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REEF DISTRIBUTION IN SOUTH FLORIDA

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ABSTRACT

The Florida Reef Tract contains approximately 96 km (kilometers) of outer bank reefs along the shallow shelf edge and more than 6000 patch reefs in the inner lagoon. Most reefs are located in the upper Keys seaward of Elliot Key and Key Largo Key. Patch reefs are extremely rare in the middle Keys although outer bank reefs are occasionally developed along the platform edge. Outer bank reef and patch reef development increases in the lower Keys between Big Pine Key and Dry Tortugas.

Reef distribution is controlled mainly by factors affecting exchange between the Reef Tract and coastal lagoons and Florida Bay. Of primary importance are: relative development of land barriers and tidal passes; orientation of the Reef Tract in relation to wind-driven winter currents; and exposure to Loop Current water and the effects of the Loop Current on local circulation.

KEY WORDS: Coral Reefs, Florida Reef Tract, Distribution (Reef), Circulation

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Introduction

The Florida Reef Tract extends from Miami southward along the Keys to Dry Tortugas. The reefs are within easy access of the densely populated Miami-Homestead area, and are important to the tourist based economy of the State as well as to the seafood and baitfish industries. The Keys have recently undergone large-scale development usually accompanied by removal of natural vegetation and shoreline modification. Increasing evidence of reef deterioration prompted the State Bureau of Coastal Zone Planning (Department of Natural Resources) to initiate a research and marine resource management program, the initial phase of which is an inventory of marine benthic communities and substrate-types, and the compilation of distribution maps. Aerial photography of the Reef Tract from Miami to the Marquesas Keys was completed last year using water-penetration aerial color film. Aerial photography coupled with ground-truthing reveals the accurate spatial distribution of benthic communities. Aerial photomosaics and color-coded maps at a scale of 1:24000 will be published upon completion of the project. Preliminary data focusing on coral reef distribution are presented in this report.

Distribution

Outer bank reefs

Approximately 96 km of outer bank reefs occur along the shallow platform edge between Fowey Rocks Lighthouse near Miami and the Marquesas Keys west of Key West, a distance of about 270 km measured at the 20 meter depth contour. The distribution of outer bank reefs is shown on Figs. 1-4. Table 1 indicates the extent of outer bank reef development at various locations in the Florida Reef Tract.

TABLE 1

Outer bank reef distribution in the Florida Reef Tract

Area	Outer Bank Reef (in kilometers)
Fowey Rocks to Broad Creek	22.2
Broad Creek to Tavernier Creek	34.3
Tavernier Creek to Big Pine Key	16.6
Big Pine Key to Marquesas Keys	22.6
TOTAL	95.8 km

The outer bank reefs are typically elongate features of variable vertical relief which occur at the shallow shelf edge between the 5 m (meters) and 10 m depth contours. Their long axes form a discontinuous line of reefs oriented parallel to the shelf edge. The northernmost reefs trend N-S and the reefs near Key West E-W reflecting the change in orientation of the arcuate shelf edge. Approximately 56 km of linear bank reefs are located north of Tavernier Creek (at the south end of Key Largo Key), 17 km of reefs in the middle Keys and 23 km in the lower Keys (west of Big Pine Key). A spur and groove system is developed on the seaward face of most of the bank reefs, with the spurs and grooves oriented generally perpendicular to the shelf edge and to the incoming waves of the Florida Current. Spurs and grooves are best developed on outer bank reefs of the upper Keys (Figs. 1 and 2) and lower Keys (Fig. 4); the spur and groove pattern on reefs in the middle Keys (Fig. 3) is generally less developed and exhibits a more random orientation.

In an ecological sense Florida outer bank reefs are roughly comparable to the barrier reefs of the Caribbean and the Pacific but are biologically less diverse, relatively small in aerial extent, and lack the vertical reflief characteristic of true barrier reefs. Typically less than 10 m of vertical relief is formed by living corals in the Florida Reef Tract.

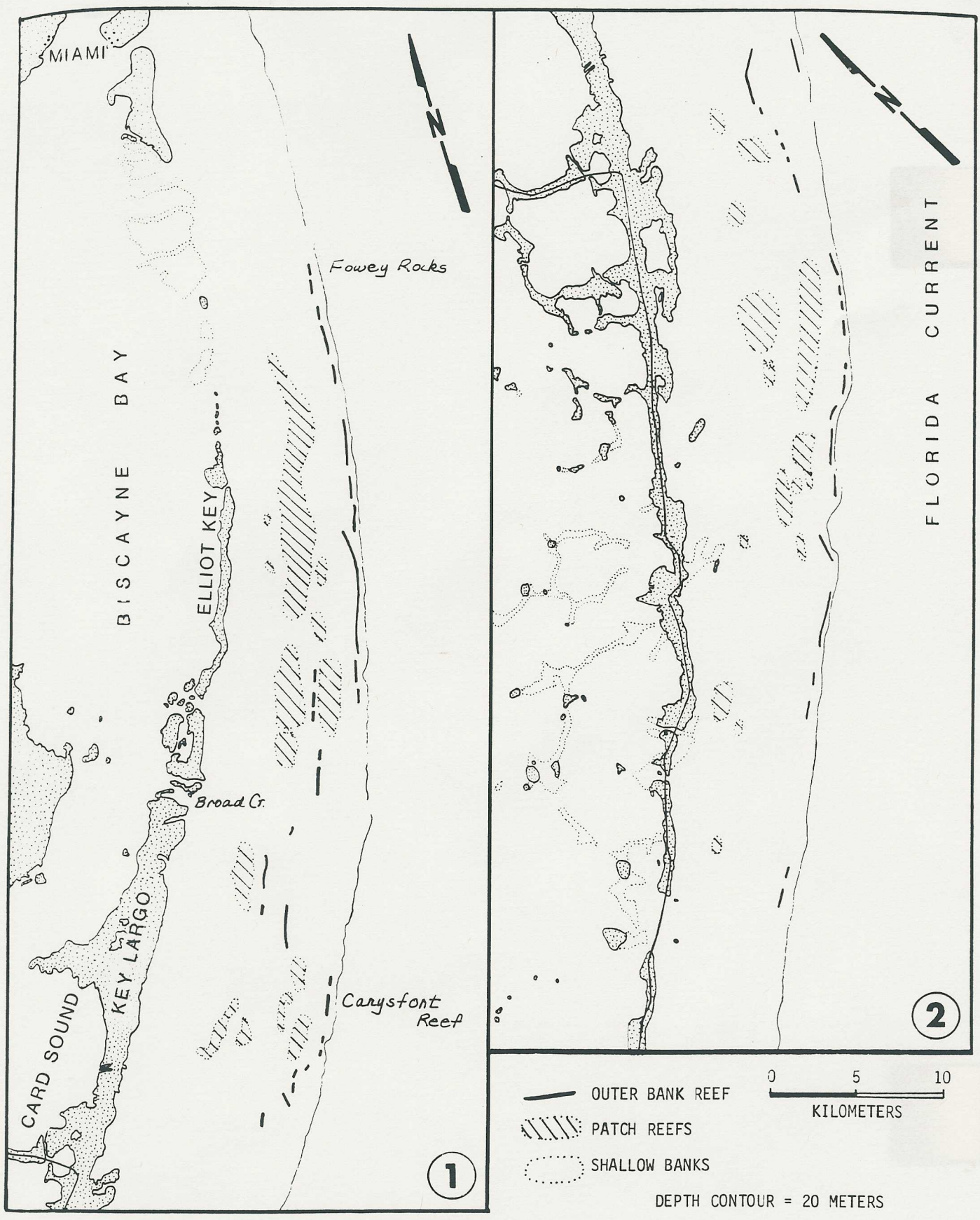
Florida outer bank reefs are highly variable in their degree of development. Our calculations of shelf-edge reef development are based on aerial photography and ground-truthing and include both well developed and poorly developed reefs.

Well developed outer bank reefs are characterized by a reef-flat formed of in situ dead encrusted Acropora palmata skeletons and rubble. Dominant reef-flat benthic macrobiota includes small heads of Acropora, Porites, and Siderastrea, encrusting Millepora, the echinoid Diadema antillarum, sponges, and the codiacean calcareous alga Halimeda opuntia. A fringe of massive oriented colonies of Acropora palmata forms the seaward face of the reef to a depth of about 4 m. Millepora complanata and the colonial zooanthid Palythoa also occur in the turbulent shallow zone. Deeper portions of the reef exhibit a diverse coral assemblage dominated by large heads of Montastrea annularis. Carysfort Reef and Key Largo Dry Rocks are representative of well-developed outer bank reefs.

At the other end of the spectrum of outer bank reefs included in our calculations are those reefs of sparse coral growth which lack the A. palmata zone. Although these reefs may have been Acropora palmata reefs in the past, they are now limestone ridges capped by a veneer of living coral and other reef organisms; most of the vertical relief including spurs and grooves is relict structure. Long Reef and French Reef in the upper Keys are representative of poorly developed outer bank reefs. Thus although approximately 34% of the platform edge between Miami and the Marquesas Keys is occupied by outer bank reefs, only a fraction of that percentage represents prolific Acropora palmata reefs.

Patch reefs

More than 6,000 patch reefs are found in the Florida Reef Tract between Miami and the Marquesas Keys. Most patch reefs occur 3 to 7 km from land between Hawk Channel and the outer bank reefs. A few isolated patch reefs, however, are found seaward of the


MIAMI
BISCAYNE BAY
ELLIOT KEY
Fowey Rocks
Broad Cr.
KEY LARGO
CARD SOUND
Carysfort Reef
FLORIDA CURRENT
1
2
OUTER BANK REEF
PATCH REEFS
SHALLOW BANKS
DEPTH CONTOUR = 20 METERS
0 5 10
KILOMETERS


FLORIDA BAY
BIG PINE KEY
3
KEY WEST
MARQUESAS KEYS 5 KM
4

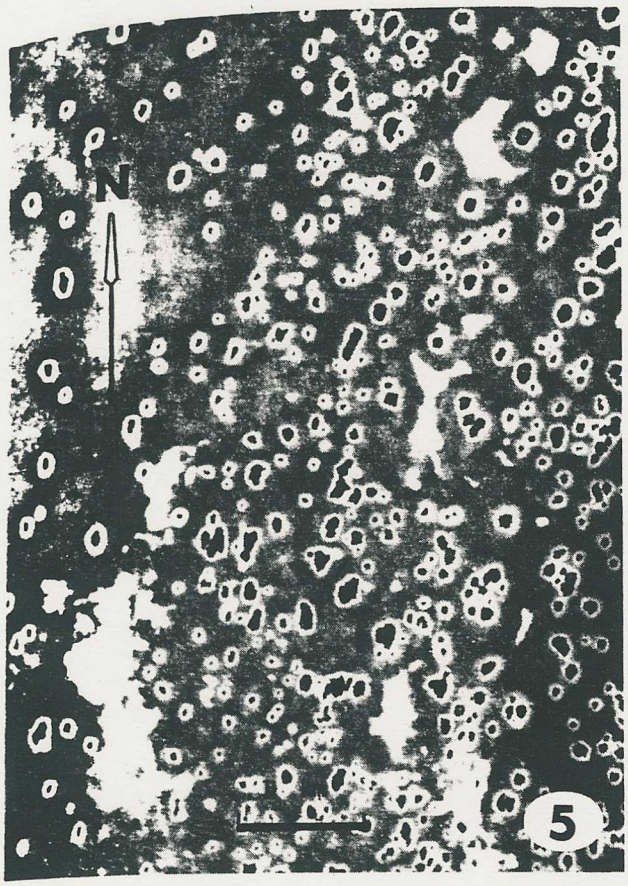


Figure 5. Patch reef density near Elliot Key, upper Keys. Note sand halos and topographic control on distribution. Dark areas are sea grasses, mainly Thalassia testudinum. Lighter areas indicate sparse sea grass cover or barren sand areas. Water depth approximately 7 m.

shallow shelf edge; others are found within 1.5 km of the Keys. Two basic types of patch reefs are recognizable: a) dome-type patch reefs, and b) linear-type patch reefs.

Dome-type patch reef are roughly circular or elliptical in plan view, show well developed sand halos, and usually occur in clusters. They range in size from a few meters to several hundred meters in diameter. Although generally less than 5 m in height, some exhibit as much as 9 m vertical relief. The patch reefs typically support a varied assemblage of scleractinian and octacorals, sponges, other invertebrates and algae. Except for the lack of A. palmata, the biota of dome-type patch reefs is similar to that found on the outer bank reefs but lacks the coral zonation characteristic of most shelf-edge reefs. Some dome-type patch reefs are formed of single enormous colonies of Montastrea annularis, usually with hollow cavernous interiors. M. annularis typically forms the highest relief on patch reefs more than 5 m in height.

Linear-type patch reefs are generally found seaward of the dome-type reefs, are arcuate or linear in plan view, tend to occur end to end in single or multiple rows, and exhibit the same orientation as nearby outer bank reefs. Unlike the dome-type patch reefs, these reefs are frequently colonized by Acropora palmata. When found on patch reefs, A. palmata colonies are smaller, more widely spaced, and lack the orientation characteristic of this species on the outer bank reefs. Linear patch reefs are clearly transitional between the bank reefs and the more numerous dome-type patch reefs.

The distribution of patch reefs in the Florida Reef Tract is highly irregular with most of the reefs clustered in relatively few areas. As seen in Table 2 and Figs. 1-4, most of the patch reefs are found in the upper Keys, very few in the middle Keys and the remainder in the lower Keys.

TABLE 2

Patch reef distribution in the Florida Reef Tract

Area	Approx. no. patch reefs
Fowey Rocks to Broad Creek	3,975
Broad Creek to Tavernier Creek	1,590
Tavernier Creek to Big Pine Key	50
Big Pine Keys to Marquesas Keys	420
TOTAL	6,035

Discussion

The preceeding data shows that south Florida reefs are not uniformly distributed along the coast but rather occur primarily in the upper Keys and secondarily in the lower Keys. Outer bank reefs are more evenly distributed than are patch reefs, which show their maximum development in the upper Keys. Field observations indicate that the most luxurient coral reefs are concentrated in the Key Largo Key area, especially within and seaward of John Pennekamp Coral Reef State Park. The observed distribution pattern is unusual in that the most prolific reef growth occurs near the northern limit for reef development in the Caribbean region. The lower Keys, although more "tropical", support fewer reefs. The remainder of this report will attempt to identify factors responsible for the observed distribution.

Factors controlling reef distribution

The Florida Reef Tract is bounded on the seaward side by the Florida Current (Gulf Stream) and on the landward side by the Keys. Exchange between the Reef Tract and coastal lagoons and Florida Bay is through a series of passes between the Keys. Tides at Miami are semidiurnal with a mean range of about 0.7 m which decreases gradually to the south. At Key West mean tidal range is about 0.4 m and tides are somewhat mixed reflecting the diurnal tides of the northern Gulf of Mexico.

Prevailing winds are from the southeast during

most of the year. Cold fronts are common during the winter and are accompanied by northerly winds, an increase in wind velocity, and a sharp drop in temperature. Circulation on the Reef Tract is affected by tides and wind-driven currents.

The northern portion of the Reef Tract exhibits the most extensive reef development. The area of luxurient reef growth is flushed by oceanic waters of the Florida Current which consistently flows near and occasionally over the platform edge in the upper Keys; the position of the Florida Current is more variable off the lower Keys, as explained later. Key Largo Key and Elliot Key effectively prevent exchange of shelf water with Barnes Sound, Card Sound, and Biscayne Bay. Outer bank reefs deteriorate from luxurient at Carysfort Reef to semi-barren rubble at Fowey Rocks over a distance of 48 km. Measurements of minimum water temperatures over various outer reefs made by Vaughn (1) during a 20 year period were 17.9°C off Key West, 18.2°C at Carysfort Reef, and 15.6°C at Fowey Rocks. The absence of coral reefs along the coast north of Biscayne Bay where tidal passes are not found indicates that waters north of Miami are generally too cold for coral reef development.

The northern extent for patch reef development, however, appears to be limited locally by tidal and wind-driven exchange between Biscayne Bay and the inner shelf, through the open area (known locally as the "Safety Valve") between Key Biscayne and the Ragged Keys. Patch reefs are extremely abundant off Elliot Key and disappear abruptly opposite the tidal passes north of the Ragged Keys. The northernmost patch reefs are mostly encrusted rubble and may have developed when sea level was lower and tidal exchange with Biscayne Bay reduced or non-existant.

Caesar's Creek and Broad Creek are tidal passes located between Elliot Key and Key Largo Key and connect the Reef Tract with south Biscayne Bay and Card Sound respectively (see Fig. 1). Patch reefs are present directly seaward of these tidal passes but are more numerous off Elliot Key (Fig. 5) to the north and Key Largo Key to the south. The presence of patch reefs near Ceasar's Creek and Broad Creek and their absence north of the Ragged Keys indicates that tidal exchange through the creeks is minimal compared to the Safety Valve. The mean tidal range which is 0.6 m in Biscayne Bay near the Safety Valve decreases to 0.22 m in Card Sound and 0.12 m in Barnes Sound (2). In a study of Biscayne Bay circulation Lee and Rooth (2) concluded that tides are not the primary flushing mechanism of the Bay, their effect being confined to the vicinity of the tidal passes. Flushing of Biscayne Bay occurs primarily through the Safety Valve (and artificial inlets to the north) during the winter months when south winds preceeding cold fronts push Card Sound water into Biscayne Bay, and Bay water out through the Safety Valve. They also observed that south winds may cause shelf water to flow into Card Sound, and Florida Bay water to flow into Barnes Sound through Jewfish Creek (2). The observed circulation in Biscayne Bay explains why patch reefs are abundant north of Ceasar's Creek and Broad Creek, and absent seaward of the Safety Valve.

Coral reefs are least developed in the middle Keys where passes between the Keys are most developed. Ginsburg and Shinn (3) noted that reefs occur mainly opposite land, where they are less exposed to Florida Bay water. The location of outer bank reefs relative to the tidal passes and the absence of patch reefs (Figs. 2 and 3) attest to the open circulation between the Reef Tract and adjacent Florida Bay. Although normal tidal exchange through the broad passes would be expected to affect reef development, the effect is intensified by the E NE - W SW orientation of the middle Keys. Northerly winds associated with cold fronts cool the shallow (2-4 m deep) Bay water and in effect push the turbid cool Bay water over the Reef Tract. During severe cold fronts and high wind velocities, Florida Bay water is likely to reach temperatures of 15°C or less. Wind-driven currents from the north coupled with the orientation of the middle Keys significantly increases the normal tide-induced encroachment of Florida Bay water over the Reef Tract. Abnormally cold water and the relative narrowness of the Reef Tract in this area prevent the development of patch reefs.

The increased land area of the lower Keys which reduces exchange of the Reef Tract with Florida Bay accounts for the observed increase in reef development west of Big Pine Key. The vast shallow shelf to the north and the E-W trend of the Reef Tract in this area, however, makes the reefs vulnerable to cold wind-driven currents during the winter months. Also detrimental to reef development are the effects of the Loop Current on circulation in the lower Keys. The Loop Current connects the Yucatan and Florida Curents in the eastern Gulf of Mexico. When least developed it occurs only in the southern Gulf; during times of maximum development the Loop Current may extend as far north as the Mississippi delta and may reach the west Florida shelf. Its exact location is highly variable throughout the year (4). Before flowing southward and eventually reaching the Keys, the Loop Current may interact with coastal water masses. Maul (4) reports the tracking of a low salinity water mass within the Loop Current which was 24 °/oo near the edge of the west Florida shelf, less than 30 °/oo along the cyclonic boundary in the Straits of Florida, and still showing low salinity values of 34.5 °/oo off the Georgia Coast. The westernmost Keys are most exposed to the Loop Current which may account for the absence of outer bank reefs along the shallow shelf edge near Dry Tortugas.

During a one year study of variation in Loop Current migration, Maul (4) observed that when found at its southernmost extent (off the coast of Cuba), the Loop Current affected circulation in the Keys causing Florida Bay water to flow south through the Keys. The Bay water moving over the shelf edge was visible in LANDSAT images and in ship track data. The combined effect of these factors is to make the lower Keys less hospitable than the upper Keys to the development of coral reefs.

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