Proc 8th Int Coral Reef Sym 2:1509-1514. 1997

RAPID ASSESSMENT OF REEFS IN THE FLORIDA KEYS: RESULTS FROM A SYNOPTIC SURVEY

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ABSTRACT

The Florida Keys Reef Tract represents the northern limit of extensive reef growth in the tropical western Atlantic and is the only continental reef system in the U.S. Scientific studies and anecdotal observations since the 1970's suggest that Florida Keys reefs are in a state of decline, as evidenced by decreasing coral cover, increasing algal cover, increased incidence of coral bleaching and other diseases, and low coral recruitment. The causes of many of these phenomena are largely unknown. However, previous assessment and monitoring studies have been limited in geographic extent and focused almost exclusively on stony corals. A one-year, large-scale survey of offshore bank-barrier reefs was conducted in 1994-95 to assess benthic coverage in relation to continental influence over a large portion (200 km) of the Florida Keys Reef Tract. The percent cover of substratum types at 20 bank reefs (3-10 m depth) was surveyed using quadrats along transects. Surveys focused on three reef types: high-relief spur and groove, relict reef flat, and linear shoal. All reefs surveyed were dominated by algae, with mean coverage m^{-2} ranging from 48-84%. Dominant functional groups of algae in most reefs were algal turf, crustose coralline algae, *Dictyota* spp., and *Halimeda* spp. Coral cover was low at all reefs (1.3-18.4%) and consisted primarily of *Acropora palmata*, *Montastraea annularis*, *Millepora complanata*, and *Porites astreoides*. Coral cover was lowest in the middle and a portion of the lower Florida Keys, indicative of Florida Bay-Atlantic Ocean exchange. Possible explanations for the dominance of algae on offshore reefs are discussed and may include the decline of *A. palmata* from disease, low recruitment by reef-building corals, die-off and recovery failure by the Caribbean long-spined sea urchin (*Diadema antillarum*), and anthropogenic nutrient input.

INTRODUCTION

The marine environment of the Florida Keys is characterized by a high diversity of species and benthic habitats comprising a complex mangrove-seagrass-reef ecosystem. Over the past 20 years, concern about the vitality of reefs in the Florida Keys has increased owing to the occurrence of coral bleaching and other diseases (Dustan 1977; Dustan and Halas 1987), declines in coral cover, increases in algal cover (Porter and Meier 1992), lack of recruitment by primary hermatypic corals (Porter and Meier 1992), evidence of near-shore eutrophication (Lapointe and Clark 1992; Szmant and Forrester 1996), and several major vessel groundings (Curtis 1985; Hudson and Diaz 1988). Severe impacts to reefs, specifically major vessel groundings in the late 1980's, prompted legislation designating the Florida Keys as a National Marine Sanctuary in 1990. Florida Keys reefs are some of the most heavily visited in the world and are located close to the metropolitan area of Miami (Jaap 1984). The northerly location of the Florida Keys Reef Tract, coupled with continental influence, results in temperature minima and sediment transport resulting from Florida Bay-Atlantic Ocean exchange of water (Hudson 1981; Roberts et al. 1982) or flow of inimical water from the Gulf of Mexico (Jaap et al. 1989). These natural environmental extremes have had a clear impact on the geomorphology (Robbin 1981; Shinn et al. 1989), distribution (Ginsburg and Shinn 1967; Hudson 1981), and community composition of reefs (Burns 1985). However, extreme natural perturbations, such as hurricane damage (Shinn 1976) and hypothermal events (Porter et al. 1982), have made the distinctions between some human and natural impacts difficult (Tilmant and Schmahl 1981; Jaap et al. 1988).

One of the main objectives for assessing the status of reefs in the Florida Keys National Marine Sanctuary (FKNMS) was the lack of a synoptic picture of the community structure of reefs sanctuary-wide (Chiappone 1996), as well as the perception among some scientists that previous studies did not encompass a large enough geographic area or include different reef types representative of the Florida Keys (Miller and Ogden 1995). Studies were undertaken to evaluate the dynamics of reefs in the Florida Keys since the early 1970's (Dustan and Halas 1987; Jaap et al. 1988; Porter and Meier 1992), however, these focused on a few select sites representing mostly high-relief spur and groove reefs. Other types of studies included assessments of community structure, however, most only included data on the abundance and/or coverage of reef corals (Wheaton and Jaap 1988; Jaap et al. 1989; Aronson et al. 1993). There are very limited data on the abundances of other reef components, most notably algae, sponges, and octocorals. Given that the Florida Keys Reef Tract is continentally influenced, and thus may be expected to exhibit less coral cover than insular environments (Hallock et al. 1993), it is critically important to evaluate the abundance of other taxa that are conspicuous components of reefs in this system.

This paper discusses the results of a synoptic survey of 20 bank reefs spanning 200 km along the Florida Keys Reef Tract during 1 year (1994-95) of field work (Fig. 1). The main goal of the sampling was to describe the community structure of reefs and determine patterns in algal and invertebrate coverage related to continental influence. Previous studies have recognized the importance of Florida Bay-Atlantic Ocean exchange on the geomorphology and distribution of reefs (Ginsburg and Shinn 1967; Marszalek et al. 1977), however, there are few data to illustrate the spatial extent and magnitude of this phenomenon. Specifically, we expected that: 1) high-relief spur and groove reefs should be characteristic of areas with limited Florida Bay influence; and 2) coral cover should be lowest in the middle Florida Keys.

MATERIALS AND METHODS

Study area

The Florida Keys comprise part of the south Florida shelf or Floridian Plateau. This shelf, which extends 360 km from Miami to the Dry Tortugas, forms part of the Florida-Bahamas carbonate province and is the only area in the continental U.S. where active carbonate deposition is occurring on a large scale (Shinn et al. 1989). The Floridian Plateau is bounded by the Straits of Florida to the east and south, and by the Gulf of Mexico to the west. The Floridian Plateau has several environments differing in circulation, sediment characteristics and bottom types: inner shelf, inner shelf margin, and outer shelf margin. These environments are represented by Florida Bay, near-shore waters of the Florida Keys, and the Florida Keys Reef Tract, respectively.

The Florida Keys are an archipelago of Pleistocene limestone islands distributed from Key Biscayne southwest to the Dry Tortugas. The islands can be partitioned into upper, middle, and lower divisions based on the size and orientation of islands, as well as the width of tidal channels permitting flow of water between Florida Bay or the Gulf of Mexico and the Atlantic Ocean (Shinn et al. 1989). The upper and middle Florida Keys are oriented roughly northeast to southwest and are composed of Key Largo Limestone. The lower Florida Keys are aligned northwest to southeast and are capped with Miami Oolite over Key Largo Limestone. West of the Marquesas Keys is a relatively open-water area influenced by the Gulf of Mexico.

Offshore of the islands is the Florida Keys Reef Tract, a semi-continuous series of offshore bank reefs or shelf margin reefs (Jaap 1984). The reef tract is relatively well circulated, averages 3 km in width, and consists of well-sorted and coarse sediments. The main physical transport mechanisms in the study area are oceanic currents (Florida Current, Loop Current), tides, and wind-driven currents (Lee et al. 1992). Circulation in the upper Florida Keys Reef Tract (ie. Carysfort Reef to Davis Reef) is characterized by Florida Current frontal eddies and low retention time of water, while the middle Florida Keys Reef Tract (Alligator Reef to Tennessee Reef) is dominated by onshore currents and tidal flow between Florida Bay and the Atlantic Ocean. Circulation in the lower Florida Keys Reef Tract (Big Pine Shoal to Cosgrove Shoal) is dominated by nearshore, wind-driven currents and tidal currents, as well as meso-scale gyres (Lee et al. 1992).

Field methods

Twenty sites representing three bank reefs types were surveyed along the Florida Keys Reef Tract during the summers of 1994 and 1995 (Fig. 1). The three bank reef types were high-relief spur and groove (Jaap 1984; Wheaton and Jaap 1988), relict reef flat (Robbin 1981), and linear shoal (Shinn et al. 1977). This study encompassed 20 of the approximately 28 shallow-water (< 10 m) bank reefs in the FKNMS, excluding the Dry Tortugas (Table 1).

Benthic coverage in reefs was determined in haphazard quadrat surveys along transects. Four transects 25-m in length were marked in 1-m intervals and placed between 3 and 10 m depth at each reef from inshore to offshore. In high-relief spur and groove reefs, transects were placed on the tops of spurs.

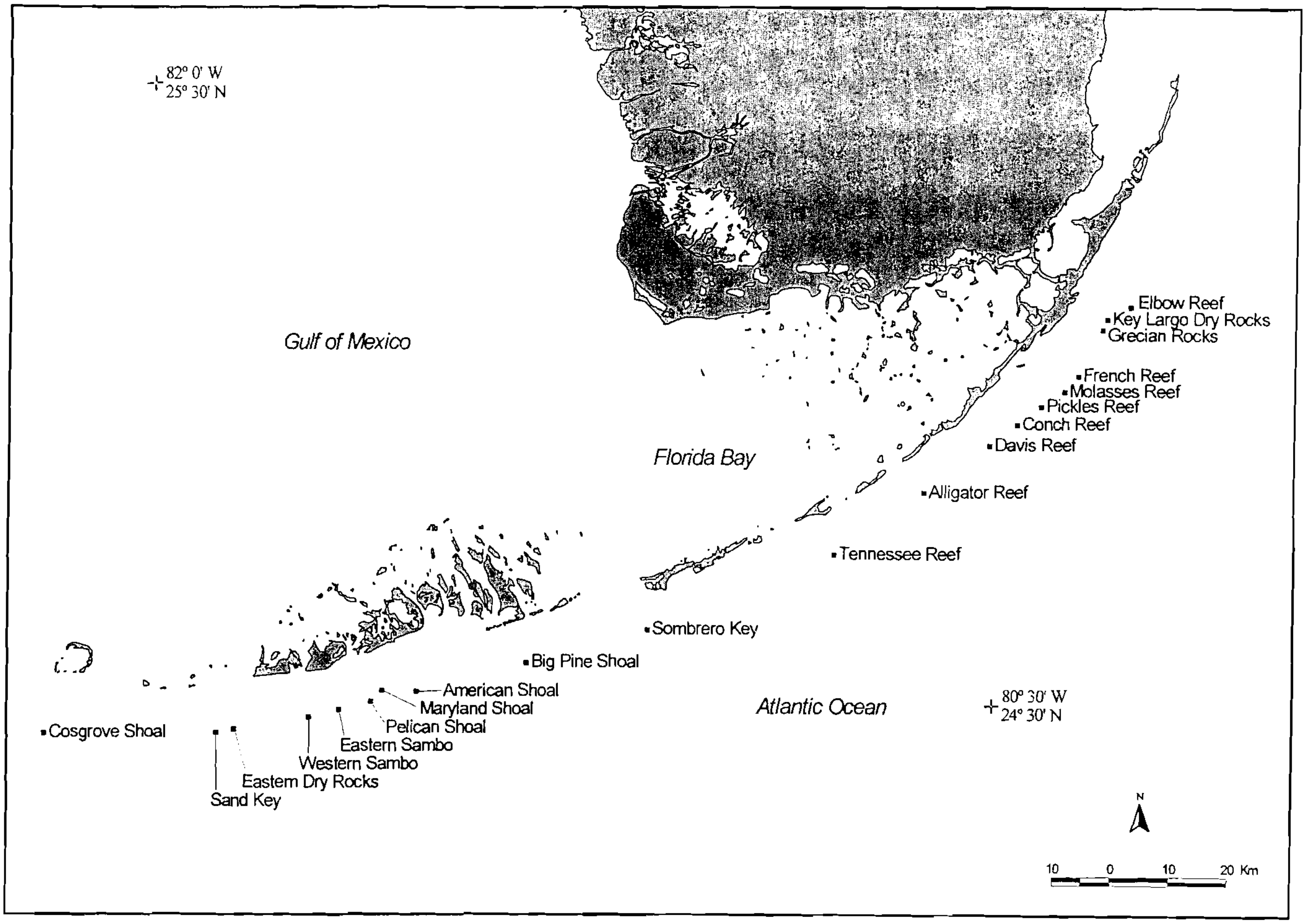

Fig. 1: Shallow-water (< 10 m) bank reefs surveyed in the Florida Keys during 1994-95.

Table 1: Bank reefs surveyed in the Florida Keys during 1994-95. Refer to Fig. 1 for reef locations. Location codes are: U-Upper Keys, M-Middle Keys, and L-Lower Keys.

Reef site	Site code	Location	Spur and groove	Relict reef flat	Linear shoal
Elbow Reef	ER	U	X		
Key Largo Dry Rocks	KLDR	U	X		
Grecian Rocks	GR	U	X		
Molasses Reef	MR	U	X		
French Reef	FR	U	X		
Pickles Reef	PR	U	X		
Conch Reef	CR	U		X	
Davis Reef	DR	U		X	
Alligator Reef	AR	M		X	
Tennessee Reef	TR	M		X	
Sombrero Reef	SR	M	X		
Big Pine Shoal	BPS	L			X
American Shoal	AS	L			X
Maryland Shoal	MS	L			X
Pelican Shoal	PS	L	X		
Eastern Sambo	ES	L	X		
Western Sambo	WS	L	X		
Eastern Dry Rocks	EDR	L	X		
Sand Key	SKR	L	X		
Cosgrove Shoal	CS	L			

In relict reef flat and linear shoal reefs, transects were placed from the nearshore ledge seaward (see Robbin 1981). Fifty 1-m intervals along the 4 transects were randomly chosen using a random number generator for sampling. Quadrats measuring 1-m x 1-m were bisected by the transects.

Three methods were used to determine benthic coverage: visual estimates (Scheer 1978), point-intercept measurements (Ohlhorst et al. 1988), and *in situ* measurements of colony or individual size (Chiappone and Sullivan 1996). Visual estimates of planar coverage were made for total algae, sponges, corals, octocorals, other benthic cnidarians, and sediment. In each 1-m^2 quadrat, bottom coverage was scored into one of seven percent cover categories: 0, < 1%, 1-5%, 5-25%, 25-50%, 50-75%, and > 75%. Percent cover data were also collected using point-intercept counts. Quadrats measuring 1-m x 1-m were partitioned by string so that 25 points were formed in each 1-m^2 sample. The bottom type under each point was identified to species when possible. Many algae, such as turf and crustose coralline species, were surveyed as functional groups (Steneck and Dethier 1994). Finally, estimates of coverage for sponges, corals, and octocorals were made using *in situ* measurements of individual and colony dimensions (Chiappone and Sullivan 1996). Data from quadrat surveys were used to compute mean percent cover m^{-2} and standard error (N=50) for all reefs. Spearman rank correlations were used to determine relationships in percent coverage of bottom components among the reefs (N=20) sampled (Zar 1984).

RESULTS

Mean percent cover m^{-2} of algae, sponges, corals, and octocorals are illustrated in Fig. 2. Algae were the dominant bottom type in all reefs, with mean coverage ranging from 48% to 84%. There were few geographic differences in total algal cover, however, the lowest coverage was found at the site (Tennessee Reef) most affected by Florida Bay-Atlantic Ocean water exchange. There was 1-2 cm of sediment overlying the reef surface at this reef. Dominant algae in spur and groove reefs were turf algae, crustose coralline algae, *Halimeda opuntia*, *H. goreauii*, and *Dictyota* spp. Relict reef flat and linear shoal reefs were generally dominated by turf and/or *Dictyota* spp (Tables 2-4).

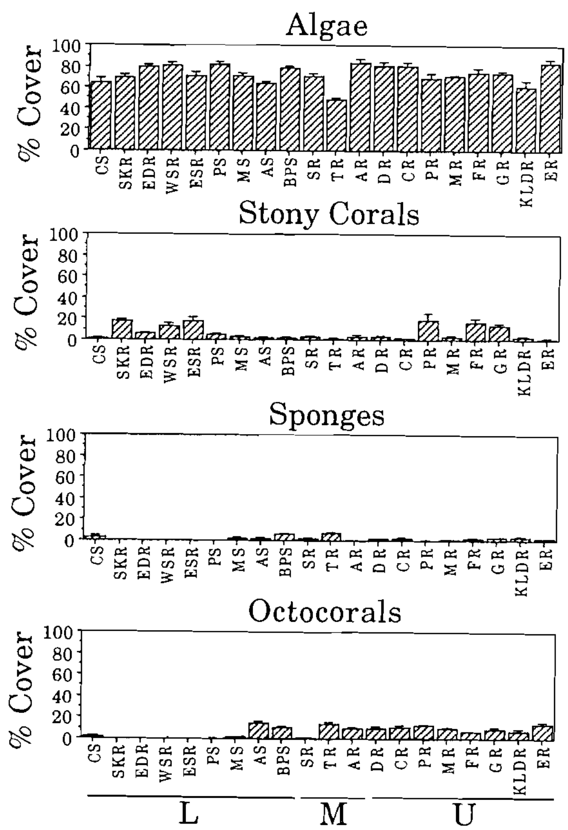

Fig. 2: Mean percent coverage m^{-2} by algae, sponges, stony corals, and octocorals in bank reefs of the Florida Keys. U: Upper Reef Tract; M: Middle Reef Tract; L: Lower Reef Tract. Error bars represent 1 standard error.

Mean coral cover ranged from 1.3% to 18.4% (Fig. 2). Coral cover was greatest in the upper and lower Florida Keys Reef Tract, particularly offshore of Key Largo, Boca Chica, and Key West. However, there was significant variation in coverage, even for reefs located within 1-2 km of each another. Coral cover was exceptionally low in the middle (1.3-3.3%) and a portion of the lower Florida Keys Reef Tract (2.4-3.3%). In high-relief spur and groove reefs (1.4-18.4% cover), dominant corals were *Acropora palmata*, *Millepora complanata*, *Montastraea annularis*, and *Porites astreoides* (Tables 2-3).

Both sponges and octocorals were minor components of the substratum in the majority of reefs surveyed (Fig. 2). Coverage by sponges and octocorals ranged from 0.2% to 6.7% and 0% to 14.3%, respectively. In spur and groove reefs, sponge coverage was less than 2.5%. Interestingly, sponge coverage was greatest in the middle and lower Florida Keys Reef Tract, specifically at Tennessee Reef (6.7%), Sombrero Reef (2.4%), and Big Pine Shoal (6.2%). Octocoral cover was greatest in the middle and upper Florida Keys Reef Tract. The colonial zoanthid, *Palythoa mammilosa*, was abundant in some reefs. Coverage by this species throughout the study area ranged from 0% to 12.80%. Mean coverage m^{-2} by *P. mammilosa* was greatest in spur and groove reefs of the middle (Sombrero Reef, 6.3%) and lower Florida Keys Reef Tract (2.3-12.8%).

Several significant relationships were found among benthic coverage parameters. Sponge cover and coral cover were inversely related ($r = -.624$, $p < 0.005$), reflecting the pattern of relatively high sponge coverage, but low coral cover, in the middle Florida Keys Reef Tract. Octocoral cover was inversely related to coral cover ($r = -.563$, $p < 0.02$), reflecting the greater coverage by octocorals, but very low coverage by stony corals, in relict reef flat and linear shoal reefs. Octocoral cover was also inversely related to *Palythoa mammilosa* cover ($r = -.635$, $p = 0.01$); this relationship reflected the greater abundance of octocorals northeast of Sombrero Reef and the greater abundance of *P. mammilosa* in the lower Florida Keys.

DISCUSSION

Reef community structure and distribution in the Florida Keys reflect patterns of water exchange between the inner shelf margin and the Atlantic Ocean (Jaap 1984). Therefore, reef development is marginal in areas opposite of tidal channels (Ginsburg and Shinn 1964; Marszalek et al. 1977). Atmospheric cold fronts and sediment transport from biogenic carbonate production result in the flow of inimical water out through tidal channels, due to the shallow nature and extreme environmental variability of Florida Bay. This process has been shown to impact corals during cold fronts (Hudson 1981). The geologic record indicates that this process occurred historically through studies of reef growth and distribution (Shinn et al. 1989). Studies north of the Florida Keys indicate extensive development of *Acropora palmata* reefs during the early Holocene (9,000-7,500 y.b.p.), however, reefs became senescent when the back reef area was flooded by rising sea level (Macintyre 1988). Reef senescence may have been caused by turbid conditions or low temperatures. These studies illustrate the nature of reef development in relation to the flooding of the previously subaerial platforms (Hallock and Schlager 1986).

The type of bank reef and benthic community structure in the Florida Keys were found to differ with respect to location. High-relief spur and groove reefs were, with the exception of one reef in the middle Florida Keys (Sombrero Reef), exclusive to the upper and lower Florida Keys, where large islands are effective in blocking the exchange of water between Florida Bay and the Atlantic Ocean. In contrast, relict reefs with less than 1 m of vertical relief were characteristic of the middle and a portion of the lower Florida Keys, where the Pleistocene islands are smaller and tidal channels are wider. A second indication of continental shelf influence was the pattern of high coral cover in the upper and lower Florida Keys Reef Tract compared to the middle Florida Keys Reef Tract. A third pattern that emerged was the low algal cover and greater sponge cover in reefs of the middle Florida Keys most affected by Florida Bay circulation (ie. Tennessee Reef). There was also greater sediment cover (as high as 40%). This pattern may indicate greater turbidity (particulate organic matter) that would be beneficial to sponges (filter feeders) and octocorals elevated above the reef surface.

A notable result of this study was the dominance of algae in all bank reefs. With the exception of Tennessee Reef, algae covered on average more than 65% of the substratum m^{-2}, in some reefs as high as 84%. Most of the algal cover was represented by species and functional groups characteristic of relatively high grazing pressure or other disturbance potential (ie. Wave energy) (Steneck and Dethier 1994).

Table 2: Percent relative cover of dominant bottom types in high-relief spur and groove reefs of the upper and middle Florida Keys. These bottom types accounted for 89-91 percent of the total benthic cover.

Bottom type	ER	FR	PR	SR
Acropora palmata		8.53		
Agelas wiedenmayaari		1.43	3.16	
Colpophyllia natans		1.08		
Crustose algae	29.58	10.84	5.68	8.16
Dictoyta spp.	9.37	2.58	15.22	
Gorgonia ventalina	2.80			
Halimeda goreauii		13.88		6.16
H. opuntia	6.98	7.44		3.92
Millepora complanata	3.23			
Montastraea annularis	1.43	2.64	20.80	
Palythoa mammilosa				22.08
Turf algae	37.91	41.86	46.96	49.04

Table 3: Percent relative cover of dominant bottom components in high-relief spur and groove reefs in the lower Florida Keys. These bottom types accounted for 89-92 percent of the total benthic cover.

Bottom type	PS	ESR	WSR	EDR	SKR
Acropora palmata		13.12			
Crustose algae	5.52	8.72	10.04	6.08	13.25
Dictyota spp.			3.10		1.10
Halimeda goreauii					2.35
H. opuntia	3.36		8.00	8.08	2.51
Millepora complanata	3.44		7.84	3.28	9.65
Palythoa mammilosa		8.64	3.67	12.80	6.59
Porites astreoides					4.47
Sediment	8.00				
Turf algae	70.88	58.48	58.20	61.76	49.41

Table 4: Percent relative cover of dominant bottom components in relict reef flat and linear shoal reefs in the Florida Keys. These bottom types accounted for 81-86 percent of the total benthic cover.

Bottom type	CR	DR	AR	MS	CS
Crustose algae	3.30	4.76		11.84	
Dictyota spp.	57.46	65.96	37.22		55.38
Halimeda goreauii				8.32	
H. opuntia			4.40		
Lobophora variegata					3.25
Millepora complanata	1.63				
Sediment				15.04	27.75
Turf algae	20.02	9.98	40.48	47.52	

The dominance by turf and crustose coralline algae in spur and groove reefs may be indicative of high grazing pressure by fishes. InLooe Key National Marine Sanctuary, Littler et al. (1986) found that the high-relief spur and groove zone was dominated by crustose and turf algae, with intense grazing by *Sparisoma* parrotfishes.

There are several possible mechanisms which may be responsible for the dominance of algae in Florida Keys bank reefs: declining *Acropora palmata*, coral diseases, low coral recruitment, mass mortality of *Diadema antillarum*, and nutrient input from land-based activities. The available evidence for each of these mechanisms is briefly discussed below.

In high-relief spur and groove and relict reef flats of the Florida Keys, *Acropora palmata* was the primary reef-builder (Shinn et al. 1977; Robbin 1981). This species was also a significant reef builder in other western Atlantic reef systems (Macintyre 1988). The synoptic survey of bank reefs indicated low coverage (< 20%) by *A. palmata* throughout the Florida Keys. On many spur and groove reefs, there did not appear to be a recent (years to decades) die-off of this species, as evident in the relatively smooth topography of the spur surfaces and the absence of dead, upright colonies. In other locations *A. palmata* was abundant during early successional stages of reef development, however, other reef-building fauna, such as *Montastraea annularis*, *Millepora complanata*, and coralline algae are now dominant (Lewis 1984). In the Florida Keys, Shinn et al. (1981) found that the interior of the *Millepora complanata* encrusted spurs were composed of *A. palmata* and that this species was actively building reefs as late as 800 years ago. The decline of *A. palmata* has been attributed to successional or gradual change (ie. rising sea level, flow of inimical water) (Shinn 1963), as well as catastrophic events (Shinn 1976).

Several studies have attributed reef decline to bleaching and other tissue abnormalities, such as white band disease and black band disease (Dustan 1977; Dustan and Halas 1987; Porter and Meier 1992). One of the more notable effects of disease has been the impact of white band disease on acroporids throughout the Caribbean since the mid-1970's (Gladfelter 1982). The disease appears to be a bacterial infection, but can not be attributed to any particular human or natural factor (Antonius 1981). Off Key Largo, Dustan and Halas (1987) and Jaap et al. (1988) documented significant declines in acroporid corals in back reef and fore reef environments during the 1970's and 1980's. At Key Largo Dry Rocks, Shinn (1976) noted the mass mortality of *Acropora palmata* and *A. cervicornis* in the back reef and reef flat environments after recovery from major hurricanes in the 1960's. Given that many reefs in the Florida Keys were constructed by acroporids, and the fact that many observations of reefs have been made in areas with dense stands *A. palmata* or *A. cervicornis* (Jaap et al. 1988; Porter and Meier 1992), most of the declines observed may primarily be a result of white band disease.

A parameter indicative of benthic community structure and the ability of reefs to recovery from disturbance is recruitment (Dustan 1977). Recent studies of Florida Keys coral reefs have shown low or no recruitment by primary hermatypic corals (e.g. *Montastraea annularis*) in some shallow (< 10 m) bank reefs (Porter and Meier 1992). These authors attributed the lack of recruitment to increasing algal cover, a result of coral mortality and die-off of *Diadema antillarum*. In a recent study, however, Chiappone and Sullivan (1996) found that coral recruits were most abundant in areas with low algal and coral cover, a result consistent with previous studies (Birkeland 1977). Moreover, several species of broadcast spawners were found as juveniles in deeper (> 10 m) reef environments. Any factor, whether natural or anthropogenic, that leads to coral mortality on Florida Keys coral reefs is likely to result in increased algal cover and low coral recruitment due to the rapid colonization rate of algae on available substrata (Hallock et al. 1993). Future studies addressing recruitment and the effects of herbivore grazing on benthic community structure could elucidate patterns of recruitment and mortality in lieu of possible recovery by echinoids.

The mass mortality of the Caribbean long-spined sea urchin, *Diadema antillarum*, in 1983-84 (Lessios et al. 1984) had severe consequences for the community structure of western Atlantic reefs, particularly those subjected to intense removal of macro-herbivores by fishing (Carpenter 1990). In the Florida Keys, data prior to 1983-84 indicate *D. antillarum* densities (0.1-2.6 urchins m^{-2}) were comparable to the Caribbean (Bauer 1980). Studies since 1990 have shown that *D. antillarum* has failed to recover, with population densities well below 0.1 individuals m^{-2} (Forcucci 1994). Our observations during 1994 at five bank reefs from Elbow Reef to Davis Reef also indicate low densities of this echinoid (< 0.01 m^{-2}), with all individuals less than 2.0 cm test diameter (Chiappone and Sullivan unpubl. data). Forcucci (1994) concluded that the lack of urchin recovery and low population densities would alter the community structure of reefs. Porter and Meier (1992) partly attributed losses in coral cover and increases in algal cover to *D. antillarum* mortality.

The popular and scientific literature abounds with suggestions and statements that declining reefs (ie. algal-dominated reefs) in the Florida Keys indicate eutrophication processes as a result of land-based sources of pollutants (Dustan 1977; Hallock et al. 1993), including injection well effluent into groundwater, septic tanks and cesspits on canals, live-aboard vessels, and surface discharge from secondary treatment plants (Lapointe et al. 1990; Szmant and Forrester 1996; Lapointe and Clark 1992; Shinn et al. 1994). As early as the 1970's, there was concern that increasing development in south Florida was increasing nutrient levels and causing changes in offshore reefs. Dustan (1977) stated that reefs closest to the metropolitan area of south Florida were in state of decline two decades ago, possibly indicative of runoff from the mainland, and that the changes observed were similar to those in areas such as Kaneohe Bay, Hawaii. However, the earliest studies, such as the work at Carysfort Reef by Dustan and Halas (1987), noted changes specific to species that were apparently not related to land-based sources of pollutants (ie. white band disease), given the circulation features and oceanic influence of the Florida Current on Florida Keys coral reefs (Marszalek 1987; Lee et al. 1992).

The FKNMS Water Quality Protection Program (USEPA 1993) suggests there are a lack of cause-and-effect data linking specific ecological problems in the Florida Keys to water quality parameters and pollution sources. Water quality data demonstrate elevated nutrient and chlorophyll levels in canals, particularly in areas affected by on-site sewage disposal systems and other sources. Some have suggested that nearshore waters of the Florida Keys have entered a "critical stage of eutrophication" (Lapointe and Clark 1992). Based on the low nutrient levels observed in sediment pore-waters, Szmant and Forrester (1996) contended that at present, nutrients threatening the reef are either minimal, or highly localized. However, Lapointe and Clark (1992) suggested that even the relatively low concentrations of nutrients offshore are too high for oligotrophic reef ecosystems. Analysis of water quality data in the Florida Keys indicate levels of soluble reactive phosphorus (< 0.05 μM), total dissolved phosphorus (0.06-0.35 μM), total dissolved nitrogen (2.0-4.7 μM), and chlorophyll-a (< 0.5 μg/L) that are lower than other areas where changes in water quality have been shown to adversely impact reefs (Tomascik and Sander 1987; Bell et al. 1989; Lapointe and Clark 1992). However, recent studies suggest that offshore movement of nutrient-enriched groundwater may provide a mechanism for delivering "excess" nutrients to offshore reefs (Shinn et al. 1994).

In conclusion, surveys of bank reefs yielded a number of significant patterns in benthic community structure related to continental influence along 200 km of the Florida Keys Reef Tract. These patterns have been alluded to or described in terms of reef distribution in previous studies, however, the quantitative data presented here allow for an examination of the geographic extent of this continental influence. These and other findings will have important consequences for evaluating human perturbations to the continentally influenced reefs of the Florida Keys.

Research efforts have been initiated to describe the community structure of deeper reefs throughout south Florida (Miller and Ogden 1995) and to monitor nearshore to offshore hard-bottom and reef communities in relation to water quality conditions (J.L. Wheaton, Florida Marine Research Institute, personal communication). Together with information on shallower bank reefs and patch reefs (Chiappone 1996), the data obtained from ongoing studies will provide a more complete picture of reef condition in the FKNMS. Moreover, the synoptic and annual monitoring of nearshore hard-bottom, patch reefs, and bank reefs as part of the FKNMS Management Plan will provide large-scale information on the dynamics of different communities over an environmental gradient. This will be critical for evaluating human and natural perturbations, determining the relationship between community structure, dynamics, and water quality, as well as providing data to evaluate the response(s) of reefs relative to restoration and other management initiatives.

ACKNOWLEDGMENTS

This project was supported by The Nature Conservancy's Rescue the Reef Program, the Florida Keys Initiative, NOAA's National Undersea Research Program (grants UNCW-9316 and UNCW-9420), and the University of Miami Marine Science Program. The authors thank M. Enstrom, J.M. Levy, G. Schmahl, R. Sluka, R. Wingrove, Marine Resources Development Foundation, U.S. Fish and Wildlife Service, Walt Disney World, Florida Keys Community College, and the crews of the R/V *Polyp*, R/V *Coral Reef II*, and the R/V *Farrell*. Research in the Florida Keys was conducted under National Marine Sanctuary Permit FKNMS-9307.

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