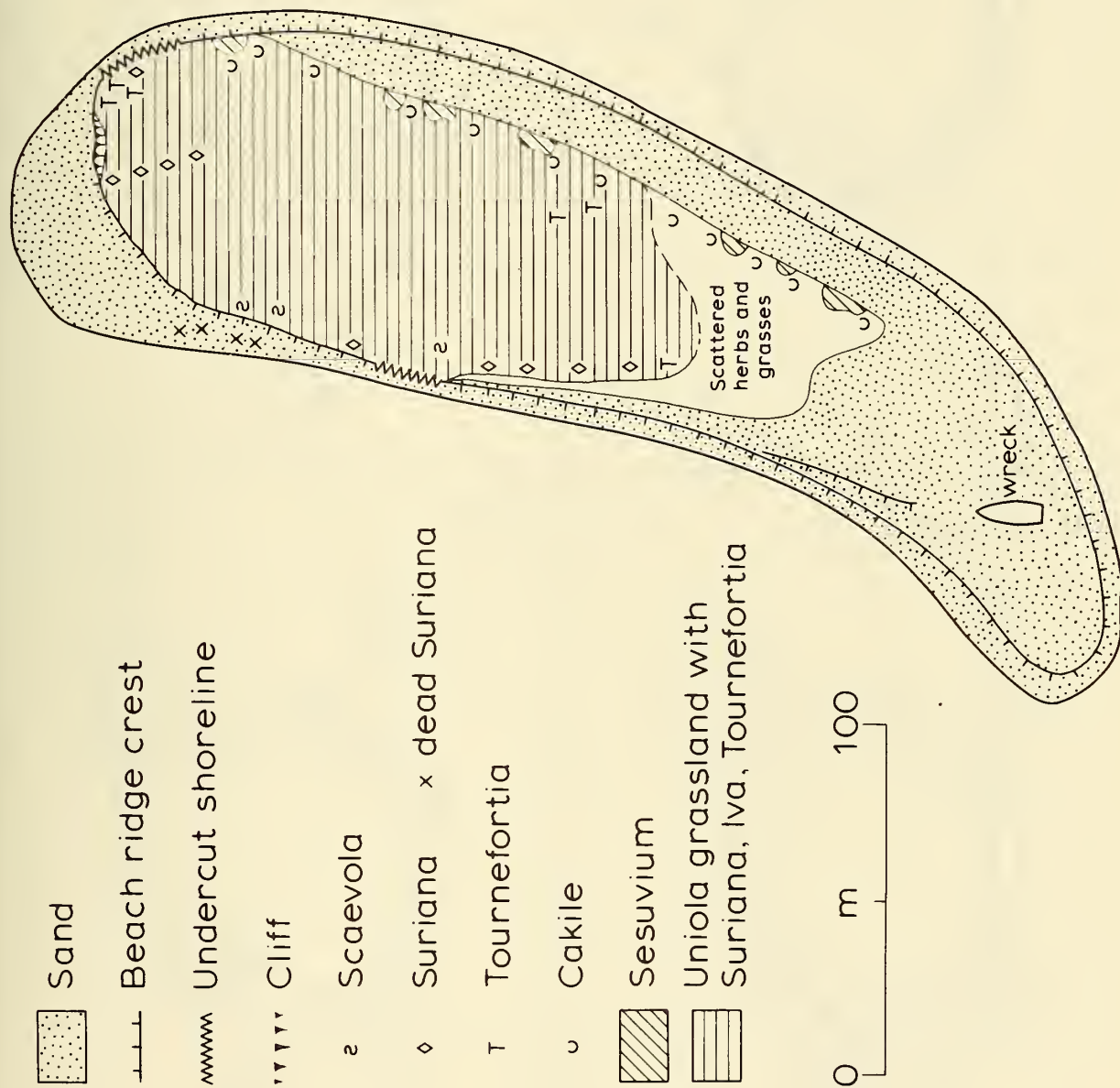
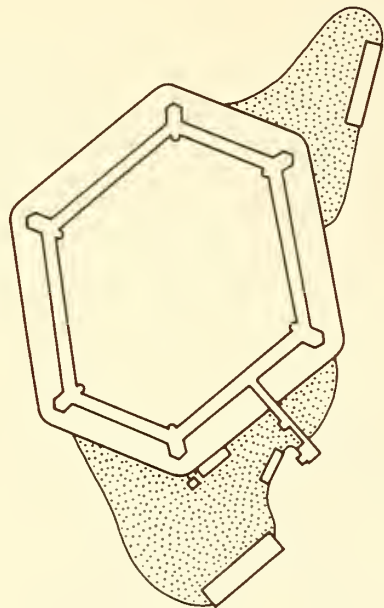
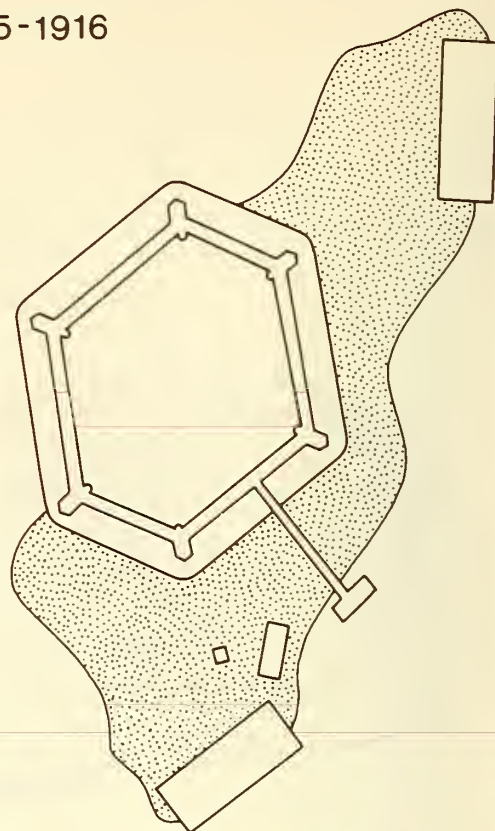


Figure 6. East Key in 1977.

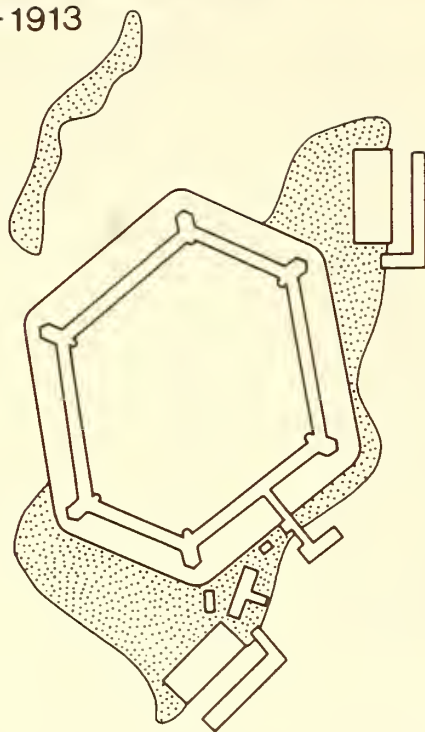
1904



1915-1916



1911-1913



1937

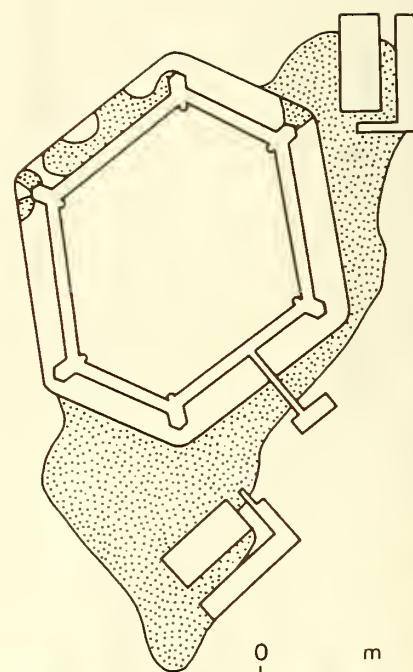


Figure 7. Garden Key in 1904, 1911-13, 1915-16, and 1937 (Millspaugh 1907, Vaughan 1918, Bowman 1918, and Davis 1942).

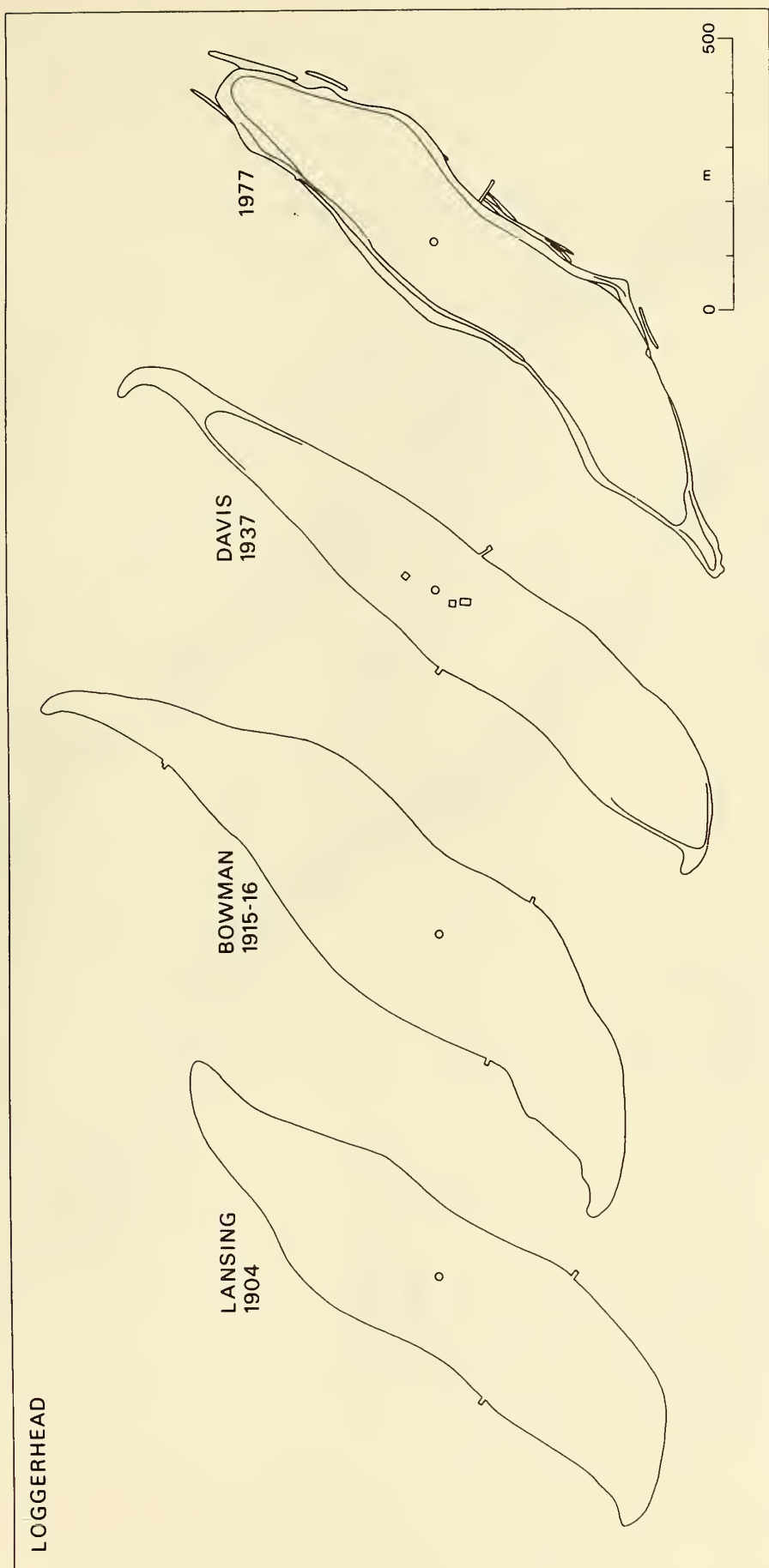
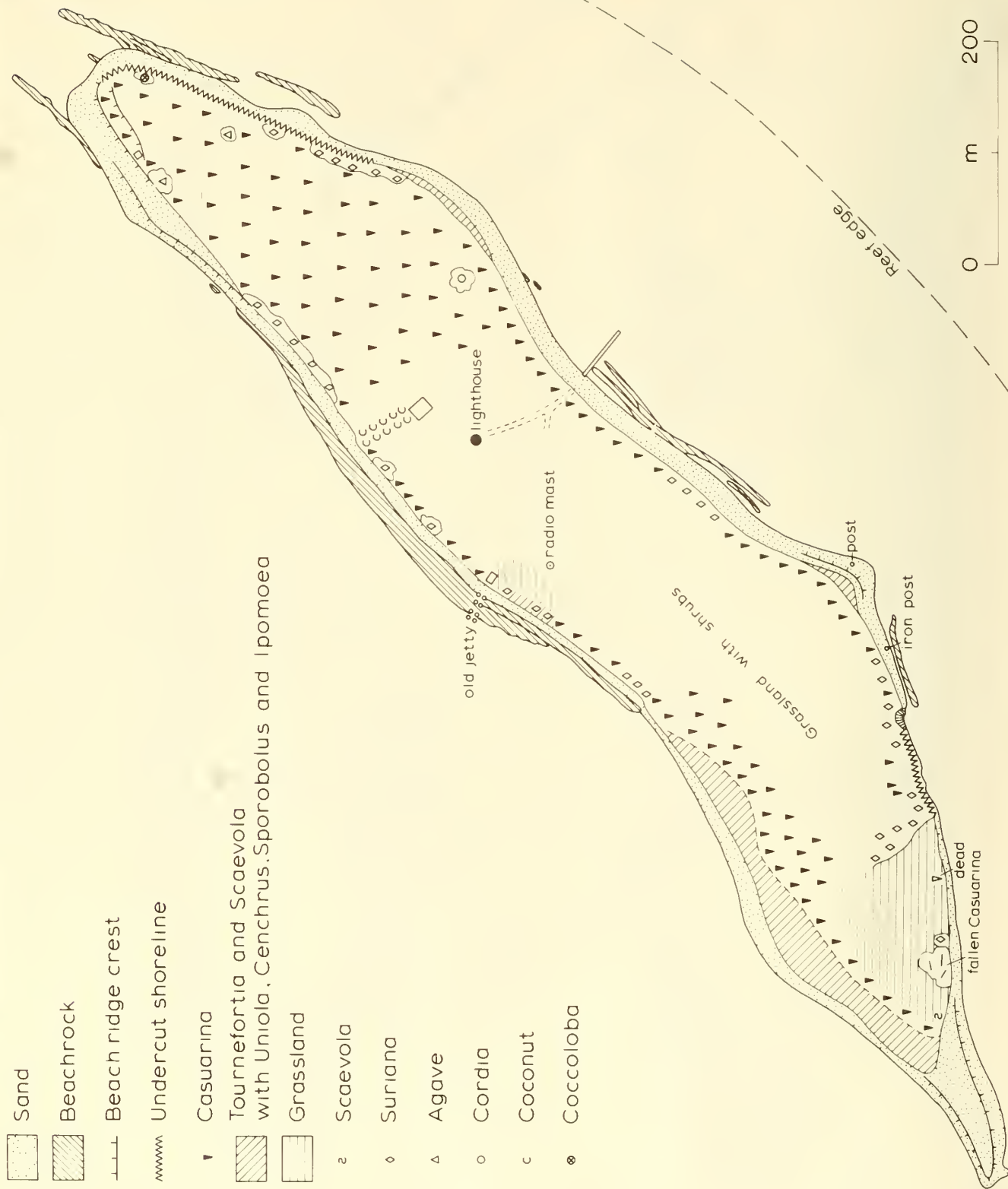


Figure 8. Loggerhead Key in 1904, 1915-16, 1937 and 1977 (Millsbaugh 1907, Bowman 1918, Davis 1942, and Stoddart in 1977).



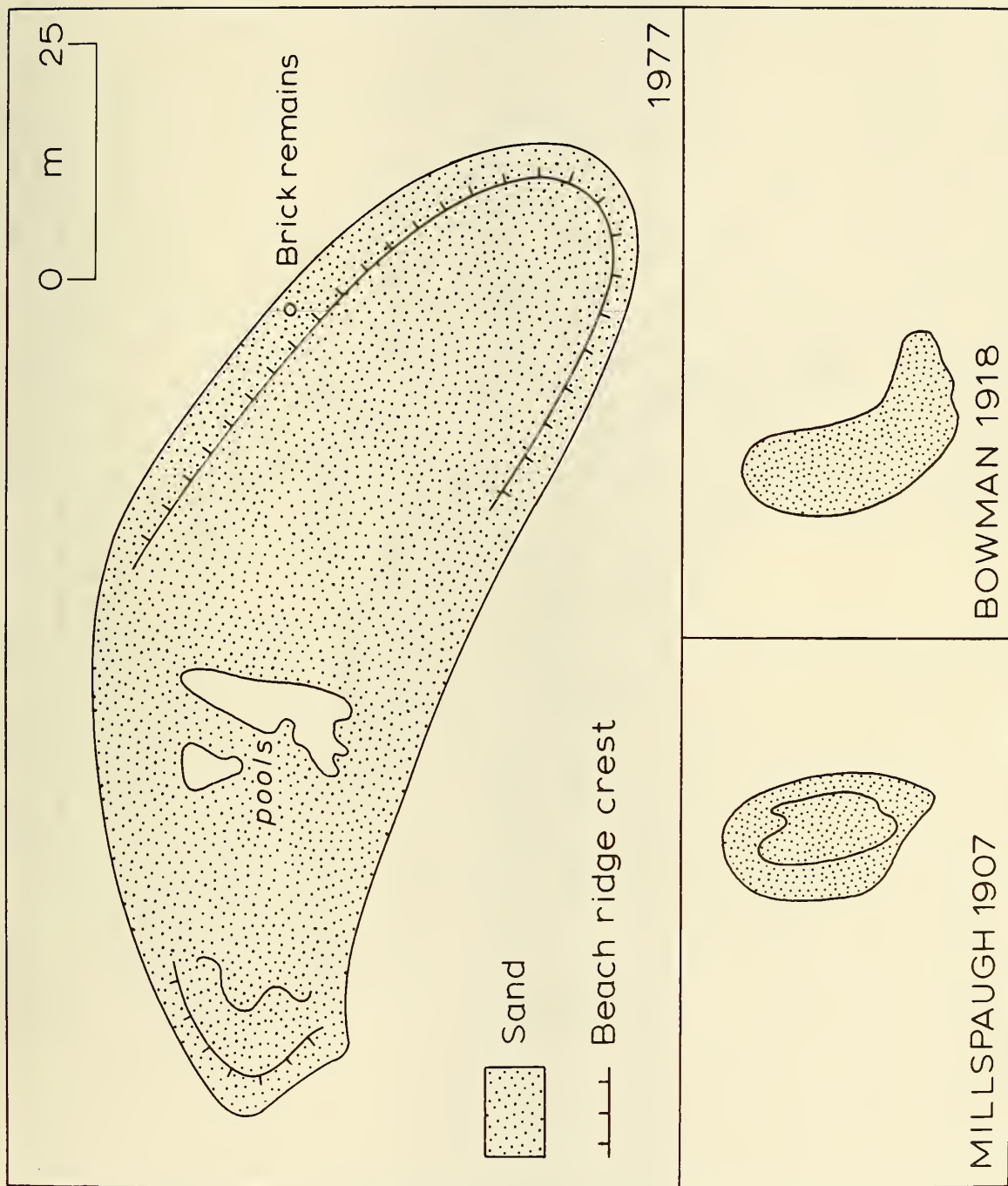


Figure 10. Sand or Hospital Key in 1904, 1915-16, and 1977 (Millspaugh 1907, Bowman 1918, and Stoddart in 1977).

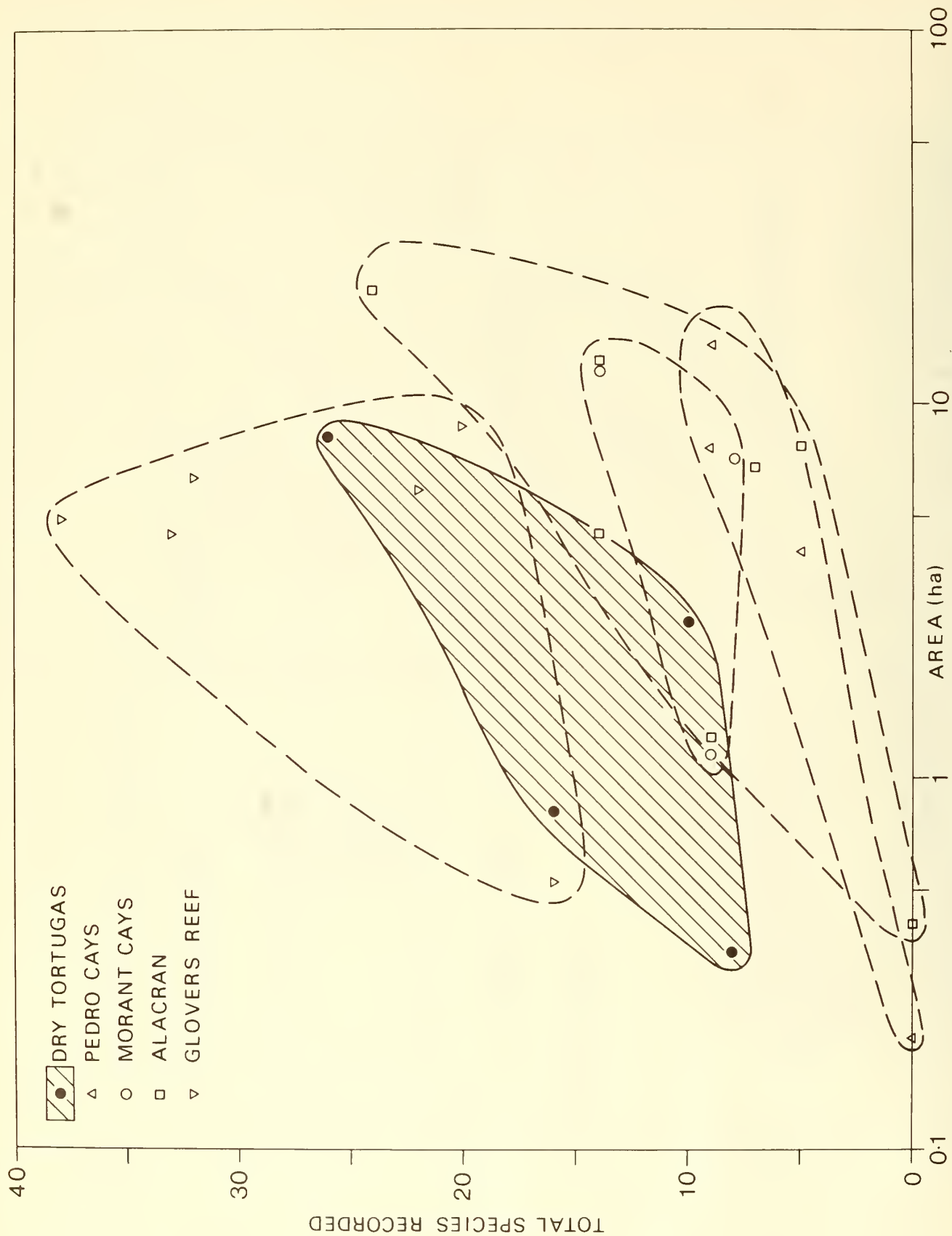


Figure 11. Species-area relationships for the Dry Tortugas keys and other coral islands in the Gulf of Mexico and Caribbean Sea. Sources: Pedro Cays: Chapman 1944, Steers 1940, Steers et al. 1940, Zans 1958, Fosberg unpublished observations in 1962; Morant Cays: Chapman 1944, Asprey and Robbins 1953; Alacran: Fosberg 1962; Glover's Reef:



Pl. 1. Bush Key (foreground) and Long Key seen from Fort Jefferson. Note the tall *Conocarpus* woodland on Bush Key and the extensive mangrove on Long Key. Compare this view with that in Davis (1940), plate 12.



Pl. 2. Bush Key: herb mat dominated by *Sesuvium* along the south coast.



Pl. 3. Bush Key: *Tournefortia* and *Opuntia* scrub on the narrow eastern spit.



Pl. 4. Bush Key: tall *Conocarpus* woodland on the eroding north shore.



Pl. 5. Bush Key: *Avicennia* woodland in the eastern bay.



Pl. 6. East Key: *Uniola paniculata* and *Iva imbricata* on the eastern ridge.



Pl. 7. East Key: *Uniola paniculata* at the eroding northeast point.



Pl. 8. East Key: open vegetation of *Uniola*, *Sesuvium*, and *Cakile* (foreground) in the south-central part of the key.



Pl. 9. Loggerhead Key: tall *Casuarina* woodland in the middle of the key, seen from the anchorage on the east side.



Pl. 10. Long Key: *Rhizophora* woodland on the west shore.



Pl. 11. Sand Key: seen from the west end

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NO. 254

**NATURAL HISTORY OF RAINE ISLAND, GREAT
BARRIER REEF**

by D. R. Stoddart, P. E. Gibbs, and D. Hopley

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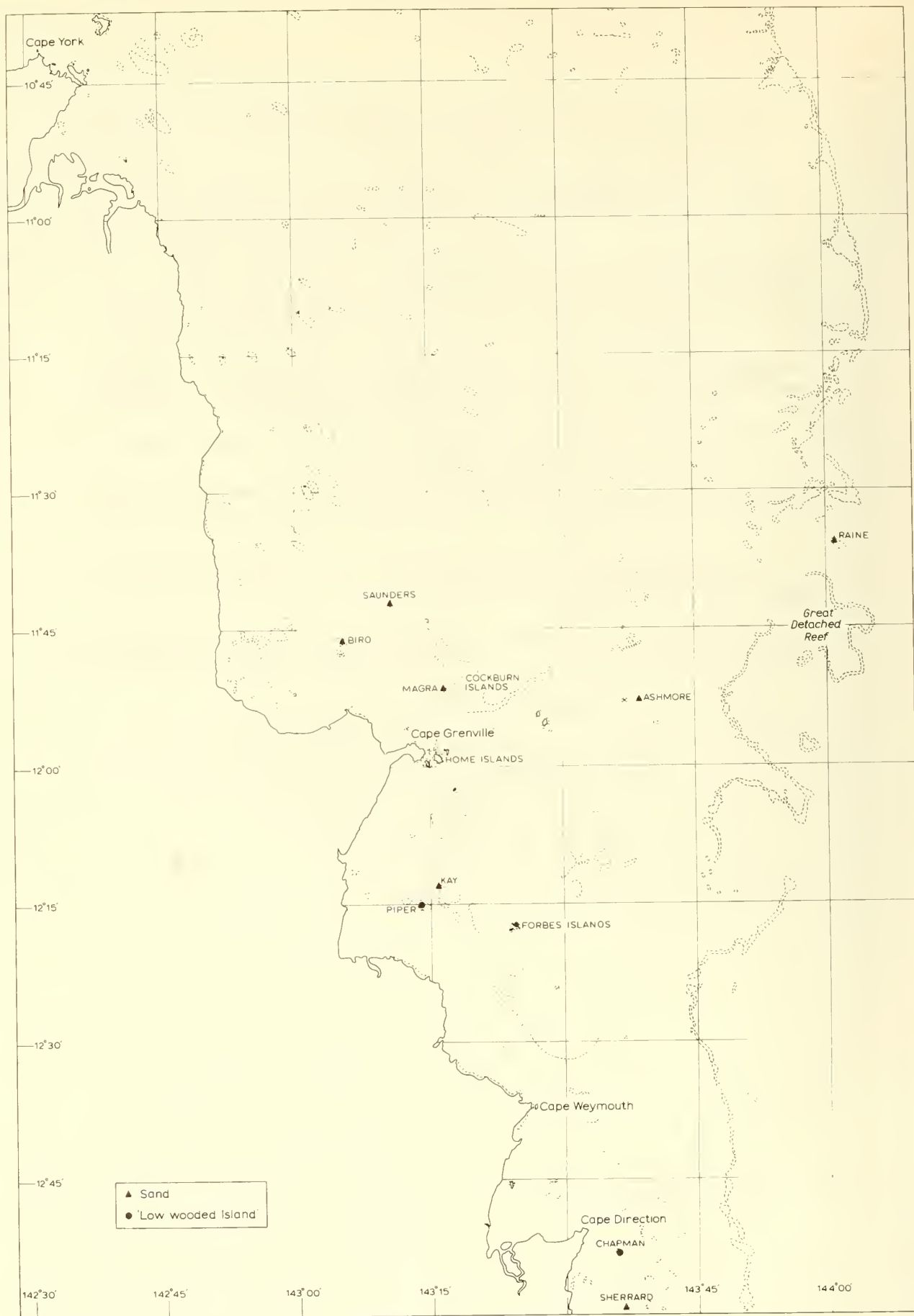


Fig. 1. The northern Great Barrier Reef, showing the location of Raine Island.

NATURAL HISTORY OF RAINE ISLAND, GREAT BARRIER REEF

by D. R. Stoddart¹, P. E. Gibbs², and D. Hopley³

INTRODUCTION

Raine Island, on the northern Great Barrier Reef, is a small sand cay 850 m long and up to 430 m wide. It was the subject of now classic descriptions by Joseph Beete Jukes and John MacGillivray during the voyage of H.M.S. *Fly* in 1843-45, when a substantial stone Beacon was built there. Several other scientific parties, including that of H.M.S. *Challenger*, have visited the island, but no general account exists of it. This is the more surprising, since it is the most important breeding station for tropical seabirds in Australia, and has recently been shown to be one of the world's largest nesting sites for the Green Turtle.

Much of Raine was originally covered with guano and lightly cemented phosphate rock, which formed the basis of a brief but considerable mining industry in 1890-92. Raine is, in fact, interesting not only in itself but also as a representative of a class of small, semi-arid guano and phosphate islands in the reef seas. Among those recently studied are several in the Amirantes in the western Indian Ocean; Laysan in the Leeward Hawaiian Islands; and several of the smaller Phoenix Islands in the central Pacific. Raine is the smallest of all of these: it is half the size of McKean and Birnie Islands in the Phoenix group, and half the size of the Marie-Louise in the Amirantes. Bird Island in the Seychelles is three times as big as Raine, and most of the other phosphate islands are much larger. But in spite of its small dimensions, Raine is of sufficient interest to merit bringing all the available information on it together, together with new observations from the work of the Royal Society and Universities of Queensland Expedition to the northern Great Barrier Reef in 1973.

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Table 1. Visitors to Raine Island

Date	Vessel	Visitors	Notes	References
1815	Surry	Thomas Raine	First recorded sighting	
1843 29-30 July	H.M.S. <i>Fly</i>	Capt.F.P. Blackwood, J.B. Jukes	Short visit	
1844 29 May-mid September	H.M.S. <i>Fly</i>	Capt.F.P. Blackwood, J.B. Jukes, J. MacGillivray (June only), Lt J.M.R. Ince	Shore party camped to build beacon; vegetable gardens established. Geological, botanical and zoological work	Blackwood 1844a, 1844b, 1844c, Jukes, 1847, 1871; J. MacGillivray 1846
1845 25 January	Heroine	Capt.M. Mackenzie	Short visit; goats introduced	Mackenzie 1845
1845 April- May	H.M.S. <i>Bramble</i>	J. Sweatman	Short visit	Sweatman, MS
1846 5 August	Heroine		Short visit	Anon. 1846
1850 24-25 July	Enchantress	Capt. I'Anson	Wrecked	Lack 1953
1860 (-)	H.M.S. <i>Salamander</i>	Capt. Mangles Denham, A. Rattray	Short visit	Rattray 1869
1862			Raine and other islands leased for guano digging	Crowther 1939
1865 March	H.M.S. <i>Herald</i>	Capt. Mangles Denham		

Table 1 continued

Date	Vessel	Visitors	Notes	References
1874 31 August	H.M.S. <i>Challenger</i>	Capt. G. Nares, with H.N. Moseley, J. Murray, J.Y. Buchanan	Short visit, botanical and zoological collections	Campbell 1876; Spry 1876; Swire 1938; Buchanan 1874; Forbes 1878; Sclater and Salvin 1878; Moseley 1879; Miers 1886; Murray 1895
1870's		Beche-de-mer fishery	Shore camps	Ellis 1936
1890-1892		Guano digging	Shore camps	Ellis 1936; Arundel, MS; Hutchinson 1950
1910 30 October		W.D.K. Macgillivray, E.H. Dobbyn	Ornithology	Macgillivray 1910; North 1912
1911 9-15 July		W.R. M'Lennan	Ornithology	Macgillivray 1914, 1917, 1918
1913 4-12 December		W.D.K. Macgillivray, W.R. M'Lennan	Ornithology	Macgillivray 1914, 1917, 1918
1957 July		D. Attenborough	B.B.C. film unit on Raine for 4 days	
1959 7-14 and 22 February		J. Warham	Ornithology; plants	Warham 1961, 1963, 1959
1961 11 November	H.M.A.S. <i>Gascoyne</i>	K.A. Hindwood, K. Keith, G.F. Mees, I. Thomas D. Woodland, A. Bartholomai	Ornithology; plants	Hindwood, Keith and Serventy 1963; Hindwood 1964

Table 1 continued

Date	Vessel	Visitors	Notes	References
1973 1-4 November	James Kirby	D.R. Stoddart, P.E. Gibbs, D. Hopley	Geomorphology, plant collection, ornithology, turtles, crabs	This report

Since 1973 there have been several visits to Raine Island by the staff of the National Parks and Wildlife Service of Queensland, the Department of Zoology of James Cook University, and the Australian Institute of Marine Science at Townsville.

GENERAL DESCRIPTION

Raine Island is located at the leeward end of an oval patch reef 3.5 km long and 0.75 km wide, with an area of 210 ha, north of the Great Detached Reef of the northern Great Barrier Reef system, and 100 km ENE of Cape Grenville, the nearest point on the Queensland mainland (Figures 1 and 2). Its co-ordinates are 11°36'S and 144°01'E. Jukes (1847) described the island as 1000 yds (915 m) long, 500 ft (150 m) wide, and up to 20 ft (6 m) high above high water level. The central part of the island he described as covered with a cap of calcareous sandstone, terminating on its seaward sides in a cliff 4-5 ft (1.2-1.5 m) high. The Raine Island Reef has been termed a "small coral atoll" (Tizard *et al.* 1885, II, 530), but in the absence of a lagoon this usage seems inappropriate.

The first full descriptions of the island are those of Jukes (1847) and MacGillivray (1846), based on observations made during the time that a beacon was being built on the eastern end of the island by Capt F.P. Blackwood and H.M.S. *Fly* in 1844. The island was subsequently occupied during 1890-92, when tens of thousands of tons of phosphate were dug and exported. Twenty years later, at the time of W. Macgillivray's visits, seabirds were abundant, and the island is still "probably the most important breeding station for tropical seabirds in Australian seas" (Warham 1961, 77). It is also a major nesting site for Green Turtles, though this has attracted less attention in the scientific literature.

No weather records have ever been kept at Raine. During April to November the Southeast Trades blow constantly; during December to March the Trades retreat to the south and are replaced by calms and northerlies. Most rainfall occurs during this second period. Mean annual rainfall has been estimated by A.T. Bath (in Warham 1961) as 1000 mm (40 inches); this is very close to the mean for Willis Island in the Coral Sea (16°18'S, 149°59'E), where the mean annual rainfall 1921-1971 was 1098 mm (Figure 3). Reliability of rainfall at Willis, and probably also at Raine, is low; annual totals at Willis over the period of record range from a minimum of 240 mm (in 1966) to a maximum of 2024 mm (in 1959). Overnight dew is probably an important source of moisture on these islands.

Tidal range has been estimated as 10-12 ft (3.0-3.7 m) (Blackwood 1844a, 540; Fairbridge 1950, 352). Mean tidal range at springs for islands closer to the mainland between Cape Grenville and Cape Melville, however, ranges from 5.2 to 6.8 ft (1.6-2.1 m), increasing northwards to 8.4 ft (2.6 m) near Cape York.

GEOLOGY AND GEOMORPHOLOGY

Topography

MacGillivray (1846, 1474) described the following main features of the island:

- (a) a steep beach, 20 yards (18 m) or more in width.
- (b) a "more or less continuous, low, wall-like border of coral rock, its faces much decomposed by the weather, and hollowed out in a singular manner. ... This rock, which ranges from a conglomerate to a coarse sandstone, is in general soft and crumbles readily. ... This bed of sandstone is not more than a few feet in thickness, and exhibits proof of its recent formation, by containing shells and fragments of coral, specifically identical with living inhabitants of the reef, and occasionally eggs of turtle, apparently as if, while *in situ* in the loose sand of what was then a mere sand-bank, some chemical agency had converted the whole to a bed of stone". According to MacGillivray the edge of the cliff reached a height of 24 ft (7.3 m) above sea level.
- (c) a lower central area with a surface cover of "rich black mould".

Jukes (1847, I, 339) presented a schematic section through these features.

Figures 4 and 5 give Jukes's map and profile of Raine Island as surveyed in 1844. Figure 6 is a map of Raine surveyed by pacing and compass traverse in November 1973, and Figure 7 is a profile across the centre of the island surveyed at that time. The datum is inferred from the measurement of a still water level at a given time, and comparison with tide predictions for Sir Charles Hardy Islands, the nearest place for which predictions are available; the Standard Port is Cairns (Department of Harbours and Marine 1973). These data show the following topographic features:

- (a) the outer beach, generally 20 m wide and 5 m high, with intermittent beachrock;
- (b) the unvegetated beach crest, horizontal or falling slightly landwards, 20-25 m wide;
- (c) a low area of tussock grassland, varying in width from 10 to 80 m but averaging 30-40 m, with average elevation 4 m or a little less;
- (d) a cliff of cemented sandstone, of intricate outline in detail and with some isolated islands of sandstone in the tussock grassland, undercut and cavernous, generally 1-1.5 m high, with the outer edge reaching a uniform height of 6 m;

- (e) a high ridge of uncemented sand, with grass and herb cover, widest in the south (average 100 m but varying from 75 to 110 m) and narrower in the north (average 35 m, varying from 25 to 75 m), with a maximum elevation of about 9 m;
- (f) a central, unvegetated flat, with a superficially-cemented surface of white guano, with an elevation of 6 m accordant with the height of the peripheral cliff edges.

Areas of the different topographic units derived by planimetry from the map in Figure 5 are as follows:

outer beach slope	3.72 ha
unvegetated beach crest	3.23 ha
tussock grass depression	6.75 ha
high ridge crest	9.58 ha
central guano flat	4.04 ha
total area	27.3 ha

These figures do not include the area of intertidal beachrock, which covers another 0.68 ha.

Lithology

The nature of the "coral rock" was first studied by Jukes, both at outcrop on his first visit in 1843 (Jukes 1847, I, 128) and in quarries opened during the erection of the Beacon in 1844 (1847, I, 337-340). He found that "the stone was made up of small round grains, some of them apparently rolled bits of coral and shell, but many of them evidently concretionary, having concentric coats ... not unlike some varieties of oolite in texture and appearance. It contained larger fragments of coral and shells, and some pebbles of pumice, and it yielded occasionally a fine sand that was not calcareous, and which was probably derived from the pumice. Some parts of it made a very fair building stone, but it got softer below, till it passed downwards into a coarser coral sand, unconsolidated and falling to pieces on being touched" (1847, I, 127-128). Excavations for the quarries revealed drusy cavities with gypsum, many recent shells, and one or two nests of turtle eggs (1847, I, 128, 340), as well as pumice pebbles (1847, I, 337).

In 1874 Moseley (1879, 299-300) observed that the rock was evenly bedded, the bedding being horizontal in the centre and towards the sea round the shore. On the northeast side near the Beacon he quotes a dip of seven degrees. Moseley also contrasts the white sand, consisting of shells, corals and Foraminifera, of the beaches, with the areas above high water mark, which were redder and had a consolidated crust (1879, 300).

Stratigraphy

Two holes were dug during the *Fly* expedition in the centre of the island. One dug by Jukes to a depth of 5 ft 1 in (1.5 m) showed the following section:

- | | |
|------------------------------|---|
| 0 - 6 inches (0 - 15 cm) | "Good black vegetable mould" |
| 6 - 9 inches (15 - 23 cm) | "Stone, brown mottled with white, hard and coarse grained" |
| 9 - 25 inches (23 - 63 cm) | "Rich moist black soil, like bog-earth" |
| 25 - 61 inches (63 - 155 cm) | "Stone of a light brown colour, rather soft, but tough, and yielding slowly to the pickaxe" |

(Jukes 1847, I, 127).

MacGillivray's pit the following year reached a depth of 16 ft (4.9 m), with the following section:

- | | |
|--------------------------------|--|
| 0 - 3 inches (0 - 7.6 cm) | "Fine coral sandstone" |
| 3 - 12 inches (7.6 - 30.5 cm) | "Moist pulverulent black earth, resembling peat, but without any trace of woody fibres" |
| 1 - 13 feet (30.5 cm - 3.96 m) | "Successive deposits, varying from coarse coral conglomerate to unconcreted calcareous sand mixed with a few small scattered fragments of coral and shells" |
| 13 - 14 feet (3.96 - 4.27 m) | "Masses and large fragments of coral (of species now alive on the reef), bleached and water-worn, loosely inbedded in coarse sand"; inflow of seawater took place at this depth. |

(MacGillivray 1846, 1474).

Sediments

Sediment samples were taken from the beach slope, beach berm and high ridge on the north, west and south sides of the island; these were mechanically analysed and components identified in the fraction coarser than 250 microns. Components were classed as coral and

coralline algae, molluscs, platey Foraminifera (mainly *Marginopora*), spherical Foraminifera (including *Baculogypsinoidea*), and *Halimeda*. All the samples are remarkably homogeneous. They lie in the size range of coarse sands ($0.4 - 0.9\phi$); are well sorted ($0.3 - 0.5\phi$); have near symmetrical distributions; and are mainly platykurtic. Two components dominate, molluscan fragments and spheroidal Foraminifera. Only on the leeward side do coral and coralline algal fragments contribute significantly to the coarse fraction. Molluscan fragments are more common on the beach and spherical Foraminifera on the berm and ridge, presumably because of the greater mobility of the latter. Small discrete lenses of platey Foraminifera, *Halimeda* and pumice were noted at the time of collection. Figure 8 gives sample curves for a beach (curve 1) and high ridge (curve 2) sample.

Two samples were also taken from the centre of the island, one (curve 3 in Figure 8) from the central depression, and one (curve 4) from its surrounding ridge. The central depression sample has a mean size of 1.0ϕ , is moderately sorted, symmetrical and leptokurtic; it differs from the beach and berm sediments in its fine tail (coarser than 2.0ϕ). The north ridge sample is much finer (mean size 2.3ϕ), is poorly sorted (1.25ϕ), symmetrical and platykurtic. Its distribution differs markedly from that of the beach sands.

Interpretation and subsequent observations

Jukes (1847, I, 339-340) believed that the geology of the island could be explained by (1) the formation of a sand cay at the leeward end of the reef; (2) the formation of a crust by solution and redeposition of calcium carbonate above high water mark; (3) the cessation of accumulation and the cliffing of the lithified material; and (4) the later resumption of sand accumulation to form the present peripheral sand ridge. The age of the whole island he believed was indicated by the thickness of up to 2 ft of "vegetable mould" in the central depression. Moseley in 1874 compared the rocks of Raine with the "calcareous sand rock" or aeolianite of Bermuda, except that the former was more evenly bedded. Jukes's interpretation is largely confirmed by recent observations, though following the large-scale guano digging of 1890-92 it is no longer possible to be sure that surface features are not of human origin, at least in the central depression.

Many later interpretations, often involving sea-level changes, are less closely related to the facts of lithology and stratigraphy than was Jukes's. Rattray (1869, 303) described Raine as "consisting of hard compact brecciated coral conglomerate, with a shelving beach of coarse coralline and shelly sand, and a scanty superstratum composed of the coral debris sparingly mixed with vegetable matter, and a thin layer of guano". He suggested that the present island had been formed beneath the sea and had then undergone emergence, and he termed the island an "extinct" coral reef. Neither Jukes nor MacGillivray had described a coral conglomerate or any raised reef. Several subsequent workers accepted Rattray's inference of emergence, however, from Agassiz (1898, 124) onwards. Fairbridge (1950, 352) states that Raine

is "in part at least, an emerged beach rock. With a tidal range of 10-12 feet and an extra 2-3 feet to include mean swash, an emergence of about 10-11 feet is indicated. Rattray (1869) also mentioned a raised coral breccia here. A definitely emerged coral reef occurs some 12 miles southwest of Raine Island (Jukes 1847). It is 2-3 miles long and 0.25 miles wide, with *Porites* colonies in the position of growth 10-12 feet above the present reef growth level". Fairbridge in a later paper (1967, 403) called Raine "the only emerged reef island on the whole outer barrier; Jukes observed that it consists of a calcareous aeolianite, with an emerged beachrock terrace here ascribed to the 3 m mid-Holocene stage. The aeolianite, by analogy with other offshore occurrences in Australia ... is probably of late glacial (Würm) age, when sea level was low enough to permit wide beaches to form and dune accumulations to develop". According to Bennett (1971, 37), Raine "consists of older, solidified reef material formed at a period when the sea level was higher", and the stone used for the Beacon was "quarried out of the solid reef".

These conclusions evidently go substantially beyond the facts so well recorded by Jukes and MacGillivray in 1843-44, and are not supported by evidence collected then or observable now. The 3 m mid-Holocene "emerged beachrock terrace" of Fairbridge is not beachrock, is not emerged (in the sense of being now at a higher level with respect to sea level than when it was formed), and does not stand at 3 m. The cliff edges stand at 6 m and are accordant with the central guano flat. All the beachrock at Raine Island is at low intertidal levels, and there is no evidence that any beachrock there is raised: a radiocarbon date (ANU-1591) on a *Tridacna* valve from beachrock at spring-tide swash level is 1180 ± 65 yr B.P. (Polach et al. 1978, 151). There is no evidence that the main cemented horizon which outcrops in the cliffs is an aeolianite (cross-bedding and similar sedimentary structures seem to be completely lacking), and all the evidence indicates that it is a superficial cementation phenomenon, decreasing with depth, in the way that Jukes envisaged. It is a cay sandstone in which the cement is partly phosphatic, and cementation probably represents a continuing process rather than a discrete event. The "raised reef" 12 miles southwest of Raine Island, described by Jukes and to which Fairbridge refers, was also visited in 1973: it is not a raised reef and there are no *Porites* colonies in the position of growth: it is simply a deposit of large storm boulders near the reef edge, all now much eroded, and having no significance with respect to changes in sea level.

Phosphate deposits

No detailed account of the Raine Island phosphates, mined in the central area in 1890-92, has been published, and no analyses of the material are known. According to Saville-Kent (1893, 120), "the deposits occur under three distinct conditions: Firstly, in layers some fifteen inches thick, immediately beneath the upper crust of coral conglomerate, which constitutes the encircling plateau described by Mr Jukes; secondly, in pothole-like hollows in the same location; and thirdly, in trench-like depressions in the central black earth basin".

The cliffs probably retain much of their original appearance, since the mining was carried out in the central flat; they closely resemble comparable cliffs on other islands with phosphatic cementation, such as Denis Island, Seychelles (Fryer 1910, 18-19, Plate 2). The cementation is greatest at higher levels and diminishes with depth; the lower surface of the cemented horizon is irregular, and forms a series of downward-directed lobes and pillars. These probably indicate differential permeability in the originally uncemented sands. T.P. Scoffin has examined specimens from the upper part of the cliffs as part of a wider study of coral island phosphates. The grains in the sands are of variable origin: Foraminifera 40%, *Halimeda* 30%, coral 10%, mollusc 10%, unknown 10%. Phosphatic cement occurs as a wavy thin film with laminated structure coating the individual grains; the grains themselves have been altered centripetally for distances of a few microns from the grain margins. The phosphate mineral is hydroxylapatite; the other main mineral present is aragonite, with a trace of calcite. The presence of aragonite suggests a young age for the material. Chemical composition is 31.0% P_2O_5 , 54.0% CaO .

WATER SUPPLY

There is no standing surface water on Raine, except possibly for a few days immediately after storms. During the *Fly* expedition water was imported from Sir Charles Hardy's Islands for the men building the Beacon. Jukes (1847, II, 266) says that "one or two wells were sunk in the island, but no fresh water was procured; although in one of the wells, at a depth of 16 feet, the water was only brackish, and could be used to slack the lime, although very unpalatable to the taste". Arundel in 1890 had to construct a seawater distillation plant for his work force. Warham (1961, 78-79) also states that there is no fresh water and that "various attempts to strike it by digging in the past have failed".

A carved inscription on the inside of the walls of the Beacon, however, apparently of mid-nineteenth century date (it is mentioned in Arundel's diary in 1890), states that fresh water can be obtained at a depth of 7 feet.

VEGETATION AND FLORA

The vegetation of Raine Island consists of low shrubs, herbs and grasses; there are no trees. To Blackwood (1844a, 539) it was the "quantity of coarse green vegetation on it" which distinguished Raine from most of the other small sand cays in this northern reef area; he was clearly thinking of unvegetated sand cays in the vicinity, such as those on Ashmore Reef.

Jukes (1847, I, 127) described "a low shrubby vegetation, partly of reed-like or umbelliferous plants, and partly with a close green carpet of a plant with succulent leaves and stem, which we subsequently found was good to eat, and so went with us by the name of 'spinach'"

(this was probably *Portulaca*). MacGillivray (1846, 1475) gave a fuller account, though unfortunately unsupported by specimens: "Of the Botany of the islet I can give but a very meagre account, for a collection of about twenty species, found by me, unfortunately went to decay for want of a proper place of storage on board ship. Several of these species I have elsewhere observed on the main land of New Holland; among others, a long, trailing, woody plant with conspicuous yellow blossoms [probably *Tribulus cistoides*], and a large white-flowered convolvulus [probably *Ipomoea macrantha*]. Two species, very abundant, on the island, were used by us as vegetables, one of them under the name of spinach [*Portulaca*], for which it was considered a very fair substitute, and as such served out to the ship's company. Most of the plants of the island are more or less succulent; there is but one shrub, a slender Acacia, five or six feet high, with small yellow flowers [probably *Sesbania*]". The surrounding sand area had "a few scattered tufts of grass and other herbage" (MacGillivray 1846, 1474). A variety of cultivated plants was introduced during the *Fly* expedition and during the visit of the *Heroine* in 1845; they are described later.

The *Challenger* Expedition in 1874 recorded 11 species of flowering plants, including two grasses. They noted fungi on dung, but no mosses, ferns or lichens. There was also no trace of the *Fly* vegetable gardens or of other introductions. No species list appears to have been published from these collections (Moseley 1879).

In 1910 W. Macgillivray (1910, 224) found "a coarse grass, a kind of pig-face weed, and a low perennial shrub of horizontal growth, not more than 1 to 1½ feet from the ground anywhere, and bearing grey-green leaves and a yellow flower". These were probably *Lepturus repens*, *Portulaca* sp., and *Tribulus cistoides*, respectively.

In February 1959, after good rains, Warham (1961, 78) found only six species of flowering plants, "the principal one being a kind of mallow (*Abutilon graveolus* or *indica*) which was flowering, a spinach-like amaranth (*Amaranthus viridis*) and a low bushy plant *Tribulus cistoides*. This bore orange flowers and is probably the 'acacia' of the early visitors of the island [*Abutilon* and *Tribulus* appear confused in this account]. Two grasses also flourished: *Eleusine indica*, an introduced species, and *Lepturus repens*, a native plant. This grew quite thickly on the dunes on the south-east side of the island. A low succulent also grew around the edges of the central depression [probably *Portulaca* sp.]. None of these plants was more than two feet high".

The only published list of Raine Island plants appears to be that of Hindwood et al. (1963, 44), based on collections made in November 1961 and lodged in the Queensland Herbarium, Brisbane, and the Division of Plant Industry, C.S.I.R.O., Canberra. Six species are recorded, and it is likely from Warham's records two years earlier that others were missed.

Plants were collected in 1973 and were identified by Miss S. Reynolds at the Queensland Herbarium, Brisbane. The following list includes the plants cited by Hindwood et al. (1963).

Gramineae

Eleusine indica (L.) Gaertn.

Stoddart 5061. Also cited by Warham (1961, 78).

Lepturus repens R.Br. cf. var. *repens*

Stoddart 5051, 5059. Also cited by Warham (1961, 78) and Hindwood et al. (1963, 44).

Nyctaginaceae

Boerhavia sp.

Stoddart 5054 (specimen lost). Hindwood et al. (1963, 44) also cite *Boerhavia tetrandra* Forst., but the specimen collected in 1973 is not this species.

Amaranthaceae

Achyranthes aspera L.

Stoddart 5053. Cited by Hindwood et al. (1963, 44).

Amaranthus viridis L.

Stoddart 5057, 5058? Warham (1961, 78) also cites *Amaranthus viridis*.

Portulacaceae

Portulaca oleracea L. (*sensu lato*)

Stoddart 5056. Possibly the plant mentioned by W. Macgillivray (1910, 224) and Warham (1961, 78).

Cruciferae

Coronopus integrifolius Spreng.

Stoddart 5060

Leguminosae

Sesbania cf. *aculeata* Poir.

Stoddart 5050. *Sesbania aculeata* is cited by Hindwood et al. (1963, 44).

Zygophyllaceae

Tribulus cistoides L.

Stoddart 5055. Cited by Warham (1961, 78) and Hindwood et al. (1963, 44); possibly the plant mentioned by MacGillivray (1846, 1475).

Malvaceae

Abutilon asiaticum var. *australiense* (Noch. ex Britt.) Fosb.

Stoddart 5052. Cited as *A. indicum* (L.) Sweet by Hindwood et al. (1963, 44); probably the plants mentioned by W. Macgillivray (1910, 224) and Warham (1961, 78).

Convolvulaceae

Ipomoea macrantha R. and S.

Not collected in 1973 or by Hindwood et al. (1963).

Possibly the plant mentioned by MacGillivray (1846, 1475).

INVERTEBRATES

Most of the collections of invertebrates made at and near Raine Island have been of marine animals during the *Challenger* Expedition. These are listed by Murray (1895, 682-688); they comprise mainly species of Ostracoda, Mollusca and Foraminifera, with only a few land or shore animals.

The most conspicuous, indeed the only, semi-terrestrial crustacean is the ghost crab *Ocypode*. Moseley collected a single male specimen of *O. ceratophthalma* (Pallas), recorded by Miers (1886, 238-239). In 1973 the population was predominantly *O. ceratophthalma* with a few *O. cordimana* Desmarest, the two species being represented in a sample of 60 individuals in a ratio of 6.5 : 1. Coenobitid hermit crabs, elsewhere common on guano islands in the central Pacific and Indian Oceans and also in the Caribbean, appear to be completely absent on Raine and other Great Barrier Reef islands. Mole-crabs of the genus *Hippa* inhabit the coarse sands of the lower beach levels; although *H. pacifica* (Dana) was the only species collected in 1973, it seems likely that *H. celaeno* (de Man), a commoner species on other reef islands in the region (see Gibbs 1978), is present also.

Among insects, MacGillivray (1846) noted a large scarab, Coleoptera including *Hister*, *Necrobia* cf. *ruficollis*, and *Dermestes murinus*; *Pimelia*; and ixodid ticks. Moseley (1879, 302) found an earwig *Forficula* under stones and a very common locust *Acridium*. No further invertebrate collections appear to have been made.

MARINE TURTLES

The Green Turtle nesting season at Raine Island is concentrated from October to December; visitors outside these times have usually made few turtle observations. Parsons (1962) in his standard work on the Green Turtle makes no mention of Raine Island, and while Bustard (1972) includes Raine Island in a map as an important nesting site he makes no mention of it in his text. Yet Raine is certainly one of the largest Green Turtle nesting sites in the world, and could be the largest remaining still undisturbed by man.

Jukes's first visit in July 1843 produced few records. "There were a few turtle tracks on the beach, but we did not succeed in taking any, though many dead ones were scattered about the island", especially at the foot of the cliff (Jukes 1847, I, 130). During the 1844 visit, MacGillivray (1846, 1479) found that "during the months of June, July and August, the turtle occurred at irregular intervals, generally

singly, but in the beginning of September they became more numerous". In the following year a party from the *Bramble* found the cliffs and quarries "full of the remains [of turtles] ... who had fallen over on their backs and perished miserably". They took 14 turtle by turning them on the beaches at night, some of them being of 250-300 lbs weight (roughly 110-140 kg). Sweatman (MS, 94-95) gives a graphic account of taking turtle during this visit. Mackenzie (1845, 494), calling with the *Heroine* on 25 January 1845, "obtained fourteen large turtles, each averaging four cwt [ca 200 kg]". In August 1874 the *Challenger* found only the carapaces of numerous dead turtles (Moseley 1879, 302).

Conversely, Macgillivray (1910, 224), on 30 October 1910, found "great numbers of turtles ... on the beach and in the shallow water round the boat". On 4 December 1913 he found that "about thirty turtles were crawling up the beach near where we landed, and the shallow water contained hundreds of them", coming ashore at night to nest (Macgillivray 1917, 67).

During the *Fly* visit, MacGillivray (1846, 1478-1479) noted that all the turtle seen were Green, *Chelonia mydas*, and that they laid clutches of at least fifty eggs. He found that the hatching young suffered predation by frigate birds and sooty terns, and sixty years later Macgillivray (1917, 84) recorded predation of eggs by Crested Tern *Sterna bergii* and Silver Gull *Larus novae-hollandiae*.

Green Turtle were nesting during the visit to Raine Island in 1973. Tracks were counted round the island each morning. Measured at the foot of the beach, the perimeter of the island occupied by sand (including the low and discontinuous narrow beachrock of the northern coast) totals 1600 m, and that occupied by beachrock 500 m (76 and 24% respectively). Numbers counted on the beach only were as follows:

	<u>Tracks</u>	<u>Animals</u>
Night of 31 October	324	162
1 November	245	123
2 November	230	115
3 November	270	135

During the night of 3 November, animals were also counted on the nest both on sandy beaches and also inland from beachrock shores. The ratio of tracks:animals on the beaches can then be used to infer the number of tracks which might be expected on the beachrock shores, to give an estimate of the total number coming ashore for the whole island on that night. The results are:

	<u>Beach</u>	<u>Beachrock</u>	<u>Whole island</u>
(a) Animals counted on nest	87	38	125
(b) Numbers inferred from tracks	135		
Ratio (b):(a)	1.55		
Inferred total numbers	135	59	194

In subsequent surveys, Birtles (1978) estimated the numbers of nesting turtles at 11,800 in 1974, 50 in 1975, 1000 maximum in 1976, and 50-100 in 1977. Kowarsky (1978) also made ground and aerial observations in January 1976, but although tracks were numerous he could not make any estimate of numbers. For comparison, at Ile Europa, Mozambique Channel, sometimes stated to be the largest Green Turtle colony in the world, Hughes (1974) estimated 5,000 emergences a year, and Servan (1976) 1300 a year.

The prime nesting habitat on Raine is the unvegetated sand areas of the beach crest, though a considerable number of turtles do nest in the outer *Lepturus* tussock grassland between the beach and the cliffs. Planimetric measurements on Figure 5 indicate a total area of unvegetated beach crest of 32,300 sq m. A turtle 1 m long requires an area of not less than 1.54 sq m for its nesting depression. Hence there are approximately 21,000 potential non-overlapping nest sites in the beach crest area. Two hundred turtles nesting in one night would have 161.5 sq m each in which to choose a nesting site. Each site would have roughly 1 chance in 100 of being selected. These calculations give some idea of the possible potential size of the Raine Island colony. Elsewhere on the Great Barrier Reef, on vegetated islands, the size of nesting area available is a limiting factor in the number of successful nestings (Bustard and Tognetti 1969): at Raine Island this is unlikely to be so. Kowarsky (1978) quotes a clutch size at Raine of 105.8 ± 22.0 eggs ($n = 6$).

The curved carapace length of females on the nest was also measured on the night of 3 November, and Figure 9 presents a histogram of the results. 124 animals were measured. The mean length was 109 cm, standard deviation 5.29 cm; the smallest measured was 90 cm long, and the largest 122 cm. Bustard (1972, 138-141) quotes average figures of 107 cm curved length for Great Barrier Reef Green Turtles, and ranges of 89-127 cm. Curved length can be converted to straight length using the formula derived for Aldabra turtles by Frazier (1971, 390), and the calculated straight lengths then used to compare populations in different parts of the world. The Raine Island turtles are very similar in size to those of Aldabra, markedly bigger than those of Ceylon, Yemen and Sarawak, and markedly smaller than those of Guyana, Ascension Island and Surinam (data listed by Frazier 1971, 380, and Servan 1976, 424). In addition to the 1973 data, Kowarsky (1978) gives mean straight length of 100.2 ± 5.5 and mean curved length 108.6 ± 5.1 cm for four individuals at Raine Island.

While measuring the turtles in 1973 it was observed that animals differed markedly in degree of curvature of carapace. In some the curvature was so shallow that it is possible they belong to *Chelonia depressa* Garman, the Flatback Turtle (Bustard 1972, 74-88) rather than to *Chelonia mydas* L.

According to Limpus (1978), tagged turtles from Raine Island have been recovered from south of Cooktown, Queensland, through the Torres Strait and southern Papua New Guinea to Aru Island, Indonesia.

In addition to the Green Turtle, Boulenger (1889) also records the Hawksbill *Eretmochelys imbricata* (as *Chelone imbricata*) from Raine, but no subsequent records are known.

BIRDS

Raine Island is a major breeding station for seabirds, and probably the most important in terms of numbers of species on the Great Barrier Reef. It has large breeding colonies of Brown and Masked Gannets, Noddies, Sooty Terns, and Wedge-tailed Shearwaters. It is also a breeding site for the Red-tailed Tropic-bird and the Lesser Frigate-bird, otherwise rare on the Great Barrier Reef. There are no comparable seabird-breeding stations (except for colonies of Noddies and Sooty Terns) between Raine and the Capricorn and Bunker Islands at the southern end of the Reef. There is also a resident land bird, the Banded Landrail, many shorebirds, and a number of migrants and vagrants recorded.

The first ornithological observations were those of Jukes and MacGillivray in 1843-44 during the visits of the *Fly*. Moseley made observations and collections during the *Challenger* visit in August 1874. The first extensive records are those of MacGillivray and M'Lennan in 1910, 1911 and 1913. The most detailed account of Raine Island birds is that of Warham (1961), following his visit in February 1959. Warham's list is used as the basis for the present account, though nomenclature follows Storrs (1973); we are most grateful to C.W. Benson for his assistance with and comments on this list. Following Warham, K.A. Hindwood and others also visited Raine during a survey of seabirds of the Coral Sea in November 1961; their records are also incorporated here.

In addition to the birds listed here, Ellis (1937, 179) also records "several long-legged and long-billed ibises", "three common crows", and "several diminutive hawks". MacGillivray (1846) also records several species of uncertain synonymy, including *Charadrius virginianus*, *Thalasseus strenuus*, *Callocalia arborea*, and *Porzana*.

Ducula spilorrhoa spilorrhoa (Gray)

Torres Strait Pigeon

One migrant bird is recorded (as *Myristicivora spilorrhoa*) by Ellis (1936, 178).

Rallus philippensis yorki (Mathews)

Banded Landrail

Recorded as *Rallus philippensis*? by MacGillivray (1846, 1476-77) in 1844, and subsequently figured by Gould (1848, VI, 76). It was "very abundant all over the island", under vegetation, beneath overhangs, and in shearwater burrows. MacGillivray found it very wary, though it ran and rarely flew. He caught "great numbers" (up to 45 in a day) with his dog.

In 1874 Moseley collected two males and one female (Forbes 1878). Under the name *Rallus pectoralis* Moseley described it as tame, and easily knocked down with sticks or caught by hand. In August there were full-fledged young (Moseley 1879, 301). On the basis of this record Kikkawa (1976) lists *R. pectoralis* Lewin Water Rail as a separate species (but see discussion below).

During 1890-92 there were initially large numbers, but "a welcome addition to the table they were. Their numbers were materially lessened during our occupation of the island, but some were left to carry on the restocking" (Ellis 1937, 177-178). Macgillivray in October 1910 simply records "numbers" running over the island (1910, 226).

There are no further records until Warham's visit in February 1959. It was then "very numerous and ... often seen in the daytime skulking among the herbage or running about beneath the caves and cavities under the cliffs. At night they spread out all over the island and were often seen on the dunes where they fed on turtle eggs exposed by the subsequent diggings of other turtles. ... Two nests were discovered ... their eggs being hidden beneath the thick herbage" (Warham 1961, 83). Warham also noted that the rails could be approached closely at night. The description agrees with the situation in 1973, except that dead birds were numerous on the ground, both on the high ridge and beneath the cliffs. Several of these dead birds were collected. Two males were also collected by Hindwood *et al.* (1963, 38) in November 1961; one is in the Western Australian Museum (no. A8755) and the other in the C.S.I.R.O. collection (no. CSIRO 301).

Storr (1973) states that *R. p. yorki*, a small, dark race, is very common in the Torres Straits islands and on low islands of the Queensland coast from Pandora Cay to Lady Musgrave Island (in 1973 we observed rails on Hope Islands, Turtle Islands, Three Isles, and Pelican Island). A second race, *R. p. pectoralis*, is of uncertain status but evidently rare in Queensland. The pectoral band in *yorki* is darker (chestnut cinnamon rather than pale cinnamon) and narrower (6-10 mm wide rather than 14-30 mm). C.J.O. Harrison has kindly re-examined specimens from Raine Island in the British Museum (Natural History), together with those taken as dead birds in 1973. The three *Challenger* specimens which included a young bird, suggesting recent breeding, are of the southern race, *pectoralis*. S.A. Parker has examined Raine Island specimens in Australian museums, and found them to be *yorki*, and the specimens taken in 1973 were also of this form. Harrison comments: "It seems probable from the evidence that both Australian races are migratory to some degree, and that both could potentially occur in Raine Island in passage. There are other references in literature to the species breeding on the island but no subspecific recognition of them. There is no clear indication of the status or origin of the birds which do or did (intermittently?) breed on the island. Dead bodies might be those of failed migrants."

Gallinula porphyrio melanotus (Temminck)

Eastern Swamp-hen

This common Torres Strait migrant is named (as *Porphyrio melanotus*) by Warham (1961) from an observation by Ellis (1936). Ellis refers to "some game-birds with dark blue plumage, a patch of white below the tail, strong red beak, and long red legs and feet ... known as pukekos in New Zealand", which were seen on "several occasions" (Ellis 1936, 179).

Diomedea chrysostoma Forster

Grey-headed Albatross

This is listed for Raine Island by Kikkawa (1976) on the basis of a reference by Hull (1925). Hull saw a bird near Lizard Island in June 1924 which "answered fairly well to the description of *Diomedea chrysostoma*, except for the neck shading. The mate ... a Filipino, said he had seen a similar bird at Raine Islet ..." (Hull 1925, 15). This is clearly an uncertain record.

Puffinus pacificus (Gmelin)

Wedge-tailed Shearwater

In May 1844 MacGillivray (1846, 1478) noted (as *Puffinus* -----?) "a small colony of these birds among some rank herbage which concealed the entrances to their burrows, in which they were easily caught ... it is possible that they are, in a great measure, nocturnal" as at Heron Island.

Under the name *Puffinus sphenurus*, Macgillivray and M'Lennan made several observations during 1910-1913. In October 1910: "At the north-western end of the island many burrows of a Petrel are found. We dug out several to a depth of 4 or 5 feet, and found them to contain either one or a pair of birds (*Puffinus sphenurus*). There are no eggs. It seems that the birds are only cleaning out their burrows and will probably lay in a month's time" (Macgillivray 1910, 226). In July 1911 the shearwater was again "in its burrows". M'Lennan "obtained several skins, and noted that each burrow contained two birds. He visited the burrows after dark, and waited for some time, and saw only one bird leave, but could hear mournful calling in all directions. A male and female in each burrow" (Macgillivray 1914, 141). In December 1913 Macgillivray (1917, 83-84) noted "many burrows", some 6 ft long, in the centre of the island, most with one egg and some with downy young.

In February 1959 Warham (1961, 80, 83) found "some hundreds of burrows", with "large young in down, some with feathers 1.25 inches long on the wings". In November 1961 Hindwood et al. (1963, 38) noted breeding, without further detail. In 1973 inhabited burrows were concentrated on the high ridge at the western end of the island.

This colony of shearwaters is the only one on the Great Barrier Reef north of the Bunker and Capricorn Island (Lavery and Grimes 1971; Serventy et al. 1971, 124). At the Heron Island colony, birds are present from October to April (Moulton 1961). In 1960 the first birds

arrived at Heron Island on 8 October, and the first eggs were laid on 15 December. Each day the birds left the island at 5 a.m. and returned at 7.45 p.m. (Gross, Moulton and Huntington 1963).

Pterodroma arminjoniana heraldica (Salvin)

Trinidad Petrel

Recorded for the first time in Australia and photographed on 22 February 1959 by Warham (1959, 1961: Serventy et al. 1971). Warham also found an egg which may belong to this bird.

Fregata minor (Gmelin)

Greater Frigate-bird

There are several early references to this species on Raine Island, possibly in error for *F. ariel*. Storr (1973, 8) states that *minor* apparently breeds in Torres Strait, while *ariel* breeds on Rocky Island (Gulf of Carpentaria), Raine Island, and 'Gillett Cay', Swains Reefs, in the southernmost sector of the Great Barrier Reef, April to August. Bennett (1971, 60) figures juvenile birds on the nest at the latter location. Serventy et al. (1971, 155) state that *minor* is not known to breed at Raine Island. It is normally a tree-nesting species, and thus might not be expected there, though small numbers are found on treeless islands in the Phoenix Group, Central Pacific.

F. minor is recorded from Raine Island as *F. aquila* by MacGillivray (1846), quoting Lt J.M.R. Ince. Specimens were said to have been sent to Gould, but they are not mentioned by Gould (1865). *F. minor* is also mentioned during the *Challenger* visit by Tizard et al. (1885), and one male and four females were so identified by Sclater and Salvin (1878, 650) as collected by the *Challenger* on 31 August 1874. These specimens were, however, cited as *F. ariel* by North (1912, 353), and they were also so listed by Ogilvie-Grant (1898, 449). Two of the specimens, in the British Museum (Natural History), have been found and re-examined by C.W. Benson, who confirms them to be *ariel* and not *minor* (see next species).

Warham (1961, 83) in 1959 saw 4-5 birds identified as *F. minor*, all apparently adult females. It was possible that an area of 40 empty nests might belong to this species, since these were on the ground and all the *ariel* nests he saw were on bushes. There is, however, no breeding record of *F. minor* yet for Australia. Lavery and Grimes (1971) cite Raine as a possible breeding site for this species, but its status there remains to be established.

Fregata ariel

Lesser Frigate-bird

Raine Island is one of only two Great Barrier Reef breeding localities for this species (Lavery and Grimes 1971). In July 1843 Jukes (1847, I, 129) found "young of all ages". In May 1844, MacGillivray (1846, 1478), under the name *Atagen ariel*, reported "small colonies of about a dozen individuals. Its nest is formed of small dry twigs, raised about a foot from the ground, or sometimes placed upon a tuft of herbage, a foot in diameter"; he noted one egg.

Ince (in Gould 1848, VII, 72) described it "breeding in colonies at its S.W. corner; the nest being composed of a few small sticks collected from the shrubs and herbaceous plants which alone clothe the island, and placed either on the ground or on the plants a few inches above it. The eggs ... generally one, but occasionally two". Ince found stages from fresh eggs to 2-3 week hatchlings. Stomach contents comprised young turtles, squid and crabs.

In August 1874 the *Challenger* found 30-40 nests with young well advanced (mostly in the air) but no eggs. All the nests were in a small patch near the cleared area, and consisted of compact platforms of twigs and grass 8 inches in diameter raised on bushes above the ground surface (Moseley 1879, 301-302; Sclater and Salvin 1878). The identity of these birds has been discussed under the previous species. Two specimens were re-examined by C.W. Benson at Tring:

No. 80.11.18.119: adult male, no date

No. 80.11.18.442: young bird still partly in down, no date.

Both are *F. ariel*, as listed by Ogilvie-Grant (1898, 449).

In October 1910 Macgillivray (1910, 226; North 1912, 355) found 50 feathered young on the east side of the island near the centre, presumably from eggs laid in May-June. The nests were flat platforms of sticks and grass 4-6 inches above the ground. In July 1911 M'Lennan found 150 nests: "Several colonies of Frigate-birds were seen near the beacon ... They were eight in number, of from three to thirty nests. I counted 150 nests altogether, several of which contained one egg each; two of these were on the point of hatching. The rest of the nests contained one young bird each, in all stages of plumage, from a couple of days old to birds ready to fly" (Macgillivray 1914, 148). In December 1913 nesting was over; fledged young were all over the island and soaring in the air. Macgillivray (1917, 181-182) took and described one male and one female specimen.

Warham in February 1959 estimated the population at 2000, many possibly from elsewhere, and counted about 150 nests. There were no eggs. The young were all able to fly though three or four still spent all day on the nest. 80 per cent of the 500 birds in the air during the day were juveniles. Each bird on the ground was perched on a dwarf shrub of *Abutilon* or *Tribulus*. The frigates were seen harrying Red-footed and Masked Gannets, and also fishing. Warham (1961, 80, 84; Serventy *et al.* 1971, 156) also gives notes on behaviour. Hindwood *et al.* (1963, 39) confirmed the breeding and collected one female in November 1961 (Queensland Museum No. 0.9135).

In November 1973 adult males and females were numerous both perched on the parapet of the Beacon and soaring in the air at the east end of the island. There were two concentrations of juveniles not yet flying: one of about 120 birds on a mound in the central guano flat (Figure 5), and another of about 65 juveniles immediately to the north, on the *Lepturus* tussocks between the cliff and the beach crest. Ogilvie

(1975) estimated the population at 300-500. For notes on diet, see under *Sula leucogaster*.

Sula leucogaster plotus (Forster)

Brown Gannet

There are several large colonies of Brown Gannets on the Great Barrier Reef islands, including those on Ashmore Banks and Pandora Cay near Raine Island, and on Raine Island itself (Lavery and Grimes 1971, Serventy et al. 1971, 172).

In the 1840s, however, numbers were apparently small. Jukes (1847, I, 129) in July 1843 found a few with young, forming a flock nesting separately from the Masked Gannet. In May 1844, under the name *Sula fiber*, MacGillivray noted: "The well-known brown booby breeds upon Raine's Islet, but in small numbers, as I found its nest there only once" (MacGillivray 1846, 1478). Specimens, presumably MacGillivray's, were reported as *Sula fusca* by Gould (1848, VII, 78), and there is a specimen (10/Sul/2/C/6) marked 'Blackwood Collection' in the University Museum of Zoology, Cambridge (C.W. Benson, pers. comm.). Moseley collected a male in August 1874 (Sclater and Salvin 1878, 651) and described "a slight nest of green twigs and grass on the ground" (Moseley 1879, 301), but gives no indication of abundance.

By the time of Macgillivray's first visit on 30 October 1910, however, ninety per cent of the nesting birds consisted of this species. In July 1911 M'Lennan found them all over the island, and Macgillivray described them "in thousands all over the place" (1917, 181). At the time of his October visit there were eggs, naked young, young in down, and young fledged. Most clutches were of two eggs, variable in size and shape. MacGillivray noted that in these cases only one survived, probably because of the initial difference in size of the hatchlings. The nest was simply a depression in the sand, 3-4 inches deep and 8-12 inches in diameter, with a few sticks surrounding it (Macgillivray 1910, 224). In July 1911 there were several nests with one egg, eight with two, but no hatched young, and nesting had clearly only just begun (Macgillivray 1914, 148). In December 1913, nesting was finished, very few eggs were left, and there were young birds everywhere (Macgillivray 1917, 181). Further observations by Macgillivray, with a photograph, are given by North (1912, 351-353).

In February 1959 it was again the most plentiful bird: Warham (1961, 80) estimated a total population of 7,000-9,000. He saw only two sets of eggs; the young were mostly in down, feathered or flying, but still fed by their parents. In addition to birds on the nest there were about 2,000 birds roosting on the beaches in lines facing the sea. Warham notes various aspects of behaviour and draws attention to the difference in call between male (hissing) and female (a deeper call).

In November 1961 Hindwood et al. (1963, 21; Hindwood 1964, 309) estimated there were at least 2,000 pairs. The nests contained well-incubated eggs or very small nestlings, and there were a few large downy

young. Most of the birds were in the central bare area. The differential survival of larger nestlings in a clutch of two was again noted.

The Brown Gannet was the most abundant nesting seabird in November 1973. Most of the birds were on the central flats. The nest was a slight depression, often broken through the surface crust, surrounded by twigs. Breeding was in the stage described by Hindwood in November 1961, except that few nests had young. In a count of 100 nests, 45 contained a single egg and 55 two eggs. Four contained hatchlings. Counts were made of birds on the ground at midday on 3 November in five sample areas of the central guano flats (Figure 5). These areas totalled 2370 sq m, or 5.9 per cent of the area of the flats. 162 birds were present, giving a mean density in the sample areas of 6.8 per 100 m². Extrapolating these figures to the whole of the central flats gives a total number of birds of 2764. This figure does not include adult birds absent while feeding, birds in the air as a result of our own presence, or birds in the high-ridge grasslands surrounding the flats. Details of the counts are given in Table 2. Data given by Nelson (1970) suggest a mean nesting density of 15 birds (7.5 pairs) per 100 m², with some colonies very much more crowded. The largest colony recorded by Nelson is of 8,000-10,000 birds; our figures suggest a total population half this size, and probably rather more than the 2,000 pairs estimated by Hindwood in 1961. Since our visit P. Ogilvie (1975) has estimated the population at 2,000-3,000.

Collections were made of regurgitations produced by adults of the gannets *Sula dactylatra* and *S. leucogaster* and the young of the lesser frigate *Fregata ariel*. The diet of the gannets appeared to be chiefly fish, with the exocoetid *Cypsilurus melanocercus* (Ogilvy) forming the predominant element, but a few small individuals (mantle length less than 10 cm) of the ommastrephid squid *Symplectoteuthis oulaniensis* (Lesson)¹ were noted. Similar small-sized specimens of this squid formed the bulk of diet of the young frigate birds. The importance of both the Exocoetidae and the Ommastrephidae in diets of birds in the Pacific has been discussed by Ashmole and Ashmole (1967).

1. The nomenclature of the forms of the 'species' *Symplectoteuthis oulaniensis* remains to be elucidated. The specimens taken on Raine all lack light organs (yellow patches) on the dorsal surface (see Clarke 1965) and thus correspond to the species A of Ashmole and Ashmole (1967).

Table 2. *Sula leucogaster* and *Sula dactylatra* in sample areas of the central guano flat, midday, 3 November 1973.

Sample area	Area, sq m	<i>Sula leucogaster</i>		<i>Sula dactylatra</i>	
		Number	Density/100 m ²	Number	Density/100 m ²
A	570	40	7.018	16	2.807
B	550	32	5.818	9	1.636
C	460	32	6.957	5	1.087
D	390	28	7.179	8	2.051
E	400	30	7.500	3	0.750
Total	2370	162	6.835	41	1.730

The sample areas cover 5.86% of the 40,440 sq m of the central guano flats. Extrapolation from the mean measured densities gives total numbers of 2764 *Sula leucogaster* and 699 *Sula dactylatra*.

Sula sula rubripes Gould

Red-footed Gannet

Under the heading "*Sula* -----?" MacGillivray (1846, 1478) described "a small species of gannet, which we named provisionally the 'white booby'. Its change of plumage are remarkable and puzzling. Early in June, this species, the young having been for some time able to fly, forsook the island during the day, returning at night to roost in a large body of several hundred". Gould (1848, VII, 79) reported this species as *Sula piscator*, breeding in "great numbers", and quotes MacGillivray's estimate of a population of "several hundreds". He also notes the variable colour. MacGillivray's specimen was later described as *Sula nicolli* by Grant and Mackworth-Praed (1933), distinguished by red feet, ash-brown upper parts, white rump and tail, but Murphy (1936) considered it to be only a colour phase of *Sula sula*, and Warham (1961) agrees. Moseley collected a female in August 1874; and this was reported as *S. piscator* in Sclater and Salvin (1878, 652). Moseley (1879, 301) described "one or two of its nests made in the bushes, like those of the noddies, raised six inches from the ground".

More information comes from the visits by Macgillivray and M'Lennan. In October 1910 Macgillivray (1910, 225) found "nests in groups in different parts of the island. All of the nests are placed on the horizontal shrubby growth, and are a clear foot or more from the ground. The nest consists of a substantial interwoven platform of sticks, about 8 to 12 inches in diameter, depressed to about an inch in the centre for the reception of the single egg". The young were then fully fledged and many roosting. In July 1911 M'Lennan found "great numbers"

building nests, several nests with one egg each, and a few with young (Macgillivray 1914, 148). In December 1913 a few stragglers were still nesting. A few nests had one egg, more had young, but the rest had left the nest. Macgillivray believed that the colour changes were age colour phases (1917, 180-181). Other observations by Macgillivray, with a photograph taken in October 1910, are given by North (1912, 348-349).

Warham (1961, 80) estimated the population as 300 in February 1959. Nesting was then over; he saw one egg and two pairs with downy young, and inferred that the breeding season lasted from June to January. The nests were built 2 ft from the ground on what he termed *Tribulus* bushes. He also found large roosts along the south side of the island, mostly in low shrubby bushes six inches from the ground or in thick grass. Most of the day is spent at sea, and the birds appear during the late afternoon. Warham also describes the colour phases. Hindwood et al. (1963, 38, 41) collected two females (C.S.I.R.O. numbers 299, 300).

In November 1973 there were two areas with Red-footed Gannets. One on the high ridge at the northwest end of the island, with about 50 birds during the day, consisted of nests on low *Abutilon* bushes 1-2 feet above the ground. Many of the nests had young in down. Another area on the high southern ridge comprised about 100 roosting birds during the day (Figure 5). Ogilvie (1975) estimated the population at 150.

According to data given by Lavery and Grimes (1971) and Serventy et al. (1971, 173-5) this small colony on Raine Island is the only breeding station for the Red-footed Gannet on the Great Barrier Reef.

Sula dactylatra personata Gould

Masked Gannet

Jukes (1847, I, 128) found a few with young in July 1843. MacGillivray (1846, 1478) reported it, as *Sula personata*, as "never very numerous" and said it left the island entirely during the day. Gould (1848, VII, 77), however, quoting Lt J.M.R. Ince, referred (again under *S. personata*) to "considerable numbers". Moseley gives no indication of abundance in 1874, but collected two females (*Sula cyanops* in Sclater and Salvin 1878, 652); he described the nest as "a circular hole in the earth, about 1½ inch deep" (Moseley 1879, 301).

In October 1910 Macgillivray found them nesting "promiscuously all over the islet" (Macgillivray 1910, 225), with fresh eggs, hatching eggs and young (Macgillivray 1917, 180). He reported that the nests "differ in no wise" from those of the Brown Gannet, except of course that there are no surrounding twigs. On 10-15 July 1911 M'Lennan found a few nesting sites but no eggs; one egg was laid during his visit (Macgillivray 1914, 148). In December 1913 nesting was almost over and only one nest had eggs (*S. cyanops* in Macgillivray 1917, 180). Further information is given from Macgillivray's 1910 visit by North (1912, 344-345), including a photograph. The nest depressions were

said to be 3-4 inches deep and 8-12 inches in diameter. Two-thirds of the clutches were of two eggs.

Warham (1961, 80-82) estimated the population in February 1959 as 400-500. The birds were found only in the central depression. Many of the nests had eggs or small young, and there were also downy chicks and flying juveniles. He inferred a breeding season from July to March. In contrast to the Brown Gannet, very few Masked Gannets roosted on the beaches. As with the Brown Gannet there is a sexual difference in call, the male whistling and the female more raucous. The nest is simply a depression in the sand, with no twigs. He noted differential survival of the larger bird in clutches of two. During the day many birds were at sea, and the number on the island increased during the night. Hindwood *et al.* (1963, 34) estimated the population at about 1000 pairs in November 1961.

The Masked Gannet was numerous on the central flats in November 1973, though less abundant than the Brown. Counts of birds on the ground were made at midday on 3 November in the five sample areas shown in Figure 5; details are given in Table 2. There were 41 birds in the 2370 sq m sampled, giving a mean density of 1.73 per 100 sq m. Extrapolation at this density gives a total number of 699 birds for the whole of the central flats, or about one quarter the number of Brown Gannets present. This figure excludes birds at sea or temporarily in the air, or in areas other than the central flats. The total is consistent with the estimate of Hindwood *et al.* (1963), also in November, and with Ogilvie's (1975) subsequent estimate of 800-1000 birds. The mean density is close to that reported for Masked Gannet colonies at Kure and the Galapagos Islands by Nelson (1970), and the colony is large in terms of the size ranges Nelson cites. Of 100 nests counted in 1973, 47 contained one egg or young and 53 two eggs or young. 35 per cent of the nests contained young. A marked size disparity was noted in clutches of two. For notes on diet see under *S. leucogaster*.

According to Lavery and Grimes (1971) and Serventy *et al.* (1971, 175-177) Raine Island is the main breeding station of this species on the Great Barrier Reef, with a further large colony at nearby Pandora Cay and another in the far south on Masthead Island. The colony is comparable in size with the colonies on Phoenix, Enderbury and McKean Islands in the Phoenix Group.

Pelecanus conspicillatus Temminck

Australian Pelican

Ellis (1937, 178) saw one bird during 1890-92. The nearest breeding station is on Pelican Island, 255 km to the south (personal observation, 1973); Serventy *et al.* (1971, 183) also record a breeding colony near Thursday Island, Torres Strait, 225 km to the north.

Phaethon rubricauda Boddaert

Red-tailed Tropic-bird

This species is generally absent from the South Pacific, and Raine Island as its only known breeding station in eastern Australia, other than on sand cays in the Coral Sea (Serventy et al. 1971, 160).

MacGillivray (1846, 1477-1478) recorded it as *Phaeton phaenicurus* (cf. Gould 1848, VII, 73). He caught about a dozen beneath the low cliffs; there were no nests, but two were sitting on eggs. Two or more were always hovering over the island. There are two specimens (10/Phae/1/C/9, 18) collected in September 1844 in the University Museum of Zoology, Cambridge (C.W. Benson, pers. comm.). In 1874 Moseley collected a young female - "the only one seen on the island". This was reported as *P. aethereus* (i.e. the Red-billed Tropic-bird, not the Red-tailed) by Sclater and Salvin (1878, 651), and Lord George Campbell also stated that "we saw no red-tailed ones" (Campbell 1876, 162). Ogilvie-Grant (1898, 453), however, lists the Moseley specimen as *P. rubricauda*. C.W. Benson has re-examined the specimen and comments that "this identification seems correct. The bird is fully feathered but not fully grown. It lacks the long tail-feathers of adults, and the bill is also smaller (it measured, from base of skull, 66 mm) and black rather than red in colour".

Macgillivray (1910, 227; 1914, 148) saw none in October 1910. M'Lennan, however, in July 1911, found a total of seven nests, three having one egg and the rest with young. These included three nests on the 9th (one with 1 egg and two with 1 young), two nests on the 10th (one with 1 egg, one with 1 young), and one nest on the 15th (with 1 egg) (Macgillivray 1914, 148-149). Macgillivray (1917, 182-183) found them still nesting in December 1913, all except one with young. In February 1959 Warham again found seven pairs nesting, six with large feathered young, and the other with an egg. Up to twelve birds were seen in the air during the afternoons. Hindwood et al. (1963, 27; Hindwood 1964, 309) found six pairs in November 1961. Two females were collected (Queensland Museum No. 0.9133: C.S.I.R.O. no. 298). Several nests were seen in 1973, either in hollows beneath the cliffs or beneath large beachrock slabs. No eggs were found, but large feathered young were present. Two or three birds were generally in the air over the island. Ogilvie (1975) found 23 nests, some with eggs, and gave the population as more than 25.

Storr (1973) lists only this species as present on Raine Island.

Hydroprogne caspia (Pallas)

Caspian Tern

Recorded by MacGillivray (1846), and listed as a breeding species by Serventy et al. (1971, 209).

Sterna bergii Lichtenstein

Crested Tern

This species was not mentioned by either Jukes or MacGillivray in 1843-44. It may be the species described by Gould (1848, VII, 23) as

Thalasseus pelecanoides, the Torres Straits Tern, on which he quotes MacGillivray's observation of "three small parties upon a low ridge on one side of the island", noting that it bred in June.

Otherwise the first record is that by M'Lennan on 9 July 1911, when he observed a small colony in the centre of the island (Macgillivray 1914, 141). Macgillivray himself found two small colonies in the centre in December 1913. "The birds themselves were very numerous ... they were frequently seen in the early morning carrying off turtles' eggs from the sandy shore when these had been unearthed by the nesting reptiles" (Macgillivray 1917, 84). A few were seen by Warham (1961, 87) in February 1959, but were not breeding; and none were seen by Hindwood *et al.* (1963, 38) in November 1961.

Lavery and Jones (1971) map large colonies of this species on Michaelmas and Upolu Cays, near Cairns, and on the Barnard Islands; Serventy *et al.* (1971, 219) record colonies in the Bunker and Capricorn Groups.

Sterna fuscata nubilosa Sparrman

Sooty Tern

The first record at Raine is that by Jukes in July 1843, when he found young of all ages (Jukes 1847, I, 129). In May 1844 MacGillivray (1846, 1476-77), under the name *Thalassipora fuliginosa*, found it breeding in large colonies, on the ground, and said that many eggs were taken. Gould (1848, VII, 33) refers to it as *Onychoprion panaya*. Moseley in August 1874 found it breeding in grass around the shore; Tizard *et al.* (1885) describe it as "exceedingly abundant" on "flat ground above the shoreline covered with grass". "The stretches of flat ground above the shore were absolutely full of the brown fledged young of this bird. Eggs were already very scarce" (Moseley 1879, 301). Saunders (1878) records *Challenger* material.

Macgillivray (1910) recorded Sooty Terns in October 1910, and in July 1911 M'Lennan found them (reported as *Onychoprion fuliginosa*) "nesting in tens of thousands all over the island" (Macgillivray 1914, 142). In December 1913, Macgillivray (1917, 85) found them coming in from the sea at about 5 p.m. "in immense numbers", circling without landing, then leaving again at dawn, presumably as a preliminary to breeding. Sooty Terns are also recorded for Raine by Alexander (1925).

In February 1959 Warham (1961, 87-88) found "vast numbers" on the dunes, especially in the south. The birds were never seen on the ground in 1959, though their numbers increased at night. Warham stated that this species breeds between April and November, and is present but does not alight between December and March. Hindwood *et al.* (1963, 38) found in present in November 1961. In November 1973 Sooty Terns were abundant on the ground in *Lepturus* grassland on the high ridge, especially towards the west end, during the hours of darkness, but they were absent during the day.

According to Lavery and Grimes (1971) and Serventy *et al.* (1971, 227), Raine Island is the major breeding site of Sooty Terns on the Great Barrier Reef, though there are several other large colonies north of Michaelmas Cay, a distribution very similar to that of the Noddy *Anous stolidus*.

Sterna anaethetus anaethetus Scopoli

Bridled Tern

Reported by Macgillivray (1910) and Macgillivray (1917, 85), who recorded this species (as *Onychoprion anaetheta*) nesting in "great numbers" in crevices and on piles of rock in the centre of the island in December 1913. Warham (1961, 88) found very few in February 1959 and thought they had already left the island. They are said to breed under the cliffs. Lavery and Grimes (1971) state that Raine is the major breeding site for this species on the Great Barrier Reef, but there are many lesser sites along the Reef (Serventy *et al.* 1971, 229).

Anous stolidus pileatus (Scopoli)

Noddy

Jukes (1847, I, 129) found young of all ages in July 1843. In May 1844 MacGillivray (1846, 1476-77) reported "myriads", building nests of small twigs and coral fragments. In August 1874 Moseley (1879, 300) found them breeding in grass around the shore, building "a rude nest of twigs and grasses amongst the low bushes, but often also ... on the ground. There were plenty of eggs of this bird"; specimens were taken (Saunders 1878).

In October 1910 Macgillivray (1910, 226) found "noddies ... in great numbers, but ... not yet commenced to nest". In July 1911 they were "nesting all over Raine Island" (M'Lennan in Macgillivray 1914, 142). In December 1913 they were "in great numbers, lining the seashore of the island or in small colonies all over the island, mostly composed of fully-fledged young and their parents. Many more were continually over the sea ... and towards nightfall many more came in to roost on the island" (Macgillivray 1917, 85).

Warham estimated the population at 2000 in February 1959. Birds were present during the day, congregating on the northern beach during the afternoon, and many coming in from the sea at dusk. There were dense flocks on the central flats during the night. Warham thought they were collecting prior to nesting (Warham 1961, 88). Hindwood *et al.* (1963, 38) found them present in November 1961, and Ogilvie (1975) found some 400 birds.

Lavery and Grimes (1971) and Serventy *et al.* (1971, 232-233) cite Raine Island as a major breeding site for this species, together with several other islands on the northern Great Barrier Reef; this distribution is similar to that of the Sooty Tern.

Anous minutus minutus Boie

White-capped Noddy

This species is recorded as *Anous leucocapillus*, White-capped Tern, by Gould (1848, VII, 36), who quotes Lt Ince's observation that it is "very abundant" at Raine Island; this observation probably refers to the Common Noddy. There is no further record of this species at Raine until Warham's visit in February 1959. He (1961, 88) found two or three, and since this species nests in trees, he did not believe it bred on Raine. Hindwood et al. (1963, 38, 42) collected a male in November 1961 (Western Australian Museum No. A8768).

All the large colonies of this species on the Great Barrier Reef are in the Bunker and Capricorn Islands in the far south (Lavery and Grimes 1971; Serventy et al. 1971, 235-237). Its status on Raine Island remains uncertain.

Larus novaehollandiae forsteri (Mathews)

Silver Gull

This may be the species recorded as *Xema Jamesonii* in 1844 by MacGillivray (1846, 1477), who noted "only a few pairs". Moseley (1879, 300) collected it in August 1874 (Saunders 1878), but said it did not breed. In December 1913 Macgillivray (1917, 86) found it "in fair numbers ... constantly to be seen early in the morning on the sandy strip above high tide mark on the look-out for turtle eggs that had been scooped out by these creatures during the night". In February 1959 Warham (1961, 88) found small numbers and no nests, and noted that there was no breeding record from Raine; he estimated the population to be 25. Hindwood et al. (1963, 38; Hindwood 1964, 310) found "a few birds", and Ogilvie (1975) 3-4. This species is very widely distributed along the Great Barrier Reef (Lavery and Grimes 1971; Serventy et al. 1971, 196), but is unimportant at Raine Island.

Arenaria interpres interpres (Linnaeus)

Turnstone

This species was recorded from Raine Island in 1844 as *Strepsilas australis* by MacGillivray (1846) and as *Strepsilas interpres* by Gould (1848, VI, 39). Moseley (1879, 300) found flocks on the shore in August 1874, but no nests; one male and two females were taken and reported as *S. interpres* by Forbes (1878). Macgillivray (1917, 86) found several small flocks on the shore in December 1913. Warham (1961, 88) found small flocks everywhere except in the vegetated areas in February 1959. It was noted as present by Hindwood et al. (1963, 38) in November 1961.

Pluvialis squatarola (Linnaeus)

Grey Plover

The only record is that of a female collected by Macgillivray on 10 December 1913 and reported as *Squatarola helvetica* (Macgillivray 1917, 86).

Pluvialis dominica fulva (Gmelin)

Eastern Golden Plover

This species was "many times noted in all parts of Raine Island" by Macgillivray (1914, 86) in December 1913. Warham (1961, 88) found 20 present on the beach, dunes and central flat in February 1959. Hindwood et al. (1963, 38) report it not present in November 1961, but in the same paper record a specimen collected there (Hindwood et al. 1963, 42), a male now in the Western Australian Museum (No. A.8754).

Numenius phaeopus variegatus (Scopoli)

Whimbrel

The only record is of a single bird seen by Warham (1961, 89) in February 1959. It was not seen by Hindwood et al. (1963, 38) in November 1961.

Limosa lapponica baueri Naumann

Bar-tailed Godwit

The only record is a sighting by Hindwood et al. (1963, 32) on 11 November 1961.

Calidris canutus (Linnaeus)

Lesser Knot

Amiet (1957, 252) mentions an earlier sighting of this species "in the vicinity of Raine Island". Kikkawa (1976, 319) lists the species for Raine from this record.

Calidris ruficollis (Pallas)

Red-necked Stint

This is probably the species recorded from Raine as *Schoeniclus albescens* by Gould (1848, VI, 31) and as *Actodromas australis* in Gould (1865, II, 257) (for synonymy see Sharpe 1896, 545). Four were seen feeding along the shore by Hindwood et al. (1963) in November 1961, and reported as *Erolia ruficollis*. One male and one female were collected and are in the C.S.I.R.O. collection (Nos. 302, 303).

Calidris acuminatus (Horsfield)

Sharp-tailed Sandpiper

Macgillivray (1917, 87) (under *Pisobia acuminata*) found it "common" in December 1913. It was not present during Warham's visit in February 1959 (Warham 1961, 89).

Egretta alba modesta (Gray)

White Egret

Warham (1961, 89) saw one bird on the south ridge on 13 February 1959.

Egretta sacra (Gmelin)

Reef Heron

This was recorded as "*Erodias*, two species" by J. MacGillivray (1846, 1477) in 1844. Both phases were present: "Some white and blue herons frequented the reef, and probably are permanent residents, judging from some deserted nests and fragments of eggs which I saw". Gould (1848, VI, 60) cites it as *Herodias jugularis* Blue Reef Heron,

and notes that it "breeds among the recesses of the rocks". William Macgillivray (1914, 145) saw one bird in 1911. It was not seen by either Warham (1961, 89) in February 1959, or by Hindwood (1964, 311) in November 1961, or by ourselves in November 1973.

Nycticorax caledonicus hilli Mathews

Nankeen Night Heron

The first record of this distinctive species is M'Lennan's record of "many" on 15 July 1911 (Macgillivray 1914, 146); he found no nests but two young birds came into his camp. Macgillivray found one egg on 9 December 1913. Attenborough recorded one or two juveniles, unable to fly, in July 1957. By contrast Warham (1961, 80, 89) found "well over a thousand" in February 1959, with several hundred clutches of eggs on ridges, under overhangs, and on piles of rocks on the central flat; there were few eggs. Warham considered that this species occupied the niche on Raine that elsewhere was occupied by the Reef Heron. But in November 1961 Hindwood et al. (1963, 33) found only "about 50 birds" and "no signs that they were breeding". In November 1973 there was one large flock of about 150 birds, generally on the beach at the east end of the island. Ogilvie (1975) later found more than 2000 birds.

Merops ornatus Latham

Australian Bee-eater

First recorded as a visitor by Ellis (1937, 178), who saw "quite a number" during 1890-92. Ten were seen in two groups on 11 November 1961 by Hindwood et al. (1963, 7).

Hirundo nigricans nigricans Vieillot

Tree Martin

First recorded by John MacGillivray in 1844. A few birds were seen by Warham (1961, 89) in February 1959 and recorded as *Hylochelidon nigricans*. It is recorded as *Petrochelidon nigricans* (Vieillot) by Kikkawa (1976, 332).

Monarcha melanopsis (Vieillot)

Black-faced Flycatcher

This is cited by Macgillivray (1918) and recorded by Kikkawa (1976, 333).

Myiagra rubecula rubecula (Latham)

Leaden Flycatcher

According to Warham (1961) this is the species cited as *Rhipidura* by John MacGillivray in 1844. One was seen by W. Macgillivray (1918, 198) on 10 December 1913, and two the following day, all in the Beacon.

Aplonis metallica metallica (Temminck)

Shining Starling

One bird was seen on the Beacon by W. Macgillivray on 10 December 1913.

DISTURBANCE BY MAN

When the *Fly* arrived at Raine there was no trace of native occupation (Jukes 1847, I, 130), and there is no reason to suppose that the island had ever been occupied before this time. During the nineteenth century, however, considerable disturbance took place, first during the building of the Beacon in 1844, most severely during the guano digging period before 1892, and to an unknown extent during visits by beche-de-mer fishermen in the 1870s and 1880s. Accessible food resources such as nesting turtles and their eggs, and ground-nesting seabirds and their eggs, must have undergone severe if spasmodic interference at these times. In addition to this direct predation, some of these visitors introduced plants, mainly vegetables which they attempted to cultivate, and on at least one occasion goats were liberated too.

During the *Fly*'s first visit, Jukes dined "upon young boobies and frigate-birds and terns' eggs — the latter were excellent, and the former very good, especially when cooked with a little curry powder" (1847, I, 129-130). In 1844 the island was occupied for four months during the building of the Beacon. Jukes estimated in June that 3000 young birds (Noddies and Sooty Terns) and about 17,000 eggs had been eaten by the shore party. Later, when a small party landed from the *Bramble* in April-May 1845, Sweatman (MS, 93) records that 36 dozen eggs a day were consumed by three men: "add to this turtle soup, eels, mutton birds (which Clark cooked magnificently) fish, spinach and damper ...". As is still the practice in egg collecting, Sweatman states that "Our first act on landing was, of course, to break every egg on the island so that all we collected afterwards were sure to be fresh, and so abundantly did the birds lay that besides supplying our own wants at the rate above stated we lined in three large casks for the use of the ship". Gardens were also established in the centre of the island by the *Fly* party, and coconuts, pumpkins, maize and other plants introduced and cultivated (Jukes 1847, II, 267).

In January 1845 (Sweatman's manuscript says February), during the *Heroine*'s visit, Mackenzie (1845, 494) planted "cocoa-nut and various other seeds, hoping they might be a benefit to some unfortunates hereafter"; four months later the coconuts were reported "growing very fast" (Anon. 1846, 549). Sweatman (MS, 91) then described them as four feet tall but choked with weeds which had already obliterated the paths and gardens. The *Bramble* party cleared the weeds from round the young trees, built fences around them, and planted four more brought from the Murray Islands (Sweatman MS, 96), but in spite of this these introductions did not long survive. When the *Challenger* called in 1874, Moseley (1879, 300) planted pumpkins, tomatoes, water melons, Cape Gooseberries, and *Capsicum*, but no later visitor mentions any of these surviving either.

Goats were introduced at an early stage, according to Lack (1953, 41) by the *Fly*, though there seems to be no contemporary evidence that this was so. In January 1845, however, the *Heroine* "left a male and female goat, with two bags of rice" (Mackenzie 1845, 494). Sweatman

(MS, 92) in April found them "frisking about the island in good condition but very wild and shy", and by August there were three young (Anon. 1846, 549). There is a mention of "numbers" of goats being present at the time of the wreck of the *Enchantress* in July 1850, but otherwise no later record. The goats were doubtless eaten during the beche-de-mer and guano digging periods, if they had not died out before, and they were themselves probably responsible for the disappearance of the *Fly*'s vegetable gardens.

Early visitors continued to obtain food supplies from the seabirds and turtles. The *Heroine* in 1845 "obtained fourteen large turtles ... also an immense number of eggs, and the crew killed birds out of number" (Mackenzie 1845, 494). The *Bramble* party also took fourteen turtle by turning them on the beaches (Sweatman MS, 94-95). Buchanan (1874, 127-128) records that the *Challenger* only left "after a sufficient number of birds had been killed". Similar incidents, though not recorded in the nautical or scientific literature, must have been numerous throughout the nineteenth century.

Construction of the Beacon

A series of shipwrecks on the Great Barrier Reef near Great Detached Reef (including those of the *Charles Eaton* in 1834, the *Ferguson* in 1840, and the *Martha Ridgway* in 1841) led to a proposal by Capt Blackwood¹ that a Beacon be erected on Raine Island to guide ships using the Outer Passage route through the Barrier Reef. The Beacon was originally to be triangular in plan and 60 ft high, but as announced by Blackwood (1844b) it was proposed to build a tower 50 ft high, 25 ft in diameter at the base, and 16 ft in diameter at the top, and to make it more conspicuous by painting it with black and white bands each one third the height of the building.

Blackwood fitted out for this expedition in Sydney, obtaining "twenty picked convicts, chiefly masons and quarry men", and taking on stores and prefabricated wooden huts. The captain had to spend £180.14.5d on mason's tools since both the Government and the Engineers Department refused to supply them. The *Fly*, with the *Bramble* and the *Prince George*, sailed on 27 March 1844, and commenced landing on Raine on 27 May. Jukes wrote to his sister Amelia on 26 May: "Our lumber consists of twenty convicts, and an immense quantity of plank timber, houses, barrows, jumpers, pickaxes, spades, and all manner of building, digging, and blasting materials. All these will have to be carried in boats through a heavy sea six miles, as the ship cannot anchor nearer

1. This account is based on the Captain's letters from H.M.S. *Fly*, Blackwood's *Remark Books*, and the engineering drawings, ink sketches and watercolour drawings in *Sketches and views*, vol. 6B, in the archives of the Hydrographic Department, Royal Navy, as well as on published accounts. We are grateful to the Hydrographer, Admiral D.W. Haslam, for access to the records.

Raine's Islet than that. I expect this will take us two or three weeks, as twenty of our crew are to be landed, and provisions and water for forty men for three months are no trifling matter. The bread alone will be 2500 lbs" (Jukes 1871, 224). On 29 May he wrote again, after his first landing, to report that he had "got on board just now wet through, and so tired I can hardly keep my eyes open. ... We have terribly hard, heavy, disagreeable work landing things on this little desolate islet, but hope finally to accomplish our object in building a beacon pretty well" (Jukes 1871, 225).

The huts and tents were erected, and a quarry was opened at the east end of the island. Jukes reported to his aunt on 21 June that "Good building stone is procured in abundance, wooden houses and tents are erected, lime is made, the foundation stone laid, and the first course of masonry nearly complete. Lieutenant Ince, with a party of forty men, occupies the island and superintends the work" (Jukes 1871, 226). Lime was made on the island by burning *Tridacna* and *Hippopus* shells. Water, however, had to be brought from Sir Charles Hardy's Islands, and timbers were obtained from the wreck of the *Martha Ridgway* 40 km to the south. After his first period of investigations on Raine, Jukes found the routine tedious: he told Amelia that "This period of inaction is becoming most oppressive to me. I would welcome any danger or any hardship even that would break the monotony. I am accordingly as dull, heavy, stupid, and spiritless as it is possible" (Jukes, 1871, 231).

But the shore party under Ince had the Beacon finished by mid-September. It had been designed by the *Fly*'s carpenter, Stephen Moore, — 'without any exception the best Ship's Carpenter I ever met', Blackwood called him — and was described by Jukes as a circular tower of stone, 40 ft high, 30 ft in diameter at the base, and with walls 5 ft thick, "divided into three stories, each of which was partially floored, and made accessible by a ladder. It was roofed at the top by a dome-shaped frame of wood, covered by painted canvas. Its summit was thus raised 70 feet above low water mark. A large tank taken from the *Martha Ridgway* was placed at the side, into which a series of spouts were led from the roof, so that it would shortly be filled with rainwater" (Jukes 1847, I, 267). The drawings for the Beacon, in the Royal Navy's Hydrographic Department archives (Figure 10), indicate that the foundation stone was 11 ft above low water mark, the height to the top of the stone balustrade was 45 ft and to the top of the canopy 63 ft 2 inches, giving an elevation overall from low water mark of 74 ft 2 inches. It was painted in black and white vertical stripes and was visible from thirteen miles. Blackwood formally reported on the work by letter to the Admiralty from Surabaya on 26 October 1844.

Four months after it was completed, the Beacon was inspected by the *Heroine*: "At daylight we went on shore to examine the beacon, when we likewise found two wooden built houses and an oven. The beacon is sixty feet in diameter, and about fifty feet high, and its walls at the base three feet in thickness, painted red on the south-east side, and the rest black, with a white cupola and black ball,

having a spout which runs off it into a deep tank, which we found full of water. Altogether it is a substantial building, and well contrived throughout" (Mackenzie 1845, 494). Later the same year the same ship "sent a boat ashore to leave a letter in the Post-Office" (since Raine at this time, as Sweatman (MS, 96) also tells, performed the same kind of function as the better known Booby Island in Torres Straits at a later date), and found that "the tank was full of water, and the beacon seemed to stand the weather very well" (Anon. 1846, 549). The Beacon itself was visible from 8-9 miles from the deck of a ship and from 12-13 miles from the masthead (Horsburgh 1855, 883-884; Horsburgh 1852, I, 798-800; Findlay 1884, 971).

When examined by Capt Denham in 1860 the dome had fallen, reducing the height to 40 ft (Findlay 1884, 971), and the beams and floors had gone and the iron tank disintegrated by the time of the *Challenger's* visit in 1874 (Tizard et al. 1885; Swire 1938, II, 47-50). The ship's plumber was sent ashore to cut the Captain's name and that of the ship in the stone inside the tower (Swire 1938, II, 50), the whole surface now being covered by overlapping inscriptions by casual visitors.

In 1959 Warham found that part of the base of the tower was starting to collapse (Warham 1963, 5, photograph), but this damage was repaired with bags of cement by H.M.A.S. *Gascoyne* in 1961. The Beacon is of some historical importance, since it is the oldest stone structure built by Europeans in North Queensland.

Wreck of the Enchantress

Lack (1953, 41) writes: "Five years later [after the Beacon was built], Captain Anson of the brig *Enchantress*, Sydney to Sourabaya, managed to put his ship ashore on the northern side of the Raine Entrance despite the warning of the tower. A young passenger named Buchan wrote a racy account of the incident to his relatives in England. He related how they landed on the island, found numbers of the much enduring goats, and quantities of sea birds' eggs on which they feasted sumptuously". The crew rapidly became drunk and were taken off by a second vessel, the *Lady Margaret*, only with difficulty.

Efforts to obtain details of this wreck and to trace the narrative account mentioned by Lack have not been altogether successful. We are indebted to Mr. H.E. Maude who has shown that the captain's name was I'Anson, not Anson, and the passenger was Mr. B. Buchanan, not Buchan. Maude notes that the *Shipping Gazette and Sydney General Trade List*, vol. 7, no. 330 (13 July 1850), p. 186, records the departure of the *Enchantress* in ballast from Sydney. The same journal, vol. 7, no. 351, p. 322, reports its loss on the Raine reef on 24 July 1850, and prints a letter from Buchanan giving the details to the owners of the ship. The wreck occurred in the afternoon, and the ship's company escaped and took shelter in the Beacon. The *Enchantress* was travelling with the *Lady Margaret*, and everyone was taken off in small boats and transferred to this ship by dusk on the following day. The details given in Lack's published account do not derive from this letter by Buchanan, and all efforts to trace the "racy account" Lack refers to

have failed. The main interest of it lies in the references to goats and to predation of seabird eggs which it evidently contains. There is also an account of the wreck in the *Sydney Morning Herald* for 3 and 4 December 1850.

Beche-de-mer Fishery

During the 1880s Cooktown was the centre of the Queensland beche-de-mer fishery, when holothurians were collected from shallow reef flats, dried, and exported to China (Ward 1972). This trade had been carried out at Raine Island at least since the early 1870s. Ellis (1937, 71-72) recounts that about 1873 the fishery there was carried out by two white and two or three natives (Chinese, kanakas and aboriginals). The beche-de-mer were boiled, sun-dried and smoked on the island, though in the absence of fuel this can hardly have been on a very large scale. According to Ellis the aboriginals on one occasion murdered one of the whites, one Chinese and two kanakas, before fleeing from Raine; the bodies were buried by the surviving white man near the centre of the island.

Phosphate mining

When phosphate was first discovered in commercial quantities on Raine Island is not known. It was first mentioned when Raine, with other islands, was included in a lease taken out in Hobart in 1862, for seven years, for the purpose of guano digging (Crowther 1939). There is no evidence that any digging under this lease took place at Raine, although the Arundel papers contain an undated newspaper cutting stating that "The *Griffin*, under the command of German Harry, cleared yesterday for Rain Island under charter to a Southern speculator, who holds the right to take guano from that locality". Most of the guano digging activity at that time was in the more accessible Bunker and Capricorn Islands.

The J.T. Arundel Company, which had been digging on the central equatorial Pacific islands during the 1880s, transferred its operations from Baker to Raine in 1890. John Arundel records in his diary that before starting work he consulted the master of the *Jennie Scott*, One-eyed Robinson, who had worked on Raine in 1879 (though on what is not known), about sources of water there and on neighbouring islands. One-eyed Robinson told Arundel of the murder of twelve men by natives on the island during the beche-de-mer fishery. Arundel went to Raine with the *Griffin* and the *Maile* in August 1890 to organise the digging. His diaries show that he was on the island from 20 August to 6 September 1890 and again from 13 February to 15 February 1891. The digging operations were conducted by Albert Ellis, who also arrived in 1890 (though Saville-Kent (1893) suggests that extraction began as early as 1882). There was a staff of 9-10 Europeans, and one hundred Asian (mainly Chinese) labourers; Arundel, a religious man, shipped Chinese Bibles to the island for their use.

A tramway was built from the workings to a new jetty, and a "locomotive" imported. A storage shed was built to house the guano between shipments. Export was by sailing ships of 1000-1500 tons, direct to Europe, with the exception of two which went direct to Melbourne. The guano was packed in 60 lb sacks for ease of handling. Water supply for so large a labour force was a major problem, and a water condenser was built for this purpose. In 1892 the digging ended and the equipment was dismantled and removed (Ellis 1937, 62-73, 98). It is estimated that "tens of thousands of tons" of guano were exported during this brief period (Hutchinson 1950, 256).

Sir Albert Ellis's mother died on Raine Island during this period, and is buried in a substantial grave with a marble stone adjacent to the Beacon. The inscription on the stone ends with a homily which seems especially appropriate in so remote a location:

In loving memory
of
Annie Eliza
wife of
George C. Ellis
entered into rest
June 29th. 1891
aged 52 years
Her last words were
Father! not my will
But thine be done.
My - God - of - Love

Reader!

Be ye also ready

ACKNOWLEDGEMENTS

This report results from a visit to Raine Island made during Phase III of the Royal Society and Universities of Queensland Expedition to the Great Barrier Reef in 1973. We thank the sponsors of the expedition, and especially James Cook University of North Queensland, which made its research vessel *James Kirby* available for this visit.

We are particularly grateful to C.W. Benson, Department of Zoology, Cambridge University, for advice and comments on the birds of Raine Island and for re-examining Raine Island specimens in the British Museum (Natural History) and in the University Museum of Zoology, Cambridge; and to C.J.O. Harrison, S.A. Parker, and H.J. Lavery for other comments on birds. We are grateful to Dr J. Kikkawa for making available unpublished material on his surveys of birds on the Great Barrier Reef, and for sending data collected by P. Ogilvie (1975), which Mr. Ogilvie has allowed to be included. Dr M.R. Clarke and Dr A. Wheeler determined squid and fish respectively from seabird regurgitate. For determinations of Crustacea we thank Dr R.W. Ingle, British Museum (Natural History). Mr E.I. Butler, Marine Biological Association, Plymouth, kindly carried out phosphate analyses of soil samples.

Professor H.E. Maude of Canberra helped greatly with the enquiry about the *Enchantress*, and Dr Harold Fox pursued various lines of enquiry in Cambridge and London. Dr J. Allen of Canberra kindly made available the relevant portion of Sweatman's journal, through Dr Roger McLean, and has allowed quotations to appear here. Mr R.A. Langdon of the Pacific Manuscripts Bureau, Canberra, made available copies of the Raine Island sections of J.T. Arundel's journals. Admiral Haslam allowed access to papers of the *Fly* survey in Hydrographic Department archives. Dr S. Everist, Director, The Queensland Herbarium, Brisbane, arranged for Miss S. Reynolds to identify the plants collected in 1973, and this material was also examined by Dr F.R. Fosberg. Dr T.P. Scoffin, Grant Institute of Geology, Edinburgh University, examined rock samples.

Mr M. Young and Mr R. Coe of the Department of Geography, Cambridge University, prepared the maps and the photographs respectively.

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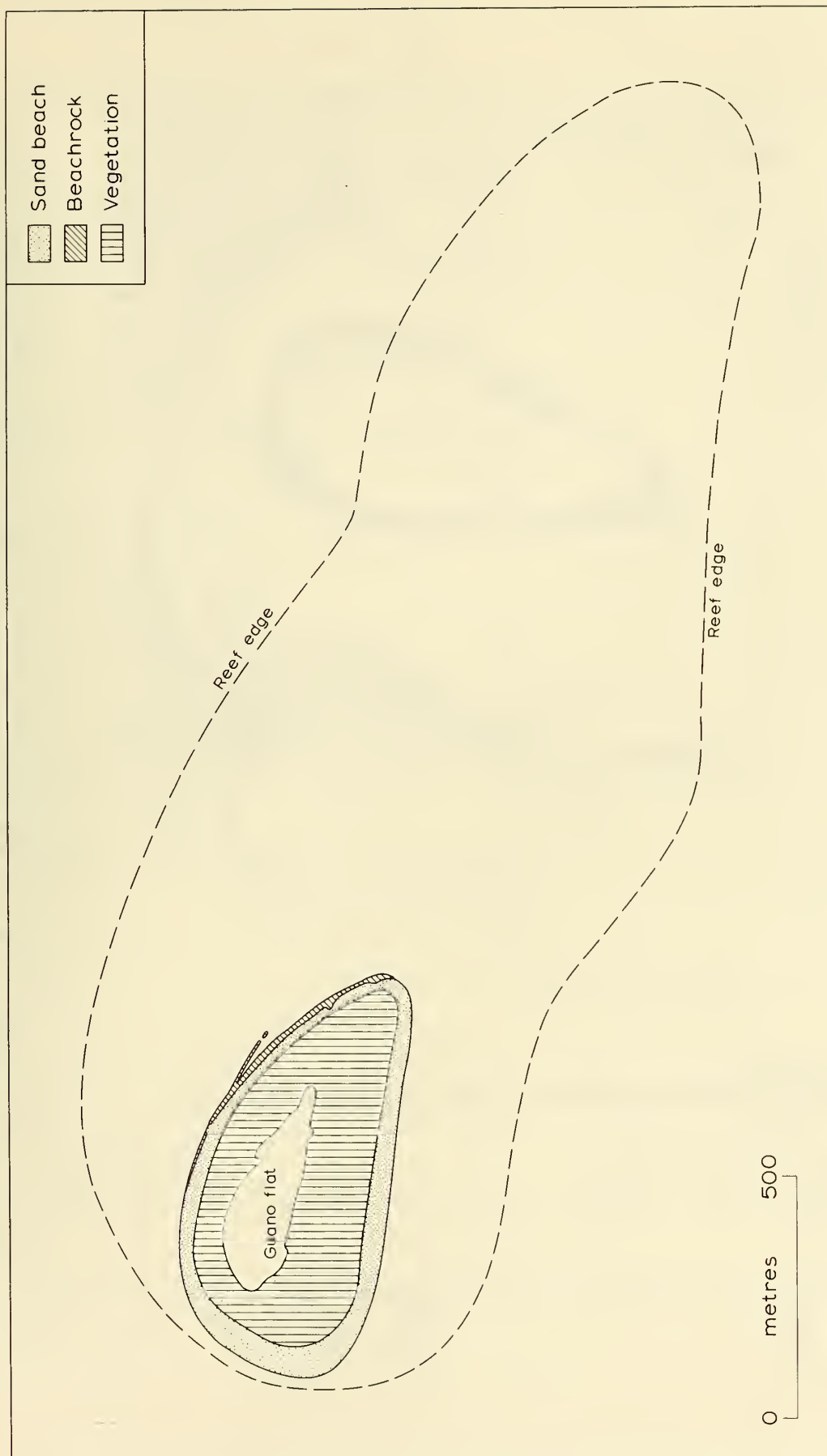


Fig. 2. Raine Island and its reef.

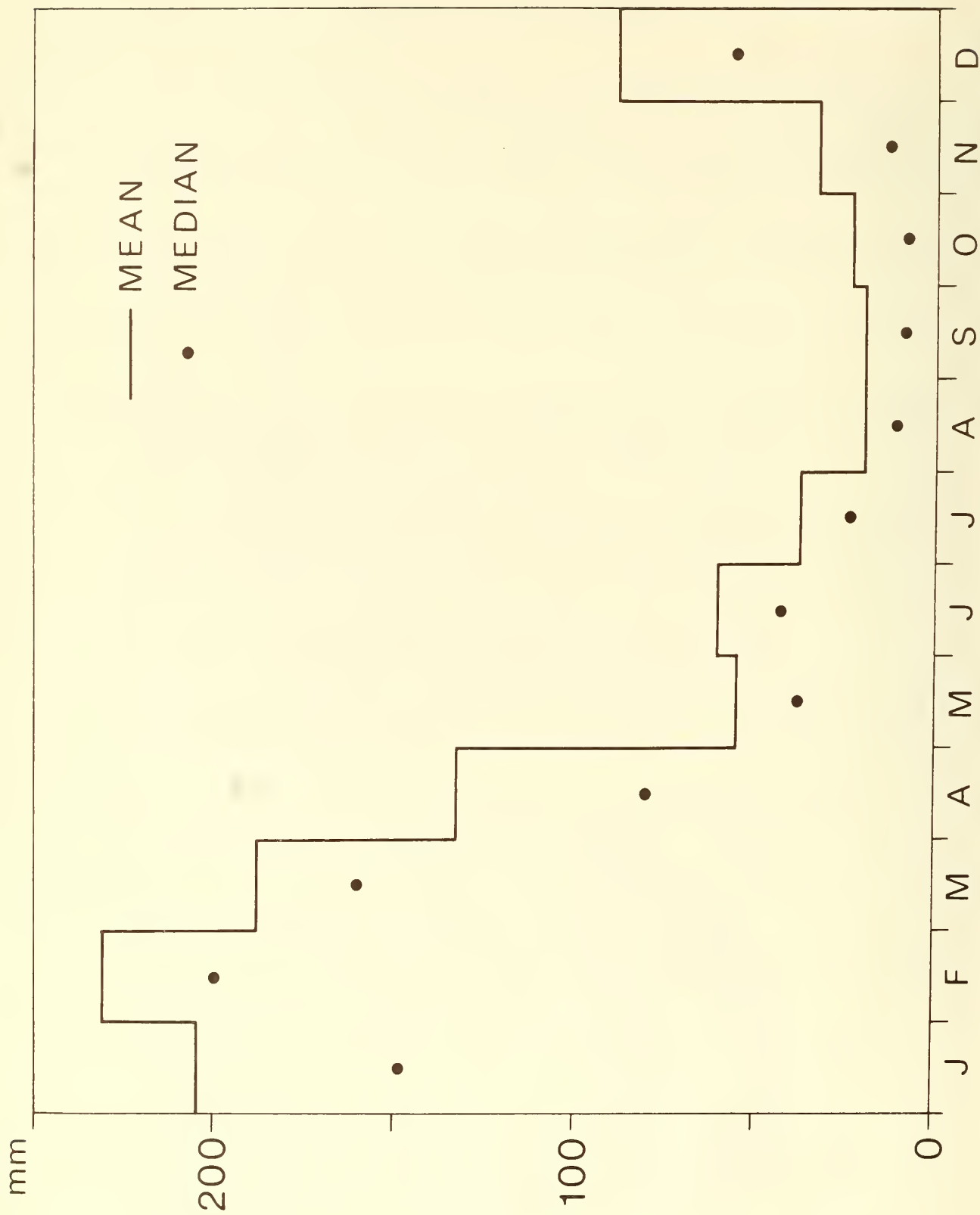
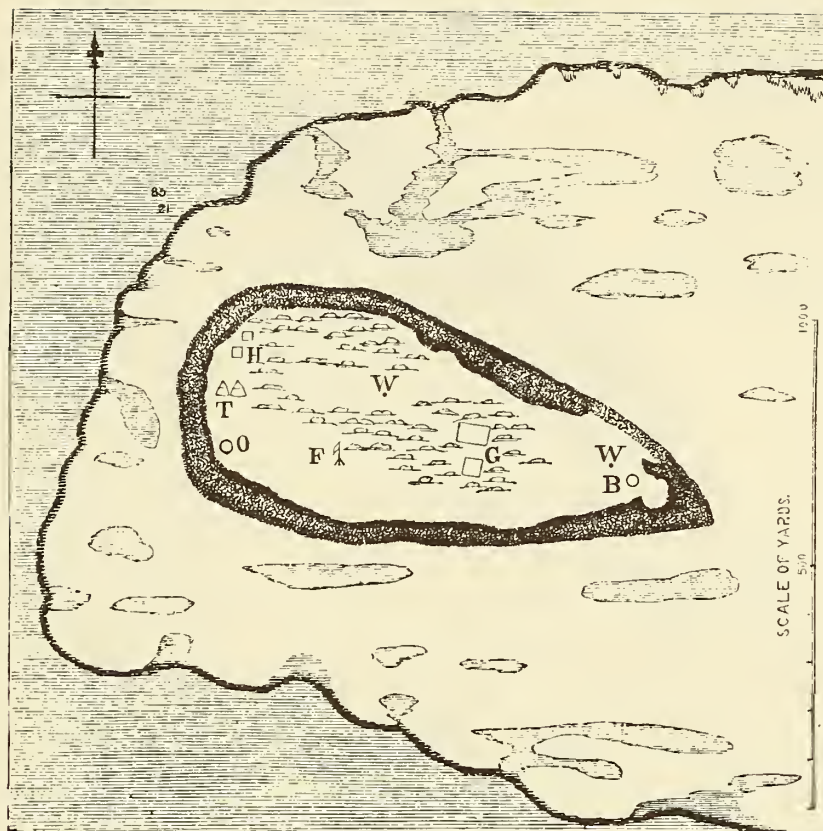


Fig. 3. Monthly distribution of rainfall at Willis Island, 1921-1971 (data from Taylor 1973).



B. The beacon. *G.* The gardens. *W.* The wells. *F.* The flagstaff.
H. The huts. *T.* The tents. *O.* The observatory.

Fig. 4. Raine Island in 1844, from Jukes (1847), vol. I, p. 338.



a. Vegetable soil. *b.* Little cliff at edge of stone.
c. Loose coral sand. *d.* Edge of reef.
e. These two lines represent high and low water level, the rise and fall being about 10 feet.

Fig. 5. Profile of Raine Island, from Jukes (1847), vol. I, p. 339.

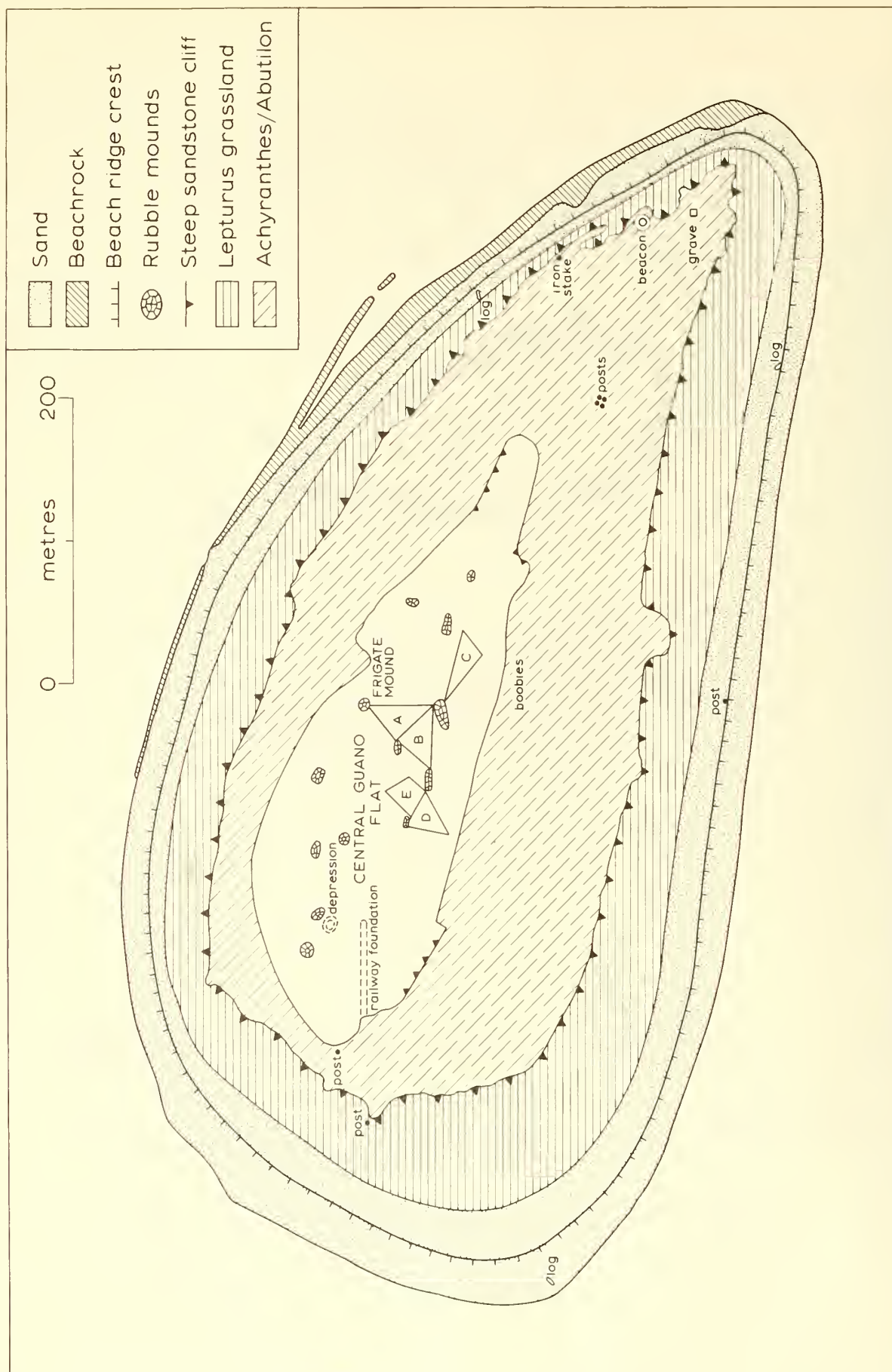


Fig. 6. Map of Raine Island. The areas in the central guano flat are the seabird survey areas detailed in Table 2.

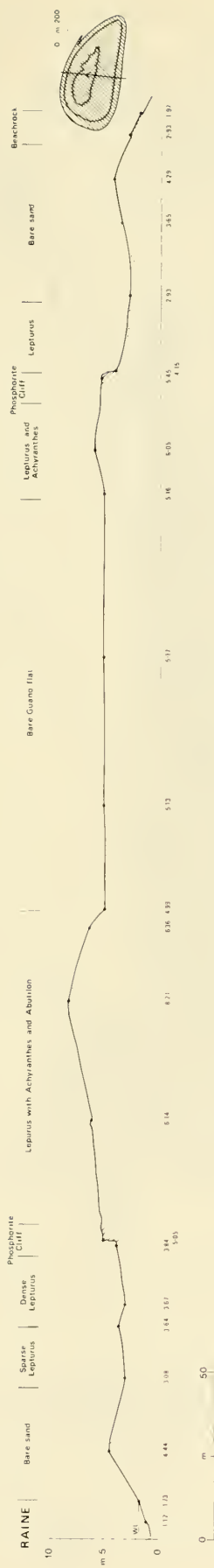


Fig. 7. Topographic profile of Raine Island.

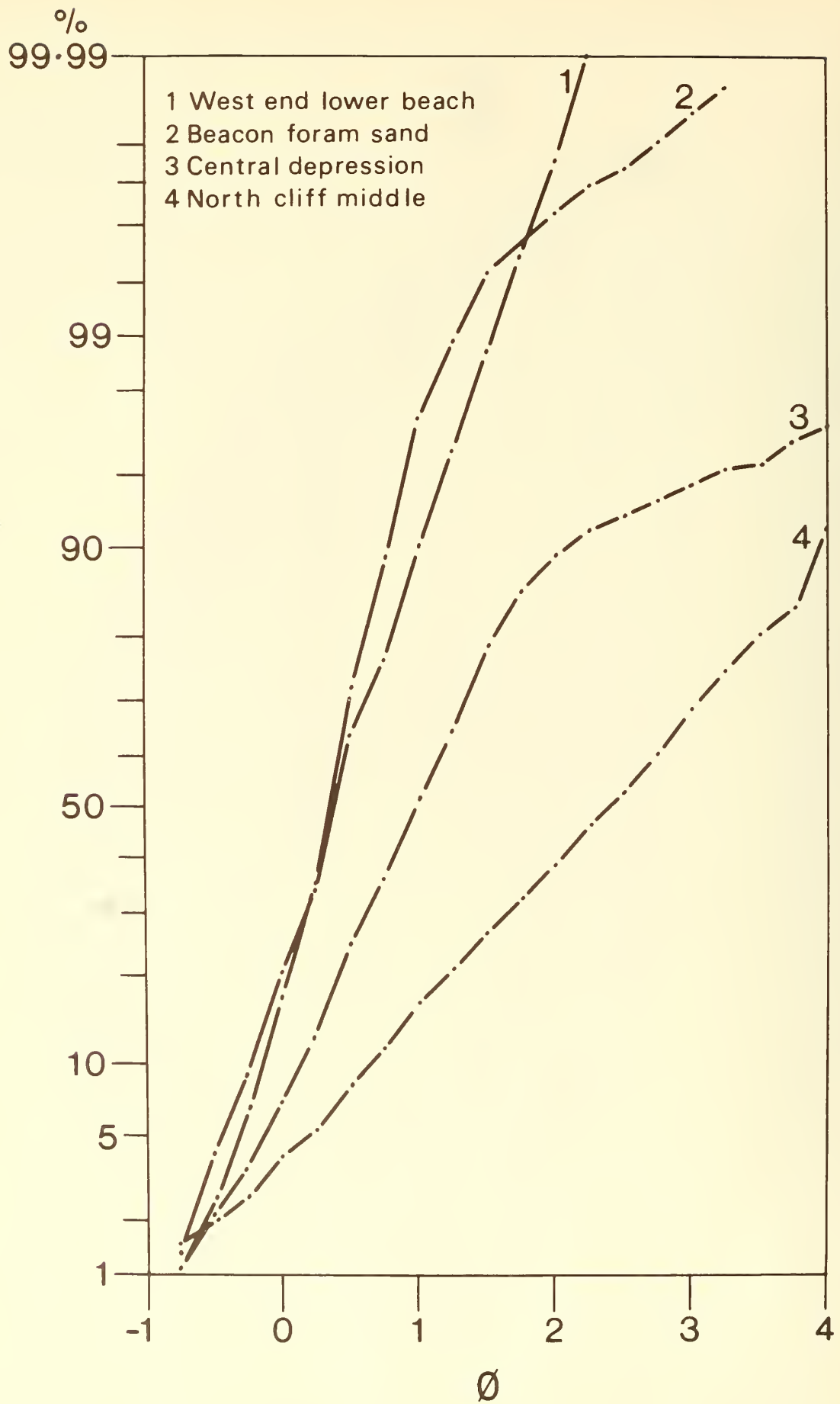


Fig. 8. Sediment samples from Raine Island.

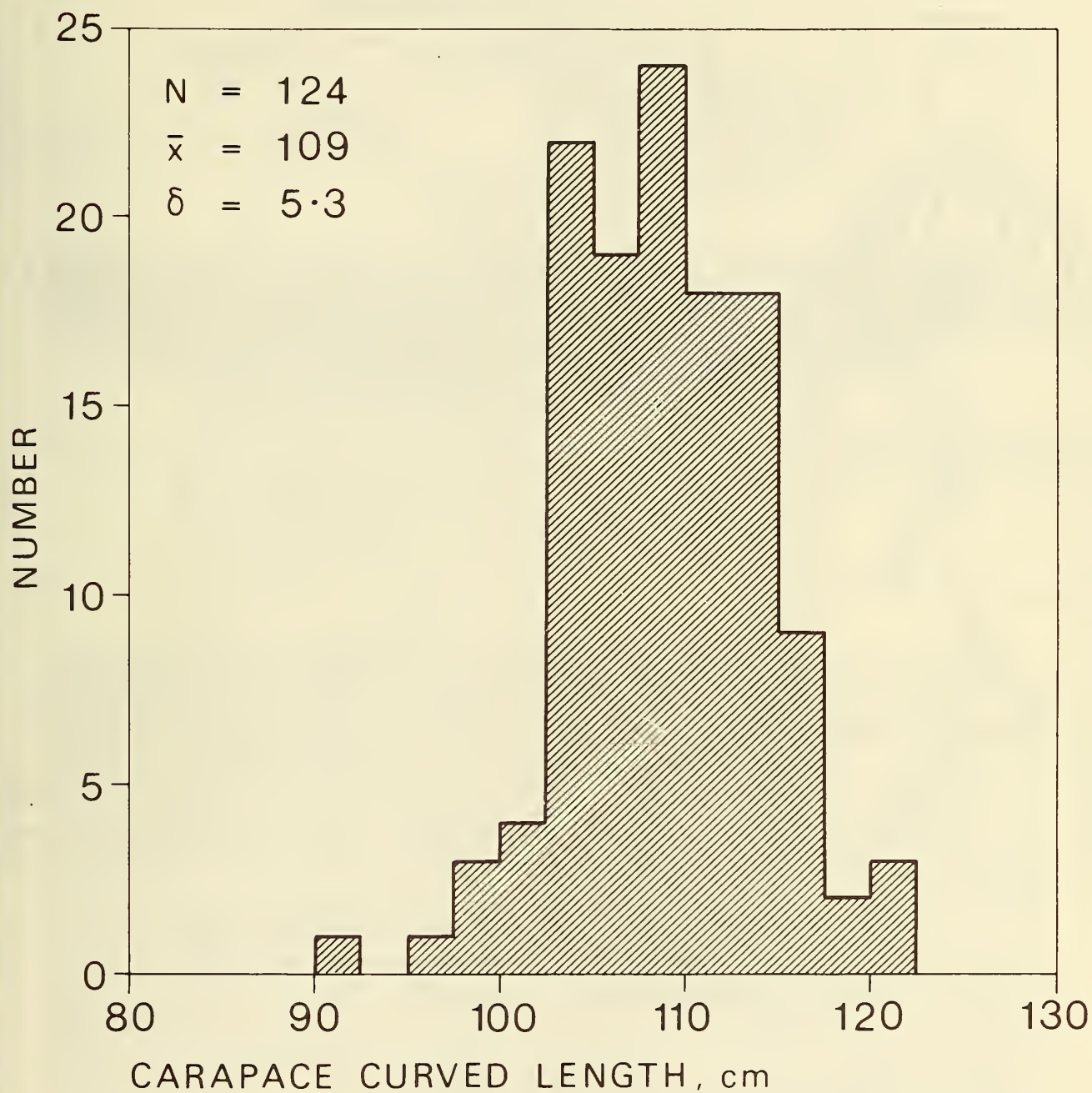


Fig. 9. Histogram of curved carapace length of turtles measured on the nest, night of 3 November 1973.

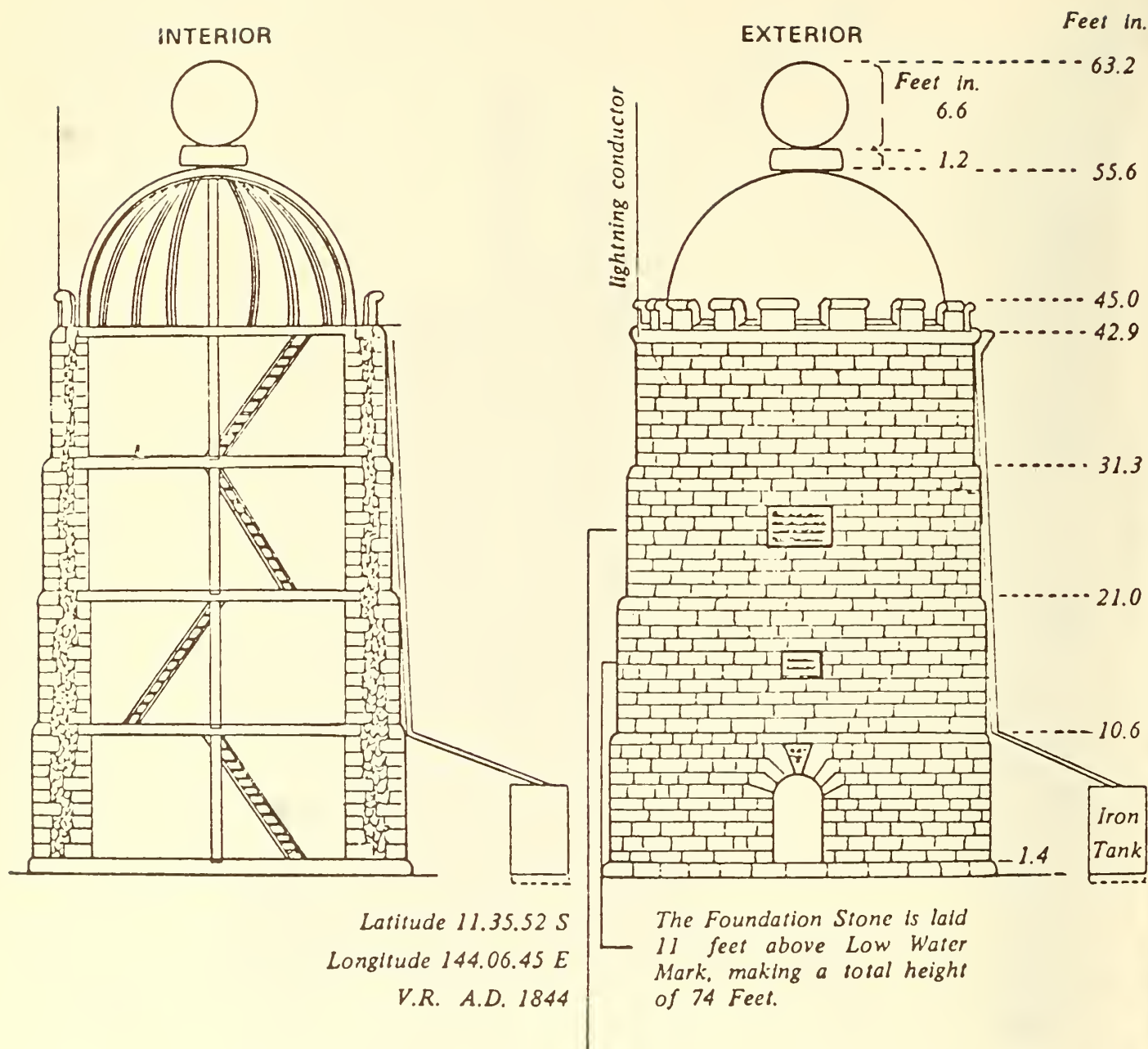
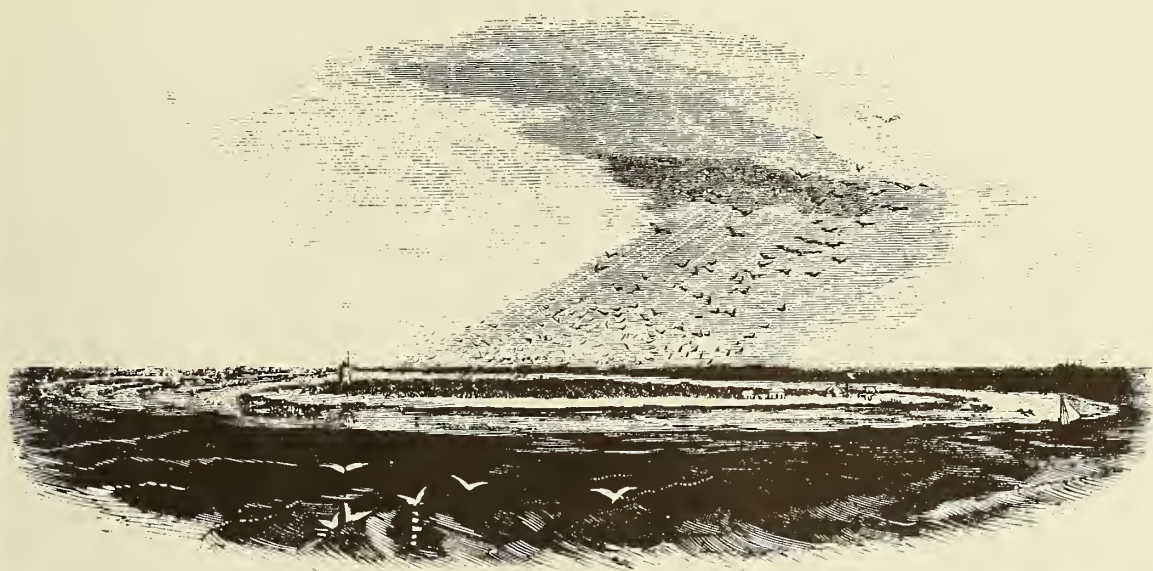


Fig. 10. Section and elevation of the Raine Island Beacon, 1844, after Bateson (1972), p. 201.



RAINE'S ISLET.

Pl. 1. Raine Island in 1844, from Jukes (1847).



Pl. 2. The central guano flat from the east end of the island, looking towards the Beacon. The ridge in the foreground is the site of the old guano railway.



Pl. 3. Eastern end of the central guano flat, with Brown and Masked Gannets.



Pl. 4. Mounds of rubble and stones in the central guano flat.



Pl. 5. Massive beachrock on the northeast shore.



Pl. 6. Grooved and furrowed beachrock on the northeast shore.



Pl. 7. Beachrock now distant from the beach on the north shore.



Pl. 8. Phosphatic beachrock uncomformably overlying old eroded beachrock at the east end of the island.



Pl. 9. Cliffs in phosphate rock at the southeast end of the island.



Pl. 10. Irregular lower surface of the phosphate rock, forming caves, on the south side of the island. Note the nesting Tropicbird beneath the overhang.



Pl. 11. Detail of the columnar structure of the phosphate rock.



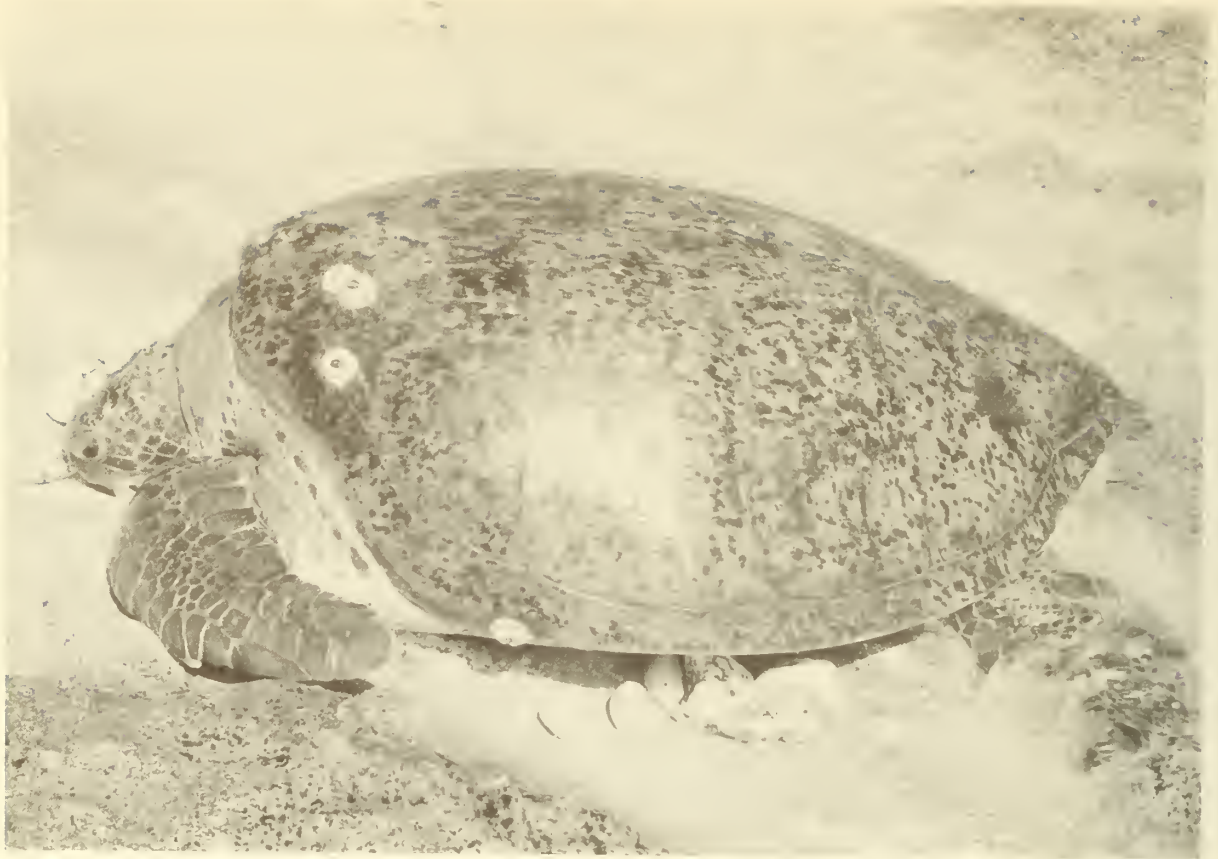
Pl. 12. Detached remnants of phosphate rock, south side of the island.



Pl. 13. Western sand beach, showing early morning turtle tracks.



Pl. 14. Turtle nests on the beach crest at the west end of the island



Pl. 15. Green Turtle on the northeast beachrock.



Pl. 16. Turtle remains in *Lepturus* grassland of the high ridge.



Pl. 17. Shearwater burrows in fine guano at the west end of the central guano flat.



Pl. 18. Mound in the central guano flat with juvenile Lesser Frigatebirds.



Pl. 19-20. Juvenile Lesser Frigate-birds.





Pl. 21. Juvenile Lesser Frigate-birds.



Pl. 22. Brown Gannets lining the beachrock at the east end of the island.



Pl. 23. Brown Gannets on beachrock on the northeast shore.



Pl. 24. Brown Gannets on the nest in the central guano area.
Note the twigs outling the nest.



Pl. 25. Brown Gannets nesting in the *Lepturus* grassland of the high ridge. No twigs surround the nest in the vegetated areas.



Pl. 26. Masked Gannets on the nest in the central guano area. The nest is simply a depression in the sand.



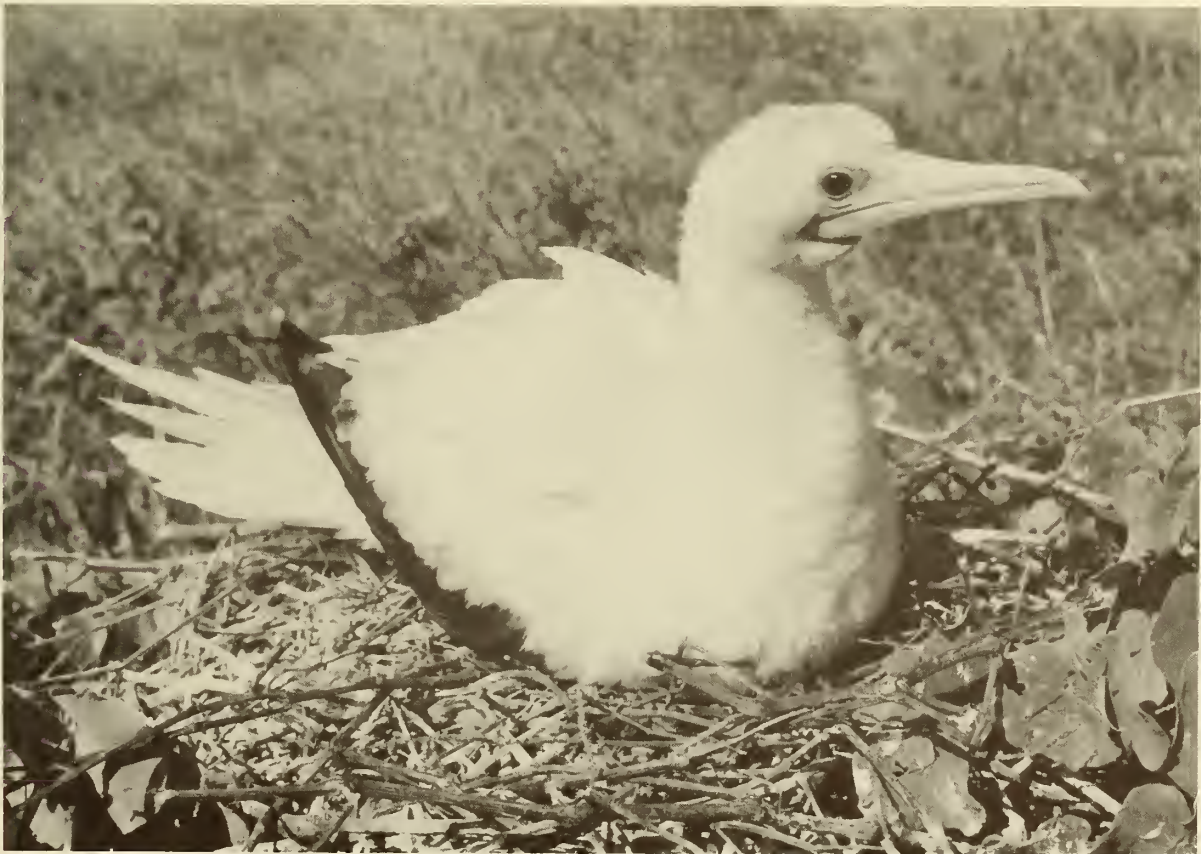
Pl. 27. Masked Gannets on the nest in the central guano area. The nest is simply a depression in the sand.



Pl. 28. Hatchling Masked Gannet in the central guano area.



Pl. 29. Hatchling Masked Gannet with regurgitated flying fish
Cypsilurus melanocercus in a nest in the central guano area.



Pl. 30. Red-footed Gannets on nests built on low *Abutilon* shrubs on
the high ridge at the west end of the island.



Pl. 31. Red-footed Gannets on nests built on low *Abutilon* shrubs on the high ridge at the west end of the island.



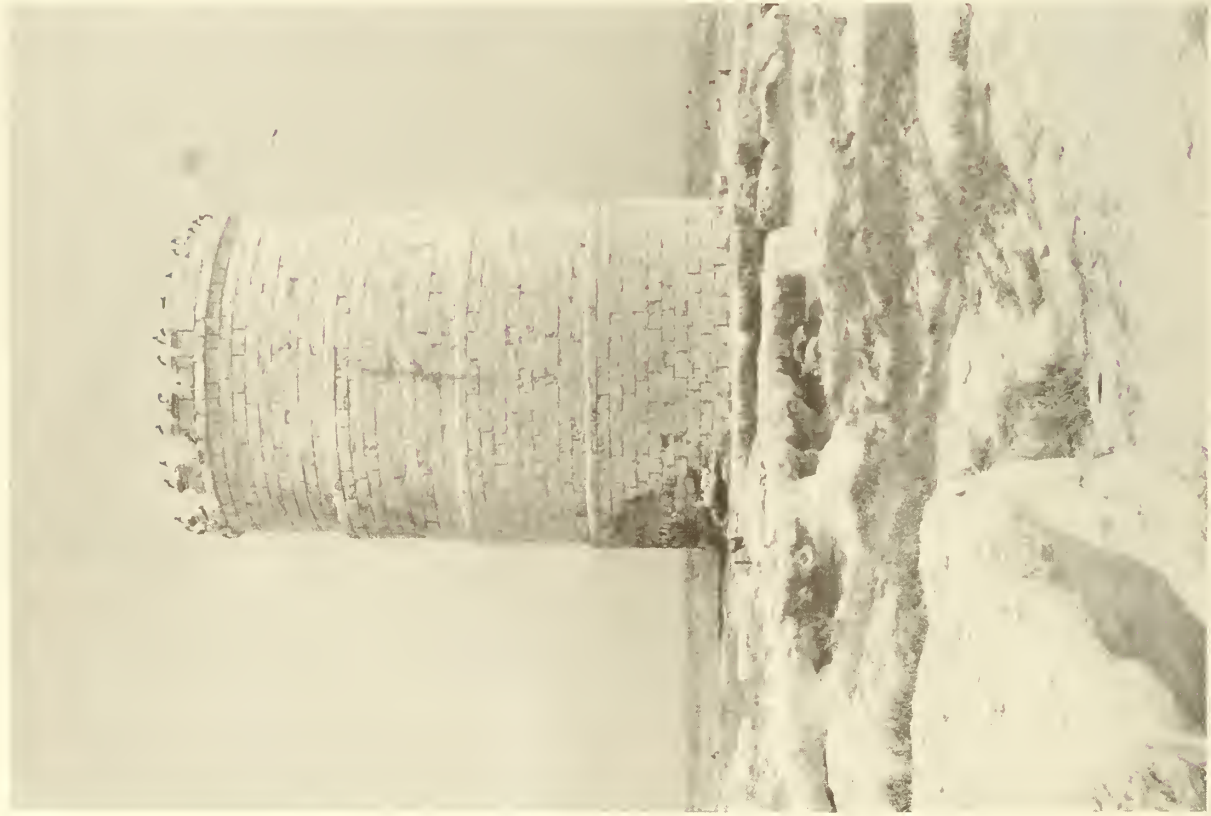
Pl. 32. Fledgling Red-footed Gannet on the nest at the west end of the island.



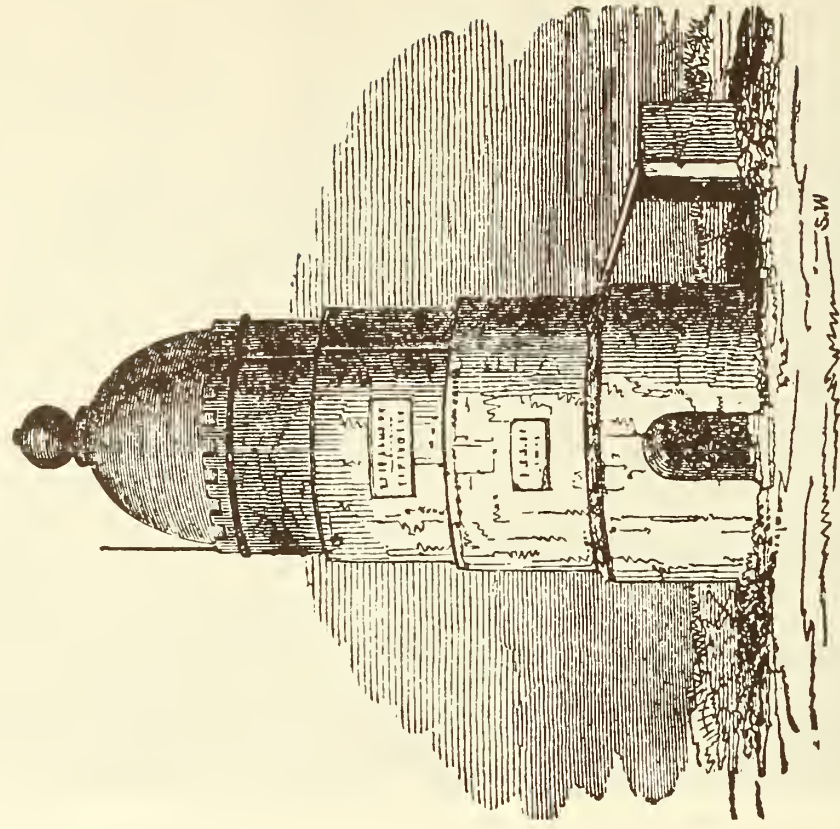
Pl. 33. Juvenile Red-tailed Tropic-bird under the phosphate cliffs at the east end of the island.



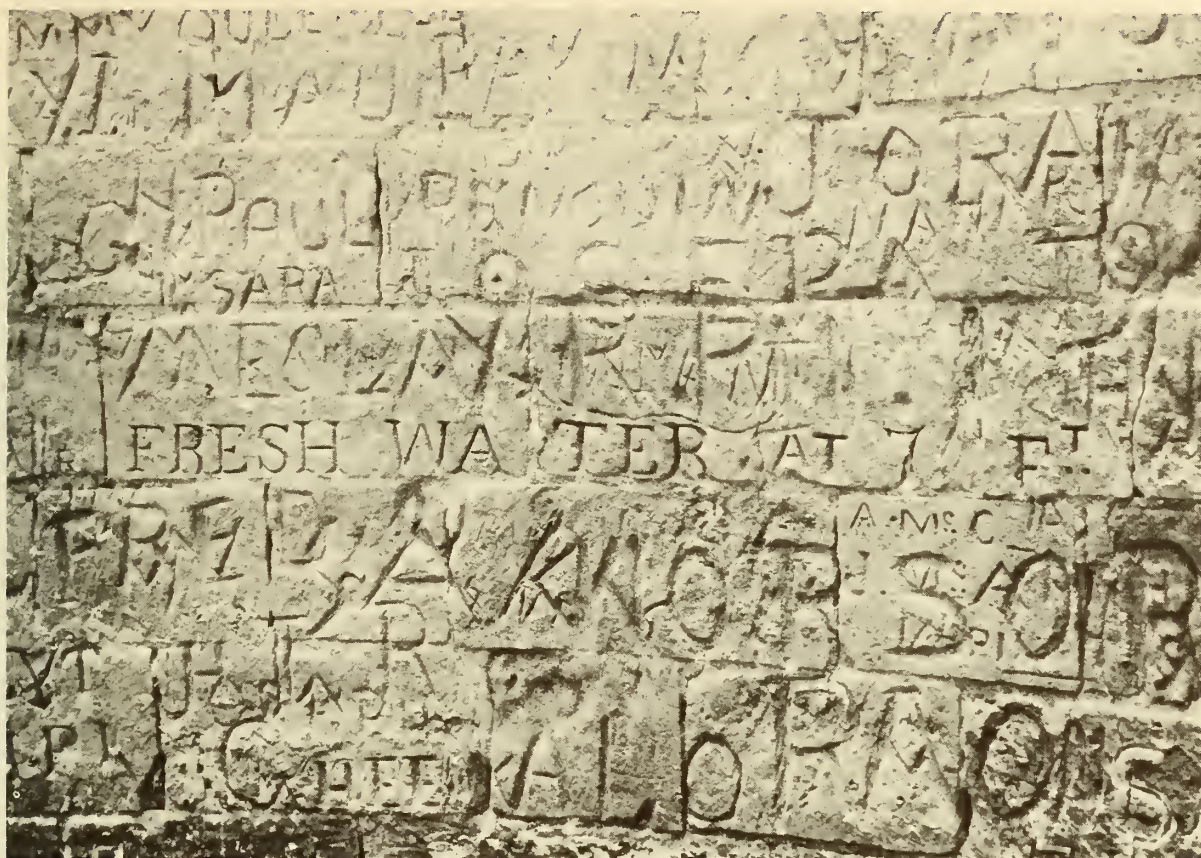
Pl. 34. The Beacon and grave at the east end of the island, seen from the south in November 1973.



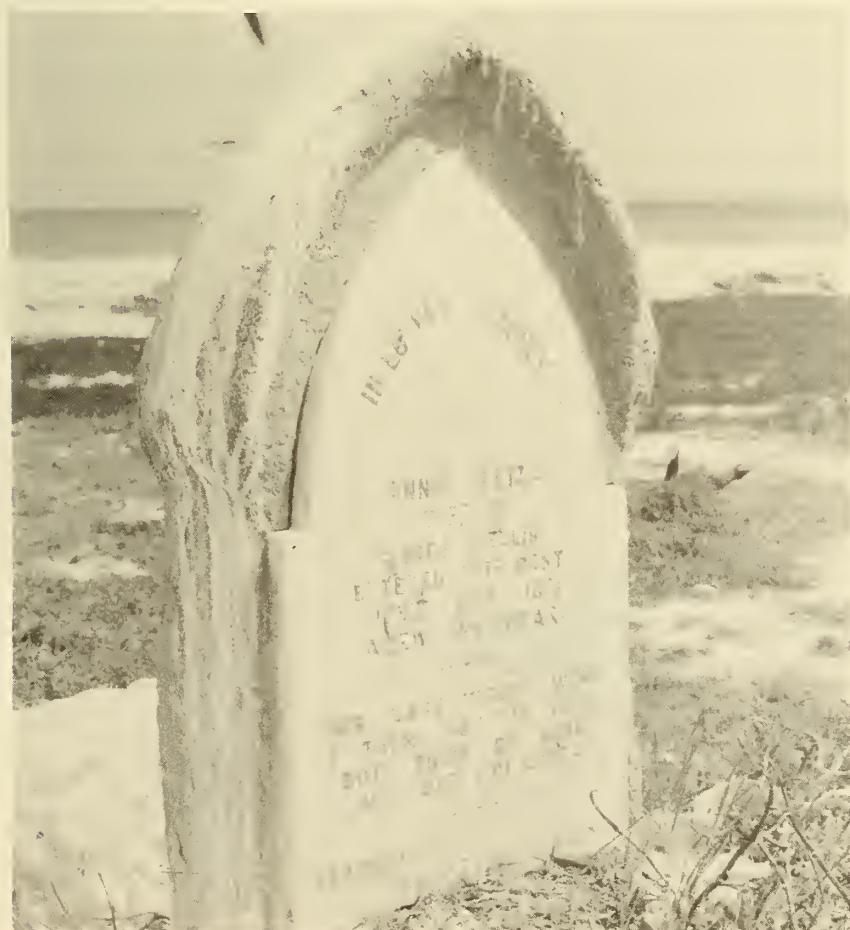
Pl. 36. The Beacon in November 1973. The dark area on the lower wall is that repaired by H.M.A.S. Gascoyne in 1961.



Pl. 35. The Beacon as erected in 1844, from *Nautical Magazine*, vol. 14 (1845), p. 267.



Pl. 37. Inscriptions inside the walls of the Beacon.



Pl. 38. The grave of Annie Eliza Ellis.



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SHORT ORIGINAL ARTICLES

by various authors

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EDITORS ' NOTE

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In line with our policy of not issuing short articles as separate numbers with their own title pages, the following articles are offered as parts of a single number. They have accumulated over a considerable period since the last Island News and Comments appeared. They are grouped roughly according to their geographic and subject interest.

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AN EARLY REPORT OF THE FLORA AND FAUNA OF THE ALDABRA GROUP

by E.P. Diamond¹

Introduction

Among the records in the National Archives of Mauritius at Port Louis is a copy of the earliest known detailed report on the flora and fauna of the Aldabra group, made by Sergt. F. Rivers of the Seychelles Constabulary. It was sent by the Civil Commissioner for the Seychelles to his superior, the Governor of Mauritius on December 30, 1878. The original was forwarded to London and a copy kept in the Seychelles National Archives and another in the Mauritius Archives. A third copy is to be found in the Günther Papers in the British Museum (Natural History) although I have not seen it. A later letter in the Mauritius Archives suggests that another, more detailed report by Rivers may have been made and sent to the Royal Society sometime in February 1879, though I have been unable to trace it. The importance of this report to the study of the changes on the Aldabra group lies in its early date and the apparently knowledgeable and careful observation of the reporter.

The report is dated 11 December 1878 and is signed by F. Rivers who is said, in a covering letter, to be of Canadian extraction and to have been a seaman before settling in Seychelles. The report is English with creole names given for most of the plants and animals. I have written the English common name, if there is one, in parentheses after the creole one and, with the first reference of each species, have included the scientific name as well. There may be some confusion in the use of creole names, which will be discussed in the conclusion. Detailed information about anchorages and geological formation of the islands will not be included in this paper but can be found in the report itself.

Astove

Rivers arrived on Astove on 10 October 1878. He reported that he could find no traces of visits by fishermen and whalers, though there was a well in the southeast which had been dug by a shipwrecked crew 'some years ago'.

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Atoll Res. Bull. No. 255: 1-10, 1981.

Coconuts and Other Vegetation

Rivers reported that the island had no trees except a few stunted 'mangliers' (mangroves of any species) and was covered with bush. He mentioned two individual coconut trees, planted in recent years, and implied that few if any others had yet been planted.

Fish

Rivers reported that fish 'are not found in quantity', but that the most common were; 'varvaras' (*Lutjanus bohar*), 'capitaines rouges' (*Lethrinus kallopterus* or *L. nebulosus*), 'carangues' (*Alectis indicus* or *Caranx* sp.) and 'vielles' (*Plectroponus maculatus* or a serranid). [These and all other translations of creole fish names are taken from J.L.B. Smith and Mary Smith *Fishes of the Seychelles*, 1969.]

Turtles

In Seychelles creole, a green turtle is a 'torti' while a Hawksbill turtle is called a 'caret'. When translating 'torti' into English, Seychellois often use only the word 'turtle' without the 'green'. Thus when Rivers uses the word turtle alone he means only green turtles, which is made clear by the context in the full report.

'Turtles' (green turtle, *Chelonia mydas*) were said to be very abundant, although it was not the breeding season and Rivers estimated that his ship, probably a small schooner, could take a complete cargo of turtles in three days. He reported finding 12 young turtles in the belly of a 'varvara'. Frigate birds (*Fregata* sp.) and 'aigrette' (egrets) were also said to prey on young turtles but no evidence was given.

Birds

Aquatic birds were said to be few with frigates and 'aigrette' present in small numbers. 'Corbijeaux' (whimbrel, *Numenius phaeopus*) and 'allouettes' (small waders and shore birds) were said to be plentiful. Of the land birds, a 'ralle' (rail, probably *Dryolimnus cuvieri*) was mentioned, also the 'crow of Madagascar' (pied crow, *Corvus albus*) a small species of 'colibri' (sunbird, probably *Nectarinia sovimanga*) and a 'cardinal' (*Foudia* sp. with red plumage). A 'merle' (bulbul, *Hypsipetes* sp.) and a 'pigeon hollandais' (*Alectroenas* sp.) were said to be present and 'smaller and paler than those found at Seychelles'.

Other animals

Land crabs were said to be plentiful and 'cypaye' (coconut crab, *Birgus latro*) was mentioned by name.

Discussion

Trees and other vegetation

Rivers describes the island as covered in bush with a few stunted mangroves, which coincides with the description of Bayne *et al.* (1970b) generally, although a large number of planted coconuts had changed the appearance of the island by 1968. It is interesting to note, however, that Rivers did not mention *Casuarina* woodland described by Bayne *et al.* on the western rim of the island. Fosberg and Renvoize (1970) record a

report of its presence in 1919, suggesting that these *Casuarina* were introduced between 1878 and 1919.

Marine Fauna

Bayne *et al.* do not mention fish but agree with Rivers that Astove is a major breeding ground for green turtles. The presence of young turtles in a fish's stomach implies that there had been laying two to 2½ months before (late July or early August). Hawksbill turtles (*Eretmochelys imbricata*) are not mentioned by Rivers and are said to be rare by Bayne *et al.*

Land fauna other than birds

Giant tortoises (*Geochelone gigantea*) reported by Rothschild on Astove in 1915 were not recorded by Rivers in 1878. This is perhaps a reflection of the low numbers of the population at that date, seen also on Aldabra (see Aldabra section). Both Rivers and Bayne *et al.* agree on the abundance of coconut crabs.

Birds

Bayne *et al.* agree with Rivers report of the small number of seabirds on Astove. They do not mention the frigates but these may have been wanderers from Cosmoledo or Aldabra. It is with his account of landbirds that Rivers differs markedly from all later reporters (summarised by Benson 1970b). The rail, pied crow and small sunbird are consistent with other reports but the 'merle', the 'pigeon hollandais' and the cardinal are not. The word 'merle' is used in Seychelles to mean a bulbul. It might possibly be applied to a medium sized thrush-like bird of another genus but there is no bird known from Astove to fit this description. Moreover Rivers was apparently a careful observer familiar with Seychelles species. The 'pigeon hollandais' is so called after the Dutch flag with distinct bands of red, white and blue. It is even less likely to be mistaken for any other species. As another *Alectroenas* appears to have become extinct at an early date on Farquahar (Stoddart and Benson 1970), it is possible that the same thing occurred on Astove, between 1878 and Dupont's visit in 1907. It is however to note that Dupont reported seeing a *Streptopelia picturata* in 1907 which no other observer has ever recorded. The 'cardinal' which, as its name implies, must have red plumage at some stage of its life cycle is the Seychelles creole name for *Foudia madagascariensis*. Rivers' cardinal must therefore have been a *Foudia sp.* (see under Aldabra discussion).

Cosmoledo

On his arrival in the Cosmoledo group Rivers reported that it was frequently visited by fishermen and whalers as indicated by turtle remains on the beaches. A hut and 'turtle park' (enclosure in the sea for keeping turtles fresh before shipment) on Menai Island had been recently burnt and destroyed. A hut on Wizard Island which had been built from the wreckage of the *Merry Monarch* had also been burnt. There were also signs of the felling of mangroves.

Trees and other vegetation

Rivers reported that some parts of the island would be suitable for growing various palms. What he describes as the 'remnants of an old grove of coconut trees' existed on Menai and those still standing were bearing fruit abundantly. He believed palms took longer to mature on Cosmoledo than on other islands because of the 'great sterility of the islands'. Menai was described as 'almost covered' with mangroves, some of about 40 or 50 feet in height and 2 or 3 feet in diameter.

Fish

Fish were abundant and he estimated that 8 men could salt or dry 8000 lbs of fish a month. In Rivers' opinion, the capture of this quantity would not exhaust the supply as no small fish were taken. The most common species were 'captaines rouges', 'varvaras', 'carangues', 'vielles', 'mulletts' (*Mulloidichthys flavilineatus*, a Mugilidae or *Polyremus kuru*, 'croissants' (specific name unknown), 'chirugiens' (surgeon fish, *Acanthuridae*), 'lions' (*Holocentridae*) and 'raies' of different kinds (rays, *Stoasodon marinari*, *Dasyatis uarnak*, *Taenuira melanospila* or *Torpedo fuscomaculata*).

Turtles and Crustacea

Both turtles (green turtles) and 'caret' (hawksbill turtles) were abundant though the late October, early November of Rivers' visit was 'not yet the season'. Crabs were said to abound in the marshes.

Birds

Birds of all kinds were plentiful. 'Fregates' (frigates), booby 'of three different species' (*Sula spp.*) 'paille en queue' (tropic-birds, (*Phaethon lepturus* or *P. rubricauda*), 'cordonniers' (lesser noddies, *Anous tenuirostris*), 'fouquets' (wedgetailed shearwaters, *Puffinus pacificus*), 'goelettes' (sooty tern, *Sterna fuscata*), and 'fanchins' (bridled terns, *Sterna anaethetus*) were listed. Rivers says that the same land birds were found on Cosmoledo as on Astove, but in greater numbers, and that there was also a 'tourtoirelle rouge' (turtle dove, *Streptopelia picturata*).

Other animals

Rivers reported a few goats on Menai but suggested that they did not do well there, as many skeletons were found in the bushes. He suggested that the reason may have been the scarcity of rain on the island on the year of his visit.

Discussion

Coconuts and other vegetation

The present vegetation of the group as described in Bayne et al. (1970a) is more varied than Rivers' brief description suggests, no doubt partly as a result of introductions since 1878. However, it is the plants already present in his time which are most interesting. The 'old grove of coconuts' of 1878 was reported in 1822 by Capt. Moresby (cited in Bayne et al. 1970a). Moresby also reported trees resembling *Casuarinas* which Rivers did not mention, though he records them on other islands.

Land fauna

Rivers did not report seeing giant tortoises, but the reasons may have been the same as on Astove (see Astove discussion). The goats which Rivers thought were doing poorly still remained, though in small numbers, in 1901 and had gone from Menai by 1968, though they were still on North-east Island in 1961 (Bayne et al. 1970a).

Sea birds

Rivers reported 3 different species of sulids as did Bayne et al. (1970a) in 1968. One species was undoubtedly *Sula sula*. It is however very easy to mistake immature white boobies (*Sula dactylatra*) for mature brown boobies (*Sula leucogaster*). The only evidence for the presence of *Sula leucogaster* is a skin in the National museum of Kenya in Nairobi. This skin has been misidentified and in fact is *Sula dactylatra* (A.W. Diamond pers. comm.). It is, of course, remotely possible that Rivers knew his boobies well and did in fact see a third species, perhaps *Sula abbotti* known from Assumption at about that date, collection by Abbott in 1893 (Stoddart, Benson and Peake 1970).

Rivers reported only 'cordonnier' or lesser noddies (*Anous tenuirostris*) while Bayne et al. saw only common noddy (*A. stolidus*) which in creole is called 'maqua'. It is possible that Rivers missed seeing common noddies which nest only on small islets around the lagoon (A.W. Diamond pers. comm.), but the fact that Bayne et al. (1970a) saw no lesser noddies, suggests that he may have mistaken the two very similar species. However, since neither party was on the island for more than a few days, the two species might both occur, possibly at different seasons.

The fact that wedgetailed shearwaters reported by Rivers were not seen by or reported to Bayne et al. (1970a) suggests that they may have become extinct since 1878. The young birds and eggs are commonly eaten by Seychellois fishermen who would therefore be aware if they were still extant; the same habit would account for their extinction. The extinction may also be the result of the rats, which were present by 1901 (cited by Bayne et al.), if not earlier.

Land birds

Rivers records the land birds as the same as Astove i.e. a rail, pied crow, sunbird, bulbul, cardinal and 'Pigeon hollandais', as well as a turtle dove. The first three and the turtle dove were also reported by Dupont in 1907 (Benson 1970a). The pied crow and the sunbird still exist and Benson suggests that further investigation of remoter parts of the atoll may reveal a relict populations of the rail and turtle dove. For the possibilities of the extinction of the bulbul 'cardinal' and 'pigeon hollandais', see the discussions on Aldabra and Astove.

Assumption Island

Rivers next went to Assumption where the extensive mining for guano had not begun. He said, in fact, that there was nothing to indicate that it had even been visited recently.

Coconuts and other vegetation

The island was covered with bushes of 'bois amanthe' (*Pemphis acidula*) and other shrubs on which were found a small liane used for dying, called 'orseille' which was common in Madagascar. There were also a few stunted 'affouche' (*Ficus sp.*) and 'bois de natte' as well as mangroves. Rivers mentioned one coconut tree as marking the landing, but gave no idea how many others there might have been. The 'affouche' was apparently the preferred food of the goats on the island who would eat even its bark.

Fish and turtles

Rivers reported that fish were found on the reefs but not in quantity, the most common being 'carangues' and 'varavaras'. The green turtles were said to be numerous and also 'better and fatter' than those of other islands. Hawksbills, however, were not numerous.

Birds

Aquatic birds were found, but not in large numbers and no names were given. Of the land birds, Rivers said 'pigeon hollandais' is not found but the rest were 'like the other islands'.

Other animals

Goats had been left on the island by passing ships and Rivers thought that there were 500 to 600 of them. He described them as being of 2 or 3 different species all in 'fine condition'.

Discussion

It seems likely that Rivers spent only a short time at Assumption, for he describes it in less detail than the other islands. By the time of later reports, mining had started or was about to start and subsequently destroyed the natural vegetation to a great extent.

Fish and turtles

The green turtle population which Rivers described as numerous has been reduced drastically on Assumption (Stoddart, Benson and Peake 1970).

Birds

Rivers describes the island birds as being the same as the other islands i.e. Cosmoledo and Astove, except for the absence of the 'pigeon hollandais'. Since he had previously said that there were turtle doves on Cosmoledo and not on Astove, his remark is ambiguous. The fact that Nicoll in 1906 and Fryer in 1908 both recorded the presence of the turtle dove (Stoddart et al. 1970) suggests that he intended to include it on his list. It is clear that he meant to include the sunbird, pied crow, 'cardinal', rail and bulbul. The sunbird still existed on Assumption in 1968 and probably the pied crow as well (Stoddart et al. 1970). A rail (*Dryolimnas abbotti*) became extinct between 1908 and 1937 (Stoddart et al. 1970). As in the case of Astove and Cosmoledo, neither the bulbul nor the 'cardinal' were recorded by any other visitors to the island. This omission is more striking on Assumption because Abbott collected there, though not in the other islands, in 1893, and yet failed to find either species. However, both

species are susceptible to rats which may have been the cause of their extinction. It is unfortunate that Rivers did not list the seabirds in detail, so that we cannot know whether he saw *Sula abbotti* which Abbott collected 15 years later.

Aldabra

Rivers appears to have spent more time on Aldabra than on the other islands. He gave details of place names and geography of the island and reported that it was frequently visited. Although he speaks of 'fishermen that have been there for a long time fishing', he makes no suggestion that there was a permanent settlement.

Coconuts and other vegetation

Coconuts and maize were grown on the small islands in the lagoon. Michel was said to have about 20 grown coconut trees while La Poste on Ile Picard was distinguished by the presence of a coconut tree. Two or three stunted takamaka trees (*Calophyllum inophyllum*) were the landmark for the well at Takamaka. Mangroves were growing on all the islands with the largest being 4 to 5 feet in diameter. The trees were, according to Rivers, commonly 2 to 3 feet in diameter and 40 to 50 feet high. Mangrove timber was said to be good for building because it was straight and long lasting. Cedar Island had some 'filao' (*Casuarina*) while 'vacoa Maron' (*Pandanus* sp.) occurred on all the islands in quantity. The 'bois tanguin' of Madagascar (*Euphorbia* ? *abbotti*?) was present as well as some 'bois de natte' and 'affouche', though Rivers did not specify where these trees occurred.

Fish, turtles and other marine fauna

Rivers reported that the fish were of the same species and in the same numbers as they were on Cosmoledo. As well as these species there were 'Licorne' (unicorn fish, *Axinurus thynnoides*) similar to the one at Mauritius. Green turtles were as abundant as on Cosmoledo, but hawksbill was far more numerous and 'generally of better quality'. The reefs were said to be full of shells, with 'pearl oysters' in quantity, but Rivers was prevented from looking for them by bad weather.

Birds

Rivers lists 'serins' (see discussion), 'cardinal' (*Foudia eminentissima* or *F. madagascariensis*, see discussion), pigeon hollandais, hawks (*Falco* sp. probably *F. newtoni*), crows (*Corvus albus*), sunbirds, turtle doves, rails, 'toulouse' (coucal, *Centropus toulou*), bulbuls (*Hypsipetes madagascariensis*), 'corbijeaux' of two species, 'one white and almost as large as a goose' [sacred ibis, *Threskiornis aethiopica*], the other the same as in Seychelles, (whimbrel), flamingoes (*Phoenicopterus ruber* or *P. minor*), 'veuve' and 'pie' (see discussion). Rivers reported that there were 'almost all kinds of aquatic birds in quantity, but lists only 'allouettes' (small shorebirds and waders) and 'cavalier' (crab plover *Dromas ardeola*).

Land animals

Rivers reported that 'by all appearances there is [sic] plenty of tortoises on these islands'. However, though he saw 'traces' of them,

he never saw a tortoise, nor did he, or any of the fishermen he spoke to, ever see a dead carcase or shell, though the fishermen sometimes captured the animals for food. Rivers said that the largest tortoises were from Ile Picard but that they were commonly caught on the plains at Cinq Cases. He felt that, as it was the dry season when he was there, the tortoises were 'hidden in holes' or shady places. When it rained, they were said to come out and be more easily caught. On Grand Ile 'some years ago' pigs were released which destroyed many young tortoises, but the pigs were believed to have died out because they were all males. There were numbers of 'flying foxes' (Fruit bats, *Pteropus seychellensis*), and land crabs 'of every description' were abundant. A few goats were found on Ile Picard and had been let loose on other islands. There were also 'large locusts of the Madagascar species'.

Discussion

Coconuts and other vegetation

It is apparent that on Aldabra in Rivers' day, as on other islands, coconut trees were not so widespread as they are today. If, as Fosberg (1971) suggests *Casuarina* is an introduced plant on the atoll, it was present by 1878. Takamaka trees are still mainly restricted to the area called after them. The largest mangroves described by Rivers are larger than any now present on the atoll, but Rivers may have been inaccurate in his estimation of proportions as his diameter seems excessive (A.W. Diamond, pers. comm.).

Birds

Rivers reported 'cardinal' and 'serin' for Aldabra, but 'cardinal' only for Astove, Cosmoledo and Assumption. 'Cardinal' is present Seychelles creole for the introduced *Foudia madagascariensis*. By implication, it must be used for a bird which has red plumage at some stage. It is never, for example, used for *F. seychellensis*, which is never red. 'Serin' on the other hand is used today for females of both species of *Foudia*. However, when white-eyes were still common in Seychelles, it was used at different times for *Zosterops modesta* and *Z. mayottensis*. Rivers probably knew one of the Seychelles white-eyes. It seems strange therefore, that he did not report white-eyes on Astove or Cosmoledo where they were recorded after 1878 (Benson 1970a, 1970b), especially since he did record 'cardinal' on these islands as well as on Assumption. No other observer has recorded *Foudia* from these islands and it might be suggested that Rivers mistook white-eyes for female *Foudia*. This mistake is however, most unlikely, since, if he did not know a white-eye he would have called a female *Foudia* a 'serin'. Therefore, the birds on Astove, Cosmoledo, and Assumption must have been *Foudia* with red plumage. *Foudia eminentissima* on Aldabra is in breeding dress in November and December when Rivers was there and it is likely that *Foudia* on other islands in the neighbourhood would have similar breeding seasons. (September - March, according to Benson and Penny, 1971). The fody on Astove, Cosmoledo and Assumption may have been *Foudia eminentissima* a subspecies of which appears on the Comores and in Madagascar as well as on Aldabra, (Benson 1967). The reason for its extinction on Astove and Cosmoledo is not known but it is reported on Aldabra to be very susceptible to rats (*Rattus rattus*, Frith 1976),

as is *Foudia seychellensis* (Diamond and Feare, in press).

Rivers mentioned a bird like a 'veuve' which is in Seychelles creole, a paradise flycatcher (*Tersiphone corvina*). However, he notes that it is not the same species, as both male and female have long tails and are black. This bird is clearly the Aldabra drongo (*Dicrurus aldabranus*). Rivers also reported hearing a 'pie' which he did not see, though he implied that fishermen had done so. 'Pie' or 'pie chanteuse' is creole for the magpie robin (*Copsychus seychellarum*), the 'pie' implying a black and white colouring and the 'chanteuse' a song. Although the fishermen probably both saw and heard this bird, Rivers only heard it. It need not therefore have been a magpie robin, which is, at present, restricted to Seychelles, but there seems no other likely candidate either resident or migrant. It does not sound like the Aldabra warbler at all. (Diamond, pers. comm.). As the magpie robin was introduced to Alphonse at a later date, it is possible that Rivers heard a bird that had been introduced to Aldabra, but this is unlikely. All the other birds listed by Rivers still occur on Aldabra.

Land animals

It is obvious from Rivers description that the tortoise population of the islands was much lower in 1878 than at present (see summary in Stoddart 1971). Rivers report merely confirms the findings of other reporters that population levels were very low at the end of the nineteenth century. It must be noted that for early visitors, travel was much more difficult than today, with no outboard motors and well cut paths. Tortoises in remoter areas would not have been found because these areas were not explored. Rivers record of goats appears to be the earliest. It is however, possible that goats as well as pigs have introduced and extirpated more than once. (Stoddart 1971)

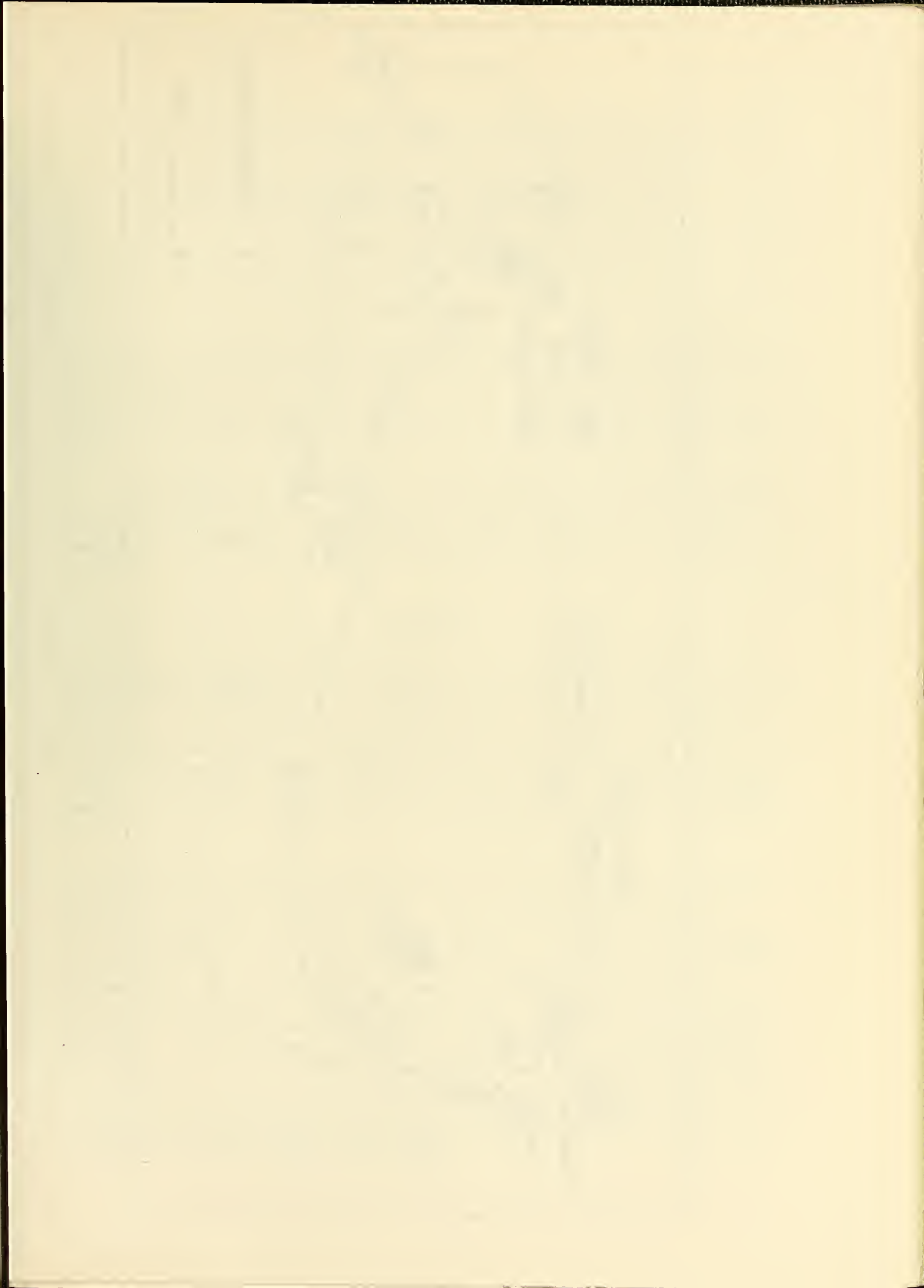
Fish and other marine fauna

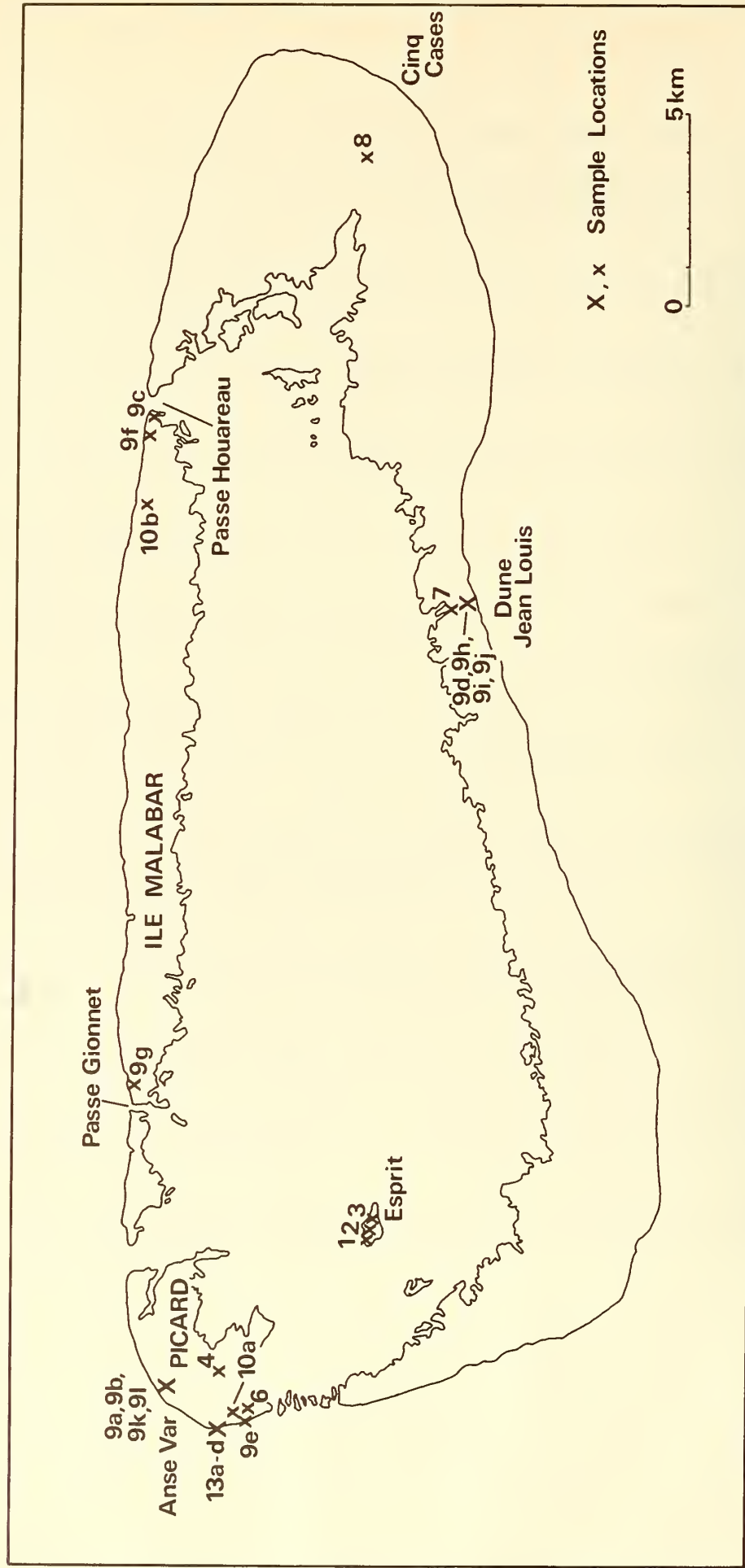
Though Aldabra is still a major breeding ground of green turtles, it is impossible to compare present day population levels with Rivers unquantified remarks. It is certain however that the population has declined on Aldabra, although the hawksbill population may not have done so. (J. Frazier 1971.) The hawksbill shell of 'better quality' was the famous Aldabra 'blonde' shell. The pearl oyster and the unicorn fish still occur.

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GEOCHEMISTRY AND MINERALOGY OF CARBONATE ROCK SAMPLES
FROM ALDABRA ATOLL, INDIAN OCEAN

Stephen T. Trudgill¹

INTRODUCTION

The stratigraphy and petrology of Aldabra have been described by Braithwaite *et al.* (1973) and Braithwaite (1975). Little is known about the geochemistry of the rocks present, apart from the analyses of two samples published by Stoddart *et al.* (1971). Accordingly, data are given in this paper which may contribute to the geological study of the island and also to the studies of soil chemistry and plant nutrition.

The samples were taken from the stratigraphic units identified by Braithwaite *et al.* (1973). These units are listed in Table 1, with the addition of beachrock. The numbers of samples within each unit are indicated. The sampling locations are given in Table 2 and shown in Figure 1.

METHODS

The rock samples have been analysed by X-Ray Fluorescence Spectrometry (Leake *et al.*, (1969)) for Ca, Mg, Na, K, Fe, Sr, Cu, Pb, Al, Zn, P, Ni, Co, Ba, S and Si. In the presence of very high levels of calcium the X-RF flowmeter became saturated and thus gave underestimates of the calcium present. Therefore analyses for calcium were also carried out by wet chemistry (acid digestion and EDTA titration; Bisque, 1961). Both data sets are reported. The wet digestion method also permits analyses of the amounts of acid insoluble residue to be carried out.

In addition, carbonate staining (Wolf *et al.*, 1967a) was also carried out on the hand specimens from which the samples for the X-RF analyses were taken. Acid Alizarin Red S solutions were used to differentiate aragonite and calcite from other minerals; a cobaltous nitrate boiling test to differentiate between aragonite and calcite and an alkaline Alizarin Red S solution to distinguish magnesium rich carbonates. As staining is not always a wholly reliable method of mineral identification, especially some shell materials, the mineralogy of seven of the samples was checked by X-Ray Diffraction using rock powders. The rocks were classified petrologically using the method of Folk (1959). The porosity of three samples was also estimated, using a

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Table 1. Stratigraphic units studied (after Braithwaite *et al.*, 1973)
(See Figure 1 for location of samples)

<u>Unit No.</u>	<u>Unit Name</u>	<u>Samples Studied</u>
1	Esprit limestone	1
2	Esprit phosphorites: oolites	2
3	Esprit phosphorites: conglomerates	3
4	Picard calcarenites	4a, b
5	Picard calcarenites + "soils"	-
6	Takamaka limestone	6
7	Soils filling subaerial fretting	7
8	Hard calcarenites	8a, b
9	Aldabra limestone	9a, b, c, d, e, f, g, h, i, j, k, l
10	Solution pit fillings	10a, b
11	Crab burrowed calcarenites	-
12	Algal stromatolites	-
13	Beachrock	13a, b, c, d

comparison of particle density and bulk density and a value of 2.7 for the specific gravity of calcite.

The samples were all near-surface samples but the actual surface was excluded from the chemical analyses (except for 13d which was a surface sample).

RESULTS

The petrology and mineralogy of the samples are shown in Table 2. The geochemical data are shown in Table 3a and 3b. The porosity data are shown in Table 4.

DISCUSSION

Substantive conclusions about each stratigraphic unit are not possible from the data presented since the samples are individuals from units which are often petrologically heterogeneous and which show considerable lateral and vertical facies diversity. However, some broad interpretations can be made. In terms of mineralogy and porosity, extreme diversity is evident. Frequently the samples appear to be simple bioclastic deposits, cemented by high magnesium calcite or aragonite.

Phosphates are present in small amounts in several rocks, as well as in the Esprit phosphorites. The X-Ray diffraction results suggest that a calcium phosphate form may be present (possibly $\text{Ca}_3(\text{PO}_4)_2 \cdot n\text{H}_2\text{O}$ with peaks at d spaces of 3.446, 2.808 and 1.937 or $\text{Ca}_4\text{P}_2\text{O}_9$ at 2.784 and

2.716). Phosphate in these forms is relatively insoluble at the soil pH values encountered and this probably accounts for the formation of residual soils with a high total phosphate content but a low available phosphate content (Trudgill, 1978).

The main features of element distribution are summarised in Table 5 which lists those rocks in which relatively high concentrations occur. Two conclusions can be drawn. Firstly, that the rock element concentrations frequently bear relationship to the presence of carbonates laid down in association with organisms known for their association with particular elements (Wolf et al., 1976b); secondly that the soils and solution pit fillings show markedly high concentrations of many elements, suggesting a residual origin for these deposits.

Silicon is of interest since it appears to be absent from many samples, apart from the pit fillings, soils and two samples of Aldabra Limestone. This is of interest in the context of the foliar chemistry of grasses which are known for their high silica content. Indeed Renvoize (personal communication) reports a scarcity of silica bodies in Aldabran grasses (Table 6). A specimen of *Sporobolus virginicus* from Esprit was analysed for silica by acid digestion and molybdenum blue spectrophotometry (Allen, 1974) and it was found to contain 0.16 mg/g (dry weight). This is low when compared with values of 0.1 to 1.5% for many U.K. grasses (Allen, 1974, Table A5).

These data are of use in indicating possible trends of concentrations of elements present in the rock samples. It is to be hoped that further work on the inputs, outputs and storage of elements may be made in the future because a geochemical study of a discrete island unit may prove to be a viable and interesting topic.

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Table 2. Location, petrology and mineralogy of samples

No.	Location*	Petrology	Mineralogy
1	Esprit	Calcarenite	<u>1.</u> A + HMC mix.
2	Esprit	Oolite	P <u>1.</u> LMC cement <u>2.</u> P + C
3	Esprit	Calcirudite	<u>1.</u> LMC, Fe <u>2.</u> C + Fe
4a	Picard	Calcarenite	<u>1.</u> C + A in points
b	Picard	Calcarenite	-
6	Picard	Calcilutite	<u>1.</u> LMC + HMC, Fe
7	Dune Jean Louis	"Soil"	<u>1.</u> C <u>2.</u> C
8a	Cinq Cases	Calcarenite	-
b	Cinq Cases	Calcarenite	<u>1.</u> C + A
9a	Anse Var	Calcarenite	<u>1.</u> grains HMC, cement A
b	Anse Var	Calcarenite	<u>1.</u> grains A, cement HMC
c	Passe Houareau	Calcarenite	<u>1.</u> HMC
d	Dune Jean Louis	Calcarenite	<u>1.</u> A
e	Picard	Calcirudite, corals	<u>1.</u> clasts A, cement C
f	Passe Houareau	Calcirudite, corals	<u>1.</u> HMC + A <u>2.</u> C + P
g	Passe Gionnet	Calcirudite	-
h	Dune Jean Louis	Calcirudite, shells	<u>1.</u> C
i	Dune Jean Louis	Calcirudite, <i>Halimeda</i>	<u>1.</u> clasts A, cement C
j	Dune Jean Louis	<i>Chama</i> shell	<u>1.</u> A + C mix
k	Anse Var	<i>Goniastrea</i> coral	<u>1.</u> septae A, C between
l	Anse Var	<i>Platygyra</i> coral	-
10a	Picard	-	<u>2.</u> C
b	Ile Malabar	-	<u>2.</u> C + P
13a	Picard	Calcirudite	<u>1.</u> clasts A + C, cement A <u>2.</u> A + HMC
b	Picard	Calcirudite	-
c	Picard	Calcirudite	-
d	Picard	Calcirudite	-

Abbreviations and key

*See Figure 1.

P = phosphate

HMC = high magnesium calcite Fe = iron

LMC = low magnesium calcite 1. = carbonate stainingA = aragonite 2. = X-Ray DiffractionC = calcite Note: The first mentioned mineral is dominant over the second mentioned, unless the word 'mix' is used which implies roughly equal quantities

Table 3a. Geochemistry of carbonate rock samples. Ca and Mg in %; others in ppm
 - = no data available 0.0 = below detectable limits
 10,000.0 ppm = 1.00000 % A.I.R. = acid insoluble residue

No.	A.I.R.	Ca (1)*	Ca (2)*	Mg	Na	K	Fe	Sr	Cu	Pb	Al
1	0.62	28.9	35.0	1.6	0.0	177.1	3108.1	-	0.4	-	7973.1
2	2.38	22.2	22.0	0.8	1892.0	141.4	4762.9	313.5	133.5	13.9	1,3251.2
3	2.83	24.3	27.4	1.5	0.0	124.3	2538.2	467.1	15.1	3.1	5891.9
4a	0.19	31.6	37.2	0.9	0.0	1174.2	2281.6	389.8	111.4	5.5	5828.9
b	4.97	27.6	33.2	1.8	0.4	4198.0	2175.9	-	0.0	-	5937.6
6	-	19.0	28.8	1.9	0.0	3351.7	2272.8	1527.0	0.0	5.9	1,8882.5
7	18.34	3.1	3.0	0.1	37,1512.4	321.6	3,4829.5	151.5	68.4	23.1	1,3189.6
8a	2.21	29.8	35.6	0.7	0.0	206.1	2362.4	697.6	62.9	17.7	6880.1
b	1.45	24.3	30.0	1.0	0.0	251.0	4414.6	985.7	54.6	15.9	2,1861.7
9a	0.58	28.9	34.2	2.4	0.0	181.4	3548.2	1438.1	0.0	5.8	1,0410.4
b	0.71	26.9	32.8	2.2	0.0	212.6	2594.3	942.4	11.4	7.7	1,1098.6
c	1.70	38.2	-	1.6	0.0	289.1	2201.2	668.6	0.0	7.5	6154.0
d	0.42	38.3	36.4	1.7	0.0	138.9	2303.7	888.0	0.0	5.5	5879.4
e	2.37	24.9	30.8	2.0	0.0	299.9	2646.1	1782.0	0.0	8.3	9140.9
f	0.83	24.8	13.2	1.6	1128.7	338.3	2379.8	394.7	5.3	8.0	6115.3
g	3.20	28.1	34.0	2.5	7225.4	7469.0	2193.2	1040.2	0.0	0.0	5592.9
h	1.99	26.7	35.5	1.0	0.0	288.7	5908.9	-	18.6	-	1,3654.7
i	2.97	21.1	31.0	1.2	0.0	363.0	2857.8	839.3	0.0	8.9	1,3084.0
j	1.44	30.4	36.0	0.6	0.0	175.5	2215.4	533.7	4.6	5.6	5655.0
k	4.73	19.7	29.6	2.4	0.0	747.7	2248.1	-	0.0	-	1,4644.8
l	8.31	30.2	33.9	1.1	0.0	728.9	3926.8	-	16.4	-	1,1167.2
10a	1.16	29.4	35.5	1.4	3799.3	635.0	4748.4	1139.5	0.0	6.7	1,3986.1
b	9.86	25.3	31.7	2.2	7.8	3472.9	1,3054.3	913.5	0.0	0.0	3856.3
13a	-	29.4	-	2.0	0.0	359.5	2261.9	1701.0	-	8.1	5939.0
b	-	19.1	-	1.3	0.0	4168.0	4052.1	-	7.2	-	5481.6
c	-	28.5	-	3.9	0.0	153.5	2167.0	1498.8	0.0	0.7	8190.6
d	-	27.5	-	1.9	1,6169.0	632.9	2779.0	1655.0	6.5	6.5	5481.6

* Ca (1) = XRF; Ca (2) = wet digestion (Bisque, 1961)

Table 3b. Geochemistry (ppm) of Aldabra rock samples (continued)
(For notes see Table 3a)

No.	Zn	P	Ni	Co	Ba	S	Si
1	19.9	9,1864.5	17.2	6.3	0.12	1656.1	0.0
2	440.8	44,6340.0	6.6	8.2	0.11	1213.9	0.0
3	10.5	33,1202.3	9.3	7.0	0.10	2328.2	0.0
4a	2.9	1,2165.4	11.4	1.0	0.10	2363.6	0.0
b	1.5	3267.8	8.6	2.7	0.10	2320.7	0.0
6	0.23	6345.5	8.2	0.0	0.09	1669.4	0.0
7	18.6	2199.3	38.3	23.9	0.20	998.9	2338.8
8a	37.4	8,0180.9	10.0	1.6	0.09	1148.9	0.0
b	149.8	29,0165.0	14.7	0.0	0.13	2141.4	0.0
9a	134.4	7,3274.6	10.3	7.3	0.11	1322.4	0.0
b	27.1	17,0094.0	10.2	0.0	0.13	1682.0	0.0
c	0.0	6468.5	10.5	0.0	0.11	1908.3	0.0
d	2.5	3,2812.6	10.4	0.0	0.10	1297.7	0.0
e	16.7	5038.2	9.2	7.0	0.11	1516.9	0.0
f	0.0	3436.8	8.4	2.1	0.09	3373.7	0.0
g	9.5	9648.0	8.2	6.0	0.12	3069.0	0.0
h	343.2	1,8402.7	12.0	0.0	0.12	785.5	0.0
i	-	43,9886.2	8.2	0.0	0.12	1897.6	4870.0
j	-	1,7418.3	8.1	6.5	0.10	1947.2	0.0
k	68.0	4293.5	8.2	2.8	0.10	2178.1	0.0
l	82.2	1,8421.6	11.9	2.8	0.13	1709.8	1442.2
10a	39.2	5,4402.1	9.6	0.0	0.10	1248.5	1327.7
b	378.8	9,5065.1	25.8	3.4	0.20	2337.8	2,2025.8
13a	-	3018.7	8.7	1.6	0.10	1789.1	0.0
b	11.6	5993.4	9.7	1.2	0.09	2043.8	0.0
c	0.0	1978.5	9.9	1.0	0.10	1591.8	0.0
d	-	2057.6	9.0	4.6	0.09	2379.3	0.0

Table 4. Porosity of selected Aldabra rock samples (%)

<u>Sample 9a</u>		<u>Sample 9f</u>		<u>Sample 9h</u>	
	42		48		10
	19		12		16
	26		1		14
	30		7		12
	24		25		7
			1		7
					8
					26
mean	28.2	mean	15.6	mean	12.5
standard deviation 8.66 standard deviation 16.76 standard deviation 6.24					

Table 5. Rocks with high concentrations of the elements measured
(Approximate ranges of high values indicated in brackets)

Aluminium (over ca. 1000 ppm): shelly calcirudites, hard calcarenite, solution pit filling, Esprit phosphorites, beachrock, Takamaka Limestone

Barium: slightly higher (0.2 ppm) in solution pit fillings

Cobalt (ca. 10-20 ppm): solution pit fillings, phosphorites, some calcarenites, some shells and corals

Copper (ca. 100 ppm and over): phosphorites, some calcarenites, beachrock, solution pit fills

Iron (over ca. 2000 ppm): solution pit fills, phosphorites, beachrock, some corals

Potassium (over ca. 1000 ppm): shelly calcirudites, beachrock, solution pit fills, algal limestones

Magnesium (over 2 per cent): beachrock, shells, corals, solution pit fills, algal material

Sodium (over ca. 2000 ppm): beachrock, some corals, "soils"

Nickel (over 20 ppm): "soils", solution pit fills

Lead (over ca. 100 ppm): algal material, some calcarenites, Esprit phosphorites, solution pit fills

Sulphur (over ca. 2000 ppm): corals, shells, solution pit fills, phosphorites

Silicon (over 2 per cent): solution pit fills

Strontium (over ca. 1500 ppm): corals, beachrock, algal material

Zinc (over ca. 300 ppm): Esprit phosphorites, shells, solution pit fills

Table 6. Silica in Aldabra grasses (S.A. Renvoize, personal communication) (microscopical examination)

Stenotaphrum clavigerum Sparse silica bodies and silica-containing cells, up to 8 μ m long

Panicum aldabrense No silica seen

Sclerodactylon macrostachyum No silica seen

Sporobolus virginicus No silica bodies seen but silica-containing cells, 4 μ m long frequent



HISTORY OF GOATS IN THE ALDABRA ARCHIPELAGO

by D.R. Stoddart¹

A summary of the history of goats on Aldabra was given by Stoddart (1971, 617-619), and references to goats on other islands are included in Stoddart (1970). In recent years further references to the early history of goats have been found, and this note summarises present knowledge on the history of goats in the Aldabra archipelago.

Assumption

Goats were said by Bergne (1901) to have been first introduced to Assumption in 1867 by Capt Bidenfield, R.N., H.M.S. *Wasp*; this is the earliest date at which goats are mentioned in the Aldabra group. Abbott (1893, 763) stated that at Assumption 'Numbers of goats run wild, having been introduced many years since from Europa Island'. Dupont (1907, 12) stated that they had been introduced about twenty years prior to his own visit in 1906.

Rivers in 1878 reported that there were some 500-600 goats of two to three 'species' on Assumption: 'they all seem to be in fine condition, they feed on shrubs such as the "Bois amanthe" [*Pemphis acidula*] but greatly prefer the "affouches" [*Ficus* spp.?] of which they even eat the bark'. In 1895 Baty estimated the numbers to be 300-400. He himself saw a party of 60 goats, and some of his group captured a further 30. He noted that 'their bellies are swollen to almost abnormal proportions'. Tonnet (1905) captured 70 in two days. In 1906 Dupont reported 'several thousands' (1907, 12), 'in splendid order' even at the end of the dry season; he thought of them as a major resource, and even suggested that a resident guardian be appointed on the island to safeguard the population and regulate cropping. In the same year Nicoll (1908, 112) found 20 very wild animals near the foot of the high dunes: 'some of the males were remarkably fine animals. They are excessively wild'.

By 1916, however, there were only 'a few' left on the island (Dupont 1916). Vesey-FitzGerald (1942) makes no mention of goats in the late 1930s, and in 1964 Gaymer found them to be absent. In 1968 Stoddart et al. (1970) saw none, but were told that some still existed in the north.

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Cosmoledo

In 1878 Rivers found 'a few goats' on Menai, together with 'a quantity of skeletons in bushes', which he attributed to lack of rain. Bergne (1900) reported goats 'in numbers'; but half a dozen earlier seen on Menai had been reported not to be doing well (Baty 1895). Griffiths reported at second-hand a comment by James Spurs in 1892 that there were 'large numbers of goats' at Cosmoledo (Fairfield, Griffith and Abbott 1893, 154).

There were no goats on Menai in 1968 (Bayne et al. 1970), though some were reported on North East Island by Piggott (1961).

Astove

Baty in 1895 drew attention to the absence of goats on Astove, and there is apparently no other reference to them on this island.

Aldabra

The first record of goats at Aldabra is that by Rivers (1878): 'There is also a few goats found at "Ile Picard" and some have been set loose on the other islands'. In 1895 Baty 'saw several goats'. He stated that one female and one kid had been placed on Picard in 1890, presumably by the lessee James Spurs, and by 1895 there were 40-50. In 1892 Griffiths had seen 'several specimens which had been taken to Aldabra' from Cosmoledo, again apparently by Spurs (Fairfield, Griffith and Abbott 1893, 154). Baty (1895) released eight more goats on Picard which had been brought from Assumption. He recommended that 'Goats should be placed on Aldabra Island, and especially on the plain near the Takamakas. There I feel sure they would do extremely well. It would however be necessary to shoot them when required for food'.

By 1900 it was reported that 'The goats introduced by Mr Spurs have thriven exceedingly, and now abound in great numbers on Picard Island'. In October 1901 Bergne saw 20-30 goats on Picard, and there were said to be several hundred. He reported Spurs's intention to capture them all.

By the time of Dupont's first visit in 1906: 'Goats... are thriving. Mr Spurs took them over from Assumption in 1890 and although they have been destroyed by the fishermen at Ile Picard I have come across herds which are scattered on the main island from Dune Jean Louis to the west end of Grande Terre (about 8 miles). They are extending every day and in the course of time they will reach the South East end where the ground and the water supply are much better' (1907, 22). In 1916 Dupont reported 'hundreds of them' at Cinq Cases, though they were very scarce in other areas, and by August 1929 'several thousands' (Dupont 1929, 14).

More recently Travis (1959, 178-181) describes considerable herds on the southern dunes, and Prosperi (1957, 198) also records goats at

the east end of Ile Malabar. Goats were present on Grande Terre, Malabar and Ile Picard at the start of the Royal Society Expedition to Aldabra in 1967.

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ABBOTT'S BOOBY ON ASSUMPTION

by D.R. Stoddart¹

Records on Assumption

Abbott's Booby *Sula abbotti* was first described by Ridgway (1893, 599) from a specimen collected by Abbott in 1892, apparently on Assumption Island. Abbott's own description of Assumption (1893, 763) does not mention boobies at all, but Ridgway (1895, 521) quotes notes supplied by Abbott. Under *S. abbotti* he quotes: "'Fou boeuf". A few breed on Assumption. Said not to be found on any other island in these seas'. Abbott (in Ridgway 1895, 520) also records *Sula sula* (as *S. piscator*) and *S. dactylatra* (as *S. cyanops*) from the same island. Of the latter he comments: "'Fou general"' : 'A few breed in Assumption, laying a single egg on bare ground on sand dunes'.

In 1906 M.J. Nicoll visited Assumption. He collected *S. dactylatra* (Nicoll 1906, 697) and photographed *Sula sula* (1908, 112), but he does not mention *S. abbotti*, and in his general account of the island he does not mention boobies at all (1908, 107-113).

J.C.F. Fryer collected two specimens of *S. abbotti* in 1908, which he records 'inhabits the large dune, never descending to low parts of the island, and only going a few miles to sea to fish; it was never seen on Aldabra' (1911, 433). He further notes: 'This species is also recorded on Christmas Island. I have not compared my specimens with those from this island but if identical the distribution becomes even more curious'.

S. abbotti has not been seen on Assumption since.

Confusion with the Iles Glorieuses?

Gibson-Hill (1950) reviewed the literature on *S. abbotti* and suggested that there had been confusion over the labelling of the type specimen, which could have been obtained on Grande Glorieuse rather than Assumption. His argument was based partly on the apparent unsuitability of treeless Assumption compared with forested Grande Glorieuse for what is on Christmas Island an arboreal species, partly on what seemed to be ambiguities in Abbott's written accounts. Thus Abbott does not describe his booby in his account of Assumption itself; but in his description of Grande Glorieuse he mentions that 'Among sea-birds there is a booby, which seems to be peculiar to the island. They breed in large numbers upon the 'fouche' [*Ficus?*] trees, in company with frigates and common

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boobies' (Abbott 1893, 764). However, the only boobies he collected on the Iles Glorieuses were *S. sula* and *S. dactylatra* (Ridgway 1895, 524), locally called 'Capucin' and 'Fou général'. Gibson-Hill (1950) suggested that the 'peculiar' booby was in fact *S. abbotti*, and that Abbott's type specimen really came from Grande Glorieuse rather than Assumption. He adduced the further point that Nicoll did not find *S. abbotti* on Assumption, which was still uninhabited and undisturbed in 1906; whereas the fact that he did not find it on Grande Glorieuse either could be explained by the settlement and partial clearance of woodland on that island by the time of his visit. Nicoll (1906), however, stated that the most common booby on Grande Glorieuse was dark-phase *S. sula*. The *S. sula* collected by Abbott on the same island was also dark-phase (Ridgway 1895, 524), and this morph could equally be the 'peculiar' booby Abbott mentions, since white-phase *sula* are predominant on western Indian Ocean coral islands (other than Tromelin: Staub 1970, 203-205).

One further piece of published evidence, hitherto overlooked, is provided by R. Dupont (1907, 45), who visited Assumption in 1906. He lists only *S. dactylatra* (as *S. cyanops*) and *S. sula* (as *S. piscator*) from Assumption, while for the Iles Glorieuses he lists *S. sula* and *S. abbotti*. This latter he notes "exists only in Gloriosa" and gives as the Creole name 'Fou glorieuse'. However, there seems to be no record of Dupont visiting the Iles Glorieuses themselves.

Nelson (1974) repeats Gibson-Hill's habitat argument, and agrees with him that *S. abbotti* 'may have nested not on Assumption but on Glorioso'.

Further evidence on Assumption

This trend of argument tends to overlook the fact that in addition to Abbott's type, *S. abbotti* was also collected on Assumption in 1908 by Fryer (who did not visit the Iles Glorieuses). Fryer (1911, 433) refers to specimens, but these were not described until 1950 (Gibson-Hill 1950, 72). Bourne comments (1976, 122) that 'there really seems no need to question Abbott's specific statement... that his booby nested on Assumption', since nesting on Assumption and the Iles Glorieuses are obviously not exclusive possibilities. Nevertheless, it would be useful to have further confirmatory field evidence of the existence of *S. abbotti* on Assumption, and some rather fragmentary and allusive evidence is available.

The first additional notice of sulids on Assumption is provided by S.C.E. Baty in 1895. He states that '... to the North East of the big sand hills at about six hundred yards therefrom and close to the next [north] and lower sand hill... There is a camp of 'boobies' on the spot'. This appears to refer to a ground-nesting species, probably *S. dactylatra* as recorded by Abbott. Baty also says: 'Boobies or Fous of different kinds are to be found in the trees all over the island'. The implication of this is that there is more than one species of tree-nesting sulid: the only two possibilities would be *S. sula* and *S. abbotti*. Finally, he says: 'On the slopes of the big

sand hills the trees are much bigger, and on their branches the Frigate birds and 'fous' make their nests'. This last reference could be to a single species, either *sula* or *abbotti*; but we may recall that Fryer (1911, 433) found that *abbotti* 'inhabits the large dune, never descending to low parts of the island'. Dupont (1907, 12) noted that 'boobies flock together in a plain of 30 acres' in the north of the island; but he lists only *S. sula* and *S. leucogaster* (which to add to the confusion he calls the Black Gannet and the Red-footed Gannet, respectively), and does not mention either the high dune or *S. abbotti*.

Fryer's published references to Assumption boobies are slight, but his manuscript diary adds more detail. On 6 September 1908 he records: 'There was a fresh species of Fou (*S. leucogaster*) and on the guano beds [word illegible] of ordinary Fou were breeding being continually preyed upon by a regular flock of Frigates of both species' (Fryer, 1908, 73). Gibson-Hill (1950, 69) has already noted that in his account of Aldabra Fryer seems to use the name *leucogaster* for *sula* (as did Dupont); but in the Diary passage the 'ordinary Fou' must be *sula*, and the 'fresh species of Fou' presumably *dactylatra*. *Leucogaster* has not been recorded on Assumption; Fryer used the name '*S. capucina*' for it on Aldabra.

On 7 September 1908, Fryer writes: 'A fresh kind of Fou (Fou Boeuf) was found: it was larger than the ordinary with a grey back tinged with pink: dark eyes and wings and long coverts black: its cry was very like a cow (from which it takes its name)' (Fryer 1908, 75). This is very clearly *S. abbotti*, and Fryer's specimens must have come from this population. Unfortunately his diary makes no comment on breeding. However, his reference to voice is remarkable. Neither Abbott (1893) nor Ridgway (1895) mention voice, though Abbott (in Ridgway 1895, 521) uses the name 'Fou boeuf'. The only reference to voice prior to Fryer's observation, with which Fryer was certainly unfamiliar, is contained in an anonymous French account of Rodriguez, ca 1730, on 'The Boeuf', said to 'bellow like a bull'. This was published by Milne-Edwards (1875, 8); Bourne (1968) tentatively identified it as *S. dactylatra*, but Nelson (1974) used the evidence of voice to determine it as *abbotti*. Nelson at Christmas Island found *abbotti* to have 'the deepest and loudest voice of any sulid, resonant and commanding' (1971, 436).

Comment

There thus seems little question, in spite of the ambiguities in Abbott's account and the clear statement by Dupont, that *abbotti* was definitely present on Assumption in 1892, possibly in 1895, and definitely in 1908. It cannot be stated with certainty that the species was breeding; but equally it is clear that its presence on the island was not inhibited by the absence of tall forest, *contra* Gibson-Hill and Nelson.

Whether *abbotti* formerly existed on the Iles Glorieuses remains unclear. Benson et al. (1975) suggest that Abbott's 'peculiar' booby (Abbott 1893, 764) is not *abbotti* as Gibson-Hill suggests but the

'capuchin' of Ridgway (1895, 532), i.e. dark-phase *S. sula*. Abbott (1893, 764) identifies 'capucin' as *sula*, as does Dupont (1907, 55): Gibson-Hill (1950, 69) is mistaken in saying, when trying to identify Fryer's '*S. capucina*', that Abbott used 'capucin' for *S. leucogaster*.

It is certainly possible that *abbotti* inhabited the Iles Glorieuses in spite of the absence of positive evidence. Bourne (1971, 188) speculated that this species would be found somewhere between Assumption and its present breeding station on Christmas Island, possibly in the Chagos Archipelago, and there has been some confirmation of this by sightings at sea in that vicinity (Bourne 1971; Hiron et al. 1976; Bourne and Nelson 1976). Bourne has also identified fossil material of *abbotti* from Mauritius and possibly Rodriguez, and has quoted historical evidence (1968; Nelson 1974) for the latter island. Becking (1976) gives a record of a foraging bird from Java. Bourne (1976, 122) particularly notes that the vernacular name (Fou boeuf) on Rodriguez in the early eighteenth century was the same as that on Assumption in the early twentieth, suggesting a previous wider occurrence and more numerous population.

When did *abbotti* become extinct on Assumption? Vesey-FitzGerald (1941, 521) says 1926, and Betts (1940, 501) says 1936, and these dates are quoted by Gibson-Hill (1950) and later writers. Settlement began at Assumption in 1908, and guano was then mined on a major scale (Stoddart et al. 1970). By the time that R. Dupont visited the island for the second time in 1916, he reported that the boobies 'have been all destroyed'; and in 1929, during a later visit, he stated that the land and sea birds had been destroyed by 1909. It thus appears that man and his activities, plus introduced predators, caused massive extinctions within a very short time of the first settlement. No boobies of any kind now breed on Assumption, though a few individuals of *dactylatra* and *sula* have been seen in recent years (Stoddart et al. 1970).

Acknowledgements

I was able to visit Assumption on 15-16 September 1967 during the Royal Society Expedition to Aldabra 1967-69, and the Iles Glorieuses on 9 December 1976 while a guest on board *Lindblad Explorer*. Literature and archival research on the faunas of western Indian Ocean islands has been carried out since 1966 as part of the Royal Society Aldabra Research Programme. I thank Lady Joan Fryer for access to Sir John Fryer's diary.

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PENETRATION OF THE HOST PLANT TISSUES BY THE STYLETS OF THE
COCCOID *ICERYA SEYCHELLARUM* (COCCOIDEA: MARGAROIDEA) ON

ALDABRA ATOLL

by S. Blackmore¹

ABSTRACT

The path of penetration of stylets of *Icerya seychellarum* through tissues of *Euphorbia pyrifolia* Lam., *Avicennia marina* (Forssk.) Vierh., *Scaevola taccada* (Gaertn.) Roxb., and *Casuarina equisetifolia* L. was studied microscopically. Most stylets were seen to end in the phloem, others in the cortex, xylem or pith. Unlike other members of the Coccoidea *I. seychellarum* frequently penetrates thick walled cells such as sclerenchyma and xylem. This suggests that the anatomy of host plants, and the distribution of thickened tissues in particular, is not a restricting factor in host plant specificity.

INTRODUCTION

Stylet penetration has been studied in coccoids which act as vectors for virus diseases of economic plants, notably the potato (Smith, 1926), apple (Glass, 1944), and cocoa (Entwistle & Longworth, 1963). Most coccoids feed on the phloem of their hosts but a few are cortex feeders. Penetration is intracellular or, less commonly, within the cell walls (Entwistle & Longworth, 1963). Smith (1926) described the penetration of xylem vessels by *Dactylopius longispinus* but otherwise penetration of thickened tissues has not been observed.

This study was intended to establish whether *I. seychellarum* conforms to the known pattern, if any tissue damage is caused by the stylets and whether host plant anatomy might influence host plant specificity of the coccoid. The biology of *I. seychellarum* on Aldabra Atoll has been studied by Renvoize (1975) and recently by Hill and Newbery (publications in preparation). *I. seychellarum* infests a wide range of plants. More than half of the one hundred and eighty flowering plant species on Aldabra Atoll have been reported as hosts. Renvoize listed about thirty species which were subject to heavy infestations,

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including all the examples discussed in this paper. In the granitic islands of the Seychelles the coccoid is a pest of Citrus crops.

MATERIALS AND METHODS

The host plants studied were *Euphorbia pyrifolia* Lam., *Avicennia marina* (Forssk.) Vierh., *Scaevola taccada* (Gaertn.) Roxb. and *Casuarina equisetifolia* L. In each case a minimum of thirty stylets were studied *in situ* in sections of stems or leaves and petioles. The plant material was fixed in Formalin-acetic-alcohol, sectioned by hand or by microtome, stained in safranine and light green and mounted. Hand cut sections were particularly useful since with careful examination the stylets were visible in the plant before it was cut. The sections were examined microscopically and the length, width and path of the stylets and the salivary sheath they secreted were recorded.

RESULTS

A number of general points were noted; these are summarized in Table 1 and discussed below.

1. Leaves and petioles were usually penetrated from below. Penetration of the upper surface was only frequent in *Ficus nautarum* and *Thespesia populnea*. The stylets usually entered the leaf to one side of the midrib.
2. The mean length of stylets was approximately 800 μ m which is shorter than the 988 μ m reported in *Pseudococcus njalensis* by Posnette & Robertson (1950). The mean length of stylet inserted into the plant was 520 μ m.
3. Stylets were usually seen to end in the phloem but were also found in the cortex, xylem, laticifers and pith.
4. Penetration was intracellular except in thickened cells where it was intercellular. When the stylet first encountered such tissues it was often withdrawn and re-inserted in a different position. If the stylet did not locate a path through less resistant tissues it was usually eventually successful in penetrating the thickened cells intercellularly.
5. Stylets usually penetrated in a transverse plane and were often found in their entirety on one or two serial sections. Entwistle & Longworth (1963) found that the plane of penetration in other coccoids was related to the orientation of the insect and the stylet was rarely to be found in so few adjacent sections.
6. There was no evidence of tissue damage other than to the cells penetrated. Small groups of callus cells were occasionally found in *Scaevola taccada*.

Table 1. Summary of stylet penetration data for four host plants.

	Euphorbia		Scaevola		Avicennia		Casuarina	
	Stem	Leaf	Stem	Leaf	Stem	Leaf	Stem	Leaf
Mean length Stylet sheath, μm	424	504	750	509	675	548	450	305
Mean number branches in sheath	1.6	0.5	2.5	1.2	3.3	3.2	1.75	0.8
% stylets ending in phloem	84	75	64	67	65	46	83	75
% stylets penetrating thickened tissues	20	23	25	13	87	83	95	85

Specific results are as follows:

Euphorbia pyrifolia

The leaves have little thickened tissue except a band of collenchyma along the midrib. Stylets enter to one side of this and frequently penetrated to the phloem without being withdrawn and relocated. Often several vascular bundles were penetrated in succession. The stems have a well developed cork which was sometimes penetrated intercellularly. Several stylets were seen to enter the stem through lenticels. Many ended in, or passed through, the abundant laticifers of the cortex. It is possible that the latex is an additional food source.

Scaevola taccada

Leaf penetration was similar to that in *Euphorbia*. The stem has more sclerenchyma around the vascular tissues which may account for the greater number of reinsertions of the stylet and resulting branching of the salivary sheath.

Avicennia marina

The undersides of the leaves have a dense cover of simple trichomes. The stylets pass between these and secrete a salivary sheath extending slightly out beyond the trichomes. The vascular tissues are completely

surrounded by sclerenchyma and reinsertion of the stylets is more frequent. The stems have large cortical air spaces. Some stylets passed through the spaces but an equal number followed a sinuous course through the surrounding cells. Additional cambia within the xylem produce small groups of phloem within the xylem. About 20% of stylets penetrated through to these inner phloem cells.

Casuarina equisetifolia

The leaves or, strictly, phyllodes have angular, ridged surfaces covered by a thick cuticle beneath which a layer of sclerenchyma overlays the chlorophyllous tissues. Between the ridges the cuticle is thin and the sclerenchyma absent and stylets entering here did not encounter so much mechanical tissue. Equal numbers of stylets entered through and between the ridges. Those passing through the sclerenchyma produced branched salivary sheaths, the others did not.

CONCLUSIONS

I. seychellarum differs from most coccoids in the ability of its stylets to penetrate thickened tissues. The ability of the stylets to locate the phloem, even if this requires passage through thickened cells, implies that the stylets are to some extent sensory.

Host plants of the coccoid on Aldabra Atoll range from fleshy leaved plants such as *Euphorbia pyrifolia* to others with heavily thickened stems such as *Casuarina equisetifolia*. The ability of the insect to feed on plants with such varied anatomy suggests that host anatomy is unlikely to be a limiting factor in the selection of hosts.

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METEOROLOGICAL DATA FROM ULUL ISLAND, NAMONUITO ATOLL

by John Byron Thomas and Mary Durand Thomas¹

Meteorological observations were conducted on Ulul Island, Namonuito Atoll, Truk District, Trust Territory of the Pacific Islands from November 8, 1973 to September 30, 1974. A record was maintained of maximum and minimum temperatures, maximum and minimum relative humidity, and rainfall. Temperatures and rainfall were recorded daily at 6:00 p.m. Relative humidity was measured twice daily at noon and 6:00 p.m.

The meteorological station was located in a cleared area permitting unobstructed exposure to rain and sun. The maximum and minimum thermometers were housed in a louvered wood structure and the rain gauge was located about four meters distant. Relative humidity, obtained with a sling psychrometer, was measured at the same location. All instruments and their associated gear were supplied by the U.S. Weather Bureau at Moen Island, Truk District.

Informants considered that meteorological conditions during the recorded period were typical for Namonuito Atoll. The data presented in the accompanying table indicate the climate to be uniformly warm and humid. Extreme temperatures ranged from 20.5°C. to 35.0°C. (69°F. to 95°F.); relative humidity from 66% to 100%; and monthly rainfall, from 137.7 mm to 396.5 mm (9.45 in. to 15.61 in.). Generally, the daily low temperature occurred just prior to sunrise and the high during early afternoon. Daily relative humidity varied from a low at about noon to a high at about the time of sunrise. (Because a daily relative humidity measurement was recorded at 6:00 p.m. rather than at sunrise, the extreme high and average high relative humidity percentages were probably somewhat higher than indicated in the table.) With a few exceptions, daily rainfall was in the form of brief, random showers. By extrapolation, the total annual rainfall would have been approximately 3213 mm (126.5 in.).

As is typical for this area of the Pacific, the greatest seasonal climatic variation is reflected in wind velocity and direction rather than in temperature, relative humidity and precipitation patterns. Northeast trade winds prevailed during the winter months. Summer months were characterized by lower velocity variable winds and occasional thunder storms. Accurate wind velocity measurements could not be obtained but the periodic use of a hand-held wind meter at a

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TEMPERATURE, HUMIDITY AND PRECIPITATION SUMMARIES
FOR ULJUL ISLAND, NAMONUITO ATOLL
NOVEMBER 8, 1973 - SEPTEMBER 30, 1974

Month	Temperature °C.				% Relative Humidity				Precipitation		
	Extreme High	Extreme Low	High	Average Low	Extreme High	Extreme Low	Average High	Average Low	Total (mm)	24-hour max. (mm)	Days with None Trace*
Nov	33.3	22.8	31.9	24.5	96	74	86	80	137.7	29.5	4 5
Dec	33.9	22.2	31.5	24.4	96	70	86	79	240.0	41.7	6 1
Jan	33.3	20.5	31.7	23.4	100	66	85	79	217.4	46.0	9 5
Feb	32.8	22.8	31.4	24.4	96	67	83	78	141.2	29.7	8 2
Mar	33.3	21.7	31.9	24.3	96	74	87	81	396.5	53.8	7 2
Apr	33.9	23.3	31.9	24.4	96	71	87	81	390.4	51.1	3 2
May	35.0	22.8	32.5	24.5	96	70	88	79	295.9	51.1	4 3
Jun	33.9	21.7	31.7	23.9	97	67	88	81	374.9	54.4	5 2
Jul	34.4	22.8	32.8	23.9	97	67	86	77	262.4	51.1	4 2
Aug	33.9	22.8	32.3	24.4	92	67	86	78	198.4	48.5	5 3
Sep	34.4	22.2	32.9	23.4	100	66	88	74	304.5	51.6	6 4

*Less than 0.25 mm.

windward beach site indicated that winter winds seldom exceeded approximately twenty knots per hour while summer winds usually ranged between five and ten knots per hour.

The meteorological measurements were compiled during the course of our respective anthropological researches at Namonuito Atoll. One of us (J.B.T.) would like to acknowledge the research support provided by Wenner-Gren Foundation for Anthropological Research Grant No. 2977 and National Science Foundation Grant No. GS-39878; the other (M.D.T.) would like to acknowledge the support provided by National Center for Health Services Research and Development special fellowship No. 5 FO3 HS50513. We would also like to express our appreciation for the assistance of Saul Price and the late William Tolliver of the U.S. Weather Bureau, Honolulu and for that of Lazaro Mayipi of the Trust Territory Weather Bureau, Truk District.



MARINE BENTHIC ALGAE OF KAYANGEL ATOLL, PALAU

by Roy T. Tsuda¹

Introduction

During January 13-17, 1976, four faculty members from the University of Guam Marine Laboratory visited Kayangel Atoll in the Palau District to conduct a preliminary biological survey of the algae, corals and fishes. Our original plan was to incorporate all of the findings under one cover, but other research priorities of the faculty directed each member to work at his own pace in getting the results in print.

This paper reports on the 51 species of marine benthic algae collected on the barrier reef flat, channel and lagoon of Kayangel Atoll. All specimens cited here are deposited in the Herbarium of the University of Guam Marine Laboratory. Previous to our visit to Kayangel Atoll, only one paper (Lowenstam, 1955) mentions the algae from this atoll; this study reports on aragonite needles secreted by the calcareous green alga *Halimeda*. Based on the collections and observations of *Sargassum crassifolium* during our visit to Kayangel Atoll, Tsuda (1976) reported its presence on atolls and speculated why this genus is rarely observed on atolls as opposed to high islands. Five species of sea-grasses were also collected during our survey and are included in another paper, presently in preparation, on Micronesian sea-grasses.

Kayangel Atoll (8°05'N, 134°43'E), about 7 km long (N-S orientation) and about 4 km wide (E-W orientation), is the northernmost atoll in the Palau Archipelago. The atoll is almost completely encircled by a barrier reef with four islets present on the eastern side. The maximum depth of the lagoon is only 11 m. Gressitt (1952) provides a description of the atoll, as well as the four islets.

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Stations

The terminology of Tracey *et al.* (1955) is used to describe the different zones of Kayangel Atoll.

- Station 1. Lagoon reef margin, northern end of atoll, .5 m deep,
Jan. 13, 1976. (RT 5088 - 5098).
- Station 2. Lagoon reef margin, northwest end of atoll, .5 m deep,
Jan. 13, 1976. (RT 5099).
- Station 3. Inner reef flat, coral mound off northwest tip of Ngariungs Islet, .3 m deep, Jan. 14, 1976 (RT 5100 - 5103).
- Station 4. Lagoon, coral mound, 1.5 km south of main channel, 1 m deep,
Jan. 14, 1976. (RT 5104 - 5117).
- Station 5. Reef flat, 1 km north of main channel, 2 m deep, Jan. 15,
1976. (RT 5119 - 5122).
- Station 6. Lagoon shelf, southwest of Ngariungs Islet, 1 m deep, Jan.
15, 1976. (RT 5124 - 5129).
- Station 7. Lagoon, coral mound, 1 km northeast of channel, 9 m deep,
Jan. 15, 1976. (RT 5130 - 5133).
- Station 8. Lagoon, coral mound, 1 km west of southern tip of Ngajangel Islet, 9 m deep, Jan. 15, 1976. (RT 5134 - 5140).
- Station 9. Reef flat, .6 km north of Ngajangel Islet, .5 m deep, Jan.
15, 1976. (RT 5144 - 5149).
- Station 10. Lagoon, coral mound, west of mid-section of Ngajangel Islet,
2-8 m deep, Jan. 16, 1976. (RT 5150 - 5157).
- Station 11. Reef flat, 2 km south of main channel entrance, .3 m deep,
Jan. 16, 1976. (RT 5158 - 5159).
- Station 12. South channel, just west of Gorak Islet, 2 m deep, Jan.
16, 1976. (RT 5161 - 5163).
- Station 13. Slope of main channel, 1-10 m deep, Jan. 16, 1976.
(RT 5164 - 5176).

Station 14. Inner reef flat, between Ngajangel and Ngariungs Islets, 1 m deep, Jan. 17, 1976. (RT 4773, 5177 - 5182).

Station 15. Slope of main channel, 2-9 m deep, Jan. 17, 1976. (RT 5183 - 5188).

Station 16. Inner reef flat, between Ngariungs and Ngaraplas Islets, 1 m deep, Jan. 17, 1976. (RT 4774, 5189).

Station 17. Reef flat, just northwest of the northwest tip of Ngajangel Islet, 1 m deep, Jan. 15, 1976. (RT 5190 - 5198).

Station 18. Lagoon shelf, sea-grass beds off Ngajangel Islet, 1 m deep, Jan. 17, 1976. (RT 5201 - 5203).

Species Listing

The species are listed alphabetically under their respective Divisions.

Cyanophyta

Calothrix confervicola (Roth) Ag. - RT 5132a (epiphytic on *Ceramium mazatlanense*).

Calothrix pilosa Harvey - RT 5162, RT 5198.

Microcoleus lyngbyaceus (Kütz.) Crouan - RT 5145 (epiphytic on *Halimeda incrassata*), RT 5203.

Schizothrix calcicola (Ag.) Gomont - RT 5111.

Chlorophyta

Avrainvillea lacerata Harvey - RT 5095, RT 5100.

Avrainvillea obscura J. Ag. - RT 5201.

Caulerpa antoenis Yamada - RT 5194 (on sand).

Caulerpa racemosa (Forsskal) J. Ag. - RT 5108, RT 5124, RT 5153, RT 5182.

Caulerpa serrulata (Forsskal) J. Ag. - RT 5096, RT 5114, RT 5129c, RT 5135, RT 5152, RT 5154.

Caulerpa taxifolia (Vahl) C. Ag. - RT 5138.

Caulerpa urvilliana Montagne - RT 5181.

Caulerpa vickersiae Boerg. - RT 5103 (on sand), RT 5133.

Dictyosphaeria cavernosa (Forsskal) Boerg. - RT 5167.

Dictyosphaeria versluysii W. v. Bosse - RT 5093, RT 5113, RT 5119, RT 5196.

Halimeda cylindracea Decaisne - RT 5104, RT 5131, RT 5183.

Halimeda discoidea Decaisne - RT 5144, RT 5150, RT 5184b.

- Halimeda gracilis* Harvey - RT 5088, RT 5165
- Halimeda incrassata* (Ellis) Lamx. - RT 5149, RT 5202b.
- Halimeda lacunalis* Taylor - RT 5091a, RT 5106, RT 5126a, RT 5134, RT 5184a.
- Halimeda micronesica* Yamada - RT 5089, RT 5105, RT 5129b, RT 5185a, RT 5192.
- Halimeda minima* (Taylor) Colinvaux - RT 5151, RT 5164, RT 5186.
- Halimeda opuntia* (L.) Lamx. - RT 5090a, RT 5107, RT 5125, RT 5187.
- Halimeda simulans* Howe - RT 5202a.
- Halimeda stuposa* Taylor - RT 5190b, RT 5202a.
- Halimeda taenicola* Taylor - RT 5126b, RT 5191.
- Microdictyon okamurai* Setchell - RT 5097, RT 5130, RT 5136, RT 5155.
- Neomeris mucosa* Howe - RT 5139.
- Rhipilia orientalis* A. & E. S. Gepp - RT 5173, RT 5189.
- Valonia utricularis* (Roth) C. Ag. - RT 5157, RT 5176, RT 5195.
- Valonia ventricosa* J. Ag. - RT 5127, RT 5172.
- Valoniopsis pachynema* (Martens) Boerg. - RT 5116.

Phaeophyta

- Dictyopteris repens* (Okamura) Boerg. - RT 5170b.
- Dictyota bartayresii* Lamx. - RT 5179.
- Feldmannia irregularis* (Kütz.) Hamel - RT 5158.
- Lobophora variegata* (Lamx.) Womersley - RT 5094, RT 5099, RT 5110, RT 5121, RT 5147, RT 5171.
- Padina tenuis* Bory - RT 5146.
- Sargassum crassifolium* J. Ag. - RT 4773, RT 4774.
- Turbinaria ornata* (Turner) J. Ag. - RT 5092, RT 5109, RT 5163.

Rhodophyta

- Amphiroa fragilissima* (L.) Lamx. - RT 5148.
- Ceramium gracillimum* v. *byssoideum* (Harv.) Mazoyer - RT 5112b.
- Ceramium mazatlanense* Dawson - RT 5132a.
- Claudea multifida* Harvey - RT 5161, RT 5168.
- Endosiphonia spinuligera* Zanard. - RT 5101a, RT 5156.
- Galaxaura oblongata* (E. & S.) Lamx. - RT 5180.
- Gelidiopsis intricata* (Ag.) Vickers - RT 5122.
- Jania capillacea* Harvey - RT 5178 (epiphytic on *Sargassum crassifolium*), RT 5197.

Laurencia cartilaginea Yamada - RT 5101b, RT 5128.

Laurencia majuscula (Harv.) Lucas - RT 5098 (intermixed with *Laurencia cartilaginea*), RT 5140 (epiphytic on *Halimeda opuntia*), RT 5169 (epiphytic on *Halimeda lacunalis*), RT 5188 (on dead coral).

Liagora pinnata Harvey - RT 5177, RT 5193.

Polysiphonia howei Hellenberg - RT 5112a, RT 5117, RT 5120, RT 5129 (mixed with *Polysiphonia scopulorum*), RT 5159, RT 5174.

Polysiphonia scopulorum Harvey - RT 5102, RT 5129 (mixed with *Polysiphonia howei*), RT 5132b.

Discussion

Claudea multifida (see Papenfuss, 1937) is the only alga collected from Kayangel Atoll which has not been previously reported from the Micronesian region. The rest of the algae represents an extension of the marine algae previously known from Palau proper or other Micronesian islands (see Tsuda and Wray, 1977).

The prostrate green alga *Microdictyon okamurai* is the dominant alga on the solid calcareous substratum of the barrier reef and on the coral mounds in the lagoon. This species covers about 23% of the consolidated substratum on the northern barrier reef and is equally abundant in the lagoon. *Lobophora variegata* and *Dictyosphaeria cavernosa* are also conspicuous in these same areas.

The calcareous green alga *Halimeda* is abundant in the channel and lagoon areas. Of the 11 species of *Halimeda* collected from this atoll, four species (*H. cylindracea*, *H. incrassata*, *H. simulans*, and *H. stuposa*) inhabit the sandy substratum which makes up the majority of the substrata type within the lagoon. Four species of *Caulerpa* (*C. antoensis*, *C. taxifolia*, *C. urvilliana*, and *C. vickersiae*) also inhabit the sandy areas of the lagoon. The turf community is developed on the coral mounds in the lagoon. *Polysiphonia howei*, *P. scopulorum*, *Jania capillacea*, and *Laurencia majuscula* are the dominant algae comprising the turf.

The small size and shallow depth of Kayangel Lagoon makes this atoll a perfect natural laboratory for distributional and seasonal studies of benthic algae, especially the *Halimeda* species, in a lagoon environment.

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QUALITATIVE ASSESSMENT OF THE ASTEROIDS, ECHINOIDS
AND HOLOTHURIANS IN YAP LAGOON¹

by Deborah A. Grosenbaugh

INTRODUCTION

A limited amount of work has been done on the echinoderm population of Yap. Two previous technical reports (Amesbury et al., 1976, 1977) list 16 echinoderms observed in two localized areas: one at the Donitsch Island sewer outfall site and the other at a proposed dock site in Colonia, Yap.

The only other observations of this group relate to the asteroids. Earlier reports (Hayashi, 1938a, 1938b) mention only Culcita novaeguineae and Fromia monilis as being identified from Yap. Clark (1954) recorded Protoreaster nodosus as also being found there.

During the period of time when Acanthaster planci infestations were a concern throughout the western and central Pacific, several separate surveys were made on Yap. Beginning in July of 1969, Chesher (1969) observed no large populations of A. planci. By late 1970 (Tsuda et al., 1970) two small populations (one consisting of 100 - 150 individuals and another of about 50 starfish) were identified outside of the barrier reef. A subsequent survey in 1971 (Marsh and Tsuda, 1973) noted an apparent increase in A. planci, but they were widely scattered with no obvious major concentrations.

This particular paper provides a qualitative assessment of the asteroid, echinoid, and holothurian populations in the Yap Lagoon, with particular reference to the latter.

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METHOD

The observations made here were done during the course of a general reef survey, conducted during July 9-20, 1977, which covered a major portion of the reef flat in the Yap Lagoon. Most observations were made as a result of towing the observer from a small boat in a zigzag pattern from the seagrass beds near shore to the barrier reef margin. When unusually conspicuous populations of echinoderms (particularly holothurians) were noted, a closer examination was made by snorkeling in the area. Periodically, more detailed observations of randomly chosen areas were made in order to note less conspicuous species.

Two 30-m transects were run in a Thalassia hemprichii bed just east of Bik Island in Tomil Harbor. In this case, all echinoderms 0.5 m on either side of a 30 m-long transect line were enumerated.

RESULTS AND DISCUSSION

Four zonal habitats (seagrass, seagrass-live coral, live coral, and coral pavement) characterize the reef flats in the Yap Lagoon.

The seagrass zone is characterized by thick beds of Thalassia and Enhalus adjacent to shore, becoming patchy and interspersed with live coral heads (predominately Porites) as one progresses out toward the reef margin. This transitional zone is referred to as the seagrass-live coral zone in this paper. As the seagrass becomes less dominant other corals (notably Acropora) along with the Porites form a live coral zone. Near the reef margin, the live corals become replaced by coral pavement. Table 1 lists the various echinoderms found in these four habitats, as well as those found on patch reefs, holes, and channel.

The densest populations of echinoderms on the reef flat occur in the seagrass beds adjacent to land, though not all of the seagrass beds surveyed exhibited obvious numbers of echinoderms. Holothurians in the seagrass beds were either absent, rare (1-2 seen per hour of snorkeling), or unusually abundant.

Table 2 presents the results of the two 30-m long transects (1 m wide) run in the Thalassia bed. Transect A was located adjacent to Tomil Harbor channel and southeast of Bik Island. Transect B was situated just east of the island. The major components in both cases were the echinoid Mespilia globulus and the holothurian Actinopyga echinites. The unusually large numbers of M. globulus present had covered themselves with seagrass detritus. Examination of the stomach contents of 25 M. globulus and four Tripneustes gratilla that were also present, revealed that Thalassia was the only food item ingested. Actinopyga echinites seemed to be feeding primarily on the detritus. In some cases, A. echinites could be seen feeding on the detritus that was attached to

Table 1. Checklist of asteroids, echinoids, and holothurians observed in various reef flat zones and other habitats in Yap Lagoon. (1. seagrass zone, 2. seagrass-live coral zone, 3. live coral zone, 4. coral pavement zone, 5. patch reefs in Tomil, Mil, and Gofenu Harbors, 6. holes in reef flat, 7. Tomil Harbor Channel).

SPECIES	Reef Flat Zones				Other Habitats		
	1	2	3	4	5	6	7
Class Asteroidea							
<u>Acanthaster planci</u> (Linnaeus)					X		
<u>Culcita novaeguineae</u> Müller & Troschel		X		X	X	X	
<u>Echinaster luzonicus</u> (Gray)			X	X			
<u>Fromia milleporella</u> (Lamarck)						X	
<u>Linckia laevigata</u> (Linnaeus)				X			
<u>Linckia multifora</u> (Lamarck)			X				
<u>Protoreaster nodosus</u> (Linnaeus)	X						
Class Echinoidea							
<u>Diadema setosum</u> (Michelin)			X		X	X	
<u>Echinothrix calamaris</u> (Pallas)				X			
<u>Heterocentrotus mammillatus</u> (Linnaeus)				X			
<u>Mespilia globulus</u> (Linnaeus)	X					X	
<u>Tripneustes gratilla</u> (Linnaeus)	X						
Class Holothuroidea							
<u>Actinopyga echinites</u> (Jaeger)	X						
<u>Bohadschia argus</u> Jaeger					X		X
<u>Bohadschia</u> sp.	X						
<u>Holothuria atra</u> Jaeger	X	X		X	X		
<u>Holothuria axiloga</u> Clark							X
<u>Holothuria edulis</u> Lesson	X	X			X	X	
<u>Holothuria hilla</u> Lesson	X						
<u>Holothuria flavomaculata</u> Semper	X	X	X		X	X	
<u>Holothuria leucospilota</u> Brandt		X	X		X	X	
<u>Holothuria nobilis</u> (Selenka)		X					
<u>Stichopus chloronotus</u> Brandt	X	X			X	X	
<u>Stichopus variegatus</u> Semper	X				X		
<u>Thelenota ananas</u> (Jaeger)							X
Unidentified synaptid	X						

M. globulus. Actinopyga echinites exhibited the clumped distribution referred to by Amesbury et al. (1976), being found often in "piles" of five or more in close association. One small dark red holothurian, which the author could not identify, was observed in Transect A.

Table 2. Density of echinoderms along two 30-m long transects (1 m wide) in a Thalassia bed off Bik Island, Tomil Harbor, Yap.

SPECIES	A	B
<u>Actinopyga echinites</u>	164	450
<u>Mespilia globulus</u>	34	245
<u>Holothuria edulis</u>	11	3
<u>Protoreaster nodosus</u>	9	4
<u>Holothuria atra</u>	4	2
<u>Stichopus chloronotus</u>	2	4
<u>Holothuria hilla</u>	1	1
Unidentified holothurian	1	-
<u>Holothuria flavomaculata</u>	-	4
<u>Tripneustes gratilla</u>	-	1

In another Thalassia bed off Pekel Island in Tomil Harbor, Actinopyga echinites was also abundant, exhibiting the same tendency toward clumping that was observed earlier. Also present but not as abundant were Stichopus variegatus and S. chloronotus and a variety of occasionally observed holothurians such as Holothuria hilla, H. atra, and the asteroid Protoreaster nodosus, along with the scyphozoan medusa Cassiopeia sp. Large population densities of H. atra were also noted in an Enteromorpha bed west of Thilimad Island, near the northern tip of Map Island. Only one synaptid was observed during the entire survey, in a seagrass bed off the northeast corner of Map.

As one progresses out toward the reef margin into the seagrass-live coral zone, Holothuria edulis replaces Actinopyga echinites as the predominant holothurian species. Stichopus chloronotus was usually present in this zone, but, as in the seagrass zone, was not particularly common. It was seen mostly in sandy areas between coral beds. Holothuria leucospilota was occasionally seen with the anterior part of its body extended out from under the Porites heads. Other holothurians observed in the seagrass-live coral zone were an occasional Holothuria atra, H. nobilis, and H. flavomaculata. The "cushion starfish" Culcuta novaeguineae was also seen.

In the live coral zone, the asteroids Linckia multifora, Fromia milleporella, and Echinaster luzonicus, along with the echinoid Diadema setosum, were common in among the Acropora, and under Porites heads.

Holothuria leucospilota was seen, as in the seagrass-live coral zone, extending out from under Porites heads, whereas H. flavomaculata was common in close association with stands of Acropora.

In the coral pavement zone out near the reef margin, only an occasional Holothuria atra represented the holothurians. The only other obvious echinoderms were Linckia laevigata and Culcita novaeguineae. The majority of the echinoderms in this zone were found in coral rubble and under rocks. These include an unidentified ophiuroid, Echinaster luzonicus, Echinothrix calamaris, and Heterocentrotus mammillatus.

Besides the general zonation across the reef flat, there exist distinct echinoderm populations in the deep holes that occur on the reef flat, and on patch reefs in the various harbor entrances. The holes are surrounded by a Porites-Acropora type community and the echinoderm fauna corresponds thusly. As the sides of the holes slope downward to a sandy bottom, those holothurians which prefer sandy substrate are seen, e.g., Holothuria edulis and Bohadschia argus.

Patch reefs in the three major harbors (Tomil, Mil, Gofenu) provide a diverse environment for a variety of echinoderms. Sandy areas with some seagrass are interspersed between areas of high coral density. The sandy areas of these reefs include the holothurians Holothuria edulis, H. atra, Stichopus chloronotus, S. variegatus, and Bohadschia argus. The holothurians H. flavomaculata and H. leucospilota were found associated with the corals Acropora and Porites, respectively. The echinoid Diadema setosum and the asteroid Fromia milleporella were found in the coral while Culcita novaeguineae was often observed in sandy patches between corals. On the downward slope of these patch reefs and along channels, the larger detritus-feeding holothurians, i.e., Thelenota ananas, Bohadschia argus, and Holothuria axiologa, were located.

While holothurians of major economic importance were identified within the reef flat (Thelenota ananas, Bohadschia argus, Holothuria nobilis), they were not observed to be present in such quantities that would make their export profitable. The Yapese, themselves, are not overly fond of the delicacy, but the Palauan community of Yap does occasionally utilize the above-mentioned species as a food source as well as Actinopyga echinites which is found in considerable abundance in some of the seagrass areas. Since the Palauan community is situated in the Colonia area, only edible holothurians in the Tomil Harbor area are likely to be harvested because of the strict reef tenure on Yap where the various villages have exclusive fishing rights on designated areas of the reef.

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ACANTHASTER IN THE CULTURES OF HIGH ISLANDS

by

Charles Birkeland^{1/}

Residents of high islands in Micronesia, Melanesia and Polynesia usually have their own special names for *Acanthaster*, each have similar advice on curing the sting of the spines, and each claim that *Acanthaster* has been abundant at certain times in the past. I believe that this familiarity of *Acanthaster* in some high island cultures implies that outbreaks are a naturally recurring phenomenon around high islands. An apparent lack of familiarity of *Acanthaster* in the cultures of atolls implies that outbreaks of *Acanthaster* are much less frequent around atolls (low islands).

In Palau (Micronesia), the *Acanthaster* is called *rrusech* (Birkeland, 1979) while other starfish are called *btuch* or *tengetang*. At Fiji (Melanesia), *Acanthaster* is called *bula* (a homonym of "hello") while the general terms for "starfish" are *gasagasan* or *basage* (Atelaite Smalley, pers. comm.). In the Cook and Society Islands (Polynesia), *Acanthaster* is called *taramea* and in Samoa and Tonga (Polynesia), *Acanthaster* is called *alamea* (Garlovsky and Bergquist, 1970; Birkeland and Randall, 1979; Flanigan and Lamberts, 1981).

In contrast, the languages from atolls appear to not contain terms for *Acanthaster*. There is no special word for *Acanthaster* on Pingelap (Spensin James, pers. comm.); the crown-of-thorns is merely referred to as *isu*, a term used for all starfish. Similarly, *Acanthaster* is called *talwalyol* on Ulithi, a general term for all starfish (Eulalia Harui, pers. comm.). Abo et al. (1976) list 12,000 entries with information on about 30,000 Marshallese words. Many fishes, three groups of sea cucumbers, and other marine organisms are mentioned, but there was no word for *Acanthaster*. It must not be important to the Marshallese.

The Gilbert Islands (Kiribati), the Ellice Islands (Tuvalu) and Fanning Island are all atolls. Lobel (1978) presented a list of 407 names of fishes and 95 names of marine invertebrates used by Gilbertese and Ellice Islanders on Fanning Island, but *Acanthaster* was not listed. These inhabitants of atolls had their own specific names for many species of fishes, mollusks and crustaceans and even distinguished between three groups of holothurians, but all seastars came under one name. *Acanthaster* may have never been abundant on these atolls.

There is an exception from the atoll of Mokil (near Ponape) at which the people do call *Acanthaster* by the name *larmi*. Of course there may be other exceptions. However, there does seem to be a general presence of words for *Acanthaster* in high island languages and an apparent lack of words for *Acanthaster* in low island languages. These tendencies suggest that *Acanthaster* may be more common around high islands.

^{1/}

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Atoll Res. Bull. No. 255: 55-58, 1981.

People from atolls say they rarely, if ever, see *Acanthaster* and they have never heard of them being common (Matuatua Smit, Takapoto Atoll, Tuamotu, French Polynesia; Eulalia Harui, Ulithi, Yap District; Spensin James, Pingelap, Ponape District, pers. comms.). Around high islands, the people remember previous outbreaks. According to local fishermen, there was an outbreak in American Samoa in 1938 (Flanigan and Lamberts 1981). Vine (1970) reported that fishermen in the Solomon Islands (Melanesia) remembered large concentrations of *Acanthaster* about 1930, forty years previous to 1970. Chesher (1969) reported that Micronesians remember an outbreak on Ponape just after World War II.

Michael Parke talked to an old Palauan fisherman who described an extensive infestation that took place just prior to World War II. According to this fisherman, the *Acanthaster* soon disappeared, leaving algae in the place of coral. Then urchins became abundant during the early years of World War II. The fisherman felt that *Acanthaster* were transitory and no real problem. The abundance of urchins that resulted were a benefit. Old people could easily collect them for food within wading depth on the reef flat. We have not heard of other cases of an abundance of urchins following *Acanthaster*. It will be interesting to see if herbivorous urchins become common following the present devastation in Palau. Except for areas around artificial sea walls, breakwaters and ramps, regular urchins are remarkably scarce in Palau at the time of this writing.

The people on high islands tell of dangers of stepping on *Acanthaster* when fishing at night at times when *Acanthaster* is abundant (Vaolui, pers. comm.; Flanigan and Lamberts, 1981). A cure for injury from stepping on *Acanthaster* is claimed by several high island cultures to be their own discovery. When I was studying an *Acanthaster* outbreak in Palau, I accidentally jabbed my knee strongly against an *Acanthaster* and came to the boat with a lot of blood dripping out of six cuts in my knee. The boatman, Ngirbauliad ("Yahd") Mineich, advised me to take one of the *Acanthaster* and place it mouth down on the bloody knee. (This was tried, but was not found to be of great help.) When asked if he heard of this cure from a Samoan or Fijian, Yahd said it has always been common knowledge in Palau. Ramon Rechebei, another Palauan, said that he knew of this cure since he was a boy.

Spensin James told me that this cure had worked for him when he tried it. This cure was common knowledge among Ponapean fishermen and it works if you are sure to use the same individual *Acanthaster* that harmed you as the individual to cure you. If you are jabbed by one *Acanthaster* and lift another to cure your pain, it will be of no use. (I am not sure I used the same individual in Palau.)

Laite Smalley told me that when Fijian fishermen step on *bula* on the reef flat, they turn over the same *bula* and put their food against the mouth so that the *bula* will suck out the poison. She said this was generally known by Fijian fishermen and there is no reason to believe it was learned from the Palauans or Samoans. Maybe the cure was discovered in Fiji.

This same cure has been known on Tonga (Richard Braley, pers. comm.), and as a proverb on Western Samoa (Garlovsky and Bergquist, 1970) and American Samoa (Birkeland and Randall, 1979; Flanigan and Lamberts, 1981).

The Secretariat of the British Solomon Islands Protectorate (1970) noted that this same cure by turning over and stepping on the underside of the *Acanthaster* was known in the Solomon Islands, New Britain, Manus Islands, and Gambier Islands.

The apparent history of recurring abundances of *Acanthaster* around high islands but not around atolls may be explained by the causal mechanism of *Acanthaster* outbreaks as suggested in Birkeland and Randall (1979) and Birkeland (1980). *Acanthaster* larvae may survive in much greater abundance following heavy rainfall. This might be because phytoplankton blooms are triggered by terrestrial runoff and this provides an abundant food source for *Acanthaster* larvae. Terrestrial runoff resulting from rains on high islands trigger phytoplankton blooms (Marsh 1977), but it is doubtful that terrestrial runoffs from low, sandy atolls carry an amount of nutrients into the coastal waters adequate to trigger blooms.

Acknowledgements

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ACANTHASTER AS A RECURRING PHENOMENON IN SAMOAN HISTORY

by John M. Flanigan¹ and Austin E. Lamberts²

Verbal history, linguistic evidence and proverbs indicate that *Acanthaster planci* have been long known and endured in Samoa.

The Crown-of-Thorns starfish (*Acanthaster planci* (L.)) has been known to science since it was described by Rumphius in 1705. Only in the past decade and a half has it stirred popular interest after great numbers of these starfish were reported almost simultaneously from Guam, the Great Barrier reef province of Australia and from other Indo-Pacific coral reef areas. Significantly, this occurred at about the time that face mask and snorkel were becoming standard equipment for visitors to coral reefs.

Recently *Acanthaster* have appeared on the reefs of Tutuila, American Samoa, in impressive numbers. The fact that collection efforts which reportedly netted nearly a half a million starfish have not significantly affected the total number attests to the host of *Acanthaster* (Sesapasaro, 1978). In previous decades this animal was a great rarity locally. Between 1967 and 1973 one of us (JF) encountered only two of these creatures during hundreds of dives on the reefs of Tutuila. Nevertheless, there is evidence that these animals have occurred in great numbers in the past.

The specificity with which objects in the Samoan environment are named bears a relationship to the importance of those objects in the culture. Thus, Samoans have a single word to refer to all types of branching corals ('amu) but distinctive word for the less conspicuous massive coral (puga) and flat coral (lapa) used for burning to make lime. The language also has a single word for nearly all starfish (aveau) but *Acanthaster* alone has the highly specific name of *alamea*. It is noteworthy that a similar word, *taramea* is used for *Acanthaster* in the Polynesian Cook and Society Islands even though there had been

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no apparent contact between these subcultures for centuries before they were rediscovered. (The cushion starfish *Culcita* has a specific name, *pālutu*, but the Samoans do not recognize it as a starfish.)

Additional indication that *Acanthaster* have occurred previously in great numbers is provided by Samoan proverbs that mention it. "*E fofō e le alamea lana sale*" or "*E fofō e le alamea le alamea*" meaning "the alamea is its own doctor," or "*falau a alamea*" meaning "cure of the alamea" refers to the belief held throughout the tropical Pacific that the excruciating pain caused by the sting of the spines of the *Acanthaster* is relieved by placing the mouth of the same animal against the wound (Herman, 1953). One of us (AEL) missed an opportunity to confirm the efficacy of this treatment when he was stung by an *Acanthaster* before hearing of the purported cure. One would expect that an animal would enter a culture's folklore only if its nature was very familiar to generations of members of that culture. It seems probable that the sting of the alamea has been known and respected by generations of Samoan fishermen.

Several Samoan fishermen, all over fifty years old reported to one of us (AEL) that in their youth there were huge numbers of alamea on the reefs of Nu'uuli and Aua, Tutuila and that all of them disappeared quite suddenly. Mary Prichard, an astute and perceptive Samoan lady of 75 recalls this vividly and dates the infestation to about 1938. She was an avid shell collector even before this but insists that she saw not a single *Acanthaster* in the intervening years. The *Acanthaster* appeared in large numbers on several reefs, were present for a time, then were not seen again until recently.

Similarly, one of us (JF) interviewed an elderly fisherman in the village of Suano, Upalu, Western Samoa and was told that perhaps forty years before, when the man was young, so many alamea appeared on the reef fronting the village that it could no longer be fished in safety. (Typically, "fishing" refers to an activity involving deep wading or swimming near the reef edge by pushing from one coral head to another with the feet.) Reportedly there were so many alamea that a fisherman could not stand on the reef without stepping on one. Consequently, fishing was done at a more distant reef. Presumably, such numbers of *Acanthaster* would cause extensive damage to living corals, yet when visited by the author, the same reefs were found to be 90% to 100% covered with healthy corals. These reports tend to confirm the hypothesis that *Acanthaster* infestations are a recurring phenomenon, and that the resulting reef damage is temporary and of no lasting consequence.

Generations of Samoans have modified their fishing habits to accommodate periodic infestations of alamea. Samoan fishermen seem less concerned about a new infestation than non-natives who view with alarm from a background richer in formal education and concern for the environment but poorer in traditional knowledge and experience.

Our first priority in the study of increases in the numbers of *Acanthaster* should be to ask the people who have lived with the reefs

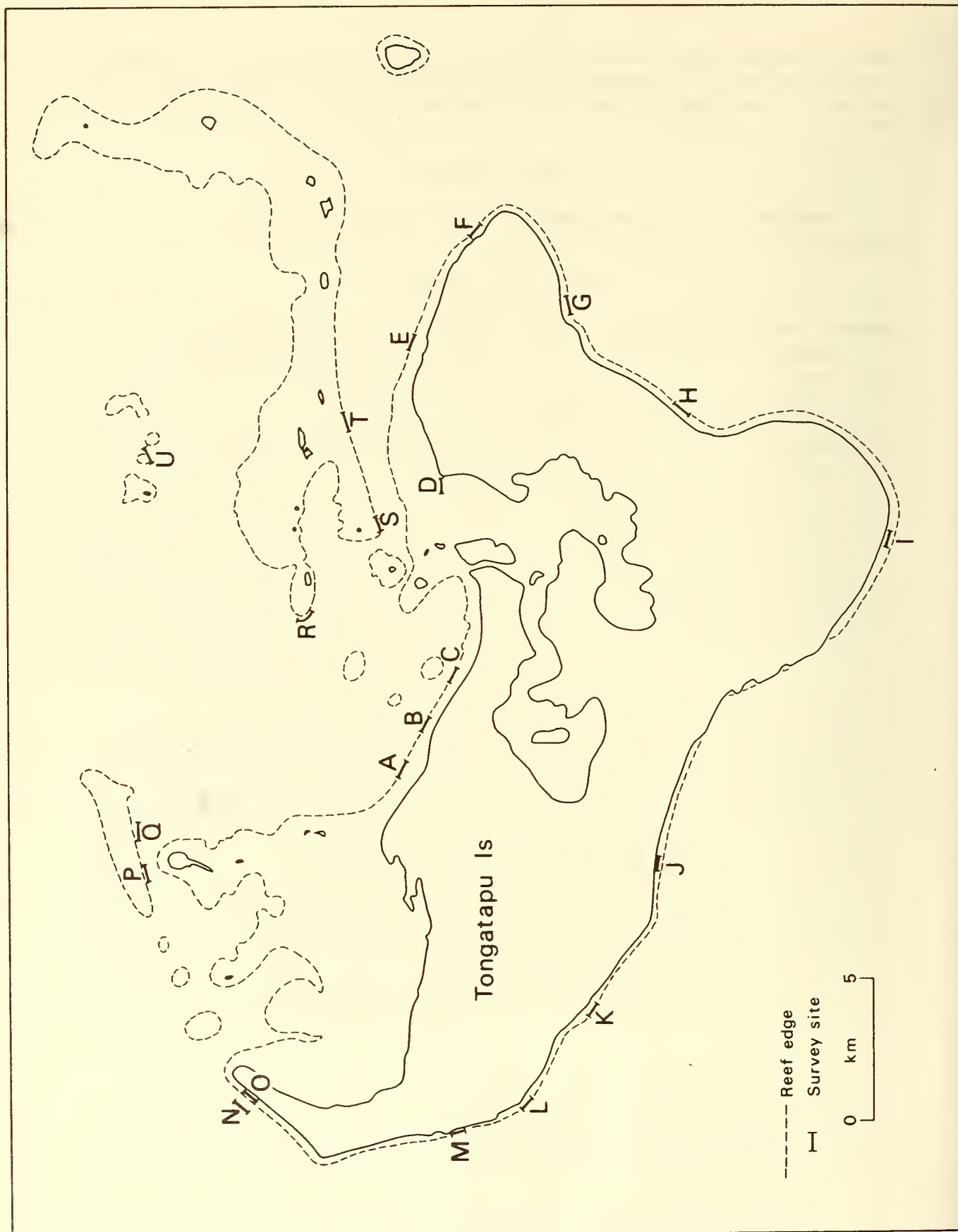
for the longest time, and to study the natural history of the affected reefs with particular emphasis on the stages of coral damage, its ecological implications, and the progressive stages of succession during the recovery of the reef corals.

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DISTRIBUTION AND ABUNDANCE OF THE CROWN-OF-THORNS STARFISH
(*ACANTHASTER PLANCI*) AROUND TONGATAPU ISLAND, TONGA

by M.P. Francis¹

Introduction

Acanthaster planci infestations have been reported from many locations in the South Pacific Ocean but Tonga has attracted little attention because of its isolation. During six man-days of searching Weber and Woodhead (1970) found *Acanthaster* "rare to common" on Tongatapu Island where "common" was defined as 6 to 25 starfish observed per man-day. Endean and Chesher (1973) cite personal communication with the Tongan Department of Agriculture in 1970 regarding a proposed *Acanthaster* control programme. The programme, however, never proceeded. The present survey covers the situation six years later.

Method

The coastline and several reefs to the north of Tongatapu were surveyed between 16.4.76 and 16.6.76 by snorkel diving (see Figure 1). Survey site N was searched at depths between ten and twenty metres using SCUBA equipment. All observed starfish were recorded and intensive searches were made in the immediate vicinity of any feeding scars. At each site a subjective estimate was made of the abundance of live hard corals.

Tongatapu Island is surrounded by a wide shallow fringing reef. On all but the northern (sheltered) side of the island the reef edge is raised to form a barrier one to two metres above the level of the reef flat. Prevailing south-easterly winds hindered searches outside this barrier, and survey sites F to M were therefore situated on the reef flat.

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Results

Survey Site	Live Coral Abundance	<i>Acanthaster</i> ¹ Relative Abundance
A	Abundant	0
B	Common	0
C	Rare	0
D	Absent	0
E	Abundant	0.5
F	Common	0
G	Rare	0
H	Rare	0
I	Rare	0
J	Rare	0
K	Absent	0
L	Rare	0
M	Common	0
N	Common (10-20 m depth)	3.0
O	Common	5.3
P	Rare	0
Q	Common	0.5
R	Rare	0
S	Abundant	0.7
T	Common	0.7
U	Common	0

¹Relative abundance is the number of starfish seen per twenty minutes searching (see Pearson and Endean, 1969).

Discussion

No *Acanthaster* were found on the coast exposed to the prevailing winds (sites F to M). Coral growth is inhibited inside the barrier by exposure to air at low tide, and outside the barrier by heavy surge. The reef outside the barrier drops slowly to a shelf at ten metres, but live coral is stunted and scattered above this depth. *Acanthaster* may occur at greater depths. The absence of *Acanthaster* from exposed reefs, and their preference for sheltered reefs, is consistent with the observations of Dana, Newman and Fager (1972) who found the starfish usually associated with "leeward seaward reefs" and "areas of moderate to luxuriant coral growth".

More than 70% of the sites examined had no *Acanthaster* and the maximum relative abundance was 5.3. Pearson and Endean (1969) consider a relative abundance less than ten to constitute a normal population. By this definition Tongatapu has normal numbers of the starfish, and the presence of luxurious growths of *Acropora hyacinthus* and *Porites* spp. in sheltered areas suggests there has been no infestation in recent years.

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RATS AS AVIAN PREDATORS: DISCUSSION

by W.R.P. Bourne¹

Since F.I. Norman concludes at the end of a review of the role of "The murine rodents *Rattus rattus*, *exulans* and *norvegicus* as avian predators" (Atoll Research Bulletin No. 182, 1975) that "it appears that the rats' role as an avian predator has been overestimated... the basic facts should be established before widespread control campaigns are undertaken", and this conclusion may be used as an argument for procrastinating over such campaigns, it should perhaps be made clear that many people have no doubt at all about the harm caused to birds by rats, and will refuse to accept such a cautious conclusion for a moment.

The situation is of course complicated, and the literature relating to it vast. Rats were introduced to many sites where the worst damage has occurred long ago, before reliable witnesses arrived, and those that were present commonly reacted by introducing cats, owls or other predators, which confused the picture. Rats do most of their work by night, and since it only takes them a few seconds to remove an egg or bird it may be hard to obtain direct evidence of their activities. They are inveterate scavengers, and may take abandoned eggs or birds which died of other causes. The extent to which they prey on other animals may vary with the relative size and numbers of the rat and its prey, the availability of alternative foods, and the occurrence of a seasonal climatic regime liable to lead to restrictions on the food-supply available to the rats at some seasons which limits the numbers able to act as predators when birds are present at other seasons. Their activities may also affect the ecology of other species indirectly, by competition for food, or through damage to the habitat, for example by eating the roots of tussock grass on subantarctic islands. It is dangerous to make facile generalisations about the situation except to say that a legion of witnesses have now reported for centuries that their presence has almost invariably been considered harmful.

The situation may be illustrated by taking a few examples:-

1. An exceptionally rich marine avifauna breeding on Amsterdam Island in the southern Indian Ocean may have been partly exterminated by hogs and cats at the beginning of the last century, but most of the surviving bones were found in rat-holes (C. Jouanin and P. Paulian, Proc. XII Intern. Orn. Congr. 368-372, 1960).

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Atoll Res. Bull. No. 255: 69-72, 1981.

2. Five native birds, *Gerygone insularis*, *Rhipidura cervina*, *Zosterops strenua*, *Apolonis fuscus hullianus*, and *Turdus xanthopus vinitinctus* disappeared from Lord Howe Island within twenty years of the arrival of *Rattus rattus* in 1918 (see especially a symposium on the island in Australian Natural History 18(2) for June 1974).

3. The havoc caused by rats among both land and sea birds in the New Zealand area is documented by a series of contributions from the Wildlife Service and Royal Bird and Forest Society to the forthcoming Proceedings of the XVI World Conference of the International Council for Bird Preservation. Norman is wrong in identifying the muttonbird virtually exterminated on Stewart Island as *Puffinus tenuirostris* since it was *Puffinus griseus*; the endemic Southern Saddleback *Philesturnus c. carunculatus* which he mentions was threatened when *Rattus rattus* reached the outer islets in 1964 was only saved by emergency transplantations elsewhere, while the local race of bush wren *Xenicus longipes variabilis* and snipe *Coenocorypha aucklandica iredalei* may have been lost entirely.

4. While the petrels *Pterodroma cahow* and *Puffinus lherminieri* do appear to have been eliminated from the main Bermuda islands and confined to outliers by the activities of rats among other predators, and rats may take occasional tropic-bird *Phaethon lepturus* eggs there, this exceptionally aggressive species has in fact managed to hold its own in the face of attacks by not only rats and cats but tens of thousands of people. Norman quotes R.C. Murphy (Oceanic Birds of South America, 1936) incorrectly in attributing the rat predation to *Rattus exulans*, since this was in fact a repetition of the original report by Gross (Auk 29:49-71, 1912) that he had seen one egg taken by *Rattus rattus*. *Rattus exulans* does not occur in the North Atlantic.

5. The impact of rats on birds in the British Isles is extremely variable. They are important predators on many species but especially those nesting on the ground inland where rat numbers are high, though it is not always easy to distinguish their work from that of other small mammals. They exterminate storm petrels wherever they go, but their impact on larger burrow-nesting birds varies. They exterminated a large Puffin *Fratercula arctica* colony on St Tudwal's Islands, North Wales, and severely reduced their numbers on Lundy, Puffin Island (also north Wales), and Ailsa Craig without exterminating them, whereas a large colony long continued to flourish in the presence of rats on the Shiant Islands. They exterminated the Manx Shearwater *Puffinus puffinus* at its type locality on the Calf of Man, and it only recolonised when they were controlled by poisoning. Small numbers survive in the presence of rats at a number of other sites, a larger colony suffers severely from predation in some years but not others on Canna, and a vast one in the hills of Rhum appears to escape it. Terns suffer severely in areas heavily infested with rats but may escape their attention elsewhere (references for some of these sites will be found in S. Cramp, W.R.P. Bourne and D. Saunders, "The Seabirds of Britain and Ireland", 1974).

The situation appears to have been particularly bad on many oceanic islands because there were no natural predators or inclement seasons to control the numbers of introduced rats, and the native wildlife had no innate defences against them. The petrels which bred there were particularly vulnerable because they leave their small, defenceless chicks alone in their burrows by day soon after they hatch. It will be noted that while Norman found that rats took the unguarded eggs of Short-tailed Shearwaters *Puffinus tenuirostris* but avoided encounters with the large, aggressive adults (J. Zool. 162:493-503, 1970) he did not investigate what occurred when the rats encountered small chicks. While the situation may often have been made worse by the introduction of alien predators in an attempt to control rats, there is an obvious correlation between a decline of the smaller and more defenceless seabirds in historic times and the introduction of rats throughout the world. However, I agree that it remains difficult to assess the full amount of harm they have caused because it is impossible to say how many insular landbirds they have exterminated as well. A rat may only need to eat two or three eggs or chicks a year to cause serious damage, whatever it eats the rest of the time.



LAYARD'S BIRD HUNTING VISIT TO TROMELIN OR SANDY
ISLAND IN DECEMBER 1856

by R.K. Brooke¹

This paper concerns the only known visit by a biologist to Tromelin Island in the XIX century.

That Edgar Leopold Layard, the Curator of the South African Museum, Cape Town, travelled as naturalist on the British Royal Navy survey ship H.M.S. *Castor* on a journey in the southern Indian Ocean in 1856 and 1857 was scarcely known at all until Brooke (1976) commented on some aspects of the journey and the bird records made on it. Subsequently Brooke (1978) reported on those birds' eggs collected on this journey which still survive in the South African Museum. He also deduced the approximate route and timing of the journey from the species collected, their known breeding seasons and migrations. As will appear below, these deductions were close to the truth. Since then I have had cause to examine in the South African Library, Cape Town, a run of the *Cape Monthly Magazine* (Series 1) published in Cape Town between 1857 and 1862. This magazine attempted to cater to the interests of the more educated residents of British stock by publishing scientific, philosophical and literary material.

In volume I of the *Magazine* the editors caused to appear on pp. 252 - 254 a notice entitled "Mr. Layard's cruise in the "*Castor*". From this we learn that H.M.S. *Castor* left Simonstown on 10 October, 1856 under sail under the command of Commodore H.D. Trotter. They intended to land first at Rodriguez but extensive fog persuaded them to head for Mauritius where they spent five weeks and made several trips to nearby Round Island. Sandy Island as Tromelin Island was then often known (Staub 1970) and the focus of this paper was the next landfall (presumably in early December 1856). Then Farquhar Island was visited prior to reaching Africa at Fazi Island, Kenya, on 4 January 1857. Thereafter, Lamu, Melinda, Kisilundini, Zanzibar, Cabo Delgado and Dibo were visited before they put out to sea for a crossing to northwestern Madagascar via the St Lazarus bank and the Comoro Islands. Anjouan was reached on 1 February and a few days later a visit was made to Moheli. Two days were spent in Madagascar at Boyana Bay at a Jesuit Mission before recrossing the Mozambique Channel to Mozambique Town. After a substantial visit they set sail for home via Durban (departed 13 March), East London, Port Elizabeth (departed 19 March) and so back to Simonstown on 25 March 1857.

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This paper is part of the commemoration of the 21st anniversary of the establishment of the Percy FitzPatrick Institute of African Ornithology

Layard promised to write a full account of his journey and his collections for the *Magazine* but he did not do so, probably through pressure of work: he was only the part-time curator of the Museum being a nearly full-time civil servant as well. However, in 1858 in vol. III, pp. 289 - 296, appeared the following from Layard's pen:

SCRAPS FROM THE NOTE-BOOK OF A NATURALIST

SPORT ON SANDY ISLAND

BY E.L. LAYARD

"LAND, HO!" hailed the look-out man from the foretopsail yard of Her Majesty's ship *Castor*, as one lovely morning the Commodore and myself paced the deck of the good old frigate.

"Whither away?" went up the responsive query from the midshipman of the deck, who, stepping up to the officer of the watch and touching his gold-banded cap, reported the fact. In his turn, the officer reported to the Commodore; and, after a few questions, the order was given to head the vessel to the land, and we resumed our walk.

The low shores of the island now became visible, and the clear blue sky was dotted with birds, winging their way to and fro; some plunging headlong into the rippling water, that vied in the intensity of its azure with the sky above it, sought their finny prey, some returned to their nests heavy laden with food for their young, while others floated contentedly on the gently heaving bosom of the sea, or rose lazily out of the path of the frigate, as she majestically ploughed her way along, her white sails gleaming in the bright sunlight. One by one the studding-sails came home, and the noble ship cautiously felt her way to the rapidly rising land; and now, while the boats are told off, we descend to have a last look at *Horsburgh's Directory*, for landing instructions, hidden dangers, currents, etc.

For the benefit of such of my readers (and I suppose they are numerous) who do not know where Sandy Island lies, I transcribe the account given by the great hydrographer of its position and appearance:-

"Sandy Island, or L'Isle de Sable, in latitude 15° 52' S., longitude 54° 40' E., is a flat, sandy spot, about fifteen feet above water, half a mile long, from N.N.W. to S.S.E., and about a quarter of a mile broad, having a sand-bank projecting three quarters of a mile towards the S.S.E. It was discovered by the ship *La Diane*, in 1722, and in 1761, the *Flute l'Utile* was wrecked there."

After the men had got their dinners, the boats were reported ready, and the first cutter, attended by the dinghy to assist in landing, were soon off from the ship's side, well furnished with baskets, guns and ammunition, harpoons, fishing-lines, etc. The vessel had stood up as near the island as the light breeze permitted with safety, and on quitting her, she tacked and stood off, the Commodore trying for soundings (though finding none with one hundred fathoms of line), and practising reefing topsails and other manoeuvres, to exercise the men. The boats pulled cheerily along, the men eager for a run on shore and a supper of turtle steaks, the sportsmen anticipating no end of sport, and myself luxuriating in the idea of visiting the breeding place of the countless frigate birds, gannets, terns, and other birds that now filled the air with their piercing cries, and darkened the sky over the island.

As we reached the coveted shore, the water suddenly changed from blue to green, and presently the surf line showed itself, thundering on the sandy beach. The dinghy being signalized to pilot the way, the two Kroomen who rowed her, amphibious fellows equally at home in the water as on the land, urged their frail skiff in advance, and we soon descried a spit of land, under the lee of which the water lay comparatively smooth, and there we determined upon effecting a landing.

The dinghy soon lay high and dry; but our attention in the cutter was diverted by a tempting object that floated on the calm water, a few dozen yards ahead, and which we all, at once, and with an instinct worthy of city aldermen, knew to be turtle soup in its raw material. An old whaleman now crept forward to the bows and drew out the glittering harpoon, the boat's crew pulled noiselessly, the officer in charge gave his orders in whispers, and we stole on our prey. "Ah! old fellow, how many basins of soup will you make?" was in many a mind, and "What a splendid shell for the Museum," in *one* at least. Look at the harpooner, he stands upright, one foot on the gunwale, the barbed weapon poised; half-a-dozen strokes and he is — No, not a bit of it, — wide-awake is Master Turtle; and without a ripple, down sunk the huge bowl of soup and we saw him no more.

Disappointed with the failure of our first essay in turtle-catching, we turned our boat's head to the shore, and pulled in, avoiding with sailor's skill the huge rollers that ever and anon broke in masses of white foam on the beach. We ran in on the top of a wave, backed and let it break, and then pulled in. Out jumped the men who were appointed to run the boat up, and to our dismay, though only a few yards from the dinghy, our fellows found no bottom. Before they could recover the confusion into which this untoward accident threw them, and the men in the boat had recovered their oars, a huge surf broke right over us, washing two men out of the boat and throwing her on her beam ends. I held on to the guns and the benches, the rest made ready to spring out at a favorable moment; fortunately, the next wave had a "long-shore" course, and though it threw us about like a nut-shell, it drove us

into shallow water. The men still clinging to the gunwale found footing; the rest of the crew sprang out, and the next moment saw us in safety, though at the expense of a good ducking, and, on my part at least, not being a swimmer, of a good fright.

After wiping our guns and spreading our superfluous clothing on the sand to dry, we walked up to what we at once saw to be the remains of a human habitation. We found the ruins of a hut, which had contained three rooms; in the largest was a square enclosure of blackened stones, which had formerly served for a fire-place; but which now held the nests of three or four noddies (*Anous Stolidus*), who, utterly heedless of our approach, pecked furiously at our hands when we attempted to possess ourselves of their lovely spotted eggs. We found the nests of these birds in every hole and corner of the ruins; they had taken possession of every stone, and while the male bird sat perched on the top, the female covered her solitary egg by the side in a depression in the soil, lined with a few seaweeds. The eggs were beautifully spotted with patches of various shades of a light purple on a delicate cream-colored ground. An average sized egg measured two inches by one and a half inches; but hardly two were of the same size, or colored alike; still, a practiced eye could at once separate them from that of *Onychoprion Fuliginosus*, which we found breeding on another part of the same island.

From the ruins, we walked to the east side of the island, which appeared covered with bushes about the height of a man's head. Up to this time, the frigate birds had kept well out of range; but now a rustling sound was heard above us, like the falling of some heavy body through the air, and glancing upward, I saw a frigate bird darting down as if to attack us. As he swept past, I leveled my gun at him, fired, and he rolled over; and now the guns had plenty of work, for the birds poured down, and the ground was soon strewn with dead and dying.

How many of the wished-for birds we might have slain, I know not, when one of the men called out, "Hold hard, sir, — don't shoot any more, — here they sit by scores on their nests." And now the truth flashed on my mind, — we had intruded on their "rookery," and the poor birds had lost their lives in their vain attempts to intimidate the two-legged monsters that had suddenly disturbed their domestic privacy. Eager to possess myself of their eggs, I dislodged bird after bird from her nest, by the aid of a long stick, — to approach one's hand, was the sure precursor of a severe bite. Every one, almost, had a callow nestling under her maternal wing; and I obtained but few eggs in a fit state for blowing.

The Tars, who roamed about, found one place where the incubation seemed not so far advanced, probably the nursery of the new-married and inexperienced couples. Jack seized the prize, and though the eggs were in most instances sat upon, they were all devoured: so much for taste! I heard one fellow say to his chum,

as he gulped one down, "Dang it, Ned, there was a bone in that un."

The frigate birds (*Attagen Ariel* and *A. ,*) and the gannets, of which there were three species, — *Sula Fasciata*, *S. Personata*, *S. Fusca*, bred side by side, in patches. Their nests were huge structures of sea-weed, dung, and fishbones, their stratified appearance testifying that each successive year added to their size. The stench from this spot was dreadful, the ground being strewn with the debris of fish and young birds. I could not account for the numbers of the latter, till I saw a huge red and hairy hermit crab (*Pagurus*), inhabiting the dead shells of a large Turbo, which lay scattered in great abundance on the ground, deliberately descending the trunk of one of the bushes, with a writhing squab in his claws. I then saw that the branches were full of these cannibals, mostly laden with fish stolen from beside the nests. I presume, the robbers only occasionally manage the more dainty morsel of a tender chick, secured when the mother is absent from the nest, though doubtless sufficiently often to keep in check the rapid growth of the birds, — robbers in their turn, for from the mouth of one I shot was disgorged no less than seventeen fish, from three to nine inches long.

After forcing our way through the bushes, we emerged on the side of the island, opposite to that on which we landed, and found a reef, or ledge of coral and rock, extending along the shore, at the outer edge of which the surf broke in fearful splendour.

A hail from one of the men in advance, and the clustering of the lads as they reached the spot, induced us, who were leisurely advancing with prying eyes, to hasten our steps. We found, on arriving at the scene, that the men were busily engaged in examining two or three heavy iron guns, that lay half buried and jammed in between the rocks, and to seaward lay the timber of a vessel, with her huge anchor still with one fluke in the reef. These, then, were the remains of the ill-fated *L'Utile*, the French man-of-war alluded to by Horsburgh: the house now tenanted by the wandering sea-fowl had been the home of the survivors during their long imprisonment on this speck in the ocean; the fire-place in the large room had witnessed the gay laugh of the thoughtless, the bitter gloom of the despairing, and the high and manly thoughts of the undaunted and brave, each, perhaps, in his own way, pondering over the means of escape, or the question of to-morrow's food. The commander sat in the little room, overlooking the remains of his lost vessel: the officers crowded in the other room, and thought of those loved ones they might never see again; and now, how many of that band of men survived? Not one! and the place of their long sojourn would never again hear the sound of their voices.

We pushed onward to the northern end of the island, and crossed an open plain that lay between the bushes and a high bank of rolled stones, cast up by the storms of ages on that end of the

island. In the centre of this plain, we came upon a circle of stones, placed round a spot, whose vivid green attested to the presence of water beneath: this was the place from whence the shipwrecked men drew their supplies. Near this spot we could hardly tread for young terns (*Anous Stolidus*) and eggs, and on turning over a stone, out sprang two mice; another and another followed from every stone moved, the place literally swarmed with them. They had probably come in the French ship, and had peopled the island. How to account for the presence of the vast quantities of huge black ants, that ran their galleries in all directions under the sward, was a more difficult matter; as also was the advent of a lizard (Gecko) that I captured, but which subsequently made his escape.

Advancing a few yards from this spot, we entered on the domains of another species of tern (*Onychoprion Fuliginosus*), of which we were first made aware by the fearless birds striking at our faces with their sharp pointed bills. As in the other places, we had not seen a single nest of this species, so now we saw not a nest or specimen of *A. Stolidus*. The noise of the congregated numbers was so great that we could barely hear the shouts of our nearest neighbor, and I was glad to escape over the high ridge of stones and gain the quiet of the dashing surf.

This is evidently the stormy side of the island, and the direction of the prevailing wind. The whole shore consisted of large rolled stones; not one of which possessed an angle; all as smooth as a cobbler's lap-stone, they irresistibly brought to mind hundreds of jolly Crispins busily tapping soles and welts. Here we found another wreck — a huge tree; from whence had this floated? Madagascar probably, and was the ark in which had come the ants, and the gecko; so are those ocean dots peopled.

Turning from the scene of speculation, we wended our way back to our boats along a broad road, cleared of every stone, and nicely smoothed. For what could the poor refugees have constructed this road? Perhaps their commander, a wise man, reflecting that idleness excited gloomy thoughts in such situations, had set his men to work to clear this road, to convey — what? Firewood from shipwrecked trees, stones thrown up by the waves to build their house, — what! as a carriage road it had certainly been used, for we found the broken wheel of a cannonade lying on a heap of stones.

While walking here, I had given my gun to the Chaplain, who wanted to try his hand at a shot. He had fired once and unsuccessfully, at an oyster catcher (*Hoematopus*); and now to my vexation, I saw a new lovely snow white bird, much resembling a tern, slowly passing him. "New bird!" I shouted; "shoot, parson, shoot!" Alas, my friend was a better hand with his Hebrew books than with Westley Richards, and that eminent individual's death-dealing tubes were leveled in vain at the lovely stranger. To the bright flash and loud report, the snowy creature made a

graceful stoop, like a damsel in white muslin at an invitation to dance, and it floated over our heads and looked us full in our faces with its large black eyes. I was frantic: eagerly I crammed in a charge of powder; but alas, no shot had I, my *fidus achates*, "Ned," and "curio-man's Jack," as the sailors had dubbed him and me, was off to the boats with my pouch. But help was at hand, — the crack-shot of the ship, Lt. -----, was hastening to the scene, attracted by my shouts and vain attempts to knock the bird over with stones. Seeing another of the queer monsters running up, my white friend turned away, and was winging his course sea-ward. Oh agony! only known to the naturalist, who sees a new species slip away from his grasp. Inwardly, I resolved never more to trust my "shooting-iron" out of my hand on these unknown coasts. The white vision took another turn this time, land-ward — "run, run! — new bird! — long shot! — ah, my beauty, the parson does not hold that steady barrel: a deadlier eye is measuring the distance which you will fly over, ere the leaden messengers will reach you." And now, the sharp flash! — plump down falls the hapless bird. The reverberating report reaches my ears, and I dashed forward and the prize is mine; and oh, how beautiful the pure white plumage, without a speck, save the one pink spot on the breast, from whence oozed the ebbing life blood, the brilliant blue bill and the large dark eye now closing in death! And now, *quam mutatus ab illo!* its dry and shriveled skin and blackened bill grace the cases of the Museum, — a mockery of life; a burlesque on the loveliest bird I think I ever saw. Reader, you may see it labeled *Gygis Candida*.

The eggs of the *Onychoprion Fuliginosus* are rather larger than those of *A. Stolidus*, being about 2 inches and 2 lines long, by 1 inch and 7 lines broad, and more thickly dotted with smaller dots at the obtuse end. They are also generally darker, and may easily be distinguished by any one who has ever taken the two, though a written description would suit for either species.

The eggs of the frigate birds, *Attagen Ariel* and *A.* , are very similar in size and shape to those of the gannets; but are smoother and thinner in texture, and free from the thick incrustation of lime which at once distinguishes those of the latter. They are both pure white when fresh laid; but get sadly soiled amidst the filth in which they lie. They measure about 2 inches 7 lines long, by 1 inch 9 lines broad.

Just as we commenced our arrangements for the night, the old frigate which had been working up for the island, suddenly backed her topsails, ran up her recall flag, and fired a gun. Jumping into the dinghy, I went on board to ascertain the reason of this change of plan, while the cutter was launched and preparations made to return, if the recall should prove general.

"What sport?" shouted the Commadore, as we got within hailing distance. "Glorious!" was my reply. "What likelihood of turtle?" was the next question. "Very little! no marks on the

land of the breeding ones." The little dinghy shot under the tall sides of the ship, when again thundered her signal gun, and the cutter's recall, in lanterns, ran up to her mast-head; and just as total darkness fell on us, the cutter dashed along side, and in another moment was swinging at her davits; the old ship filled her sails, bowed to the night breeze, and we stood off from the island.

"I don't like the current hearabout," said the Commadore, as I finished my narration of our afternoon's adventure. "We must not lay the *Castor's* bones alongside those of *L'Utile*."."

The rest of what Layard did, collected or saw on that journey is lost save for the fragmentary allusions in his 1863 paper, his 1867 book (brought together in Brooke 1976) and what little can be learnt from the surviving eggs discussed in Brooke (1978).

It is possible now to present a picture of the bird life on Tromelin Island as it was in December 1856, 98 years before Brygoo's (1955) visit, believed to be the first ornithological visitor by Staub (1970). As Mr. A.S. Cheke has pointed out (in litt.) Brooke (1976, 1978) was mistaken in assuming that Layard's Sandy Island was the Sandy Island off Rodriguez. The Rodriguez records in those publications were all made on Tromelin Island (Layard 1858).

Sula dactylatra: a youngster and adults brought back to Cape Town (Brooke 1976), young in the nest (Layard 1858 sub nom. *S. personata*). It still breeds here (Staub 1970). The nest site fidelity described by Layard should be noted.

Sula sula: a pair and two youngsters brought back to Cape Town (Brooke 1976), young in the nest (Layard 1858 sub nom. *S. fasciata* for normal birds and *S. fusca* for dark phase birds). I know of no other usage of *S. fasciata*, let alone who proposed the name if, indeed, it is not just a misconception in Layard's mind. It still breeds here (Staub 1970).

Fregata ariel: adults collected, most nests held young but a few held eggs, usually well incubated (Layard 1858). Staub (1970) is uncertain whether it still breeds on Tromelin.

Fregata minor: as for *F. ariel* (Layard 1858). It still breeds here (Staub 1970).

Haematopus ostralegus: shot at but missed (Layard 1858). Not recorded on any Indian Ocean island by Watson et al. (1963) and there are no subsequent records (A.S. Cheke in litt.).

Larus cirrocephalus: an adult brought back to Cape Town (Brooke 1976). He gives reasons for not rejecting the record even though the specimen

no longer survives and there are no later records. Presumably it was a vagrant from Madagascar nearly 400 km to the west.

Sterna fuscata: eggs collected (Layard 1858 sub nom. *Onychoprion fuliginosus*). Not recorded by Staub (1970) whose visit was in late August when the birds would not have been breeding.

Sterna dougallii: Staub (1970) suggests that the terns described by Morris (1964) as "with light grey mantles and black crowns" were this species. They might equally have been *S. bergii thalassina* since no indication of size is given. Layard (1858) makes no suggestion that either species was present during his visit.

Gygis alba: an adult brought back to Cape Town (Brooke 1976). It does not appear from Layard (1858) sub nom. *Gygis candida* that it was breeding at the time of his visit. Not recorded by Staub (1970).

Anous stolidus: a youngster and adults brought back to Cape Town (Brooke 1976) as well as eggs (Brooke 1978). They had both eggs and young in their nests (Layard 1858). Not recorded by Staub (1970).

Anous tenuirostris: adults brought back to Cape Town (Brooke 1976) but it does not appear from Layard (1858) that he realised that two species of *Anous* were present. Not recorded by Staub (1970).

As for the fauna other than birds it appears from Layard (1858) that *Mus musculus* was by then well established and it has remained so (Staub 1970). Layard's belief that they had come from the wrecked *L'Utile* is likely enough. He does not mention *Rattus norvegicus*, the other well established rodent noted by Staub. Hermit crabs *Pagurus* sp. were common both in the 1850s and 1950s: Layard's remarks on their predation on the young of *Sula dactylatra* should be noted. Layard's gecko (Reptilia, Gekkonidae) was probably, as he said, a drifted vagrant since there is no mention of lizards in Staub. I am unable to equate Layard's (1858) "huge black ants" with Skaife's (1953) description of *Pheidole megacephala*, the only ant recorded by Staub (1970).

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A SUBMERSIBLE, RECHARGEABLE, ELECTRIC DRILL

by W. H. Easton¹

Abstract

A light weight, cordless, rechargeable, electric hand drill mounted in a submersible plastic case is linked by a shaft through the housing to an external bit extension. Tungsten carbide masonry bits or small diamond core drills can be attached to the end of the bit extension without opening the underwater housing. The assemblage has been used to set survey points used in measuring shoreline erosion and to take core samples for radiometric dating and for determining growth rates of corals by X-radiography. Other applications have been suggested.

Design

The prototype model (Figure 1) was designed to accommodate the smallest rechargeable drill in order to reduce weight and volume taken on flights to distant islands. A submersible housing was constructed of 3/8" and 1/2" acrylic plastic to fit two inter-changeable models of drills — the Craftsman Rechargeable 1/4" Model No. 135.111100, and Skilshop Model 1702 Type 1 Cordless 1/4" Reversing Drill. The assemblage weighs 3 kg (6.7 lbs) and will float. General information and materials used in the construction of plastic housings can be obtained from hobby shops, plastics salesrooms, and Toggweiler (1970). Prefabricated control glands with O-rings, and levers, shafts, and stud retainers with studs and nylon wing nuts for closing housings are available from some dive shops and Toggweiler.

A few special requirements must be met in designing the apparatus. The acrylic plate in front of the drill chuck must be at a right angle to the axis of the chuck, because the control gland containing an O-ring through which the shaft of the bit extension passes also must be aligned perfectly with the axis of the chuck after the gland has been cemented to the front plate of the housing. The rear of the drill case must just touch the inner surface of the rear plate of the housing so that a thrust applied to the housing by the operator will

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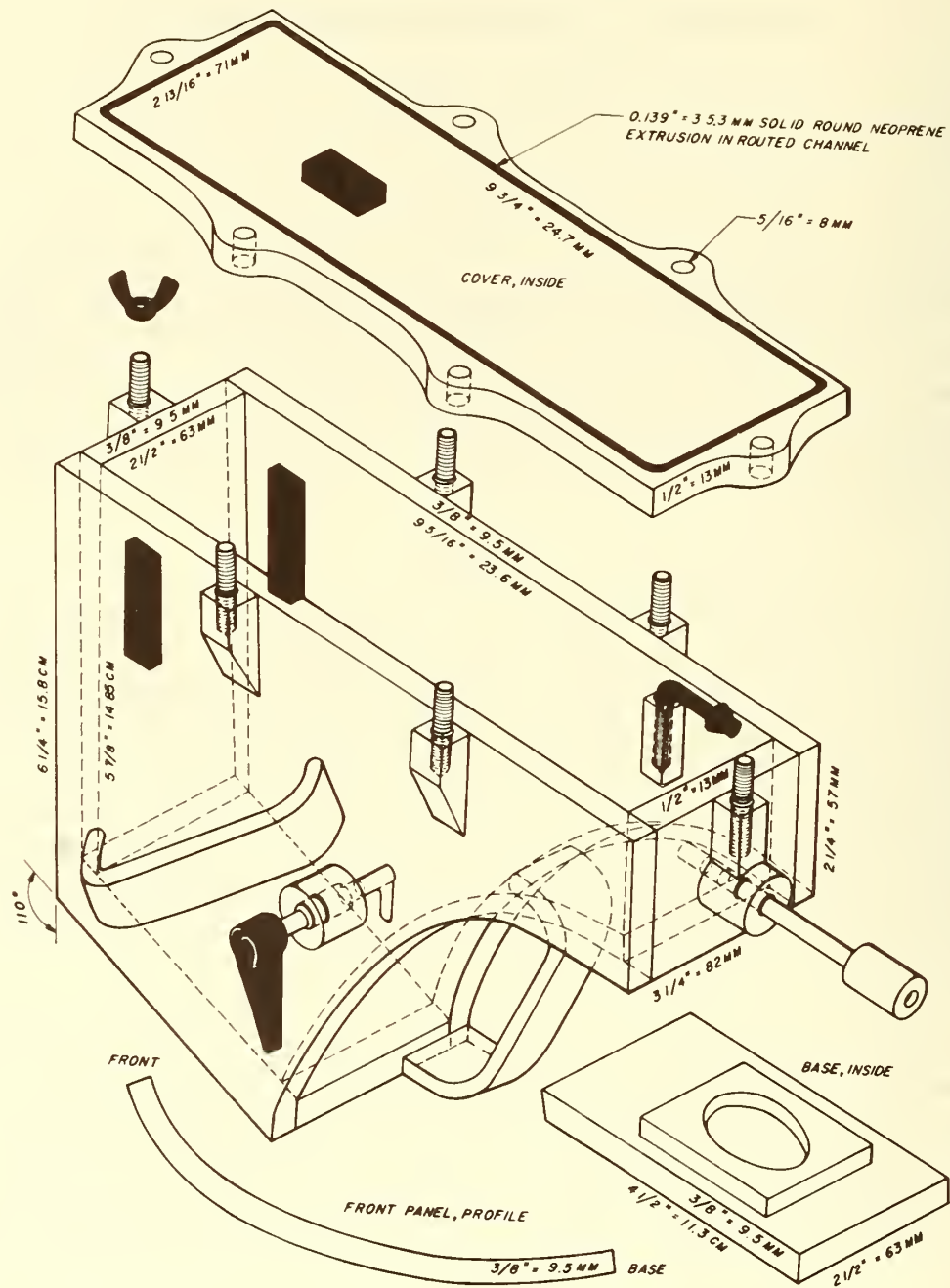


Figure 1. Submersible housing with bit extension attached.

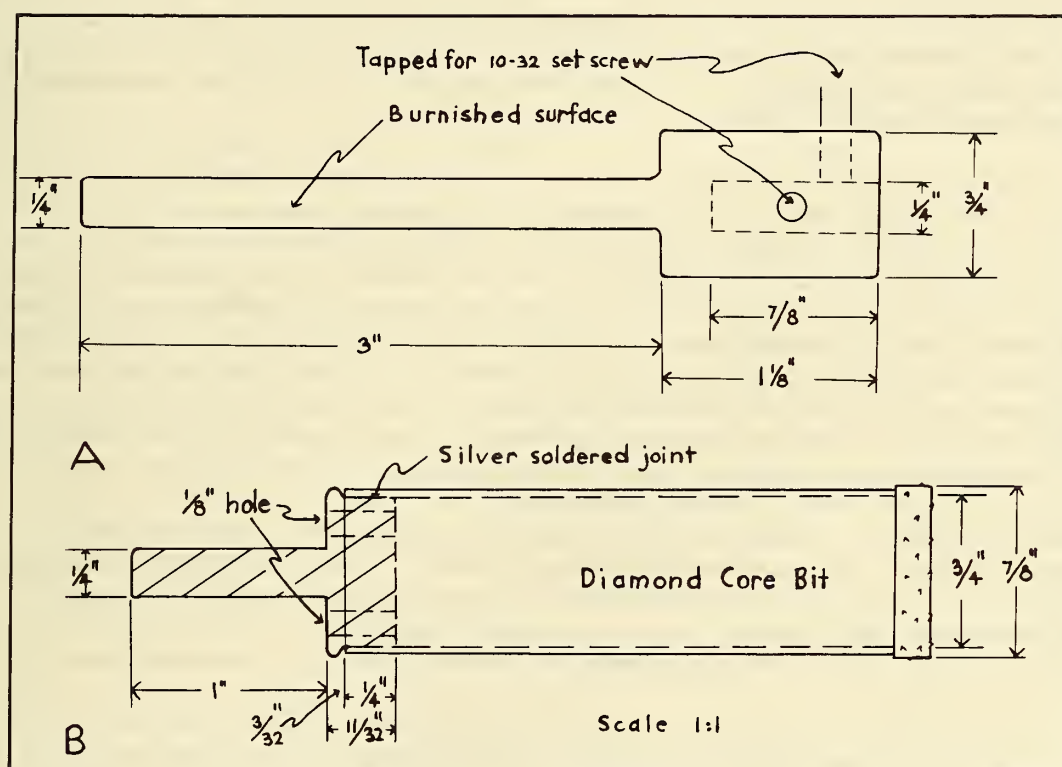


Figure 2. A. Specifications for the bit extension.
B. Specifications for the diamond core bit assemblage.

be transmitted to the electric drill. Lateral wobble of the drill handle is controlled by the oval receptacle in the base and by cushions of vinyl foam cemented to the two side walls of the housing and to the inside of the cover. The chuck key is stored inside the housing.

A short bevelled piece of shaft brazed to the long trigger release shaft at a right angle provides the contact with the trigger switch. If the case is designed with the greatest economy of inner space, the trigger release shaft will be too long to be inserted through the control gland from inside the housing. In this event a small hole can be drilled laterally through the plastic trigger on the drill and a thin diameter screw can be threaded through the hole and extended about 3/8" (=9.5 mm) to the right side where it will be engaged by the bevelled flange brazed on the control shaft. No provision was made for external activation of the on/off safety switch or the reversing switch on the motor case.

The bit extension (Figure 2) is fabricated from stainless steel stock, including the two set screws. The shaft must be 1/4" in diameter in order to pass through the prefabricated control gland. However, the hole for the reception of the shank of the masonry bit or the diamond core bit may be of different diameter, depending upon the size and brand of masonry bit. Some bits are of uniform diameter from the tip, along the twist, and on the shank. Others are of smaller diameter behind the tip, so the bit must be selected before the receptacle in the bit extension is bored. Furthermore, the shank of stainless steel brazed on the diamond core bit must be the same diameter as the shank of the masonry bit if these tools are to be interchangeable. Machine shop experience indicates that it is advisable first to turn the 1/4"-deep recess on the shank assemblage and braze it into the rear opening of the diamond core bit before machining the 1/4" shank. This ensures that errors of alignment causing wobble when the apparatus is operated will be eliminated.

The diamond core bit is Type SICD, Serial N. 55955, without collet, 7/8" O.D., available through Felker Operations, Dresser Industries, Inc., 1900 South Crenshaw Boulevard, Torrance, California, 90509. Other core bits are available in sizes as small as 1/8" and larger than the one selected, so there is a wide selection of sizes enabling a choice of bits calculated to provide the volume of material required. In ordering any brand of core bit one must specify that the bit must not have anything fastened to the open end opposite the cutting edge.

Uses

The apparatus was designed to facilitate collecting coral samples for three lines of research being conducted on various islands in the Pacific Ocean. Growth rates of some corals (for example, species of *Porites*) can be determined by X-radiography of slices taken normal to the direction of growth (Knutson, Buddemeier, and Smith, 1972). The length of the cores (about 7.5 cm or 3") and the facility with which variously oriented and positioned samples can be obtained are ideal for

this line of research. Growth rates also could be determined by the ^{228}Ra , ^{90}Sr , and ^{210}Pb methods if two or more cores of 7/8" diameter were taken, or if a larger core bit were utilized (Moore, Krishnaswami, and Bhat, 1973).

Cores 7/8" in diameter weigh about 25 grams and contain enough material for either ^{14}C or uranium series ($^{230}\text{Th}/^{238}\text{U}$ and $^{234}\text{U}/^{238}\text{U}$) analyses (Barnes, Lang, and Potratz, 1956; Thurber, et al., 1965). Radiometric dating of samples by these techniques is used to determine ages of raised shorelines containing corals, ages of certain reefs, and changes of sea level.

Masonry bits were used to drill holes in coral, limestone, and several kinds of igneous rocks. Bronze nails driven into plastic molly fasteners (hollow wall hangers) inserted in the drill holes serve as reference points against which amounts of erosion can be measured from time to time along shorelines.

The fully charged prototype assemblage drilled as many as 20 1/4" holes of four 3" cores in coral. Four drill holes or one core one inch long can be cut in hard, siliceous limestone or in moderately hard igneous rock. A spare motor was carried in order to accomplish more work and to ensure against motor failure in remote places. Although the electric drill lacks the power of the commercial pneumatic drills and impact wrenches, it has the advantages of light weight, portability, low cost, and replacement of parts from hardware stores. Furthermore, it can be recharged almost anywhere that electricity is generated.

Biologists and geologists who observed the drill in operation suggested additional uses. In the tropics a drill must be insulated from normal high humidity, rain, and water splashed around boats, even if it is not used underwater. This light drill could be equipped with circular core saws or scroll saws to cut plugs of wood encrusted with lichens, mosses, algae, and other plants. Plugs are transplanted from one tree to another when studying recovery of vegetation, adaptations of plant communities, and certain environmental problems.

Attachments such as screw drivers, routers, grinding wheels, mills, and facing plates could be employed, particularly if an adjustable drill chuck were added to the bit extension.

Operation and Maintenance

Both the masonry bit and the core bit cut most effectively if the holes are kept free from cuttings. Otherwise grooves in the twist of the masonry bit become solidly packed with fine debris, preventing the cutting edges of the bit from biting into any hard ground. The core bit does not become jammed as readily as the masonry bit. Debris can be flushed from holes quite effectively using a rubber ear syringe.

It is difficult to maintain a force against a solid object when thrusting underwater, but bits cut most effectively when a steady pressure is maintained. Instructions with cutting tools warn against

letting them rotate ineffectually against the surface to be cut, lest the cutting edge of the tool be damaged. Fortunately, the drill is so light or buoyant that borings can be completed in awkward situations by holding on to the work surface with one hand and operating the drill with the other.

Heat created by the motor warms the air inside the housing, causing a pressure increase. This is a beneficial development to a certain extent because the pressure differential tends to prevent leakage around the O-rings in the control glands and the cover. It is possible, although not personally observed, that long-continued operation of the motor might raise the interior air pressure to unacceptable levels. Intermittent running of the motor seems to permit adequate radiation of heat through the acrylic housing when the apparatus is submerged. It is probable that careful attention should be paid to the O-rings in cold water, for if air should leak out under high pressure, then possibly water might bypass the O-rings when the apparatus cools off. So far I have not observed any leakage in either direction in shallow water.

The O-ring around the drive shaft is subject to increased wear if it becomes dirty. Drilling generates fine abrasive material, so it is beneficial to maintain an excess of thick lubricant such as silicone grease between the shaft and the control gland. Evidence of wear appears as a grey or black stain in the lubricant near the O-ring. Periodic replacement of the O-ring and grease in the drive shaft control gland is advisable.

The steels from which both bits are made rust quickly so they should be given protective coatings of grease when not in use. Moreover, rust-prone shafts should not be left in the receptacle of the bit extension.

Modifications

The two models of drills used in the prototype require from 16 to 20 hours for total recharging. However, a later model, Skil Model 2006, is 3/8" cordless drill requiring only one hour for complete recharging. Furthermore, it has much more torque capability, greater battery capacity, and other special features, yet it has the same dimensions as the 1/4" models used in this project and therefore will fit the same housing.

Other slightly larger models of various brand names may be provided with removeable battery packs so that spare packs can be attached to the motor unit. If two drills are to be provided, it is important to verify their dimensions, because dimensions of the plastic motor cases of one model are significantly different, yet they both bear the same model number.

Some persons who have examined the drill indicate that they might tap the motor with leads that could be fastened to battery packs either in an enlarged submersible housing or carried externally.

Commercial belt packs of batteries are available for under-water photography and might be adaptable for the drill. In any case it would be necessary to ascertain the electrical engineering specifications of any motor being modified.

Acknowledgements

John Wilson fabricated the bit extension and core bit shank. Anna Dillon drafted Figure 1. The manuscript benefitted from constructive criticism by A. C. Hine and D. Hubbard. This project is an outgrowth of National Science Foundation grant EAR 77-13680.

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Addendum

Skil Corporation recently introduced two models of 3/8 inch rechargeable drills that are interchangeable with the 1/4 inch drill originally used. The newer drills have much more torque and much faster recharge times than the 1/4 inch drill. Skil model 2003 can be recharged in three hours, whereas model 2006 can be recharged in only one hour and also has a ready light that indicates when charging is complete. The dimensions of all three drills are identical.

ARTIFICIAL REEFS IN DISCOVERY BAY, JAMAICA

by Michael J. Risk¹

Introduction

Many studies have been done of artificial reefs placed in the marine environment. In some cases, the emphasis has been on augmentation of nearshore fisheries (for example, see Turner *et al.*, 1969). In other studies, the motivation has been largely to gain insight into the ecology and ethology of reef fishes (Randall, 1963; Luckhurst, 1972).

Present-day coral reefs are not only highly productive in themselves, but frequently act as a rampart or barrier, protecting coastal lagoons and bays which in turn may be highly productive (Odum, 1957). The submarine vegetation in these embayments (usually *Thalassia*, in the Caribbean) is typically under-utilized by herbivorous fishes and invertebrates due to lack of refugia from predators. Where small patch reefs occur in lagoons, they are commonly surrounded by "halos" of bare sand from which the vegetation has been completely grazed. These halos have been attributed to grazing by fishes (Randall, 1963, 1965; Luckhurst, 1972) and by sea urchins (Ogden *et al.*, 1973). The scarcity of hiding-places in lagoons is probably a result of the relative inability of corals to attach and grow on soft substrates in murky water (for a review of factors affecting corals, see Endean, 1976).

As one of the many unpleasant things which the future has in store for us is undoubtedly increasing shortages of high-protein food in Third World countries, many of which are located in or on tropical oceans, it would be valuable to investigate the possibility of utilizing more fully the vegetation in shallow coastal areas. Artificial reefs which attract fish populations may be a means of essentially converting the high-carbohydrate plant material into high-protein fish. The total productivity of the system would, of course, not be changed, but less carbon would be incorporated into the sediments.

The topography of reefs (both natural and artificial) dictates that modern high-yield fishing methods cannot be used; the common Antillean fish pot "is still the most effective way to catch bottom fish around the Caribbean" (Brownell, 1972, p. 29). Several designs

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of trap exist, of which the Jamaican "Z-trap" seems to be the most effective (Crossland, 1976). Trapping by individual local fishermen would seem, therefore, to be a reasonably efficient way of "harvesting" artificial reefs.

As a necessary preliminary, the morphology of various types of artificial reefs should be investigated, as should the relative cost (both in money and in labour) of building different types. This paper is a preliminary report on three such reefs, constructed in Discovery Bay, Jamaica, W.I.

Methods

(a) Reef construction

The artificial reefs had to fulfil two criteria: the construction materials had to be locally abundant and relatively cheap, and the finished reefs had to present a wide variety of available interstices and crevices. Therefore, the reefs were constructed out of various combinations of beach boulders and cinder blocks.

Three reefs were constructed on December 10, 11 and 12, 1973, on the east side of Discovery Bay, Jamaica (Fig. 1), equidistant from each other, in 4.3 m of water. The precise location is 100 m directly offshore from a concrete retaining wall and dock painted pink, and is marked with a small white buoy. (The author's last visit to the area was in early 1975, so both landmarks may have changed or disappeared.) The reefs are readily visible from the surface, and are located in a large *Thalassia* bed. A description of each of the three reefs follows (from south to north):

Reef One (Organized Reef) was constructed solely of concrete blocks, placed in such a way as to maximize the amount of holes and spaces available (Plates 1 and 2). Approximately 35 blocks were used in construction. The finished reef was rectangular, long dimension parallel to the shoreline, and 2.8 m long, 1.0 m wide, and 0.7 m high.

Reef Two (Rock Reef) was constructed of subrounded boulders of Pleistocene beachrock, average diameter approximately 25 cm, placed so as to maximize the porosity. The finished reef was elongate parallel to the shoreline, 2.2 m long, 0.9 m wide, and 0.7 m high (Plate 3).

Reef Three (Veneered Reef) combined both construction materials: there was a core of beach rock, over which was placed a layer or veneer of about 15 concrete blocks. The finished reef was elongate parallel to the shoreline, 2.5 m long, 1.8 m wide, and 1.0 m high (Plate 4).

Cost of concrete blocks was \$20 Canadian (1973), and total time for construction of all three reefs was two man-days' shore time (loading and transporting materials), and 6-8 man-hours' underwater labour. All rocks and blocks were placed by hand, underwater; the original research plan called for construction of a fourth reef by simply throwing beachrock overboard, but a family emergency forced the

author to return to Canada before this could be accomplished.

(b) Reef monitoring

Return visits to the reefs were in late June, 1974, and late February, 1975 (or at 6- and 14-month intervals). Fishes were identified and counted on both occasions. On each visit, several censuses were taken of each reef on successive days, sometimes with two operators. Estimates of the length of the more abundant fishes were made by comparison with the length of the concrete blocks (20 cm). Fish were identified with the aid of Randall (1968), and the boring sponges were identified using Pang (1973) and Rützler (1974). Major invertebrates in and around the reefs were also identified, in some cases to major group only.

Data were supplemented with observations made by biologists working at the Discovery Bay Marine Laboratory.

Results and Observations

A summary of the fish census data is given in Table 1.

The day after construction, Reef One had attracted two fish: a small Dusky Damselfish (*Eupomacentrus fuscus*) and a Spotted Moray (*Gymnothorax moringa*). Within a few weeks, all three reefs had attracted fish, and had grown a covering of algae (Paul Sammarco, personal communication).

Two spiny lobsters were seen on Reef Three in June, 1974.

After 14 months, the reefs had attracted a wide variety of organisms other than fish, including calcareous and fleshy algae, sponges, hydroids, anemones, sabellid polychaetes, hammer oysters, arrow crabs, *Stenopus*, tunicates and urchins (*Diadema antillarum*, *Eucidaris tribuloides*, *Tripneustes ventricosa* and *Lytechinus variegatus*). In addition, the concrete blocks of Reefs One and Three supported small colonies of the corals *Porites astreoides* and *Dichocoenia stokesii*, and colonies of *Millepora alcicornis* up to 20 cm high. Coral colonies occurred on the beachrock, but much less frequently.

Both the concrete blocks and the beachrock were infested with boring algae and boring sponges (*Siphonodictyon coralliphagum*, *Cliona lampa*, *Cliona laticavola*). Infestation was highest in the beach rock; amount of material removed from the exposed outer part of some rocks was estimated to be about 8%. Some samples of beach rock contained fossil (Pleistocene) *Montastrea annularis*. Sponges boring into these fossil corals exhibit the same boring pattern as does *Cliona vermicifera* in living *Montastrea annularis*: the sponge colony advances up the vacated corallite, cutting back the septa to the septathecal wall (Ward and Risk, in press). Boring pattern is evidently a response to substrate hardness.

TABLE 1. SPECIES COMPOSITION AND ABUNDANCE OF FISHES
FOUND ON ARTIFICIAL REEFS IN DISCOVERY BAY.

	JUNE 1974			FEBRUARY 1975		
	Reef 1	Reef 2	Reef 3	Reef 1	Reef 2	Reef 3
Grunts (mostly <i>Haemulon sciurus</i> ; some <i>H. flavolineatum</i>)	9	73	155	58	175	256
Squirrelfish (mostly <i>Holocentrus rutus</i>)	2	7	6	5	5	8
<i>Apogon binotatus</i>	1		4		4	5
<i>Hypoplectrus puella</i>		1	1	1	1	1
<i>Amblycirrhitis pinos</i>		1				
<i>Priacanthus cruentatus</i>		1	1			
<i>Petrometopon cruentatum</i>	3					
<i>Pseudupeneus maculatus</i>	2	1		1	1	1
<i>Eupomacentrus fuscus</i>			1	1		1
<i>Halichoeres bivittatus</i>		2	3	2	4	5
<i>Halichoeres maculipinna</i>	1				1	1
<i>Hemipteronotus martinicensis</i>			1			
<i>Sparisoma rubripinne</i>	4	2	3		2	4
<i>Scarus croicensis</i>	3	1	2	4	2	3
<i>Acanthurus chirurgus</i>	2	2	2	1	2	2
<i>Acanthurus coeruleus</i>				4		2
<i>Bothus lunatus</i>		1				
<i>Synodus</i> sp.			1			
<i>Chaetodon capistratus</i>				1	1	
Total no. species	9	11	12	10	11	13
Total no. individuals	27	92	180	78	197	290
Estimated average length of grunts (<i>Haemulon</i> sp.), cm:	12	8	4	11	8	7
Estimated average length of squirrelfish (<i>Holocentrus</i> sp.), cm:	11	9	9	12	9	10

(Fish numbers are averages of at least three separate estimates; fish lengths are averages of several hundred underwater length estimates, checked with photographs.)

Although no grazing halo was developed around any of the reefs, comparison of 6-month and 14-month bottom photographs suggests a decrease in length and density of *Thalassia* blades in the immediate vicinity of the reefs. Grazing marks were common on the concrete blocks, but not on the beachrock.

Trapping by local fishermen around the reefs began after about six months.

Discussion

Most of the fishes on the reefs were carnivores or microcarnivores, an observation made previously by Randall (1963) and Luckhurst (1972). It is likely that the reefs were exploited more for shelter from larger predators than for the fact that there is some *in situ* food production.

Reef Three (beachrock core, block veneer) supported the highest density and the largest number of species of the three reefs at both 6-month and 14-month visits. The average size of the dominant species of fish was greater on Reef One (concrete blocks), however; Reef Two (beachrock) was intermediate in all respects. Reef One had fewer nocturnal fishes, perhaps due to its open construction, and also supported more large carnivores.

The relationships among reef size, crevice size and shape, fish density and fish diversity remain obscure, due largely to the limited scope of the experiment and the short observation span. It is likely, however, that most of the fish attracted to the reefs are those which are nocturnal transients over the sand and grass flats of tropical lagoons. These fish would readily take refuge in the large cavities in the concrete blocks. The open construction of Reef One may account for the lower density of smaller fish (lack of small holes) and the larger average size. The relationship between fish populations and reef morphology has been emphasized by several authors (Bardach, 1959; Hiatt and Strasburg, 1960; Randall, 1963; Risk, 1972).

Longevity of artificial reefs also remains unknown. Rates of infestation by boring organisms seem comparable to rates observed in live corals. Undermining by *Callianassa* was also observed to cause some foundering. Bioerosion and bioturbation, therefore, would seem to set an upper limit on the age of the reefs. On the other hand, settlement and growth of corals on the reefs could prolong their life as shelters. Coral growth on artificial reefs is rarely observed (Luckhurst, 1972). Growth of corals on the reefs under discussion may be a result of relatively clear lagoon waters and a high resident diversity and density of corals (Goreau and Wells, 1967).

Artificial reefs may be constructed relatively quickly and inexpensively. Results of this study suggest only that the construction of an artificial reef affects the fishes attracted to it. Further monitoring of the reefs in Discovery Bay is necessary. It

would also be important to undertake a major experiment, based on these preliminary results, using larger reefs in sets of replicates, in order to determine the degree in which fish size and species may be influenced by the type of reef construction.

The author regrets that financial restrictions terminated his site visits. Persons visiting Discovery Bay are invited to observe the reefs, as this is the only way in which further information may be obtained.

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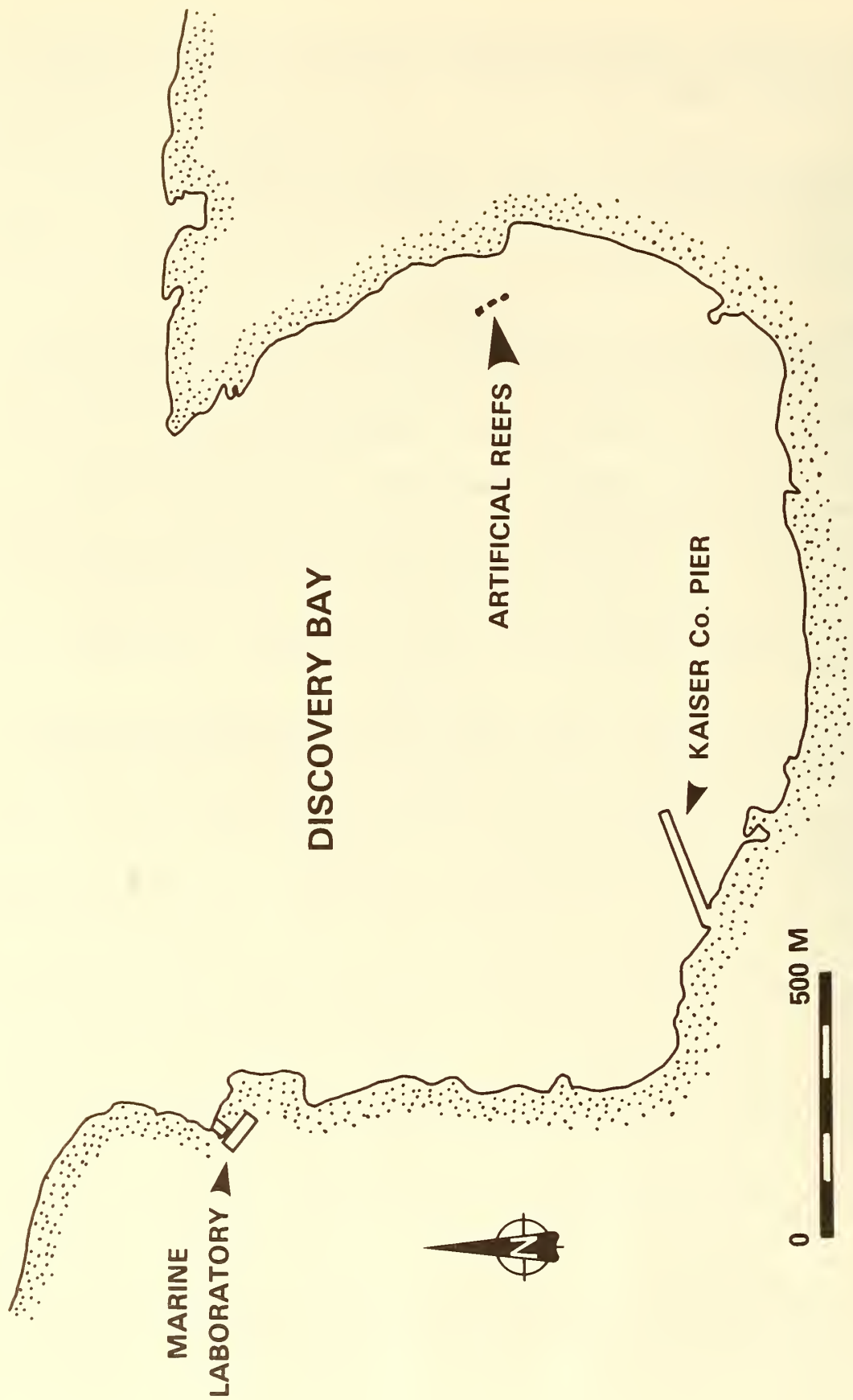


Fig. 1: Map of Discovery Bay, Jamaica, showing the location of the three artificial reefs.



Plate 1: Reef One in June, 1974.



Plate 2: Reef One in February, 1975; note increase in encrusting organisms.



Plate 3: Reef Two in June, 1974.



Plate 4: Reef Three in June, 1974.

DISTRIBUTION OF THE DECAPODS BRACHYURA AND ANOMURA
(EXCLUDING PAGURIDEA) OF THE CRYPTOFAUNA IN THE
REEFS NEAR TULEAR

By Mireille Peyrot-Clausade¹

This study of the distribution of the Decapods Brachyura and Anomura (excluding Paguridea) is a part of a broader work about the whole cryptofauna of the reef flats of Tuléar. The Great Reef of Tuléar, two zones of which were studied in detail, is the principal field of my investigations. Some samples were also extracted from the reefs of Sarodrano, Nosy Tafara, and Songoritelo (map 1).

Cryptofauna consists in all the small fauna of mobile invertebrates which shelter in the little holes on the organic tracts of the reef flats; these holes are 0.5mm to 5 centimeters in diameter. The cryptofauna was extracted from the blocks of hard hollowed-out substrate, the volume of which is 1dm^3 . This volume of 1dm^3 has been defined as the minimum in which it is possible to obtain almost all the species present in the biota studied (Clausade, 1970). For every station studied, 5 samples of 1dm^3 have been extracted.

Altogether 34 stations, which represent 170dm^3 of hollowed-out substrate containing cavities, subsequently broken into pieces, yielded 84 species of Brachyura and Anomura. The determination of these species has been confirmed by Mr. Serène. Those which appeared particularly interesting from a systematic point of view formed the subject of a separate paper (Peyrot-Clausade and Serène 1976).

The areas studied on the Great Reef are shown in map 1. In the northern area (here called Sector 1), 9 stations have been studied. Fig. 1 shows their localities (for clarification of terminology, refer to *Téthys* suppl. 2, 1972). In the area situated in the center of the Great Reef (Sector 2) at the place named Antseteky, 12 stations have been studied (fig. 2): 4 in the outer reef flat, 3 in the boulder tract and 5 in the inner reef flat. Samples have been studied on the other reef flats where some formations have appeared new in relation to those of the Great Reef.

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The reef flat of Sarodrano is subjected to the alluvial deposits of the river Onilahy, rich in clay particles in suspension. Moreover, it is situated in an unstable zone and is tilting more and more towards the open sea (J. Picard, personal information). The different formations present on this reef, in order to stay at the degree of dampness which is suitable to them, counterbalance this tilting by an upper growth or elevation. Thus, the little *Vermetus Dendropoma* sp., which form only simple veneerings at the base of the blocks of the boulder tract of the Great Reef, forms at Sarodrano thick pads rich in cavities, on the upper part of the blocks. For this reason, I have studied two kinds of samples in this zone: the first among the blocks of the boulder tract, the second among the *Dendropoma* sp. formations. At the back of the reef flat, micro-atolls are present. Five samples have been taken at the base of these formations which are widely covered with Algae and rich in sandy particles.

The reef of Songoritelo results from the junction of two initial shields (J. Picard, personal communication). The boulder tract, present on the old shields, is absent from this junction zone. This zone is used as an out-fall through which the water of the channel situated between the reef and the Mangrove flows out at ebb-tide. This sea water, rich in sandy earthy particles coming from the river Fiherenana, promotes colonization and growth of the Sabellariids *Idanthyrus pennatus*. Between this area of *Idanthyrus* and the boulder tract are found layered Melobesiae formations. They are calcareous Algae, more or less intermingled, and creating interstices partially filled up by sand. It is in this zone that the boulder tract later forms, when the reef has reached a certain degree of evolution. Seven stations have been studied at Songoritelo: two on the outer reef flat (one on the spur upper platform, one on the outer moat rich in Algae) and two others around the outer creeks (on the edge and towards the back among madreporarian coral colonies covered by Zoantharian colonies). The last third are distributed in the following manner: one in the boulder tract, one in the *Idanthyrus* formations and the last one in the layered Melobesiae.

Nosy Tafara can be distinguished from other reefs by its boulder tract which is a boulder-rampart.

At each station, the abundance and average dominance of the species present have been determined and is shown in table 1.* From this table, I have constructed tables 2, 3, 4 in which is recorded the dominance of the different Brachyura and Anomura families, for each station.

Figs. 3 and 4 show in the two sectors of the Great Reef, the evolution of the settlements from the spur upper platform to the blocks of sea grass bed basins. The population of each station is represented by a circle in which each family is represented by an arc in a direct ratio to its average dominance.

*Table 1 not reproduced here, available from author.

POPULATION OF THE OUTER REEF FLATS

For this study, I deal with 60 samples from 12 stations: 8 from the outer reef flats: 2 from Sector 1, 4 from Sector 2, and 2 from Songoritelo (fig. 5). The last 4 come from the flat around the outer creeks of Sector 1 and Songoritelo. For all the outer stations, the total populations vary from 209 for the settlement of the station of the glacis in Sector 1 to 47 in the station on the edge of the outer creek in this same Sector. The average population is 17.8 individuals for 1dm^3 of hollowed-out substrate; the number of species varies considerably: 4 in the station of the spur upper platform in Sector 2, and 24 for the one in the glacis of Sector 1.

The Sector 2 shows an increase in the diversity of species of Brachyura as we move away from the front of the reef. The number of species varies from 4 to 19. Indeed, in station 12, 97% of the settlement belong to the single sub-family of Chlorodinae and are *Liocarpilodes integerrimus* (Dana 1852) 71%, *Pilodius paumotensis* (Stimpson 1858) 18%, and *Chlorodiella laevisissima* (Dana 1852) 8%. *Daira perlata* constitutes the remaining 3%.

In the next station (no. 13), ten species have been collected. The Xanthidae family still represents 85%, the dominant species are *Chlorodiella laevisissima* and *Pilodius paumotensis*. *Liocarpilodes integerrimus* is absent but I find *Liomera rugata* (H. Milne Edwards 1834) and *Zozymus aeneus* (Linné 1758) that will be found again in the next two stations. This is true also, for the two species of Anomura *Pisidia delagoae* (Barnard 1955) and *Pachycheles penicillatus* (Heller 1862).

Station 14, established on the outer moat, contains 13 species but they are not abundant. Indeed, in the 5dm^3 , I number only 58 individuals. Among Xanthidae, *Liocarpilodes integerrimus* and *Pilodius paumotensis* are not very abundant. The dominant species is still *Chlorodiella laevisissima*, and near the species already mentioned, I collected *Pilumnus purpureus* (A. Milne Edwards 1873), the dominance of which will increase twofold in the next station as will the Pilumninae ind. The Porcellanids are also enriched by a new species: *Petrolisthes lamarckii* (Leach 1820). I note for the first time the presence of Portunidae with *Thalamita* at a juvenile stage.

Station 15 is on the outer reef flat just in front of the boulder tract, in an area of layered Melobesia; 19 species or 101 individuals were collected. Porcellanidae (with essentially *Petrolisthes lamarckii*) have an increasing dominance at the expense of Xanthidae. In this last family the two more abundant species are *Chlorodiella laevisissima* and *Actaeodes tomentosus* (H. Milne Edwards 1839). I note an increase of *Liomera rugata* and a complete disappearance of *Liocarpilodes integerrimus* and *Pilodius paumotensis*. Portunidae are represented by *Thalamita gloriensis* (Crosnier 1962) and Grapsidae by some individuals of *Pachygrapsus minutus* (A. Milne Edwards 1873).

If I compare the population of the stations of the outer reef flat of Antseteky (Sector 2) with that of the station of the outer reef flat

of Sector 1, I see a real similitude of settlement between the station 14-15 and the stations 1-2. Thus, in station 11 on the spur upper platform, I found 133 individuals belonging to 17 species. In station 2, on the reef glacis rich in Algae *Turbinaria*, there are 24 species and 209 individuals. Twelve species are common to these two stations but their dominances vary. *Liocarpilodes integerrimus* (16%) and *Pilodius paumotensis* (18%) are dominant in station 1, whereas *Pilumnus purpureus* (23%) is more abundant in the 2nd station. In this last station, I find also *Liomera rugata* and *Actaeodes tomentosus*. Three species are collected solely on the outer reef flat of Sector 11. They are: *Actumnus elegans* (de Mann 1888), *Domecia glabra* (Alcock 1899) and *Pachycheles garciaensis* (Ward 1942).

The settlement of the outer reef flat of Songoritelo appears quite different from those previously studied. Indeed, the diversity is more important in the station of the spur upper platform than in that realized on the outer moat. Contrary to previous recordings, the abundance and average dominance of *Liocarpilodes integerrimus* also increase in the inner station. *Chlorodiella cytherea* (Dana 1852) and *C. laevissima* are abundant, but *Pilodius paumotensis* and *Pilumnus purpureus* are completely absent.

The station around the outer creeks have settlements which resemble more closely those of the outer reef flat stations. Indeed, at Songoritelo, Xanthidae represent in the two stations more than 96% of the individuals collected. Chlorodinae are the most abundant with essentially the three following species: *Liocarpilodes integerrimus*, *Chlorodiella cytherea* and *C. laevissima*. In sector 1, Xanthidae constitute only 70-78% of the settlement of these stations around the creeks. The outer station contains: Dromiacea, Oxyrhyncha, Grapsidae and Porcellanidae, the inner one has no Grapsidae nor Dromiacea but 8% of Portunidae.

All the settlements of the outer reef flat show a certain homogeneity, despite some variations. Among Xanthidae, Chlorodinae dominates with three species more particularly abundant: *Liocarpilodes integerrimus*, *Pilodius paumotensis* and *Chlorodiella laevissima*. Fig. 6 shows the dominance of these species in the different stations of the outer reef flats. Although the extension of *Chlorodiella laevissima* is not limited to the outer reef flats, the dominance increase from the outer station to the inner one and is non-existent in the boulder tracts. At Antseteky, after a peak of dominance in the dead madreporian colonies, it is clear that this species diminishes in importance up to the boulder tract. The dominance of *Pilodius paumotensis* diminishes regularly as we move from the front to the back of these outer reef flats.

Liocarpilodes integerrimus, is, of these three, the most abundant species. It is seen on fig. 6 that in all the biota studied, its abundance and its dominance decrease towards the back of the outer flat, except on the reef of Songoritelo. On this reef, the dominance of *Liocarpilodes integerrimus* is lower on the outer station than in the inner one (although its value is similar to that recorded on the other

outer stations); but on the inner station (situated on the outer moat) the value of dominance is greater than on homologous stations (about twice as great as that on homologous stations). An explanation of this abundance can be found in the fact that, the front of this reef being in a phase of very fast growth, the outer moat is not very old. This outer moat is very rich in burrowing organisms (small sipunculids). The size of the network and of cavities is very well suited to the *Liocarpilodes integerrimus* which are very small individuals. This area is between two phases of colonisation: the first colonisation characterizes zones exposed to the beating of the waves (at present in the outer station, on the spur upper platform) and the second characterizes a well degraded substrate (found in Sector 1 of the Great Reef of Tuléar, in the zone rich in Algae *Turbinaria*). Among the "no carpilodea", *Liomera rugata* seems also to characterize quite well the settlement of the outer reef flats. This species is absent from the biota the most exposed to the beating of the waves. *Zozymus aeneus* (Zozymoidea) is never abundant, but is present in almost all the stations studied. *Pilumnus purpureus* and *Actumnus elegans* are also linked to this zone of the reef. They are still more abundant in the calmer biota. Among the Anomura, I find essentially Porcellanidae with *Pachycheles natalensis* (Krauss 1843), *Petrolisthes lamarkii*, *P. penicillatus*, *Pachycheles garciaensis* and *P. pisoides* (Heller 1865). The last third are solely recorded on the outer reef flats.

A problem is posed by the Oxyrhyncha. Some of them are known to live in the thallus of Algae but *Acanthonyx quadridentatus* (Krauss 1843) alone is limited to the biota very rich in Algae, thus species is not included in the cryptofauna.

POPULATION OF THE BOULDER TRACTS AND OF THEIR BIOTA SUBSTITUTES

As has been seen in the first part of this paper, the structure of the boulder tracts varies on the reef flats; the various stations were established according to these variations in structure. So, in Sector 1, samples were collected on the crags. In Sector 2, over and above the station identical to that of Sector 1, two others have been established: one in the gravel tail and the other in the filtering dike. On the reef of Songoritelo, I have three stations: one on the crags, one on the *Idanthyrus* formations and the last in the layered *Melobesia*. On the Sarodrano reef flat, I studied the settlement of the crags and of the little *Vermetus Dendropoma* sp. formations. At Nosy Tafara, one station is in the gravel sheet at the back of the boulder rampart.

All these stations in the boulder tracts are qualitatively poor. From 4 to 13 species are found. The two stations on the crags of the Great Reef have very similar settlement. Grapsidae are dominant (56 and 44%) with only two species: *Pachygrapsus minutus* (A. Milne Edwards 1873) and *Nanosesarma minutum* (De Mann 1887). Among Xanthidae, I find *Zozymodes xanthoides* (Krauss 1843) *Actaeodes tomentosus*, *Eriphia scabricula* (Dana 1852) and *Pilumnopeus trispinosus* (Sakai 1965). This last species represents from 16 to 18% of the settlement.

Porcellanidae, with only one species — *Petrolisthes lamarckii* — constitute 5 to 9% of the individuals present. The station on the filtering dike differs from those of the crags by a considerable decrease in Grapsidae and increase in Xanthidae (*Pilumnopus trispinosus* 32% and *Actaeodes tomentosus* 24, 5%) and in Porcellanidae (*Petrolisthes lamarckii* 17%). On the gravel tail, 71% of the settlement is constituted by Porcellanidae (still *Petrolisthes lamarckii*). *Pachygrapsus minutus* constitutes only 1% of the individuals collected on this station. *Chlorodiella cytherea* is, of Xanthidae, the most abundant species (15%). If I compare this settlement to that of the gravel sheet of Nosy Tafara, I see that they are quite identical. On this station, *Petrolisthes lamarckii* represents 67% of the population, *Chlorodiella cytherea* 22%, *Pachygrapsus minutus* 6% and *Pilumnopus trispinosus* 4%.

On the reef of Songoritelo, the crags have settlements similar to those of the crags of the Great Reef, yet with a greater diversity of species. Some species come from settlement of the outer flat (*Pilodius paumotensis*, *Liomera rugata*, *Liocarpilodes integerrimus*) and some species come from the inner reef flat such as *Pilodius spinipes* (Heller 1861). None of them have a high dominance. In these crags, Grapsidae are represented only by *Pachygrapsus minutus* 27%. *Nanosesarma minutum* (de Mann 1887) is absent. It has been seen supra that at Songoritelo, in absence of the boulder tract, we find *Idanthysus* formations and layered Melobesiae. These formations have very different populations. In the cavities between the tubes of the *Idanthysus pennatus*, Grapsidae are very abundant and constitutes 49% of the individuals collected. Porcellanidae are less abundant: *Petrolisthes lamarckii* does not reach 5,5% of settlement.

The population of layered Melobesiae differs by the very feeble proportion of Grapsidae (1,4%), the presence of Portunidae (14%) and of Ocypodidae-*Macrophtalmus boscii* Audouin (et Savigny) 1825 7%. Xanthidae family is the most important (68% of the individuals) with essentially three species: *Chlorodiella cytherea*, *Actaeodes tomentosus* and *Pilodius areolatus* (H. Milne Edwards 1834).

The last two series of samples are those of the boulder tract of Sarodrano, among the crags and the formations of little *Dendropoma* sp. In these two stations, the most abundant species is *Pilumnopus trispinosus* which constitutes 54% of the settlement of the first and 87% of the second. The crags of the boulder tract are characterized by the absence of *Pachygrapsus minutus* and by the quite important number of *Macrophtalmus boscii*.

Among the boulder tracts, four species have an important part in the settlement. They are: *Pachygrapsus minutus*, *Nanosesarma minutum*, *Pilumnopus trispinosus* and *Petrolisthes lamarckii*. In examining the first three species, I note that *Pachygrapsus minutus* is a very mobile species whereas *Nanosesarma minutum* and *Pilumnopus trispinosus* are more or less non-mobile. The study of table 1 shows that *Nanosesarma minutum* is present only on the Great Reef and more abundant in the biota in the highest part of the mid coast-level. Its abundance

decreases in the filtering dike which is lower. In the same three stations, *Pilumnopus trispinosus* has an opposite behaviour and is more abundant in the filtering dike. When this species reaches its maximum of dominance in the stations of the reef of Sarodrano, I see the diminution and absence of *Pachygrapsus minutus*. I think that this absence can be explained by the salinity of the sea-water around Sarodrano reef being often very feeble, owing to the river Onilahy. On the hard substrate on the coast Plante (1964) did not find this *Pachygrapsus* where it would normally be collected, and it is also absent from the hard substrate of the mangrove. In the absence of *Pachygrapsus minutus*, *Pilumnopus trispinosus*, which is no doubt more resistant to the variations of salinity, inhabit all the little cavities. Porcellanidae — *Petrolisthes lamarckii* — have an abundance and dominance which increase as we move from the crags to the gravel sheet or tail of the boulder tracts, this species goes deep into the chips of dead Madreporian as the sea-water level gets lower, and so protects itself from drying up at low tide. Apart from *Pilumnopus* already cited, I find also *Actaeodes tomentosus* in all the stations. *Zozymodes xanthoides* is only collected on the crags.

POPULATION OF THE INNER REEF FLATS

It has been possible to study these settlements by means of the eleven stations (five in every Sector of the Great Reef) and one in the zone of micro-atolls of the reef of Sarodrano. The average number of individuals collected in 1dm^3 of hollowed-out substrate is about 16. However, if I suppress the two series of samples from the branched Melobesiae which constitute a special biota by the abundance of very little cavities between the thallus of these calcareous Algae, there are only 10 individuals per dm^3 in the other biota. The number of species is situated between 6 and 19 and reaches 23 in the branched Melobesiae. All the families found on the outer reef flats and on the boulder tracts are represented in this part of the reef flats, but it seems that Xanthidae are more abundant. Anomura, particularly Galatheididae, play in some biota a very important in the inner reef flats and particularly with the species *Macrophtalmus boscii*, in the compact reef flat in the two sectors studied. This species is also found abundantly in the blocks of the sea-grass bed basins of Sector 2. Among Xanthidae, the two most important sub-families are Actaeinae and Chlorodinae. In the first sub-family, *Actaeodes tomentosus* is the dominant species. It has its maximum abundance in the branched Melobesiae, but they are chiefly individuals at a juvenile stage. *Actaea cavipes* (Dana 1852) is also frequent but not very abundant in Sector 2. In Chlorodinae sub-family, *Chlorodiella cytherea*, *C. laevis* and *C. barbata* and *Pilodius spinipes* are the most abundant. The last two species are only recorded on the inner reef flats and have their maximum average dominance among the branched Melobesiae. The "no carpilodea" are also represented by some species gathered only in the inner reef flats. They are: *Liomera bella* (Dana 1852), *L. cinctimana* (White 1857), *L. semigranosa* (de Mann 1888) and *L. monticulosa* (H. Milne Edwards 1873). Among Anomura, one can notice a gradual replacement of Porcellanidae by Galatheididae, as we

move off the boulder tracts towards the sea-grass bed basins. The most abundant Porcellanids are: *Pisidia delagoae* (Barnard 1955) which reach their maximum in the branched Melobesiae. Galatheidæ are represented by several species. The most frequent is *Galathea humilis* (Nobili 1905) which is present in 7 of the eleven stations studied, the maximum dominance is recorded in the micro-atolls of Sarodrano. *Galathea affinis* (Ortmann 1892) is the species dominating in the biota of the blocks in the sea-grass bed basins of Sector 1. *Galathea platycheles* (Miyake 1933), like many other species, reaches its maximum dominance in the branched Melobesiae.

This study of the population on the different reef flats allow us to make certain inferences about the distribution of the families even of some species of brachyura and Anomura. The Dromiacea are represented by only one species in these samples; it is *Dynomene hispida* (Desmarest 1825) exclusively found on the outer reef flats. It is also on the outer reef flats that the majority of Oxyrhyncha are recorded: *Menaethiops natalensis* (Barnard 1955), *Hyastenus aff. elongatus* (Ortmann 1893), *Daira perlata*, *Elamena matthei* (Desmarest 1825) and more particularly among the places rich in Algae. Among Portunidae, *Thalamita gloriensis* is the only species determined. The three biota in which it is the most abundant are, in an increasing order: the layered Melobesiae of the outer reef flats of Sector 2, the madreporian colonies on the edge of the outer creeks of Sector 1 and layered Melobesiae of the reef of Songoritelo where it represents 13.7% of the settlement. In almost all the stations, juvenile forms of *Thalamita* have been collected, and above all on the spur upper platform of the outer reef flat of Songoritelo. Xanthidae family is the most important qualitatively and quantitatively of all the families of Brachyura in these cavities.

(a) no Carpiloidea

Liomera rugata seems to be particularly well adapted to the outer reef flats just behind the spur upper platform, the other species of *Liomera* — *L. bella*, *L. monticulosa*, *L. semigranosa*, *L. cinctimana*, all came from the inner reef flats and more especially from the branched Melobesiae.

(b) Zozymoidea

Five species belong to this group: *Zozymus aeneus*, *Zozymoides xanthoides*, *Atergatis aff. subdentatus* (de Mann 1835), *Platypodia cristata* (A. Milne Edwards 1865) and *Platypodia anaglypta* (Heller 1861). The first species of this list, which is found above all in the outer reef flat biota, like *Zozymoides xanthoides* settled only on the boulder tracts, are the most abundant.

(c) Xanthoidea

The five species of this group are never abundant. The best represented is *Leptodius nudipes* (Dana 1851) which come from the gravel

tail of the boulder tract of Sector 2.

(d) Galenoidea

Actaeinae and Chlorodinae are the most frequent and abundant.

(1) Actaeinae includes 9 species:

Actaea quadriareolata which come from the boulder tract is not abundant. Excluding *Actaea consobrina* and aff. *Pseudoliomera varialosa* (Borradaile 1902), which are only samples on the outer reef flats, the other species are collected in the different biota. The most abundant is *Actaeodes tomentosus* which is found at all the stages of growth from a few mm to several centimeters, in all the stations, the branched *Melobesia* having in their cavities an important concentration of juvenile forms.

(2) Chlorodinae are, with 12 species, the richest group.

It has been seen that *Liocarpilodes integerrimus* and *Pilodius paumotensis* are quite localized exclusively on the outer reef flats. On the other hand *Liocarpilodes armiger* has been collected only in the inner reef flats. The most abundantly represented genus in all the reef flat formations, except on the boulder tracts, is the genus *Chlorodiella* with three species. *Chlorodiella laevisissima* although present in all the stations, dominates especially on the outer reef flats where it can represent up to 56% of the settlement (such as in the Zoantharian zone of Songoritelo creek) *Chlorodiella cytherea* is the one of these three species which resist best to drying-up, for it is the one collected in the gravel tail and sheet. *Chlorodiella barbata*, never sampled on the outer reef flats, is abundant on the inner reef flats and particularly among the branched *Melobesia*. In the Chlorodinae, the genus *Pilodius* is also well represented. With *Pilodius paumotensis* collected in the outer reef flats, *Pilodius areolatus* present in the inner reef flats and reaching its maximum abundance in the *Idanthyrus* formations and the layered *Melobesia*, there is also *Pilodius spinipes* which plays an important role in the settlements of the biota of the inner reef flats and more especially in the blocks in the sea-grass-bed basins and reef flat with scattered coral growth. *Pilodius pugil* Dana 1852 is nowhere abundant. Among the *Phymodius*, only one species — *Phymodius unguatus* (H. Milne Edwards 1834) is quite well represented in the inner reef flats. *Paretisus globulus* (Ward 1933), not abundant, is collected in 4 different biota.

(e) Cymoidea

Eriphia scabricula seems to characterize the settlement of the boulder tracts.

(f) In the Hyperomista, only the Pilumnidae are abundant.

Domecia glabra (Alcock 1899), on the spur upper platform is the only Mennipinae collected. Among the Pilumninae, only two species have been determined: *Pilumnus purpureus* and *Actumnus elegans*. Both occupy only the cavities in the outer reef flats. The extension of *Actumnus elegans* is however limited to Sector 1. *Pilumnopeus trispinosus* is

among the Heteropanopeidea, the most abundant species. If some rare individuals are on the outer reef flats, it reaches very high dominance on the boulder tracts particularly in the reef of Sarodrano on the Vermetus *Dendropoma* sp. where there are 18 individuals per dm^3 . *Lybia leptochelis* (Zehntner 1894) is essentially present in the inner reef flats, but always in very feeble number.

Ocypodidae family is represented by one species — *Macrophtalmus boscii* — which is particularly abundant in the inner reef flats, in calm biota where colloidal suspension can form a deposit in which this species makes its hole. This *Macrophtalmus* is also recorded in the boulder tract of Sarodrano, where as we have seen the water of the river Onilahy covers the reef.

Grapsidae. *Pachygrapsus minutus* is the most abundant of this family. It occupies all levels of the mid-coast level and takes shelter in the highest part of the reef constituted by the boulder tracts. As it is a very mobile species, at low tide, it moves away and so can be collected in the biota surrounding the boulder tracts. In the absence of boulder tracts at Songoritelo the highest biota is the *Idanthyrus* formations where the *Pachygrapsus* are abundant. The samples realized at Sarodrano show that this species does not like fresh water, but reappears when the degree of salinity increases (as at Nosy Tafara). *Nanosesarma minutum* lives at the high part of the mid coast-level and is collected only on the Great Reef.

Anomura

Two families are abundant in the cryptofauna: Galatheididae and Porcellanidae.

(a) Porcellanidae family, is, with 11 species, the most important. A succession of species is clearly found moving from the front to the back of reef flats. *Petrolisthes penicillatus* is strictly localized on the outer reef flats, as are *Pachycheles garciaensis*, *P. pisoides* and *P. natalensis*. *Petrolisthes lamarckii*, which is found also on the outer reef flats, reaches its maximum dominance in the boulder tracts and particularly in the gravel tail and sheet where it constitutes 67% of the settlement. *Pisidia delagoae* is recorded on all the reef formations and more abundantly in the inner reef flats. It is also in that zone that *Polyonix triungulatus* (Zehntner 1894) and *P. aff. maccullochi* (Haig 1965) are found.

(b) Galatheididae. Six species are collected essentially in the inner reef flats, and their dominance increases as we move from the boulder tracts to the sea grass bed basins. The most two abundant species are *Galathea humilis* and *G. affinis*. The 1st is frequent on the whole of the Great Reef, and very abundant in the micro-atolls of Sarodrano; the 2nd dominates the settlement of the blocks in the sea grass bed basins in Sector 1 representing more than half of the local cryptofauna.

From this study, some settlement appear quite typical of certain reef zones. Thus, for a stabilized reef, it is possible to define an outer reef settlement which increases in diversity as we move away from the breaking waves. In the outer stations, *Dynomena hispida*, *Liocarpilodes integerrimus*, *Pilodius paumotensis*, *Actumnus elegans*, *Pilumnus purpureus* and *Petrolisthes penicillatus* are sampled. *Liomera rugata*, *Zozymus aeneus* are added to the species already cited in calmer zones. In the boulder tract, it can be said that the classic population of the crags is composed of: *Pachygrapsus minutus*, *Zozymodes xanthoides*, *Eriphia scabricula*, *Petrolisthes lamarckii* and *Pilumnopeus trispinosus*. This last species increases very much when, because of the weak salinity of the sea water, *Pachygrapsus minutus* disappears almost completely. In the gravel zone, *Petrolisthes lamarckii* and *Chlorodiella cytherea* are the dominating species. In the inner reef flats, *Pilodius spinipes*, *Chlorodiella barbata*, *Actaeodes tomentosus*, *Galathea humilis* play an important part in the populations. It is in this zone that the highest density of individuals per dm^3 is found among the branched Melobesiae which are also quantitatively very rich.

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Tables

- Table 1: Abundance and average dominance of the species in the different stations. (Not reproduced here).
- Table 2: Average dominance of the different families on the outer reef flats.
- Table 3: Average dominance of the different families on the boulder tracts.
- Table 4: Average dominance of the different families in the inner reef flats.

Table 2. Outer Reef-Flats

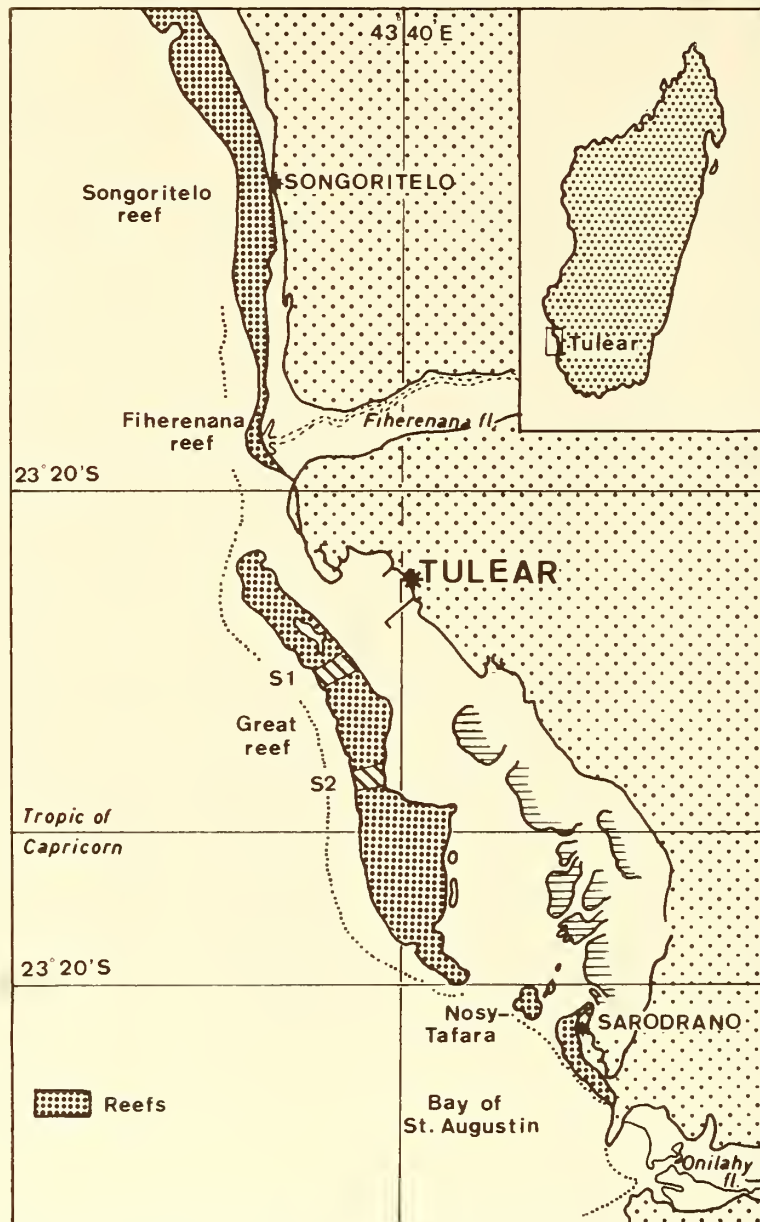
STATIONS	1	2	10	11	12	13	14	15	27	28	29	30
Number of individuals	133	207	47	97	77	60	55	101	63	76	78	58
Number of species	17	24	13	19	4	10	13	19	13	9	11	7
Dromiacea	3.00	0.96	2.12			8.23			1.51	3.94		
Oxystomata												
Oxyrhyncha	2.25	9.47	6.38	4.12	2.59		7.12	2.97	7.57	1.31		
Brachyryncha: Portunidae	0.75	3.82		8.24			5.4	5.94	10.60		1.28	3.45
Xanthidae	78.91	67.22	78.68	70.07	97.32	84.96	70.63	63.36	77.25	88.13	97.38	96.50
Ocypodidae												
Grapsidae			10.63					1.98	1.51	2.63		
Anomura	15.03	17.69	2.12	16.48		6.66	12.32	25.74	1.51	3.94		
Xanthidae												
Hyperolissa	0.75	4.79		1.03		5.00	1.72	6.95	1.51			1.72
No Carpiloida												
Zozymoida		0.96	2.12			1.66	1.72	0.99		1.31		
Galenoidea - Actaeinae	15.03	5.26	12.76	20.62		3.33	6.88	14.85	9.09	5.26	7.68	15.51
Chlorodinae	41.34	29.18	59.56	40.12	97.32	74.97	41.36	27.76	66.64	81.57	88.42	79.31
Cymoida	0.75											
Lyboida												
Menippinae	0.75											
Pilumninae - Pilumnoida	15.78	24.17		8.24			15.51	11.88			1.28	
Heteropanopoida		2.87	2.12				1.72					
Trapezinae	4.51											
Carcinoplacinae								1.98				
Galatheididae				1.03		1.66		0.99				
Porcellanidae	15.03	17.69	2.12	15.45		4.99	11.45	24.75	1.51	3.94		

Table 3. Boulder Tracts

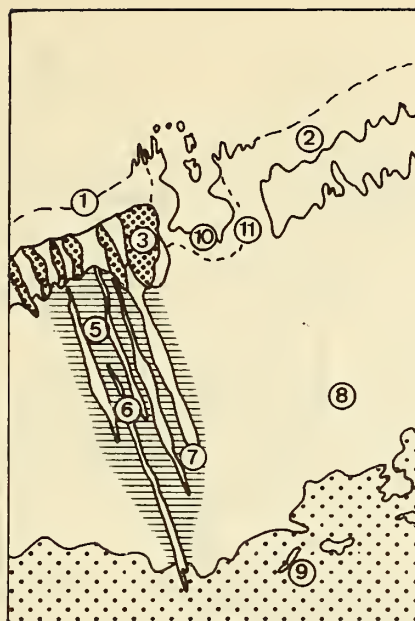
STATIONS	3	16	22	24	25	32	33	34	38	41
Number of individuals	43	55	53	107				36	141	46
Number of species	7	8	8	9				13	6	4
Dromiacea					2.70					
Oxystomata				1.40		1.28		2.72		
Oxyrhyncha							0.62	13.70		
Brachyrhyncha-Portunidae										
Xanthidae	39.52	47.24	64.12	92.99	64.86	65.33	46.66	68.47	27.59	26.09
Ocypodidae										
Grapsidae	55.80	43.63	18.86	1.40		26.92	49.37	1.36	1.41	6.52
Anomura	4.65	9.09	16.98	4.21	27.01	6.41	3.75	6.84	70.92	67.40
Xanthidae										
Hyperolissa No Carpiloida				0.47		1.28				
Zozymoida	9.30	9.08				1.28				
Xanthoida										
Galenoida-Actaeinae	9.30	16.36	28.29	1.40	10.81	23.06	11.26	20.55	4.22	
Chlorodinae			1.88	3.74		23.06	22.50	42.46	15.59	21.73
Cymoida	4.35	3.63	1.88							
Hyperomista Menippinae										
Pilumninae - Pilumnoida										
Heteropanopeidea	16.27	18.17	32.07	87.39	54.05	16.66	11.88	4.10	3.54	4.35
Trapezinae										
Carcinoplacinae										
Anomura - Galatheididae										
Porcellanidae	4.65	9.09	16.98	4.21	27.02	6.41	3.75	6.84	70.92	67.40

Table 4. Inner Reef Flats

STATIONS	5	7	8	6	9	17	18	19	20	21	26
Number of individuals	25	61	32	184	56	40	46	259	102	45	44
Number of species	9	14	8	23	11	7	12	23	19	8	6
Dromiacea											
Oxystomata											
Oxyrhyncha	8.00			3.25	1.78		2.17	1.59	1.96		9.09
Brachyrynychia: Portunidae		1.63		0.54	1.78			0.79			
Xanthidae	56.00	94.96	96.11	85.25	57.10	62.50	82.48	88.03	91.16	88.85	52.25
Ocypodidae	16.00					37.5	2.17		0.98	11.11	
Grapsidae								0.39	0.98		
Galatheidae	20.00	3.26	3.84	10.86	39.27		13.03	9.12	3.92		38.63
Xanthidae											
non Carpiloida		1.63		1.62				1.96	1.96		
Zozymoida			3.84	1.08				1.18			
Xanthoida											
Actaeinae	40.00	34.41	34.60	20.64	12.49	17.50	28.17	28.17	43.13	13.32	34.08
Chlorodinae	16.00	50.77	53.83	59.21	41.05	42.50	54.31	55.54	45.09	75.53	15.90
Cymoida											
Menippinae											
Pilumninae I		1.63			1.78			0.79	0.98		2.27
Heteropanopeida											
Lyboida											
Trapezinae		4.91	3.84						0.98		
Carcinoplacinae		1.63		1.08	1.78						
Galatheidae: Galathea		1.63	3.84	8.69	39.27	2.50	19.03	3.96	2.94		38.63
Procellanidae	20.00	1.63		2.17				5.16	0.98		

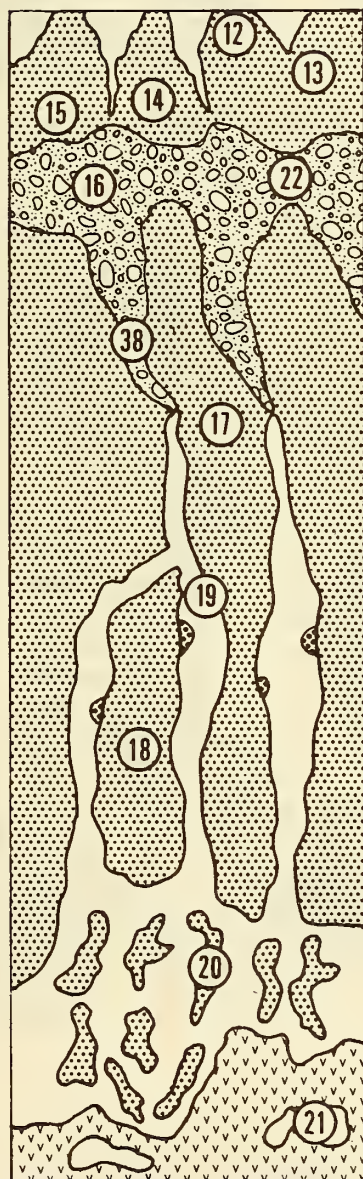


Map 1: The coral reef in the vicinity of Tuléar.



- ① Spur upper platform
- ② Glacis
- ③ Boulder tract
- ⑤ Compact reef flat
- ⑥ Branched melobesia
- ⑦ Reef flat with coral alignments and sandy couloirs
- ⑧ Reef flat with scattered coral growth
- ⑨ Sea-grass-bed basin
- ⑩ Outer creek
- ⑪ Zoantharian zone

Fig. 1: Localities of the stations in Sector 1.



OUTER REEF FLAT

- 12 Spur upper platform
- 13 Outer moat
- 14 Glacis
- 15 Layered melobesia

BOULDER TRACT

- 16 Crag
- 22 Filtering dike
- 38 Gravel tail

INNER REEF FLAT

- 17 Compact reef flat
- 18 Reef flat with coral alignments and sandy couloirs
- 19 Branched melobesia
- 20 Reef flat with scattered coral growth
- 21 Sea-grass-bed basin

Fig. 2: Localities of the stations in Sector 2.

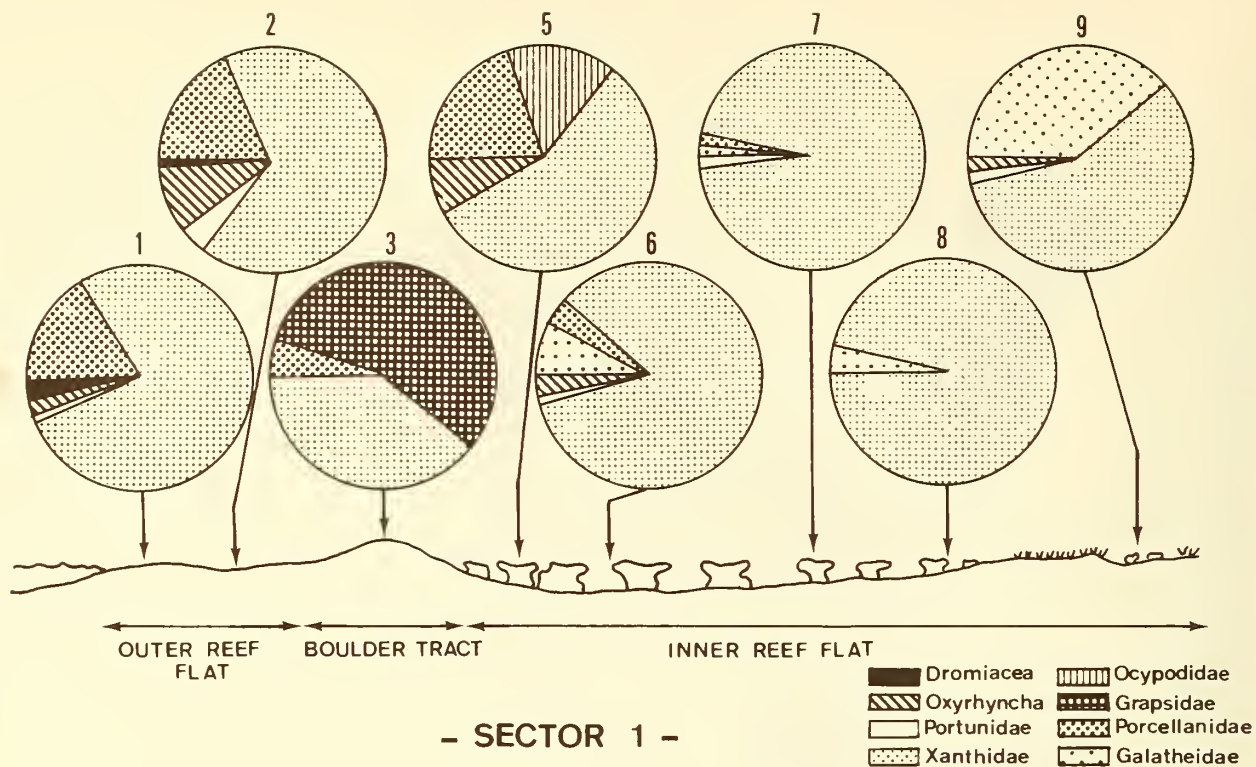


Fig. 3: Distribution of Brachyura and Anomura in the different stations in Sector 1.

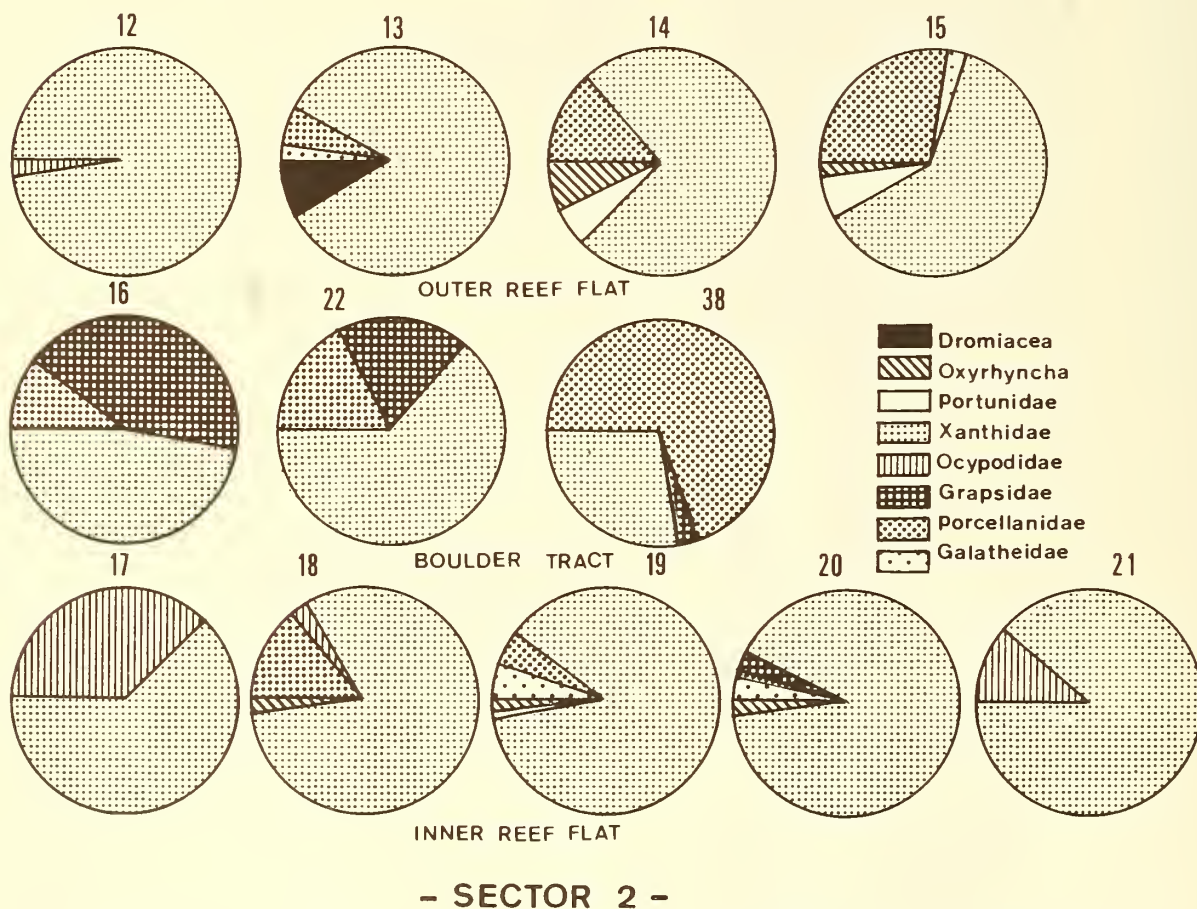


Fig. 4: Distribution of Brachyura and Anomura in the different stations in Sector 2.

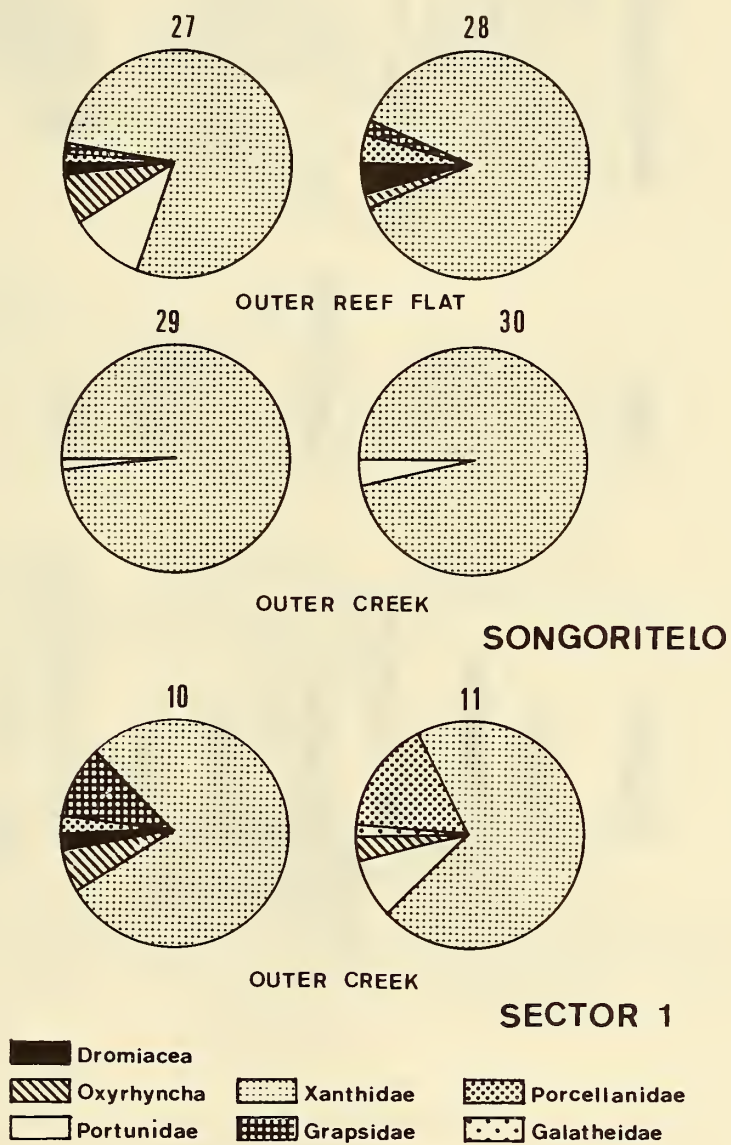


Fig. 5: Distribution of Brachyura and Anomura in the outer reef flat and outer creek of Songoritelo and of outer creek of Sector 1.

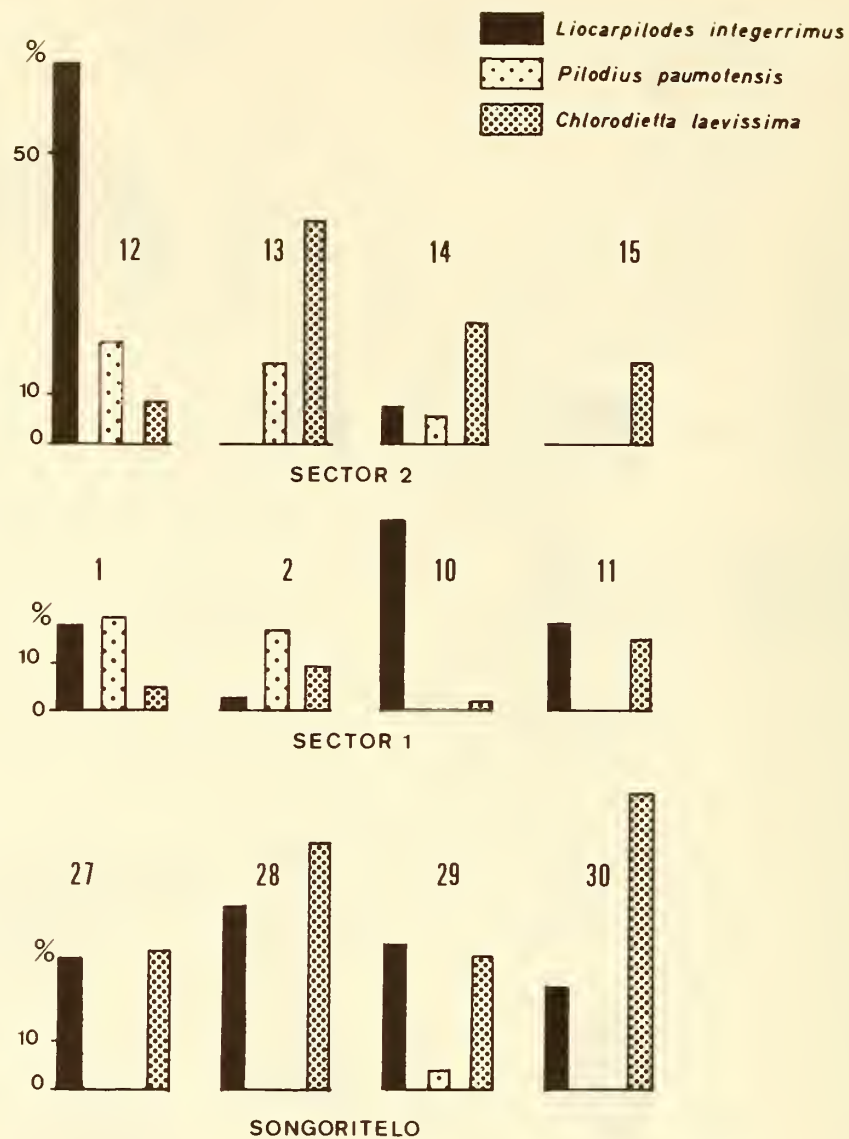


Fig. 6: Dominance of the three more abundant species of Chlorodinae in all the stations of the outer reef flats.

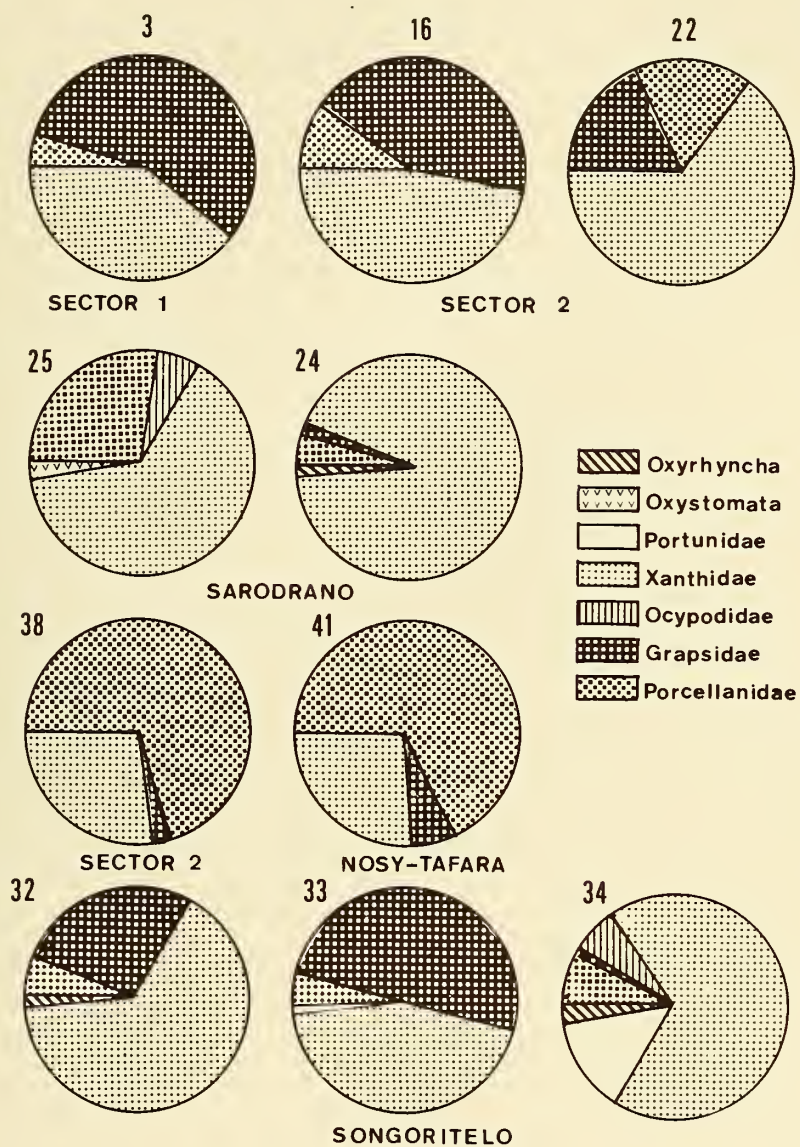
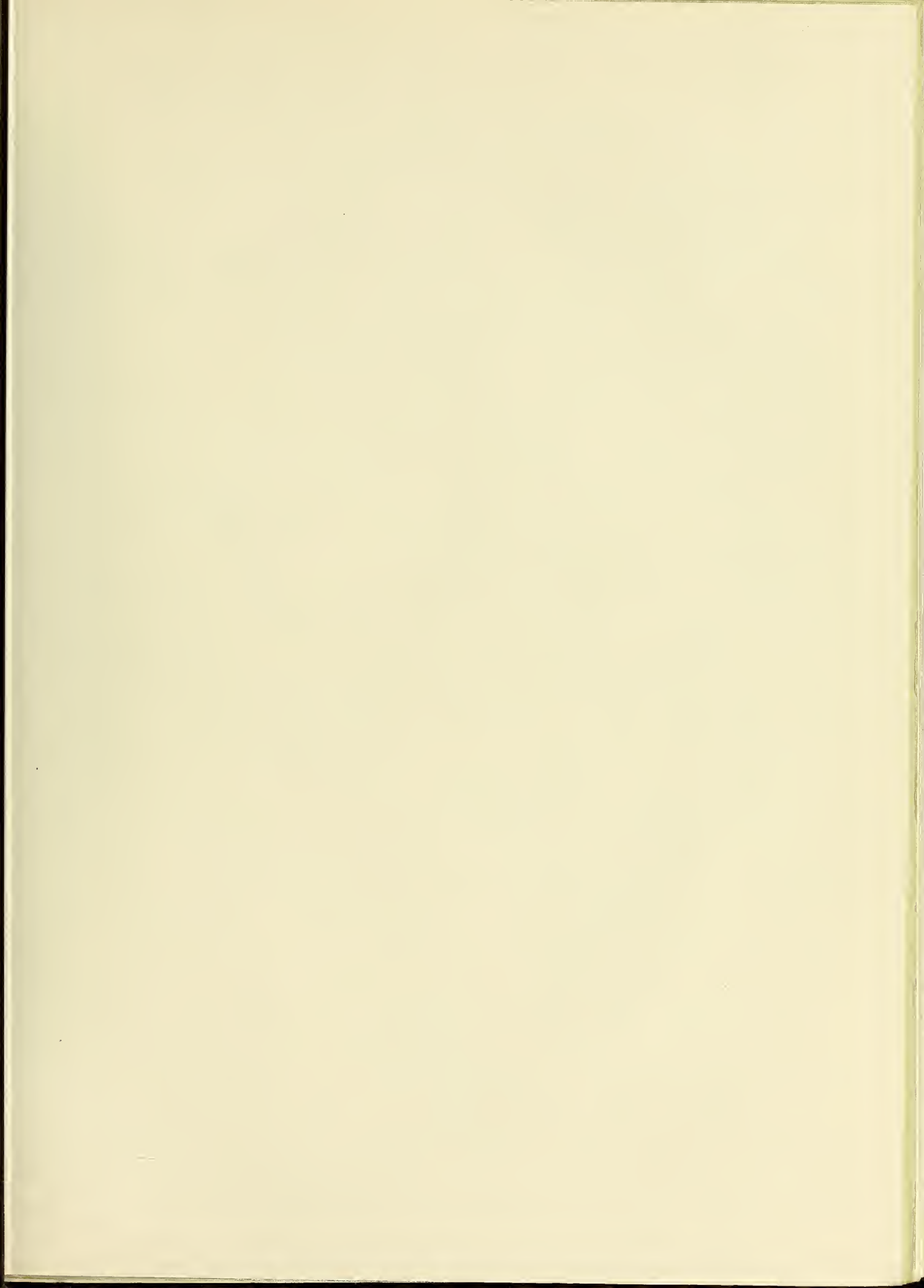


Fig. 7: Distribution of Brachyura and Anomura in the different stations on the boulder tracts.





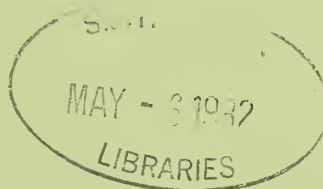






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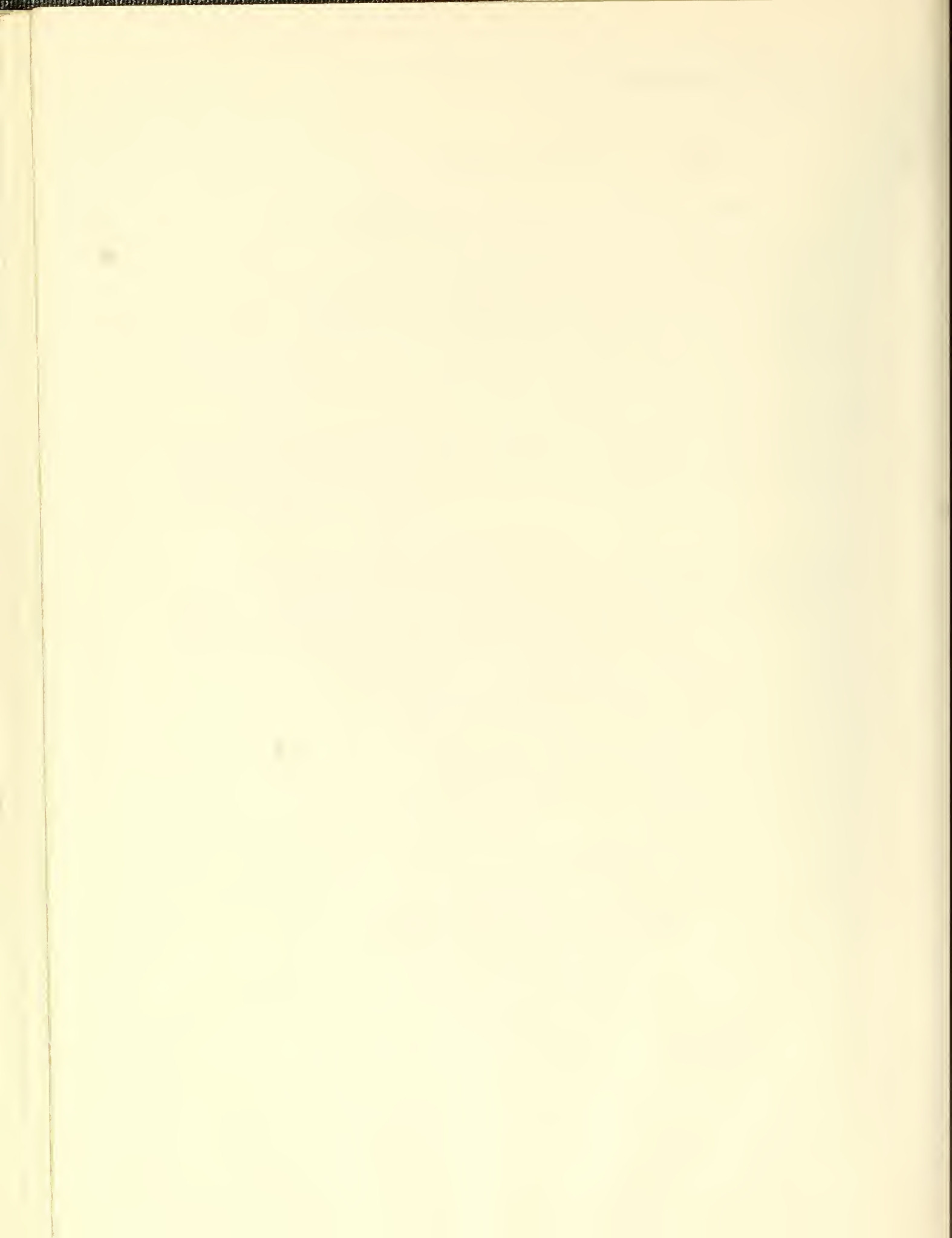
ATOLL RESEARCH BULLETIN
No. 256

CAYS OF THE BELIZE BARRIER REEF AND LAGOON

by

D. R. Stoddart, F. R. Fosberg and D. L. Spellman

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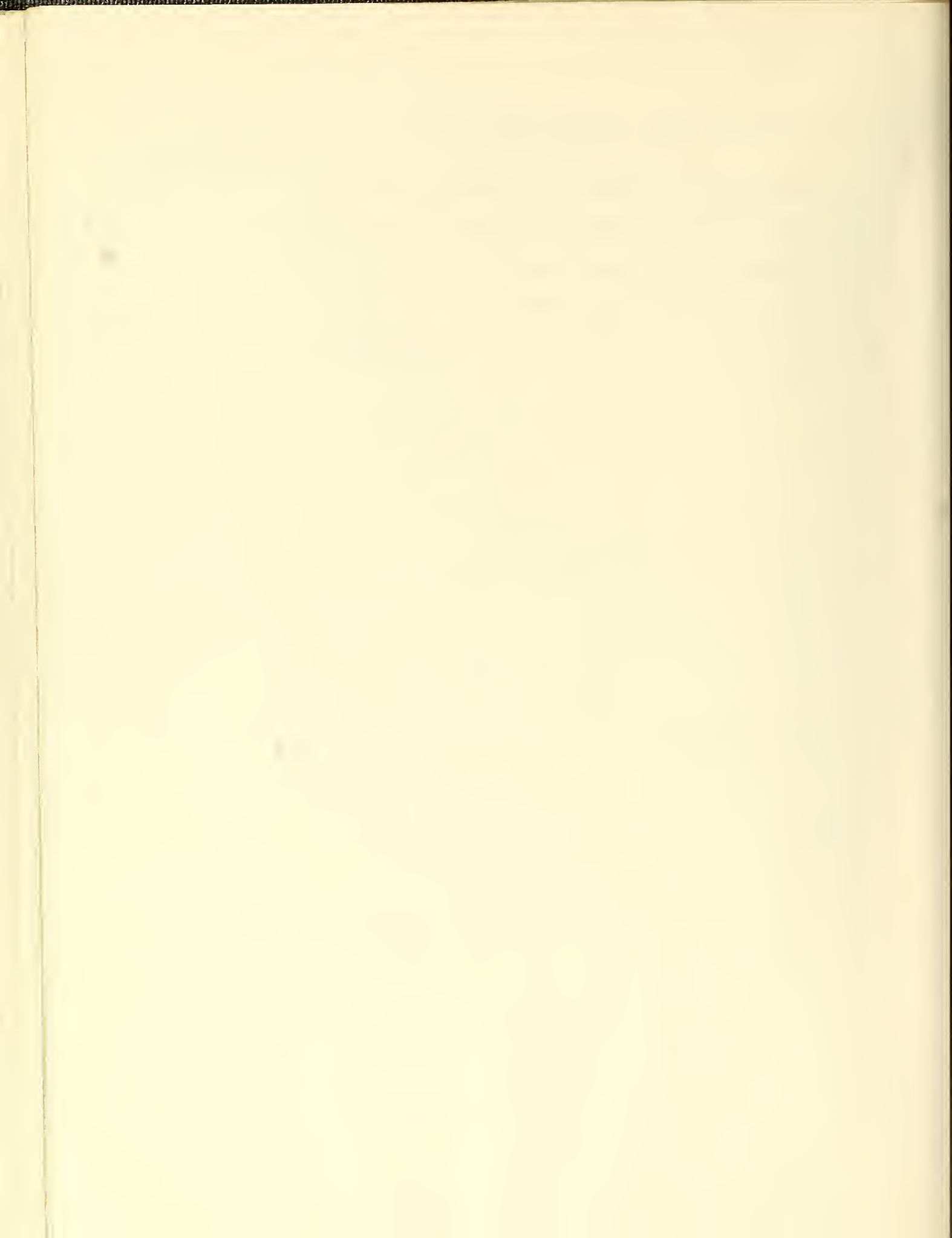
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CAYS OF THE BELIZE BARRIER REEF AND LAGOON

by D.R. Stoddart,¹ F.R. Fosberg,² and D.L. Spellman³

ABSTRACT

25 islands of the Belize barrier reef are mapped in this paper, together with 10 islands of the barrier reef lagoon. A further 4 barrier reef and 28 lagoon islands are described. For 22 islands comparative maps are presented showing topographic change between 1960-61 and 1972. Lists of vascular plants recorded from each island are given. Eleven types of island are recognised. Most of the islands have undergone erosion during the period of the surveys, notably during individual catastrophic hurricane events. The flora of the cays comprises 164 species. Vegetation units are briefly described, with special reference to the vegetation of dry mangrove cays and mangrove ranges, and to plant succession following major hurricane damage.

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1. INTRODUCTION

"The whole extent of the main reef is ... studded with numerous islets of every variety of size and solidity: first the spot of sand, just raised above the water; then the more extended beach, which nurtures into trees the cocoa-nut cast upon its shores; next those places composed of sand and mud, where the mangrove springs out of the water, and which are in this neighbourhood called by the appropriate name of 'drowned cays'; and lastly, the island, a mile or more across, whose soil produces the grapewood tree, button-wood tree (very hard and valuable for cogs of wheels), and other species of trees, with a girth of more than 3 feet" (Allen 1841, p.85).

" ... so deceitful are the different keys found from the general resemblance they bear to each other, that the most experienced seaman, when placed amongst them, often becomes fatally perplexed. ... A more particular description of these spots, so numerous scattered over the whole of this coast, would extend far beyond any moderate limits; nor could any material value be affixed to it, from the little characteristic difference that would be found connected with them" (Henderson 1811, pp. 20, 24).

This paper presents an account of the cays of the barrier reef and coastal shelf of Belize (British Honduras), Central America. It is based on data collected during five expeditions between 1959 and 1972. The first of these studied most of the barrier reef islands between St George's East Cay and Ragged Cay during the Cambridge Expedition to British Honduras 1959-60, when the field party consisted of Stoddart and J.D. Poxon. In 1961 Stoddart and S.P. Murray re-surveyed several of these islands, and also visited the Punta Gorda cays in the southernmost Gulf of Honduras, during a season supported by the Office of Naval Research and the Coastal Studies Institute, Louisiana State University. Following the catastrophic Hurricane Hattie of 30-31 October 1961, Stoddart remapped the barrier reef islands as far south as Carrie Bow Cay and also studied the numerous islands of the central coastal shelf between Placentia and Gladden Spit, during March-April 1962; this visit was supported by the Royal Society. The barrier and central shelf islands were again mapped, with Royal Society support, in March-April 1965, primarily to establish the nature of recovery following catastrophic hurricane damage. Finally, in June-July 1972 a comprehensive study was undertaken of the barrier and shelf cays (including the southernmost barrier reef cays only briefly visited previously in 1960) as part of the Smithsonian Institution's IMSWE (Investigations of Marine Shallow Water Ecosystems) Programme centred on Carrie Bow Cay. The

field party consisted of Stoddart (responsible for mapping and geomorphology), Fosberg and Spellman (vegetation and flora), and Henry Pelzl (ornithology).

Some of the information presented here has appeared in preliminary form in earlier papers. The regional setting and environment were described, together with general features of the reefs, in an account of parallel studies of the Belize offshore atolls (Stoddart 1962a). Hurricane effects on the northern and central barrier reef cays were considered in a paper on Hurricane Hattie (Stoddart 1963). Island recovery in the northern and central areas was considered in an account of the 1965 re-survey (Stoddart 1969). A preliminary account has appeared (Stoddart 1974) of changes on five of the cays monitored in 1972. The southern barrier reef cays (south of the Silk Cays) and those of the Punta Gorda area in the Gulf of Honduras have received only incidental mention in the published literature (Stoddart 1962b, 1965), and studies on them appear here for the first time. With the publication of a full account of the vascular plants of the cays (Fosberg et al. 1981), the nomenclature used in previous papers is here revised, and lists are given of species recorded from each of the islands during successive surveys. An analysis of plant species diversity on the cays has been published by Stoddart and Fosberg (1981).

With a few exceptions, all of the islands here mapped were surveyed by pace-and-compass methods as described by Stoddart (1962a, p.129). Maps from successive surveys were related to each other by reference to prominent objects. Islands such as Rendezvous Cay and Carrie Bow Cay were also mapped by tape-and-compass methods, and the results used to calibrate the scales of the other maps. Oblique low-level air photographs were taken of many of the islands in 1960, 1961, 1962 and 1965. All the maps of cays in this report are orientated conventionally (i.e. with magnetic north at the top).

When this study began in 1959 virtually nothing was known of any of the islands of the Belize coast, or indeed of the reefs themselves. The first detailed hydrographic charts were made during the 1830s by Richard Owen, Edward Barnett and Bird Allen, but their ships carried no scientific men and only brief accounts were published (Owen 1838, Allen 1841). Darwin utilized their information and called the Belize barrier "the most remarkable reef in the West Indies" (1842, p.201), but this led to no further field investigation. Both Agassiz (1894, p.162) and Vaughan (1919, p.300) called on evidence from Belize in support of their own theories of reef development, but neither visited the area. Not until 1957 were the cays investigated, in a pioneer reconnaissance study by Vermeer (1959). Three major series of investigations have, however, subsequently made the Belize shelf and barrier reef one of the best known reef provinces in the world. The Rice University studies of shelf sediments directed by Edward G. Purdy during 1960-67, recently summarised by Wantland and Pusey (1975), led to Purdy's classic papers (1974a, 1974b) on reef structure and morphology. Deep-diving submersible and geophysical studies by James and Ginsburg (1960) have led to new insights into the form and evolution

of the central barrier reef. Finally the IMSWE investigations directed by Klaus Ruetzler at Carrie Bow Cay have greatly extended knowledge of reef biota, ecology and growth. The present paper is thus concerned only with the most recent and ephemeral accumulations of clastic carbonate sediments on the top of these massive reef structures; with their vegetation cover; and with their short-term variability in form and location in response to environmental events.

We thank the British Department of Scientific and Industrial Research, the Royal Society of London, the Office of Naval Research, and the Coastal Studies Institute of Louisiana State University for support of the investigations in 1959-1965, and the Smithsonian IMSWE Programme for that in 1972. The support of the Government of Belize has greatly assisted this work from the time of its initiation, and nothing would have been achieved without the practical assistance of many Belizeans. We are especially grateful to Mr M. Young and Mr R. Coe, of the Department of Geography, Cambridge University, for their cartographic and photographic skills over many years.

Several of the diagrams within this paper have been prepared from copies of charts and surveys provided by the Hydrographer of the Navy and with the sanction of Her Majesty's Stationery Office. It is a pleasure to thank successive Hydrographers, notably Rear Admiral Sir Edmund Irving and Rear Admiral D.W. Haslam, both surveyors of the Belize coast and reefs, for their interest in this work.

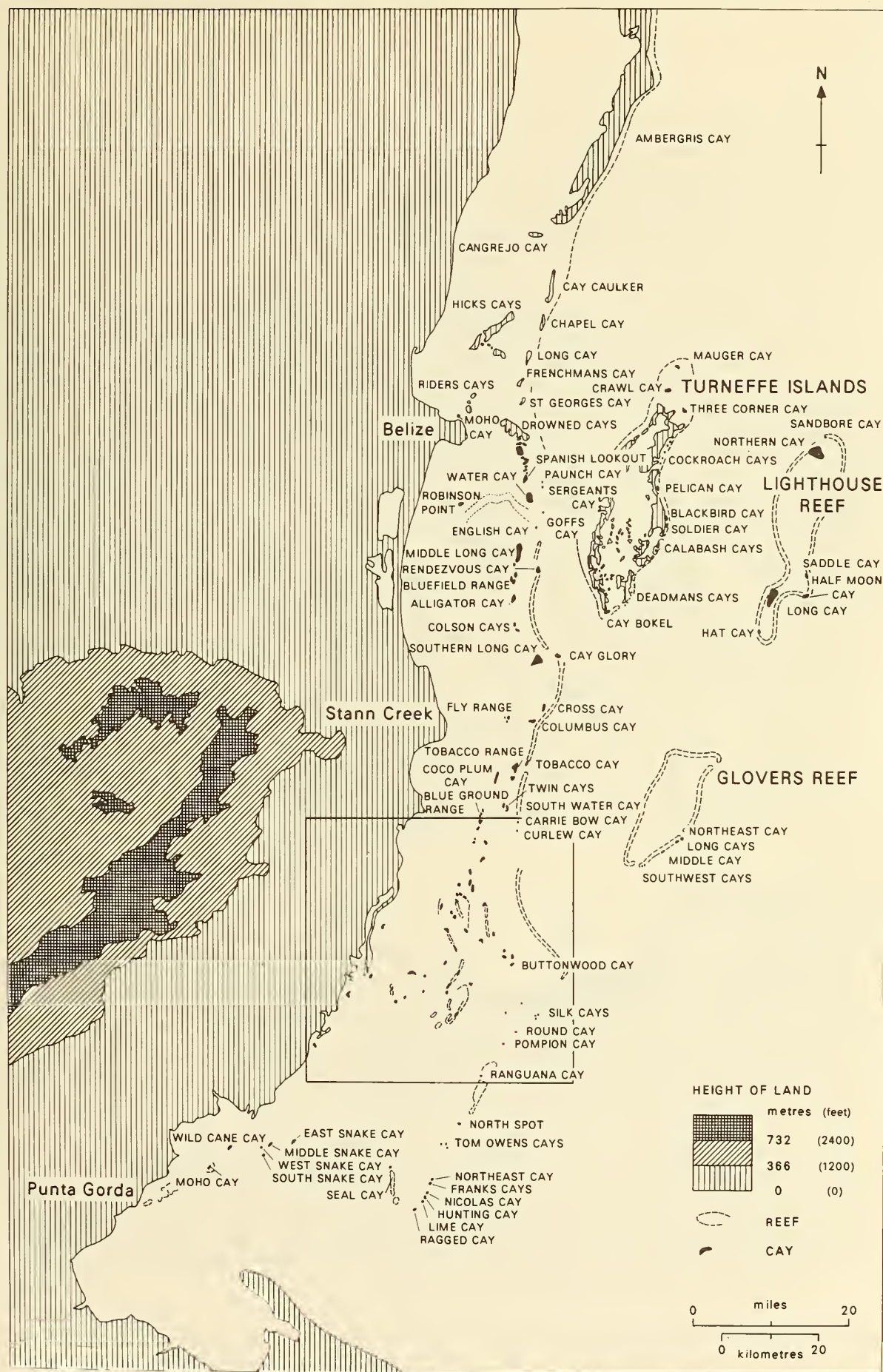


Figure 1. Location of the Belize reefs and cays
For detail of the enclosed area, see Figure 2

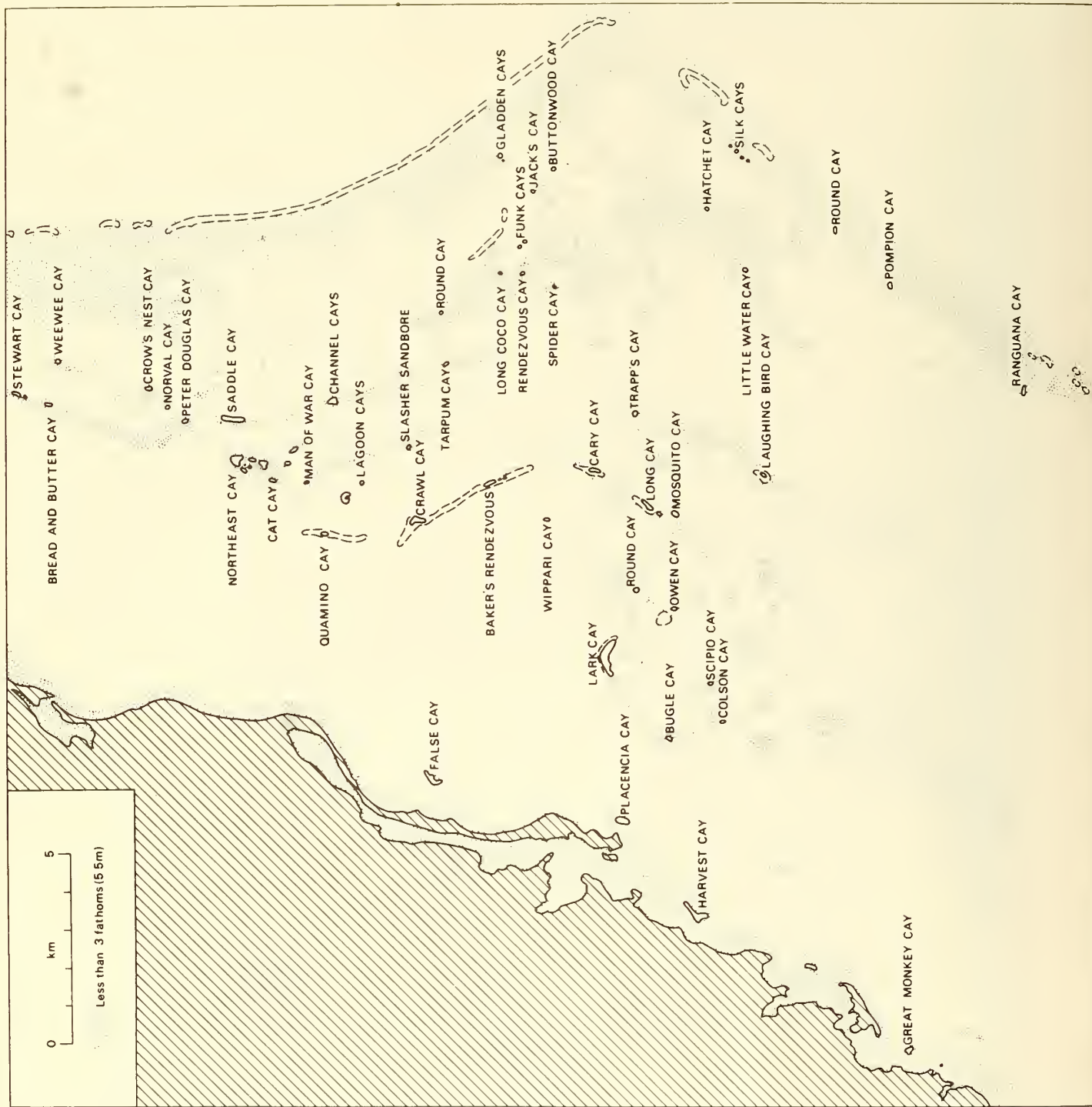


Figure 2. Reefs and cays of the central barrier reef lagoon

2. STRUCTURE AND ENVIRONMENT

Belize is located in the southeastern part of the Yucatan Peninsula, central America. The southern part of the country consists of an uplifted block of Palaeozoic metamorphosed sediments and intrusives, rising in the Maya Mountains to 1110 m above sea-level. The block is partly surrounded by hills of Cretaceous limestones, which are themselves overlain by low, flat-lying Cenozoic limestones which make up the greater part of the Yucatan Peninsula. The northern part of the east coast of the Peninsula, between Cabo Catoche and Ambergris Cay, is remarkably straight, formed by low cliffs with a fringing reef. South of Ambergris Cay, however, the Belize coastal shelf forms a major indentation up to 37 km wide. It is edged by a broadly arcuate barrier reef more than 200 km long. North of the city of Belize the shelf is generally less than 5 m deep; immediately south of Belize it increases to 10-12 m, and deepens southwards to depths of 45-55 m in the Gulf of Honduras. Seaward of the barrier reef the sea floor falls very steeply to more than 300 m, and depths of 1500 m are found within 6 km of the reef edge, except in the lee of the offshore atolls (Figure 1) (Dillon and Vedder 1973; James and Ginsburg 1980). Pronounced topographic lineations (notably connecting the southern barrier reef, the eastern side of Glover's Reef and the east side of Lighthouse Reef; the central barrier reef and the eastern side of Turneffe; and the coastline of Ambergris Cay) are clearly fault blocks aligned en echelon along the northern margin of the Cayman Trough, a major tectonic structure up to 7 km deep.

Purdy *et al.* (1975) have drawn attention to the very different characteristics of the shelf-edge reefs north and south of Belize City. To the north, where the shelf is shallow, there is a prominent chain of linear islands (Cay Caulker, Cay Chapel) located 2.5-4 km landward of the shelf edge; the edge itself is fringed by a discontinuous reef which lacks any well-developed reef flat. Purdy *et al.* (1975, 3) comment on the resemblance between this situation and that of the Bahama Banks. There are no true sand cays on these reefs north of latitude 17°33'N (the site of St George's East Cay which disappeared in 1961).

South of Belize City the deeper coastal shelf is edged by a barrier platform, in the terminology of Purdy *et al.* (1975). This has quite different characteristics north and south of Gladden Spit in latitude 16°30'N. In the northern sector, 80 km long, the shelf floor reaches depths of 20-24 m at distances of 8-15 km from the mainland coast; the shelf edge platform is 3-5 km wide and its upper surface 4-5 m deep. At its outer edge there is a well-developed reef flat 450-550 m wide, and there are numerous small patch reefs in its lee. South of Gladden Spit the same units are recognisable but with differing degrees of development. The shelf here has a constant width of 30 km,

and its maximum depth increases southwards from 35 to 77 m. The barrier platform maintains its depth on its upper surface of 4-5 m, but it is less than 2 km wide, is dissected by deep channels, and carries little surface reef. In spite of these differences in dimension, however, the volume of the barrier platform remains constant along the entire shelf edge (Stoddart 1977, p.47).

Within the coastal shelf there are three main groups of islands, in addition to those of the shelf edge reefs, which are considered here. The reefs of the Southern Triangles are developed at the inner end of the Belize Deepwater Channel. They are scattered isolated patch reefs, many of which have small mangrove cays on their upper surfaces. In the latitude of Gladden Spit there is a complex array of lenticular reefs, mostly slightly submerged (Stoddart 1963, figs. 35-36), fully described by Purdy (1974b), termed 'shelf atolls' by Purdy *et al.* (1975, p.15) and 'rhomboid platform atolls or faroes' by James and Ginsburg (1979). Surface reefs are irregularly developed on these structures, but where they do occur islands are common. Finally, small patch reefs rise from shallow water near the mainland coast in the Gulf of Honduras, north of Punta Gorda, and carry sand and mangrove cays.

Purdy (1974b) has shown that the present surface reefs at the Belize barrier are relatively thin Holocene structures capping an older antecedent and possibly karst-eroded reef topography. The Holocene reefs are 8-20 m thick, and average 12 m. The positive features on which they grow are presumed to be reefs of last interglacial age. In contrast to many other parts of the Caribbean there are no last interglacial reefs standing above present sea-level anywhere on the coast of Belize, though they are described at the usual heights of 2-4 m, with ages of 120-125,000 years, in northeastern Yucatan and Cozumel by Szabo *et al.* (1978). Their greater depth beneath the Belize reefs must indicate long-continued subsidence connected with the horst structures north of the Cayman Trough.

Modern reef growth on the Belize shelf must have post-dated the flooding of the antecedent topography on which the present reefs stand during the Holocene transgression, about 6000-8000 yr B.P. The deeper surface of the southern shelf would have flooded earlier, and Purdy (1974b, 854) has obtained dates of 6000-10,000 yr B.P. for shelf floor peats. Halley *et al.* (1977) have documented the sequence of Holocene reef growth on a pre-existing Pleistocene limestone prominence for a small patch reef of the central barrier reef. This and other Belize reefs have grown in the Holocene at rates of 1-2 m per 1000 yr (Purdy 1974a, p.67). The date at which reef flat development close to low-tide level could provide a platform on which clastic sediments could accumulate to form cays will thus be a function of the depth and dimensions of the reef foundations, governing both the time at which they were flooded by the Holocene transgression and the volume of constructional reef growth required for the reef to reach the present sea-level. The actual age of reef flat formation has yet to be determined for Belize reefs.

The Belize reefs lie in the zone of Northeast Trades, which blow with great constancy, especially during the summer months of April-September. At Belize, for the period 1917-1949, 56% of winds at 0600 hours came from the east and southeast and 23% from the northwest (means for the years), while at 1800 hours 75% came from the east and northeast. The Trades are interrupted during the months of November to February by 'northerners', 4-5 day periods of northerly winds and low temperatures associated with the southerly extension of the North American high pressure system.

Rainfall over the east coast of the Yucatan Peninsula is about 1500 mm. June-September are the wettest months, and there is a pronounced dry season in February-April. Annual totals increase markedly southwards, to nearly 1900 mm at Belize, 2400 mm at Mango Creek, and 4200 mm at Punta Gorda (Table 1); the dry season is also very much less pronounced in these wetter areas. There are no rainfall records for any of the islands of the coastal shelf, but it is reasonable to presume that annual totals on the cays mirror those of coastal localities. Certainly there is evidence in the southernmost cays of much more humid conditions than in the north.

Minimum temperatures at Belize vary from 20°C in January and December (monthly means), with a mean maximum of 31.1°C in August. Mean temperatures range from 24° in winter to 27° in summer. Extreme temperatures recorded at Belize during 1951-60 were 9.4° and 36° (Portig 1976, p.470).

Hurricanes occur during the months of July to October. Especially destructive storms have been recorded in 1787, 1813, 1827, 1831, 1931, 1942, 1945, 1955 and 1961; for an annotated list of recorded storms see Stoddart (1963, pp. 127-130). The most recent significant storm to affect the reefs was Hurricane Greta in September 1978; this post-dated all the surveys reported here. The effects of the lesser Hurricane Fifi of October 1974 have been documented for Carrie Bow Cay by Miller and Macintyre (1977, p.27).

Mean tidal range at springs is only 0.2 m, and water level may be more affected by wave set-up and wind than by the astronomical tides. The main Caribbean current which flows from east to west from the Lesser Antilles is diverted northwards through the Yucatan Channel by the Yucatan Peninsula. Water movement on the coastal shelf is mainly to the south, into the Gulf of Honduras (Purdy et al. 1975, p.13).

Table 1. North-south variation in rainfall, east coast of the Yucatan Peninsula

Locality	Latitude	Length of record, yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Cozumel	23.31	10	83	31	57	54	177	177	76	127	213	302	121	85	1502
Chetumal	18.30	15	77	22	29	30	138	176	131	106	142	214	87	96	1247
Corozal	18.24	10	76	43	18	45	131	196	199	159	278	127	104	111	1487
Belize	17.30	39	136	63	38	51	105	206	163	168	235	307	209	185	1866
Stann Creek	16.58	10	146	70	75	77	138	262	291	253	276	265	257	155	2264
Mango Creek	16.33	10	121	77	48	47	133	363	382	290	335	288	195	115	2393
Toledo	16.25	10	193	70	109	72	146	556	766	613	468	292	201	153	3639
Punta Gorda	16.06	10	297	147	112	117	320	612	610	584	564	307	292	279	4239

Source: Wernstedt (1972, p.105); Romney *et al.* (1959, p.16).

3. SAND CAYS OF THE NORTHERN BARRIER REEF

This chapter describes the sand cays of the shelf-edge reefs between St George's East Cay in the north and Curlew Cay, south of Carrie Bow Cay, in the south, a distance of some 90 km. In each case, citations are given of previously published accounts, together with a list of plants recorded from the island. Since some of these cays have been treated in previous papers, the descriptions in this chapter are abbreviated.

St George's East Cay (17°33'N, 88°03'W)

Plate 2

When mapped in 1960, this was an arcuate shingle ridge 110 m long with a maximum altitude of about 1 m. It had an area of 0.3 ha. The vegetation cover consisted of herbs and vines, with taller shrubs of *Tournefortia*, *Conocarpus* and *Borrighia* at the northeastern end. The island disappeared completely during Hurricane Hattie in 1961, and had not re-formed when the site was visited in April 1962. For a fuller account see Stoddart (1963, pp. 40-41). Plants recorded are:

<i>Sesuvium portulacastrum</i> 60S ⁺	<i>Conocarpus erectus</i> 60S
<i>Canavalia</i> sp. 60S	<i>Ipomoea</i> sp. 60S
<i>Euphorbia mesembrianthemifolia</i> 60S	<i>Tournefortia gnaphalodes</i> 60S
<i>Rhizophora mangle</i> 60S (seedling)	<i>Borrighia arborescens</i> 60S

Paunch Cay (17°24'N, 88°02'W)

Plate 1

Charted as Punchgut Kay by Speer (1771) and as Paunchgut by Jefferys (1775). It was vegetated in 1830 and in 1896-7 had coconut palms 10 m tall. The island was destroyed in the 1931 hurricane. When mapped in 1960 it was an unvegetated sandbore 45 m long, with three parallel lines of beachrock up to 45 m long on its south side. The sandbore disappeared but the relict beachrock survived the 1961 hurricane. No land was present in 1962 and the site has not been visited since. See Stoddart (1963, p.41 and fig. 21). The only

+ In the plant lists the numeral refers to the year of record, and S or C refer to sight records or collections respectively. Species preceded by an asterisk are not native to the Belize cay flora, though this does not necessarily imply that they have been deliberately introduced on the cays where they occur.

plant recorded is:

**Cocos nucifera* 1896S

Sergeant's Cay (17°23½'N, 88°02'W)

Figure 3, Plates 3-4

This island was charted by Speer (1771) and Jefferys (1775); at the time of the survey by H.M.S. *Rambler* in 1896-7 it had palm trees 15 m tall. It was first mapped in 1960, when it was a triangular sand cay with greatest length of 100 m and width of 45 m. Its area was 3680 sq m. The island was occupied by a large clubhouse, and the ground surface beneath the coconut palms was cleared. The cay was almost completely destroyed during Hurricane Hattie and was reported awash a few days later. In March 1962 a triangular sand cay had re-formed, with longest dimension of 70 m and area of 2000 sq m. The surface was colonised by patches of *Portulaca oleracea*, together with *Sesuvium portulacastrum* and *Euphorbia mesembrianthemifolia*. By 1965 the island was more elongate, but only 68 m long and with an area of 1640 sq m. The pioneer *Portulaca* had disappeared. A central area, occupying about 25 per cent of the surface and persisting from before the hurricane, had a continuous cover of *Ipomoea*, *Wedelia* and *Euphorbia*; *Sesuvium* was also absent. Shrubs were represented by three *Conocarpus* up to 3 m tall, six *Suriana* up to 1.5 m tall, and three *Tournefortia* less than 1 m tall; there was a single *Coccoloba* seedling. *Euphorbia* and *Ipomoea* were colonising fresh sand areas. The number of plant species had risen from 4 in 1962 to 13 in 1965. For further details, see Stoddart (1963, pp. 41-42, fig. 22; 1969, p.8, fig. 4) and Vermeer (1959, pp. 71-74).

The island was re-mapped on 11 July 1972, when it was 90 m long and 25 m wide, with an area of 1750 sq m. The vegetated area was still largely limited to that part of the surface inherited from before the hurricane: it was covered with a mat of *Euphorbia*, *Ipomoea*, *Vigna*, and *Sesuvium*. All the 1965 shrub species were present, but the *Coccoloba* was in danger of being undermined as the south shore continued to be eroded. Fresh sand to the west of the main vegetated area was being colonised by *Portulaca*. A new coloniser was *Spartina spartinae*, the only grass, forming a conspicuous clump near the centre of the island. Three species had become extinct since 1965: *Batis maritima*, *Euphorbia blodgettii* and *Eustoma exaltatum*. 14 species were present in 1972, bringing the total recorded for the island to 20:

<i>Spartina spartinae</i> 72C	<i>Canavalia rosea</i> 72C
<i>Cocos nucifera</i> 1896S 60S	<i>Suriana maritima</i> 65S 72C
<i>Coccoloba uvifera</i> 65S 72C	<i>Euphorbia blodgettii</i> 65S
<i>Batis maritima</i> 65C	<i>Euphorbia mesembrianthemifolia</i>
<i>Philoxerus vermicularis</i> 65S 72C	62C 65S 72C
<i>Portulaca oleracea</i> 62C 72C	
<i>Sesuvium portulacastrum</i> 62C 72C	<i>Rhizophora mangle</i> 62S
<i>Cakile lanceolata</i> 65C 72C	(seedling)

<i>Conocarpus erectus</i> 65S 72C	<i>Tournefortia gnaphalodes</i> 65S 72C
<i>Eustoma exaltatum</i> 65C	<i>Avicennia germinans</i> 60S
<i>Ipomoea macrantha</i> 65S 72C	<i>Wedelia trilobata</i> 65S 72C
<i>Ipomoea pes-caprae</i> 65S 72C	

Curlew Cay (17°23'N, 88°02'W)

Curlew Cay is described by Speer (1765, 19) as "very low", with "only a few bushes", and comparable to Paunch Cay. The *Honduras Almanack* for 1830 stated that "there are no trees on Curlew, but bush, such as bay cedar [*Suriana maritima*] and lilly-root grass". It was charted by Owen in 1830 and by H.M.S. *Rambler* in 1896-7, but disappeared some time after that date, possibly in the 1931 hurricane. When visited in 1960 it was a small sandbore 20 m long and 0.6 m high; it was not seen in 1962. Plants recorded:

Gramineae indet. 1830S

Suriana maritima 1830S

Goff's Cay (17°21'N, 88°02'W)

Figure 4, Plates 5-6

In February 1960 Goff's Cay was triangular, with sides 65-75 m long, built of grey sand, with a fresh sandspit at the north end. It was charted by Speer (1765, p.19 - a "small round Kay ... not so big as English Kay") Jefferys (1775), and H.M.S. *Rambler* in 1896-7, when it had coconuts 14 m tall. Coconuts dominated the vegetation in 1960. There were a few *Coccoloba* and *Avicennia* trees. The ground beneath the coconuts was sparsely covered with *Euphorbia*, *Ipomoea* and *Canavalia*; the fresh sand was being colonised by *Sesuvium*, *Ipomoea* and *Canavalia*. The area of the island was 2920 sq m, and 7 plant species were recorded. The island suffered severe erosion during Hurricane Hattie. The old island surface was reduced to about 800 sq m. By March 1962, however, marginal fresh sand accumulation had increased the surface area to 2280 sq m. Surface sand was stripped from the old island area; two or three coconuts and some broken *Coccoloba* survived. The only new coloniser was *Portulaca oleracea*. Relict beachrock, not previously visible, was exposed on the south and east sides of the cay. For further details of the island in 1960 and 1962, see Stoddart (1963, pp. 43-44, fig. 23). By 1965 slight recession of the south coast had been balanced by considerable aggradation on the north side, increasing the total area to 2870 sq m, approximately that of the pre-1961 island. Dense vegetation - a mat of *Euphorbia*, *Sesuvium*, *Ipomoea* and *Ernodea* - was limited to the surface area surviving from before the storm, though vines if *Ipomoea* were colonising fresh sand. Eighteen coconuts planted since 1961 were up to 1 m tall. In both 1962 and 1965 there was a small unvegetated sandbore about 400 m north of the main cay. For details of the island in 1965 see Stoddart (1969, p.8, fig. 4).

Goff's Cay was re-mapped on 11 July 1972. The core island remained, with some marginal erosion on the east side, but the marginal sand accumulations had considerably increased to give a total island area of 3190 sq m. The herb mat consisted of *Portulaca*, *Sesuvium*, *Ipomoea*, *Ernodea* and *Cakile*, and 17 coconuts survived. The eastern sand spit was being colonised by *Cakile*. A substantial concrete jetty had been built on the leeward side (the island is much used for recreational purposes), and a deep depression near the centre was presumably the sand source for the concrete. 10 plant species were recorded in 1972, compared with 2 in 1962 and 4 in 1965. No species became extinct either between 1962 and 1965 or between 1965 and 1972 except for the broken *Coccoloba* which did not survive. New colonisers in the first three years were *Cocos* (planted), *Sesuvium*, *Ipomoea* and *Euphorbia*; after 1965 they included two grasses (*Andropogon*, *Eragrostis*), a sedge (*Cyperus planifolius*), and *Cakile*. A total of 13 species is now recorded from the island:

<i>Andropogon glomeratus</i> 72C	<i>Cakile lanceolata</i> 72C
<i>Eragrostis prolifera</i> 72C	<i>Canavalia</i> sp. 60S
<i>Cyperus planifolius</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Cocos nucifera</i> 1896S, 60S 65S 72S	<i>Euphorbia</i> sp. 60S 65S
* <i>Coccoloba uvifera</i> 60S 62S	<i>Ipomoea pes-caprae</i> 72C
<i>Portulaca oleracea</i> 72C	<i>Ipomoea</i> sp. 60S 65S
<i>Portulaca</i> sp. 62S	<i>Avicennia germinans</i> 60S
<i>Sesuvium portulacastrum</i> 60S 65S 72C	<i>Erithalis fruticosa</i> 65S 72C

Seal Cay (17°21'N, 88°02'W)

Seal Cay was noted by Speer (1766, p.19) as "a very low, small, sandy Kay". It was not charted by Owen in 1830, but the *Rambler* survey noted a sandbore awash at high water immediately on the north side of the entrance to the Belize Deepwater Channel. It was not seen during our own surveys. The seal in question was presumably the West Indian Monk Seal *Monachus tropicalis*, though the animal itself does not appear ever to have been recorded from the Belize coast, which is not included in King's (1956, p.217) map of the range of this species. That it was reasonably common in the eighteenth century is shown by the presence of other 'Seal Cays' on the barrier reef.

English Cay (17°20'N, 88°03'W)

Figure 5, Plates 7-10

English Cay was charted by Speer (1765, p.19: "a short, round, bluff Kay"; 1771) and Jefferys (1775). It has been a lighthouse and pilot station for many years; the present lighthouse was built in 1935. In 1960 the island was triangular, with sides 75-90 m long, and with an area of 6510 sq m. The eastern shore was largely artificial, being partly a masonry wall and partly a ridge of conch shells. A leeward

sand spit seen in January 1960 was evidently a seasonal feature (Vermeer 1959, p.75). The vegetation was limited to coconuts 12-15 m tall, with the ground surface kept clear; there were two mature *Rhizophora* and one *Coccoloba* tree. During Hurricane Hattie in 1961 the island suffered severe marginal erosion and stripping of surface sand; its area was reduced to 3390 sq m. 90 of the 98 coconuts disappeared together with all the houses, but the lighthouse remained standing. *Rhizophora* survived but the *Coccoloba* was killed. No new plant species had colonised the island by March 1962 (see Stoddart 1963, pp. 44-45, fig. 24). By 1965 there had been virtually no change in the morphology of the island. 18 coconuts had been planted, and there was a patchy ground cover of *Sesuvium*, *Portulaca* and *Euphorbia*. The area of the cay was stable at 3520 sq m (Stoddart 1969, p.9, fig. 6). By 1972, however, walls had been built round almost the entire periphery of the cay, close to the position of the 1960 shoreline, and low-lying sand had accreted within this area. There were two main areas of *Euphorbia*, *Sesuvium*, *Portulaca* and *Ipomoea*, and several smaller patches; a strip of littoral *Sporobolus*; a single small shrub each of *Tournefortia* and *Suriana*; and 25 coconuts. The total dry-land area had increased to 4940 sq m, and the number of plant species from 2 in 1962 to 6 in 1965 and 18 in 1972. Two species recorded by Dwyer, Elias and Maxwell in 1967 (*Ernodea littoralis*, *Eclipta prostrata*) were not found either in 1965 or in 1972. Since the island is subject to continuous human interference it is clear that the vegetation is also much disturbed, notably by periodic clearing of the ground cover. Species recorded from English Cay are:

<i>Paspalum distichum</i> 72C	<i>Euphorbia</i> sp. 65S
<i>Sporobolus virginicus</i> 72C	<i>Phyllanthus amarus</i> 72C
* <i>Cocos nucifera</i> 60S 62S 65S 72S	* <i>Carica papaya</i> 65S
<i>Coccoloba uvifera</i> 60S	* <i>Citrullus lanatus</i> 72C
<i>Philoxerus vermicularis</i> 65S 72C	<i>Rhizophora mangle</i> 60S 62S
<i>Portulaca oleracea</i> 67C 72C	<i>Ipomoea pes-caprae</i> 72C
<i>Portulaca</i> sp. 65S	<i>Ipomoea stolonifera</i> 72C
<i>Sesuvium portulacastrum</i> 65S 67C 72C	(seedling)
* <i>Tamarindus indica</i> ? 72C (seedling)	<i>Tournefortia gnaphalodes</i> 72C
<i>Suriana maritima</i> 72C	<i>Ernodea littoralis</i> 67C
<i>Euphorbia blodgettii</i> 72C	<i>Hedyotis corymbosa</i> 72C
<i>Euphorbia mesembrianthemifolia</i>	<i>Eclipta alba</i> 72C
67C 72C	<i>Eclipta prostrata</i> 67C
* <i>Euphorbia thymifolia</i> 72C	

Sandbore south of English Cay (17°19½'N, 88°03'W)

H.M.S. *Vidal* charted this sandbore in 1957-8; it was not charted by H.M.S. *Rambler* in 1896-7 or earlier surveys. In 1960 it was 55 m long and up to 1 m high, and unvegetated. It has not been seen since.

Samphire Spot (17°17'N, 88°02½'W)

This was charted as Saphire Kay by Jefferys in 1775 but omitted by him in 1792 and 1800; it was not noted by Speer or Owen in 1765 and 1830, but appears as Samphire Spot following the 1896-7 *Rambler* survey. In 1959-61 it was a small unvegetated sandbore; it presumably disappeared during Hurricane Hattie, but in 1962 was again a small sandbore 23 m in diameter.

Rendezvous Cay (17°15'N, 88°03'W)

Figure 6, Plates 11-15, 17-18

During the 1920s and 1930s this island was inhabited by a local fisherman, and in consequence is still locally known by some as 'Brown's Cay'. It was the headquarters of the Cambridge Expedition to British Honduras in 1959-60. At that time it was a slightly arcuate island, aligned north-south, 90 m long and 9-23 m wide. It was formed entirely of sand and its greatest height was less than 1 m. The leeward shore had been extended by accumulations of conch shells, giving a crenulate outline and forming small-boat harbours. The total area of the cay was 2610 sq m. Speer (1765, p.19) described it as "a low sand Kay, with only one bush on it". It was also charted by Jefferys in 1775 and Owen in 1830. In 1921-22 H.M.S. *Mutine* recorded coconuts 14 m high. In 1960 the taller coconuts reached almost 20 m; there were mature *Coccoloba* and *Avicennia* trees; and frequently cleared patches of *Sesuvium*, *Euphorbia* and *Sporobolus*. *Rhizophora* was represented by numerous seedlings round the shore. The island was greatly damaged during Hurricane Hattie. The house disappeared and all the coconuts were destroyed. The overall dimensions remained much the same, but the island shifted slightly to the west and the area was reduced to 2180 sq m. The *Avicennia* was killed and the *Coccoloba* much broken. By March-April 1962, however, there was a varied though patchy cover of herbs, grasses and sedges. *Portulaca* was the most common species, together with *Cyperus planifolius* and *Sporobolus*. *Sesuvium*, *Euphorbia mesembrianthemifolia* and *Ipomoea pes-caprae* were also widespread. Shrub species were represented by seedlings of *Suriana*, *Conocarpus* and *Tournefortia*. Stoddart planted over 40 young coconuts on the cay in April 1962. For further details, see Stoddart (1963, fig. 4; 1963, pp. 47-49, fig. 28).

In 1965 the cay was of similar dimensions but had continued to migrate lagoonwards: the seaward shore in 1965 stood 10-15 m westwards of its 1962 position, and the area had declined slightly to 2000 sq m. The planted coconuts were 3 m tall, and in the north there were low shrubs of *Tournefortia* and *Suriana*. The ground surface was covered with a dense mat of *Ipomoea* and *Euphorbia*, with areas of *Wedelia* and *Sesuvium*; *Portulaca* had become rare. There was a single *Casuarina* 2 m tall at the north end (Stoddart 1969, pp. 9-10, fig. 7).

In 1972 these trends had continued. The cay had maximum dimensions of 92 x 32 m, and an area of 1840 sq m. Both its seaward and lagoonward shores were located up to 10 m westward of their 1965 positions (and hence up to 16 m westward of their 1960 locations). Some of the coconuts were already bearing. The ground cover was dominated by *Euphorbia*, *Ipomoea*, *Philoxerus*, *Sesuvium*, *Portulaca*, *Cyperus*, *Sporobolus* and other grasses. One clump of *Coccoloba* still survived from before the hurricane, but the *Casuarina* had disappeared and the *Suriana* appeared dead. There were several clumps of *Conocarpus*, *Rhizophora* and *Avicennia*. A small hut had been built and appeared to be intermittently occupied. There was evidence that the conch fishery had been resumed.

The total number of species recorded from Rendezvous Cay is now 24. 7 were recorded in 1960, 16 in 1962, 16 in 1965 and 16 in 1972. The uniformity of these figures disguises considerable turnover, however, as the detailed records show. The following species are recorded:

<i>Paspalum distichum</i> 62C 72C	<i>Cakile lanceolata</i> 62C 65S
<i>Sporobolus</i> sp. 60S 62S 65S	<i>Suriana maritima</i> 65S 72C
<i>Cyperus ligularis</i> 62C	<i>Euphorbia mesembrianthemifolia</i>
<i>Cyperus planifolius</i> 72C	62C 72C
<i>Cyperus</i> sp. 65S	<i>Euphorbia</i> sp. 60S 65S
<i>Fimbristylis cymosa</i> 62C 72C	<i>Rhizophora mangle</i> 60S 62S 65S 72C
* <i>Cocos nucifera</i> 20S 60S 65S 72S	<i>Conocarpus erectus</i> 65S 72C
* <i>Casuarina equisetifolia</i> 65S	<i>Laguncularia racemosa</i> 72C
<i>Coccoloba uvifera</i> 60S 62S 65S	<i>Ipomoea pes-caprae</i> 62S 72C
72C	<i>Ipomoea</i> sp. 65S
<i>Philoxerus vermicularis</i> 62C 72C	<i>Tournefortia gnaphalodes</i> 65S 72S
<i>Portulaca oleracea</i> 62C 65S 72C	<i>Avicennia germinans</i> 60S 72S
<i>Portulaca</i> sp. 62S	<i>Solanum campechiense</i> 62C
<i>Sesuvium portulacastrum</i> 60S 62C	* <i>Solanum lycopersicum</i> 62C
65S 72C	<i>Ageratum</i> sp. 65S
	<i>Wedelia trilobata</i> 62S 65S

Jack's Cays (17°14'N, 88°02½'W)

These are intermittent sandbores 20-40 m long. One was often visible in 1959-60, the other was seen in 1962. They are unvegetated.

Skiff Sand (17°13'N, 88°03'W)

An ephemeral sandbore on the outer barrier, charted by H.M.S. *Mutine* in 1921-22, and occasionally visible; it is unvegetated.

Cay Glory (17°06'N, 88°01'W)

Plate 16

Cay Glory was mapped in 1960: it was 105 m long, up to 21 m wide, and had an area of 1430 sq m. There was a single young coconut 1.2 m tall, and a small vegetated area covered with *Sesuvium*, *Euphorbia*, *Philoxerus*, *Cakile*, *Paspalum* and *Ipomoea*. The island was built of well-sorted beach sand (Stoddart 1964, figs. 4, 6) and its outline was clearly very variable. The island was previously larger. H.M.S. *Mutine* noted coconuts 21 m tall in 1922, but these must have been destroyed by either the 1931 or 1945 hurricanes. Beachrock relics of this older island are widespread north and west of the 1960 cay. The island disappeared entirely during Hurricane Hattie in 1961, and no land was seen on its site in 1962, 1965 or 1972. For further details, see Stoddart (1963, pp. 52-53, fig. 30). The following 7 plant species have been recorded:

<i>Paspalum distichum</i> 60C	<i>Cakile lanceolata</i> 60C
* <i>Cocos nucifera</i> 22S 60S	<i>Euphorbia mesembrianthemifolia</i> 60C
<i>Philoxerus vermicularis</i> 60C	<i>Ipomoea asarifolia</i> 60C
<i>Sesuvium portulacastrum</i> 60C	

Tobacco Cay (16°54½'N, 88°03½'W)

Figures 8-9, Plates 19-21

Tobacco Cay lies on the north side of one of the most important entrances in the central barrier reef. It was charted by Speer in 1771 and Jefferys in 1775, and there is an unverified suggestion that the island is named after tobacco cultivation during the early years of the English settlement in 1630-40 (Winzerling 1946; Caiger 1951, 28-29). The most recent hydrographic chart of the area was made by Owen in 1834. The cay was mapped in 1960, 1961 (in July after Hurricane Abby), 1962 (April, after Hurricane Hattie), 1965, and 1972.

In 1960 the island was roughly triangular, with a greatest north-south dimension of 275 m and a greatest width of 140 m; its area was 2.74 ha. The whole island was built of sand, with a flat featureless surface at about 1.2 m above sea-level. There were ridges of fresh sand along the south shore, and relict strips of beachrock 35 m offshore. The cay was inhabited and densely vegetated. In 1834 Owen had noted coconut trees 20 m tall, and Smith (1842, p.732) described a fig tree 20 m tall near the northeast point. In 1960 many of the coconuts were old, reaching up to 25 m, and there were also mature trees of *Terminalia*, *Coccoloba* and *Cordia*. There was a dense ground cover of *Stachytarpheta*, *Wedelia*, *Ipomoea pes-caprae*, *Ipomoea stolonifera*, *Sesuvium*, *Hymenocallis*, *Euphorbia*, *Canavalia* and *Vigna*. Hurricane Abby on 15 July 1960 removed the fresh sand ridges and blew down a number of coconuts; the inhabitants also cleared a good deal of the ground vegetation.

During Hurricane Hattie there was severe marginal erosion, stripping of surface sand, and deposition of fresh sand along the south and west shores. At the southeast point these new deposits reached a

height of 2 m, and were up to 14 m wide. 70 per cent of the coconuts were felled, the trunks being aligned N40°E. *Coccoloba* and *Cordia* were much broken, though *Terminalia* was less damaged. Since the cay was not inundated by the storm surge the ground vegetation survived with little change, though shade-seeking *Wedelia* had given way to *Ipomoea* in many places. The fresh sand ridges were also colonised by *Ipomoea*. By 1965 the fallen trees had been cleared and *Wedelia* had greatly expanded. *Ipomoea* and *Sesuvium* had expanded on the sand ridges, where *Tournefortia* had also appeared. The general ground cover, however, was similar in composition, though not in pattern, to that seen in 1960. The cay had been reduced in size to 2.25 ha immediately after Hurricane Hattie; by 1965 it had increased to 2.30 ha. For further details, see Stoddart (1963, pp. 53-55, fig. 31; 1969, p.10, fig. 8).

The island was re-mapped on 24 June 1972. Its area had increased to 2.50 ha, largely because of the presence of a fresh sand spit at the north point; the southern sand ridges had disappeared. The area of the vegetated cay has, however, remained very largely constant since 1960. Many new coconuts were growing, together with tree species (*Terminalia*, *Coccoloba*, *Cordia*) surviving from before Hurricane Hattie. The ground cover beneath the coconuts again consisted of *Wedelia*, *Stachytarpheta*, *Sesuvium*, *Euphorbia*, *Vigna*, *Hymenocallis*, *Portulaca*, sedges and grasses, though the central part of the island had been recently cleared and was bare. The southern sand ridge was colonised by *Tournefortia*, *Suriana*, *Euphorbia* and *Ipomoea*. The prominent rubble ridge on the reef flat to the southeast of the cay supported small patches of *Philoxerus* and *Sesuvium*.

The number of plants species recorded in 1960 was 8, in 1961 12, 1962 13, 1965 21 and 1972 41; the total recorded for the island is 44. Undoubtedly this increase results from more thorough collecting rather than from new colonisation. There is only one certain extinction over this period of record: a single *Sophora tomentosa*, 0.7 m tall near the south point, had disappeared by 1972. The plants recorded are as follows:

* <i>Eleusine indica</i> 62C 72C	<i>Coccoloba uvifera</i> 61S 62S 65S 72C
<i>Eragrostis ciliaris</i> 62C	<i>Philoxerus vermicularis</i> 72C
<i>Paspalum distichum</i> 72C	<i>Portulaca oleracea</i> 60C 61S 62S
<i>Phragmites</i> cf. <i>australis</i> 72C	65S 72C
<i>Spartina patens</i> 72C	<i>Sesuvium portulacastrum</i> 61S 65S
<i>Sporobolus virginicus</i> 65S 72C	72C
<i>Sporobolus</i> sp. 65C	<i>Caesalpinia bonduc</i> 72C (seedling)
<i>Cyperus ligularis</i> 72C	<i>Canavalia rosea</i> 60C 72C
<i>Cyperus planifolius</i> 72C	<i>Sophora tomentosa</i> 65S
<i>Cyperus</i> sp. 61S 65S	<i>Vigna luteola</i> 60C 62C 65S 72C
* <i>Cocos nucifera</i> 60S 61S 62S 65S	<i>Suriana maritima</i> 72C
72S	<i>Euphorbia blodgettii</i> 62C 72C
<i>Crinum amabile</i> 72C	<i>Euphorbia glomerifera</i> 72C
<i>Hymenocallis littoralis</i> 61S 62S	<i>Euphorbia mesembrianthemifolia</i>
65S 72C	62C 72C
<i>Ficus</i> sp. 1842S	<i>Euphorbia prostrata</i> 72C

<i>Euphorbia</i> sp. 60S 65S	<i>Cordia sebestena</i> 60C 61S 65S 72C
<i>Phyllanthus amarus</i> 72C	<i>Tournefortia gnaphalodes</i> 65S 72C
* <i>Carica papaya</i> 65S 72S	<i>Avicennia germinans</i> 61S 65S 72C
<i>Rhizophora mangle</i> 62S 65S 72C	<i>Stachytarpheta jamaicensis</i> 60C 61S 65S 72C
<i>Conocarpus erectus</i> 61S 65S 72C	<i>Spermacoce assurgens</i> 72C
* <i>Terminalia catappa</i> 61S 62S 65S 72C	<i>Ageratum littorale</i> 72C
<i>Bumelia retusa</i> 65C 72S	<i>Bidens cynapiifolia</i> 72C
* <i>Catharanthus roseus</i> 72C	<i>Melanthera nivea</i> 72C
<i>Ipomoea pes-caprae</i> 62C 65S 72C	<i>Pluchea symphytifolia</i> 72C
<i>Ipomoea stolonifera</i> 60C 72C	<i>Wedelia trilobata</i> 60C 61S 62S 65S 72C
<i>Ipomoea</i> sp. 65S	

Purdy (1974b, pp. 841, 853) drilled a core hole 16.4 m deep on Tobacco Cay, the upper 14 m of the section being Holocene in age.

South Water Cay (16°49'N, 88°05'W)

Figure 10, Plates 22-24

South Water Cay is the largest inhabited sand cay on the barrier reef. It is prominently marked on Jefferys's chart in 1775, and in 1830 Owen noted coconut trees 15 m tall. The island was mapped in 1960, visited again in 1961, and mapped again in 1962, 1965 and 1972. In addition to the collections made during these visits a large collection made by J. Pringle in 1979-80 considerably increased the recorded flora.

In 1960 the island had a north-south extent of about 640 m; its width varied from 70 to 180 m; and it had an area of 8.18 ha. The northern part, closest to the reef, was covered with a dense palm thicket and had an eastern shore of coral rubble. The rest of the island was settled, covered with open coconut woodland, and formed of sand. In the northern palm thicket the ground cover consisted of *Wedelia*, *Euphorbia*, *Ipomoea*, grasses and sedges, with *Sesuvium*, *Tournefortia* and *Suriana* along the coast. Both *Borrighia* and *Coccoloba* were common along the seaward margins of the woodland, and extended southwards along the east side of the island. The rest of the cay had a varied vegetation of planted exotics and weedy species which were frequently cleared.

During Hurricane Hattie the cay was subject to considerable marginal erosion, especially in the southwest bay and at the northeast point. There was considerable wind damage to coconuts, the mean direction of fall being N30-40°E, but the island was not overtopped by the storm surge. In the centre of the island about 80 per cent of the trees were felled. Along the shores *Coccoloba*, *Avicennia* and much *Borrighia* survived the storm. All the jetties and several houses were destroyed. For details, see Stoddart (1963, pp. 55-57, fig. 32).

By 1965 physiographic change had been slight. The seaward beaches had retreated slightly, but the leeward beaches had accreted; there had been continuing erosion at the south point. The vegetation of the northern part of the island was little changed, with *Wedelia*, *Ipomoea*, *Batis*, *Euphorbia* and *Sesuvium*, and thriving *Thrinax* and *Coccoloba* under the coconuts. In the centre of the island there was a dense growth of *Euphorbia*, *Ipomoea*, *Stachytarpheta*, *Ambrosia* and *Cassytha*, with some *Hymenocallis* and *Coccoloba*. Along the eastern shore there was bushy *Borrchia* with much *Cassytha*, a few *Tournefortia* seedlings, and a ground cover of *Sesuvium*, *Ipomoea*, *Euphorbia* and *Sporobolus*. Many young coconuts planted in the southern part of the cay after the hurricane were 3-4.5 m tall. Two juvenile *Casuarina* were growing by the lagoon shore, but there were many fewer *Rhizophora* seedlings round the shores and especially along the east coast than in 1960. A jetty and several new buildings had been erected and the effects of the hurricane were no longer obvious. For further details, see Stoddart (1969, p.11).

In 1972 the trends of erosion and accretion had continued. There was retreat at the south point, along the southwest bay and at the north point. The island had a maximum length of 660 m, a width varying from 55 to 175 m, and an area of 6.49 ha. Masonry and rubble walls had been inadequate to prevent continuing erosion both in the southwest bay and at the northeast point. Apart from a sector in the south, recently cleared, there was a dense ground cover of herbs, vines and grasses under the open coconut woodland. *Hymenocallis*, *Ipomoea stolonifera*, *Ambrosia* and *Wedelia* were all common and conspicuous. *Borrchia* was the most common shrub colonising the east shore, with *Sesuvium* as ground cover; a single seedling of *Morinda* was noted on the beach crest.

No attempt was made during the earlier visits to make a complete collection of plants from South Water Cay, and by 1965 only 26 species had been recorded. 68 were recorded in 1972, bringing the total to 69, and Pringle's collections in 1979-80 raise the total to 80. This is the highest number for any of the Belize cays, but clearly reflects the continuous and prolonged human disturbance of the vegetation. The following species have been recorded:

<i>Andropogon glomeratus</i> 61C 72C 79C	<i>Sporobolus virginicus</i> 72C 79C
<i>Antheophora hermaphrodita</i> 79C	<i>Sporobolus</i> sp. 60S 65S
<i>Cenchrus incertus</i> 72C 79C	<i>Cyperus ligularis</i> 72C
<i>Distichlis spicata</i> 79C	<i>Cyperus peruvianus</i> 72C 79C
<i>Eragrostis ciliaris</i> 72C 79C	<i>Cyperus planifolius</i> 72C 79C
<i>Eustachys petraea</i> 72C 79C	<i>Cyperus</i> sp. 60S
<i>Panicum virgatum</i> 79C	<i>Fimbristylis cymosa</i> 72C 79C
<i>Paspalum blodgettii</i> 72C	* <i>Cocos nucifera</i> 60S 61S 62S 65S
<i>Paspalum distichum</i> 72C	72S
<i>Phragmites</i> cf. <i>australis</i> 72C	<i>Thrinax radiata</i> 65S 72C
<i>Spartina patens</i> 72C 79C	<i>Agave</i> sp. 72C
<i>Spartina spartinae</i> 72C	<i>Crinum amabile</i> 72C

<i>Dracaena</i> sp. 72C 79C	<i>Conocarpus erectus</i> 72C 79C
<i>Hymenocallis littoralis</i> 65S 72C 79C	<i>Laguncularia racemosa</i> 72C 79C
* <i>Casuarina equisetifolia</i> 65S 72C 79C	* <i>Terminalia catappa</i> 72C
<i>Coccoloba uvifera</i> 60S 65S 72C 79C	* <i>Psidium guajava</i> 72C
<i>Batis maritima</i> 65S 72C 79C	<i>Polypremum procumbens</i> 72C 79C
<i>Philoxerus vermicularis</i> 72C 79C	* <i>Nerium oleander</i> 79C
<i>Boerhavia coccinea</i> 79C	* <i>Plumeria rubra</i> 72C
<i>Portulaca oleracea</i> 72C 79C	<i>Ipomoea macrantha</i> 65S 79C
<i>Sesuvium portulacastrum</i> 60S 65S 72C 79C	<i>Ipomoea pes-caprae</i> 72C 79C
<i>Cassytha filiformis</i> 60S 65S 72C 79C	<i>Ipomoea stolonifera</i> 65C 72C 79C
<i>Cakile lanceolata</i> 60S 72C 79C	<i>Ipomoea</i> sp. 60S 65S
<i>Chrysobalanus icaco</i> 72C	<i>Jacquemontia havanensis</i> 72C 79C
<i>Canavalia rosea</i> 72C 79C	<i>Cordia sebestena</i> 72C 79C
<i>Crotalaria retusa</i> 72C 79C	<i>Tournefortia gnaphalodes</i> 60C 61S 65S 72C 79C
<i>Desmodium incanum</i> 72C 79C	<i>Avicennia germinans</i> 60S 72C 79C
<i>Desmodium tortuosum</i> 79C	<i>Lippia nodiflora</i> 72C 79C
<i>Erythrina</i> sp. 72C	<i>Stachytarpheta jamaicensis</i> 65S 72C 79C
<i>Sophora tomentosa</i> 65S 72C 79C	* <i>Solanum lycopersicum</i> 79C
<i>Vigna luteola</i> 72C 79C	<i>Erithalis fruticosa</i> 72C 79C
<i>Suriana maritima</i> 60S 79C	<i>Ernodea littoralis</i> 72C 79C
<i>Euphorbia blodgettii</i> 60S 72C 79C	<i>Hedyotis corymbosa</i> 72C
<i>Euphorbia mesembrianthemifolia</i> 72C 79C	* <i>Hedyotis lancifolia</i> 79C
<i>Euphorbia trichotoma</i> 72C 79C	<i>Morinda citrifolia</i> 72C
<i>Euphorbia</i> sp. 60S 65S	<i>Spermacoce assurgens</i> 72C 79C
<i>Phyllanthus amarus</i> 72C 79C	<i>Ageratum littorale</i> 72C 79C
* <i>Hibiscus rosa-sinensis</i> 72C	<i>Ambrosia hispida</i> 65S 72C 79C
<i>Waltheria indica</i> 72C 79C	<i>Borrchia arborescens</i> 60S 65S 72C 79C
<i>Passiflora suberosa</i> 72C 79C	<i>Conyza canadensis</i> 72C
<i>Rhizophora mangle</i> 60S 65S 72C 79C	<i>Eclipta alba</i> 79C
	<i>Emilia sonchifolia</i> 79C
	<i>Melanthera nivea</i> 72C
	<i>Wedelia trilobata</i> 60S 65S 72C 79C

Carrie Bow Cay (16°48'N, 88°05'W)

Figure 11, Plates 25-28

Carrie Bow Cay, named after the Bowman family of Stann Creek, was charted by Owen as "Jack Ellin's Cay" and appears on charts as "Ellen Cay". Owen noted "tops of bushes 20 feet", but by 1960 the cay was covered with an open coconut woodland surrounding large houses; the ground surface was kept cleared. The island was then 140 m long and 32-40 m wide, with an area of 5450 sq m. It was built of sand, its surface about 1 m above sea level, with several strips of relict beach-rock 25-30 m off the east shore. During Hurricane Hattie there was some beach retreat, especially at the northern and southern ends, exposing fresh beachrock. Many coconuts were felled in a generally northerly direction. Immediately after the storm the main coloniser

was *Euphorbia*. For details see Stoddart (1963, pp. 57-58, fig. 33). By 1965 a number of young coconuts had been planted, and low *Tournefortia* bushes were growing along the northern part of the seaward shore. The ground cover comprised sparse *Euphorbia*, *Sesuvium* and *Ipomoea*, but was repeatedly cleared (Stoddart 1969, p.11).

By 1972 erosion had continued at the south point and along the southern end of the leeward shore, where the shore had retreated up to 15 m since 1962. Seasonal sandspits at both the northern and southern points partly mask the intensity of this continuing erosion. As a result the area of the island declined from 5450 sq m in 1960 to 4260 sq m in 1965 and 3940 sq m in 1972. A number of new coconuts had been planted, but the ground surface was kept bare, apart from two clumps of *Tournefortia* on the seaward shore. Further erosion occurred at the northern and southern points during Hurricane Fifi in December 1974, and the island was remapped by K. Ruetzler and H. Pulpan (in Miller and Macintyre 1977, p.27); its area was reduced to 2810 sq m. In spite of the fact that vegetation was regularly cleared from the cay surface, many seedlings germinate. Some were recorded in 1972, and others in a collection by J.D. Ferraris in May 1978. 22 species have now been recorded from Carrie Bow Cay, at least 9 of them only as seedlings. The list is as follows:

<i>Paspalum distichum</i> 72C	<i>Cakile lanceolata</i> 72C 78C
<i>Cyperus planifolius</i> 72C	(seedling)
<i>Cocos nucifera</i> 60S 62C 65S	<i>Bursera simaruba</i> 72C (seedling)
72S	<i>Euphorbia blodgettii</i> 72C 78C
<i>Eichhornia crassipes</i> 78C	<i>Euphorbia mesembrianthemifolia</i>
(seedling)	72C 78C
<i>Hymenocallis littoralis</i> 78S	<i>Euphorbia</i> sp. 60S 62S
(seedling) 79C	* <i>Terminalia catappa</i> 72C (seedling)
* <i>Casuarina equisetifolia</i> 78C	<i>Ipomoea pes-caprae</i> 72C (seedling)
<i>Coccoloba uvifera</i> 72C 78C	<i>Ipomoea</i> sp. 65S
(seedling)	<i>Tournefortia gnaphalodes</i> 65S
<i>Suaeda linearis</i> 78C	72C 78C (seedling)
<i>Philoxerus vermicularis</i> 72C 78C	<i>Eclipta alba</i> 78C
<i>Portulaca oleracea</i> 72C 78C	<i>Wedelia trilobata</i> 72C
<i>Sesuvium portulacastrum</i> 65S	
72C 78C	

Salvin visited South Water Cay in May 1863 and collected birds (Coues 1864, p.391).

Curlew Cay (16°47½'N, 88°05'W)

Owen (1830) noted bushes 6 m tall here, at a time when Curlew Cay must have closely resembled Carrie Bow Cay. In 1960 and 1961, however, the island was a low crescentic sandbore 36 m long and up to 9 m wide. It was unvegetated apart from two *Rhizophora* seedlings. There is extensive beachrock east of the present site of the cay. The date of destruction of the vegetated island is unknown; it may have been during the 1945 hurricane. The sandbore disappeared after Hurricane Hattie,

but had reappeared by April 1962. It was present in 1972, but clearly still ephemeral and of fluctuating dimensions. Its area in 1960 was 370 sq m. Only one species of plant is recorded:

Rhizophora mangle 60S

For further details see Stoddart (1963, p.58, fig. 34). Salvin visited this island in 1863 and collected birds (Coues 1864, p.391).

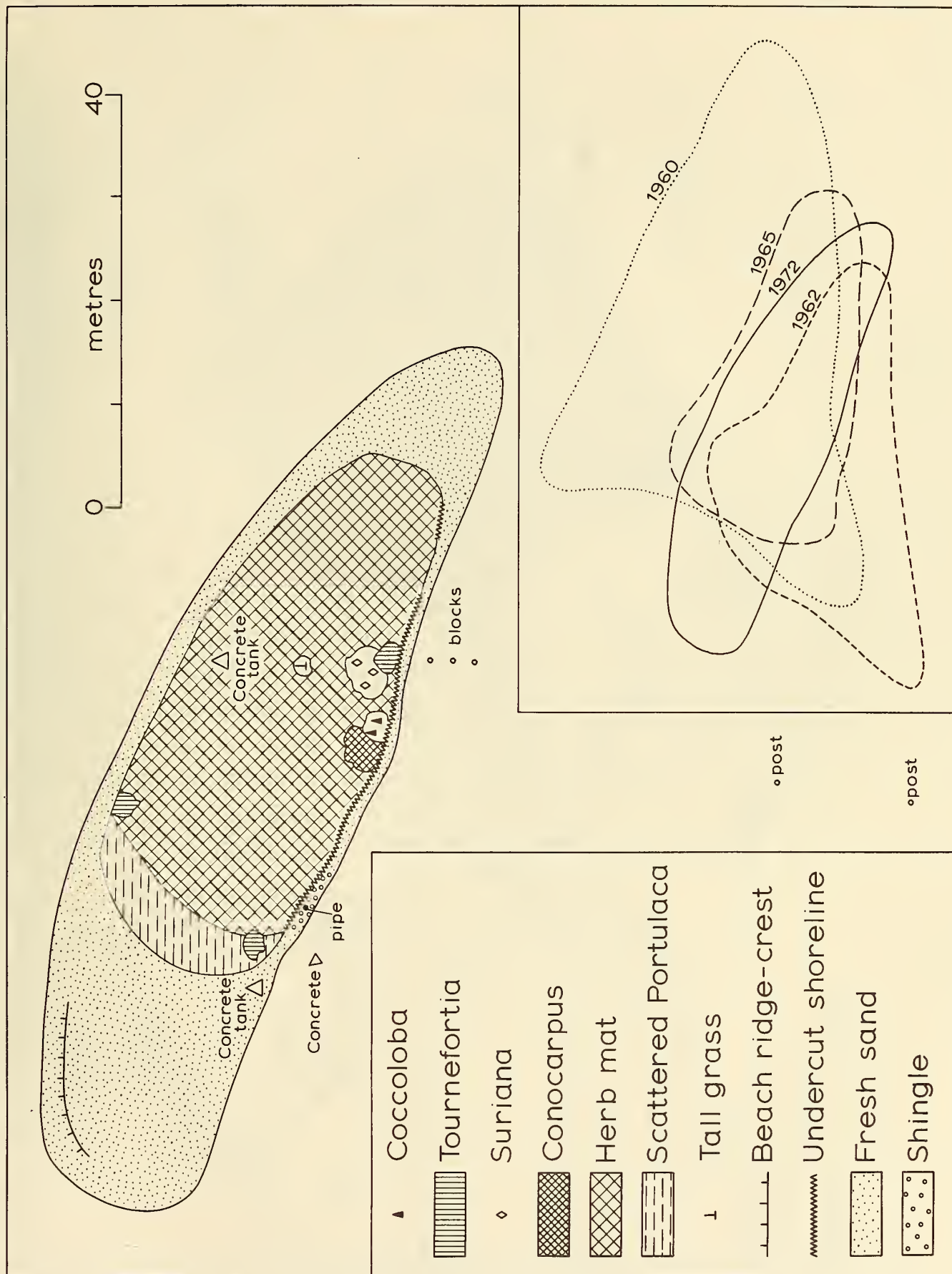


Figure 3. Sergeant's Cay 1972

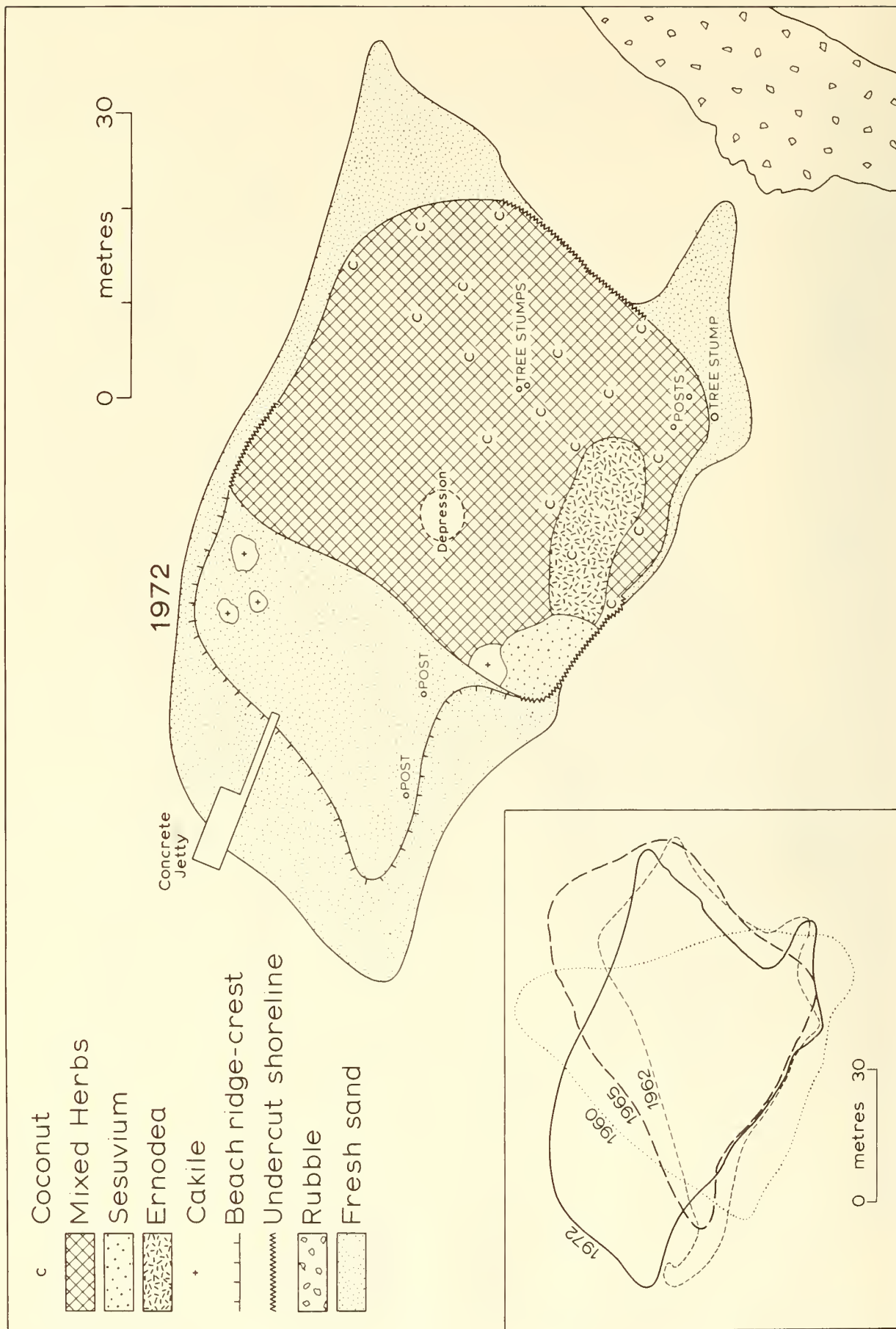


Figure 4. Goff's Cay 1972

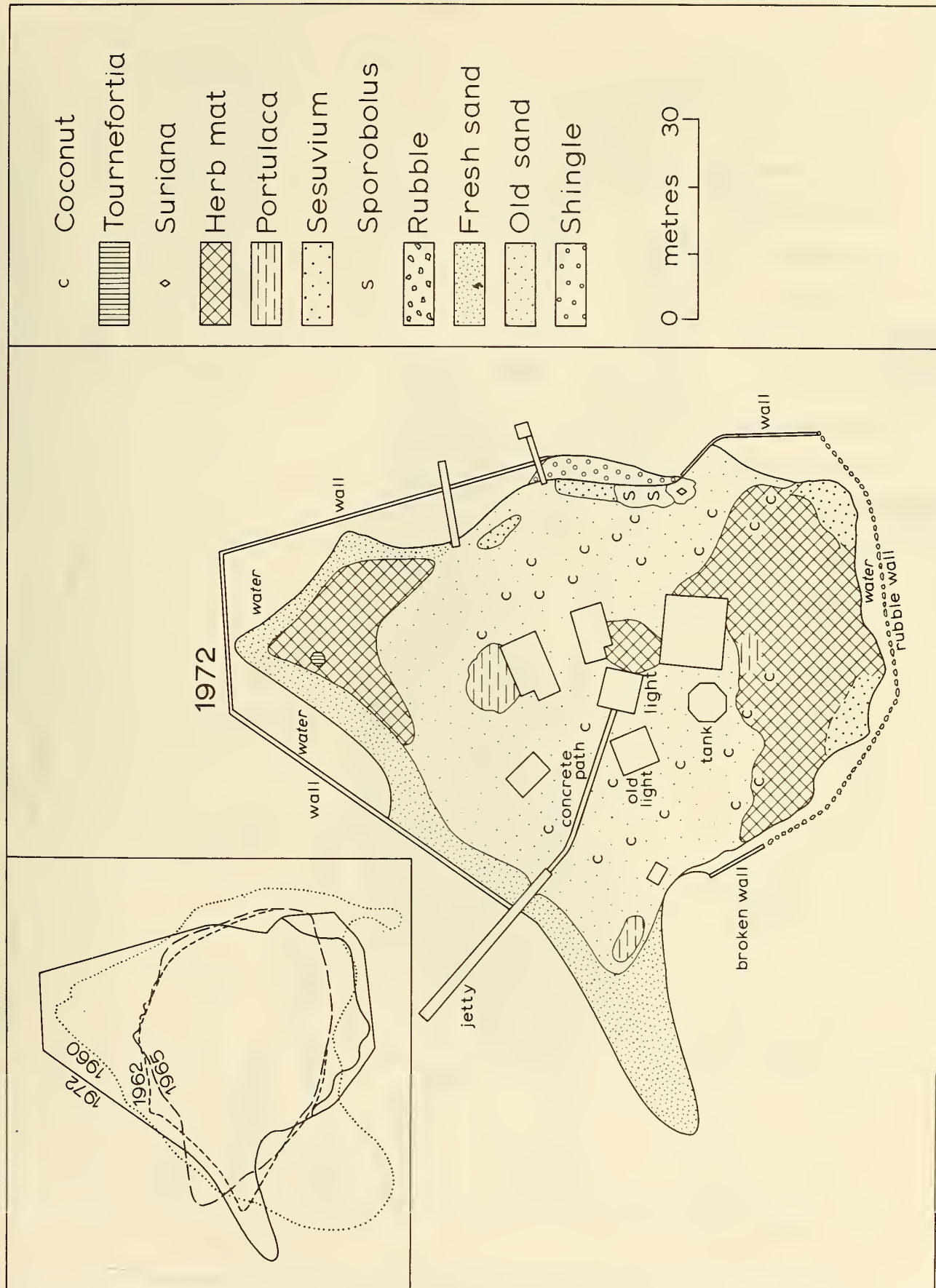


Figure 5. English Cay 1972

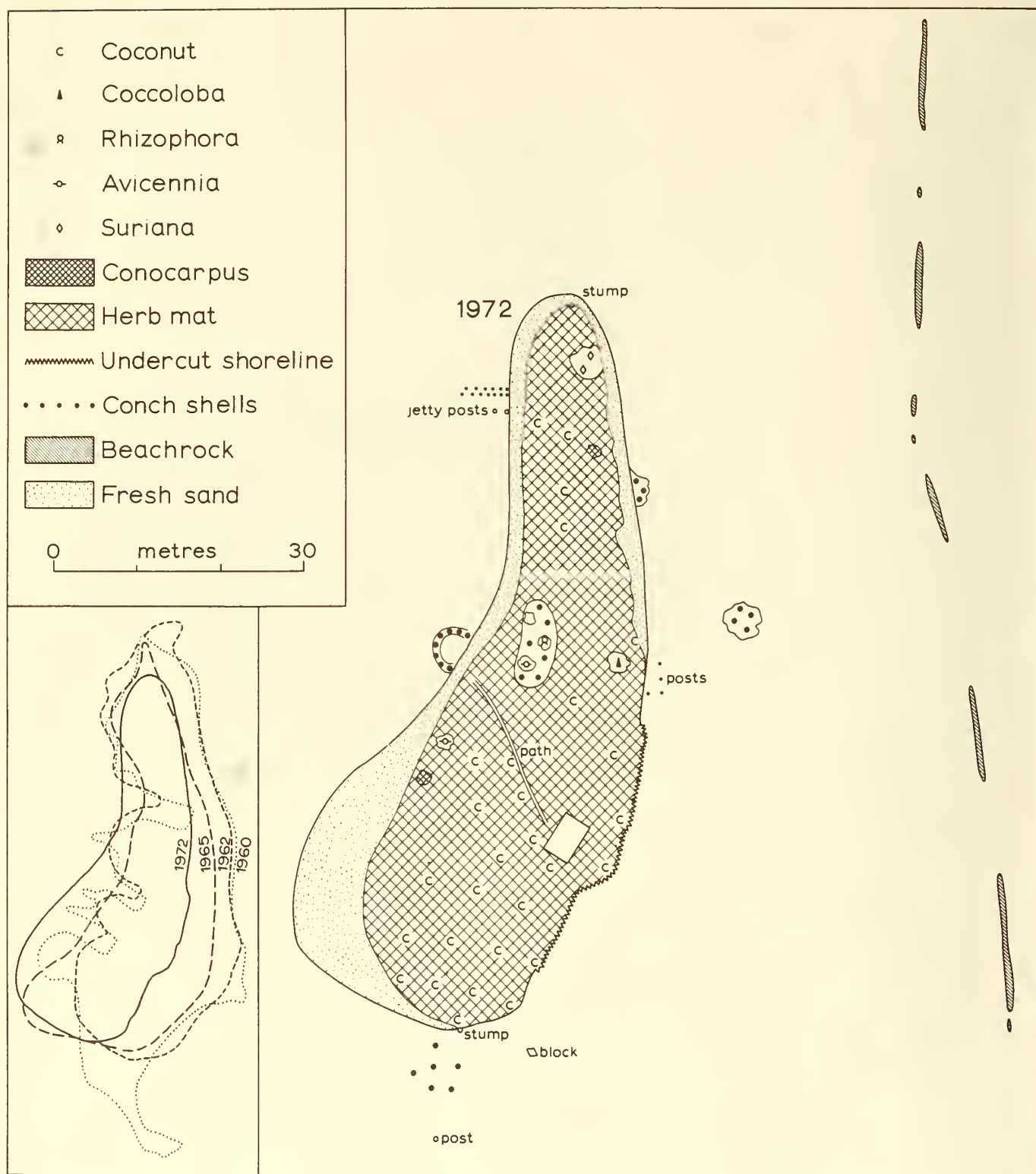


Figure 6. Rendezvous Cay 1972

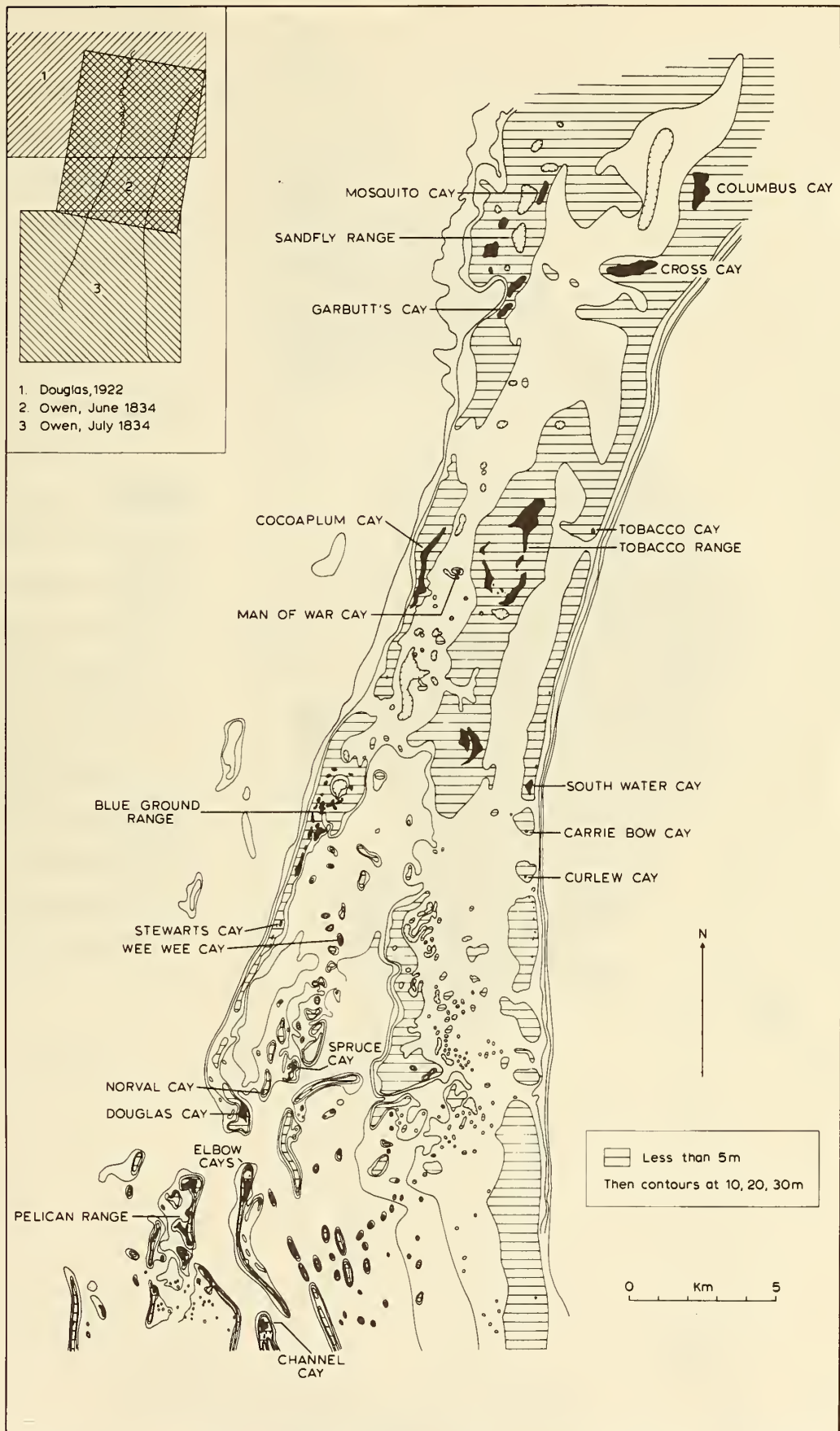


Figure 7. Reef topography between Columbus Cay and Channel Cay

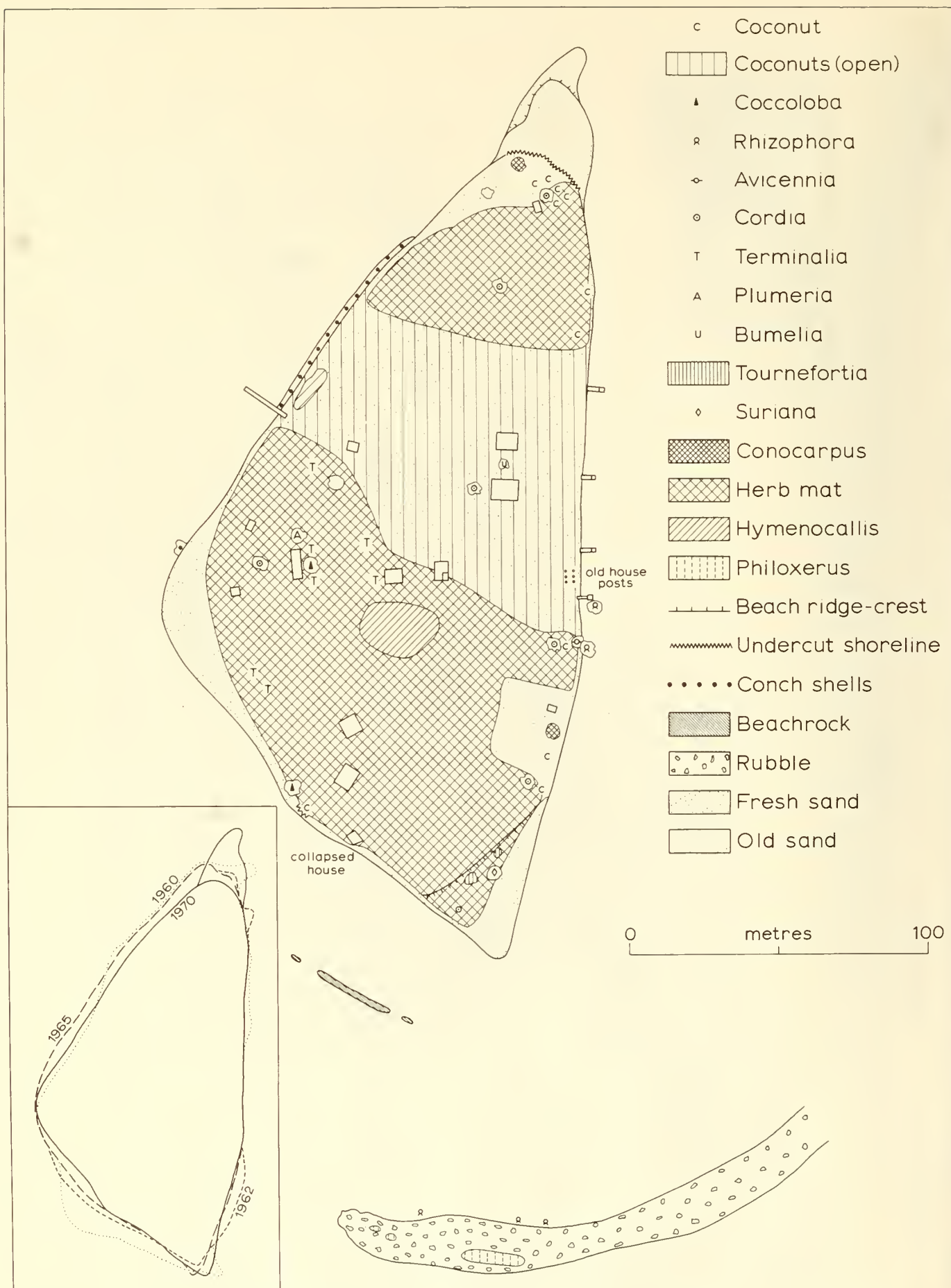


Figure 8. Tobacco Cay 1972

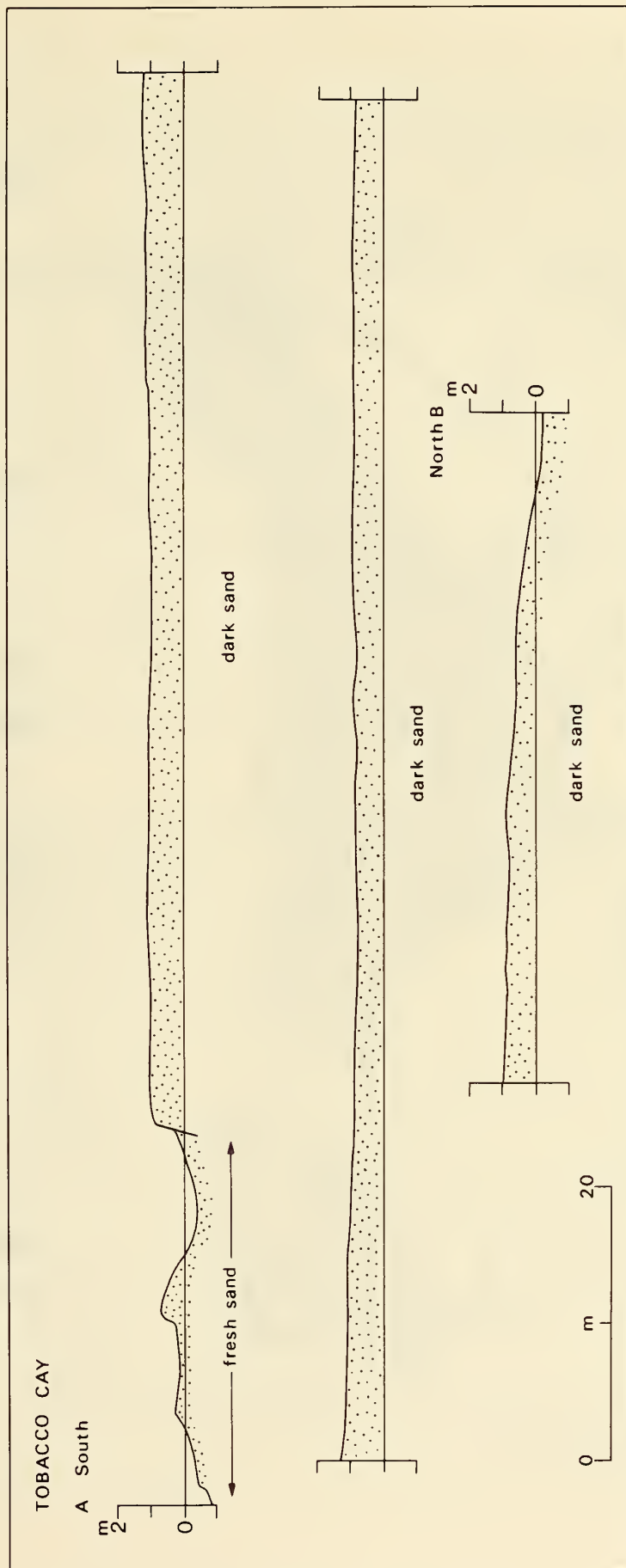


Figure 9. North-south profile of Tobacco Cay 1960

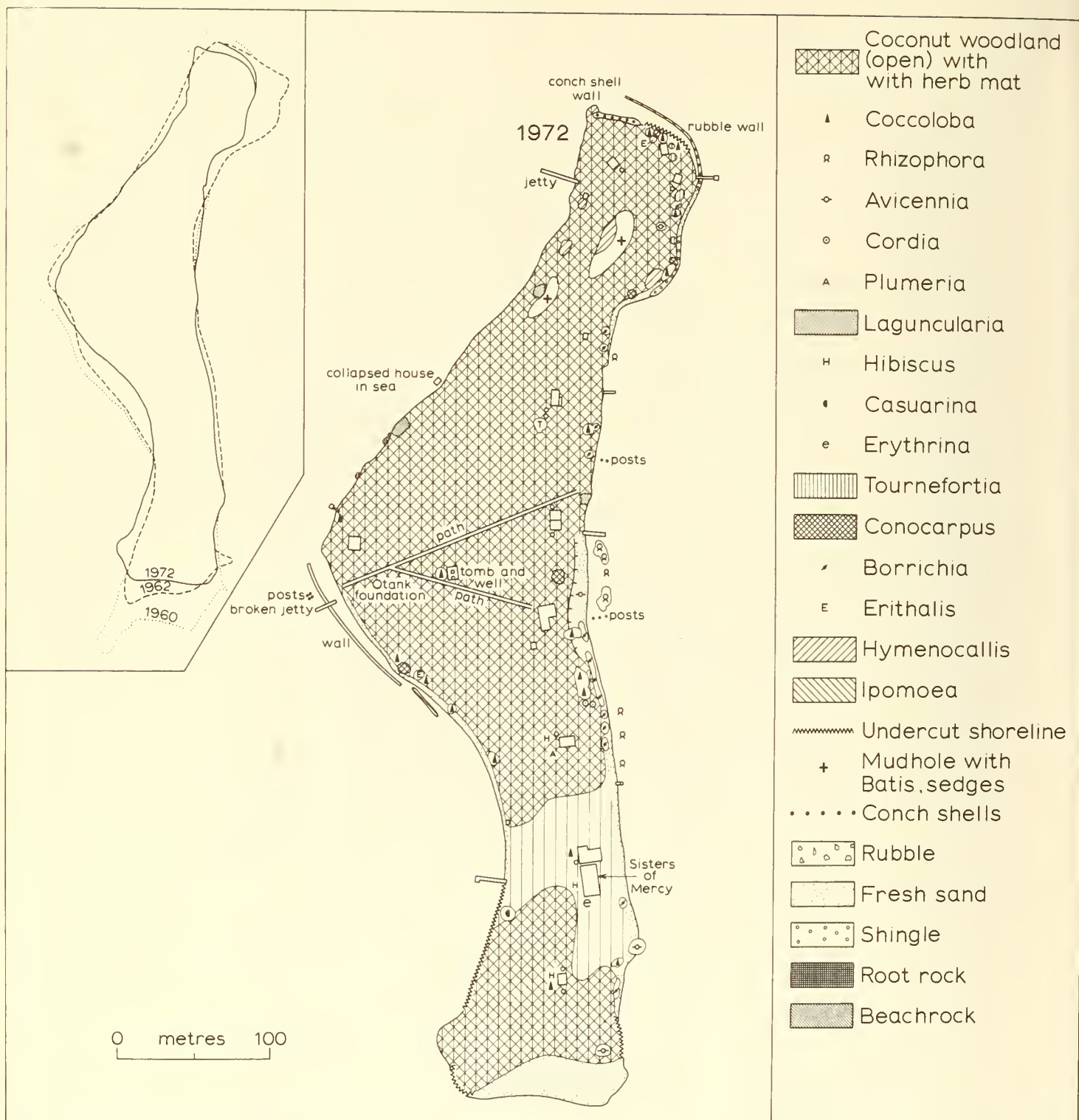


Figure 10. South Water Cay 1972

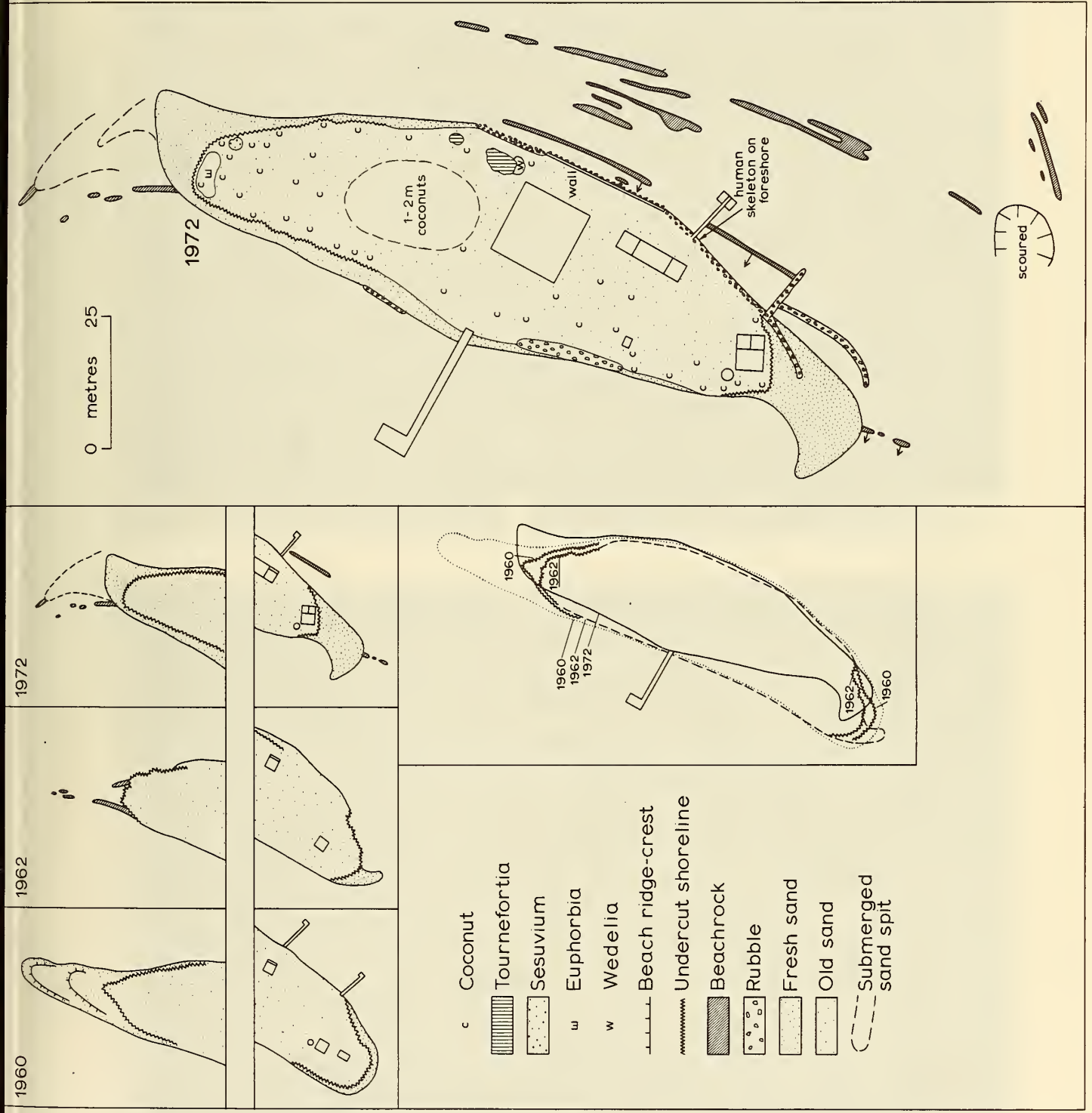


Figure 11. Carrie Bow Cay 1972



Plate 1. Paunch Cay: aerial view from the southeast 1961



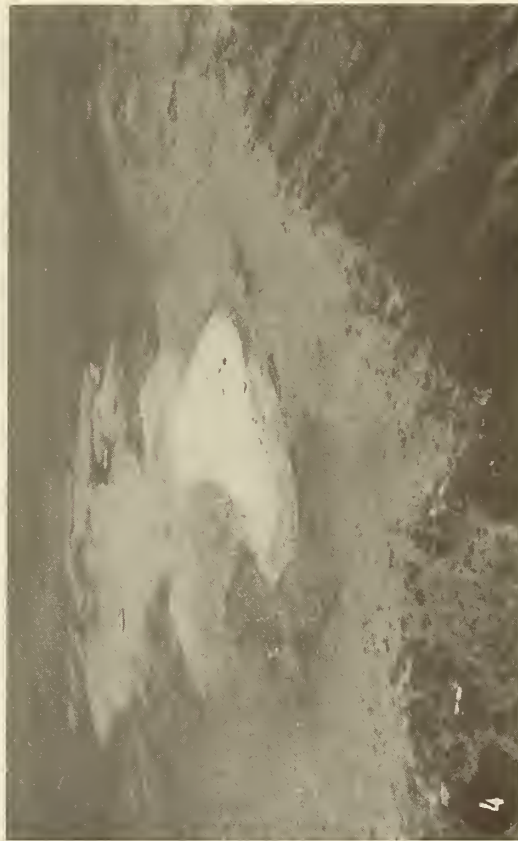
Plate 2. St George's East Cay: aerial view from the northwest 1961



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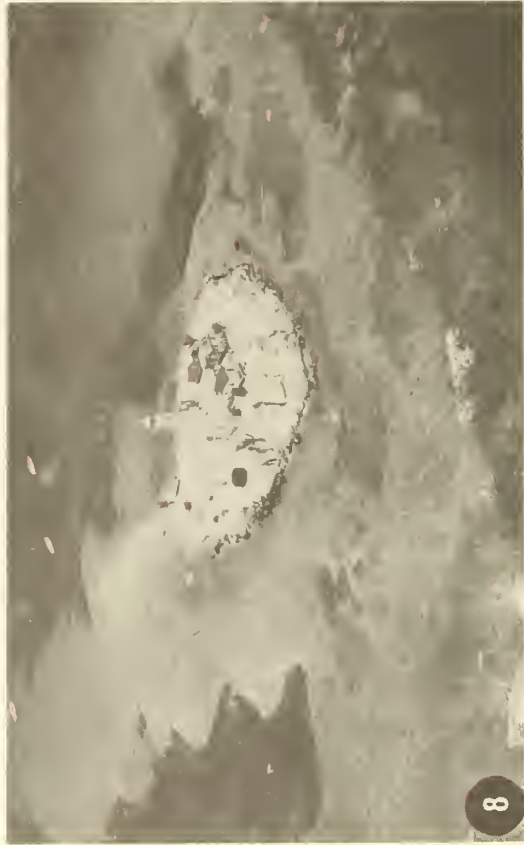
Plate 3. Sergeant's Cay: aerial view from the east 1961
 Plate 4. Sergeant's Cay: aerial view from the east 1962
 Plate 5. Goff's Cay: aerial view from the east 1961
 Plate 6. Goff's Cay: aerial view from the east 1962



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Plates 7 and 8. English Cay: aerial views from the southeast 1961 and 1962
1962

Plates 9 and 10. English Cay from the south 1961 and 1962



Plate 11. Rendezvous Cay from the south 1960



Plate 12. Rendezvous Cay: aerial view from the southeast 1962



Plate 13. Rendezvous Cay from the east 1962



Plate 14. Rendezvous Cay from the west 1972
 Plate 15. Rendezvous Cay from the southwest 1972
 Plate 16. Cay Glory: aerial view from the east 1961



Plate 17. Rendezvous Cay: erosion on the east shore 1972



Plate 18. Rendezvous Cay: aggradation on the southwest shore 1972



Plate 19. Tobacco Cay: aerial view from the northwest 1960



Plate 20. Tobacco Cay: aerial view from the east 1962



Plate 21. Tobacco Cay from the south, seen from the reef-crest rubble ridge 1960



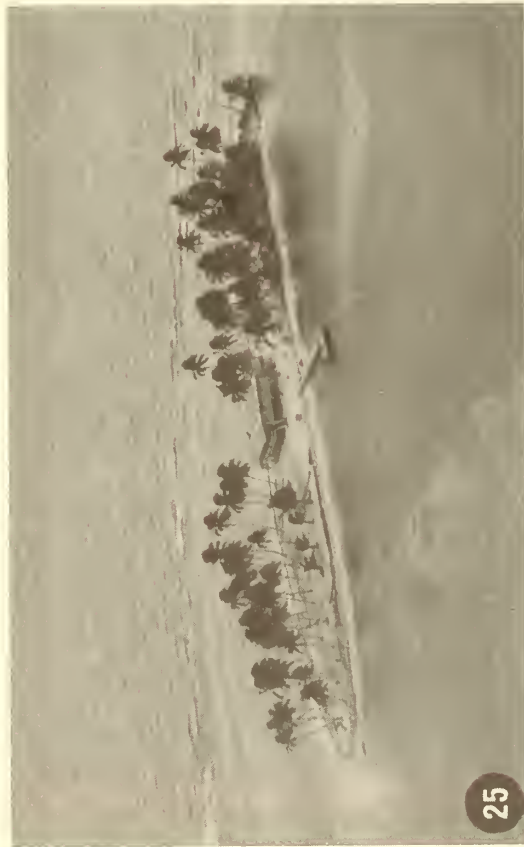
Plate 22. South Water Cay: aerial view from the south 1961



Plate 23. South Water Cay: aggradation at the southwest point 1972



Plate 24. South Water Cay: erosion on the northwest shore 1972



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Plates 25 and 26. Carrie Bow Cay: aerial views in 1960 (from the northwest) and 1962 (from the east)

Plates 27 and 28. Carrie Bow Cay: views from the southwest 1965 and 1972

4. SAND CAYS OF THE SOUTHERN BARRIER REEF

South of Gladden Spit (16°31'N, 87°59'W) the barrier reef extends in a northeast-southwest direction for 55 km to Ragged Cay, though surface reef patches are discontinuous and small. There are several scattered cays in the northern part of this reef, and a group of islands known as the Sapodilla Cays in the south. At its southernmost extent the barrier reef curves sharply west and north, and terminates at Seal Cay. The islands are described from north to south.

Silk or Queen Cays

The Silk Cays are situated 9 km southwest of Gladden Spit, at a channel through the barrier reef carrying 6 m of water. They are charted as "Queen Cays", a name applied to them by the officers of the 1830 survey. Winzerling (1946) states that the name derives from a seventeenth century local vessel *Queen of Bohemia*, but we have seen no evidence for this. Smith (1842, p.732), however, states that "the Queen cays ... were formerly named the Seal Cays, now altered to prevent confusion [with other islands of this name in 17°21'N and 16°08'N]". The name Silk Cays is used locally and should be retained, though the Admiralty usage is well-established on charts and in pilot books, and has been used by James and Ginsburg (1979) for one of their reef survey sites. The group consists of three small vegetated islands standing on patch reefs; for a survey of their location see the survey by Barnett in 1840, inset to Admiralty Chart 1797.

North Silk Cay (16°27½'N, 88°02½'W)

Figure 12, Plates 29 and 33

North Silk Cay is an oval-shaped island built of concentric shingle ridges enclosing a small shallow pool, and with a leeward sand beach masking the shingle. It was mapped in 1961 and 1972. During this interval the distribution of the shingle ridges changed slightly; the greatest dimension increased from 62 to 70 m; the width remained the same at 48 m; and the area increased from 0.24 to 0.25 ha. Pumice lay thickly on the pool margins in 1960 but was no longer conspicuous in 1972. In 1960 the centre of the island was covered with a low thicket of *Suriana*, *Tournefortia*, *Conocarpus* and *Avicennia*, with several *Rhizophora* round the pool margins, and patches of *Ipomoea*, *Sesuvium*, *Erithalis* and *Cyperus* on the shingle surface. There were no coconuts. In June 1972 the vegetation was more extensive, but still dominated by *Rhizophora* and *Avicennia* around the pool. The main shrubs were again

Tournefortia and *Suriana*, and the ground cover included *Sesuvium*, *Ipomoea*, *Portulaca* and *Hymenocallis*. There were three young coconuts. No beachrock was seen during either survey. Altogether 13 species of plants have been recorded, 9 in 1961 and 12 in 1972. New records in the second survey included *Portulaca*, *Hymenocallis*, *Cocos* and *Paspalum*; *Erithalis* disappeared. The species recorded are as follows:

<i>Paspalum distichum</i> 72C	<i>Suriana maritima</i> 61S 72C
<i>Cyperus planifolius</i> 72C	<i>Rhizophora mangle</i> 61S 72C
<i>Cyperus</i> sp. 61S	<i>Conocarpus erectus</i> 61S 72C
* <i>Cocos nucifera</i> 72S	<i>Ipomoea macrantha</i> 72C
<i>Hymenocallis littoralis</i> 72C	<i>Ipomoea</i> sp. 61S
<i>Portulaca oleracea</i> 72C	<i>Tournefortia gnaphalodes</i> 61S 72C
<i>Sesuvium portulacastrum</i> 61S	<i>Avicennia germinans</i> 61S 72C
72C	<i>Erithalis fruticosa</i> 61S

Middle Silk Cay (16°28'N, 88°02½'W)

Figure 13, Plate 34

Middle Silk lies about 300 m southwest of North Silk Cay. In 1961 it was oblong in shape, with maximum dimensions of 80 x 45 m and an area of 0.43 ha. It was built of concentric sand ridges rising about 1 m above sea level, with sand spits extending to southeast, northeast and northwest. It stands on a small patch reef, the windward crest of which is outlined by emergent rubble. Relict beachrock off the southern side of the island indicated northerly migration of at least 50 m. The vegetation cover was restricted to a cluster of *Tournefortia* and *Suriana* bushes at the eastern end of the cay, some scattered shrubs of *Suriana*, and a few coconuts, with a ground cover of *Sesuvium*, *Ipomoea* and *Euphorbia*. By June 1972 there had been considerable changes. The island was now triangular, with a cliffed southern shore and aggradation on the northern side; one line of old beachrock was visible, passing beneath the cay sands. The area was reduced to 0.40 ha, but the vegetation cover had substantially increased. It was dominated by *Tournefortia*, *Suriana* and *Conocarpus* bushes, with three tall coconuts and about 20 recently planted juveniles. The ground surface was covered with *Euphorbia*, *Sesuvium*, *Ipomoea*, *Cyperus*, *Wedelia* and *Erithalis*. A temporary hut had been constructed in the middle of the island. Six species of plants were seen in 1961 and 7 more in 1972, making a total flora of 13 species:

<i>Eragrostis prolifera</i> 72C	<i>Conocarpus erectus</i> 72C
<i>Paspalum distichum</i> 72C	<i>Ipomoea macrantha</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Ipomoea pes-caprae</i> 72C
* <i>Cocos nucifera</i> 61S 72S	<i>Ipomoea</i> sp. 61S
<i>Sesuvium portulacastrum</i> 61S	<i>Tournefortia gnaphalodes</i> 61S
72C	72C
<i>Suriana maritima</i> 61S 72C	<i>Erithalis fruticosa</i> 72C
<i>Euphorbia mesembrianthemifolia</i>	<i>Wedelia trilobata</i> 72C
72C	

South Silk Cay (16°27½'N, 88°03'W)

Figure 14, Plates 30 and 35

South Silk Cay is situated 460 m southwest of Middle Silk Cay, and like it is built wholly of sand. In 1961 it was a lens-shaped island 90 m long and up to 32 m wide, with an area of 0.17 ha. Its surface stood about 1 m above sea level. It was covered by a scrub of *Suriana*, with *Hymenocallis* and *Sesuvium*, and less than a dozen scattered coconuts. There was a single *Coccoloba* tree at the eastern end. By June 1972 the island was of similar shape but had changed its orientation and location. The vegetated area had been eroded and cliffed at its eastern end, and then extended by a broad sandspit. The cay was then 110 m long and 30 m wide, with an area of 0.23 ha. The single *Coccoloba* tree survived, and as before the dominant vegetation was of *Suriana*, *Hymenocallis* and *Sesuvium*. There were six coconuts. No beachrock was seen during either survey. The extent of *Hymenocallis* is of particular interest on this cay. Five species of plants were noted in 1961 and a further four in 1972, giving a total of 9 for the island:

<i>Eragrostis prolifera</i> 72C	<i>Portulaca oleracea</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Sesuvium portulacastrum</i> 61S 72C
* <i>Cocos nucifera</i> 61S 72S	<i>Suriana maritima</i> 61S 72C
<i>Hymenocallis littoralis</i> 61S 72C	<i>Euphorbia mesembrianthemifolia</i>
<i>Coccoloba uvifera</i> 61S 72C	72C

Samphire Cay (16°26½'N, 88°03'W)

This was charted by Barnett in 1840, 1.6 km south of South Silk Cay, but had disappeared by 1913. It has not been seen since. It was apparently vegetated and must have resembled the Silk Cays. "Samphire" usually denotes *Sesuvium portulacastrum* in this area.

Round Cay (16°25'N, 88°05'W)

Figures 15 and 17, Plate 31

Round Cay stands on a patch reef at the inner edge of the barrier platform, about 1.6 km from the shelf edge. In 1960 it was a lens-shaped island 120 m long, up to 45 m wide, and with an area of 0.25 ha. The northern and southern shores consisted of ridges of shingle and rubble, with coral boulders up to 0.3 m in diameter. The ridges rose to 1.8 m above sea level; the centre of the island, of sand and fine shingle, stood at about 1.5 m. The eastern end of the island was formed by a broad sand beach, overlooking a zone of broken intertidal rubble. The island was covered with a dense coconut woodland with marginal *Tournefortia* and *Suriana*. Under the coconuts there was a thick cover of *Hymenocallis* and grasses. There were two lines of beachrock along the southern shore. By 1972 the island had extended to 110 x 40 m, and its area increased to 0.31 ha. The southern shingle

shore had extended to cover the beachrock, and the eastern sand beach to largely cover the rubble zone. The island continued to be covered with a coconut woodland with *Hymenocallis* beneath. The marginal *Tournefortia* was much less extensive, however, presumably as a result of substrate erosion; and there was a large clump of *Conocarpus* at the south point. Nine species were noted in 1960 and 15 in 1972, giving a total flora of 16 species; only one (*Cakile lanceolata*) had disappeared between the surveys. Species recorded are:

<i>Paspalum distichum</i> 72C	<i>Cakile lanceolata</i> 60S
<i>Paspalum</i> sp. 60S	<i>Suriana maritima</i> 60S 72C
<i>Cyperus planifolius</i> 72C	<i>Euphorbia mesembrianthemifolia</i>
<i>Cyperus</i> sp. 60S	72C
* <i>Cocos nucifera</i> 60S 72C	<i>Euphorbia</i> sp. 60S
<i>Hymenocallis littoralis</i> 60S 72C	<i>Conocarpus erectus</i> 72C
<i>Ficus</i> sp. 72C	<i>Ipomoea macrantha</i> 72C
<i>Rivina humilis</i> 72C	<i>Ipomoea pes-caprae</i> 72C
<i>Portulaca oleracea</i> 72C	<i>Tournefortia gnaphalodes</i> 60S 72C
<i>Sesuvium portulacastrum</i> 60S 72C	<i>Morinda citrifolia</i> 72C

Pompion Cay (16°24'N, 88°06½'W)

Figures 16 and 17, Plates 32 and 40

Pompion Cay, like Round Cay, is situated on a reef patch rising from the inner edge of the barrier platform, 3.2 km southwest of Round Cay. It stands about 1.6 km from the seaward edge of the barrier platform, and with the exception of four small patch reefs nearby it is the only reef to reach the surface between Round and Ranguana Cays, a distance of 11.5 km. When the island was mapped in 1960 it was of simple outline, 115 m long and up to 50 m wide, with an area of 0.35 ha. The eastern end of the cay was low and sandy; the northern and western shores are built of shingle and rubble rising to 1.3 m above sea level. There was no beachrock. On the northwest side the beach crest was colonised by a mat of *Sesuvium* with scattered *Tournefortia*. To the northeast there is a clump of *Coccoloba*, and along the south shore mature trees of *Bursera* and *Cordia*. The main part of the cay was under coconut woodland with a ground cover of *Hymenocallis*, *Erithalis* and *Cakile*. By 1972 the island had expanded, both by sand accretion at the east end and shingle accretion at the west end, to a total length of 123 m; it was slightly narrower (45 m maximum), and had an area of 0.42 ha. The *Coccoloba* clump and trees of *Bursera* and *Cordia* could still be located. The area of *Hymenocallis* beneath the coconuts had expanded and coalesced; the rest of the vegetated surface was covered with *Sesuvium*, *Cyperus* and *Euphorbia*. The area of coconut woodland was very similar to that of 1960. Hydrographic charts mark a prominent "White Rock" to the west of the cay. This is a small shingle island, 40 m in diameter and 1 m above sea level, built of *Acropora* sticks in concentric ridges, situated about 500 m to the west of the cay. It is not vegetated and owes its colour to guano staining. Eleven plant species were noted on Pompion in 1960 and 19 in 1972, giving a total of 21 species. Of those noted in 1960, *Cakile* and *Erithalis* were not found in 1972. The species recorded are as follows:

<i>Sporobolus virginicus</i> 72C	<i>Bursera simaruba</i> 60S 72C
<i>Cyperus planifolius</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
* <i>Cocos nucifera</i> 60S 72C	
<i>Hymenocallis littoralis</i> 60S 72C	<i>Euphorbia</i> sp. 60S
<i>Ficus</i> sp. 72C	<i>Rhizophora mangle</i> 72C (seedling)
<i>Coccoloba uvifera</i> 60S 72C	<i>Conocarpus erectus</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Ipomoea pes-caprae</i> 72C
<i>Rivina humilis</i> 72C	<i>Cordia sebestena</i> 60S 72C
<i>Portulaca oleracea</i> 72C	<i>Tournefortia gnaphalodes</i> 70S 72C
<i>Sesuvium portulacastrum</i> 60S 72C	
<i>Cakile lanceolata</i> 60S	<i>Erithalis fruticosa</i> 60S
<i>Suriana maritima</i> 60S 72C	<i>Morinda citrifolia</i> 72C (seedling)

Ranguana Cay (16°20'N, 88°09½'W)

Figure 18, Plates 36, 41 and 42

Ranguana Cay stands on the north side of a channel (Ranguana Entrance) through the barrier platform, carrying 6.7 m of water. It is located on a patch reef at the lagoonward side of the barrier platform about 1.8 km from the seaward edge. Speer (1766, p.24) noted the island, "called by the Baymen Renegado Kay", and Jefferys marks both names on his 1775 chart. Barnett's survey in 1840 noted trees 15 m tall.

In 1960 the island was 255 m long, with a constant width of 55 m, and had an area of 1.33 ha. About 80 per cent of the total area formed a core of older darker sand with cliffed margins, extended southeastwards by a fresh sand spit with pioneer vegetation. The whole of the northeast shore was cliffed, with fallen coconuts; the island surface here is at its highest, reaching 1.5 m. The vegetated area is dominated by coconut woodland. *Suriana*, *Coccoloba* and more rarely *Tournefortia* were found along the northeast shore, with *Hymenocallis*, sedges and grasses beneath the coconuts. The fresh sand spit was colonised by young *Tournefortia*, *Euphorbia* and grasses. By 1972 the cay had been much eroded at its eastern end, though it still consisted of an older core area and a southeastern sand spit. Its length was reduced to 240 m and its area to 1.12 ha. Much of the margin of the core area was cliffed. The coconut woodland had a ground cover of *Euphorbia*, grasses and sedges, with patches of *Hymenocallis*. There were several clumps of *Coccoloba* near the north point, one collapsed into the sea as a result of shore erosion. The sand spit was colonised by *Sesuvium*. In both 1960 and 1972 there was a rubble ridge about 25 m long located 45 m northwest of the north point of the cay; in 1972 this was colonised by *Philoxerus*.

In 1972 there were 35 pelicans at the cay (on 3 July), 30 boobies, 6 frigates, 16 sooty terns, and several shorebirds. 11 species of plants were noted in 1960 and 22 in 1972, giving a total of 24. In addition, one moss was collected (*Bryum coronatum* Schwaegr., Spellman and Stoddart 124). The plants recorded are:

<i>Eragrostis prolifera</i> 60S 72C	<i>Sophora tomentosa</i> 60C
<i>Eustachys petraea</i> 72C	<i>Vigna luteola</i> 72C
<i>Paspalum distichum</i> 72C	<i>Suriana maritima</i> 60S
<i>Paspalum</i> sp. 60S	<i>Euphorbia blodgettii</i> 72C
<i>Sporobolus virginicus</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Sporobolus</i> sp. 60S	<i>Euphorbia</i> sp. 60S
<i>Cyperus planifolius</i> 72C	<i>Rhizophora mangle</i> 72C (seedling)
<i>Cyperus</i> sp. 60S	<i>Terminalia catappa</i> 72C (seedling)
* <i>Cocos nucifera</i> 57S 60S 72S	<i>Ipomoea macrantha</i> 72C
<i>Hymenocallis littoralis</i> 60S 72C	<i>Tournefortia gnaphalodes</i> 60S 72C
<i>Coccoloba uvifera</i> 60S 72C	<i>Stachytarpheta jamaicensis</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Wedelia trilobata</i> 72C
<i>Portulaca oleracea</i> 72C	
<i>Sesuvium portulacastrum</i> 72C	
<i>Cassytha filiformis</i> 72C	
<i>Cakile lanceolata</i> 72C	

North Spot (16°15'N, 88°11'W)

Figure 19, Plates 37, 38 and 44

North Spot lies 10 km southwest of Ranguana Cay, on the south side of a channel through the barrier platform which carries 6.4 m of water. It stands on a patch reef about 360 m wide. When mapped in 1960 the island was a ridge of *Acropora* shingle 85 m long, with a maximum width of 27 m and an area of 0.05 ha. It was orientated northeast-southwest. It was covered with a thick mat of *Sesuvium*, *Portulaca* and *Ipomoea*, with a single juvenile coconut and some grasses. Barnett's survey in 1840 noted that the island was "very low sand with grass and clump of cocoas". Presumably the coconuts had been destroyed during a hurricane and the cay re-formed. In 1972 the geomorphology was transformed. North Spot was then a near-circular island, with greatest dimensions of 53 x 35 m, and an area (0.13 ha) double that of 1960. The surface was covered with a mat of *Sesuvium* over coarse rubble, with patches of *Ipomoea*. In addition there were single trees of *Rhizophora* and *Avicennia*, and a clump of *Tournefortia*. The surviving coconut was about 5 m tall. There was a flock of about 100 sooty terns on the island on 4 July 1972. Three species of plants were recorded in 1960 and 7 in 1972, giving a total of 8:

* <i>Cocos nucifera</i> 60s 72S	<i>Rhizophora mangle</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Ipomoea macrantha</i> 72C
<i>Portulaca</i> sp. 60S	<i>Ipomoea pes-caprae</i> 72C
<i>Sesuvium portulacastrum</i> 60S 72C	<i>Tournefortia gnaphalodes</i> 72C

Red Rock and Black Rock (16°14'N, 88°11½'W; 16°13'N, 88°11½'W) of charts are unvegetated rubble islets between North Spot and Tom Owen's Cays.

"Tom Owen's Cay" (16°12'N, 88°13'W)

Figures 20 and 21

South of 16°15'N the history and nomenclature of the barrier reef cays becomes complex. Owen in his 1835 survey charted three islands near the major channel which intersects the barrier platform in latitude 16°11½'N. One on the north side he named Tom Owen's Cay; it was described as having "one Cocoa N. Tree & Shrubs". Two small un-named islands on the south side were described as having "one large tree and high shrubs" (on the west) and "grass and bushes" (on the east) (Admiralty Ms L45). The northern cay has now disappeared, though still marked on Admiralty Chart 1573, and the name Tom Owen's Cays is now given locally to the two southern islands. Both are conspicuous islands, the eastern cay with a cluster of tall coconuts, and the western with a larger coconut woodland.

The earlier nomenclature of these islands is uncertain. Speer in his sailing directions (1766, p.24) mentions "a Kay called Cohune's Kay; and a very remarkable small Kay, that has many tall Palmetoe Trees on it; which look like so many round balls hanging in the air". He states that "Cohune's Kay, and the easternmost of the Sappatilla Kays [i.e. Northeast Sapodilla Cay], are N. by E. and S. by W. of each other; distance about 5 miles". This would bring Cohune's Kay to the position of the former Tom Owen's Cay; Speer carefully described the deep channel lying between the two. "Cohune's Kay", he continues, "is full of bushes and trees. A little to the eastward of Cohune's Kay there are two Sand Boors; but they join to one another, and to Cohune's Kay by a Reef. You leave them on your starboard side; and on your larboard side, you leave a Sand Boor that has breakers all round it, and no bushes on it. And about two cable's length to the N.W. of this Sand Boor there is a small spot of Rocks, which breaks when it blows fresh. And to the eastwards of that Sand Boor there is another Boor. There is a channel between them of 2 1-half, and 3 fathom water" (1766, p.24). This would suggest the identity of Cohune's Kay with the present Tom Owen's West Cay, and that in the eighteenth century the present Tom Owen's East Cay was one of the sandbores joined to Cohune by a reef. In this case the "very remarkable small Kay" with palmettoes was probably old Tom Owen's Cay, now disappeared. Jefferys marks Cohune Kay on his 1775 chart, and immediately north of it, across a main channel, "Halls Key". Thus Hall's may also be tentatively identified with old Tom Owen's. We have no information on when, after 1835, this island disappeared; there is certainly no trace of it now.

Tom Owen's East Cay (16°11½'N, 88°13½'W) Figure 22, Plates 39, 43, 46 and 47

Tom Owen's East Cay is the smaller of the two. When mapped in 1960 it was triangular in shape, with sides 35-45 m long. It abuts on its north side on the reef-crest rubble zone, and the northwest and northeast shores were built of shingle. Most of the cay was built of sand, however, rising up to 1 m above sea level. There were four

tall coconuts on the island, and a number of smaller ones, together with a scrub of *Tournefortia* and *Coccoloba* and extensive *Hymenocallis* and *Sesuvium*. The island had changed considerably by 1972. The old island had been eroded and then extended southwards by a new sand spit. The area had increased from 0.10 to 0.12 ha. The area of *Coccoloba* had greatly increased, and there was also a patch of *Conocarpus*. Otherwise the vegetation resembled that in 1960. No beachrock was seen in either survey. In 1972 the area of rubble along the north shore was much more extensive than in 1960, and probably represented a hurricane event.

Ten plant species were recorded in 1960 and 11 in 1972, giving a total of 15. The following are recorded:

<i>Paspalum distichum</i> 72C	<i>Sesuvium portulacastrum</i> 60S 72C
<i>Sporobolus virginicus</i> 72C	<i>Bursera simaruba</i> 60S
<i>Cyperus planifolius</i> 72C	<i>Euphorbia mesembrianthemifolia</i>
<i>Cyperus</i> sp. 60S	72C
* <i>Cocos nucifera</i> 60S 72S	<i>Euphorbia</i> sp. 60S
<i>Hymenocallis littoralis</i> 60S 72S	<i>Conocarpus erectus</i> 72C
<i>Coccoloba uvifera</i> 60S 72C	<i>Tournefortia gnaphalodes</i> 60S
<i>Philoxerus vermicularis</i> 72C	<i>Erithalis fruticosa</i> 60S
<i>Portulaca oleracea</i> 72C	<i>Wedelia trilobata</i> 60S
<i>Portulaca</i> sp. 60S	

Tom Owen's West Cay (16°11½'N, 88°14'W) Figure 23, Plates 45, 46 and 48

In 1960 Tom Owen's West Cay was about 90 m long and 35 m wide; it had an area of 0.26 ha. It was fringed along its northern side by a zone of coral rubble, and both north and south shores were formed of shingle. The interior was sandy with occasional blocks of coral rubble, and there were sand beaches at both east and west ends. The general surface stood about 1 m above sea level. The island was covered with coconut woodland, especially dense at the western end, with an undercover of *Wedelia*, *Cakile*, *Ambrosia*, *Sesuvium*, *Euphorbia*, sedges and grasses. There was some marginal *Coccoloba*, *Conocarpus* and *Tournefortia*. No beachrock was seen. The island remained very much the same in 1972, with rather minor changes in outline; the area had decreased to 0.24 ha. It was still covered with coconut woodland, but *Conocarpus* and *Caesalpinia* appeared much more extensive. *Cordia* survived from 1960 on the south shore. *Portulaca* was extensive on the windward beach crests. Fifteen species of plants were recorded in 1960 and 17 in 1972, giving a total of 22:

<i>Paspalum distichum</i> 72C	* <i>Cocos nucifera</i> 60S 72S
<i>Paspalum</i> sp. 60S	<i>Coccoloba uvifera</i> 60S 72C
<i>Sporobolus virginicus</i> 72C	<i>Iresine diffusa</i> 72C
<i>Sporobolus</i> sp. 60S	<i>Rivina humilis</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Portulaca oleracea</i> 72C
<i>Cyperus</i> sp. 60S	<i>Portulaca</i> sp. 60S

<i>Sesuvium portulacastrum</i> 60S 72C	<i>Ipomoea pes-caprae</i> 72C
<i>Cakile lanceolata</i> 60S	<i>Tournefortia gnaphalodes</i> 60S
<i>Caesalpinia bonduc</i> 72C	72C
<i>Canavalia rosea</i> 60S	<i>Lippia nodiflora</i> 72C
<i>Thespesia populnea</i> 72C	<i>Erithalis fruticosa</i> 60S
<i>Rhizophora mangle</i> 60S 72C	<i>Ambrosia hispida</i> 60S
<i>Conocarpus erectus</i> 60S 72C	<i>Wedelia trilobata</i> 60S
<i>Ipomoea macrantha</i> 72C	

One of the present Tom Owen's Cays was visited by the Marshall Field Expedition in 1923, when K.P. Schmidt and L.L. Walters collected two lizards (*Aristelliger georgeensis* and *Anolis sagrei*) (Schmidt 1941).

Cays between Tom Owens Cays and Northeast Sapodilla Cay Figures 20 and 21

Owen in 1835 (Admiralty MS L45) charted two small islands lying respectively 3.2 and 4 km southsouthwest of the present Tom Owen's Cays. The northern island had "dry sand, one Cocoa N. Tree and Shrubs"; the other "Dry Sand, 2 Cocoa N. Trees, Shrubs & bushes". They were situated on the south side of the main channel between Tom Owen's and Northeast Sapodilla Cays, and are probably the "Sand Boors" referred to by Speer (1766, p.24; quoted above). Both islands have now disappeared, though still marked on charts; when they were destroyed is not known.

The Sapodilla Cays

Figures 20 and 21, Plate 49

The southern six kilometres of the barrier reef consists of a series of large shoal patches intersected by deep channels. The six islands now existing on these patches are termed the Sapodilla Cays (Admiralty MS L45, 1835) or Zapotilla Cays (Chart 1573), and there is some informal suggestion of a territorial claim to them by the Republic of Honduras (Aguilar Paz 1954). The main islands are here referred to as Northeast Sapodilla, Frank's, Nicolas, Hunting, Lime and Ragged Cays. Speer (1766, 24) refers to them as "six large Champaign Kays" [champaign: "an expanse of level, open country. Unenclosed or common land" (*Shorter Oxford English Dictionary*, I (1933), p.289)].

Northeast Sapodilla Cay (16°08'N, 88°15'W) Figure 24, Plates 50, 52 and 53

Northeast Sapodilla Cay, the most northerly, is a rectangular island with greatest north-south and east-west dimensions of 300 m. In 1960 its area was 4.79 ha. The seaward shore was formed by a shingle ridge rising 2 m above sea level, highest near the northeast point and declining southwards. The northwest and southwest beaches are formed by low sand ridges. The centre of the cay is low-lying and poorly drained. The main dry land areas were to leeward of the seaward

shingle ridge and at the west end of the cay. In the southeast bay there are 8, possibly 9, lines of relict beachrock, standing up to 30 m from the present beach; the outer lines carry up to 1 m of water. In 1960 there was a further patch of beachrock, 15 m long, poorly cemented, on the southwest shore. The low-lying centre of the island was occupied by hundreds of young coconut palms, surrounded by *Acrostichum aureum*. The sandy areas were occupied by taller coconut woodland. *Coccoloba* and *Thrinax* grew along the seaward beach crest. A large patch of rubble at the eastern point was colonised by *Sesuvium*. Little morphological change had occurred by July 1972 except for erosion along the northwest bay. This averaged 10 m and reached 20 m at one point, leaving a cliffed shore with fallen coconut trees. The southwest sandy shore had been covered with shingle for its entire length and the small beachrock exposure hidden. On the northeast shore the beach itself was formed of sand overlying the face of the high shingle ridge, and low beachrock was exposed for part of its length. The vegetation was observed in greater detail than in 1960. In the low-lying coconut woodland with *Acrostichum*, the dominant woody species beneath the coconuts was *Erithalis*. *Chrysobalanus* was common round the margins of the area on slightly higher ground, and individuals were scattered through the woodland itself. *Coccoloba*, *Conocarpus* and *Suriana* formed a littoral hedge on the beach crest round much of the windward side of the cay, but *Tournefortia* was surprisingly absent. Trees in the coconut woodland included *Ficus*, *Terminalia*, *Hibiscus tiliaceus*, and *Citharexylum caudatum*, this last forming trees 3-6 m tall near the south point. The island was inhabited in 1960 but had been abandoned by 1972, when the main house was in ruins and the jetty broken.

26 plant species were recorded in 1972, which with the six noted in 1960 brings the total recorded to 28:

<i>Acrostichum aureum</i> 60S 72C	<i>Cakile lanceolata</i> 60C
<i>Eragrostis prolifera</i> 72C	<i>Chrysobalanus icaco</i> 72C
<i>Eustachys petraea</i> 72C	<i>Sophora tomentosa</i> 72C
<i>Paspalum blodgettii</i> 72C	<i>Suriana maritima</i> 72C
<i>Paspalum distichum</i> 72C	<i>Euphorbia blodgettii</i> 72C
<i>Sporobolus jacquemontii</i> 72C	<i>Hippocratea volubilis</i> 72C
<i>Stenotaphrum secundatum</i> 72C	<i>Hibiscus tiliaceus</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Passiflora suberosa</i> 72C
* <i>Cocos nucifera</i> 60S 72S	<i>Conocarpus erectus</i> 72C
<i>Thrinax radiata</i> 60S 72C	* <i>Terminalia catappa</i> 72C
* <i>Musa sapientum</i> 72C	<i>Citharexylum caudatum</i> 72C
<i>Ficus</i> sp. 72C	<i>Stachytarpheta jamaicensis</i> 72C
<i>Coccoloba uvifera</i> 60S 72C	<i>Erithalis fruticosa</i> 72C
<i>Sesuvium portulacastrum</i> 60S	<i>Wedelia trilobata</i> 72C

Frank's Cays (16°08'N, 88°15'W)

Figure 25, Plate 54

Owen in 1835 charted a single island 0.5 km south of Northeast Sapodilla Cay, named "Grass Cay", and this is marked on Admiralty Chart

1573. Three islands now exist at this point and are known as Frank's Cays: a main island (Frank's Cay) and two smaller ones (Frank's Cay East, Frank's Cay West). Whether these have formed by fragmentation of the earlier island or whether the small cays have formed since 1835 is not known.

Frank's Cay in 1960 was 230 m long and up to 100 m wide. It was low and formed entirely of a dark sand. The beaches were low and uneroded. At the eastern end of the cay there was a dense belt of mangroves (*Rhizophora*, *Conocarpus*, *Laguncularia*, *Avicennia*). The rest of the island was covered with a dense coconut woodland with herbs and grasses. *Conocarpus*, *Coccoloba* and *Thrinax* were found around the shores. There were two patches of poorly cemented beachrock at the eastern end of the south shore. By 1972 much of the north shore was cliffed and a substantial area of mangroves at the northeast point had been destroyed. The area of the cay had declined from 1.94 ha to 1.76 ha. The eastern mangrove fringe was much narrower and consisted mainly of *Conocarpus* and *Laguncularia*. *Chrysobalanus*, *Pithecellobium* and *Thrinax* were common round the shores. The south shore beachrock was still exposed.

Frank's Cay East is separated from the main cay by a shallow channel 25 m wide. In 1960 it was an arcuate island 120 m long, but by 1970 the western embayment had been infilled and the shape of the island was more regular; the area had increased from 0.5 to 0.57 ha. None of the shores were undercut in 1960, but the northeast and southeast shores were cliffed in 1972. Mangroves fringe the west side of the cay. The rest is covered with coconut woodland, with much *Conocarpus*, *Laguncularia* and *Thrinax*. A continuous belt of *Coccoloba* along the northeast shore in 1960 had been reduced to two clumps in 1972, presumably by shore erosion.

Frank's Cay West lies 75 m southwest of the main cay, and in 1960 was a lens-shaped sandy island 70 m long with an area of 0.11 ha. It was covered with a thicket of *Conocarpus* and coconut; a single *Avicennia* was prominent on the northwest shore. This tree still existed in 1972 but the northwest shore was cliffed; the southeast shore had been colonised by *Rhizophora* immediately offshore. *Thrinax*, *Ficus* and *Laguncularia* were noted in addition to *Cocos* and *Conocarpus*.

31 plant species have been recorded from the main island (13 in 1960, 30 in 1972). In addition the moss *Calymperes richardii* C. Müll. was collected (Spellman and Stoddart 129a). Plants recorded are:

<i>Andropogon glomeratus</i> 72C	<i>Stenotaphrum secundatum</i> 72C
<i>Eragrostis prolifera</i> 72C	<i>Cyperus peruvianus</i> 60C 72C
<i>Eustachys petraea</i> 60C 72C	<i>Cyperus planifolius</i> 72C
<i>Paspalum blodgettii</i> 72C	<i>Fimbristylis cymosa</i> 72C
<i>Paspalum</i> sp. 60S	* <i>Cocos nucifera</i> 60S 72S
<i>Spartina patens</i> 72C	<i>Thrinax radiata</i> 60S 72C
<i>Sporobolus virginicus</i> 72C	<i>Ficus</i> sp. 72C
<i>Sporobolus</i> sp. 60S	<i>Coccoloba uvifera</i> 60S 72C

<i>Cakile lanceolata</i> 60S	<i>Rhizophora mangle</i> 60S 72C
<i>Chrysobalanus icaco</i> 72C	<i>Conocarpus erectus</i> 60S 72C
<i>Gliricidia sepium</i> 72C	<i>Laguncularia racemosa</i> 60S 72C
<i>Pithecellobium keyense</i> 72S	* <i>Terminalia catappa</i> 72C
<i>Sophora tomentosa</i> 72C	<i>Avicennia germinans</i> 72C
<i>Euphorbia blodgettii</i> 72C	<i>Lippia nodiflora</i> 72C
<i>Euphorbia mesembrianthemifolia</i> 72C	<i>Stachytarpheta jamaicensis</i> 72C
<i>Euphorbia</i> sp. 60S	<i>Erithalis fruticosa</i> 72C
<i>Passiflora suberosa</i> 72C	<i>Wedelia trilobata</i> 60S 72C

Seventeen species are recorded from Frank's Cay East (12 in 1960, 11 in 1972). They include the uncommon orchid *Brassavola nodosa* from the *Rhizophora* at the easternmost point. Species recorded are:

<i>Acrostichum aureum</i> 72C	<i>Cakile lanceolata</i> 60S
<i>Andropogon</i> sp. 60S	<i>Pithecellobium keyense</i> 72S
<i>Eustachys petraea</i> 60S	<i>Euphorbia</i> sp. 60S
<i>Paspalum</i> sp. 60S	<i>Rhizophora mangle</i> 60S 72S
* <i>Cocos nucifera</i> 60S 72S	<i>Conocarpus erectus</i> 60S 72S
<i>Thrinax radiata</i> 60S 72S	<i>Laguncularia racemosa</i> 60S 72S
<i>Brassavola nodosa</i> 72C	<i>Avicennia germinans</i> 60S
<i>Coccoloba uvifera</i> 60S 72S	<i>Erithalis fruticosa</i> 72S

Twelve species are recorded from Frank's Cay West (9 in 1960 and 6 in 1972). They are:

<i>Andropogon</i> sp. 60S	<i>Canavalia rosea</i> 60S
<i>Paspalum</i> sp. 60S	<i>Euphorbia</i> sp. 60S
<i>Sporobolus</i> sp. 60S	<i>Rhizophora mangle</i> 60S 72S
* <i>Cocos nucifera</i> 60S 72S	<i>Conocarpus erectus</i> 60S 72S
<i>Thrinax radiata</i> 72S	<i>Laguncularia racemosa</i> 72S
<i>Ficus</i> sp. 72S	<i>Avicennia germinans</i> 60S

Nicolas Cay (16°07'N, 88°16'W)

Figure 26, Plates 51 and 57

Nicolas Cay lies 2 km southsoutheast of Frank's Cays, on the northern side of a channel carrying 11 m of water. It is oval-shaped, and in 1960 had maximum dimensions of 310 x 190 m. There was some beach erosion at the north and southwest ends of the cay, but most of the shore is formed by a broad sand beach. No beachrock was exposed. By 1972 there had been considerable erosion, averaging 10-15 m, on all sides of the cay except the south and southeast. Shores were cliffed on the west and northeast sides, and a soft root filled lithified material ('root rock') was exposed on the west shore. The area had declined from 4.53 to 3.86 ha. The cay is densely vegetated with coconut woodland, with an understorey of *Psychotria nervosa*. On the seaward side of the cay the beach crest is lined by *Coccoloba*, *Conocarpus*, *Cordia* and *Sophora*, with *Erithalis* and *Chrysobalanus*,

partly fronted by a strip of herbs and grasses with germinating drift coconuts. A patch of *Tournefortia* growing at the east point in 1960 had disappeared as a result of beach retreat by 1972, and this removed the species from the island. The littoral hedge on the west shore is largely formed by *Erithalis* and *Conocarpus*. Other species noted include *Terminalia* and a large *Ficus*. There are temporary fishing huts on the cay, but it is uninhabited. Sherds of red Maya pottery were eroding from superficial midden deposits in the area of root rock exposure on the west shore in 1972 (Stoddart 1980, p.162). When mapped by Owen in 1835 the island was inhabited and had fresh water.

32 species have been recorded from the cay (4 in 1960, 31 in 1972). In addition four mosses were collected in 1972: *Taxithelium planum* (Brid.) Mitt. (Spellman and Stoddart 125b), *Callicostella depressa* (Hedw.) Jaeg. (Spellman and Stoddart 125c), *Calymperes erosum* C. Müll. (Spellman and Stoddart 126B0), and *Calymperes richardii* C. Müll. (Spellman and Stoddart 127a). The plant species recorded are:

<i>Nephrolepis multiflora</i> 72C	<i>Pithecellobium keyense</i> 72C
<i>Polypodium lycopodioides</i> 72C	<i>Sophora tomentosa</i> 72C
<i>Polypodium polypodioides</i> 72C	* <i>Citrus aurantiifolia</i> 72C
<i>Andropogon glomeratus</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Eragrostis prolifera</i> 72C	<i>Passiflora suberosa</i> 72C
<i>Eustachys petraea</i> 72C	<i>Conocarpus erectus</i> 60S 72C
<i>Paspalum blodgettii</i> 72C	* <i>Terminalia catappa</i> 72C
<i>Paspalum distichum</i> 72C	<i>Pouteria campechiana</i> 72C
<i>Sporobolus virginicus</i> 72C	* <i>Nerium oleander</i> 72C
<i>Cyperus peruvianus</i> 72C	<i>Tournefortia gnaphalodes</i> 60S
<i>Cyperus planifolius</i> 72C	<i>Lippia nodiflora</i> 72C
<i>Fimbristylis cymosa</i> 72C	<i>Diodia serrulata</i> 72C
* <i>Cocos nucifera</i> 60S 72S	<i>Erithalis fruticosa</i> 72C
<i>Thrinax radiata</i> 72C	<i>Ernodea littoralis</i> 72C
<i>Ficus</i> sp. 72C	<i>Psychotria nervosa</i> 72C
<i>Coccoloba uvifera</i> 60S 72C	
<i>Chrysobalanus icaco</i> 72C	

Hunting Cay (16°07'N, 88°16'W)

Figure 27, Plates 55, 56 and 58

Hunting Cay lies 0.6 km south of Nicolas Cay, on the south side of the channel which divides the barrier platform at this point. When mapped in 1960 it had a maximum north-south length of 440 m and was up to 220 m wide; its area was 5.79 ha. The west and south coasts were formed by broad sand beaches. The east coast was more complex, with two projections separated by a wide sandy bay facing a gap in the reef. The northeast shore was built of shingle but the other seaward shores of sand. Both in the bay and on the southern headland beachrock indicated beach retreat. There was some undercutting near the north-west point. By 1972 there had been erosion on the west and south shores as well as in the east bay. The west shore was cliffed, with fallen coconuts, for much of its length. More beachrock had been exposed on the eastern side.

The island is covered with a dense coconut woodland. *Coccoloba* formed an extensive littoral hedge along the east shores in 1960 and again in 1972. Grasses and juvenile *Casuarina* were colonising the fresh sand accumulations in the south in 1960 and 1972. Beach retreat in the east bay had destroyed the only colony of beach-crest *Tournefortia* between the two surveys, and this species was not found in 1972. *Hymenocallis* is particularly common in the southeast part of the island. Vermeer (1959, p.90) mentions *Manilkara zapota* in the coconut woodland, but this record has not been confirmed. The cay is inhabited and has a lighthouse. Craig (1966) mentions it as one of the islands with Maya remains, but these were not seen during our surveys.

58 species of plants have been recorded, 7 in 1960 and 57 in 1972. They are:

- | | |
|--|---|
| <i>Acrostichum aureum</i> 72C | <i>Euphorbia blodgettii</i> 72C |
| * <i>Eleusine indica</i> 72C | <i>Euphorbia mesembrianthemifolia</i> 72C |
| <i>Eragrostis ciliaris</i> 72C | <i>Phyllanthus amarus</i> 72C |
| <i>Eragrostis prolifera</i> 72C | <i>Hippocratea volubilis</i> 72C |
| <i>Eustachys petraea</i> 72C | <i>Hibiscus tiliaceus</i> 72C |
| <i>Paspalum blodgettii</i> 72C | <i>Passiflora suberosa</i> 72C |
| <i>Paspalum distichum</i> 72C | * <i>Cucumis melo</i> 72C |
| <i>Sporobolus virginicus</i> 72C | <i>Conocarpus erectus</i> 60S 72C |
| <i>Sporobolus</i> sp. 60S | * <i>Terminalia catappa</i> 72C |
| <i>Cyperus ligularis</i> 72C | <i>Eugenia</i> sp. 72C |
| <i>Cyperus peruvianus</i> 72C | [<i>Manilkara zapota</i> Vermeer (1959, p.90)] |
| <i>Cyperus planifolius</i> 72C | * <i>Nerium oleander</i> 72C |
| <i>Fimbristylis cymosa</i> 72C | * <i>Plumeria rubra</i> 72C |
| * <i>Cocos nucifera</i> 60S 72S | <i>Rhabdadenia biflora</i> 72C |
| <i>Thrinax radiata</i> 72C | <i>Tournefortia gnaphalodes</i> 60S |
| <i>Hymenocallis littoralis</i> 60S 72C | <i>Citharexylum caudatum</i> 72C |
| <i>Brassavola nodosa</i> 72C | <i>Lippia nodiflora</i> 72C |
| * <i>Casuarina equisetifolia</i> 60S 72C | <i>Stachytarpheta jamaicensis</i> 72C |
| <i>Ficus</i> sp. 72C | * <i>Russelia equisetiformis</i> 72C |
| <i>Coccoloba uvifera</i> 60S 72C | <i>Enallagma latifolia</i> 72C |
| <i>Portulaca oleracea</i> 72C | <i>Diodia serrulata</i> 72C |
| (seedling) | <i>Erithalis fruticosa</i> 72C |
| <i>Cakile lanceolata</i> 72C | <i>Ernodea littoralis</i> 72C |
| * <i>Kalanchoe pinnata</i> 72C | * <i>Ixora coccinea</i> 72C |
| <i>Chrysobalanus icaco</i> 72C | <i>Spermacoce assurgens</i> 72C |
| <i>Canavalia rosea</i> 72C | <i>Spermacoce prostrata</i> 72C |
| <i>Gliricidia sepium</i> 72C | <i>Ageratum littorale</i> 72C |
| <i>Pithecellobium keyense</i> 72C | <i>Bidens pilosa</i> 72C |
| <i>Sophora tomentosa</i> 72C | <i>Conyza canadensis</i> 72C |
| <i>Vigna luteola</i> 72C | |
| * <i>Citrus aurantiifolia</i> 72C | |
| * <i>Codiaeum variegatum</i> 72C | |

Lime Cay (16°06'N, 88°16½'W)

Figure 28, Plates 59-61

Lime Cay, the "Low Cay" of charts, lies nearly 1 km south of Hunting Cay. In 1960 the island was 300 m long and up to 110 m wide; it had an area of 1.83 ha. The northeastern point was built of shingle and abutted on a semicircular reef-crest rubble zone; the other shores were sandy. Much of the northwest-facing shore was cliffed, and beachrock offshore indicated past beach retreat. The shingle hook at the northeast point was apparently a recently formed and perhaps still mobile feature. In 1972 the hook had disappeared and the northeastern and northwestern shores were cliffed and eroding. The width of the island in this sector had decreased from 75 to as little as 35 m. Conversely there was a great deal of fresh sand forming two large spits at the southwest end (in July 1972), and as a result the island had increased in length to nearly 330 m and in area to 2.07 ha.

The island is covered with a coconut woodland, which is most dense in the southwest. In the centre, on low-lying poorly-drained ground, there is an area of *Hymenocallis*, *Thrinax* and *Acoelorrhaphe*. Beach-crest vegetation consists of discontinuous *Erithalis*, *Coccoloba*, *Conocarpus* and *Sophora*; in particular the small patch of *Conocarpus* noted on the shingle hook in 1960 had greatly expanded by 1970. In 1970 there was also a small patch of *Sesuvium* on the seaward rubble.

Thirty species of plants have been recorded from Lime Cay, 5 in 1960 and 28 in 1972. The *Rhizophora* seedlings colonising inside the shingle hook in 1960 had disappeared by the later survey. Species recorded are:

<i>Nephrolepis multiflora</i> 72C	<i>Hymenocallis littoralis</i> 72C
<i>Andropogon glomeratus</i> 72C	<i>Coccoloba uvifera</i> 60S 72C
<i>Antheophora hermaphrodita</i> 72C	<i>Sesuvium portulacastrum</i> 60S 72S
<i>Cenchrus incertus</i> 72C	<i>Pithecellobium keyense</i> 72C
<i>Eragrostis prolifera</i> 72C	<i>Sophora tomentosa</i> 72C
<i>Eustachys petraea</i> 72C	<i>Euphorbia mesembrianthemifolia</i>
<i>Panicum pilosum</i> 72C	72C
<i>Paspalum blodgettii</i> 72C	<i>Passiflora suberosa</i> 72C
<i>Sporobolus virginicus</i> 72C	<i>Rhizophora mangle</i> 60S (seedlings)
<i>Stenotaphrum secundatum</i> 72C	<i>Conocarpus erectus</i> 60S 72C
<i>Cyperus peruvianus</i> 72C	* <i>Terminalia catappa</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Lippia nodiflora</i> 72C
<i>Fimbristylis cymosa</i> 72C	<i>Stachytarpheta jamaicensis</i> 72C
<i>Acoelorrhaphe wrightii</i> 72C	<i>Diodia serrulata</i> 72C
* <i>Cocos nucifera</i> 60S 72S	<i>Erithalis fruticosa</i> 72C
<i>Thrinax radiata</i> 72C	

In addition the moss *Calymperes richardii* C. Müll. was also collected (Spellman and Stoddart 128a).

Ragged Cay (16°05'N, 88°17½'W)

Figure 29, Plates 62-63

Ragged Cay, the southernmost on the barrier reef, appears on charts as "South Cay" and "Zapotilla Cay". It stands on a small reef patch with deep channels to east and west. In 1960 it was triangular, with sides 40-70 m long, and with an area of 0.24 ha. It was built entirely of concentric ridges of coarse shingle, reaching about 1 m above sea level. By 1972 it had changed considerably, and was an oval island, orientated north-south, 75 m long and 35 m wide, with an area of 0.22 ha. It was still built of shingle, with a small southern sand spit. Owen in 1835 noted a "Small cluster of cocoanut trees, grasses and bushes". In 1960 there were five *Casuarina* trees, one a mature specimen 15 m tall, together with 10 coconuts. The ground surface was covered with a thick mat of *Sesuvium* with bushes of *Conocarpus* and *Rivina*. In 1972 the vegetation remained dominated by the *Casuarina* and the coconuts, with *Sesuvium* and *Rivina*. A feature of this island is the great number of coenobitid hermit crabs inhabiting it. Only seven plant species have been recorded from Ragged Cay (5 in 1960 and 5 in 1972); they are:

<i>Cyperus planifolius</i> 72C	<i>Portulaca oleracea</i> 72C
* <i>Cocos nucifera</i> 1835S 60S 72S	<i>Sesuvium portulacastrum</i> 60C
* <i>Casuarina equisetifolia</i> 60S 72C	72C
<i>Rivina humilis</i> 60C	<i>Conocarpus erectus</i> 60S

Seal Cays (16°10½'N, 88°20'W)

Figure 30, Plates 64-65

At Ragged Cay the barrier reef trends westwards for 3.7 km and northwards for 9 km, forming a narrow hook. Where not occupied by surface reefs this carries 4-5 m of water over it; inside the hook the water depths are 29-33 m, and outside it 55 m. The reef is uninterrupted by channels in its north-south limb. Admiralty Chart 1573 shows Seal Cays on this reef at 16°08'N: these are the "Observation Seal" Cays mapped by Owen in 1835. They then comprised two islands on an arcuate reef, one with a "cluster of cocoa-nut trees", the other with a "grove of cocoa-nut trees, huts". Only an unvegetated sandbore occupies this site now; the cays are said to have been destroyed in the 1945 hurricane. At the northern end of the reef there are two large reef patches. The southernmost possessed a cay in 1835, with "one bushy tree"; this, too, is now an unvegetated sandbore. The other forms a perfect faro or circular reef enclosing a lagoon, about 150 m in diameter, at the end of the barrier reef. It has a cay at its northeast point, and Owen noted a "small cluster of cocoa-nut trees" in 1835. This is the present Seal Cay. A group of small sandbores lies north of the cay, bearing 335°, 003°, 013° and 021° from its north point.

Seal Cay is a small sandy island sheltering in the lee of a rubble ridge which occupies the reef top on the windward side of the faro. It is arcuate in shape, about 65 m long and only 15-20 m wide, with an

area when mapped in 1972 of 0.14 ha. Its main vegetation is *Rhizophora*, with single trees of *Cordia*, *Coccoloba*, *Avicennia* and *Cocos*. There are shrubs of *Concarnus* at the west point. The ground cover consists of *Hymenocallis*, *Ipomoea*, *Sesuvium* and *Rivina*. The island is uninhabited but is used as a fishing station: the leeward beach has been modified by conch shells to form small boat harbours. Seal Cay was approached but not visited in 1960; there is a note on it in Vermeer (1959, p.90). Sixteen species of plants are recorded:

<i>Paspalum distichum</i> 72C	<i>Thespesia populnea</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Rhizophora mangle</i> 72C
<i>Cocos nucifera</i> 1835S 57S 60S 72S	<i>Conocarpus erectus</i> 72C
<i>Hymenocallis littoralis</i> 72C	<i>Laguncularia racemosa</i> 72C
<i>Coccoloba uvifera</i> 72C	<i>Ipomoea macrantha</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Cordia sebestena</i> 72C
<i>Rivina humilis</i> 72C	<i>Avicennia germinans</i> 72C
<i>Portulaca oleracea</i> 72C	<i>Lippia nodiflora</i> 72C

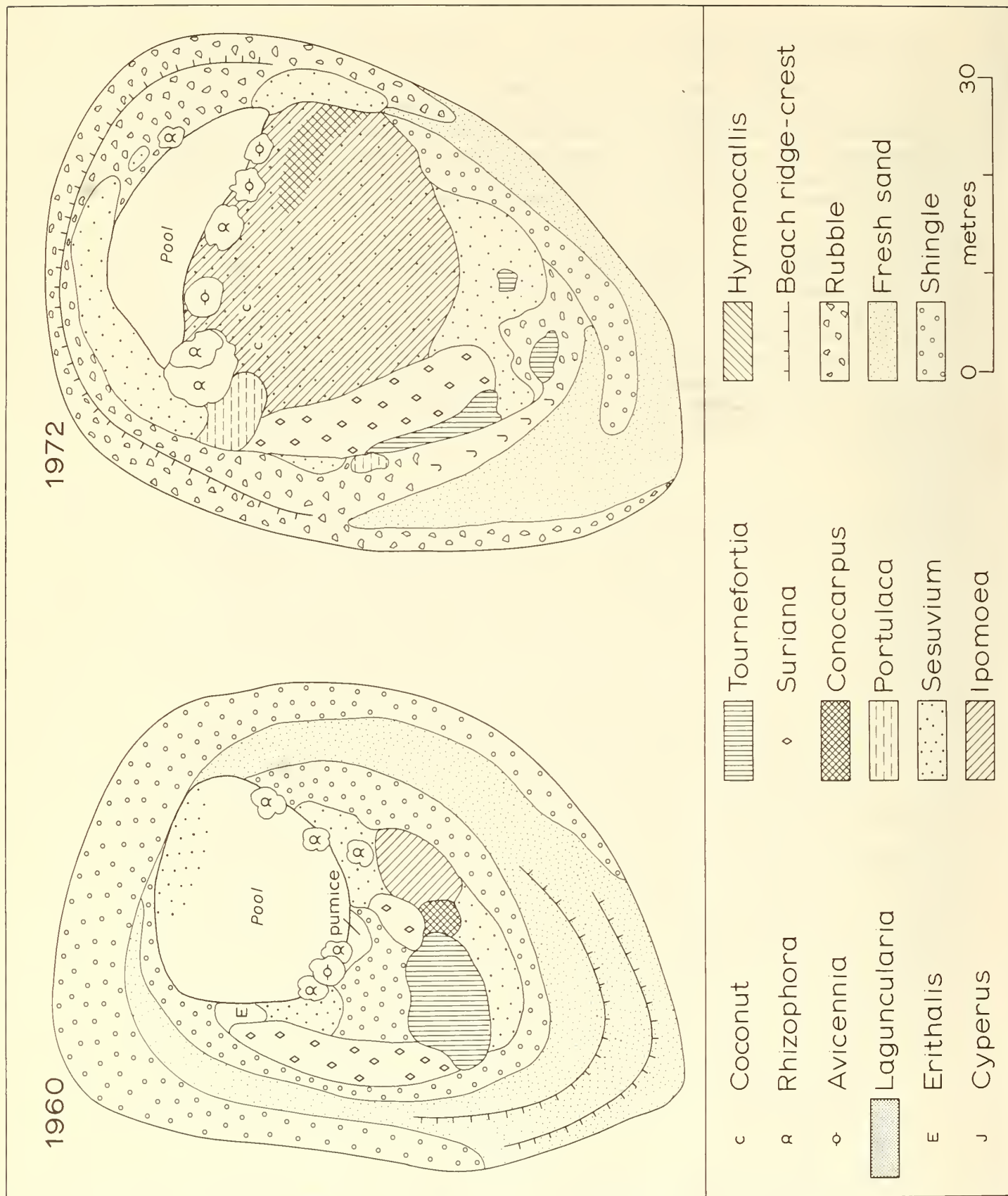


Figure 12. North Silk Cay 1961 and 1972

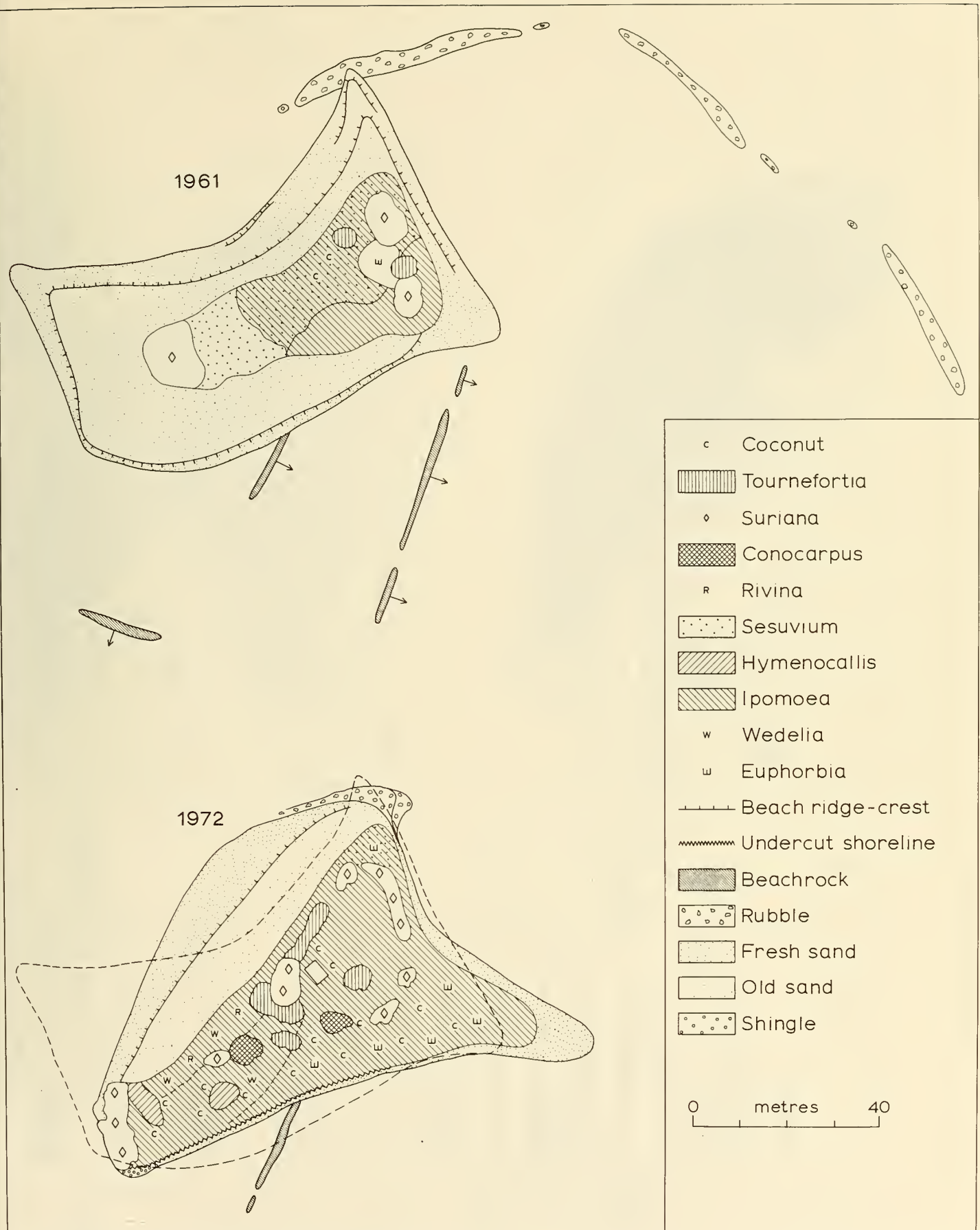


Figure 13. Middle Silk Cay 1961 and 1972

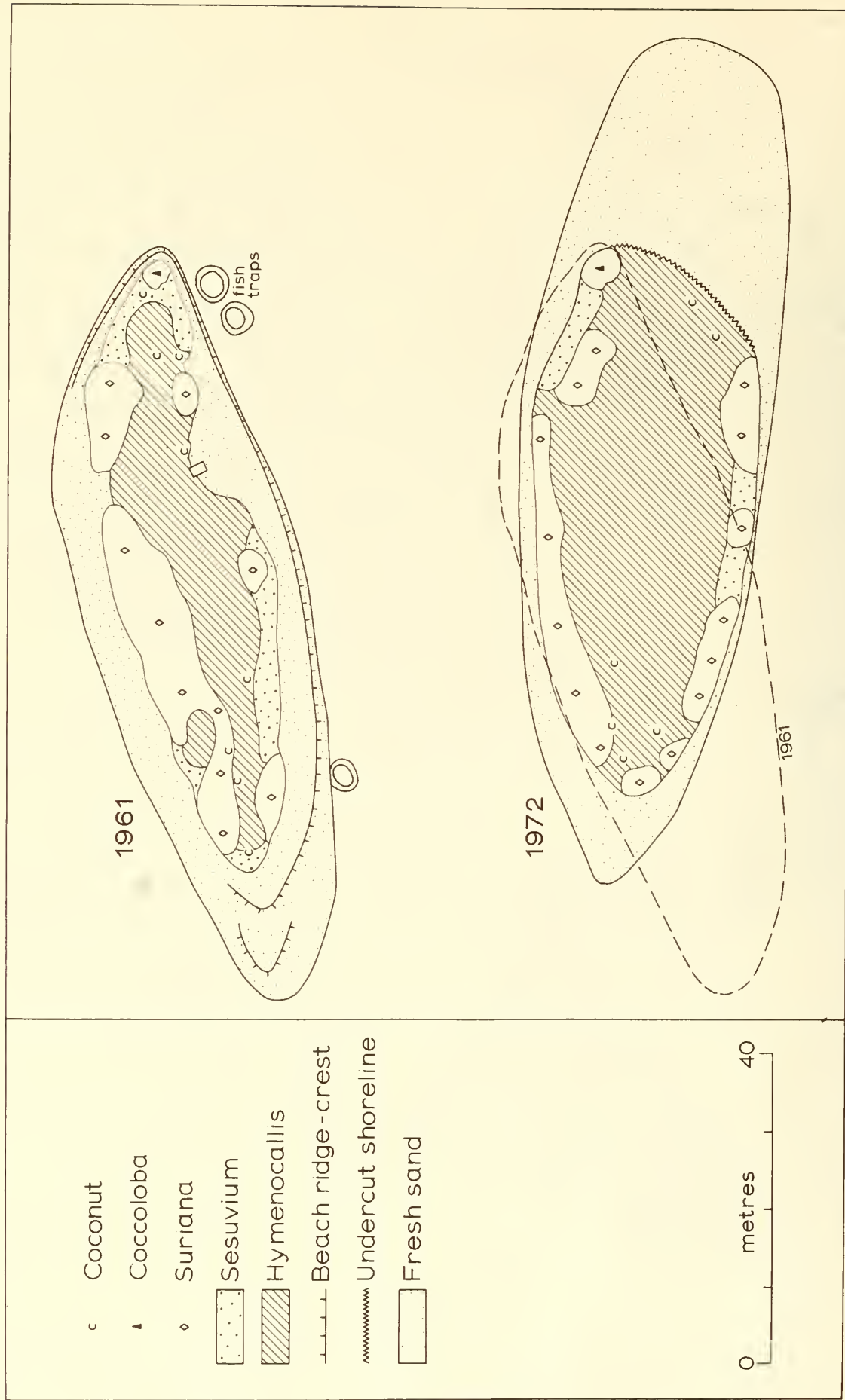


Figure 14. South Silk Cay 1961 and 1972

Dense coconuts
with grasses
and Hymenocallis



Tournefortia



◊ Suriana



Conocarpus



R Rivina



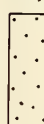
Herb mat



Portulaca



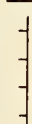
Sesuvium



Ipomoea



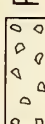
Beach ridge-crest



Beachrock



Rubble



Banked Thalassia
Leaves



Fresh sand

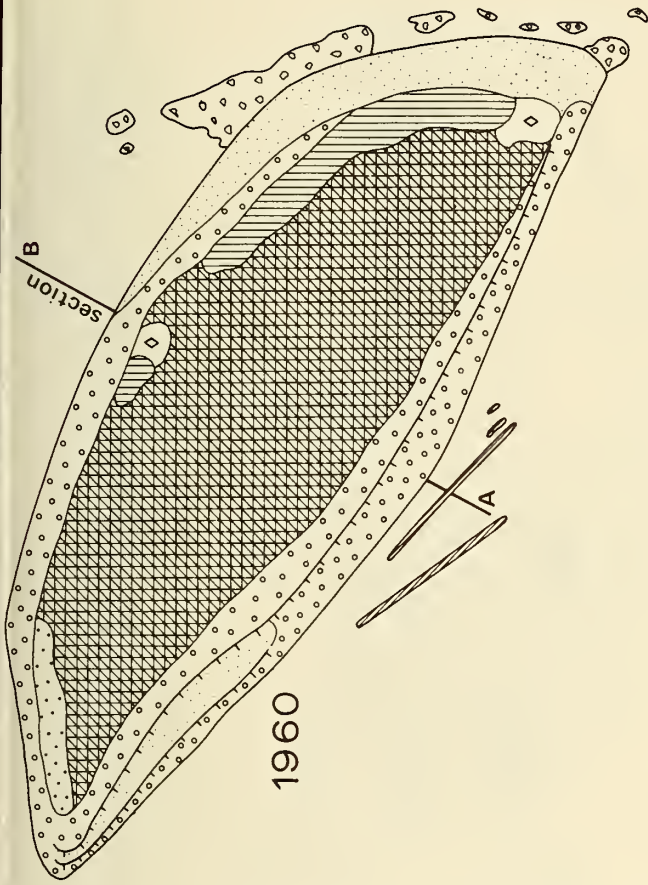


Shingle



0 metres 40

1960



1972

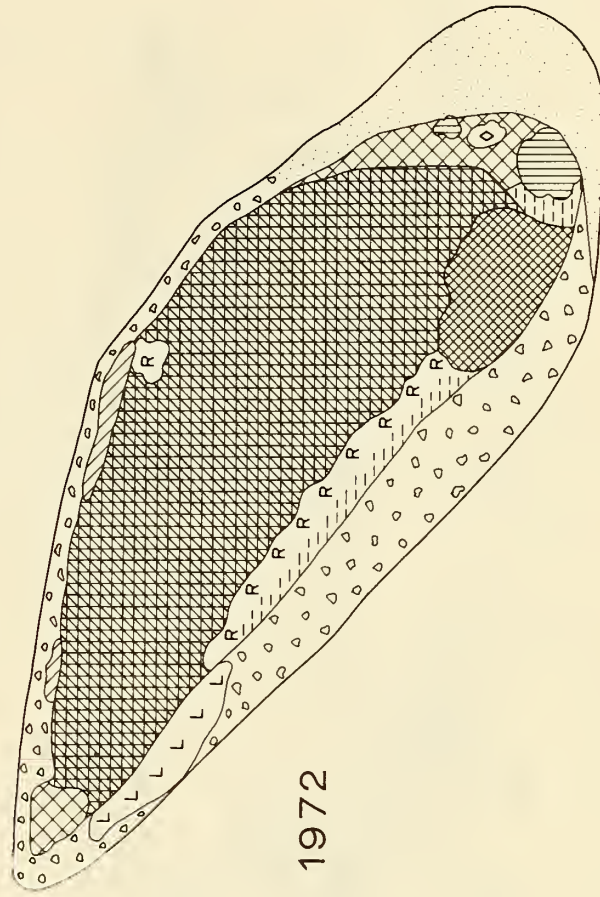


Figure 15. Round Cay 1960 and 1972

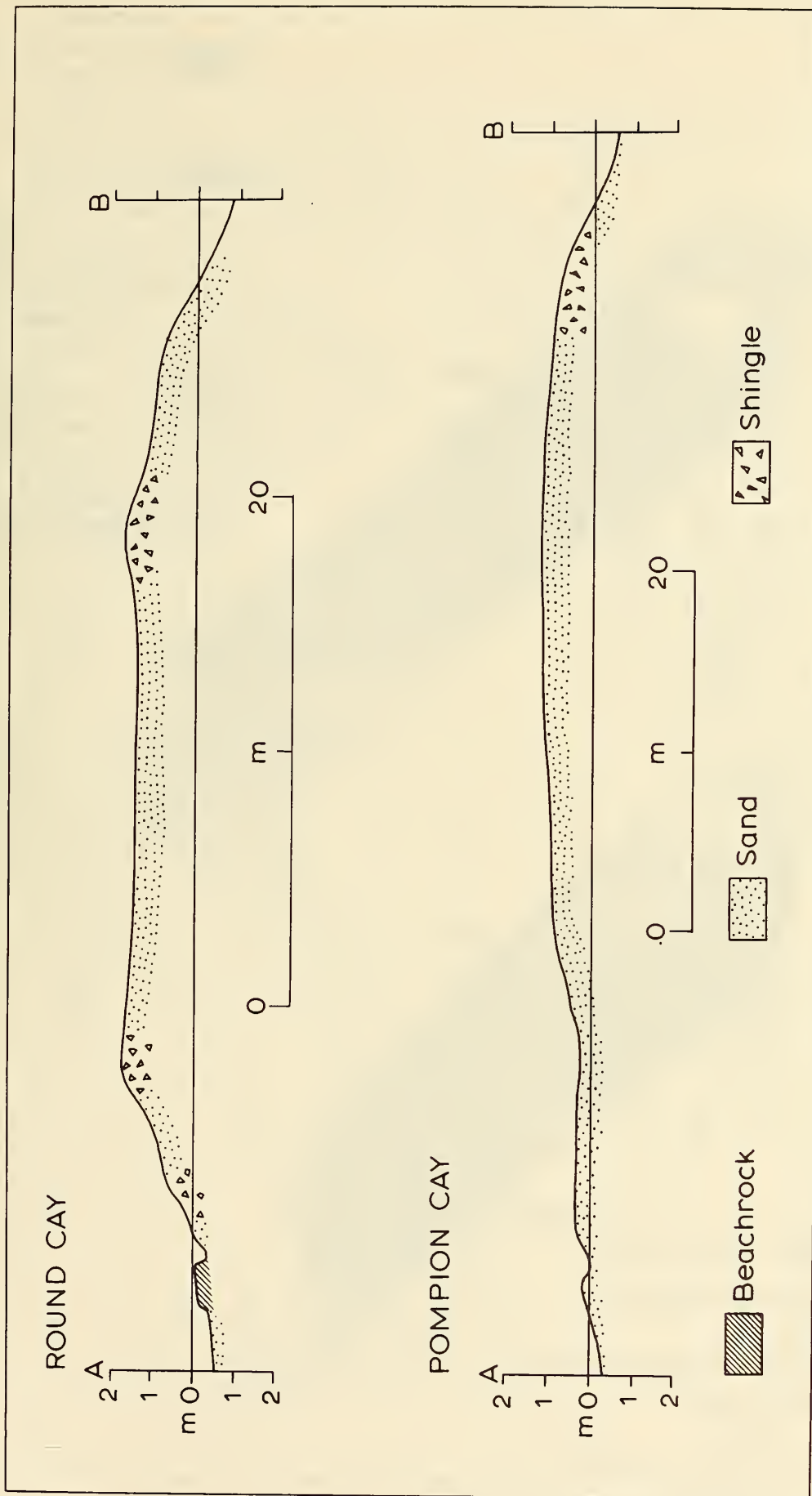


Figure 17. Profiles of Round and Pompion Cays 1960. For locations see Figures 14 and 15

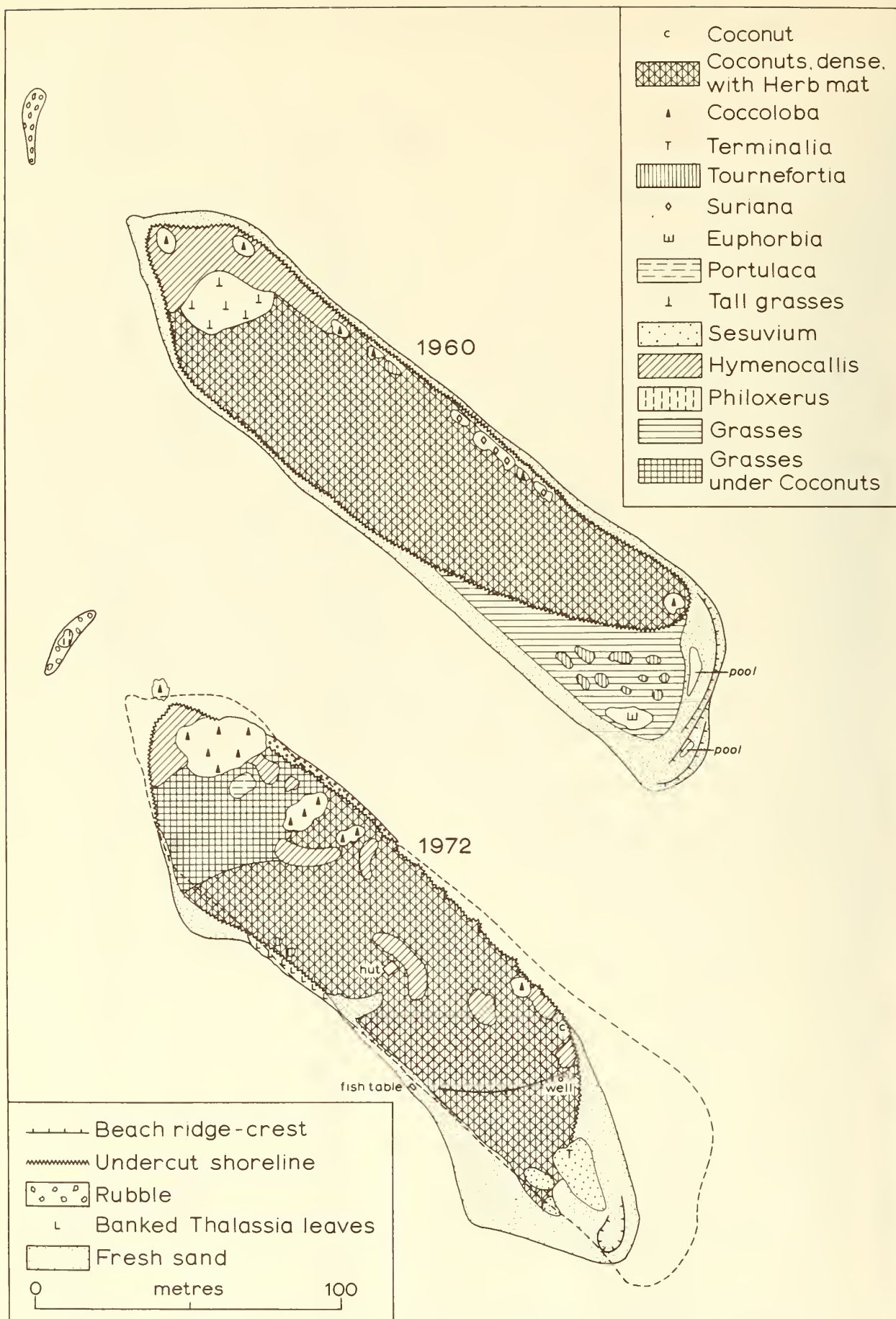
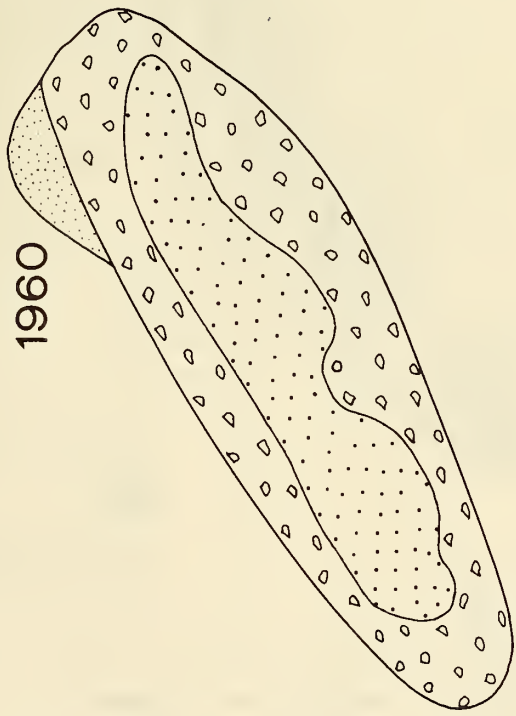
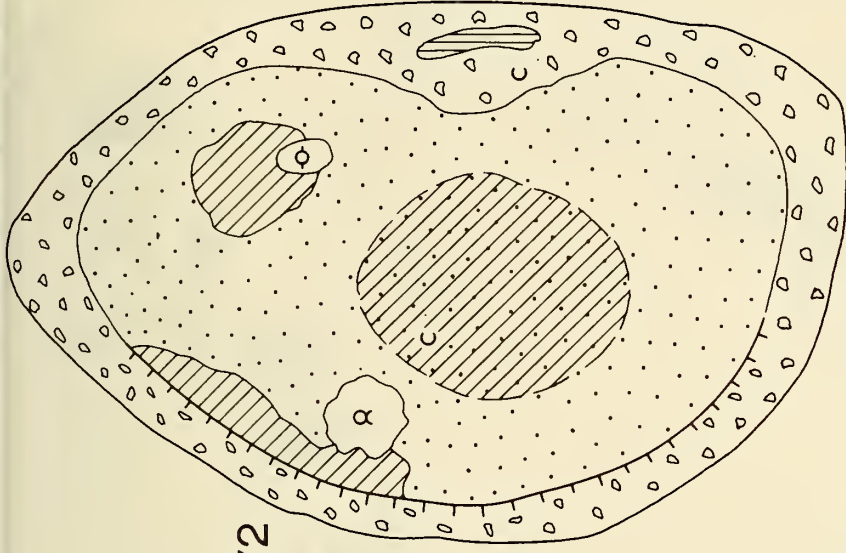


Figure 18. Ranguana Cay 1960 and 1972

1960



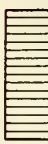
1972

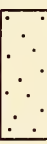


c Coconut

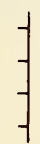
α Rhizophora

○ Avicennia

 Tournefortia

 Sesuvium

 Ipomoea

 Beach ridge-crest

 Rubble

 Fresh sand

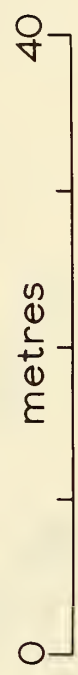


Figure 19. North Spot 1960 and 1972

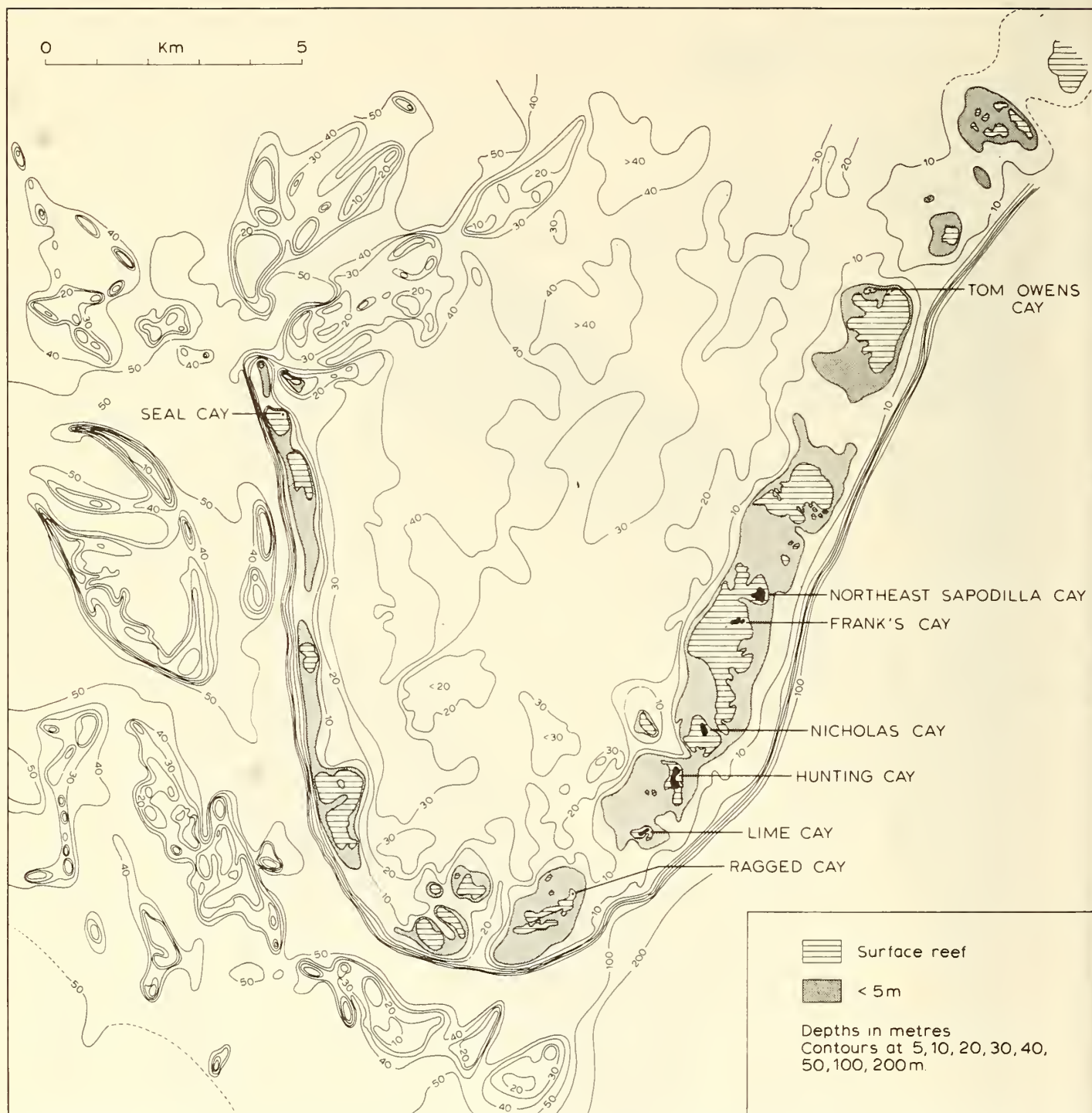


Figure 20. Reefs and cays of the southernmost barrier reef. Based on original plots by R. Owen, 1835

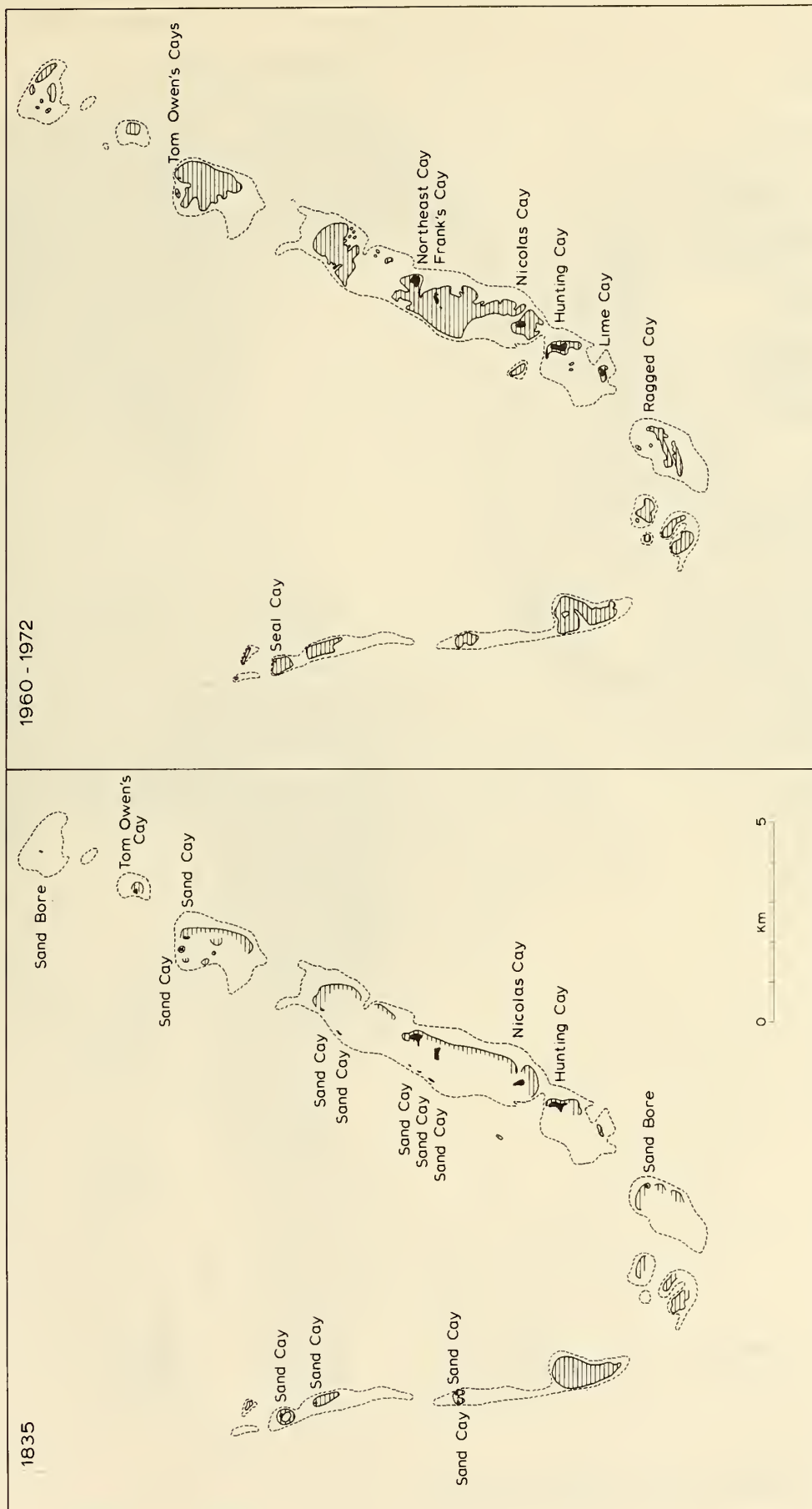


Figure 21. Topographic change on the southernmost barrier reef, between the surveys of Owen (1830) and those of 1960-1972

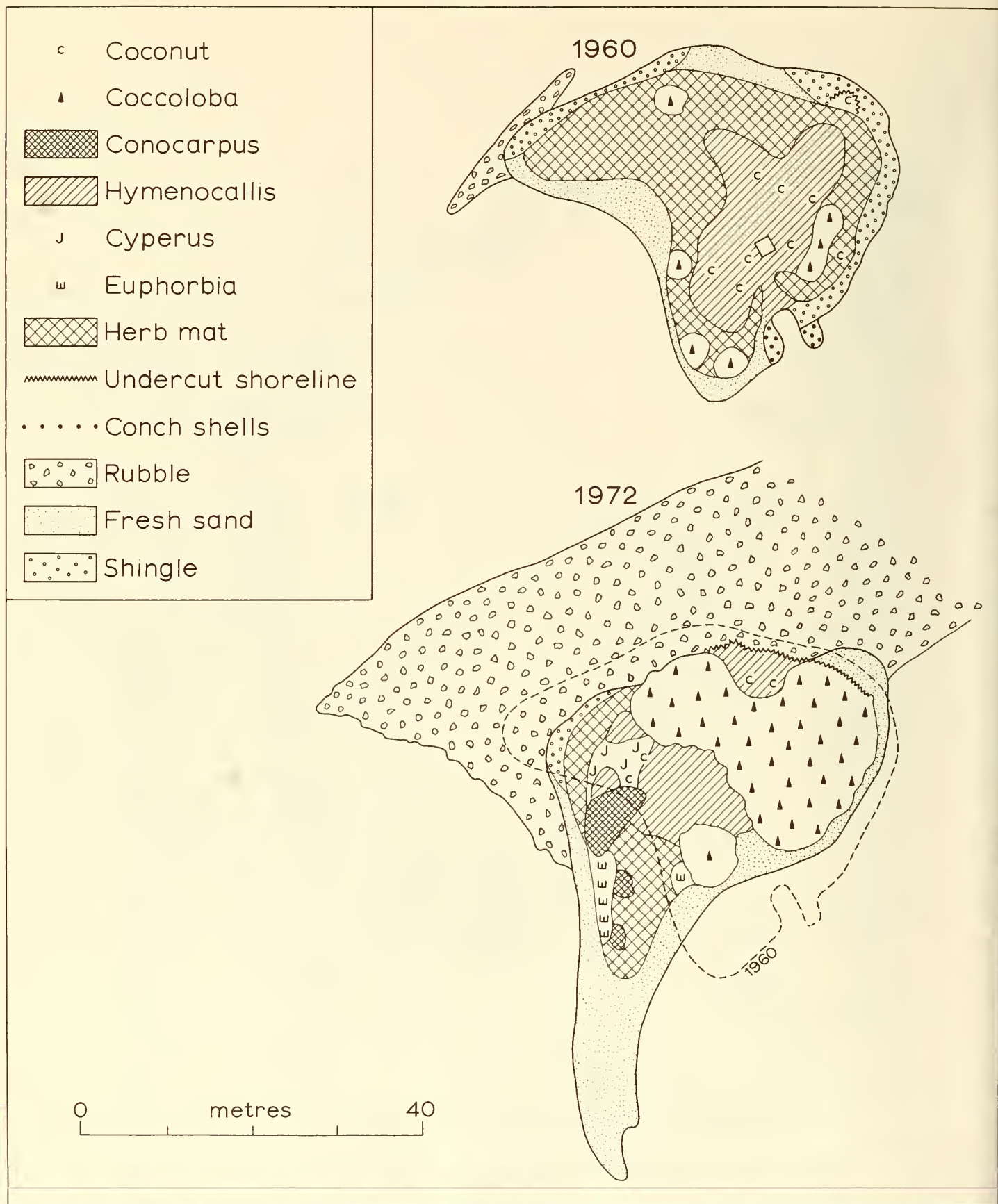


Figure 22. Tom Owen's East Cay 1960 and 1972

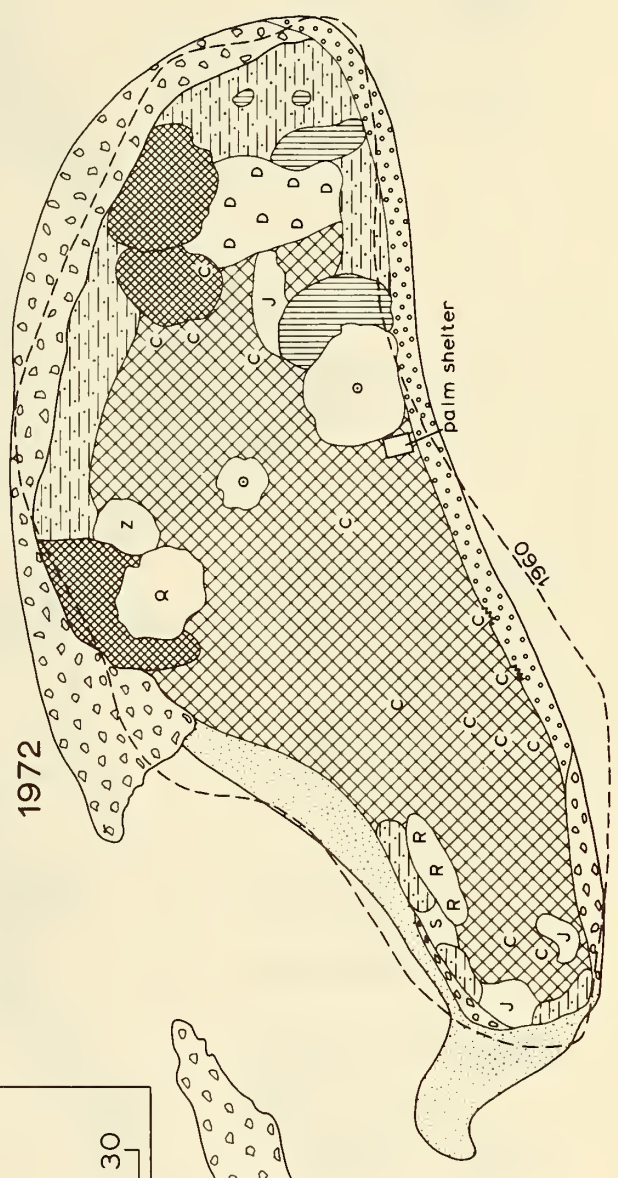
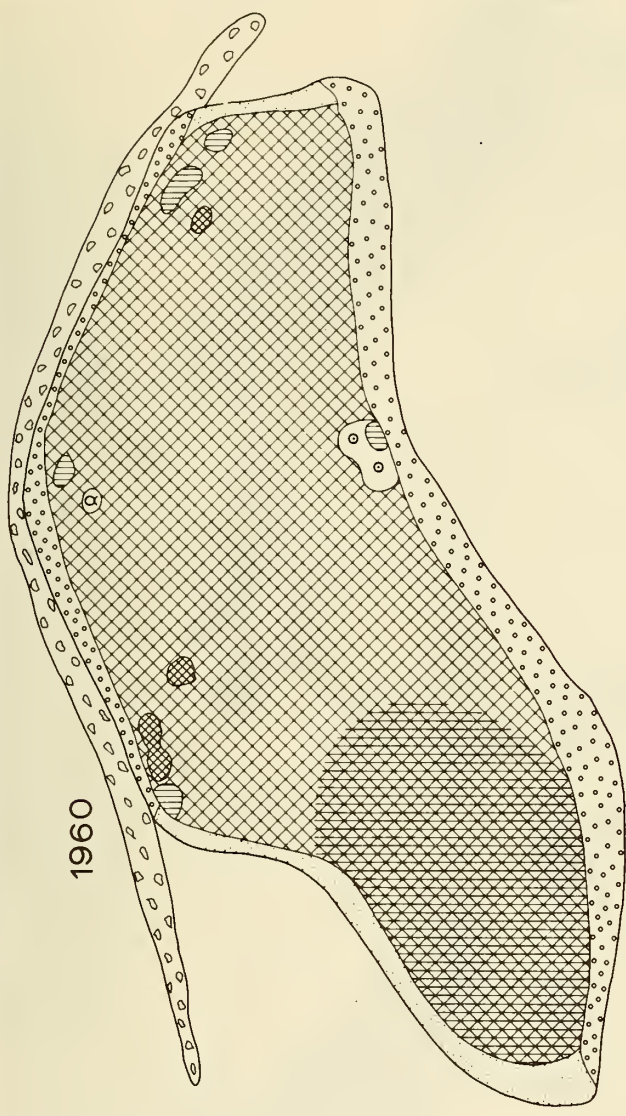
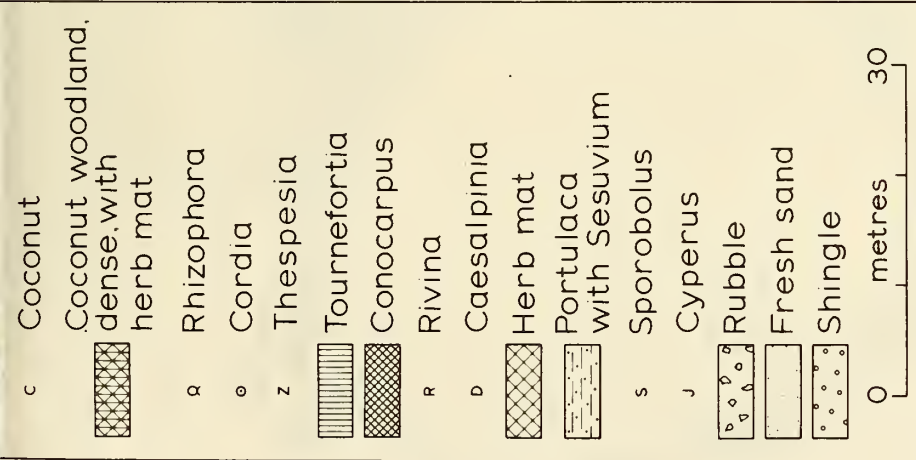


Figure 23. Tom Owen's West Cay 1960 and 1972

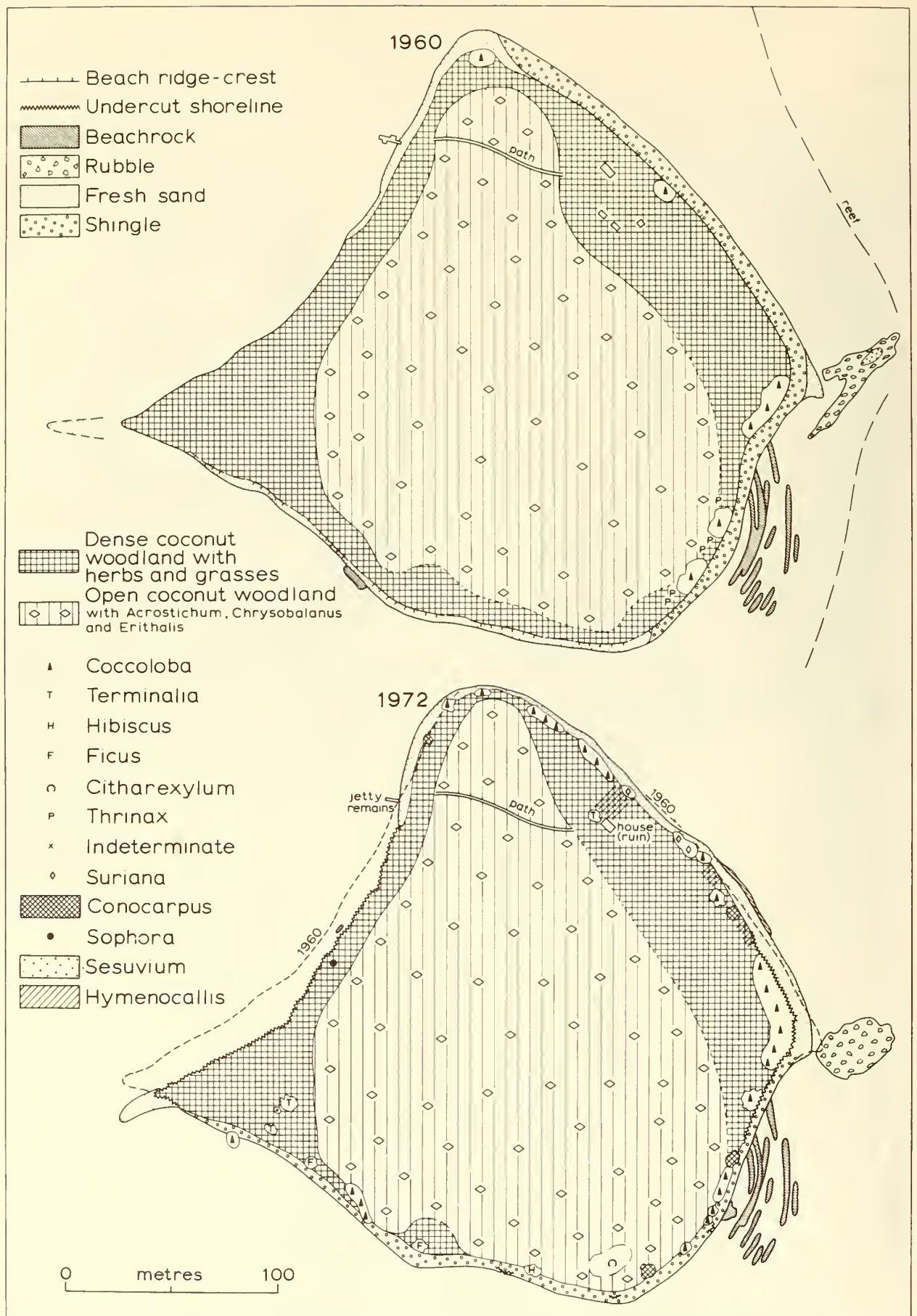


Figure 24. Northeast Sapodilla Cay 1960 and 1972

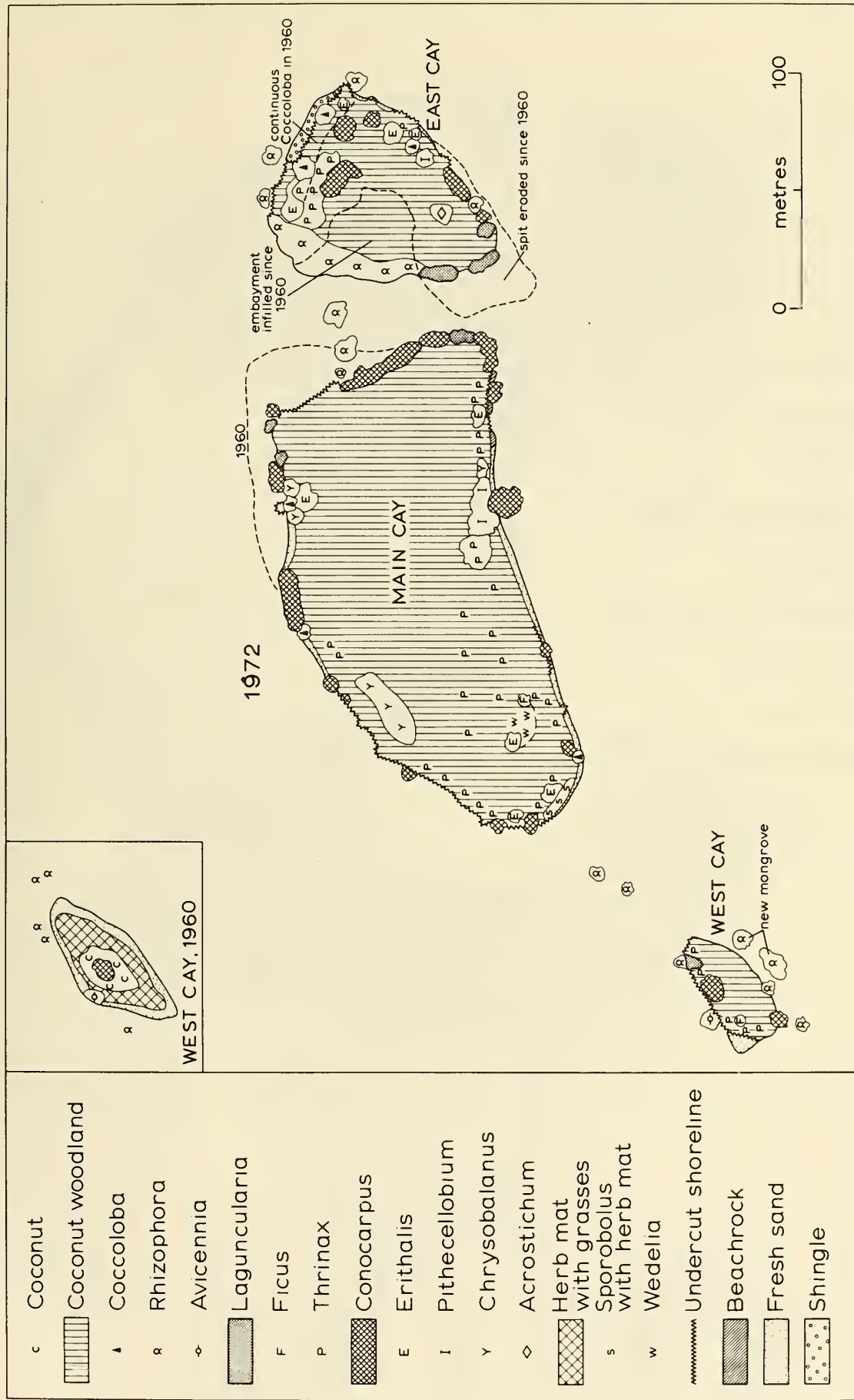


Figure 25. Frank's Cays 1972

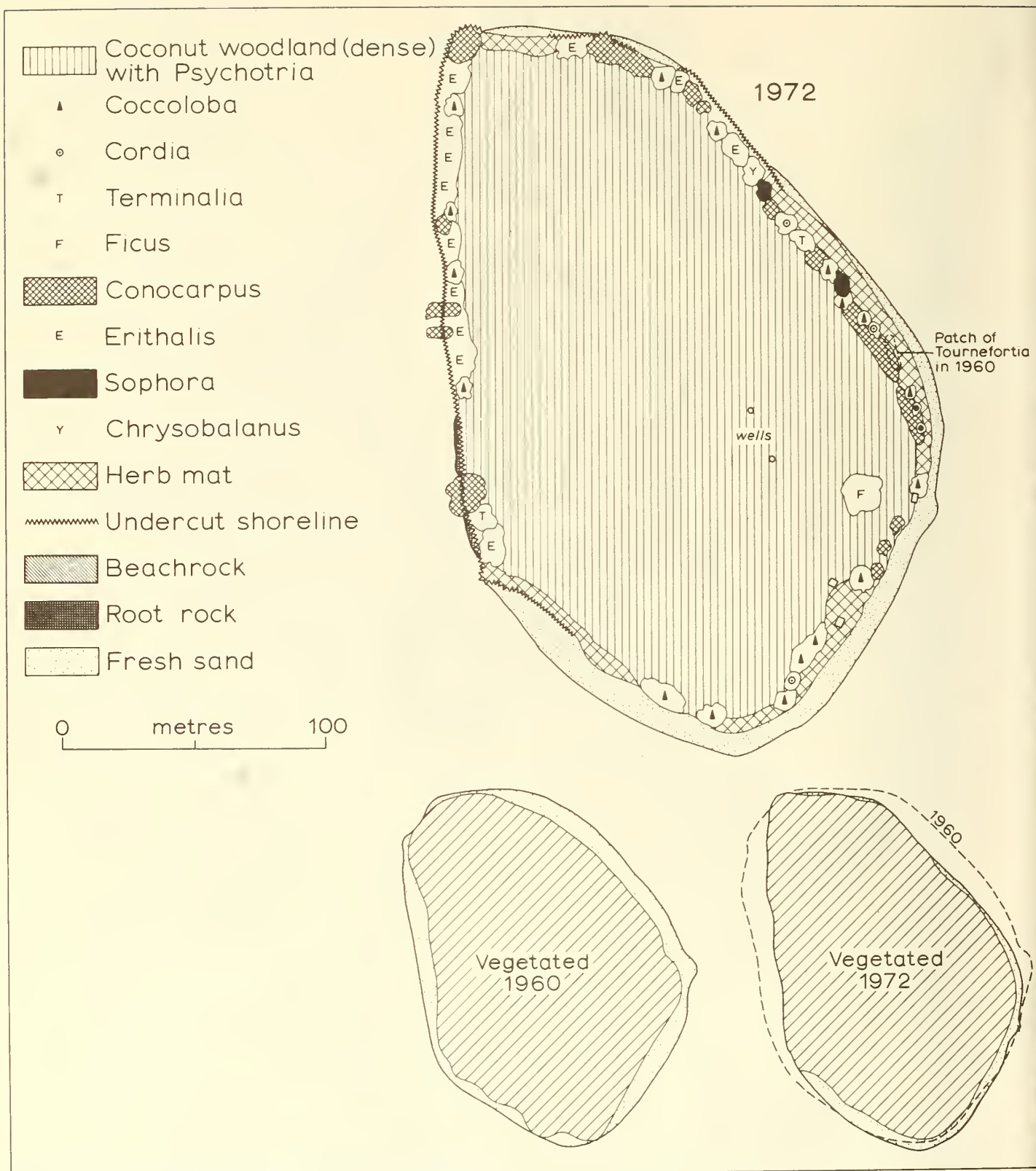


Figure 26. Nicolas Cay 1960 and 1972

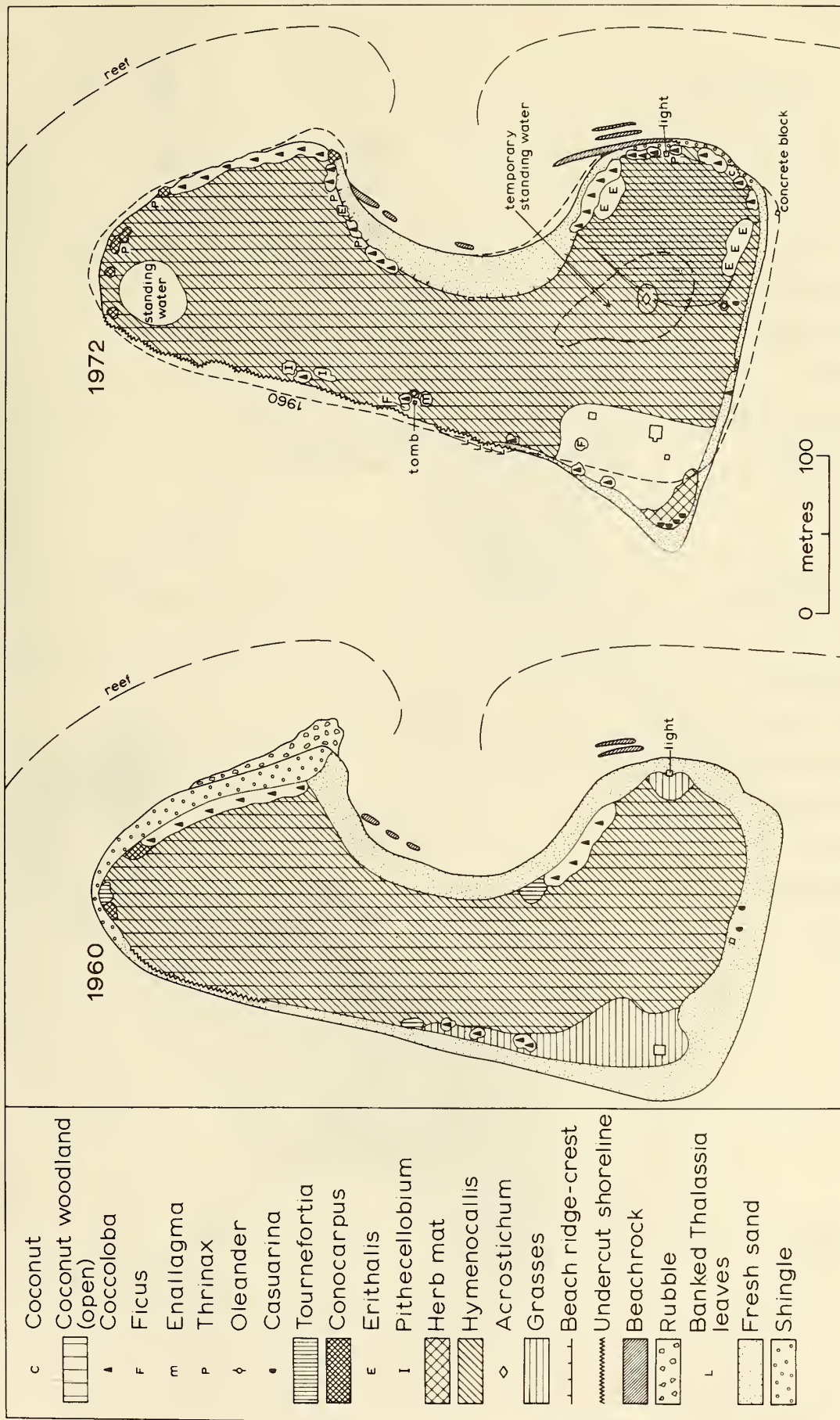


Figure 27. Hunting Cay 1960 and 1972

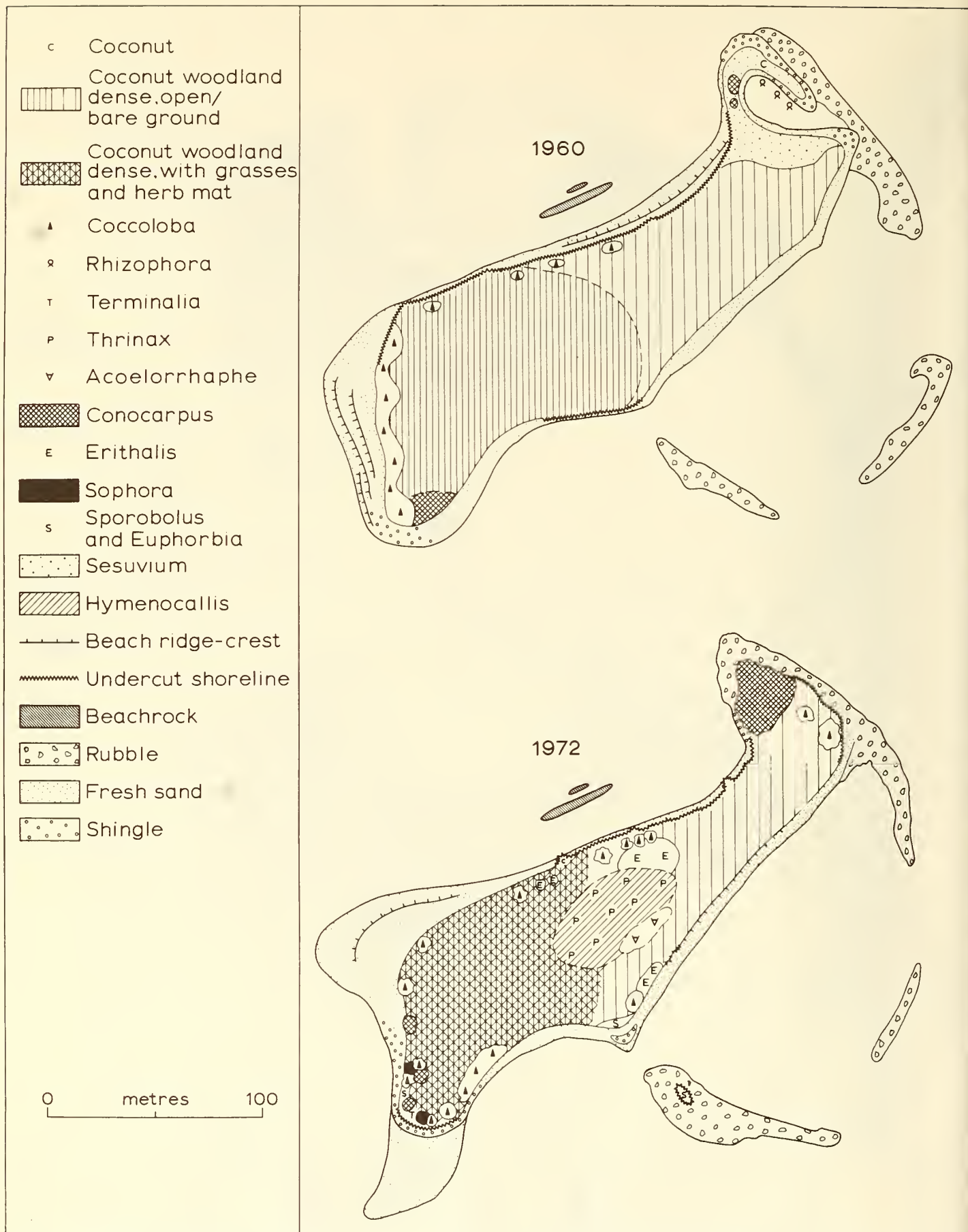


Figure 28. Lime Cay 1960 and 1972

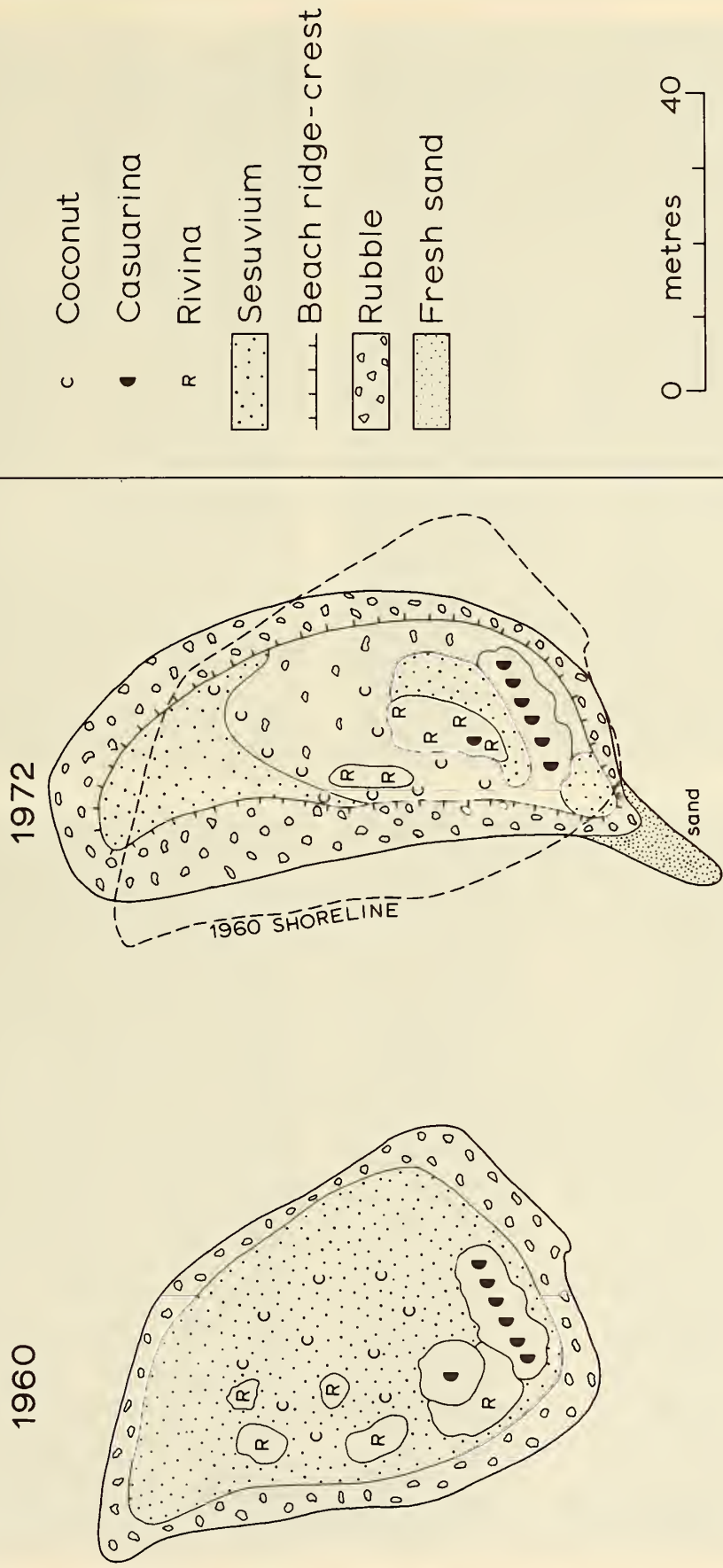


Figure 29. Ragged Cay 1960 and 1972

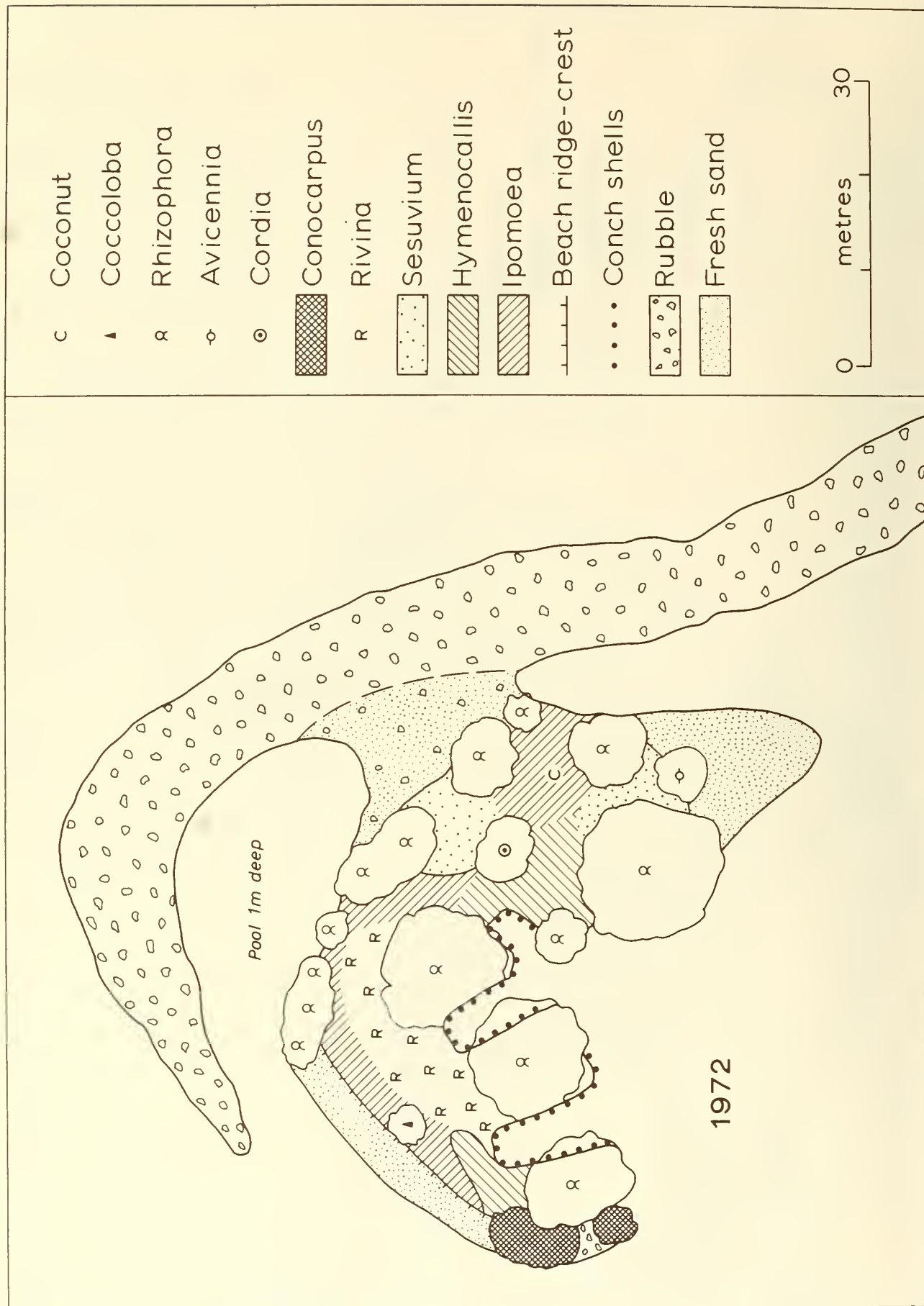
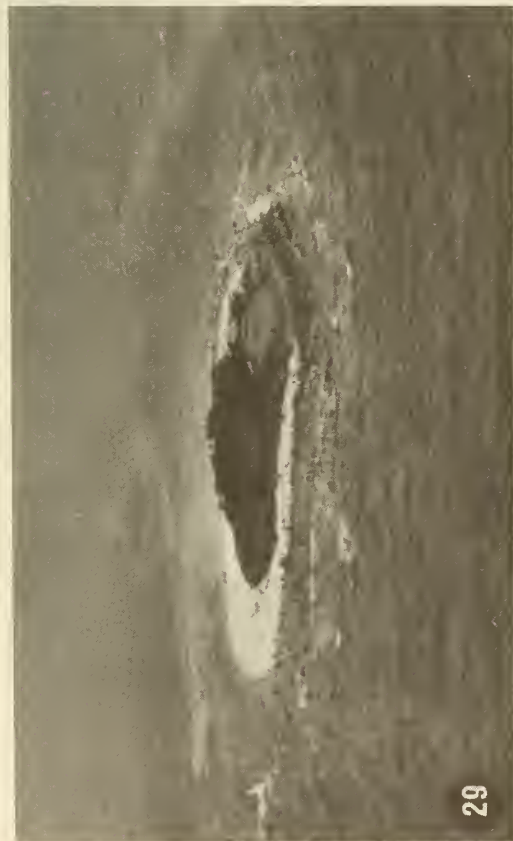
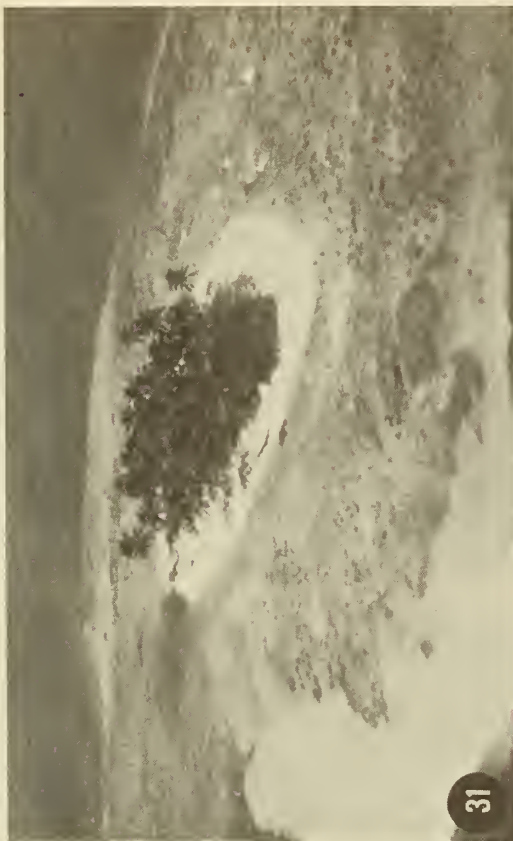


Figure 30. Seal Cay 1972



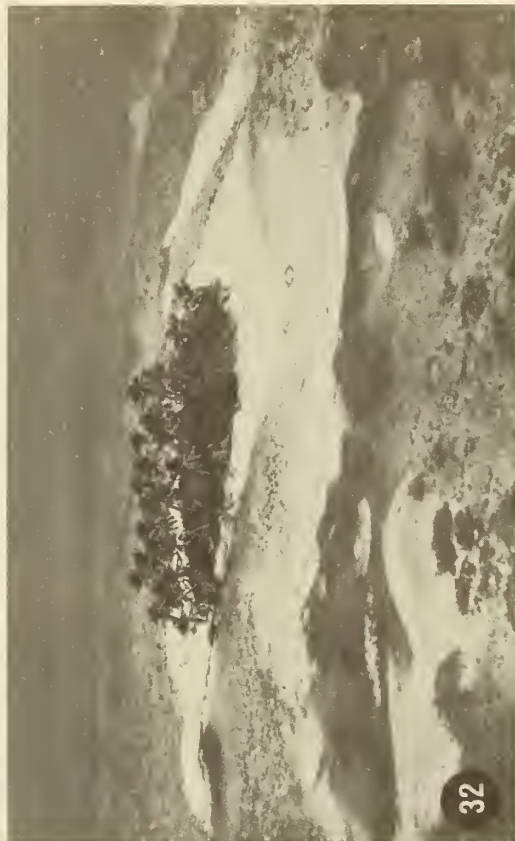
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Plate 29. North Silk Cay: aerial view from the east 1962
 Plate 30. South Silk Cay: aerial view from the south 1962
 Plate 31. Round Cay: aerial view from the southeast 1962
 Plate 32. Pompion Cay: aerial view from the southeast 1962



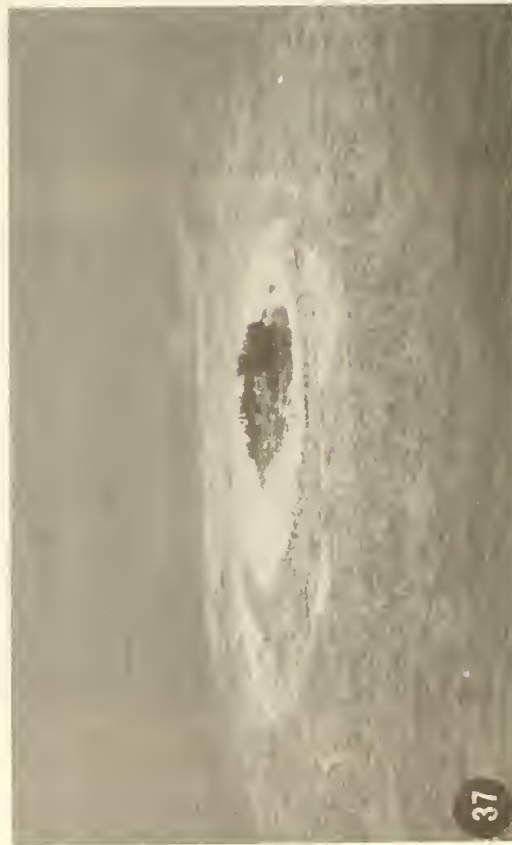
Plate 33. Pool on North Silk Cay 1961
 Plate 34. Middle Silk Cay 1961
 Plate 35. South Silk Cay 1961



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- Plate 36. Ranguana Cay: aerial view from the northeast 1962
 Plate 37. North Spot: aerial view from the southeast 1962
 Plate 38. North Spot from the south 1972
 Plate 39. Tom Owen's Cays: aerial view from the northeast 1961



Plate 40. *Hymenocallis littoralis* under coconuts at Pompion Cay 1972



Plate 41. Ranguana Cay: erosion on the north shore 1972



Plate 42. Ranguana Cay seen from the shingle islet at the west end 1972



Plate 43. Tom Owen's East Cay from the southwest 1972



Plate 44. North Spot 1972



Plate 45. Tom Owen's West Cay: north shore 1972



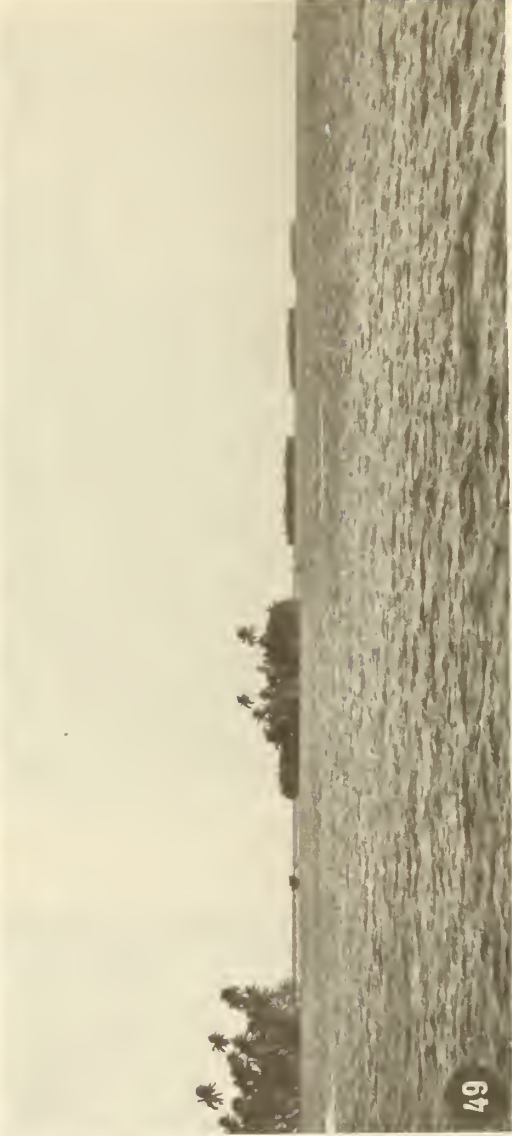
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Plate 46. Tom Owen's Cays from the west 1972
 Plate 47. Tom Owen's East Cay: aerial view from the south 1962
 Plate 48. Tom Owen's West Cay: aerial view from the southwest 1962
 Plate 49. The Sapodilla Cays 1972: left-right Frank's Cay, Frank's Cay West, Nicolas Cay, Hunting Cay, Lime Cay, Ragged Cay



Plate 50. Northeast Sapodilla Cay: aerial view from the east 1962



Plate 51. Nicolas Cay: aerial view from the northeast 1962



Plate 52. Northeast Sapodilla Cay: northeast shingle ridge 1972



Plate 53. Northeast Sapodilla Cay: eroding northwest shore 1972

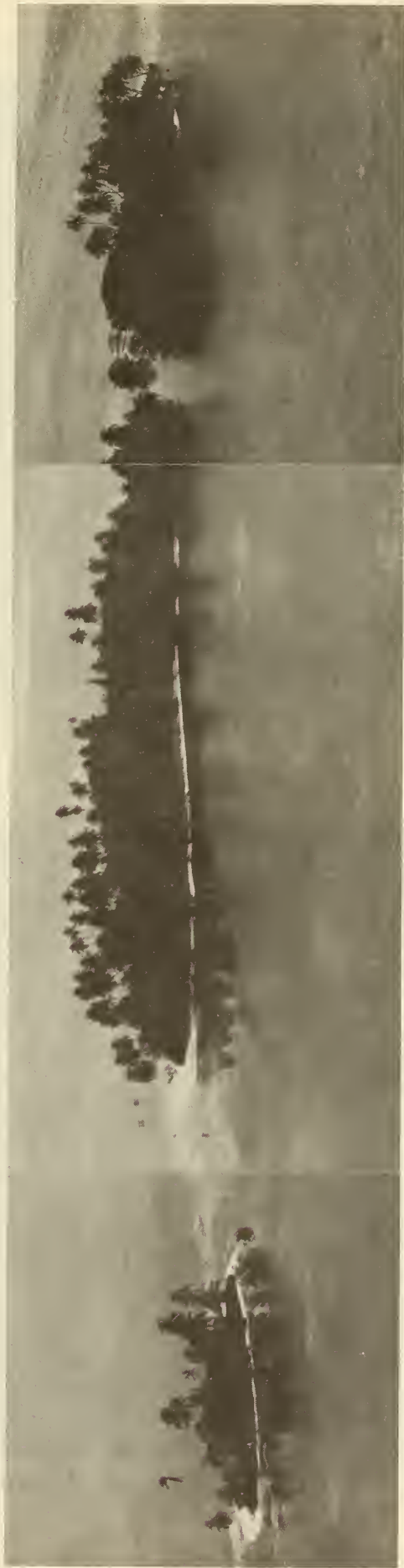


Plate 54. Frank's Cays: aerial view from the south 1961



Plate 55. Hunting Cay: aerial view from the north 1961



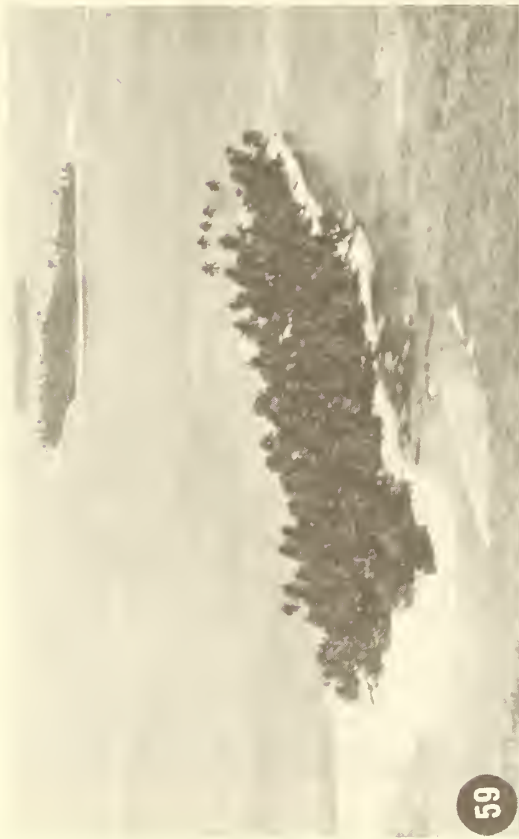
Plate 56. Hunting Cay: aerial view from the southeast 1962



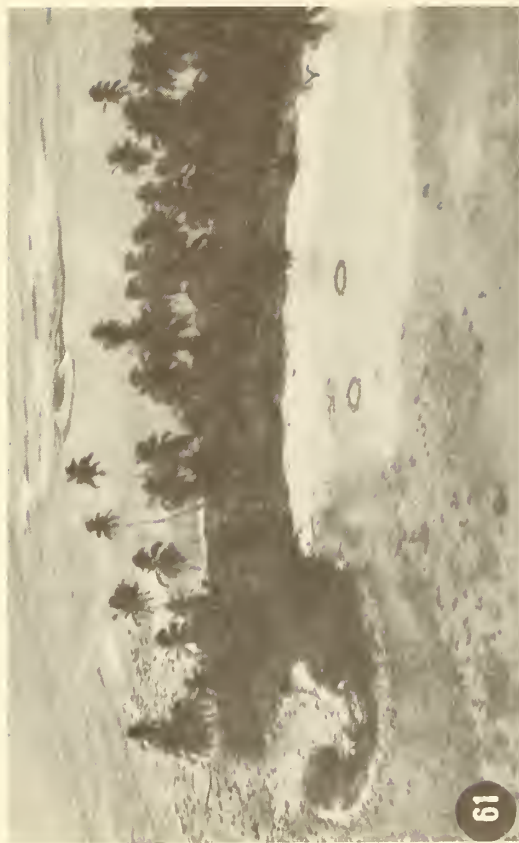
Plate 57. Nicolas Cay: 'rootrock' exposed on the eroding west shore 1972



Plate 58. Hunting Cay east bay from the north 1972



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Plates 59-61. Lime Cay: aerial views in 1962 from the south; of the west end from the north; of the east end from the north
Plate 62. Ragged Cay: aerial view from the south 1962



Plate 63. Ragged Cay from the west 1972

Plate 64. Seal Cay: aerial view of the cay and faro from the east 1962

Plate 65. Seal Cay: east rampart and moat 1972

5. CAYS OF THE BARRIER REEF LAGOON

The barrier reef lagoon contains islands of many different types and widely differing sizes. The great majority are mangrove islands, and these have been very little studied. Others are of more complex form and vegetation, but only a few of these have been studied in the same detail as the barrier reef cays. The lagoon cays fall into several distinct groups, and these are described from north to south.

A. The northern lagoon

North of latitude 17°30'N the coastal shelf has an average width of 24 km, and between Belize and the Bulkhead Reef (which extends as a shallow bar from the mainland to Ambergris Cay) is 2.5-4.5 m deep. The Bulkhead itself carries only 0.5-1.4 m, and encloses the 90 km long Bahia de Chetumal, a shallow embayment with depths of 2-6 m. The cays of the northern lagoon consist mainly of a series of linear mangrove-sand cays (mangrove islands with a sand ridge on their windward sides) and mangrove cays located 3.5-4 km landward of the barrier reef and separated from it by a depression termed the "reef lagoon" by Ebanks (1975, p.238) and less than 4.5 m deep. In the southern part of the area, large mangrove cays (Hicks Cays, Hen and Chickens, Peter's Bluff, North Drowned Cay, the Drowned Cays) extend across the shelf towards the mainland.

Ambergris Cay

This is the largest island of the Belize coastal shelf, extending for 40 km southwards from the largely artificial cut Boca Bacalar Chico which forms the Belize-Mexico boundary. It varies in width from 6.5 km to less than 90 m. Jefferys noted in his 1775 chart that there were "plenty of deer in it and Ambergrease often found on its Beach". Henderson (1811, p.24) described it as "of considerable size, abounding with extensive fresh water lakes, and at most seasons ... plentifully stocked with many kinds of game. This Key is likewise said to produce Logwood, and the more valuable kind of Dye-wood, named Brasileto." Allen (1841, p.80) also stated that the cay was named "from the produce of its shores". It was visited by Stoddart in 1960, 1962 and 1965 and briefly described (1963, pp. 31-33, fig. 16; 1969, pp. 5-6), and by H. Pelzl in 1972. Sediments and geology have been studied in detail by Ebanks (1975) and Tebbutt (1975). Stoddart's vegetation map (1963, fig. 16) may be compared with Ebanks's geological

map (1975, fig. 3): there is a broad correspondence between vegetated supratidal flat of Ebanks and mangrove swamp of Stoddart; between Pleistocene limestone and high and low woodland; and between coconut woodland and windward beach ridge. Ebanks distinguishes four main components to the island:

(a) Windward beach ridge, a linear sand body along the east side of the island, about 3 m thick above bedrock, reaching 1.2-2.4 m above sea level (with a maximum of 6.6 m at San Pedro), and 90-460 m wide. Sediment analyses of 19 samples showed that 90.8% of the sediments on average are of skeletal origin (*Halimeda* 35.5%, molluscs, 18.0%, coralline algae 14.8%, corals 8.6%) (Ebanks 1975, p.247). Most of our floristic information about Ambergris Cay comes from this unit.

(b) Supratidal flats, formed of fine sediments with dolomitic crusts and extreme environmental conditions (mean salinity 76.3‰, range 41.5-123.8‰; maximum water temperature 42°C). This unit is vegetated by *Rhizophora* and *Avicennia* on the flats, with some shelly windward sand ridges carrying a palmetto-salt grass-mangrove assemblage (Ebanks 1975, p.253); these ridges reach 0.3-1.3 m above sea level.

(c) Intra-island lagoons: oval-shaped ponds, often with arcuate and smooth lee shores and irregular windward shores, the bigger ones 1.3-2 m deep, the shoaler areas less than 0.6 m deep, occupying about one-third the total area of the cay (Ebanks 1975, p.265).

(d) Limestone surface. This is of uncertain age: north of Boca Bacalar Chico Butterlin and Bonet (1960a, 1960b) map the limestones in the Xcalak area as belonging to the Carrillo Puerto Formation of Upper Miocene-Pliocene age; Sapper (1896) mapped those on Ambergris Cay as Quaternary; and Flores 1952, p.409) by implication states that they are Miocene to Pliocene. Tebbutt (1975, p.300) believes them to be Pleistocene, and broadly correlative with the Key Largo Limestone of Florida, of Last Interglacial Age. Reef facies in this limestone outcrop at Reef Point on Ambergris Cay in a manner comparable to that of the widespread "ironshore" of other Caribbean localities, but no absolute dates are available. The existence of Last Interglacial reef limestones further north along the Yucatan coast has already been noted (Szabo *et al.* 1978). The deep well drilled by Gulf-Shell at Basil Jones revealed 425 m of Tertiary rocks (post-Eocene) and 1790 m of Lower Cretaceous. The vegetation of the Ambergris limestone area is clearly an extension of that of neighbouring Quintana Roo. Wagner (1964, p.223) simply and misleadingly maps this as Tropical Rain Forest, but from casual observation it is more realistically classed in Beard's (1955; 1949, p.82) categories of Dry Evergreen Woodland, Dry Evergreen Thicket, and Evergreen Bushland (cf. Stoddart 1980, pp. 55-58). This is the view taken by Romney *et al.* (1959, p.28). No collections have been made on the surface limestone on Ambergris Cay and the flora is thus unknown.

The windward sand ridge is vegetated by a coconut woodland with a mainly weedy ground vegetation, and a beach-crest vegetation of shrubs

and pioneer grasses and herbs. On the leeward side the ridge is abutted by mangroves. At the small village of San Pedro there are introduced trees, shrubs and herbs. It is worth noting that the vegetation of Ambergris Cay has been influenced by man since pre-European times (Stoddart 1980, pp. 160-161). It has several Maya sites, two of which were located by Romney et al. (1959, fig. 10) and Hammond (1977, p.48). Several were excavated by Gann (1926, p.59). He found them to be "for the most part kitchen middens, composed of enormous numbers of conch, cockle, whelk and oyster shells, turtle carapaces, crab and crayfish shells, and vast quantities of such fish as inhabit the surrounding waters. Amongst these were numerous potsherds, all of the coarse, red and gray, domestic varieties, broken flint spear-heads in great numbers, with a few broken obsidian knives, and greenstone celts, many stone and pottery net sinkers, and a few broken hand corn mills of Esquipulas stone. There were also found the bones of a few small mammals, including the gibbon and armadillo, but none of deer or wild hog, such as are usually found at most Maya sites on the mainland." Later Gann mentioned "innumerable burial and kitchen-midden mounds along the coast" (1927, p.95).

Only 22 species of plants have been recorded from Ambergris Cay so far; undoubtedly a complete list would be very much larger. Those, recorded are:

<i>Distichlis spicata</i> West (1977)	<i>Terminalia catappa</i> 62S 65S
<i>Sporobolus</i> sp. 62S 65S	<i>Ipomoea macrantha</i> 65S
<i>Cyperus</i> sp. 62S	<i>Ipomoea</i> sp. 65S
* <i>Cocos nucifera</i> 57S 60S 62S 65S	<i>Cordia sebestena</i> 65S
<i>Thrinax radiata</i> 62S	<i>Tournefortia gnaphalodes</i> 65S
<i>Hymenocallis littoralis</i> 65S	<i>Avicennia germinans</i> 60S
<i>Sesuvium portulacastrum</i> 62S	<i>Solanum blodgettii</i> 65C
<i>Sophora tomentosa</i> 65S	<i>Hamelia patens</i> 72C
<i>Suriana maritima</i> 65S	<i>Ambrosia hispida</i> 65S
<i>Euphorbia</i> sp. 65S	<i>Borreria arborescens</i> 65C
<i>Rhizophora mangle</i> 60S	<i>Flaveria linearis</i> 65C
<i>Bucida spinosa</i> 72C	

Mangrove cays in the lee of Ambergris Cay (Deer Cay, Swab Cay, Blackadore Cay, Mosquito Cay) have only been observed from the air. There are small mangrove islands at the southern tip of Ambergris Cay, and also Cay Cangrejo (17°50½'N, 88°03'W), a mangrove island.

Cay Caulker

Cay Caulker (the Cay Corker of Jefferys (1775) and Owen (1830)) is a large mangrove-sand cay 8 km south of Ambergris Cay and 1.5-2.4 km from the edge of the coastal shelf. It has been described briefly by Vermeer (1959, pp. 55-58), Stoddart (1963, pp. 33-35, fig. 17) and Stoddart (1969, p.6). It is 7.2 km long and 60 m to 1.2 km wide. Its windward side is formed by a sand ridge generally less than 1 m

high, but rising at the village site to over 2 m. In places there are clumps of mangroves on the seaward side of the ridge. On the western side there are extensive mangroves, with in places a low leeward sand ridge. Palm thicket occupies the interior areas not cleared for coconut woodland. During Hurricane Hattie there was much marginal erosion and surface sand-stripping and scouring on the seaward side of the windward sand ridge. Some coconuts and other trees were felled near the seaward shore, and exposed mangroves were defoliated. But in general, away from the cleared area of the village, physiographic effects were negligible and vegetation damage moderate. 34 species of plants have been recorded (30 of them in 1965), and this is undoubtedly a partial list. They are:

<i>Eragrostis prolifera</i> 65C	<i>Hibiscus tiliaceus</i> 65C
<i>Eustachys petraea</i> 65C	<i>Sida acuta</i> 65C
<i>Cyperus ligularis</i> 65C	<i>Turnera ulmifolia</i> 65C
<i>Fimbristylis cymosa</i> 65C	<i>Rhizophora mangle</i> 60S
* <i>Cocos nucifera</i> 57S 60S 61S	<i>Bucida spinosa</i> 65C
62S 65S	* <i>Terminalia catappa</i> 61S 65S
* <i>Musa paradisiaca</i> 57S	* <i>Catharanthus roseus</i> 65C
* <i>Casuarina equisetifolia</i> 62S 65C	<i>Ipomoea</i> sp. 62S
<i>Coccoloba uvifera</i> 62S 65C	<i>Cordia sebestena</i> 65C
<i>Philoxerus vermicularis</i> 65C	<i>Tournefortia gnaphalodes</i> 65C
<i>Crotalaria verrucosa</i> 65C	<i>Lantana involucrata</i> 65C
<i>Pithecellobium keyense</i> 65C	<i>Stachytarpheta mutabilis</i> 65C
<i>Vigna luteola</i> 65C	<i>Solanum blodgettii</i> 65C
<i>Suriana maritima</i> 65C	<i>Ernodea littoralis</i> 65C
<i>Euphorbia blodgettii</i> 65C	<i>Spermacoce suaveolens</i> 65C
<i>Euphorbia mesembrianthemifolia</i>	<i>Ageratum littorale</i> 65C
65C	<i>Borrchia arborescens</i> 65C
* <i>Mangifera indica</i> 57S 60S	<i>Wedelia trilobata</i> 65C

Cay Chapel (17°41'N, 88°02'W)

Cay Chapel lies 1.6 km south of Cay Caulker and 2.5 km from the shelf edge. It is 3.6 km long and up to 460 m wide, and built of parallel sand ridges rising to 2 m above sea level. The leeward mangrove is not well developed, and most of the sand ridges are covered by coconut woodland: mechanical clearing has destroyed not only the original vegetation but also the surface topography. This clearing has taken place since 1775 when Jefferys noted a single "large cocoa tree"; the greater part, however, took place in 1960-61. During Hurricane Hattie it is said that some 60% of the coconuts were felled, and there was much marginal erosion and surface sand stripping. For details see Stoddart (1963, pp. 35-36, fig. 17). By 1965 the windward shore had been extensively colonised by *Conocarpus*, *Borrchia*, *Suriana* and *Tournefortia*, with herbs and grasses beneath the coconut woodland. For an account of recovery from Hurricane Hattie see Stoddart (1969, pp. 6-7). Eighteen species of plants have been recorded, and many more must be present. The list is:

<i>Cenchrus incertus</i> 62S 65S	<i>Euphorbia</i> sp. 62S 65S
<i>Cyperus</i> sp. 62S	<i>Rhizophora mangle</i> 62S 65S
* <i>Cocos nucifera</i> 1775S 62S 65S	<i>Conocarpus erectus</i> 65S
<i>Thrinax radiata</i> 62S	<i>Merremia dissecta</i> 65C
<i>Coccoloba uvifera</i> 62S 65S	<i>Tournefortia gnaphalodes</i> 62C 65S
<i>Rivina humilis</i> 65C	<i>Ernodea littoralis</i> 65S
<i>Cassytha filiformis</i> 65S	<i>Ageratum</i> sp. 65S
<i>Cakile lanceolata</i> 65S	<i>Conyza canadensis</i> 65S
<i>Suriana maritima</i> 62S 65S	<i>Wedelia trilobata</i> 65C

Craig (1966, p.21) describes a mound faced with shaped stone blocks, with broken pottery and conch shells, on this island.

St. George's Cay (17°33½'N, 88°04'W)

Plates 66-68

St. George's Cay is an arcuate mangrove-sand cay standing 2.5 km from the shelf edge. The western part is about 1.6 km long and 90-180 m wide, and consists entirely of mangrove. At the northeast end is a low sandy ridge 1.2 km long and 40-90 m wide, with some mangrove on its lee side. The sandy area was cleared and settled at the end of the eighteenth century and was entirely devoted to residential use at the time of Hurricane Hattie. It was overtopped by the storm surge during the hurricane and five channels were cut through the ridge. Most coconuts were felled and mangroves defoliated, though ground vegetation survived in patches. By 1965 two of the scoured channels had been blocked, some of the mangrove was still living, and there was a luxuriant growth of herbs and grasses. Detailed accounts of the island before and immediately after Hurricane Hattie, and in 1965, are given by Stoddart (1963, pp. 37-40, figs. 18 and 19; 1969, pp. 7-8, fig. 3). Romney et al. (1959, fig. 10) describe the cay as a shell midden site. 30 plant species are recorded (16 during the earlier surveys and 21 by Spellman in 1972). They are:

<i>Eustachys petraea</i> 72C	<i>Conocarpus erectus</i> 65S 72C
<i>Paspalum</i> sp. 62S	<i>Eustoma exaltatum</i> 72C
<i>Sporobolus</i> sp. 65S	<i>Echites umbellata</i> 72C
<i>Cyperus</i> sp. 62S 65S	<i>Ipomoea pes-caprae</i> 62S
* <i>Cocos nucifera</i> 60S 62S 65S 72S	<i>Ipomoea stolonifera</i> 72C
<i>Hymenocallis littoralis</i> 62S 65S	<i>Ipomoea</i> sp. 65S
<i>Coccoloba uvifera</i> 62S 65S	<i>Cordia sebestena</i> 72C
<i>Batis maritima</i> 65S 72C	<i>Tournefortia gnaphalodes</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Stachytarpheta jamaicensis</i> 65S
<i>Portulaca oleracea</i> 72C	72C
<i>Sesuvium portulacastrum</i> 60S	<i>Erithalis fruticosa</i> 72C
65S 72C	<i>Ernodea littoralis</i> 72C
<i>Cakile lanceolata</i> 62S	<i>Spermacoce verticillata</i> 72C
<i>Canavalia rosea</i> 72C	<i>Ageratum</i> sp. 62S 65S
<i>Euphorbia mesembrianthemifolia</i>	<i>Melanthera nivea</i> 72C
72C	<i>Synedrella nodiflora</i> 72C
<i>Euphorbia</i> sp. 62S 65S	<i>Wedelia trilobata</i> 62S 65S 72C
<i>Rhizophora mangle</i> 62S 65S	

Cays between Cay Chapel and Belize

There are numerous large mangrove islands on the coastal shelf between 17°30'N and 17°45'N. They include Long Cay (the northernmost of that name), Hicks Cays, Montego and Frenchman's Cays, Hen and Chicken Cays, Rider's Cays, and the northernmost Drowned Cays. Apart from a narrow seaward sand ridge with coconut woodland on Long Cay and on the Drowned Cays north of Gallows Point, these islands consist wholly of mangrove. Thus the Hicks Cays consist of a dozen islands, four of them large, separated by deep meandering channels through which tidal currents set with great rapidity. The Drowned Cays too are intersected by a number of east-west tidal channels or 'bogues', namely Shag Cay Bogue, Bannister Bogue, Farls Bogue and Goring Bogue, most of which carry 5-7.5 m of water. For further details on these islands, none of which have been studied in detail, see Vermeer (1959, pp. 58-59) and Stoddart (1963, pp. 36-37).

Moho Cay (17°31½'N, 88°12'W)

Moho Cay is a small island immediately north of the Belize delta. Gann (1925, p.19) mentions "innumerable flint spear-heads ... with thousands of circular pottery rings, probably used as net sinkers." He suggested that the island had been used as a Maya fishing station: "Many tons of manatee bones have been washed out from the northern end of the cay." Craig (1966, p.20) found habitation sites exposed by wave erosion for 125 m along the shore, with "numerous pottery sherds, abundant chert cores, flakes, and stone artifacts, including jadeite celts, and large (25 cm) fine-wrought projectile points." In addition to manatee bones, Craig also found oyster and conch shells, and two human burial sites. The island was not visited during our own surveys.

Stake Bank (17°28'N, 88°07½'W)

This is a mangrove island approximately 400 m long and 120 m wide, standing on a shoal area 2.3 km long and 1.4 km wide. There is a widespread tradition that the shoal was built with ballast deposited by ships in the harbour (Anderson 1958, p.95), though this could only account for a small part of the shoal volume. In the survey of Belize harbour by Anthony de Mayne in 1828 the Bank had only one or two mangrove seedlings. The bank was described as "dry in some parts" by Speer in 1765, and was marked by Jefferys in 1775.

Spanish Lookout Cay (17°24'N, 88°04'W)

This very small island at the southern end of the Drowned Cays was visited briefly in 1965. It is largely artificial, built of conch shells collected by fishermen, and surrounded by a coral block wall. It has no natural vegetation.

Water Cay (17°23'N, 88°03½'W)

This large mangrove island is immediately south of the Drowned Cays; it has a sand ridge along its windward side. J. Dwyer collected *Euphorbia mesembrianthemifolia*, *Lantana involucrata* and *Conocarpus erectus* there in 1967. It was not visited by us.

B. The Southern Triangles

Though this name no longer appears on charts it is convenient to use it for the groups of islands at the inner end of the Belize Deepwater Channel: it was used on the charts of Speer (1765, 1771) and Jefferys (1775) and also in the Anglo-Spanish Treaties of 1753 and 1783. Altogether there are some two dozen islands standing on the flat tops of steep-sided shoals. On the north side of the channel Robinson Point and Robinson Island both have dry-land vegetation in addition to mangroves, but the other islands (Grennels Cay, Ramseys Cay, One Man Cay) are entirely of mangrove. On the south side Spanish Cay is a sand cay and the others (Long, Crayfish, Simmonds and other unnamed cays) are mangrove.

Robinson Point Cay (17°22'N, 88°11½'W)

This island, totalling about 29 ha, has the largest dry land area in the Southern Triangles. It is described by Vermeer (1959, pp. 75-79, fig. 16) and Stoddart (1963, pp. 46-47, fig. 26). There is a low narrow sand ridge along the east and southwest sides of the cay; it is nowhere more than 50 m wide and about 900 m long. Before Hurricane Hattie it was covered with a dense thicket of coconuts, *Thrinax* and other strand species, except at the small settlement near the light-house, built at the western point in 1939. During the storm most of the dry-land vegetation was destroyed and the mangroves defoliated, and in 1962 the island had been abandoned by its inhabitants. The following plant species were noted in 1961 before the storm:

<i>Cyperus</i> sp. 61S	<i>Hymenocallis littoralis</i> 61S
* <i>Cocos nucifera</i> 57S 61S	<i>Coccoloba uvifera</i> 61S
<i>Thrinax radiata</i> 61S	<i>Suriana maritima</i> 61S

<i>Euphorbia</i> sp. 61S	<i>Cordia sebestena</i> 61S
<i>Rhizophora mangle</i> 61S	<i>Avicennia germinans</i> 61S
<i>Conocarpus erectus</i> 61S	<i>Stachytarpheta jamaicensis</i> 61S

Robinson Island (17°22½'N, 88°10½'W)

There is a less well-developed sand ridge along the south side of Robinson Island. The palm thicket here was badly damaged during Hurricane Hattie, and the mangroves defoliated (Stoddart 1963, p.47). Only two species were noted in passing in 1961:

* <i>Cocos nucifera</i> 61S	<i>Rhizophora mangle</i> 61S
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Spanish Cay (17°21'N, 88°09½'W)

Spanish Cay when mapped in 1961 was a low-lying sandy island 100 m long and 10-18 m wide. The southern end of the cay was fringed with *Rhizophora*, and there were several tall *Avicennia* trees. It appeared that mangroves had previously been more extensive but had been cleared. There were several coconuts and a ground cover of sedges, grasses and ornamental plants. Much of the vegetation disappeared during Hurricane Hattie; the island has not been revisited since (see Stoddart 1963, p.47, fig. 27). Its total area in 1961 was 1260 sq m. The following plant species were recorded, but the list is certainly partial:

* <i>Cocos nucifera</i> 61S 62S	<i>Conocarpus erectus</i> 61S 62S
<i>Euphorbia</i> sp. 61S	<i>Avicennia germinans</i> 61S 62S
<i>Rhizophora mangle</i> 61S 62S	

C. Cays of the Central Lagoon

For 60 km southwards from the Southern Triangles to the latitude of South Water Cay the coastal shelf has an extremely simple topography. The floor shelves gradually eastwards from the mainland coast to depths of 20-24 m, and the shelf is edged by a barrier platform 5-8 km wide and 4-6 m deep. There are no patch reefs or cays within the lagoon. Near the inner edge of the barrier platform there is a series of linear mangrove islands, aligned north-south, and generally about 1.8 km from the lagoon edge and 3.4 km from the seaward edge of the platform. These islands include Middle Long Cay, Bluefield Range, Alligator Cay and Colson Cays. Others, such as Southern Long Cay, Columbus Cay and Cross Cay, are less regular islands closer to the seaward margin of the platform. All are mangrove islands; none has been investigated in detail. The linear islands occupy the same relative position as do the mangrove-sand cays of the northern barrier reef (Cay Caulker, Cay

Chapel), but they lack the windward sand ridge and strand flora. South of 17°N the mangrove islands near the inner edge of the barrier platform become more complex. Instead of simple linear cays they are complexes of smaller mangrove islands, often arranged in an ellipse, and known as "ranges". These include Fly Range, Tobacco Range, South Water Range and Blue Ground Range. Some of these have been visited and will be described below. For further brief notes on this sector of the reef, see Vermeer (1959, pp. 59-71 and 79) and Stoddart (1963, pp. 51-52).

South of South Water Cay the barrier reef swings southeastwards in a broad continuous arc to Gladden Spit and then turns sharply southwestwards. There are no sand cays on the southeast-trending sector, and only small patch reefs with small cays (already described) to the south of it. At Gladden Spit the coastal shelf reaches its maximum width of nearly 40 km, and the greatest lagoon depths reach 35 m. The barrier platform on the edge of the shelf becomes narrower and less regular in this sector, and lacks mangrove islands. Within the lagoon the topography is extremely intricate, with either long arcuate ridges or elongate elliptical ring-like structures with deep central depressions, the largest being up to 13 km long. These ridges rise to within 5 m of the surface; they are interrupted by deep gaps; and their upper surfaces are often pitted with deep holes; active coral reefs reaching the surface are comparatively rare. The inference from morphology that these structures resulted from karst erosion of older reef limestones (Stoddart 1963, p.60) has been amply confirmed by Purdy (1974a, 1974b), who terms them "shelf atolls". This intricate topography provides a wide range of substrates and exposure conditions for island development: all types of island from true sand cay to mangrove island are found.

The islands of this central lagoon area are described from north to south, beginning with the Ranges of the northern area.

Tobacco Range (16°53'N, 88°05'W)

Plates 69-70

Tobacco Range is an elliptical array of mangrove islands with a shallow central lagoon, standing near the middle of the barrier platform at Tobacco Entrance; it is roughly 4.8 km long north-south and 1.8 km wide. The largest northeastern island was visited in 1972 at its northern and southern ends. At its northern end there is a seaward sand ridge 0.6 m high and 18 m wide; a zone 60 m wide of low boggy ground with coconuts and no other ground vegetation; and a zone 90 m wide of *Batis maritima*, open pools, and standing dead mangrove trunks. These are 4-4.5 m tall and date from Hurricane Hattie's effects in 1961. The mangrove zone in the lee is low and presumably regenerated since that time. Beach shrubs include *Tournefortia*, *Sophora*, *Suriana*, *Borrchia* and *Laguncularia*, with some *Rhizophora* on the seaward shore. The ground cover includes *Spartina*, *Ageratum*, *Cyperus* and *Euphorbia*, with carpets of *Sesuvium*. *Pithecellobium* takes

the place of *Conocarpus*, and *Pluchea symphytifolia* and *Echites umbellata* are also unusual additions to the flora. Both north and south from the point of survey the coconut zone narrows until it is only 2 m wide, separating the *Batis* zone from coastal *Sesuvium*. At the southern end of the island the seaward sand ridge is 20 m wide, with *Rhizophora* and *Avicennia* clumps on its seaward side. Inland there is a zone of mangroves 20-30 m wide and then open standing water. The sand ridge itself supports a dense scrub of *Thrinax*, *Conocarpus* and coconuts, with *Cyperus*, *Batis*, *Spartina*, *Sesuvium* and *Borrchia*. Coconut boles 3-4 m offshore and outcropping lightly-cemented root rock on the shore indicate beach retreat. At both of the sites visited the effects of Hurricane Hattie are still very apparent. Before the storm tall mangrove presumably extended to the beach ridge. The death of a zone of mangrove up to 100 m wide, indicated by the standing dead trees, has allowed colonisation by *Batis maritima*, and because of the high level of the substrate, apparently rarely flooded, there is no opportunity for recolonisation by mangroves. One might expect colonisation in due course by sedges, grasses, and shrubs such as *Conocarpus* and *Pithecellobium*.

Thirty species of plants were recorded in 1972:

<i>Eragrostis prolifera</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Eustachys petraea</i> 72C	
<i>Paspalum distichum</i> 72C	<i>Passiflora suberosa</i> 72C
<i>Phragmites</i> cf. <i>australis</i> 72C	<i>Rhizophora mangle</i> 72C
<i>Spartina spartinae</i> 72C	<i>Conocarpus erectus</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Laguncularia racemosa</i> 72C
* <i>Cocos nucifera</i> 72S	<i>Bumelia retusa</i> 72C
<i>Thrinax radiata</i> 72C	<i>Echites umbellata</i> 72C
<i>Crinum amabile</i> 72C	<i>Tournefortia gnaphalodes</i> 72C
<i>Batis maritima</i> 72C	<i>Avicennia germinans</i> 72C
<i>Salicornia perennis</i> 72C	<i>Erithalis fruticosa</i> 72C
<i>Sesuvium portulacastrum</i> 72C	<i>Ernodea littoralis</i> 72C
<i>Pithecellobium keyense</i> 72C	<i>Ageratum littorale</i> 72C
<i>Sophora tomentosa</i> 72C	<i>Borrchia arborescens</i> 72C
<i>Suriana maritima</i> 72C	<i>Pluchea symphytifolia</i> 72C
<i>Euphorbia blodgettii</i> 72C	

Coco Plum Cay (16°53'N, 88°07'W)

Coco Plum Cay is a linear mangrove island near the inner edge of the barrier platform, immediately west of Tobacco Range. Like Tobacco Range it has a low beach-ridge area with similar vegetation. Seventeen plant species are recorded:

<i>Paspalum distichum</i> 72C	<i>Fimbristylis spadicea</i> 72C
<i>Spartina spartinae</i> 72C	<i>Thrinax radiata</i> 72C
<i>Sporobolus virginicus</i> 72C	<i>Batis maritima</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Suriana maritima</i> 72C

<i>Euphorbia mesembrianthemifolia</i> 72C	<i>Tournefortia gnaphalodes</i> 72C
<i>Rhizophora mangle</i> 72C	<i>Avicennia germinans</i> 72C
<i>Conocarpus erectus</i> 72C	<i>Erithalis fruticosa</i> 72C
<i>Laguncularia racemosa</i> 72C	<i>Pluchea symphytifolia</i> 72C
	<i>Wedelia trilobata</i> 72C

Phillips Petroleum drilled a hole 91.5 m deep through Coco Plum Cay; the sub-Holocene unconformity was reached at 9.2 m depth (Purdy 1974b, pp. 841, 853).

Man-o'-War Cay (16°52½'N, 88°07'W)

This island, one of several of the same name on this coast (e.g. at 16°39'N, 88°12'W) lies at the southern end of Coco Plum Cay. It is a small mangrove island, with *spartina* and succulents. Six plant species are recorded:

<i>Spartina spartinae</i> 72C	<i>Rhizophora mangle</i> 72C
<i>Batis maritima</i> 72C	<i>Laguncularia racemosa</i> 72C
<i>Sesuvium portulacastrum</i> 72C	<i>Avicennia germinans</i> 72C

Water Range (16°50'N, 88°06'W)

This is the group of mangrove islands (the Twin Cays of charts and Figure 1) 2.2 km northwest of South Water Cay. There is a small sand patch measuring 100 x 18 m at the south end on the seaward side, and another of shell sand on the lee side. Both support a scrub of *Thrinax*, *Conocarpus*, *Laguncularia*, *Suriana*, *Erithalis* and *Borrchia*, with grasses, sedges and succulents. On their inner sides they pass into *Rhizophora* swamp through *Laguncularia* and *Avicennia*. Twenty plant species are recorded:

<i>Eustachys petraea</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Paspalum distichum</i> 72C	
<i>Sporobolus virginicus</i> 72C	<i>Rhizophora mangle</i> 72C
<i>Cladium jamaicense</i> 72C	<i>Conocarpus erectus</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Laguncularia racemosa</i> 72C
* <i>Cocos nucifera</i> 72S (juvenile)	<i>Avicennia germinans</i> 72C
<i>Thrinax radiata</i> 72C	<i>Erithalis fruticosa</i> 72C
* <i>Casuarina equisetifolia</i> 72C	<i>Ageratum littorale</i> 72C
<i>Batis maritima</i> 72C	<i>Borrchia arborescens</i> 72C
<i>Salicornia perennis</i> 72C	<i>Wedelia trilobata</i> 72C
<i>Suriana maritima</i> 72C	

Weewee Cay (16°46'N, 88°08½'W)

Weewee Cay stands on an isolated patch reef 6.5 km southwest of South Water Cay. It is a small triangular island with sides 90-140 m long, surrounded by dense *Rhizophora*, with a low-lying central sandy area about 70 m in diameter. The dry-land vegetation is limited to coconuts with an undercover of grasses and sedges. It is used as a fishing station. Hurricane Hattie in 1961 killed some *Rhizophora* at the south end and felled many coconuts; the island has not been visited since 1962. For a brief account of it at that time see Stoddart (1963, p.61). Six species of plants are recorded:

<i>Eustachys petraea</i> 62C	* <i>Cocos nucifera</i> 62S
<i>Cyperus peruvianus</i> 62C	<i>Batis maritima</i> 62C
<i>Fimbristylis cymosa</i> 62C	<i>Rhizophora mangle</i> 62S

Cat Cay (16°40'N, 88°12'W)

This is one of the small constituent islands of the Pelican Cays, the northernmost shelf atoll of the central lagoon. It was visited in 1962 (Stoddart 1963, p.62). It has a narrow fringe of *Rhizophora* on its north and east shores and much of the west shore. The centre of the island is low-lying and sandy, with a woodland of coconuts, *Thrinax* and *Thespesia*. Ospreys were nesting here in 1962. Eight plant species are recorded:

<i>Cyperus</i> sp. 62S	<i>Thespesia populnea</i> 62C
* <i>Cocos nucifera</i> 62S	<i>Conocarpus erectus</i> 62S
<i>Thrinax radiata</i> 62S	<i>Avicennia germinans</i> 62S
<i>Euphorbia</i> sp. 62S	<i>Wedelia trilobata</i> 62S

Lagoon Cays between Stewart Cay (16°46'N, 88°10'W) and Baker's Rendezvous (16°34'N, 88°12'W)

These are briefly noted by Stoddart (1963, pp. 61-62). They are mainly mangrove islands and have not been studied in detail. Peter Douglas Cay (16°43'N, 88°10'W) and the adjacent Little Peter Cay both have an area of palm thicket with *Sophora tomentosa*. There are coconuts on Peter Douglas Cay and Baker's Rendezvous.

Jack's Cay (16°33'N, 88°04'W)

Jack's Cay is a mangrove island on an isolated reef patch in the lee of the Gladden Spit reef, 5.5 km from the reef edge. It is dominated by mature *Rhizophora* trees. Seven plant species are recorded:

Sporobolus virginicus 72C
Brassavola nodosa 72C
Batis maritima 72C
Sesuvium portulacastrum 72C

Rhizophoramangle 72C
Laguncularia racemosa 72C
Avicennia germinans 72C

Buttonwood Cay (16°32½'N, 88°03'W)

Figure 31

Buttonwood Cay lies 1 km southeast of Jack's Cay. It was mapped in 1961 (Stoddart 1963, p.64, fig. 39) and again in 1972. It is surrounded on its eastern side by *Rhizophora*, with a low-lying central sand area measuring 95 x 75 m. The sand area is covered with a coconut woodland with a ground cover of grasses and herbs; there is a discontinuous fringe of *Conocarpus*, *Laguncularia* and *Coccoloba* between the coconut woodland and the *Rhizophora*. The island was mapped in 1961 before both Hurricane Anna and Hurricane Hattie: the northeastern mangrove area has since decreased in area, and the sand area has accreted to leeward. The island is a fishing station with accumulations of conch shells along the shores. Its area in 1972 was 0.72 ha. 26 species of plants have been recorded:

<i>Andropogon glomeratus</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Eragrostis prolifera</i> 61C 72C	<i>Euphorbia</i> sp. 61S
<i>Eustachys petraea</i> 61C 72C	<i>Hibiscus tiliaceus</i> 72C
<i>Spartina spartinae</i> 72C	<i>Rhizophora mangle</i> 61S 72C
<i>Cyperus ligularis</i> 61C 72C	<i>Conocarpus erectus</i> 61S 72C
<i>Cyperus planifolius</i> 72C	<i>Laguncularia racemosa</i> 72C
<i>Fimbristylis cymosa</i> 72C	<i>Avicennia germinans</i> 61S 72C
* <i>Cocos nucifera</i> 61S 72S	<i>Lantana involucreta</i> 72C
<i>Coccoloba uvifera</i> 61S 72C	<i>Hedyotis corymbosa</i> 72C
<i>Batis maritima</i> 72C	<i>Eclipta alba</i> 72C
<i>Protulaca oleracea</i> 72C	<i>Melanthera nivea</i> 72C
<i>Sesuvium portulacastrum</i> 72C	<i>Pluchea symphytifolia</i> 72C
<i>Vigna luteola</i> 61C 72C	<i>Wedelia trilobata</i> 72C
<i>Euphorbia blodgettii</i> 61C 72C	

Trapp's Cay (16°30½'N, 88°10'W)

Trapp's Cay (the Moho Cay of charts) stands on an isolated patch reef in the deepest part of the lagoon. It was mapped after Hurricane Hattie in 1962 (Stoddart 1963, pp. 63-64, fig. 38). It is a sandy island with maximum dimensions of 240 x 190 m, and an area of 4.54 ha. The north and east sides of the cay were blanketed with fresh shingle up to 0.6 m thick and 9-23 m wide during Hurricane Hattie. The island is covered with a woodland of coconuts and *Thrinax*, with *Coccoloba* and *Thespesia*. The vegetation was not studied in detail and only 10 species are recorded:

<i>Cyperus</i> sp. 62S	<i>Sesuvium portulacastrum</i> 62S
* <i>Cocos nucifera</i> 62S	<i>Phyllanthus amarus</i> 62C
<i>Thrinax radiata</i> 62S	<i>Thespesia populnea</i> 62S
<i>Hymenocallis littoralis</i> 62S	<i>Rhizophora mangle</i> 62S
<i>Coccoloba uvifera</i> 62S	<i>Conocarpus erectus</i> 62S

Cary Cay (16°31½'N, 88°12'W)

Plate 71

Cary Cay stands on one of the longest reef ridges in the central lagoon: it is 460 m long and has a total area of 4.29 ha. In the north there is an extensive mangrove swamp up to 180 m wide; in the south there is a narrow tapering sand and shingle ridge. In the centre of the island there is an *Acrostichum* marsh with standing water. The dry sand area has a palm thicket with *Cocos*, *Thrinax*, *Coccoloba* and *Cordia*. Much fresh shingle was deposited along the east and southeast sides of the island during Hurricane Hattie, but vegetation damage was minor. For details see Stoddart (1963, pp. 62-63, fig. 37); the island has not been visited since. Only 11 plant species are recorded:

<i>Acrostichum aureum</i> 62S	<i>Cordia sebestena</i> 62S
* <i>Cocos nucifera</i> 62S	<i>Avicennia germinans</i> 62S
<i>Thrinax radiata</i> 62S	<i>Stachytarpheta jamaicensis</i> 62S
<i>Hymenocallis littoralis</i> 62S	<i>Ageratum</i> sp. 62S
<i>Coccoloba uvifera</i> 62S	<i>Wedelia trilobata</i> 62S
<i>Rhizophora mangle</i> 62S	

Bugle Cay (16°29½'N, 88°19'W)

Bugle Cay is a mangrove island only 5.5 km from the mainland coast at Placentia Point. The western end of the island is an arcuate strip of low sand 150 m long and 15-45 m wide. The island is a lighthouse station, and the sand area is planted to coconuts. The island was much damaged by marginal erosion and surface sand-stripping during Hurricane Hattie, and many coconuts were destroyed. In 1965 new coconuts had been planted, and the ground surface was being colonised by herbs and grasses. The sand sector had an area of 0.5 ha in 1962. Only seven plant species have been recorded:

<i>Cyperus</i> sp. 65S	<i>Euphorbia</i> sp. 65S
* <i>Cocos nucifera</i> 62S 65S	<i>Rhizophora mangle</i> 62S 65S
<i>Batis maritima</i> 65S	<i>Avicennia germinans</i> 62S
<i>Sesuvium portulacastrum</i> 65S	

For further details, see Stoddart (1963, pp. 67-68, fig. 43; 1969, p.11).

Owen Cay (16°29½'N, 88°15½'W)

Owen Cay, 6.5 km east of Bugle Cay, is a sand and shingle island 165 m long and up to 35 m wide, with an area of 0.49 ha. In the centre of the island there are clumps of *Rhizophora* and *Avicennia*, with a ground cover of *Batis*. The sand areas are covered with coconuts, *Thrinax*, *Cordia* and *Hymenocallis*. Fresh shingle was deposited round the whole margin of the cay in 1961, forming ridges up to 1.5 m high. For details see Stoddart, 1963, pp. 65-66, fig. 41). Only seven plant species are recorded:

* <i>Cocos nucifera</i> 62S	<i>Rhizophora mangle</i> 62S
<i>Thrinax radiata</i> 62S	<i>Cordia sebestena</i> 62S
<i>Hymenocallis littoralis</i> 62S	<i>Avicennia germinans</i> 62S
<i>Batis maritima</i> 62S	

Scipio Cay (16°28½'N, 88°18'W)

Plate 72

Scipio Cay resembles Owen Cay 4 km to the eastnortheast. It is 250 m long and up to 90 m wide, with an area of 1.67 ha. It is covered by coconut woodland, with a central *Avicennia* swamp, and with stands of *Thrinax* on the beach ridges. During Hurricane Hattie fresh shingle was deposited round almost the entire periphery of the cay. By 1965 these ridges had moved inland and been colonised by *Sesuvium*, *Sporobolus* and *Euphorbia*. For details see Stoddart (1963, pp. 66-67, fig. 42; 1969, pp. 11-12, fig. 9). Only 11 plant species have been recorded:

<i>Sporobolus virginicus</i> 65S	<i>Rhizophora mangle</i> 62S 65S
* <i>Cocos nucifera</i> 62S 65S	<i>Ipomoea</i> sp. 62S
<i>Thrinax radiata</i> 62S 65S	<i>Cordia sebestena</i> 62S
<i>Sesuvium portulacastrum</i> 65S	<i>Tournefortia gnaphalodes</i> 65S
<i>Sophora tomentosa</i> 65S	<i>Avicennia germinans</i> 62S 65S
<i>Euphorbia</i> sp. 65S	

Colson Cay (16°28'N, 88°19'W)

Plate 73

Colson Cay closely resembles Scipio Cay, only 1.6 km away. It is triangular, with sides of 140-175 m and an area of 2.03 ha. It is low and sandy, with a dense vegetation of coconuts and *Thrinax*, and with a central *Avicennia* swamp. Fresh shingle was deposited all round the cay during Hurricane Hattie in 1961. These ridges had eroded and moved landward by 1965, and had been colonised by *Sesuvium*, *Euphorbia*, *Sporobolus*, *Cassytha* and two small *Tournefortia* bushes. For details see Stoddart (1963, p.67, fig. 42; 1969, p.12, fig. 10). 11 plant species have been recorded:

<i>Sporobolus</i> sp. 65S	<i>Euphorbia</i> sp. 65S
* <i>Cocos nucifera</i> 62C 65C	<i>Rhizophora mangle</i> 62S 65S
<i>Thrinax radiata</i> 62S 65S	<i>Cordia sebestena</i> 62S 65S
<i>Sesuvium portulacastrum</i> 65S	<i>Tournefortia gnaphalodes</i> 65S
<i>Cassytha filiformis</i> 65S	<i>Avicennia germinans</i> 62S 65S
<i>Sophora tomentosa</i> 65S	

Purdy (1974b, pp. 841, 853) drilled a 19.2 m hole through Colson Cay. The entire section was in Holocene material. A date of 5550 ± 140 yr from a sample at 6.4-7.3 m indicated a Holocene reef growth rate of 1.2 m/1000 yr.

Hatchet Cay ($16^{\circ}28'N$, $88^{\circ}04\frac{1}{2}'W$)

Figure 32

Hatchet Cay lies 3.3 km lagoonward of the Silk Cays, close to the edge of the coastal shelf south of Gladden Spit. It is a low-lying sandy island 240 m long and 45-85 m wide, with an area when mapped in 1972 of 1.30 ha. It is almost completely surrounded by a zone of *Rhizophora* woodland from 5 to 40 m wide. The interior of the cay is occupied by coconut woodland. It thus closely resembles Weewee, Buttonwood and Trapp's Cays. Hatchet is inhabited, and has two wells. 38 species of plants have been recorded, and this more accurately reflects the floras of this type of island than the collections made on the other three islands mentioned. The species are:

* <i>Cymbopogon citratus</i> 72C	* <i>Citrus aurantiifolia</i> 72C
<i>Eragrostis ciliaris</i> 72C	<i>Euphorbia blodgettii</i> 72C
<i>Eragrostis prolifera</i> 72C	<i>Euphorbia mesembrianthemifolia</i> 72C
<i>Eustachys petraea</i> 72C	<i>Hibiscus tiliaceus</i> 72C
<i>Paspalum laxum</i> 72C	<i>Rhizophora mangle</i> 72C
<i>Spartina spartinae</i> 72C	<i>Conocarpus erectus</i> 72C
<i>Sporobolus jacquemontii</i> 72C	<i>Laguncularia racemosa</i> 72C
<i>Cyperus peruvianus</i> 72C	* <i>Terminalia catappa</i> 72C
<i>Cyperus planifolius</i> 72C	* <i>Psidium guajava</i> 72C
<i>Fimbristylis cymosa</i> 72C	* <i>Nerium oleander</i> 72C
<i>Fimbristylis spadicea</i> 72C	<i>Ipomoea pes-caprae</i> 72C
* <i>Cocos nucifera</i> 72S	<i>Avicennia germinans</i> 72C
<i>Thrinax radiata</i> 72C	<i>Lantana involucrata</i> 72C
<i>Hymenocallis littoralis</i> 72C	<i>Lippia strigulosa</i> 72C
<i>Batis maritima</i> 72C	<i>Ageratum littorale</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Melanthera nivea</i> 72C
<i>Portulaca oleracea</i> 72C	* <i>Vernonia cinerea</i> 72C
<i>Sesuvium portulacastrum</i> 72C	<i>Wedelia trilobata</i> 72C
<i>Cakile lanceolata</i> 72C	
<i>Vigna luteola</i> 72C	

A discontinuous ridge of rubble extending along the reef crest to the southwest of the cay, about 35 m offshore, may date from Hurricane Hattie in 1961.

Little Water Cay (16°27½'N, 88°06'W)

Figure 33, Plate 75

Little Water Cay lies 3.7 km southwest of Hatchet Cay. It is a triangular island 255 m long and up to 170 m wide, with an area in 1972 of 2.07 ha. Most of the island is covered with a dense coconut woodland, with an interior area of sedge marsh and narrow fringes of *Rhizophora* at the west end and along the east shore. There are some patches of *Conocarpus* along the shore, especially on the north side, but generally the coconut woodland extends to the beach. The whole of the south shore is cliffed and eroding, with fallen coconuts. There is an extensive zone of rubble on the reef crest at the east end of the cay, which may date from Hurricane Hattie. The island is uninhabited. 29 plant species are recorded:

<i>Eragrostis prolifera</i> 72C	<i>Vigna luteola</i> 72C
<i>Eustachys petraea</i> 72C	<i>Suriana maritima</i> 72C
<i>Paspalum blodgettii</i> 72C	<i>Euphorbia blodgettii</i> 72C
<i>Paspalum distichum</i> 72C	<i>Euphorbia mesembrianthemifolia</i>
<i>Spartina spartinae</i> 72C	72C
<i>Sporobolus virginicus</i> 72C	<i>Hibiscus tiliaceus</i> 72C
<i>Stenotaphrum secundatum</i> 72C	<i>Rhizophora mangle</i> 72C
<i>Cyperus ligularis</i> 72C	<i>Conocarpus erectus</i> 72C
<i>Cyperus planifolius</i> 72C	<i>Laguncularia racemosa</i> 72C
<i>Fimbristylis cymosa</i> 72C	* <i>Terminalia catappa</i> 72C
* <i>Cocos nucifera</i> 72S	<i>Avicennia germinans</i> 72C
<i>Batis maritima</i> 72C	<i>Lippia strigulosa</i> 72C
<i>Philoxerus vermicularis</i> 72C	<i>Eclipta alba</i> 72C
<i>Portulaca oleracea</i> 72C	<i>Melanthera nivea</i> 72C
<i>Sesuvium portulacastrum</i> 72C	<i>Wedelia trilobata</i> 72C

Laughing Bird Cay (16°27'N, 88°12'W)

Laughing Bird Cay is the southernmost of the islands in the central lagoon. It stands on an elongate reef ridge 23 km from the coast and 14 km from the shelf edge: water depths to the southeast reach 45 m, but Purdy has shown that the Holocene sequence beneath this island is 18.3 m thick, giving a pre-Holocene relief above the present lagoon floor of about 20 m (Purdy 1974b, p.841). The island itself is an elongate sand ridge about 460 m long and 9-40 m wide. During Hurricane Hattie rubble and shingle were deposited at the northeast and southwest ends of the cay, and along the southeast shore. When mapped in 1962 the area of the cay was 1.36 ha; it has not been visited since (Stoddart 1963, p.65, fig. 40). The island is covered with coconut woodland, with scattered coastal mangroves. Only seven plant species have been recorded:

* <i>Cocos nucifera</i> 62S	<i>Rhizophora mangle</i> 62S
<i>Hymenocallis littoralis</i> 62S	<i>Ipomoea</i> sp. 62S
<i>Sesuvium portulacastrum</i> 62S	<i>Avicennia germinans</i> 62S
<i>Euphorbia</i> sp. 62S	

Placentia Cay (16°31'N, 88°21½'W)

This is a mangrove island with a small area of strand vegetation and coconuts located 1 km east of Placentia Point on the mainland coast. It was mapped as True Point Patience Kay of Speer (1966, p.23) and as Patience Brother Island of Jefferys (1775). Jefferys also mapped the small mangrove islets at the mouth of Placentia Lagoon as The Virgins, and Speer commented on these "several small Kays ... at the mouth of a large lagoon, where there is plenty of Turtle passes morning and evening" (1766, p.23). No plant collections have been made on these islands, which are part of the coastal quartz and carbonate sand accretional sequences.

Harvest Cay (16°29'N, 88°24'W)

Harvest Cay, 5.5 km to the southwest, is the "Hobbe's Kay" of Speer (1766, p.23). This and other nearshore islands to the south, such as Palmetto Cay, are properly barrier beaches built of terrigenous quartz sand, backed by mangrove swamp, rather than true coral cays. Harvest Cay has a dense vegetation of coconuts, *Thrinax* and mangroves, with a tall undergrowth of *Cladium*, together with succulents and grasses. The island was briefly visited in 1962. Four species were noted:

Cladium jamaicense 62C
**Cocos nucifera* 62S

Thrinax radiata 62S
Batis maritima 62S

D. The Punta Gorda Cays

The cays of the Port Honduras Bight between Punta Gorda and Punta Ycacos, in the southern part of the barrier reef lagoon, stand on numerous steep-sided knolls, rising from a shelving lagoon floor in from 8-24 m of water. The innermost cays, from Stuart Cay at the mouth of the Rio Grande to Bedford Cays at the mouth of the Ycacos Lagoon, all surrounded by water less than 10 m deep, are wholly mangrove. Further lagoonward there are some islands with dry land in addition to mangrove, notably Frenchman's Cay and Wild Cane Cay, but most of the islands are un-named and wholly of mangrove. On many of them the mangrove in 1961 was less than 2 m tall, suggesting recent growth following hurricane damage. The Moho Cays are all mangrove, except for the outer one, which is a sand cay. The outermost islands, the Snake Keys, stand on patches rising from a lagoon floor 20-30 m deep; they are sand cays with shingle ridges; only these patches have significant amounts of coral on them. All of these islands come under the influence of freshwater discharge from the Deep River and the Rio Grande; the rainfall in this area (4239 mm at Punta Gorda) is much higher than elsewhere on the coastal cays. The published chart of the Gulf of Honduras dates from surveys in 1835-1841 and is rather generalised, and

the islands are known only through a brief reconnaissance visit in 1961. They would repay further investigation.

East Snake Cay (16°12½'N, 88°30½'W)

Figure 34, Plates 76 and 79

East Snake Cay consists of a densely vegetated sand cay wholly surrounded by shingle ridges which enclose a shallow moat containing mangroves. The total area is 1.94 ha, of which the main core, excluding the moat and rampart, comprises 1.04 ha. The whole complex is 260 m long and up to 110 m wide, and the reef patch on which it stands is only slightly larger. Vegetation on the shingle rampart is limited to patches of *Ipomoea* and *Rhizophora*. On the sand cay there is a dense woodland of coconuts, *Thrinax*, *Cordia*, *Coccoloba*, *Terminalia* and *Ficus*. There is an automatic lighthouse on the island. For a brief account, see Stoddart (1965, p.138, fig. 4). 20 species of plants have been recorded:

<i>Cyperus</i> sp. 61S	<i>Rhizophora mangle</i> 61S
* <i>Cocos nucifera</i> 57S 61S	<i>Conocarpus erectus</i> 61S
<i>Thrinax radiata</i> 61S	* <i>Terminalia catappa</i> 61C
<i>Hymenocallis littoralis</i> 61S	<i>Ipomoea</i> sp. 61S
<i>Brassavola nodosa</i> 61C	<i>Cordia sebestena</i> 61S
<i>Ficus</i> sp. 61C	<i>Tournefortia gnaphalodes</i> 61S
<i>Coccoloba uvifera</i> 61S	<i>Avicennia germinans</i> 61S
<i>Erythrina</i> sp. 61C	<i>Stachytarpheta jamaicensis</i> 61S
<i>Sophora tomentosa</i> 61C	<i>Erithalis fruticosa</i> 61S
<i>Euphorbia</i> sp. 61S	<i>Wedelia trilobata</i> 61S

Purdy (1974b. p.841) drilled a hole 39.7 m deep through East Snake Cay. Recent reef material gave way to pre-Recent terrestrial sediments at a depth of 25.9 m.

Middle Snake Cay (16°12'N, 88°33'W)

Figure 35

Middle or Ragged Snake Cay comprises two islands built of shingle, each having an area of 0.66 ha. The northeastern island is about 275 m long but is everywhere less than 40 m wide. It is built of two linear shingle ridges with an intervening partly water-filled depression. The outer ridges, presumably hurricane-formed, include coral blocks 1 m in diameter. The vegetation is limited to succulents and grasses, with low shrubs of *Coccoloba*, *Suriana*, *Tournefortia* and mangroves. 7 plant species were noted in 1961:

<i>Coccoloba uvifera</i> 61S	<i>Conocarpus erectus</i> 61S
<i>Sesuvium portulacastrum</i> 61S	<i>Ipomoea</i> sp. 61S
<i>Suriana maritima</i> 61S	<i>Avicennia germinans</i> 61S
<i>Rhizophora mangle</i> 61S	

The southern island is also built of shingle ridges, but is triangular, with sides of 75-110 m. The interior is more sandy, and the concentric ridges enclose linear pools. There is a dense growth of *Avicennia* and *Rhizophora* along the north side, with a woodland of coconuts, *Thrinax* and *Coccoloba* on the rest of the cay. 15 species of plants were noted in 1961:

<i>Cyperus</i> sp. 61S	<i>Sophora tomentosa</i> 61S
* <i>Cocos nucifera</i> 61S	<i>Suriana maritima</i> 61S
<i>Thrinax radiata</i> 61S	<i>Euphorbia</i> sp. 61S
<i>Hymenocallis littoralis</i> 61S	<i>Conocarpus erectus</i> 61S
<i>Brassavola nodosa</i> 61S	<i>Ipomoea</i> sp. 61S
<i>Coccoloba uvifera</i> 61S	<i>Tournefortia gnaphalodes</i> 61S
<i>Sesuvium portulacastrum</i> 61S	<i>Wedelia trilobata</i> 61S
<i>Cakile lanceolata</i> 61S	

West Snake Cay (16°11½'N, 88°34'W) Figures 36 and 37, Plates 77 and 80

West Snake Cay is a complex island with a leeward sand area, a central mangrove swamp, a moat, and a windward shingle ridge, with a total area of 5.35 ha. It has been described briefly by Stoddart (1965, p.137, fig. 4), and recalls the features of low wooded islands of the northern Great Barrier Reef and of Djakarta Bay. The shingle rampart follows the eastern edge of the reef patch for about 370 m, rising to 1 m above sea level. The moat enclosed by the shingle ridge is about 200 m long and up to 100 m wide: it is less than 0.6 m deep; and with its enclosing shingle ridges has an area of 2.5 ha. There are many *Rhizophora* seedlings in the moat and along the inner margin of the ridge, and the shingle ridge itself is patchily covered with *Sesuvium*, *Tournefortia*, *Coccoloba*, mangroves and grasses. The most extensive vegetation unit is the mangrove swamp, consisting of *Rhizophora*, *Avicennia* and *Acrostichum*, but much of it is open standing water. The leeward dry sand area is 15-30 m wide and rises to 1 m above sea level. It is under coconut woodland with *Coccoloba* and *Tournefortia* and a diverse ground cover. 13 species of plants were recorded in 1961:

<i>Acrostichum aureum</i> 61C	<i>Euphorbia</i> sp. 61S
<i>Sporobolus virginicus</i> 61C	<i>Rhizophora mangle</i> 61S
<i>Cyperus</i> sp. 61S	<i>Ipomoea macrantha</i> 61C
* <i>Cocos nucifera</i> 61S	<i>Ipomoea pes-caprae</i> 61C
<i>Coccoloba uvifera</i> 61S	<i>Tournefortia gnaphalodes</i> 61S
<i>Sesuvium portulacastrum</i> 61S	<i>Avicennia germinans</i> 61S
<i>Cakile lanceolata</i> 61C	

150 m northwest of the main island is a small shingle island, West Island. It is 140 m long, up to 23 m wide, has an area of 800 sq m, and rises 1 m above sea level. Most of the islet is covered with *Sesuvium* and *Ipomoea*, with some shrubby *Coccoloba*, *Suriana* and *Conocarpus*. Six species were recorded in 1961:

Sporobolus sp. 61S
Coccoloba uvifera 61S
Sesuvium portulacastrum 61S

Suriana maritima 61S
Conocarpus erectus 61S
Ipomoea sp. 61S

South Snake Cay (16°11'N, 88°34'W)

Figure 38, Plate 78

South Snake Cay is very similar to West Snake Cay, but the eastern shingle rampart is uninterrupted and adjoins the main cay at each end. The mangrove area is smaller and the leeward sand area forms the largest part of the complex (Stoddart 1965, pp. 137-138, fig. 4). The shingle rampart is 20 m wide and 1.5 m high at its southeast end; it becomes narrower and lower northwards. The moat is shallow and completely enclosed, and contains much stranded pumice; the area of the moat and enclosing rampart is 1.05 ha. The rampart itself is not vegetated and there are no *Rhizophora* seedlings in the moat. The dry sand area has maximum dimensions of 180 x 90 m, has an area of 1.7 ha, and is strongly undercut along its southwest shore, where the surface stands at 1 m above sea level. Poorly cemented beachrock outcrops along this shoreline between the small bluffs formed by the boles of coconut trees. The sand area is covered with a dense thicket of coconuts and *Thrinax*. 11 species of plants were noted in 1961:

Andropogon sp. 61S
Cyperus sp. 61S
 **Cocos nucifera* 61S
Thrinax radiata 61S
Hymenocallis littoralis 61S
Dalbergia ecastophyllum 61C

Sophora tomentosa 61S
Suriana maritima 61S
Rhizophora mangle 61S
Conocarpus erectus 61S
Wedelia trilobata 61S

Wild Cane Cay (16°12½'N, 88°38'W)

Figure 39

This is a mangrove island 7.5 km southwest of Punta Ycacos. The whole island is about 1 km long. At its southern end there is a rectangular dry area measuring 300 x 100 m, with an area of 2.0 ha. Mangroves are growing at several points along its shores. The dry area is only about 0.6 m above sea level; the soil is dark and humic and parts are boggy. The vegetation consists of coconut woodland with marginal *Conocarpus*. The island is inhabited and there are several introduced food and ornamental plants. The most striking feature of the cay, however, is the presence of large stone-faced Maya burial mounds. One of these constituted Mound 39 in Gann's excavations (1918, pp. 135-136). This was a mound 3 m high consisting of sand and blocks of reef limestone covering a surface burial. Gann found pottery, obsidian knives, the femur of a deer with an incised design, and copper ornaments (rings, gorgets, studs) which he suggested showed Spanish influence. In another account (1927, p.238) Gann speaks of "great numbers of interments in four large mounds."

When mapped in 1961 the four mounds still existed, the largest being 65 m long. They have, however, been much disturbed. In 1918 Gann noted that they were used as a source of stone, and in 1927 (p.238) he stated that "when the Cabral family needs a little ready money, they excavate a small area and sell the beads, pottery, spear-heads, etc., which invariably turn up." In 1961 the ground surface was littered with obsidian flakes up to 4 cm long, and with fragments of coarse red pottery. A drilled jade bead and a projectile point 16 cm long were also found. Other remains included grey pottery net sinkers and small animal figures. The most remarkable object from Wild Cane Cay, however, is an animal-shaped jar 13.7 cm high of Plumbate Ware. It is described by Bray (1970, p.32, plate 27): "The head is frog-like, but the feet and stumpy tail belong to a different kind of animal. The creature wears a necklace, each end of which terminates in a disc ornamented with six pits. The body of the pot is further decorated with broad line designs incised through the greenish-brown slip." Plumbate Ware was manufactured in Guatemala and widely traded: the use of zoomorphic shapes began about 1000 A.D. and this serves as a time-marker for the early Postclassic period. Bray dates this particular object between 1000 and 1200 A.D.

Fifteen plant species were noted in 1961; undoubtedly more are present.

<i>Pityrogramma calomelanos</i> 61C	* <i>Mangifera indica</i> 61S
<i>Sporobolus jacquemontii</i> 61C	<i>Sida acuta</i> 61C
<i>Fimbristylis spadicea</i> 61C	<i>Opuntia</i> sp. 61S
* <i>Cocos nucifera</i> 61S	<i>Rhizophora mangle</i> 61S
<i>Laelia tibicinis</i> 61C	<i>Conocarpus erectus</i> 61S
<i>Coccoloba uvifera</i> 61S	* <i>Psidium guajava</i> 61C
* <i>Citrus</i> sp. 61S	<i>Stachytarpheta jamaicensis</i> 61C
* <i>Pedilanthus tithymaloides</i> 61C	

Frenchman's Cay (16°11½'N, 88°38'W)

Frenchman's Cay is very similar to Wild Cane Cay, though almost the whole shoreline is lined by mangroves. The sandy interior is covered with coconut woodland, and the centre is low-lying and swampy. There is a freshwater well, several huts, and an area of cultivated plants. There are several burial mounds faced with limestone blocks, seen in 1961. Gann (1927) reported the excavation of gold ornaments and other artefacts from these sites. Only five species of plants were noted in 1961; many must remain to be recorded. They are:

* <i>Saccharum officinarum</i> 61S	* <i>Mangifera indica</i> 61S
* <i>Cocos nucifera</i> 61S	<i>Rhizophora mangle</i> 61S
* <i>Musa paradisiaca</i> 61S	

Apart from coastal mangrove islets, Moho Cay is the southernmost cay in the Punta Gorda group, and the only sand cay. It is a narrow island 160 m long, with an average width of 18-35 m, and an area of 0.54 ha. Owen in 1835 noted a solitary coconut at its northern end, but since then the vegetation has been cleared and the island is now covered with coconut woodland, except for an area of dense woodland at the south end. There is a varied ground cover of herbs, grasses and sedges beneath the coconuts. The dense woodland includes coconuts, *Thrinax* and some mangroves. The whole island is sandy and low-lying, and the south and southeast shores are undercut and eroding. There is a freshwater well and a small hut. Twenty species of plants were recorded in 1961:

<i>Eragrostis prolifera</i> 61C	<i>Thrinax radiata</i> 61S
<i>Eustachys petraea</i> 61C	<i>Hymenocallis littoralis</i> 61S
<i>Paspalum paniculatum</i> 61C	<i>Coccoloba uvifera</i> 61S
<i>Sporobolus virginicus</i> 61C	<i>Sophora tomentosa</i> 61C
<i>Stenotaphrum secundatum</i> 61C	<i>Vigna luteola</i> 61C
<i>Cyperus ligularis</i> 61C	<i>Euphorbia blodgettii</i> 61C
<i>Cyperus peruvianus</i> 61C	<i>Bidens cynapiifolia</i> 61C
<i>Fimbristylis cymosa</i> 61C	<i>Conyza canadensis</i> 61C
<i>Fimbristylis spadicea</i> 61C	<i>Melanthera nivea</i> 61C
* <i>Cocos nucifera</i> 61S	<i>Wedelia trilobata</i> 61C

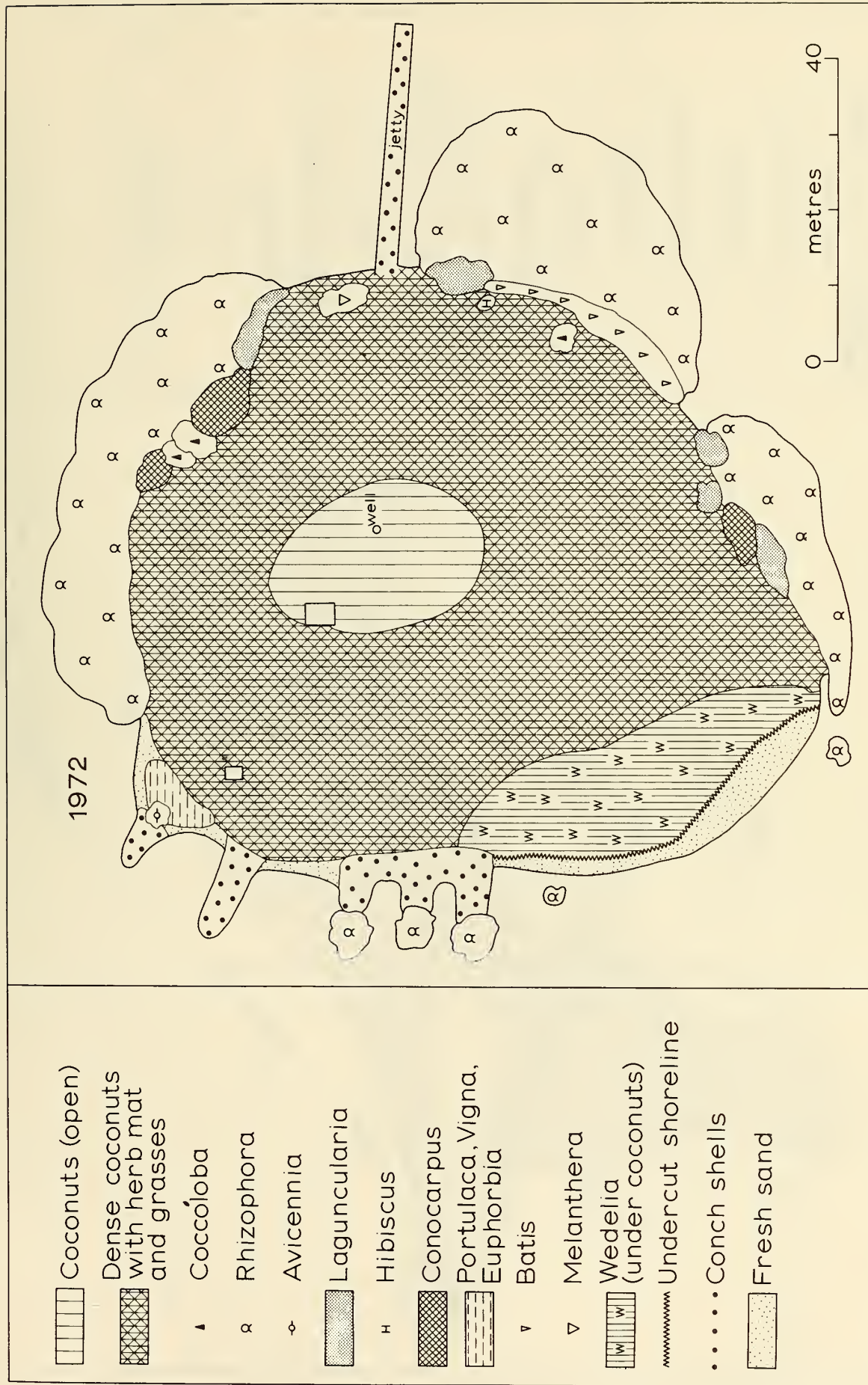


Figure 31. Buttonwood Cay 1972

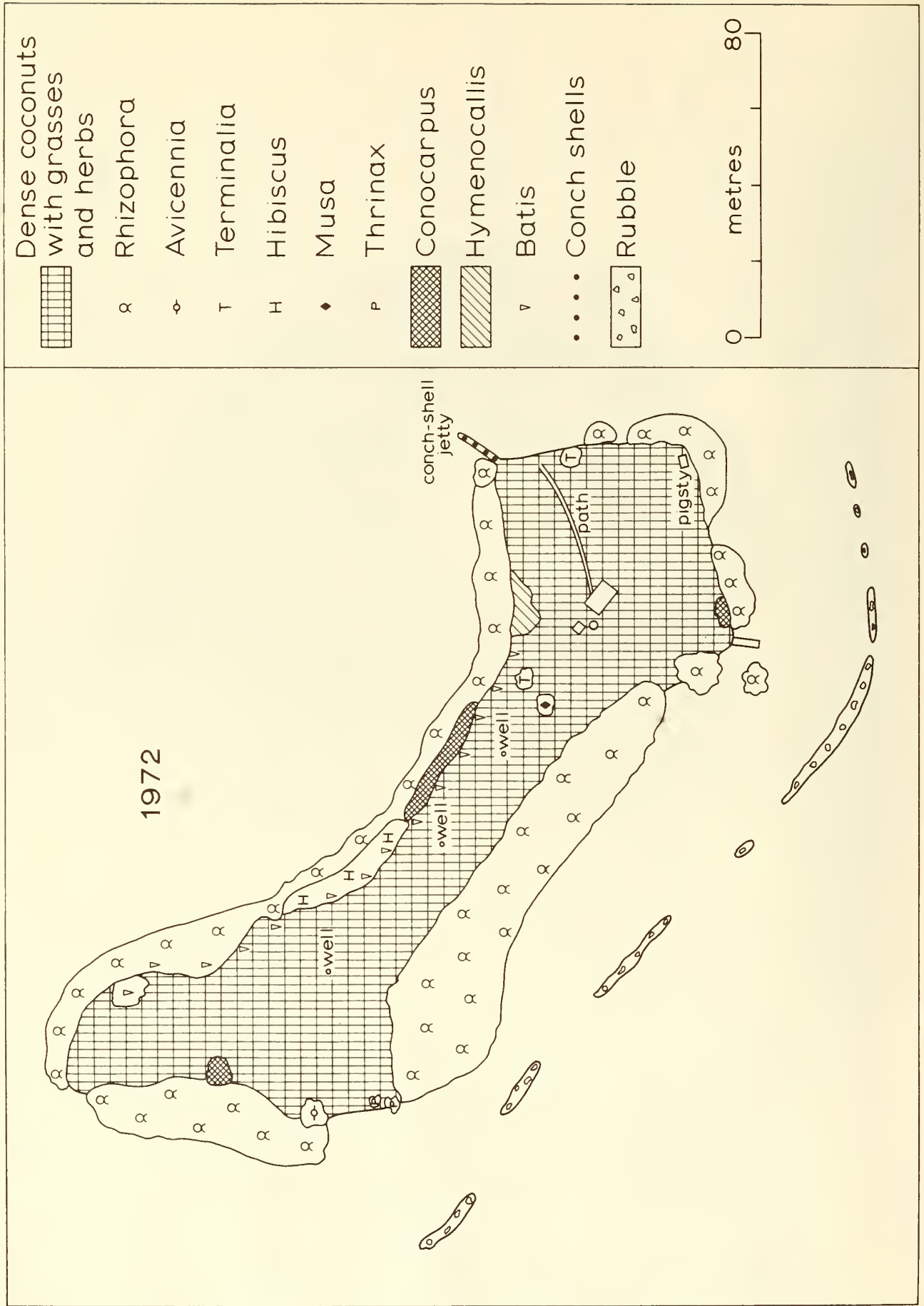


Figure 32. Hatchet Cay 1972

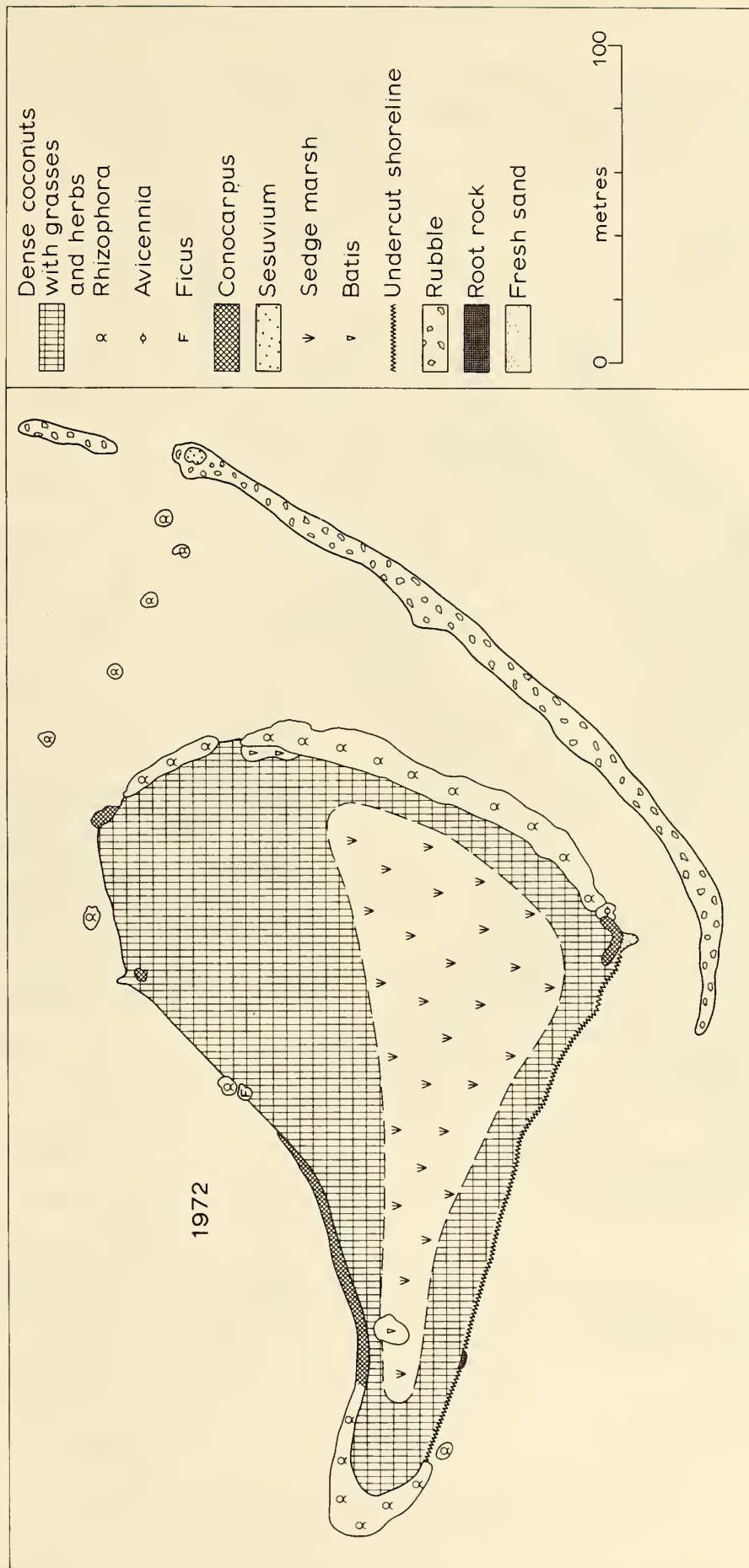


Figure 33. Little Water Cay 1972

Growing coral in lagoon entrance
Porites porites *P. astreoides* and
Siderastrea radians

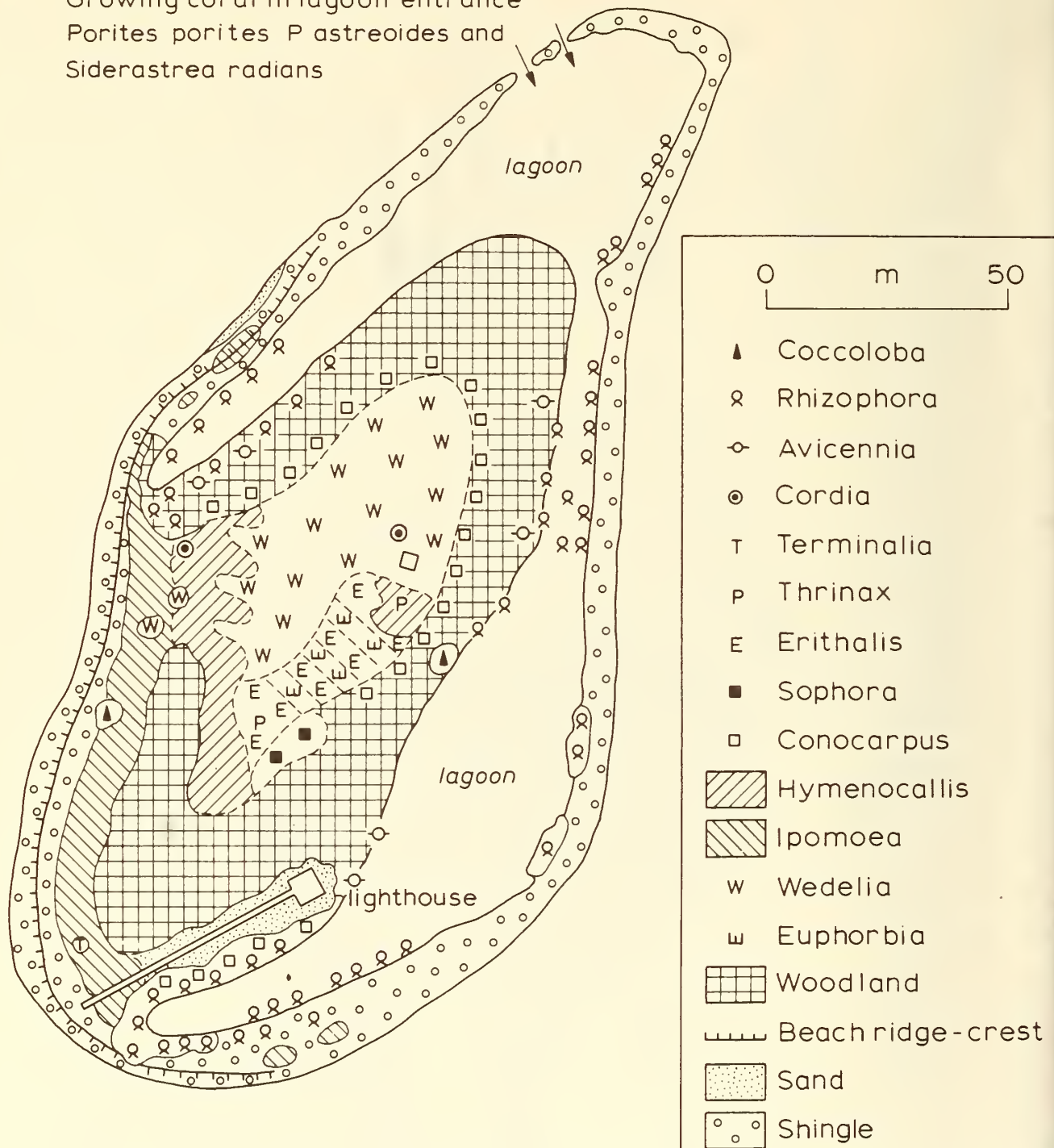


Figure 34. East Snake Cay 1961

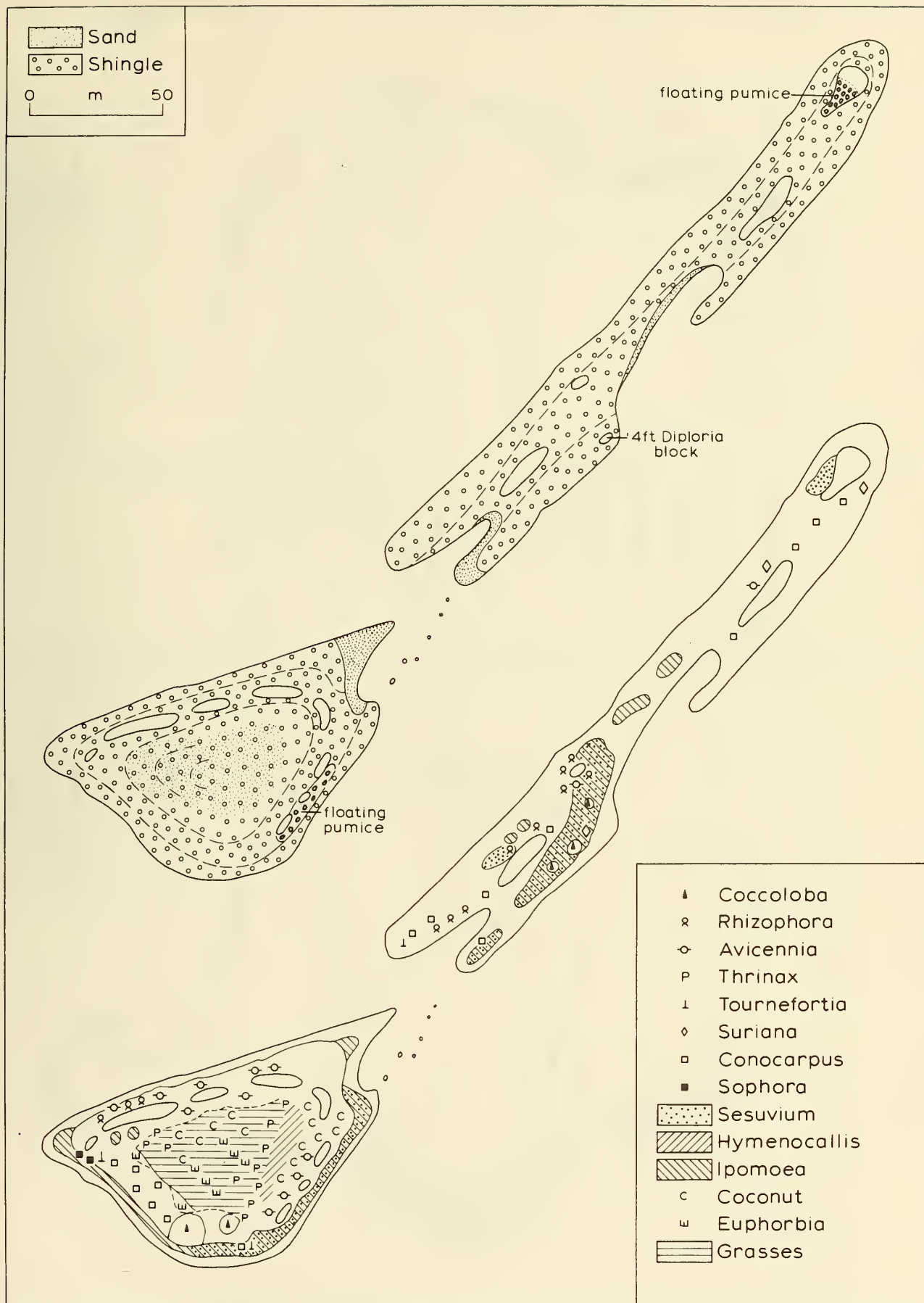


Figure 35. Middle Snake Cay 1961

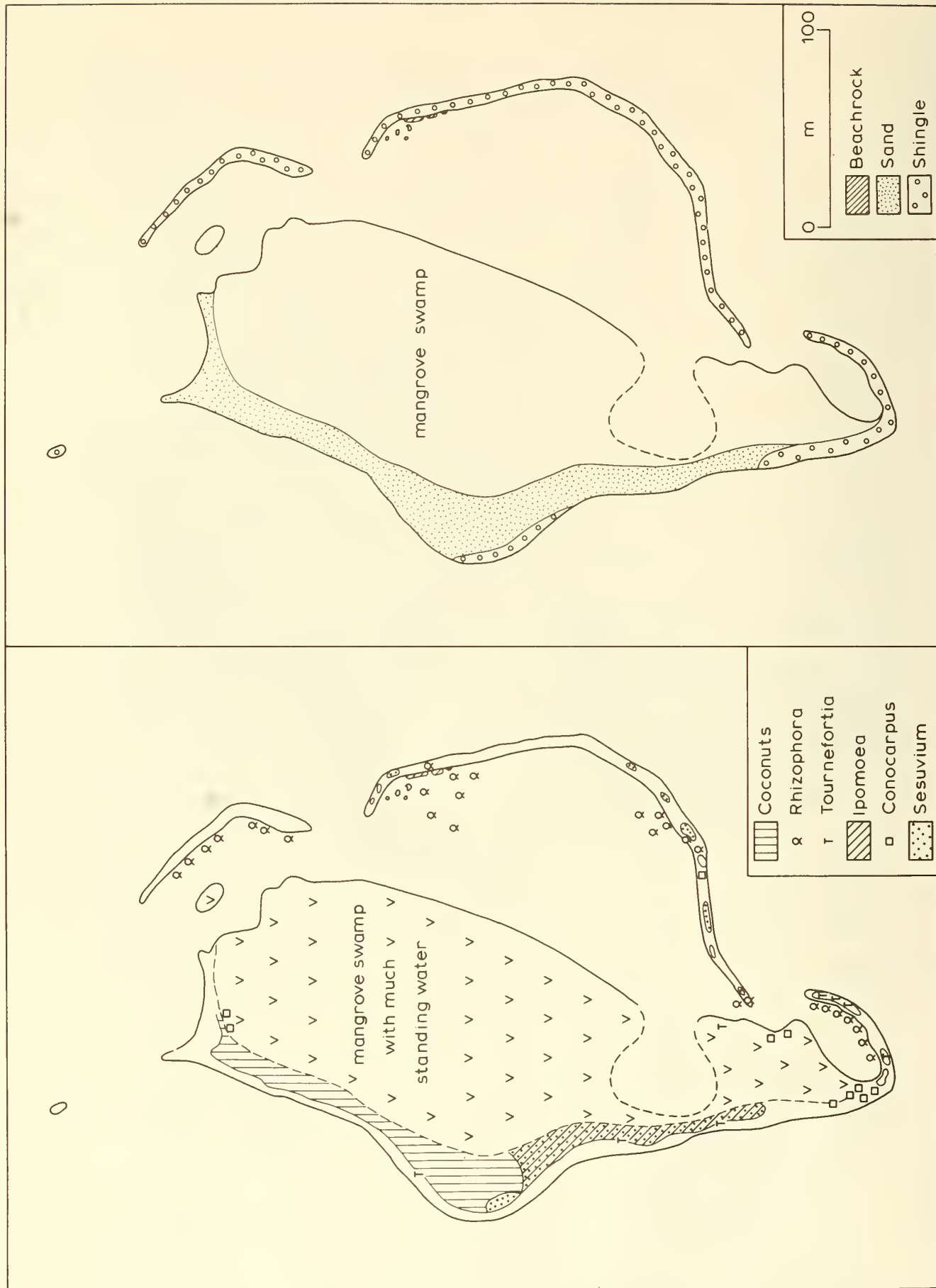


Figure 36. West Snake Cay 1961

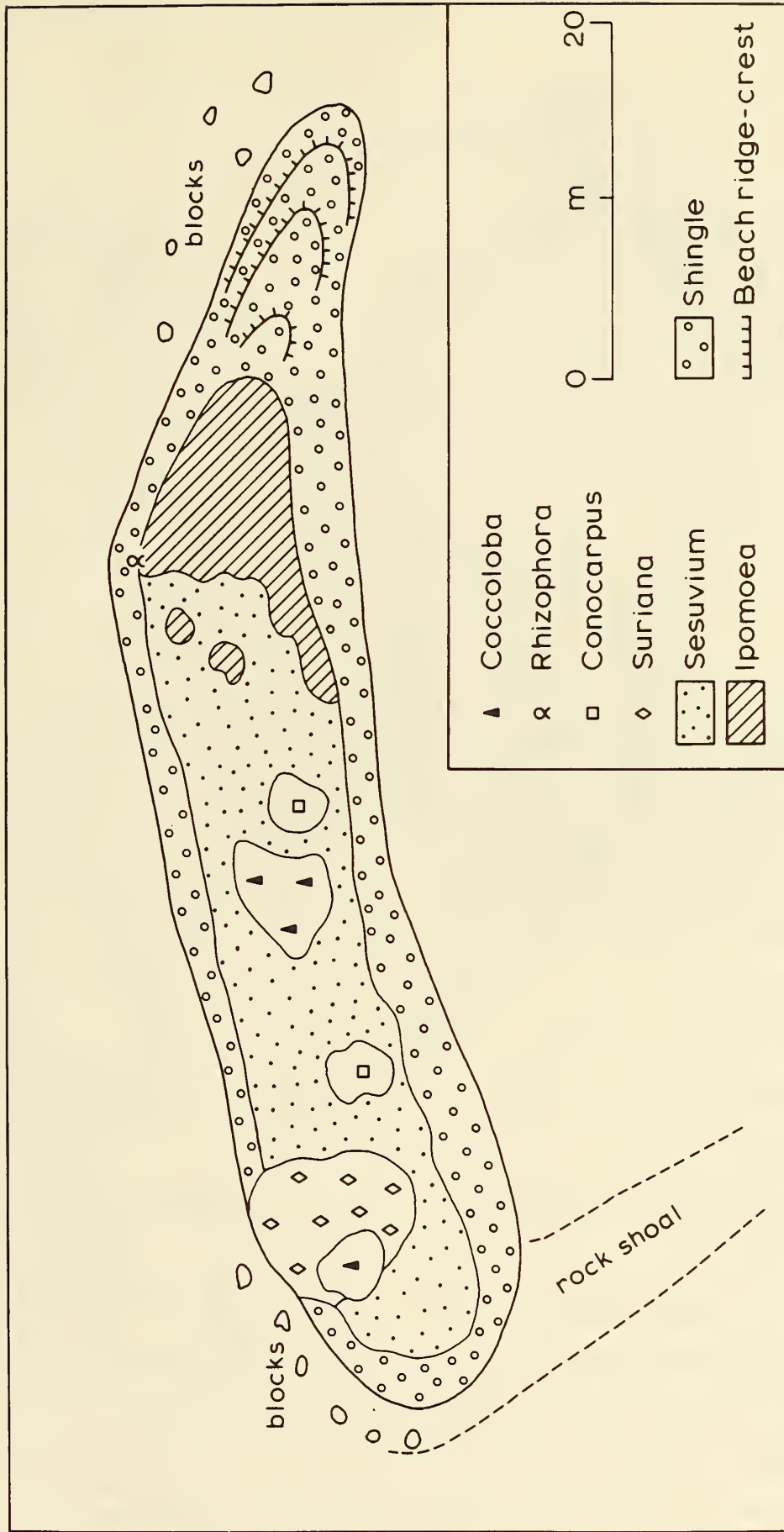


Figure 37. West Island West Snake Cay 1961

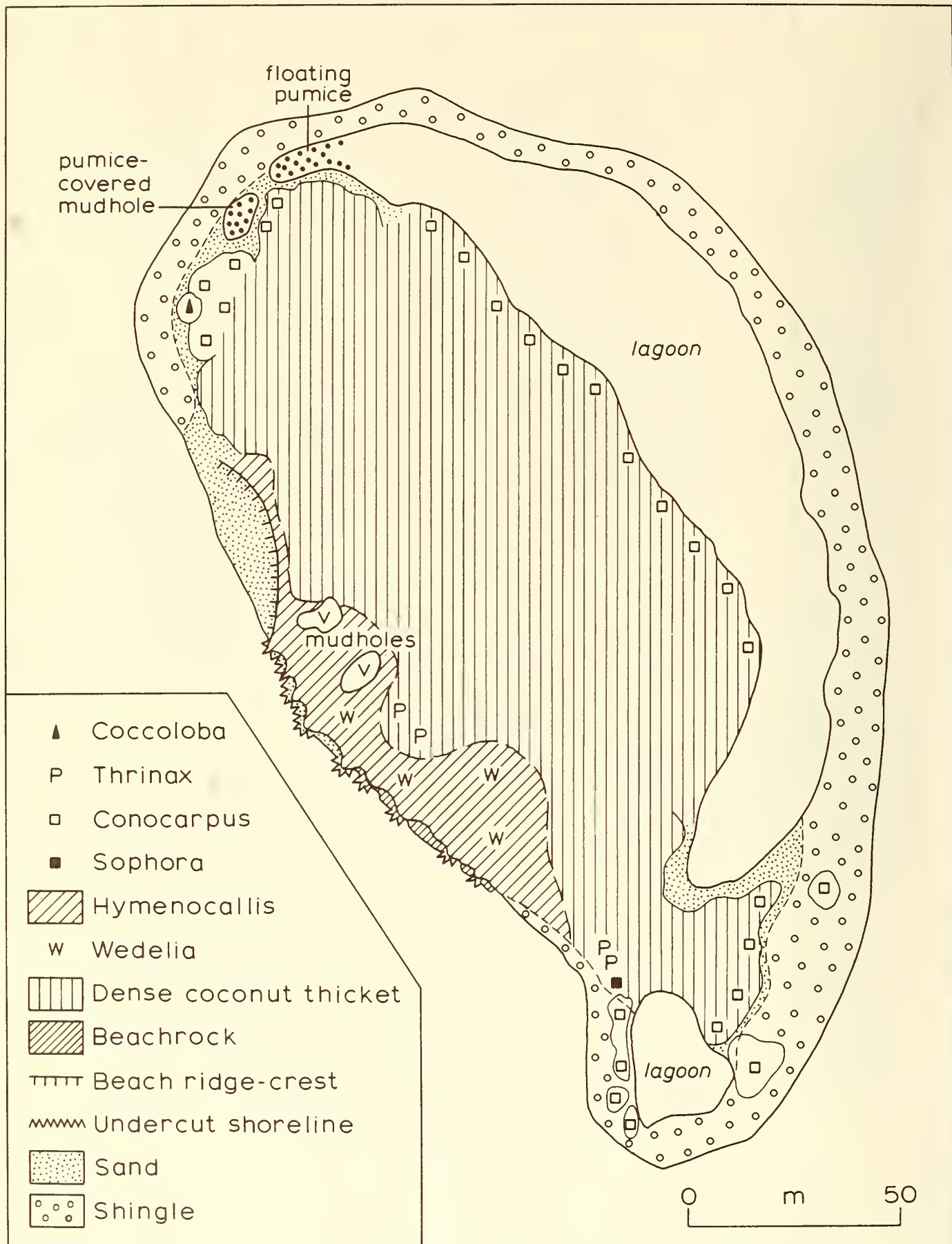


Figure 38. South Snake Cay 1961

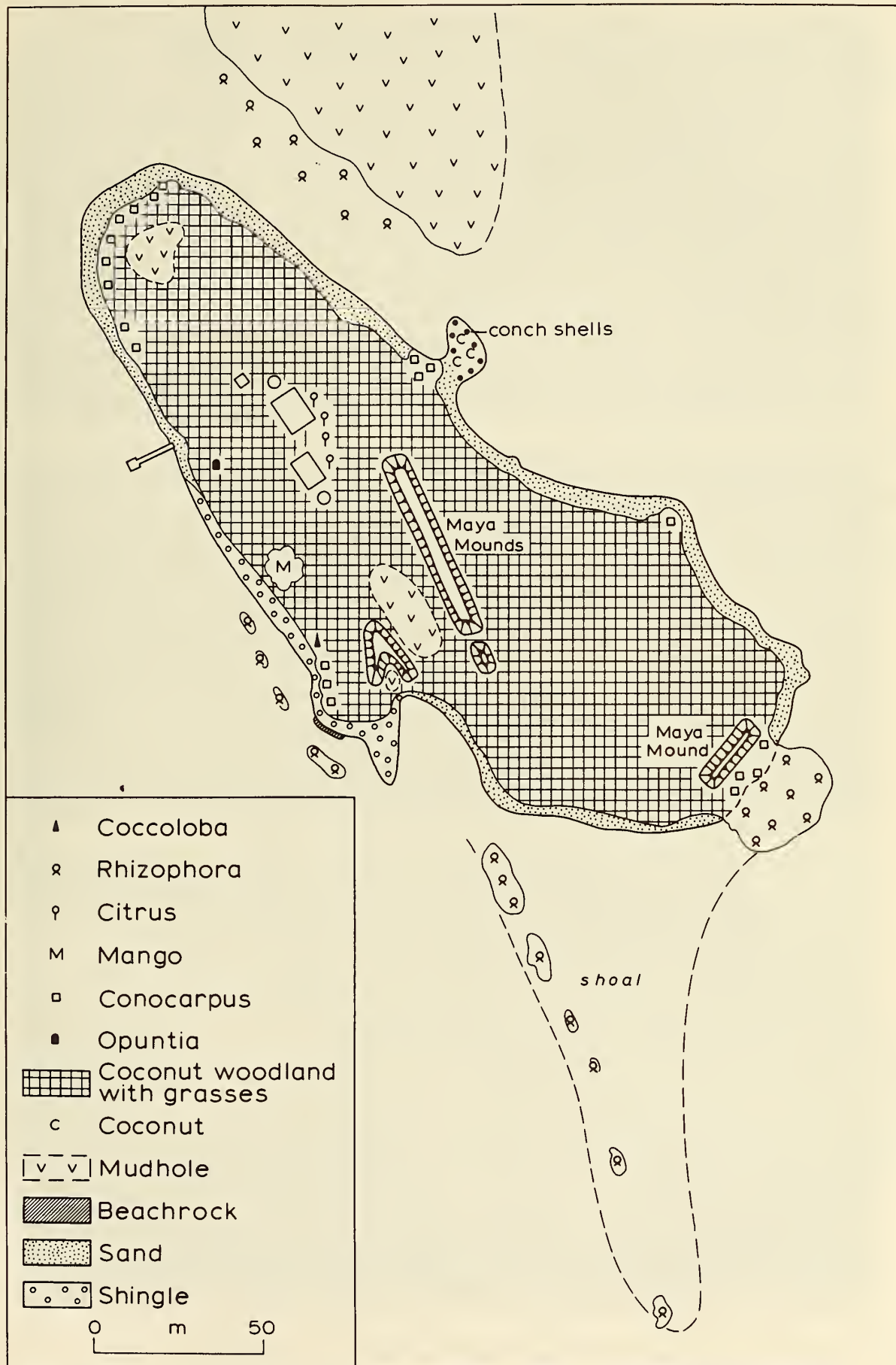


Figure 39. Wild Cane Cay 1961

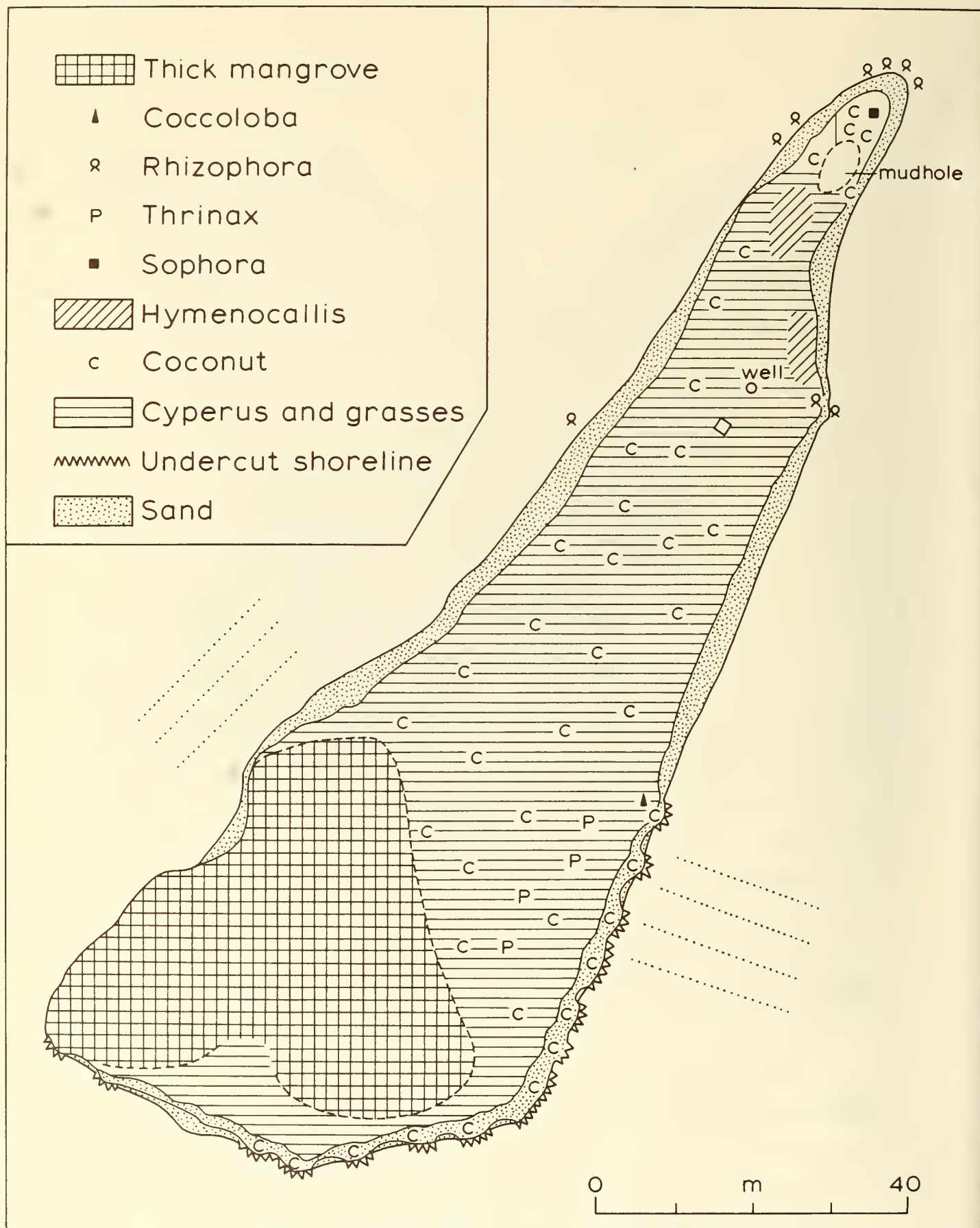


Figure 40. Moho Cay 1961

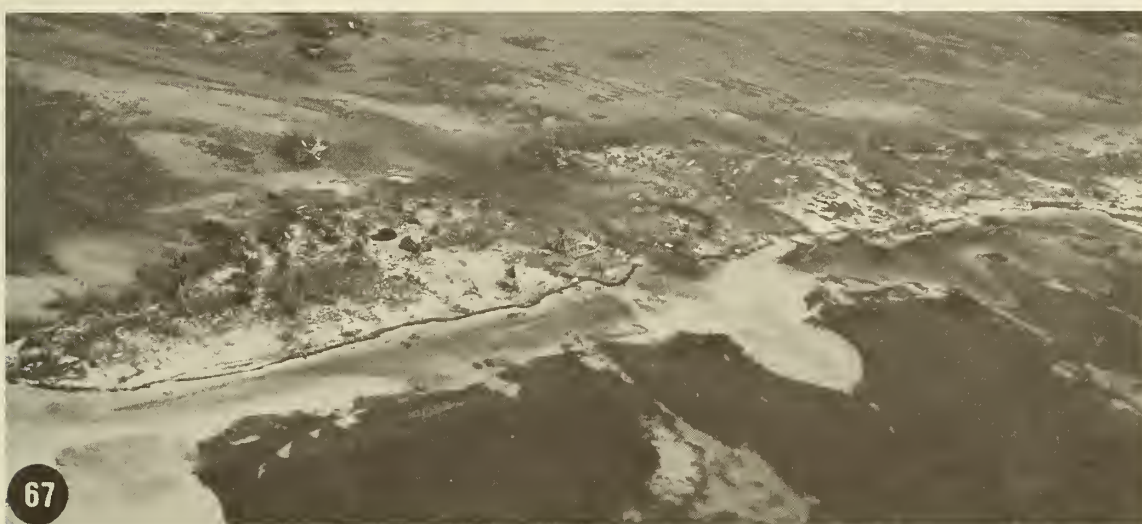


Plate 66. St. George's Cay: aerial view from the north 1962 (channel A)

Plate 67. St. George's Cay: aerial view from the north 1962 (channel C)

Plate 68. St. George's Cay: aerial view from the east 1962 (channels D and E)
 (For the location of these channels see Stoddart 1963, fig. 19)



Plate 69. Tobacco Range 1972: view inland from the northeast sand ridge
 Plate 70. Tobacco Range 1972: *Rhizophora* killed by Hurricane Hattie in 1961, invaded by *Batis*, at the northeast point



Plate 71. Cary Cay: hurricane-deposited shingle on the east side 1962
 Plate 72. Scipio Cay: hurricane-deposited shingle ridge 1962
 Plate 73. Colson Cay: hurricane-deposited shingle on the southeast shore 1962



Plate 74. Water Range (Twin Cays): *Thrinax* thicket, south shore 1972



Plate 75. Little Water Cay: shingle rampart on the southeast shore 1972



Plate 76. East Snake Cay: aerial view from the southeast 1961
 Plate 77. West Snake Cay: aerial view from the northeast 1961
 Plate 78. South Snake Cay: aerial view from the southeast 1961



Plate 79. East Snake Cay rampart and moat from the north 1961



Plate 80. West Snake Cay rampart and moat from the south 1961

6. SUMMARY AND CONCLUSIONS

A. Types of islands

This consideration of the cays of the Belize barrier and shelf has indicated the variability of reef island types in such an extensive province. In a previous paper (Stoddart 1965, pp. 134-142), nine types of island were distinguished on the Belize reefs as a whole and their distribution mapped. This classification can now be extended and the following types recognised:

1. Unvegetated sand cay. These are ephemeral islands, usually less than 50 m long and often overtopped by swash, and lacking contemporary beachrock. Many on the Belize reefs are second-generation features which have re-formed following the destruction of an earlier larger island by hurricane damage; the location and extent of the former island can be recognised by relict beachrock. Examples are Paunch Cay and Curlew Cay.

2. Vegetated sand cay. These are larger islands with a vegetation of strand scrub and strand woodland, though in most cases the woodland has been removed for coconut plantations. Examples are Nicolas and Tobacco Cays. Smaller vegetated sand cays with maximum dimensions of about 100 m are still subject to major modification or even destruction during hurricanes. Most vegetated islands, however, persist or rapidly re-form in the same locations (e.g. Sergeant's, Goff's, English and Rendezvous Cays). The largest vegetated islands to disappear completely in the 1961 hurricane were St. George's East Cay (110 m long, 0.3 ha) and Cay Glory (105 m long, 0.13 ha).

3. Unvegetated shingle cay. These are small, ephemeral, and located in exposed situations. Often they may be reef-top ridges adjacent to a larger cay. They may from time to time be colonised by patches of *Philoxerus* or *Sesuvium* and mangrove seedlings.

4. Vegetated shingle cay. These are also small, located in exposed situations, often on small patch reefs, and are topographically mobile. Good examples showing substantial changes during 1960 and 1972 are North Spot and Ragged Cays.

5. Sand and shingle cays. These are larger and more stable islands, in more exposed situations than simple sand cays, and consist of islands with a windward shingle ridge and leeward sand area, with or without an intervening depression. Such islands are lacking on the barrier reef in the lee of the offshore atolls, where only simple sand

cays are found. Because of their size and stability these islands are always vegetated. Strand woodland survives on Nicolas Cay, but elsewhere has been replaced by coconuts. Examples are Lime, Hunting and Northeast Sapodilla Cays, the latter with a large interior depression. This type is also typical of the windward sides of the atolls. Most such islands have both modern and relict beachrock, the latter indicating beach retreat on their windward shores.

6. Mangrove cays. On the Belize shelf these are dominated by *Rhizophora mangle*; Jack's Cay is an example. Ebanks (1975, p.278) describes them as "little more than mud mounds colonised by vegetation". They are found only within the lagoon and not on the barrier reef itself.

7. Shelf islands. This term is introduced by Ebanks (1975, pp. 277-278) for islands which "form by sediment accretion on a partly submerged topographic prominence" on a wide shallow shelf. These islands are located on the shallow shelf north of Belize, 3.5-5 km back from the reef edge. They are elongate islands, parallel to the shelf edge, with a windward sand ridge of variable height and width, generally less than 2 m above sea level but exceptionally reaching 6 m. Their leeward sides are formed by mangroves, bays and intertidal flats. Examples include Ambergris Cay, Cay Chapel and Cay Caulker, and Ebanks draws attention to similar shelf islands in the Bahamas and Florida. Previously they had been included in the general category of mangrove-sand cay by Vermeer (1959, pp. 35-39) and Stoddart (1965, p.139).

8. Mangrove cay with dry sand areas. Many mangrove islands have low-lying sand areas, often but not exclusively on the windward side, and usually flat and featureless. These cays are found in fairly protected situations, and may be a late stage in the evolution of ordinary mangrove cays. Frequently the dry-land areas have been cleared and planted to coconuts. Examples are Weewee, Buttonwood, Hatchet, Wild Cane and Frenchman's Cays.

9. Mangrove range. These are extensive and complex arrays of mangrove islands, often with intermittent low sand ridges on their windward sides. They probably owe their location and arrangement to pre-existing topographic variations in the substrate. The islands are separated by partly enclosed bays and lagoons, rather than by intertidal flats, and also by sinuous, deep, narrow tidal channels known as 'bogues'. Tobacco Range and Water Range are typical mangrove ranges; bogues are particularly well seen in the Drowned Cays, as well as in the extensive mangroves of Turneffe.

10. Moat islands. This term has been applied to characteristic associations of leeward sand area, interior mangrove swamp, reef-top shallow lagoon or moat, and windward-reef-edge shingle ridge formed on small patch reefs in the southern shelf lagoon (Stoddart 1965). East and West Snake Cays are good examples. Topographically these islands have features in common with reef islands on the Queensland coast (Steers 1937) and in Djakarta Bay (Umbgrove 1928). The Snake Cays owe

their distinctiveness to their relatively exposed situation in deep water facing the open southern shelf, which allows the formation of shingle ridges on the windward reef edges; the other features have formed in the lee of these ridges.

11. Coastal barrier islands. On the Belize coast the term 'cay' is applied to any island, not only those of reef origin. Many islands near the mainland coast are barrier beaches or detached cusped headlands, formed of terrigenous sediments (High 1975). Harvest Cay is an example.

B. Topographic change

These surveys have shown considerable topographic change on almost all islands of the coastal shelf and barrier reef for which we have comparative data. Of 24 islands mapped in 1960-61 and again in 1972, 11 decreased in area and 13 increased. The greatest percentage loss was 31 per cent at Rendezvous Cay, and the greatest percentage increase was 160 per cent at North Spot. Aggregating all these islands together, the total area decreased from 35.7 to 33.3 ha, a decrease of 6.6 per cent (cf. the changes on the islands of Glover's Reef, where the total area of six islands declined from 33.6 to 31.8 ha, a decrease of 5.4 per cent: Stoddart et al., 1981). As might be expected, the percentage changes are most marked on the smallest cays. Four modes of topographic change may be distinguished:

1. Catastrophic change caused by a single event, in this case Hurricane Hattie of October 1961, which affected barrier reef islands in northern Belize. Small vegetated sand cays were spectacularly eroded and two (Cay Glory and Paunch Cay) disappeared. Recovery took place over the ensuing decade, so that comparative figures between 1961 and 1972 give a very conservative indication of change: Goff's Cay gained 10 per cent, and Sergeant's, English and Rendezvous Cays lost 54, 25 and 31 per cent respectively.

2. Severe marginal erosion by an unknown event, but probably by a specific hurricane. This is widespread on the cays of the southern barrier reef, e.g. Frank's, Lime and Nicolas Cays. This must be a fairly common consequence of hurricanes of lesser severity than Hattie.

3. The re-working of small islets, notably of shingle islands in exposed situations. This may be accomplished by ordinary storms over periods of years, or it may result from single hurricanes. A moderate example is given by North Silk Cay, and more extreme examples by North Spot and Ragged Cay.

4. The accumulation, probably mainly on a seasonal basis, of sand in the form of spits, lobes and bars during ordinary non-catastrophic conditions. This mostly results in ephemeral topographic features, but some become vegetated and stabilized.

There is some suggestion in the number of cays which have disappeared since Owen's surveys in 1830, as well as in the widespread erosion during 1960-1972, that reef islands in the Belize province may be undergoing a period of diminution. It is not possible to say whether this relates to the results of fluctuating sea levels, increased frequency of catastrophic storms, or both, but it has been argued (Stoddart 1964) that an important factor in the present disequilibrium is the destabilising effect of the replacement of natural strand woodland by coconut woodland during the past century.

C. Flora and Vegetation

A total of 178 species of vascular plants has been recorded from the Belize cays, including 32 non-native species (18 per cent) (Fosberg et al. 1981). Of these, 90 species are found only on the barrier reef and shelf islands, and not on the atolls; these include 28 non-native species or 31 per cent; 15 are found only on the atolls and not on the barrier reef and shelf (no non-native species); and 73 are common to the barrier and shelf cays and to the atolls (3 non-native species, or 4 per cent).

The total flora of the barrier reef and lagoon islands comprises 164 species, including 31 non-native species (19 per cent). Of these, 61 are found only on the barrier reef islands (17 of them non-native, or 11 per cent), and 22 only on the shelf islands (4 non-native, or 7 per cent). 37 species are extremely widespread, and include strand grasses and sedges, strand shrubs, common weedy species of coconut woodland, and mangroves. They are:

<i>Acrostichum aureum</i>	<i>Euphorbia mesembrianthemifolia</i>
<i>Eragrostis prolifera</i>	<i>Rhizophora mangle</i>
<i>Paspalum distichum</i>	<i>Conocarpus erectus</i>
<i>Spartina patens</i>	<i>Laguncularia racemosa</i>
<i>Sporobolus virginicus</i>	<i>Terminalia catappa</i>
<i>Cyperus ligularis</i>	<i>Ipomoea macrantha</i>
<i>Cyperus planifolius</i>	<i>Ipomoea pes-caprae</i>
<i>Fimbristylis cymosa</i>	<i>Ipomoea stolonifera</i>
<i>Cocos nucifera</i>	<i>Cordia sebestena</i>
<i>Thrinax radiata</i>	<i>Tournefortia gnaphalodes</i>
<i>Hymenocallis littoralis</i>	<i>Avicennia germinans</i>
<i>Coccoloba uvifera</i>	<i>Stachytarpheta jamaicensis</i>
<i>Batis maritima</i>	<i>Erithalis fruticosa</i>
<i>Philoxerus vermicularis</i>	<i>Ernodea littoralis</i>
<i>Portulaca oleracea</i>	<i>Ageratum littorale</i>
<i>Sesuvium portulacastrum</i>	<i>Borrchia arborescens</i>
<i>Canavalia rosea</i>	<i>Eclipta alba</i>
<i>Sophora tomentosa</i>	<i>Wedelia trilobata</i>
<i>Vigna luteola</i>	

It is clear that the native woodland of the cays has been greatly disturbed by planting of coconuts, and on most islands has entirely disappeared. Its main components probably included *Thrinax radiata*, *Coccoloba uvifera*, *Ficus* sp., *Neea choriophylla*, and *Bursera simaruba*. Strand shrubs are represented mainly by *Tournefortia gnaphalodes*, *Suriana maritima*, *Conocarpus erectus* and *Borrchia arborescens*. The complete absence of *Scaevola plumieri* from these islands is remarkable (it occurs on the north coast of Yucatan, on Alacran and Cayo Arcas, and in the Cayman Islands to windward), as is the rarity of *Chrysobalanus icaco*.

The plants of the dry mangrove cays and the mangrove ranges are quite distinctive, with many more grasses, sedges and succulents than the sand cays of the reef edge. Species which are characteristic of the dry mangrove cays (but most of which are very widespread) are *Eragrostis prolifera*, *Eustachys petraea*, *Paspalum distichum*, *Spartina spartinae*, *Fimbristylis cymosa*, *Fimbristylis spadicea*, *Thrinax radiata*, *Batis maritima* and *Pluchea symphytifolia*. Two species (*Salicornia perennis*, *Lippia strigulosa*) are found only on these islands. Conversely, some species which are common on the reef-edge sand cays are absent from the dry mangrove cays. These include *Cakile lanceolata*, *Canavalia rosea*, *Bursera simaruba*, *Pouteria rivicoa*, *Morinda citrifolia* and *Ambrosia hispida*.

It is also instructive to compare the plants recorded on the two mangrove ranges visited, Tobacco Range and Water Range. 33 species are recorded in total, with 15 in common. Apart from the mangroves, these are *Eustachys petraea*, *Paspalum distichum*, *Cyperus planifolius*, *Thrinax radiata*, *Batis maritima*, *Salicornia perennis*, *Suriana maritima*, *Euphorbia mesembrianthemifolia*, *Erithalis fruticosa* and *Borrchia arborescens*. A larger sample would undoubtedly include as characteristic plants of these islands *Eragrostis prolifera*, *Phragmites* cf. *australis*, *Spartina spartinae*, *Cladium jamaicense*, *Sesuvium portulacastrum*, *Pithecellobium keyense*, *Ernodea littoralis*, and others. It is particularly interesting to observe the long term effects of hurricane damage on Tobacco Range, where mortality of mangroves in 1961 has led to their replacement by *Batis maritima*, even though the dead tree trunks still stand.

We have already noted the existence of a fairly steep rainfall gradient from north to south along the Belize coast. The effects of this appear in the distribution of ferns and orchids. Ferns other than *Acrostichum aureum* occur only on Nicolas Cay (3 species), Lime and Wild Cane Cays. Orchids have been recorded only on Frank's, Hunting, Jack's, East Snake and Middle Snake Cays (as well as on Northeast Cay, Glover's Reef). The climbing vine *Rhabdadenia biflora* is only recorded from the southern shelf (Hunting Cay) and Glover's Reef (Southwest Cay).

Finally, the catastrophic damage caused to some of the northern sand cays by Hurricane Hattie has allowed the observation of successional processes over the ensuing decade. The primary coloniser on

bare sand after the storm was *Portulaca oleracea*, together with *Sesuvium portulacastrum* and *Euphorbia mesembrianthemifolia*; these were well established as scattered colonies within five months of the storm. By 1965 *Portulaca* had greatly declined in importance, and the main species present were *Sesuvium*, *Euphorbia* and *Ipomoea pes-caprae*. By 1972 many more species were present, including shrub species such as *Tournefortia*, *Conocarpus* and *Suriana*. The following table gives the number of species recorded on the most damaged islands following Hurricane Hattie:

<u>Island</u>	<u>1962</u>	<u>1965</u>	<u>1972</u>
Sergeant's Cay	4	12	14
Goff's Cay	2	4	10
English Cay	2	5	18
Rendezvous Cay	16	16	17

The opportunity clearly exists to monitor vegetational changes on these islands in the future, as well as topographic change in general, to establish the long-term response of islands to normal as well as to extreme events.

We do not wish in this paper to consider the floristic biogeography of the cays in greater detail. A preliminary paper has been prepared (Stoddart and Fosberg, in press), and a more detailed treatment is in preparation. We can, however, note that there is a very close association between island area and number of species of vascular plants present, and that area appears to be the major control of floristic diversity on islands of the Belize barrier reef and shelf.

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TEN YEARS OF CHANGE ON THE GLOVER'S REEF CAYS

by

D. R. Stoddart, F. R. Fosberg and M.- H. Sachet

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9. Long Cay: sandy island surface with backslope of the windward shingle ridge 1971
10. Long Cay: mud hole and standing water at the east end, seen from the windward shingle ridge 1961
11. Middle Cay: windward shingle ridge with hedge of *Tournefortia* 1971
12. Middle Cay: low lagoon shore with *Conocarpus* 1971
13. Middle Cay: *Rhizophora* at the east end of the lagoon shore 1971
14. Southwest Cay I: seaward rubble shore 1971
15. Southwest Cay I: mangrove pool at the southern end of the island 1961
16. Southwest Cay II: exposed 'rootrock' on the retreating lagoon shore 1971
17. Southwest Cay I: open mangrove 1961
18. Southwest Cay II: beachrock with landward dip on the seaward shore 1961

TEN YEARS OF CHANGE ON THE GLOVER'S REEF CAYS

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ABSTRACT

Scientific studies on the atoll of Glover's Reef, Belize, since an initial survey in 1961 are reviewed. Comparative maps are presented of each of the six islands on the atoll, showing morphology and vegetation, between the 1961 survey and a re-survey in 1971. Most of the islands show shoreline erosion and remodelling of windward shingle ridges as a result of hurricane activity. The recorded terrestrial plants are catalogued for each of the islands, and some extinctions are noted. Species-numbers on the cays are related to area, and are much higher than those for other Caribbean and Gulf of Mexico coral islands, presumably because of higher rainfall.

INTRODUCTION

Glover's Reef (16°45'N, 87°50'W) is one of three atolls off the mainland coast of Belize (British Honduras), central America. When visited in 1961 it was one of the least-known reefs in the Caribbean, in spite of its typical atoll features. It was delineated on charts (Admiralty Chart 1797 of 1929) in the most rudimentary manner, and published scientific literature about it was limited to brief reports on visits by the ornithologist Salvin in 1862, by the Pawnee Expedition in 1925, and by the Mandel Caribbean Expedition in 1940. The account of the atoll published by Stoddart (1962, pp. 17-30, 83-98) was thus necessarily of a preliminary nature.

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Since then, however, there has been a great deal of scientific investigation on Glover's Reef. The CITRE project (Comparative Investigations of Tropical Reef Ecosystems) included the atoll as one of its potential study sites, and reconnaissance visits were made to it in January and June 1971, followed in November 1971 by a planning workshop for 40 scientists held at Long Cay (Smith, in Sachet and Dahl (1974), lists participants). Descriptions of the reefs resulting from CITRE studies were given by Dahl et al. (1974, pp. 55-58), and marine algae and sea-grasses collected during the project were reported by Tsuda and Dawes (1974). In 1972 N. James, R. N. Ginsburg and associates carried out studies of the deep reefs using the deep-diving submersible *Nekton* (James and Ginsburg 1980). Finally, reef structures within the atoll lagoon have been studied by Hughes (1973), Schafersman (1972), Wallace (1974), and Wallace and Schafersman (1977). Apart from studies carried out during the CITRE workshop, terrestrial studies on the cays have been limited to plant collections made by Pippen in 1972 and by Linhart and students in 1973 (Linhart 1980; Fosberg et al. 1981).

This paper reports on the re-survey of the cays carried out during the CITRE workshop in 1971. Comparative maps of all the islands in 1961 and 1971 are presented, together with complete lists of terrestrial plants recorded from each cay (including those reported by Linhart (1980)). All of the islands were mapped by pace-and-compass methods. They were also photographed from the air in colour and black-and-white in 1961 and 1962, and more briefly in 1971. The maps of each of the islands are orientated conventionally (i.e. magnetic north at the top of the diagram).

HISTORY

The early history of the atoll is obscure, as indeed is that of most of the reefs in the western Caribbean. It can possibly be identified as the "Ilbob" or "Ylbob" of maps by Herrera dated 1601-1615 and of De Laet in 1625, and derivative charts (Vindel 1955). It appears as "Longorif" in the *Plano de la Costa de Honduras* of 1756; as "Arrecife de Guaneros" in a map by J. J. de Castillo, dated 1753 (reproduced by Craig 1966, p. 38); and as Glover's Reef by Speer (1771) and Arrecife Largo, Glover's Reef or Long Reef by Jefferys (1775). Speer's map marks three un-named cays; Jefferys's map has five un-named cays in the south and "The Two Spots" at the northern end. The first Admiralty survey by Richard Owen in 1830 adopts the name of Glover's Reef, which then became standard, and also for the first time names Northeast, Long, Middle, and Southwest Cays.

The only event of any significance in the recorded history of the atoll is the wreck of the schooner *Susan*, Captain Harry Maury, which sailed from Mobile on 4 December 1858 with emigrants and filibusters bound for Omoa, Republic of Honduras, wrecked 10-12 miles from the cays on 16 December (Doubleday 1886; Scroggs 1916). The vessel was found by a fishing boat which had taken fish, green turtle and coconuts to the Belize market, and the passengers and crew were taken to Middle Cay.

Table 1. Visitors to Glover's Reef

<u>Date</u>	<u>Visitor</u>	<u>Work</u>	<u>Publication</u>
1858 December	Susan, Capt. Maury		Maury 1859
1862 May	Mary Ann, O. Salvin	Ornithology	Salvin 1864; Coues 1864
1925 April 14-20	Pawnee, H. P. Bingham	Marine fauna	Boone 1927, 1928a-d, Breder 1927
1940 January 18	Mandel Caribbean Expedition	Marine mollusca Reptiles	Haas 1941; Schmidt 1941
1961	D. R. Stoddart S. P. Murray	Geomorphology Vegetation	Stoddart 1962
1969 March	D. M. Devaney	Echinoderms	Devaney 1974
1971 January 17-22	J. Weber A. Antonius	CITRE studies	Dahl et al 1974 Tsuda and Dawes 1974
June 20-27	A. Antonius, A. Dahl, K. Ruetzler		This paper
November 1-13	S. V. Smith and party of 40		
1972	N. P. James, R. N. Ginsburg, Nekton	Deep reef	James and Ginsburg 1980
1972	Pippen	Flora	
1973 July	Y. B. Linhart	Flora	Linhart 1980

This was said to be an island of 30 acres (12 ha), with a "continuous grove of cocoa palms ... [and] entire freedom from underbrush" (Doubleday 1886, p. 212). Here they lived on "conch and green-turtle soup, fish in great variety, cocoa-nuts, yams, plantains, and bread-fruit, all in great abundance", until rescued by H.M.S. *Basilisk*, sent from Belize, on Christmas Day 1858. There are brief accounts of this incident in *Harper's Weekly*, 8 January 1859, p. 22, and 15 January 1859, p. 39, and in the *Mobile Mercury* at the same time [not seen], but the most circumstantial account is contained in letters by Captain Maury published in *The Mobile Daily Register*, vol. 32 (no. 1329), p. 1 for 4 January 1859. We are grateful to Mr M. M. Weinstein, Library of Congress, for copies of these documents.

The present study began with a visit to Glover's Reef by Stoddart and S. P. Murray in 1961. This was a brief reconnaissance supported by the Office of Naval Research and the Coastal Studies Institute of Louisiana State University as part of a wider study of the British Honduras cays, and we are grateful to the late Professor Richard J. Russell and Miss Evelyn Pruitt for making it possible. The second visit took place as part of the CITRE workshop on 1-13 November 1971. The islands were re-mapped and plants collected by Stoddart, Fosberg and Sachet, and we are grateful to Dr Stephen V. Smith, Principal Investigator, for the opportunity to participate in the CITRE planning sessions. We also thank Mr M. Young and Mr R. Coe, of the Department of Geography at Cambridge University, for much cartographic and photographic work, and Mr M. M. Weinstein, Library of Congress, who obtained newspaper records relating to the wreck of the *Susan*.

STRUCTURE AND FORM

The structure of the east coast of the Yucatan Peninsula is controlled by a series of northeast-southwest trending fault blocks, arranged en echelon on the northwestern flank of the Cayman Trench. One of these lineaments underlies the Belize barrier reef south of Gladden Spit, Glover's Reef, and Lighthouse Reef; another the central barrier reef, Turneffe, and Banco Chinchorro; and a third the mainland coast north of Ambergris Cay. Of these, the first is best developed, and in places (as on the east side of Lighthouse Reef) has a seaward-facing scarp nearly 3000 m high. At Glover's Reef itself, the sea floor falls sharply to over 1000 m on the east side of the atoll, but only to shallow saddles of 300-400 m between the atoll and the barrier reef and the atoll and Lighthouse Reef. Wells drilled through the offshore reefs have reached metamorphic rocks probably equivalent in age to the mainland Santa Rosa Group (Carboniferous-Early Permian) at between 777 and 959 m on Glover's Reef, and extrusive volcanics of similar age at 1692 m on Turneffe.

The surface reefs, therefore, stand on fault-block structures, as originally inferred from topography and fully confirmed by seismic investigations (Dillon and Vedder 1972, 1973; Uchupi 1973). The deep well on Glover's Reef showed 260 m of calcareous siltstone of Late

Cretaceous age, overlain by 560 m of Tertiary reef facies; similarly, on Turneffe, 660 m of shale with limestone is overlain by 1030 m of reef facies (Dillon and Vedder 1973, p. 2721). These sequences indicate reef upgrowth on subsiding fault blocks at rates (1-2 cm/1000 yr) and over time periods (ca 60 million yr) comparable to those of upgrowth on open Pacific subsiding volcanoes such as Bikini and Enewetak.

Glover's Reef itself is an elongate rectangular atoll up to 32 km long and 12 km wide, with an area of 260 sq km. It is surrounded by a shallow reef flat, generally about 450-700 m wide but which reaches 1200 m on the eastern (windward) reefs. Living reef reaches the surface at the outer edge of the reef flat for about 150 m on the windward reefs. There is no algal ridge directly comparable to those of some Indo-Pacific atolls, but rather an algal pavement with rhodoliths of *Goniolithon boergesenii*, clearly the functional equivalent of the algal ridge. The leeward reefs are less well-defined and lack the algal-pavement zone (Stoddart 1962, pp. 23, 25-26). There are three gaps through the peripheral reefs; one in the northeast, 1300 m wide; one in the south, 1600 m in width and up to 12 m deep; and a smaller exposed channel at the southeast point.

The lagoon enclosed by the reefs has two components: a shallow shelf or platform 6-8 m deep and generally 1-2 km wide, and a central basin. The platform is similar to the "barrier platform" of the coastal shelf, and is probably a reef surface of last interglacial age on which the present surface reefs have grown. The central basin is probably about 20 m deep (no bathymetric survey has been undertaken), and contains some 700 patch reefs. Variation in patch reef ecology and sedimentology has been studied by Schaefersman (1972), Hughes (1973), Wallace (1974), and Wallace and Schaefersman (1977).

The coral fauna of Glover's Reef is known only in outline. York's (1971) list of the corals of the southern Belize barrier lists 18 genera. With the addition of *Mussa* and *Meandrina* this gives 20 genera recorded from the Belize reefs (Stoddart 1962, p. 19). 13 genera have been recorded from Glover's Reef (ibid), but unpublished CITRE records will undoubtedly increase this total. There are few other marine faunistic records from Glover's Reef. Devaney (1974) records 3 asteroids, 15 ophiuroids, one holothurian and 4 echinoids from collections made in 1969. Collections of crustaceans, molluscs, echinoderms, coelenterates and fishes made during the Pawnee Expedition are listed by Boone (1927, 1928a, 1928b, 1928c) and Breder (1927). Tsuda and Dawes (1974) list four sea-grasses and 100 species of marine algae from the CITRE investigations. Terrestrial records are limited to two reptiles (*Anolis sagrei*, *Ctenosaura similis*) collected by the Mandel Caribbean Expedition in 1940 (Schmidt 1941) and a hummingbird (*Ancathothorax prevosti*) listed by Todd (1942).

There are no environmental records from Glover's Reef. The atoll is under the influence of the Northeast Trades. There is a marked rainy season from June to September, and mean annual rainfall is probably about 2500 mm. Mean tidal range at springs is probably about 0.2 m.

The atoll is frequently affected by hurricanes, and reference to their effects will be made in the accounts of the cays.

There are six small islands on the southeastern reef of the atoll. Their combined area is about 32 ha, and it is with the changing morphology and vegetation of these cays that this paper is concerned.

THE CAYS OF GLOVER'S REEF

There are at present six cays on Glover's Reef, all on the southeast side. Five of these (Northeast, Long, Middle, Southwest I and Southwest II) are sizeable islands 360-600 m long; the sixth (Long Cay North or Small Cay) is an islet 160 m long northeast of Long Cay. In addition to the main islands, Jefferys in his 1775 chart marked "The Two Spots" at the north end of the atoll: these were presumably ephemeral sandbores and no longer exist. Admiralty Chart 1797 of 1929 also marks a further cay lying within the lagoon on the west side of the atoll, 7 km from the northwest corner; it is described as having trees 6 m tall (*West Indies Pilot*, 1956, pp. 459-460). This island did not exist in 1961, though an ephemeral sandbore near its location was known as "Bushy Spot" or "Bushy Cay". Owen in his 1830 chart (Admiralty MS chart H57) also shows no cay at this location. Owen in 1830 also noted two small sandbores between Middle Cay and Southwest Cays. Each of the existing islands was mapped in 1961 and 1971; they are described from north to south.

Northeast Cay (16°45'N, 87°45½'W)

Figures 4-5, Plates 1-2

Northeast Cay is situated at the south end of the unbroken eastern reef of Glover's Reef, on the north side of the entrance between it and Long Cay. It is semicircular in shape, with maximum dimensions of 360 x 200 m. Its southern and southwestern shores, facing the reef and the channel, are formed by a shingle ridge with a maximum height of about 2 m. In 1961 there was evidence of recent shore erosion on the east side of the cay, indicated by shore cliffing, surface sand stripping, and coral blocks on the cay surface; by 1971 the shingle ridge had extended northwards to cover much of this area. A small area of beachrock on the south shore in 1961 had also increased in length to about 90 m in 1971, and a further small exposure had appeared, indicating slight retreat of this shore. The northern shore is low and sandy, and was stable during 1961-1971. The interior of the island is also low and sandy, and there is a small mudhole. The area of the island was 4.73 ha in 1961 and 4.48 ha in 1971. The island is covered with coconut woodland, which is most dense and contains tall trees of *Bursera simaruba*, *Neea choriophylla* and *Thrinax radiata* near the south shore. There is a luxuriant undercarpet of *Wedelia*, *Euphorbia*, *Ambrosia* and grasses. The most extensive shrub on the seaward side of the island is *Tournefortia gnaphalodes* with scattered *Conocarpus*, *Coccoloba* and *Cordia*. There were extensive mats of *Sesuvium* along the lagoon shore. For further details of the island in 1961 see Stoddart (1962, pp. 87-88, figs. 38 and 39).

Forty species of plants have been recorded from the island (21 in 1961, 32 in 1971, and 32 by Linhart in 1973). Of the species collected in 1961 the orchid *Brassavola nodosa* was not found in 1971 or by Linhart in 1973, and the single shrub of *Suriana maritima* on the southwest shore had disappeared by 1971. In the following species list, C denotes a collection and S a sight record; the 1973 records are those listed by Linhart (1980, pp. 62-63). Species marked with an asterisk are not native to the Belize cay flora, but this does not necessarily imply that they have been deliberately introduced on all the islands on which they occur.

<i>Acrostichum aureum</i> 71C 73	* <i>Terminalia catappa</i> 71C 73
<i>Cenchrus incertus</i> 73	<i>Bumelia retusa</i> 71C 73
<i>Eragrostis prolifera</i> 61C 71C 73	<i>Pouteria campechiana</i> 71C 73
<i>Eustachys petraea</i> 71C 73	<i>Cordia sebestena</i> 61C 71C 73
<i>Paspalum distichum</i> 71C 73	<i>Tournefortia gnaphalodes</i> 61S
<i>Paspalum laxum</i> 61C 73	71C 73
<i>Sporobolus virginicus</i> 71C	<i>Stachytarpheta jamaicensis</i> 73
<i>Sporobolus</i> sp. 61S	<i>Pithecellobium keyense</i> 73
<i>Cyperus ligularis</i> 73	<i>Suriana maritima</i> 61S
<i>Cyperus planifolius</i> 61C 71C	<i>Bursera simaruba</i> 61S 71C 73
73	<i>Euphorbia blodgettii</i> 61C 71C
<i>Fimbristylis cymosa</i> 71C 73	<i>Euphorbia mesembrianthemifolia</i>
* <i>Cocos nucifera</i> 61S 71S 73	61C 71C 73
<i>Thrinax radiata</i> 61C 71S 73	<i>Euphorbia</i> sp. 61S 73
<i>Crinum amabile</i> 71C	<i>Passiflora suberosa</i> 61C 71C 73
<i>Hymenocallis littoralis</i> 71C	<i>Conocarpus erectus</i> 61C 71C 73
<i>Brassavola nodosa</i> 61C	<i>Laguncularia racemosa</i> 73
<i>Ficus</i> sp. 61C 71C 73	<i>Erithalis fruticosa</i> 61C 71C 73
<i>Coccoloba uvifera</i> 61S 71C 73	<i>Ernodea littoralis</i> 71C
<i>Neea choriophylla</i> 61C 71C 73	<i>Ambrosia hispida</i> 61C 71C 73
<i>Sesuvium portulacastrum</i> 61C	<i>Borrchia arborescens</i> 71C
71C 73	<i>Wedelia trilobata</i> 61C 71C 73
<i>Chrysobalanus icaco</i> 71C 73	
<i>Mucuna</i> sp. 71S	

Long Cay North (16°45'N, 87°46'W)

Figures 6-7, Plates 3-4

This is a small shingle cay on a detached reef patch in the main channel between Northeast Cay and Long Cay; it was so named by Stoddart (1962, pp. 88-89, fig. 40), though Dahl et al. (1974, p. 56) call it Little Cay and Fosberg et al. (1981) Small Cay. In 1961 it was mainly composed of sand with some shingle in the central part and along the east shore; it formed an island 145 m long and up to 48 m wide, with an area of 0.44 ha. It was probably not more than 1 m above sea-level. It was covered with a scrub of *Suriana maritima* 3 m tall with *Borrchia*, *Tournefortia* and *Conocarpus* and a ground cover of *Sesuvium*, *Euphorbia* and grasses. There were a few juvenile coconuts. By 1971 there had been some erosion on the south shore and considerable accretion on the north, and the greater part of the island was formed of shingle. The position of the group of coconuts on the south shore enables the relative locations to be plotted accurately. The

vegetation is still dominated by *Suriana* scrub, but *Conocarpus* and *Tournefortia* have greatly increased. There were several more juvenile coconuts. The length of the island remained at 145 m, but the maximum width had increased to 63 m and the area of 0.53 ha.

22 species of plants have been recorded from the island (9 in 1961, 16 in 1971 and 19 by Linhart in 1973). *Sophora tomentosa*, which existed as a single plant on the south shore in 1961, had disappeared by 1971. The species recorded are:

<i>Paspalum distichum</i> 71C 73	<i>Philoxerus vermicularis</i> 71C
<i>Sporobolus virginicus</i> 71C 73	<i>Sesuvium portulacastrum</i> 61S 71C 73
<i>Cyperus ligularis</i> 73	<i>Sophora tomentosa</i> 61S
<i>Cyperus planifolius</i> 71C 73	<i>Suriana maritima</i> 61S 71C 73
<i>Cyperus</i> sp. 61S	<i>Euphorbia blodgettii</i> 71C
* <i>Cocos nucifera</i> 61S 71S 73	<i>Euphorbia mesembrianthemifolia</i>
<i>Crinum amabile</i> 71C	71C 73
<i>Hippeastrum puniceum</i> 73	<i>Euphorbia</i> sp. 61S 73
<i>Hymenocallis littoralis</i> 73	<i>Conocarpus erectus</i> 61S 71C 73
* <i>Casuarina equisetifolia</i> 71S 73	<i>Ipomoea macrantha</i> 71C 73
<i>Coccoloba uvifera</i> 73	<i>Ipomoea pes-caprae</i> 71C 73
<i>Batis maritima</i> 73	<i>Tournefortia gnaphalodes</i> 61S 71C 73
	<i>Borrchia arborescens</i> 61S 71C 73

Long Cay (16°45'N, 87°46'W)

Figures 8-9, Plates 5, 7, 8, 9 and 10

Long Cay is situated at the northeastern extremity of the continuous southeast reef of the atoll. When first mapped in 1961 it was 620 m long and varied in width from 70 m in the centre to 150 m at each end; its eastern end was prolonged lagoonward by a low sandy peninsula. The area of the cay was 6.69 ha. The seaward side of the island was formed by a massive double shingle ridge. The outer ridge reached up to 2 m above sea level and the inner ridge 3 m; the shingle complex was 30-40 m along the whole seaward shore. The inner ridge was formed of older and coarser material, with blocks up to 0.6 m in diameter. There was an abrupt junction between the inner margin of the shingle and the low-lying sandy surface of the rest of the cay, especially at the eastern end where there was a depression with standing water. The north shore is low and sandy and faces a shallow bay carpeted with sea-grasses. The morphology of the cay had changed quite considerably by 1971. The seaward shingle ridge had been reworked, especially at its western end where it had been pushed back over the sand surface and had become a triple ridge. Retreat of a few metres had occurred along much of the seaward shore, increasing the length of a beachrock ridge exposed from 180 to 360 m. The greatest change, however, had taken place at the eastern end of the cay, where the shoreline had retreated from 15 to 25 m along its entire length. The northeastern peninsula had also narrowed and moved westwards. As a result the total length of the island had decreased to 600 m, and the width now varied from 65-130 m; the area in 1971 was 5.85 ha.

In 1961 Long Cay was covered with a coconut plantation. The island was inhabited, and the ground beneath the coconuts was kept cleared. Most of the seaward shingle ridges were bare, except for scattered *Tournefortia* and *Coccoloba*, and an extensive area at the eastern end of *Hymenocallis* with *Conocarpus*. The northeastern peninsula was covered with a low scrub of *Suriana*, *Conocarpus*, *Tournefortia* and *Laguncularia*, and indeed resembled Long Cay North. The general aspect of the cay was much the same in 1971. The extensive ridge-crest area of *Hymenocallis* remained, but all the *Coccoloba* and *Tournefortia* of the seaward coast had disappeared. The northeastern peninsula was covered with *Tournefortia*, *Laguncularia*, *Conocarpus* and *Sesuvium*.

In 1971 the mudhole area was found to be partly surrounded by a surface outcrop of phosphate rock, previously overlooked. This has a P_2O_5 content of 21.7% (Scoffin and Stoddart, in prep.). Long Cay is no longer a bird island. Salvin, who visited it on 12 May 1862, found a few terns and some pelicans (Salvin 1864, p. 384; Coues 1864). The date of formation of the phosphate rock is not known. The physiographic changes between 1961 and 1971 must be attributed to hurricanes. Possibly much of the coastal change resulted from Hurricane Hattie in 1961. Antonius (1972) was on Long Cay at the time of Hurricane Laura on 20 November 1971. This had winds of 35 m/sec, for a time reaching more than 50 m/sec, but although some coconut palms were felled the effects were negligible. Long Cay was occupied by a local family in 1961 to look after the plantation. By 1971 an American-owned tourist resort had opened on the cay, with a series of holiday chalets at the east end. These were damaged in Hurricane Laura.

28 plant species have been recorded from the cay (10 in 1961, 21 in 1971, and 22 by Linhart in 1973); in addition there are some collections made by Pippen in 1972. One species found in 1961 (*Sophora tomentosa*) has not been seen since. In addition to the species listed below, the sea-grasses *Thalassia testudinum* and *Syringodium filiforme* occur in shallow water on the lagoonward side of the cay. In the following list species marked 72 were collected by Pippen in that year. For further notes on this island, see Stoddart (1962, pp. 89-91, figs. 41, 42 and 44).

<i>Psilotum nudum</i> 72	<i>Ficus</i> sp. 73
<i>Acrostichum aureum</i> 73	<i>Coccoloba uvifera</i> 61S 71C 73
<i>Spartina patens</i> 71C	<i>Sesuvium portulacastrum</i> 71C 73
<i>Sporobolus virginicus</i> 71C 72	<i>Mucuna</i> sp. 71C
73	<i>Sophora tomentosa</i> 61S
<i>Cyperus ligularis</i> 73	<i>Suriana maritima</i> 61S 71C 73
<i>Cyperus planifolius</i> 71C 72	<i>Euphorbia blodgettii</i> 73
<i>Cyperus</i> sp. 61S	<i>Euphorbia mesembrianthemifolia</i>
<i>Fimbristylis cymosa</i> 71C 72 73	71C 73
* <i>Cocos nucifera</i> 61S 71S 73	<i>Euphorbia</i> sp. 61S 73
<i>Thrinax radiata</i> 71C 73	<i>Rhizophora mangle</i> 73
<i>Hymenocallis littoralis</i> 61S	<i>Conocarpus erectus</i> 61S 71C 72 73
71C 73	<i>Bumelia retusa</i> 71C 72 73

Cordia sebestena 71C 73
Tournefortia gnaphalodes 61S
 71C 73
Erithalis fruticosa 71C 73

Ageratum littorale 61C 71C 73
Ageratum (abnormal) *littorale*
 71C
Borrchia arborescens 71C 72 73
Melanthera nivea 71C

Middle Cay (16°44'N, 87°48'W)

Figures 10-11, Plates '11-13

Middle Cay is located near the centre of the unbroken southeast reef of Glover's Reef. It is aligned northeast-southwest, parallel to the trend of the reef. When mapped in 1961 it was about 415 m long and up to 175 m wide, with an area of 6.03 ha. In 1971 erosion at the southwest point had been counterbalanced by aggradation at the northeast spit, and the overall dimensions and area (5.97 ha) remained the same. The seaward shore is formed by a shingle ridge up to 35 m wide and 2 m high; beachrock outcrops at the foot of this ridge, more extensively in 1961 than in 1971. Most of the rest of the cay is low-lying and sandy, with a low leeward sand beach, but at the southwestern end there is an extensive swamp area with standing water about 170 m long and 45 m wide. In 1961 this was separated from the sea by a belt of tall *Rhizophora*, but by 1971 this had been greatly reduced and the shore showed signs of erosion. The sand spit at the northeast end of the cay had expanded lagoonward during this interval and increased in size.

Most of the island is covered with coconut woodland. In 1961 the seaward shingle was largely bare, except for extensive *Hymenocallis* and *Tournefortia* at the eastern end. This had almost completely disappeared by 1971, but *Tournefortia* had colonised afresh along most of the seaward shore. There had also been much growth of *Laguncularia*, *Conocarpus*, *Rhizophora* and *Borrchia* along the lagoon shore and on the northeast spit. There is a luxuriant ground cover beneath the coconuts. These were the dominant vegetation as early as 1858 when Maury found a "continuous grove of cocoa palms" and "entire freedom from underbush" (Doubleday 1886, p. 212). That the swampy area was also then in existence is shown by Salvin's record of *Acrostichum aureum* in May 1862 (Salvin 1864).

42 plant species have been recorded from the cay (11 in 1961, 40 in 1971, and 32 by Linhart in 1973). *Hibiscus tiliaceus*, collected in 1961, has not been seen since. Plants recorded are:

Acrostichum aureum 1862S
 71C 73
Andropogon glomeratus 71C 73
Cenchrus incertus 71C
Eragrostis prolifera 71C 73
Eustachys petraea 71C 73
Paspalum distichum 71C 73
Paspalum laxum 71C
Sporobolus virginicus 71C
Cyperus ligularis 71C 73
Cyperus planifolius 71C 73
Fimbristylis cymosa 61C 71C 73

**Cocos nucifera* 61S 71S 73
Thrinax radiata 71C
Hymenocallis littoralis 61S
 71C 73
Ficus sp. 71C 73
Coccoloba uvifera 71C 73
Neea choriophylla 71C
Sesuvium portulacastrum 71C
Pithecellobium keyense 71C 73
Sophora tomentosa 71C 73
Suriana maritima 71C 73
Euphorbia blodgettii 71C

<i>Euphorbia mesembrianthemifolia</i>	<i>Tournefortia gnaphalodes</i> 61S
71C 73	71C 73
<i>Euphorbia</i> sp. 61S 73	<i>Stachytarpheta jamaicensis</i>
<i>Hibiscus tiliaceus</i> 61C	61S 71C 73
<i>Passiflora suberosa</i> 71C 73	<i>Diodia serrulata</i> 71C
<i>Rhizophora mangle</i> 61S 71C 73	<i>Erithalis fruticosa</i> 71C 73
<i>Conocarpus erectus</i> 61S 71C 73	<i>Ernodea littoralis</i> 71C 73
<i>Laguncularia racemosa</i> 71C 73	<i>Ageratum littorale</i> 71C
* <i>Terminalia catappa</i> 71C	<i>Ageratum maritimum</i> 73
<i>Bumelia retusa</i> 71C 73	<i>Ambrosia hispida</i> 61S 71C 73
<i>Pouteria campechiana</i> 71C 73	<i>Borrchia arborescens</i> 61S 71C 73
<i>Cordia sebestena</i> 71C 73	<i>Wedelia trilobata</i> 71C 73

There is in addition the casual record in 1858, already mentioned, of *Dioscorea* sp., *Musa* sp., and *Artocarpus altilis* (Doubleday 1886, p. 212).

For further details of Middle Cay, see Stoddart (1962, pp. 92-93; figs. 43-45).

Southwest Cay I (16°42'N, 87°49½'W) Figures 12-13, Plates 14, 15 and 17

Southwest Cays are located at the southwest extremity of the southeast reef of the atoll, immediately east of the broad southern entrance to the lagoon. Southwest Cay I is the easterly of the two. It is a trapezoidal island with maximum dimensions in 1961 of 360 x 270 m. The seaward shore is formed by a low carpet of rubble and shingle rather than by a distinct shingle ridge, as on the other cays, though there was a sector of shingle ridge up to 2 m high at the southern point of the cay. This seaward rubble zone is backed by a zone of swamp and standing water measuring some 230 x 130 m at the eastern end of the island, with a second smaller zone at the western end. Only in the lee of the shingle ridge is the land surface continuous to the lee shore. The lagoon shore is low, sandy, and in 1961 was undercut, with a number of fallen coconuts. By 1971 there were only minor physiographic changes. There was some rearrangement of rubble on the seaward side, and the seaward shingle ridge was much smaller and eroded. The gross dimensions of the island remained the same, and the area was only slightly smaller (8.70 ha compared with 9.02 ha).

The vegetation of the island consists of coconut woodland and mangroves. The western shore has a stand of tall *Rhizophora* closing the entrance to the western marsh. *Rhizophora* was also found at the eastern marsh entrance, together with *Avicennia*, and there was a large clump of *Avicennia* on the seaward shore. The larger marsh was fringed with *Conocarpus* and other shrubs, and many coconuts had recently been planted in it. Changes by 1971 were relatively minor. Much of the mangrove at the entrance to the larger marsh had disappeared, as had most of the *Avicennia* on the seaward shore. There had, however, been extensive colonisation of the shingle ridge by *Cordia* at the south point.

40 species of plants are recorded from the cay, and this total doubtless reflects the diversity of habitat on the island. 16 were recorded in 1961, 24 in 1971 and 34 by Linhart in 1973. Of the species recorded in 1961 only *Euphorbia trichotoma* has not been seen since, but this suggests oversight rather than extinction. In particular the island was less thoroughly collected, except for the west end, than the other Glover's Reef cays. Species in the following list marked 72 were collected by Pippen in 1972. In the following list *Ageratum maritimum* must be considered a dubious record, probably a misidentification of *A. littorale*.

<i>Andropogon glomeratus</i> 73	<i>Euphorbia blodgettii</i> 72
<i>Cenchrus incertus</i> 71C 73	<i>Euphorbia mesembrianthemifolia</i> 73
<i>Eragrostis prolifera</i> 71C 73	<i>Euphorbia trichotoma</i> 61C
<i>Eustachys petraea</i> 71C 73	<i>Euphorbia</i> sp. 61S 73
<i>Paspalum distichum</i> 71C 73	<i>Passiflora suberosa</i> 71C 73
<i>Paspalum laxum</i> 73	<i>Rhizophora mangle</i> 61S 71S 73
<i>Spartina patens</i> 71C	<i>Conocarpus erectus</i> 61S 71S 73
<i>Sporobolus</i> sp. 61S	<i>Laguncularia racemosa</i> 71C
<i>Cyperus ligularis</i> 73	<i>Rhabdadenia biflora</i> 73
<i>Cyperus planifolius</i> 73	<i>Ipomoea pes-caprae</i> 61S 73
<i>Cyperus</i> sp. 61S	<i>Cordia sebestena</i> 61S 71C 73
<i>Fimbristylis cymosa</i> 73	<i>Tournefortia gnaphalodes</i> 61S 71C 73
<i>Fimbristylis</i> sp. 61S	<i>Avicennia germinans</i> 61S 71C 73
* <i>Cocos nucifera</i> 61S 71S 73	<i>Stachytarpheta jamaicensis</i> 71C 73
<i>Hymenocallis littoralis</i> 71S 73	<i>Capraria biflora</i> 71C 73
<i>Myrica cerifera</i> 73	<i>Erithalis fruticosa</i> 71C 73
<i>Coccoloba uvifera</i> 61S 71S 73	<i>Ageratum littorale</i> 71C
<i>Batis maritima</i> 71C 73	<i>Ageratum maritimum</i> 73
<i>Iresine diffusa</i> 61C 72 73	<i>Borrchia arborescens</i> 71C 73
<i>Philoxerus vermicularis</i> 73	<i>Eclipta alba</i> 73
<i>Portulaca oleracea</i> 71S	<i>Wedelia trilobata</i> 71S 73
<i>Sesuvium portulacastrum</i> 61S 73	
<i>Suriana maritima</i> 61S 71S 73	

For further notes on this island, see Stoddart (1962, pp. 93-95, figs. 46-47).

Southwest Cay II (16°41½'N, 87°50'W)

Figures 14-15, Plates 6, 16 and 18

Southwest Cay II is the most southerly island on Glover's Reef. Although immediately adjacent to Southwest Cay I it is of very different character. It is aligned at an angle of 45° to the reef edge, and shingle is only found along the southern shore close to the reef. The rest of the island is sandy, and there is no interior depression or mangrove swamp. When mapped in 1961 the island was 560 m long and had a maximum width of 235 m; its area was 6.66 ha. The narrow southern shingle ridge reached about 1.5 m above sea level. Much of the eastern shore was low and sandy, with many *Rhizophora* seedlings, in spite of being on the seaward side of the island; it faced a broad

shallow reef flat connecting with Southwest Cay I. The western shore is also sandy, but narrow and undercut: in its northern part it was lined with coconut boles and fallen trunks. There were several exposures of relict beachrock on this western shore, indicating both beach retreat and re-alignment as the shoreline moved in a clockwise direction. There was further evidence of shore erosion at the southwest point, though masked in 1961 by a fresh sandspit. Beach retreat was likewise evident on the east shore, as shown by undercut coconuts and small patches of beachrock which unusually showed landward dip. Physiographic changes had been minor by 1971. There had been erosion round the southern part of the cay, and the southern shingle ridge was more extensive; there had also been erosion at the northern end. As a result the overall length of the cay had decreased to 540 m and the area to 6.23 ha. The previous beachrock outcrops were still visible, together with another on the south shore.

The island is entirely covered with coconut woodland. Except in the southern part this has an undergrowth of herbs and grasses. Apart from occasional *Conocarpus* and *Suriana* bushes the only coastal vegetation is a narrow belt of *Rhizophora* on part of the east shore. 40 species of plants are recorded from the island (12 in 1961, 37 in 1971, and 31 by Linhart in 1973), a reflection of the diversity of the ground cover under the coconut woodland. They are:

<i>Andropogon glomeratus</i> 61S 71C	<i>Canavalia rosea</i> 71C 73
<i>Cenchrus incertus</i> 71C 73	<i>Suriana maritima</i> 71C 73
<i>Eragrostis prolifera</i> 71C	<i>Euphorbia blodgettii</i> 61C 71C
<i>Eustachys petraea</i> 71C 73	<i>Euphorbia mesembrianthemifolia</i>
<i>Paspalum distichum</i> 71C	71C 73
<i>Paspalum laxum</i> 71C	<i>Euphorbia</i> sp. 61S 73
<i>Spartina patens</i> 71C	<i>Passiflora suberosa</i> 71C 73
<i>Spartina spartinae</i> 73	<i>Rhizophora mangle</i> 61S 71C 73
<i>Sporobolus virginicus</i> 71C 73	<i>Conocarpus erectus</i> 61S 71C 73
<i>Sporobolus</i> sp. 61S	<i>Terminalia catappa</i> 71C
<i>Cyperus ligularis</i> 73	<i>Ipomoea macrantha</i> 71C 73
<i>Cyperus planifolius</i> 71C 73	<i>Ipomoea pes-caprae</i> 71C 73
<i>Fimbristylis cymosa</i> 71C 73	<i>Ipomoea stolonifera</i> 71C 73
* <i>Cocos nucifera</i> 61S 71S 73	<i>Ipomoea</i> sp. 61S
<i>Hymenocallis littoralis</i> 61S 71C 73	<i>Tournefortia gnaphalodes</i> 71C 73
<i>Coccoloba uvifera</i> 71C	<i>Stachytarpheta jamaicensis</i>
<i>Batis maritima</i> 73	61C 71C 73
<i>Iresine diffusa</i> 71C 73	<i>Capraria biflora</i> 71C 73
<i>Rivina humilis</i> 71C 73	<i>Erithalis fruticosa</i> 71C 73
<i>Portulaca oleracea</i> 71C 73	<i>Ernodea littoralis</i> 71C 73
<i>Sesuvium portulacastrum</i>	<i>Morinda citrifolia</i> 71C
61S 71C 73	<i>Ageratum littorale</i> 71C 73
<i>Cakile lanceolata</i> 61S 71C	<i>Wedelia trilobata</i> 71C 73

Salvin visited this island on 12 May 1862. He found "noddies everywhere ... many thousands in all", and speculated "what must the numbers have been when the Sooty Terns flocked to the same island" (Salvin 1864, p. 383). Coues (1864) listed *Anous stolidus* (on coconuts)

and *Anous tenuirostris* (on mangroves). The brown noddies still inhabit the cay but in small numbers; there are no records of Sooty Terns breeding there. For further details, see Stoddart (1962, pp. 95-98, fig. 48).

SUMMARY AND CONCLUSIONS

These surveys have established the variability of reef islands even over so short a period as a decade. All of the larger islands have decreased in area (Table 2), with the possible exception of Middle Cay, and these changes have been mainly effected by erosion and remodelling of windward coasts during major storms. Change has been most severe at the eastern end of Long Cay, but can be traced on all the islands in changed shore morphology, distribution of windward shingle ridges, and exposure of beachrock. Leeward or lagoon shores, on the other hand, have been more stable, and in some cases leeward sand spits have increased in area (Long Cay, Middle Cay). The islet of Long Cay North is the only one to have increased markedly in size, but it is so small that the change could readily be reversed.

Our data do not allow inferences about colonisation of the cays by new plant species between the surveys, nor do we wish to discuss the floristic biogeography of the islands in this paper. We can, however, record the following local extinctions: *Brassavola nodosa* and *Suriana maritima* on Northeast Cay; *Hibiscus tiliaceus* on Middle Cay; and *Sophora tomentosa* on Long Cay and Long Cay North. All were represented in 1961 by single specimens. *Brassavola* is an uncommon epiphyte; the *Hibiscus* was a single lagoon-shore tree; *Sophora* is a beach legume liable to substrate disturbance. This last effect is also seen in the widespread disappearance of *Tournefortia* and *Coccoloba* on the windward shingle ridges of Long Cay between 1961 and 1971, as a result of topographic change; they did not become locally extinct only because they existed in other habitats on the cay.

The total recorded terrestrial flora of Glover's Reef now stands at 70 species. Of these, 30 per cent (21 species) occur on only one island. Taking the species recorded from all the Belizean atolls (Lighthouse Reef, Turneffe, Glover's Reef), 28 species or 40 per cent of the Glover's Reef flora are recorded only from that atoll: this undoubtedly reflects the state of collecting on the other atolls rather than any local peculiarity on Glover's Reef. There is a simple relationship between number of plant species and area of the cays, though the anomalously low figure of species for Long Cay indicates the effect of coconut planting and clearing on that island. The species diversity figures for the Glover's Reef cays are markedly higher (by a factor of two) than those of other Caribbean and Gulf of Mexico reef island groups, such as the Dry Tortugas, Alacran, the Pedro Cays, and the Morant Cays. This probably results from the much wetter environment of Glover's Reef rather than from differing proximity of islands to source areas. The floristic biogeography of western Atlantic reef islands will form a separate paper; that of the Belize cays in general has been examined by Stoddart and Fosberg (in press).

Table 2. Change on the cays 1961-1971

Island	Area in hectares		Percentage change	Species of land plants according to Linhart (1980)	Total number of species of land plants recorded
	1961	1971			
Northeast	4.73	4.48	-5.2	32	40
Long North	0.44	0.53	+20.8	19	22
Long	6.69	5.85	-12.6	21	28
Middle	6.03	5.97	-1.0	32	42
Southwest I	9.02	8.70	-3.5	35	40
Southwest II	6.66	6.23	-7.1	31	40
Total	33.57	31.76	-5.39	59	70

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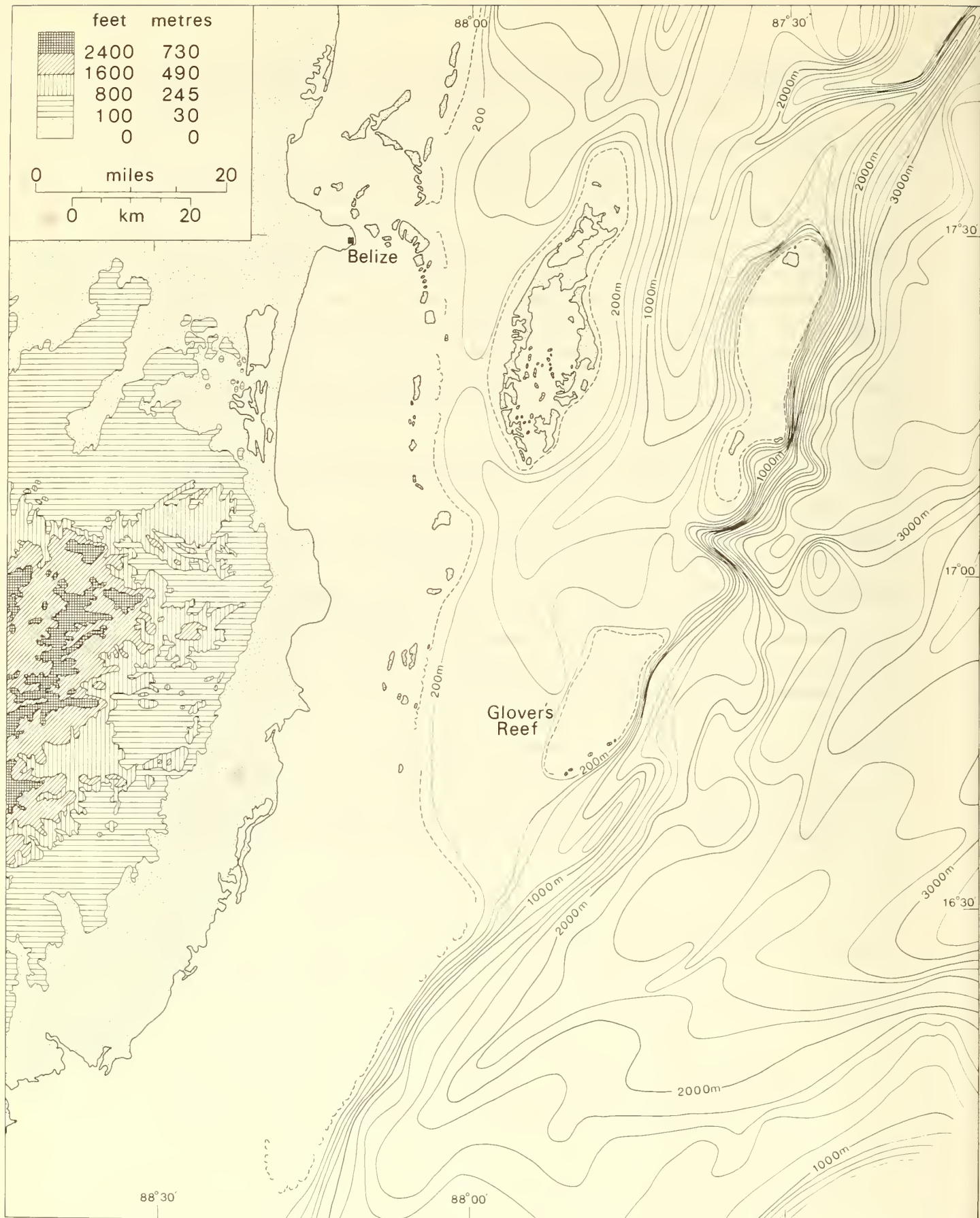


Figure 1. Location and submarine topography of Glover's Reef. After Dillon and Vedder (1973)

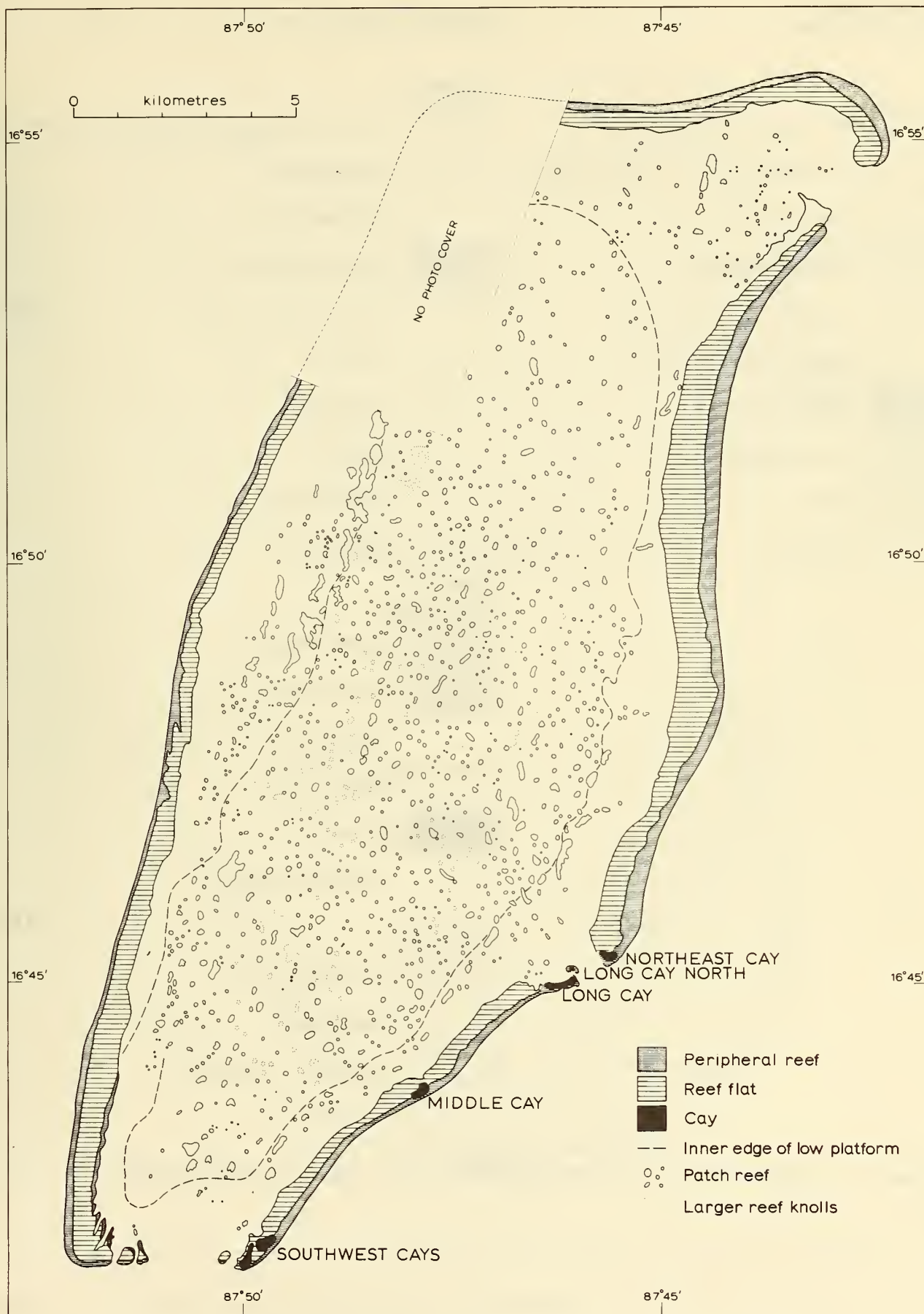


Figure 2. Topography of Glover's Reef. From Stoddart (1962, fig. 37)

PHYSICAL

	Rubble
	Shingle
	Sand
	Fresh sandspit
	Undercut shoreline
	Beach ridge - crest
	Beachrock
	Phosphate rock
	Peat
	Marsh

VEGETATION

Trees

	Coconut; Coconut woodland (dense, open)
	Rhizophora
	Avicennia
	Laguncularia
	Coccoloba
	Cordia
	Morinda
	Ficus
	Terminalia
	Bursera

Shrubs

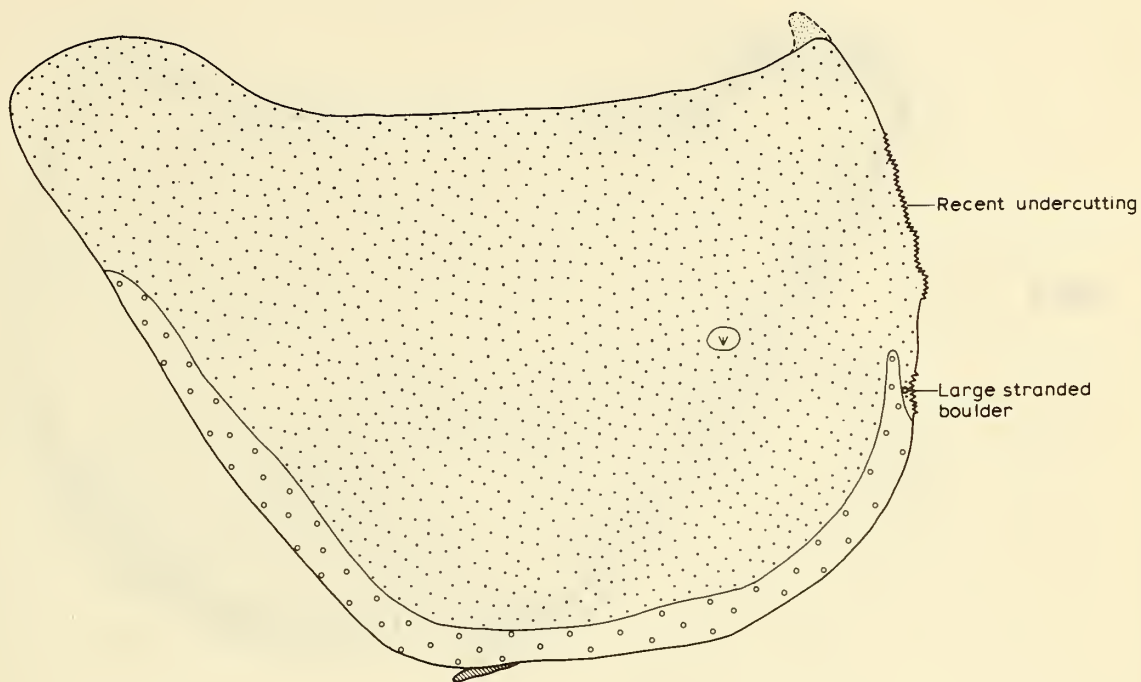
	Tournefortia
	Conocarpus
	Suriana
	Borrnichia
	Sophora
	Indeterminate

Herbs

	Hymenocallis
	Sesuvium
	Herbs and grasses

Figure 3. Legend to the detailed physical and vegetation maps of the cays

1961



1971

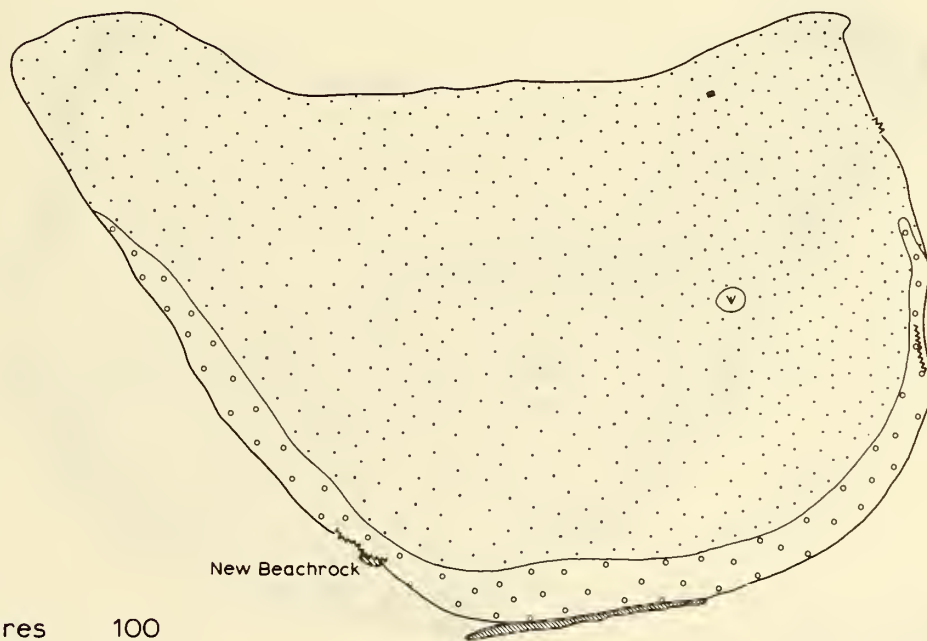
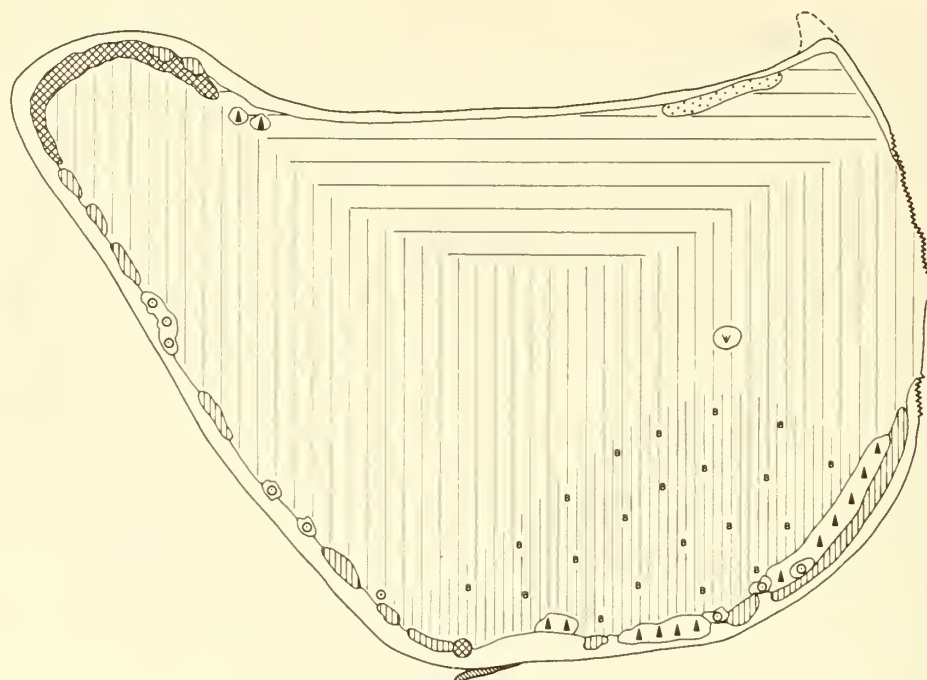
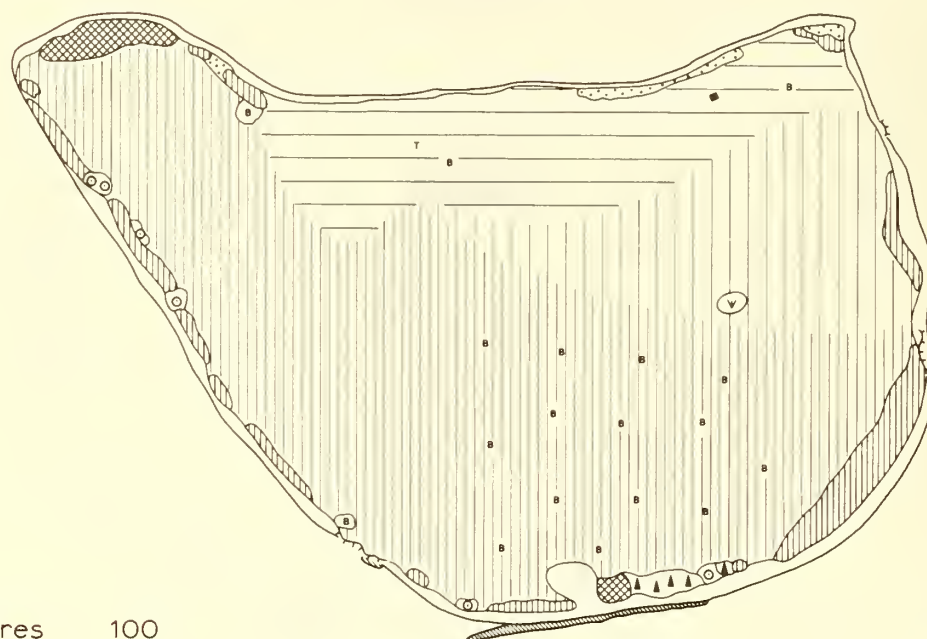


Figure 4. Northeast Cay 1961 and 1971: topography

1961



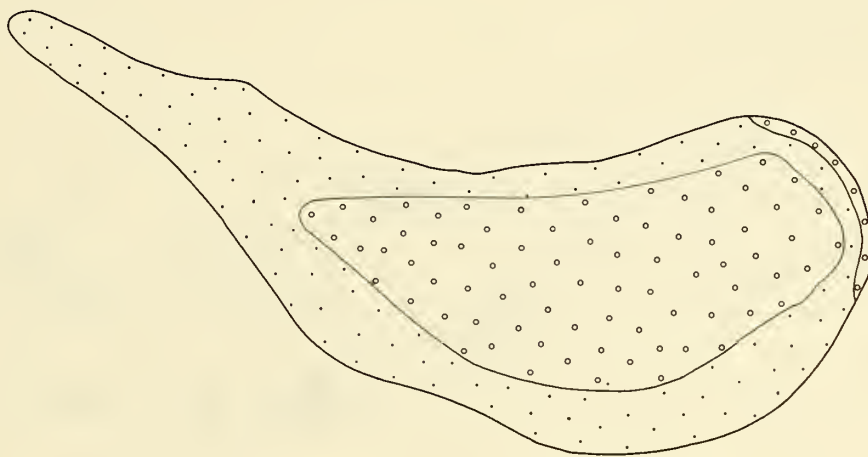
1971



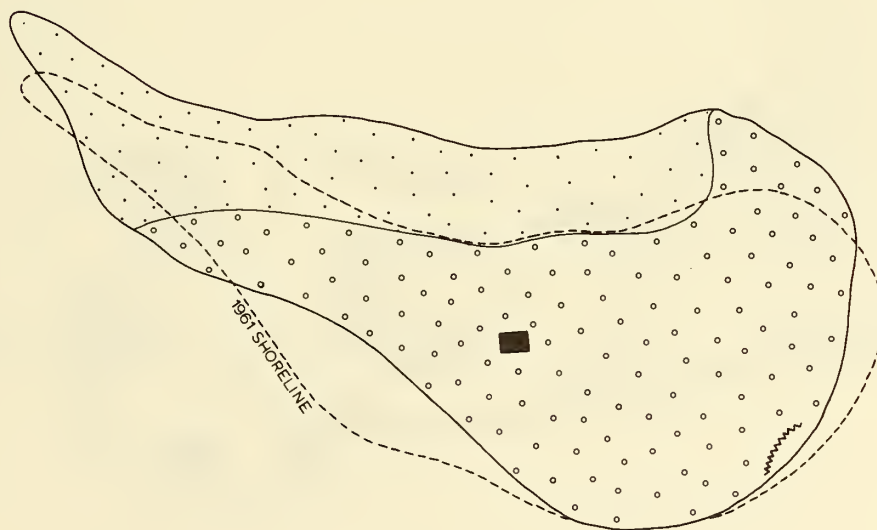
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Figure 5. Northeast Cay 1961 and 1971: vegetation

1961



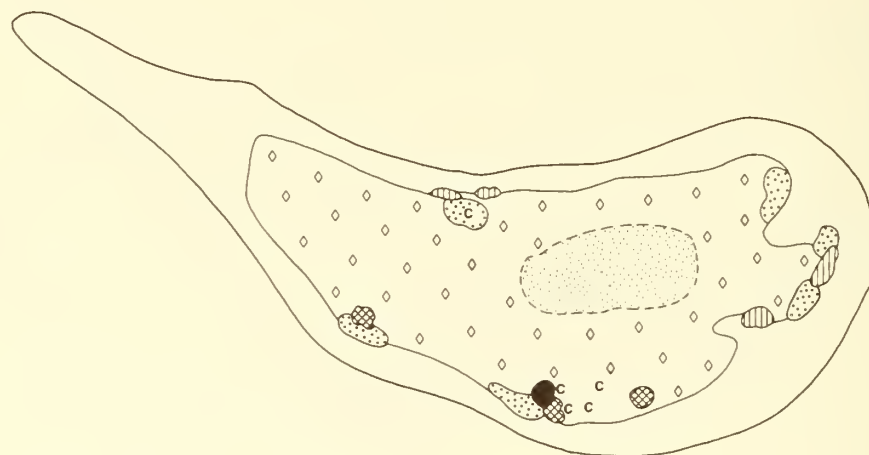
1971



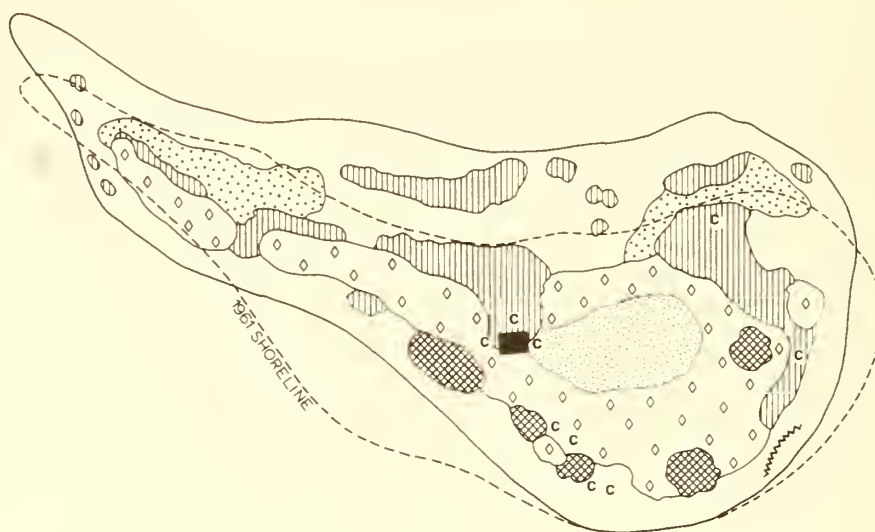
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Figure 6. Long Cay North 1961 and 1971: topography

1961



1971



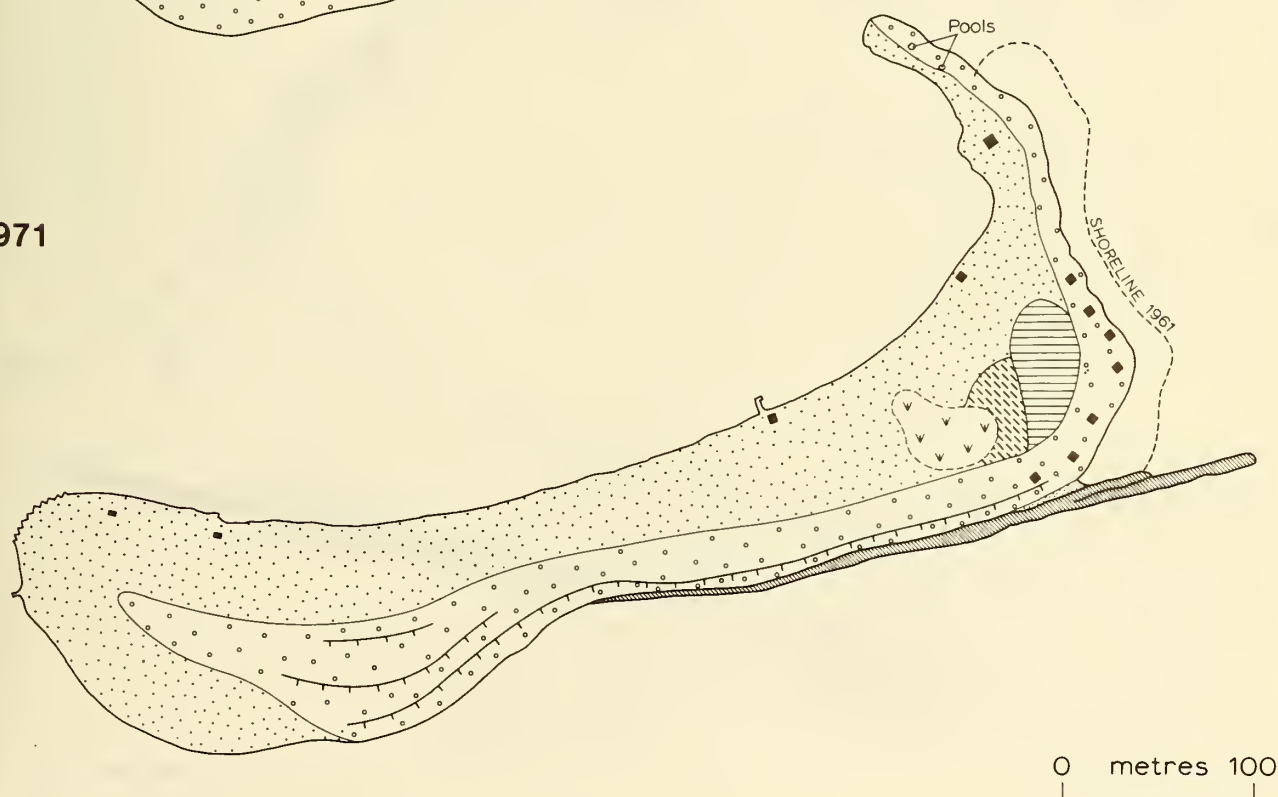
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Figure 7. Long Cay North 1961 and 1971: vegetation

1961



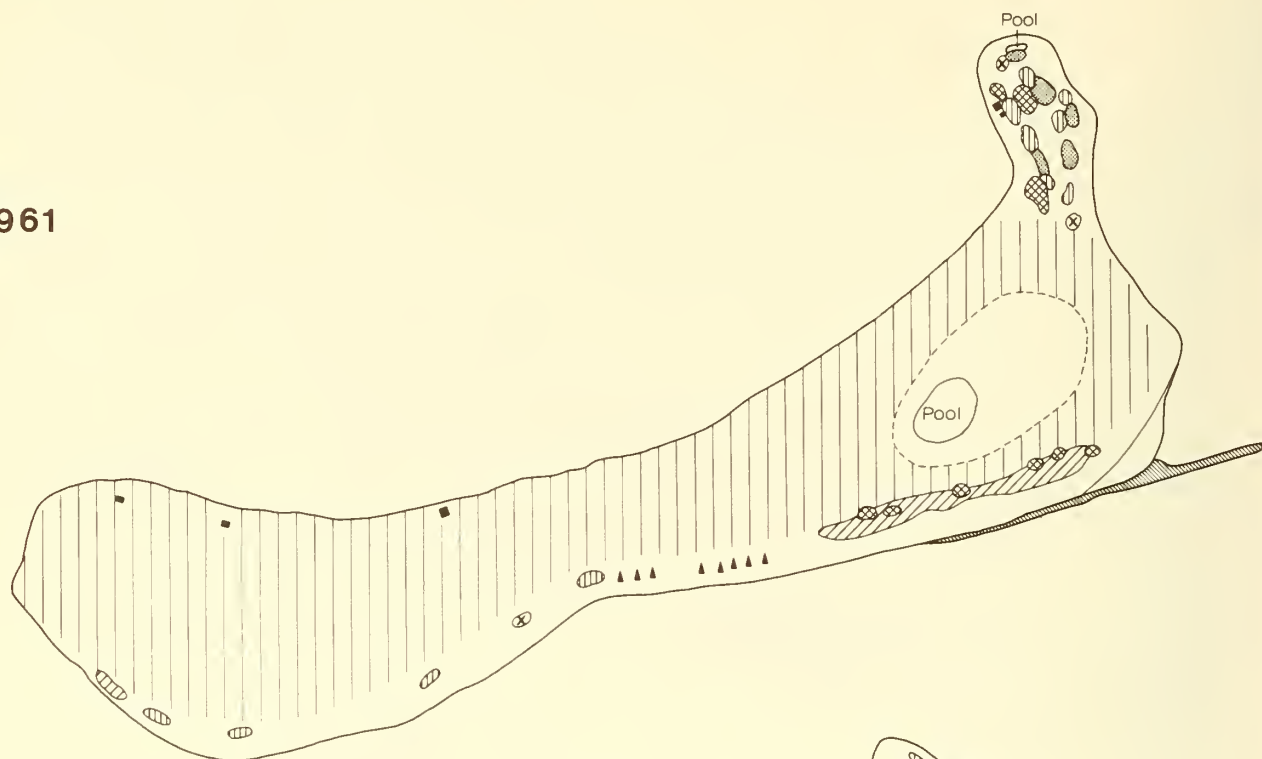
1971



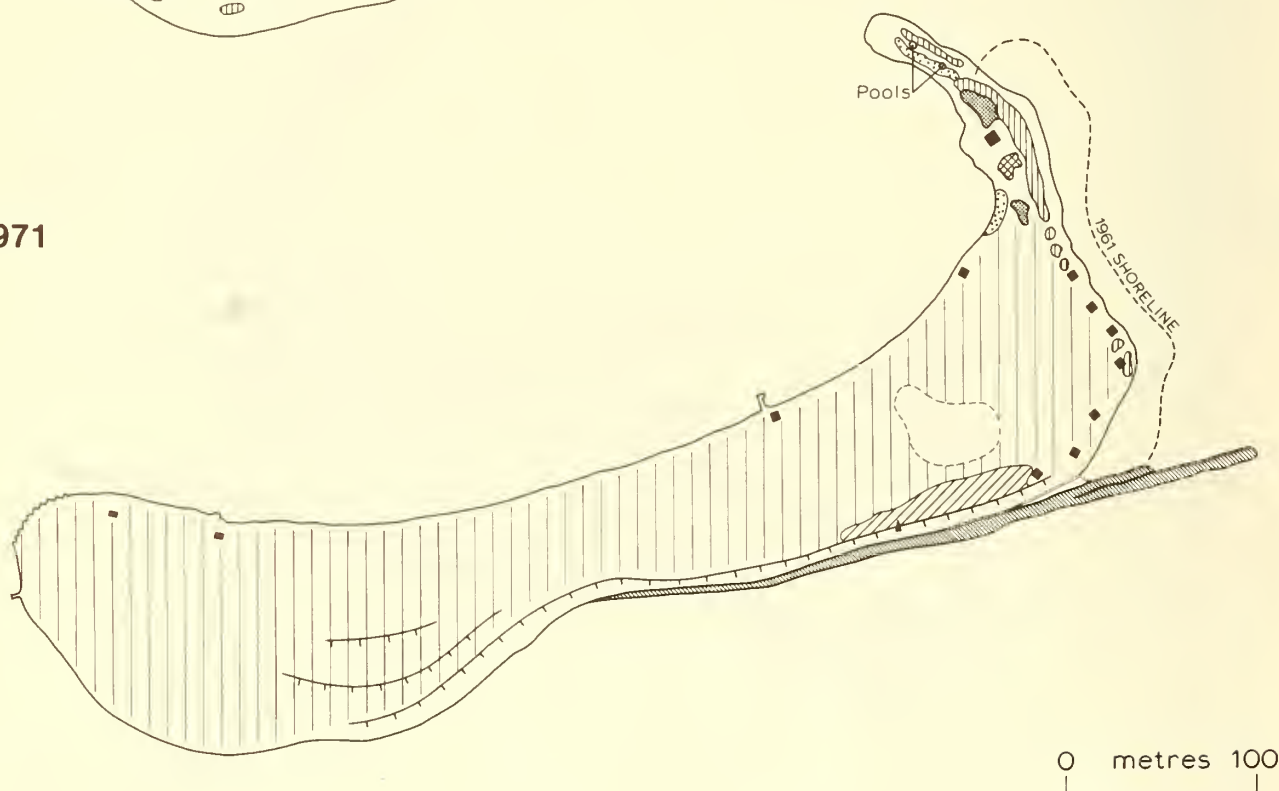
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Figure 8. Long Cay 1961 and 1971: topography

1961



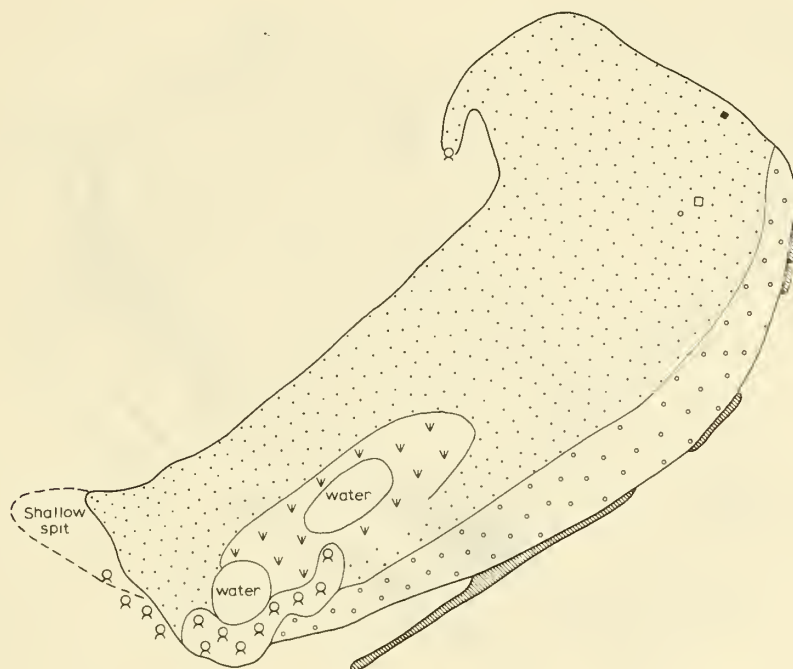
1971



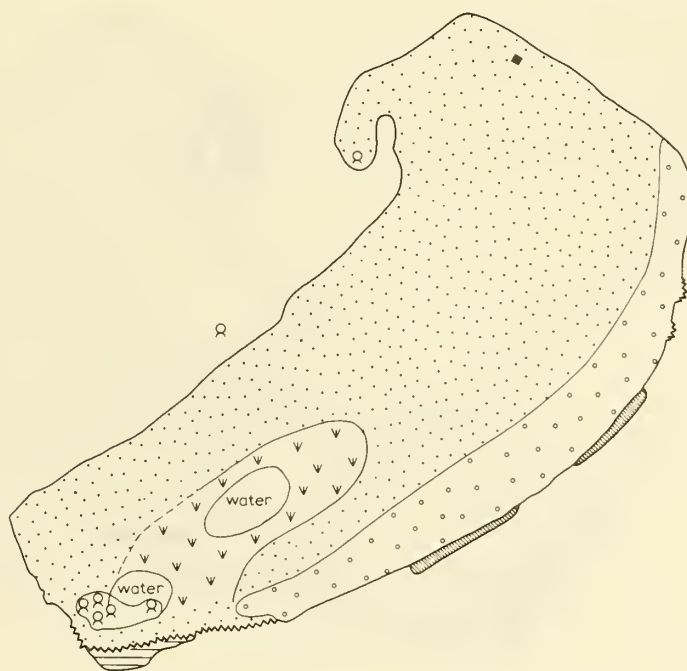
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Figure 9. Long Cay 1961 and 1971: vegetation

1961



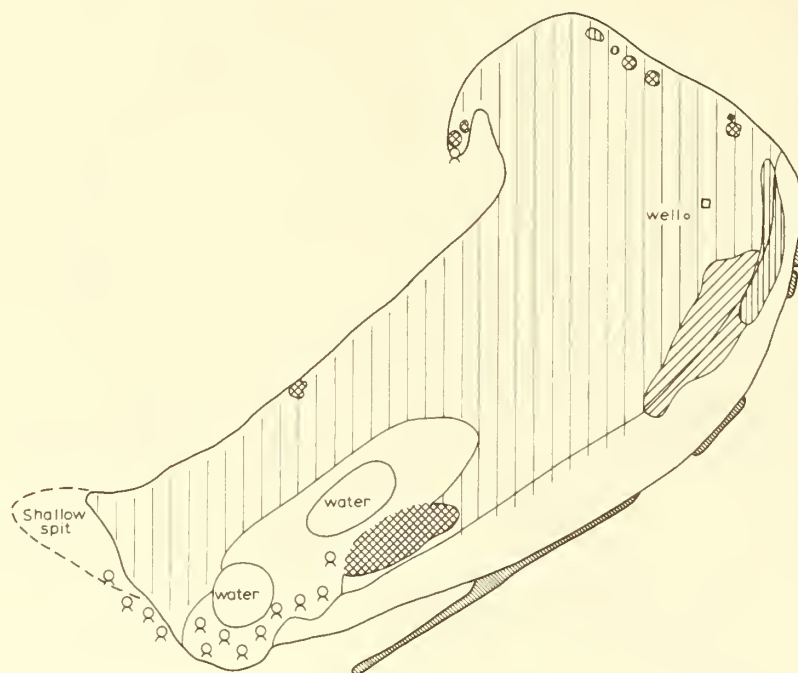
1971



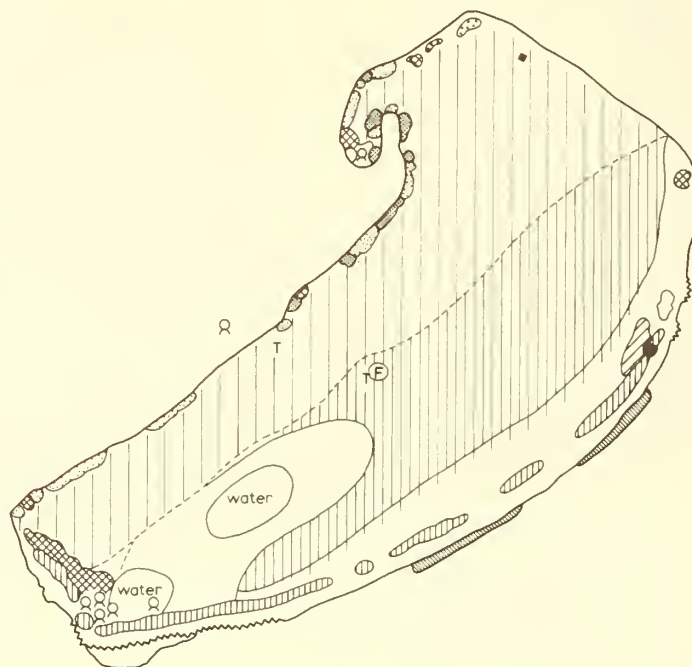
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Figure 10. Middle Cay 1961 and 1971: topography

1961



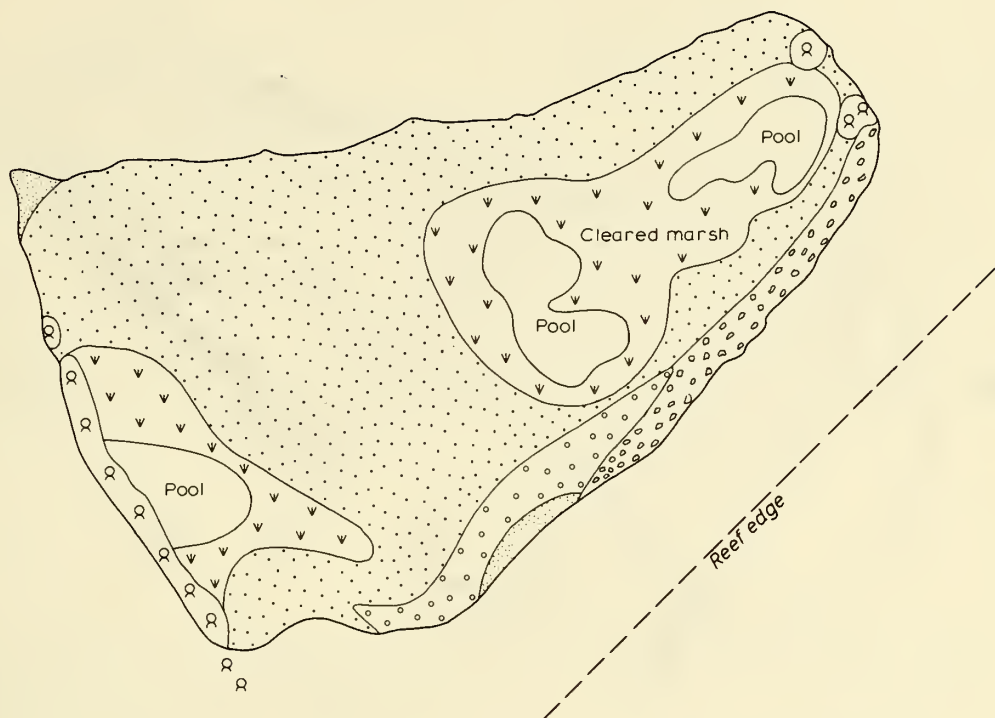
1971



0 metres 100

Figure 11. Middle Cay 1961 and 1971: vegetation

1961

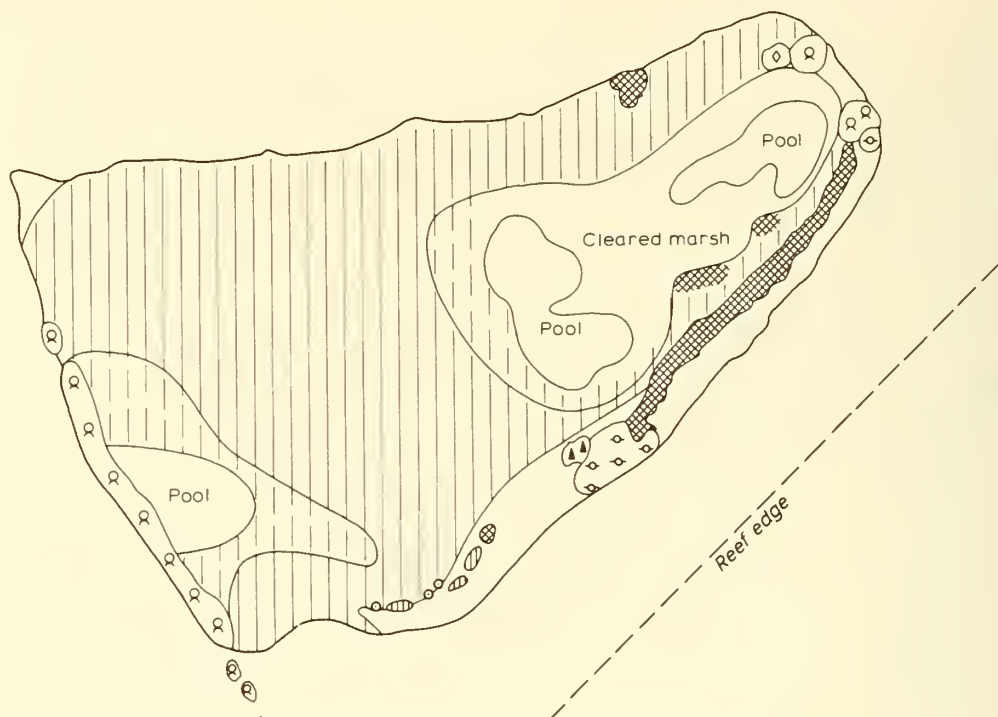


1971

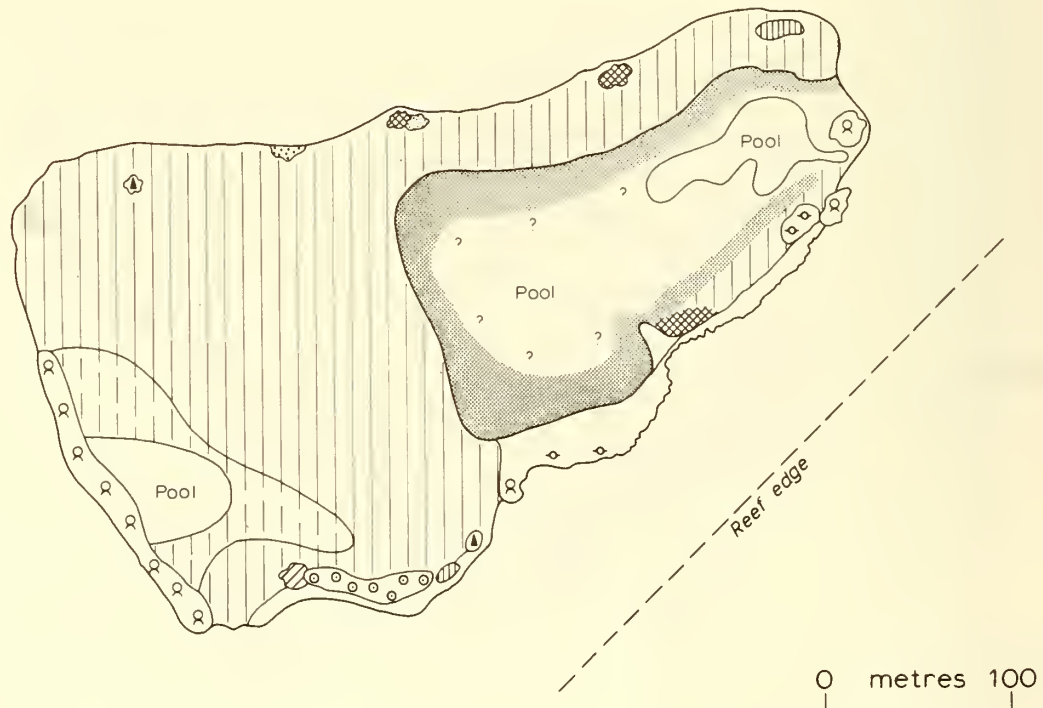


Figure 12. Southwest Cay I 1961 and 1971: topography

1961



1971



0 metres 100

Figure 13. Southwest Cay I 1961 and 1971: vegetation

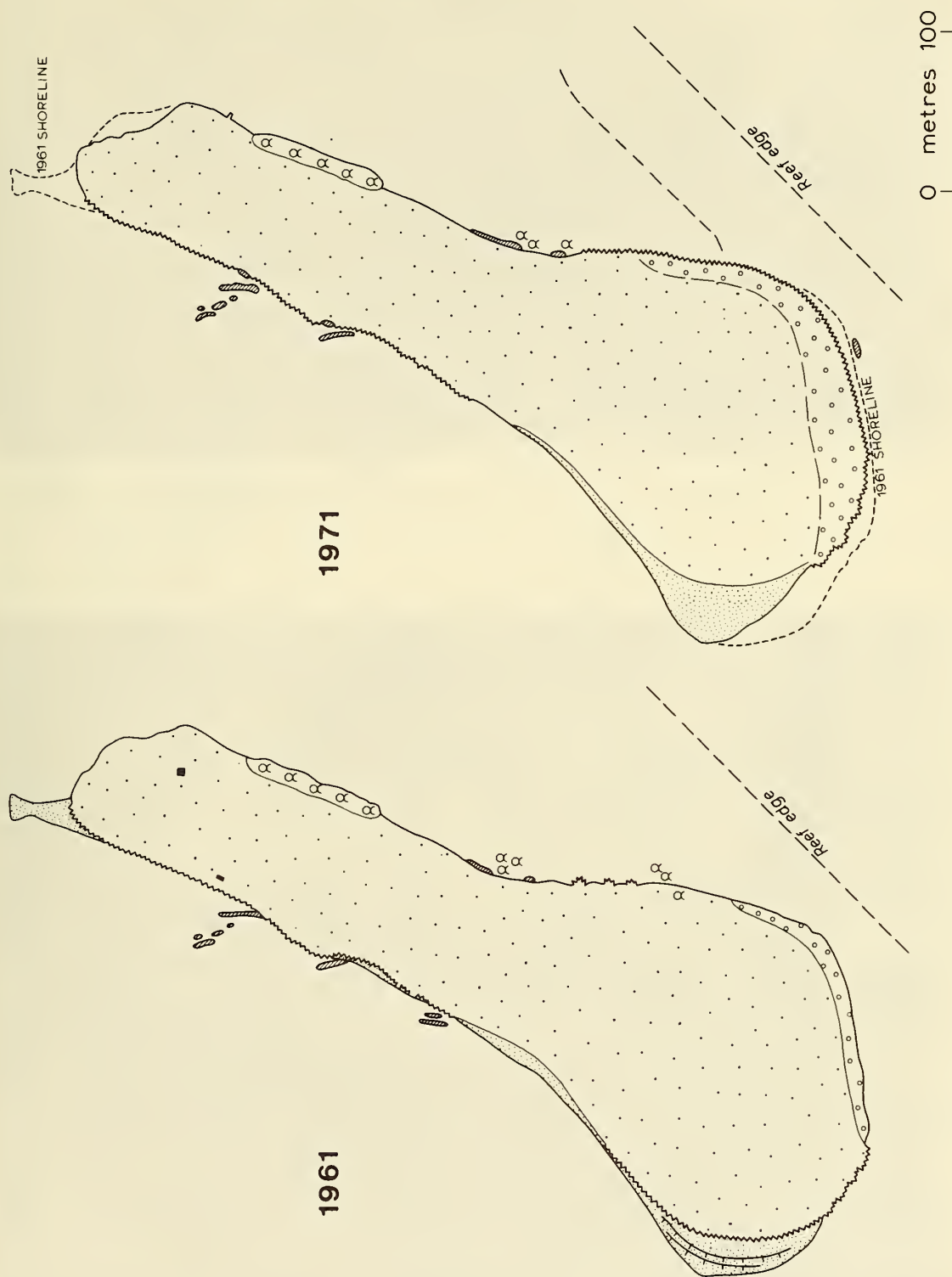


Figure 14. Southwest Cay II 1961 and 1971: topography

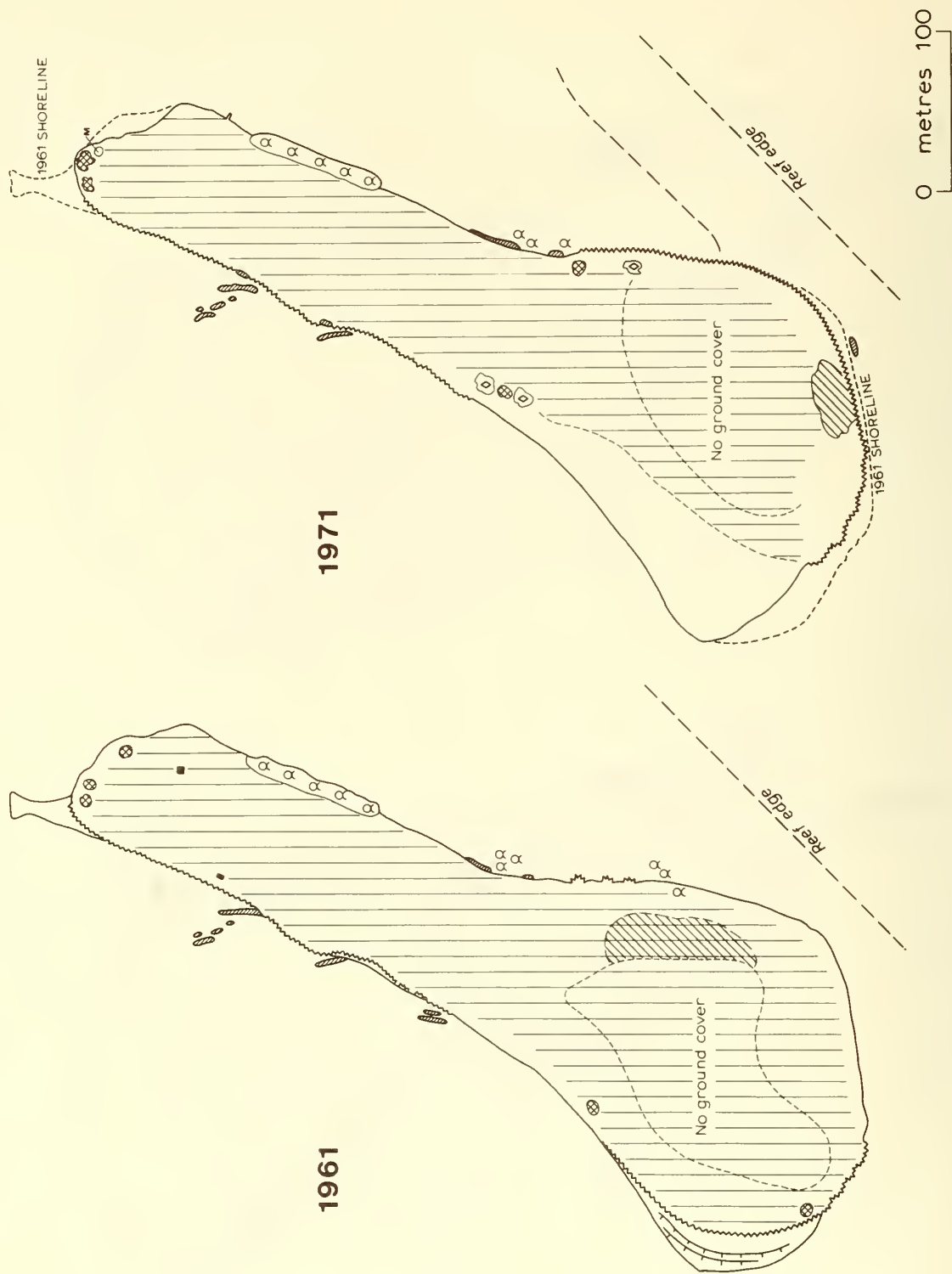


Figure 15. Southwest Cay II 1961 and 1971: vegetation

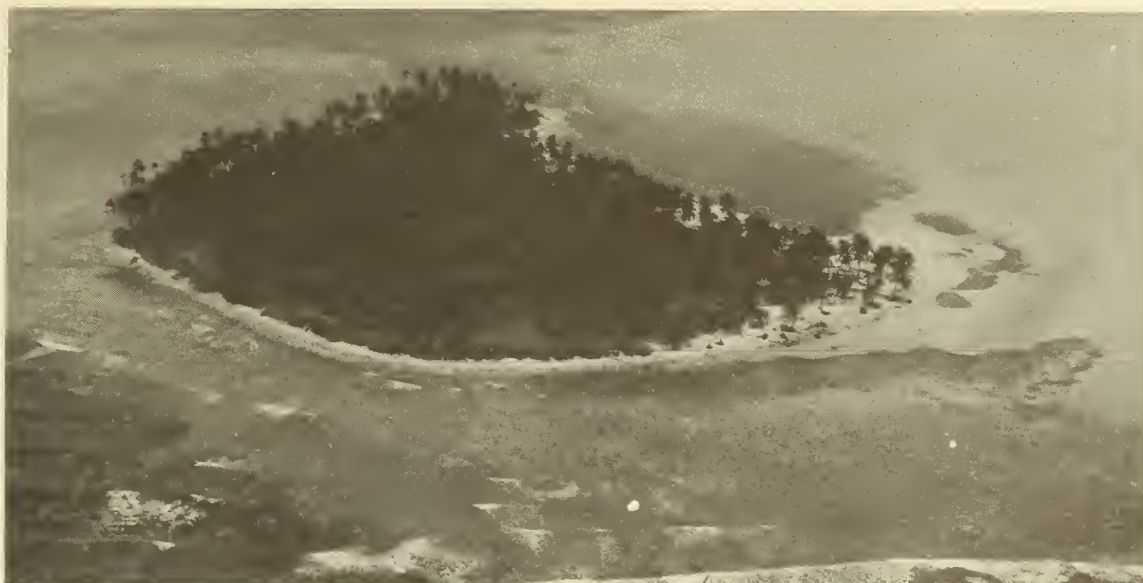


Plate 1. Northeast Cay: aerial view from the east 1961



Plate 2. Northeast Cay: storm block and shore erosion on the east side 1961



Plate 3. Long Cay North: *Suriana* scrub on the north shore 1961



Plate 4. Long Cay North: the south shore in 1971

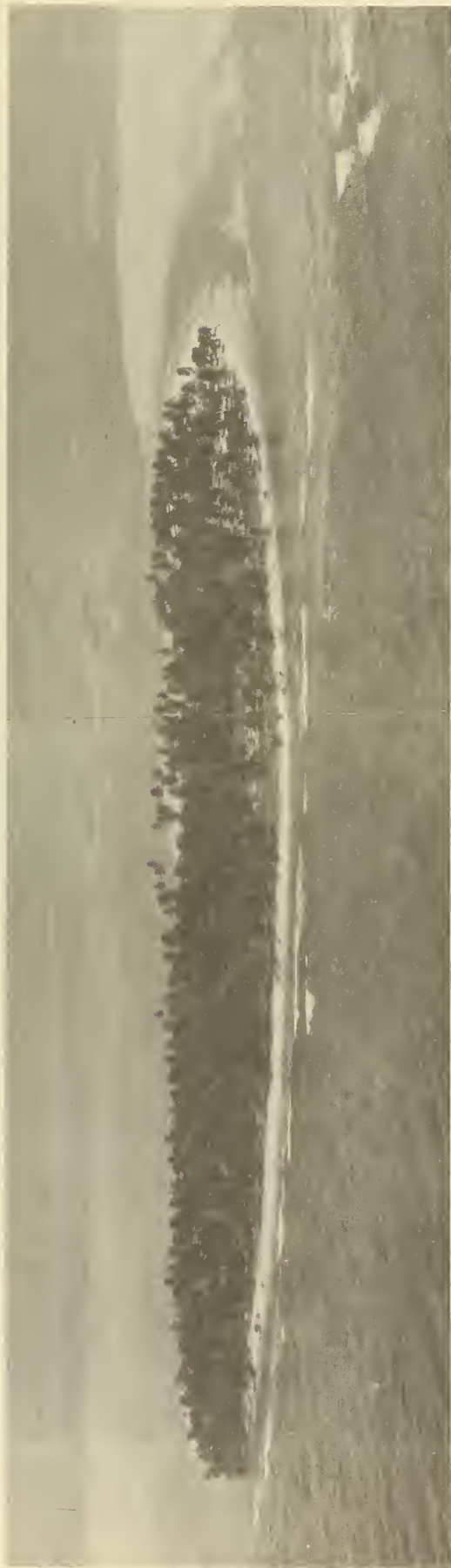


Plate 5. Long Cay: aerial view from
the southeast 1962



Plate 6. Southwest Cay II: aerial
view from the southeast 1962

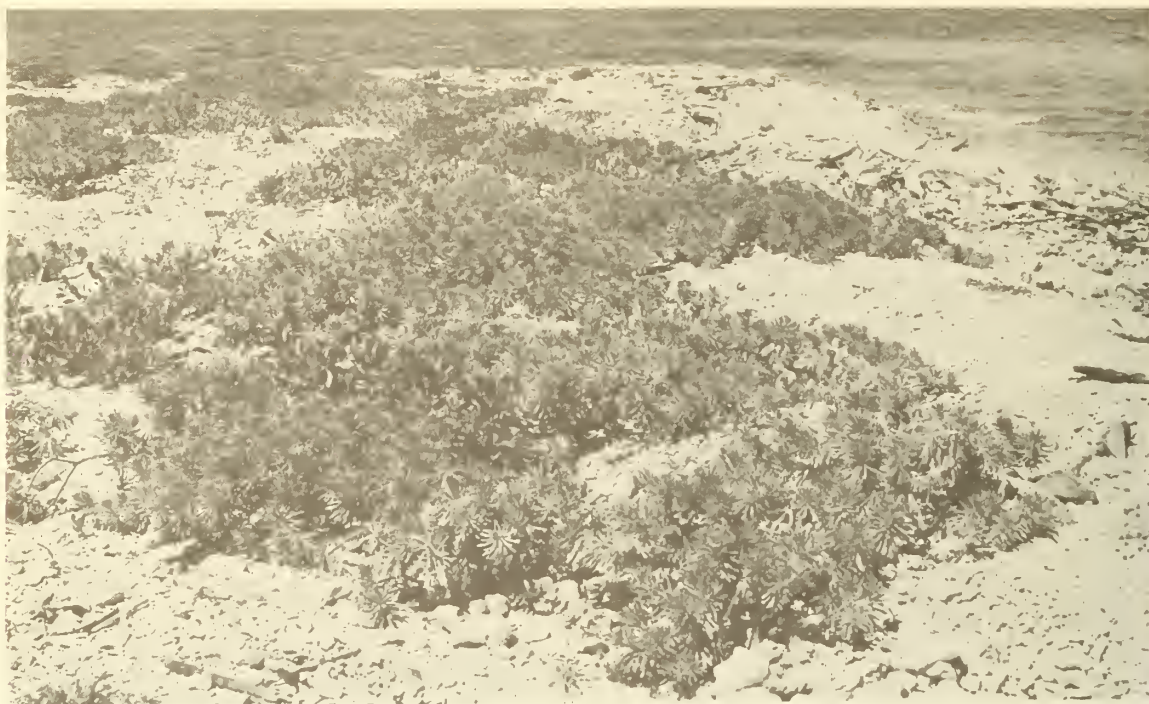


Plate 7. Long Cay: *Tournefortia* on the northeast spit 1961



Plate 8. Long Cay: upper surface of the windward shingle ridge 1961



Plate 9. Long Cay: sandy island surface with backslope of the windward shingle ridge 1971



Plate 10. Long Cay: mud hole and standing water at the east end, seen from the windward shingle ridge 1961



Plate 11. Middle Cay: windward shingle ridge with hedge of *Tournefortia* 1971



Plate 12. Middle Cay: low lagoon shore with *Conocarpus* 1971



Plate 13. Middle Cay: *Rhizophora* at the east end of the lagoon shore 1971



Plate 14. Southwest Cay I: seaward rubble shore 1971



Plate 15. Southwest Cay I: mangrove pool at the southern end of the island 1961



Plate 16. Southwest Cay II: exposed 'rootrock' on the retreating lagoon shore 1971



Plate 17. Southwest Cay I: open mangrove 1961



Plate 18. Southwest Cay II: beachrock with landward dip on the seaward shore 1961



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PLANTS OF THE BELIZE CAYS

by

F. R. Fosberg, D. R. Stoddart, Marie-Hélène Sachet, and
David L. Spellman

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PLANTS OF THE BELIZE CAYS

by F.R. Fosberg,¹ D.R. Stoddart,² Marie-Hélène Sachet,¹ and
David L. Spellman³

ABSTRACT

All of the vascular plants known to us from the sand and mangrove cays off the coast of Belize, Central America, are listed, with citations of specimens, sight records, and literature records. 178 species of land plants in 145 genera are listed, together with 4 species and 4 genera of sea-grasses. Citations are by individual islets or cays. These are classified into atoll cays, barrier reef cays, and lagoon cays.

INTRODUCTION

This is an annotated checklist of the vascular plants of the small islands off the coast of Belize, formerly British Honduras, Central America, as known to date. It is based principally on specimens and observations collected during a series of investigations on these islands by Stoddart in 1959, 1960, 1961, 1962, 1965, 1971 and 1972; by Sachet in 1971; by Fosberg in 1971 and 1972; and by Spellman in 1972. In addition specimens are cited collected by Dr John Dwyer and his students in 1967 and 1980, and by R.W. Pippen in 1972, James Pringle in 1979-80, and by several other visitors to the area. Citations of literature records are also included, notably those listed by Linhart (1980) based on a visit to Glover's Reef in 1973. When we have not

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seen the specimens we have adjusted the nomenclature as best we could to that based on actual specimens that we have seen. We cannot, of course, vouch for the correctness of these identifications, or of our interpretations of them. Nor can we vouch for the correctness of the numerous sight records included, but since the flora is a small and simple one, they are probably mostly reliable. The records cited from literature refer to the papers listed at the end of this paper.

Entries cited with a generic name and sp. are mostly for literature citations by genus only. In a few instances, e.g., "*Ficus* sp. probably new", no binomial is available for the species, or as in the case of *Eugenia* sp. our material is inadequate for determination. When we are reasonably certain that species are of human introduction, their names are preceded by an asterisk.

The herbarium symbols in parentheses after the specimen citations, indicating where the specimens are deposited, are those in Index Herbariorum, ed. 6, by Holmgren and Keuken, *Regnum Vegetabile* 92 (1974), except for the symbol Fo, which indicates specimens still in possession of the authors. These latter will mostly be deposited eventually in the Pomona College Herbarium (POM).

In listing the species we have made every effort to use the names that seem to us correct according to our ideas of the taxonomy of the plants and following the International Code of Botanical Nomenclature. We have cited few synonyms, only those that we know to have been used in records of the plants of these cays or that are necessary to clarify difficult applications of names. We hope that we have caught and corrected all inconsistencies resulting from the many revisions of this list.

We gratefully acknowledge the courtesy of R.W. Pippen and James Pringle in showing us and permitting us to cite their collections from the cays, and that of John Dwyer in giving us a list of his collections from the area. We appreciate the hospitality of the Missouri Botanical Garden and the privilege of examining specimens housed there. Special thanks must go to Miss Dulcie A. Powell for her patient and meticulous work in assembling and arranging the specimen citations. Stoddart's initial investigations were supported by the British Department of Scientific and Industrial Research, the Royal Society of London, the Office of Naval Research, and the Coastal Studies Institute of Louisiana State University. We also acknowledge the financial support of the Smithsonian CITRE (Comparative Investigations of Tropical Reef Ecosystems) Programme in 1971, and of the Smithsonian IMSWE (Investigations of Marine Shallow Water Ecosystems) Programme in 1972, of which this investigation is a part.

PSILOTACEAE

Psilotum Sw.

Psilotum nudum (L.) Beauv.

Atoll Cays. -- Glover's Reef: Long Cay, S. end, Pippen 907 (WMU), "25 July '72, rare, 9 depauperate plants, sporulating on 2 burned out decaying coconut stumps."

POLYPODIACEAE

Acrostichum L.

Acrostichum aureum L.

(Mangrove fern, swamp fern)

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg & Sachet 53849 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1631 (US), Salvin (1864) in 1862, Linhart (1980, p. 162). Lighthouse Reef: Half Moon Cay, Stoddart 48 (Fo).

Barrier Reef Cays. -- Northeast Sapodilla Cay, Stoddart sight record in 1960, Spellman & Stoddart 2299 (US, MO, BH, Fo); Frank's East Cay, Spellman & Stoddart 2420 (US, MO); Hunting Cay, Spellman & Stoddart 2477 (US, MO).

Lagoon Cays. -- Cary Cay, Stoddart sight record in 1962 (1963, p. 62); West Snake Cay, Stoddart 18 (Fo) (1965, p. 137).

Nephrolepis Schott

Nephrolepis multiflora (Roxb.) Jarrett ex Morton

(Boston fern)

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2330 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2363 (US, MO, BH, Fo).

Polypodium L.

Polypodium lycopodioides L.

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2332 (US, MO, BH, Fo).

Polypodium polypodioides (L.) Watt var. *polypodioides* (Hard fern, Resurrection fern)

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2336 (US, MO, BH, Fo).

Pityrogramma Link

Pityrogramma calomelanos (L.) Link (Silver-backed fern)

Lagoon Cays. -- Wild Cane Cay, Stoddart 20 (Fo).

ZOSTERACEAE

Halodule Endl.

Halodule wrightii Aschers. (Small sea-grass)

Diplanthera Wrightii (Aschers.) Aschers.

Atoll Cays. -- Glover's Reef: Long Cay, Fosberg 53802 (US, MO, BH, Fo, BM); southeast sector of lagoon, Tsuda 4256 (US) (Tsuda and Dawes 1974).

Barrier Reef Cays. -- Tom Owen's East Cay, Spellman & Stoddart 2279 (US, MO); Frank's Cay, Spellman & Stoddart 2389 (US, MO); Nicolas Cay, Spellman & Stoddart 2323 (US, MO).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54454 (US); Buttonwood Cay, Fosberg & Spellman 54427 (US); Hatchet Cay, Fosberg & Spellman 54397 (US); Little Water Cay, Fosberg & Spellman 54355 (US).

Syringodium Kütz.

Syringodium filiforme Kütz. (Eel grass, Manatee grass)

Cymodocea manatorum Aschers.

Atoll Cays. -- Glover's Reef: Long Cay, Fosberg & Sachet 53850 (US), Tsuda 4165 (US) (Tsuda and Dawes 1974); southeast sector of lagoon, Tsuda 4257 (US) (Tsuda and Dawes 1974).

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2512 (US, MO, BH); South Water Cay, Pringle 1920 (HAM, UNA), 1923 (HAM, MO, UNA); Carrie Bow Cay, Fosberg & Spellman 54443 (US), Rützler 3 (US).

Lagoon Cays. -- Little Water Cay, Fosberg & Stoddart 54358 (US).

HYDROCHARITACEAE

Halophila Thouars

Halophila engelmanni Ascherson

Atoll Cays. -- Glover's Reef: southeast sector of lagoon, Tsuda 4258 (US) (Tsuda and Dawes 1974).

Thalassia König

Thalassia testudinum Banks ex König (Turtle-grass)

Atoll Cays. -- Turneffe Atoll: s.l. Burdon s.n. (K); Indian Cay, Colman in 1937 (BM) (citations from den Hartog 1970, p. 226); Crickozen Creek, Stoddart sight record in 1962 (1963, p. 87); Harry Jones, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash Cay, Stoddart sight record in 1960 (1962a, p. 42); Little Calabash Cay, Stoddart sight record in 1960 and 1962 (1962a, p. 41, 1963, p. 76). Lighthouse Reef: Northern Cay, Stoddart sight records in 1960 and 1962 (1962a, p. 59, 1963, p. 92); Sandbore Cay, Stoddart sight record in 1962 (1963, p. 90); Saddle Cay, Stoddart sight record in 1960 (1962a, p. 63); Long Cay, Stoddart sight record in 1960 (1962a, p. 79); Half Moon Cay, Stoddart sight record in 1960. Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88); Long Cay, Stoddart sight record in 1961 (1962a, p. 91), Tsuda 4164 (US) (Tsuda and Dawes 1974); Middle Cay, Stoddart sight record in 1961 (1962a, p. 93); Southwest Cay I, Stoddart sight record in 1961 (1962a, p. 95); West Channel, Fosberg 53907 (US); southeast sector of lagoon, Tsuda 4255 (US) (Tsuda and Dawes 1974).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight records in 1960 and 1962 (1963, p. 42); English Cay, Stoddart sight record in 1960 (1963, p. 45); Rendezvous Cay, Stoddart sight records in 1960 and 1962 (1963, p. 48); Cay Glory, Stoddart sight record in 1960 (1963, p. 53); South Water Cay, Stoddart sight records in 1960 and 1962 (1963, p. 56), Pringle 1918 (HAM); Carrie Bow Cay, Stoddart sight record in 1960 (1962a, p. 164, 1963, p. 57), Fosberg & Spellman 54441 (US), 54435 (US); Curlew Cay, Stoddart sight record in 1960 (1963, p. 58); South Water Cay, Stoddart sight records in 1960 and 1962 (1963, p. 56).

Lagoon Cays. -- Cay Chapel, Stoddart sight record in 1962 (1969, p. 7); Little Water Cay, Fosberg & Spellman 54359 (US).

GRAMINEAE

Andropogon L.

Andropogon glomeratus (Walt.) Britton, Sterns & Poggenburg (Broom-sedge)

Atoll Cays. -- Lighthouse Reef: Northern Cay, Stoddart sight record in 1960 (1962a, p. 62); Sandbore Cay, Stoddart 553 (Fo) (1962a, p. 57, 1963, p. 90). Glover's Reef: Middle Cay, Sachet & Stoddart 1621 (US, MO, BH, Fo), Linhart (1980, p. 162); Southwest Cay I, Linhart (1980, p. 162); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 98), Fosberg & Stoddart 53860 (US, MO, BH, Fo, BM).

Barrier Reef Cays. -- Goff's Cay, Spellman & Stoddart 2525 (US, MO, BH, Fo); South Water Cay, Stoddart 92 (Fo) (1963, p. 56), Spellman & Stoddart 2210 (US, MO, BH), Pringle 1919 (HAM); Frank's Cay, Spellman & Stoddart 2391 (US, MO, BH); Nicolas Cay, Spellman & Stoddart 2342 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2376 (US, MO, BH, Fo).

Andropogon sp.

Barrier Reef Cays. -- Frank's East Cay, Stoddart sight record in 1961; Frank's West Cay, Stoddart sight record in 1961.

Lagoon Cays. -- South Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

Antheophora Schreb.

Antheophora hermaphrodita (L.) Kuntze

Barrier Reef Cays. -- South Water Cay, Pringle 1926 (HAM, MO); Lime Cay, Spellman & Stoddart 2368 (US, MO BH).

Cenchrus L.

Cenchrus incertus M. A. Curtis

(Sand-burr)

Cenchrus pauciflorus Benth.

Atoll Cays. -- Lighthouse Reef: Northern Cay, Stoddart sight record in 1962 (1963, p. 93, as *Cenchrus*); Sandbore Cay, Stoddart sight record in 1962 (1963, p. 91) and 1965 (1969, p. 17, as *C. tribuloides*); Half Moon Cay, Stoddart 134 (Fo) (1963, p. 98). Glover's Reef: Northeast Cay, Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1625 (US); Southwest Cay I, Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53891 (US), Linhart (1980, p. 162); Southwest Cay, Pippen 896 (US).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2149 (US, MO, BH, Fo), Pringle 1906 (HAM); Lime Cay, Spellman & Stoddart 2364 (US, MO, BH, Fo).

Lagoon Cays. -- Cay Chapel, Stoddart sight records in 1962 (1963, p. 35) and 1965.

**Cymbopogon* Spreng.

**Cymbopogon citratus* (DC) Stapf (Fever grass, Lemon grass)

Andropogon citratus DC.

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54361 (US).

Digitaria Heist. ex Fabr.

Digitaria horizontalis Willd. (Crab grass)

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 133 (Fo).

Distichlis Raf.

Distichlis spicata (L.) Greene (Seashore saltgrass)

Barrier Reef Cays. -- South Water Cay, Pringle 1894 (HAM).

Lagoon Cays. -- Ambergris Cay, West (1977, p. 198, fig. 9.3).

**Eleusine* Gaertn.

**Eleusine indica* (L.) Gaertn. (Goose grass)

Barrier Reef Cays. -- Tobacco Cay, Stoddart 112 (Fo) (1963, p. 55), Fosberg & Spellman 54222 (US); Hunting Cay, Spellman & Stoddart 2444 (US, MO, BH, Fo).

Eragrostis Wolf

Eragrostis ciliaris (L.) R. Br. (Love grass)

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 547 (Fo), 136 (Fo) (1962a, p. 76).

Barrier Reef Cays. -- Tobacco Cay, Stoddart 113 (Fo) (1963, p. 55); South Water Cay, Spellman & Stoddart 2197 (US, MO, BH), Pringle 1895 (HAM); Hunting Cay, Spellman & Stoddart 2446 (US, MO, BH).

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54364 (US).

Eragrostis prolifera (Sw.) Steud.

(Love grass)

Eragrostis domingensis (Pers.) Steud.

Atoll Cays. -- Lighthouse Reef: Long Cay, Stoddart 456 (Fo) (1969, p. 18 as *E. domingensis*). Glover's Reef: Northeast Cay, Stoddart 62 (Fo) (1962a, p. 88), Fosberg & Sachet 53818 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1619 (US), Linhart (1980, p. 162); Southwest Cay I, Fosberg & Stoddart 53863 (US), Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53871 (US).

Barrier Reef Cays. -- Goff's Cay, Spellman & Stoddart 2534 (US, MO); Middle Silk Cay, Fosberg & Spellman 54285 (US, MO), 54277 (US, MO); South Silk Cay, Fosberg & Spellman 54259 (US, MO, BH, Fo, BM); Ranguana Cay, Stoddart sight in 1960, Spellman & Stoddart 2252 (US, MO); Northeast Sapodilla Cay, Spellman & Stoddart 2300 (US, MO, BH, Fo); Frank's Cay, Spellman & Stoddart 2405 (US, MO); Nicolas Cay, Spellman & Stoddart 2325 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2454 (US, MO); Lime Cay, Spellman & Stoddart 2378 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 417 (Fo) (1969, p. 6); Tobacco Range, Fosberg & Spellman 54459 (US, MO); Buttonwood Cay, Stoddart 90 (Fo) (1963, p. 64), Fosberg & Spellman 54415 (US, MO, BH, Fo); Hatchet Cay, Fosberg & Spellman 54383 (US, MO, BH, Fo); Little Water Cay, Fosberg & Spellman 54329 (US, MO, BH, Fo, BM); Moho Cay, Stoddart 4 (Fo).

Eustachys Desv.

Eustachys petraea (Sw.) Desv.

Chloris petraea Sw.

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg & Sachet 53812 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1620 (US), Linhart (1980, p. 162); Southwest Cay I, Fosberg & Stoddart 53862 (US), Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53870 (US), 53902 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2175 (US, MO, BH), Pringle 1913 (HAM); Ranguana Cay, Spellman & Stoddart 2250 (US, MO, BH, Fo, BM); Northeast Sapodilla Cay, Spellman & Stoddart 2312 (US, MO, BH); Frank's Cay, Spellman & Stoddart 2410 (US, MO, BH, Fo, BM), Stoddart 504 (Fo); Frank's Cay East, Stoddart sight record in 1960; Nicolas Cay, Spellman & Stoddart 2348 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2437 (US, MO, BH, Fo, BM); Lime Cay, Spellman & Stoddart 2362 (US, MO, BH, Fo).

Lagoon Cays. -- Cay Caulker, Stoddart 416 (1969, p. 6, as *Chloris petraea*), St George's Cay, Spellman 1457 (MO, US); Tobacco Range, Fosberg & Spellman 54462 (US); Water Range, Spellman & Stoddart 2236 (US, MO, BH, Fo, BM); Weewee Cay, Stoddart 123 (Fo) (1963, p. 61, as *Chloris petraea*); Buttonwood Cay, Stoddart 86 (Fo), Fosberg & Spellman 54403 (US); Hatchet Cay, Fosberg & Spellman 54370 (US); Little Water Cay, Fosberg & Spellman 54248 (US); Moho Cay, Stoddart 10 (Fo), 117 (Fo).

Panicum L.

Panicum pilosum Sw.

Barrier Reef Cays. -- Lime Cay, Spellman & Stoddart 2374 (US, MO, BH).

Panicum virgatum L.

Barrier Reef Cays. -- South Water Cay, Pringle 1925 (HAM, MO).

Paspalum L.

Paspalum blodgettii Chapman

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2213 (US), 2176 (US, MO, BH, Fo, BM); Northeast Sapodilla Cay, Spellman & Stoddart 2321 (US, MO); Frank's Cay, Spellman & Stoddart 2401 (US, MO, BH, Fo), 2407 (US, MO, BH, Fo); Nicolas Cay, Spellman & Stoddart 2335 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2464 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2380 (US, MO, BH, Fo, BM).

Lagoon Cays. -- Little Water Cay, Fosberg & Spellman 54349 (US, MO, BH, Fo, BM).

Paspalum distichum L.

(Salt grass)

Paspalum vaginatum Sw.

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg & Sachet 53838 (US, MO, BH), Linhart (1980, p. 162); Small Cay (Long Cay North), Fosberg & Sachet 53776 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1627 (US), Linhart (1980, p. 162); Southwest Cay I, Fosberg & Stoddart 53859 (US), Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53873 (US) (all Linhart citations as *P. vaginatum*).

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2531 (US); Rendezvous Cay, Spellman & Stoddart 2508 (US), 2509 (US, MO), 2510 (US, MO), Stoddart 105 (Fo); Cay Glory, Stoddart 511 (Fo) (1963, p. 52); Tobacco Cay, Fosberg & Spellman 54244 (US); South Water Cay, Spellman & Stoddart 2214 (US, MO, BH, Fo, TI); Carrie Bow Cay, Spellman &

Stoddart 2218 (US, MO), 2219 (US), 2574 (US, MO), Fosberg & Spellman 54437 (US), 54438 (US), Ferraris 3 (US); North Silk Cay, Fosberg & Spellman 54269 (US); Middle Silk Cay, Fosberg & Spellman 54290 (US); Round Cay, Fosberg & Spellman 54302 (US); Ranguana Cay, Spellman & Stoddart 2251 (US, MO); Tom Owen's Cays (West), Spellman & Stoddart 2278 (US, MO, BH, Fo); Tom Owen's Cays (East), Spellman & Stoddart 2285 (US, MO, BH); Northeast Sapodilla Cay, Spellman & Stoddart 2317 (US, MO); Nicolas Cay, Spellman & Stoddart 2350 (US, MO); Hunting Cay, Spellman & Stoddart 2465 (US, MO, BH); Seal Cay, Spellman & Stoddart 2487 (US, MO).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54448 (US); Coco Plum Cay, Spellman & Stoddart 2564 (US, MO, BH); Water Range, Spellman & Stoddart 2230 (US); Little Water Cay, Fosberg & Spellman 54342 (US).

Paspalum laxum Lam.

Atoll Cays. -- Glover's Reef: Northeast Cay, Stoddart 63 (Fo), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1616 (US); Southwest Cay I, Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53872 (US).

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54386 (US, MO, BH), 54391 (US).

Paspalum paniculatum L.

Lagoon Cays. -- Moho Cay, Stoddart 118 (Fo).

Paspalum sp.

Barrier Reef Cays. -- Ranguana Cay, Stoddart sight in 1960; Round Cay, Stoddart sight in 1960; Tom Owen's Cays (West), Stoddart sight in 1960; Frank's Cay (West), Stoddart sight in 1960; Frank's Cay (East), Stoddart sight in 1960.

Lagoon Cays. -- St George's Cay, Stoddart sight in 1962 (1963, p. 38).

Phragmites Trin.

Phragmites cf. *australis* (Cav.) Trin. ex Steud.

(Reed)

Phragmites communis Trin.

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54211 (US, MO); South Water Cay, Spellman & Stoddart 2181 (US, MO, BH).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54467 (US, MO, BH).

**Saccharum* L.

**Saccharum officinarum* L.

(Sugar-cane)

Lagoon Cays. -- Frenchman's Cay: Stoddart sight in 1961.

Spartina Schreb.

Spartina patens (Ait.) Muhl.

Atoll Cays. -- Glover's Reef: Long Cay, Fosberg & Sachet 53916 (US, MO, BH); Southwest Cay I, Fosberg & Stoddart 53858 (US); Southwest Cay II, Fosberg & Sachet 53875 (US).

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54226 (US); South Water Cay, Spellman & Stoddart 2206 (US), Pringle 1929 (HAM); Frank's Cay, Spellman & Stoddart 2418 (US, MO).

Spartina spartinae (Trin.) Merr.

Atoll Cays. -- Glover's Reef: Southwest Cay II, Linhart (1980, p. 162) (could this be *Spartina patens*?).

Barrier Reef Cays. -- Sergeant's Cay, Spellman & Stoddart 2553 (US, MO); South Water Cay, Spellman & Stoddart 2191 (US, MO, BH, Fo, TI).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54447 (US); Coco Plum Cay, Spellman & Stoddart 2562 (US, MO, BH, Fo); Man-o'-War Cay, Fosberg & Spellman 54208 (US, MO); Buttonwood Cay, Fosberg & Spellman 54423 (US); Hatchet Cay, Fosberg & Spellman 54375 (US); Little Water Cay, Fosberg & Spellman 54335 (US).

Sporobolus R. Br.

Sporobolus jacquemontii Kunth

Sporobolus indicus of authors, non (L.) R. Br.

Barrier Reef Cays. -- Northeast Sapodilla Cay, Spellman & Stoddart 2304 (US, MO, BH, Fo).

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54360 (US); Wild Cane Cay, Stoddart 23 (Fo).

Sporobolus virginicus (L.) Kunth

(Salt grass)

Atoll Cays. -- Lighthouse Reef: Sandbore Cay, Stoddart 145 (Fo); Half Moon Cay, Stoddart 40 (Fo), 137 (Fo); Long Cay, Stoddart 455 (Fo). Glover's Reef: Northeast Cay, Fosberg & Sachet 53825 (US); Small Cay (Long Cay North), Fosberg & Sachet 53779 (US), Linhart (1980, p 162);

Long Cay, Pippen 910 (US), Fosberg & Sachet 53805 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1628 (US); Southwest Cay II, Fosberg & Sachet 53874 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2526 (US, MO, BH, Fo, TI); Tobacco Cay, Fosberg & Spellman 54213 (US); South Water Cay, Sampson 27 (US), Spellman & Stoddart 2182 (US, MO, BH, Fo), 2215 (US, MO), Pringle 1911 (HAM); Pompion Cay, Fosberg & Spellman 54311 (US); Ranguana Cay, Spellman & Stoddart 2253 (US, MO, BH, Fo); Tom Owen's East Cay, Spellman & Stoddart 2286 (US, MO, BH, Fo, TI); Tom Owen's West Cay, Spellman & Stoddart 2275 (US, MO, BH, Fo, TI); Frank's Cay, Spellman & Stoddart 2414 (US, MO, BH, Fo); Nicolas Cay, Spellman & Stoddart 2354 (US, MO, BH, Fo); Hunting Cay, Spellman & Stoddart 2462 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2382 (US, MO, BH, Fo).

Lagoon Cays. -- Coco Plum Cay, Spellman & Stoddart 2573 (US, MO, BH, Fo); Water Range, Spellman & Stoddart 2234 (US, MO); Jack's Cay, Fosberg & Spellman 54429 (sterile) (US); Little Water Cay, Fosberg & Spellman 54328 (US, MO, BH, Fo, BM); Moho Cay, Stoddart 7 (Fo).

Sporobolus sp.

Atoll Cays. -- Turneffe Atoll: Soldier Cay, Stoddart sight records in 1960 and 1962 (1962a, p. 44, 1963, p. 75, 1969, p. 13); Big Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Deadman Cay II, Stoddart sight records in 1960 and 1962 (1962a, p. 38, 1963, p. 80); Deadman Cay III, Stoddart sight records in 1960 and 1962 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight records in 1961 and 1965 (1962a, p. 39, 1963, p. 81, 1969, p. 15); Deadman Cay V, Stoddart sight records in 1960 and 1962 (1962a, p. 40, 1963, p. 82); Big Cay Bokel, Stoddart sight record in 1965. Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1961 and 1965 (1962a, p. 57, 1963, p. 90, 1969, p. 17); Northern Cay, Stoddart sight records in 1960 and 1965 (1962a, p. 62, 1969, p. 17); Hat Cay, Stoddart sight record in 1960 (1962a, p. 81, 1963, p. 100); Half Moon Cay, sight records in 1960, 1961 and 1965 (1962a, p. 75, 1963, p. 98, 1969, p. 17); Long Cay, Stoddart sight record in 1960 (1962a, p. 79, 1969, p. 18). Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88); Southwest Cay I, Stoddart sight record in 1961 (1962a, p. 95); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 97).

Barrier Reef Cays. -- Rendezvous Cay, Stoddart sight records in 1960, 1962 and 1965 (1963, p. 48, 1969, p. 9); Tobacco Cay, Stoddart sight record in 1965 (1969, p. 10); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11); Ranguana Cay, Stoddart sight record in 1960; Tom Owen's West Cay, Stoddart sight record in 1960; Frank's Cay, Stoddart sight record in 1960; Frank's West Cay, Stoddart sight record in 1960; Hunting Cay, Stoddart sight record in 1960 (1962b, p. 164).

Lagoon Cays. -- Ambergris Cay, Stoddart sight records in 1962 and 1965 (1969, p. 6); St George's Cay, Stoddart sight record in 1965 (1969, p. 12); Colson Cay, Stoddart sight record in 1965 (1969, p. 12); Scipio Cay, Stoddart sight record in 1965 (1969, p. 12); West Snake Cay, Stoddart sight record in 1961 (1965, p. 137); West Snake Cay, West Islet, Stoddart sight record in 1961.

Stenotaphrum Trin.

Stenotaphrum secundatum (Walt.) O. Ktze. (Buffalo grass, pimento grass, crab grass)

Barrier Reef Cays. -- Northeast Sapodilla Cay, Spellman & Stoddart 2313 (US, MO, BH, Fo); Frank's Cay, Spellman & Stoddart 2409 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2370 (US, MO, BH, Fo).

Lagoon Cays. -- Little Water Cay, Fosberg & Spellman 54346 (US); Moho Cay, Stoddart 2a (Fo), 15 (Fo).

CYPERACEAE

Cladium P. Browne

Cladium jamaicense Crantz (Saw-grass)

Mariscus jamaicensis (Crantz) Britt.

Lagoon Cays. -- Harvest Cay, Stoddart 120 (Fo) (1963, p. 68); Water Range, Spellman & Stoddart 2239 (US, MO).

Cyperus L.

Cyperus ligularis L.

Atoll Cays. -- Glover's Reef: Northeast Cay, Linhart (1980, p. 162); Small Cay (Long Cay North), Linhart (1980, p. 162); Long Cay, Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1622 (US, MO, BH), Linhart (1980, p. 162); Southwest Cay I, Linhart (1980, p. 162); Southwest Cay II, Linhart (1980, p. 162).

Barrier Reef Cays. -- Rendezvous Cay, Stoddart 103 (Fo); Tobacco Cay, Fosberg & Spellman 54227 (US); South Water Cay, Spellman & Stoddart 2211 (US, MO); Hunting Cay, Spellman & Stoddart 2450 (US, MO, BH, Fo, TI).

Lagoon Cays. -- Cay Caulker, Stoddart 402 (Fo) (1969, p. 6); Buttonwood Cay, Fosberg & Spellman 54413 (US), 54414 (US), Stoddart 87 (Fo), 89 (Fo) (1963, p. 64, as *C. planifolius*); Little Water Cay, Fosberg & Spellman 54338 (US); Moho Cay, Stoddart 8 (Fo).

Cyperus peruvianus (Lam.) Williams*Kyllinga peruviana* Lam.

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2171 (US, MO, BH, Fo, TI), Pringle 1893 (HAM); Frank's Cay, Stoddart 505 (Fo), Spellman & Stoddart 2400 (US, MO, BH); Nicolas Cay, Spellman & Stoddart 2343 (US, MO, BH, Fo); Hunting Cay, Spellman & Stoddart 2469 (US, MO, BH); Lime Cay, Spellman & Stoddart 2381 (US, MO, BH).

Lagoon Cays. -- Weewee Cay, Stoddart 121 (Fo) (1963, p. 61); Hatchet Cay, Fosberg & Spellman 54376 (US); Moho Cay, Stoddart 14 (Fo).

Cyperus planifolius L. C. Rich

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 41 (Fo) (1962, p. 76). Glover's Reef: Northeast Cay, Stoddart 64 (Fo), Fosberg & Sachet 53820 (US, MO, BH, Fo, BM), Linhart (1980, p. 162); Small Cay (Long Cay North), Fosberg & Sachet 53780 (US, MO, BH, Fo), 53781 (US, MO), Linhart (1980, p. 162); Long Cay, Fosberg & Sachet 53913 (US, MO, BH, Fo, BM), Pippen 909 (US), Linhart (1980, p. 126); Middle Cay, Sachet & Stoddart 1614 (US, MO, BH, Fo, BM), Linhart (1980, p. 126); Southwest Cay I, Linhart (1980, p. 126); Southwest Cay II, Fosberg & Sachet 53884 (US, MO, BH, Fo), 53899 (US, MO, BH, Fo, BM), Linhart (1980, p. 126).

Barrier Reef Cays. -- Goff's Cay, Spellman & Stoddart 2537 (US, MO, BH, Fo); Rendezvous Cay, Spellman & Stoddart 2503 (US, MO, BH, Fo); Tobacco Cay, Fosberg & Spellman 54216 (US), 54248 (US); South Water Cay, Spellman & Stoddart 2170 (US, MO, BH, Fo), 2196 (US, MO), 2202 (US, MO, BH, Fo), Pringle 1892 (HAM, MO); Carrie Bow Cay, Spellman & Stoddart 2216 (US); North Silk Cay, Fosberg & Spellman 54270 (US); Middle Silk Cay, Fosberg & Spellman 54282 (US); South Silk Cay, Fosberg & Spellman 54262 (US, MO); Round Cay, Fosberg & Spellman 54296 (US), 54299 (US), 54304 (US); Pompion Cay, Fosberg & Spellman 54326 (US); Ranguana Cay, Spellman & Stoddart 2257 (US, MO, BH, Fo); Tom Owen's West Cay, Spellman & Stoddart 2272 (US, MO, BH, Fo); Tom Owen's East Cay, Spellman & Stoddart 2289 (US, MO, BH, Fo); Northeast Sapodilla Cay, Spellman & Stoddart 2310 (US, MO, BH, Fo); Frank's Cay, Spellman & Stoddart 2408 (US, MO, BH); Nicolas Cay, Spellman & Stoddart 2324 (US, MO, BH, Fo), 2347 (US, MO, BH, Fo, TI); Hunting Cay, Spellman & Stoddart 2422 (US, MO, BH); Lime Cay, Spellman & Stoddart 2372 (US, MO), 2379 (US, MO, BH, Fo); Ragged Cay, Spellman & Stoddart 2385 (US, MO, BH, Fo); Seal Cay, Spellman & Stoddart 2488 (US, MO, BH, Fo).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54469 (US); Coco Plum Cay, Spellman & Stoddart 2560 (US, MO, BH, Fo); Water Range, Spellman & Stoddart 2237 (US, MO, BH, Fo); Buttonwood Cay, Fosberg & Spellman 54413 (US); Hatchet Cay, Fosberg & Spellman 54382 (US); Little Water Cay, Fosberg & Spellman 54334 (US).

Cyperus sp.

Atoll Cays. -- Turneffe Atoll: Mauger Cay, Stoddart sight record in 1960 (1962a, p. 47, 1963, p. 71, as *C. planifolius*); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Cockroach Cay, Stoddart sight records in 1962 and 1965 (1969, p. 13); Soldier Cay, Stoddart sight records in 1962 and 1965 (1963, p. 75, 1969, p. 13); Deadman Cay I, Stoddart sight records in 1960 and 1962 (1963, p. 80, 1969, p. 15); Deadman Cay V, Stoddart sight record in 1960 (1962a, p. 40, as *C. planifolius*). Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1961 and 1962; Northern Cay, Stoddart sight records in 1962 (1963, p. 93); Half Moon Cay, Stoddart sight record in 1965 (1969, p. 18); Long Cay, Stoddart sight record in 1962 (1963, p. 99, as *C. planifolius*). Glover's Reef: Small Cay (Long Cay North), Stoddart sight record in 1961; Long Cay, Stoddart sight record in 1961; Southwest Cay I, Stoddart sight record in 1971.

Barrier Reef Cays. -- Rendezvous Cay, Stoddart sight record in 1965 (1963, p. 49, as *C. planifolius*, 1969, p. 9); Tobacco Cay, Stoddart sight records in 1961 and 1965 (1969, p. 10); South Water Cay, Stoddart sight record in 1960 (1963, p. 56, as *C. planifolius*); North Silk Cay, Stoddart sight record in 1961; Round Cay, Stoddart sight record in 1960; Ranguana Cay, Stoddart sight record in 1960; Tom Owen's East Cay, Stoddart sight record in 1960; Tom Owen's West Cay, Stoddart sight record in 1960.

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1962; Cay Chapel, Stoddart sight record in 1962; St George's Cay, Stoddart sight records in 1962 and 1965 (1963, p. 40, 1969, p. 7); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46, as *C. planifolius*); Trapp's Cay, Stoddart sight record in 1962 (1963, p. 64); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Bugle Cay, Stoddart sight record in 1965 (1969, p. 11); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138, as *C. ligularis*); Middle Snake Cay North Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961; West Snake Cay, Stoddart sight record in 1961 (1965, p. 137).

Fimbristylis Vahl

Fimbristylis cymosa R. Br. var. *spathacea* (Roth) Koyama

Fimbristylis spathacea Roth

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 135 (Fo). Glover's Reef: Northeast Cay, Fosberg & Sachet 53815 (US), Linhart (1980, p. 162); Long Cay, Fosberg & Sachet 53792 (US, MO, BH, Fo, BM), Pippen 908 (US), Linhart (1980, p. 162); Middle Cay, Stoddart 80 (Fo), Sachet & Stoddart 1615 (US, MO, BH, Fo), Linhart (1980, p. 162); Southwest Cay I, Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53869 (US, MO, BH, Fo), Linhart (1980, p. 162).

Barrier Reef Cays. -- Rendezvous Cay, Stoddart 106 (Fo) (1963, p. 49), Spellman & Stoddart 2511 (US, MO, BH); South Water Cay, Spellman & Stoddart 2177 (US, MO, BH, Fo), Pringle 1888, 1892 (HAM); Frank's Cay, Spellman & Stoddart 2415 (US, MO, BH, Fo); Nicolas Cay, Spellman & Stoddart 2345 (US, MO, BH, Fo, TI); Hunting Cay, Spellman & Stoddart 2457 (US, MO, BH, Fo, TI); Lime Cay, Spellman & Stoddart 2377 (US, MO, BH, Fo).

Lagoon Cays. -- Cay Caulker, Stoddart 414 (Fo) (1969, p. 6); Weewee Cay, Stoddart 122 (Fo) (1963, p. 61); Buttonwood Cay, Fosberg & Spellman 54401 (US); Hatchet Cay, Fosberg & Spellman 54371 (US); Little Water Cay, Fosberg & Spellman 54344 (US); Moho Cay, Stoddart 11 (Fo).

Fimbristylis spadicea (L.) Vahl

Lagoon Cays. -- Coco Plum Cay, Spellman & Stoddart 2565 (US, MO); Hatchet Cay, Fosberg & Spellman 54374 (US); Wild Cane Cay, Stoddart 22 (Fo); Moho Cay, Stoddart 3 (Fo).

Fimbristylis sp.

Atoll Cays. -- Glover's Reef: Southwest Cay I, Stoddart sight record in 1971.

PALMAE

Acoelorrhaphe H. Wendl.

Acoelorrhaphe wrightii (Griseb. & Wendl.) Wendl. ex Becc.

Paurotis wrightii (Griseb. & Wendl.) Britt. ex Britt. & Schafer

Barrier Reef Cays. -- Lime Cay, Spellman & Stoddart 2356 (US, MO).

**Cocos* L.

**Cocos nucifera* L.

(Coconut palm)

Atoll Cays. -- Turneffe Atoll: Vermeer (1959, p. 93); Dixon (1956, p. 26); Romney et al. (1959, p. 59); Mauger Cay, Stoddart sight record in 1960 (1962a, p. 47, 1963, p. 71); Dogflea Cay, Stoddart sight record in 1960 (1962a, p. 46); Three Corner Cay, Stoddart sight record in 1960, (1963, p. 71); Pelican Cay (Cockroach Group), Stoddart sight record in 1962 (1963, p. 72); Cockroach Cay, Stoddart sight records in 1960 and 1962 (1962a, p. 46, 1963, p. 73); Cockroach Cay V, Stoddart sight record in 1962 (1963, p. 73); Pelican Cay, Stoddart sight record in 1960 (1962a, 45, 1963, p. 74); Blackbird Cay, Stoddart sight record in 1960 (1962a, p. 44); Soldier Cay, Stoddart sight

records in 1960 and 1962 (1962a, p. 44, 1963, p. 75); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash Cay, Stoddart sight records in 1960, 1962 and 1965 (1962a, p. 42, 1963, p. 77, 1969, p. 14); Big Calabash East Cay I, Stoddart sight records in 1960 and 1962 (1963, p. 78); Big Calabash East Cay II, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Little Calabash Cay, Stoddart sight record in 1960 (1962a, p. 41, 1963, p. 76); Grand Bogue Point, Stoddart sight record in 1962 (1963, p. 84); Deadman Cay I, Stoddart sight records in 1960, 1962 and 1965 (1962a, p. 38, 1963, p. 79, 1969, p. 15); Deadman Cay II, Stoddart sight records in 1960, 1962 and 1965 (1963, p. 80, 1969, p. 15); Deadman Cay III, Stoddart sight records in 1960 and 1962 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight records in 1960, 1962 and 1965 (1962a, p. 39, 1963, p. 81, 1969, p. 15); Deadman Cay V, Stoddart sight records in 1960 and 1962 (1962a, p. 40, 1963, p. 82); Big Cay Bokel, Stoddart sight record in 1962 (1963, p. 83); Cay Bokel, Glennie sight record in 1921, Stoddart sight record in 1961 (1962a, p. 37, 1963, p. 82). Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960, 1961 and 1962 (1962a, p. 57, 1963, p. 89); Northern Cay, Stoddart sight records in 1960, 1961, 1962, and 1965 (1962a, p. 61, 1963, p. 93); Saddle Cay, Stoddart sight record in 1960 (1962a, p. 63, 1963, p. 94); Half Moon Cay, Uring in 1720, Owen in 1828 (1962a, p. 73), *Honduras Almanack* (1830, p. 150), Salvin sight record in 1862 (Salvin 1864, p. 378), Vermeer (1959, figs. 23 and 25), Stoddart sight records in 1960 and 1961 (1962a, p. 75), 1962 (1963, p. 95), and 1965 (1969, p. 17); Long Cay, Vermeer (1959, p. 97, fig. 21), Stoddart sight records in 1960, 1961, 1962 and 1965 (1962a, p. 78, 1963, p. 99, 1969, p. 18). Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88), Fosberg and Sachet sight record in 1971, Linhart (1980, p. 162); Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89), Fosberg and Sachet sight record in 1971, Linhart (1980, p. 162); Long Cay, Stoddart sight record in 1961 (1962a, p. 91), Fosberg and Sachet sight record in 1971, Linhart (1980, p. 162); Middle Cay, Stoddart sight record in 1961 (1962a, p. 93), Fosberg and Sachet sight record in 1971, Linhart (1980, p. 162); Southwest Cay I, Stoddart sight record in 1961 (1962a, p. 94), Fosberg and Sachet sight record in 1971, Linhart (1980, p. 162); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 98), Fosberg and Sachet sight record in 1971, Linhart (1980, p. 162).

Barrier Reef Cays. -- Vermeer (1959, p. 30); Paunch Cay, H.M.S. *Rambler* sight record in 1896-7; Sergeant's Cay, H.M.S. *Rambler* sight record in 1896-7, Vermeer (1959, figs. 1, 11, 13), Stoddart sight record in 1960 (1963, p. 42); Goff's Cay, H.M.S. *Rambler* sight record in 1896-7, Vermeer (1959, fig. 15), Stoddart sight records in 1960 and 1965 (planted) (1969, p. 9, 1974, p. 479); English Cay, Stoddart sight records in 1960, 1962 and 1965 (1963, p. 44, 1969, p. 9); Rendezvous Cay, H.M.S. *Mutine* sight record in 1921-2, Stoddart sight records in 1960, 1965 (planted) and 1972 (1969, p. 9, 1974, p. 480); Cay Glory,

Stoddart sight record in 1960 (1962b, p. 164, 1963, p. 52); Tobacco Cay, Stoddart sight records in 1960, 1961, 1962, 1965 and 1972 (1963, p. 54); South Water Cay, Stoddart sight records in 1960, 1961, 1965 and 1972 (1969, p. 11), Pringle, sight record in 1980; Carrie Bow Cay, Stoddart sight records in 1960, 1965, and 1972 (1962b, p. 164; 1963, p. 57; 1969, p. 11); North Silk Cay, Stoddart sight records in 1961 and 1972; Middle Silk Cay, Stoddart sight records in 1961 and 1972; South Silk Cay, Stoddart sight records in 1961 and 1972; Round Cay, Stoddart sight records in 1960 and 1972; Pompion Cay, Stoddart sight records in 1960 and 1972; Ranguana Cay, Vermeer (1959, p. 91), Stoddart sight records in 1960 and 1972; North Spot, Stoddart sight records in 1960 and 1972; Tom Owen's East Cay, Stoddart sight records in 1960 and 1972; Tom Owen's West Cay, Stoddart sight records in 1960 and 1972; Northeast Sapodilla Cay, Stoddart sight records in 1960 (1962b, p. 164) and 1972; Frank's Cay, Stoddart sight records in 1960 and 1972; Frank's Cay East Islet, Stoddart sight records in 1960 and 1972; Frank's Cay West Islet, Stoddart sight records in 1960 and 1972; Nicolas Cay, Stoddart sight records in 1960 and 1972; Hunting Cay, Stoddart sight records in 1960 and 1972 (1962b, p. 164); Lime Cay, Stoddart sight records in 1960 and 1972; Ragged Cay, Owen sight record in 1835, Stoddart sight records in 1960 and 1972; Seal Cay, Owen sight record in 1835, Vermeer (1959, p. 90), Stoddart sight records in 1960 and 1972.

Lagoon Cays. -- Ambergris Cay, Vermeer (1959, p. 30, fig. 6), Stoddart sight records in 1960 and 1965 (1963, p. 33, 1969, p. 6); Cay Caulker, Vermeer (1959, fig. 7), Stoddart sight records in 1960, 1961, 1962 and 1965 (1963, p. 34); Cay Chapel, Jefferys in 1775, Stoddart sight records in 1962 and 1965 (1963, p. 35, 1969, p. 6); St George's Cay, Stoddart sight records in 1960, 1962, 1965 (1969, p. 7 and 1972); Robinson Point Cay, Vermeer (1959, p. 92) Stoddart sight record in 1961 (1963, p. 46); Robinson Cay, Stoddart sight record in 1962 (1963, p. 47); Spanish Cay, Stoddart sight records in 1961 and 1962 (1963, p. 47); Tobacco Range, Stoddart sight record in 1972; Weewee Cay, Stoddart sight record in 1965; Buttonwood Cay, Stoddart sight records in 1961 (1963, p. 64) and 1972; Cary Cay, Stoddart sight records in 1962 (1963, p. 63); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Laughing Bird Cay, Stoddart sight record in 1962 (1963, p. 65); Colson Cay, Stoddart sight records in 1962 and 1965 (1963, p. 67); Scipio Cay, Stoddart sight records in 1962 and 1965 (1963, p. 66); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Bugle Cay, Stoddart sight records in 1962 and 1965; Harvest Cay, Stoddart sight record in 1962 (1963, p. 68); Trapp's Cay, Stoddart sight records in 1962 (1963, p. 64) and 1972; Moho Cay, Stoddart sight record in 1961; Frenchman's Cay, Stoddart sight record in 1961; Wild Cane Cay, Stoddart sight record in 1961; East Snake Cay, Vermeer (1959, p. 92), Stoddart sight record in 1961 (1965, p. 138); Middle Snake Cay, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138); West Snake Cay, Stoddart sight record in 1961 (1965, p. 137).

Thrinax Sw.

Thrinax radiata Lodd. ex Schultes & Schultes.

(Sea thatch)

Thrinax parviflora sensu auct.

Thrinax floridana Sarg.

Thrinax multiflora sensu Read in Adams, *Flowering Plants of Jamaica* (1972, p. 76).

Atoll Cays. -- Turneffe Atoll: Pelican Cay (Cockroach Group), Stoddart sight record in 1962 (1963, p. 72); Deadman Cay I, Stoddart sight record in 1965 (1969, p. 15); Deadman Cay II, Stoddart sight record in 1965 (1969, p. 15); Deadman Cay IV, Stoddart sight records in 1960 and 1962 (1963, p. 81); Big Cay Bokel, Stoddart sight record in 1965. Lighthouse Reef: Northern Cay, Stoddart sight record in 1965 (1969, p. 17); Half Moon Cay, *Honduras Almanack* (1830, p. 150). Glover's Reef: Northeast Cay, Stoddart 77 (Fo), Linhart (1980, p. 162); Long Cay, Fosberg & Sachet 53791 (US, MO, BH, Fo, BM), Linhart (1980, p. 162); Middle Cay, Fosberg & Stoddart 53919 (US, MO).

Barrier Reef Cays. -- South Water Cay, Stoddart sight record in 1965 (1969, p. 11), Spellman & Stoddart 2145 (US); Northeast Sapodilla Cay, Stoddart sight record in 1960 (1962b, p. 164), Spellman & Stoddart 2298 (US, MO); Frank's Cay, Stoddart sight record in 1960, Spellman & Stoddart 2417 (US, MO); Frank's Cay East Islet, Stoddart sight record in 1960; Nicolas Cay, Spellman & Stoddart 2333 (US, MO); Hunting Cay, Spellman & Stoddart 2476 (US, MO); Lime Cay, Spellman & Stoddart 2357 (US, MO).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1962 (1963, p. 33); Cay Chapel, Stoddart sight record in 1962 (1963, p. 35); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Tobacco Range, Fosberg & Spellman 54445 (US), 54446 (US); Coco Plum Cay, Spellman & Stoddart 2557 (US, MO); Water Range, Spellman & Stoddart 2222 (US, MO), 2240 (US, MO, BH, Fo, TI); Hatchet Cay, Fosberg & Spellman 54372 (US); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Colson Cay, Stoddart sight records in 1962 and 1965 (1963, p. 67, 1969, p. 12); Scipio Cay, Stoddart sight records in 1962 and 1965 (1963, p. 66, 1969, p. 11); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Cary Cay, Stoddart sight record in 1962; Moho Cay, Stoddart sight record in 1961; Trapp's Cay, Stoddart sight record in 1962 (1963, p. 63); Harvest Cay, Stoddart sight record in 1962 (1963, p. 68); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Middle Snake Cay North Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

PONTEDERIACEAE

Eichhornia Kunth

Eichhornia crassipes (Mart.) Solms (Water hyacinth)

Barrier Reef Cays. -- Carrie Bow Cay, Ferraris 17 (US) (seedling).

LILIACEAE sensu lato

Agave L.

Agave sp. (Century plant, maypole)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2189 (US).

Crinum L.

**Crinum amabile* Donn ex Ker-Gawl. (Crinum lily)

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg & Sachet 53842 (US); Small Cay (Long Cay North), Fosberg & Sachet 53779 (US).

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54209 (US); South Water Cay, Spellman & Stoddart 2193 (US, MO).

Lagoon Cays. -- Tobacco Range, south end of principal cay, Fosberg & Spellman 54450 (US).

**Dracaena Vandelli* ex L.

**Dracaena* sp.

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2159 (US, MO, BH, Fo, BM), Pringle sight record in 1980.

Hippeastrum Herb.

Hippeastrum puniceum (Lam.) Urb.

Atoll Cays. -- Glover's Reef: Small Cay (Long Cay North), Linhart (1980, p. 162).

Hymenocallis Salisb.

Hymenocallis littoralis (Jacq.) Salisb.

(Spider-lily)

Pancratium littorale Jacq.

Atoll Cays. -- Turneffe Atoll: Eastern sand ridge, Stoddart sight record in 1960 (1962a, p. 47); Harry Jones Point, Stoddart 512 (Fo) (1962a, p. 48); Deadman Cay I, Stoddart sight records in 1962 and 1965 (1963, p. 79, 1969, p. 15); Deadman Cay II, Stoddart sight records in 1962 and 1965 (1969, p. 15); Cay Bokel, Stoddart sight record in 1961 (1962a, p. 37, 1963, p. 82). Lighthouse Reef: Northern Cay, Stoddart sight record in 1962 (1963, p. 93); Half Moon Cay, Stoddart 39 (Fo), Stoddart sight records in 1960 and 1965 (1962a, p. 75, 1963, p. 98, 1969, p. 18); Long Cay, Stoddart sight record in 1960 (1962a, p. 80); Hat Cay, Stoddart sight record in 1961 (1962a, p. 81, 1963, p. 100). Glover's Reef: Northeast Cay, Fosberg & Sachet 53841 (US); Small Cay (Long Cay North), Linhart (1980, p. 162); Long Cay, Fosberg & Sachet 53915 (US), Stoddart sight record in 1961 (1962a, p. 91), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1634 (US), Stoddart sight record in 1961 (1962a, p. 93), Linhart (1980, p. 162); Southwest Cay I, Stoddart sight record in 1971, Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53905 (US), Stoddart sight record in 1961 (1962a, p. 98), Linhart (1980, p. 162).

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54228 (US), Stoddart sight records in 1961, 1962 and 1965 (1963, p. 54, 1969, p. 10); South Water Cay, Spellman & Stoddart 2168 (Fo), Stoddart sight record in 1965 (1969, p. 11), Pringle 1930 (HAM); Carrie Bow Cay, Ferraris 16 (?) (US) (Seedling), Ferraris, photograph, Pringle, single plant observed in 1979; North Silk Cay, Fosberg & Spellman 54265 (US); South Silk Cay, Fosberg & Spellman 54258 (US), Stoddart sight record in 1961; Round Cay, Fosberg & Spellman 54308 (US), Stoddart sight record in 1960; Pompion Cay, Fosberg & Spellman 54327 (US), Stoddart sight record in 1960; Ranguana Cay, Spellman & Stoddart 2244 (US, MO), Stoddart sight record in 1960; Tom Owen's East Cay, Spellman & Stoddart 2288 (US, MO), Stoddart sight record in 1960; Hunting Cay, Spellman & Stoddart 2449 (US, MO, BH, Fo), Stoddart sight record in 1960 (1962b, p. 164); Lime Cay, Spellman & Stoddart 2360 (US, MO); Seal Cay, Spellman & Stoddart 2478 (US, MO).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); St George's Cay, Stoddart sight records in 1962 and 1965 (1963, p. 38, 1969, p. 7); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Trapp's Cay, Stoddart sight record in 1962 (1963, p. 64); Hatchet Cay, Fosberg & Spellman 54389 (US); Moho Cay, Stoddart sight record in 1961; Cary Cay, Stoddart sight record in 1962 (1963, p. 63); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Laughing Bird Cay, Stoddart sight record in 1962, (1963, p. 65); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Middle Snake Cay North Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

MUSACEAE

**Musa* L.

**Musa sapientum* L.

(Banana)

Barrier Reef Cays. -- Northeast Sapodilla Cay, Spellman & Stoddart 2326 (US, MO).

**Musa paradisiaca* L.

(Plantain)

Lagoon Cays. -- Cay Caulker, Vermeer (1959, p. 58), Stoddart sight record in 1960 (1963, p. 34); Frenchman's Cay, Stoddart sight record in 1961.

ORCHIDACEAE

Brassavola R. Br.

Brassavola nodosa (L.) Lindl.

(Orchid)

Atoll Cays. -- Glover's Reef: Northeast Cay, Stoddart 65 (Fo).

Barrier Reef Cays. -- Frank's East Cay, Spellman & Stoddart 2396 (US, MO); Hunting Cay, Spellman & Stoddart 2423 (US, MO).

Lagoon Cays. -- Jack's Cay, Fosberg & Spellman 54428 (US, MO, BH, Fo); East Snake Cay, Stoddart 94 (Fo); Middle Snake Cay South Islet, Stoddart sight record in 1961.

Laelia Lindl.

Laelia tibicinis (Batem. ex Lindl.) L. Wms.

(Orchid)

Schomburgkia tibicinis Batem. ex Lindl.

Lagoon Cay. -- Wild Cane Cay, Stoddart 21 (Fo) (on prone tree trunk on sand-mangrove cay).

CASUARINACEAE

**Casuarina* Adans.

**Casuarina equisetifolia* L.

(Iron-wood)

Atoll Cays. -- Glover's Reef: Small Cay (Long Cay North), Fosberg and Sachet sight record in 1971, 1 seedling only, 2.5 dm tall, Linhart (1980, p. 162).

Barrier Reef Cays. -- Rendezvous Cay, Stoddart sight record in 1965 (1969, p. 9); South Water Cay, Spellman & Stoddart 2199 (US, MO), Stoddart sight record in 1965 (1969, p. 11), Pringle sight record in 1980; Carrie Bow Cay, Ferraris 14 (US); Hunting Cay, Spellman & Stoddart 2472 (US, MO, BH), Stoddart sight record in 1960; Ragged Cay, Spellman & Stoddart 2384 (US, MO, BH, Fo), Stoddart sight record in 1960.

Lagoon Cays. -- Cay Caulker, Stoddart 410 (Fo), Stoddart sight record in 1962 (1969, p. 6); Water Range, Spellman & Stoddart 2224 (US, MO).

MYRICACEAE

Myrica L.

Myrica cerifera L.

Atoll Cays. -- Glover's Reef: Southwest Cay I, Linhart, s.n. (MO), Linhart (1980, p. 163).

MORACEAE

Ficus L.

Ficus sp. probably new

Ficus cf. *hemsleyana* Standley of Linhart (1980)

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8, 1961, p. 574), Stoddart (1962a, p. 74, 1963, p. 95). Glover's Reef: Northeast Cay, Stoddart 71 (Fo) (1962a, p. 88, as *F. ovalis*), Fosberg & Sachet 53845 (US, MO, BH, Fo, BM), Linhart (1980, p. 163); Long Cay, Linhart (1980, p. 163); Middle Cay, Sachet & Stoddart 1630 (US, MO, BH, Fo), Linhart (1980, p. 163).

Barrier Reef Cays. -- Tobacco Cay, Smith (1842, p. 732); Water Cay, Dwyer et al. 672 (MO) (figs pedunculate); Round Cay, Fosberg & Spellman 54298 (US); Pompion Cay, Fosberg & Spellman 54310 (US); Northeast Sapodilla Cay, Spellman & Stoddart 2307 (US, MO, BH); Frank's Cay, Spellman & Stoddart 2397 (MO, Fo); Nicolas Cay, Spellman & Stoddart 2328 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2434 (US, MO).

Lagoon Cays. -- East Snake Cay, Stoddart 95 (Fo) (1965, p. 138, as *F. ovalis*).

OLACACEAE

Ximenia L.

Ximenia americana L.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8, 1961, p. 582), Stoddart (1962a, p. 74).

POLYGONACEAE

Coccoloba P. Browne

Coccoloba uvifera L. (Sea-grape)

Atoll Cays. -- Turneffe Atoll: Cockroach Cay V, Stoddart sight records in 1962 and 1965 (1963, p. 73, 1969, p. 13); Cockroach Cay, Stoddart sight record in 1962; Soldier Cay, Stoddart sight records in 1962 and 1965 (1963, p. 75, 1969, p. 14); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Deadman Cay IV, Stoddart sight records in 1960 and 1962 (1963, p. 81); Big Cay Bokel, Stoddart sight record in 1965. Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960, 1961, 1962 and 1965 (1962a, p. 57, 1963, p. 89, 1969, p. 16); Northern Cay, Stoddart sight records in 1960, 1961 and 1965 (1962a, p. 62, 1969, p. 17); Half Moon Cay *Honduras Almanack* (1830, p. 150). Glover's Reef; Northeast Cay, Fosberg & Sachet 53831 (US), Stoddart sight in 1961 (1962a, p. 88), Linhart (1980, p. 163); Small Cay (Long Cay North), Linhart (1980, p. 163); Long Cay, Fosberg & Sachet 53926 (US), Stoddart sight record in 1961 (1962a, p. 91), Linhart (1980, p. 163); Middle Cay, Sachet & Stoddart 1633 (US), Linhart (1980, p. 163); Southwest Cay I, Stoddart sight records in 1961 and 1971 (1962a, p. 94), Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53894 (US).

Barrier Reef Cays. -- Goff's Cay, Stoddart sight records in 1960 and 1962 (1963, p. 43, 1969, p. 9); Sergeant's Cay, Spellman & Stoddart 2542 (US, MO), Stoddart sight records in 1965 (seedling) and 1972 (1969, p. 8, 1974, p. 478); English Cay, Stoddart sight record in 1960

(1963, p. 45); Rendezvous Cay, Spellman & Stoddart 2495 (US, MO), Stoddart sight records in 1960, 1962, 1965 and 1972 (1963, p. 48, 1969, p. 9, 1974, p. 480); Tobacco Cay, Fosberg & Spellman 54214 (US), Stoddart sight records in 1961, 1962, and 1965 (1963, p. 54, 1969, p. 10); South Water Cay, Spellman & Stoddart 2151 (US, MO, BH), Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11), Pringle 1889 (HAM); Carrie Bow Cay, Spellman & Stoddart 2220 (US, MO), Ferraris 11 (US); South Silk Cay, Fosberg & Spellman 54261 (US), Stoddart sight record in 1961; Pompion Cay, Fosberg & Spellman 54322 (US), Stoddart sight record in 1960; Ranguana Cay, Spellman & Stoddart 2242 (US, MO, BH), Stoddart sight record in 1960; Tom Owen's West Cay, Spellman & Stoddart 2265 (US, MO), Stoddart sight record in 1960; Tom Owen's East Cay, Spellman & Stoddart 2290 (US, MO, BH), Stoddart sight record in 1960; Northeast Sapodilla Cay, Spellman & Stoddart 2306 (US, MO), Stoddart sight record in 1960 (1962b, p. 164); Frank's Cay, Spellman & Stoddart 2390 (US, MO), Stoddart sight record in 1960; Frank's Cay East Islet, Stoddart sight record in 1960; Nicolas Cay, Stoddart sight record in 1960; Hunting Cay, Spellman & Stoddart 2448 (US, MO), Stoddart sight record in 1960 (1962b, p. 164); Lime Cay, Spellman & Stoddart 2358 (US, MO, BH, Fo), Stoddart sight record in 1960; Seal Cay, Spellman & Stoddart 2479 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 430 (Fo), Stoddart sight record in 1962 (1963, p. 35); Cay Chapel, Stoddart sight records in 1962 and 1965 (1963, p. 35); St George's Cay, Stoddart sight records in 1960 and 1965 (1963, p. 38, 1969, p. 7); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Buttonwood Cay, Fosberg & Spellman 54416 (US), Stoddart sight record in 1961 (1963, p. 64); Trapp's Cay, Stoddart sight record in 1962 (1963, p. 64); Moho Cay, Stoddart sight record in 1961; Cary Cay, Stoddart sight record in 1962 (1963, p. 63); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Middle Snake Cay North Islet, Stoddart sight record in 1961; Middle Snake Cay South Islet, Stoddart sight record in 1961; West Snake Cay, Stoddart sight record in 1961 (1965, p. 137); West Snake Cay West Islet, Stoddart sight record in 1961; Wild Cane Cay, Stoddart sight record in 1961.

BATIDACEAE

Batis P. Browne

Batis maritima L.

(Samphire, Pickle-weed)

Atoll Cays. -- Turneffe Atoll: Mauger Cay, Stoddart 542 (Fo) (1963, p. 71); Big Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Little Calabash Cay, Stoddart sight record in 1965 (1969, p. 14). Lighthouse Reef: Long Cay, Stoddart sight record in 1962 (1963, p. 99). Glover's Reef: Small Cay (Long Cay North), Linhart (1980, p. 162); Southwest Cay I, Fosberg & Stoddart 53853 (US), Linhart (1980, p. 162); Southwest Cay II, Linhart (1980, p. 162).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart 440 (Fo) (1969, p. 8); South Water Cay, Spellman & Stoddart 2144 (US), Stoddart sight record in 1965 (1969, p. 11), Pringle 1904 (HAM).

Lagoon Cays. -- St George's Cay, Spellman 1476 (MO), Stoddart sight record in 1965 (1969, p. 7); Tobacco Range, Fosberg & Spellman 54458 (US); Coco Plum Cay, Spellman & Stoddart 2568 (US, MO, BH, Fo); Water Range, Spellman & Stoddart 2232 (US, MO); Weewee Cay, Stoddart 124 (Fo) (1963, p. 61); Man-o'-War Cay, Fosberg & Spellman 54206 (US); Jack's Cay, Fosberg & Spellman 54431 (US); Buttonwood Cay, Fosberg & Spellman 54419 (US); Hatchet Cay, Fosberg & Spellman 54379 (US); Little Water Cay, Fosberg & Spellman 54336 (US); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Bugle Cay, Stoddart sight record in 1965 (1969, p. 6); Harvest Cay, Stoddart sight record in 1962 (1963, p. 68).

CHENOPODIACEAE

Salicornia L.

Salicornia perennis Miller

(Samphire, glasswort)

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54455 (US); Water Range, Spellman & Stoddart 2221 (US, MO, BH, Fo).

Suaeda Forsk. ex Scop.

Suaeda linearis (Ell.) Moq.

Barrier Reef Cays. -- Carrie Bow Cay, Ferraris 18 (US).

AMARANTHACEAE

Alternanthera Forsk.

Alternanthera ramosissima (Mart.) Chod.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 42 (Fo), 140 (Fo), 551 (Fo) (1962a, p. 76).

Iresine P. Browne

Iresine diffusa H. B. ex Willd.

Iresine celosia L.

Atoll Cays. -- Turneffe Atoll: Harry Jones Point, Stoddart 28 (Fo) (1962a, p. 48, as *I. celosia*); Deadman Cay II, Stoddart 129 (Fo)

(1963, p. 80). Lighthouse Reef: Half Moon Cay, Stoddart 452 (Fo)
 (1969, p. 18). Glover's Reef: Southwest Cay I, Stoddart 82 (Fo),
Pippen 899 (US), Linhart (1980, p. 162); Southwest Cay II, Fosberg &
Sachet 53888 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- Tom Owen's West Cay, Spellman & Stoddart 2274
 (US, MO, BH, Fo).

Philoxerus R. Br.

Philoxerus vermicularis (L.) Beauv.

Atoll Cays. -- Glover's Reef: Small Cay (Long Cay North), Fosberg
& Sachet 53785 (US); Southwest Cay I, Linhart (1980, p. 162).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight record in 1965
 (1969, p. 8), Spellman & Stoddart 2556 (US, MO); English Cay, Spellman
& Stoddart 2523 (US, MO); Rendezvous Cay, Spellman & Stoddart 2506
 (US, MO), Stoddart 107 (Fo) (1963, p. 49); Cay Glory, Stoddart 508 (Fo)
 (1963, p. 52); Tobacco Cay, Fosberg & Spellman 54236 (US), 54256 (US);
 South Water Cay, Spellman & Stoddart 2146 (US, MO, BH, Fo, TI), Pringle
1905 (HAM); Carrie Bow Cay, Spellman & Stoddart 2141 (US, MO),
Ferraris 6 (US); Pompion Cay, Fosberg & Spellman 54313 (US); Ranguana
 Cay, Spellman & Stoddart 2241 (US); North Spot, Spellman & Stoddart
2292 (US); Tom Owen's East Cay, Spellman & Stoddart 2284 (US); Seal
 Cay, Spellman & Stoddart 2492 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 415 (Fo), 440a (Fo) (1969,
 p. 6); St George's Cay, Spellman 1475 (US, MO); Hatchet Cay, Fosberg &
Spellman 54398 (US); Little Water Cay, Fosberg 54357 (US).

NYCTAGINACEAE

Boerhavia L.

Boerhavia coccinea Mill.?

Barrier Reef Cays. -- South Water Cay, Pringle 1866 (HAM).

Neea Ruiz & Pavon

Neea choriophylla Standl.

The Glover's Reef specimens fit this well enough in leaf shape,
 though the leaves of some of the specimens are larger than any so named
 in the US. The leaves are comparably thick, the panicle is similarly
 large and complex. The staminodia on the one pistillate collection
 are 5, 6, 8, 5, 7, 7, 7, in the anthocarps examined on Fosberg 53846,
 and two staminate collections Sachet & Stoddart 1600 and 1636 have 6-7

and 6-8 stamens respectively. Whether this species is more than varietally distinct from *Neea psychotrioides* Donn.-Sm. of the Central American mainland is debatable. The latter has 8-10 staminoids according to Lundell.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8, 1961, p. 582), Stoddart (1962a, p. 74, 1963, p. 95). Glover's Reef: Northeast Cay, Stoddart 68 (Fo), Fosberg & Sachet 53832 (US, MO, BH), 53846 (US, MO, BH, Fo, BM) (1962a, p. 88), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1636 (US, MO, BH, Fo), 1600 (US, MO, BH, Fo, BM).

PHYTOLACCACEAE

Rivina L.

Rivina humilis L. (Bloodberry, Dog's blood)

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 44 (Fo), 545 (Fo) (1962a, p. 75, 1963, p. 98). Glover's Reef: Southwest Cay II, Fosberg & Sachet 53889 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Round Cay, Fosberg & Spellman 54307 (US); Pompano Cay, Fosberg & Spellman 54320 (US); Tom Owen's West Cay, Spellman & Stoddart 2270 (US, MO, BH); Ragged Cay, Stoddart 503 (Fo), Spellman & Stoddart 2387 (US, MO); Seal Cay, Spellman & Stoddart 2494 (US, MO).

Lagoon Cays. -- Cay Chapel, Stoddart 442 (Fo).

PORTULACACEAE

Portulaca L.

Portulaca oleracea L. (Purslane, Pusly)

Atoll Cays. -- Turneffe Atoll: Soldier Cay, Stoddart sight record in 1962 (1963, p. 75). Lighthouse Reef: Hat Cay, Stoddart 56 (Fo). Glover's Reef: Southwest Cay II, Fosberg & Sachet 53868a (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart 110 (Fo) (1963, p. 42), Stoddart sight record in 1972 (1974, p. 478), Spellman & Stoddart 2554 (US, MO); Goff's Cay, Spellman & Stoddart 2540 (US, MO); English Cay, Spellman & Stoddart 2513 (US, MO), Dwyer et al. 669 (MO); Rendezvous Cay, Stoddart 108 (Fo) (1963, p. 49), Stoddart sight record in 1965 (1969, p. 9), Spellman & Stoddart 2504 (US, MO); Tobacco Cay, Stoddart 510 (Fo), Stoddart sight records in 1961, 1962 (1963, p. 55) and 1965, Fosberg & Spellman 54254 (US); South Water Cay, Spellman &

Stoddart 2147 (US, MO), 2166 (US, MO), Pringle 1896 (HAM, MO); Carrie Bow Cay, Fosberg & Spellman 54436 (US), Spellman & Stoddart 2137 (US, MO), Ferraris 8 (US); North Silk Cay, Fosberg & Spellman 54271 (US); South Silk Cay, Fosberg & Spellman 54264 (US); Round Cay, Fosberg & Spellman 54300 (US), 54305 (US); Pompion Cay, Fosberg & Spellman 54314 (US); Ranguana Cay, Spellman & Stoddart 2246 (US, MO); Tom Owen's Cay, Spellman & Stoddart 2276 (US, MO); Tom Owen's West Cay, Spellman & Stoddart 2281 (US, MO); Hunting Cay, Spellman & Stoddart 2442 (US) (seedling); Ragged Cay, Spellman & Stoddart 2388 (US, MO); Seal Cay, Spellman & Stoddart 2491 (US, MO).

Lagoon Cays. -- St George's Cay, Spellman 1480 (US, MO); Buttonwood Cay, Stoddart 91 (Fo) (1963, p. 64), Fosberg & Spellman 54424 (US); Hatchet Cay, Fosberg & Spellman 54363 (US); Little Water Cay, Fosberg & Spellman 54350 (US).

Portulaca sp.

Atoll Cays. -- Glover's Reef: Southwest Cay I, Stoddart sight record in 1971.

Barrier Reef Cays. -- Goff's Cay, Stoddart sight record in 1962 (1963, p. 44, 1969, p. 9, as *P. oleracea*); English Cay, Stoddart sight record in 1965 (1969, p. 9); North Spot, Stoddart sight record in 1960; Tom Owen's East Cay, Stoddart sight record in 1960; Tom Owen's West Cay, Stoddart sight record in 1960.

AIZOACEAE

Sesuvium L.

Sesuvium portulacastrum (L.) L.

(Seaside Purslane)

Atoll Cays. -- Turneffe Atoll: Mauger Cay, Stoddart sight record in 1960 (1962a, p. 47, 1963, p. 71); Pelican Cay, Stoddart sight record in 1960 (1962a, p. 45); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Cockroach Cay, Stoddart sight records in 1962 and 1965 (1969, p. 13); Pelican Cay (Cockroach Group), Stoddart sight record in 1965 (1969, p. 13); Blackbird Cay, Stoddart sight record in 1960 (1962, p. 44); Soldier Cay, Stoddart sight records in 1960 and 1965 (1962a, p. 44, 1963, p. 75, 1969, p. 13); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash East Cay I, Stoddart sight record in 1960 and 1962 (1969, p. 14); Little Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Deadman Cay I, Stoddart sight records in 1960 and 1965 (1962a, p. 38, 1963, p. 79, 1969, p. 15); Deadman Cay II, Stoddart sight records in 1960, 1962, and 1965 (1962a, p. 38, 1963, p. 80, 1969, p. 15); Deadman Cay III, Stoddart sight records in 1960 and 1962 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight records in 1960, 1962 and 1965 (1962a, p. 39, 1963, p. 81, 1969, p. 15); Deadman Cay V, Stoddart sight record in 1960 (1962a, p. 39, 1963, p. 82). Lighthouse Reef: Sandbore Cay, Stoddart sight

record in 1965 (1969, p. 16); Northern Cay, Stoddart sight records in 1960 and 1961 (1962a, p. 62); Saddle Cay, Stoddart sight record in 1960 (1962a, p. 63, 1963, p. 94); Half Moon Cay, Stoddart 46 (Fo), 449 (Fo), (1962a, p. 75, 1969, p. 17); Long Cay, Stoddart sight records in 1960, 1961, and 1962 (1962a, p. 80, 1963, p. 99); Hat Cay, Stoddart 57 (1962a, p. 81, 1963, p. 100). Glover's Reef: Northeast Cay, Stoddart 75 (Fo), Fosberg & Sachet 53835 (US) (1962a, p. 88), Linhart (1980, p. 162); Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89), Fosberg & Sachet 53790 (US), Linhart (1980, p. 162); Long Cay, Fosberg & Sachet 53910 (US), Linhart (1980, p. 162); Middle Cay, Fosberg & Stoddart 53920 (US); Southwest Cay I, Stoddart sight record in 1971, Linhart (1980, p. 162); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 97), Fosberg & Sachet 53878 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 38, 1969, p. 7); Sergeant's Cay, Stoddart 111 (Fo) (1963, p. 42), Spellman & Stoddart 2547 (US, MO, BH); Goff's Cay, Stoddart sight records in 1960 and 1965 (1963, p. 43, 1974, p. 479), Spellman & Stoddart 2538 (US); English Cay, Stoddart sight record in 1965 (1969, p. 9), Spellman & Stoddart 2516 (US, MO, BH), Dwyer et al. 667a (MO); Rendezvous Cay, Stoddart 101 (Fo), Stoddart sight records in 1960 and 1965 (1963, p. 48, 1969, p. 9), Spellman & Stoddart 2505 (US, MO); Cay Glory, Stoddart 513 (Fo) (1962b, p. 164, 1963, p. 52); Tobacco Cay, Stoddart sight records in 1961 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54234 (US); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11), Spellman & Stoddart 2148 (US) Pringle 1867 (HAM); Carrie Bow Cay, Stoddart sight record in 1965 (1969, p. 11), Spellman & Stoddart 2136 (US), Ferraris 7 (US); North Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54268 (US); Middle Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54288 (US); South Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54260 (US); Round Cay, Stoddart sight record in 1960, Fosberg & Spellman 54306 (US); Pompion Cay, Stoddart sight record in 1960, Fosberg & Spellman 54318 (US); Ranguana Cay, Spellman & Stoddart 2258 (US); North Spot, Stoddart sight record in 1960, Spellman & Stoddart 2291 (US); Northeast Sapodilla Cay, Stoddart sight record in 1960 (1962b, p. 164); Tom Owen's East Cay, Stoddart sight record in 1960, Spellman & Stoddart 2280 (US); Tom Owen's West Cay, Stoddart sight record in 1960, Spellman & Stoddart 2277 (US); Lime Cay, Stoddart sight record in 1960 and 1972; Ragged Cay, Spellman & Stoddart 2386 (US, MO, BH), Stoddart sight record in 1960.

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1962; St George's Cay, Stoddart sight records in 1960 and 1965 (1963, p. 38, 1969, p. 7), Spellman 1458 (US, MO); Tobacco Range, Fosberg & Spellman 54465 (US); Man-o'-War Cay, Fosberg & Spellman 54207 (US); Jack's Cay, Fosberg & Spellman 54430 (US); Buttonwood Cay, Fosberg & Spellman 54426 (US); Hatchet Cay, Fosberg & Spellman 54399 (US); Little Water Cay, Fosberg & Spellman 54356 (US); Trapp's Cay, Stoddart sight record in 1962; Colson Cay, Stoddart sight record in 1965 (1969, p. 12); Scipio Cay, Stoddart sight record in 1965 (1969, p. 12); Laughing Bird Cay, Stoddart sight record in 1962 (1963, p. 65); Bugle Cay, Stoddart sight record in 1965 (1969, p. 11); West Snake Cay, Stoddart sight record in

1961 (1965, p. 137); West Snake Cay West Islet, Stoddart sight record in 1961; Middle Snake Cay North Islet, Stoddart sight record in 1961; Middle Snake Cay South Islet, Stoddart sight record in 1961.

LAURACEAE

Cassytha L.

Cassytha filiformis L.

(Love vine)

Atoll Cays. -- Lighthouse Reef: Sandbore Cay, Stoddart sight record in 1965 (1969, p. 16); Northern Cay, Stoddart sight record in 1960; Half Moon Cay, Stoddart 32 (Fo); Long Cay, Stoddart sight records in 1961 and 1965 (1969, p. 18).

Barrier Reef Cays. -- South Water Cay, Stoddart sight records in 1960 and 1965, Spellman & Stoddart 2163 (US, MO), Pringle 1861 (HAM); Ranguana Cay, Spellman & Stoddart 2256 (US, MO).

Lagoon Cays. -- Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); Colson Cay, Stoddart sight record in 1965 (1969, p. 12).

CRUCIFERAE

Cakile Mill.

Cakile lanceolata (Willd.) O. E. Schulz

(Sea rocket)

Atoll Cays. -- Turneffe Atoll: Cockroach Cay, Stoddart sight record in 1962; Little Calabash Cay, Stoddart sight record in 1962 (1963, p. 77); Deadman Cay II, Stoddart 127 (Fo) (1963, p. 80). Lighthouse Reef: Sandbore Cay, Stoddart sight record in 1962 (1963, p. 91); Northern Cay, Stoddart sight records in 1960 and 1962 (1963, p. 93); Half Moon Cay, Stoddart 132 (Fo), Stoddart sight records in 1961 (1962a, p. 75, 1963, p. 98). Glover's Reef: Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 98), Fosberg & Sachet 53883 (US).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart 439 (Fo) (1969, p. 8), Spellman & Stoddart 2548 (US); Goff's Cay, Spellman & Stoddart 2536 (US, MO) (1974, p. 479); Rendezvous Cay, Stoddart 104 (Fo), Stoddart sight record in 1965 (1963, p. 49, 1969, p. 9); Cay Glory, Stoddart 509 (Fo) (1963, p. 52); South Water Cay, Stoddart sight record in 1960 (1969, p. 11), Spellman & Stoddart 2200 (US, MO), Pringle 1884 (HAM); Carrie Bow Cay, Spellman & Stoddart 2575 (US) (seedling), Ferraris 2; Round Cay, Stoddart sight record in 1960, (US); Ranguana Cay, Spellman & Stoddart 2261 (US, MO); Pompion Cay, Stoddart sight record in 1960; Northeast Sapodilla Cay, Stoddart 507 (Fo); Tom Owen's

West Cay, Stoddart sight record in 1960; Frank's West Cay, Stoddart sight record in 1960; Frank's East Cay, Stoddart sight record in 1960; Hunting Cay, Spellman & Stoddart 2473 (US, MO).

Lagoon Cays. -- Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); St George's Cay, Stoddart sight record in 1962 (1963, p. 40, 1969, p. 7); Hatchet Cay, Fosberg & Spellman 54385 (US); Middle Snake Cay North Islet, Stoddart sight record in 1961; West Snake Cay, Stoddart 19 (Fo) (1965, p. 137).

CAPPARIDACEAE

Capparis L.

Capparis flexuosa (L.) L. (Bottle-cod root)

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959, 3-8), Stoddart (1962a, p. 75).

CRASSULACEAE

**Kalanchoe* Adans.

**Kalanchoe pinnata* (Lam.) Pers. (Air plant, leaf of life)

Bryophyllum pinnatum (Lam.) Oken

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2460 (US, MO).

ROSACEAE

Chrysobalanus L.

Chrysobalanus icaco L. (Coco plum, Icaco plum)

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg & Sachet 53830 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2207 (US, MO); Northeast Sapodilla Cay, Spellman & Stoddart 2308 (US, MO, BH); Frank's Cay, Spellman & Stoddart 2412 (US, MO, BH); Nicolas Cay, Spellman & Stoddart 2329 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2456 (US, MO).

LEGUMINOSAE

Caesalpinia L.

Caesalpinia bonduc (L.) Roxb. (Nicker nuts, ticksie, nickol)

Caesalpinia crista L.

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54237 (US) (seedling); Tom Owen's West Cay, Spellman & Stoddart 2262 (US, MO, BH).

Canavalia DC.

Canavalia rosea (Sw.) DC. (Seaside bean)

Canavalia maritima (Aubl.) Urb.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 59 (Fo), 451 (Fo) (1969, p. 18). Glover's Reef: Southwest Cay II, Fosberg & Sachet 53879 (US), Linhart (1980, p. 163) (as *C. maritima*).

Barrier Reef Cays. -- Sergeant's Cay, Spellman & Stoddart 2552 (US, MO, BH, Fo); Tobacco Cay, Stoddart 515 (Fo), 516 (Fo) (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54250 (US); South Water Cay, Spellman & Stoddart 2184 (US, MO), Pringle 1863 (HAM); Tom Owen's West Cay, Stoddart sight record in 1960; Hunting Cay, Spellman & Stoddart 2433 (US, MO).

Lagoon Cays. -- St George's Cay, Spellman 1466 (US, 2 sheets, MO).

Canavalia sp.

Atoll Cays. -- Turneffe Atoll: Cockroach Cay, Stoddart sight record in 1965 (1969, p. 13). Lighthouse Reef: Sandbore Cay, Stoddart sight record in 1965 (1969, p. 17).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 40); Goff's Cay, Stoddart sight record in 1960 (1963, p. 43).

Crotalaria L.

Crotalaria retusa L. (Rattle-pod, rattleweed)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2164 (US, MO), Pringle 1883 (HAM).

Crotalaria verrucosa L. (Rattle-pod, blue rattleweed)

Lagoon Cays. -- Cay Caulker, Stoddart 407 (Fo) (1969, p. 6).

Dalbergia L. f.

Dalbergia ecastophyllum (L.) Taub.

Lagoon Cays. -- South Snake Cay, Stoddart 93 (Fo) (1965, p. 138).

Desmodium Desv.

Desmodium incanum DC. (Beggar's lice)

Desmodium canum (Gmel.) Schinz & Thell.

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2165
(US, MO, BH), 2212 (US), Pringle 1907 (HAM).

Desmodium tortuosum (Sw.) DC.

Barrier Reef Cays. -- South Water Cay, Pringle 1922 (HAM).

Erythrina L.

Erythrina sp. (Coral tree)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2205
(Fo).

Lagoon Cays. -- East Snake Cay, Stoddart 98 (Fo).

Gliricidia Kunth ex Endl.

Gliricidia sepium (Jacq.) Kunth ex Griseb. (Quickstick, St Vincent plum)

Barrier Reef Cays. -- Frank's Cay, Spellman & Stoddart 2402 (US);
Hunting Cay, Spellman & Stoddart 2439 (Fo, MO).

Leucaena Benth.

Leucaena leucocephala (Lam.) de Wit (Lead tree)

Leucaena latisiliqua sensu Gillis & Stearn non (L.) Gillis

Leucaena glauca sensu auct. non (L.) Benth.

Atoll Cays. -- Turneffe Atoll: Grand Bogue Point, Stoddart 131 (Fo) (1963, p. 85).

Mucuna Adans.

Mucuna sp. (Horse eye bean, sea bean)

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg sight record in 1971; Long Cay, Fosberg & Sachet 53796 (US).

Pithecellobium Mart.

Pithecellobium keyense Britt.

Pithecolobium keyense Britt. ex Coker

Atoll Cays. -- Lighthouse Reef: Northern Cay, Stoddart 450 (Fo) (1969, p. 17); Half Moon Cay, Verner (1961, p. 582), Stoddart (1962a, p. 74). Glover's Reef: Northeast Cay, Linhart (1980, p. 163); Middle Cay, Fosberg & Stoddart 53917 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Water Cay, Dwyer et al. 673 (MO); Frank's Cay, Stoddart sight record in 1972; Frank's Cay East, Stoddart sight record in 1972; Nicolas Cay, Spellman & Stoddart 2339 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2453 (US, MO); Lime Cay, Spellman & Stoddart 2367 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 424 (Fo) (1969, p. 6); Tobacco Range, Fosberg & Spellman 54474 (US), 54475 (US).

Sophora L.

Sophora tomentosa L.

Atoll Cays. -- Turneffe Atoll: Pelican Cay (Cockroach Group), Stoddart sight record in 1965 (1969, p. 13); Cockroach Cay, Stoddart sight record in 1965 (seedling) (1969, p. 13); Soldier Cay, Stoddart sight record in 1965 (1969, p. 14); Deadman Cay I, Stoddart sight record in 1965 (seedling) (1969, p. 15). Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1961 and 1965 (1969, p. 16); Long Cay, Stoddart sight records in 1960, 1961 and 1965 (1962a, p. 80, 1969, p. 18). Glover's Reef: Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89); Long Cay, Stoddart 79 (Fo); Middle Cay, Sachet & Stoddart 1635 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Tobacco Cay, Stoddart sight record in 1965 (1969, p. 10); South Water Cay, Stoddart sight record in 1965, Spellman & Stoddart 2153 (US, MO, BH, Fo), Pringle 1886 (HAM); Ranguana Cay, Stoddart 501 (Fo); Northeast Sapodilla Cay, Spellman & Stoddart 2314 (US, MO); Frank's Cay, Spellman & Stoddart 2393 (US, MO, BH); Nicolas

Cay, Spellman & Stoddart 2352 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2459 (US); Lime Cay, Spellman & Stoddart 2371 (US, MO, BH).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); Tobacco Range, Fosberg & Spellman 54453 (US), 54470 (US); Peter Douglas Cay, Stoddart sight record in 1961 (1963, p. 61); Little Peter Cay, Stoddart sight record in 1961 (1963, p. 61); Colson Cay, Stoddart sight record in 1965; Scipio Cay, Stoddart sight record in 1965; East Snake Cay, Stoddart 97 (Fo) (1965, p. 138); Middle Snake Cay North Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Moho Cay, Stoddart 1 (Fo).

**Tamarindus* L.

**Tamarindus indica* L.? (Tamarind)

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2529 (seedling) (US).

Vigna Savi

Vigna luteola (Jacq.) Benth. (Beach pea)

Vigna repens (L.) Kuntze

Barrier Reef Cays. -- Tobacco Cay, Stoddart 115 (Fo), 518 (Fo), Stoddart sight in 1965 (1963, p. 54), Fosberg & Spellman 54240 (US); South Water Cay, Spellman & Stoddart 2173 (US, MO, BH), 2217 (US) (seedling), Pringle 1874 (HAM); Ranguana Cay, Spellman & Stoddart 2260 (US, MO); Hunting Cay, Spellman & Stoddart 2435 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 405 (Fo); Buttonwood Cay, Stoddart 88 (Fo), Fosberg & Spellman 54407 (US); Hatchet Cay, Fosberg & Spellman 54394 (US); Little Water Cay, Fosberg & Spellman 54353 (US); Moho Cay, Stoddart 2 (Fo).

RUTACEAE

**Citrus* L.

**Citrus aurantiifolia* (Christm.) Swingle (Lime)

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2327 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2440 (US, MO).

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54367 (US).

**Citrus* sp.

Lagoon Cays. -- Wild Cane Cay, Stoddart sight record in 1961.

SURIANACEAE

Suriana L.

Suriana maritima L.

(Bay Cedar)

Atoll Cays. -- Turneffe Atoll: Dogflea Cay, Stoddart sight record in 1960 (1962a, p. 46); Cockroach Cay, Stoddart sight record in 1965 (1969, p. 13); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Soldier Cay, Stoddart sight records in 1960 and 1965 (1962a, p. 44, 1963, p. 75, 1969, p. 13); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash East Cay I, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Big Calabash East Cay II, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Little Calabash Cay, Stoddart sight record in 1965 (seedlings) (1969, p. 14); Deadman Cay II, Stoddart sight record in 1960 (1962a, p. 38, 1963, p. 80); Deadman Cay III, Stoddart sight record in 1960; Deadman Cay IV, Stoddart sight records in 1960 and 1965 (1969, p. 15); Deadman Cay V, Stoddart sight record in 1965; Big Cay Bokel, Stoddart sight record in 1965. Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1961, 1962 and 1965, Stoddart 541 (Fo) (1962a, p. 57, 1963, p. 89, 1969, p. 16); Northern Cay, Stoddart sight records in 1960, 1961 and 1965 (1962a, p. 62, 1963, p. 93, 1969, p. 17); Half Moon Cay, Stoddart 47 (Fo) (Stoddart 1962a, p. 75, 1963, p. 98); Long Cay, Stoddart sight records in 1960 and 1965 (1962a, p. 80, 1969, p. 18); Hat Cay, Stoddart sight record in 1961 (1962a, p. 81, 1963, p. 100). Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88); Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89). Fosberg & Sachet 53775 (US, MO, BH, Fo), Linhart (1980, p. 163); Long Cay, Stoddart sight record in 1961 (1962a, p. 91), Fosberg & Sachet 53909 (US, Fo), Linhart (1980, p. 163); Middle Cay, Sachet & Stoddart 1623 (US), Linhart (1980, p. 163); Southwest Cay I, Stoddart sight records in 1961 and 1971, Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53893 (US, Fo), Linhart (1980, p. 163).

Barrier Reef Cays. -- Sergeant's Cay, Spellman & Stoddart 2551 (US, MO, BH), Stoddart sight record in 1965 (1969, p. 8, 1974, p. 478); English Cay, Spellman & Stoddart 2530 (US, MO); Rendezvous Cay, Spellman & Stoddart 2496 (US, MO), Stoddart sight record in 1965 (1969, p. 9, 1974, p. 480); Tobacco Cay, Fosberg & Spellman 54217 (US); South Water Cay, Stoddart sight record in 1960 (1963, p. 56), Pringle 1869 (HAM); North Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54266 (US); Middle Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54287 (US); South Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54263 (US); Round Cay, Stoddart sight record in 1960, Fosberg & Spellman 54292 (US); Pompion Cay, Stoddart sight record

in 1960, Fosberg & Spellman 54324 (US); Ranguana Cay, Stoddart sight record in 1960; Northeast Sapodilla Cay, Spellman & Stoddart 2315 (US, MO).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); Cay Caulker, Stoddart 421 (Fo) (1969, p. 6); Cay Chapel, Stoddart sight records in 1962 and 1965 (1963, p. 35, 1969, p. 7); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Tobacco Range, Fosberg & Spellman 54472 (US); Coco Plum Cay, Spellman & Stoddart 2566 (US, MO); Water Range, Spellman & Stoddart 2233 (US, MO, BH, Fo); Little Water Cay, Fosberg & Spellman 54352 (US); Middle Snake Cay North Islet, Stoddart sight record in 1961; Middle Snake Cay South Islet, Stoddart sight record in 1961; West Snake Cay West Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

BURSERACEAE

Bursera Jacq. ex L.

Bursera simaruba (L.) Sarg.

(Red birch, Gumbo-limbo)

Atoll Cays. -- Turneffe Atoll: Pelican Cay (Cockroach Group), Stoddart sight records in 1962 and 1965 (1963, p. 72, 1969, p. 13). Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8, 1961, p. 582), Stoddart sight records in 1960, 1961, and 1965 (1962a, p. 74, 1963, p. 95, 1969, p. 18). Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88), Fosberg & Sachet 53834 (US), 53847 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- Carrie Bow Cay, Fosberg & Spellman 54440 (US) (seedling); Pompion Cay, Stoddart sight record in 1960, Fosberg & Spellman 54323 (US); Tom Owen's East Cay, Stoddart 506 (Fo).

MELIACEAE

Swietenia Jacq.

Swietenia macrophylla King

(Honduras mahogany, mahogany)

Atoll Cays. -- Turneffe Atoll: Soldier Cay, Romney et al. (1959, p. 254), Stoddart (1962a, p. 44: not seen), Calabash Cays, Romney et al. (1959, p. 254), Rope Walk, Romney et al. (1959, p. 254).

EUPHORBIACEAE

**Codiaeum* Rumph. ex Juss.

**Codiaeum variegatum* (L.) Blume (Croton)

Barrier Reef Cays. -- Hunting Cay, cult., Spellman & Stoddart 2475 (US, MO).

Drypetes Vahl

Drypetes brownii Standl.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 60 (Fo).

Euphorbia L.

Euphorbia blodgettii Engelm. ex Hitchc.

Chamaesyce blodgettii (Engelm. ex Hitchc.) Small

Atoll Cays. -- Glover's Reef: Northeast Cay, Stoddart 70 (Fo), Fosberg & Sachet 53843 (US, MO, BH, Fo, BM), 53822 (US, MO, BH, Fo), 53823 (US), 53828 (?identification) (US); Small Cay (Long Cay North), Fosberg & Sachet 53782 (US, MO, BH, Fo, BM), 53786 (US, MO, BH, Fo, BM); Long Cay, Linhart (1980, p. 163, ?as *Euphorbia* sp.); Middle Cay, Sachet & Stoddart 1611 (US, MO, BH, Fo); Southwest Cay I, Pippen 902 (US); Southwest Cay II, Fosberg & Sachet 53887 (US, MO, Fo, BH), 53876 (US, MO, BH, Fo, BM), Stoddart 84 (Fo).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight record in 1965 (1969, p. 8); English Cay, Spellman & Stoddart 2515 (US, MO, BH, Fo), 2518 (US, MO, BH, Fo, BM); Tobacco Cay, Fosberg & Spellman 54235 (US, MO, BH, Fo), 54232 (US), 54247 (US, MO), 54255 (US, MO, BH, Fo, BM), Stoddart 114a (Fo) (1963, p. 55); South Water Cay, Spellman & Stoddart 2142a (US, MO, BH, Fo), 2178 (US, MO, BH), Stoddart sight record in 1960 (1963, p. 55), Pringle 1899 (HAM); Carrie Bow Cay, Spellman & Stoddart 2138 (US, MO, BH), Ferraris 5 (US); Ranguana Cay, Spellman & Stoddart 2243 (US, MO, BH, Fo); Northeast Sapodilla Cay, Spellman & Stoddart 2320 (US, MO); Frank's Cay, Spellman & Stoddart 2411 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2431 (US).

Lagoon Cays. -- Cay Caulker, Stoddart 418 (Fo) (1969, p. 6); Tobacco Range, Fosberg & Spellman 54466 (US, MO, BH, Fo, BM); Buttonwood Cay, Fosberg & Spellman 54404 (US, MO, BH, Fo, BM), 54406 (US, MO, BH), Stoddart 85 (Fo); Hatchet Cay, Fosberg & Spellman 54380 (US, MO, BH, Fo, BM); Little Water Cay, Fosberg & Spellman 54345 (US, MO, BH, Fo, BM), 54330 (US, MO, BH, Fo, BM); Moho Cay, Stoddart 6 (Fo).

Euphorbia glomerifera (Millsp.) Wheeler

Chamaesyce glomerifera Millsp.

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54225 (US); South Water Cay, Stoddart 522 (Fo).

(Stearn also determines Stoddart 6, from Moho Cay, as this, but our specimen is *E. blodgettii*. The same is true of no. 85 from Buttonwood Cay.

Euphorbia mesembrianthemifolia Jacq.

Euphorbia buxifolia Lam.

Chamaesyce buxifolia (Lam.) Small

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 33 (Fo), 58 (Fo) (1963, p. 98). Glover's Reef: Northeast Cay, Stoddart 74 (Fo), Fosberg & Sachet 53811 (US, MO, BH, Fo, MO), 53837 (US, MO, BH, Fo, BM), Linhart (1980, p. 163); Small Cay (Long Cay North), Fosberg & Sachet 53788 (US, MO, BH), 53787 (US, MO, BH, Fo) (prostrate form), Linhart (1980, p. 163); Long Cay, Fosberg & Sachet 53797 (US, MO, BH), Linhart (1980, p. 163); Middle Cay, Fosberg, Sachet & Stoddart 53925 (US, MO, BH, Fo, BM), Sachet & Stoddart 1610 (US, MO, BH, Fo), Linhart (1980, p. 163); Southwest Cay, Pippen 901 (US); Southwest Cay I, Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53885 (US, MO, BH), Linhart (1980, p. 163).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 40); Sergeant's Cay, Stoddart 109 (Fo), Spellman & Stoddart 2546 (US, MO, BH, Fo), 2550 (US, MO, BH), Stoddart sight record in 1965 (1963, p. 42, 1969, p. 8); Goff's Cay, Spellman & Stoddart 2533 (US, MO, BH, Fo, BM); English Cay, Dwyer et al. 670 (MO), Spellman & Stoddart 2514 (US, MO, BH), 2517 (US, MO, BH, Fo, BM); Rendezvous Cay, Stoddart 102 (Fo) (1963, p. 49), Spellman & Stoddart 2500 (US, MO, BH, Fo, BM); Cay Glory, Stoddart 502 (Fo) (1963, p. 52); Tobacco Cay, Stoddart 114 (Fo), Fosberg & Spellman 54239 (US, MO), 54249 (US, MO); South Water Cay, Spellman & Stoddart 2180 (US, MO, BH, Fo), Pringle 1876, 1880 (HAM); Carrie Bow Cay, Spellman & Stoddart 2139 (US, MO, BH), Ferraris 4 (US); Middle Silk Cay, Fosberg & Spellman 54278, 54281, 54283 (all US, MO); South Silk Cay, Fosberg & Spellman 54257 (US, MO); Round Cay, Fosberg & Spellman 54301 (US, MO); Pompion Cay, Fosberg & Spellman 54319 (US, MO), 54321 (US, MO); Ranguana Cay, Spellman & Stoddart 2245 (US, MO, BH); Tom Owen's East Cay, Spellman & Stoddart 2287 (US, MO, BH, Fo, BM); Frank's Cay, Spellman & Stoddart 2395 (US, MO, BH, Fo, BM); Nicolas Cay, Spellman & Stoddart 2344 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2424 (US, MO); Lime Cay, Spellman & Stoddart 2361 (US, MO, BH).

Lagoon Cays. -- Cay Caulker, Stoddart 427 (Fo) (1969, p. 6); St George's Cay, Spellman 1478 (US, MO) (ordinary more or less erect form), 1479 (US, MO) (habit diffuse, leaves large, ovate, oblique at base); Water Cay, Dwyer et al. 677 (MO); Tobacco Range, Fosberg & Spellman 54460 (US, MO); Coco Plum Cay, Spellman & Stoddart 2558 (US, MO, BH, Fo, BM); Water Range, Spellman & Stoddart 2229 (US, MO, BH, Fo); Buttonwood Cay, Fosberg & Spellman 54400 (US, MO), 54402 (US, MO); Hatchet Cay, Fosberg & Spellman 54388 (US, MO); Little Water Cay, Fosberg & Spellman 54337 (US, MO).

**Euphorbia prostrata* Ait.

Chamaesyce prostrata (Ait.) Small

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54219 (US).

**Euphorbia thymifolia* L.

Chamaesyce thymifolia (L.) Millsp.

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2519 (US, MO, BH, Fo, BM).

Euphorbia trichotoma Kunth

Atoll Cays. -- Glover's Reef: Southwest Cay I, Stoddart 81 (Fo).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2203 (US, MO, BH, Fo), Pringle 1900, 1901 (HAM).

Euphorbia sp.

Atoll Cays. -- Turneffe Atoll: Three Corner Cay, Stoddart sight record in 1962 (1963, p. 71); Cockroach Cay, Stoddart sight records in 1960 and 1962 (1962a, p. 46, 1963, p. 73, 1969, p. 13); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Soldier Cay, Stoddart sight records in 1960 and 1965 (1962a, p. 44, 1963, p. 75, 1969, p. 13); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Big Calabash East Cay I, Stoddart sight record in 1960 (1969, p. 14); Little Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Deadman Cay I, Stoddart sight record in 1962 (1962a, p. 38, 1963, p. 79, 1969, p. 15); Deadman Cay II, Stoddart sight record in 1962 (1962a, p. 38, 1963, p. 80, 1969, p. 15); Deadman Cay IV, Stoddart sight records in 1960 and 1965 (1962a, p. 39, 1963, p. 81, 1969, p. 15); Deadman Cay V, Stoddart sight record in 1962 (1963, p. 82); Big Cay Bokel (Stoddart sight records in 1961 and 1965 (1963, p. 83). Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960, 1961, 1962 and 1965 (1962a, p. 57, 1963, p. 89, 1969, p. 16); Northern Cay, Stoddart sight records in 1960, 1961, 1962 and 1965 (1962a, p. 62, 1963, p. 92, 1969, p. 17); Half Moon Cay, Stoddart sight record in 1965 (1969, p. 17); Long Cay, Stoddart sight records in 1960, 1961,

1962 and 1965 (1962a, p. 80, 1963, p. 99, 1969, p. 18). Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88), Linhart (1980, p. 163); Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89), Linhart (1980, p. 163); Long Cay, Stoddart sight record in 1961 (1962a, p. 91), Linhart (1980, p. 163); Middle Cay, Stoddart sight record in 1961, Linhart (1980, p. 163); Southwest Cay I, Stoddart sight record in 1961 (1962a, p. 95), Linhart (1980, p. 163); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 97), Linhart (1980, p. 163).

Barrier Reef Cays. -- Goff's Cay, Stoddart sight records in 1960 and 1965 (1963, p. 43, 1969, p. 9, as *E. mesembrianthemifolia*); English Cay, Stoddart sight record in 1965 (1969, p. 9); Rendezvous Cay, Stoddart sight records in 1960 and 1965 (1963, p. 48); Tobacco Cay, Stoddart sight records in 1960 and 1965 (1963, p. 54, 1969, p. 10); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11); Carrie Bow Cay, Stoddart sight record in 1960 (1963, p. 57); Round Cay, Stoddart sight record in 1960; Pompon Cay, Stoddart sight record in 1960; Tom Owen's East Cay, Stoddart sight record in 1960; Frank's Cay, Stoddart sight record in 1960; Frank's East Cay, Stoddart sight record in 1960; Frank's West Cay, Stoddart sight record in 1960.

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); Cay Chapel, Stoddart sight records in 1962 and 1965 (1963, p. 35); St George's Cay, Stoddart sight records in 1962 and 1965 (1963, p. 38, 1969, p. 7); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Colson Cay, Stoddart sight record in 1965 (1969, p. 12); Scipio Cay, Stoddart sight record in 1965 (1969, p. 12); Laughing Bird Cay, Stoddart sight record in 1962 (1963, p. 65); Bugle Cay, Stoddart sight record in 1965 (1969, p. 11); Buttonwood Cay, Stoddart sight record in 1961 (1963, p. 64); Spanish Cay, Stoddart sight record in 1961; West Snake Cay, Stoddart sight record in 1961 (1965, p. 137); Middle Snake Cay North Islet, Stoddart sight record in 1961; East Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

Pedilanthus Poit.

**Pedilanthus tithymaloides* (L.) Poit. (Monkey fiddle, shoe flower)

Lagoon Cays. -- Wild Cane Cay, Stoddart 27 (Fo).

Phyllanthus L.

Phyllanthus amarus Schum. & Thonn. (Carry-me-seed, Egg woman)

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2522 (US, MO, BH); Tobacco Cay, Fosberg & Spellman 54221 (US); South Water Cay, Spellman & Stoddart 2190 (US, MO, BH, Fo, BM), Pringle 1875 (HAM); Hunting Cay, Spellman & Stoddart 2445 (US, MO, BH).

Lagoon Cays. -- Trapp's Cay, Stoddart 116 (Fo) (1963, p. 64).

ANACARDIACEAE

**Mangifera* L.

**Mangifera indica* L.

Lagoon Cays. -- Cay Caulker, Vermeer (1959, p. 58), Stoddart sight record in 1960 (1963, p. 34); Frenchman's Cay, Stoddart sight record in 1961; Wild Cane Cay, Stoddart sight record in 1961.

HIPPOCRATEACEAE

Hippocratea L.

Hippocratea volubilis L.

Barrier Reef Cays. -- Northeast Sapodilla Cay, Spellman & Stoddart 2303 (US); Hunting Cay, Spellman & Stoddart 2425 (US).

MALVACEAE

Hibiscus L.

**Hibiscus rosa-sinensis* L. (Hibiscus, shoe-black)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2158 (US).

Hibiscus tiliaceus L. (Seaside mahoe)

Atoll Cays. -- Glover's Reef; Middle Cay, Fosberg & Stoddart 53921 (US).

Barrier Reef Cays. -- Northeast Sapodilla Cay, Spellman & Stoddart 2309 (US, MO); Hunting Cay, Spellman & Stoddart 2429 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 435 (Fo); Buttonwood Cay, Fosberg & Spellman 54422 (US); Hatchet Cay, Fosberg & Spellman 54384 (US); Little Water Cay, Fosberg & Spellman 54340 (US, MO).

Sida L.

Sida acuta Burm. f.

(Broom-weed)

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Vermeer (1959, pp. 3-8), Stoddart (1962a, p. 75).

Lagoon Cays, -- Cay Caulker, Stoddart 411 (Fo) (sensu lato) (1969, p. 6); Wild Cane Cay, Stoddart 26 (Fo).

Thespesia Solander ex Correa

Thespesia populnea (L.) Solander ex Correa

(Seaside mahoe)

Barrier Reef Cays. -- Tom Owen's West Cay, Spellman & Stoddart 2264 (US, MO); Seal Cay, Spellman & Stoddart 2484 (US, MO).

Lagoon Cays. -- Cat Cay, Stoddart 119 (Fo) (1963, p. 62); Trapp's Cay, Stoddart sight record in 1962 (1963, p. 64).

STERCULIACEAE

Waltheria L.

Waltheria indica L.

(Raichie)

Waltheria americana L.

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2195 (US, MO), Pringle 1877 (HAM), Backman s.n. (MO).

TURNERACEAE

Turnera L.

Turnera ulmifolia L.

(Ramgoat dashalong)

Lagoon Cays. -- Cay Caulker, Stoddart 404 (Fo), 419 (Fo) (1969, p. 6).

PASSIFLORACEAE

Passiflora L.

Passiflora suberosa L.

(Passion flower)

Atoll Cays. -- Glover's Reef: Northeast Cay, Stoddart 66 (Fo), Fosberg & Sachet 53819 (US), Linhart (1980, p. 163); Middle Cay, Middle Cay, Sachet & Stoddart 1618 (US), Linhart (1980, p. 163); Southwest Cay I, Fosberg & Stoddart 53866 (US), Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53886 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2142 (US, MO, BH), Pringle 1924 (HAM, MO); Northeast Sapodilla Cay, Spellman & Stoddart 2322 (US, MO); Frank's Cay, Spellman & Stoddart 2404 (US, MO); Nicolas Cay, Spellman & Stoddart 2337 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2436 (US, MO); Lime Cay, Spellman & Stoddart 2366 (US, MO).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54461 (US).

CARICACEAE

**Carica* L.

**Carica papaya* L. (Papaya, Paw-paw)

Barrier Reef Cays. -- English Cay, Stoddart sight record in 1965 (1969, p. 9); Tobacco Cay, Stoddart sight record in 1965 (1969, p. 10), Fosberg & Spellman 54218 (US).

CACTACEAE

Opuntia Mill.

Opuntia sp.

Lagoon Cays. -- Wild Cane Cay, Stoddart sight record in 1961.

CUCURBITACEAE

**Citrullus* Schrad. ex Eckl. & Zeyh.

**Citrullus lanatus* (Thunb.) Matsum. & Nakai (Water melon)

Citrullus vulgaris Schrad.

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2527 (US).

**Cucumis* L.

**Cucumis melo* L.

(Melon)

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2447
(US, MO).

RHIZOPHORACEAE

Rhizophora L.

Rhizophora mangle L.

(Red mangrove)

Atoll Cays. -- Turneffe Atoll: Mauger Cay, Stoddart sight record in 1960 (1962a, p. 47, 1963, p. 71); Pelican Cay (Cockroach Group), Stoddart sight record in 1962 (1963, p. 73); Cockroach Cay, Stoddart sight records in 1960 and 1962 (1962a, p. 46, 1963, p. 73, 1969, p. 13); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Pelican Cay, Stoddart sight record in 1960 (1962a, p. 45, 1963, p. 74); Crawl Cay, Stoddart sight record in 1960 (1962a, p. 46, 1963, p. 72); Three Corner Cay, Stoddart sight record in 1960 (1962a, p. 46, 1963, p. 71); Blackbird Cay, Stoddart sight record in 1960 (1962a, p. 44, 1963, p. 75); Soldier Cay, Stoddart sight record in 1960 (1962a, p. 44, 1963, p. 75); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash Cay, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 77, 1969, p. 14); Big Calabash East Cay I, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Big Calabash East Cay II, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Deadman Cay I, Stoddart sight record in 1960 (1962a, p. 38, 1963, p. 79); Deadman Cay II, Stoddart sight record in 1960 (1962a, p. 38, 1963, p. 80); Deadman Cay III, Stoddart sight record in 1960 (1962a, p. 39); Deadman Cay IV, Stoddart sight records in 1960 and 1965 (1962a, p. 39, 1963, p. 81, 1969, p. 15); Deadman Cay V, Stoddart sight record in 1960 (1962a, p. 40, 1963, p. 42); Big Cay Bokel, Stoddart sight record in 1962 (1963, p. 83); Cay Bokel, Stoddart sight record in 1960 (1962a, p. 37, 1963, p. 82). Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960 and 1961 (1962a, fig. 28); Northern Cay, Stoddart sight records in 1960 and 1961 (1962a, p. 59, 1963, p. 93); Saddle Cay, Stoddart sight record in 1960 (1962a, p. 63, 1963, p. 94); Half Moon Cay, Stoddart sight record in 1962 (seedlings); Long Cay, Stoddart sight records in 1960, 1961 and 1962 (1962a, p. 78, 1963, p. 99); Hat Cay, Stoddart sight record in 1961 (1962a, p. 81), 1963, p. 100). Glover's Reef: Long Cay, Linhart (1980, p. 163); Middle Cay, Stoddart sight record in 1961 (1962a, p. 92), Sachet & Stoddart 1603 (US, MO), Linhart (1980, p. 163); Southwest Cay I, Stoddart sight records in 1961 and 1971 (1962a, p. 94), Linhart (1980, p. 163); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 96), Fosberg & Sachet 53904 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 48); Sergeant's Cay, Stoddart sight record in 1962 (seedlings); English Cay, Stoddart sight records in 1960 and 1962 (1963, p. 45); Rendezvous Cay, Stoddart sight records in 1960, 1962, 1965 and 1972 (1963, p. 48, 1969, p. 9, 1974, p. 480), Spellman & Stoddart 2497 (US, MO, BH); Tobacco Cay, Stoddart sight records in 1962 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54229 (US); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11), Spellman & Stoddart 2155 (US, MO, BH), Pringle 1862 (HAM); North Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54273 (US); Pompion Cay, Fosberg & Spellman 54325 (US) (seedling); Ranguana Cay, Spellman & Stoddart 2247 (US) (seedling); North Spot Cay, Spellman & Stoddart 2295 (US, MO, BH); Tom Owen's West Cay, Stoddart sight record in 1960, Spellman & Stoddart 2263 (US); Frank's Cay, Spellman & Stoddart 2406 (US, MO, BH, Fo, TI); Frank's East Cay, Stoddart sight record in 1960; Frank's West Cay, Stoddart sight record in 1960; Lime Cay, Stoddart sight record in 1960; Seal Cay, Spellman & Stoddart 2480 (US, MO).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1960 (1963, p. 32); Cay Caulker, Stoddart sight record in 1960 (1963, p. 34, 1969, p. 6); Cay Cangrejo, Stoddart sight records in 1960 and 1962 (1963, p. 62); Cay Chapel, Stoddart sight records in 1962 and 1965 (1963, p. 35); St George's Cay, Stoddart sight records in 1962 and 1965 (1963, p. 38, 1969, p. 8); Hick's Cays, Stoddart sight record in 1962 (1963, p. 36); Rider's Cays, Stoddart sight record in 1962 (1963, p. 36); Drowned Cays, Stoddart sight record in 1962 (1963, p. 36); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Robinson Cay, Stoddart sight record in 1961 (1963, p. 47); Spanish Cay, Stoddart sight records in 1961 and 1962 (1963, p. 47); Trapp's Cay, Stoddart sight record in 1962 (1963, p. 64); Simmonds Cay, Stoddart sight record in 1962 (1963, p. 47); Southern Long Cay, Stoddart sight record in 1962 (1963, p. 51); Stewart Cay, Stoddart sight record in 1962 (1963, p. 61); Peter Douglas Cay, Stoddart sight record in 1962 (1963, p. 61); Weewee Cay, Stoddart sight record in 1962 (1963, p. 61); Baker's Rendezvous, Stoddart sight record in 1962 (1963, p. 62); Quamino Cay, Stoddart sight record in 1962 (1963, p. 62); Tobacco Range, Fosberg & Spellman 54457 (US); Coco Plum Cay, Spellman & Stoddart 2570 (US); Water Range, Spellman & Stoddart 2226 (US, MO, BH, Fo); Man-o'-War Cay, Fosberg & Spellman 54203 (US); Jack's Cay, Fosberg & Spellman 54434 (US); Buttonwood Cay, Stoddart sight record in 1961, Fosberg & Spellman 54418 (US); Hatchet Cay, Fosberg & Spellman 54396 (US); Little Water Cay, Fosberg & Spellman 54341 (US); Cary Cay, Stoddart sight record in 1962 (1963, p. 62); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Colson Cay, Stoddart sight records in 1962 and 1965 (1963, fig. 42); Scipio Cay, Stoddart sight records in 1962 and 1965 (1963, fig. 42); Bugle Cay, Stoddart sight records in 1962 and 1965 (1963, p. 67); Placencia Cay, Stoddart sight record in 1962 (1963, p. 68); Laughing Bird Cay, Stoddart sight record in 1962 (1963, p. 65); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Middle Snake Cay South Islet, Stoddart sight record in 1961; West Snake Cay, Stoddart sight record in 1961 (1965, p. 137); South Snake Cay,

Stoddart sight record in 1961 (1965, p. 137); Frenchman's Cay, Stoddart sight record in 1961; Wild Cane Cay, Stoddart sight record in 1961.

COMBRETACEAE

Bucida L.

Bucida spinosa (Northrop) Jennings

Lagoon Cays. -- Ambergris Cay, Pelzl (US); Cay Caulker, Stoddart 431 (Fo) (1969, p. 6, as *Reynosia* sp.).

Conocarpus L.

Conocarpus erectus L.

(Buttonwood mangrove)

Atoll Cays. -- Turneffe Atoll: Mauger Cay, Stoddart 549 (Fo); Cockroach Cay, Stoddart sight record in 1962 (1963, p. 73); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Pelican Cay, Stoddart sight record in 1960 (1962a, p. 45, 1963, p. 74); Soldier Cay, Stoddart sight record in 1965 (1969, p. 14); Blackbird Cay, Stoddart sight record in 1960 (1962a, p. 44, 1963, p. 75); Big Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Big Calabash East Cay I, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Little Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Deadman Cay II, Stoddart sight records in 1960 and 1965 (1962a, p. 38, 1963, p. 80, 1969, p. 15); Deadman Cay III, Stoddart sight records in 1960 and 1962 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight record in 1960. Lighthouse Reef; Sandbore Cay, Stoddart 538 (Fo), Stoddart sight records in 1961, 1962 and 1965, (1962a, p. 57, 1963, p. 89, 1969, p. 16); Northern Cay, Stoddart sight records in 1960, 1961 and 1965 (1962a, p. 62, 1963, p. 92, 1969, p. 17); Saddle Cay, Stoddart sight record in 1960 (1962a, p. 63, 1963, p. 94); Half Moon Cay, Stoddart sight record in 1961 (1962a, p. 76, 1963, p. 98); Long Cay, Stoddart sight record in 1960 (1962a, p. 80); Hat Cay, Stoddart sight record in 1961 (1962a, p. 81, 1963, p. 100). Glover's Reef: Northeast Cay, Stoddart 67 (Fo) (1962a, p. 88), Fosberg & Sachet 53826 (US); Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89), Fosberg & Sachet 53777 (US), Linhart (1980, p. 162); Long Cay, Stoddart sight record in 1961 (1962a, p. 91), Fosberg & Sachet 53803 (US), Pippen 911 (US), Linhart (1980, p. 162); Middle Cay, Stoddart sight record in 1961 (1962a, p. 93), Sachet & Stoddart 1632 (US), Linhart (1980, p. 162); Southwest Cay I, Stoddart sight records in 1961 and 1971 (1962a, p. 94), Linhart (1980, p. 162); Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 97), Fosberg & Sachet 53890 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 41); Sergeant's Cay, Stoddart sight records in 1965 and 1972 (1969, p. 8, 1974, p. 478), Spellman & Stoddart 2543 (US, MO, BH); Rendezvous Cay, Stoddart sight records in 1965 and 1972 (1974, p. 480), Spellman & Stoddart 2502 (US); Tobacco Cay, Stoddart sight records in 1961 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54230 (US); South Water Cay, Spellman & Stoddart 2194 (US, MO), Pringle 1891 (HAM); North Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54274 (US); Middle Silk Cay, Fosberg & Spellman 54276 (US); Round Cay, Fosberg & Spellman 54297 (US); Pompion Cay, Fosberg & Spellman 54316 (US); Northeast Sapodilla Cay, Spellman & Stoddart 2305 (US, MO); Tom Owen's East Cay, Spellman & Stoddart 2283 (US, MO); Tom Owen's West Cay, Stoddart sight record in 1960, Spellman & Stoddart 2267 (US, MO); Frank's Cay, Stoddart sight record in 1960, Spellman & Stoddart 2399 (US, MO); Frank's East Cay, Stoddart sight record in 1960; Frank's West Cay, Stoddart sight record in 1960; Nicolas Cay, Stoddart sight record in 1960, Spellman & Stoddart 2351 (US, BH, MO, Fo); Hunting Cay, Stoddart sight record in 1960 (1962b, p. 164), Spellman & Stoddart 2426 (US, MO); Lime Cay, Stoddart sight record in 1960, Spellman & Stoddart 2365 (US, MO); Ragged Cay, Stoddart sight record in 1960; Seal Cay, Spellman & Stoddart 2485 (US, MO, BH, Fo).

Lagoon Cays. -- Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); St George's Cay, Stoddart sight record in 1965 (1969, p. 7), Spellman 1464 (US, MO); Water Cay, Dwyer et al. 676 (MO); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Spanish Cay, Stoddart sight records in 1961 and 1962 (1963, p. 47); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Trapp's Cay, Stoddart sight record in 1962 (1963, p. 63); Tobacco Range, Fosberg & Spellman 54449 (US); Coco Plum Cay, Spellman & Stoddart 2559 (US, MO, BH, Fo); Water Range, Spellman & Stoddart 2227 (US, MO, BH); Buttonwood Cay, Stoddart sight record in 1961 (1963, p. 64), Fosberg & Spellman 54417 (US); Hatchet Cay, Fosberg & Spellman 54369 (US); Little Water Cay, Fosberg & Spellman 54331 (US); East Snake Cay, Stoddart sight record in 1961; Middle Snake Cay North Islet, Stoddart sight record in 1961; Middle Snake Cay South Islet, Stoddart sight record in 1961; West Snake Cay West Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Wild Cane Cay, Stoddart sight record in 1961.

Laguncularia Gaertn. f.

Laguncularia racemosa (L.) Gaertn. f.

(White mangrove)

Atoll Cays. -- Turneffe Atoll: Harry Jones Point, Stoddart sight record in 1960; Deadman Cay II, Stoddart sight records in 1960 and 1962 (1962a, p. 38, 1963, p. 80); Deadman Cay III, Stoddart sight record in 1960 (1963, p. 81); Deadman Cay IV, Stoddart sight record in 1960 (1962a, p. 39, 1963, p. 81). Glover's Reef: Northeast Cay, Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1602 (US), Linhart (1980, p. 162); Southwest Cay I, Fosberg & Stoddart 53855 (US).

Barrier Reef Cays. -- Rendezvous Cay, Spellman & Stoddart 2501 (US, MO); Tobacco Cay, Fosberg & Spellman 54245 (US); South Water Cay, Spellman & Stoddart 2156 (US, MO, BH, Fo), Pringle 1891 (HAM); Frank's Cay, Stoddart sight record in 1960, Spellman & Stoddart 2392 (US, MO); Frank's Cay East, Stoddart sight record in 1960; Seal Cay, Spellman & Stoddart 2486 (US, MO, BH, Fo).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54476 (US); Coco Plum Cay, Spellman & Stoddart 2561 (US, MO); Water Range, Spellman & Stoddart 2228 (US, MO); Man-o'-War Cay, Fosberg & Spellman 54205 (US); Jack's Cay, Fosberg & Spellman 54432 (US, MO); Buttonwood Cay, Fosberg & Spellman 54420 (US); Hatchet Cay, Fosberg & Spellman 54390 (US); Little Water Cay, Fosberg & Spellman 54333 (US).

**Terminalia* L.

**Terminalia catappa* L. (Almond, Indian Almond, Tropical Almond)

Atoll Cays. -- Glover's Reef: Northeast Cay, Fosberg & Sachet 53809 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1629 (US); Southwest Cay II, Fosberg & Sachet 53882 (US).

Barrier Reef Cays. -- Tobacco Cay, Stoddart sight records in 1961, 1962 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54215 (US); South Water Cay, Spellman & Stoddart 2204 (US, MO); Carrie Bow Cay, Fosberg & Spellman 54439 (US) (seedling); Ranguana Cay, Spellman & Stoddart 2259 (US); Northeast Sapodilla Cay, Spellman & Stoddart 2301 (US, MO); Frank's Cay, Spellman & Stoddart 2394 (US, MO, BH, Fo); Nicolas Cay, Spellman & Stoddart 2334 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2421 (US, MO); Lime Cay, Spellman & Stoddart 2359 (US, MO, BH, Fo).

Lagoon Cays. -- Ambergris Cay, Stoddart sight records in 1962 and 1965 (1963, p. 33); Cay Caulker, Stoddart sight records in 1961 and 1965 (1963, p. 34); Hatchet Cay, Fosberg & Spellman 54387 (US); Little Water Cay, Fosberg & Spellman 54332 (US); East Snake Cay, Stoddart 96 (Fo) (1965, p. 138).

MYRTACEAE

Eugenia L.

Eugenia sp. (Rodwood)

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2427 (US).

**Psidium* L.

**Psidium guajava* L.

(Guava)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2161
(US, MO).

Lagoon Cays. - Hatchet Cay, Fosberg & Spellman 54366 (US); Wild
Cane Cay, Stoddart 24 (det. W. T. Stearn, not seen).

SAPOTACEAE

Bumelia Sw.

Bumelia retusa Sw.

Bumelia americana (Mill.) Stearn

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959,
pp. 3-8, 1961, p. 582), Stoddart (1962a, p. 74). Glover's Reef:
Northeast Cay, Fosberg & Sachet 53824 (US), Linhart (1980, p. 163);
Long Cay, Fosberg & Sachet 53796 (US), Pippen 912 (US), Linhart (1980,
p. 163); Middle Cay, Sachet & Stoddart 1601 (US), Linhart (1980,
p. 163).

Barrier Reef Cays. -- Tobacco Cay, Stoddart 437 (Fo).

Lagoon Cays. -- Tobacco Range, Fosberg & Spellman 54444 (US).

Manilkara Adans.

Manilkara zapota (L.) P. van Royen

(Naseberry, Sapodilla, Nispero,
Chiclé)

Atoll Cays. -- Turneffe Atoll: Soldier Cay, Romney et al. (1959,
p. 254), Stoddart (1962a, p. 44: not seen); Calabash Cays, Romney et
al. (1959, p. 254), Rope Walk, Romney et al. (1959, p. 254).

Barrier Reef Cays. -- Hunting Cay, Vermeer (1959, p. 90).

Pouteria Aubl.

Pouteria rivicoa (Gaertn.f.) Ducke

(Egg fruit)

Lucuma rivicoa Gaertn.f.

Pouteria campechiana (H.B.K.) Baehni

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8, 1961, p. 582), Stoddart (1962a, p. 74). Glover's Reef: Northeast Cay, Fosberg & Sachet 53833 (US), Linhart (1980, p. 163); Middle Cay, Sachet & Stoddart 1604 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2338 (US, MO, BH).

LOGANIACEAE

Polypremum L.

Polypremum procumbens L.

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2209 (US, MO, BH) Pringle 1903 (HAM, NY).

GENTIANACEAE

Eustoma Salisb.

Eustoma exaltatum (L.) G. Don

Barrier Reef Cays. -- Sergeant's Cay, Stoddart 438 (Fo) (1969, p. 8).

Lagoon Cays. -- St George's Cay, Spellman 1472 (US, MO).

APOCYNACEAE

**Catharanthus* G. Don

**Catharanthus roseus* (L.) G. Don (Ramgoat rose, Madagascar
periwinkle)

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54224 (US, MO).

Lagoon Cays. -- Cay Caulker, Stoddart 409 (Fo).

Echites Browne

Echites umbellata Jacq.

Atoll Cays. -- Turneffe Atoll, Deadman Cay I, Stoddart 458 (Fo) (1969, p. 15).

Lagoon Cays. -- St George's Cay, Spellman 1461 (MO); Tobacco Range, Fosberg & Spellman 54473 (US).

**Nerium* L.

**Nerium oleander* L. (South Sea rose, Oleander)

Barrier Reef Cays. -- South Water Cay, Pringle sight record in 1980; Nicolas Cay, Spellman & Stoddart 2331 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2452 (US, MO).

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54365 (US, MO).

Plumeria L.

**Plumeria rubra* L. (Frangipani)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2150 (US, MO); Hunting Cay, Spellman & Stoddart 2474 (US, MO).

Rhabdadenia Müll.-Arg.

Rhabdadenia biflora (Jacq.) Müll.-Arg.

Rhabdadenia paludosa (Mill.) Miers

Atoll Cays. -- Glover's Reef: Southwest Cay I, Linhart (1980, p. 162).

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2432 (US, MO, BH).

CONVOLVULACEAE

Ipomoea L.

Ipomoea asarifolia (Desr.) R. & S.

Barrier Reef Cays. -- Cay Glory, Stoddart 516 (Fo) (1963, p. 52).

Ipomoea macrantha R. & S. (Moon flower)

Ipomoea tuba (Schlect.) Don

Atoll Cays. -- Turneffe Atoll: Pelican Cay (Cockroach Group), Stoddart 146 (Fo) (1963, p. 72 as *I. tuba*). Lighthouse Reef: Half Moon Cay, Stoddart 34 (det. W. T. Stearn, not seen), Stoddart 448 (Fo).

Glover's Reef: Small Cay (Long Cay North), Fosberg & Sachet 53784 (US), Linhart (1980, p. 163) (as *I. tuba*); Southwest Cay II, Fosberg & Sachet 53896 (US), Linhart (1980, p. 163) (as *I. tuba*).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight record in 1965 (1969, p. 8), Spellman & Stoddart 2549 (US, MO); South Water Cay, Stoddart sight record in 1965, Pringle 1928 (HAM); North Silk Cay, Fosberg & Spellman 54267 (US); Middle Silk Cay, Fosberg & Spellman 54280 (US); Round Cay, Fosberg & Spellman 54303 (US); Ranguana Cay, Spellman & Stoddart 2249 (US, MO); North Spot Cay, Spellman & Stoddart 2293 (US, MO); Tom Owen's West Cay, Spellman & Stoddart 2273 (US, MO), 2271 (US) (seedling); Seal Cay, Spellman & Stoddart 2482 (US, MO).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6, as *I. tuba*); West Snake Cay, Stoddart 17 (Fo) (1965, p. 137).

Ipomoea pes-caprae ssp. *brasiliensis* (L.) v. Ooststr. (Beach morning-glory)

Ipomoea pes-caprae (L.) R. Br.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 31 (det. W. T. Stearn, not seen). Glover's Reef: Small Cay (Long Cay North), Fosberg & Sachet 53789 (US), Linhart (1980, p. 163); Southwest Cay I, Stoddart sight record in 1971, Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53892 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight record in 1965 (1969, p. 8), Spellman & Stoddart 2555 (US, MO); Goff's Cay, Spellman & Stoddart 2541 (US, MO, BH); English Cay, Spellman & Stoddart 2532 (US, MO, BH, Fo); Rendezvous Cay, Stoddart sight record in 1962 (1963, p. 49), Spellman & Stoddart 2507 (US, MO); Tobacco Cay, Stoddart sight records in 1962 and 1965 (1963, p. 54), Fosberg & Spellman 54253 (US); South Water Cay, Spellman & Stoddart 2187 (US, MO), Pringle 1881 (HAM, MO); Carrie Bow Cay, Spellman & Stoddart 2576 (US) (seedling); Middle Silk Cay, Fosberg & Spellman 54284 (US); Round Cay, Fosberg & Spellman 54294 (US); Pompion Cay, Fosberg & Spellman 54315 (US); North Spot Cay, Spellman & Stoddart 2294 (US, MO); Tom Owen's West Cay, Spellman & Stoddart 2269 (US, MO).

Lagoon Cays. -- St George's Cay, Stoddart sight record in 1962 (1963, p. 38); Hatchet Cay, Fosberg & Spellman 54381 (US); West Snake Cay, Stoddart 16 (Fo) (1965, p. 137).

Ipomoea stolonifera (Cyr.) Gmel.

Atoll Cays. -- Glover's Reef, Southwest Cay II, Fosberg & Sachet 53901 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2524 (US, MO), 2528 (US) (seedling); Tobacco Cay, Stoddart 526 (Fo) (1963,

p. 54), Fosberg & Spellman 54238 (US); South Water Cay, Stoddart 436 (Fo), Spellman & Stoddart 2174 (US, MO, BH, Fo), Pringle 1913 (HAM); Carrie Bow Cay, Ferraris 10 (US).

Lagoon Cays. -- St George's Cay, Spellman 1460 (US, MO).

Ipomoea sp.

Atoll Cays. -- Turneffe Atoll: Cockroach Cay, Stoddart sight record in 1965 (1969, p. 13); Soldier Cay, Stoddart sight record in 1965 (1969, p. 13); Deadman Cay III, Stoddart sight records in 1960 and 1962 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight record in 1965; Eastern Sand Ridge, Stoddart sight records in 1960 and 1961 (1962a, p. 47). Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960, 1961 and 1965 (1962a, p. 57, 1963, p. 89, 1969, p. 16); Half Moon Cay, Stoddart 37 (Fo), Stoddart sight records in 1960 and 1961 (1962a, p. 75, 1963, p. 98). Glover's Reef: Southwest Cay II, Stoddart sight record in 1961 (1962a, p. 97).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 40); Goff's Cay, Stoddart sight records in 1960 and 1965 (1963, p. 43, 1969, p. 9); Rendezvous Cay, Stoddart sight record in 1965; Tobacco Cay, Stoddart sight record in 1965 (1969, p. 10); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11); Carrie Bow Cay, Stoddart sight record in 1965 (1969, p. 11); North Silk Cay, Stoddart sight record in 1961; Middle Silk Cay, Stoddart sight record in 1961.

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); Cay Caulker, Stoddart sight record in 1962; St George's Cay, Stoddart sight record in 1965 (1969, p. 8); Scipio Cay, Stoddart sight record in 1962; Laughing Bird Cay, Stoddart sight record in 1962 (1963, p. 65); West Snake Cay West Islet, Stoddart sight record in 1961; Middle Snake Cay North Islet, Stoddart sight record in 1961; Middle Snake Cay South Islet, Stoddart sight record in 1961; East Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

Jacquemontia Choisy

Jacquemontia havanensis (Jacq.) Urb.

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2167 (US, MO), Pringle 1865 (HAM).

Merremia Dennst. ex Endl.

Merremia dissecta (Jacq.) Hall. f.

(Noyo)

Lagoon Cays. -- Cay Chapel, Stoddart 441 (Fo) (1969, p. 7).

BORAGINACEAE

Cordia L.*Cordia sebestena* L.

(Geiger Tree, Scarlet Cordia)

Atoll Cays. -- Turneffe Atoll: Pelican Cay (Cockroach Group), Stoddart sight records in 1962 and 1965 (1963, p. 72, 1969, p. 12); Cockroach Cay, Stoddart sight record in 1962 (1963, p. 73); Harry Jones Point, Stoddart sight record in 1962 (1963, p. 86). Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8), Stoddart sight records in 1960, 1962 and 1965 (1962a, p. 75, 1963, p. 95, 1969, p. 18), Stoddart 38 (Fo); Long Cay, Stoddart sight record in 1965 (1969, p. 18). Glover's Reef: Northeast Cay, Stoddart 76 (Fo) (1962a, p. 88), Fosberg & Sachet 53839 (US), Linhart (1980, p. 162); Long Cay, Fosberg & Sachet 53914 (US), Linhart (1980, p. 162); Middle Cay, Sachet & Stoddart 1605 (US), Linhart (1980, p. 162); Southwest Cay I, Fosberg & Stoddart 53856 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- Tobacco Cay, Stoddart 517 (Fo), Stoddart sight records in 1961 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54241 (US); South Water Cay, Spellman & Stoddart 2152 (US, MO, BH); Pringle 1921 (HAM); Pompion Cay, Stoddart sight record in 1960, Fosberg & Spellman 54309 (US); Seal Cay, Spellman & Stoddart 2483 (US, MO, BH, Fo).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); Cay Caulker, Stoddart 403 (Fo) (1969, p. 6); St George's Cay, Spellman 1459 (MO); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Cary Cay, Stoddart sight record in 1962 (1963, p. 63); Scipio Cay, Stoddart sight record in 1962 (1963, p. 66); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Colson Cay, Stoddart sight records in 1962 and 1965 (1963, p. 67, 1969, p. 12); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138).

Tournefortia L.*Tournefortia gnaphalodes* (L.) Kunth

(Seaside Lavender)

Mallotonia gnaphalodes (L.) Britt.

Atoll Cays. -- Turneffe Atoll: Pelican Cay (Cockroach Group), Stoddart sight record in 1965 (1969, p. 12); Cockroach Cay, Stoddart sight records in 1962 and 1965 (1969, p. 13); Cockroach Cay V, Stoddart sight record in 1965 (1969, p. 13); Soldier Cay, Stoddart sight records in 1960 and 1965 (1962a, p. 44, 1963, p. 75, 1969, p. 13); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Little Calabash Cay, Stoddart sight record in 1965 (1969, p. 14) (seedlings); Deadman Cay I, Stoddart sight records in 1960 and 1965 (1962a, p. 38, 1963, p. 79, 1969, p. 14); Deadman Cay II,

Stoddart sight records in 1960 and 1965 (1962a, p. 38, 1963, p. 80, 1969, p. 15); Deadman Cay II, Stoddart sight records in 1960 and 1962 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight record in 1960 (1962a, p. 39, 1963, p. 81); Big Cay Bokel, Stoddart sight record in 1965. Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960, 1961, 1962 and 1965 (1962a, p. 57, 1963, p. 89, 1969, p. 16); Northern Cay, Stoddart sight records in 1960, 1961 and 1965 (1962a, p. 62, 1963, p. 93, 1969, p. 17); Half Moon Cay, Stoddart 45 (Fo), Stoddart sight record in 1965 (1962a, p. 75, 1963, p. 98, 1969, p. 17); Long Cay, Stoddart sight record in 1965 (1969, p. 18). Glover's Reef: Northeast Cay, Stoddart sight record in 1961 (1962a, p. 88), Fosberg & Sachet 53836 (US), Linhart (1980, p. 162); Small Cay (Long Cay North), Stoddart sight record in 1961 (1962a, p. 89), Fosberg & Sachet 53783 (US), Linhart (1980, p. 162); Long Cay, Stoddart sight record in 1961, (1962a, p. 91), Fosberg & Sachet 53908 (US), Linhart (1980, p. 162); Middle Cay, Stoddart sight record in 1961 (1962a, p. 93), Fosberg & Stoddart 53924 (US), Sachet & Stoddart 1606 (US), Linhart (1980, p. 162); Southwest Cay I, Stoddart sight record in 1961 (1962a, p. 95), Fosberg & Stoddart 53861 (US), Linhart (1980, p. 162); Southwest Cay II, Fosberg & Sachet 53900 (US), Linhart (1980, p. 162).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 40); Sergeant's Cay, Stoddart sight records in 1965 and 1972 (1969, p. 8, 1974, p. 478), Spellman & Stoddart 2544 (US, MO); English Cay, Spellman & Stoddart 2525 (US); Rendezvous Cay, Stoddart sight records in 1965 and 1972 (1969, p. 8, 1974, p. 478); Tobacco Cay, Stoddart sight record in 1965 (1969, p. 10), Fosberg & Spellman 54231 (US); South Water Cay, Stoddart 520 (Fo), Stoddart sight records in 1961 and 1965 (1963, p. 56, 1969, p. 11), Spellman & Stoddart 2143 (US, MO), Pringle 1914, 1927 (HAM); Carrie Bow Cay, Stoddart sight record in 1965 (1969, p. 11), Spellman & Stoddart 2140 (US, MO), Ferraris 9 (US); North Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54275 (US); Middle Silk Cay, Stoddart sight record in 1961, Fosberg & Spellman 54289 (US); Round Cay, Stoddart sight record in 1960, Fosberg & Spellman 54295 (US); Pompion Cay, Stoddart sight record in 1960, Fosberg & Spellman 54312 (US); Ranguana Cay, Stoddart sight record in 1960, Spellman & Stoddart 2255 (US, MO); North Spot Cay, Spellman & Stoddart 2296 (US, MO); Tom Owen's West Cay, Stoddart sight record in 1960, Spellman & Stoddart 2266 (US, MO); Tom Owen's East Cay, Stoddart sight record in 1960; Nicolas Cay, Stoddart sight record in 1960; Hunting Cay, Stoddart sight record in 1960.

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6); Cay Caulker, Stoddart 422 (Fo) (1969, p. 6); Cay Chapel, Stoddart sight records in 1962 and 1965 (1963, p. 35, 1969, p. 7); St George's Cay, Spellman 1465 (MO); Tobacco Range, Fosberg & Spellman 54463 (US); Coco Plum Cay, Spellman & Stoddart 2569 (US, MO); Colson Cay, Stoddart sight record in 1965 (1969, p. 12); Scipio Cay, Stoddart sight record in 1965; East Snake Cay, Stoddart sight record in 1961; Middle Snake Cay North Islet, Stoddart sight record in 1961; West Snake Cay, Stoddart sight record in 1961 (1965, p. 137).

VERBENACEAE

Avicennia L.

Avicennia germinans (L.) L.

(Black mangrove)

Avicennia nitida Jacq.

Atoll Cays. -- Turneffe Atoll: Cockroach Cay, Stoddart sight record in 1962 (1963, p. 73); Pelican Cay, Stoddart sight record in 1960 (1962a, p. 45, 1963, p. 74); Blackbird Cay, Stoddart sight record in 1960 (1962, p. 44, 1963, p. 75); Soldier Cay, Stoddart 461 (Fo) (1969, p. 14); Harry Jones Point, Stoddart sight record in 1960 (1962a, p. 48); Big Calabash Cay, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 77); Big Calabash East Cay I, Stoddart sight records in 1960 and 1962 (1962a, p. 42, 1963, p. 78); Big Calabash East Cay II, Stoddart sight record in 1960 (1962a, p. 42, 1963, p. 78); Deadman Cay I, Stoddart sight records in 1960 and 1962 (1962a, p. 38, 1963, p. 79, 1969, p. 15); Deadman Cay II, Stoddart sight records in 1960 and 1962 (1962a, p. 38, 1963, p. 80); Deadman Cay III, Stoddart sight records in 1960 and 1961 (1962a, p. 39, 1963, p. 81); Deadman Cay IV, Stoddart sight record in 1960 (1962a, p. 39, 1963, p. 81); Deadman Cay V, Stoddart sight record in 1960 (1963, p. 82); Big Cay Bokel, Stoddart sight record in 1962. Lighthouse Reef: Sandbore Cay, Stoddart sight records in 1960 and 1961 (1962a, p. 57, 1963, p. 89); Northern Cay, Stoddart sight records in 1960 and 1961 (1962a, p. 62); Saddle Cay, Stoddart sight record in 1960 (1962a, p. 63, 1963, p. 94); Long Cay, Stoddart sight records in 1960 and 1961 (1962a, p. 80); Hat Cay, Stoddart 55 (Fo) (1962a, p. 81, 1963, p. 100). Glover's Reef: Southwest Cay I; Stoddart sight record in 1961 (1962a, p. 94), Fosberg & Stoddart 53854 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight record in 1960 (1963, p. 42); Goff's Cay, Stoddart sight record in 1960 (1963, p. 43); Rendezvous Cay, Stoddart sight records in 1960 and 1972 (1963, p. 48, 1974, p. 480), Spellman & Stoddart 2498 (US, MO, BH, Fo); Tobacco Cay, Stoddart sight records in 1961 and 1965 (1969, p. 10), Fosberg & Spellman 54243 (US); South Water Cay, Stoddart sight record in 1960 (1965, p. 57), Spellman & Stoddart 2157 (US, MO), Pringle 1908, 1909 (HAM); North Silk Cay, Stoddart sight record in 1960, Fosberg & Spellman 54272 (US); Frank's Cay, Stoddart sight record in 1960, Spellman & Stoddart 2419 (US, MO, BH, Fo); Frank's Cay East, Stoddart sight record in 1960; Frank's Cay West, Stoddart sight record in 1960; Seal Cay, Spellman & Stoddart 2481 (US, MO, BH, Fo).

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1960 (1963, p. 33); Spanish Cay, Stoddart sight records in 1961 and 1962 (1963, p. 47); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Cary Cay, Stoddart sight record in 1962 (1963, p. 63); Tobacco Range, Fosberg & Spellman 54456 (US); Coco Plum Cay, Spellman & Stoddart 2567 (US, MO);

Water Range, Spellman & Stoddart 2225 (US, MO); Man-o'-War Cay (west of Tobacco Cay), Fosberg & Spellman 54204 (US); Jack's Cay, Fosberg & Spellman 54433 (S); Buttonwood Cay, Stoddart sight record in 1961 (1963, p. 64), Fosberg & Spellman 54421 (US); Hatchet Cay, Fosberg & Spellman 54395 (US); Little Water Cay, Fosberg & Spellman 54343 (US); Owen Cay, Stoddart sight record in 1962 (1963, p. 66); Colson Cay, Stoddart sight records in 1962 and 1965 (1963, p. 67, 1969, p. 12); Scipio Cay, Stoddart sight records in 1962 and 1965 (1963, p. 66, 1969, p. 11); Laughing Bird Cay, Stoddart sight record in 1962; Bugle Cay, Stoddart sight record in 1962; East Snake Cay, Stoddart sight record in 1961; Middle Snake Cay South Islet, Stoddart sight record in 1961; West Snake Cay, Stoddart sight record in 1961 (1965, p. 137).

Citharexylum L.

Citharexylum caudatum L.

Barrier Reef Cays. -- Northeast Sapodilla Cay, Spellman & Stoddart 2302 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2455 (US, MO, BH, Fo).

Lantana L.

Lantana involucrata L.

Atoll Cays. -- Lighthouse Reef: Northern Cay, Stoddart 53 (Fo); Long Cay, Stoddart 453 (Fo) (1969, p. 18).

Lagoon Cays. -- Cay Caulker, Stoddart 429 (Fo), 434 (Fo) (1969, p. 6); Water Cay, Dwyer et al. 675 (MO); Buttonwood Cay, Fosberg & Spellman 54405 (US, MO); Hatchet Cay, Fosberg & Spellman 54378 (US, MO).

Lippia L.

Lippia nodiflora (L.) Michx. (Lippia)

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2183 (US, MO, BH, Fo, BM), Pringle 1885 (HAM); Tom Owen's West Cay, Spellman & Stoddart 2268 (US, MO, BH); Frank's Cay, Spellman & Stoddart 2398 (US); Nicolas Cay, Spellman & Stoddart 2349 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2471 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2375 (US, MO, BH, Fo); Seal Cay, Spellman & Stoddart 2489 (US, MO).

Lippia strigulosa Martens & Gal.

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54377 (US); Little Water Cay, Fosberg & Spellman 54354 (US).

Stachytarpheta Vahl*Stachytarpheta jamaicensis* (L.) Vahl

(Vervine, false verbena)

Atoll Cays. -- Turneffe Atoll: Big Cay Bokel, Stoddart sight record in 1965. Lighthouse Reef: Half Moon Cay, Stoddart 35 (Fo), Stoddart sight record in 1965 (1962a, p. 75, 1963, p. 98, 1969, p. 18); Long Cay, Stoddart sight records in 1962 and 1965 (1963, p. 99, 1969, p. 18). Glover's Reef: Northeast Cay, Linhart (1980, p. 163); Middle Cay, Stoddart sight record in 1961 (1962a, p. 93), Sachet & Stoddart 1609 (US), Linhart (1980, p. 163); Southwest Cay I, Fosberg & Stoddart 53864 (US), Linhart (1980, p. 163); Southwest Cay II, Stoddart 83 (Fo), Fosberg & Sachet 53880 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Tobacco Cay, Stoddart 525 (Fo), Stoddart sight records in 1961 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54251 (US); South Water Cay, Stoddart sight record in 1965 (1969, p. 11), Spellman & Stoddart 2188 (US, MO, BH), Pringle 1882 (HAM); Ranguana Cay, Spellman & Stoddart 2248 (US); Northeast Sapodilla Cay, Spellman & Stoddart 2319 (US, MO, BH); Frank's Cay, Spellman & Stoddart 2416 (US, MO, BH, Fo); Hunting Cay, Spellman & Stoddart 2458 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2369 (US, MO, BH).

Lagoon Cays. -- St George's Cay, Stoddart sight record in 1965 (1969, p. 8), Spellman 1467 (US, MO); Robinson Point Cay, Stoddart sight record in 1961 (1963, p. 46); Cary Cay, Stoddart sight record in 1962 (1963, p. 63); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Wild Cane Cay, Stoddart 25 (Fo).

Stachytarpheta mutabilis (Jacq.) Vahl var. *maxonii* Mold. ?

Lagoon Cays. -- Cay Caulker, Stoddart 408 (Fo) (1969, p. 6).

SOLANACEAE

Solanum L.*Solanum blodgettii* Chapm.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 139 (US).

Lagoon Cays. -- Ambergris Cay, Stoddart 443 (US, MO, Fo, BM) (1969, p. 6); Cay Caulker, Stoddart 412 (US, MO, Fo, BM), Stoddart 423 (US) (1969, p. 6).

Solanum campechiense L.

Barrier Reef Cays. -- Rendezvous Cay, Stoddart 126 (Fo).

**Solanum lycopersicum* L.

(Tomato)

Barrier Reef Cays. -- Rendezvous Cay, Stoddart 125 (Fo) (1963, p. 49); South Water Cay, Pringle sight record in 1980.

SCROPHULARIACEAE

Capraria L.

Capraria biflora L.

Atoll Cays. -- Glover's Reef: Southwest Cay I, Fosberg & Stoddart 53867 (US), Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53877 (US), Linhart (1980, p. 163); Southwest Cay, Pippen 905 (US).

**Russelia* Jacq.

**Russelia equisetiformis* Cham. & Schlecht. (Mary's tears, Fire-cracker flower)

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2468 (US, MO, BH, Fo).

Stemodia L.

Stemodia maritima L.

Atoll Cays. -- Turneffe Atoll: Big Cay Bokel, Stoddart 459 (Fo). Lighthouse Reef: Half Moon Cay, Stoddart 49 (Fo); Long Cay, Stoddart 143 (Fo).

BIGNONIACEAE

Enallagma (Miers.) Baill.

Enallagma latifolia (Mill.) Small

(Wild Calabash)

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2441 (US, MO, BH, Fo).

RUBIACEAE

Diodia L.

Diodia serrulata (Beauv.) Tayl.

Diodia maritima Thonn.

Atoll Cays. -- Glover's Reef: Middle Cay, Fosberg & Stoddart 53922 (US).

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2346 (US, MO, BH, Fo, BM); Hunting Cay, Spellman & Stoddart 2428 (US, MO, BH, Fo); Lime Cay, Spellman & Stoddart 2373 (US, MO, BH, Fo).

Erithalis P. Browne

Erithalis fruticosa L.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 30 (Fo), Stoddart 546 (Fo) (1962a, p. 76). Glover's Reef: Northeast Cay, Stoddart 73 (Fo) (1962a, p. 88), Fosberg & Sachet 53814 (US), Linhart (1980, p. 163); Long Cay, Fosberg & Sachet 53806 (US), Linhart (1980, p. 163); Middle Cay, Fosberg & Stoddart 53918 (US), 53923 (US), Sachet & Stoddart 1607 (US), Linhart (1980, p. 163); Southwest Cay I, Fosberg & Schreiber 53868 (US), Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53895 (US), Linhart (1980, p. 163); Southwest Cay, Pippen 897 (US).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2160 (US, MO, BH), Pringle 1864 (HAM); North Silk Cay, Stoddart sight record in 1961; Middle Silk Cay, Fosberg & Spellman 54286 (US); Pompion Cay, Stoddart sight record in 1960; Northeast Sapodilla Cay, Spellman & Stoddart 2316 (US, MO); Tom Owen's West Cay, Stoddart sight record in 1960; Tom Owen's East Cay, Stoddart sight record in 1960; Frank's Cay, Spellman & Stoddart 2413 (US, MO, BH, Fo); Nicolas Cay, Spellman & Stoddart 2340 (US, MO, BH); Hunting Cay, Spellman & Stoddart 2463 (US, MO, BH); Lime Cay, Spellman & Stoddart 2383 (US, MO).

Lagoon Cays. -- St George's Cay, Spellman 1463 (US, MO); Tobacco Range, Fosberg & Spellman 54452 (US); Coco Plum Cay, Spellman & Stoddart 2572 (US, MO, BH, Fo); Water Range, Spellman & Stoddart 2238 (US, MO, BH); East Snake Cay, Stoddart sight record in 1961.

Ernodea Sw.

Ernodea littoralis Sw.

Atoll Cays. -- Turneffe Atoll: Deadman Cay I, Stoddart sight record in 1965 (1969, p. 15). Lighthouse Reef: Sandbore Cay,

Stoddart sight record in 1965 (1969, p. 17); Northern Cay, Stoddart 51 (Fo), Stoddart sight record in 1965 (1969, p. 17); Half Moon Cay, Stoddart 552 (Fo) (1962a, p. 76, 1963, p. 98); Long Cay, Stoddart 141 (Fo), Stoddart 457 (Fo) (1963, p. 99, 1969, p. 18). Glover's Reef: Northeast Cay, Fosberg & Sachet 53827 (US); Middle Cay, Sachet & Stoddart 1613 (US), Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53898 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Goff's Cay, Stoddart sight record in 1965 (1969, p. 9, 1974, p. 479), Spellman & Stoddart 2539 (US, MO); English Cay, Dwyer et al. 667 (MO); South Water Cay, Spellman & Stoddart 2162 (US, MO), Pringle 1898 (HAM); Nicolas Cay, Spellman & Stoddart 2353 (US, MO); Hunting Cay, Spellman & Stoddart 2461 (US, MO, BH).

Lagoon Cays. -- Cay Caulker, Stoddart 432 (Fo) (1969, p. 6); Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); St George's Cay, Spellman 1473 (US, MO); Tobacco Range, Fosberg & Spellman 54451 (US).

Hamelia Jacq.

Hamelia patens Jacq.

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Stoddart 36 (Fo), Stoddart 138 (Fo) (1962a, p. 76).

Lagoon Cays. -- Ambergris Cay, Stoddart 444 (Fo) (1969, p. 6).

Hedyotis L.

Hedyotis corymbosa (L.) Lam.

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2521 (US, MO); South Water Cay, Spellman & Stoddart 2208 (US, MO).

Lagoon Cays. -- Buttonwood Cay, Fosberg & Spellman 54410 (US).

**Hedyotis lancifolia* Schum.

Oldenlandia lancifolia (Schum.) DC.

Oldenlandia herbacea sensu auct. non (L.) Roxb.

Barrier Reef Cays. -- South Water Cay, Pringle 1902 (HAM).

**Ixora* L.

**Ixora coccinea* L.

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2451
(US, MO).

Morinda L.

Morinda citrifolia L. (Hog apple)

Atoll Cays. -- Glover's Reef: Southwest Cay II, Fosberg & Sachet 53881 (US).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2198
(US, MO); Round Cay, Fosberg & Spellman 54293 (US); Pompion Cay,
Fosberg & Spellman 54317 (US) (seedling).

Psychotria L.

Psychotria nervosa Sw. sensu lato

Psychotria undata Jacq.

Psychotria granadensis Benth. ?

Barrier Reef Cays. -- Nicolas Cay, Spellman & Stoddart 2341 (US,
MO, BH, Fo).

Spermacoce L.

Spermacoce assurgens R. & P. (Peeny bush, button weed)

Spermacoce suffrutescens Jacq.

Borreria laevis sensu auct., non Lam.

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54223 (US,
MO); South Water Cay, Spellman & Stoddart 2179 (US, MO, BH, Fo, BM),
Pringle 1868 (HAM); Hunting Cay, Spellman & Stoddart 2470 (US, MO, BH,
Fo).

Spermacoce prostrata Aublet

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2430 (US,
MO, BH, Fo, BM).

Spermacoce suaveolens (Mey.) O. Ktze.

Borreria suaveolens Meyer

Lagoon Cays. -- Cay Caulker, Stoddart 426 (Fo) (1969, p. 6).

Spermacoce verticillata L.

Borreria verticillata (L.) G. F. W. Meyer

Lagoon Cays. -- St George's Cay, Spellman 1477 (US, MO).

COMPOSITAE

Ageratum L.

Ageratum littorale Gray

Atoll Cays. -- Turneffe Atoll: Mauger Cay, Stoddart 543 (Fo) (1962a, p. 47, 1963, p. 71, as *A. maritimum*); Deadman Cay II, Stoddart 128 (Fo), Stoddart 130 (Fo), Stoddart sight record in 1965 (1963, p. 80, 1969, p. 15). Lighthouse Reef: Half Moon Cay, Stoddart 43 (Fo), Stoddart 48 (Fo) (1962a, p. 76, as *A. maritimum*). Glover's Reef: Long Cay, Fosberg & Sachet 53793 (US) (abnormal), 53911 (US, MO, BH, Fo, BM), 53912 (US, MO), Stoddart 78 (Fo), Linhart (1980, p. 163); Middle Cay, Sachet & Stoddart 1612 (US, MO, BH, Fo, BM); Southwest Cay I, Fosberg & Stoddart 53865 (US); Southwest Cay II, Fosberg & Sachet 53897 (US, MO, BH, Fo, BM), Linhart (1980, p. 163); Southwest Cay, Pippen 9 (WMU).

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54212 (US, MO); South Water Cay, Spellman & Stoddart 2185 (US, MO, BH, Fo, BM), Pringle 1870 (HAM); Hunting Cay, Spellman & Stoddart 2438 (US, MO, BH, Fo, BM).

Lagoon Cays. -- Cay Caulker, Stoddart 413 (Fo), 425 (Fo), 428 (Fo) (1969, p. 6, inc. *A. maritimum*); Tobacco Range, Fosberg & Spellman 54468 (US); Water Range, Spellman & Stoddart 2223 (US); Hatchet Cay, Fosberg & Spellman 54392 (US).

Ageratum maritimum Kunth

Atoll Cays. -- Lighthouse Reef: Half Moon Cay, Verner (1959, pp. 3-8). Glover's Reef: Middle Cay, Linhart (1980, p. 163); Southwest Cay I, Linhart (1980, p. 163) (probably all *A. littorale* Gray).

Ageratum maritimum Kunth f. *calvum* Robinson

"Keys off the coast, N. S. Stevenson 152". Stanley & Record, Flora of British Honduras, *Fieldiana, Botany* 12: 394, 1936 (probably *A. littorale* Gray).

Ageratum sp.

Atoll Cays. -- Turneffe Atoll: Three Corner Cay, Stoddart sight record in 1962 (1963, p. 71); Cockroach Cay, Stoddart sight records in 1962 and 1965 (1969, p. 13); Cockroach Cay V, Stoddart sight record in 1962 (1963, p. 73); Soldier Cay, Stoddart sight records in 1962 and 1965 (1963, p. 75, 1969, p. 13); Big Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Little Calabash Cay, Stoddart sight records in 1960, 1962 and 1965 (1963, p. 76, 1969, p. 14); Deadman Cay I, Stoddart sight record in 1962 (1963, p. 80, 1969, p. 15); Deadman Cay IV, Stoddart sight record in 1962 (1963, p. 81). Lighthouse Reef: Sandbore Cay, Stoddart sight record in 1965 (1969, p. 17, as *A. maritimum*); Long Cay, Stoddart sight record in 1965 (1969, p. 18).

Barrier Reef Cays. -- Rendezvous Cay, Stoddart sight record in 1965 (1969, p. 9).

Lagoon Cays. -- Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); St George's Cay, Stoddart sight records in 1962 and 1965 (1963, p. 40, 1969, p. 7); Cary Cay, Stoddart sight record in 1962 (1963, p. 63).

Ambrosia L.

Ambrosia hispida Pursh

(Bay tansy)

Atoll Cays. -- Turneffe Atoll: Harry Jones Point, Stoddart sight record in 1960; Cay Bokel, Stoddart sight record in 1961 (1962a, p. 37, 1963, p. 82). Lighthouse Reef: Sandbore Cay, Stoddart 50 (Fo), 554 (Fo), Stoddart sight records in 1962 and 1965 (1962a, p. 57, 1963, p. 89, 1969, p. 16); Northern Cay, Stoddart sight records in 1960 and 1961 (1962a, p. 62, 1963, p. 92); Long Cay, Stoddart sight record in 1965 (1969, p. 18). Glover's Reef: Northeast Cay, Stoddart 72 (Fo) (1962a, p. 88), Fosberg & Sachet 53840 (US), Linhart (1980, p. 163); Middle Cay, Stoddart sight record in 1961 (1962a, p. 93), Sachet & Stoddart 1608 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- South Water Cay, Stoddart sight record in 1965 (1963, p. 56, 1969, p. 11), Spellman & Stoddart 2201 (US, MO), Pringle 1897 (HAM); Tom Owen's West Cay, Stoddart sight record in 1960.

Lagoon Cays. -- Ambergris Cay, Stoddart sight record in 1965 (1969, p. 6).

Bidens L.

Bidens cynapiifolia Kunth (Spanish needle, beggar's ticks)

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54246 (US) (seedling).

Lagoon Cays. -- Moho Cay, Stoddart 5 (Fo).

Bidens pilosa L. (Spanish needle, beggar's ticks)

Barrier Reef Cays. -- Hunting Cay, Spellman & Stoddart 2443 (US, MO).

Borrichia Adans.

Borrichia arborescens (L.) DC. (Seaside ox-eye)

Atoll Cays. -- Turneffe Atoll: Cockroach Cay, Stoddart sight record in 1962; Cockroach Cay V, Stoddart sight record in 1962 (1963, p. 73); Blackbird Cay, Stoddart sight record in 1960; Soldier Cay, Stoddart sight record in 1960; Big Calabash Cay, Stoddart sight records in 1960 and 1965 (1969, p. 14); Big Calabash East Cay I, Stoddart sight records in 1960 and 1962 (1963, p. 78, 1969, p. 14); Big Calabash East Cay II, Stoddart sight record in 1960; Little Calabash Cay, Stoddart sight record in 1965 (1969, p. 14); Deadman Cay I, Stoddart sight record in 1960 (1963, p. 80, 1969, p. 15); Deadman Cay II, Stoddart sight records in 1960, 1962 and 1965 (1963, p. 80, 1969, p. 15); Deadman Cay III, Stoddart sight record in 1960; Deadman Cay IV, Stoddart sight record in 1965 (1969, p. 15); Deadman Cay V, Stoddart sight record in 1965. Lighthouse Reef: Sandbore Cay, Stoddart sight record in 1965 (1969, p. 17); Northern Cay, Stoddart sight record in 1965 (1969, p. 17); Half Moon Cay, Stoddart 548 (Fo); Long Cay, Stoddart 142 (Fo), Stoddart sight record in 1965 (1963, p. 99, 1969, p. 18); Hat Cay, Stoddart 54 (Fo) (1962a, p. 81, 1963, p. 100). Glover's Reef: Northeast Cay, Fosberg & Sachet 53810 (US); Small Cay (Long Cay North), Stoddart sight record in 1961, Fosberg & Sachet 53778 (US), Linhart (1980, p. 163); Long Cay, Fosberg & Sachet 53804 (US), Pippen 916 (US), Linhart (1980, p. 163); Middle Cay, Stoddart sight record in 1961, Sachet & Stoddart 1624 (US), Linhart (1980, p. 163); Southwest Cay I, Fosberg & Stoddart 53897 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- St George's East Cay, Stoddart sight record in 1960 (1963, p. 41); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11), Spellman & Stoddart 2154 (US, MO, BH, Fo), Pringle 1871 (HAM).

Lagoon Cays. -- Ambergris Cay, Stoddart 445 (canescent form) (Fo), 446 (Fo) (1969, p. 6); Cay Caulker, Stoddart 420 (Fo) (1969, p. 6); Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); Tobacco Range, Fosberg & Spellman 54464 (US); Water Range, Spellman & Stoddart 2231 (US, MO).

Conyza L.

Conyza canadensis (L.) Cronquist var. *pusilla* (Nutt.) Cronq.
(Small horse-weed)

Erigeron canadensis L.

Atoll Cays. -- Lighthouse Reef: Long Cay, Stoddart 454 (Fo)
(1969, p. 18).

Barrier Reef Cays. -- South Water Cay, Spellman & Stoddart 2192
(US, MO); Hunting Cay, Spellman & Stoddart 2467 (US, MO).

Lagoon Cays. -- Moho Cay, Stoddart 9 (Fo) (seedling).

Eclipta L.*Eclipta alba* (L.) Hassk.

Atoll Cays. -- Glover's Reef: Southwest Cay I, Linhart (1980,
p. 163).

Barrier Reef Cays. -- English Cay, Spellman & Stoddart 2520 (US,
MO); South Water Cay, Pringle 1879 (HAM); Carrie Bow Cay, Ferraris
12 (US).

Lagoon Cays. -- Buttonwood Cay, Fosberg & Spellman 54409 (US);
Little Water Cay, Fosberg & Spellman 54339 (US).

Eclipta prostrata (L.) L.

Barrier Reef Cays. -- English Cay, Dwyer et al. 666 (MO).

Emilia Cass.*Emilia sonchifolia* (L.) DC. ex Wight

Barrier Reef Cays. -- South Water Cay, Pringle 1878 (HAM).

Flaveria Juss.*Flaveria linearis* Lag.

Lagoon Cays. -- Ambergris Cay, Stoddart 447 (Fo) (1969, p. 6).

*Melanthera Rohr**Melanthera nivea* (L.) Small

Atoll Cays. -- Turneffe Atoll: Big Cay Bokel, Stoddart 460 (Fo).
 Lighthouse Reef: Sandbore Cay, Stoddart 144 (Fo). Glover's Reef:
 Long Cay, Fosberg & Sachet 53794 (US) (sterile).

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54233 (US),
54252 (US, MO); South Water Cay, Spellman & Stoddart 2169 (US, MO).

Lagoon Cays. -- St George's Cay, Spellman 1468 (US, MO);
 Buttonwood Cay, Fosberg & Spellman 54412 (US); Hatchet Cay, Fosberg &
 Spellman 54393 (US); Little Water Cay, Fosberg & Spellman 54351 (US,
 MO); Moho Cay, Stoddart 12 (Fo).

Pluchea Cass.

Pluchea symphytifolia (Mill.) Gillis (Wild tobacco)

Pluchea carolinensis (Jacq.) G. Don

Pluchea odorata (L.) Cass.

Barrier Reef Cays. -- Tobacco Cay, Fosberg & Spellman 54210 (US).

Lagoon Cays. -- Tobacco Range, coconut grove in northern part of
 Cay, Fosberg & Spellman 54471 (US); Coco Plum Cay, Spellman & Stoddart
 2571 (US, MO); Buttonwood Cay, Fosberg & Spellman 54408 (US).

Synedrella Gaertn.

Synedrella nodiflora (L.) Gaertn.

Lagoon Cays. -- St George's Cay, Spellman 1469 (MO), 1474 (US,
 MO).

Vernonia Schreb.

**Vernonia cinerea* (L.) Less. (Little ironweed)

Lagoon Cays. -- Hatchet Cay, Fosberg & Spellman 54362 (US).

Wedelia Jacq.

Wedelia trilobata (L.) Hitchc. (Seaside marigold)

Atoll Cays. -- Turneffe Atoll: Soldier Cay, Stoddart sight record

in 1965 (1969, p. 13); Little Calabash Cay, Stoddart sight records in 1962 and 1965 (1963, p. 77, 1969, p. 14); Deadman Cay I, Stoddart sight record in 1965 (1969, p. 15); Big Cay Bokel, Stoddart sight record in 1965, Lighthouse Reef: Sandbore Cay, Stoddart sight record in 1965 (1969, p. 17); Half Moon Cay, Stoddart 61 (Fo), Stoddart sight record in 1965 (1962a, p. 73, 1969, p. 17); Long Cay, Stoddart sight record in 1965 (1969, p. 18). Glover's Reef: Northeast Cay, Stoddart 69 (Fo) (1962a, p. 88), Fosberg & Sachet 53821 (US), Linhart (1980, p. 163); Middle Cay, Sachet & Stoddart 1617 (US), Linhart (1980, p. 163); Southwest Cay I, Stoddart sight record in 1971, Linhart (1980, p. 163); Southwest Cay II, Fosberg & Sachet 53903 (US), Linhart (1980, p. 163).

Barrier Reef Cays. -- Sergeant's Cay, Stoddart sight record in 1965 (1969, p. 8), Spellman & Stoddart 2545 (US); Rendezvous Cay, Stoddart sight records in 1962 and 1965 (1969, p. 9); Tobacco Cay, Stoddart 527 (Fo), Stoddart sight records in 1961, 1962 and 1965 (1963, p. 54, 1969, p. 10), Fosberg & Spellman 54242 (US); South Water Cay, Stoddart sight records in 1960 and 1965 (1963, p. 56, 1969, p. 11), Spellman & Stoddart 2172 (US, MO, BH, Fo), 2186 (US, MO), Pringle 1872 (HAM); Carrie Bow Cay, Spellman & Stoddart 2135 (US, MO); Middle Silk Cay, Fosberg & Spellman 54291 (US); Ranguana Cay, Spellman & Stoddart 2254 (US, MO); Tom Owen's East Cay, Spellman & Stoddart 2282 (US, MO, BH); Tom Owen's West Cay, Stoddart sight record in 1960; Northeast Sapodilla Cay, Spellman & Stoddart 2318 (US, MO, BH, Fo); Frank's Cay, Stoddart sight record in 1960, Spellman & Stoddart 2403 (US, MO, BH, Fo, BM).

Lagoon Cays. -- Cay Caulker, Stoddart 401 (Fo), 406 (Fo) (1969, p. 6); Cay Chapel, Stoddart sight record in 1965 (1969, p. 7); St George's Cay, Stoddart sight records in 1962 and 1965 (1963, p. 8, 1969, p. 7), Spellman 1471 (MO); Cat Cay, Stoddart sight record in 1962 (1963, p. 62); Cary Cay, Stoddart sight record in 1962; Coco Plum Cay, Spellman & Stoddart 2563 (US, MO, BH, Fo); Water Range, Spellman & Stoddart 2235 (US, MO); Buttonwood Cay, Fosberg & Spellman 54425 (US); Hatchet Cay, Fosberg & Spellman 54368 (US); Little Water Cay, Fosberg & Spellman 54347 (US); East Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Middle Snake Cay North Islet, Stoddart sight record in 1961; South Snake Cay, Stoddart sight record in 1961 (1965, p. 138); Moho Cay, Stoddart 13 (Fo).

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LIST OF CAYS CITED

The islands in the systematic lists are grouped into Atoll Cays (Turneffe Islands; Lighthouse Reef; Glover's Reef); Barrier Reef Cays; and Lagoon Cays. Within each category the islands are cited from north to south. For locations of cays on Turneffe Islands and Lighthouse Reef, see *Atoll Res. Bull.* 87 (1962); for location of cays on Glover's Reef, the Barrier Reef, and in the Lagoon, see *Atoll Res. Bull.*, this issue.

TURNEFFE ISLANDS

Mauger Cay
Dogflea Cay
Three Corner Cay
Crawl Cay
Pelican Cay (Cockroach Group)
Cockroach Cay
Cockroach Cay V
Pelican Cay
Blackbird Cay
Soldier Cay
Harry Jones Point
Big Calabash Cay
Big Calabash East Cay I
Big Calabash East Cay II
Little Calabash Cay
Grand Bogue Point
Deadman Cay I
Deadman Cay II
Deadman Cay III
Deadman Cay IV
Deadman Cay V
Big Cay Bokel
Cay Bokel

LIGHTHOUSE REEF

Sandbore Cay
Northern Cay
Saddle Cay
Long Cay
Half Moon Cay
Hat Cay

GLOVER'S REEF

Northeast Cay
Long Cay North (Small Cay)
Long Cay
Middle Cay
Southwest Cay I
Southwest Cay II

BARRIER REEF CAYS

St George's East Cay
Paunch Cay
Sergeant's Cay
Goff's Cay
English Cay
Rendezvous Cay
Cay Glory
Tobacco Cay
South Water Cay
Carrie Bow Cay
North Silk Cay
Middle Silk Cay
South Silk Cay
Round Cay
Pompion Cay
Ranguana Cay
North Spot
Tom Owen's East Cay
Tom Owen's West Cay
Northeast Sapodilla Cay
Frank's Cay
Frank's Cay East
Frank's Cay West
Nicolas Cay
Hunting Cay
Lime Cay
Ragged Cay
Seal Cay

LAGOON CAYS

Ambergris Cay
Cay Cangrejo
Cay Caulker
Cay Chapel
St George's Cay
Hick's Cays
Rider's Cays
Drowned Cays
Water Cay
Robinson Point Cay

Robinson Cay
Spanish Cay
Tobacco Range
Stewart Cay
Weewee Cay
Coco Plum Cay
Water Range (Twin Cays)
Peter Douglas Cay
Cat Cay
Man-o'-War Cay
Crawl Cay
Baker's Rendezvous
Quamino Cay
Jack's Cay
Moho Cay (northern)
Buttonwood Cay
Simmond's Cay
Southern Long Cay
Trapp's Cay
Hatchet Cay

Little Water Cay
Cary Cay
Laughing Bird Cay
Owen Cay
Colson Cay
Scipio Cay
Bugle Cay
Placencia Cay
Harvest Cay
Moho Cay (southern)
Frenchman's Cay
Wild Cane Cay
East Snake Cay
Middle Snake Cay
Middle Snake Cay North Islet
Middle Snake Cay South Islet
South Snake Cay
West Snake Cay
West Snake Cay West Islet



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FLORISTIC OBSERVATIONS ON SOUTH WATER AND CARRIE BOW
CAYS, STANN CREEK DISTRICT, BELIZE, in 1979-1980

by

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FLORISTIC OBSERVATIONS ON SOUTH WATER AND
CARRIE BOW CAYS, STANN CREEK DISTRICT,
BELIZE, IN 1979-1980¹

James S. Pringle

South Water Cay is an island of ca. 5.17 ha in Stann Creek District, Belize, 16° 48' 21-42" N, 88° 04' 50-58" W, 22.4 km SE of Dangriga (Stann Creek Town) and 20.9 km from the nearest mainland point. It is at the southern tip of Tobacco Reef (part of the Barrier Reef), with the reef edge paralleling its eastern and southern coasts 150-250 m offshore. This cay is much used for teaching and research by biologists from Queen's University, the Smithsonian Institution, and elsewhere. Therefore, records of its flora are especially desirable, for use in ecological research and as a basis for observations of floristic changes.

The cays of Belize have been described by Stoddart (1962a, 1965a). South Water Cay is a sand cay. (In the more detailed classification of Stoddart 1965a, it is mapped, from pre-1961 observations, as a vegetated sand cay with a windward shingle ridge. The shingle ridge, however, is confined to a very small area at the northeast tip, and in 1979-1980 was poorly developed.) On sand cays, deposits of sand, derived from coral and shell fragments, permit the development of diverse vegetation including many species tolerant of the dry coral-sand habitats, in contrast to that of the mangrove cays. The vegetation of the uncleared sand cays consists largely of thickets in which *Bursera simaruba* (L.) Sarg., *Coccoloba uvifera*, *Cordia sebestena*, and *Thrinax radiata* Lodd. ex J.A. & J.H. Schultes are among the dominant species (Stoddart, 1965b). This was probably the original vegetation of South Water Cay, although some of the usual dominant species are now absent. Many of the sand cays, including South Water Cay, have been cleared of much of this vegetation and planted to coconuts, *Cocos nucifera*. Clearing has left such cays more susceptible to wind erosion, and extensive areas of largely bare sand are now common (Stoddart, 1965b).

On 30-31 October 1961, Hurricane Hattie, the most severe of several hurricanes since coconut planting had become widespread, killed so many coconut palms and demolished so many structures that many of the coconut plantations and associated facilities on the Belizean cays were abandoned, and some recovery of the original thicket vegetation has been noted since then. The hurricane also caused extensive physiographic modifications and damage to natural vegetation. Mangroves -- *Avicennia germinans*, *Conocarpus erectus*, *Laguncularia racemosa* (L.) Gaertn. fil., and *Rhizophora mangle* -- were killed through defoliation, and the littoral thickets of such species as *Sophora tomentosa*, *Borrchia arborescens*, *Suriana maritima*, and *Tournefortia gnaphalodes* were extensively eliminated by uprooting, to the extent that, shortly after the hurricane, the three last-named species, although they had been extensively dominant in the cays, could not be found within 20 mi (ca. 32 km) of the center of the storm-track (Stoddart, 1965b). South Water Cay, ca 54 km from the storm-track's center, was less severely affected than some of the cays studied by Stoddart. There was, however, extensive erosion at the southern tip of the island, as shown in Stoddart's (1963) maps of the 1960 and 1962 coastlines, and also significant erosion on the west-central coast, where a large resort building was destroyed (Stoddart, 1963). Fresh exposure of beach-rock and some sand-

¹Contribution No. 42 from the Royal Botanical Gardens, Hamilton, Ontario, Canada.
Royal Botanical Gardens, Box 399, Hamilton, Ontario, Canada L8N 3H8.

stripping and root exposure were noted at several places along the coast of the island (Stoddart, 1962b). New plantings of coconuts were made on South Water and Carrie Bow cays following the 1961 hurricane (Stoddart, 1969).

Human use of South Water Cay was originally focused around a well near the center of the island, now surrounded by concrete pavement. Near this well are buildings used as a field station by biologists. Elsewhere there are vacationers' cottages, fishermen's residences, and a retreat belonging to a religious order. Except for coconuts, no food crops or other economic plants are grown. Ornamental gardens were planted behind the above-mentioned resort building near the center of the island, and a hard-surfaced tennis court (not extant) was constructed just north of these gardens prior to 1960 (Stoddart, 1963, 1969). Some additional ornamentals were planted around several of the existing buildings and along paths. Most of the introduced ornamentals remain confined to the sites where they were planted, with no tendency to spread. *Hymenocallis littoralis*, in contrast, has become extensively naturalized throughout the island, and some plants of *Casuarina equisetifolia* likewise appear to be spontaneous. Whether all plants of these species are derived from those planted on the island, or whether natural colonization has also occurred, cannot be determined. *Erithalis fruticosa* has been used in the ornamental plantings, but can be assumed to be part of the native flora.

Much of South Water Cay is covered by coconut palms. Vegetation is sparse in their shade, consisting of small, scattered plants of *Fimbristylis cymosa*, *Cyperus peruvianus*, *C. platifolius*, and several species that are more abundant and luxuriant elsewhere, e.g., *Euphorbia mesembryanthemifolia* and *Wedelia trilobata*. Only two herb-subshrub communities are at all extensive. A dry, sunny area of ca. 0.29 ha near the field station is dominated by *Ipomoea stolonifera*, with numerous plants of *Ageratum littorale* and *Stachytarpheta jamaicensis*, moderate numbers of *Crotalaria retusa*, *Desmodium incanum*, and *Waltheria indica*, and scattered individuals of many other species (Fig. 1). Just north of this community, an evidently less xeric area of ca. 0.44 ha is densely covered by approximately equal quantities of *Ipomoea pes-caprae*, *Vigna luteola*, and *Wedelia trilobata* (Fig. 2). There are some relatively high areas where dryness, probably in combination with wind action and foot traffic, keeps the vegetation very sparse, with only a few plants of such species as *Euphorbia blodgettii*, *E. trichotoma*, *Phyllanthus amarus*, and *Sporobolus virginicus* being present (Fig. 3). Some areas near the spring are regularly mowed as well as being much trampled; these are the principal habitats of such prostrate or semi-prostrate species as *Polypermum procumbens* and *Hedyotis lancifolia*. Along the eastern coast are occasional plants or groups of *Avicennia germinans* and *Conocarpus erectus* at the water's edge and *Rhizophora mangle* in the shallows (Fig. 4), but there are no extensive mangrove communities. Immediately inshore from the mangroves are remnants of a littoral-thicket community, with a few plants of *Borreria arborescens*, *Cordia sebestena*, and *Sophora tomentosa*, as well as the more abundant *Coccoloba uvifera*. Patches of *Sesuvium portulacastrum* (the most abundant of these succulents), *Phloxeris vermicularis*, and *Batis maritima* grow in open areas near the water's edge, especially around exposed beach-rock and shingle near the northeast tip of the island. *Panicum virgatum* grows in a dense stand just north of the field station and in smaller patches elsewhere, and other graminoids, especially *Sporobolus virginicus* and *Fimbristylis cymosa*, occasionally form dense patches. A few other species, including *Lippia nodiflora*, *Ernodea littoralis*, and *Ambrosia hispida*, form patches up to several m in diameter, but do not dominate more extensive communities. *Cassytha filiformis* infestations are conspicuous in parts of both *Ipomoea*-dominated communities (on numerous hosts) and on *Ernodea littoralis*. Large, dense beds of *Thalassia testudinum*, *Syringodium filiforme*, and mixtures of both occur submerged between the cay and the reef edge to the east and south and in a narrower zone along the west coast.

Sixty-eight vascular-plant species, listed in Table 1, were found on South Water Cay and in the immediately adjacent shallow waters.

Table 1. Vascular plant species observed on South Water Cay in 1979 and 1980.

Hydrocharitaceae

Thalassia testudinum K.D. Koenig 11 - 1918, HAM

Cymodoceaceae

Syringodium filiforme Kützing (*Cymodocea filiformis* (Kützing) Correll)
11 - 1920, HAM, UNA; 1923, HAM, MO, UNA

Gramineae

Andropogon glomeratus (Walt.) B.S.P. 7 - 1919, HAM, MO
Antheophora hermaphrodita (L.) Kuntze 7 - 1926, HAM, MO
Cenchrus incertus M.A. Curtis (*C. pauciflorus* Benth.) 5,3 - 1906, HAM, MO
Distichlis spicata (L.) Greene var. *spicata* 3 - 1894, HAM
Eragrostis ciliaris (L.) R.Br. 7 - 1895, HAM
Eustachys petraea (Sw.) Desv. (*Chloris petraea* Sw.) 7 - 1913, HAM
Panicum virgatum L. var. *virgatum* 7 - 1925, HAM, MO
Spartina patens (Ait.) Muhl. 3,7 - 1929, HAM
Sporobolus virginicus (L.) Kunth 3 - 1911, HAM

Cyperaceae

Cyperus peruvianus (Lam.) F.N. Williams (*Kyllinga peruviana* Lam.) 7,6? -
1893, HAM
Cyperus planifolius L.C. Rich. 7,6? - 1892, HAM, MO
Fimbristylis cymosa R. Br. subsp. *spathacea* (Roth) Koyama (*F. spathacea* Roth)
1,7 - 1887, 1888, HAM

Palmae

Cocos nucifera L. 9

Liliaceae

Dracaena sp. 9

Amaryllidaceae

Hymenocallis littoralis (Jacq.) Salisb. 10 - 1930, HAM

Casuarinaceae

Casuarina equisetifolia J.R. & G. Forst. 10

Amaranthaceae

Philoxerus vermicularis (L.) Beauv. 3,1 - 1905, HAM

Polygonaceae

Coccoloba uvifera (L.) L. 1,6 - 1889, HAM

Bataceae

Batis maritima L. 3,2,1 - 1904, HAM

Nyctaginaceae

Boerhavia coccinea Mill. (*B. diffusa* L., s. lat.) 5 - 1866, HAM

Aizoaceae

Sesuvium portulacastrum (L.) L. var. *portulacastrum* 3,7 - 1867, HAM

Portulacaceae

Portulaca oleracea L. 1,7,2? - 1896, HAM, MO

Portulaca pilosa L. 7 - 1873, HAM

Lauraceae

Cassytha filiformis L. 1,6 - 1861, HAM

Cruciferae

Cakile lanceolata (Willd.) O.E. Schultz 1 - 1884, HAM

Leguminosae

Canavalia rosea (Sw.) DC. (*C. maritima* (Aubl.) Thouars; *C. obtusifolia* (Lam.) DC.) 1 - 1863, HAM

Crotalaria retusa L. 1 - 1883, HAM

Desmodium incanum DC. var. *incanum* (*D. canum* Schinz & Thell.) 5 - 1907, HAM

Desmodium tortuosum (Sw.) DC. 5 - 1922, HAM

Sophora tomentosa L. 1 - 1886, HAM

Vigna luteola (Jacq.) Benth. 1 - 1874, HAM

Surianaceae

Suriana maritima L. 1,3 - 1869, HAM

Euphorbiaceae

Euphorbia blodgettii Engelm. ex Hitchc. (*Chamaesyce blodgettii* (Engelm. ex Hitchc.) Small) 7 - 1899, HAM, MO

Euphorbia mesembryanthemifolia Jacq. (*Chamaesyce mesembryanthemifolia* (Jacq.) Dugand; *E. buxifolia* Lam.) 7,1? - 1876, 1880, HAM

Euphorbia trichotoma H.B.K. 7 - 1900, 1901, HAM

Phyllanthus amarus Schum. (*P. niruri* sensu auctt., non L.) 7 - 1875, HAM

Malvaceae

Hibiscus rosa-sinensis L. 9

Sterculiaceae

Walteria indica L. (*W. americana* L.) 7,6? - 1877, HAM; Backman s.n., MO

Passifloraceae

Passiflora suberosa L. 6,1? - 1924, HAM, MO

Rhizophoraceae

Rhizophora mangle L. 2 - 1962, HAM

Myrtaceae

Psidium guajava L. 9

Combretaceae

Conocarpus erectus L. 1,3 - 1891, HAM

Terminalia catappa L. 9?,1?

Loganiaceae

Polypremum procumbens L. 7 - 1903, HAM, NY

Apocynaceae

Nerium oleander L. 9

Plumeria rubra L. 9

Convolvulaceae

Ipomoea macrantha Roem. & Schult. 1 - 1928, HAM

Ipomoea pes-caprae (L.) R. Br. ssp. *brasiliensis* (L.) Ooststr. 1 - 1881, HAM, MO

Ipomoea stolonifera (Cyrillo) J.F. Gmel. 1 - 1913, HAM

Jacquemontia havanensis (Jacq.) Urb. (*J. jamaicensis* (Jacq.) Hallier fil.) 1 - 1965, HAM

Boraginaceae

Cordia sebestena L. 1 - 1921, HAM

Tournefortia gnaphalodes (L.) R.Br. ex Roem. & Schult. (*Mallotonia gnaphalodes* (L.) Britt.) 1,7 - 1914, 1927, HAM

Verbenaceae

Avicennia germinans (L.) L. (*A. nitida* Jacq.) 2 - 1908, 1909, HAM

Lippia nodiflora (L.) Michx. (*Phyla nodiflora* (L.) Greene) 6,7 - 1885, HAM

Stachytarpheta jamaicensis (L.) Vahl 7,1? - 1882, HAM

Solanaceae

Lycopersicon esculentum Mill. (*Solanum lycopersicum* L.) 8

Rubiaceae

- Spermacoce assurgens* Ruiz & Pavon (*Borreria laevis* sensu auctt., non (Lam.) Griseb.) 7 - 1868, HAM
Erithalis fruticosa L. 6 - 1864, HAM
Ernodea littoralis Sw. 6 - 1898, HAM
Hedyotis lancifolia Schumach. (*Oldenlandia lancifolia* (Schumach.) DC.; *O. herbacea* sensu auctt., non (L.) Roxb.) 7 - 1902, HAM

Compositae

- Ageratum littorale* A. Gray f. *setigerum* Robins. 5,4 - 1870, HAM
Ambrosia hispida Pursh (*A. crithmifolia* DC.) 1 - 1897, HAM
Borrchia arborescens (L.) DC. 1,3 - 1871, HAM
Eclipta alba (L.) Hassk. (*E. prostrata* (L.) L.) 5,7 - 1879, HAM, MO
Emilia sonchifolia (L.) DC. ex Wight 4,5 - 1878, HAM
Wedelia trilobata (L.) Hitchc. 1 - 1872, HAM

The first number following each name indicates the probable most important means of inter-island dispersal, or status if introduced, according to the list below. The second is my collection number for the voucher specimen(s), with abbreviations for herbaria following Holmgren & Keuken (1974).

Probablê Dispersal Adaptations

1. Adapted to dispersal by oceanic transport of seeds or fruits; seeds or fruits are capable of floating, often for long periods.
2. Adapted to dispersal by oceanic transport of young seedlings; includes viviparous species (seedlings transported with fruit).
3. Dispersal probably effected by oceanic transport of whole plants, stem fragments, rhizomes, or bulbs; plants may be characterized by ample, buoyant storage tissue, brittle stems, etc.
4. Adapted to dispersal by wind; fruits or seeds are plumed or winged.
5. Having definite adaptations to transport attached to feathers or feet of birds, hair of mammals, and/or clothing; seeds, fruits, or associated structures are barbed or sticky.
6. Adapted to internal transport by birds; seeds are protected by hard seed coats, endocarps, etc., and in many cases are enclosed in fleshy fruits.
7. Probably dispersed largely as fruits or seeds on "rafts" of dislodged vegetation or floating debris, in mud adhering to feet of birds, shoes of humans, etc.; in many cases lacking obvious adaptations to other means of long-distance dispersal; seeds often small and numerous.
8. Probably introduced via seeds discarded in garbage; not established.

9. Introduced species persisting where planted but not spreading.
10. Planted species now reproducing spontaneously and spreading.
11. Marine species dispersed largely through fragmentation.

The *Dracaena* sp. is a cultivated species seen only without flowers.

Carrie Bow Cay, a smaller islet 1.14 km S of South Water Cay, is likewise largely vegetated by planted coconut palms. The herbaceous vegetation was sparse in 1979, comprising only small patches and a few scattered individuals of *Sesuvium portulacastrum*, *Portulaca oleracea*, and *Cakile lanceolata*, plus one *Hymenocallis littoralis* near one of the buildings.

Most of the species listed above are widely distributed in the Caribbean area. Of the 60 native and naturalized species, all but two -- *Panicum virgatum* and *Euphorbia trichotoma* -- are also present in the flora of Jamaica (1015 km EbN) and/or the Cayman Islands (on the basis of being listed by Adams, 1972, with the addition of *Ageratum littorale* from Johnson, 1971), and all but three - *Antheophora hermaphrodita*, *Cyperus peruvianus*, and *Hedyotis lancifolia* -- are known from southern Florida (ca. 1080-1230 km NE) (Long & Lakela, 1971). Some of the widespread species, e.g., *Canavalia rosea*, *Sophora tomentosa*, *Suriana maritima*, and *Waltheria indica*, occur along seacoasts throughout much of the tropics or at least in widely separated areas, presumably as a result of long-distance dispersal by ocean currents. Of the 26 species listed by Fosberg (1974) as being characteristic of coral-island vegetation throughout the tropics, 11 are present on South Water Cay. Other species, such as *Desmodium incanum*, *Eclipta alba*, and *Emilia sonchifolia*, are weedy, commonly colonizing recently disturbed sites, and in many localities are evidently introduced inadvertently through human activities (see Johnston, 1949).

Adaptations to dispersal listed above are based on my observations, published descriptions of fruits and seeds, and information compiled by Guppy (1917), Ridley (1930), and Gunn & Dennis (1976). A high proportion of the plants of this cay are adapted to oceanic dispersal of seeds or fruits. Some of these are in families and genera in which most species do not exhibit such adaptations, e.g., the Cyperaceae, Leguminosae, and Compositae (cf. Ridley, 1930, p. 250). Because of the relatively short distances among the cays and from the mainland, buoyancy for two or three days or even less would probably sometimes suffice for dispersal.

Stoddart's (1962b, 1965a) observations of shoreline erosion and the disappearance of many populations of shrubs that characteristically grow close to the water's edge indicates the frequency with which large portions of plants, including storage organs, may be uprooted during storms and presumably carried by ocean currents to other islands. Many species, including most of the perennials, may sometimes be dispersed in this way.

Seeds of virtually all of these species could at times be dispersed via floating vegetation, in mud adhering to the feet of birds, or in debris inadvertently transported by humans. Guppy (1917), Ridley (1930, esp. p. 252), and authors cited by them considered transport of fruits and seeds on floating logs to be particularly important in the inter-island dispersal of many shoreline shrubs, specifically mentioning *Borrighia arborescens* and *Suriana maritima*, among others, and also some of the annual psammophytes such as *Portulaca oleracea*. According to F.R. Fosberg (personal communication in 1980), this

concept should be expanded to emphasize "rafts" of dislodged vegetation more than smaller fragments such as logs; such "rafts" may carry seeds and similar small propagules as well as transporting the larger plants they comprise. In the above list, this mode of transport is noted only when it seems likely to be of major importance.

The Great-tailed Grackle, *Cassidix mexicanus*, a common species on South Water Cay, is probably by far the most important agent of endornithochorous dispersal in the Belizean cays. This species consumes a wide range of food items, including various berry-like fruits (Skutch, 1958). Only those species appearing to be specifically adapted to endornithochorous dispersal are noted in the list, but a small percentage of seeds normally destroyed when eaten by birds may occasionally be egested undamaged. Likewise, wind, during severe storms, may transport a wide range of relatively light seeds.

Stoddart's (publ. 1963, 1969) observations of cays including South Water and Carrie Bow cays in 1960, 1962, and 1965 provide a basis for assessing changes in the vegetation over a 20-year period. Following the destruction of the major resort building on South Water Cay in 1961, the ornamental gardens have scarcely been maintained as such, and much of the area is now more or less open coral sand or vegetated by the *Ipomoea stolonifera*-dominated community, although many of the ornamental shrubs remain. The effects of the weather and the spread of vegetation, plus new cottage construction and coconut plantings on or near the site, have eliminated all traces of the tennis court. The present field station and most of the cottages have been built since 1961. Early in this period, further clearing was carried out on the northern part of the island, where several cottages were built. The vegetation there can no longer be called "dense palm thickets" as it was by Stoddart in 1963, and none of the *Thrinax radiata* palms recorded (as *T. parviflora* Sw.) as "thriving" there as late as 1965 was seen in 1979 or 1980. The swampy zone of standing water mapped by Stoddart (1963) near the northern tip of the island apparently no longer forms, although intermittently damp depressions remain. Most of the ground-cover species recorded for the northern part of the island in 1962 were still fairly plentiful in 1979-1980. Along the shingle ridge at the northern end, *Sesuvium portulacastrum* was still present although perhaps less extensive, but the crest-zone of *Tournefortia* and *Suriana* on this part of the island had disappeared, presumably because of further erosion.

Comparing the present vegetation with that recorded by Stoddart in 1965 (publ. 1969), the two *Ipomoea*-dominated communities on South Water Cay, described above, appear to have changed little; the dominants then present in both were present in similar quantities in 1979-1980. With the exception of *Thrinax radiata*, all of the other species mentioned by Stoddart (1969) in his description of the vegetation of South Water Cay were still present.² *Rhizophora mangle* has continued to recover since the 1961 hurricane; Stoddart reported only "one or two" individuals surviving in 1965, whereas several sizeable colonies and numerous small seedlings were present in 1979-1980. *Tournefortia gnaphalodes* has made less of a recovery, with only a few small plants being present in 1980. The coconuts planted on the southern part of the island during the 1960's are now large trees.

²According to F.R. Fosberg (personal communication in 1980), however, specimens collected on South Water Cay by Stoddart & Spellman in 1972 or earlier by Stoddart included *Erythrina* sp. (Leguminosae); *Euphorbia glomerifera* (Millsp.) L.C. Wheeler (*Chamaesyce glomerifera* Millsp.) (Euphorbiaceae); *Laguncularia racemosa* (L.) Gaertn. fil. (Combretaceae); and *Hedyotis corymbosa* (L.) Lam. (*Oldenlandia corymbosa* L.) (Rubiaceae), none of which were encountered in 1979 or 1980.

According to F.R. Fosberg (personal communication in 1979), recurrent colonizations and extinctions are characteristic of the flora of Carrie Bow Cay. Since 1965, its vegetation has declined both in biomass and in number of species, although human use of the island remains similar. *Euphorbia* (presumably *E. blodgettii*) was said to form a "patchy ground cover" in 1965, and *Ipomoea* (probably *I. stolonifera*), *Tournefortia*, and grasses were also reported, but none of these were seen in 1979. Of the taxa mentioned by Stoddart, only *Sesuvium portulacastrum* and the planted coconuts remained.

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NOTE

As this paper was going to press, new information was provided by Robert H. Sims, just returned from Carrie Bow Cay. He reported that, for some years, the proprietors of the island have, at intervals, systematically removed the vegetation, excepting coconut trees, with the purpose of discouraging or eliminating insects.

This would account for the paucity of the flora of this tiny cay (see pages 7 and 9).

[Editors]

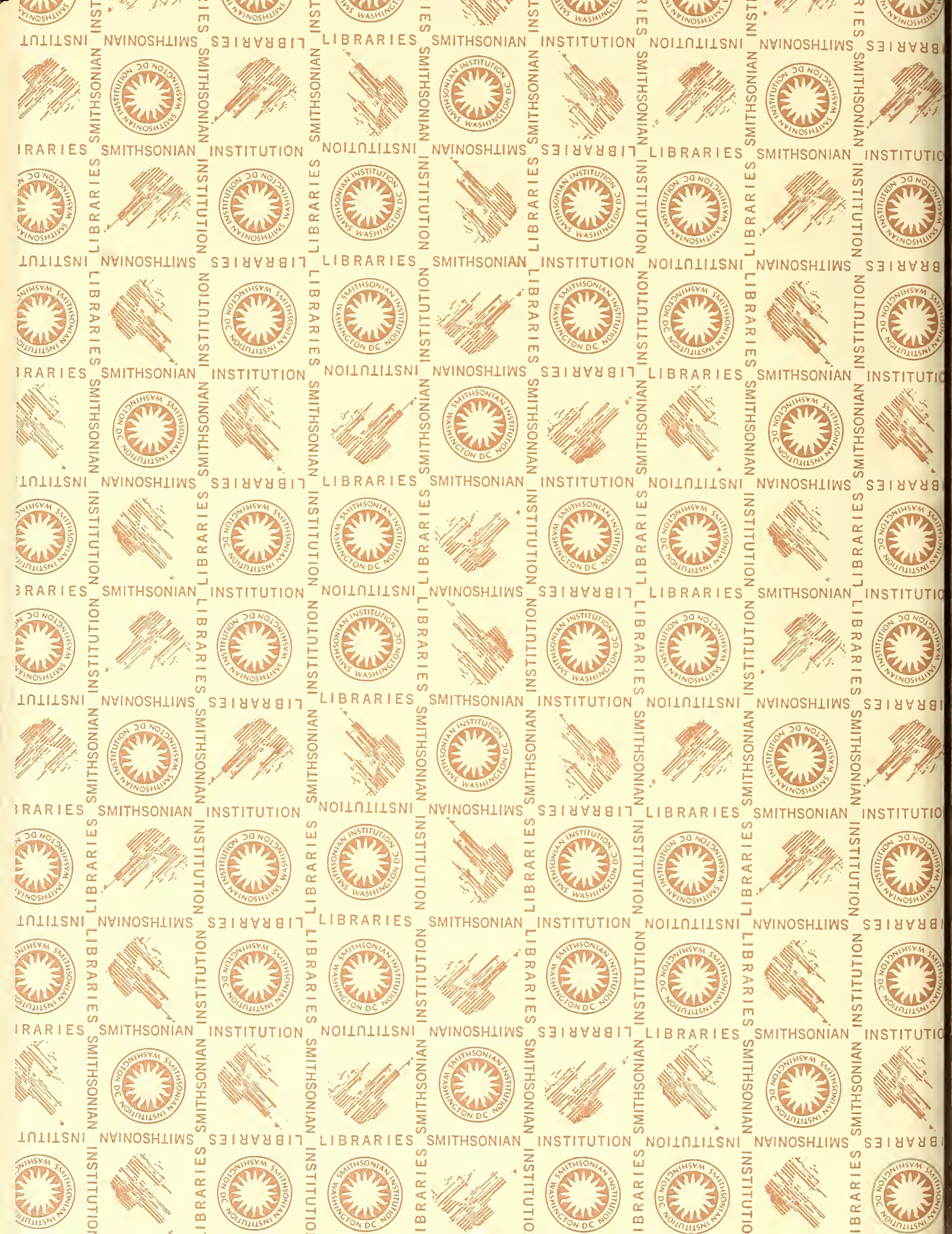


Figs. 1-4. Plant communities on South Water Cay, photographed in 1979. Fig. 1. Community dominated by *Ipomoea stolonifera*. Fig. 2. Community dominated by *Ipomoea pes-caprae*, *Vigna luteola*, and *Wedelia trilobata*, with *Cocos nucifera* trees in the background.



Fig. 3. Sparsely vegetated area with *Euphorbia* spp. and graminoids, and planted row of *Hymenocallis littoralis*. Fig. 4. Mangroves -- *Rhizophora mangle* and *Avicennia germinans* -- along windward (east) side of island.







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