CHANGES IN A PUERTO RICAN CORAL REEF FROM 1936-1979 USING AERIAL PHOTOANALYSIS

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ABSTRACT

Panchromatic aerial photographs of Cayo Enrique, La Parguera, Puerto Rico, were obtained for the years 1936, 1951, 1963, 1971, 1978 and 1979. Enlargements were made to the approximate scale of 1:4000 to differentiate the various reef zones. Features seen in the photographs were substantiated by surface reconnaissance. Rhizophora mangle and Thalassia testudinum areas, measured with a planimeter, showed the maximum variation of all reef zones for a 43-year period. Hurricane effects appear as boulder-rampart formations on the reef flat composed mainly of dead Acropora palmata fragments. Past aerial coverage of coral reefs provides the baseline data needed to assess present-day effects of human interference and natural catastrophes on coral reef ecosystems.

INTRODUCTION

Over the last 40 years, the use of aerial photography in coral reef studies has been limited mostly for illustrative purposes and to map and differentiate reef zones (Steers 1945, Teichert and Fairbridge 1948, 1950, Kelly and Conrad 1969, Kumpf and Randall 1961, Slatter and Phipps 1977, and others). Guidelines for the use of aerial photography in reef studies are provided by Hopley (1977) and Hopley and Steveninck (1977).

METHODOLOGY

This paper attempts to measure changes on the reef morphology and features of Cayo Enrique, La Parguera, Puerto Rico, over a 43-year period using aerial photoanalysis. Vertical panchromatic aerial photographs were analyzed from the years 1936, 1951, 1963, 1971, 1978 and 1979. Old photographs were obtained from the Department of Public Works, San Juan, Puerto Rico, while recent coverage was obtained by the author using a small airplane.

All photographs were enlarged to the approximate scale of 1:4000. To compute a more exact scale for each photograph, man-made structures were measured in the field and compared to their equivalent photographic image measurements. Areas were measured with a planimeter. Field work was essential to properly interpret the features seen in the photographs and to determine the effect of hurricanes. Low altitude oblique aerial photographs were used to define reef zones more clearly. Different reef features and zones were defined in old aerial photographs according to their tones and location on the reef (Table 1).

THE STUDY SITE

Cayo Enrique is located 1.5 km south of the village of La Parguera on the southwestern coast of Puerto Rico. It is approximately 1.4 km long by 0.4 km at its widest point and aligned almost parallel to shore (Fig. 1).

Cayo Enrique was selected for this study for its relatively large size and presence of various biotic macrassemblages such as seagrass beds and mangrove areas. Due to its proximity to land, it also appears in most old aerial photographs of the area.

The temperature-salinity characteristics of La Parguera are indicative of a mild hydrographic climate (Glynn 1973). A continuous surface current flow over the reef plus the fact that the maximum daily tidal range is only 40 cm prevents marked temperature and salinity differences. This provides reef flat and back reef organisms with a stable environment. Although heavy mortality of reef flat organisms related to midday extreme low tidal exposure do occur (Glynn 1968), their effect on the reef's macroflora and fauna is negligible when compared to other catastrophic events such as hurricanes.

Cayo Enrique can be classified as an apron reef with a shallow (0.5-3 m) area of sand deposition leeward of the reef flat (Fig. 2). These sediments are medium and coarse-grained sands composed mainly of Acropora, Porites and Halimeda fragments (Morelock et al. 1977). Both seagrass beds and small patch reefs occur in this area. Thalassia testudinum areas occur at both ends of the sandy lagoon and on
Table 1. Criteria used to define reef features and zones of Cayo Enrique using panchromatic photographs.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Location</th>
<th>Tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acropora palmata zone</td>
<td>Windward side of reef to 3 m depth</td>
<td>Medium to dark gray contrasting with light substrate</td>
</tr>
<tr>
<td>Millepora-Palythoa zone</td>
<td>Reef crest</td>
<td>Light gray, usually defined by white line of breaking waves</td>
</tr>
<tr>
<td>Living and dead Porites and other corals</td>
<td>Leeward and adjacent to reef crest</td>
<td>Light gray mixed with sandy areas</td>
</tr>
<tr>
<td>Thalassia-Zoanthus zone</td>
<td>Most of reef flat areas</td>
<td>Medium to dark gray</td>
</tr>
<tr>
<td>Mangroves</td>
<td>Limited to reef flat areas</td>
<td>Even medium gray tone, mottled appearance</td>
</tr>
<tr>
<td>Thalassia seagrass beds</td>
<td>East and west ends of back reef lagoon</td>
<td>Light to medium gray tones</td>
</tr>
<tr>
<td>Sandy areas</td>
<td>Back reef lagoon and slope</td>
<td>White to very light gray tones that vary with depth</td>
</tr>
<tr>
<td>Small patch reefs</td>
<td>Back reef lagoon</td>
<td>Dark to very dark spotted pattern over light gray lagoon sands</td>
</tr>
<tr>
<td>Boulder ramparts</td>
<td>Reef flat areas behind reef crest</td>
<td>Brilliant white tones with dark edges</td>
</tr>
</tbody>
</table>

Figure 1. Outline of Puerto Rico with an arrow indicating the location of La Parguera. A detailed map of La Parguera showing the study site, Cayo Enrique, in relation to the coast and other reefs.
the reef flat while patch reefs occur on the middle and western parts of the lagoon.

The reef flat is composed mainly of living *Thalassia*, *Zoanthus*, *Porites* and occasionally *Halimeda* clumps. *Rhizophora mangle* occurs in the middle and both ends of the reef flat.

The reef crest is dominated by the hydrocoral *Millepora complanata*. The zoanthid *Palythoa caribbea* is found near the reef crest encrusting on dead corals.

At the eastern end, the fore reef of Cayo Enrique is relatively broad and gradually slopes to a depth of 20 m while it gets narrower and steeper moving westward. This reef lacks a spur and groove development of the fore reef but has a well defined coral zonation. *Acropora palmata* occurs seaward of the crest to a depth of 3 m followed by *Acropora cervicornis* to a depth of 5 m. A zone of massive corals occurs from 5 to 15 m and is composed mainly of *Montastrea*, *Diploria* and *Agaricia*.

The lagoon coral patch reefs are dominated by the coral *Montastrea annularis* in addition to numerous sponges and gorgonians. Other corals present include *Acropora cervicornis*, *Siderastrea siderea* and *Diploria labyrinthiformis*. Dead coral heads covered with algae are common in this area.

**RESULTS**

1. **THALASSIA TESTUDINUM AREAS:**

Approximately a two-fold increase in lagoonal seagrass areas occurred in Cayo Enrique (Table 2
and Fig. 3). This represents an average increase of 756 m²/year over a 43 year period. The eastern Thalassia bed doubled its area between 1936 and 1951 while on the western end of the reef, an almost complete disappearance of Thalassia occurred during the same time period. Since the meteorological record shows no major hurricanes affecting the area during those years, an alternate mechanism for such a widespread destruction is yet to be found. One possibility is overgrazing by reef fishes and echinoids that underwent a population explosion.

In Florida, Camp et al. (1973) observed massive destruction of sea grass beds by the urchin Lytechinus variegatus. Areas hundreds of meters long were heavily grazed by these urchins.

Table 2. Mangrove and Thalassia area measurements for each photograph.

<table>
<thead>
<tr>
<th>Year</th>
<th>Rhizophora (m²)</th>
<th>Thalassia (m²)</th>
</tr>
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<tbody>
<tr>
<td>1936</td>
<td>1.227</td>
<td>19.129</td>
</tr>
<tr>
<td>1951</td>
<td>2.478</td>
<td>13.150</td>
</tr>
<tr>
<td>1963</td>
<td>8.022</td>
<td>35.770</td>
</tr>
<tr>
<td>1971</td>
<td>13.284</td>
<td>45.569</td>
</tr>
<tr>
<td>1978</td>
<td>15.432</td>
<td>51.596</td>
</tr>
<tr>
<td>1979</td>
<td>13.873</td>
<td>51.667</td>
</tr>
</tbody>
</table>

2. RHIZOPHORA MANGLE:

Mangrove areas increased fifteen times between 1936 and 1978 (Table 2 and Fig. 3). An approximate decrease in mangrove area of 1,560 m² occurred in 1979 due to catastrophic effects of hurricane David. While some mangroves were completely uprooted, most damage was caused by hurricane winds and sea spray scalding of the leaves with subsequent defoliation. Mechanical damage of Rhizophora prop roots resulted from abrasion and piling-up of coral boulders against them.

Levine (pers. comm.) reported increase in mangrove area of 1,360 m²/year for Joyuda lagoon on the west coast of Puerto Rico. While this rate is more than five times the average rate of mangrove increase for Cayo Enrique, the difference is easily explained when one considers the two environments: a calm, nutrient-rich, protected lagoon compared to an exposed, high energy reef environment.

3. HURRICANE EFFECTS:

The effects of hurricane Edith on the reefs of La Parguera were documented by Glynn et al. (1964). Although extensive coral destruction on the outer reefs was observed, Cayo Enrique and other inner reefs suffered Acropora destruction to the extent of 10-50 percent. No coral shingle inlet formation was reported for Cayo Enrique. Analysis of old aerial photographs reveal no detectable changes due to the passage of hurricane Edith in 1963.

Sixteen years later, hurricane David (Aug. 25-Sept. 8, 1979), considered one of the severest storms of the century, passed approximately 120 km south of Puerto Rico. A survey of Cayo Enrique after the storm showed the following effects:

A) Recently dead corals formed boulder rumparts on the eastern and middle windward reef flat areas. These newly formed islets were composed mainly of large pieces of Acropora palmata and smaller fragments of Millepora and Porites (Figs. 4 and 5).

B) Numerous dead invertebrates, mostly echinoderms and mollusks, were present on the reef flat.

C) Thalassia and Syringodium blades accumulated on mangrove roots and boulder rumparts. These seagrasses probably broke free from the outer reefs due to wave action and were carried downcurrent and deposited on Cayo Enrique.

Four phototransects made on the western fore reef of Cayo Enrique showed a significant (p<.001) difference in Acropora coverage while no significant difference was observed in the massive coral zone (Ramirez, pers. comm.).

The following changes were detected on the 1979 aerial photograph of Cayo Enrique taken one month after hurricane David: 1) a decrease in mangrove area as explained previously in this paper and 3) no major effects on the lagoon’s Thalassia beds. This agrees with Thomas et al. (1961) report of light damage to the Thalassia beds of Biscayne Bay after the passage of hurricane Donna. Oppenheimer (1963) states that after hurricane Carla, not only did the grass flats remain intact, but that they appeared more healthy than at any time during the last three years. He suggests that the wave motion apparently removed the old and unattached grasses and algae leaving clean grass flats.

4. HUMAN INTERFERENCE:

Cayo Enrique is frequently visited by pleasure boats that stay up to 3-4 days anchored on the calm, sandy lagoon. No detrimental effects on the reef have been observed that can be related to boating activities. They tend to avoid Thalassia beds in favor of sandy areas that provide a better holding ground for anchoring. Destruction of Thalassia caused by boat propellers in shallow bays has been reported by Phillips (1960). This was not observed in Cayo Enrique probably due to the deeper distribution of Thalassia there.

Local fishermen frequently walk on the reef flat searching for octopus and other edible mollusks.
Figure 3. Relative changes in Thalassia and mangrove coverage for a 43-year period. Arrows indicate location of boulder ramps formed by hurricane David in 1979.
Figure 5. Oblique low altitude photograph of south windward side of Cayo Enrique taken after hurricane David in 1979. Boulder rampart accumulation can be seen on the reef piling up against the mangroves.
Although these activities could potentially destroy fragile corals such as Porites furcata and other reef organisms, its real effect is yet to be determined.

Oil pollution, in the form of tar balls, was observed on the boulder ramparts in the last two years. This could represent, if it continues and increases over the years, a major source of pollution and unnecessary stress on the reef environment.

CONCLUSIONS

Detectable changes in Cayo Enriquillo during a 43-year period using aerial photoanalysis include an increase in seagrass and mangrove coverage and boulder rampart formation on the reef flat due to hurricane effects. Hurricane David reduced the area of mangroves by 1,560 m² while Thalassia beds were not adversely affected. Human activities in Cayo Enriquillo appear to have no detectable effects on the reef environment. Whether this can be said in future years will depend on whatever measures are taken today to protect this reef, as well as the other reefs of La Parguera, from future adverse direct and indirect effects by man.

The rate at which seagrasses are covering lagoon areas and the extent of mangrove colonization of the reef flat could indicate that Cayo Enriquillo is approaching a climax zonation dominated primarily by plant species.

When available, a series of aerial photographs taken over the years, is a useful tool in detecting and measuring trends in coral reefs and providing baseline data by which present and future comparisons can be made.

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REFERENCES


