

Biscayne National Park Research Proposal

Principal Investigator: Pamela Hallock-Muller

Co-Investigator: Elizabeth Fisher; K'wasi Barnes

Institution: University of South Florida
College of Marine Science
140 Seventh Avenue South
St. Petersburg, FL 33701

Office phone: 727-553-1567

Email: pmuller@seas.marine.usf.edu;
efisher@seas.marine.usf.edu; kbarnes@seas.marine.usf.edu

Project title: Larger Foraminifera as Bioindicators of Coral Reef Health

Symbiont-bearing foraminifera as indicators of reef health

Foraminifera with algal symbionts are useful indicators of reef health because they require similar water-quality conditions as scleractinian corals; are abundant and easy to collect with minimal impact; have relatively short life spans and therefore have a relatively rapid response to stress in the environment (Cockey et al., 1996; Hallock et al., 2003). A healthy coral reef is characterized by abundant larger symbiotic foraminifera in the sediment (Cockey et al., 1996; Hallock et al., 2003).

Population dynamics of *Amphistigina gibbosa*

Amphistigina gibbosa are symbiont-bearing foraminifera found on reefs throughout the Caribbean from the shallowest subtidal to as deep as 100m depth; they tend to be most abundant between 15m and 40m depth (Hallock, 1999). *Amphistegina* individuals live on coralline and filamentous algae on reef substrate as well as some macrophytes. Their distribution is controlled by light, temperature, salinity, and substrate

(Hallock, 1999). Williams (2002) found that densities of *A. gibbosa* were not affected by differences in light attenuation, which may be explained by adaptations in phototactic behavior, test thickness, or associated symbionts.

Bleaching in Amphistegina gibbosa

Amphistegina individuals host a diatom endosymbiont, which provide them with their main source of carbon. Therefore, light is necessary for growth and calcification, but too much light can cause photoinhibition (Muller, 1978; Lee, 1980) and loss of symbionts (Hallock et al., 1995). Bleaching was first observed in *Amphistegina* populations in September of 1991, possibly due to ozone depletion following the eruptions of Mt. Pinatubo in May-June 1991 (Hallock et al., 1992; 1995). Since then *Amphistegina* populations in the Florida Keys have been monitored (Hallock et al., 1992; 1995; Williams et al., 1997) for changes in condition (e.g., shell breakage and color changes). *Amphistegina* individuals were characterized as either "normal" (uniform brown color), "mottled" (specimens with any white patches but half the specimen retained some color); and "bleached" (specimens with <50% brown color remaining). Talge and Hallock (1995) and Talge (2002) demonstrated cytologically that loss of symbiont color is caused by degradation and digestion of the diatom endosymbionts. Williams et al. (1997) observed an appearance of symptoms each March with the proportions of mottled or bleached individuals peaking in July with subsequent decline to a winter low from November to February. Bleaching in *Amphistegina* appears to be irreversible therefore the severity of bleaching increases with increasing size (Talge and Hallock, 1995). Individuals smaller than 0.5mm in diameter seldom exhibited symbiont

loss, while specimens larger than 1.0 mm were seldom “normal” in affected populations (Williams et al., 1997).

Temperature, which has been linked to coral bleaching, has not been linked to bleaching in *A. gibbosa* since bleaching begins to increase in March when water temperatures are near their lowest and declines before the water temperatures are at their warmest (Williams et al., 1997). Talge (2002) demonstrated using culture experiments that exposure to 32° C for 4 weeks induced detectable symbiont loss. However, in the same experiments, she found that photic stress produced far more symbiont loss at more environmentally relevant light intensities. Her results are consistent with earlier experiments demonstrating light-induced bleaching in these foraminifera (Hallock et al., 1986, 1995). Williams (2002) concluded that the cause of bleaching in the *A. gibbosa* is linked to solar radiation, based on laboratory experiments, seasonal and latitudinal trends in bleaching in field populations, and the significantly higher prevalence of bleaching at field sites with significantly higher water transparency. One theory states that bleaching is caused by oxidative stress (Downs et al., 2002) and it is possible that a synergistic effect between light and another stressor (e.g., heavy metals, pesticides, organic pollutants) would make the forams more sensitive to light (Williams, 2002). With the loss of symbionts, increases in breakage and predation were also observed (Toler and Hallock, 1998; Toler, 2002).

Based on studies of abundance of larger foraminifera in reef environments and on observations of bleaching and anomalous breakage in *Amphistegina* populations worldwide through the 1990s, Hallock (2000) proposed using these parameters as indicators of reef vitality. This study provides an opportunity to monitor *A. gibbosa*

populations at sites where the visual and physiological conditions of corals are being monitored (by another study), thereby enabling further test of the efficacy of using these foraminifera as surrogate indicators.

This project will:

- a) Continue long-term monitoring of bleaching activity and its causes in larger foraminiferal populations of Florida Keys Reefs;
- b) Complete a study that compares physiological responses and bleaching in *A. gibbosa*, to physiological responses in corals (*Montastrea* spp.) and other organisms being studied by Craig Downs, Cheryl Woodley and John Halas under separate permits; and
- c) Determine if seasonal or spatial differences in algal symbiont populations influences bleaching in *A. gibbosa*.

Objectives

The primary goal of the foraminiferal research is to develop a bioindicator of stress on coral reefs that does not require consumptive sampling of corals and that can distinguish between local and global stressors.

Specific objectives of this study are to:

1. *Create an archive of bleaching, breakage and other anomalies in foraminifera using digital photographs.*
2. *Determine any differences in densities of symbiont-bearing foraminifera among or within sites.* Studies (Cockey et al., 1996; Hallock et al., 2003) suggest that higher densities of symbiont-bearing foraminifera would be found at sites with better water quality and suitable habitat.

3. *Determine any differences in bleaching in A. gibbosa among or within sites.* Based on Williams et al. (1997), it is expected that the percentage of bleaching will be higher at sites with lower sedimentation and turbidity.
4. *Determine whether there are any correlations between the abundance of symbiont-bearing foraminifera and any described environmental conditions (e.g., sedimentation, temperature, etc.).* The density of a population is indicative of the adequacy of a habitat for survival of a population and is an indirect measurement of the success of reproduction and recruitment in a population (Murray, 1973; Noda and Nakao, 1996; Williams, 2002). This project will be testing and revising an *Amphistegina* Index (Hallock, in progress) which is based on density, % juveniles, prevalence of bleaching, prevalence of breakage, and other anomalies. This index states that low densities of *Amphistegina* with high % of juveniles indicate areas that are marginal for occasional recruitment but not suitable for survival of a full life span. High abundances of both juveniles and adults indicate an area with suitable habitat and good water quality.
5. *Assess temporal and spatial variability of algal symbionts in A. gibbosa.* This will examine whether the diversity of symbiont populations within *A. gibbosa* are a factor in inter-reef, depth, or seasonal differences in bleaching response.
6. *Determine whether there are any correlations between bleaching in A. gibbosa and any of the described environmental conditions (e.g.,*

sedimentation, temperature, etc.). High prevalence of bleaching is indicative of photic stress and the degree of symbiont loss can be used to assess the progression and extent of stress in the population (Williams, 2002). Higher percentages of bleaching are predicted at sites with lower sedimentation and turbidity (Williams, 2002). A seasonal trend correlated with light is expected but there should be no correlation between bleaching in *A. gibbosa* and temperature (Williams et al., 1997; Williams, 2002).

7. *Are stress responses in corals (i.e., regeneration rates and biochemical changes) related to conditions (i.e., densities and mottling) of foraminifera?* This project will be evaluating the use of symbiont-bearing foraminifera as surrogate indicators for stress responses in coral communities. They have been used as indicators because they require the same water quality conditions as scleractinian corals and are relatively abundant and easy to sample (Hallock et al., 2003). If the survival and condition of symbiont-bearing foraminifera are dependent on the same conditions as corals then you would expect populations of foraminifera to be stressed at the same sites as corals.
8. *Evaluate, using US EPA Guidelines for Ecological Indicators, the sensitivity of these foraminifera in distinguishing responses to local stressors from responses to stresses associated with global change.*

Methods

Foraminifera will be collected at patch reef sites, Alina's Reef (25° 23.185 N, 80° 09.775 W) and East Bache Shoal (25° 28.982 N, 80° 08.330 W), in Biscayne National Park on a quarterly basis. SCUBA divers will collect five samples of about three or four pieces of small reef rubble (~10^{or 6 inches} cm diameter) and sediment from the vicinity of coral colonies, which are being monitored in another study. The rubble will be placed in resealable plastic bags and brought to the surface where it is placed in a shaded bucket. The rubble will be scrubbed in the lab, with a toothbrush to remove the sediment containing the foraminifera. The sediment will be distributed among petri dishes, and placed in a culture chamber, maintained between 23 and 28° C (depending on the time of year) and on a 12-hour light/dark schedule. All *Amphistegina gibbosa* specimens will be picked out of the sediment using forceps and placed into another petri dish. The living specimens will be counted, maximum diameter measured to the nearest 0.05mm, and their appearance will be characterized according to symbiont color and degree of breakage (methods similar to Williams 2002). If a sample contains high numbers of individuals, all will be counted, but a random sub-sample of 150-200 individuals will be measured and characterized. All "mottled" specimens greater than 0.7 mm will be digitally photographed and analyzed for percentage of area affected to gain a quantitative analysis of mottling. The photographed specimens will be archived onto a compact disc.

Specimens isolated from these samples will be crushed and their algal symbionts either cultured and identified or assessed using molecular-genetic techniques (18S and Rubisco

genes) to assess symbiont diversity. Additional "bulk" samples of 6-10 pieces of rubble may occasionally be needed for symbiont and foraminiferal isolation and culture studies.

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