Fish Fauna as Indicators of Coastal Restoration Goals

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ABSTRACT

Coastal development is proceeding at a rapid and often unregulated pace throughout the wider Caribbean, but most especially in The Bahamas where the Family Islands of the archipelago are targeted for anchor tourism developments. Often sites selected for development already have some environmental concerns ranging from habitat destruction due to past dredge-and-fill activities to coastal erosion accelerated by invasive coastal plant species. The establishment of baseline studies of the habitats, flora and fauna throughout the major island groups is critical to building the case for mitigation and coastal protection as part of the cost of new tourism developments. A case study from Savannah Sound, Eleuthera, The Bahamas is presented as one location where impacted and disturbed mangrove lagoon sites were studied over an 18-month period to establish differences in fish species assemblages and abundance as a bench-mark for restoration planning.

KEYWORDS: Restoration, mangroves, coastal development

La Ictiofauna como Indicador del Éxito de la Restauración Costera

El desarrollo costero en el gran Caribe está ocurriendo a un ritmo acelerado y en muchas ocasiones no regulado, especialmente en Las Bahamas, donde las islas más apartadas del archipiélago (hacia el este) son objeto de un desarrollo del turismo del tipo permanente. A menudo, los sitios seleccionados para ese desarrollo ya arrastran problemas ambientales viejos por la erosión causada por procesos dragado y relleno, acelerado por la invasión de plantas invasoras. La realización de estudios básicos de referencia en los principales grupos de islas es esencial para justificar actividades de remediación y protección costera como parte del costo del nuevo desarrollo. Se presenta el caso de estudio de Savannah Sound, en la isla de Eleuthera, donde las lagunas de mangle impactadas y perturbadas se estudiaron por espacio de por año y medio para establecer diferencias en las asociaciones de peces y su abundancia, como referencia para la planificiación de los proyectos de restauración.

PALABRAS CLAVES: Restauración lagunas de mangle desarrollo costero

INTRODUCTION

Tourism contributes to an estimated 40 percent of the Gross Domestic Product (GDP) of The Bahamas, with an additional 10 percent of the GDP resulting from tourist-driven construction (US Dept of State 2007). The value of the tourism product in any country is dependent upon the quality of its natural resources, namely its native flora and fauna, beaches and coastal waters. The protection of the natural environment is especially important in The Bahamas where the marketing of the country to potential visitors focuses on the high quality of its natural resources. Special attention is given to the opportunities available to not only partake in fishing activities in waters teeming with marine organisms but also to enjoy the consumption of organisms harvested from the sea such as lobster, conch, grouper and snapper.

Small Island Developing States (SIDS) need innovative development policies that will be sustainable and preserve the natural beauty of a country as well as increase economic activity in the tourism sector. Sustainable development as defined by the Brundtland Commission (formally the World Commission on Environment and Development or WCED) is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). For many SIDS, tourism development is focused on the re-development of sites that have either failed as resorts, or need updating to appeal to contemporary markets. In many areas of The Bahamas mitigations may need to restore historical damage to the coastal zone from decades of anthropogenic disturbances. A large majority of previous developments now typically require coastal and seafloor mitigations, where coasts have been altered to accommodate housing and where seafloors have been dredged and filled for marina construction. These mitigations are essential, because coastal and beach erosion issues represent a significant threat to tourism property and may be amplified with global climate change which will possibly increase both storm intensity and frequency (Wong 2003).

Ecologists are trying to identify environmental characteristics, especially in the coastal zone, that may serve as indicators of overall health of coastal systems and highlight the degree of success mitigations have had in restoring ecological function. These characteristics must be measurable and interpretable by policy makers to ensure "sustainable practices" are being conducted; however there is very little pre-impact baseline data available for comparisons. As a result it is difficult for restoration planning to even begin making recommendations from a sustainable tourism perspective since there is no knowledge about the original state of the environment of the proposed tourism project. In order for The Bahamas to incorporate sustainable tourism practices and understand their effectiveness, local environmental characteristics (e.g. coral, algae and fish communities) that relay on a healthy environment must be determined so the performance of the practices can be evaluated. One way to establish healthy environment characteristics and establish new guidelines for restorations and mitigations is to use historical development sites that have been altered as case studies and compare the environmental characteristics of the site to a similar un-altered site. Then environmental benchmarks for evaluating the health of coastal systems can be established.

Fish and fisheries are dependent upon the overall health of the environment, and face a serious threat in the wider Caribbean from land-based sources of pollutants (Nero and Sullivan Sealey 2005). Yet, the assessment of fish habitats and impacts on these habitats from anthropogenic interferences such as coastal development are rarely considered in the development process. Near-shore fish assemblages and related biotic and abiotic environmental characteristics serve as excellent indicators of coastal health due to their sensitivity to habitat alterations. Attributes including species abundance, density and trophic composition allow for the characterization of fish assemblages in a particular area. Once benchmark conditions for healthy fish species community composition and related biotic and abiotic characteristics of the environment are determined, comparisons can be made of altered and mitigated environments to gauge the effectiveness of mitigation practices (Cushion *et al.* 2006), thereby providing a critical tool for setting ecological benchmarks for "sustainability".

This paper presents a case study in The Bahamas using the diversity and abundance of near-shore fish fauna at two sites in a tropical lagoon, Savannah Sound, Eleuthera. Although both sites are similar in geomorphology, one site was impacted by a large-scale dredge and fill alteration almost 40 years ago, while the second site has remained un-impacted by any human alteration. It is expected that the community patterns of fish assemblages will be different between the two sites since the historic alterations to one site resulted in the loss of critical seagrass habitats (Vanderklift and Jacoby 2003). Other key environmental factors compared between these two different coastal environments were water quality parameters such as turbidity, and benthic habitat quality based on benthic plants. Overall, this study highlights the degree of recovery and stabilization possible when attempts are made to restore degraded coastal sites.

METHODS

Study Site

Windermere Island is a long sandy ridge off the east coast of central Eleuthera. It runs in a north-south direction for a distance of seven kilometres (Figure 1). Windermere Island is separated from the main island Eleuthera by a water body called the Savannah Sound and is connected to it by a single bridge. The southern four kilometres of the Windermere Island has been developed as a resort residential community since the early 1960's and is the site of about 200 private homes, a club house and a hotel. The northern three kilometres of the island were recently purchased for a new residential resort community and hotel (Windermere Island Northern Development (WIND)). At WIND, the area that has been identified as the location for the proposed hotel was a mangrove shrub land that was back-filled in the 1960s in order to raise the elevation of the land. The fill was obtained from a large channel basin which was dredged in Savannah Sound to a depth of 20 feet (six meters) adjacent to the filled area. This dredged area covers an area of 410 meters by 190 meters. This impacted coastal area was designated as "WIND SOUTH", and includes the filled shoreline, the adjacent near shore section of the dredged basin and remaining fringing mangroves at the edges of the cove.

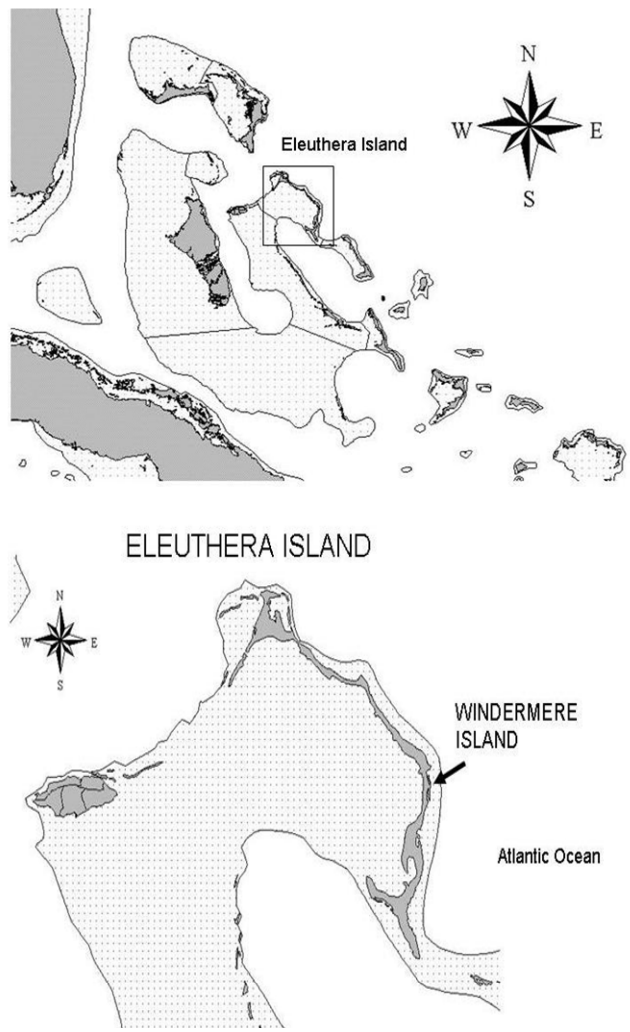

Figure 1. Location of Windermere Island off Eleuthera Island in the central Bahamas. A: Location of Eleuthera 85 miles east of the capital of Nassau on New Providence Island. B: Location of Windermere Island of the Atlantic coast of central Eleuthera. Savannah Sound is the lagoon between Eleuthera and Windermere.

To the north of the dredged coastal area, there are three other beaches with similar coastal geomorphology to the impacted site. These beaches are separated by small rocky headlands, and have varying amounts of fringing mangroves. One of these three beaches was chosen as the un-altered comparison site and was designated "WIND NORTH". This beach is 1.5 kilometres north of WIND SOUTH and has near shore sea grass beds and sparse fringing mangroves. (shoreline pictures in Figure 2).

Figure 2. Photographs of WIND NORTH (upper) coastal site with intact coastal vegetation, and a shallow lagoon beach environment, and WIND SOUTH (lower) coastal site with a dredged basin, and wide un-vegetated shoreline.

Survey Methods

The water quality of these two contrasting sights was assessed in terms of the variability in turbidity at four selected sampling stations. Turbidity was measured using calibrated sensors over daily, tidal and seasonal cycles with a LaMott Turbidity meter and two Hach Data Sonde 4a Hydrolabs. All turbidity measurements were taken in NTUs (Nephloid Turbidity Units). Turbidity measurements were necessary as WIND SOUTH (impacted beach) has a history of cloudy water. This problem is exacerbated by coastal run-off during heavy rains and the clearing of adjacent vegetation to re-grade the land in preparation for development.

From May 2006 to October 2007, nine field surveys were carried out at each of the two sites. The benthic algal and fish habitat survey methods used are described in Nero and Sealey 2005. Seagrass and benthic macroalgae have been shown to be critical refuge and foraging components for small fishes (Nero and Sealey 2005). Benthic macroalgae were collected in plastic bags during a number of hour long surveys conducted at each site. Species identification was done in the field laboratory using hand lenses and microscopes (species names followed the taxonomy of Littler and Littler 2002). Presence – absence data are recorded for each field survey. Near shore fishes were assessed using two surveying techniques; beach seines and roving-diver visual surveys. Seining protocols are described in Nero and Sealey 2005. The roving diver visual surveys (i.e., a random swim approximately confined to an area with a radius of 100-m), were conducted by snorkelers who recorded the species name and relative abundance of all fish observed. During each swim, all positively identified species were recorded in four broad categories (i.e. single = 1, few = 2 – 10, many = 11 – 100, and abundant >100) (www.reef.org).

All fish surveys covered seasons and tidal cycles. Data analyses focused on identifying differences in species composition and diversity for both benthic algae and fish over seasonal cycles between the two sites. Studies have shown that seasonal and inter-annual changes in near shore lagoon communities can be dramatic with natural perturbations such as storm events (Wright *et al.* In press). Therefore, it was important to document the variability in algal and fish species assemblages as one component of the overall lagoon ecosystem resilience and stability. Over the sampling period, although there were no hurricanes in the area, there were a number of large and severe winter frontal systems that passed through.

RESULTS

Fish Fauna

The two sites were quite distinct in terms of fish species composition. From the combined visual surveys and seining data, a total of 81 fish species were observed at the two sites. Due to the inherent nature of the two fish surveying techniques utilized, there were predictable differences in the results obtained (Table 1). Notably, each method captured a different component of the fish faunal community. Both methods provided abundance information, however, seines provided biomass data as well. Greater species richness was recorded at both sites when visual surveys were used as the sampling methodology as compared to seining as the methodology. Based on visual survey data alone, there was little difference between sites in terms of species diversity; 57 species were seen at WIND NORTH, and 61 species were seen at WIND SOUTH. Poor visibility over most of the dredged near shore area of WIND SOUTH forced the sampling effort using visual surveys to be concentrated around the edges. These edge habitats were composed of red mangroves and had much clearer water which made fish observation easier. The high fish abundance and diversity around the basin margin of the WIND SOUTH illustrated the importance of these types of transitional habitats (e.g. steep depth gradient adjacent to mangrove over-wash forests not found in other parts of Savannah Sound) to fish fauna.

Seining, which was done evenly throughout the near shore habitat of WIND SOUTH and NORTH showed greater differences between the two sites; diversity being overall greater at WIND NORTH (19 vs. 14), the intact coastal site. The seines showed high abundances of small silvery fishes such as silversides, mullets, mojarras and jacks, which are generally difficult to see when conducting visual surveys. The seine data also showed that there was less than 53.7% similarity in species composition between WIND NORTH and SOUTH. *Leptocephalus* (Family Elopidae) larvae which were captured in the seines during the spring months at the WIND SOUTH site contributed the most to the differences seen between sites (Table 2). These leptocephali were never seen nor collected at the WIND NORTH site despite its closer proximity to the lagoon opening to the open Atlantic. Although the seine collections from WIND SOUTH had fewer species than WIND NORTH there were higher abundances of flagfin mojarra, silversides and white mullet at this site.

The deeper, cooler water of the dredged basin attracted larger fishes, especially during the summer months; evidenced by the sightings of large jacks and sharks.

Table 1. Summary statistics for the two sites (WIND NORTH intact beach and WIND SOUTH impacted beach) for the two fish survey methods used. Seining (S) and Visual Surveys (VS) captured different species. Three different diversity indices are presented that show both sites are very similar in fish diversity based on Visual Surveys, but WIND SOUTH fish assemblages are less diverse than WIND NORTH assemblages based on Seining Data for two out of the three indices.

STATION – METHOD	Total # of fish species	Margulef's Index (d)	Simpson Diversity Index	Shannon-Wiener Diversity Index (H')
WN VS	**57**	**12.082**	**0.971**	**3.925**
WS VS	*61*	*13.115*	*0.967*	*3.977*
WN SEINE	**19**	**4.701**	**0.959**	**2.826**
WS SEINE	*14*	*3.573*	*0.967*	*2.552*

Table 2. Differences in fish fauna between sites based on both visual surveys and seine results using multivariate statistical analyses of Dissimilarity between sites (SIMPER). The species in italics are characteristic of the WIND NORTH intact coastal site, The normal font indicates species that are characteristic of the WIND SOUTH dredged coastal site.

Species	Average Dissimilarity	Contribution to % dissimilarity	Cumulative percentages
Leptocephalus Larva	1.90	3.55	3.55
Trunkfish	0.81	3.53	7.08
Silver Jenny	0.81	2.65	9.72
Pipefish	0.81	2.65	12.37
Bluehead Wrasse	1.03	2.33	14.90
Yellow Jack	1.47	2.33	17.23
Mottled Mojarra	1.33	2.20	19.44
Bonefish	1.35	2.20	21.63
Redfin Needlefish	1.35	2.20	23.83
Bucktooth Parrotfish	1.56	2.11	25.94
Gray Snapper	0.87	1.97	27.91
Schoolmaster	0.87	1.97	29.88
Ocean Surgeonfish	0.87	1.97	31.86
Slippery Dick	0.87	1.97	33.83
Bluestriped Grunt	0.87	1.97	35.80
French Grunt	0.87	1.97	37.77
Beaugregory	0.87	1.97	39.75
Sergeant Major	1.06	1.88	41.63
Palometa	0.82	1.77	43.40
Pompano	0.82	1.77	45.17
Peacock Flounder	0.81	1.76	46.94

Green turtles were also notably common at this site. It is hypothesised that the turtles were attracted to the cooler water within the basin and the presence of a large population of upside down jellyfish (*Cassiopea xamachana*).

It is interesting to note that although WIND SOUTH was not necessarily impoverished in fish fauna, the fish species composition was different from WIND NORTH. Notwithstanding the fact that this site was dredged over 30 years ago, the little intact habitat that remained (mangroves at the edge of the basin and benthic algae) was still able to support a unique fish community.

Benthic Plants as Fish Habitat

Notable differences were found in the benthic plant diversity between WIND NORTH and SOUTH. WIND NORTH was characterized as diverse and variable over seasons while WIND SOUTH was found to be less diverse and not variable over seasons. Table 3 illustrates the fluctuations of the benthic plant assemblages over time and season for the two sites. At WIND NORTH, a total of 61

Table 3. Changes in benthc magro algae species assemblages over time at the two sites (WN = WIND NORTH intact beach; and WS WIND SOUTH impacted beach, S = summer samples, W = winter samples). Benthic macro-algae species assemblages are dynamic and change seasonally. Diversity was always higher at the WIND NORTH intact beach, regardless of season.

Site and survey trip	Number of algal species	Shannon diversity index
WN2 S06	16	2.772589
WN3 W07	20	2.995732
WN4 W07	19	2.944439
WN5 S07	20	2.995732
WN6 S07	16	2.772589
WN7 S07	21	3.044522
WS2 W07	8	2.079442
WS3 W07	12	2.484907
WS4 S07	6	1.791759
WS5 S07	8	2.079442

Table 4. Analysis of the similarity of benthic plant species composition between WIND SOUTH and WIND NORTH coastal sites. The species in italics are characteristic of the WIND NORTH intact coastal site, The normal font indicates species that are characteristic of the WIND SOUTH dredged coastal site.

Species	Group	Average Abundance	% Dissimilarity	% Cumulative Dissimilarity
Acetabularia crenulata	Calcareous Green	0.33	5.50	5.50
Rhipocephalus oblongus	Calcareous Green	0.33	4.45	9.95
Penicillus lamourouxii	Calcareous Green	0.67	3.94	13.88
Penicillus capitatus	Calcareous Green	0.67	3.88	17.76
Laurencia intricata	Fleshy Red	0.83	3.70	21.46
Acetabularia calyculus	Calcareous Green	0.17	3.47	24.93
Penicillus pyriformis	Calcareous Green	0.50	3.43	28.36
Batophora oerstedii	Calcareous Green	0.83	3.29	31.65
Syringodium filiforme	Seagrass	0.67	3.15	34.80
Halodule beaudettei	Seagrass	0.67	3.15	37.95
Halimeda incrassata	Calcareous Green	0.83	3.06	41.01
Cladophora catenata	Fleshy Green	0.67	3.01	44.02
Thalassia testudinum	Seagrass	0.67	3.00	47.02

benthic plant species were recorded, even though the maximum number of species observed during each sampling session was 16 to 21 species. It was interesting to note that at this site the species composition changed over seasons and years. Overall, a much lower number of species was observed at WIND SOUTH, only 17, with 8 to 12 species identified on each survey. At this site, the benthic plants were dominated by a few species of calcareous green algae, with very little change in species composition over time. The benthic plant species listed in Table 4 contributed to over 50% of the variability between WIND NORTH AND SOUTH.

Water Quality

A comparison of the turbidity data between WIND NORTH and SOUTH highlighted the elevated turbidity levels associated with the altered shoreline of WIND SOUTH. Generally, WIND SOUTH experiences coastal

Table 5: Turbidity mean values for wet and dry season measurements at the two survey stations.

STATION	WET SEASON TURBIDITY (June through November samples) Mean NTUs ± S.D	DRY SESON TURBIDITY (December through May samples) Mean NTUs ± S.D
WIND NORTH – intact	**0.76 ± 0.75**	**0.72 ± 0.51**
WIND SOUTH – impacted	**3.14 ± 3.15**	**1.38 ± 0.77**

DISCUSSION

Savannah Sound is the only lagoon on the island of Eleuthera with a north and south entrance to the sea. As a result, it represents a unique coastal lagoon ecosystem hosting a biologically significant combination of marine habitats. This rare lagoon system may be critical to the health of the offshore reef system of Eleuthera (Harborne *et al.* 2006). However, it faces numerous threats from ongoing and anticipated development projects with the end result possibly being a reduction in the area of seagrass and mangrove habitat critical to fisheries production. This study highlights the effects that development on Windermere Island has already had on the benthic components and fish fauna within Savannah Sound. It also illustrates how all aspects of the near shore environment (fish, habitat, and water quality) can be unintentionally affected by poorly planned development projects.

The high fish diversity along the intact habitat (red mangrove stands) at the edges of the dredged basin at WIND SOUTH demonstrates how even small areas of preserved habitat may contribute to maintaining both the diversity and abundance of fish species. This small amount of edge habitat was critical to the recruitment of a number of fish species including leptocephus larvae, yellow jack and white mullet. The diverse fish fauna that was supported by this marginal habitat may provide an indication of the fish community structure that was present within the area prior to the dredging of the basin and can potentially be monitored to evaluate the impact of coastal stabilization and erosion control.

While the fish fauna collected using the seines in the near shore area of the dredged basin was less diverse than the marginal habitats and WIND NORTH, the low visibility of the basin may provide an advantage to forage fish (silversides and mullet) that aggregate there that cannot be discounted. WIND SOUTH had greater abundances of flagfin mojarra, silversides, and white mullets. These species use the murky waters to their advantage; reducing detection by predators. It was notable that fish species that rely on the seagrass habitats (pipefish, grunts, trunkfish, and bucktooth parrotfish) were missing from WIND SOUTH yet were common at WIND NORTH. This was not totally unexpected with the loss of any significant seagrass habitat at WIND SOUTH.

Although the algal communities in the dredged area were less dynamic than those at the intact beach and had little change over time, this recovered benthic community can potentially provide conditions that fish species can exploit. In addition, the seasonal heterogeneity of this benthic macroalgal community may be critical to the seasonal recruitment of fishes to the lagoon environment of Savannah Sound. Algal communities can be expected to influence abundance of fishes that are dependent on them for food and refuge (Nero and Sealey 2005).

In the absence of baseline data going back 40 years prior to the initial disturbance at WIND SOUTH, it is impossible to predict the exact fish, seagrass, and algal community structure or water quality levels for this area. Thus, the major issue in coastal restoration of this site is to stabilize the area and enhance the existing habitats rather than strive for a drastic restoration back to an approximation of historical conditions. Large areas of the dredged channel at WIND SOUTH have a fine, flocculate material covering the bottom, some of which may have come from seasonal rainfall run-off as evidenced by the coastal erosion along the WIND SOUTH shoreline. In order to provide the substrate necessary for the colonization by macroalgal and seagrass communities, these fine sediments need to be stabilized. Stabilization will prevent re-suspension with wave, wind and boat traffic. One possible way to stabilize the area is to deposit “pea rock” (course gravel over 5 mm diameter) in the dredged basin to depths of up to 20 cm. This course gravel could allow the establishment of seagrass plugs and improve the water quality of the channel environs by holding finer sediments under the larger-sized sediments. Although practical, this level of mitigation can be prohibitively expensive and so may not be an option at this time.

Addressing the issues of restoration requires bench-mark information and reachable goals for restoration that can only be established once baseline comparison studies such as this one are conducted (Cambers 1997). At WIND SOUTH, coastal stabilization and re-vegetation should be implemented with on-going monitoring to determine if further mitigation is warranted. Monitoring fish fauna and related environmental parameters will be a valuable way to gauge the effectiveness of restoration efforts, and may also be important in examining how this site can recover from acute disturbance events such as major storms.

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