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Kathleen Sullivan Sealey
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Ethan Freid

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Cover photograph –Barn Owl (*Tyto alba*) at Owl's Hole Pit Cave courtesy of Elyse Vogeli

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MACROALGAE IN NEAR SHORE WATERS OF THE BAHAMAS: INDICATORS OF ETROPHICATION AND HABITAT QUALITY

Anastasia Gibson [1], Nicolle Cushion[2], and Kathleen Sullivan Sealey [1, 2]
[1] Marine and Environmental Studies Institute, College of The Bahamas, Oakes Field, Nassau, The Bahamas
[2] Department of Biology, University of Miami, Coral Gables, Florida 33124 USA

ABSTRACT

Macroalgae play a critical role in the structuring and are generally classified into three major groups: green (*Chlorophyta*), red (*Rhodophyta*) and brown (*Phaeophyta*). There are over 628 described species of benthic macroalgae in the wider Caribbean. Macroalgae play a critical role in the structuring and functioning of near shore habitats. The assessment of macroalgae assemblages (diversity and abundance) can be important in first the characterization of benthic habitats, and the on-going monitoring of coastal environments. Macroalgae species assemblages respond rapidly to changes in water quality and nutrient availability in both the water column and sediment and thus may be considered bio-indicators. Macroalgae diversity can also influence the overall diversity of benthic invertebrates and fishes. Thus, long term monitoring of macroalgae species assemblages is effective for evaluating eutrophication or coastal development impacts.

This research is part of the Coastal Ecology of The Bahamas project to survey islands throughout the archipelago. Macroalgae surveys consisted of visual surveys and collections within specific benthic habitat types (e.g. moderate to dense seagrass beds, or hard bar). Many species of algae required identification in the laboratory with the aid of hand lens and microscope. Presence-absence data were analyzed using both univariate and multivariate statistical methods to look at the similarity between islands and between habitats. A method for basic macroalgae characterization was developed as a monitoring tool for near shore habitats.

INTRODUCTION

Growth in tourism development and resort infrastructure has lead to the need for better information on ecological criteria for sustainable development and the definintion of "best practices" for carbonate island development. Small Island States are particularly susceptible to development impacts in the coastal zone with limited land areas and capacity process solid waste, sewage and land cover change. Hence, long-term ecological studies are needed to: a) determine the composition of near shore flora and fauna prior to coastal development, b) outline bio-indicators that will be useful in detecting impacts from developments, and c) discern the influences of anthropogenic and natural disturbance on near shore species compositions.

The species compositions of biotic communities, including macroalgae, are impacted by natural disturbances such as hurricanes, and anthropogenic activities such as physical restructuring of the shoreline, removal of coastal vegetation and coastal developments. Natural disturbances tend to lead to episodic alterations and recovery while anthropogenic stresses may irreversibly change natural communities. Impacts from coastal developments may include sewage discharge, leaching of fertilizers and land clearing, and are characterized by an increased influx of sediments, nutrients and organic material from land to sea. Notably, eutrophication from coastal development has been shown to increase epiphytic growth on seagrasses and alter macroalgae species assemblages (LaPointe *et al.* 2004).

Near shore flora and benthic fauna may serve as excellent bio-indicators of coastal development impacts, because of their close proximity to the coastal zone, habitat-specific assemblages and sensitivity to environmental changes (US EPA 2006). Long-term and frequent characterization of macroalgae assemblages can aid in elucidating trends and discerning the differences in impacts from natural or anthropogenic stressors. An ideal way to assess the impacts of coastal development on near shore environments and habitats (seagrass beds, patch reefs, hard bar or artificial reefs) is to assess the near shore environments of an undeveloped island prior to major development. Such an opportunity was presented in the baseline characterization of northern Guana Cay prior to the construction of Bakers Bay Golf and Ocean Club, Abacos.

This project looked at the macroalgae communities around the northern end of Great Guana Cay over a two year period. Fortuitously, during this period there were several major hurricanes to pass through the area, thus the analysis of storm-induced changes on the macroalgal community could be explored. The project will continue for an additional three years to look at changes as resort development proceeds on island.

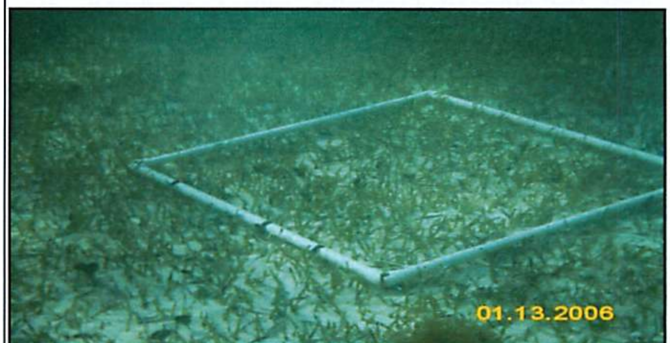
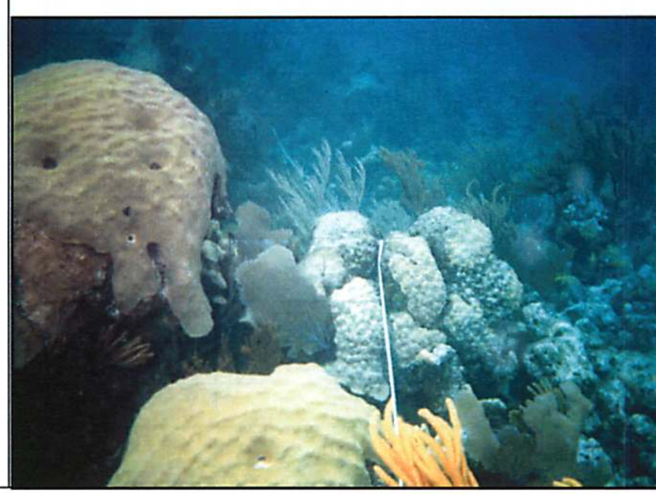
Table 1. Hurricanes directly impacting the Abacos (1999-2005).

Hurricane	Date	Max Winds	Category	Speed and Direction	Rainfall
Floyd	9/14/1999 - 9/15/1999	115 kt	4	N – NW	9.32 in
Michelle	11/5/2001	63 kt	1	NE	12.5 in
Frances, Jeanne	9/4/2004, 9/25/2004	85 kt, 105 kt	2, 3	NW, W	N/A
Wilma	10/24/2005	105 kt	3	NE	N/A

METHOD

The near shore habitats adjacent to Great Guana Cay were classified according to Allee et al. 2000. Habitats include: patchy seagrass, algal hardbar, patch reef and artificial reef, totalling eleven sites (Table 2). At each site the conspicuous species of macroalgae were collected in zip lock bags by roving divers. Additionally, observed species and their abundance categories were recorded in waters to a depth of approximately 2 meters. Each survey lasted for at least 60 minutes. Unknown samples were preserved in formalin for later identification. Species identification was confirmed through use of dichotomous keys. PRIMER ecological software was used for all data analyses.

Figure 1. Northern Great Guana Cay and development components. Large-scale land conversions proposed include home sites, an 18-hole golf course and a marina.

Table 2. Marine habitat classification. Classification adapted from Allee et al. 2000.	
1. Artificial reefs- Artificial structures generally placed in habitats to enhance existing habitat, or replace lost habitat. Artificial reefs can be constructed or structures such as ships may used.	
2. Seagrass Communities - The shallowness of the Sea of Abaco facilitates the persistence of stable seagrass communities, which are largely composed of turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filliforme*), with some shoal grass (*Halodule wrightii*) present. These marine grasses play important roles in the ecosystem, providing nutrients and serving as protection for marine creatures, as well as providing substrate on which epizootic organisms may live. Queen conch and marine turtles spend a large part of their lives in seagrass beds.	
3. Non-Reefal Hard Bottom Communities – These communities are typically located on extensions of island platforms, and are dominated by soft corals, corallimorphs, macoalgae, and stony corals. Coral assemblages do not accrete and build up topography and instead remain flush with the substrate. Yet, these habitats support similar diversity to coral reefs and are far more common in The Bahamas.	
4. Patch Reefs Patch reefs are the topographical result of coral, algae, worms, mollusk, and sponge contributions of calcium carbonate to "build their own habitats." Coral reefs are known for their high biodiversity an extreme ecological complexity. These communities are typically located on extensions of island platforms, and are dominated by soft corals, corallimorphs, macoalgae, and stony corals. Coral assemblages do not accrete and build up topography and instead remain flush with the substrate. Yet, these habitats support similar diversity to coral reefs and are far more common in The Bahamas. interactions. Abaco boasts one of the largest barrier reefs in the world, which serves as protection for the Sea of Abaco and the Abaco cays from Atlantic waves and storm surge.	

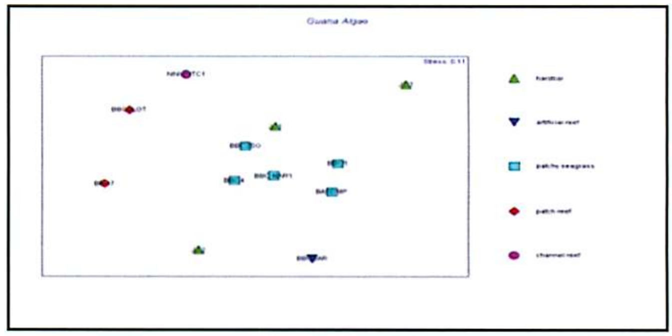
RESULTS

Table 3 outlines the sampling effort and Shannon-Weiner indices for the study sites. A predictable trend of higher diversity at the patch reef sites is outlined. Figure 2 depicts a Multi-Dimensional Scaling (MDS) plot of algae and seagrass study sites adjacent to northern GGC, with specific habitats denoted. The algae and seagrass communities did not group together based on species presence and abundance, although there is some grouping in similarity between patchy seagrass sites. The plot outlines that distinct algae and seagrass community assemblages are found in between habitats and study sites. This determination follows suit with previous findings that near shore habitats are distinct and comprised of varying ecological communities. The findings also stress that future comparisons should be done on a site-by-site basis, being cautious not to compare ecologically unrelated habitats.

Table 3. Summary of study sites and Shannon-Weiner analysis for seagrass and algae sampling.

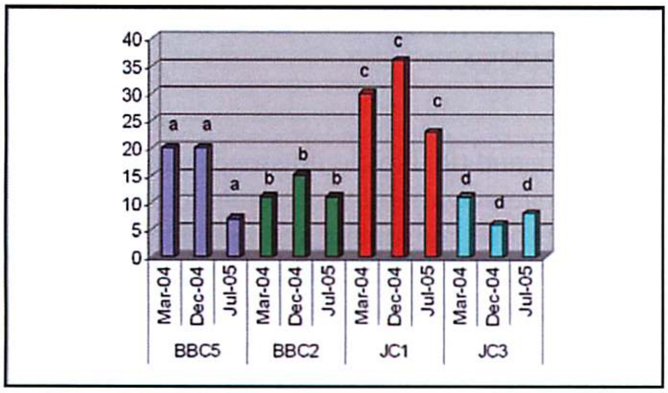
Habitat Type	Station Identifier	Average # species per 1 hour survey	Shannon-Weiner Diversity Index
Patchy Seagrass	BBC5	12	2.485
	MAR1	17	2.833
	BBC2	30	3.389
	BBC4	26	3.21
Hardbar	JC1	17	2.813
	JC2	17	2.776
	JC3	5	1.499
Artificial Reef	AR	18	2.857
Patch Reef	BBC7	32	3.429
	KPR	31	3.388
	Lots 69-71	24	3.103

Figure 2. A Multi-Dimensional Scaling plot (MDS) of algae and seagrass study sites adjacent to northern Great Guana Cay. Communities have been outlined by habitat.



Additional statistical tests were employed to investigate possible hurricane effects at four study sites ((BBC5 (Patchy seagrass), BBC2 (Patchy seagrasss), JC1 (Hardbar), and JC3 (Hardbar)). GGC was hit by Hurricane Frances (Category 4 at impact) in early September 2004, and then by Hurricane Jeanne (Category 3 at impact) in late September 2004. Benthic flora data was collected six months prior to, three months after, and 10 months after hurricane activity to evaluate ecological impacts, changes and recoveries that occur from nature-based disturbances. A non-parametric, nested Analysis of Similarity (ANOSIM) test revealed **no significant differences** of species presence and abundance categories between survey dates at survey sites. Thus, temporally, natural-disturbances had no impacts on community compositions or species abundance. Because these particular seagrass and algae communities are stable in species presence and abundance over time and in the presence of natural stressors, deviation in community assemblages may be taken as potential evidence of development stress on near shore marine habitats.

Figure 3. Analysis of Similarity (ANOSIM) between study sites pre and post hurricanes Francis and Jeanne (2004). No significant differences were found between species abundances or diversity amongst the study sites, inferring community stability.



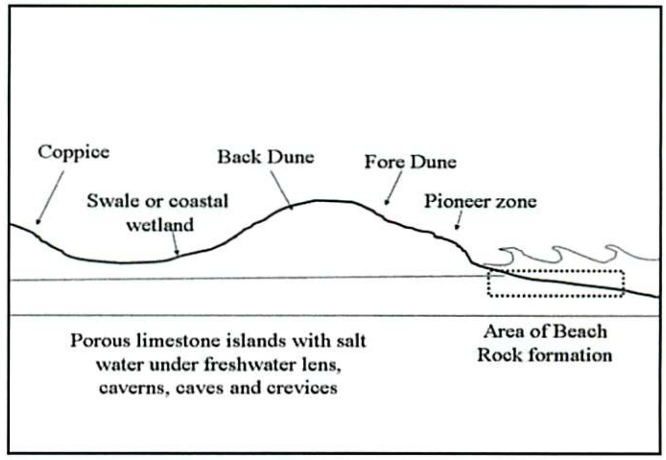


Figure 4: Topography of coastal systems that facilitates the rapid movement of nutrients from unvegetated coastal zones to near shore marine environments.

DISCUSSION AND CONCLUSION

Macroalgae and seagrass communities represent a large habitat expanse located around the northern end of GGC, and provide both food and shelter for fish, conch, and crustaceans. Macroalgae are important community members in hardbar and reefal systems, and provide both spatial complexity and serve as a food resource for numerous organisms. Nutrient inputs, whether natural (storms) or anthropogenic (sewage runoff, or removal of dune plant filtering system) can cause substantial changes in the proportion of macroalgae and cyanobacteria to epifauna (e.g. corals) represented in a given community (Figure 4).

Marine plant monitoring is particularly essential in determining the effects of coastal development on near shore systems, due to the incredible sensitivity and of these species to changes in habitat quality, which often occur on short time scales. Proliferation of 'weedy' (pollutant tolerant) algae species, and seagrass and algae coverage and diversity are employed for this study as reference conditions and bio-indicators (US EPA 2006) and will be used in subsequent surveys to evaluate environmental quality.

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