EFFECTS OF HURRICANE EDITH ON MARINE LIFE IN LA PARGUERA, PUERTO RICO

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RESUMEN

Un estudio de los efectos del huracán Edith sobre la vida marina y la topografía de los arrecifes de coral en la vecindad de La Parguera indica que éstos fueron afectados notablemente. El disturbio tropical, aunque pequeño y un poco desorganizado, afectó grandemente esta área de estudio durante los días 26 y 27 de septiembre de 1963. El centro de la tormenta se acercó a una distancia mínima aproximada de 49 millas náuticas de esta zona.

En La Parguera los vientos de este huracán soplaron con velocidades máximas de 42 a 49 nudes, dando origen a un mar que a pesar de tornarse embravecido, su nivel normal no subió marcadamente. La temperatura del aire bajó considerablemente, mientras que la del mar bajó muy poco. Aunque la precipitación pluvial fue muy alta, la salinidad no bajó mucho.

Las observaciones meteorológicas e hidrográficas tales como vientos, corrientes, amontonamiento de agua, bajas en temperatura, precipitación, la reducción en la salinidad y la accion del oleaje fueron cuidadosamente analizadas en relación con la forma en que estos factores modificaron la vida animal y vegetal de esta área.

La fuerte acción del oleaje resultó en un extenso desarraigo de las algas bénticas de lugares poco profundos, destrucción de los corales y modificación de las islas que constituyen algunos arrecifes. En los cayos más apartados de la orilla se depositó una gran cantidad de fragments de coral. También, como resultado de esta acumulación de material fragmentario, se formaron tres islitas nuevas.

INTRODUCTION

SEVERAL REPORTS on the catastrophic effects of major cyclonic disturbances in the marine environment of tropical eastern America have appeared in the literature in recent years. In the Gulf of Mexico in September, 1947, a severe hurricane devastated the inshore oyster reef fauna over a wide geographical area (Engle, 1948). Hurricane Donna in September, 1960, passed through southern Florida where it affected this region considerably. Thomas, *et al.* (1961) reported on the great amounts of seagrass washed ashore in Biscayne Bay; Tabb and Jones (1962) observed heavy mortality of fishes and invertebrates in North Florida Bay; Ball, *et al.* (1963) noted widespread storm effects on local sedimentary processes. Hurricane Carla in September, 1961, passed close by the sandy shore environment of Port Aransas, Texas. Studies of the effects of this storm (Oppenheimer, 1963) revealed that major erosion occurred, but that inshore grass flats and bottom flora were virtually unchanged. Stoddart (1962, 1963) described fully the extreme damage suffered in British Honduras from hurricane Hattie, which passed through that area in October, 1961. In addition, Vermeer (1963) studied the physical changes of cays on the northern side of the track of Hattie.

The present paper is a report of the disturbing effects on shallow water marine life and coral reef topography caused by a mild cyclonic storm, hurricane Edith, which passed by the southwestern region of Puerto Rico on September 26-27, 1963. Previous studies in the vicinity of La Parguera, particular at the coral reef Laurel (hereafter referred to as Cayo Laurel), made possible critical evaluation of resulting changes and damage. Although considered to be a minor hurricane some drastic alterations occurred, and for this reason it is important to record these environmental effects in order to learn how such a storm may modify the physiography and biota of a marine area.

Much of the meteorological information presented here in relation to the hurricane was generously offered to the authors by R. L. Higgs, Director of the U. S. Weather Bureau station at Isla Verde International Airport, San Juan. Also, D. C. McDowell of the Institute of Tropical Meteorology, University of Puerto Rico, Rio Piedras, provided some data on the storm. Rainfall, temperature, and humidity measurements reported for Magueyes Island, La Parguera, were made at a weather station established by the U. S. Weather Bureau. Unfortunately, the anemometer was nonfunctional just prior to the storm.

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STORM STATISTICS

The first report of hurricane Edith came on September 22 from observations made by a vessel located approximately 500 miles NE of French Guiana. As reported by the Isla Verde forecast center the trajectory of Edith's vortex extended over a distance of more than 23 degrees of longitude in a NW direction, terminating on September 27 approximately 30 miles off the north central coast of the Dominican Republic.

On September 26, between 1245 and 1945 AST (Atlantic Standard Time), Edith abruptly changed its course to a NE bearing and moved toward Puerto Rico. During this period the storm had decelerated its forward speed and weakened. The closest approach of the vortex to Puerto Rico was located by a U. S. Naval reconnaissance aircraft at 2215 AST at latitude 17°40' N, longitude 67°46' W, approximately 40 nautical miles SW of Cabo Rojo, or 49 nautical miles from La Parguera. After this time Edith again changed its course and moved toward the WNW and then NW crossing the coast line of the Dominican Republic a short distance west of La Romana.

The highest wind velocity reported near the southwest coast of Puerto Rico was at Mona Island (in the Mona Passage about halfway between Puerto Rico and the Dominican Republic), where 65 knots from the NE was recorded between 2000 and 2100 AST, with rough seas and heavy driving rain. At the same time and about 60 nautical miles to the west, the steamship «Cristina Pikuritz» reported winds up to 88 knots from the same direction, and the Cabo Rojo Coast Guard Lighthouse Station reported ESE winds up to 40 knots gusting to 52 knots and very rough seas and surf. This hurricane was classified as small and disorganized; the wind velocity at Mona Island exceeded by only nine knots the minimum wind velocity of 56 knots for a hurricane (e. g. Petterssen, 1941; p. 25, Beaufort scale of wind force).

WEATHER AND HYDROGRAPHIC OBSERVATIONS IN LA PARGUERA

By 9:00 P.M. on September 26 the barometric pressure in La Parguera had dropped to a minimum value of 29.77 inches. This measurement was made aboard the «Booby» (Donald Erdman, personal communication) with an aneroid barometer calibrated against a mercury barometer, For this time of year the normal range of barometric pressure is 29.90-29.95 inches.

Estimates of wind velocities in the region of La Parguera during the transit of the storm were as follows. Inshore areas and reefs during the afternoon of September 26 were subjected to winds equal to a Beaufort number of 7, equivalent to 24-30 knots. Men working at the field station of the Institute of Marine Biology estimated that wind velocities increased to whole gale velocities of 50 mph, equal to a Beaufort number of 10 which is equivalent to a range of 42-49 knots, during the late hours of September 26 and the early hours of September 27.

These winds generated a sea that broke on the windward shore of outer reefs from a SE direction as six to eight foot combers during the afternoon of September 26. Waves that approached circular patch reefs from both windward and leeward directions were funneled skyward as waterspouts up to 15 feet high. The sea may well have increased in height during the night. The outer reefs served in reducing the force of the sea; consequently wave action on the windward sides of inner reefs was slight-–not exceeding about two feet in height. At the eastern ends of some reefs which lie in an ESE and WSW line (such as Cayo Laurel and Cayo Media Luna; see Plate 1), at irregular intervals, waves of three to four feet in height bent around the reef and moved across the leeward sides toward the reef front where they broke in the shallows on the reef flat. Normally, windward breakers range from one to three feet in height while the lee of the reef is calm.

Both the inshore and offshore storm surge (« . . . the difference between the observed water level and that which would have been expected at the same place in the absence of the storm.»; Harris, 1963) amounted to only 12-18 inches, aside from greater sporadic fluctuations caused by waves in more exposed locations. The storm surge in La Parguera persisted over the period during which the hurricane passed close to Puerto Rico. Outer reef islands were inundated and washed by waves breaking on the foreshore. For example, at times the floor of the reef island on Cayo Laurel, which normally is about two feet above sea level, was completely covered by water to a depth of six inches. When washed by waves the depth increased from 12 to 18 inches. Because of breaking waves and a strong surge it was very difficult to land and moor the skiff used in making these observations on the island in the afternoon of September 26. Along protected shores mangrove coastal areas were also flooded, but generally without wave action.

Minimum and maximum atmospheric temperatures of 16° C and 30° C were recorded on September 27. The minimum temperature represents the lowest temperature observed at Magueyes Island over the three-year period 1961-1963. In 1962, on one and two occasions in January and February respectively, minimum temperatures reached a low of 18° C. Relative humidity measurements increased from 69%, on September 26 to 84% on September 27. These values were calculated from dry and wet bulb temperature readings made at 9:00 A.M. The mean relative humidity for the month was 73% which represents a normal figure for September.

The sea temperature at Cayo Laurel was lowered slightly by about one degree C. Surface temperatures taken on September 19 during the late morning hours on the seaward side and on the reef flat were 28.9° C and 29.6° C, respectively. Comparable measurements made one day after the storm passed, on September 28, were 28.2° C and 28.6° C. From October 1 throughout the remainder of the month, the temperatures at these stations consistency demonstrated higher readings of the order of one degree C.

Precipitation amounted to 8.00 inches, which fell mainly during the night of September 26-27. The amount of rain during this one night was the highest daily reading recorded since March, 1958, and represented 23% of the total annual rainfall for 1963, *viz.* 34.80 inches. However, it should be noted that on August 2 and 3 the rainfall amounted to 2.51 inches and 5.25 inches, respectively. This year was atypical in that precipitation on September 3 was also the second highest recorded over the six-year period 1958-1963. In La Parguera the annual rainfall is usually around 30 inches, distributed rather irregularly throughout the year (Coker and Gonzalez, 1960).

Resulting dilution of both inshore and offshore surface waters was relatively slight. The lowest surface salinity observations made at the dock in the mangrove canal separating Magueyes Island from the mainland and from nearby Cayo Májimo were 27.16‰ and 31.40‰, respectively. A surface salinity of 33.84‰ was recorded at Cayo Turrumote, an outer coral reef. That little dilution was experienced in shallow water on the outer reefs is illustrated by the following observations. One week before hurricane Edith, on September 19, a water sample taken at the surface on the reef flat at Cayo Laurel over three feet of water had a salinity of 34.13‰. A comparable sample collected on September 28 had a salinity of 33.93‰. Previous studies of surface salinity conditions in this area demonstrated a range of 34.0-36.7‰ over the period of November, 1957-October, 1958 for the dock at Magueyes (Coker and González, 1960) and 35.05-35.77‰ in open water between the reefs beyond the 10 meter isobath over the period July-August, 1958 (Margalef, 1961).

EFFECTS ON BIOTA

Prevailing winds were not strong enough to uproot of blow over such major coastal vegetation as coconut palms and mangroves. Only slight defoliation of the mangroves *Rhizophora mangle*, *Laguncularia racemosa*, and *Avicennia nitida* was evident in more exposed- localities. However, on the reef islands, such as at Cayo Turrumote and Cayo Laurel, the leaves of *Rhizophora* vegetation bordering the intertidal zone were «burned by the combined action of wind and sea up to a height of six feet above sea level. The «burned» leaves turned brown in color and later dropped from the plants.

Observations at Cayo Caballo Blanco, a cattle egret *(Bulbulcus ibis)* rookery about 1500 feet in front of the laboratory, showed that over 50% of the nestlings were knocked out of the nests by the wind or drowned. The birds in this colony during July and August numbered at least 500 individuals. Two to three weeks following the storm, nest building activity was again resumed by at least 200 of the birds, and by December fledglings again appeared in the colony. A few fledglings were last seen on this islet as late as March 13, 1964. Limited studies carried on by Mr. José Aponte in the eastern sector of Puerto Rico show that the earliest courtship and nest building behavior in cattle egrets appear in April or May, with the last young leaving the nests in November (Harold Heatwole, personal communication). These findings suggest that the second breeding period was perhaps a compensatory response induced by the high mortality of young.

Two days after the storm large drifts of *Sargassum natans* and *S. fluitans* began to accumulate on the islands of reefs and along the shore at La Parguera. Evidently these algae drifted shoreward under the influence of the winds generated by the hurricane. These two species of *Sargassum*, plus numerous other species of algae, drifted ashore at Beaufort, North Carolina, also under the influence of a hurricane (Blomquist and Pyron, 1943).

That an influx of oceanic water occurred is evident from the following typically offshore copepod species that were collected on September 27: *Farranula gracilis*, *Oncaea* sp., and juveniles of one species of pontellid. It should be noted, however, that the presence of these species in the plankton is not particularly unusual, as they have been taken on other occasions when offshore currents approach the coast.

On October 1, a high concentration of phytoplankters was observed in all of the inshore waters and seaward as far as the outer reefs. The water appeared green in color and a water sample taken from the surface on the windward side of Cayo Laurel and filtered through a No. 20 nylon net contained seven ml of plankton (wet settled volume) per M^3. Before the storm, on September 19, a comparable sample contained three ml of plankton per M^3. Analysis of the plankton samples taken after the storm showed very high concentrations, on the order of 99%, of the diatom *Skeletonema costatum*. Of other diatoms present, the following represented the more abundant species: *Chaetoceros didymun*, *Rhizosolenia stolterfothi*, *Thalassionema nitzschioides* and *Thalassiothrix frauenfeldii*. By October 4 the phytoplankton bloom had practically faded out.

Sea water samples filtered through a milepore filter (pore size 0.45μ±0.2μ) also showed comparatively high amounts of particulate matter. For example, on October 1 sea water from the station referred to above at Cayo Laurel, contained 3.1 gm dry weight particulate matter per M^3. A comparable sample taken on September 19 contained 2.2 gm per M^3.

One other observation that deserves mention is that the luminescence in Bahia Fosforescente decreased considerably. Margalef (1957) noted that the characteristic species responsible for the luminescence in the Bay is the armored dinoflagellate, *Pyrodinium bahamense*. Following the storm the concentration of dinoflagellates was typically high, but *Ceratium furca* greatly outnumbered *P. bahamense*.

In protected coastal areas where the storm surge was not markedly influenced by wave action no high mortality of littoral, air-breathing animals was detected. Animals of the mangrove forest, such as the pulmonate gastropod *Melampus coffeus* and the brachyuran crab *Aratus pisonii*, moved up the trees to a higher level during the flooding. Crabs living on the muddy floor of mangrove swamps and capable of respiring underwater, like *Uca pugnax rapax* and *Cardisoma guanhumi* (Gifford, 1962) remained submerged in their holes during the flooding.

Hundreds of individuals of the hermit crab *Coenobita clypeatus* climbed from the inundated ground of the small easternmost island of Cayo Laurel to cluster together in bushes and trees. Some of these aggregates contained as many as 48 individual crabs and were nine feet high, located most frequently in crotches or between supporting branches and dense foliage of the mangrove canopy. Also, the entire population of the gastropod *Tectarius muricatus* was shifted higher on the shore for a horizontal distance of three to four feet. The distributions of other mollusks of the rocky intertidal zone, e. g. *Acanthopleura granulata* and *Nerita tessellate*, were not noticeably altered.

No mortalities were observed from the lower air and sea water temperatures which accompanied the storm. Also, other than the nestlings of *Bulbulcus* that were drowned in the downpour, precipitation and accompanying reduction in salinity caused essentially no permanent damage to the flora and fauna. The frequent mass mortalities following heavy rains described for Kingston Harbor, Jamaica (Goodbody, 1961), have never been observed in the region of La Parguera in recent, years. Even the 8.00 inches of precipitation that fell in a single day, equivalent to 203 mm, caused no apparent mortality, as compared with 121 mm, 156 mm, and 195 mm in Jamaica, which resulted in nearly complete decimation of the sedentary fauna. Although Kingston Harbor is somewhat more enclosed from the sea than the coast line of La Parguera, the biota of the nearly landlocked Bahia Fosforescente demonstrated no signs of destruction. The average annual rainfall in these two regions is nearly equal, however, Kingston Harbor receives the discharge of two permanent rivers. There are no rivers in La Parguera.

Of the various physical factors investigated, wave action affected the biota the greatest. The following algae, growing attached to the coral *Porites furcata* or otherwise associated with this coral in the shallows of the reef flat at Cayo Laurel, were broken loose by the action of strong currents that moved over the reef: Chlorophyta— *Caulerpa racemosa, Cladophoropsis membranacea, Halimeda opuntia, Valonia ventricosa;* Rhodophyta— *Acanthophora spicifera, Amphiroa fragilissima, Ceramium nitens, Laurencia obtusa, L. papillosa.* The following green algae, growing in shallow sandy patches among *P. furcata*, were uprooted or buried bu the shifting sands and calcareous debris: *Caulerpa racemosa, C. sertularioides, Halimeda monile, Penicillus capitatus.* Filamentous algae growing attached to the substrate on the windward shore of the reef, such as *Lyngbya majuscula* (Cyanophyta), *Cladophoropsis membranacea*, and *Ceramium nitens* received the direct impact of large waves which uprooted and fragmented them. Two weeks after the storm, rocks and calcareous debris in the shallow water of the reef flat were dominated by the filamentous green alga, *Bryopsis hydnoides*. This alga was collected only once before in Puerto Rico, at Patinas near the outlet of a fresh-water stream.

Of the common species of benthic phanerogams in La Parguera, *Syringodium filiforme (= Cymodocea manatorum)* was most noticeably affected. In certain regions along the southwestern coast of Puerto Rico dense beds of *Syringodium* occur subtidally in shallow water and in the intertidal zone; however, Phillips (1960) has placed *Syringodium* at a deeper level in his scheme of seagrass zonation for the Tampa Bay area. Apparently the in. creased wave action on the shallow grass flats fragmented the brittle blades of this species. Little *Thalassia testudinum* was found in the drift line on the shore in contrast to the large piles of this plant deposited on the shores at Biscayne Bay by hurricane Donna (Thomas, *et al*,, 1961).

Some animal species found dead on the shore were numerous colonies of the sea fan *Gorgonia flabellum,* a few individuals of the sea urchin *Diadema antillarum,* and one specimen each of the relatively sluggish fishes *Antennarius multiocellatus* and *Diodon hystrix.* Bloated, foulsmelling individuals of the fish family Scaridae *were* observed in the drift line and floating in the coastal waters.

Coral destruction on all of the outer reefs was extensive. Dense, thriving stands of *Acropora palmata were* completely demolished over broad areas on the windward sides of outer reefs (Figs, 1 and 2). Large colonies of *A. palmata were* knocked down and fragmented and sometimes moved over a great distance. The weigth one individual colony, exeluding fragments that were broken off by the fall and thus lost or rendered unidentifiable, was nearly one-half of a short metric ton (Table 1), This specimen and the next largest colony of *Acropora* that was weighed were not dislocated appreciably from their sites of attachment. Large fragments of .4. *palmata* ranging in weight from 39.5 kg to 45.1 kg were deposited on the reef flat and in the sandy lagoon. The effect of rough seas on the more resistent groove and buttress

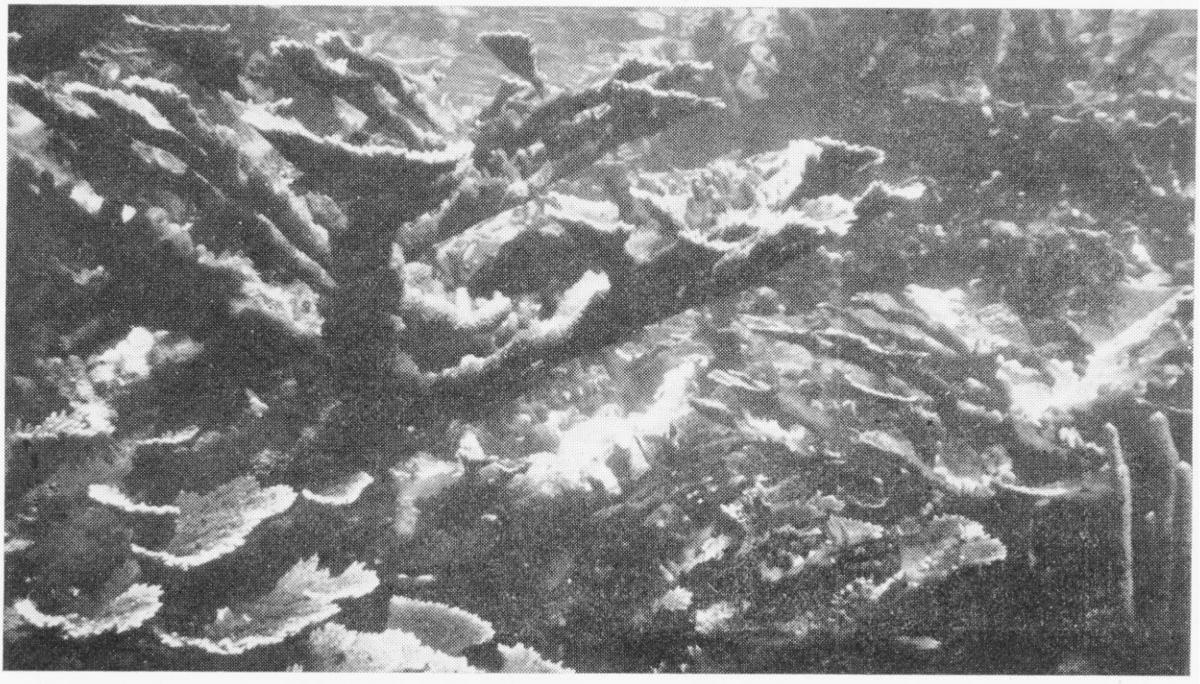

FIGURE 1. Underwater photograph of a luxuriant stand of *Acropora palmata* taken prior to the hurricane at a depth of about five feet on the seaward edge of Májimo reef (September 12, 1963). Even though the photographs shown in Figures 1 and 2 were not taken at the same reef they are comparable and clearly illustrate the destruction suffered by the *Acropora* association.

FIGURE 2. Underwater photograph showing complete destruction of *Acropora palmata* at a depth of about ten feet on the seaward edge at the eastern end of Cayo Laurel (January 31, 1964). A yardstick lies in a horizontal position near the center of the field.

TABLE 1. Wet weights of some species of corals, and the hydrocoral *Millepora*, knocked down, overturned or otherwise moved by the waves generated by hurricane Edith. This tabulation represents a sample of the largest colonies encountered at random of each species near the eastern end of Cayo Laurel and in the *Porites* reef flat and sandy lagoon of the western portion of Cayo Media Luna. Weights were determined with a spring scale accurate to the nearest 0.1 kg. All of the branches on the two largest colonies of *Acropora* were marked with a red wax pencil for identification, and then broken into smaller pieces with a sledge hammer for easier transport to the laboratory.

Species	Weight (kg)
Acropora palmata	417.3
	116.1
	45.1
	43.3
	39.5
Dendrogyra cylindrus	41.0
	31.7
Diploria labyrinthiformis	17.9
	15.7
Millepora complanata	41.0
	41.0
	19.0
Montostrea annulatis	46.2
	45.9
	33.9

zone of the windward shore, so well developed on some other reefs in the tropical western Atlantic (Goreau, 1959; Shinn, 1963), could not be studied because of the absence of this formation in the area investigated.

The various species of smaller coral colonies listed in the Table were also transported across the reef. In their movement across the reef some of these structures actually formed tracks of fallen and crushed *Porites furcata* (Fig. 3). *Percnon gibbesi*, a brachyuran crab inhabiting «...outlying rocks washed by spray. (Rathbun, 1933; p. 94), was found on three occasions adhering to large transported pieces of the hydrocoral *Millepora complanata* in four to six feet of water in the lee of the reef.

The extent of transportation and deposition of large coral fragments contributed significantly to the numbers of coral boulders already present on the leeward side of reefs. As observed by Stoddart (1962) corals which survived best were the large, massive and hemispherical species such as *Montastrea annu-*

laris, *Diploria* spp., and *Porites astreoides*. Nonetheless, Table 1 shows that relatively small colonies of these species were broken loose. Conversely, fragile, arborescent colonies of *Acroporu cervicornis were* often completely broken apart and strewn over the bet. tom.

Observations following the storm, up to March 13, 1964, showed that many of the dam. aged colonies of A. *palmata* were still growing; the edges of colonies turned upside down had grown upwards toward the surface. Most other coral species that were knocked down or moved, but still right side up, also appeared to be flourishing,

A survey of coral destruction in the inshore reef areas was made by visual estimates at frequent intervals from the 30 foot isobath to the edge of the reef. This reconnaissance demonstrated the following regions of destruction and its intensity (Plate 1). The windward sides of outer reefs, such as Cayo Turrumote and Cayo Media Luna, out to a depth of 30 feet, showed more than half to complete demolition of *Acropora*. In the lee of these reefs the shallow beds of *Porites* on the reef flat displayed destructive effects from corals that were washed across the reef into the waters of the lagoon. The seaward fronts on inner reefs, such as Cayo Enrique and Cayo Májimo, showed *Acropora* destruction to the extent of 10 to 50 per cent. Only the *Porites* at the western end of Cayo Enrique showed signs of destruction. *Porites* coral associations, while well developed on other parts of Cayo Enrique and at Isla La Gata, Cayo Caracoles, and other inshore areas, showed no signs of damage. *Porites divaricata*, which is often found bordering the exposed or windward sides of mangrove islets close to the coast line, was also unaffected.

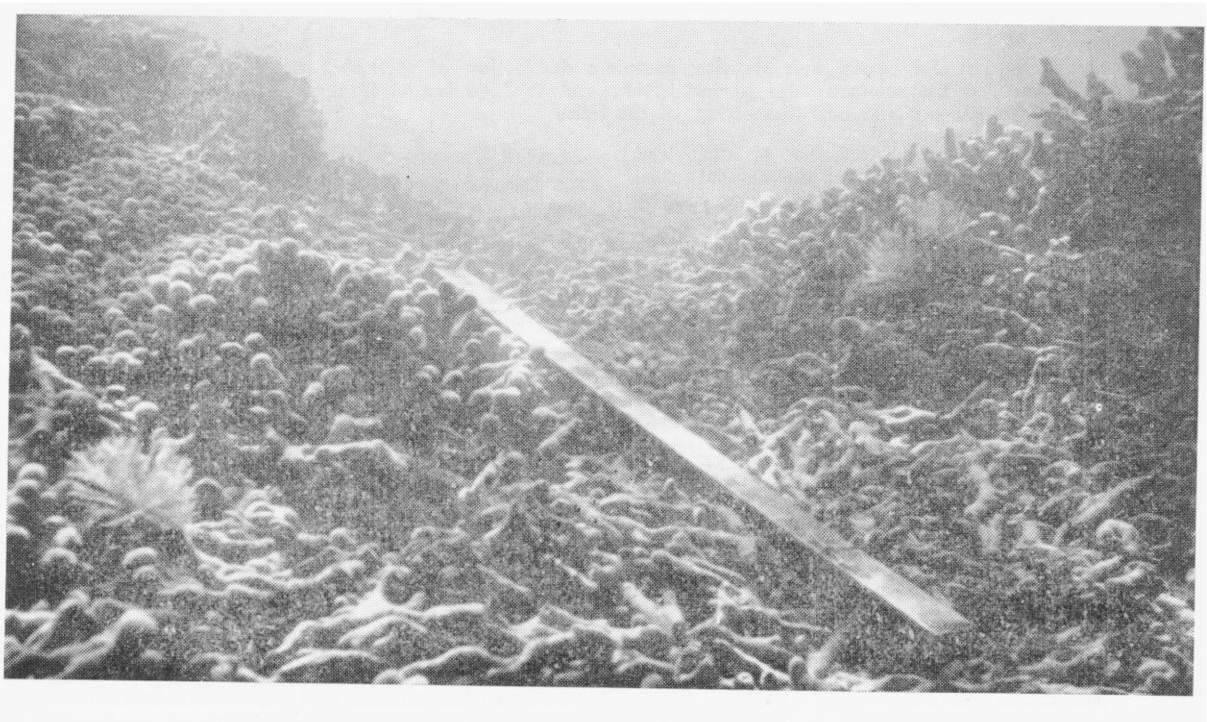

FIGURE 3. Underwater photograph showing a portion of a crushed trail of *Porites furcata* at a depth of three feet toward the western end of Cayo Laurel (January 2, 1964). Not shown in the photograph is a detached coral boulder that was deposited at the end of the trail. A yardstick lies in a diagonal position across the field.

EFFECTS ON TOPOGRAPHY

Under the influence of strong wave action and shifting currents coral debris was deposited on the outer coral islands and formed new islets on three different reefs (Figs. 4 and 5). One portion of the floor of Cayo Laurel was covered with coral rubble to a depth of five inches, Where mangroves provided support, coral deposits reached a depth of 18 inches. *Porites furcata* contributed considerably to the debris deposited on all of the reef islets. Underlying the coral is a base layer of *Halimeda opuntia* which was located at the surface before the storm.

Broken fragments of *Porites furcata* also represented the principal constituent of the coral shingle forming the new islets. The largest of these islets, at Cayo Media Luna (Fig. 5), measures 86 feet around and has a maximum elevation of 20 inches above sea level. They have maintained their same form up to March 13, nearly six months following the hurricane. Three *Rhizophora mangle* seedlings have sprouted on the newly-formed islet at Cayo Májimo.

New channels communicating between the reef front and lagoon were observed on Cayo Turrumote de Guanica following the storm (Donald Erdman, personal communication). This reef is located about two miles to the east of Cayo Corral, at latitude 17°55'48" N, longitude 66°58'24" W. The main channel at the southeastern end of Cayo Turrumote (shown in Plate 1) appeared to have been widened by the storm.

A survey of the exposed portions of reefs conducted on March 20, 1964, demonstrated that the land and shallows have changed

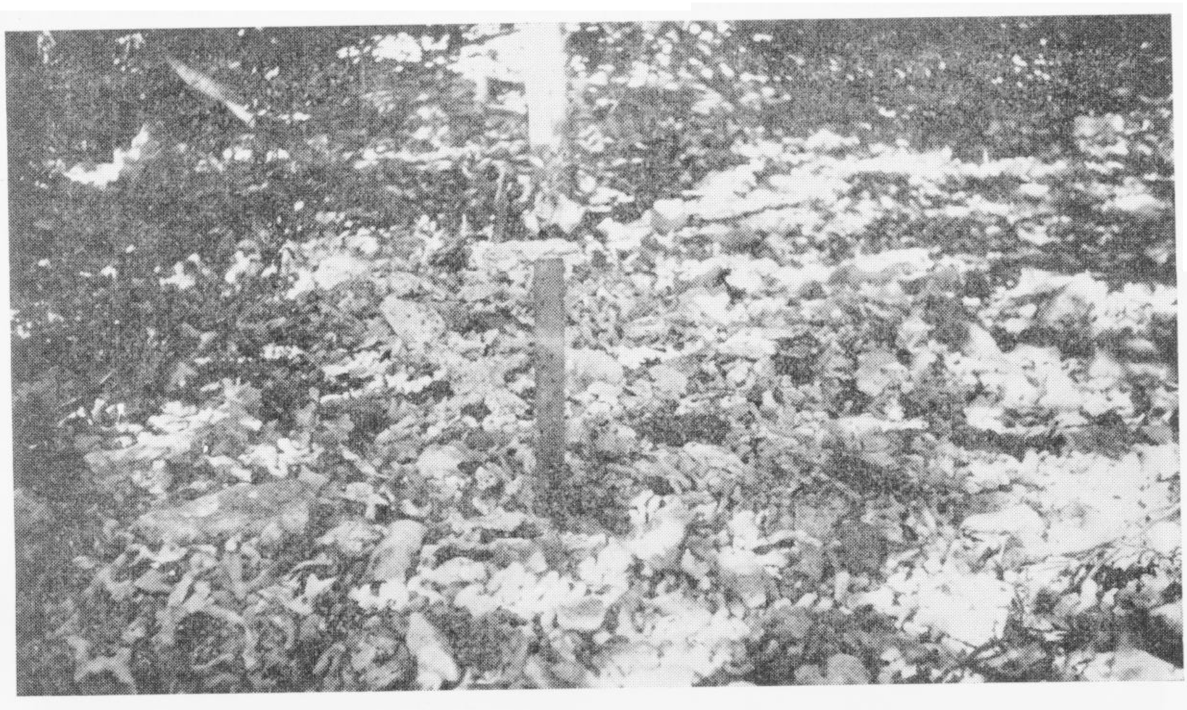

FIGURE 4. Floor of the mangrove-covered island at Cayo Laurel showing coral debris deposited to a depth of five inches (December 1, 1963). A 15-inch rule is shown embedded in the debris in the center of' the field.

markedly from their appearance on the U.S. Geological Survey topographic map of the Parguera Quadrangle, which was based on surveys conducted in 1949 and in 1951. For example, besides the new islets formed by hurricane Edith three reefs showed the following discrepancies: a.) Cayo Media Luna has only two islands above sea level instead of four, b.) Cayo Laurel has two large islands, whereas only the easternmost one is evident on the chart, c.) Cayo San Cristóbal has only one short island in the position of the longest island shown on the chart. These inconsistencies were observed before hurricane Edith passed and must have developed since 1951. In 1956 hurricane Greta approached the south. western coast of Puerto Rico (but never came nearer than 275 miles) and generated high and rough seas. It is possible that this storm produced to some extent some of the topographic alterations noted. Cays resurveyed on the Florida coral reef tract likewise demonstrated marked short-term changes in form and position (Vaughan and Shaw, 1916).

In the fairly recent past, other devastating hurricanes that have certainly influenced the marine environment of the southwestern coast were San Ciriaco of 1898 and San Felipe of 1928. The frequency with which hurricanes may modify the environment of eastern America can be appreciated by the fact that a total of 286 hurricanes have occurred over the period 1900-1962, with an annual average of 4.5 storms (U.S. Weather Bureau, 1963). No hurricanes were reported in 1907 or in 1914, but a maximum number of 11 occurred in 1916 and in 1950. Over this same time span a total of 212 tropical storms of less severity were recorded. That these may also affect local conditions was demonstrated by Robins (1957) for the shallow-water fish fauna of southern Florida.

FIGURE 5. View toward the west of the new, crescent-shaped coral islet formed on Cayo Media Luna (March 19, 1964). A yardstick is shown embedded in the islet to the right.

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