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Post-hurricane assessment of reefs and banks in the northwestern Gulf of Mexico

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Abstract. This study characterized and compared the benthic habitats of four banks in the northwestern Gulf of Mexico (Sonnier, McGrail, Geyer, and Bright Banks) and documented potential hurricane damage at these banks. Hurricane Rita, a Category 3 storm, passed 12 km east of McGrail Bank and 24 km west of Sonnier Bank on September 23, 2005. Hydrodynamic hindcast models indicated water velocities of 4 m/s in the vicinity of the banks and estimated maximum wave heights of 13–26 m, which could have exposed even the deeper banks. Results of this study revealed that Sonnier Bank exhibited the lowest live cover at all depth ranges (2–38%) and the highest diversity of all banks, while Bright Bank exhibited the highest live cover (86%). Live cover was significantly different across banks and multivariate statistical analyses using benthic cover data showed significant differences between banks. No obvious signs of hurricane damage were observed at McGrail, Geyer, and Bright Banks; however, a loss of live cover was observed at Sonnier Bank. The results of this study suggest that hurricane impacts to algal and sponge dominated banks may be harder to detect more than a year after a hurricane has passed.

Key words: hurricane, McGrail Bank, Geyer Bank, Sonnier Bank, Bright Bank, Gulf of Mexico

Introduction

Hurricane Rita passed through the Gulf of Mexico in September 2005. Several sensitive habitats within the northwestern Gulf of Mexico were in close proximity to the path of Hurricane Rita, including Sonnier Bank (SB), McGrail Bank (MB), Geyer Bank (GB), and Bright Bank (BB), which were all located within ~75 km of the storm track (Fig. 1). Suspected large wave heights may have exposed some bank caps, even those located at depths of 20–30 m. Preliminary assessments of the coral reef cap (18–29 m) at the neighboring East Flower Garden Bank (EFGB) following Hurricane Rita indicated substantial mechanical impacts: fractured and displaced corals, sediment-scoured corals bordering sand flats, and corals scarred and dented by waterborne objects (Hickerson, EL and Schmahl, GP, pers. comm.). The goals of this study were: 1) to characterize and compare the benthic habitats within four depth ranges at SB, MB, GB, and BB; and 2) to document potential hurricane damage at these banks. Additionally, it was an important goal of this study to distinguish between storm damage and damage from oil and gas activities, which might be apparent at greater depths.

Figure 1: Track of Hurricane Rita, 18–26 September 2005 in relation to the banks evaluated in this study. Image courtesy of A. Hazra.

Material and Methods

In order to understand the wave and current conditions in the vicinity of SB, MB, GB, and BB during the passage of Hurricane Rita, a wave study was conducted using hindcast data provided by Oceanweather, Inc. This study consisted of two distinct analyses: (1) a numerical modeling effort using the REF/DIF program to determine the magnitude of wave transformation from the hindcast wave location to the bank locations and (2) an analytical model to estimate the potential currents resulting from the transformed wave conditions.

In April and May 2007, videographic transects were collected by divers and a remotely operated vehicle (ROV) to characterize the benthic habitats of SB, MB, GB, and BB. Previous descriptions of biological communities at banks in the northwestern Gulf of Mexico (Rezak et al. 1985, Boland 1999, Rezak and Bright 1979, Schmahl and Hickerson 2006) were considered during the sampling design for this study.

Four distinct depth zones were sampled within the habitat types described by Rezak et al. (1985; Table 1). The depth discontinuities between the four sampling zones were purposely established to prevent overlap at the margins of each depth zone.

Table 1. Summary of data collected by divers and ROV in four depth zones. D = sampled by diver; R = sampled by ROV; NS = not sampled; "-" = zone not present; number following dash represents number of transects.

Depth Zone (m)	Bank			
	Sonnier	McGrail	Geyer	Bright
22–27	D–2	-	-	-
30–36.5	D–8	-	D–8	D–3
45–50	R–7	R–12	R–4	NS
55–60	R–6	R–8	R–7	NS

Divers videotaped transects within no-decompression diving limits (to ~36.5 m depth). Video footage was collected at a height of 40 cm and perpendicular to the substratum using a digital video camera in an Ikelite® underwater housing fitted with a wide-angle lens and underwater video lights (Aronson et al. 2005). A TrackLink® 1500 High Accuracy Ultra Short Baseline acoustic positioning system (USBL) with two beacons and an accuracy of 0.25 degrees was used to track the location of videotaping divers/ROV. Data were converted into a GIS format to visualize the location of diver/ROV transects in geographic space (Fig. 2).

Eight randomly positioned transects (each 10 m long) were videotaped at SB within the 22 to 27 m depth range. Because these transects were positioned with reference to a single line (pseudoreplicates), the data from these eight transects were pooled, creating a single long transect for statistical analysis. An additional transect was laid in this depth zone, beginning 21 m northeast of the U-bolt and videotaped in a 90° direction. In the 30–36.5 m depth range at SB, GB, and BB, transects were set along depth contours. Continuous and unidirectional video footage began at random locations.

ROV video footage was collected along depth contours in the 45–50 m and 55–60 m depth zones at SB, MB, and GB using a Seabotix LBV 300S-6[2] ROV. The TrackLink USBL system was used to track the ROV and the position of the ROV was recorded in real time. Due to impending foul weather, ROV data was not collected at BB.

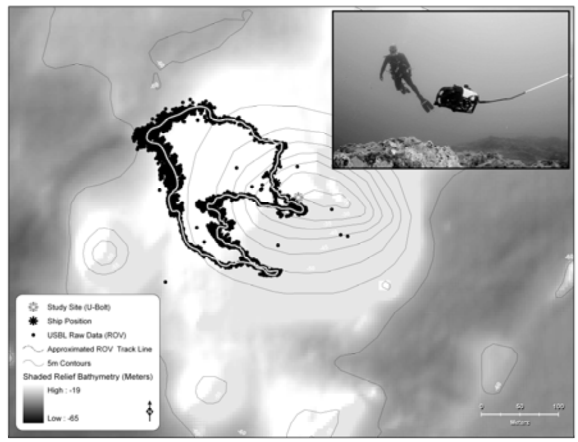

Figure 2: Map of ROV track at Sonnier Bank to and from the ship to a maximum depth of ~60 m. Image courtesy of A. Hazra.

To capture landscape-scale views of all four banks, divers recorded video footage during their descents and along the seafloor. Roving diver video was recorded at 1–2 m above the substrate, while looking down at a 45° angle. The roving diver video was qualitatively analyzed for possible hurricane impacts and compared to video from previous surveys, which acted as an estimate of pre-hurricane conditions and benthic community structure. The ROV also collected landscape-scale views at deeper depth ranges.

Transect video footage collected at SB in the 22–27 m depth range was cut into non-overlapping still images using ULead® VideoStudio® 9. Each 10 m transect yielded ~4 m^2 of benthic imagery. For contour video collected at all other depth ranges, random start times were used to generate 37 consecutive still images from the video footage (4 m^2), which were equivalent to one 10 m transect. A random number of frames were skipped before beginning the next 37 frame transect. Randomly placed dots were then added to each frame using Coral Point Count® (CPCe), for a total of 500 dots per transect. Organisms positioned beneath each random dot were identified to the lowest possible taxonomic level. Quality assurance/control consisted of independent analyses by trained observers on the same segment of captured video. There was agreement between pairs of observers at least 95% of the time.

Results

Hydrodynamic Model Predictions

The REF/DIF model was run to determine the potential effects of banks on waves generated by the storm. Results showed that wave heights increased dramatically in the vicinity of the banks due to the large difference in water depth between the seabed and the summit of the bank. The modeling effort suggests that wave heights are potentially increased to just below the wave-breaking point in the vicinity of the banks. Therefore, the wave heights from the hindcast study were increased to just below breaking—approximately 60% of the water depth at each bank location—in order to estimate the water velocities induced by the waves on the banks. These transformed waves were then input into the Stream Function Wave Theory program to estimate water velocity. Table 2 displays the maximum bottom velocity and maximum wave height at each bank.

Table 2. Results of the hydrodynamic modeling effort in relation to bank depth and distance from the Hurricane Rita storm track.

Bank	Bank Depth (m)	Distance from Storm (km)	Max Bottom Velocity (m/s)	Max Wave Height (m)
McGrail	45	12	4.0	26
Sonnier	22	24	4.0	13
Geyer	39	58	4.0	26
Bright	33	75	4.5	20

Benthic Characteristics

Live cover data were pooled for each bank and data were square-root transformed in order to perform a one-way analysis of variance (ANOVA). Live cover was significantly different across banks (F = 16.49, df = 3,61, P<0.0001). Tukey's HSD test showed significant differences between all pairs containing SB, as well as between BB and MB (Table 3).

Table 3. Tukey's HSD test performed on square-root transformed live cover estimates from diver and ROV transects. Asterisk (*) denotes significant difference at α = 0.05; ns = not significant.

Bank	Sonnier	McGrail	GB	Bright
Sonnier	–	*	*	*
McGrail		–	ns	*
GB			–	ns
Bright				–

Sonnier Bank, the only bank in this study located east of the storm track, exhibited the lowest live cover at all depth ranges (~2–38%) when compared to MB, GB, and BB (~17–86%). SB was dominated by brown macroalgae, sponges, and *Millepora alcicornis* in shallow areas, while deeper zones were dominated by "fine turfs (< 3 mm) and bare space" (TB) and "rubble" (rock or coral rubble - bare or covered in fine turf algae). With increasing depth, percent live cover decreased at SB (22–27 m, 38.3%; 30–36.5 m, 30.1%; 45–50 m, 6.8%; 55–60 m, 1.8%). Qualitative analyses of video footage collected at SB by divers in 1996, 2002, and 2005 showed differences in benthic cover compared to video collected in 2007. Algal and sponge cover appeared to be higher in the previous years. Another notable difference was the apparent disappearance of *Xestospongia muta* colonies. This species was present in 1996, declined to one individual with disease-like characteristics in 2002, and then was not recorded in 2005 or 2007.

McGrail Bank lies only ~12 km west of the storm track and has the deepest reef cap of any bank evaluated in this study (45 m). Live cover at MB ranged from 17–38%. In the 45–50 m depth range, rubble and sand were the dominant features, while live cover (38%) was dominated by macroalgae and hard corals. The coral cover consisted mostly of *Stephanocoenia intersepta* (4.8%) with *Millepora alcicornis*, *Agaricia* sp., and *Montastraea cavernosa* comprising the remaining 0.7%. Because the percent cover of *S. intersepta* appeared to be much higher in some areas within this depth range (ranging from 0–32% within the transect data), multidimensional scaling (MDS) analysis was performed on the 45–50 m transect data based on multivariate cover of the four hard-coral taxa. The MDS plot (Fig. 3) reveals that there is indeed high variability among transects in the composition of the coral assemblage at MB in the 45–50 m depth range.

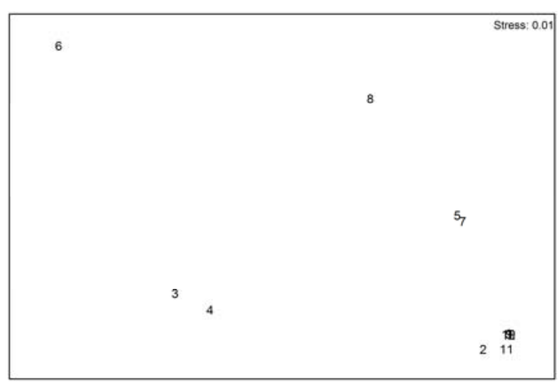

Figure 3. Two-dimensional MDS plot, based on square-root transformed Bray-Curtis similarities, comparing multivariate cover of the four hard-coral taxa at McGrail Bank within the 45–50 m depth range.

In the 55–60 m depth range at MB, rubble and sand were the major benthic components, while live cover (17%) was comprised mostly of algal nodules (6.5%) and the brown macroalga, *Lobophora variegata* (3%).

Previous videos were not available for qualitative analysis. No apparent hurricane damage in the form of overturned or injured corals was observed.

Live cover at GB ranged from 30–60% and was mostly comprised of brown macroalgae, corals, and sponges. Geyer Bank is the only bank evaluated in this study with an observed population of *Tubastraea coccinea*, an exotic, invasive, azooxanthellate scleractinian coral that has recently invaded the Gulf of Mexico (Fenner and Banks 2004). Live cover was 60% within the 30–36.5 m depth range and was dominated by brown macroalgae (42%), with *Sargassum* being the dominant genus at 27%. Rubble and TB were important contributors to overall cover. In the 45–50 m depth range, live cover was ~30%, with brown macroalgae as the dominant taxonomic group at ~22%, and rubble and TB comprising 32% and 31%, respectively, in this depth range. In the 55–60 m depth range, live cover was ~35% and was comprised mostly of brown macroalgae (22%). Rubble and TB accounted for 43% and 12% of the total cover, respectively. Diver video collected at GB in 2003 showed similar benthic cover to the video that was recorded in 2007 with no obvious signs of hurricane damage.

Due to foul weather, only one depth range (30–36.5 m) was surveyed at BB, which exhibited the highest live cover of all four banks examined in this study (86%), with brown macroalgae (44%), green macroalgae (13%), and turf algae (12%) as the dominant groups. Coral cover was ~8% and was comprised of four species: *Millepora alcicornis, Diploria strigosa, Stephanocoenia intersepta,* and *Montastraea cavernosa*. Diver video taken in September 2003 revealed mostly bare substrate, low macroalgal cover, and few large coral colonies. No hurricane damage was observed at BB.

Statistical Analyses

The Shannon-Wiener Diversity Index (H') was calculated for each bank at each depth using the lowest taxonomic group possible. Diversity was highest at SB from 22–27 m, due largely to the variety of sponges present there. Diversity decreased with depth at SB (Table 4). Both GB and MB exhibited the highest diversity values in the 45–50 m depth range. The brown macroalgae accounted for these high diversity values. Notably, diversity at 45–50 m was very low at SB compared to GB and MB. Brown algae distinguishable to genus or species were virtually absent from SB between 45 and 50 m. Turf algae, rubble, and sand were the dominant categories at SB from 55–60 m, accounting for the zero-value of H' in that depth range. It should be noted that in this study, turf algal species were lumped into a single taxonomic unit because individual taxa were not distinguishable from video; however, the actual species diversity of turf algae would be expected to be high, and if known, would likely increase the H' for the deeper transects at SB.

Table 4. Shannon-Wiener Diversity (H') at all banks and depths surveyed.

Depth (m)	Sonnier	Geyer	McGrail	Bright
22-27	2.86	----	----	----
30-36.5	1.55	1.65	----	1.81
45-50	0.23	2.13	2.08	----
55-60	0*	1.47	0.83	----

*only turf algae, rubble, and sand

Multivariate statistical analyses were performed using benthic cover data at SB, MB, GB, and BB. Analysis of Similarity (ANOSIM) showed significant differences between banks (Global R = 0.54, P = 0.001). Within site comparisons showed less dissimilarity between depths. MDS highlighted the dissimilarities among banks, with depths within sites grouping more closely (Figure 4).

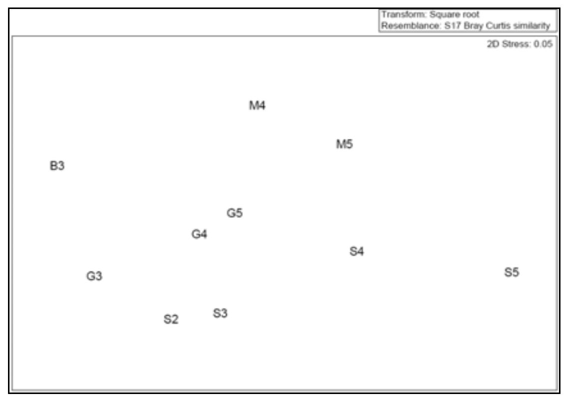

Figure 4. Two-dimensional MDS plot, based on square-root-transformed Bray–Curtis similarities, comparing multivariate benthic cover data among Sonnier, McGrail, Geyer, and Bright Banks at the depth ranges sampled. Data were pooled within depths at each site. Abbreviations: S2, Sonnier Bank 22–27 m; S3, Sonnier Bank 30–36.5 m; S4, Sonnier Bank 45–50 m; S5, Sonnier Bank 55–60 m; M4, McGrail Bank 45–50 m; M5, McGrail Bank 55–60 m; G3, Geyer Bank 30–36.5 m; G4, Geyer Bank 45–50 m; G5, Geyer Bank 55–60 m; B3, Bright Bank 30–36.5 m.

Discussion

Little is known about the effects of hurricanes on benthic communities not dominated by corals (e.g., SB, MB, GB, and BB). This study suggests that hurricane impacts to algal and sponge dominated banks may be harder to detect more than a year after the hurricane has passed. Since the passage of Hurricane Rita, algal communities have had time to re-grow and sponges may have healed/regenerated. Furthermore, corals, sponges, and other organisms that may have been removed from these banks during the hurricane were likely fractured and dispersed by the predicted water velocity of ~4 m/s, leaving little or no detectable remnants 20 months after the storm. Vast areas of rubble, documented at SB and at deeper depths on MB and GB may have represented hurricane effects; however, this may not be the case as normal reef processes also create rubble zones on banks in the northwestern Gulf of Mexico (Rezak et al. 1985).

A wave study was conducted to better understand the wave and current conditions in the vicinity of SB, MB, GB, and BB during the passage of Hurricane Rita. The REF/DIF model wave height estimates represent the largest theoretical wave heights that may have occurred at each bank cap. Based on these results, larger wave heights may have occurred at banks with caps located in deeper water (i.e., MB and GB). However, it is interesting to note that the analysis of transect video in this study did not show the greatest damages at MB and GB, as might be expected by the results of the wave model. Furthermore, the shallowest bank included in this study (SB at 22 m depth) experienced the most observable damage, with the appearance of bare substrate and rubble fields in the 2007 transect video. While one might assume that the greatest damage would likely occur at banks located closest to the storm track, the results of this study do not support this assumption. MB is located closest to the storm track (12 km); however, no hurricane damages were observed at this bank. Significant damages were detected at SB, which is the only bank in this study located east of the storm track. It is common knowledge that the right side of a hurricane (relative to its direction of travel) is the most powerful portion of the storm in terms of wind speed and storm surge. This may be a contributing reason for the damages observed at SB.

Potential Hurricane Effects

As the shallowest bank located on the east side of the hurricane track, with hindcast water velocities up to 4 m/s and estimated waves up to 13 m, SB likely sustained hurricane damage in late September 2005. Benthic survey results showed that SB had lower live cover than any of the other banks in this study. At the shallowest depth (22 m), divers with previous experience noted that the bank surface appeared very different from previous visits. Areas of bare bedrock appeared in places previously occupied by live cover.

The depth of MB (45 m) may have protected the scleractinians and algal nodules from hurricane damage, even though the hurricane essentially passed over the bank. Wave heights of up to 26 m were modeled to have passed over MB. Undoubtedly, the pressure and velocity of water during the storm affected the top of the bank, even at 45 m depth. However, the absence of baseline data with which to compare the observations and data gathered at MB during this study prevents statistical comparisons and limits our ability to draw inferences from these data. Because ROV footage was taken at night, landscape-scale views were not possible to discern. It may be that hurricane damage was not detected for this reason. The colonies that were observed appeared undamaged; however, the high variability of coral cover observed in the 45–50 m depth range could have been a consequence of the hurricane. On the other hand, that high variability could reflect the patchiness of the benthic biota caused by variability of coral recruitment or post-settlement processes, or previous perturbations.

Video footage from 2003 was analyzed qualitatively for pre-hurricane conditions at GB and BB. The subject of both videos was the fish populations at these banks; therefore, a thorough characterization of the benthic community structure was not possible. Video from BB showed largely bare, uncolonized areas, with *Lobophora variegata* being the only discernible macroalgal genus. Video from GB showed coverage of the benthos by brown macroalgae, including *Sargassum* spp., which was the dominant macroalgae in 2007. From these pre-hurricane videos we can conclude: (1) that the unique biological characteristics were not established after the hurricane; and (2) that as of April–May of 2007, the benthic assemblages had recovered to some extent.

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