

The Effect of Amazon and Orinoco Rivers on the Sea Surface
Temperature and Salinity Cycles off Barbados: A Record from
Montastrea sp. and *Siderastrea sp.* Corals

Senior Honors Thesis

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Abstract

Four *Montastrea sp.* coral cores and four *Siderastrea sp.* coral cores were collected from the west coast of Barbados in June-July 2009. Samples were cut Washington and Lee University in Lexington, Virginia and x-rayed at the Virginia Institute of Marine Sciences in Williamsburg, Virginia to determine coral growth rates. They were then drilled with a micromill and prepared for $\delta^{18}\text{O}$, $\delta^{13}\text{C}$ and Sr/Ca analyses. This study attempts to extract a salinity signal using $\delta^{18}\text{O}$ and Sr/Ca from coral carbonate. Incorporation of Sr/Ca into coral skeleton is known to only be affected by ambient temperature, while $\delta^{18}\text{O}$ is affected by both temperature and salinity. Calculated temperature and salinity measurements from each coral were compared with in situ temperature data provided by the National Oceanic and Atmospheric Administration and the Coastal Zone Management of Barbados. The data indicate that the southwest coast of Barbados provides the best record of sea surface temperature and salinity changes. The results also show a steady increase in temperature since 1988. Annual temperature and salinity maxima and minima align with the peak outflow of the Amazon and Orinoco Rivers, which arrive at Barbados in August. This study shows the utility of $\delta^{18}\text{O}$ and Sr/Ca in determining temperature and salinity, though error in Sr/Ca data prevents a full salinity record. $\delta^{13}\text{C}$ measurements and lack of a resolved salinity signal in the *Siderastrea sp.* indicate the species' relative inability to accurately record sea surface salinity and temperature. With increased global ocean acidification and the influx of less saline, more acidic water from the Amazon and Orinoco Rivers, the health of Bajan corals may suffer.

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Table of Contents

Abstract	i
Acknowledgements	ii
List of Figures and Tables	iii
Introduction	1
Stable Isotope Fractionation	1
Stable Isotope Fractionation in Corals: $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$	1
Measuring Stable Isotopes	4
Strontium/Calcium	5
The Effects of the Amazon and Orinoco Rivers on Barbados Water Chemistry	6
Methods and Materials	8
Study Site	8
Sample Collection	10
Analysis	10
<i>X-Radiograph Analysis</i>	10
<i>Mass Spectrometer Analysis</i>	12
<i>ICP-OES Analysis</i>	13
Results	13
$\delta^{18}\text{O}$ Data	13
Sr/Ca Data	17
$\delta^{13}\text{C}$ Data	19
Skeletal Extension Rates	21
Environmental Observations	22
Discussion	22
Paleotemperature Equations	23
Temperature	25
Salinity	32
Spatial Variance	37
Temporal Variation	42
Species Variation	44
Sampling Error	45
Conclusions	48
References	50
Figures	28
Tables	52
Appendix A: Sample Locations	54
Appendix B: $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ Data	69
Appendix C: Sr/Ca Data	86
Appendix D: Coastal Zone Management Unit SST and SSS Data	92

List of Figures and Tables

Figure 1: Coral Calcifying Region	4
Figure 2: Map of Ocean Currents Past Barbados	7
Figure 3: Map of Sample Sites	9
Figure 4: Hydraulic Carbonate Saw	11
Figure 5: X-radiograph of Coral Slice AC4-D	11
Figure 6: <i>Montastrea sp.</i> $\delta^{18}\text{O}$	14
Figure 7: <i>Siderastrea sp.</i> $\delta^{18}\text{O}$	14
Figure 8: SST from NOAA for 2010	15
Figure 9: Average $\delta^{18}\text{O}$ of Barbados Corals	15
Figure 10: <i>Montastrea sp.</i> Sr/Ca	18
Figure 11: <i>Siderastrea sp.</i> Sr/Ca	18
Figure 12: <i>Montastrea sp.</i> $\delta^{13}\text{C}$	19
Figure 13: <i>Siderastrea sp.</i> $\delta^{13}\text{C}$	20
Figure 14: Average $\delta^{13}\text{C}$ of Barbados Corals, 2004-2009	20
Figure 15: $\delta^{18}\text{O}$ -derived temperature for All <i>Montastrea sp.</i> samples	26
Figure 16: $\delta^{18}\text{O}$ -derived temperature for All <i>Siderastrea sp.</i> samples	26
Figure 17: $\delta^{18}\text{O}$ -derived Temperature and Salinity from MI5	27
Figure 18: $\delta^{18}\text{O}$ -derived Temperature and Salinity from MI6	28
Figure 19: $\delta^{18}\text{O}$ -derived Temperature and Salinity from BR8	28
Figure 20: $\delta^{18}\text{O}$ -derived Temperature and Salinity from BR2 and BR3	29
Figure 21: Temperature Signal from All Southern Corals and NOAA	30
Figure 22: Sr/Ca-derived Temperature From All <i>Montastrea sp.</i>	31
Figure 23: Sr/Ca-derived Temperature From All <i>Siderastrea sp.</i>	32
Figure 24: SC1 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	33
Figure 25: BR2 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	33
Figure 26: BR3 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	33
Figure 27: MI6 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	34
Figure 28: MI5 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	35
Figure 29: AC4 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	35
Figure 30: AC7 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca	36
Figure 31: SST NOAA and Coral Averages	38
Figure 32: Average $\delta^{18}\text{O}$ for All Samples	39
Figure 33: Trajectory of NBC Rings	40
Figure 34: $\delta^{18}\text{O}$ -derived Temperature from AC4	41
Figure 35: Average Annual Temperature from NOAA and AC4	43
Figure 36: Average $\delta^{13}\text{C}$ of Barbados Corals	44
Figure 37: Time-Averaging	46
Figure 38: $\delta^{18}\text{O}$ of BR2 and BR3	47
Figure 39: Sr/Ca of BR2 and BR3	47
Table 1: Summary of Average Temperature and Salinity Values	17
Table 2: Average and Range of $\delta^{13}\text{C}$ for All Samples	21
Table 3: Change in Growth Rates for <i>Montastrea sp.</i>	21
Table 4: Change in Growth Rates for <i>Siderastrea sp.</i>	22
Table 5: Paleotemperature Equations	24
Table 6: Average Salinity Effects	37

I. Introduction

A. Stable Isotope Fractionation

There are 300 stable isotopes, and all but 21 elements have more than one stable isotope. Two rules govern the stability of an atom. The symmetry rule is based on the coulomb repulsion of protons within a nucleus. With increased number of protons, there is greater repulsion; thus more neutrons must be in the nucleus to give stability. Larger atoms therefore will have a higher N/Z (proton:neutron) ratio. The second rule is that there are more even atomic number stable isotopes than odd (Oddo-Harkins rule) (Freeze and Cherry, 1979).

The isotopic composition of a substance is altered from its surroundings through fractionation. Fractionation can occur during condensation, freezing, melting, chemical reactions, biological reactions, or evaporation (Freeze and Cherry, 1979). There are two types of fractionation: kinetic and metabolic. Kinetic (nonequilibrium) fractionation is mass-dependent because lighter elements such as oxygen have a relatively larger difference in mass between its stable isotopes than a heavier element, such as Strontium. In the case of evaporation, the lighter isotope of oxygen preferentially evaporates out of seawater over the heavier oxygen isotope, due to its greater kinetic energy ($K=1/2Mv^2$) leaving the ocean water with a relatively higher isotopic value. In contrast to evaporation, condensation is an example of equilibrium fractionation. At full humidity, a cloud mass can no longer incorporate any more evaporated water and must condense at the same rate as evaporation. The process switches from a unidirectional fractionation, to an equilibrium fractionation (McConnaughey, 1989). Metabolic (or equilibrium) fractionation, unlike kinetic fractionation, cannot be explained by classical mechanics but requires quantum mechanics to give a net effect of the different vibrational energies possible (Young et al., 2002).

B. Stable Isotope Fractionation in Corals: $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$

The stable isotopes particularly relevant to this study include those of oxygen and carbon. Oxygen has three stable isotopes: ^{18}O , ^{17}O , and ^{16}O . The abundance of ^{17}O is negligible, and the

normal ratio of $^{16}\text{O}:$ ^{18}O is 500:1, with higher $^{18}\text{O}:$ ^{16}O in seawater than in freshwater (Goldschmidt, 1958). Carbon has two stable isotopes. ^{12}C has an abundance of 99%, while ^{13}C has an abundance of 1% (Smith, 1972).

The first use of stable oxygen isotopes in carbonates as a proxy for paleotemperatures was established by Urey (1948) on the principle of equilibrium isotope effects, which dictates that the preference for isotope incorporation between two phases (in the case of corals, between water and biogenic carbonate) is dependent on temperature in a $1/T^2$ relationship. This difference is expressed with the fractionation factor alpha:

$$\alpha_{A-B} = R_A/R_B, \text{ (eq 1)}$$

which governs the relative differences in isotopic composition between two substances, rather than absolute differences (Sharp, 2007). The isotopic composition of seawater with respect to oxygen is expressed as $\text{H}_2^{18}\text{O}/\text{H}_2^{16}\text{O}$ and reported in permille ($^{\circ}/_{\text{oo}}$). The composition of a sample is reported with respect to standard mean ocean water (SMOW):

$$\delta^{18}\text{O} (‰) = ({}^{18}\text{O}/{}^{16}\text{O}_{\text{sample}} - {}^{18}\text{O}/{}^{16}\text{O}_{\text{SMOW}} / {}^{18}\text{O}) / {}^{16}\text{O}_{\text{SMOW}} * 100 \text{ (eq 2) (Fairbanks, 1982)}$$

or relative to Peedee belemnite (PDB):

$$\delta^{18}\text{O} (‰) = 1000 ({}^{18}\text{O}/{}^{16}\text{O}_{\text{sample}} / {}^{18}\text{O}/{}^{16}\text{O}_{\text{standard}} - 1) \text{ (eq 3) (Weber and Woodhead, 1972).}$$

Seawater is the primary source of $\delta^{18}\text{O}_{\text{H}_2\text{O}}$ that corals use for calcification. This allows the use of measurements of $\delta^{18}\text{O}_{\text{CaCO}_3}$ as recorders of past seawater conditions (Grottoli and Eakin, 2006). The $\delta^{18}\text{O}$ signal varies as a result of changes in seawater $\delta^{18}\text{O}$ and temperature-dependent kinetic fractionation, giving a negative slope for $\delta^{18}\text{O}$ versus temperature (Weber and Woodhead, 1972; Sharp, 2007). An increase in temperature results in depleted $\delta^{18}\text{O}$ due to kinetic fractionation (Grottoli and Eakin, 2006). The lighter ^{16}O molecules have a greater velocity due to their smaller mass than ^{18}O molecules, separating isotopes based on mass differences. An increase in temperature increases the kinetic energy of the molecules and subsequently the intensity of the fractionation (Faure, 1977). Kinetic fractionation results in ^{18}O

depletion in coral aragonite by up to 3.7 ‰ (McConnaughey, 1989). A 1°C increase in ambient temperature results in an average 0.22 ‰ decrease in skeletal $\delta^{18}\text{O}$, with the specific variability depending on the species (Weber and Woodhead, 1972; Grottoli and Eakin, 2006).

Seawater is also depleted in ^{18}O during times of increased precipitation or freshwater input. This influx of freshwater coincides with decreased sea surface salinity. The exact correlation between $\delta^{18}\text{O}_{\text{seawater}}$ and salinity depends on location, water depth, and specific ocean basin, precipitation, and evaporation (Grottoli and Eakin, 2006). There is therefore a positive correlation between seawater $\delta^{18}\text{O}$ and sea surface salinity (SSS).

A third influence on $\delta^{18}\text{O}$ is related to biological processes within the coral. Corals do not precipitate calcium carbonate in equilibrium with seawater. The ‘vital effect’ is the disequilibrium in isotopic composition between coral carbonate deposition in a hermatypic coral’s internal organic carbon pool (or extracellular calcifying fluid/ECF), from which it draws calcium carbonate to form its skeleton, and seawater. The movement of seawater and interaction with different parts of the coral create places for isotopic fractionation (Emiliani et al., 1978). Emiliani et al. (1978) reports a 13-17 ‰ difference in metabolic carbon and 10 ‰ difference in metabolic oxygen than bicarbonate in seawater.

McConnaughey (1989) attributes the majority of the vital effect to kinetic isotope effects that occur during hydration and hydroxylation of CO_2 . Adkins et al. (2003) does not rely on the kinetic fractionation explanation for the vital effect but has instead cited “thermodynamic responses to the enzyme-mediated chemistry of the semi-isolated calcification pool” to explain skeletal isotope fractionation. Their study uses deep sea corals to avoid photosynthetic-induced variation. Calcium enters the coral’s calcicoblastic cell either through the ambient seawater or by mediation by the enzyme Ca-ATPase (Figure 1). This enzyme serves to create a pH gradient, allowing hydrogen ion transfer out of the cell wall. The pH and pCO_2 gradients create the fractionation in both oxygen and carbon isotopes. For carbon, when the pH is high in the ECF, there is little carbon and the skeleton is more in equilibrium with the incoming carbon. $\delta^{18}\text{O}$ is also dependent on the ECF’s pH because the $^{18}\text{O}/^{16}\text{O}$ depends on dissolved inorganic carbon speciation (H_2CO_3 , HCO_3^- , CO_3^{2-}), in which each species is offset differently from δ_{water} . The transfer of CO_2 is less restricted, as it is uncharged, but requires a hydration step to be precipitated into the carbonate. This step is kinetically the slowest and therefore has a significant

kinetic fractionation factor, which is important if precipitation occurs faster than the system can equilibrate (Adkins et al., 2003).

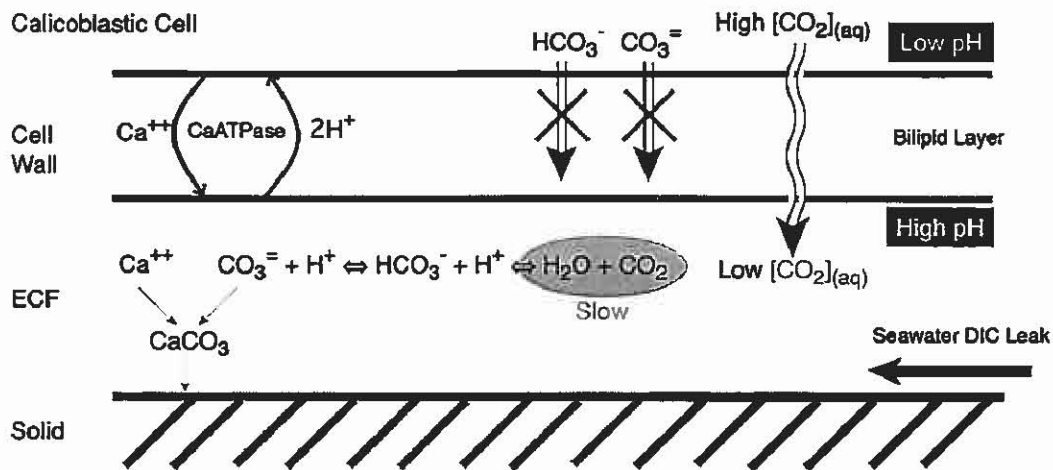


Figure 1: Figure taken from Adkins et al. (2003) showing the calcifying region and the mechanism of calcium incorporation, mediated by the enzyme Ca-ATPase.

In addition to kinetic fractionation, metabolic fractionation through photosynthesis and respiration causes an offset in $\delta^{13}\text{C}$ in dissolved inorganic carbon in seawater, from which the coral draws to calcify. Positive offset (increased carbonate $\delta^{13}\text{C}$) results from photosynthesis and negative offset (decreased carbonate $\delta^{13}\text{C}$) from respiration (Fairbanks and Dodge, 1979; McConnaughey, 1989). The positive offset from photosynthesis results from zooxanthellae increasing uptake of $^{12}\text{CO}_2$, leaving greater concentration of $^{13}\text{CO}_2$ for coral calcification from the dissolved inorganic carbon pool. When the photosynthesis to respiration ratio decreases, fractionation decreases, and respiration increases the amount of ^{12}C (Swart et al., 1996).

C. Measuring Stable Isotopes

The stable isotopic composition of carbonate is measured using mass spectrometry. The mass spectrometer is based on the principle that lighter atoms will have a greater deflection in a magnetic field than heavier atoms (Clark, 2000). Mass is determined by the machine, which detects ions at specific velocities from a detector plate. The atoms are first ionized in an ionization chamber by removing electrons onto a positively charged electron trap after being bombarded with electrons from a metal coil, giving the ion a positive charge. The positively

charged ions are forced from the ionization chamber by repulsion with the positively charged electron trap. The ions are accelerated to equal kinetic energies ($KE=1/2mv^2$). They are then focused through three metal slits with decreasingly less voltage. The ions encounter a magnetic field and are deflected based on their mass and the size of their charge, giving a mass/charge ratio. Electron beams that are deflected too far to pass through to the detector are neutralized by electrons near the wall. These ions are detected by altering the magnetic field. Ion beams that reach the detector are balanced with electrons from the detector. The electrons that leave the box to neutralize the protons create space within the wire of electrons. These leftover electrons are mobilized by the empty space and as they move, they create an electric current, which can be detected. The detector creates a graph of the relative current amplitudes for each m/z (charge-to-mass ratio) detected (Clark, 2000).

D. Strontium/Calcium

The aragonite secreted by corals to form their skeletons consists of both Sr and Ca. The relative abundances of each depend on the Sr/Ca of the ambient sea water and the distribution coefficient of Sr/Ca between seawater and aragonite, which is influenced by seawater temperature (Beck et al., 1992). Beck et al. (1992), using in situ SST measurements and $\delta^{18}O$, reports that this technique can have a precision of ± 0.05 °C.

Weber (1973) suggests that the relationship between temperature and Sr/Ca reflects Sr incorporation's dependence on calcification rate, which increases with higher temperatures. From an experiment testing the dependence of coral Sr/Ca on salinity changes, nutrients, light and other variables, Smith et al. (1979) reports no dependence of Sr/Ca on any other variables apart from temperature and the Sr/Ca of the calcifying fluid. By examining the *Pocillopora damicornis* coral they report a Sr/Ca ratio change of 8×10^{-5} mmol/mol per °C. The compositions of the calcifying fluid and that of seawater are different. There is an inverse correlation of Sr/Ca ratio to temperature, indicating that the calcifying fluid's Sr/Ca ratio is most similar to the ratio in seawater during the coldest months of the year. During summer, the calcifying fluid is enriched with the calcium cation by 50 %, while in the winter it is depleted by 50% (Smith et al., 1979; Gaetani and Cohen, 2006).

Research conducted since the Smith et al. (1979) study shows other variables affecting the coral Sr/Ca, which prevents a purely temperature-dependent signal. A study by Gaetani and Cohen (2006) shows that the vital effect also affects the Sr/Ca of corals. The partition coefficient for the strontium cation between the calcifying fluid and aragonite is greater than the coefficient for the calcium cation. Therefore with increasing aragonite precipitation from the calcifying fluid, the Sr/Ca ratio of the aragonite will decrease (Saenger et al., 2008). Cohen and Thorrold (2007) also suggest that Sr/Ca ratios may have an indirect dependence on temperature via Rayleigh fractionation. In addition to vital effects and fractionation, Cohen and Thorrold (2007) cite growth patterns as a possible culprit for variability in Sr/Ca ratios.

Meibom et al. (2003) observes monthly oscillations of Sr/Ca in samples of *Porites lutea*. Finding that the Sr/Ca oscillations are seasonal and larger than predicted by SST, they propose that the oscillations are caused by spawning and larval release cycles, which affect the coral's metabolism by averting nutrients from calcification sites. These processes are affected by lunar cycles and take place in the warmest months (highest SST), which are associated with maximum coral growth and are indicated by higher amplitude oscillations. They are also associated with low Sr/Ca ratios, consistent with observations that temperature and Sr/Ca ratios are inversely related (Meibom et al., 2003; Cohen and Thorrold, 2007).

E. The Effects of the Amazon and Orinoco Rivers on Barbados Water Chemistry

Two South American Rivers have a potential influence on the temperature and salinity recorded in Caribbean corals. The Amazon and Orinoco Rivers account for 10% of riverine outflow to oceans globally (Figure 2). They have a recordable effect on the salinity signature in the South Atlantic and Caribbean Oceans (Moses and Swart, 2006). The Orinoco floods in August and September due to the Intertropical Convergence Zone (ITCZ) movement northward and the maximum of the South American Monsoon (Moses and Swart, 2006). The ITCZ is defined as a zone of increased precipitation centered around the equator where the trade winds converge over a low-pressure zone (Linsley et al., 1994). It is the furthest north in January and furthest south in July. The increased precipitation makes the $\delta^{18}\text{O}$ of seawater relatively lighter (Linsley et al., 1994). Atlantic Ocean currents transport the source water. The plumes reach greater than 100 km in width and continue to the Atlantic for 1000 km. The Amazon then joins

the North Equatorial Countercurrent, and the Orinoco reaches Puerto Rico by October. Immediate consequences of the freshwater plume include algal blooms and flux of nutrients and organics in the Caribbean and tropical Atlantic (Muller-Karger et al., 1995). Riverine water is also more saturated with respect to $p\text{CO}_2$ than oceanic water and acts to increase the acidity of the affected ocean water (Salisbury et al., 2008). The North Brazil Current is the main current originally transporting the plume. It shifts east to the Equatorial Countercurrent between July and January and northwest in the spring (Hellweger and Gordon, 2002 and Figure 2). It is responsible for transporting the shallow, warm South Atlantic waters northward in exchange for the colder deep waters of the Meridional Overturning Cell (MOC), which is transported to the south by the Atlantic Branch of the MOC (Johns et al., 2001). Paris et al. (2002) observed that the North Brazil Current (NBC) rings upstream of Barbados capture Amazon water, transporting it to Barbados' west coast via the Guyana current up to 4 or 5 times annually (Paris et al, 2002).

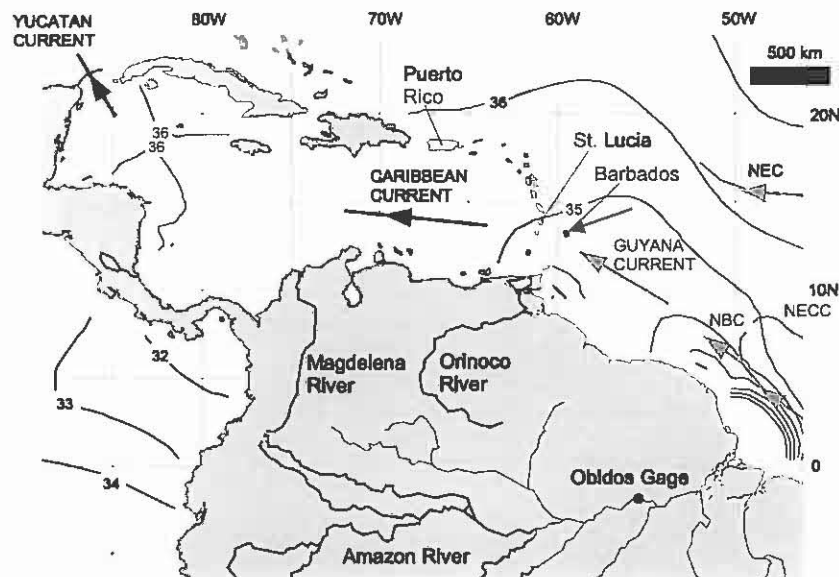


Figure 2: Map modified from Hellweger and Gordon (2003), showing the ocean currents and riverine flow past Barbados.

Eighteen hundred kilometers from the Amazon mouth, Barbados is an ideal location to study the reach of riverine outflow (Figure 2). Evidence of Amazon water decreases with increasing distance from Barbados towards the Caribbean. Upstream of the island, the NBC retroflexion pattern distorts the clear trace of Amazon outflow (Hellweger and Gordon, 2002). The Amazon alone accounts for 60% of Caribbean freshwater, and although the Orinoco outflow

has an inverse signal to the salinity off Barbados, the Amazon is shown to be a more significant driver of sea surface salinity off the island (Hellweger and Gordon, 2002). With a 70-80 day lag to account for travel time, the Amazonian discharge correlates to a salinity decrease off Barbados (Hellweger and Gordon, 2002). Deuser et al. (1988) observed a decrease in salinity between December and August from 35 ‰ to 30 ‰, aligning with the peak Amazon discharge between May and June, and the origination of the plumes between August and November (Deuser et al., 1988; Hellweger and Gordon 2002). Muller-Karger et al. (1995) also observed a decrease in salinity from July values (20.5 to 24.5 psu) to September values (31 and 32 psu).

Tracing salinity changes can serve as a proxy for tracing riverine water. The acidity of this water contributes to the increasing environmental stress on corals. De'ath et al. (2009) reports a 14.2% decrease in coral skeletal calcification due to physiological stress from climate change and ocean acidification. The Global Coral Reef Alliance (2007) also illustrates the rising threat of global warming and disease on the health of corals. The average sea surface temperature near Barbados has been steadily increasing over the past 30 years to an average of 28°C. This study focuses on decreased salinity from riverine outflow, which, with global warming and ocean acidification, poses a serious hazard to Caribbean corals.

II. Methods and Materials

A. Study Site

At 13° 5'N, 59° 32'W, Barbados is the easternmost island of the Caribbean, lying 150 km east of the Lesser Antilles (Figure 3). Corals in this study were collected from the west coast of the island, which is the lee side of the island and has considerably calmer water when compared to the east coast. Sample sites, indicated in Figure 3, were chosen in the northern, middle, and southern portions of the coast to sample the potential impacts of eddies circulating around different parts of the west coast on water quality. Samples were taken from Maycox Inner, Sunset Crest, Bellairs, and Accra between June 27 and July 1, 2009 (Figure 3).

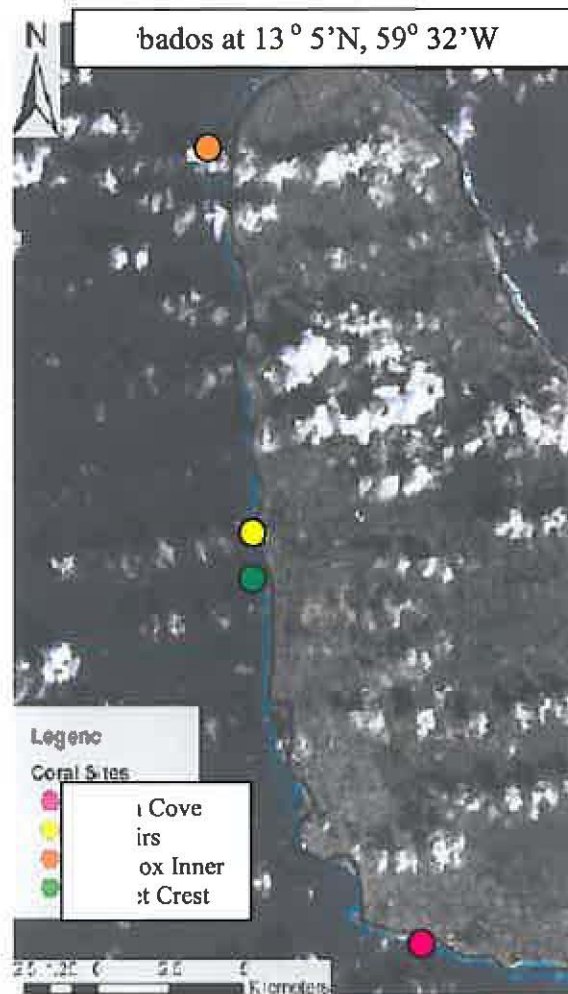


Figure 3: Location of sample sites off the West Coast Barbados (Google-modified map by Joe Stockmeyer). The pink circle is Accra, yellow is Bellairs, green is Sunset Crest, and orange is Maycox Inner. Sample Core IDs: Accra (AC4, AC7), Bellairs (BR2, BR3, BR8), Sunset Crest (SC1), Maycox Inner (MI5, MI6).

In situ temperature data is provided by the Coastal Zone Management of Barbados and the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Watch stations. CZM gives just one or two in situ temperature and salinity measurements per year for comparison, while NOAA's temperature dataset is twice weekly from 2000-2010. The NOAA sampling site is 13° N 60° W, which is just west of the study's sampling sites and closest to Accra.

B. Sample Collection

Eight cores of *Montastrea annularis sp. complex* and *Siderastrea sidera sp. complex* were collected using SCUBA and a pneumatic hand drill at each site (Appendix A). The drill consisted of metal barrels attached to a drill gun and powered by an oxygen tank. One *Montastrea sp.* core (MI5) and one *Siderastrea sp.* core (MI6) were collected from the north, two *Montastrea sp.* cores (BR2 and BR3) and one *Siderastrea sp.* core (BR8) were collected from Bellairs, one *Siderastrea sp.* core (SC1) was collected from Sunset Crest, one *Montastrea sp.* core (AC4) and one *Siderastrea sp.* core (AC7) were collected from Accra (Figure 3). Temperature and salinity measurements of surface water and water at sample depth (collected at sample site in 2L Sprite bottles) were taken with a refractometer. Additionally, three polyethylene bottles at each site were rinsed 3 times with sampled water before being filled to the threads. The bottle to be tested for $\delta^{18}\text{O}$ had only the sample, the bottle for Sr/Ca sample had a few drops of HCL, and the bottle for $\delta^{13}\text{C}$ analysis had powdered mercuric chloride (Appendix A).

C. Growth Rate and Geochemical Analysis

C1. X-Radiograph Analysis

Cores were prepared for x-radiograph analysis with a hydraulic carbonate saw by cutting cores into thin (2-5 mm) slices (Figure 4). X-rays were taken at the Virginia Institute of Marine Science (VIMS) sedimentology lab. X-ray exposure times varied according to the thickness of coral slices and ranged from 0.03 sec - 0.12 sec. To scale the negatives, we measured the length of the core and took three width measurements to get a proportionality constant and sized the images accordingly using Image J software. Negatives of the x-rays were traced onto transparencies and density bands were measured with a caliper to determine growth rates (Figure 5).



Figure 4: Hydraulic carbonate saw used to slice coral cores into slabs for x-radiograph analysis.

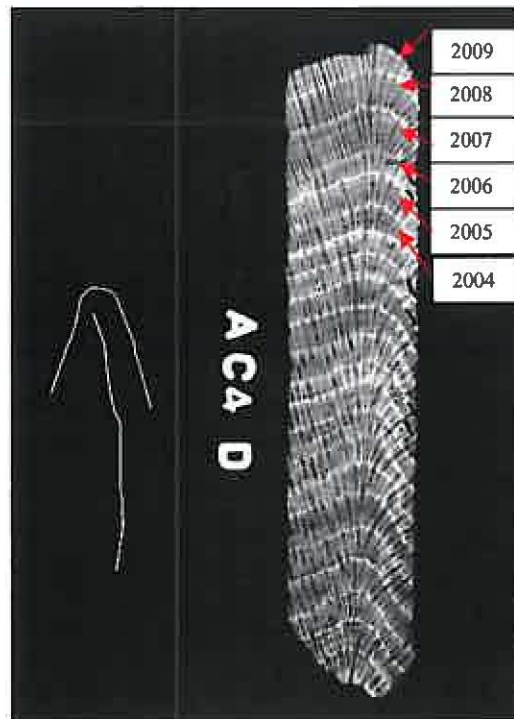


Figure 5: X-radiograph of coral slice AC4-D, showing the annual density bands from 2004-2009.

C2. Mass Spectrometer Analyses

Powder samples for mass spectrometer analysis were collected using a MerchanteK micromill at intervals determined from growth rates to obtain approximately 12 samples per coral year. Samples were taken only from the exothecal wall to prevent variability of $\delta^{18}\text{O}$ and Sr/Ca measurements due to skeletal location differences (Saenger, 2006). The depth of the drill run ranged between 1000-3000 μm . A ThermoQuest Finnigan delta plus mass spectrometer at the University of Miami's Rosenstiel School of Marine and Atmospheric Sciences (RSMAS) was used for $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ measurement.

To prepare samples for the mass spectrometer, they are combined with orthophosphoric acid, which reacts to CO_2 and H_2O at 75°C . The temperature is important because fractionation of the carbonate oxygen to CO_2 depends on temperature. The Kiel Autocarbonate Device automatically prepares the carbonate sample, injects the CO_2 necessary for the Mass Spectrometer, and sets the reaction time (Adkins et al 2003). The values for oxygen are compared to two standards: the Vienna Standard Mean Ocean Water (VSMOW) of 0.0 ‰ and the Pee Dee Belemnite (PDB) formation (Patterson, 2003). The PDB standard is used for both carbon and oxygen stable isotopic compositions because they are based off a carbonate fossil (CaCO_3), which includes both carbon and oxygen. Samples are reported relative to the lab standard OCC, and corrected to PDB using an isocorrect macro. The use of a standard accounts for variances between machines. Machine error variable is accounted for in a drift correction to account for fractionation of the CO_2 within the machine.

To calculate temperature, an equation converting carbonate values to SMOW and then converting to PDB is used:

$$T^\circ\text{C} = 5.33 - 4.519 (+/- .19) (\delta\text{c} - \delta\text{w}) \text{ (eq 4) (Leder et al, 1996).}$$

Annual cycles were observed from the $\delta^{18}\text{O}$ and temperature plots, and $\delta^{18}\text{O}$ minima and temperature maxima were interpreted as August. The points in between August were fixed to be evenly spaced throughout the year. The year interpolations were then checked against the x-rays taken at VIMS. We overlaid transparency paper over the x-rays and marked the drilled line

and the light bands, indicating years of growth. The two sets of interpolations matched, except AC7, which shows 4 years from the isotope data and 5 years from the x-ray. The *Siderastrea sp.* growth bands are generally less distinct than those of the *Montastrea sp.*, making the interpolation for the *Siderastrea sp.* potentially less accurate.

C3. ICP-OES Analyses

Inductively coupled plasma optical emission spectroscopy (ICP-OES) is a destructive technique that determines the composition and concentration of cations. It uses plasma to ionize the atoms in the liquid sample and measures the intensity of the emitted spectra when the excited atoms returns to ground state (Varnes, 1997).

Strontium and calcium concentrations are determined using the ICP-OES at RSMAS. A calibration curve is constructed based on a blank solution of Yttrium and nitric acid and a standard. The calibration standard is determined based on the expected concentrations of Sr^{2+} and Ca^{2+} in a coral. Analysis requires an external standard in addition to an internal standard in order to compare results between laboratories. The external standard used at RSMAS is from the University of Southern Florida (Monica Arienzo, pers. comm., 2009). The emitted spectral lines are compared to the calibration curve to determine Sr^{2+} and Ca^{2+} concentrations. Sample preparation required diluting each sample with 5 mL of blank solution consisting of Yttrium and 5% nitric acid for a fast run and further diluting the sample according to its size for a more precise, slow run. Precision reported from RSMAS is between 0.15 – 0.18%.

III. Results

A. $\delta^{18}\text{O}$ Data

The $\delta^{18}\text{O}$ values for the 4 *Montastrea sp.* and 4 *Siderastrea sp.* samples are summarized in Figures 6 and 7. Sample variance within a species falls within a narrow range, with maximum values between -3.50 and -4.00 ‰ and minimum values between -4.50 and -5.00 ‰. In order to interpolate dates for the samples, minimum isotope data points are chosen to reflect August (low salinity and high temperature), in accordance with observations from Hellweger and

Gordon (2002). NOAA data also shows maximum temperatures in August and September (Figure 8).

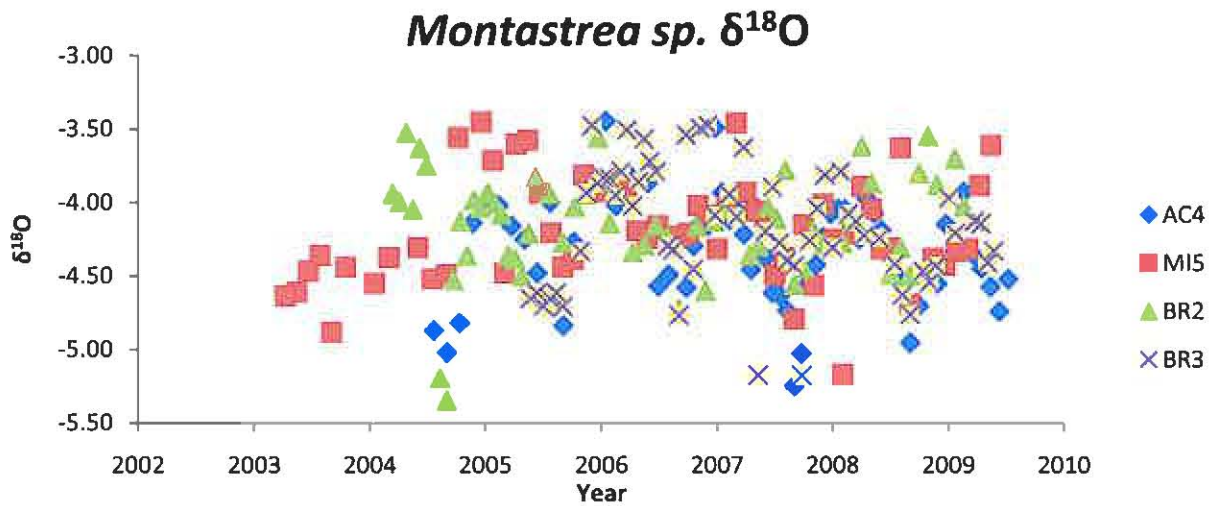


Figure 6: $\delta^{18}\text{O}$ values plotted from 2002 through 2010 for the *Montastrea sp.* samples. The samples have an annual minimum in August.

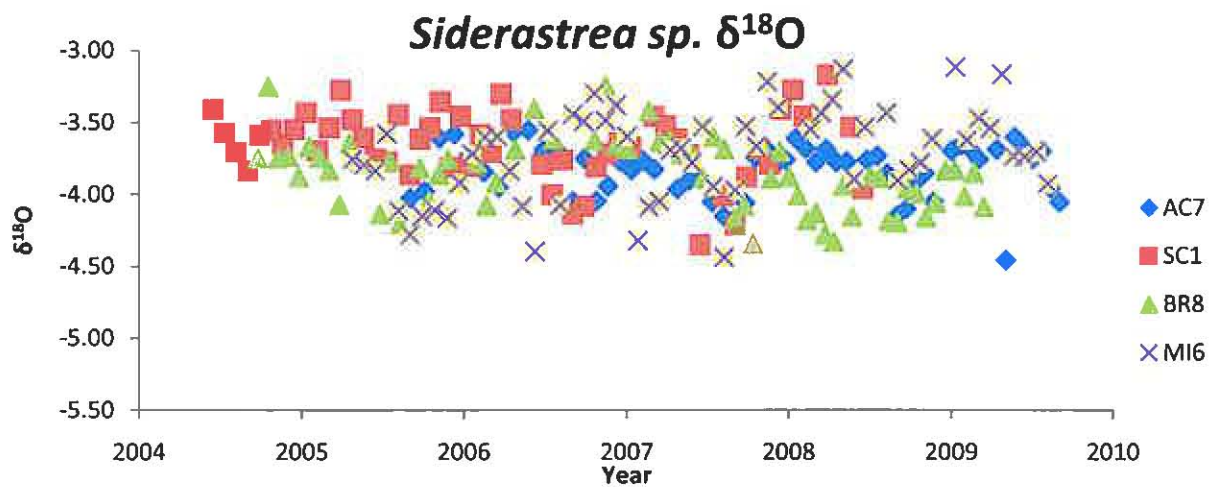


Figure 7: $\delta^{18}\text{O}$ values plotted from 2002 through 2010 for the *Siderastrea sp.* samples. The *Siderastrea sp.* samples have a much narrower range in isotopic values than the *Montastrea sp.* samples.

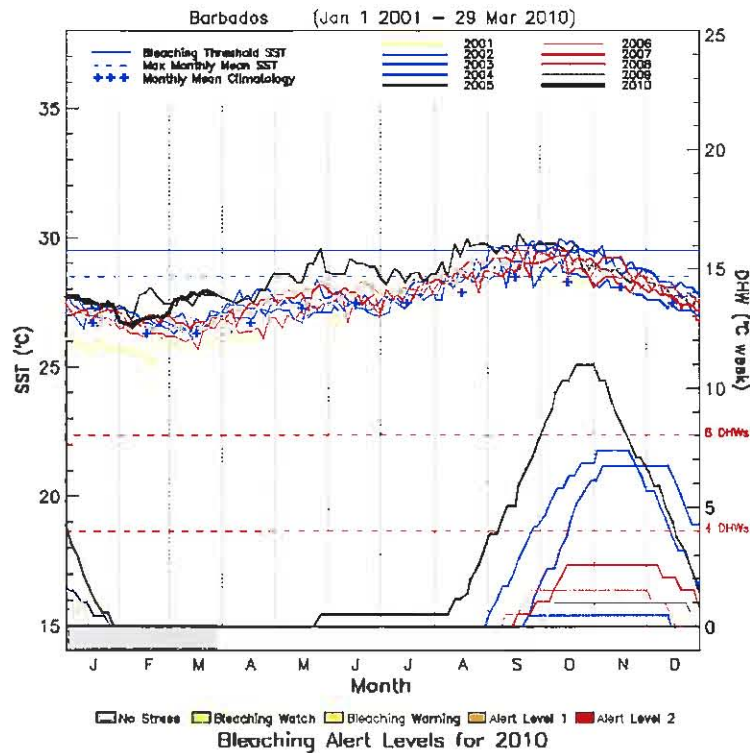


Figure 8: SST data from NOAA for 2010 (http://coralreefwatch.noaa.gov/satellite/virtual_stations/greater_caribbean.html#exp_Barbados). Maximum temperatures occur in August and September, and minimum temperatures occur in February.

Average $\delta^{18}\text{O}$ of Barbados Corals

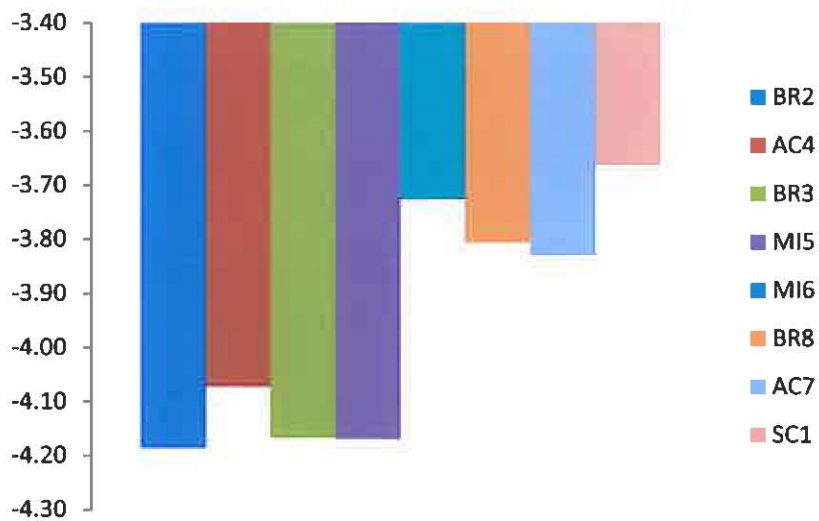


Figure 9: Average $\delta^{18}\text{O}$ values for all corals. AC4 sample period extends to 1988.

Average $\delta^{18}\text{O}$ for all samples are shown in Figure 9. The *Montastrea sp.* samples have more negative values by nearly -0.5‰ than the *Siderastrea sp.* The isotope results are summarized in Appendix B. This appendix includes the temperature and salinity estimates derived from the isotope data using paleotemperature equations from Leder et al. (2006), Moses et al. (2006), Maupin et al. (2008), and Ganssen and Kroon (2000). Precision for both $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ are reported from RSMAS as 0.1‰ . The average temperature values vary depending on the equation used both between species and within species (Table 1). The paleotemperature equation for *Siderastrea sp.* from Maupin et al. (2008) gives the highest temperature values of both *Montastrea sp.* and *Siderastrea sp.*, while the *Montastrea sp.* values are generally lower than those derived from either *Siderastrea sp.* equation. The range in calculated values for temperature within a sample varies from as low as 3°C up to a range of 20°C , indicating significant error in some samples (Table 1). Salinity averages are mostly around 28 psu for salinity derived from *Siderastrea sp.* $\delta^{18}\text{O}$ data. The salinity data from the *Montastrea sp.* are higher and more variable (Table 1).

		Temperature Leder (Mont) or Moses (Sid)	Temperature (2-Maupin)	Salinity	Temperature (Sr/Ca)
NORTH					
MI5	average	24.17		37.92	18.80
	range	18.25 - 28.69		23.09 - 45.92	9.46 - 25.44
MI6	average	26.94	28.79	28.43	25.15
	range	24.59 - 29.70	24.37 - 33.96	27.14-29.53	10.07 - 33.05
MIDDLE					
BR2	average	24.24		40.26	19.66
	range	17.97 - 37.87		34.18 - 45.94	17.05 - 24.46
BR3	average	24.16		34.37	17.84
	range	16.98 - 33.75		33.81 - 34.98	13.80 - 23.63
BR8	average	27.25	29.37	28.28	
	range	21.75 - 29.33	19.03 - 33.27	27.31-30.86	13.80 - 23.63
SC1	average	24.94	28.33	28.54	24.78
	range	24.80 - 29.36	24.77 - 33.33	27.30-29.43	4.29 - 32.64
SOUTH					
AC4	average	24.94		34.27	23.46
	range	20.90 - 37.87		22.83 - 45.94	3.57 - 25.44
AC7	average	27.34	29.53	28.24	25.86
	range	26.19 - 29.76	27.38 - 34.08	27.11-28.78	14.02 - 32.67

Table 1: Table summary of average temperature and salinity values using each equation.

B. Sr/Ca Data

Sr/Ca and the temperature derived from Sr/Ca for each sample are summarized in Appendix C. The temperatures derived from Sr/Ca measurements give lower average temperature values than of all the temperatures derived from $\delta^{18}\text{O}$ (Table 1; Figures 10 and 11). The average values for temperature derived from Sr/Ca are as low as 17.84 °C and the largest average is 25.86 °C.

The Sr/Ca data for *Montastrea sp.* are shown in Figure 10. The data are clustered between 9.0 and 9.5 mmol/mol, with values from AC4 noticeably less than the other values. However, AC7 is not significantly lower than other *Siderastrea sp.* values (Figure 11). There is a more cyclical trend observed from the *Siderastrea sp.* samples, with distinct light values at the beginning of every August. Both Accra samples (AC4 and AC7) show a particularly negative point in August 2008. Data from the Bellairs core BR8 is incomplete due to small sample size.

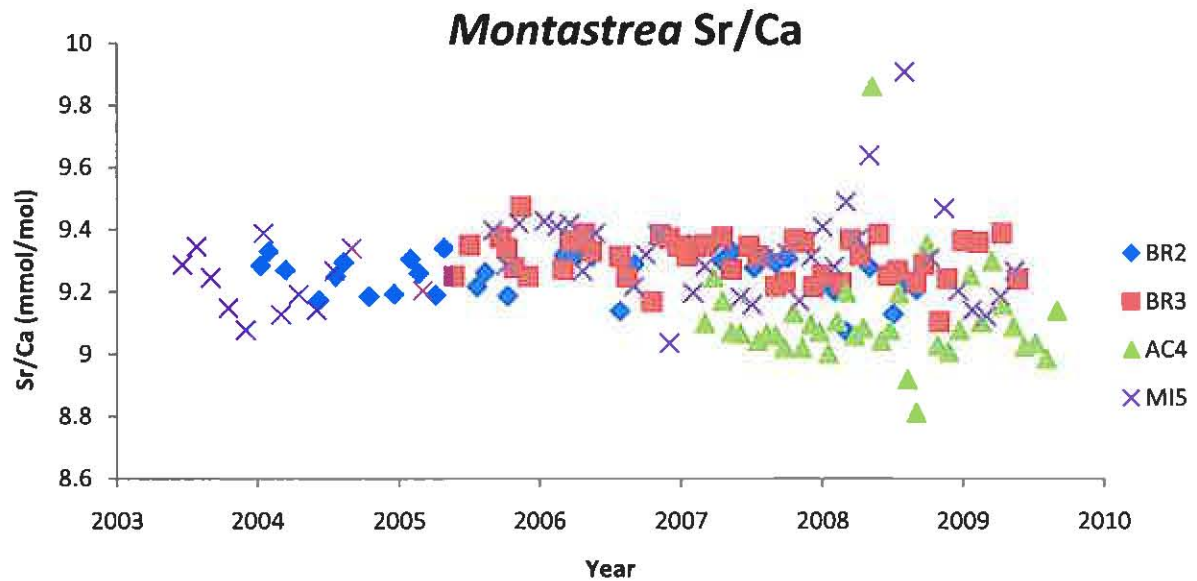


Figure 10: Sr/Ca from *Montastrea sp.* There is no clear cyclicality, and values from AC4 are lower than for the other samples.

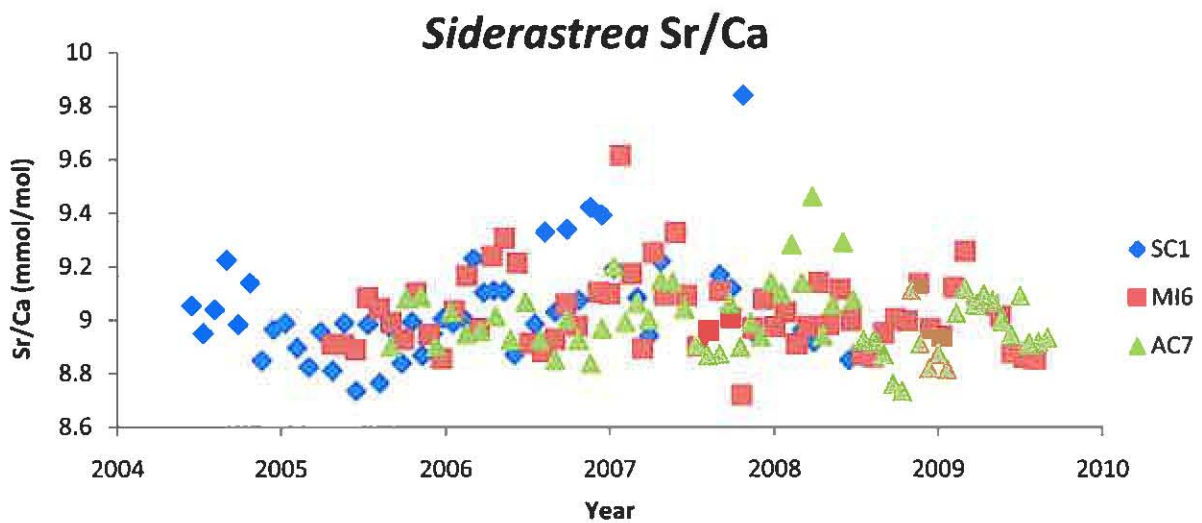


Figure 11: Sr/Ca from *Siderastrea sp.*, showing a better trend than the *Montastrea sp.* samples. The range of values is clustered at a lower Sr/Ca than the *Montastrea sp.*

C. $\delta^{13}\text{C}$ Data

The $\delta^{13}\text{C}$ for *Montastrea sp.* are summarized in Figure 12 and Appendix B. AC4 shows more negative values and shows a generally decreasing trend where data from the other samples increase beginning in 2007. All the samples show a dramatic decrease between mid-2006 and mid-2007. The $\delta^{13}\text{C}$ data for *Siderastrea sp.* are shown in Figure 13. MI6 is the only sample that captures the same decrease between 2006 and 2007 that the *Montastrea sp.* show. The same trend is observable between SC1 and BR8 (both from the middle), but there is little correlation between sampling sites. Average $\delta^{13}\text{C}$ values for all samples are shown in Figure 14 and Table 2. The middle cores show the heaviest averages with the north being the lightest, with the exception of MI6 being lighter than AC7. The *Montastrea sp.* samples show the greatest range in $\delta^{13}\text{C}$, while the *Siderastrea sp.* are mostly constrained between 0 and -2‰ .

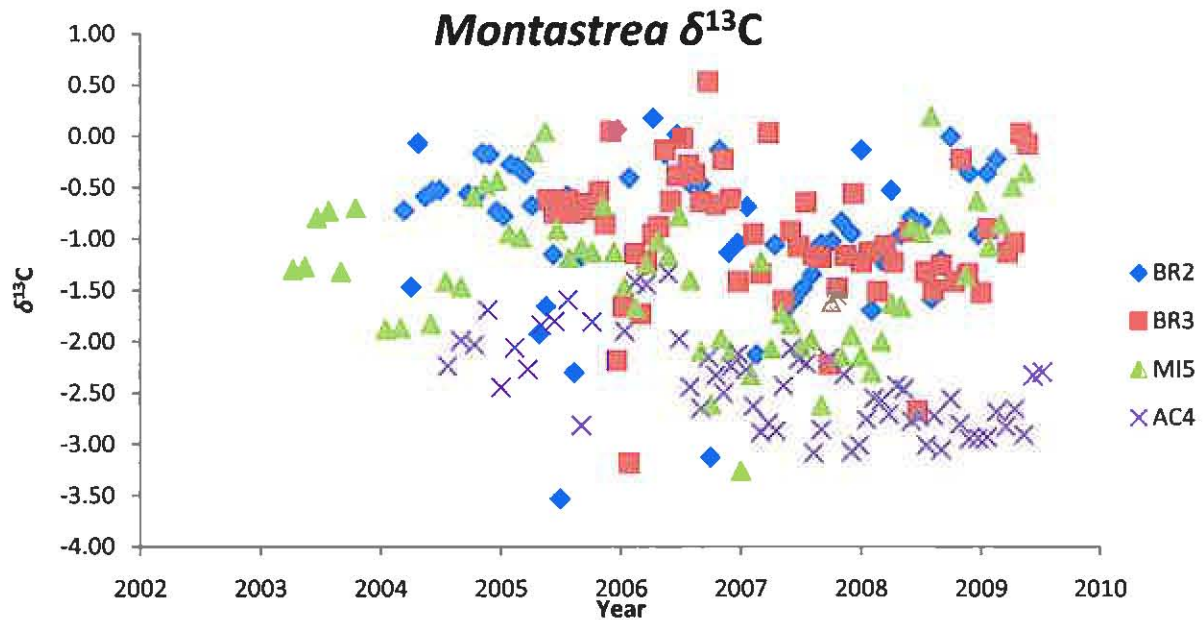


Figure 12: $\delta^{13}\text{C}$ values plotted from 2002 through 2010 for the *Montastrea sp.* samples. All of the samples show a decrease until 2008, in which all but AC4 spike more positively.

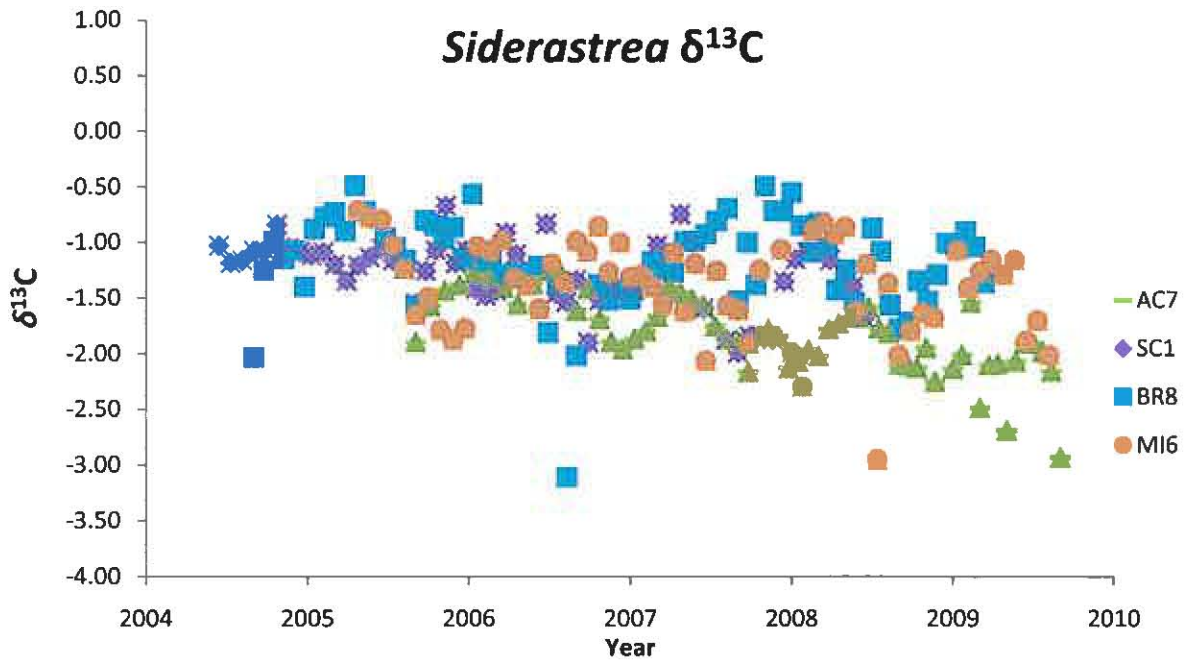


Figure 13: $\delta^{13}\text{C}$ values plotted from 2002 through 2010 for the *Siderastrea* samples. The *Siderastrea sp.* show a much cleaner resolution than the *Montastrea sp.* samples. AC7 shows the most significant decrease with time.

Average $\delta^{13}\text{C}$ for Barbados Corals

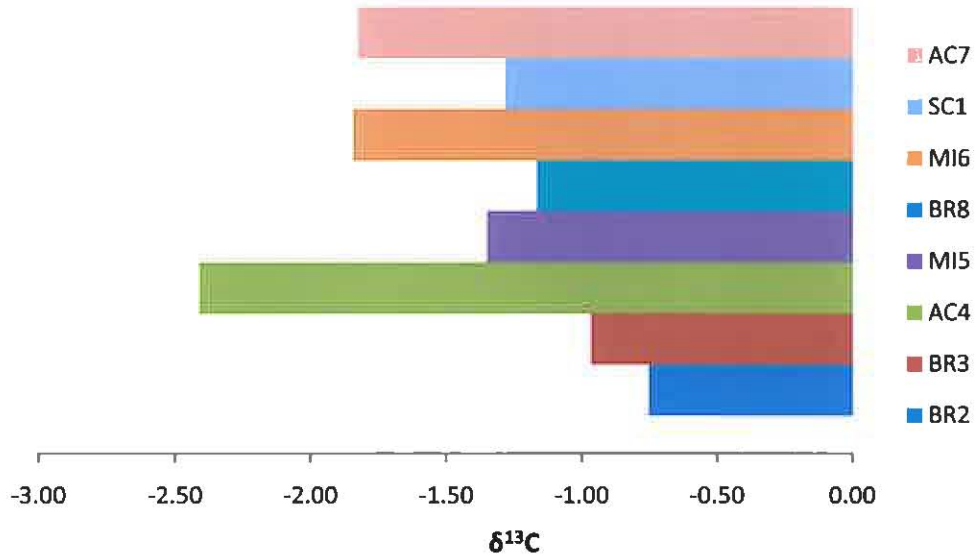


Figure 14: Average Carbon Isotope Values, 2004-2009

$\delta^{13}\text{C}$	Average	Range
MI5	-1.35	-3.26
		0.20
MI6	-1.35	-2.06
		-0.71
BR2	-0.75	-2.30
		2.99
BR3	-0.96	-3.19
		0.53
SC1	-1.28	-1.99
		-0.67
BR8	-1.12	-2.02
		-0.49
AC4	-1.85	-3.09
		0.04
AC7	-1.82	-2.93
		-1.25

Table 2: Average and range of $\delta^{13}\text{C}$ values for this study.

D. Skeletal Extension Rates

Growth rates were calculated manually using a caliper to measure bands on the x-rays taken at VIMS. Average extension rates for *Montastrea sp.* were 8.88, 8.07, 7.94, and 6.54 mm for whole cores of AC4, BR3, BR2, and MI5, respectively (Table 3). Over the length of the *Montastrea sp.* corals, growth rate has decreased on average, but in the last 10 years, growth rate has increased. The *Siderastrea sp.* cores show the reverse trend, with the exception of MI6, which decreases over the entire coral and in the past 10 years (Table 4).

	Change in Growth Rate (entire coral, mm/yr)	Growth Rate (1999- 2008, mm/yr)
AC-4-AVG	-0.0417	0.0783
BR-3-AVG	-0.0266	0.0405
MI-5-AVG	-0.0615	0.1376
BR-2-AVG	-0.0257	0.0919

Table 3: Change in growth rates for *Montastrea sp.*

	Δ Growth Rate (entire coral, cm/yr)	Δ Growth Rate (1999-2008, cm/yr)
SC-1-AVG	0.0016	-0.0058
MI-6-AVG	-0.0052	-0.0046
AC-7-AVG	0.0013	-0.0159

Table 4: Change in growth rates for *Siderastrea sp.*

E. Environmental Observations

Environmental observations, including reef condition, reef size and shape, surrounding plant and animal life, and on-site water measurements (temperature, salinity, pH, total dissolved solids, conductivity) are summarized in Appendix A. Many of the reefs are in poor condition. There is abundant algae and some yellow band disease among the reefs. During our collection at Accra, the current was especially strong, with green and murky water, which the Bajans attribute to the arrival of Amazon water.

IV. Discussion

The combination of $\delta^{18}\text{O}$ and Sr/Ca is used to determine the relative influence of δ_{seawater} , temperature, and salinity components on $\delta^{18}\text{O}$. Applications of this method have been used to trace water chemistry changes due to ENSO events, glacial events, or freshwater inputs (McCulloch et al., 1994; de Villiers et al., 1995; Alibert and McCulloch, 1997). Changes in coral $\delta^{18}\text{O}$ not attributable to temperature are a result of changing seawater $\delta^{18}\text{O}$ from either precipitation or freshwater influx (McCulloch et al., 1994). This study attempts to use the temperature derived from Sr/Ca to strip out the temperature component of $\delta^{18}\text{O}$ in order to determine the salinity effects on $\delta^{18}\text{O}$ of these corals. The results show both spatial and temporal variations in temperature and salinity. This variance could be due to the arrival of the North Brazil Current Rings transporting South American River water past Barbados, as the variance coincides with the peak outflow from the Amazon and Orinoco Rivers adjusted for lag time.

A. Paleotemperature Equations

There are various coral paleotemperature equations that have been calibrated for each species to derive SST and sea surface salinity (SSS). Weber and Woodhead (1972) show that, with the appropriate equation to account for each species' 'vital effect', a linear relationship between $\delta^{18}\text{O}$ data and temperature exists. The most appropriate preexisting equation used depends on the species of coral and the isotopic composition of the water at the location used for calibration (Weber and Woodhead, 1972; Fairbanks, 1982; Table 5). The equations for both temperature and salinity used in this study for the *Montastrea sp.* are taken from Leder et al. (1996):

$$T\text{ }^{\circ}\text{C} = 5.33 - 4.519 (+/- .19) * (\delta_c - \delta_w) \quad (\text{eq 4})$$

$$\text{Salinity} = 35 + 0.2 * \delta_w \quad (\text{eq 5})$$

$$\delta_w = \delta^{18}\text{O} - (5.33 - T_{\text{Sr/Ca}}) / 4.519 \quad (\text{eq 6})$$

The average $\delta^{18}\text{O}$ *Montastrea sp.* values from this study are more negative than the average value from the four corals used in the Leder et al. (1996) study: -4.07- -4.19 ‰ (this study) versus -3.74-3.96 ‰ (Leder et al., 1996). The Leder et al. (1996) study examines corals from 1988-1991, which, when the $\delta^{18}\text{O}$ is compared to the AC4 average (-3.60) from that time, is actually more negative. This variation may result from either sampling error or a variation between the Barbados and Florida sampling sites in temperature and salinity. If sampling variances are negligible, then the more negative values represent either the warmer temperatures of Barbados waters and/or decreased salinity from the riverine influence.

Sr/Ca		
Equation	Source	Location
$Sr/Ca * 103 = 10.48 - 0.0615 * T$	Allbert and McCulloch, 1997	Davies Reef, ~19S, Great Barrier Reef
$Sr/Ca * 103 = 10.72 - 0.0624 * SST$	Beck et al., 1992	Noumea and Tahiti
$T(^{\circ}C) = -10.08(+/-0.38) * Sr/Ca(mmol/mol) + 114.53(+/-3.14)$	Cohen and Thorrold, 2007	John Smith Bay, Bermuda
$Sr/Ca(atomic) * 103 = 10.956 - 0.07952 * T$	de Villiers et al., 1994	Hawaiian and Galapagos islands
$Sr/Ca = 10.008 - 0.039 * SST$	Maupin et al., 2008	Dry Tortugas, Florida
$Sr/Ca(atomic) = 0.00030 * \delta^{18}O + 0.0104$	McCulloch et al., 1994	Pandora Reef, Great Barrier Reef
$Sr/Ca(mmol/mol) = 10.165 + 0.0471 * SST(^{\circ}C)$	Swart et al., 2002	Bahamas
$Sr/Ca = 9.722 + 0.2 * \delta^{18}O$	Swart et al., 2002	Bahamas
$Sr/Ca = 9.994 - 0.0377 * SST$	Swart et al., 2002	Bahamas
$\delta^{18}O$ water and $\delta^{18}O$ coral		
Equation	Source	Location
$T = 16.9 - 4.21 * (\delta_c - \delta_w) + 0.14 * (\delta_c - \delta_w)^2$	Craig, 1965	modified from Epstein et al., 1953
$\delta^{18}O_{water} = 0.273 * salinity(psu) - 9.14\text{‰}$	Fairbanks et al., 1997	Tropical Pacific network of coral sites
$\delta^{18}O = 0.442 * S - 15.55$	Fairbanks, 1982	North of Gulf of St. Lawrence
$\delta^{18}O = 0.421 * S - 14.66$	Fairbanks, 1982	Maine surface water and intermediate water
$\delta^{18}O = 0.258 * S - 9.14$	Fairbanks, 1982	NY Bight Surface and Cold Pool
$Salinity = (\delta^{18}O + 19.448) / 0.53302$	Ganssen and Kroon,	Mid Atlantic
$\delta^{18}O_{water} = \delta^{18}O_{coral} + 0.22 * T - 3$	Halley et al., 1994	Hen and Chickens Reef, Florida
$T(^{\circ}C) = 5.33 - 4.519 * (\delta_c - \delta_w)$	Leder et al., 1996	Florida
$\delta^{18}O = 0.247 - 0.138 * SST$	Maupin et al., 2008	Dry Tortugas, Florida
$SST = 12.56 - 3.86 * (\delta_c - \delta_w)$	Moses et al., 2006	Cape Verde Islands

Table 5: Paleotemperature equations for deriving temperature and salinity from Sr/Ca and $\delta^{18}O$. Equations used in this study are highlighted in red.

Siderastrea sp. temperature calibrations are taken from both Moses et al. (2006) and Maupin et al. (2008):

$$T(^{\circ}C) = 12.56 - 3.86 * \delta^{18}O \quad (\text{eq 7}) \quad (\text{Moses et al., 2006})$$

$$T(^{\circ}C) = (\delta^{18}O - 0.247) / -0.138 \quad (\text{eq 8}) \quad (\text{Maupin et al., 2008})$$

The temperature values produced by the two *Siderastrea sp.* equations give similar patterns, but the equation from Moses et al. (2006) produces consistently lower temperatures than the equation from Maupin et al. (2008) by an average of two degrees Celsius. This offset may result from the different study sites of the calibrations. Maupin's study uses corals from

Dry Tortugas, Florida, while Moses' study is off the Cape Verde Islands, which has negligible terrestrial runoff (Moses et al., 2006). The Dry Tortugas, like Barbados, is affected by eddy circulation and receives the freshest water and warmest temperatures beginning in the early fall. Additionally, the temperature results yielded from Maupin's study most similarly match SST data from the Coastal Zone Management in Barbados.

Salinity values from *Siderastrea sp.* $\delta^{18}\text{O}$ are taken from Ganssen and Kroon (2000) :

$$\text{Salinity} = (\delta^{18}\text{O} + 19.448) / 0.533025 \text{ (eq 9)}$$

The salinity measurements for the *Siderastrea sp.* are on average around 28 psu. Salinity measurements from CZM are much higher, between 32.61 psu and 34.48 (Appendix D). This may result from the difference in the isotopic signature between the corals in our study and the foraminifera in their study. The samples used in the Ganssen and Kroon (2000) study have $\delta^{18}\text{O}$ values between -0.2 ‰ and 1.0 ‰ .

B. Temperature

Temperature derived from the *Montastrea sp.* $\delta^{18}\text{O}$ data shows an annual cycle with the lowest temperature in August and the highest temperature between late December and March (Figure 15). Temperature derived from the *Siderastrea sp.* is, on average, $4.04 \text{ }^\circ\text{C}$ higher than the temperature from *Montastrea sp.* using the equation from Maupin et al. (2008) and $1.53 \text{ }^\circ\text{C}$ using the equation from Moses et al. (2006) (Figure 16). The annual temperature signal is much less clear with the *Siderastrea sp.* samples and any visible cyclicity essentially degrades prior to 2006.

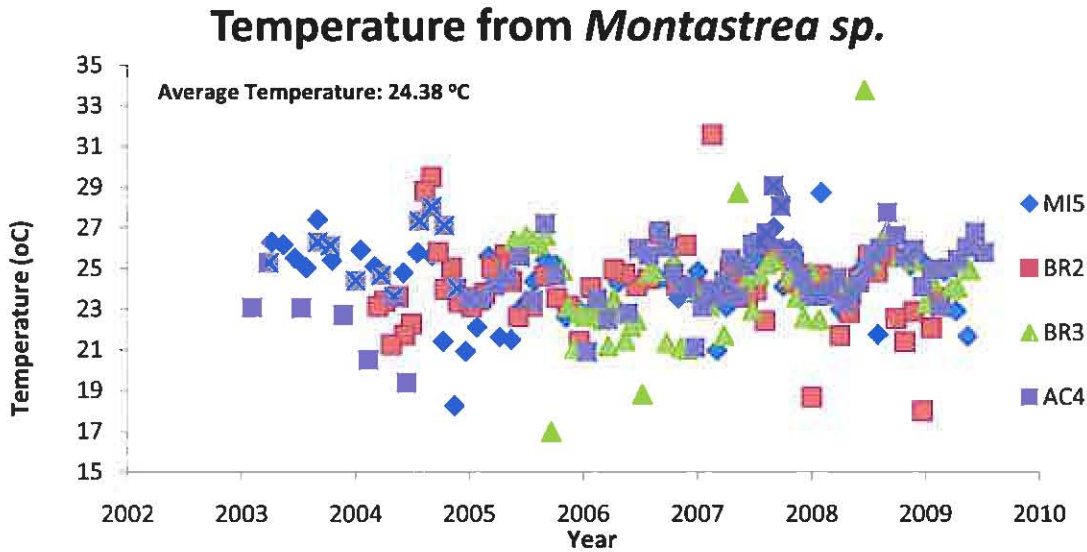


Figure 15: $\delta^{18}\text{O}$ -derived temperature for all *Montastrea sp.* samples. The lowest temperatures are in August and the highest temperatures are between late December and March.

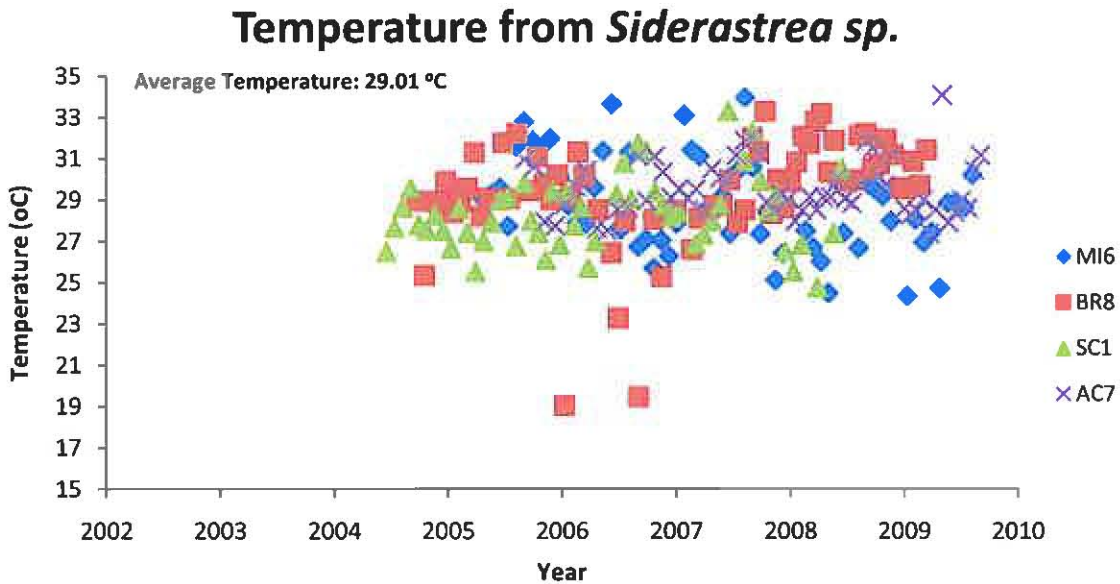


Figure 16: $\delta^{18}\text{O}$ -derived temperature for all *Siderastrea sp.* samples, using the equation from Maupin et al. (2008). The temperatures are higher than those derived from the Leder et al. (2006) equation for *Montastrea sp.*

The $\delta^{18}\text{O}$ -derived temperature is compared to the in situ SST data provided by NOAA and CZM. In the north (samples MI5 and MI6), there is little correlation between the CZM data and the temperature calculated from MI5, but MI6 shows the same peaks and is much closer to the in situ data (Figures 17 and 18). Samples BR2 and BR3 from Bellairs give much lower $\delta^{18}\text{O}$ -

derived temperature than the in situ data provided by CZM, and the peaks are offset. The *Siderastrea sp.* sample from Bellairs (BR8) is less offset from the in situ data than either BR2 or BR3, but two of the four CZM samples do not align with BR8 peaks (Figure 19 and 20). The NOAA dataset is much more comprehensive than that provided by CZM, but the sampling location is closest to the Accra sampling site. The Accra samples (AC4 and AC7) show a similar cyclicity to the in situ data provided by both NOAA and CZM, though there is an offset (Figure 21). The similarity in the temperature patterns of in situ data and $\delta^{18}\text{O}$ -derived temperature with a consistent offset between absolute values indicates that there is another driver of the $\delta^{18}\text{O}$ signal that is not solely dependent on temperature.

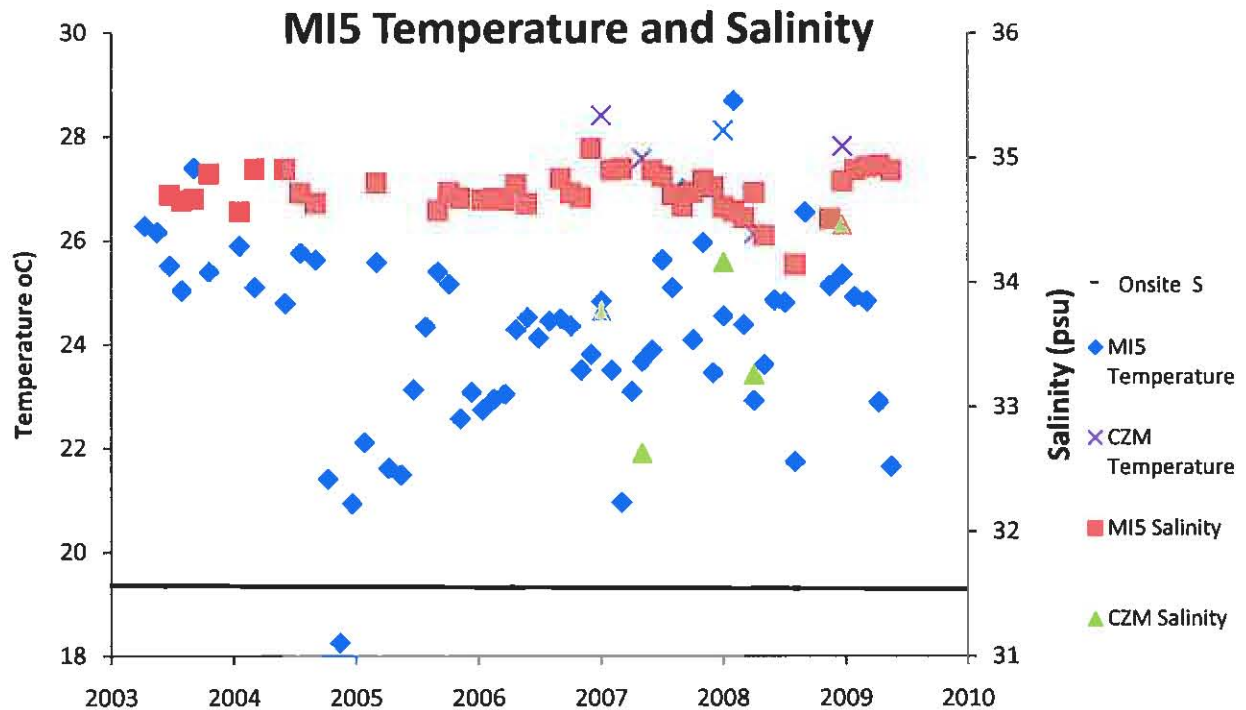


Figure 17: $\delta^{18}\text{O}$ -derived Temperature and Salinity from MI5 and in situ temperature and salinity data from CZM. Temperature is plotted on the left axis and salinity is plotted on the right axis. There is little correlation between the in situ data and the calculated data, though the relative peaks occur at the same time. The black line indicates the average salinity from onsite measurements.

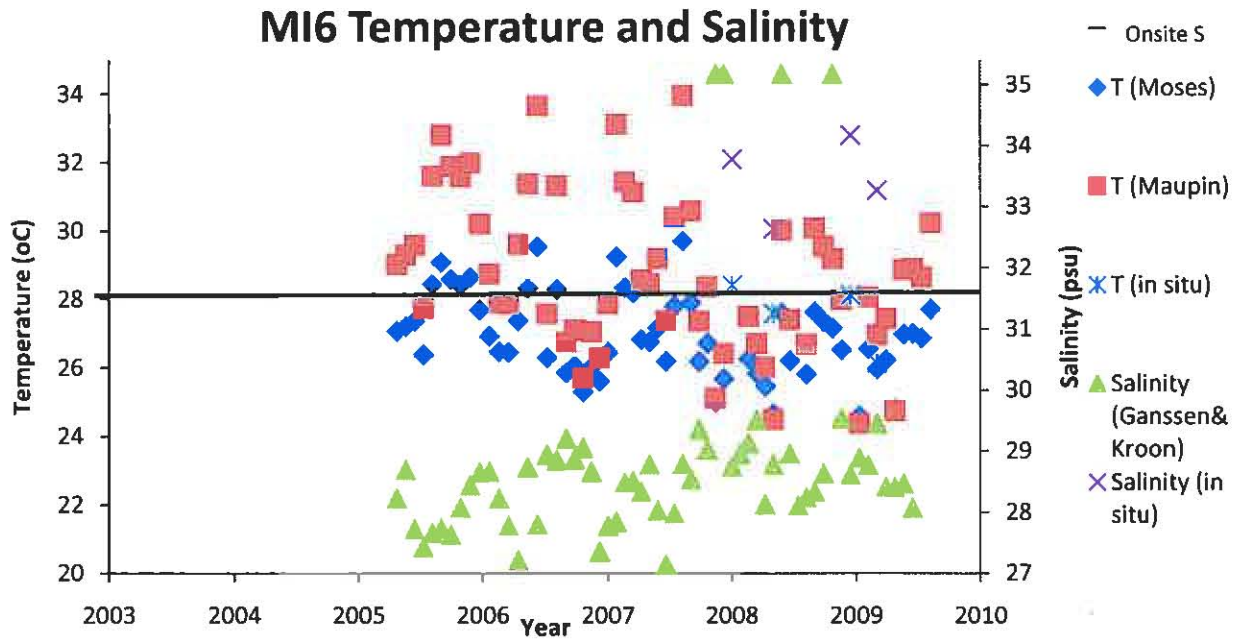


Figure 18: $\delta^{18}\text{O}$ -derived Temperature and Salinity from MI6 and in situ measurements from CZM. The calculated salinity data is significantly less than the in situ data, while the calculated temperature is much higher than the in situ data.

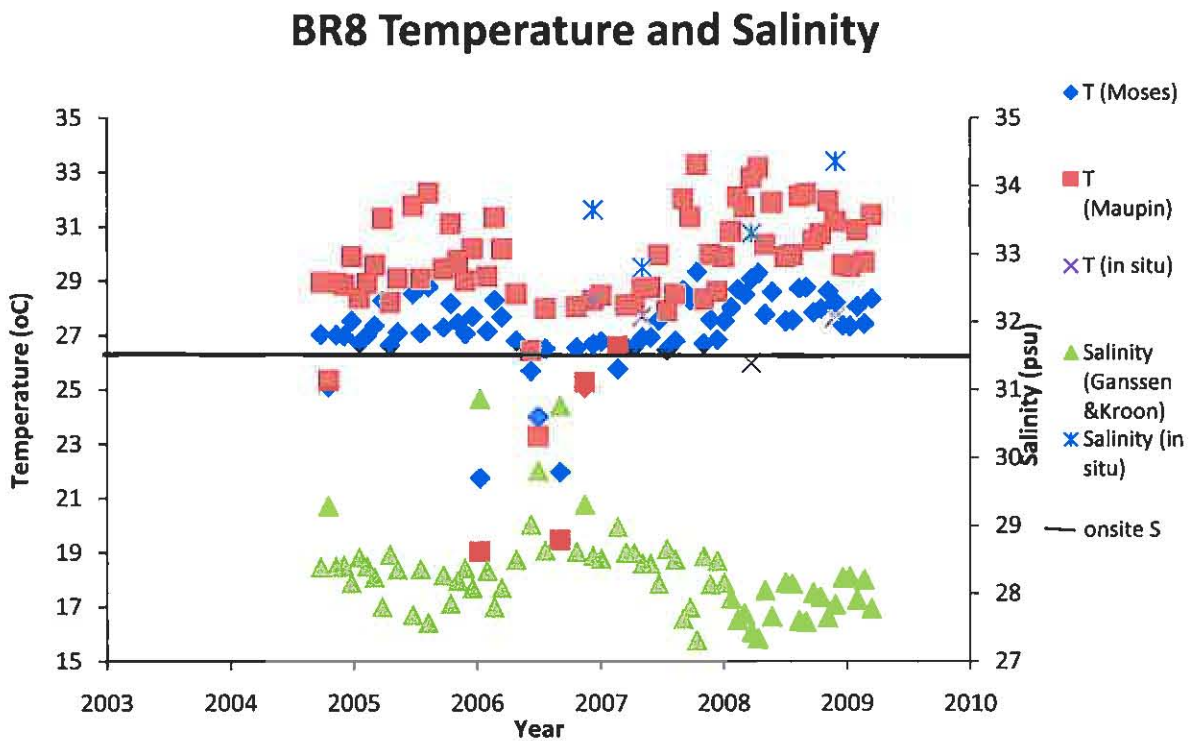


Figure 19: $\delta^{18}\text{O}$ -derived Temperature and Salinity from BR8 plotted with in situ data from CZM. BR8 calculated data shows the same relative difference to CZM as MI6.

Bellairs *Montastrea sp.* Temperature and Salinity

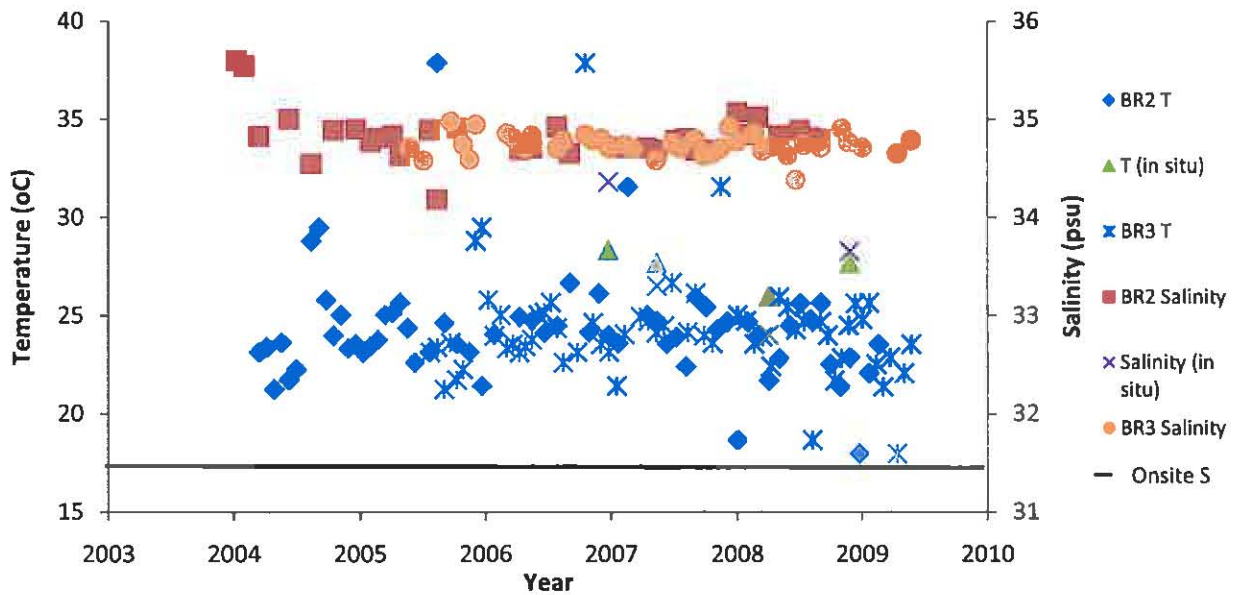


Figure 20: $\delta^{18}\text{O}$ -derived Temperature and Salinity from BR2 and BR3 (same coral head) plotted with in situ data from CZM. The offset from in situ data is much less for the *Montastrea sp.* than for the *Siderastrea sp.*

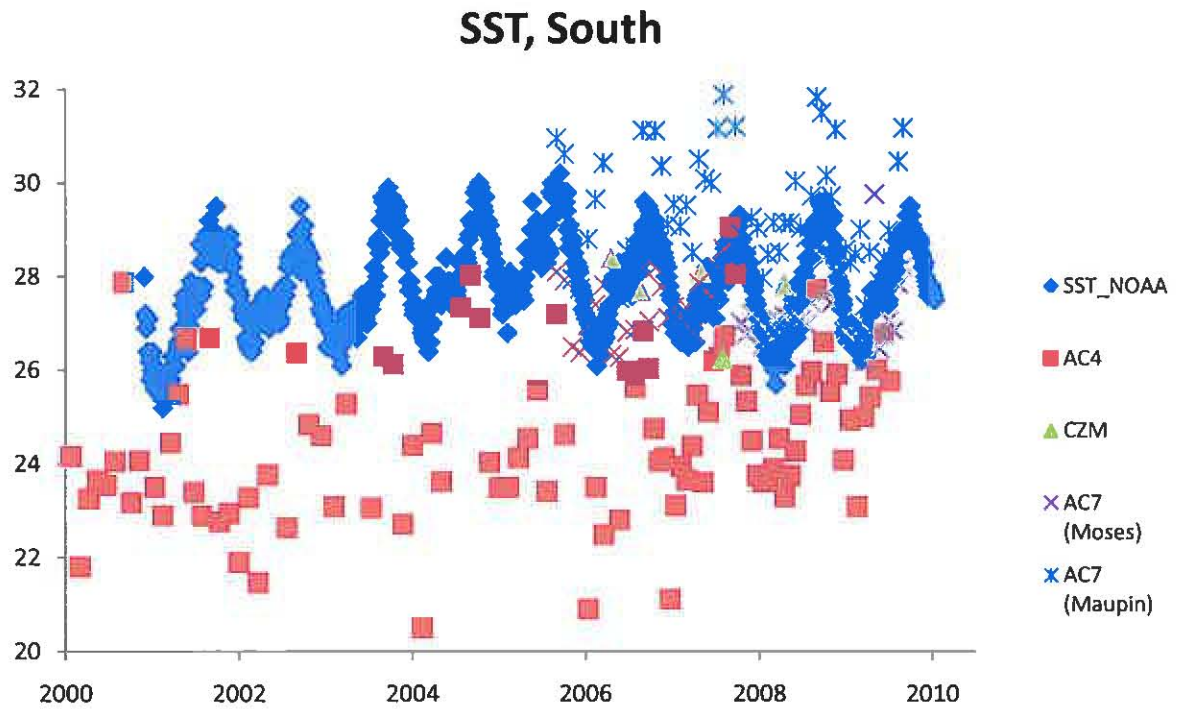


Figure 21: Temperature data from the southern corals (AC4 and AC7) $\delta^{18}\text{O}$ plotted with in situ temperature data from NOAA. The in situ SST shows a clear annual cycle, while the coral samples derived temperature is less resolved due to other influences on $\delta^{18}\text{O}$.

For the *Montastrea sp.*, Sr/Ca are converted to temperature values from the calibrations from Swart et al. (2002):

$$T(^{\circ}\text{C}) = (\text{Sr/Ca (mmol/mol)} - 9.994) / -0.0377 \text{ (eq 10)}$$

The equation used for *Siderastrea sp.* is:

$$T(^{\circ}\text{C}) = (\text{Sr/Ca (mmol/mol)} - 10.008) / -0.039 \text{ (eq 11) (Maupin et al., 2008)}$$

Swart et al. (2002) lists various potential Sr/Ca thermometry equations of the form:

$$T(^{\circ}\text{C}) = (\text{Sr/Ca} - a) / b \text{ (eq. 12)}$$

where a and b are constants (Swart et al., 2002). The equations used for *Montastrea sp.* are selected somewhat arbitrarily, selecting from four equations based on *Montastrea sp.* Equation 10 above is selected because it yields the closest temperature to the in situ data. This is a valid choice because Sr/Ca should reflect only temperature variation (Smith et al., 1979). The Sr/Ca derived temperatures in this study are much lower than in situ measurements, which are on average around 28 °C, and they do not show as clear of an annual signal as the $\delta^{18}\text{O}$ -derived temperatures (Figures 22 and 23). Much of the Sr/Ca-derived temperature record is incomplete due to machine error or insufficient sampling size.

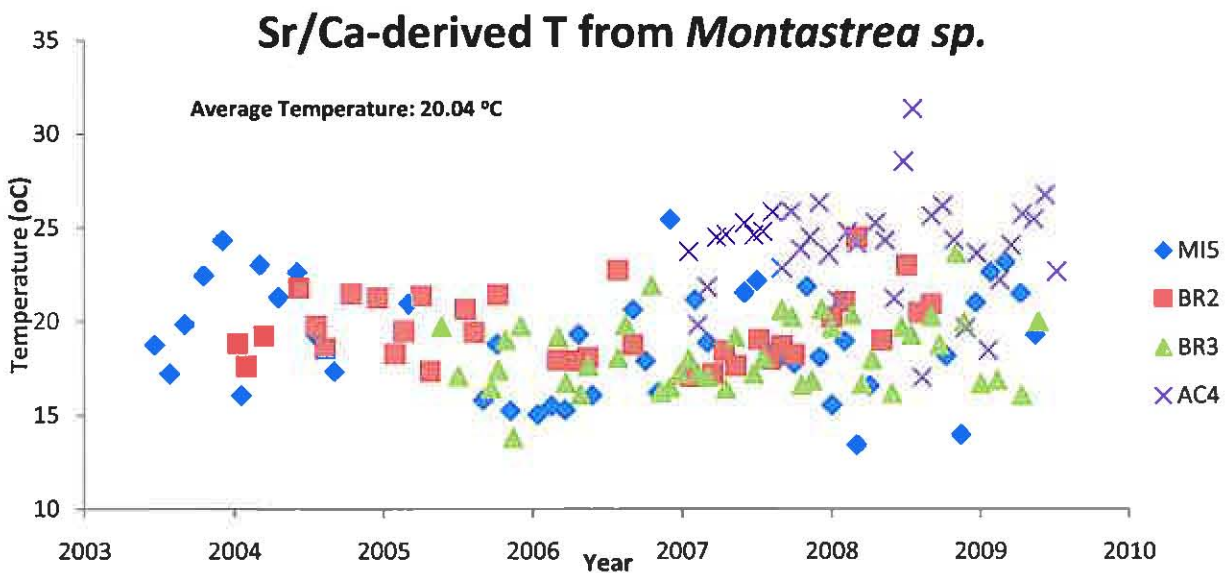


Figure 22: Temperature derived from the Sr/Ca in the *Montastrea sp.* samples.

Sr/Ca-derived T from *Siderastrea sp.*

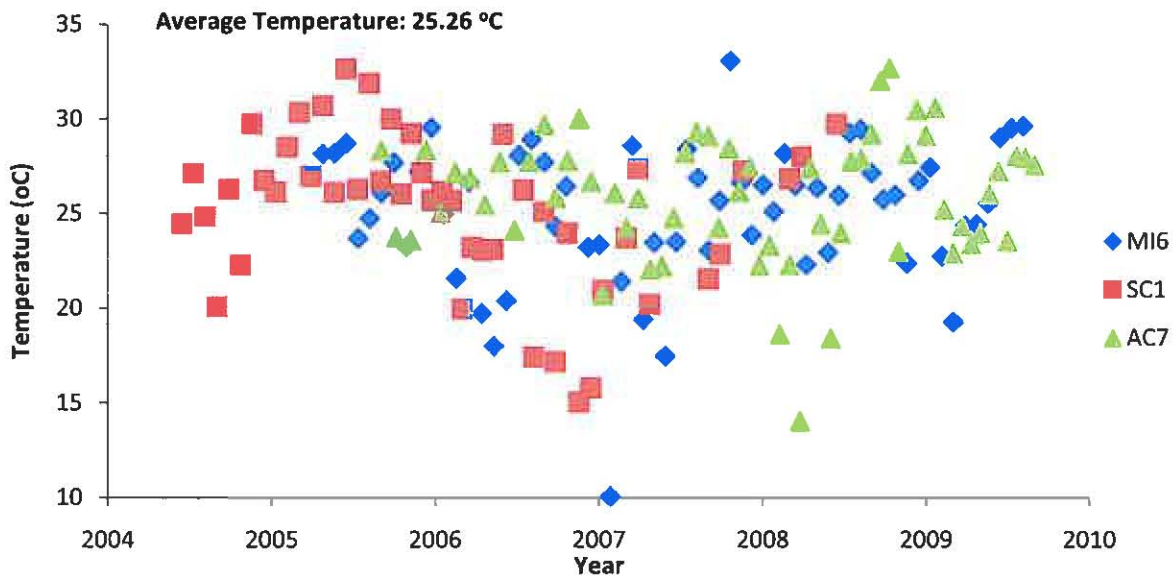


Figure 23: Temperature derived from Sr/Ca in the *Siderastrea sp.* samples. BR8 is not included as there was insufficient sample size. The temperatures are much more variable and give a higher value than those of the *Montastrea sp.* This value, however, is still lower than expected from in situ temperature data.

C. Salinity

Typically, Sr/Ca can be compared to $\delta^{18}\text{O}$ values to determine its accuracy if salinity is not suspected to be a major contributor to $\delta^{18}\text{O}$ (Swart et al. 2002). However, this study intends to use Sr/Ca as a tool to strip the temperature signal from $\delta^{18}\text{O}$ to determine the salinity signal and cannot be used to determine the accuracy of the Sr/Ca calibration.

The offset of $\delta^{18}\text{O}$ -derived temperature from in situ temperature data supports the idea that there is an additional driver of the $\delta^{18}\text{O}$ signal apart from temperature. The comparison of $\delta^{18}\text{O}$ -derived temperature to Sr/Ca also shows that temperature is not the only driver of the $\delta^{18}\text{O}$ signal (Figures 24-30). Sr/Ca has a negative linear relationship with temperature; however, these figures show no such relationship, further indicating that temperature is not the only driver of $\delta^{18}\text{O}$ (de Villiers, 1995).

SC1 Temperature vs Sr/Ca

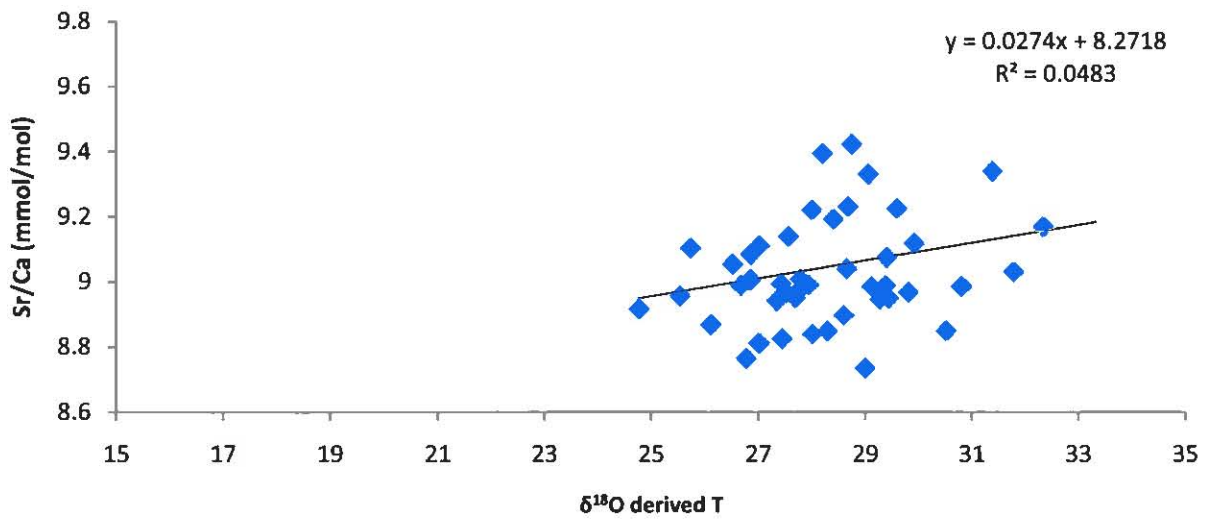


Figure 24: SC1 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca. If temperature was the only driver of the $\delta^{18}\text{O}$ signal, there would be a negative linear relationship. This figure shows a positive relationship with a low R^2 value, indicating that $\delta^{18}\text{O}$ is driven by more than temperature.

BR2 Temperature vs Sr/Ca

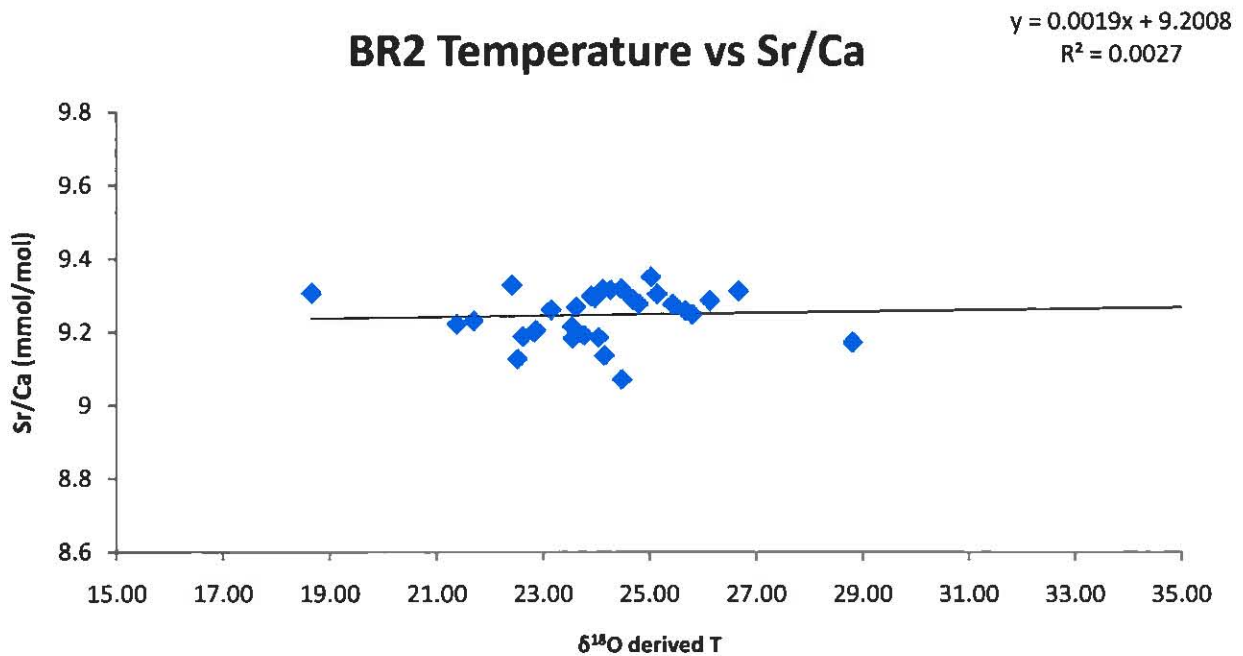


Figure 25: BR2 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca. There is no correlation between $\delta^{18}\text{O}$ -derived temperature and Sr/Ca

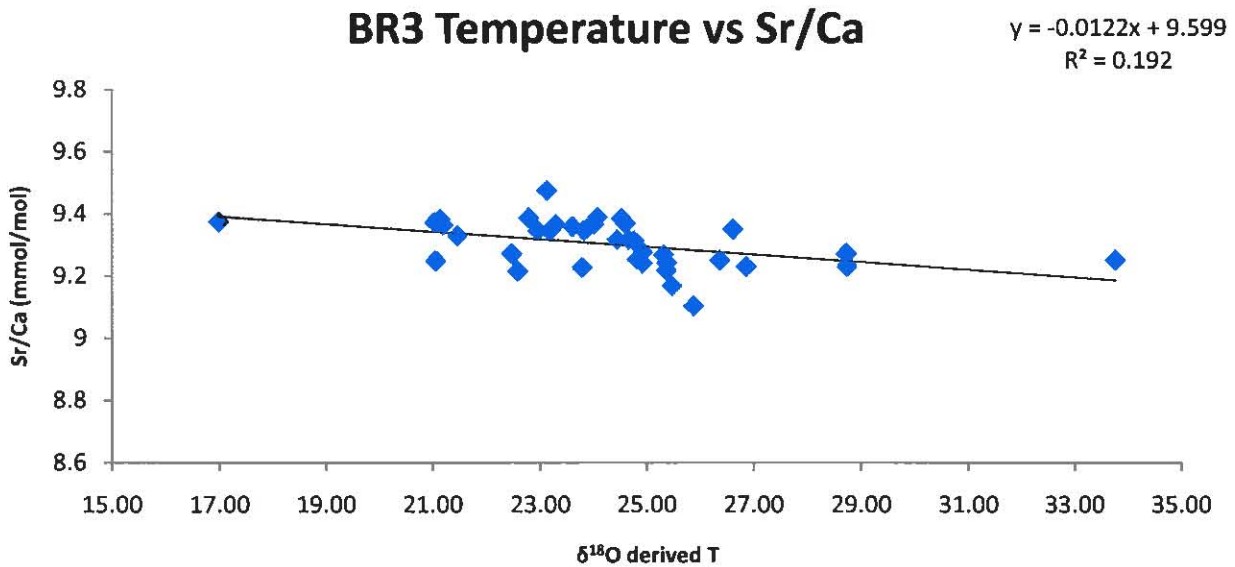


Figure 26: BR3 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca. This sample shows a negative linear relationship but a very low correlation factor.

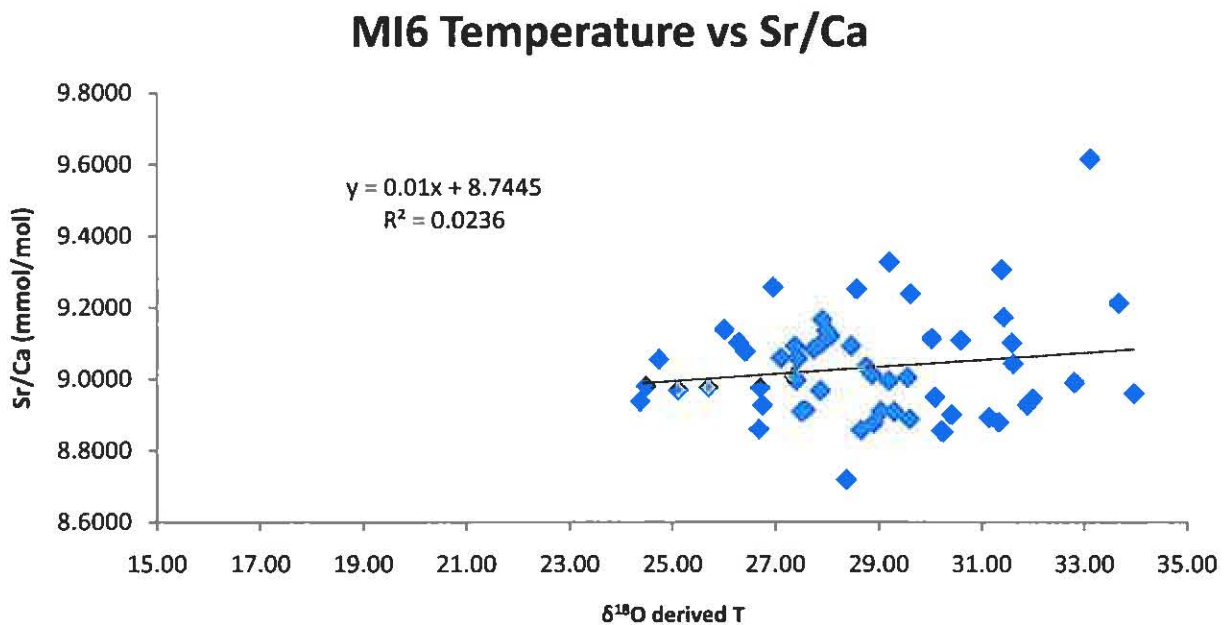


Figure 27: MI6 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca. The graph shows a positive relationship and very low correlation.

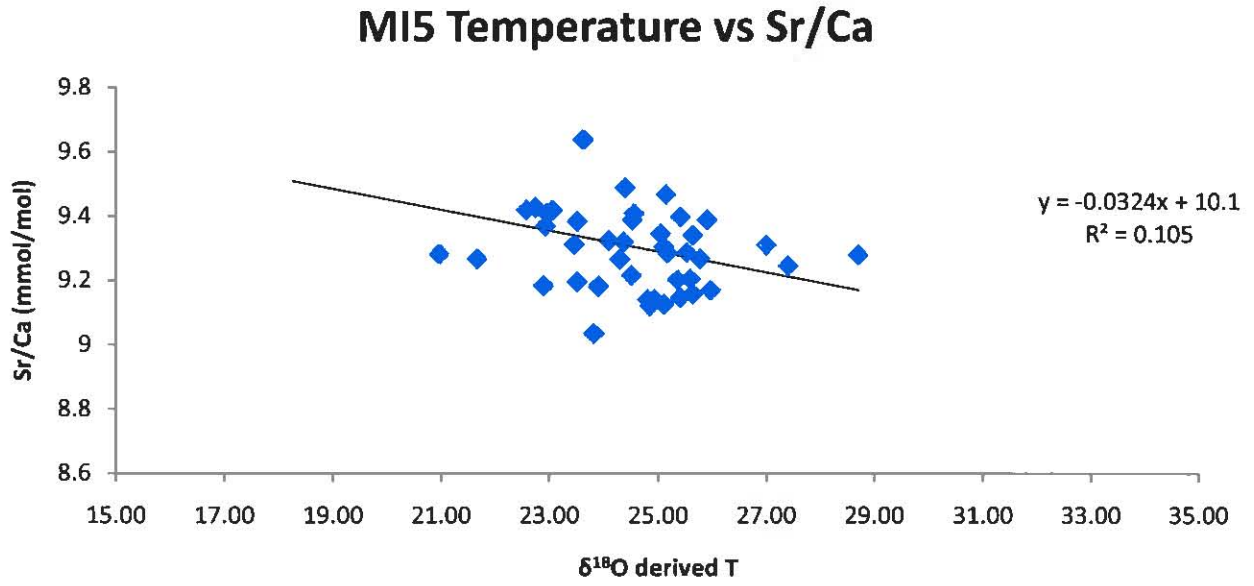


Figure 28: MI5 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca. This sample shows a negative relationship but very low correlation.

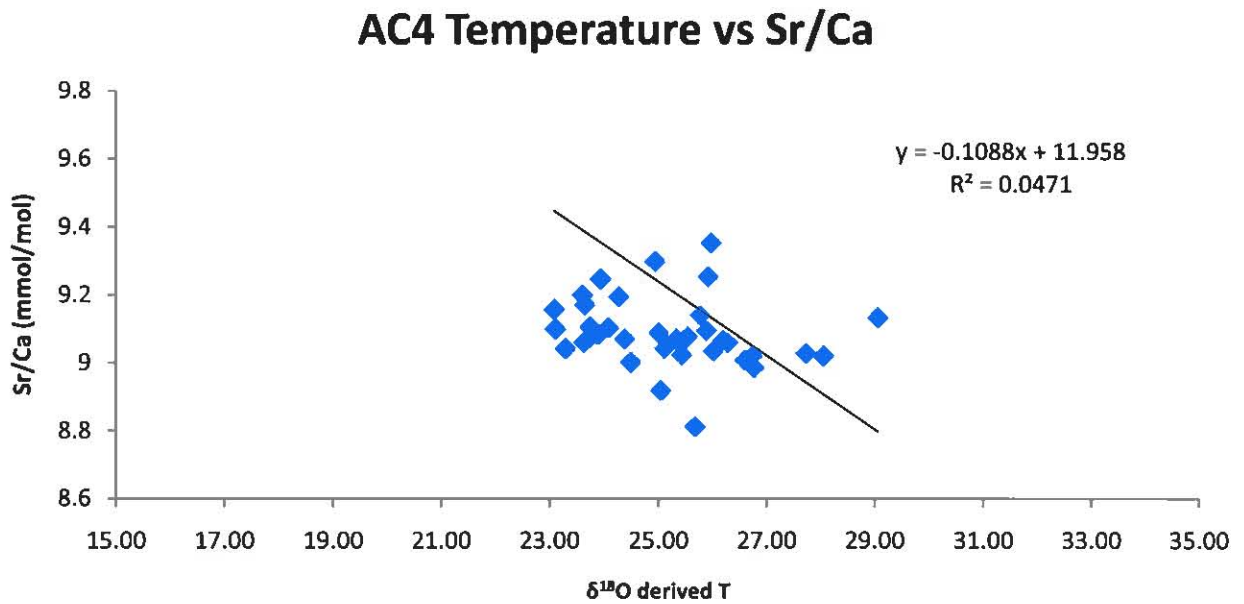


Figure 29: AC4 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca, with no correlation between $\delta^{18}\text{O}$ -derived temperature and Sr/Ca

AC7 Temperature vs Sr/Ca

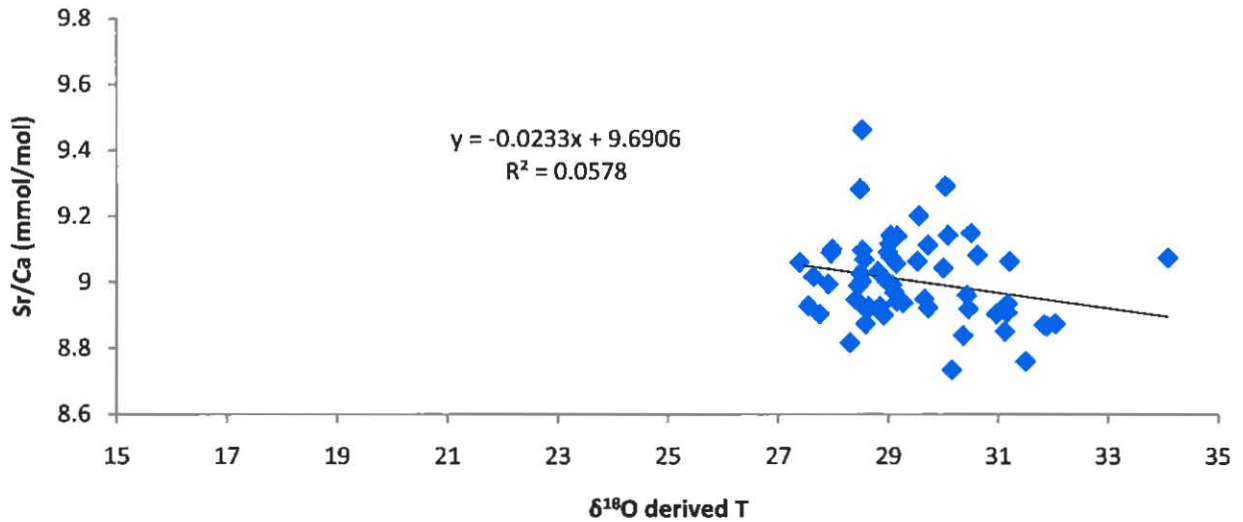


Figure 30: AC7 $\delta^{18}\text{O}$ -derived temperature plotted against Sr/Ca. There is a slight negative relationship but no correlation.

A third line of evidence to show that $\delta^{18}\text{O}$ is driven by both salinity and temperature relies on quantitative analysis. In order to quantitatively determine the influence of salinity on $\delta^{18}\text{O}$ measurements for *Montastrea sp.*, it is necessary to strip out the temperature dependence using Sr/Ca via the following equations (McCulloch et al., 1994):

$$T_{\text{Sr/Ca}} = (\text{Sr/Ca} - 11.01) / -0.071 \text{ (eq 13)}$$

$$T_{\delta^{18}\text{O}} = 5.33 - 4.519 * \delta^{18}\text{O} \text{ (eq 14)}$$

The salinity effect is the difference of these two temperatures in °C. This difference is then back-calculated to permille by reversing equations 4 and 6:

$$\text{‰} = (\text{salinity diff} - 5.33) / 4.519 \text{ (eq 15)}$$

$$\delta_w = \text{‰} - ((5.33 - T_{\text{Sr/Ca}}) / 4.519) \text{ (eq 16)}$$

This is then converted to real salinity:

$$\text{salinity effect} = 35 + 0.2 * \delta_w \text{ (eq 17)}$$

This salinity value (from eq. 17) is then subtracted from the calculated salinity using $\delta^{18}\text{O}$ (eq. 5) to determine the influence of salinity on $\delta^{18}\text{O}$. The salinity effect decreases from north to south. The salinity component for AC4's $\delta^{18}\text{O}$ between 2004 and 2009 ranged between 0.84 and 0.87 psu. The average value was 0.86 psu, which is higher than the values for the other *Montastrea sp.*: 0.84, 0.85, and 0.85 psu for MI5, BR2, and BR3, respectively. All of these values are relatively large, considering in situ salinity data varies less than 2.00 psu throughout the year and between locations (Table 6).

Average Salinity Effects	
AC4	0.86
MI5	0.84
BR2	0.85
BR3	0.85

Table 6: Average salinity differences between salinities calculated using eq. 5 and eq. 17 for *Montastrea sp.* Salinity effects are only calculated using *Montastrea sp.* since salinity values from *Siderastrea sp.* are unreliable.

D. Spatial Variance

To assess the temperature variability between sites, average values were compared to the NOAA SST dataset for each sample (Figure 31). The NOAA dataset shows consistent average temperatures with a slight peak in 2005. None of the samples show this trend, which further supports the conclusion that temperature is not the only driver of the $\delta^{18}\text{O}$ signal. The annual temperature averages for the middle coast corals are generally lower than either the temperatures from the north or south (Figure 31). However, the north shows an increase in temperature toward the end of the sampling period, while the south and middle decrease. Between 2004 and 2009, AC4 has the lowest average $\delta^{18}\text{O}$ (-4.32 ‰) and the highest average temperature (24.94°C) for the *Montastrea sp.* samples, while AC7 has the most negative $\delta^{18}\text{O}$ (-3.83 ‰) and the highest average temperature (27.34°C, 29.53°C) for the *Siderastrea sp.* samples (Figure 32).

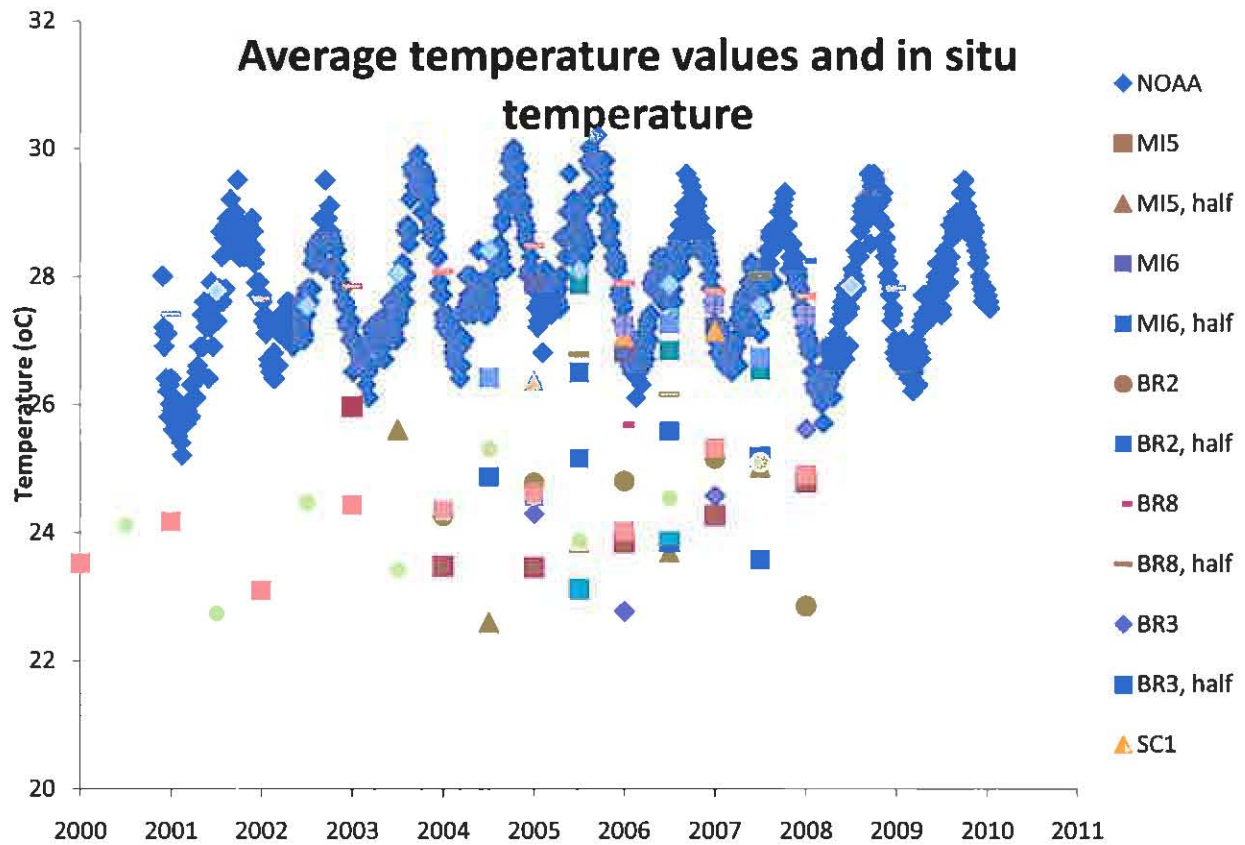


Figure 31: SST from in situ NOAA data plotted with yearly and half-yearly averages for each sample. The half-yearly averages are averages taken from July of one year to July of the next. None of the samples show the same trend as the averages from NOAA.

Average $\delta^{18}\text{O}$ 2004-2009 for BDS corals

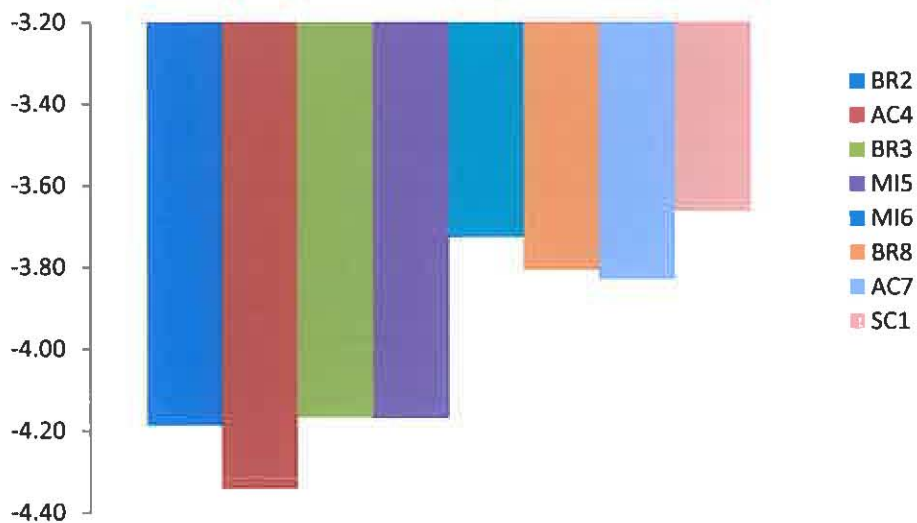


Figure 32: Average $\delta^{18}\text{O}$ for all samples. The *Montastrea sp.* samples are more negative than the *Siderastrea sp.* samples, and Accra samples are more negative than other samples within each species.

Temperature and salinity variation between sampling sites may be explained by ocean current variability. The cyclicity of the $\delta^{18}\text{O}$ signal is annually influenced by the outflow of the Amazon and Orinoco Rivers. Due to Barbados location downstream of the North Brazil Current retroflection region and its changing bathymetry due to the Barbados Ridge, there is ocean current variability around the island. This should be accompanied by changes in temperature and salinity (Hellweger and Gordon, 2002, Stansfield et al., 1995).

A study by Stansfield et al. (1995) demonstrates variation in temperature and salinity in a 1990-1991 attributing changes in current velocity south of Barbados to, what they termed, a “large, anticyclonic, horizontally sheared circulation.” Using current meters, they show an increase in flow to the southeast by 110 cm/s over one week. With the changing currents, there is a low-salinity pool southeast of the island (33.1 to 33.7 psu) in May 1991. The NBC rings pass the west coast of Barbados and dissipate in the Lesser Antilles (Fratantoni and Richardson, 2006 and Figure 33). As already discussed, our study also shows temperature and salinity anomalies in the south, especially between 1989 and 1991 (Figure 34). Their study does not look at other years, so it is not determinate whether the 1990-91 current is more extreme than other

years. Between 2004 and 2009, the samples from Accra yield the most negative isotopic composition and highest $\delta^{18}\text{O}$ -derived temperatures of the coral samples (Figures 6 and 7). The Accra samples have the highest Sr/Ca-derived temperature within their species (Figure 22). Using Sr/Ca, AC4 is an average of 4.69 °C higher than the other *Montastrea sp.* samples, compared to the temperature derived from $\delta^{18}\text{O}$, which is only on average 0.16 °C higher than the other *Montastrea sp.* samples. This relative difference indicates a significant salinity component in the AC4 $\delta^{18}\text{O}$ signal. This same trend is not apparent in the AC7.

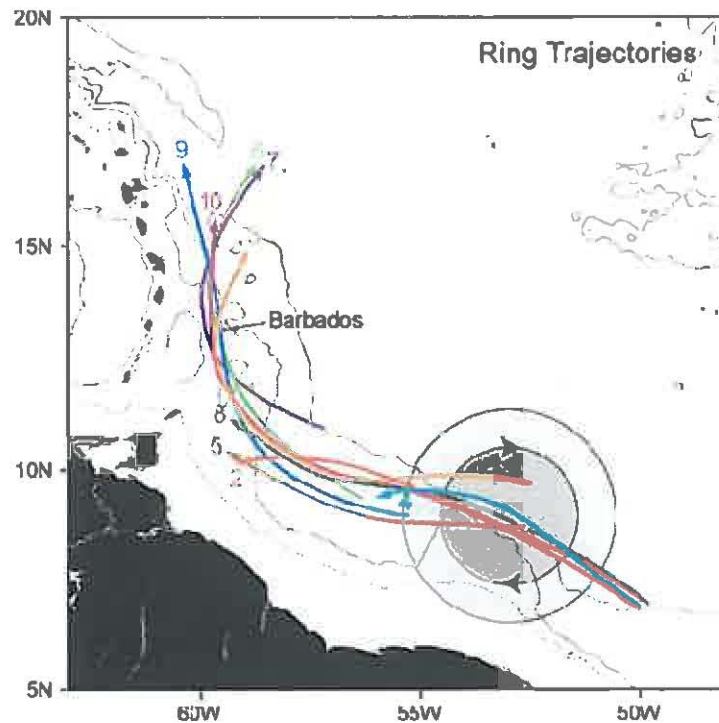


Figure 33: Figure modified from Stansfield et al. (1995), showing the trajectory of NBC rings. The solid color lines indicate the center of the rings. Most rings pass by or hit Barbados head on.

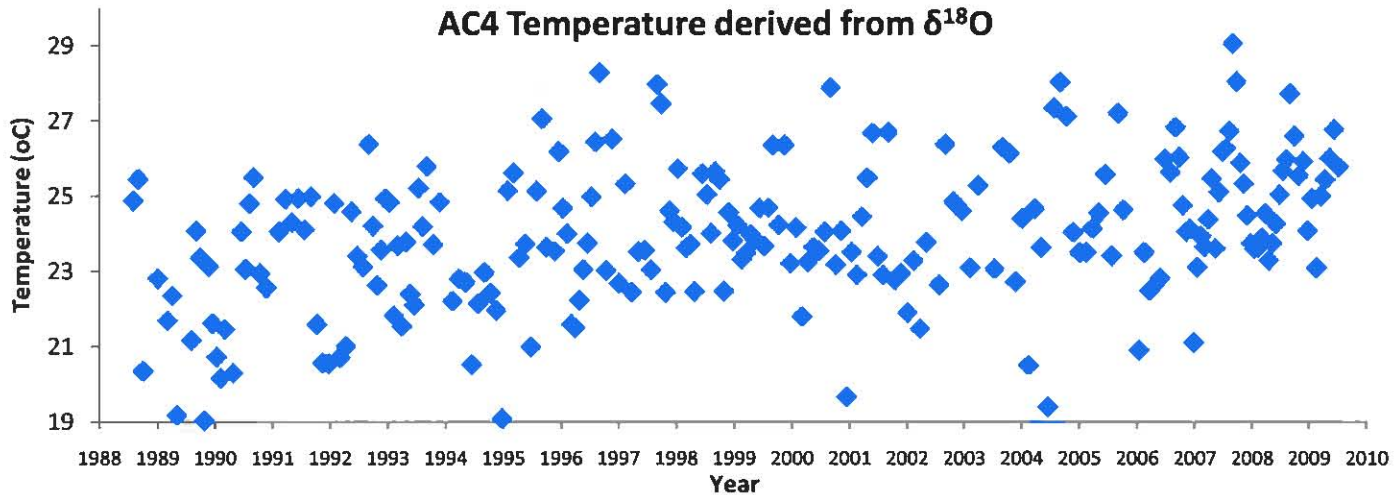


Figure 34: The full record of $\delta^{18}\text{O}$ -derived temperature for sample AC4. Years 1989 and 1990 show the lowest temperature values, and the resolution of the annual cycles decreases further back in time.

Variation between sites is also evident from the $\delta^{13}\text{C}$ signal. The $\delta^{13}\text{C}$ of coral skeletons is driven by $\delta^{13}\text{C}$ of the ambient seawater which, in addition to photosynthesis and dissolved inorganic carbon, is affected by $\delta^{13}\text{C}$ of the atmosphere. $\delta^{13}\text{C}$ of the global oceans is steadily decreasing due to the lighter carbon isotopic composition of anthropogenic CO_2 uptake by the oceans, termed the ^{13}C Suess effect (Swart et al., 2009). The samples from Accra (AC4 and AC7) demonstrate this effect more clearly than the other samples, indicating the regular arrival of oceanic water past Accra (Figures 12 and 13). The other *Montastrea sp.* samples show this trend until 2008, when the ^{13}C signal spikes up. The other samples may not show the expected trend if the Amazon-carrying ocean currents mainly pass the southern portion of the island and if there is recirculating water in the north and middle of the island.

An alternate source of freshwater off Barbados could be the aquifers beneath the island (Kelly et al., 2000). Even though there are no rivers on Barbados, there are 493 km of ravines that empty below the sea, particularly in the southwest (Brathwaite et al., 2008). Kelly and Moran (2002), studying ^{226}Ra activities and observing an advance in low-salinity water from offshore towards the island, conclude that local freshwater is probably not a significant contributor to low-salinity water.

Kelly et al. (2000) also discuss the relative inputs of the Amazon and the Orinoco. They disregard the Orinoco as a significant source of low-salinity water based on activity ratios of $^{228}\text{Ra}/^{226}\text{Ra}$ at the mouth of the river and at Barbados. They credit the North Brazil Current

rings, which originate in the spring, with bringing most of the low-salinity water to Barbados. The rings lasted between 100 and 120 days, allowing time to travel to Barbados, where the pools of low-salinity water generally last between 14 and 33 days, the last of which lingered 94 days, during the study period May 1996 through November 1997. The authors of that study do not find any consistency in whether the pools surround Barbados from the north or the south, which may be a result of the disintegration of the rings as they near Barbados (Kelly et al., 2000). Or, as Fratantoni and Richardson (2006) predict, the rings may hit Barbados head on.

E. Temporal Variation

Less well explained than spatial variation in $\delta^{18}\text{O}$ is the temporal variation apparent in some samples. Apart from annual cyclicity, there are distinct periods of increased amplitude in some $\delta^{18}\text{O}$ measurements. The *Montastrea sp.* $\delta^{18}\text{O}$ show two periods of particularly negative values at the end of 2007 and the end of 2005, both of which appear in more than one coral record (Figure 6). The *Siderastrea sp.* corals show the anomalously low point in 2007 but not in 2005 (Figure 7). The NOAA data shows the spike in temperature, corresponding to very negative $\delta^{18}\text{O}$, in 2005, but not in 2007, indicating that this spike in negative $\delta^{18}\text{O}$ may instead be due to a salinity effect. Data quantifying the Amazon outflow would inform this possibility. Since three of the four *Montastrea sp.* and all four of the *Siderastrea sp.* samples capture this anomaly, it is unlikely that it is machine error.

Analysis of the temporal variation also shows a degradation of the annual signal. The earlier years show a much less resolved signal than the more recent years: there are clusters of minimums and maximums but not a consistent trend. AC4 gives the clearest signal in the initial sampling time from 2004-2009 and was further analyzed to acquire a longer temperature record. The extended dataset to 1988 shows that the annual average $\delta^{18}\text{O}$ -derived temperature increases steadily through to the present (Figures 34 and 35). Since there is no Sr/Ca data to derive a salinity component and since the NOAA data does not extend as far back in time, it is uncertain whether the change in $\delta^{18}\text{O}$ is due to salinity or temperature. The resolution of the signal decreases, indicating that there may be a salinity component affecting the annual temperature signal (Figure 34). The absolute $\delta^{18}\text{O}$ values change significantly over the sampling period. The average $\delta^{18}\text{O}$ of AC4, when compared to the other *Montastrea sp.* samples from 2009-2004, is

the most negative $\delta^{18}\text{O}$ (Figure 32). However, the full range of AC4 measurements from 2009 to 1988 give an average that is the least negative $\delta^{18}\text{O}$ (Figure 36). The average $\delta^{13}\text{C}$ data also become more positive, consistent with the Suess effect, when measured over the full time range, though it remains the most negative *Montastrea sp.* sample.

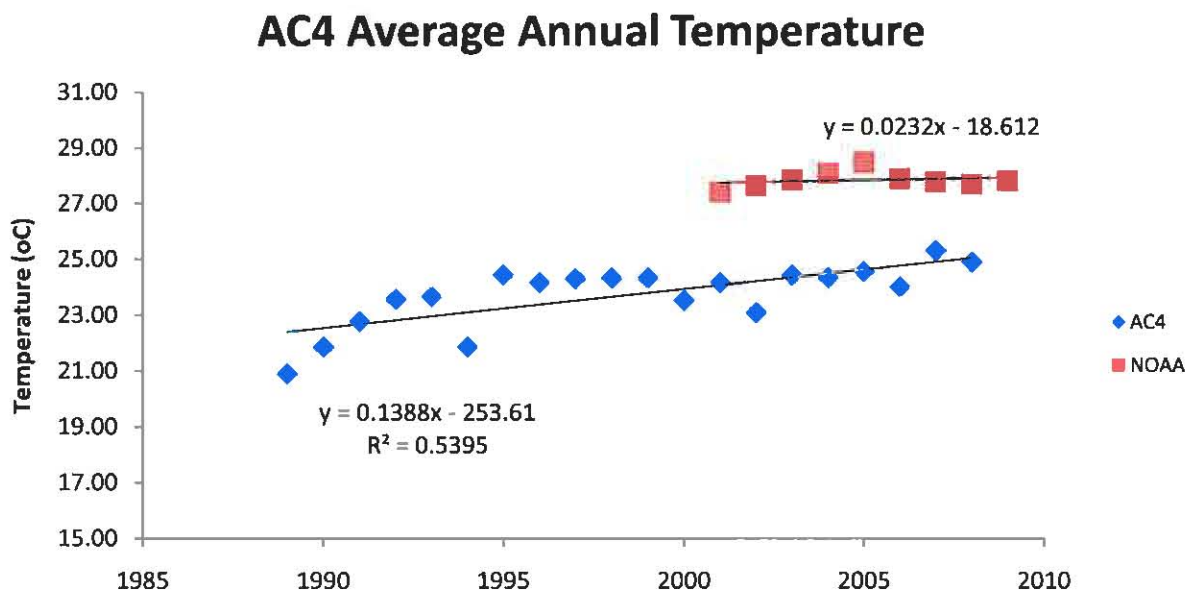


Figure 35: Average Annual temperature derived from $\delta^{18}\text{O}$ of AC4 plotted with SST from NOAA. There is an increase over time in SST.

Average $\delta^{18}\text{O}$ of Barbados Corals

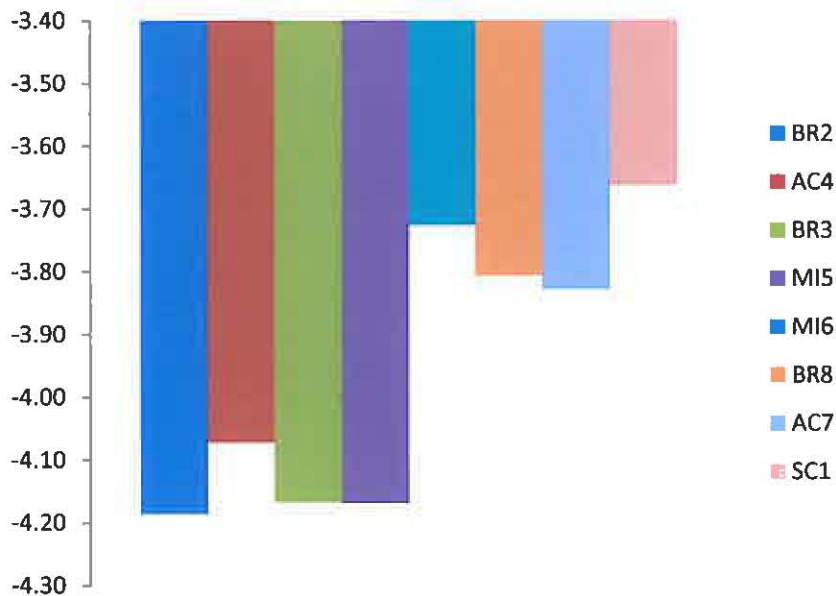


Figure 36: Average $\delta^{18}\text{O}$ for all samples over the full AC4 sampling period. With this extended time frame, AC4 becomes the least negative, indicative of the lower temperatures further back in time.

F. Species Variation

The analysis of temperature and salinity variances between locations and over time indicate the relative resistance of the *Siderastrea sp.* to record changes in salinity. The temperature derived from *Siderastrea sp.* $\delta^{18}\text{O}$ is much closer in value to the CZM reported temperature. This is especially apparent in the comparison of AC4 to the NOAA dataset. AC4 shows a similar pattern to the NOAA data but is consistently lower. The temperature derived using Maupin et al (2008) calculation is also offset but less so and the temperature derived using Moses et al (2006) is hardly offset (Figure 21). This indicates that *Siderastrea sp.* is less likely to record salinity effects on $\delta^{18}\text{O}$ than the *Montastrea sp.* Furthermore, the salinity calculated from $\delta^{18}\text{O}$ is not close to the in situ data. Salinities calculated from the Ganssen and Kroon (2000) equation are between 27 and 30 psu, whereas the average salinity from onsite measurements is 31.5 psu and those provided by the CZM are between 32.61 and 34.48 psu (Figures 18 and 19). As mentioned above, the relative differences between Sr/Ca and $\delta^{18}\text{O}$ -

derived temperatures in the AC4 and AC7 samples show the effects of salinity on each species. AC4 has a higher temperature derived from Sr/Ca, but the difference is muted using $\delta^{18}\text{O}$, indicating there is a significant salinity component. AC7, from the same area, does not show this same difference between Sr/Ca-derived temperature and $\delta^{18}\text{O}$ -derived temperature. Using Sr/Ca, AC7 has on average a 0.90 °C higher temperature than other locations and using $\delta^{18}\text{O}$, a 0.96 °C higher temperature. These discrepancies are due to the *Siderastrea sp.*'s relative lack in chronicling salinity variations. Muthiga and Szmant (1987) show that the *Siderastrea sp.*'s biological processes, especially photosynthesis and respiration, are not affected by changing salinity up to the 10 ‰ that accompanies freshwater runoff. Additionally, the *Siderastrea sp.* samples show a clearer cyclicity of $\delta^{13}\text{C}$ than the *Montastrea sp.*, which is also an indication that its photosynthesis and respiration rates are not as affected by changes in salinity (Figures 12 and 13).

G. Sampling Error

Additional sources for unexplained variation in $\delta^{18}\text{O}$ and Sr/Ca include sampling error. One source may be time averaging. While the sample interval is calculated using skeletal extension rates, the interval is taken as an average monthly extension rate over the whole coral, which is then applied to each month. Using the same average extension rate does not account for differences in growth rate throughout the year. Additionally, planar growth surfaces are not parallel over the thickness of the sample—the differences between vertical and growth surfaces can vary significantly—giving a temperature representative of multiple time lines, termed “time-transgressive” or “time averaging” (Leder et al., 2006; Moses et al., 2006; Figure 37). However, since we do not see a muted signal in the cyclicity of $\delta^{18}\text{O}$, it is unlikely that time-averaging is a significant source of error. It may have a greater effect on the earlier years of AC4 where there does appear to be a degraded signal. The drop in resolution shown in AC4 may also be a result of the later sampling date or air transportation. Prior to 2002, the cycle is more irregular. Knowing the extent of time-averaging would better inform the effects of environmental changes on the $\delta^{18}\text{O}$ signal prior to 2005 where the signal is muted.

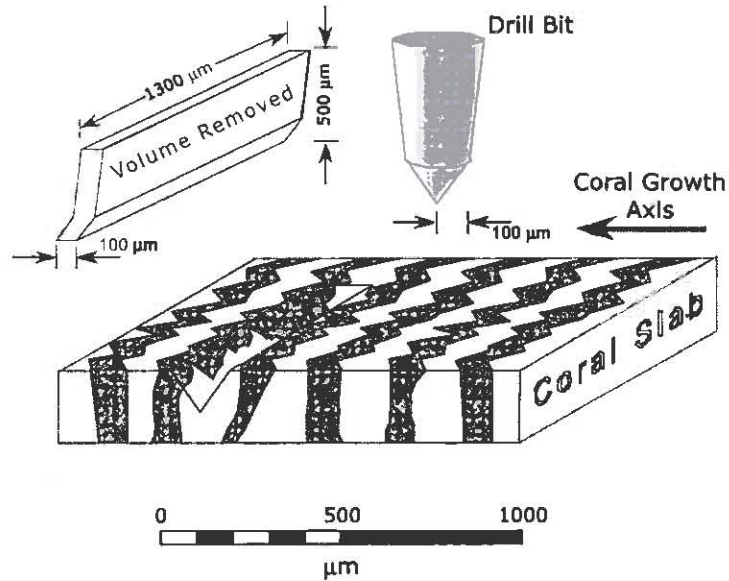


Figure 37: Figure taken from Moses et al. (2006) showing the effect of time-averaging.

Sampling error during mass spectrometer runs also required eliminating some of the produced data. Data that produced a standard deviation—from machine error or unreadable sample size—greater than 0.1 was eliminated from the data set (Monica Arienzo, pers. comm., 2009). This resulted in some incomplete isotope data, but the overall trend for each sample was preserved.

In order to gauge the effects of sampling error, the differences between BR2 and BR3 can be studied, since they are from the same coral head. The bottom half of core BR3 is in poor shape, but the portion used for analysis is comparable to the condition of BR2. The sampling for both cores was done by the same sampler (Salley Gould). The growth rate, calculated using x-rays, is different for the two samples, which may result from the location on the coral head. The sample intervals are: samples 1-25 from the top are 640 μm and samples 26-70 are 647.2 μm for BR2, and all samples for BR3 are 590.3 μm . Though the growth rates are calculated independently, they are similar since they are from the same core, though there may be differences depending on the location within the core. Figures 38 and 39 show the discrepancy between the samples. The total averages for $\delta^{18}\text{O}$ are -4.19 (BR2) and -4.17 (BR3) and for Sr/Ca, the averages are 9.25 (BR2) and 9.31 (BR3), both of which are very similar. The overall averages are not significantly different, but the graphs show the offset more clearly. The data sets appear to be much less correlated in the beginning and end of the sampling series. The

graphs do, however, show a similar cyclicity and even similar outliers, indicating an environmentally caused variance rather than sampling error.

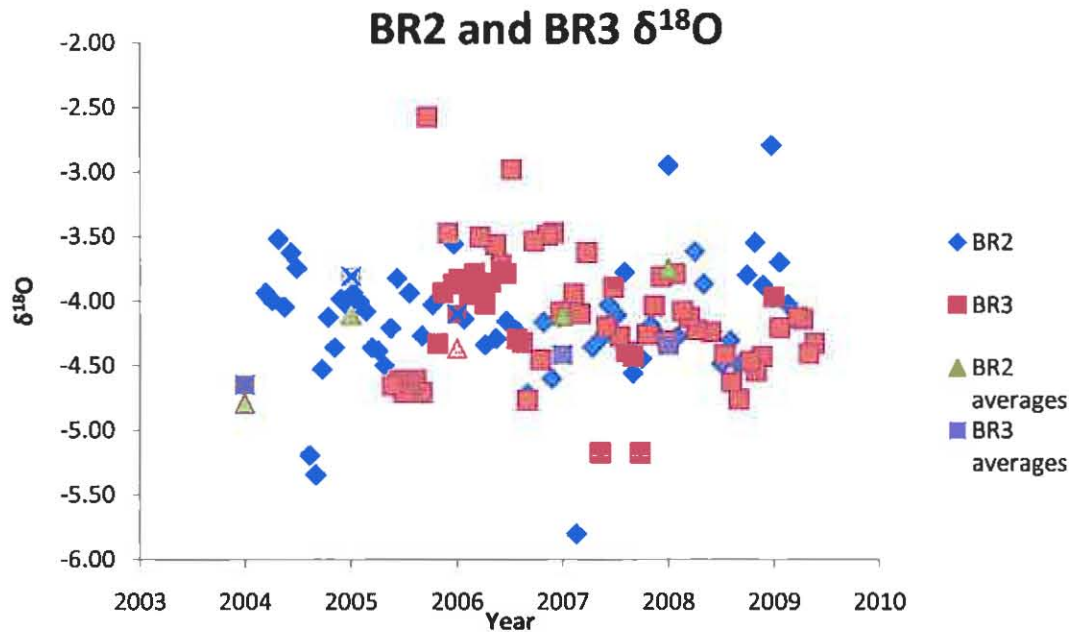


Figure 38: Comparison of $\delta^{18}\text{O}$ for BR2 and BR3 from the same coral head. The peaks of the two samples are the same, but the pattern of the two samples is not well correlated.

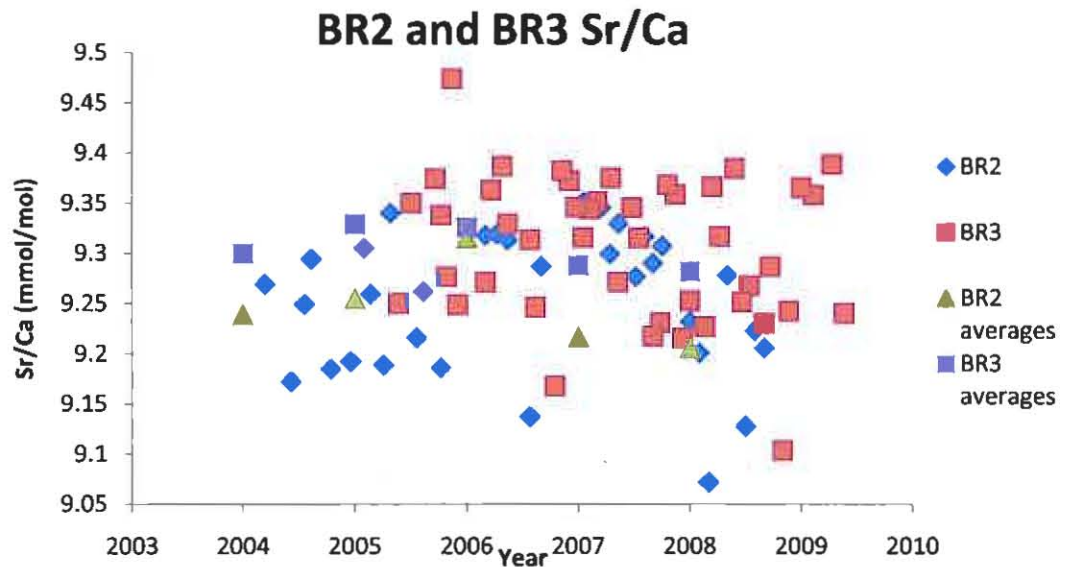


Figure 39: Comparison of Sr/Ca for BR2 and BR3 from the same coral head. BR3 has a consistently higher average than BR2, but the overall patterns between the samples is the same. They show the mostly the same outliers, indicating that these points are likely environmentally caused rather than from machine error.

The temperatures calculated from Sr/Ca are generally lower than those calculated using $\delta^{18}\text{O}$, but the reliability of the Sr/Ca data is questionable. Many of the samples had to be reanalyzed. Sample size was insufficient to run the full set of BR8 samples, so a Sr/Ca-temperature record is missing for that sample. The unreliability of Sr/Ca data prevents a successful derivation of actual salinity. Analytical precision ranged from 0.15 - 0.18% for the Sr/Ca runs on the ICP. Precision may be improved using methods discussed in Beck et al. (2002), such as thermal ionization mass spectrometry, which gives a precision of better than 0.05%. The temperature range derived from Sr/Ca does, however, lie within the maximum Sr/Ca variation in seawater ($\sim 2.5^\circ\text{C}$) reported by De Villiers et al. (1994).

V. Conclusions

This study shows the effectiveness, complications, and implications of determining salinity and temperature effects from the corals *Montastrea sp.* and *Siderastrea sp.* With the subtraction of Sr/Ca, there is a consistent salinity effect on the corals' $\delta^{18}\text{O}$ signature. The dependence of $\delta^{18}\text{O}$ on salinity is also apparent from the offset in $\delta^{18}\text{O}$ -derived temperature and in situ measurements. This influence is attributed to the outflow of the Amazon and Orinoco Rivers, as reported by previous studies. Most of the samples show an annual cycle; however, there is doubt in the precision and accuracy of some of the data. The equations used affect the outcome of the data. The temperatures derived from each equation show similar cycles, but the relative offsets are significant, resulting in different interpretations of the salinity effect.

The southern corals (AC4 and AC7) appear to be the best recorders of regional ocean current influence and their effect on Barbados. Not only do they give the most resolved signal, but they have the most negative $\delta^{18}\text{O}$ between 2004 and 2009. They also show the expected trend in decreasing $\delta^{13}\text{C}$. The extended analysis of AC4 shows an increase in SST over time, with significantly low temperatures between 1989 and 1990.

The *Siderastrea sp.* samples are poor recorders of salinity changes. They do not give a resolved $\delta^{18}\text{O}$ signal, and their offset from in situ temperature is much less than the temperatures derived from *Montastrea sp.* The *Siderastrea sp.* resiliency is also apparent from the $\delta^{13}\text{C}$ signal, where strong salinity variations do not appear to affect their photosynthesis and respiration. The

lack of a clear salinity record from *Siderastrea sp.* is especially remarkable considering the large annual influx of fresh Amazon and Orinoco water.

Much of the uncertainty in explaining the spatial and temporal trends observed may be solved with accurate records of ocean currents passing Barbados. A salinity dataset similar to the temperature dataset received from NOAA will also help determine the accuracy of the $\delta^{18}\text{O}$ calculations. In addition to an ocean current and salinity dataset, rainfall and Amazon and Orinoco outflow data can be used to determine how much variation in riverine discharge and South American precipitation patterns Bajan corals may record. Additional work may be able to show the relative influences of the Amazon and the Orinoco Rivers on the temperature, salinity, and acidity around Barbados by tracing characteristics specific to each river.

Given the declining state of the health of many Bajan coral reef communities, the effect of an annual influx of freshwater is important to quantify and understand. The salinity changes can also be used as a proxy for the arrival of riverine water, which results in increased acidity in the coral's habitat. Many of the reefs are already in poor health, indicated by yellow-band disease, abundant algae, and smaller reef size. With the global increase in ocean acidification, the corals off Barbados may be less likely to tolerate the acidic fresh water influx from the Amazon and Orinoco Rivers.

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Appendix A—Sample Locations and Field Data

Field Data and Drilling Data

	BDS-SC1	BDS-BR2	BDS-BR3	BDS-AC4	BDS-MI5	BDS-MI6	BDS-AC7	BDS-BR8
Date Collected	6/27/2009	6/28/2009	6/28/2009	6/29/2009	6/30/2009	6/30/2009	7/1/2009	7/1/2009
Location	Sunset Crest	Bellairs	Bellairs	Accra Cove	Maycocks Inner	Maycocks Inner	Accra Cove	Bellairs
GPS	N 13°10.729' W 59°38.486'	N13 °11.519' W 59°38.449'	N13 °11.519' W 59°38.449'	N13°04.288'W 59°35.497'	N13°18.383'W 59°39.281'	N13°18.383'W 59°39.281'	N 13°04.289' W 59°35.499'	N 13°11.519' W 59°38.449'
Species	<i>Siderastrea siderea</i>	<i>Montastrea annularis</i>	<i>Montastrea annularis</i>	<i>Montastrea annularis</i>	<i>Montastrea annularis</i>	<i>Siderastrea siderea</i>	<i>Siderastrea siderea</i>	<i>Siderastrea siderea</i>
Height	4'	8'	8'	6'	4'	2'		4'
Diameter	8-10'	6-7'	6-7'	6'		1'		
Depth	12'	12'	12'	32'	16'	18'	24'	11'
Core Length	33 cm	22 cm	35 cm	25 cm	25 cm	22.5 cm	23.5 cm	58 cm
H ₂ O ID	SC-1	BR-2	BR-2	AC-3	MI-4	MI-4	AC-3	BR-2
Temp. @ Depth	33.6° C	33° C *after sitting on deck for ~30 min	Same as BR-2	31.8° C	31.3° C	31.3° C	30.3° C	32.2° C
Temp. @ Surface		31.1° C				31.3° C	30.7° C	31.6° C
pH @ Depth	8.19	8.21		8.24	8.28	8.28	8.34	8.27
pH @ Surface	8.22	8.25		NA	8.3	8.3	8.35	8.37
Salinity @ Depth	32 ppt	30,31,31 o/oo		32, 32, 32°/∞	31,32,32 o/oo	31,32,32 o/oo	31,33,32 ppt	31,30,31 ppt
Salinity @ Surface					33,33,34 o/oo	33,33,34 o/oo	32,32,31 ppt	32,31,32 ppt
TDS @ Depth	OR	OR		OR	OR	OR	OR	OF
TDS @ Surface	OR	OR		OR	OR	OR	OR	OF
Cond. @ Depth	OR	OR		OR	OR	OR	OR	OF
Cond. @ Surface	OR	OR		OR	OR	OR	OR	OF
Driller Name	Joe	Salley	Salley	Kat	Kat	Joe	Joe	Catherine
Drill Interval	416.8 μm	Samples 1-25: 640 μm Samples 26-70: 647.2 μm	590.3 μm	572.19 μm	819 μm	320 μm	399.3 μm	

North

Maycox Inner





Date: 06/30/09

Weather Conditions: partly cloudy, ~85 °F

Sample	Montastrea	Siderastrea
Sample ID	BDS-MI5	BDS-MI6
GPS	N 13°18.383	N 13°18.383
	W 59°39.281	W 59°39.281
Sample depth	Bottom 16 ft, top 12 ft	Bottom 20 ft, top 18 ft.
Head diameter		1'
Core Length	25 cm	22.5 cm
Drilled Sample Interval	819 µm	320 µm
Bottom Water		
Temp	31.3° C	
Salinity	31,32,32 ppt	

Visibility	40 ft.
pH	8.28
Surface Water	
pH	8.3
TDS	OR*
Salinity	33,33,34 ppt
Cond	OR
Water Samples Collected	
Oxygen	BDS-MI4
Carbon	BDS-MI4
Sr/Ca	BDS-MI4

Environment Observations:

Reef Condition: poor; abundant algae

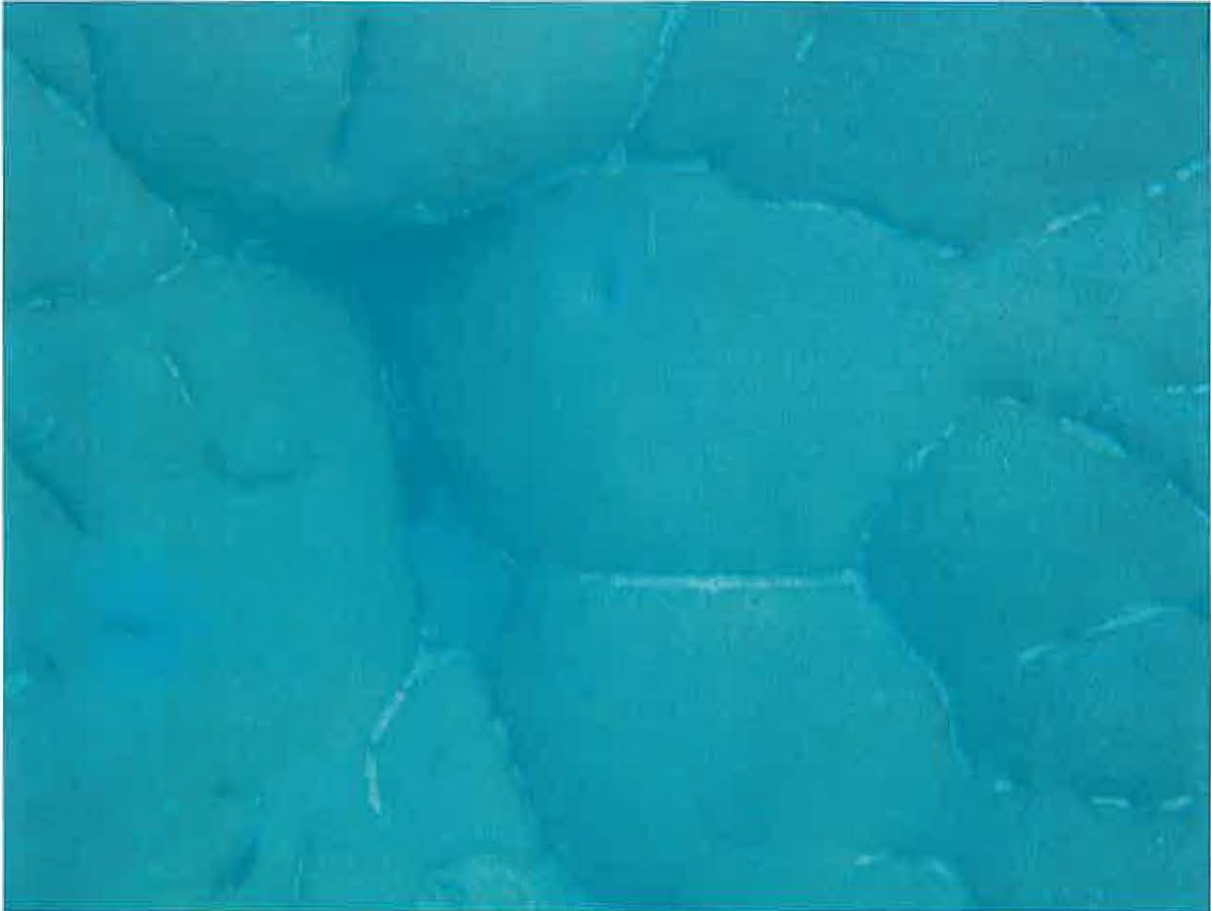
Montastrea head: lumpy, moderate size

Siderastrea: small, mound-shaped

Other species: fire, brain, porites, mounding, fan, branching, finger, staghorn, acrapora corals, damselfish, few other fish

Middle

Sunset Crest





sp. siderastrea

Date: 06/27/09

Weather: 86 °F

Sample	Siderastrea
Sample ID	BDS-SC1
GPS	N 13°10.729
	W 59°38.486
Sample depth	12 ft.
Sample Size	8-10 ft diameter, 4 ft high
Core Length	33 cm
Drilled Sample Interval	416.8 µm
Bottom Water	
Temp	33.6°C
Salinity	32 ppt
Visibility	15-20 ft
pH	8.19

Surface Water	
pH	8.22
TDS	NA
Water Samples Collected	
Oxygen	BDS-SC1
Carbon	BDS-SC1
Sr/Ca	BDS-SC1

Environment Observations:

Reef Condition: nice domal shape, good health, shallow, small patch reefs; coral head is solitary in sandy bottom; yellow band disease present at site

Other species: *montastrea annularis*, fire coral, encrusters

Bellairs



sp. montastrea core and head

Date: 06/28/09

Weather Conditions: 86 °F

Sample	Montastrea	Montastrea
Sample ID	BDS-BR2	BDS-BR3 (same head)
GPS	N 13°11.519	N 13°11.519
	W 59°38.449	W 59°38.449
Sample depth	11 ft	
Sample dimensions	8' height; 6-7' diameter	
Core length	22 cm	35 cm
Drilled sample interval	Samples 1-25: 640 µm; 26-70: 647.2 µm	590.3 µm
Bottom Water		
Temp	33°C (After sitting on deck)	
Salinity	30-31 ppt	
visibility	15-20 ft	
pH	8.21	
Surface Water		
pH	8.25	
TDS	NA	
Samples Collected		
Oxygen	BDS-BR2	
Carbon	BDS-BR2	
Sr/Ca	BDS-BR2	



sp. siderastrea head

Date: 07/01/09

Weather Conditions: partly cloudy

Sample	Siderastrea
Sample ID	BDS-BR8
GPS	N 13°11.519
	W 59°38.448
Sample depth	15 ft (top 11 ft)
Sample height	4'
Core length	58 cm
Bottom	
Water	
Temp	32.2°C
Salinity	31,30,31 ppt
Visibility	15 ft
Cond.	OR
TDS	OR
pH	8.27
Surface	
Water	
pH	8.31

TDS	OR
Salinity	32,31,32 ppt
Samples Collected	
Oxygen	BDS-BR6
Carbon	BDS-BR6
Sr/Ca	BDS-BR6

Environment Observations:

Reef Condition: coral is brown-orange, lumpy; inner reef is in bad shape; abundant algae; the northern part of the reef is in the best condition

Other species: abundant parrotfish and damselfish; blennies, small and mounding corals, porites

South

Accra



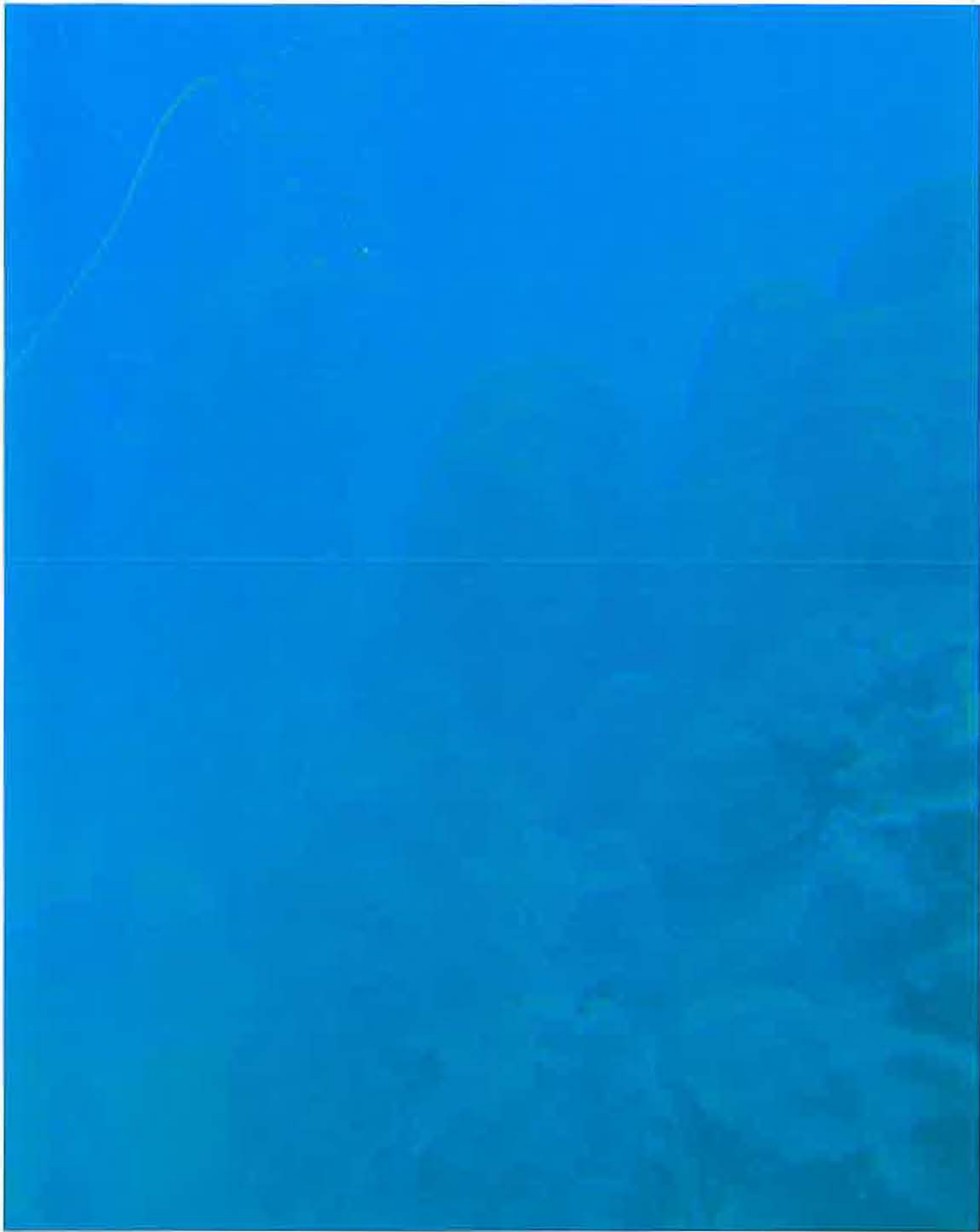
sp. montastrea

Date: 06/29/09

Weather Conditions: 82 °F

Sample	Montastrea
Sample ID	BDS-AC4
GPS	N 13°04.288
	W 59°35.497
Sample depth	30 ft
Sample dimension	Height: 6'; diameter: 6'
Core Length	25 cm
Drilling interval	

Bottom Water	
Temp	31.8° C
Salinity	32,32,32 ppt
visibility	30 ft
pH	8.24
Surface Water	
pH	NA
TDS	NA
Samples Collected	
Oxygen	BDS-AC3
Carbon	BDS-AC3
Sr/Ca	BDS-AC3



sp. siderastrea

Date: 07/01/09

Weather: showers, partly cloudy, ~85 °F

Sample	Siderastrea
Sample ID	BDS-AC7
GPS	N 13°04.289
	W 59°35.499
Sample depth	24 ft
Core length	23.5 cm
Drilling interval	399.3 μ m
Bottom Water	
Temp	30.3°C
Salinity	31,33,32 ppt
visibility	10 ft
Cond.	OR
TDS	OR
pH	8.34
Surface Water	
pH	8.35
TDS	OR
Salinity	32,32,31 ppt
Samples Collected	
Oxygen	BDS-AC5
Carbon	BDS-AC5
Sr/Ca	BDS-AC5

Environment Conditions:

Water is green, murky, and colder; stronger currents

Reef condition: patch reef, sandy, algae

Other species: brain, branching, porties, fan, sea urchins; damselfish, sgt. major, squirrel, and other small fish

Appendix B: $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$

Appendix B: $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$						
<i>Montastrea sp.</i>						
Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity	
MI5-G-1	2008.88	-0.36	-3.61	21.65	34.90	
MI5-G-2	2008.75	-0.49	-3.89	22.89	34.94	
MI5-G-3	2008.63	-0.86	-4.32	24.83	34.93	
MI5-G-4	2008.50	-1.08	-4.33	24.92	34.90	
MI5-G-5	2008.38	-0.63	-4.43	25.35	34.81	
MI5-G-6	2008.25	-1.36	-4.38	25.13	34.51	
MI5-G-7	2008.13					
MI5-G-8	2008.00	-0.86	-4.70	26.55	45.56	
MI5-G-9	2007.92	0.20	-3.63	21.74	34.14	
MI5-G-10	2007.83	-0.94	-4.31	24.81	45.63	
MI5-G-11	2007.75	-0.88	-4.32	24.85	45.63	
MI5-G-12	2007.67	-1.66	-4.05	23.62	34.37	
MI5-G-13	2007.58	-1.63	-3.89	22.92	34.72	
MI5-G-14	2007.50	-2.00	-4.22	24.38	34.52	
MI5-G-15	2007.42	-2.30	-5.17	28.69	34.57	
MI5-G-16	2007.33	-2.15	-4.25	24.55	34.60	
MI5-G-17	2007.25	-1.94	-4.01	23.45	34.76	
MI5-G-18	2007.17	-2.15	-4.56	25.96	34.82	
MI5-G-19	2007.08	-1.62	-4.15	24.09	34.72	
MI5-G-20	2007.00	-2.62	-4.79	26.99	34.61	
MI5-G-21	2006.92	-1.98	-4.37	25.09	34.70	
MI5-G-22	2006.83	-2.06	-4.49	25.63	34.85	
MI5-G-23	2006.75	-1.83	-4.11	23.89	34.90	
MI5-G-24	2006.67	-1.73	-4.06	23.67	45.68	
MI5-G-25	2006.58	-2.07	-3.93	23.09	45.71	
MI5-G-26	2006.50	-1.22	-3.46	20.96	34.91	
MI5-G-27	2006.42	-2.33	-4.02	23.50	34.90	
MI5-G-28	2006.33	-3.26	-4.32	24.83	45.63	
MI5-G-29	2006.25	-2.10	-4.09	23.81	35.07	
MI5-G-30	2006.17	-1.97	-4.02	23.51	34.68	
MI5-G-31	2006.08	-2.61	-4.21	24.35	34.71	
MI5-G-32	2006.00	-2.10	-4.24	24.50	34.83	
MI5-G-33	2005.91	-1.40	-4.23	24.45	45.65	
MI5-G-34	2005.82	-0.78	-4.16	24.12	45.66	
MI5-G-35	2005.73	-1.17	-4.25	24.52	34.63	
MI5-G-36	2005.64	-1.02	-4.19	24.29	34.78	
MI5-G-37	2005.55	-1.25	-3.92	23.05	34.66	
MI5-G-38	2005.45	-1.68	-3.90	22.94	34.67	
MI5-G-39	2005.36	-1.46	-3.85	22.74	34.66	
MI5-G-40	2005.27	-1.13	-3.93	23.08	45.71	
MI5-G-41	2005.18	-0.68	-3.82	22.57	34.68	

Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
MI5-G-42	2005.09	-1.13	-4.39	25.16	34.72
MI5-G-43	2005.00	-1.09	-4.44	25.40	34.58
MI5-G-44	2004.90	-1.18	-4.21	24.34	45.65
MI5-G-45	2004.80	-0.91	-3.94	23.13	45.71
MI5-G-46	2004.70	0.05	-3.58	21.49	45.78
MI5-G-47	2004.60	-0.15	-3.60	21.62	45.78
MI5-G-48	2004.50	-0.98	-4.48	25.58	34.80
MI5-G-49	2004.40	-0.94	-3.71	22.11	45.75
MI5-G-50	2004.30	-0.43	-3.45	20.93	45.81
MI5-G-51	2004.20	-0.47	-2.86	18.25	45.92
MI5-G-52	2004.10	-0.59	-3.56	21.41	45.78
MI5-G-53	2004.00	-1.47	-4.49	25.63	34.63
MI5-G-54	2003.88	-1.41	-4.52	25.76	34.71
MI5-G-55	2003.75	-1.83	-4.31	24.79	34.90
MI5-G-56	2003.63				35.71
MI5-G-57	2003.50	-1.87	-4.37	25.09	34.91
MI5-G-58	2003.38	-1.88	-4.55	25.89	34.56
MI5-G-59	2003.25				35.84
MI5-G-60	2003.13	-0.70	-4.44	25.40	34.87
MI5-G-61	2003.00	-1.32	-4.88	27.40	34.67
MI5-G-62	2002.90	-0.73	-4.36	25.04	34.65
MI5-G-63	2002.80	-0.79	-4.47	25.52	34.70
MI5-G-64	2002.70	-1.27	-4.61	26.16	45.57
MI5-G-65	2002.60	-1.30	-4.64	26.28	45.57
	Average	-1.35	-4.17	24.17	37.92
	Range	-3.26	-5.17	18.25	32.09
		0.20	-2.86	28.69	45.92
BR2-D-1	2009.13	-0.22	-4.03	23.53	45.69
BR2-D-2	2009.05	-0.36	-3.70	22.06	45.76
BR2-D-3	2008.97	-0.96	-2.80	17.97	45.94
BR2-D-4	2008.90	-0.36	-3.88	22.86	45.72
BR2-D-5	2008.82	-0.23	-3.55	21.37	45.79
BR2-D-6	2008.74	0.00	-3.80	22.51	45.74
BR2-D-7	2008.67	-1.21	-4.49	25.63	34.79
BR2-D-8	2008.58	-1.59	-4.31	24.79	34.81
BR2-D-9	2008.50	-0.85	-4.49	25.61	34.88
BR2-D-10	2008.42	-0.79	-4.24	24.48	45.65
BR2-D-11	2008.33	-0.96	-3.87	22.82	34.83
BR2-D-12	2008.25	-0.53	-3.62	21.68	45.77
BR2-D-13	2008.17	-1.21	-4.13	23.98	35.02
BR2-D-14	2008.08	-1.70	-4.28	24.66	34.84
BR2-D-15	2008.00	-0.13	-2.95	18.66	35.07
BR2-D-16	2007.92	-0.95	-4.28	24.68	45.64
BR2-D-17	2007.83	-0.83	-4.19	24.27	45.66
BR2-D-18	2007.75	-1.03	-4.45	25.43	34.68

Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
BR2-D-19	2007.67	-1.05	-4.56	25.94	34.68
BR2-D-20	2007.59	-1.35	-3.78	22.40	34.80
BR2-D-21	2007.51	-1.48	-4.11	23.91	34.78
BR2-D-22	2007.44	-1.60	-4.03	23.55	45.69
BR2-D-23	2007.36	-1.70	-4.29	24.73	34.69
BR2-D-24	2007.28	-1.06	-4.36	25.02	34.71
BR2-D-25	2007.21				
BR2-D-26	2007.13	-2.13	-5.80	31.56	45.34
BR2-D-27	2007.05	-0.69	-4.04	23.60	34.71
BR2-D-28	2006.97	-1.04	-4.13	23.98	45.67
BR2-D-29	2006.90	-1.13	-4.60	26.13	45.58
BR2-D-30	2006.82	-0.13	-4.16	24.15	45.66
BR2-D-31	2006.74				
BR2-D-32	2006.67	-0.47	-4.72	26.66	34.65
BR2-D-33	2006.57	-0.45	-4.23	24.46	34.92
BR2-D-34	2006.47	0.02	-4.16	24.12	45.66
BR2-D-35	2006.37	-0.18	-4.29	24.72	34.71
BR2-D-36	2006.27	0.18	-4.34	24.94	34.69
BR2-D-37	2006.17				
BR2-D-38	2006.07	-0.41	-4.14	24.04	45.67
BR2-D-39	2005.97	0.07	-3.56	21.41	45.78
BR2-D-40	2005.87	-0.84	-3.94	23.15	45.71
BR2-D-41	2005.77	-0.60	-4.03	23.54	34.91
BR2-D-42	2005.67	-1.17	-4.27	24.63	45.64
BR2-D-43	2005.61	-2.30	-7.20	37.87	34.18
BR2-D-44	2005.55	-0.58	-3.94	23.13	34.89
BR2-D-45	2005.49				
BR2-D-46	2005.43	-1.15	-3.82	22.61	39.52
BR2-D-47	2005.37	-1.66	-4.21	24.36	39.87
BR2-D-48	2005.31	-1.92	-4.50	25.66	40.13
BR2-D-49	2005.25	-0.67	-4.38	25.14	40.03
BR2-D-50	2005.20	-0.36	-4.36	25.04	40.01
BR2-D-51	2005.14	-0.30	-4.08	23.76	39.75
BR2-D-52	2005.08	-0.27	-4.00	23.43	39.69
BR2-D-53	2005.02	-0.78	-3.94	23.11	39.62
BR2-D-54	2004.96	-0.73	-4.03	23.55	39.71
BR2-D-55	2004.90	-0.18	-3.98	23.33	39.67
BR2-D-56	2004.84	-0.17	-4.36	25.03	40.01
BR2-D-57	2004.78	-0.59	-4.13	23.97	39.79
BR2-D-58	2004.73	-0.56	-4.53	25.79	40.16
BR2-D-59	2004.67	2.99	-5.35	29.49	40.90
BR2-D-60	2004.61	2.89	-5.19	28.80	40.76
BR2-D-61	2004.55				
BR2-D-62	2004.49	-0.52	-3.75	22.26	45.75
BR2-D-63	2004.43	-0.53	-3.63	21.73	35.00
BR2-D-64	2004.37	-0.58	-4.05	23.62	45.69

Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
BR2-D-65	2004.31	-0.07	-3.52	21.25	45.79
BR2-D-66	2004.25	-1.47	-4.00	23.38	45.70
BR2-D-67	2004.20	-0.72	-3.94	23.13	34.83
BR2-D-68	2004.14				
BR2-D-69	2004.08				
BR2-D-70	2004.02				
	Average	-0.75	-4.19	24.24	40.26
	Range	-2.30	-7.20	17.97	34.18
		2.99	-2.80	37.87	45.94
BR3-F-1	2009.39	-0.08	-4.33	24.91	34.78
BR3-F-2	2009.33	0.03	-4.41	25.26	33.88
BR3-F-3	2009.28	-1.04	-4.14	24.06	34.65
BR3-F-4	2009.22	-1.13	-4.13	23.99	33.94
BR3-F-5	2009.17				
BR3-F-5	2009.11				
BR3-F-6	2009.06	-0.90	-4.21	24.35	33.92
BR3-F-7	2009.00	-1.53	-3.97	23.28	34.71
BR3-F-8	2008.94				
BR3-F-9	2008.89	-1.34	-4.43	25.37	34.76
BR3-F-10	2008.83	-0.22	-4.55	25.87	34.90
BR3-F-11	2008.78	-1.42	-4.47	25.53	33.87
BR3-F-12	2008.72				
BR3-F-13	2008.67	-1.26	-4.76	26.86	34.71
BR3-F-14	2008.60	-1.50	-4.63	26.25	33.84
BR3-F-15	2008.53	-1.32	-4.42	25.31	34.73
BR3-F-16	2008.47	-2.68	-6.29	33.75	34.38
BR3-F-17	2008.40	-0.93	-4.24	24.51	34.63
BR3-F-18	2008.33				
BR3-F-19	2008.27	-1.23	-4.23	24.43	34.71
BR3-F-21	2008.20	-1.07	-4.13	23.99	34.68
BR3-F-22	2008.13	-1.51	-4.08	23.77	34.85
BR3-F-23	2008.07	-1.13	-3.79	22.46	34.01
BR3-F-24	2008.00	-1.23	-4.31	24.80	34.77
BR3-F-25	2007.93	-0.56	-3.81	22.57	34.92
BR3-F-26	2007.87	-1.17	-4.04	23.59	34.70
BR3-F-27	2007.80	-1.48	-4.26	24.59	34.65
BR3-F-28	2007.73	-2.22	-5.18	28.73	34.62
BR3-F-29	2007.67	-1.19	-4.43	25.36	34.79
BR3-F-30	2007.60	-1.16	-4.40	25.20	33.88
BR3-F-31	2007.54	-0.65	-4.28	24.65	34.71
BR3-F-32	2007.48	-1.08	-3.90	22.95	34.75
BR3-F-33	2007.42	-0.93	-4.20	24.30	33.92
BR3-F-34	2007.35	-1.60	-5.18	28.72	34.58
BR3-F-35	2007.29				
BR3-F-36	2007.23	0.03	-3.63	21.72	34.04

	Sample	Year	δ13C	δ18O	T (Leder)	Salinity
	BR3-F-37	2007.17	-1.34	-4.10	23.86	34.70
	BR3-F-38	2007.10	-0.95	-3.95	23.17	34.74
	BR3-F-39	2007.04				
	BR3-F-40	2006.98	-1.42	-4.09	23.81	34.71
	BR3-F-41	2006.92	-0.61	-3.47	21.03	34.80
	BR3-F-42	2006.85	-0.23	-3.50	21.13	34.78
	BR3-F-43	2006.79	-0.67	-4.46	25.47	34.84
	BR3-F-44	2006.73	0.53	-3.54	21.33	34.06
	BR3-F-45	2006.67	-0.64	-4.77	26.88	33.81
	BR3-F-46	2006.62	-0.36	-4.32	24.87	34.78
	BR3-F-47	2006.57	-0.28	-4.30	24.75	34.70
	BR3-F-48	2006.52	-0.02	-2.98	18.81	34.17
	BR3-F-49	2006.47	-0.38	-3.79	22.46	34.01
	BR3-F-50	2006.42	-0.63	-3.72	22.15	34.02
	BR3-F-51	2006.37	-0.13	-3.57	21.45	34.83
	BR3-F-52	2006.32	-0.89	-3.86	22.77	34.71
	BR3-F-53	2006.27	-0.96	-4.02	23.52	33.96
	BR3-F-54	2006.22	-1.23	-3.51	21.18	34.80
	BR3-F-55	2006.17	-1.73	-3.79	22.46	34.85
	BR3-F-56	2006.12	-1.15	-3.95	23.19	33.97
	BR3-F-57	2006.07	-3.19	-3.84	22.67	34.00
	BR3-F-58	2006.02	-1.66	-3.83	22.65	34.00
	BR3-F-59	2005.97	-2.19	-3.87	22.82	33.99
	BR3-F-60	2005.92	0.05	-3.48	21.04	34.94
	BR3-F-61	2005.87	-0.85	-3.94	23.11	34.59
	BR3-F-62	2005.82	-0.54	-4.33	24.91	34.74
	BR3-F-63	2005.77				
	BR3-F-64	2005.72	-0.72	-2.58	16.98	34.98
	BR3-F-65	2005.67	-0.65	-4.71	26.61	33.82
	BR3-F-66	2005.61	-0.75	-4.61	26.18	33.84
	BR3-F-67	2005.56	-0.62	-4.65	26.36	33.83
	BR3-F-68	2005.50	-0.65	-4.71	26.61	34.58
	BR3-F-69	2005.44	-0.75	-4.61	26.18	33.84
	BR3-F-70	2005.39	-0.62	-4.65	26.36	34.71
		Average	-0.96	-4.17	24.16	34.44
		Range	-3.19	-6.29	16.98	33.81
			0.53	-2.58	33.75	34.98
	AC4-D-1	2009.51	-2.30	-4.52	25.77	35.03
	AC4-D-2	2009.44	-2.33	-4.74	26.76	35.08
	AC4-D-3	2009.36	-2.91	-4.57	26.00	35.08
	AC4-D-4	2009.28	-2.66	-4.45	25.43	35.11
	AC4-D-5	2009.21	-2.83	-4.35	25.00	35.09
	AC4-D-6	2009.13	-2.69	-3.93	23.08	35.13
	AC4-D-7	2009.05	-2.93	-4.34	24.93	34.96
	AC4-D-8	2008.97	-2.94	-4.15	24.07	35.12

Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
AC4-D-9	2008.90	-2.95	-4.55	25.91	34.95
AC4-D-10	2008.82	-2.81	-4.47	25.53	35.08
AC4-D-11	2008.74	-2.56	-4.70	26.59	35.07
AC4-D-12	2008.67	-3.06	-4.96	27.72	35.01
AC4-D-13	2008.60	-2.73	-4.57	25.96	34.88
AC4-D-14	2008.54	-3.01	-4.50	25.67	35.23
AC4-D-15	2008.48	-2.74	-4.36	25.04	35.20
AC4-D-16	2008.42	-2.78	-4.19	24.26	35.06
AC4-D-17	2008.35	-2.47	-4.07	23.74	35.15
AC4-D-18	2008.29	-2.43	-3.97	23.29	35.20
AC4-D-19	2008.23	-2.71	-4.25	24.53	34.63
AC4-D-20	2008.17	-2.58	-4.11	23.89	35.14
AC4-D-21	2008.10	-2.55	-4.05	23.63	35.17
AC4-D-22	2008.04	-2.76	-4.04	23.60	35.08
AC4-D-23	2007.98	-3.01	-4.07	23.74	35.14
AC4-D-24	2007.92	-3.08	-4.24	24.48	35.17
AC4-D-25	2007.85	-2.32	-4.42	25.32	35.09
AC4-D-26	2007.79	-1.55	-4.55	25.88	35.05
AC4-D-27	2007.73	-2.16	-5.03	28.05	35.00
AC4-D-28	2007.67	-2.86	-5.25	29.06	34.88
AC4-D-29	2007.60	-3.09	-4.74	26.73	35.06
AC4-D-30	2007.54	-2.22	-4.63	26.27	35.05
AC4-D-31	2007.48	-2.18	-4.62	26.19	35.05
AC4-D-32	2007.42	-2.07	-4.38	25.10	35.12
AC4-D-33	2007.35	-2.43	-4.04	23.60	33.96
AC4-D-34	2007.29	-2.87	-4.46	25.46	35.09
AC4-D-35	2007.23	-2.80	-4.21	24.38	35.13
AC4-D-36	2007.17	-2.89	-4.05	23.65	35.10
AC4-D-37	2007.10	-2.63	-4.12	23.93	35.04
AC4-D-38	2007.04	-2.28	-3.93	23.10	35.17
AC4-D-39	2006.98	-2.12	-3.49	21.10	
AC4-D-40	2006.92	-2.25	-4.16	24.13	
AC4-D-41	2006.85	-2.50	-4.14	24.05	
AC4-D-42	2006.79	-2.33	-4.30	24.75	
AC4-D-43	2006.73	-2.16	-4.58	26.03	
AC4-D-44	2006.67	-2.65	-4.76	26.83	
AC4-D-45	2006.58	-2.45	-4.49	25.63	
AC4-D-46	2006.48	-1.98	-4.57	25.98	
AC4-D-47	2006.39	-1.34	-3.87	22.80	
AC4-D-48	2006.30				
AC4-D-49	2006.21	-1.44	-3.80	22.48	
AC4-D-50	2006.12	-1.42	-4.02	23.50	
AC4-D-51	2006.03	-1.90	-3.45	20.90	
AC4-D-52	2005.94				
AC4-D-53	2005.85				
AC4-D-54	2005.76	-1.81	-4.27	24.63	

	Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity	
	AC4-D-55	2005.67	-2.82	-4.84	27.19		
	AC4-D-56	2005.56	-1.60	-4.00	23.41		
	AC4-D-57	2005.44	-1.81	-4.48	25.57		
	AC4-D-58	2005.33	-1.84	-4.25	24.54		
	AC4-D-59	2005.22	-2.27	-4.16	24.13		
	AC4-D-60	2005.11	-2.06	-4.02	23.50		
	AC4-D-61	2005.00	-2.45	-4.02	23.49		
	AC4-D-62	2004.89	-1.69	-4.14	24.03		
	AC4-D-63	2004.78	-2.03	-4.82	27.11		
	AC4-D-64	2004.67	-1.99	-5.02	28.03		
	AC4-D-65	2004.56	-2.24		27.34		
	AC4-D-67	2004.44	-2.26	-3.11	19.39		
	AC4-D-68	2004.33	-1.20	-4.05	23.62		
	AC4-D-69	2004.22	-2.43	-4.28	24.66		
	AC4-D-70	2004.11	-1.90	-3.36	20.50		
	AC4-D-71	2004.00	-1.77	-4.22	24.40		
	AC4-D-72	2003.89	-1.31	-3.85	22.71		
	AC4-D-73	2003.78	-1.64	-4.60	26.13		
	AC4-D-74	2003.67	-2.43	-4.64	26.29		
	AC4-D-75	2003.52	-2.29	-3.92	23.06		
	AC4-D-76	2003.38					
	AC4-D-77	2003.24	-2.13	-4.41	25.28		
	AC4-D-78	2003.10	-2.56	-3.93	23.09		
	AC4-D-79	2002.95	-2.08	-4.26	24.60		
	AC4-D-80	2002.81	-2.30	-4.32	24.84		
	AC4-D-81	2002.67	-2.34	-4.66	26.37		
	AC4-D-82	2002.56	-2.28	-3.83	22.63		
	AC4-D-83	2002.44	-0.86	-3.01	18.95		
	AC4-D-84	2002.33	-2.35	-4.08	23.76		
	AC4-D-85	2002.22	-2.23	-3.57	21.47		
	AC4-D-86	2002.11	-1.95	-3.97	23.28		
	AC4-D-87	2002.00	-2.06	-3.67	21.89		
	AC4-D-88	2001.89	-1.13	-3.90	22.94		
	AC4-D-89	2001.78	-1.53	-3.86	22.76		
	AC4-D-90	2001.67	-2.49	-4.73	26.69		
	AC4-D-91	2001.58	-1.76	-3.89	22.89		
	AC4-D-92	2001.48	-1.14	-4.00	23.39		
	AC4-D-93	2001.39	-2.08	-4.72	26.67		
	AC4-D-94	2001.30	-2.23	-4.46	25.48		
	AC4-D-95	2001.21	-2.23	-4.23	24.45		
	AC4-D-96	2001.12	-1.62	-3.89	22.90		
	AC4-D-97	2001.03	-2.10	-4.02	23.50		
	AC4-D-98	2000.94	-2.55	-3.17	19.66		
	AC4-D-99	2000.85	-2.63	-4.15	24.06		
	AC4-D-100	2000.76	-2.93	-3.95	23.17		
	AC4-D-101	2000.67	-1.45	-4.99	27.88		

Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
AC4-D-102	2000.57	-0.46	-4.14	24.04	
AC4-D-103	2000.47	-1.76	-4.03	23.54	
AC4-D-104	2000.37	-1.64	-4.05	23.64	
AC4-D-105	2000.27	-1.49	-3.96	23.24	
AC4-D-106	2000.17	-1.39	-3.64	21.80	
AC4-D-107	2000.07	-2.39	-4.17	24.15	
AC4-D-108	1999.97	-0.53	-3.96	23.20	
AC4-D-109	1999.87	-1.71	-4.65	26.35	
AC4-D-110	1999.77	-2.51	-4.18	24.23	
AC4-D-111	1999.67	-1.59	-4.65	26.35	
AC4-D-112	1999.59	-1.44	-4.28	24.69	
AC4-D-113	1999.51	-2.19	-4.06	23.67	
AC4-D-114	1999.44	-2.44	-4.28	24.67	
AC4-D-115	1999.36	-2.35	-4.09	23.83	
AC4-D-116	1999.28	-2.01	-4.12	23.97	
AC4-D-117	1999.21	-2.12	-4.02	23.49	
AC4-D-118	1999.13	-1.57	-3.98	23.32	
AC4-D-119	1999.05	-0.91	-4.18	24.22	
AC4-D-120	1998.97	-1.43	-4.09	23.81	
AC4-D-121	1998.90	-1.19	-4.26	24.56	
AC4-D-122	1998.82	-0.01	-3.79	22.47	
AC4-D-123	1998.74	-1.72	-4.45	25.43	
AC4-D-124	1998.67	-1.74	-4.50	25.65	
AC4-D-125	1998.60	-0.61	-4.13	24.01	
AC4-D-126	1998.52	-1.15	-4.36	25.03	
AC4-D-127	1998.45	-1.95	-4.48	25.59	
AC4-D-128	1998.38				
AC4-D-129	1998.31	-1.17	-3.79	22.46	
AC4-D-130	1998.24	-0.59	-4.07	23.71	
AC4-D-131	1998.17	-0.60	-4.05	23.62	
AC4-D-132	1998.10	-1.44	-4.17	24.17	
AC4-D-133	1998.02	-2.13	-4.51	25.73	
AC4-D-134	1997.95	-2.04	-4.20	24.31	
AC4-D-135	1997.88	-2.01	-4.26	24.60	
AC4-D-136	1997.81	-1.30	-3.79	22.44	
AC4-D-137	1997.74	-2.38	-4.90	27.45	
AC4-D-138	1997.67	-2.54	-5.01	27.97	
AC4-D-139	1997.56	-1.00	-3.92	23.04	
AC4-D-140	1997.44	-1.94	-4.03	23.55	
AC4-D-141	1997.33	-1.35	-4.02	23.52	
AC4-D-142	1997.22	-2.14	-3.79	22.45	
AC4-D-143	1997.11	-1.98	-4.42	25.32	
AC4-D-144	1997.00	-2.21	-3.84	22.68	
AC4-D-145	1996.89	-2.27	-4.69	26.52	
AC4-D-146	1996.78	-2.01	-3.91	23.02	
AC4-D-147	1996.67	-1.68	-5.08	28.28	

Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
AC4-D-148	1996.60	-1.69	-4.67	26.43	
AC4-D-149	1996.52	-1.31	-4.35	24.98	
AC4-D-150	1996.45	-1.31	-4.08	23.75	
AC4-D-151	1996.38	-1.56	-3.92	23.05	
AC4-D-152	1996.31	-0.93	-3.74	22.23	
AC4-D-153	1996.24	-0.68	-3.58	21.49	
AC4-D-154	1996.17	-0.99	-3.60	21.59	
AC4-D-155	1996.10	-1.89	-4.13	24.00	
AC4-D-156	1996.02	-2.12	-4.28	24.68	
AC4-D-157	1995.95	-2.29	-4.61	26.18	
AC4-D-158	1995.88	-1.87	-4.03	23.54	
AC4-D-159	1995.81				
AC4-D-160	1995.74	-1.95	-4.05	23.64	
AC4-D-161	1995.67	-3.02	-4.81	27.05	
AC4-D-162	1995.57	-2.39	-4.38	25.13	
AC4-D-163	1995.47	-0.59	-3.46	20.99	
AC4-D-164	1995.37	-1.97	-4.07	23.72	
AC4-D-165	1995.27	-1.06	-3.99	23.37	
AC4-D-166	1995.17	-1.51	-4.49	25.62	
AC4-D-167	1995.07	-1.57	-4.38	25.14	
AC4-D-168	1994.97	-1.46	-3.04	19.09	
AC4-D-169	1994.87	-1.14	-3.68	21.96	
AC4-D-170	1994.77	-0.94	-3.78	22.42	
AC4-D-171	1994.67	-1.06	-3.90	22.97	
AC4-D-172	1994.56	-0.71	-3.72	22.14	
AC4-D-173	1994.44	-0.92	-3.36	20.52	
AC4-D-174	1994.33	-1.08	-3.85	22.71	
AC4-D-175	1994.22	-2.05	-3.86	22.80	
AC4-D-176	1994.11	-1.55	-3.74	22.22	
AC4-D-177	1994.00				
AC4-D-178	1993.89	-2.20	-4.32	24.84	
AC4-D-179	1993.78	-1.36	-4.07	23.71	
AC4-D-180	1993.67	-1.40	-4.53	25.79	
AC4-D-181	1993.60	-0.65	-4.17	24.19	
AC4-D-182	1993.52	-1.79	-4.40	25.21	
AC4-D-183	1993.45	-1.90	-3.71	22.11	
AC4-D-184	1993.38	-2.14	-3.78	22.39	
AC4-D-185	1993.31	-2.27	-4.08	23.78	
AC4-D-186	1993.24	-2.12	-3.59	21.54	
AC4-D-187	1993.17	-1.77	-4.06	23.68	
AC4-D-188	1993.10	-1.12	-3.65	21.82	
AC4-D-189	1993.02	-1.60	-4.32	24.83	
AC4-D-190	1992.95	-1.31	-4.34	24.92	
AC4-D-191	1992.88	-2.03	-4.03	23.56	
AC4-D-192	1992.81	-1.77	-3.83	22.62	
AC4-D-193	1992.74	-1.82	-4.18	24.20	

	Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Leder)	Salinity
	AC4-D-148	1996.60	-1.69	-4.67	26.43	
	AC4-D-149	1996.52	-1.31	-4.35	24.98	
	AC4-D-150	1996.45	-1.31	-4.08	23.75	
	AC4-D-151	1996.38	-1.56	-3.92	23.05	
	AC4-D-152	1996.31	-0.93	-3.74	22.23	
	AC4-D-153	1996.24	-0.68	-3.58	21.49	
	AC4-D-154	1996.17	-0.99	-3.60	21.59	
	AC4-D-155	1996.10	-1.89	-4.13	24.00	
	AC4-D-156	1996.02	-2.12	-4.28	24.68	
	AC4-D-157	1995.95	-2.29	-4.61	26.18	
	AC4-D-158	1995.88	-1.87	-4.03	23.54	
	AC4-D-159	1995.81				
	AC4-D-160	1995.74	-1.95	-4.05	23.64	
	AC4-D-161	1995.67	-3.02	-4.81	27.05	
	AC4-D-162	1995.57	-2.39	-4.38	25.13	
	AC4-D-163	1995.47	-0.59	-3.46	20.99	
	AC4-D-164	1995.37	-1.97	-4.07	23.72	
	AC4-D-165	1995.27	-1.06	-3.99	23.37	
	AC4-D-166	1995.17	-1.51	-4.49	25.62	
	AC4-D-167	1995.07	-1.57	-4.38	25.14	
	AC4-D-168	1994.97	-1.46	-3.04	19.09	
	AC4-D-169	1994.87	-1.14	-3.68	21.96	
	AC4-D-170	1994.77	-0.94	-3.78	22.42	
	AC4-D-171	1994.67	-1.06	-3.90	22.97	
	AC4-D-172	1994.56	-0.71	-3.72	22.14	
	AC4-D-173	1994.44	-0.92	-3.36	20.52	
	AC4-D-174	1994.33	-1.08	-3.85	22.71	
	AC4-D-175	1994.22	-2.05	-3.86	22.80	
	AC4-D-176	1994.11	-1.55	-3.74	22.22	
	AC4-D-177	1994.00				
	AC4-D-178	1993.89	-2.20	-4.32	24.84	
	AC4-D-179	1993.78	-1.36	-4.07	23.71	
	AC4-D-180	1993.67	-1.40	-4.53	25.79	
	AC4-D-181	1993.60	-0.65	-4.17	24.19	
	AC4-D-182	1993.52	-1.79	-4.40	25.21	
	AC4-D-183	1993.45	-1.90	-3.71	22.11	
	AC4-D-184	1993.38	-2.14	-3.78	22.39	
	AC4-D-185	1993.31	-2.27	-4.08	23.78	
	AC4-D-186	1993.24	-2.12	-3.59	21.54	
	AC4-D-187	1993.17	-1.77	-4.06	23.68	
	AC4-D-188	1993.10	-1.12	-3.65	21.82	
	AC4-D-189	1993.02	-1.60	-4.32	24.83	
	AC4-D-190	1992.95	-1.31	-4.34	24.92	
	AC4-D-191	1992.88	-2.03	-4.03	23.56	
	AC4-D-192	1992.81	-1.77	-3.83	22.62	
	AC4-D-193	1992.74	-1.82	-4.18	24.20	

	Sample	Year	$\delta^{13}C$	$\delta^{18}O$	T (Leder)	Salinity	
	AC4-D-240	1988.58	-1.48	-4.32	24.86		
		Average	-1.85	-4.07	23.73		
		Range	-3.09	-5.25	13.66		
			0.04	-1.84	29.06		
	<i>Siderastrea sp.</i>						
	Sample	Year	$\delta^{13}C$	$\delta^{18}O$	T (Moses)	T (Maupin)	Salinity (G&K)
	MI6-J-1	2009.00	-2.01	-3.92	27.71	30.23	28.07
	MI6-J-2	2008.92	-1.70	-3.71	26.87	28.65	28.46
	MI6-J-3	2008.85	-1.89	-3.74	27.00	28.90	28.40
	MI6-J-4	2008.77	-1.16	-3.74	26.98	28.86	28.41
	MI6-J-5	2008.69	-1.29	-3.17	24.78	24.74	29.44
	MI6-J-6	2008.62	-1.16	-3.54	26.22	27.44	28.77
	MI6-J-7	2008.54	-1.26	-3.47	25.96	26.95	28.89
	MI6-J-8	2008.46	-1.41	-3.62	26.55	28.06	28.61
	MI6-J-9	2008.38	-1.08	-3.12	24.59	24.37	29.53
	MI6-J-10	2008.31					
	MI6-J-11	2008.23	-1.68	-3.61	26.51	27.98	28.63
	MI6-J-12	2008.15	-1.63	-3.78	27.15	29.18	28.33
	MI6-J-13	2008.08	-1.80	-3.83	27.34	29.54	28.24
	MI6-J-14	2008.00	-2.01	-3.90	27.63	30.08	28.11
	MI6-J-15	2007.93	-1.37	-3.43	25.82	26.68	28.96
	MI6-J-16	2007.87					
	MI6-J-17	2007.80	-1.20	-3.53	26.20	27.40	28.78
	MI6-J-18	2007.73	-1.62	-3.90	27.59	30.01	28.12
	MI6-J-19	2007.67	-0.86	-3.13	24.65	24.48	29.50
	MI6-J-20	2007.60	-0.93	-3.34	25.46	26.01	29.12
	MI6-J-21	2007.53	-0.83	-3.44	25.83	26.70	28.95
	MI6-J-22	2007.47	-0.89	-3.55	26.25	27.50	28.75
	MI6-J-23	2007.40					
	MI6-J-24	2007.33					
	MI6-J-25	2007.27	-1.06	-3.40	25.68	26.41	29.02
	MI6-J-26	2007.20	-1.85	-3.22	24.98	25.11	29.35
	MI6-J-27	2007.13	-1.25	-3.67	26.72	28.37	28.53
	MI6-J-28	2007.07	-1.91	-3.53	26.18	27.36	28.79
	MI6-J-29	2007.00	-1.61	-3.97	27.90	30.58	27.98
	MI6-J-30	2006.93	-1.57	-4.44	29.70	33.96	27.14
	MI6-J-31	2006.87	-1.26	-3.95	27.80	30.40	28.03
	MI6-J-32	2006.80	-2.06	-3.53	26.19	27.38	28.78
	MI6-J-33	2006.73	-1.19	-3.78	27.16	29.19	28.33
	MI6-J-34	2006.67	-1.62	-3.68	26.76	28.46	28.51
	MI6-J-35	2006.60	-1.09	-3.69	26.82	28.57	28.49
	MI6-J-36	2006.53	-1.56	-4.05	28.19	31.13	27.84
	MI6-J-37	2006.47	-1.40	-4.09	28.34	31.42	27.77
	MI6-J-38	2006.40	-1.29	-4.32	29.24	33.11	27.35

	Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Moses)	T (Maupin)	Salinity (G&K)
	MI6-J-39	2006.33	-1.31	-3.60	26.45	27.87	28.66
	MI6-J-40	2006.27	-1.00	-3.38	25.61	26.29	29.05
	MI6-J-41	2006.20	-1.27	-3.49	26.02	27.05	28.86
	MI6-J-42	2006.13	-0.86	-3.30	25.30	25.70	29.20
	MI6-J-43	2006.07	-1.08	-3.49	26.05	27.11	28.85
	MI6-J-44	2006.00	-0.99	-3.44	25.85	26.75	28.94
	MI6-J-45	2005.92	-1.36	-4.07	28.29	31.32	27.80
	MI6-J-46	2005.85	-1.19	-3.56	26.30	27.58	28.73
	MI6-J-47	2005.77	-1.60	-4.40	29.54	33.66	27.21
	MI6-J-48	2005.69	-1.39	-4.08	28.32	31.38	27.78
	MI6-J-49	2005.62	-1.32	-3.84	27.38	29.61	28.22
	MI6-J-50	2005.54	-0.98	-3.60	26.45	27.86	28.66
	MI6-J-51	2005.46	-1.07	-3.60	26.47	27.90	28.65
	MI6-J-52	2005.38	-1.04	-3.72	26.92	28.75	28.44
	MI6-J-53	2005.31	-1.77	-3.92	27.70	30.20	28.08
	MI6-J-54	2005.23	-1.88	-4.17	28.64	31.98	27.63
	MI6-J-55	2005.15	-1.79	-4.11	28.43	31.58	27.73
	MI6-J-56	2005.08	-1.49	-4.15	28.59	31.87	27.66
	MI6-J-57	2005.00	-1.65	-4.28	29.08	32.80	27.43
	MI6-J-58	2004.92	-1.24	-4.11	28.44	31.61	27.73
	MI6-J-59	2004.85	-1.02	-3.58	26.38	27.73	28.69
	MI6-J-60	2004.77	-0.80	-3.84	27.37	29.59	28.23
	MI6-J-61	2004.69	-0.78	-3.80	27.21	29.29	28.30
	MI6-J-62	2004.62	-0.71	-3.76	27.07	29.03	28.37
		Average	-1.35	-3.73	26.94	28.79	28.43
		Range	-2.06	-4.44	24.59	24.37	27.14
			-0.71	-3.12	29.70	33.96	29.53
	BR8-D-1	2009.20	-1.36	-4.09	28.34	31.42	27.77
	BR8-D-2	2009.14	-1.04	-3.85	27.42	29.70	28.20
	BR8-D-3	2009.08	-0.90	-4.01	28.05	30.87	27.91
	BR8-D-4	2009.02	-1.03	-3.83	27.33	29.52	28.25
	BR8-D-5	2008.96	-1.01	-3.83	27.36	29.58	28.23
	BR8-D-6	2008.90	-1.29	-4.06	28.22	31.18	27.83
	BR8-D-7	2008.84	-1.53	-4.16	28.61	31.93	27.65
	BR8-D-8	2008.78	-1.34	-3.99	27.97	30.73	27.95
	BR8-D-9	2008.73	-1.72	-3.96	27.85	30.49	28.01
	BR8-D-10	2008.67	-1.78	-4.20	28.76	32.19	27.58
	BR8-D-11	2008.61	-1.56	-4.18	28.71	32.11	27.60
	BR8-D-12	2008.56	-1.08	-3.89	27.56	29.95	28.14
	BR8-D-13	2008.50	-0.87	-3.88	27.52	29.88	28.16
	BR8-D-14	2008.44					

	Sample	Year	δ13C	δ18O	T (Moses)	T (Maupin)	Salinity (G&K)
	BR8-D-15	2008.39	-1.54	-4.15	28.59	31.88	27.66
	BR8-D-16	2008.33	-1.25	-3.94	27.77	30.34	28.04
	BR8-D-17	2008.28	-1.43	-4.33	29.28	33.18	27.34
	BR8-D-18	2008.22	-1.05	-4.28	29.08	32.80	27.43
	BR8-D-19	2008.17	-0.83	-4.13	28.50	31.71	27.70
	BR8-D-20	2008.11	-1.09	-4.18	28.70	32.08	27.61
	BR8-D-21	2008.06	-0.85	-4.01	28.02	30.82	27.92
	BR8-D-22	2008.00	-0.55	-3.88	27.52	29.88	28.16
	BR8-D-23	2007.94	-0.72	-3.70	26.84	28.60	28.48
	BR8-D-24	2007.89	-0.72	-3.89	27.57	29.97	28.13
	BR8-D-25	2007.83	-0.49	-3.66	26.69	28.31	28.55
	BR8-D-26	2007.78	-1.38	-4.34	29.33	33.27	27.31
	BR8-D-27	2007.72	-1.00	-4.08	28.30	31.34	27.79
	BR8-D-28	2007.67	-1.53	-4.17	28.66	32.01	27.63
	BR8-D-29	2007.60	-0.69	-3.69	26.79	28.51	28.50
	BR8-D-30	2007.53	-0.81	-3.60	26.46	27.89	28.65
	BR8-D-31	2007.47	-0.93	-3.89	27.56	29.95	28.14
	BR8-D-32	2007.40	-0.99	-3.72	26.93	28.76	28.44
	BR8-D-33	2007.33	-0.99	-3.72	26.91	28.73	28.44
	BR8-D-34	2007.27	-1.27	-3.63	26.58	28.11	28.60
	BR8-D-35	2007.20	-1.24	-3.63	26.58	28.10	28.60
	BR8-D-36	2007.13	-1.17	-3.42	25.77	26.59	28.98
	BR8-D-37	2007.07					
	BR8-D-38	2007.00	-1.51	-3.68	26.77	28.47	28.51
	BR8-D-39	2006.93	-1.42	-3.66	26.67	28.28	28.56
	BR8-D-40	2006.87	-1.52	-3.24	25.07	25.28	29.31
	BR8-D-41	2006.80	-1.38	-3.62	26.55	28.05	28.61
	BR8-D-42	2006.73					
	BR8-D-43	2006.67	-2.02	-2.44	21.97	19.45	30.76
	BR8-D-44	2006.61					
	BR8-D-45	2006.55	-1.39	-3.61	26.51	27.98	28.63
	BR8-D-46	2006.49	-1.81	-2.96	24.00	23.27	29.81
	BR8-D-47	2006.43	-1.21	-3.40	25.69	26.44	29.01
	BR8-D-48	2006.37					
	BR8-D-49	2006.31	-1.27	-3.69	26.80	28.52	28.50
	BR8-D-50	2006.25					
	BR8-D-51	2006.20	-1.28	-3.92	27.68	30.18	28.08
	BR8-D-52	2006.14	-1.10	-4.08	28.29	31.33	27.80
	BR8-D-53	2006.08	-1.18	-3.78	27.15	29.17	28.33
	BR8-D-54	2006.02	-0.57	-2.38	21.75	19.03	30.86
	BR8-D-55	2005.96	-1.14	-3.92	27.69	30.19	28.08
	BR8-D-56	2005.90	-0.86	-3.76	27.06	29.02	28.37
	BR8-D-57	2005.84	-0.97	-3.86	27.47	29.77	28.18
	BR8-D-58	2005.78	-0.85	-4.05	28.18	31.10	27.85
	BR8-D-59	2005.73	-0.80	-3.82	27.29	29.44	28.27

	Sample	Year	$\delta^{13}C$	$\delta^{18}O$	T (Moses)	T (Maupin)	Salinity (G&K)
	BR8-D-60	2005.67					
	BR8-D-61	2005.60	-1.16	-4.20	28.78	32.24	27.57
	BR8-D-62	2005.54	-1.05	-3.76	27.09	29.07	28.36
	BR8-D-63	2005.48	-0.96	-4.14	28.53	31.77	27.69
	BR8-D-64	2005.42					
	BR8-D-65	2005.35	-0.72	-3.77	27.11	29.10	28.35
	BR8-D-66	2005.29	-0.49	-3.65	26.64	28.21	28.57
	BR8-D-67	2005.23	-0.90	-4.07	28.28	31.30	27.80
	BR8-D-68	2005.17	-0.73	-3.83	27.36	29.57	28.23
	BR8-D-69	2005.10	-0.77	-3.74	27.01	28.92	28.40
	BR8-D-70	2005.04	-0.88	-3.67	26.72	28.38	28.53
	BR8-D-71	2004.98	-1.40	-3.88	27.53	29.90	28.15
	BR8-D-72	2004.92	-1.07	-3.74	26.98	28.86	28.41
	BR8-D-73	2004.85	-1.14	-3.75	27.02	28.94	28.39
	BR8-D-74	2004.79	-0.99	-3.25	25.11	25.35	29.29
	BR8-D-75	2004.73	-1.25	-3.75	27.03	28.96	28.39
		Average	-1.12	-3.81	27.25	29.37	28.28
		Range	-2.02	-4.34	21.75	19.03	27.31
			-0.49	-2.38	29.33	33.27	30.86
	SC1-I-1	2008.52					
	SC1-I-2	2008.45	-1.68	-3.96	27.86	30.51	28.00
	SC1-I-3	2008.38	-1.39	-3.53	26.19	27.39	28.78
	SC1-I-4	2008.31					
	SC1-I-5	2008.24	-1.16	-3.17	24.80	24.77	29.43
	SC1-I-6	2008.17					
	SC1-I-7	2008.10	-1.09	-3.46	25.91	26.84	28.92
	SC1-I-8	2008.02	-1.15	-3.28	25.21	25.54	29.24
	SC1-I-9	2007.95	-1.35	-3.41	25.72	26.50	29.00
	SC1-I-10	2007.88	-1.88	-3.79	27.20	29.27	28.31
	SC1-I-11	2007.81	-1.84	-3.68	26.76	28.45	28.51
	SC1-I-12	2007.74	-1.85	-3.88	27.54	29.91	28.15
	SC1-I-13	2007.67	-1.99	-4.21	28.83	32.33	27.55
	SC1-I-14	2007.60	-1.88	-4.01	28.05	30.87	27.91
	SC1-I-15	2007.52					
	SC1-I-16	2007.45	-1.60	-4.35	29.36	33.33	27.30
	SC1-I-17	2007.38	-1.00	-3.72	26.93	28.77	28.44
	SC1-I-18	2007.31	-0.75	-3.62	26.51	27.99	28.63
	SC1-I-19	2007.24	-1.12	-3.52	26.16	27.33	28.79
	SC1-I-20	2007.17	-1.03	-3.46	25.91	26.86	28.91
	SC1-I-21	2007.10					
	SC1-I-22	2007.02	-1.43	-3.67	26.73	28.40	28.53
	SC1-I-23	2006.95	-1.42	-3.64	26.62	28.19	28.58
	SC1-I-24	2006.88	-1.42	-3.72	26.92	28.74	28.44
	SC1-I-25	2006.81	-1.52	-3.81	27.27	29.40	28.28

	Sample	Year	$\delta^{13}\text{C}$	$\delta^{18}\text{O}$	T (Moses)	T (Maupin)	Salinity (G&K)
	AC7-1	2009.67	-2.93	-4.05	28.21	31.17	27.83
	AC7-2	2009.61	-2.16	-3.96	27.83	30.46	28.01
	AC7-3	2009.56	-1.99	-3.70	26.84	28.60	28.48
	AC7-4	2009.50	-1.91	-3.75	27.05	28.99	28.38
	AC7-5	2009.44	-1.90	-3.67	26.73	28.40	28.53
	AC7-6	2009.39	-2.07	-3.60	26.47	27.90	28.65
	AC7-7	2009.33	-2.69	-4.46	29.76	34.08	27.11
	AC7-8	2009.28	-2.09	-3.69	26.80	28.51	28.50
	AC7-9	2009.22	-2.10	-3.53	26.19	27.38	28.78
	AC7-10	2009.17	-2.49	-3.76	27.06	29.00	28.38
	AC7-11	2009.11	-1.54	-3.68	26.78	28.48	28.51
	AC7-12	2009.06	-2.01	-3.66	26.68	28.29	28.55
	AC7-13	2009.00	-2.14	-3.70	26.83	28.58	28.48
	AC7-14	2008.94					
	AC7-15	2008.89	-2.25	-4.05	28.19	31.14	27.84
	AC7-16	2008.83	-1.95	-3.85	27.43	29.71	28.20
	AC7-17	2008.78	-2.13	-3.91	27.67	30.15	28.09
	AC7-18	2008.72	-2.10	-4.10	28.38	31.49	27.75
	AC7-19	2008.67	-2.10	-4.15	28.56	31.83	27.67
	AC7-20	2008.60	-1.81	-3.85	27.44	29.72	28.20
	AC7-21	2008.54	-1.77	-3.73	26.97	28.84	28.42
	AC7-22	2008.48	-1.59	-3.76	27.08	29.04	28.37
	AC7-23	2008.42	-1.67	-3.90	27.61	30.04	28.12
	AC7-24	2008.35	-1.68	-3.77	27.13	29.13	28.34
	AC7-25	2008.29	-1.73	-3.78	27.13	29.15	28.34
	AC7-26	2008.23	-1.78	-3.69	26.79	28.51	28.50
	AC7-27	2008.17	-2.02	-3.78	27.13	29.15	28.34
	AC7-28	2008.10	-1.96	-3.68	26.77	28.47	28.51
	AC7-29	2008.04	-2.07	-3.61	26.50	27.97	28.63
	AC7-30	2007.98	-2.13	-3.76	27.07	29.03	28.37
	AC7-31	2007.92	-1.84	-3.79	27.19	29.26	28.31
	AC7-32	2007.85	-1.78	-3.68	26.76	28.44	28.52
	AC7-33	2007.79	-1.84	-3.74	27.00	28.90	28.40
	AC7-34	2007.73	-2.16	-4.06	28.23	31.20	27.83
	AC7-35	2007.67	-1.88	-4.17	28.67	32.04	27.62
	AC7-36	2007.60	-1.87	-4.15	28.59	31.88	27.66
	AC7-37	2007.52	-1.75	-4.05	28.21	31.16	27.84
	AC7-38	2007.45	-1.57	-3.89	27.58	30.00	28.13
	AC7-39	2007.38	-1.51	-3.90	27.63	30.08	28.11
	AC7-40	2007.31	-1.45	-3.96	27.86	30.50	28.00
	AC7-41	2007.24	-1.40	-3.69	26.79	28.51	28.50
	AC7-42	2007.17	-1.67	-3.83	27.33	29.52	28.25
	AC7-43	2007.10	-1.80	-3.76	27.09	29.07	28.36
	AC7-44	2007.02	-1.87	-3.83	27.35	29.55	28.24
	AC7-45	2006.95	-1.96	-3.77	27.11	29.11	28.35

	Sample	Year	$\delta^{13}C$	$\delta^{18}O$	T (Moses)	T (Maupin)	Salinity (G&K)
	AC7-46	2006.88	-1.89	-3.94	27.78	30.36	28.04
	AC7-47	2006.81	-1.69	-4.05	28.18	31.11	27.85
	AC7-48	2006.74	-1.41	-3.75	27.04	28.97	28.38
	AC7-49	2006.67	-1.61	-4.05	28.18	31.12	27.85
	AC7-50	2006.58	-1.30	-3.70	26.86	28.63	28.47
	AC7-51	2006.48	-1.25	-3.69	26.81	28.55	28.49
	AC7-52	2006.39	-1.37	-3.55	26.27	27.53	28.74
	AC7-53	2006.30	-1.56	-3.57	26.32	27.63	28.72
	AC7-54	2006.21	-1.40	-3.95	27.81	30.43	28.02
	AC7-55	2006.12	-1.31	-3.84	27.40	29.65	28.22
	AC7-56	2006.03	-1.27	-3.73	26.95	28.80	28.43
	AC7-57	2005.94	-1.38	-3.58	26.38	27.74	28.69
	AC7-58	2005.85	-1.43	-3.61	26.49	27.95	28.64
	AC7-59	2005.76	-1.57	-3.98	27.92	30.62	27.97
	AC7-60	2005.67	-1.89	-4.03	28.10	30.96	27.89
		Average	-1.82	-3.83	27.34	29.53	28.24
		Range	-2.93	-4.46	26.19	27.38	27.11
			-1.25	-3.53	29.76	34.08	28.78

Appendix C: Sr/Ca

<i>Montastrea sp.</i>					<i>Siderastrea sp.</i>				
Sample	Year	Sr/Ca	T (Swart)		Sample	Year	Sr/Ca	T (Maupin)	
MI5-G-1	2008.88	9.27	19.29		MI6-J-1	2009.00	8.85	29.62	
MI5-G-2	2008.75	9.18	21.49		MI6-J-2	2008.92	8.86	29.50	
MI5-G-3	2008.63	9.12	23.17		MI6-J-3	2008.85	8.88	29.00	
MI5-G-4	2008.50	9.14	22.63		MI6-J-4	2008.77	9.01	25.52	
MI5-G-5	2008.38	9.20	21.01		MI6-J-5	2008.69	9.06	24.42	
MI5-G-6	2008.25	9.47	13.97		MI6-J-6	2008.62	9.06	24.37	
MI5-G-7	2008.13	9.31	18.18		MI6-J-7	2008.54	9.26	19.26	
MI5-G-8	2008.00				MI6-J-8	2008.46	9.12	22.74	
MI5-G-9	2007.92	9.91			MI6-J-9	2008.38	8.94	27.43	
MI5-G-10	2007.83				MI6-J-10	2008.31	8.97	26.72	
MI5-G-11	2007.75				MI6-J-11	2008.23	9.14	22.38	
MI5-G-12	2007.67	9.64	9.46		MI6-J-12	2008.15	9.00	25.97	
MI5-G-13	2007.58	9.37	16.57		MI6-J-13	2008.08	9.00	25.73	
MI5-G-14	2007.50	9.49	13.42		MI6-J-14	2008.00	8.95	27.12	
MI5-G-15	2007.42	9.28	18.96		MI6-J-15	2007.93	8.86	29.42	
MI5-G-16	2007.33	9.41	15.55		MI6-J-16	2007.87	8.87	29.24	
MI5-G-17	2007.25	9.31	18.10		MI6-J-17	2007.80	9.00	25.95	
MI5-G-18	2007.17	9.17	21.86		MI6-J-18	2007.73	9.11	22.92	
MI5-G-19	2007.08	9.32	17.77		MI6-J-19	2007.67	8.98	26.35	
MI5-G-20	2007.00	9.31	18.16		MI6-J-20	2007.60	9.14	22.28	
MI5-G-21	2006.92	9.30	18.30		MI6-J-21	2007.53	8.98	26.46	
MI5-G-22	2006.83	9.16	22.18		MI6-J-22	2007.47	8.91	28.17	
MI5-G-23	2006.75	9.18	21.55		MI6-J-23	2007.40	9.03	25.09	
MI5-G-24	2006.67				MI6-J-24	2007.33	8.97	26.50	
MI5-G-25	2006.58				MI6-J-25	2007.27	9.08	23.86	
MI5-G-26	2006.50	9.28	18.88		MI6-J-26	2007.20	8.97	26.63	
MI5-G-27	2006.42	9.20	21.16		MI6-J-27	2007.13	8.72	33.05	
MI5-G-28	2006.33				MI6-J-28	2007.07	9.01	25.66	
MI5-G-29	2006.25	9.03	25.44		MI6-J-29	2007.00	9.11	23.05	
MI5-G-30	2006.17	9.38	16.21		MI6-J-30	2006.93	8.96	26.87	
MI5-G-31	2006.08	9.32	17.90		MI6-J-31	2006.87	8.90	28.40	
MI5-G-32	2006.00	9.22	20.64		MI6-J-32	2006.80	9.09	23.49	
MI5-G-33	2005.91				MI6-J-33	2006.73	9.33	17.47	
MI5-G-34	2005.82				MI6-J-34	2006.67	9.09	23.47	
MI5-G-35	2005.73	9.39	16.07		MI6-J-35	2006.60	9.25	19.40	
MI5-G-36	2005.64	9.27	19.32		MI6-J-36	2006.53	8.89	28.58	
MI5-G-37	2005.55	9.42	15.28		MI6-J-37	2006.47	9.17	21.40	
MI5-G-38	2005.45	9.41	15.51		MI6-J-38	2006.40	9.62	10.07	
MI5-G-39	2005.36	9.43	15.05		MI6-J-39	2006.33	9.10	23.34	
MI5-G-40	2005.27				MI6-J-40	2006.27	9.10	23.21	
MI5-G-41	2005.18	9.42	15.25		MI6-J-41	2006.20			

Sample	Year	Sr/Ca	T (Swart)	Sample	Year	Sr/Ca	T (Maupin)
MI5-G-42	2005.09	9.29	18.80	MI6-J-42	2006.13	8.98	26.43
MI5-G-43	2005.00	9.40	15.82	MI6-J-43	2006.07	9.06	24.33
MI5-G-44	2004.90			MI6-J-44	2006.00	8.93	27.70
MI5-G-45	2004.80			MI6-J-45	2005.92	8.88	28.91
MI5-G-46	2004.70			MI6-J-46	2005.85	8.91	28.06
MI5-G-47	2004.60			MI6-J-47	2005.77	9.21	20.39
MI5-G-48	2004.50	9.20	20.96	MI6-J-48	2005.69	9.31	18.00
MI5-G-49	2004.40			MI6-J-49	2005.62	9.24	19.72
MI5-G-50	2004.30			MI6-J-50	2005.54	8.97	26.66
MI5-G-51	2004.20			MI6-J-51	2005.46	9.17	21.58
MI5-G-52	2004.10			MI6-J-52	2005.38	9.03	24.97
MI5-G-53	2004.00	9.34	17.34	MI6-J-53	2005.31	8.86	29.54
MI5-G-54	2003.88	9.27	19.28	MI6-J-54	2005.23	8.95	27.23
MI5-G-55	2003.75	9.14	22.64	MI6-J-55	2005.15	9.10	23.24
MI5-G-56	2003.63	9.19	21.30	MI6-J-56	2005.08	8.93	27.69
MI5-G-57	2003.50	9.13	23.02	MI6-J-57	2005.00	8.99	26.08
MI5-G-58	2003.38	9.39	16.07	MI6-J-58	2004.92	9.04	24.73
MI5-G-59	2003.25	9.08	24.33	MI6-J-59	2004.85	9.08	23.69
MI5-G-60	2003.13	9.15	22.47	MI6-J-60	2004.77	8.89	28.71
MI5-G-61	2003.00	9.25	19.86	MI6-J-61	2004.69	8.91	28.19
MI5-G-62	2002.90	9.34	17.23	MI6-J-62	2004.62	8.91	28.15
MI5-G-63	2002.80	9.29	18.76				
MI5-G-64	2002.70						
MI5-G-65	2002.60						
	Average	9.30	18.80		Average	9.03	25.15
	Range	9.03	9.46		Range	8.72	10.07
		9.91	25.44			9.62	33.05
BR2-D-1	2009.13			SC1-I-1	2008.52		
BR2-D-2	2009.05			SC1-I-2	2008.45	8.85	29.71
BR2-D-3	2008.97			SC1-I-3	2008.38		
BR2-D-4	2008.90			SC1-I-4	2008.31		
BR2-D-5	2008.82			SC1-I-5	2008.24	8.92	27.99
BR2-D-6	2008.74			SC1-I-6	2008.17	8.96	26.81
BR2-D-7	2008.67	9.21	20.92	SC1-I-7	2008.10		
BR2-D-8	2008.58	9.22	20.46	SC1-I-8	2008.02		
BR2-D-9	2008.50	9.13	22.98	SC1-I-9	2007.95		
BR2-D-10	2008.42			SC1-I-10	2007.88	8.95	27.24
BR2-D-11	2008.33	9.28	18.99	SC1-I-11	2007.81	9.84	4.29
BR2-D-12	2008.25			SC1-I-12	2007.74	9.12	22.84
BR2-D-13	2008.17	9.07	24.46	SC1-I-13	2007.67	9.17	21.53
BR2-D-14	2008.08	9.20	21.04	SC1-I-14	2007.60		
BR2-D-15	2008.00	9.23	20.22	SC1-I-15	2007.52		
BR2-D-16	2007.92			SC1-I-16	2007.45		
BR2-D-17	2007.83			SC1-I-17	2007.38		
BR2-D-18	2007.75	9.31	18.22	SC1-I-18	2007.31	9.22	20.20

Sample	Year	Sr/Ca	T (Swart)	Sample	Year	Sr/Ca	T (Maupin)
BR2-D-19	2007.67	9.29	18.67	SC1-I-19	2007.24	8.94	27.36
BR2-D-20	2007.59	9.32	17.97	SC1-I-20	2007.17	9.08	23.70
BR2-D-21	2007.51	9.28	19.03	SC1-I-21	2007.10		
BR2-D-22	2007.44			SC1-I-22	2007.02	9.19	20.92
BR2-D-23	2007.36	9.33	17.63	SC1-I-23	2006.95	9.39	15.76
BR2-D-24	2007.28	9.30	18.43	SC1-I-24	2006.88	9.42	15.03
BR2-D-25	2007.21	9.35	17.20	SC1-I-25	2006.81	9.07	23.95
BR2-D-26	2007.13			SC1-I-26	2006.74	9.34	17.15
BR2-D-27	2007.05	9.35	17.05	SC1-I-27	2006.67	9.03	25.08
BR2-D-28	2006.97			SC1-I-28	2006.60	9.33	17.41
BR2-D-29	2006.90			SC1-I-29	2006.54	8.99	26.22
BR2-D-30	2006.82			SC1-I-30	2006.48		
BR2-D-31	2006.74			SC1-I-31	2006.42	8.87	29.18
BR2-D-32	2006.67	9.29	18.75	SC1-I-32	2006.35	9.11	23.09
BR2-D-33	2006.57	9.14	22.73	SC1-I-33	2006.29	9.11	23.02
BR2-D-34	2006.47			SC1-I-34	2006.23	9.10	23.21
BR2-D-35	2006.37	9.31	18.06	SC1-I-35	2006.17	9.23	19.94
BR2-D-36	2006.27	9.32	17.90	SC1-I-36	2006.10	9.01	25.66
BR2-D-37	2006.17	9.32	17.93	SC1-I-37	2006.04	8.99	26.15
BR2-D-38	2006.07			SC1-I-38	2005.98	9.01	25.69
BR2-D-39	2005.97			SC1-I-39	2005.92	8.95	27.16
BR2-D-40	2005.87			SC1-I-40	2005.85	8.87	29.23
BR2-D-41	2005.77	9.19	21.43	SC1-I-41	2005.79	8.99	26.02
BR2-D-42	2005.67			SC1-I-42	2005.73	8.84	29.98
BR2-D-43	2005.61	9.26	19.42	SC1-I-43	2005.67	8.97	26.70
BR2-D-44	2005.55	9.22	20.64	SC1-I-44	2005.60	8.76	31.88
BR2-D-45	2005.49			SC1-I-45	2005.52	8.98	26.27
BR2-D-46	2005.43			SC1-I-46	2005.45	8.73	32.64
BR2-D-47	2005.37			SC1-I-47	2005.38	8.99	26.11
BR2-D-48	2005.31	9.34	17.34	SC1-I-48	2005.31	8.81	30.69
BR2-D-49	2005.25	9.19	21.36	SC1-I-49	2005.24	8.96	26.96
BR2-D-50	2005.20			SC1-I-50	2005.17	8.82	30.34
BR2-D-51	2005.14	9.26	19.48	SC1-I-51	2005.10	8.90	28.51
BR2-D-52	2005.08	9.31	18.28	SC1-I-52	2005.02	8.99	26.13
BR2-D-53	2005.02			SC1-I-53	2004.95	8.96	26.74
BR2-D-54	2004.96	9.19	21.26	SC1-I-54	2004.88	8.85	29.74
BR2-D-55	2004.90			SC1-I-55	2004.81	9.14	22.28
BR2-D-56	2004.84			SC1-I-56	2004.74	8.98	26.28
BR2-D-57	2004.78	9.18	21.46	SC1-I-57	2004.67	9.23	20.08
BR2-D-58	2004.73			SC1-I-58	2004.60	9.04	24.84
BR2-D-59	2004.67			SC1-I-59	2004.52	8.95	27.13
BR2-D-60	2004.61	9.29	18.56	SC1-I-60	2004.45	9.05	24.46
BR2-D-61	2004.55	9.25	19.75		Average	9.04	24.78
BR2-D-62	2004.49				Range	8.73	4.29
BR2-D-63	2004.43	9.17	21.79			9.84	32.64
BR2-D-64	2004.37						

Sample	Year	Sr/Ca	T (Swart)	Sample	Year	Sr/Ca	T (Maupin)
BR2-D-65	2004.31						
BR2-D-66	2004.25						
BR2-D-67	2004.20	9.27	19.22				
BR2-D-68	2004.14						
BR2-D-69	2004.08	9.33	17.61				
BR2-D-70	2004.02	9.28	18.84	AC7-1	2009.67	8.93	27.54
	Average	9.25	19.66	AC7-2	2009.61	8.92	27.93
	Range	9.07	17.05	AC7-3	2009.56	8.91	28.03
		9.35	24.46	AC7-4	2009.50	9.09	23.54
				AC7-5	2009.44	8.95	27.22
BR3-F-1	2009.39	9.24	20.00	AC7-6	2009.39	8.99	26.00
BR3-F-2	2009.33			AC7-7	2009.33	9.07	23.95
BR3-F-3	2009.28	9.39	16.07	AC7-8	2009.28	9.10	23.38
BR3-F-4	2009.22			AC7-9	2009.22	9.06	24.32
BR3-F-5	2009.17			AC7-10	2009.17	9.12	22.89
BR3-F-5	2009.11	9.36	16.88	AC7-11	2009.11	9.03	25.19
BR3-F-6	2009.06			AC7-12	2009.06	8.82	30.57
BR3-F-7	2009.00	9.36	16.69	AC7-13	2009.00	8.87	29.09
BR3-F-8	2008.94			AC7-14	2008.94	8.82	30.46
BR3-F-9	2008.89	9.24	19.95	AC7-15	2008.89	8.91	28.13
BR3-F-10	2008.83	9.10	23.63	AC7-16	2008.83	9.11	22.97
BR3-F-11	2008.78			AC7-17	2008.78	8.73	32.67
BR3-F-12	2008.72	9.29	18.77	AC7-18	2008.72	8.76	32.00
BR3-F-13	2008.67	9.23	20.27	AC7-19	2008.67	8.87	29.16
BR3-F-14	2008.60			AC7-20	2008.60	8.92	27.84
BR3-F-15	2008.53	9.27	19.27	AC7-21	2008.54	8.93	27.74
BR3-F-16	2008.47	9.25	19.71	AC7-22	2008.48	9.07	23.94
BR3-F-17	2008.40	9.38	16.18	AC7-23	2008.42	9.29	18.39
BR3-F-18	2008.33			AC7-24	2008.35	9.06	24.41
BR3-F-19	2008.27	9.32	17.97	AC7-25	2008.29	8.94	27.36
BR3-F-21	2008.20	9.37	16.66	AC7-26	2008.23	9.46	14.02
BR3-F-22	2008.13	9.23	20.35	AC7-27	2008.17	9.14	22.28
BR3-F-23	2008.07			AC7-28	2008.10	9.28	18.61
BR3-F-24	2008.00	9.25	19.67	AC7-29	2008.04	9.10	23.30
BR3-F-25	2007.93	9.22	20.65	AC7-30	2007.98	9.14	22.22
BR3-F-26	2007.87	9.36	16.86	AC7-31	2007.92	8.94	27.45
BR3-F-27	2007.80	9.37	16.61	AC7-32	2007.85	8.99	26.15
BR3-F-28	2007.73	9.23	20.25	AC7-33	2007.79	8.90	28.42
BR3-F-29	2007.67	9.22	20.60	AC7-34	2007.73	9.06	24.23
BR3-F-30	2007.60			AC7-35	2007.67	8.87	29.08
BR3-F-31	2007.54	9.32	18.01	AC7-36	2007.60	8.87	29.25
BR3-F-32	2007.48	9.35	17.21	AC7-37	2007.52	8.91	28.21
BR3-F-33	2007.42			AC7-38	2007.45	9.04	24.75
BR3-F-34	2007.35	9.27	19.17	AC7-39	2007.38	9.14	22.20
BR3-F-35	2007.29	9.37	16.42	AC7-40	2007.31	9.15	22.04
BR3-F-36	2007.23			AC7-41	2007.24	9.00	25.80

Sample	Year	Sr/Ca	T (Swart)	Sample	Year	Sr/Ca	T (Maupin)
BR3-F-37	2007.17	9.35	17.05	AC7-42	2007.17	9.06	24.22
BR3-F-38	2007.10	9.34	17.24	AC7-43	2007.10	8.99	26.07
BR3-F-39	2007.04	9.32	18.00	AC7-44	2007.02	9.20	20.69
BR3-F-40	2006.98	9.35	17.19	AC7-45	2006.95	8.97	26.66
BR3-F-41	2006.92	9.37	16.50	AC7-46	2006.88	8.84	30.00
BR3-F-42	2006.85	9.38	16.23	AC7-47	2006.81	8.93	27.77
BR3-F-43	2006.79	9.17	21.92	AC7-48	2006.74	9.00	25.82
BR3-F-44	2006.73			AC7-49	2006.67	8.85	29.68
BR3-F-45	2006.67			AC7-50	2006.58	8.93	27.74
BR3-F-46	2006.62	9.25	19.84	AC7-51	2006.48	9.07	24.10
BR3-F-47	2006.57	9.31	18.06	AC7-52	2006.39	8.93	27.71
BR3-F-48	2006.52			AC7-53	2006.30	9.02	25.44
BR3-F-49	2006.47			AC7-54	2006.21	8.96	26.86
BR3-F-50	2006.42			AC7-55	2006.12	8.95	27.16
BR3-F-51	2006.37	9.33	17.63	AC7-56	2006.03	9.03	25.04
BR3-F-52	2006.32	9.39	16.11	AC7-57	2005.94	8.90	28.34
BR3-F-53	2006.27			AC7-58	2005.85	9.09	23.59
BR3-F-54	2006.22	9.36	16.74	AC7-59	2005.76	9.08	23.75
BR3-F-55	2006.17	9.27	19.17	AC7-60	2005.67	8.90	28.33
BR3-F-56	2006.12				Average	9.00	25.86
BR3-F-57	2006.07				Range	8.73	14.02
BR3-F-58	2006.02					9.46	32.67
BR3-F-59	2005.97						
BR3-F-60	2005.92	9.25	19.77				
BR3-F-61	2005.87	9.47	13.80				
BR3-F-62	2005.82	9.28	19.03				
BR3-F-63	2005.77	9.34	17.40				
BR3-F-64	2005.72	9.37	16.44				
BR3-F-65x	2005.67						
BR3-F-66	2005.61						
BR3-F-67	2005.56						
BR3-F-68	2005.50	9.35	17.08				
BR3-F-69	2005.44						
BR3-F-70	2005.39	9.25	19.74				
	Average	9.31	18.25				
	Range	9.10	13.80				
		9.47	23.63				
AC4-D-1	2009.51	9.14	22.66				
AC4-D-2	2009.44	8.99	26.75				
AC4-D-3	2009.36	9.03	25.45				
AC4-D-4	2009.28	9.02	25.73				
AC4-D-5	2009.21	9.09	24.05				
AC4-D-6	2009.13	9.16	22.20				
AC4-D-7	2009.05	9.30	18.45				
AC4-D-8	2008.97	9.10	23.63				

Sample	Year	Sr/Ca	T (Swart)					
AC4-D-9	2008.90	9.25	19.65					
AC4-D-10	2008.82	9.08	24.33					
AC4-D-11	2008.74	9.01	26.17					
AC4-D-12	2008.67	9.03	25.63					
AC4-D-13	2008.60	9.35	17.00					
AC4-D-14	2008.54	8.81	31.34					
AC4-D-15	2008.48	8.92	28.53					
AC4-D-16	2008.42	9.19	21.21					
AC4-D-17	2008.35	9.08	24.32					
AC4-D-18	2008.29	9.04	25.25					
AC4-D-19	2008.23							
AC4-D-20	2008.17	9.08	24.14					
AC4-D-21	2008.10	9.06	24.77					
AC4-D-22	2008.04	9.20	21.09					
AC4-D-23	2007.98	9.11	23.57					
AC4-D-24	2007.92	9.00	26.32					
AC4-D-25	2007.85	9.07	24.50					
AC4-D-26	2007.79	9.09	23.86					
AC4-D-27	2007.73	9.02	25.85					
AC4-D-28	2007.67	9.13	22.85					
AC4-D-29	2007.60	9.02	25.84					
AC4-D-30	2007.54	9.06	24.79					
AC4-D-31	2007.48	9.07	24.60					
AC4-D-32	2007.42	9.04	25.26					
AC4-D-33	2007.35							
AC4-D-34	2007.29	9.07	24.63					
AC4-D-35	2007.23	9.07	24.50					
AC4-D-36	2007.17	9.17	21.84					
AC4-D-37	2007.10	9.25	19.82					
AC4-D-38	2007.04	9.10	23.73					
AC4-D-39	2006.98							
	Average	9.09	24.01					
	Range	8.81	17.00					
		9.35	31.34					

4-Dec-07			36	6	Accra Bank	28.18	34.13	0.1	Surface
11-Mar-08			31	6	Accra Bank	26.24	33.63	26	Bottom
11-Mar-08			32	6	Accra Bank	26.24	33.64	25.6	Bottom
11-Mar-08			33	6	Accra Bank	26.24	33.65	25.5	Bottom
11-Mar-08			34	6	Accra Bank	26.15	33.18	0.1	Surface
11-Mar-08			35	6	Accra Bank	26.15	33.19	0.1	Surface
11-Mar-08			36	6	Accra Bank	26.15	33.19	0.1	Surface
16-Dec-08	N 13ø04'01.9"	W 59ø35'40.6"	28	6	Accra Bank	27.8	34.47	21.8	Bottom
16-Dec-08	N 13ø04'01.9"	W 59ø35'40.6"	29	6	Accra Bank	27.83	34.45	21.9	Bottom
16-Dec-08	N 13ø04'01.8"	W 59ø35'40.7"	30	6	Accra Bank	27.82	34.48	21.7	Bottom
16-Dec-08	N 13ø04'01.7"	W 59ø35'41.1"	31	6	Accra Bank	27.89	34.43	0.2	Surface
16-Dec-08	N 13ø04'01.7"	W 59ø35'41.1"	32	6	Accra Bank	27.89	34.43	0.2	Surface
16-Dec-08	N 13ø04'01.6"	W 59ø35'41.2"	33	6	Accra Bank	27.88	34.44	0.2	Surface
* deep=above seabed									