

**DIGITAL ANALYSIS OF A PATCH REEF COMMUNITY:
RAINBOW GARDENS REEF, LEE STOCKING ISLAND,
EXUMA CAYS, BAHAMAS**

Thesis by

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August 1995

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Exuma Cays, Bahamas

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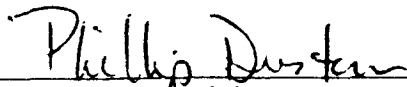
Allison J. King

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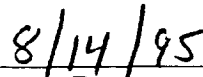
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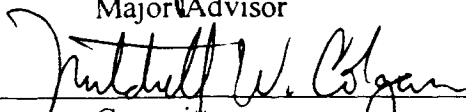
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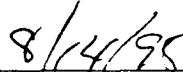
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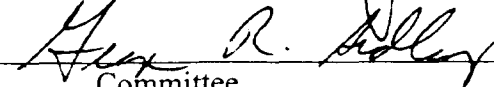
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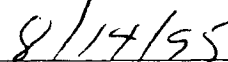
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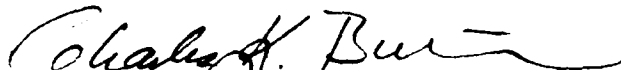
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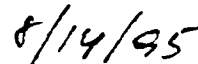
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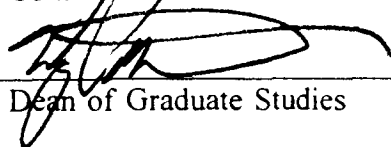
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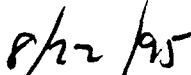
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ABSTRACT

Rainbow Gardens Reef, a shallow water Bahamian patch reef, was used as a test site to determine if digital analyses of a low altitude, color aerial photograph can provide information appropriate for routine ecological monitoring. An aerial photograph was digitally scanned into a raster image format and rectified to known ground control points. A simple spectral correction for the water column was applied, and an unsupervised multispectral classification was performed. Geographic Information System (GIS) software was then used to compare estimates of coral cover (Scleractinia and Alcyonaria) with ground-truth data collected by three independent in-water survey techniques.

Coral cover as estimated with the digital analysis was 14.5%, which compared favorably to ground-truth linear intercept estimates of 15.0%. Patterns in distribution of coral cover examined on individual transects were not significantly different as estimated with the linear intercept survey and the digital analysis. Color aerial photographs could not be used to discriminate between stony and soft corals, nor between coral species, probably as the color of both is influenced by populations of symbiotic algae, zooxanthellae. The techniques described herein may lend themselves to routine synoptic mapping and monitoring, and to documenting changes in reef distribution patterns in a time- and cost- effective manner.

INTRODUCTION

Coral reefs are diverse, highly productive tropical ecosystems considered to be important both economically and ecologically (Dustan 1979; Wells 1988; Crosby *et al.* 1995). Their strength, size, and topographic complexity provide barriers that protect coastal regions from storms and habitat for many organisms to live and reproduce. Their biodiversity and productivity have economic importance, principally in fisheries, and their physical beauty attracts an increasing number of sports divers and tourists each year (Hawkins 1994).

Coral reefs thrive in temperatures ranging from 25 to 29° C with tolerances of 20 to 36° C (Storr 1964). Major reef formations are typically found in shallow waters where light is abundant. Light is necessary for the symbiotic zooxanthellae that are embedded within the tissues of corals to provide nutrients from photosynthesis. Because of these physical requirements, reefs of the Caribbean are found near coastal tropical regions, which are presently under pressures from urbanization due to economic development and population growth.

Reefs are subjected to stresses associated with human development. Overfishing (Rogers 1985; Bohnsack 1994), increased sedimentation, nutrient loading (Lapoint *et al.* 1994) and exploitation have resulted in coral degradation (Ogden and Gladfelter 1986; Ginsburg and Glynn 1994). There is a general concensus within the scientific community that coral cover and diversity currently are in decline on shallow

coral reefs throughout the Caribbean (Rogers 1985; Dustan 1987, 1994; Dustan and Halas 1987; Wells 1988; Porter and Meir 1992; Aronson 1993; Jaap and Sargent 1994; Smith *et al.* 1994). Increased algal cover due to several factors, such as the mortality of *Diadema antillarum* (Hay 1984; Lessios *et al.* 1984), bleaching events (Brown and Ogden 1993; Lang *et al.* 1994), hurricanes (Woodley *et al.* 1981), and diseases (Gladfelter 1982; Rützler and Santovy 1983) have also contributed to a loss in live coral tissue (Porter and Meier 1992; Smith *et al.* 1994).

Coral communities are presently undergoing rapid changes, generating an immediate need to monitor and document the present status of coral reefs and measure changes in the community structure over time to support resource management efforts and education programs. For these and other reasons it is becoming increasingly important to develop non-invasive non-destructive tools for the remote sensing of shallow water coral reef systems.

The first objective of this study was to test the feasibility of using digital interpretation of a color aerial photograph to describe patterns of coral distribution and coverage on shallow patch reefs. The community structure data from the processed image of the photograph were compared to data derived from two independent chain transect studies and a hand-drawn underwater map. Data sets acquired from a variety of sources were integrated using a Geographic Information System (GIS). The results provided a sensitivity analysis on the limits of detection and class discrimination with respect to corals and other benthic organisms. The necessity for ground-truth for the photographic interpretation required descriptions of the reef, which led to a second

objective of the study, to describe the coral community structure of Rainbow Gardens Reef, Lee Stocking Island, Exumas, Bahamas. This research has established Rainbow Gardens as a monitoring site for studying changes that may occur in the future.

I. PATCH REEF COMMUNITY STRUCTURE

INTRODUCTION

Most scientific investigations on the zonation and community structure of coral reefs have focused on large-scale barrier and fringing reef complexes (Curran *et al.* 1994). Less attention has been paid to the smaller patch reefs which are frequently scattered in the lee of the principal reef tract or develop as small communities on or around shallow irregular land masses (Wells 1988). While the larger reefs are usually well-charted, there are probably no reliable estimates of the numbers of patch reefs found throughout the Western Atlantic (including the Bahamas) and the Caribbean. Patch reefs, formed with stony corals as their predominate structural component, are important ecological habitats for both adult and juvenile fish and invertebrates. One important aspect of patch reefs is that they provide habitat for the development of many species which, upon maturation, may migrate to the outer reef habitat.

Patch reefs, like islands, lend themselves well to studies of community structure because they are discrete entities and typically small enough to be explored to their boundaries, and each one represents an independent ecological experiment in the assemblage of communities (MacArthur and Wilson 1967). With the recent realization that processes of reef degradation may be accelerating, the study of patch reef communities takes on a greater priority (Brown and Dunne 1980; Fenner 1988;

Ramsey and Mason 1990; Chiappone and Sullivan 1991; Rice and Hunter 1992; Sullivan and Chiappone 1992; Curran *et al.* 1994).

The present study utilized two different survey methods (*in situ* linear intercepts and video-based point counts) to describe the benthic invertebrate community of a shallow patch reef with respect to community structure, species diversity, and apparent condition of coral colonies. Conditions assigned to individual colonies (Table 1) helped to infer the relative proportions of healthy, stressed (biologically and/or physically) and dead, as well as juvenile corals.

The principal study site was Rainbow Gardens Reef, a shallow patch reef named for its beauty, color, and vibrant appearance. For the past decade, it has been a favorite locale for recreational snorkeling and diving. Rainbow Gardens was chosen as the primary study site as it was the most extensively developed patch reef of its type found in the local area of the Caribbean Marine Research Center (CMRC). CMRC operates a NOAA/NURP field station on Lee Stocking Island (23° N, 76° W), Exuma Cays, Bahamas (Fig. 1). The Exuma Cays consist of many small islands that extend over 130 miles (209 km) along the eastern edge of Great Bahama Bank (Wells 1988). Small fringing reefs border the windward edge of Exuma Sound, and shallow patch reefs are distributed in their lee and in the tidal channels between the islands (Lang *et al.* 1988). These reefs experience minimal human impact because of their remote location from densely populated areas (Kendall *et al.* 1988; Wells 1988; Lang *et al.* 1994). Since the late 1980s, qualitative changes in the appearance of Rainbow Gardens Reef, resulting from repeated coral bleaching events and increased algal

colonization, has generated concern given this site's distance from densely populated regions (Wicklund pers. comm.).

Rainbow Gardens Reef is located on the lee side of Iguana Cay approximately 3 km northwest of Lee Stocking Island (Fig. 2). The patch reef is situated near Adderley Cut, a channel that experiences a strong semidiurnal tidal exchange (up to 150 cm/s) between the waters of Great Bahama Bank and Exuma Sound. These very different water masses alternatively bathe the reef with warm, saline, turbid waters from the shallow Bank and cooler clear oceanic waters from the Sound (Kendall *et al.* 1988, Lang *et al.* 1988). Seawater temperatures range from ~21 to ~32° C annually (Wicklund *et al.* 1993).

The reef begins approximately 100 m from shore where outcrops of hard carbonate rock substrate appear on the mostly coarse carbonate sand bottom. Moving deeper, away from Iguana Cay, biomass increases rapidly as large colonies of *Montastrea annularis*, *Siderastrea sidera*, and *Diploria strigosa* become increasingly more abundant. Smaller colonies of *Porites asteroides* and *Agaricia agaricites* also increase in number and many outcrops are colonized by erect gorgonians and sponges. Such outcrops form small communities that scale into the larger mega-colony of *M. annularis* that approaches 7 m in diameter, referred to as the bommie. This extremely large knobby colony, which dominates the reefscape, comes within 60 cm of the water surface at low tide and virtually forms a patch reef within a patch reef as it has many small colonies of other species within its crevices. Southeast of the bommie, along the edge of Adderley Cut, there is a gorgonian forest comprised principally of

Pseudopterogorgia spp., *Plexura* spp., and *Gorgonia* spp. which forms in the region swept by fast moving tidal currents.

Although the original purpose of conducting this study was for ground-truth of the aerial photographic analysis, a subsequent goal was to offer a statistically valid census of the coral community at Rainbow Gardens Reef to establish a framework for long-term monitoring. The small size of the reef makes it possible to estimate coral coverage over the range of the reef and facilitated in mapping its entire extent. The community structure of Rainbow Gardens was characterized in terms of species composition, coverage, average colony size, species diversity and evenness, distribution patterns, and apparent coral conditions.

METHODS

Rainbow Gardens Reef covers an area of approximately 2800 m² (70 m perpendicular to shore and 40 m parallel to shore) (Fig. 3). Initial dives gave evidence for an approximate long axis of the reef extending 30° east of north, shallow to deep (3 m to 10 m). Copper clad survey stakes (12 in.) were hammered into the substrate and used in securing the ends of transect lines. Placement of transects (Loya 1972, 1978; Dustan and Halas 1987) began with positioning a starting point estimated to be near the middle of the shallow end of the axis of the reef and swimming along the axis to the deep end. The deep end of the reef was staked and a taut line was stretched between the two points. This baseline (70 m in length) was marked at each end and at 5 m intervals providing points for 15 perpendicular crosslines, one on either side of the baseline (coded L and R, respectively for the left and right sides of the baseline when facing the shoreline) for a total of 30 line transects. Six main transects were secured with permanent stakes at 0 m, 40 m, and 70 m from the shallow end of the reef (Fig. 4). Each transect extended approximately 20 m from the baseline, continuing past the reef structure into peripheral sandy areas with very few corals. A total of 615 m of transect line was established. The initial data set was acquired during the summer of 1991.

Color photographs of each transect were taken for a permanent record of the reef community at that time. Adjacent photographs directly above each transect with

the line centered in the field of view (2 m from substratum) were overlapped approximately 1 m by visually locating a reference point between frames. The photographs were taken using a Nikonos-V camera with a 20-mm lens and Ektachrome ASA 200 film.

LINEAR INTERCEPT SURVEY

A chain (15 m in length) was placed directly below a taut transect line, following the curvature of the substrate (Porter 1972). Coral colonies were measured by counting the number of links (2 cm each) covering the living tissue to obtain estimates of relative coverage and size, and to calculate species diversity and evenness (Dustan and Halas 1987). Scleractinian corals and alcyonarians were identified to species level. Sponges were grouped into families or genera. Any coral colony growing independently of adjacent corals was considered to be an individual colony. An individual colony divided into two or more sections by the death of portions of the colony was still defined as one individual (Loya 1972). Branching species were measured across the colony from tip to tip of the outermost branches. Groups of branches were defined as a single colony if the branches originated from a central area (Dustan and Halas 1987).

Traditional studies with descriptions of patterns or trends in coverage and diversity regress these parameters with depth to illustrate zonation. Since there was no statistically significant increase in depth over the reef with increased distance from shore ($F = 0.002$, where $F_{0.05(1),1,13} = 4.67$, $P=0.97$), multiple regression analyses were performed using both depth and distance along transect (representing distance from

