Terrestrial Environment and Climate, Carrie Bow Cay, Belize

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ABSTRACT

Severe hurricane activity during the past 20 years has reduced Carrie Bow Cay (16°48′N, 88°05′W) to half its pre-1960 size of 0.8 ha. At present, Carrie Bow Cay (0.4 ha area) is one of the smallest inhabited sand cays on the barrier reef of Belize. The island measures 120 × 36 m, rises 40 cm above mean tide level, and supports three wooden cottages with freshwater tanks. The only permanent terrestrial plants are about 60 coconut trees. Other vegetation appears periodically and spreads until it is destroyed by intermittent storm tides. Conspicuous animals include a few birds, a lizard, and some supratidal crustaceans. About one-third of the island's surface is intertidal and occupied mainly by algae, crustaceans, and mollusks that are adapted to this habitat. The climate is oceanic and is dominated largely by northeasterly trade winds.

Introduction

Previous terrestrial investigation of Carrie Bow Cay was based on brief topographic and floristic surveys (Stoddart, 1963; 1969; 1974) and a short-term meteorological study (Kjerfve, 1978). Our own first topographic survey was prompted by the severe impact of hurricane Fifi, in 197, on the shape and size of the island. From then on we monitored morphological changes of the cay, condition of the remaining coconut tree population, and recovery of the vegetation that had been entirely eliminated by salt water flooding. Our other observations on the terrestrial and intertidal flora and fauna of the islet are of casual qualitative nature and restricted to large and conspicuous organisms. Meteorological records were taken regularly during the months of our field work, mainly in spring and early summer, but are sporadic during the remaining parts of the year. Carrie Bow Cay has been the base of the Smithsonian Institution coral reef study since the initiation of the program in 1972. The small island provided the necessary support in close proximity of reef and lagoon habitats without having noticeable terrestrial effects on these environments.

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Methods

Geodetic Surveys.—Tape measure, sighting compass, and sighting along permanent or temporary markers were used for determining shape and size of the island and position of trees and artificial structures. The concrete boat dock on the lagoon side and the wooden main house in the center of the cay provided the principal points of reference. Vertical photographs from a helicopter, in March 1976, helped to improve the documentation of the island's physiography.

Plant Abundance.—The first quantitative survey of plants made in 1978 consisted of subjective visual estimates of five categories of relative abundance. More objective measurements of area of plant coverage were made in 1979 by placing a 50 × 50 cm (0.25 m^2) frame subdivided into 10 × 10 cm (100 cm^2) fields over all surfaces of the island showing vegetation. The number of frames occupied by a given species was recorded to the nearest half frame (50 cm^2).

Meteorology.—Generally, meteorological conditions were recorded three times a day (0600–0800 h; 1200–1400 h; 1800–2000 h) whenever the laboratory on Carrie Bow Cay was in operation, most commonly during the periods January–June and October/November, 1976–1978. Temperature was measured with ±0.5° C accuracy in shaded air, in sun-exposed sand (5 cm below surface), in water on the reef flat (0.2 m average bottom depth), and below low-tide level at the boat dock (lagoon, 0.8 m average bottom depth). Some continuous analog chart recordings of solar radiation were made by pyranograph (WeatherMeasure B211). Wind speed and direction were read from a cup anemometer with air foil vane (WeatherMeasure W121). Precipitation was measured with two rain gauges (10 cm diameter), one installed on the cay, and the other one on the mainland at Pelican Beach Motel, Dangriga. The rainy season (June–September) of 1979 was also monitored by an unattended tipping-bucket raingauge (WeatherMeasure P501-I) with solar-powered event recorder on Carrie Bow Cay. Humidity was calculated from psychrometer (Psychro-Dyne PP100) readings.

Physiography

Location.—Carrie Bow Cay (16°48′N, 88°05′W) is a small sand island located on top of the barrier reef that lines the outer shelf edge of Belize (formerly British Honduras), Central America (Plate 1: *center right*). Its former name, Ellen Cay, is still recorded on many nautical charts. The nearest significant settlement is Dangriga (Stann Creek), a town of 7000 inhabitants on the mainland, 24 km due 320° (NW). The cay belongs to H.T.A. Bowman of Dangriga and is used as a vacation place for his family. The nearest islands are South Water Cay, 1.5 km due 0° (N), a sand cay populated by a few fishermen and occasional vacationers, and Twin Cays (also known as South Water Range) 4 km due 323° (NW), an uninhabited mangrove development. Carrie Bow Cay is protected from open ocean waves by a crescent-shaped reef crest to the east and a 100 m wide reef flat that extends from the crest to the island's seaward shore (Plate 5: *top left*).

Shape and Size.—With a surface area of less than 0.4 ha, Carrie Bow Cay belongs among the smallest inhabited cays on the Belizean shelf (Stoddart and Fosberg, herein: 527) (Figure 51; Plate 1: *bottom left*). The island formerly was double its present size (H.T.A. Bowman, pers. comm.) and bordered by mangrove, but clearing of these trees in 1944 led to progressive erosion by storm tides. Stranded beachrock as far as 30 m east and south of the present seaward shore documents both a shift in dimensions and slow migration leewards. At present, the cay has an eliptical shape with approximate north-south exten-

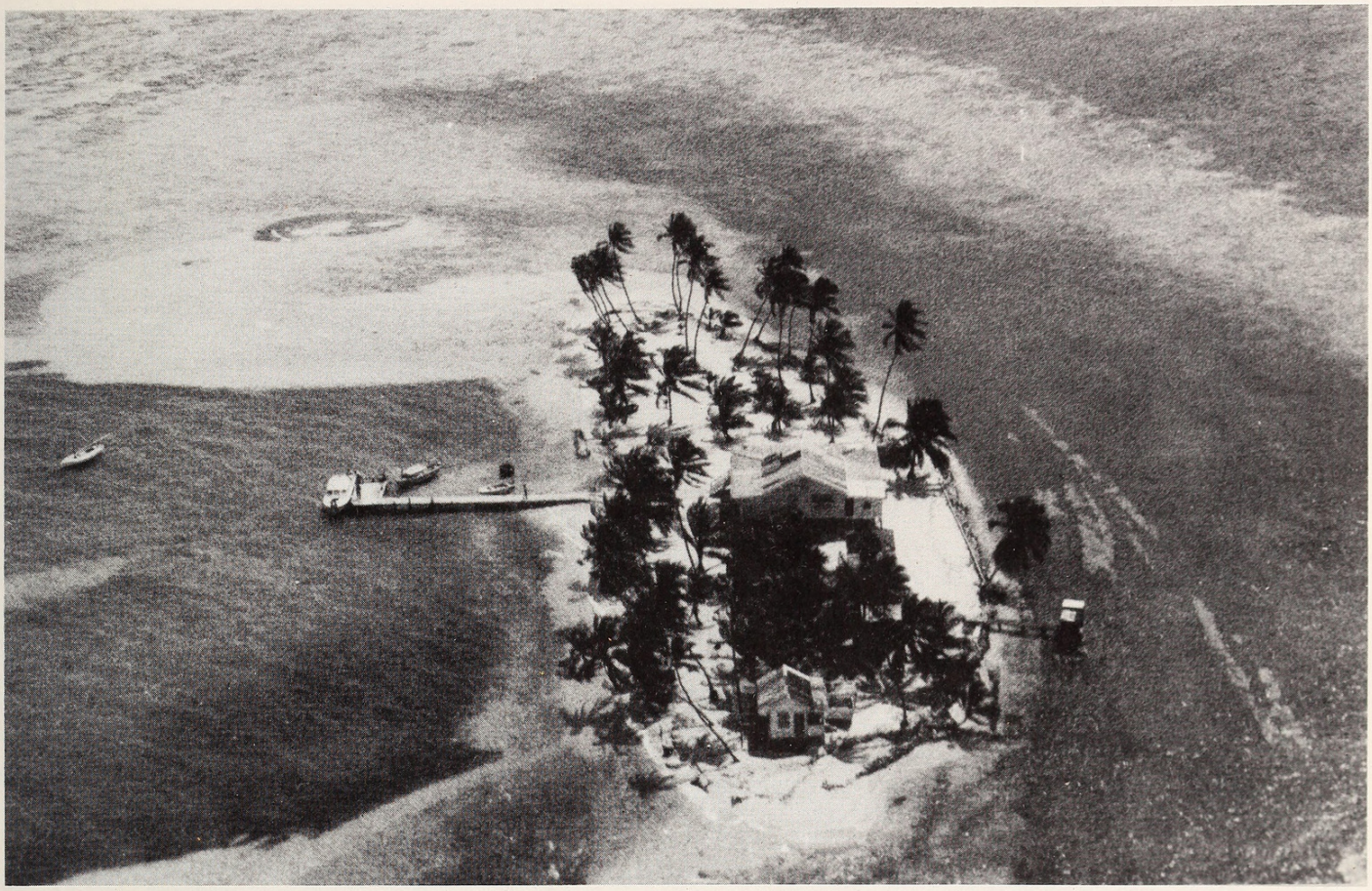

FIGURE 51.—Carrie Bow Cay, aerial view from the south, May 1973; note exposed beach rock on the reef flat east of the island.

sion. The longer axis is directed due 30° (NNE) and measures 120 m between mean tide level (MTL) points; the greatest dimension perpendicular to this axis lies along a line transecting the center of the isle and measures 36 m. Surface area calculated from planimetry is 0.36 ha to MTL, 0.25 ha if only dry-land (supratidal) area is measured. Highest elevation, which is approximately 40 cm above MTL, occurs at the central portion of the island.

SUBSTRATES.—Reef-derived carbonate sand and rubble on a base of Pleistocene bedrock (Shinn et al., herein: 63) make up the entire natural substrate of the cay (Figure 52*a*). Accumulation of beach sand varies with the direction and force of wind and currents. Under the influence of the predominant northeasterly trade winds, sand is deposited at the north point and northwest beach and around the south tip; at times separate intertidal sand spits are formed to the north. Concrete block seawalls and rubble and coral rock landfills built up over many years to delay erosion dominate the northwest (Figure 52*b*) and southeast shorelines, which also have a few small sandy beaches here and there. Conch shells abandoned by generations of local fishermen are accumulated along the southwest coast.

STRUCTURES.—Other than seawalls, artificial structures on Carrie Bow Cay include two docks and three buildings with water vats (Figure 51; Plates 1: *bottom right*, 5: *top left*). The main or boat dock to the west (lagoon side) of the cay is 26 m long and built of concrete. A smaller wooden dock over the reef flat (SE) serves the two outhouses. The buildings are wooden and include the main house, 14 × 12.5 m, "Junior's House," 13 × 3.5 m (now serving as our project's laboratory), and a small cabin, 5 × 5 m (Figure 60).

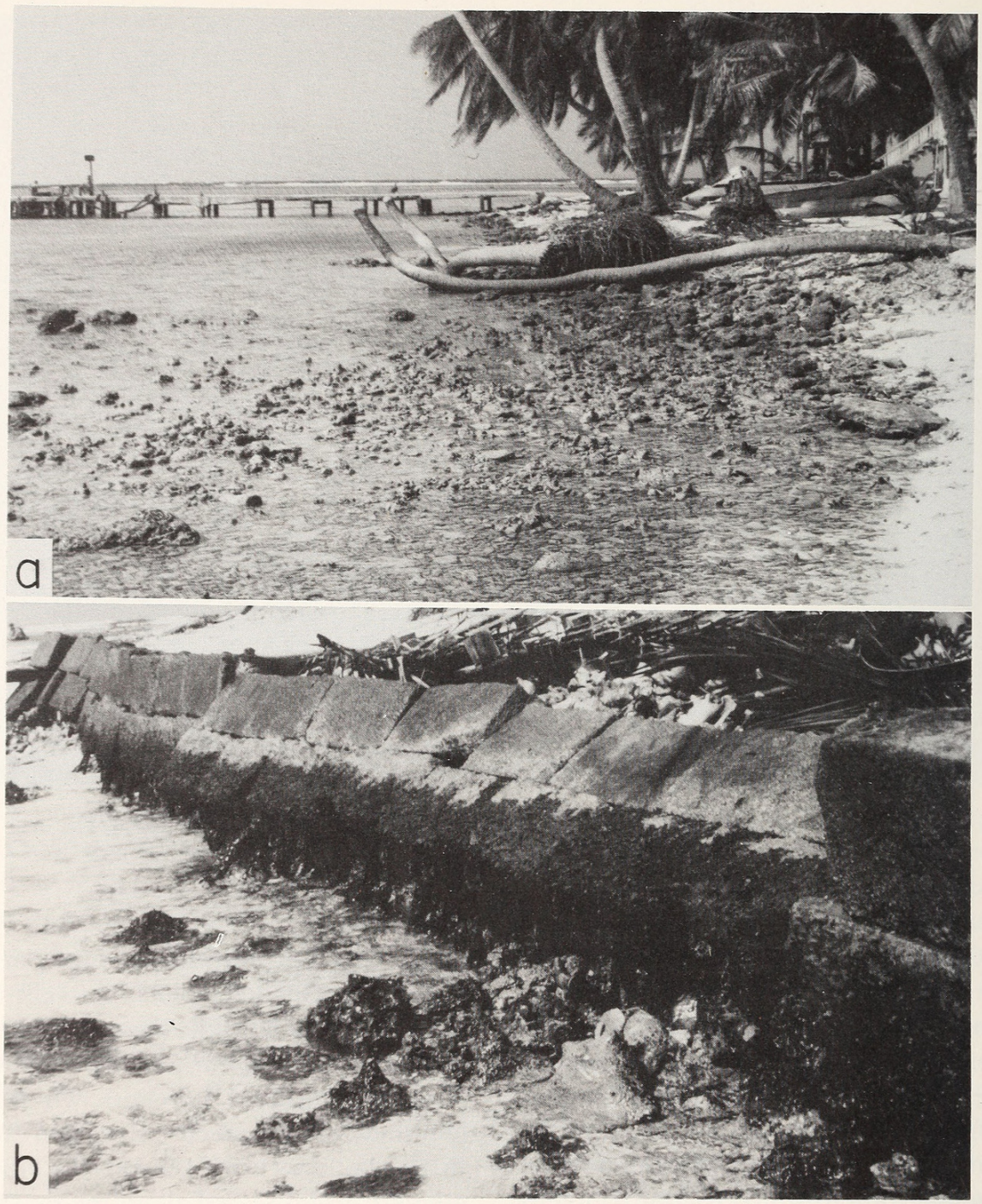

FIGURE 52.—Intertidal substrates: *a*, sandand rubble (mainly conch shells) on western shore, looking north (coconut palms felled by hurricane Greta); *b*, northwest seawall, coated by algae *Cladophoropsis* and *Oscillatoria*, toppled by Greta.

Flora and Fauna

Carrie Bow Cay's small size, lack of a freshwater lens, and exposed location near the open ocean are responsible for the absence of a complex permanent terrestrial environment. We distinguish between an intertidal zone along the shore and a central island area above the high-tide beach undercut, which, in our experience, has been flooded by sea water only during hurricane tides (see below).

SUPRATIDAL ORGANISMS.—The most conspicuous, and only permanent, plants, except perhaps for the lichens, are coconut palms (*Cocos nucifera* L.) most of which were planted during the past 35 years in at least five recognizable N-S rows. In

May 1979 this population consisted of 58 healthy trees, of which 38 were mature and showed either nuts or flowers, 8 were immature (one or more years established), and 12 were freshly planted after hurricane Greta (less than one year established). The remaining vegetation observed in May 1978 and May 1979 (before and after hurricane Greta; Table 7) recolonized Carrie Bow Cay after salt water flooding associated with hurricane Fifi (September 1974) had washed away

TABLE 7.—Systematic list and relative abundance of Carrie Bow Cay plants, excluding coconut and others artificially introduced; figures for 1978 show recolonization of the island after hurricane Fifi (September 1974), when all vegetation was destroyed, and are visual estimates; data for 1979 reflect minor changes and losses (indicated by dash) in plant cover caused by hurricane Greta (September 1978) and are compiled from quadrat counts (see "Methods"); likely methods of dispersal are indicated for each plant (B = bird, D = drift, W = wind); approximation of size and frequency of plants is given for 1978

Species (*Family*)	*1978* m^2	*1979*			*Method of dispersal*
		m^2	*% total*	*rank*	
Paspalum distichum L. (Gramineae)	>5	0.010	0.08	9a	D?
Sesuvium portulacastrum (L.) L. (Aizoaceae)	0.02–0.50*	2.585	19.94	3	D?, B?
Philoxerus vermicularis (L.) Beauvois (Amaranthaceae)	0.02–0.50*	–	–	–	D, B?
Suaeda linearis (Elliott) Moquin (Chenopodiaceae)	<0.01	0.015	0.12	8a	D, B?
Portulaca oleracea L. (Portulacaceae)	1–5**	4.825	37.22	1	B?
Coccoloba uvifera L. (Polygonaceae)	<0.01	–	–	–	D, B?
Cakile lanceolata (Willdenow) O. E. Schulz (Cruciferae)	0.5–1.0†	3.275	25.26	2	D
Rhizophora mangle L. (Rhizophoraceae)	–	0.010	0.08	9b	D
Euphorbia blodgettii Engelmann ex Hitchcock (Euphorbiaceae)	1–5**	0.185	1.43	6	B?
Euphorbia mesembrianthemifolia Jacquin (Euphorbiaceae)	1–5**	1.820	14.04	4	B?
Ipomoea pescaprae brasiliensis (L.) van Ooststroom (Convolvulaceae)	>5	0.190	1.47	5	D
Ipomoea stolonifera (Cyrillo) Gmelin (Convolvulaceae)	<0.01	–	–	–	?
Tournefortia gnaphalodes (L.) Kunth (Boraginaceae)	<0.01	0.035	0.27	7	D
Eclipta alba (L.) Hasskark (Compositae)	<0.01	–	–	–	W, B?
Unidentified seedling					
1	<0.01	0.015	0.12	8b	D
2	<0.01	–	–	–	D
Total plant cover	not determined	12.965	100.03		

* few medium-sized plants, each 0.02–0.30 m^2

** numerous small plants, each 0.01–0.02 m^2

† few large plants, each >0.3 m^2

or killed all plants except the majority of coconut trees (Figure 53). In addition to the species listed in Table 7, two were recently artificially introduced: *Casuarina equisetifolia* L. (Casuarinaceae) and *Hymenocallis littoralis* (Jacquin) Salisbury (Liliaceae, sensu lato). At least three species of lichens are common on the northeast surfaces of wind exposed palm trunks: *Lecanora subfusca* (L.) Acharius, *Pyxine cocoes* (Swartz) Nylander, and *Chiodecton* sp.

Although we have noted a variety of insects and a few spiders on Carrie Bow Cay, we have not determined the species and do not know whether they are breeding resident populations. Some ants, cockroaches, and spiders are no doubt introduced by supply boats carrying produce. Fleas and ticks have been left behind by dogs, the former at times plaguing sensitive investigators. Flying insects are commonly blown over from land or larger islands during westerly winds. Most of the island's invertebrate fauna, however, consists of three crustaceans: the hermit crab *Coenobita clypeatus* (Herbst), and the crabs *Ocypode quadrata* (Fabricius) and *Gecarcinus lateralis* (Freminville).

FIGURE 53.—Plant cover on north point, May 1978: *Ipomoea pescaprae*, *Cakile lanceolata* (foreground, with 0.25 m^2 frame), and freshly planted *Casuarina* tree.

Only the lizard *Anolis sagrei* Duméril and Bibron, a species widespread in the West Indies and apparently expanding its range onto Caribbean Mexico and Middle America (R. Crombie, pers. comm.), occurs as resident population of vertebrates on Carrie Bow Cay. A sea turtle, *Caretta caretta* (L.), was last seen laying eggs on the island on 28 May 1972 (A. Antonius, pers. comm.). Birds that feed regularly around the cay are the Brown Pelican (*Pelecanus occidentalis* L.), Frigatebird (*Fregata magnificens* Mathews), and Osprey (*Pandion haliaetus* (L.)). Other birds commonly seen include the Boat-tailed Grackle (*Cassidix mexicanus* (Gmelin)), Common Tern (*Sterna hirundo* L.), Brown Booby (*Sula leucogaster* (Boddaert)), Snowy Egret (*Leucophoyx thula* (Molina)), and Barn Swallow (*Hirundo rustica* L.). An assortment of involuntary visitors from the mainland, such as warblers and flycatchers, arrive exhausted on the island after periods of strong westerly winds. All birds, except the grackle and the swallow, roost eleswhere, most likely on South Water Cay. The grackle may even breed on Carrie Bow Cay because a female was observed gathering materials for nest building.

INTERTIDAL ORGANISMS.—The mean tidal range at Carrie Bow Cay is only 15 cm (Kjerfve et al., herein: 47, Table 4). The observed maximum range, however, partly because of wind forcing is more than 40 cm. With a shoreline slope of 90° to 4° the width of the intertidal zone on Carrie Bow Cay ranges between 40 cm on vertical cinder block walls and 6 m at the flat northern point, on the average between 0.5 and 2.0 m. Only during spring tides are wide areas on the reef flat exposed (Plate 1: *bottom right*).

Sandy beaches have a diverse and rich intertidal meiofauna (Kirsteuer, in prep.) but only one

benthic macro-organism, the cerianthid *Arachnanthus nocturnus* den Hartog, could be observed at low tide buried in exposed sand on the northeast shore. *Ocypode quadrata* crabs, however, temporarily establish burrows in sand areas exposed at low tide.

Rocky substrates support a more varied intertidal flora and fauna but differences in abundance can be observed between the leeward (west) and windward (east) sides of the island. Coral rock, rubble, and concrete blocks of the leeward sea wall are thickly covered by algae (Figures 52*b*, 54*a*). *Oscillatoria submembranacea* Ardissone and Strafforella and *Schizothrix mexicana* Gormont (Cyanophyta), and *Cladophoropsis membranacea* (C. Agardh) Børgesen (Chlorophyta) occupy the upper zone, *Padina jamaicans* (Collins) Papenfuss (Phaeophyta) and *Neomeris annulata* Dickie (Chlorophyta) the zone below. On the windward side only the calcareous green alga *Halimeda opuntia* (L.) Lamouroux, red *Laurencia papillosa* (Forsskål) Greville, and some of the *Oscillatoria* were found exposed.

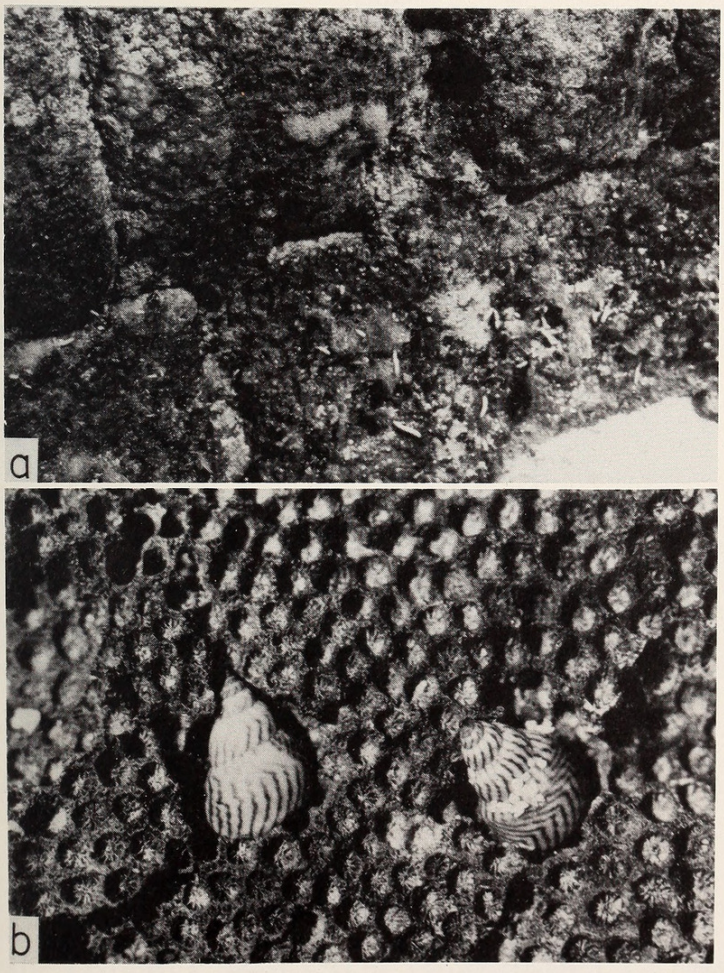

FIGURE 54.—Intertidal organisms; *a*, algae *Cladophoropsis* and *Oscillatoria* (top), *Neomeris* and *Padina* (bottom) on concrete block seawall; *b*, gastropod *Littorina ziczac* on coral boulder. (Picture width, *a* = 70 cm; *b* = 5 cm.)

A few specimens of the actinian *Stoichactis anemone* (Ellis) and barnacle *Tetraclita stalactifera* (Lamarck) were also encountered on the windward side. The most abundant crustaceans on the lagoon shore are the hermit crab *Clibanarius tricolor* (Gibbes), which clusters in great numbers on intertidal rock and rubble, and the elusive isopod *Ligia olfersii* Brandt, which is particularly common around empty conch shells near the concrete boat dock. Several crabs are common among rubble and concrete blocks all around the cay. *Grapsus grapsus* L. is the largest and most abundant; other crabs include *Pachygrapsus transversus* (Gibbes), *Cyclograpsus integer* Milne Edwards, and *Petrolisthes quadratus* Benedict. Among the mollusks only gastropods occur intertidally at Carrie Bow Cay. On the windward side *Nerita peloronta* L., *N. versicolor* (Gmelin), *Littorina nebulosa* Lamarck, *L. ziczac* (Gmelin) (Figure 54b), and *Tectarius muricatus* (L.) are found on vertical coral rock and concrete block surfaces of the seawall. Several size classes of juvenile *Cittarium pica* (L.) cluster among rubble or on beach rock below. *Nerita versicolor*, *L. ziczac*, and *T. muricatus* also occur on the leeward seawall but are less abundant there. A few specimens of a single species of echinoderm, the echinoid *Echinometra viridis* Agassiz, are found here and there under tide-exposed rocks.

Climatic Parameters

The climate of Belize is subtropical to tropical, with temperatures ranging from 10° to 36° C (average range in Belize City, 23°–33° C), and rainfall averaging 125–450 cm a year. Temperatures are lowest in the highlands and during the cool period of the year (November to March). Average rainfall increases from north to south; the rainy season lasts from June to October. The overall climate of the country, particularly of the outer cays, is influenced by northeasterly trade

winds that prevail at velocities of 4–5 m/s during about 70% of the year. Our meteorological records from Carrie Bow Cay, although not continuous, indicate major patterns of temperatures, solar radiation and cloudiness, wind, and rainfall and allow some comparisons with conditions prevailing on the mainland. In addition, 12-day continuous measurements of radiation, evaporation, wind, and air-water-sand temperatures in June 1975 were reported by Kjerfve (1978).

Temperature and Solar Radiation.—Figure 55 presents monthly temperature records, except for July and December. Data for January, February, and August to October are the result of a single year's readings; other data were derived from at least three consecutive years of observation. Values are plotted against a background of ten-year average minimum and maximum temperature readings provided by the Melinda Forest Station near Dangriga, on the mainland of Belize. Temperature conditions on the cay follow closely those on land, where the highest averages occur during May and August (33° C) and the lowest during January and February (22° C, 21° C). Solar radiation measurements are only available for the cay and for the months of March through June, and November. The highest total radiation reaching the ground on a single day was recorded during April and May and amounted to 490 cal/cm^2. Monthly averages of daily radiation related to this value give an indication of cloudiness and haze (Figure 55).

Wind.—Measurements of wind direction, speed, and frequency on Carrie Bow Cay are summarized in Figures 56 and 57. Values for March–June show the typical situation: northeasterly trade winds predominate and compare well with published wind roses from the open ocean surface off Belize (United States Naval Oceanographic Office, 1963). Our observations on wind for the rest of the year are sparse and may not be representative of long-term averages. Speed values for the infrequent winds from the northwest sector are somewhat low because of the shading effect of the big house and of coconut trees.

Rainfall and Humidity.—Long-term rainfall

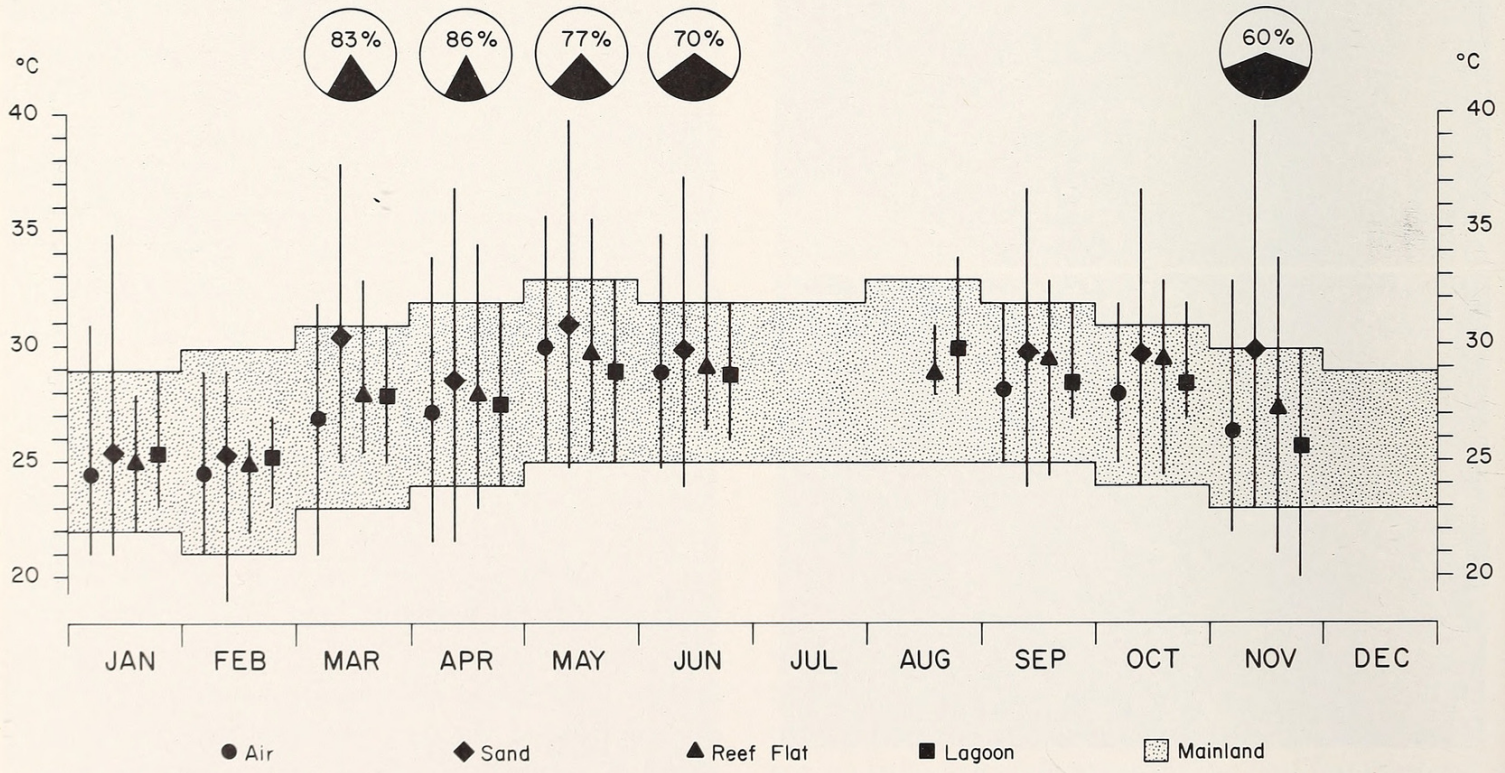

Figure 55.—Monthly temperatures (mean, range) 1976–1980 and solar radiation (percentage of maximum) 1978–1980 for Carrie Bow Cay; monthly temperature range (shaded area) at Melinda Forest Station on mainland, averaged over a ten-year period, 1965–1975.

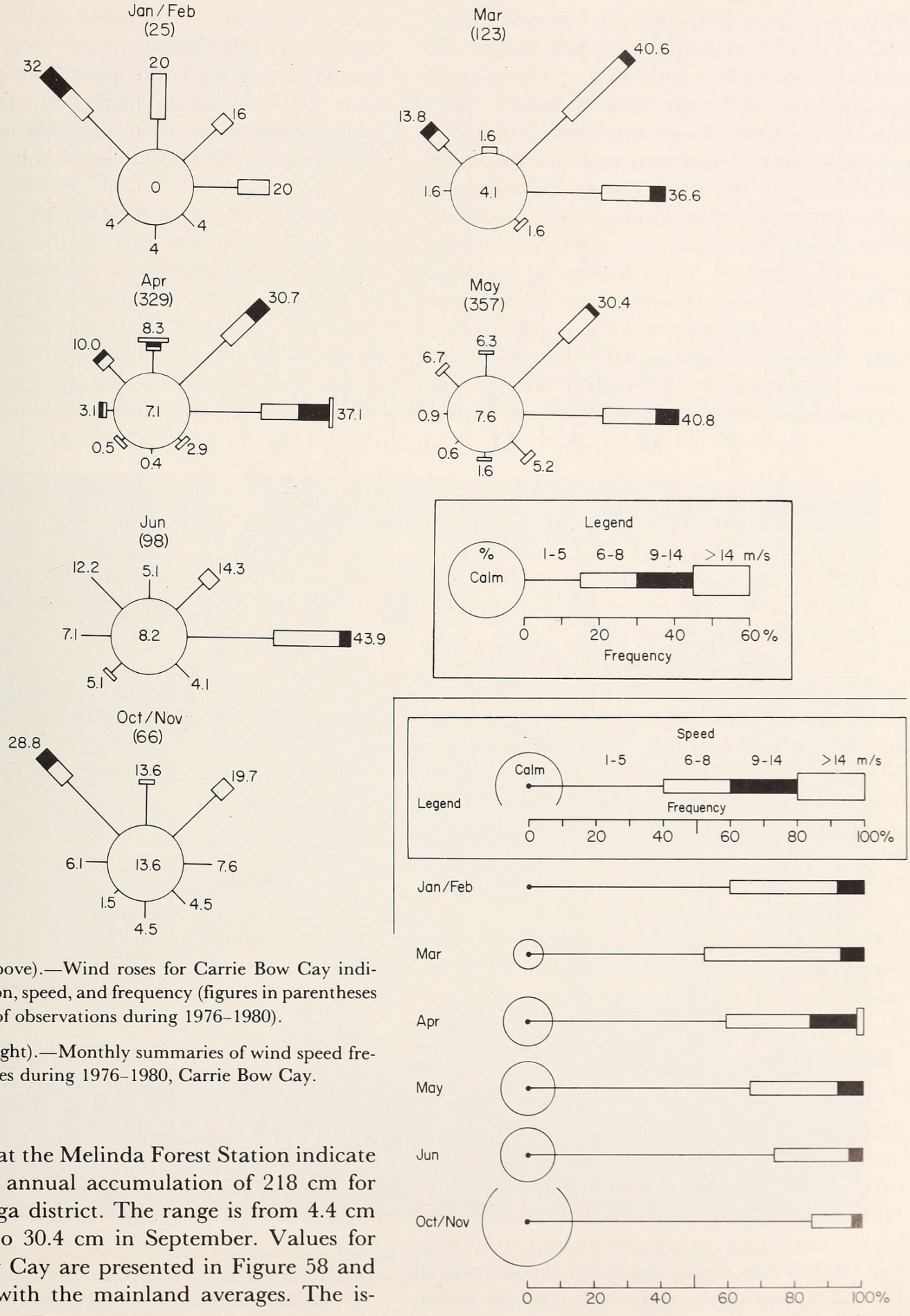

FIGURE 56 (above).—Wind roses for Carrie Bow Cay indicating direction, speed, and frequency (figures in parentheses are numbers of observations during 1976–1980).

FIGURE 57 (right).—Monthly summaries of wind speed frequencies during 1976–1980, Carrie Bow Cay.

data taken at the Melinda Forest Station indicate an average annual accumulation of 218 cm for the Dangriga district. The range is from 4.4 cm in March to 30.4 cm in September. Values for Carrie Bow Cay are presented in Figure 58 and compared with the mainland averages. The is-

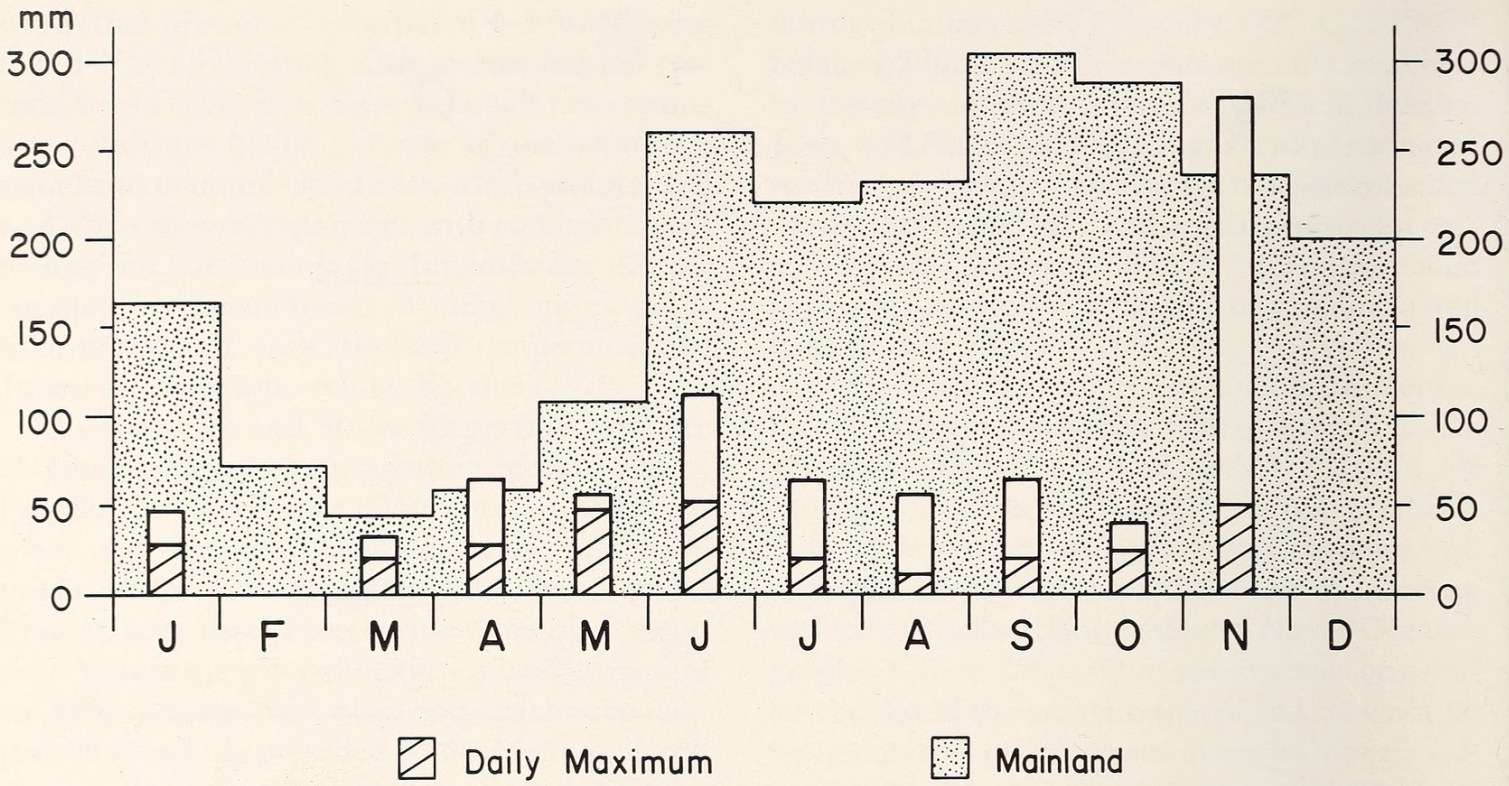

FIGURE 58.—Monthly average (total bar) and daily maximum rainfall on Carrie Bow Cay (1976–1980), compared with mainland monthly rainfall (Melinda Forest Station) averaged over a 71-year period (1906–1977).

land receives, on the average, only 42 prcent of the mainland rainfall if one excludes February and December for which comparative data are lacking. The high value (279 mm) for November may be a peculiarity of the year (1979) in which the record was taken. On the other hand, a second but incomplete measurement of 213 mm (1978, November 14–26) indicates a similarly high or even higher rainfall during that month.

Humidity measured between March and June averaged 78 percent, with a range of 58–96 percent.

Recent Hurricane Effects on Carrie Bow Cay

Computer files of the United States National Hurricane Center (P. J. Hebert, pers. comm.) indicate that at least 20 hurricanes and 45 tropical cyclones have passed within 100 nautical miles (185 km) of Belize City (17°30′N, 88°18′W) during the last century (records date back to November 1889). From these data it can be determined that nine hurricanes and seven tropical storms have passed Carrie Bow Cay within a 50 km radius. Storm activity in this area seems to have increased recently as six of the hurricanes and the most violent of tropical storms (Laura) have occurred within the last 20 years (Table 8).

Hattie is the only storm for which the long-term effects on Belizean reefs and cays, including Carrie Bow Cay, have been monitored (Stoddart,

TABLE 8.—Hurricanes passing within 50 km radius of Carrie Bow Cay, 1960–1980, including name, date, and maximum sustained wind speed while storm center was within 50 km of Carrie Bow Cay

Name	*Month/Year*	*Wind speed (km/h)*
Abby	Jul 1960	128
Anna	Jul 1961	148
Hattie	Oct 1961	259
Francelia	Aug 1969	182
Laura*	Nov 1971	111
Fifi	Sep 1974	176
Greta	Sep 1978	176

* Officially declared a tropical storm.

1963, 1969, 1974). Other recent hurricane reports include a brief eyewitness account of tropical cyclone Laura passing over Glover's Reef and Stann Creek (Dangriga) (Antonius, 1972), and observations on the impact of hurricane Greta on the reef community near Carrie Bow Cay (Highsmith et al., 1980).

Hurricane Fifi (14–22 September 1974).—A tropical depression south of Puerto Rico and Hispaniola moving westward developed into hurricane Fifi on 17 September. Fifi, as reported by Hope (1975), acquired its maximum sustained winds of 95 kt (176 km/h) while it moved along the coast of Honduras, 18–19 September, where heavy rains caused a high number of deaths by inland flooding of rivers. The hurricane crossed the barrier reef approximately 20 km south of Carrie Bow Cay and reached the coast of southern Belize during the afternoon of 19 September.

Our observations on the effects of Fifi on Carrie Bow Cay rely on a survey in December 1974 as no eyewitness reports are available. Storm surge flooded the entire island, and most of the unconsolidated sand was either piled up high inside the buildings or carried away, leaving a surface of coral rubble and exposed palm tree roots. A comparison of photographs (Figure 59) and a map of Carrie Bow Cay prepared by D. R. Stoddart in 1972 (Figure 60*a*) indicate that coastal erosion was strongest to the north, northeast, and

Figure 59.—Carrie Bow Cay silhouettes looking east: *a*, February 1972; *b*, December 1974, three months after hurricane Fifi. Note reduction of island size, in number of trees, and density of leaves caused by the hurricane.

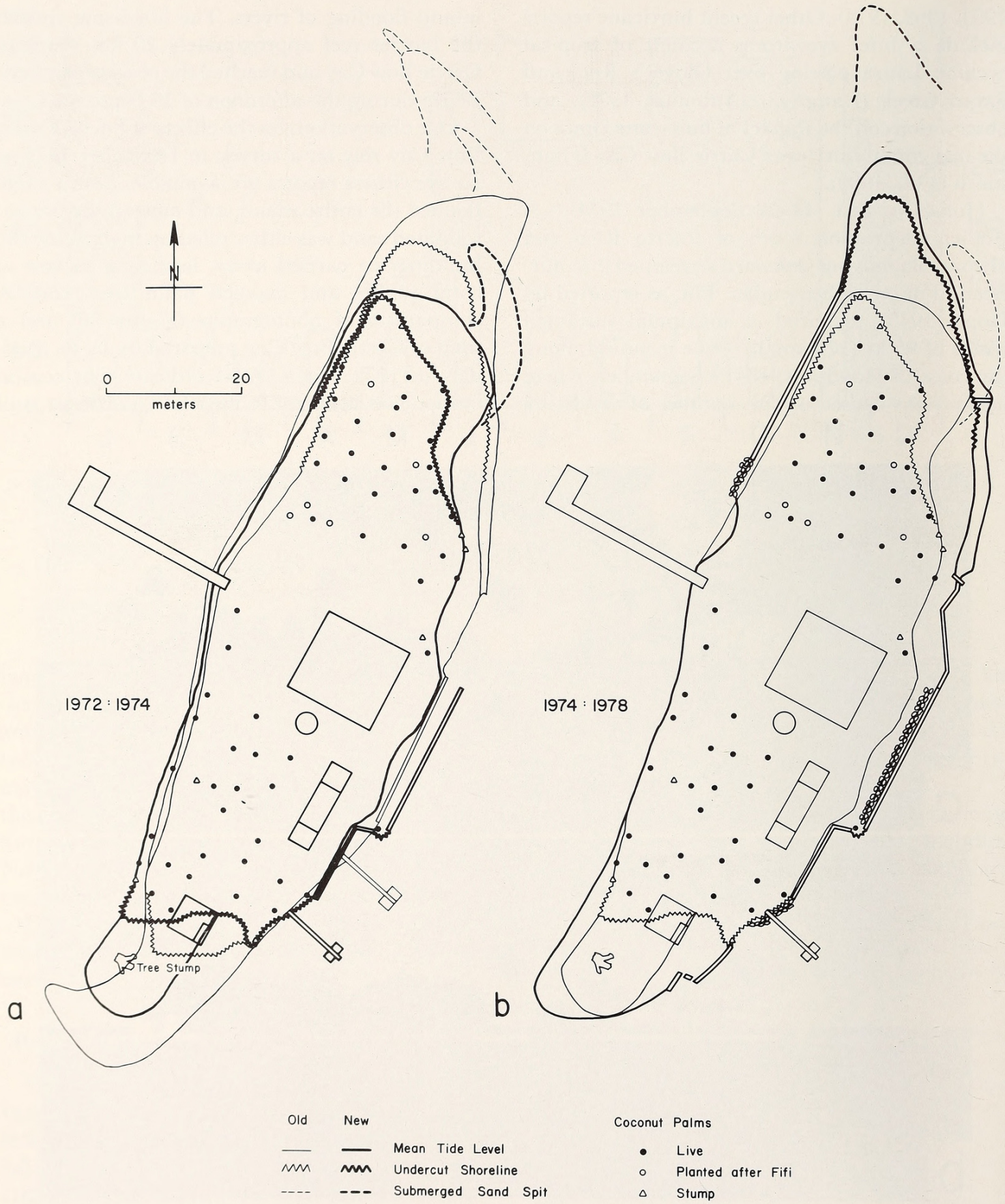

FIGURE 60.—Maps of Carrie Bow Cay showing hurricane effects and poststorm recovery: *a*, changes 1972–1974, caused principally by hurricane Fifi, September 1974; *b*, recovery, December 1974 to May 1978.

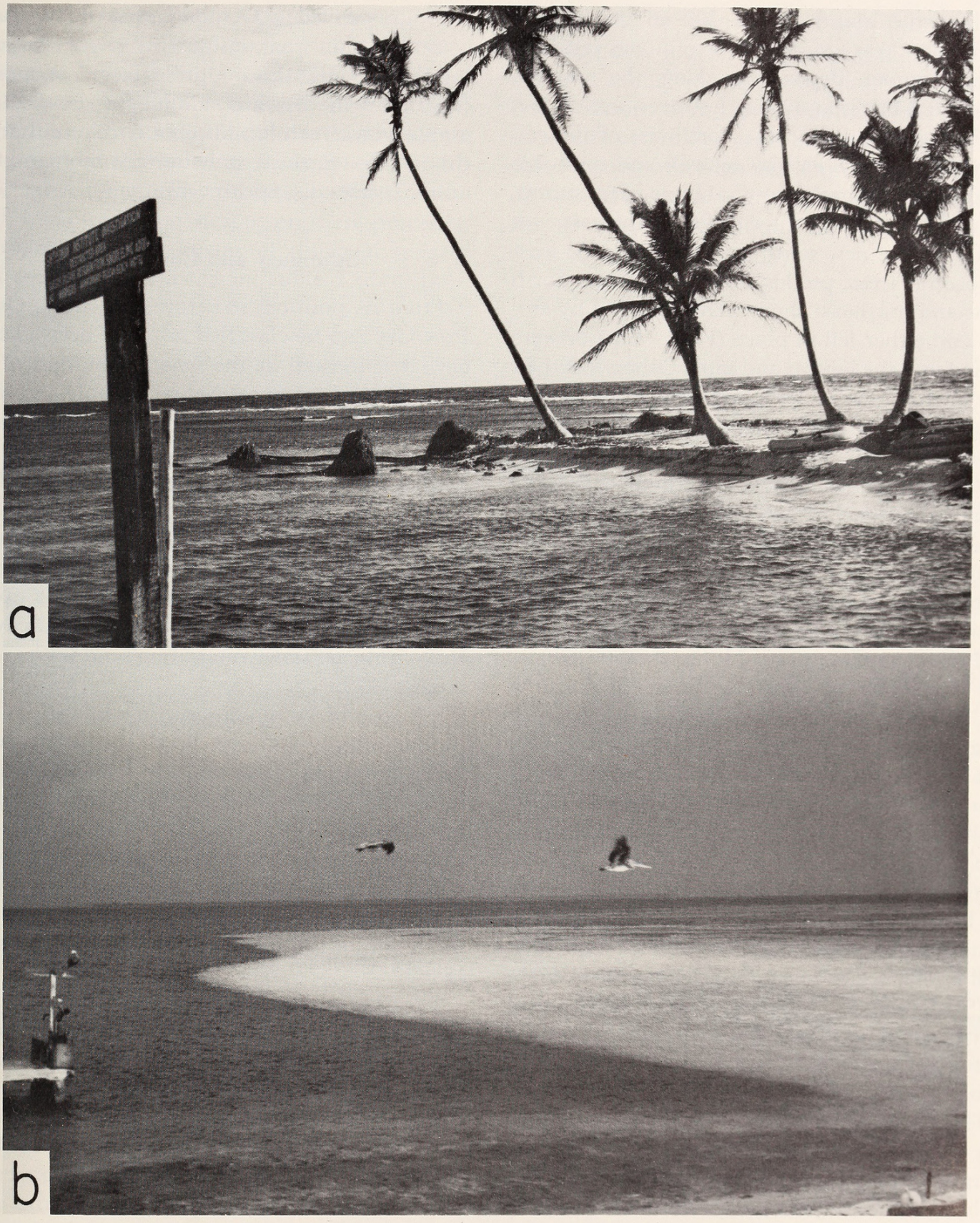

FIGURE 61.—Effects of hurricane Fifi: *a*, eroded north point of Carrie Bow Cay with fallen coconut palms, looking northeast; *b*, submerged bank of sand originating from northern portion of the island, looking northwest.

south of the island. About 30% of the island's surface area was lost, but some of it was regained by subsequent deposition along the western shoreline. Most island sand, however, settled as a subtidal sand bank to the northwest of the cay (Figure 61*b*). The eastern seawall and outhouse dock were destroyed and a huge tree stump, situated for years on the reef flat to the east, was floated to the new south tip of the cay. At least 14 coconut trees, predominantly from the north point and northeast shore were uprooted by erosion and either fell in place (Figure 61*a*) or were carried into the lagoon and sank. Others lost their tops in the storm or withered from overexposure to salt water. All other plants previously recorded (Stoddart, 1969), such as low *Tournefortia* bushes, *Euphorbia*, *Ipomoea*, and *Sesuvium* ground cover, and grasses, disappeared and did not recover to the approximate prehurricane condition until spring 1978. By that time, with the help of seawalls and rubble fills, much of the prehurricane island outline was restored (Figure 60*b*).

Hurricane Greta (13–23 September 1978).— The track of Greta was almost identical to that of Fifi, and both storms occurred at almost the same time in September. The meterorological history of Greta is described by Lawrence (1979). A depression formed northwest of Trinidad on 13 September. Hurricane force with sustained winds of 115 kt (213 km/h) developed at a position south of Jamaica on 16 September. Moving over the Bay Islands off the north coast of Honduras, Greta weakened and made its landfall with 80 kt (148 km/h) winds near Dangriga on the evening of 19 September. Greta was a much more severe hurricane than Fifi but despite locally heavy rain it did not cause devastating river floods (P. J. Hebert, pers. comm.).

The eye of hurricane Greta passed Carrie Bow Cay about 6 km to the north and brought the island winds of approximately 95 kt (176 km/h). Although direct observations are lacking, a considerable storm tide (about two meters above normal, estimated from events at Dangriga) must have flooded the island because the smallest cottage disappeared and the ocean-side wall of the laboratory caved in. Despite damage to buildings, coastal erosion was considerably lower than during Fifi. About 20 coconut trees were lost, most of these from the leeward side of the island. Other plants were much less affected by Greta than by the 1974 hurricane as only one common and four minor species disappeared (Table 7).

Summary and Conclusions

From its position, structure, and flora, Carrie Bow Cay can be classified as a reef-derived sand cay. It is located at the seaward margin of the barrier reef, is composed of reef rubble and sand, and is held together primarily by coconut rootlets and, to a lesser degree, by ground cover and artificial structures. The island measured a little over two acres (0.8 ha) when it was bought by the present owners in 1943. Today it is less than half that size and exposed beachrock on the windward side indicates westward (leeward) migration, which confirms the view that sand cays of this nature are slowly migrating sand waves (Milliman, 1973).

Because of its small size, low elevation, and porous substrate, Carrie Bow Cay lacks a freshwater lens and it has not developed a complex terrestrial environment. Considering the occasional salt water flooding during storm tides, the island may be described as a supralittoral habitat. The climate, too, is dominated by the surrounding ocean and by northeasterly trade winds; it is moderate in comparison with the nearest mainland.

Clearing of vegetation during this century and increased hurricane activity in the area during the past two decades are mainly responsible for the rapid shrinking of Carrie Bow Cay. Captain Owen, who mapped the island as "Jack Ellin's Cay" in 1830, noted "tops of bushes 20 feet" (Stoddart, 1963), presumably seagrape, baycedar, and mangrove. Coconuts planted in the early 1900s, and repeatedly again since, may not be equally effective in holding the sand, also, they do not protrude into the intertidal to trap sediments or break the power of waves or currents.

Although physiographic change of the cay was minor during hurricane Hattie (Stoddart, 1963, 1969), later storms, Fifi in particular, took severe toll. Recovery of plant cover destoyed by Fifi took about four years. Colonization of sand cays is thought to be primarily by floating seeds or by seeds carried by birds (Stoddart, 1960), or by wind, but direct observations on these processes are sparse. Possible means of dispersal judged from seed type are listed in Table 7 (data provided by M.-H. Sachet). Our own findings suggest that only four of 16 species of plants—coconut, red mangrove, and two unidentified seedlings—arrived by sea and sprouted. None of them survived beyond two years because of the unsuitable location of settlement. Experimental studies on natural means of island colonization should be the next step in elucidating the terrestrial development of Carrie Bow Cay.

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