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# *In-situ* measurement of metabolic status in three coral species from the Florida Reef Tract

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## HIGHLIGHTS

- Coral cover has declined in the FL Keys except on some inshore patch reefs.
- Calcification, lipids, symbionts and chlorophyll were measured in three species.
- Lipid content may not necessarily predict population level *in-situ* resilience.
- Lipids may be metabolized differently in benign versus stress conditions.
- Future work needed to understand factors driving resilience of "winner" species.

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## ABSTRACT

The goal of this study was to gain an understanding of intra- and inter-specific variation in calcification rate, lipid content, symbiont density, and chlorophyll *a* of corals in the Florida Reef Tract to improve our insight of *in-situ* variation and resilience capacity in coral physiology. The Florida Keys are an excellent place to assess this question regarding resilience because coral cover has declined dramatically since the late 1970s, yet has remained relatively high on some inshore patch reefs. Coral lipid content has been shown to be an accurate predictor of resilience under stress, however much of the current lipid data in the literature comes from laboratory-based studies, and previous *in-situ* lipid work has been highly variable. The calcification rates of three species were monitored over a seven-month period at three sites and lipid content was quantified at two seasonal time points at each of the three sites. *Montastraea cavernosa* had the highest mean calcification rate (4.7 mg $cm^{-2}$ $day^{-1}$) and lowest mean lipid content (1.6 mg $cm^{-2}$) across sites and seasons. In contrast, *Orbicella faveolata* and *Porites astreoides* had lower mean calcification rates (2.8 mg $cm^{-2}$ $day^{-1}$ and 2.4 mg $cm^{-2}$ $day^{-1}$, respectively) and higher mean lipid contents (3.5 mg $cm^{-2}$ and 2.3 mg $cm^{-2}$, respectively) across sites and seasons. Given the recent Endangered Species Act (ESA) listing of *O. faveolata* and the relative persistence of *M. cavernosa* and *P. astreoides* on a population-scale, this study suggests that the hypothesis that coral lipids are good indicators of resilience may be species-specific, or more complex and interrelated with other environmental factors than previously understood. Additionally, coral lipid storage under benign thermal conditions may differ from lipid storage before, during, and after thermal stress events.



## 1. Introduction

Corals reefs are biodiverse ecosystems with numerous cultural, economic, medical, and recreational values (Costanza et al., 1997). Today's coral reefs are facing multiple stressors including, but not limited to, anthropogenic pollution, nutrification, overfishing, habitat destruction, and climate change. The detrimental effects of these stressors on coral reefs are well-established, but the metrics and baselines that should be used to improve science-based policy decisions are still somewhat unclear. In order to help protect this important ecosystem and all of its resources, it is imperative to understand which coral species at which sites are going to be

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most resilient to stress. Resilience is the ability of an organism to return to its original state after experiencing a disturbance (Lewontin, 1969), and thus resilience is about having the means to overcome stress. Following the disappearance of Acroporid corals in the Caribbean, massive coral species with slower growth rates, i.e. *Montastraea* species, have become primary reef builders, and weedy corals, i.e. *Porites* species, have started to increase in abundance (Alvarez-Filip et al., 2009). Specifically, *Montastraea cavernosa* and *Porites astreoides* were found to be some of the most abundant coral species on today's Caribbean reefs (Alvarez-Filip et al., 2011, 2013). Identifying coral species that will be "winners" and "losers" on reefs of the future, as well as sites to focus stronger conservation efforts on, have become major foci of the field of coral eco-physiology and conservation science.

Lipid content in reef-building corals represents an alternative source of fixed carbon that can be used to maintain vital processes under stress, i.e. calcification and daily metabolism (Grottoli et al., 2006; Rodrigues and Grottoli, 2007; Anthony et al., 2009). Different species may partition their resources (use for calcification vs. use for reproduction vs. general storage) differently and this allocation differential may affect resilience to bleaching and other stressors. Due to the fact that stored lipids can serve as energy reserves during times of stress, measuring lipid content may be an accurate predictor of the potential resilience capacity of a certain species.

The density of a coral's symbiotic algal population is also a good proxy for overall coral condition and health because the symbiosis between the coral host and its zooxanthellae is the fundamental building block of reef-building coral success (Davy et al., 2012). Under normal, unstressed conditions, a coral may receive up to 95% of its daily metabolic requirements from the transfer of photosynthate from the symbiont to the coral (Muscatine, 1990). Therefore, the amount of chlorophyll *a*, the major photosynthetic pigment of coral's symbiotic algae, is also a good indicator of the status of the symbiont. Lipids and zooxanthellae density have been shown to vary considerably by coral species, reef site, sampling season, and sampling year (Fitt et al., 2000; Teece et al., 2011; Pisapia et al., 2014), and thus trying to compare results between studies where one or more of these factors differ can be inconclusive. Due to the variability associated with these parameters, as well as the fact that many sites have changed since early observations were published, it is important to continue to monitor the parameters that could indicate capability for resilience or indicate a 'red flag' regarding sites or species in distress. Additionally, measuring these metabolic indicators could give us more insight into coral condition (and stressor-response mechanisms) than the typical population-level (percent live coral cover) monitoring programs do, i.e. it may be instructive to measure coral condition before the corals experience stress events instead of just measuring the loss of live colonies following disturbances.

Millions of people visit coral reefs in the Florida Keys every year, and these reefs are estimated to have an asset value of $7.6 billion (Johns et al., 2003). Unfortunately, coral reefs in the Florida Reef Tract have experienced dramatic declines in coral cover since the late 1970s (Dustan and Halas, 1987; Porter and Meier, 1992). This decline has continued after the 1997–1998 El Nino event and since then has been mainly due to the continued attrition in the *Orbicella annularis* species complex (Ruzicka et al., 2013; Toth et al., 2014). An exception to this trend is found on some inshore patch reefs of the Florida Reef Tract where coral cover and growth have remained relatively high (Lirman and Fong, 2007; Ruzicka et al., 2013; Manzello et al., 2015a,b). These inshore reefs of the Florida Keys present an opportunity to study the physiology behind this observed resilience success. Possible hypotheses for resilience are coral thermal acclimatization/adaption to higher inshore temperatures and/or relatively high inshore aragonite saturation states due to proximity to seagrass beds (Lirman and Fong, 2007; Soto et al., 2011; Manzello et al., 2015a), or inshore turbidity helping to ameliorate bleaching stress via shading (Zepp et al., 2008; Ayoub et al., 2009). Previous work exploring other mechanisms for resilience, such as elevated lipid content given the potential for increased heterotrophy due to increased turbidity (Teece et al., 2011), have been inconclusive as lipid content can be highly variable for the same species due to differing nutrient levels and plankton abundance on reefs. However, using lipids as a metric for resilience may prove to be useful when comparing between a few dominant reef-building species at specific sites and time points. Many studies to date on coral calcification and lipids as indicators of resilience to stress have been assessed in laboratory settings. Less is known regarding *in-situ* inter- and intra-specific variation with respect to calcification and lipid content.

The purpose of this study was to quantify inter-and intra-specific variation in calcification, lipid content, zooxanthellae density, and chlorophyll *a* in three common species of corals in the Florida Reef Tract at three different sites in two sampling seasons (summer vs. winter). These data will provide an important updated and *in-situ* baseline for coral metabolic indicators. This baseline will be useful for measuring future change and in comparison with laboratory results on climate change effects.

## 2. Methods

### 2.1. Collection

Three species of scleractinian corals, *Porites astreoides*, *Montastraea cavernosa*, and *Orbicella faveolata*, were collected in August 2013 and March 2014 from three different sites throughout the Florida Reef Tract. The coral fragments used in this study were the same ones presented in Manzello et al. (2015b) and detailed information on sampling and collection can be found there. Briefly, coral fragments (9–16 $cm^2$) were obtained with hammer and chisel from healthy parent colonies in 2010. One to two fragments were collected per parent colony. The fragments had been previously affixed to cement plugs using All-Fix epoxy and were secured to the seafloor on PVC frames that were approximately 1 mL × 0.5 mW × 0.5 mH. PVC frames were affixed to rebar that had been hammered into the reef framework substrate and were maintained at these sites through the end of the present study (March 2014). The three sites were Lower Keys Inshore (LKI) by Marker 50A (24.59723N, 81.45505W), Upper Keys Inshore (UKI), also known as Tavernier Rocks (24.9398° N, 80.56272° W) and Upper Keys Offshore (UKO), also known as Little Conch Reef (24.94650° N, 80.50207° W). A map of the collection sites is shown in Fig. 1. All sites were approximately four to six meters maximum depth. Approximately five individuals per species (× three) per site (× three) per season (× two) were collected totaling approximately 90 measurements per parameter, although there was some mortality over the seven month study. Corals were retrieved by SCUBA divers at each sampling point, cleaned of all non-coral flora and fauna, and transported on ice back to the University of Miami to be analyzed for calcification, total lipid content, zooxanthellae density, and chlorophyll *a* content. HOBO loggers were deployed at all reefs sites during the seven month study to monitor sea temperature data, but unfortunately only the loggers at UKI and UKO were able to be retrieved. Molasses Reef (MLRF1) (25.012N, 80.376W) data from the Coastal Marine Automated Network (C-MAN) was obtained from www.ndbc.noaa.gov and used as a quality control reference to compare with the HOBO logger data from the upper keys sites.