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Session number 1

REAL-TIME CORAL STRESS OBSERVATIONS BEFORE, DURING, AND AFTER BEACH NOURISHMENT DREDGING OFFSHORE SOUTHEAST FLORIDA, USA.

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Abstract. Beach nourishment in Southeast Florida involves dredging sand source borrow areas located between offshore reefs. From May 2005 to February 2006 Broward County, FL. nourished 10.9 km of beach with 1.5 $\times 10^6$ m^3 of sand. As part of a program to monitor potential reef community impacts, a visual stress index was developed from laboratory experiments and histological analyses for three stony coral species (*Montastrea cavernosa*, *Solenastrea bournoni*, and *Siderastrea siderea*). Scoring involved healthy = 0; moderately stressed = 1 (polyp swelling, increased mucus); markedly stressed = 2 (coloration changes, increased mucus secretion, tissue thinning); and severely stressed = 3 (severe swelling/thinning tissue erosion/necrosis). Colonies were scored weekly at sites adjacent to borrow areas and control sites pre-, during, and post-dredging. Permit conditions were established which would suspend dredging based on mean stress index values above 1.5 at 50% of monitored sites adjacent to borrow areas. This condition was never met. However, three hurricanes, passing the region during dredging, contributed to an elevated mean stress level above 1.0. Post-dredging observations documented recovery to pre-dredging stress levels. This program was effectively used to monitor stress on a sensitive marine habitat adjacent to sediment dredging activities.

Key words: Coral stress, dredging, beach nourishment.

Introduction

Beach nourishment in Southeast Florida is commonly accomplished by dredging from sand deposits located between offshore coral reefs and moving the sand to shore. Broward County, Florida, USA constructed 10.9 km of beach from May, 2005 through February, 2006, utilizing a hopper-dredge and placing 1.5 million cubic meters of sand, from 5 different sand borrow areas (Figure 1), onto the beach. Dredging can cause elevated turbidity due to suspension of sediments. This can result in stressful conditions, including smothering and/or reduction of photosynthesis, for sessile reef organisms, such as stony corals. To monitor a real-time response of stony corals to a potentially increased, sediment induced, stress environment during the dredging process, an observational stress index was developed for three coral species (*Montastraea cavernosa*, *Solenastrea bournoni*, and *Siderastrea siderea*). This stress index was incorporated into State and Federal permits issued for the dredge operation and an average stress index threshold was developed to allow for cessation of dredging at specific borrow areas should the stress threshold be exceeded. Recovery to below threshold stress levels would subsequently allow dredging activity at the specific borrow area to resume.

Material and Methods

The stress index was developed in the laboratory and verified histopathologically (Vargas-Angel, et al., 2006). Average values above 1.5 (n=6) at 50% of sites surrounding a particular borrow area would trigger cessation of dredging at that borrow until average stress fell below threshold. Figure 2 shows typical observable stress responses of *Montastraea cavernosa* for each stress index level. Treatment study sites were established adjacent to each borrow area (Figure 1) and control sites established 4-5 km north (3 sites) and south (5 sites) of the dredge operating area. Six colonies among the three species were selected at each site. Sites were visited and stress observations made weekly for thirteen weeks pre-construction, weekly during construction (38 continuous weeks with two exceptions due to tropical cyclone activity, and weekly for eight weeks post-construction. Additional observations from non-project colonies were made occasionally from outside

the study sites to verify that visual observations were close or identical to histological stress determined in the lab.

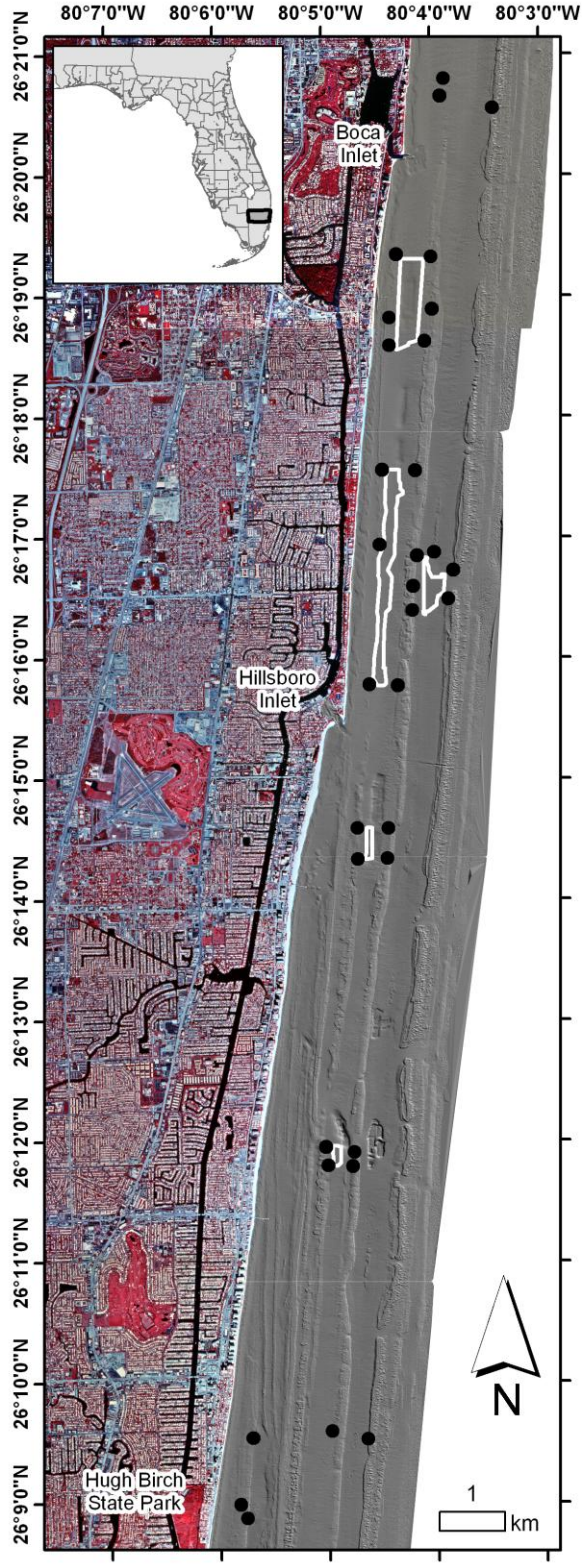

Figure 1: Map depicting sun-shaded laser bathymetry of the bottom offshore Broward County, Florida, USA. Reefs can be seen as ridges paralleling the shoreline (see Walker et al, 2008 for maps of the reefs). Dark circles are sediment monitoring sites where coral stress observations took place. Light colored boxes denote sand borrow areas between the reefs.

Figure 2a: STRESS LEVEL 0: Color appears normal; polyps are fully extended or loosely retracted; no tissue swelling; no apparent mucus sheets over colony.

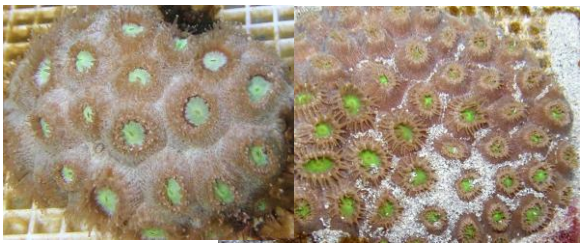

Figure 2b: STRESS LEVEL 1: Normal coloration, natural texture lines. Polyps are fully extended or loosely retracted; no apparent mucus sheets over colony; slight tissue swelling some unusual mouth opening shape and changes in the appearance of oral disk.

Figure 2c: STRESS LEVEL 2: Normal coloration to patchy bleaching. Normal texture lines begin to disappear; polyps appear "melted"; severe tissue swelling and apparent tissue thinning; presence of mucus sheets and sand accumulations between polyps.

Figure 2d: STRESS LEVEL 3: Coloration dull to brown to bleached; obvious tissue erosion and necrosis; polyps tightly retracted, deflated-looking with sunken-in oral disk areas; tissue thinning; skeleton starts to appear thru tissue. Mucus sheets present and colony shows an inability to remove sediments.

Results

Figure 3 presents photographic evidence that the observed level of stress for a *Montastraea cavernosa* colony from one of the treatment sites changed from level 0 to level 2 during construction and returned to

level 1 after construction was completed. Average stress values (Figure 4) at treatment sites (n = 26 sites and 156 colonies) and control sites (n = 8 sites and 48 colonies) remained below 0.5 during the thirteen week pre-construction period and through the 14th week of dredging. The passing of Hurricane Katrina during construction week 15, Hurricane Rita during week 19, and Hurricane Wilma during week 24 contributed to immediate elevated observed average stress values between 0.5 and 1.0. Average histological stress was the highest during the summer maximum temperature (31.9^{o}) that occurred in August, 2005 (Vargas-Angel, personal communication). Average stress remained between 0.5 and 1.0 for the eight weeks of post-event analysis, indicating a recovery period to pre-impact levels longer than 8 weeks.

Figure 3a. Example of a monitored *M. cavernosa* colony at stress level 0 during construction on July 5, 2005.

Figure 3b. The same colony at stress level 2 during construction on December 5, 2005, after the passage of three tropical cyclones.

Figure 3c. The same colony showing some tissue loss in the upper left, however, the remaining colony has recovered to stress level 1 during post construction on March 22, 2006

Discussion

Results indicate that in-situ morphological inspection and evaluation of gross changes associated with stress was an effective tool in detecting and adaptively managing impacts to corals during a dredging event adjacent to sensitive coral habitat. Due to the influence of the hurricanes during construction we can easily separate colony stress levels as a result of storms versus dredging. Average stress remained low prior to the first storm. Average stress levels only exceeded level 2 for two of six sites on two occasions at BA1. Threshold shut-down criteria were not exceeded throughout the project.

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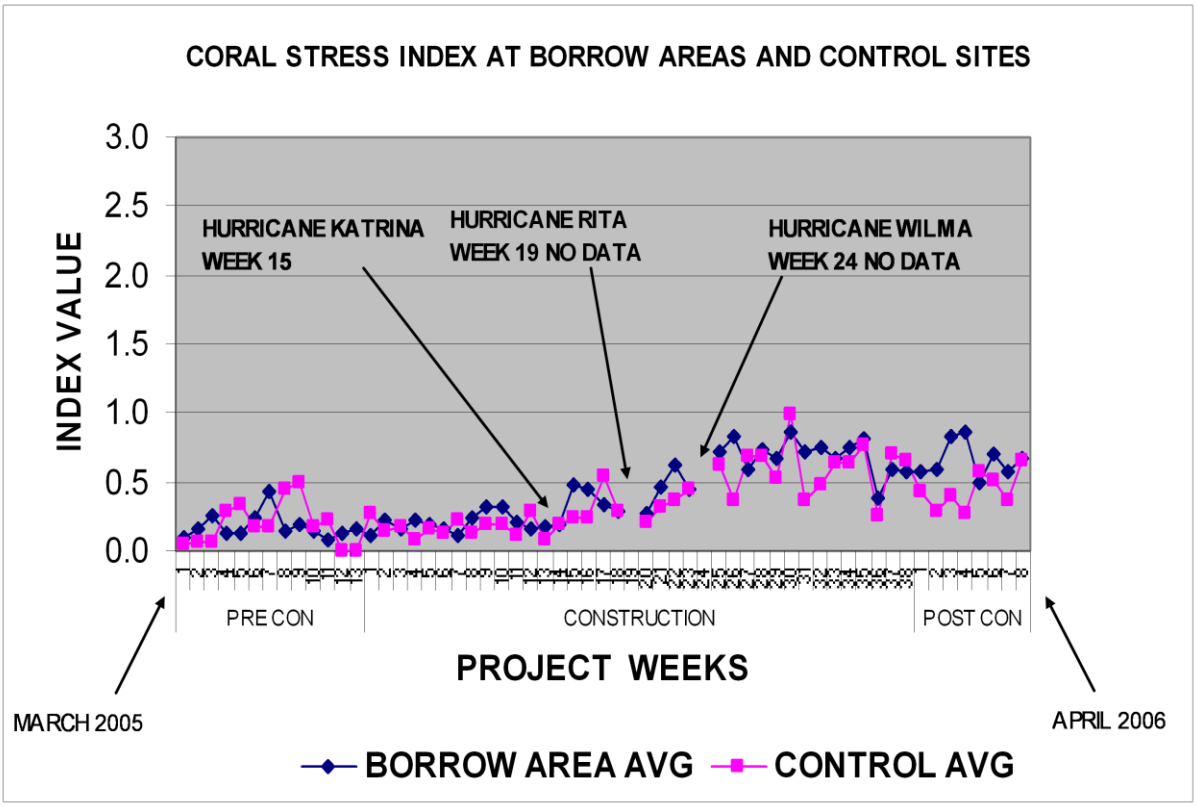

Figure 4. Mean observed stress index values for all corals at all monitoring sites pre- (precon), during (construction), and post-dredging (postcon) . Stress values at treatment and control sites began increasing after the passage of Hurricane Katrina and remained elevated after the passage of Hurricane Wilma throughout the remaining monitoring period.