PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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Research Advisor: Karl R. Wirth, Macalester College

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ILIAN A. DECORTE, Macalester College
Research Advisor: Karl R. Wirth

INTRODUCTION

Over the last several decades, *Acropora cervicornis* has seen a massive die-off in the Caribbean resulting in designation on the Endangered and Threatened Wildlife List (Aronson and Precht 2001; Gardner et al., 2003; Greer et al., 2009). The potential causes of decline in *A. cervicornis* in the Caribbean include: extremes in sea surface temperatures (SST), ocean acidification, eutrophication, white band disease, salinity stress, storm disturbances, sediment influxes and other anthropogenic disturbances (Gardner et al., 2003; Greer et al., 2009; Randall and van Woesik, 2015). In their recent work, Randall and van Woesik (2015) connected climate change and rising SST to white band disease as a cause for *Acropora sp.* corals decimation in the Caribbean.

Contrary to the declines in *A. cervicornis* described above, Coral Gardens on the Belize Barrier Reef has an *Acropora sp.* population that appears to be thriving. Through a combination of sclerochronology, stable isotope analysis, and in situ sensor data, this project intends to capitalize on the opportunity to study reef conditions in a site where micro-environmental conditions appear to be favorable for healthy coral growth. We use core from two *Orbicella faveolata* colonies located within *Acropora* stands because *A. cervicornis* does not have annual banding, and therefore is not well suited for studies of historical change. We show that, although there are no significant differences in the $\delta^{18}O$ and $\delta^{13}C$ signatures between Rocky Point and Coral Gardens, there is a clear difference in the stress histories at these locations as inferred from linear extension rates and annual banding patterns. Furthermore, we show that there may be a long-term trend in declining linear extension rates at Coral Gardens consistent with work on the Great Barrier Reef (De'ath et al., 2009).

GEOLOGIC SETTING

To study these coral microenvironments, we compare two locations on the Belizean Barrier Reef: Coral Gardens and Rocky Point. Both locations have similar regional weather patterns. Belize's climate is characterized by a wet and a dry season. The rainy season tends to span from June to November, along with highest temperatures, and the dry season covers the rest of the year. The peak low temperatures are in December to February (www.hydromet.gov.bz/climate-summary).

One coral colony is at Coral Gardens (N 17°50'00.3", W 087°59'32.1") and was chosen and cored in 2011 because of its thriving *A. cervicornis* community. The back reef lagoon is relatively deep (3-5 m) and roughly 10 kilometers from the Belizean mainland, and 2 kilometers from Ambergris Caye. It is in a large lagoon and protected from the open ocean by a reef break. The immediate land surface is dominated by coastal mangrove forest.

The other coral colony is located at Rocky Point (N 18º10'32", W 087º50'11") on the northern tip of Ambergis Caye. The coral head is less than 300 meters from land and ~300-500 meters from the reef break. Live *A. palmata, A. cervicornis,* and *A. prolifera* have been identified at Rocky Point, but are not as high abundance as at Coral Gardens. The coral colony sits just beneath the water surface, and the lagoon is much shallower than that at Coral Gardens. The shoreline is a rocky, sandy shoreline, without mangrove forest.

METHODOLOGY

Field Methods

Coral coring was accomplished using a pneumatic drill connected to a scuba tank. The coring device was a steel extension tube with a diamond bit. Coring was aimed parallel to the growth axis of the coral head to obtain the longest continuous growth record.

Lab Methods

Samples for stable isotope analysis were drilled on a Merchantek MicroMill with a 0.5mm dental drill bit. Sampling resolution ranged from 10 - 15 samples per cm. Sampling strategy matches that of Greer and Swart, 2006. Samples were analyzed for stable carbon ($\delta^{13}C$) and oxygen ($\delta^{18}O$) isotope composition using a brand new Thermo-Scientific Stable Isotope Mass Spectrometer at Washington and Lee University. NBS-19 limestone standards were used to normalize data. Data were corrected to lab standards at Washington and Lee University, Virginia (Greer, personal communication).

X-radiographs of coral cores were obtained at the University of Minnesota in the X-Ray Computed Tomography Lab. X-radiographs use a 23x29 cm Dexela 2923 detector with a resolution of 3073x3889 pixels. The power was set to 20 watts and a voltage of 100 kV. Core slides were X-rayed in multiple sections for highest resolution and sections were stitched together manually using Photoshop software.

ImageJ software was used to construct a digital number profile along the axis of linear extension of the x-radiograph. In the x-radiograph, high-density (HD) bands appear dark (low digital number values) and low-density growth intervals appear light gray (high digital number values). Dark bands in the x-radiograph are interpreted to reflect higher density aragonite.

To establish an age model, "coral years" are defined as the intervals between minima in digital number values (darkest point on the coral x-radiograph). Photographs of the coral cores were superposed with the x-radiographs in Adobe Illustrator so that the geochemical sample locations could be correlated with the density bands in the radiographs.

Temperature

Temperature data were collected in situ at the *O. faveolata* coral colony at Coral Gardens using a HOBO datalogger from Onset from June 2012 -2014. These data were combined with air temperatures from San Pedro city, Ambergris Caye obtained from Weather Underground (http:weatherundergound.com/history/).

RESULTS

Density Banding

The most striking feature of the radiographs of the Coral Gardens 2014 core is a thick dark band at roughly 9 cm from the top of the core (Fig. 1). A similarly dark band is also evident at roughly 6 cm from the top of the core in the Coral Gardens 2011 core. The anomalous dark band is estimated to have developed in coral year 2000 on both cores. The density-banding pattern that formed before and after the anomalous dark band is distinctly different from

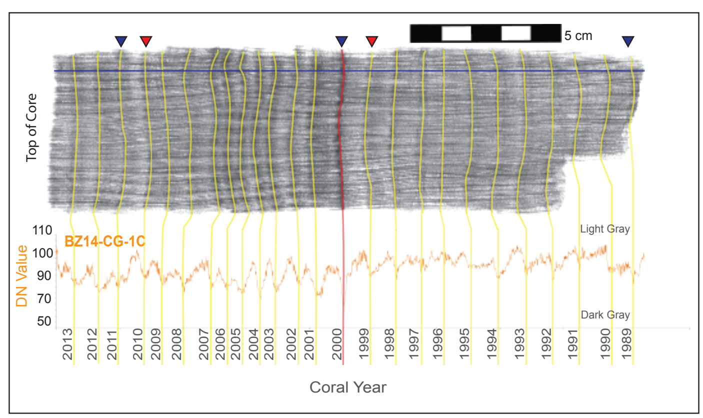

Figure 1. The Coral Gardens 2014 (CG14-1C) x-radiograph paired with its digital number value plot. Each yellow designated a year, counting backwards from 2013. Yellow lines transition to a curve that follows the HD band. The location of the digital number transect is marked by the orange line in the x-radiograph. Strong La Niña (blue) and El Niño (red) years are marked with triangles (http://ggweather.com/enso/oni.htm).Ç

each other. The most recent density band pattern is wider and darker relative to the banding pattern that formed prior to coral year 2000 band. The more recent density banding also appears to curve more across the short axis on the coral cores. The Rocky Point core does not display any discernable changes in density band thickness or darkness.

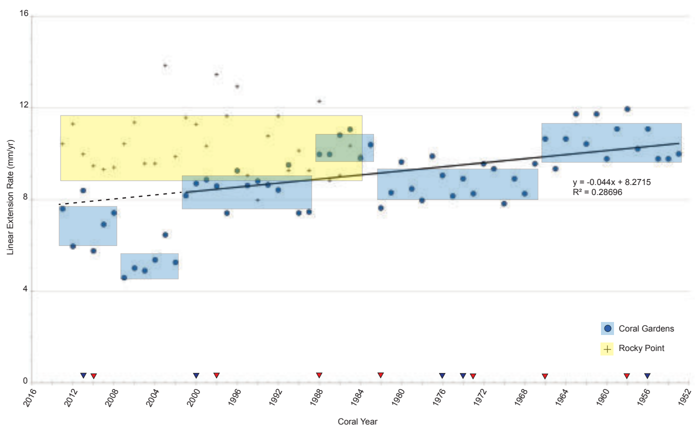

Figure 2. This plot shows the linear extension rates (LER's) from Coral Gardens (blue circles) and Rocky Point (+). Each box represents one standard deviation from the mean LER. There is no significant trend in increasing or decreasing growth rates over time at Rocky Point. Only the Coral Gardens 2011 core (cored by Lisa Greer) is represented by the points prior to 1990. Starting in 1990, the LER's reflects are an average of the Coral Gardens 2011 and 2014 cores. There is a decreasing trend in LER (.04 mm/year) from 1953-2001 (R2 = 0.2709). The points are clustered based on distinct changes in LER and changes in HD band appearance in the coral x-radiographs. Strong La Niña (blue) and El Niño (red) years are marked with triangles (http://ggweather.com/enso/oni.htm).

Linear Extension Rates

Both the 2011 (cored by Lisa Greer) and 2014 Coral Gardens cores show a distinct change in linear extension rate (LER), as defined by the distance between high-density bands, after the 2000 dark band (Fig. 2). Before 2002, LER's range between ~8-12 mm/year (Fig. 2) which is consistent with the extension rates from the Rocky Point core. However, from 2002-2007, the LER's from the Coral Gardens cores drops to an average of 5.26 mm/year. In 2008 growth rates appear to increase slightly to an average of 7.00 mm/year. This drop in LER happens at the same time as we see a visual change in the character of the density banding (Fig. 2). More generally there does appear to be a trend in declining growth rates in the Coral Gardens core of about .044 mm/year between 1952 and 2002 ($R^2 = 0.29$). Rocky point shows no trend in changing growth rates.

Stable Isotopic Data

We analyzed the oxygen and carbon stable isotopes to narrow down the possible causes of stress events, determine seasonality in coral x-radiograph linear extension, and learn more about significant environmental differences between the two study sites. Oxygen isotopic composition ($\delta^{18}O$) is used as a proxy for annual ranges in sea-surface temperatures and salinity and carbon isotopic composition ($\delta^{13}C$) is used primarily as a proxy for zooxanthellae photosynthesis and terrestrial carbon inputs. Both cores exhibit clear annual variability for both $\delta^{18}O$ and $\delta^{13}C$. This annual variability is not strongly correlated with changes in seasonality or temperature (Figs. 3, 4). Furthermore, Coral Gardens and Rocky Point show very similar ranges in the stable isotope signatures (Tbl. 1).

Core	Location	δ^{13C} range (per mil)	$\delta^{18}O$ range (per mil)	Time Range
CG14-1C	Coral Gardens	-0.5 to 2.5	3 - 6	2008-2014
RP14-1B	Rocky Point	0 to 2	2.5 - 4	2011-2014

Table 1. Stable Isotope data summary from cores CG14-1C and RP14-1B.

Temperature Data

Sea surface temperatures (SST's) were measured on site at the Coral Gardens coral colony. The SST's range between ~26-33°C. The highest SST's occur in late August to late September, and the lowest SST's happen in January to March (3, 4). Land surface temperatures were collected in San Pedro city, Ambergris Caye and reported by Weather Underground. We use this temperature record as a comparison to the SST data, and to fill in gaps in the SST record. The atmospheric temperatures range from roughly 25-35°C. There is a clear lag in the SST relative to the atmospheric temperatures on the order of a week to a couple of weeks.

DISCUSSION

Density Banding and Growth Rates

There is a regular lag between peak atmospheric temperatures and peak Sea Surface Temperatures

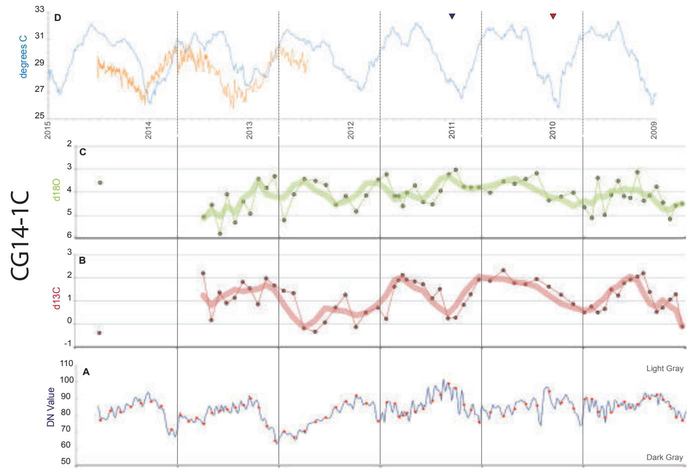

Figure 3. Results from the Coral Gardens 2014 (CG14-1C) core. A longitudinal digital number profile from the x-radiograph (A), measured $\delta^{13}C$ (B), measured $\delta^{18}O$ (C), and temperature (D). Red dots represent sample locations in A. Individual isotope analyses and a three-point running averages (thick line) are shown in B and C. Land surface temperatures in San Pedro, Ambergris Caye (blue line) are from Weather Underground are compared with SST (orange line) from a sensor directly next to the O. faveolata coral colony (D). Strong La Niña (blue) and El Niño (red) years are marked with triangles (http://ggweather.com/enso/oni.htm).

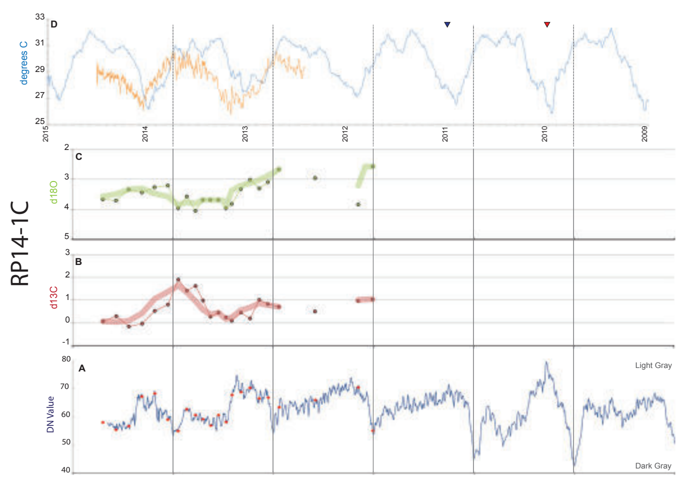

Figure 4. This figure is exactly like Figure 3, but for the Rocky Point 2014 (RP14-1B) core from Rocky Point. The orange line represents SST from a sensor directly next to the O. faveolata core at Coral Gardens, not Rocky Point (D). Strong La Niña (blue) and El Niño (red) years are marked with triangles (http://ggweather.com/enso/oni.htm).

(SST's) and the annual HD bands appear to correlate with peak SST's. The core was taken at the same time as the temperature data was collected so we know that the start of the coral core matches the end of the in situ temperature record in time. By placing the start of the digital number graphs with the start of the HOBO meter SST record, we place the growth banding in the summer of each year. This methodology places the high density bands in September in the calendar year, concurrent with peak SST's (Figs. 3, 4).

This is consistent with corals from Wee Wee Caye, south of Coral Gardens on the Belizean Barrier Reef (Doss et al., 2014). Since coral growth rates are not constant throughout the year, we do not make any connections between the coral x-radiograph and inter-seasonality in the temperature record. Ideally, coupled $\delta^{13}C$ and $\delta^{18}O$ data would show seasonality and, in this way, determine seasonality in the growth bands, but our data does not allow for this at this time.

According to the change in extension rates and the appearance of the HD bands in the x-radiographs, we infer a stress event in or around coral year 2000 (Fig. 1) (Hudson et al., 1976; Dodge et al., 1993). The coral year 2000 high-density (HD) band on the x-radiograph (Fig. 1) is very significantly darker than any other HD band in the x-radiograph. There is no HOBO meter SST data at this time, but air temperature data is not extreme so it does not appear that air temperatures alone caused this stress. According to Allen Curran (personal correspondence), a former student has identified a very dark stress band from this event in a core from a coral colony farther south on the Belizean Barrier Reef (Wee Wee Caye) that was caused by the 1997-1998 El Niño event that caused widespread bleaching in the Caribbean (Aronson et al., 2002). It is possible that this stress band reflects a multiple-year disruption in extension due to the same event. With that said, this seems unlikely due to the 2001 linear extension rate (LER) of 8.17 mm (Fig. 2).

Between coral years 2002 to 2007, the coral exhibits anomalously slow extension rates (average of 5.26 mm/year) and the HD bands appear dark and curvy along the axis perpendicular to linear extension. From 2008 to 2013, the growth bands start to transition back to an appearance and LER (7.00 mm/year). While not yet at baseline as defined by >8 mm/year LER's, do appear to be more close to pre-stress appearance. Even when we extrapolate the potential declining LER of 0.04 mm/year from 1952 to 2001, the 2008-2013 LER's indicate incomplete recovery (Fig. 2). This is consistent with the finding of De'ath et al. (2009) who showed LER's decreased by 13.3% between 1990 and 2008 on the Great Barrier Reef (0.74% per year). Over the same time period, we see a decrease in LER by 40.5% (2.25% per year). This includes the major stress event and major fall in LER starting in 2002. From 1953 to 2001, before the major fall in LER, we see a decrease in LER by 20.4% (0.42% per year).

Stable isotopic data

For both of the Coral Gardens and the Rocky Point cores, the $\delta^{18}O$ and $\delta^{13}C$ records show a typical range in variation consistent with results from Doss et al. (2015) from Wee Wee Caye, Belize. We do not discern a clear and rhythmic annual $\delta^{18}O$ or $\delta^{13}C$ isotope values. Rocky Point and Coral Gardens have very similar ranges of stable isotope values (Tbl. 1). Although we predict significantly different isotopic signatures due to differences in water depth and proximity to land and open ocean, these differences are not translated to the stable isotopic signatures from these coral colonies (Figs. 3 and 4).

Hopefully with further geochemical analysis, we may gain a better understanding of these causal mechanisms. With more stable isotopic data coupled with elemental data (Sr/Ca), we may be able to gain a better understanding of how the corals react to stress, conditions and what causes these stresses.

CONCLUSION

This study set out to investigate the historical micro-environmental conditions between two locations in the Belizean Barrier Reef using sclerochronology and stable isotope geochemistry. We find that the annual high-density bands in coral x-radiographs of *O. faveolata* can be matched to the early fall of each calendar year. We infer a significant difference in the stress history between Coral Gardens and Rocky Point, although we do not see any differences in SST or salinity in the $\delta^{18}O$ signature or any differences in photosynthesis or terrestrial carbon imprint in the $\delta^{13}C$ signature between the two study sites. Coral Gardens appears to have had a major stress event in 2000, while acknowledging that this stress event may have happened earlier and underwent a multiple year disruption in linear extension. We see a clear change of linear extension rates (LER's) before and after this stress band. Prior to 2002, LER's range between ~8-12 mm/year but drop to 5.26 mm/year from 2002-2007. Furthermore, the coral appears to exhibit some rebound (average LER of 7.00 mm/year) from 2008-2013. Finally, we see that there may be a long-term trend of decreasing growth rates for one *O. faveolata* coral colony, consistent with the findings of De'ath et al. (2009) in the Great Barrier Reef.

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REFERENCES

Allen Curran, e-mail message, January 22, 2015.

Aronson, R. B., et al. "The 1998 bleaching event and its aftermath on a coral reef in Belize." *Marine Biology* 141.3 (2002): 435-447.

Aronson, Richard B., and William F. Precht. "White-band disease and the changing face of Caribbean coral reefs." *The Ecology and Etiology of Newly Emerging Marine Diseases*. Springer Netherlands, 2001. 25-38.

De'ath, Glenn, Janice M. Lough, and Katharina E. Fabricius. "Declining coral calcification on the Great Barrier Reef." *Science* 323.5910 (2009): 116-119.

Dodge, Richard E., et al. "Skeletal structural basis of density banding in the reef coral *Montastrea annularis*." (1993).

Doss, W. et al., "Chapter III. Seasonal cycles and decadal trends in *Orbicella faveolata* Sr/Ca, $\delta^{18}O$, $\delta^{13}C$, and B/Ca along the Belize Barrier Reef from 1962-2002" (Ph.D. thesis, University of Colorado, 2014).

"El Niño and La Niña Years and Intensities." *El Niño and La Niña Years and Intensities*. Web. 15 Mar. 2015. <http://ggweather.com/enso/oni.htm>.

Gardner, T. A., Côté, I. M., Gill, J. A., Grant, A., & Watkinson, A. R. . "Long-term region-wide declines in Caribbean corals." *Science* 301.5635 (2003): 958-960.

Greer, Lisa, and Peter K. Swart. “Decadal cyclicity of regional mid-Holocene precipitation: Evidence from Dominican coral proxies.” *Paleoceanography* 21.2 (2006).

Greer, Lisa, et al. “How vulnerable is Acropora cervicornis to environmental change? Lessons from the early to middle Holocene.” *Geology* 37.3 (2009): 263-266.

Grottoli, Andréa G., and C. Mark Eakin. “A review of modern coral δ 18 O and Δ 14 C proxy records.” *Earth-Science Reviews* 81.1 (2007): 67-91.

Hudson, J. Harold, et al. “Sclerochronology: a tool for interpreting past environments.” *Geology* 4.6 (1976): 361-364.

Randall, C. J., and R. van Woesik. “Contemporary white-band disease in Caribbean corals driven by climate change.” *Nature Climate Change* (2015).

Swart, Peter Koenraad, Richard E. Dodge, and Harold J. Hudson. “A 240-year stable oxygen and carbon isotopic record in a coral from South Florida: Implications for the prediction of precipitation in southern Florida.” *Palaios*(1996): 362-375.

Web. 15 Mar. 2015. <http:weatherundergound.com/history/>.