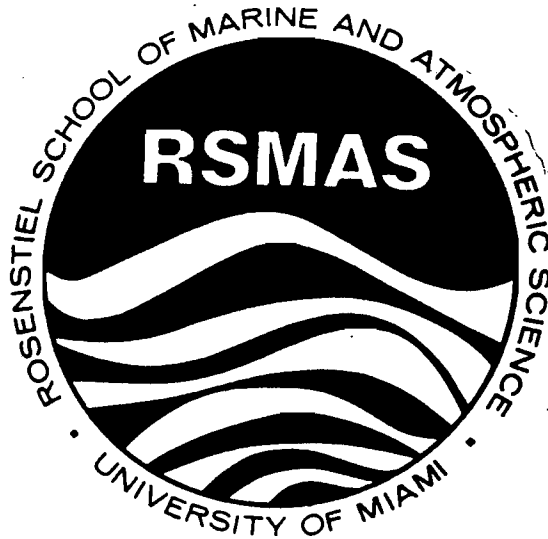


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Historical Salinity of Florida Bay Reconstructed from Isotopic Compositions of Corals

Report on statistical analyses, methods, results, assumptions,
and calculations of Florida Bay salinity history

Task 7 Report
September 1996

South Florida Water Management District
Contract Number C-E5267

***Historical Salinity of Florida Bay Reconstructed
from Isotopic Compositions of Corals***

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Executive Summary

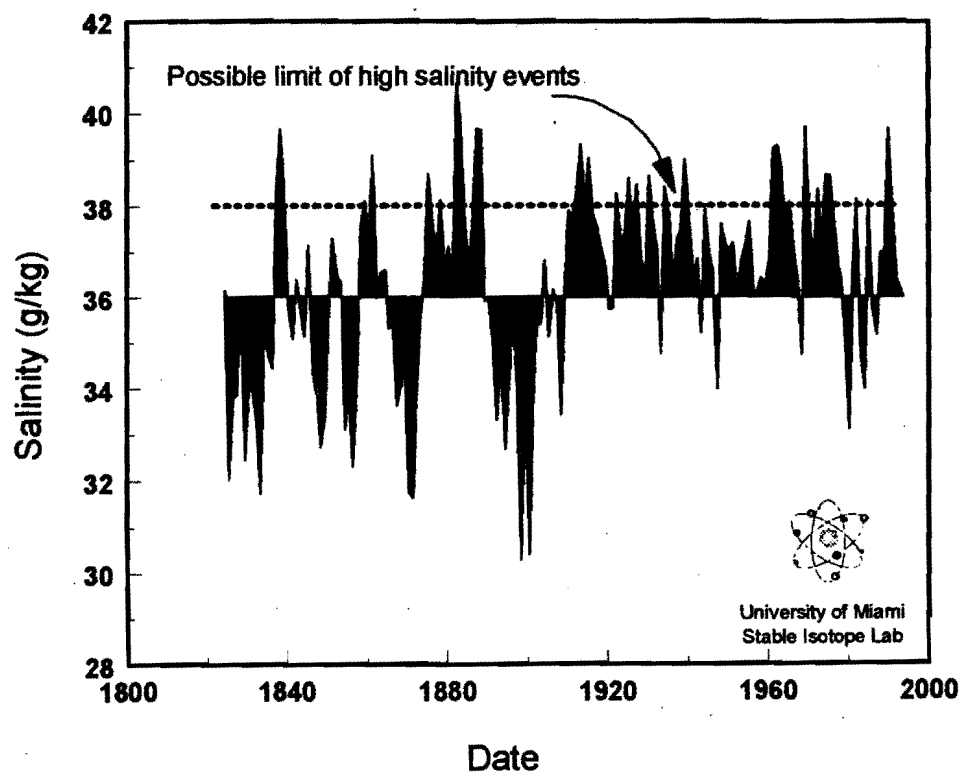
The following executive summary details the research carried out by the *University of Miami* group into the geological evidence of past salinity changes in Florida Bay. The following conclusions have been reached from our study.

- Changes in the salinity and temperature of the water in Lignumvitae Basin (Basin 30), situated north of lower and upper Matecumbe Keys, are highly correlated with the oxygen isotopic composition of the coral skeleton allowing the oxygen isotopic composition of the skeleton after removal of the temperature affect, to be used to calculate the salinity of the water.
- This improved correlation allows the interpretation of a 160 year record of oxygen isotopes from a coral growing in this basin. The results of this interpretation reveal that a previous study (Swart et al., 1996) underestimated the inter-annual range in salinity, but confirms the interpretation that there have been no long term changes in salinity other than those associated with the construction of the Flagler railway between 1905 and 1912.
- A comparison between the oxygen isotopic composition associated with the late 1980s high salinity episode and the remainder of the record indicates that there have been multiple such events throughout the 160 year history of Florida Bay.
- Prior to railway construction, inter-annual variations in salinity were much greater than post construction presumably resulting from a reduction in the exchange of water between the Bay and the reef tract.
- Although long-lived corals are only present close to the Florida Keys, smaller, short-lived corals are present throughout the Bay. Isotopic records from these small corals generally show similar patterns to the Lignumvitae Basin corals. In particular, the severe salinity episode experienced between 1989 and 1991 is evident in all of the small corals. This supports the idea that corals from Lignumvitae Basin can be used as general indicators of environmental conditions in the remainder of Florida Bay.

Corals are generally considered to be the trees of the sea. Within their skeletons they record continuous records of the environmental conditions present during their formation. In addition, many species form annual bands consisting of a narrow region of dense material and a broader portion of less dense carbonate. Using these bands, it is possible to accurately date

during the summer, although the timing can vary resulting in uncertainty in the intra-annual timing.

One of the most useful proxies of environmental conditions in the coral skeleton is the ratio of two of the oxygen isotopes, oxygen-18 and oxygen-16. The ratio of these isotopes has been shown to be strongly influenced by both temperature and salinity. In a previous study by the University of Miami group, a 160 year record from a coral collected in 1986 growing in Lignumvitae Basin was analyzed. It was determined that there was a strong relationship between the oxygen isotope ratio in the skeleton and salinity. From this relationship, we were able to calculate salinities in Lignumvitae Basin over the past 160 years. There were, however, several problems with this study. The most important was that the salinity data used in the relationship was collected by a variety of different researchers on a non-continuous basis. Beginning in 1989, the quantity and quality of all types of data collected in Florida Bay dramatically improved. Hence, an opportunity became available to calibrate the oxygen isotopic composition of the coral skeleton grown since 1986 and through the severe salinity crises which Florida Bay experienced in the late 1980s.



Annual average salinity calculated for Lignumvitae Basin from 1824 to 1993. The upper line suggests a limit above which high salinity events were present in the bay. If this interpretation is correct multiple such events have occurred throughout the past 160 years.

In this recent study, the oxygen isotopic composition of the skeleton was carefully analyzed and after correcting for the effect of temperature, a high statistically significant correlation between the oxygen isotopic composition and salinity was determined. This correlation was a significant improvement over our initial effort because we were able to consider temperature in addition to salinity as a controlling factor. We have now applied this new correlation

to our existing 160 year data set using annual average oxygen isotopic values which factors out the influence of temperature. The new correlation suggests that our original estimate was in error in that it did not truly reflect the range in salinities present in Lignumvitae Basin. However, many of our original conclusions remain valid. In particular, there appear to be no

major changes in the salinity of this basin other than those associated with the construction of the railway from Miami to Key West between 1905 and 1912. Our data confirm the existence of a much more variable salinity regime prior to railway construction than since. An example of our analyses in which we determined the average annual salinity of Lignumvitae Basin from 1824 to 1993 is shown in the figure above. Intervals which experienced greater than normal salinity, perhaps equivalent to the episode seen in the late 1980s, are shown as peaks that exceed the dashed line on this figure.

A second aspect of our work has been to relate changes in the oxygen isotopic composition of the coral in Lignumvitae Basin to smaller corals in other basins within Florida Bay. Although most of these corals only have short records (5 to 10 years), most of these corals, like the coral from Lignumvitae Basin, record the salinity crises in the late 1980s. This result is significant as it shows that Lignumvitae Basin can be used as a barometer of conditions in other areas of the bay.

Remaining Undetermined Aspects

Despite the promising results of this study there remain two aspects of this work which need to be continued.

- The salinity analyses which is shown in this executive report is based on a coral from only one basin. Although we have shown that the high salinity episode of the late 1980s was evident in the small coral records from interior basins, the oldest of these corals was only about 15 years. We have discovered two other corals, one near East Key in central Florida Bay and one near the mouth of Manatee Bay near Barnes Sound. The East Key record is in excess of 80 years old while the Manatee Bay coral is approximately 40 years old. The analysis of these two longer-lived corals which are located in closer proximity to the mainland than the Lignumvitae corals, will not only verify the conclusions from the other two coral studies, but may also show evidence of pre- and post canal construction as well as other high impact water management events.
- The determination of salinity in the coral records and indeed in sediment cores relies on the interpretation of the oxygen isotope signal as a proxy indicator of salinity. While it is generally true that increases in the oxygen isotopic ratio are correlated with increases in salinity, the hydrology of South Florida is very complex and different relationships exist between the oxygen isotopic ratio in near shore compared to marine waters. In addition, such relationship change during dry years and wet years. Our objective is to continue to collect and analyze the isotopic composition of waters from Florida Bay, the Everglades, and the surrounding marine environment in order to understand how these changes are related. At the present time we have collected waters since 1994 and our collection represents condition during essentially normal and very wet years. It is important that we continue our sampling and analysis throughout a dry period in order to ascertain how changes in salinity related to climate are manifested in the isotopic record of the corals and sedimentary components.

Historical Salinity of Florida Bay Reconstructed from Isotopic Compositions of Corals

INTRODUCTION

The environmental characteristics of Florida Bay have been a local and national concern over the past decade. Although significant efforts have been expended toward restoring the ecosystem to its natural state, a critical aspect of this effort, the natural salinity levels within Florida Bay, remain unknown. As instrumental records are inadequate for this task, scientists have been forced to use proxy records of salinity contained within sediments or organisms such as corals which secrete a skeleton that can be accurately dated. One such proxy is the ratio of ^{18}O to ^{16}O contained within the skeletons of massive corals which secrete annual bands of alternating dense and less dense calcium carbonate. Although large corals are not normally found in extreme environments such as Florida Bay, one particular species, *Solenastrea bournoni*, is resilient to adverse conditions. Within Lignumvitae Basin (Basin 30), two specimens of this species have been discovered (Fig. 1), one of which is at least 170 years old. This specimen was cored in 1986 and was the subject of a stable isotopic study that attempted to correlate the oxygen isotopic composition of the skeleton with salinity (Swart et al., 1996). These researchers concluded that there was no significant change in the salinity over the past 80 years, but there was a decrease in the inter- and intra-annual variability of salinity after the construction of the Flagler railway between 1905 and 1912. This work was a significant advance in understanding historical changes in salinity within Florida Bay. However, the absence of continuous salinity data prior to 1989 posed problems

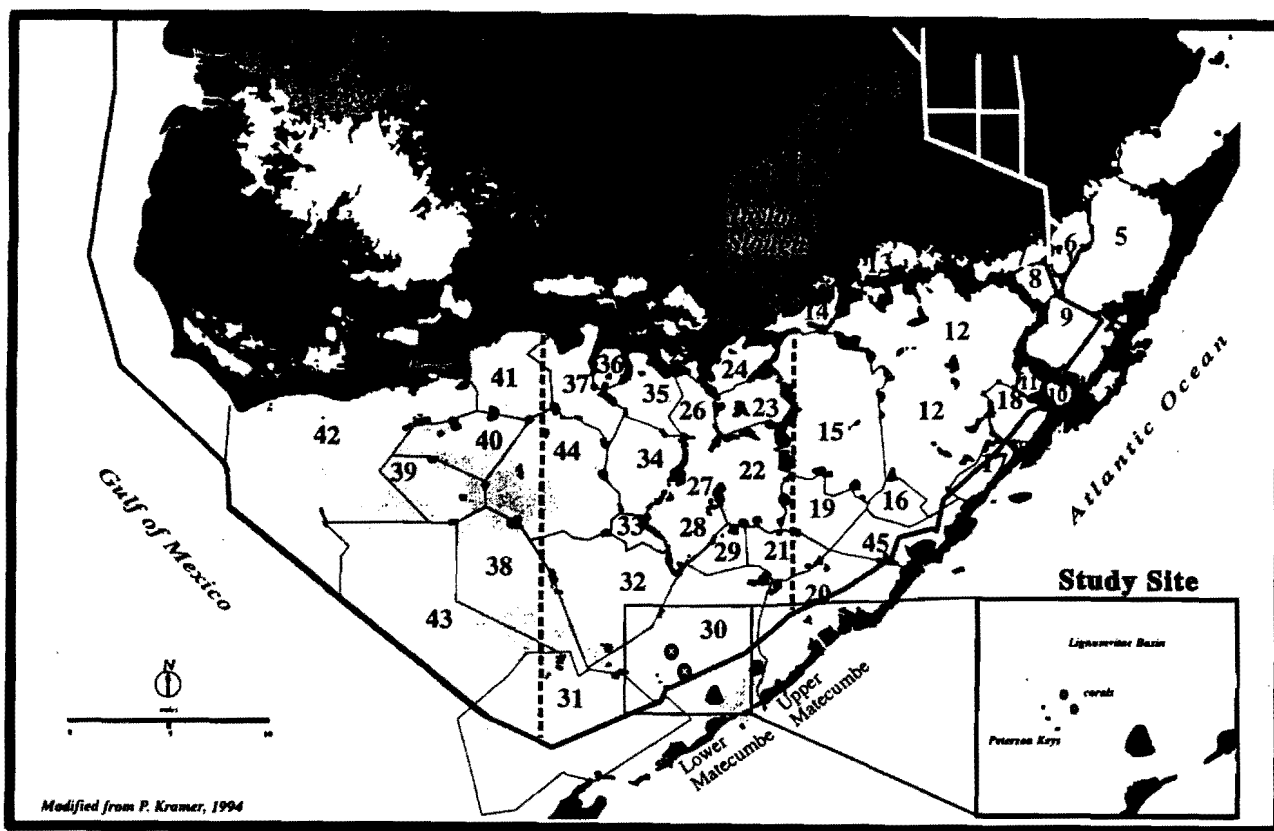


Figure 1. Site location map of Florida Bay and the two *Solenastrea bournoni* corals located in the Lignumvitae Basin (Basin 30). Basin 30 is one of 45 unique basins within Florida Bay, separated naturally by Holocene carbonate mudbanks.

when attempting to correlate the oxygen isotopic data from the coral skeleton with salinity.

In order to test this initial relationship between salinity and the oxygen isotopic ratio of the coral skeleton, it was decided to attempt to correlate temperature and salinity to the coral's oxygen isotopic composition over a time period during when high quality environmental data were available (1989-1993). Thus, the corals were re-cored in 1993. The following report describes the results of the new correlation and its application to the initial data set (Swart et al., 1996). In addition, this report discusses the relationship between oxygen isotopic composition of smaller corals discovered in other basins situated in more interior regions of the bay. These analyses help determine the merits of using Lignumvitae Basin as a barometer of changes within Florida Bay.

APPROACH

Corals are considered to be the marine counterpart of dendrochronology, or the study of tree rings. Many coral species form annual bands which are used as chronological time markers. As the coral grows over time, a continuous record of environmental conditions is recorded in the coral skeleton. The two *Solenastrea bournoni* corals form these annual bands (Fig. 2) which enables us to accurately date the coral. Conclusions may then be made concerning the coral's environmental history by comparing its chemical composition with instrumental data collected over the same time.

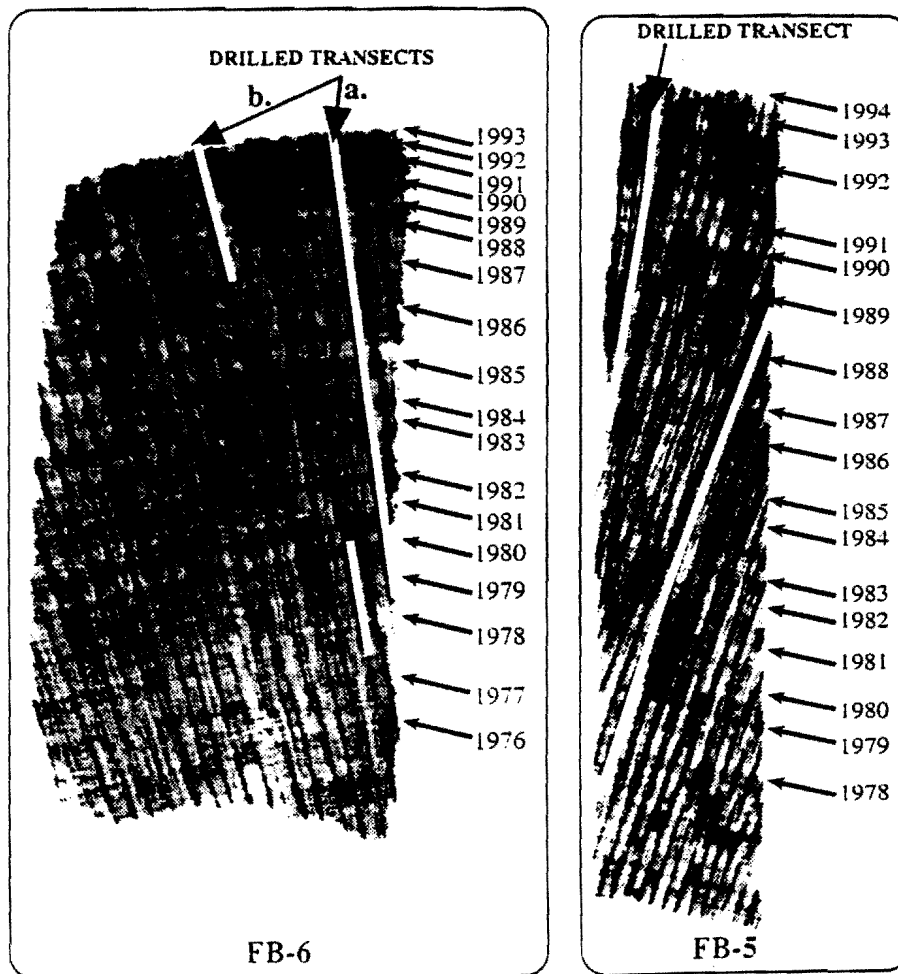


Figure 2. X-radiograph images of the two *Solenastrea bournoni* corals showing annual ages assigned by comparing density bands with the coral's oxygen isotopic composition.

The recent coral skeletons were continuously sampled at monthly resolutions (~12 samples/year) in a linear path along a transect parallel to the growth axis. Sampling of the old FB-6 coral was non-continuous and produced a seasonal sampling resolution (~4-6 samples/year). The final chronology for the old record included 160 years of C and O isotopic data between 1826 and 1986, while the recent FB-5 and FB-6 coral records represent data between 1978-1994 and 1977-1993, respectively (Fig. 3). The previous technical reports focused primarily on the accurate establishment of a chronology for the two *Solenastrea bournoni* corals (FB-5 and FB-6) by analyzing their extension rates, fluorescence and stable isotopic compositions. These reports thoroughly describe these analytical procedures. Final isotopic chronologies were established by using both the extension rate and the oxygen isotopic composition of the corals.

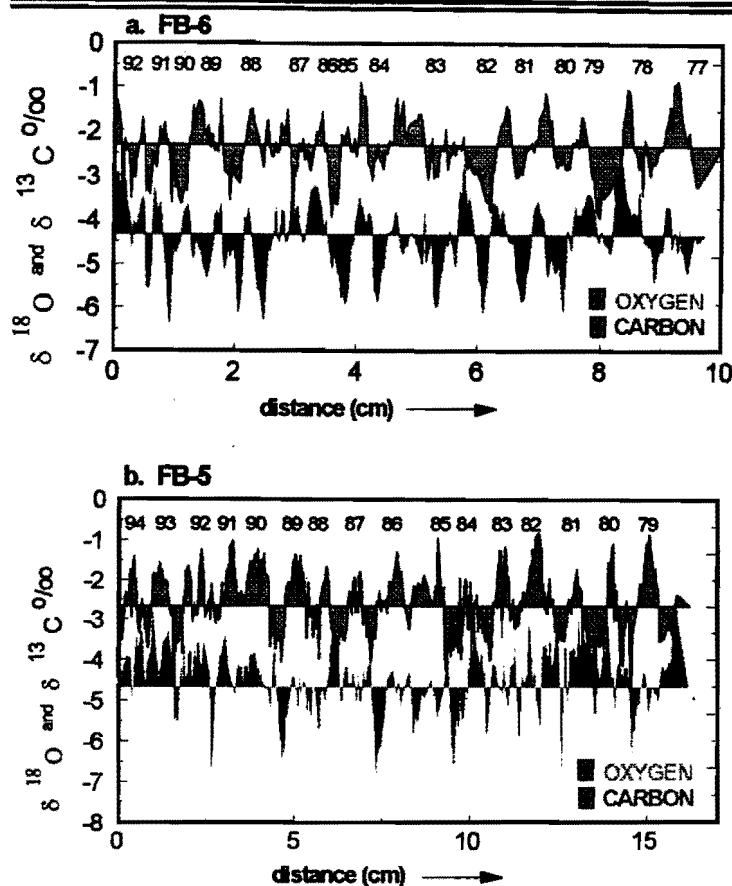


Figure 3. Carbon and oxygen isotopic chronologies for (a) FB6 and (b) FB-5 monthly sampling resolutions.

measure continuous temperature and salinity readings at hourly intervals. Florida International University scientists have also been collecting monthly water quality readings (FIUWQMN) at 28 different locations throughout the bay since 1987. Although this data set is continuous, it only contains one measurement from one specific location each month.

Both water temperature and salinity data from the Basin 30 ENPMMN were averaged monthly, seasonally, and yearly in order to establish correlations with the isotopic data from the corals. Data from Basin 30 ENPMMN were used most frequently throughout this study because of its proximity of the Hydrolab to the corals and its high measurement frequency. In the interest of statistical comparisons, the two other salinity datasets were correlated with coral $\delta^{18}\text{O}$, but were not used in the final salinity reconstruction because of their limited measurement frequency. Hence, the following results reflect the use of the ENPMMN hourly data set in order to reconstruct the decadal- and century-scale salinity history of the bay.

Correlations between $\delta^{18}\text{O}$ of the coral skeleton and temperature and salinity were performed using three different data sets: 1) Basin 30 ENPMMN continuous hourly (Everglades National Park Marine Monitoring Network, 1989-1993; Smith), 2) Basin 30 FIU monthly (Florida International University, 1987-1993; FIU/SERP), and 3) Basin 31 Historical (1956-1991; Robblee). The initial study conducted by Swart et al. (1996) utilized salinity and temperature data from the historical data set compiled by Mike Robblee from ENP. This dataset includes non-continuous salinity and water temperature measurements obtained from various scientific studies conducted randomly throughout the bay between 1956 and 1992. The availability of the two improved environmental data sets (Basin 30 ENPMMN and Basin 30 FIU) has enabled this study to be used as a calibration model. The mounting environmental problems occurring in the bay through the 1980's prompted the Everglades National Park (ENP) to install Hydrolab recorders at 17 locations throughout Florida Bay (Fig. 4); one of which is ideally located near the Lignumvitae Basin (Basin 30). These Hydrolabs are recording multiprobes that

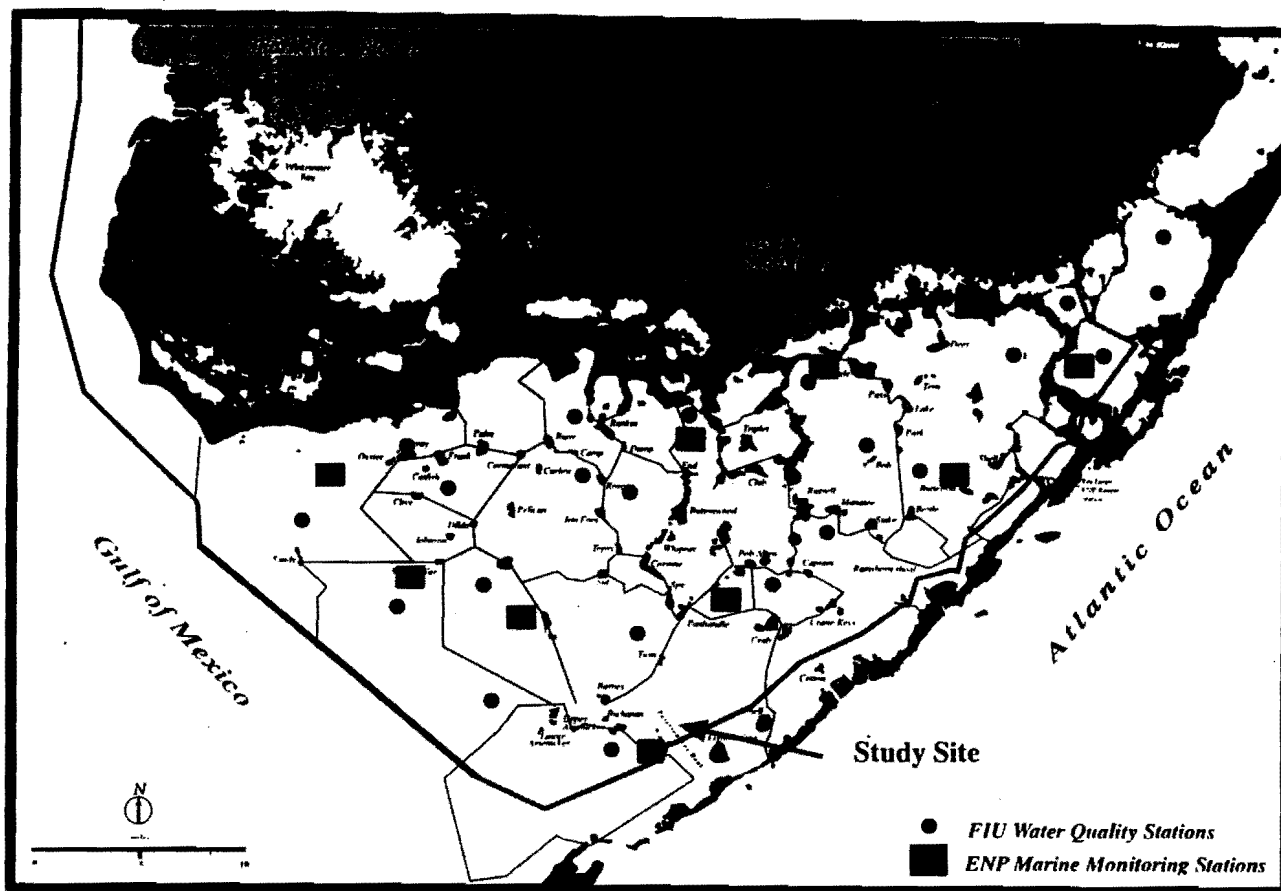


Figure 4. Site locations for Everglades National Park hourly monitoring stations and Florida International University monthly monitoring stations.

RESULTS AND DISCUSSION

A unique characteristic of this project is the availability of high resolution water quality and climatic data from locations adjacent to the location of the corals. Therefore, once the chronological timescale was established within the coral skeleton, the isotopic compositions of the corals were compared with instrumental data sets. Isotopic compositions of the corals were compared with temperature and salinity, and results are discussed below.

It is well understood that the $\delta^{18}\text{O}$ of coral carbonate is a proxy indicator for local sea surface temperatures. This association has been effectively documented in recent studies conducted along the Florida Reef Tract by Leder et al. (1996). The relationship between water temperature and the $\delta^{18}\text{O}$ of calcium carbonate is such that for every 1° rise in temperature there is a corresponding 0.22‰ decrease in $\delta^{18}\text{O}$ (Epstein, 1953) which should result in inverse correlations between these two variables. Statistically significant inverse correlations to >95% confidence levels did, in fact, occur between oxygen and temperature over an

over an approximately three year timespan in both corals used in this study (Table 1). The FB-5 coral exhibited the strongest inverse correlation of $r = -0.67$, while slightly weaker correlations were observed in FB-6 ($r = -0.54$).

Table 1. Correlations (r-values) for relationships between skeletal $\delta^{18}\text{O}$, δ_w , salinity, and temperature for the period 1978-1992.								
CORALS	N	Basin 30 Temp ENP	N	Basin 30 Sal ENP	N	Basin 30 Sal FTU	N	Basin 31 Sal ENP*
1FB-6 $\delta^{18}\text{O}$ - Original coral	~200	.08	~200	.41*	N/S	N/S	N/S	N/S
2FB-6 $\delta^{18}\text{O}$	52	-0.54	52	-0.48	67	-0.40	114	-0.07
FB-6 δ_w	N/S	N/S	35	0.11	45	0.43	33	0.32
3FB-5 $\delta^{18}\text{O}$	55	-0.67	55	-0.02	73	-0.29	114	0.11
FB-5 δ_w	N/S	N/S	38	0.71	48	0.66	33	-0.01

* Correlation made using Historical Salinity Dataset (Robblee, 1995)

¹Original FB-6 coral specimen cored by Hudson et al. 10/86

²Recent FB-6 coral specimen cored by Hudson 5/93

³Recent FB-5 coral specimen cored by Swart 6/94

Correlations between $\delta^{18}\text{O}$ of the coral skeleton and salinity were then performed using the three different salinity data sets as discussed previously. No statistically significant correlations were observed between the $\delta^{18}\text{O}$ of the corals and any of the various salinity data sets from the Lignumvitae Basin as shown in table 1. The original coral study (Swart et al., 1996) generated a 0.41 correlation using historical salinities from Basins 30 and 31.

Reconstructing Decadal-Scale Salinities

One objective of this research was to attempt to improve the correlation generated from the initial study conducted by Swart et al. (1996) by using improved high resolution coral isotope data and continuous environmental data. As observed in table 1 of the results, however, correlations between $\delta^{18}\text{O}$ and salinity from the recent study are not as strong as the 0.41 correlation obtained from the initial study. A number of possible explanations may be put forth. First, inaccuracies in establishing annual chronologies for the recent coral study are likely since comparisons between the high resolution isotopic and environmental data demand increased precision to obtain good correlations. Second, the ENP Hydrolab measuring salinity data in Basin 30 is located near a mudbank and may not be reflecting salinities representative of the waters where the corals reside. This may possibly be affecting the positive correlation expected between $\delta^{18}\text{O}$ and salinity. A third explanation may result from the strong water temperature signal. This signal influences the coral $\delta^{18}\text{O}$ and is probably masking the effect of salinity. One way of improving $\delta^{18}\text{O}$ /salinity correlation is to remove this temperature effect from the $\delta^{18}\text{O}$ as described in more detail below. This technique was not performed in the initial Swart et al. (1996) study because a lower sample extraction technique was employed producing only ~4-6 samples per year compared with the new technique that produced about 12-15 samples per year. This old method inherently produced sample averaging and a seasonal rather than a monthly signal and thus, temperature averaging over time. In addition, the coral isotopic record covered a 160 year span of time with only 30 years of non-continuous temperature data available for comparisons; an insufficient amount of data to properly remove the temperature effect.

In order to determine the sole effect of salinity on the $\delta^{18}\text{O}$ of the coral, a variation of the Epstein et al. (1953) paleotemperature equation formulated by Leder et al. (1996) representative of conditions occurring along the Florida reef tract was used (Fig. 5) where T = water temperature, δ_c = oxygen isotopic composition of skeletal carbonate, and δ_w = oxygen isotopic composition of the water.

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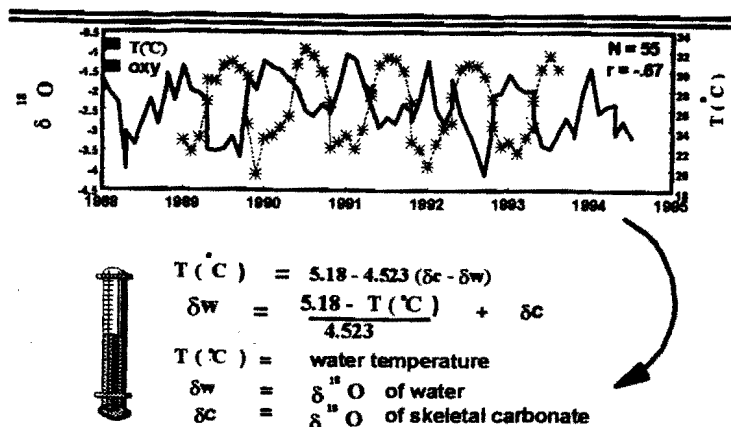


Figure 5. Both temperature and salinity influence the oxygen isotopic composition of the coral. To obtain the effect of only salinity, the paleotemperature equation is used to remove the temperature effect.

Substituting the continuous temperature data into the equation allows calculations of the δw ($\delta^{18}\text{O}$ of the water) term (Halley, 1994). Previous studies have shown that there is a positive relationship between δw and salinity (Friedman, 1965; Craig and Gordon, 1965; Broecker, 1974; Epstein et al., 1953), thus, it is theoretically possible to use this relationship to reconstruct salinities in Basin 30. The new δw was correlated with ENPMMN Basin 30 salinity data to obtain an r-value of 0.71 ($y = 4.98x + 25.89$) (Fig. 6) which is statistically significant to >95% confidence levels. The same procedure was performed on the FB-6 coral, but produced no significant correlation ($r = 0.11$). Two explanations why the FB-5 coral exhibits a stronger correlation than FB-6 are: 1) the growth rate of FB-5 is greater than that of FB-6 which allows for more samples to be extracted within a year, thus producing a more representative monthly isotopic chronology and a better intra-annual climatic signal; and 2) the difficulty in assigning years to the FB-6 density/isotope patterns may have produced misalignment that could have affected annual chronologies and produced weaker correlations. The stronger correlations associated with the FB-5 coral may also imply that the isotopic

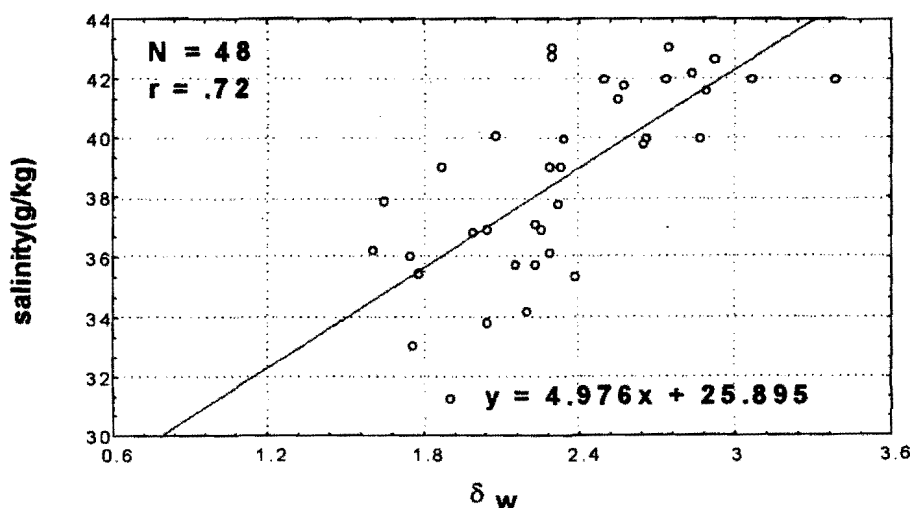


Figure 6. Correlation between adjusted oxygen (δw) and ENP hourly salinity. A statistically significant correlation of 0.71

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timescale established for this coral is more precise than the FB-6 timescale.

By using the equation of the line generated from the δw /salinity correlation (Fig. 6) and substituting in new δw values, a reconstructed decal-scale salinity history for Basin 30 was developed. Figures 8 and 9 illustrate the Basin 30 reconstructed salinity record generated from the δw /salinity correlations. The two reconstructed salinities show both similarities and differences. Timescale comparisons of predicted FB-5 salinities were plotted with Basin 31 Historical salinity data. Data from this basin were used because it was the longest period of record in a basin situated close to the corals. Results show that salinities in this basin have gradually increased over the past 15 years. A t-test performed on the FB-5 data comparing salinities between 1978-1985 and 1986-1993

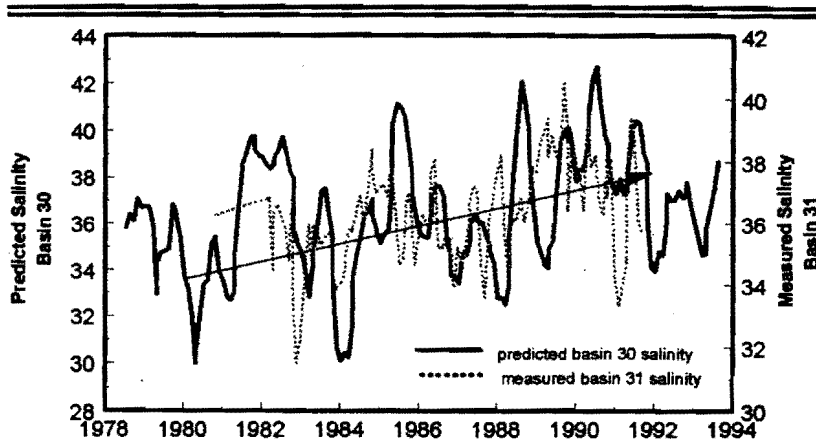


Figure 8. Predicted salinity for Basin 30 using FB-5 oxygen isotope correlations and Basin 30 ENPMMN continuous salinity data. The predicted Basin 30 salinity is compared with the Basin 31 Historical salinity record because this historical data set has the longest and most complete record of salinity measurements in this basin of the bay.

revealed a 1% difference in means and a significant p-value of .007 suggesting relevant changes in salinities. Salinity peaks range from 37‰ to 42‰ between 1978 and 1991. Salinities gradually increase in 1985 and again between 1988 and 1990 coincident with drought years, and then begin to decrease after a climax around 1990 associated with greater average annual rainfall in the region. Statistically significant correlations between reconstructed FB-5 salinity and the three salinity datasets shown in table 2 suggest that the FB-5 δw is a good proxy indicator of actual salinity patterns in Basin 30 and an effective indicator of regional climatic conditions.

Table 2. Correlations between predicted and actual salinities for Basin 30.						
Measured salinities → Predicted salinity ↓	N	Basin 30 ENPMMN	N	Basin 30 FIU	N	Basin 31 Historical
FB-5 Reconstructed	55	.30	38	.72	114	.35
FB-6 Reconstructed	52	.03	35	.44	114	.12

Contrary to FB-5 results, a t-test performed on the reconstructed FB-6 salinity covering the same time interval as the FB-5 coral shows an insignificant increase in salinity over the past 15 years (Fig. 9). Similar to FB-5 patterns, the FB-6 coral shows small increases in salinity occurring in 1985 and between 1988 and 1990 and gradually decreasing thereafter, coincident with drought years and increases in precipitation. However, the FB-6 trends are not as pronounced and do not show any long term salinity increases. Interestingly, these results confirm salinity conclusions from the original coral study which focused on the FB-6 coral. The differences observed in the 15 year salinity trends between the two corals is most likely a function of growth rate. The faster growth rate of the FB-5 coral allows for more samples per year and a more accurate reflection of the salinity variations in this basin over this short time interval.

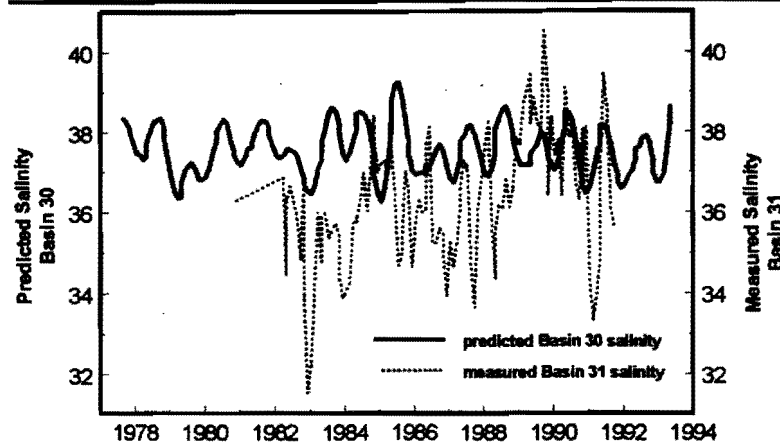


Figure 9. Predicted Lignumvitae Basin (Basin 30) salinities covering the period between 1978-1993 using FB-6 oxygen isotopic correlations with Basin 31 Historical salinity data.

Reconstructing Century-scale Salinities

The reconstruction of century-scale salinity for Basin 30 was performed by averaging oxygen isotopic data on an annual basis. This approach allowed the influence of temperature to be removed as inter-annual temperature variations are essentially very small. Hence, the salinity/ δw relationship determined from this study was combined with the equation from Leder et al. (1996) relating temperature to δw and δc and these equations were then applied to the data from Swart et al. (1996). Figure 10 illustrates the yearly reconstructed salinity history for Basin 30 together with the new data collected from FB5. This salinity reconstruction supports the conclusions generated from the initial study by Swart et al. (1996). However, the new calibration indicates a much wider range of salinity in Lignumvitae Basin than determined by the original work. This

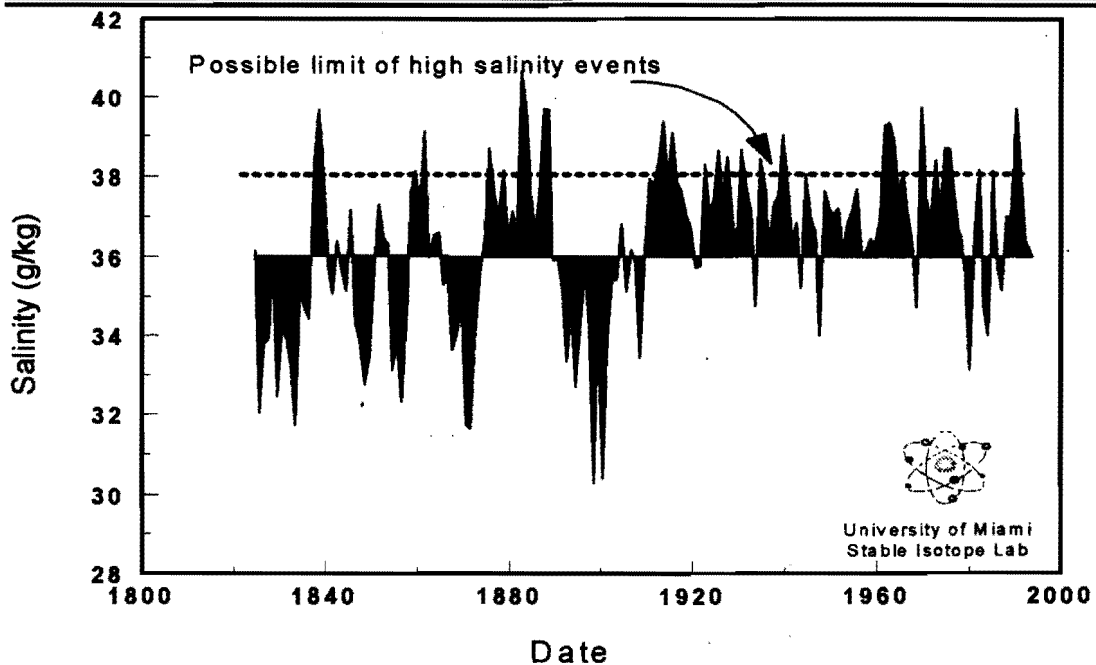


Figure 10. Lignumvitae Basin (Basin 30) yearly reconstructed salinity. The water temperature effect was removed from the Florida Reef Tract paleotemperature equation by assuming the average annual water temperature is approximately 25C.

difference is basically a result of the improved calibration of the new study. Based on a comparison between the FB-5 and FB-6 records it can be seen that a salinity episodes of the magnitude seen in the late 1980s have occurred previously but they certainly not the norm.

Reconstructing Basin to Basin Salinities

One concern regarding the research using the *Lignumvitae* coral is how salinities in *Lignumvitae* Basin are related to salinities throughout the entire bay. Salinity ranges are extremely variable throughout the bay (Fig. 11). Correlations between basins were performed using both the ENP and FIU Basin 30 salinity data sets. Correlations were best using ENPMMN data, and therefore, these correlations rather than FIU correlations were used to reconstruct the baywide salinity perspective. Correlations between basins using Basin 30 ENP salinity data in most cases revealed significant relationships. Basin 30 monthly salinity correlations were stronger than the weekly or daily correlations. Understandably, lowest correlations occurred between Basin 30 and basins closest to freshwater discharges from the Everglades (i.e./Basin 13; $r = 0.53$). The strongest correlations were between Basin 12 and Basin 30 (0.86), both adjacent to each other. Significant correlations between basins are critical when performing transfer functions between Basin 30 and all other basins for the establishment of a baywide salinity perspective (Figure 12).

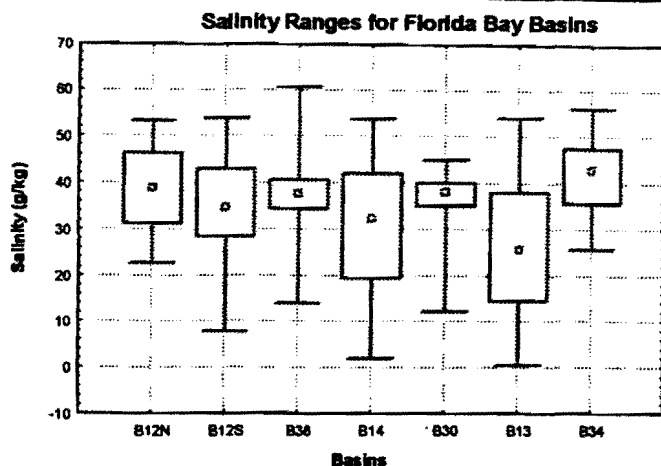


Figure 11. Salinity ranges and means for various Florida Bay basins. Salinity data comes from Everglades National Park continuous hourly monitoring network.

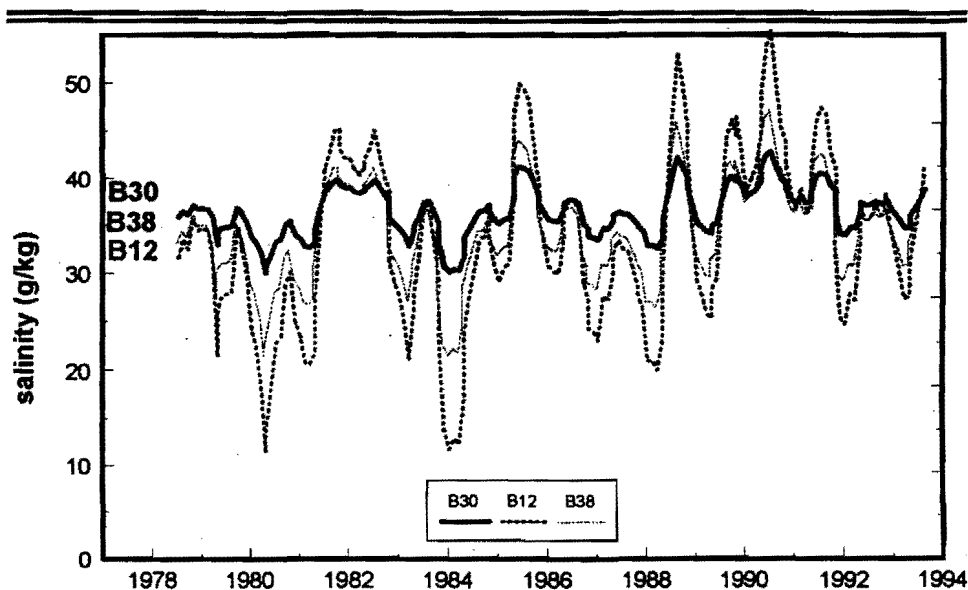


Figure 12. Salinities were reconstructed for various basins using the FB-5 coral correlations. Reconstructed salinities in this figure represent the southern (Peterson Key/*Lignumvitae* Basin B30), northeastern (Butternut Key B12), and western (Johnson Key B38) portions of Florida Bay. It appears that there are gradual increases in salinities over the past 15 years.

difference is basically a result of the improved calibration of the new study. Based on a comparison between the FB-5 and FB-6 records it can be seen that a salinity episodes of the magnitude seen in the late 1980s have occurred previously but they certainly not the norm.

Reconstructing Basin to Basin Salinities

One concern regarding the research using the *Lignumvitae* coral is how salinities in *Lignumvitae* Basin are related to salinities throughout the entire bay. Salinity ranges are extremely variable throughout the bay (Fig. 11). Correlations between basins were performed using both the ENP and FIU Basin 30 salinity data sets. Correlations were best using ENPMMN data, and therefore, these correlations rather than FIU correlations were used to reconstruct the baywide salinity perspective. Correlations between basins using Basin 30 ENP salinity data in most cases revealed significant relationships. Basin 30 monthly salinity correlations were stronger than the weekly or daily correlations. Understandably, lowest correlations occurred between Basin 30 and basins closest to freshwater discharges from the Everglades (i.e./Basin 13; $r = 0.53$). The strongest correlations were between Basin 12 and Basin 30 (0.86), both adjacent to each other. Significant correlations between basins are critical when performing transfer functions between Basin 30 and all other basins for the establishment of a baywide salinity perspective (Figure 12).

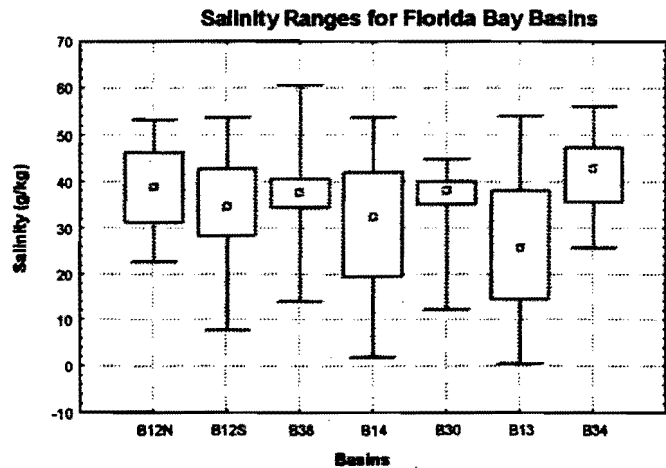


Figure 11. Salinity ranges and means for various Florida Bay basins. Salinity data comes from Everglades National Park continuous hourly monitoring network.

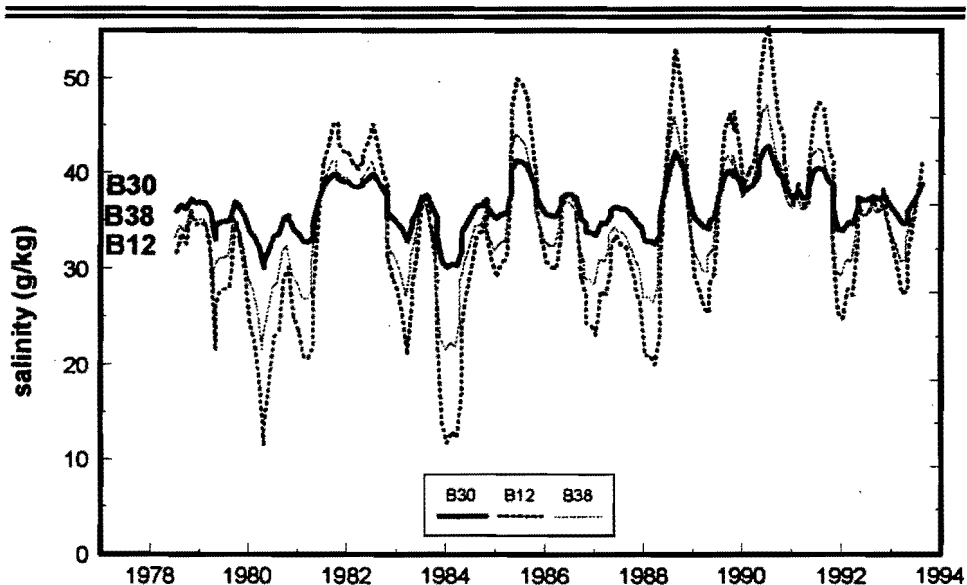


Figure 12. Salinities were reconstructed for various basins using the FB-5 coral correlations. Reconstructed salinities in this figure represent the southern (Peterson Key/*Lignumvitae* Basin B30), northeastern (Butternut Key B12), and western (Johnson Key B38) portions of Florida Bay. It appears that there are gradual increases in salinities over the past 15 years.

Using the FB-5 correlation from figure 6, and transfer functions between Basin 30 and other basins, a 15 year baywide salinity perspective was constructed for basins 12, 34 and 38 (Fig. 11). It appears that salinities in other Florida Bay basins over the past 15 years follow the same trends as Basin 30 salinities with slightly different salinity ranges depending on their proximity to other water sources. For example, salinity correlations are best between Basin 30 and other basins not directly affected by freshwater flow from the Everglades. This seems to imply that salinities in Basin 30 are not significantly influenced by waters emerging from the Everglades. The current speculation supports the idea that salinities have been on the increase over the past couple of decades as a result of water management practices. Reconstructed baywide salinities steadily increase up to 1991 and then a gradually decline thereafter, however, we believe that a 15 year retrospective analyses of salinity is too short a time period to convincingly report that these observed salinity increases are primarily anthropogenically induced. Small salinity fluctuations, especially in basins close to Everglades outflow, may reflect water management practices, but as far as the bay as a whole is concerned, larger, long-term changes in salinity are more likely the result of regional climatic conditions. For example, the apparent salinity increases during two significant drought periods that occurred in 1984-85 and 1989-90 suggest the strong influence of climatic conditions on salinities in the bay. In addition, increases in annual rainfall after 1991 are most likely responsible for the gradual decreases in salinity.

Small Coral Salinity Analysis

In order to relate the oxygen isotopic data from Lignumvitae Basin to other basins in Florida Bay, and therefore determine the salinity in these basins, we analyzed specimens of *Siderastrea radians* collected from eight different basins (Fig. 12). Some of these corals only had short records of 5 to 10 years, but one near

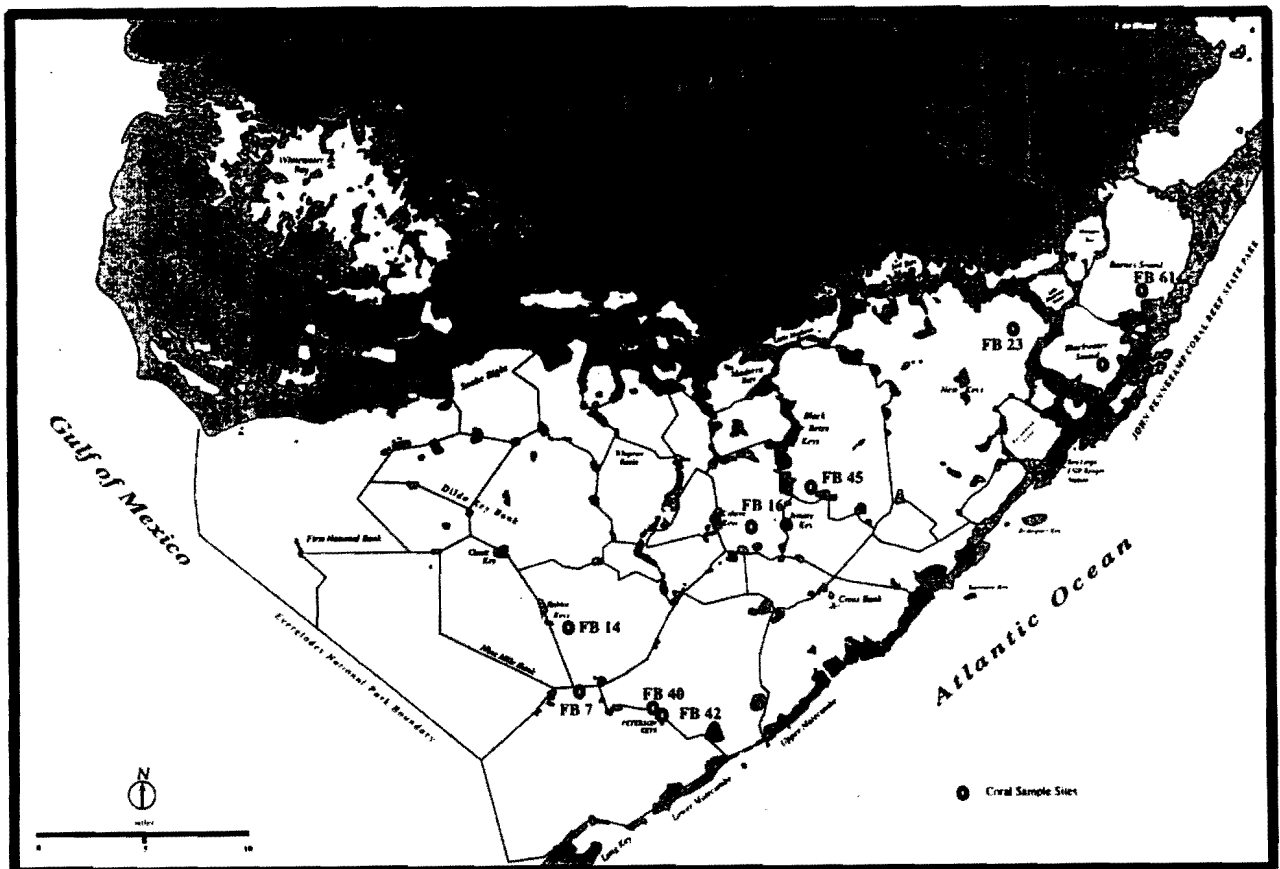


Figure 12. Site location map of small *Siderastrea radians* corals. These corals range between 5 and 15 years old and have been collected in eight different basins throughout Florida Bay.

Manatee Key (FB-45), extended back to 1966. Most of these corals exhibited a high oxygen isotopic signal in the late 1980s coincident with the high oxygen isotopic composition seen in FB-5 and the high salinity episode known at that time (Fig. 14). The magnitude of the increase in the $\delta^{18}\text{O}$ is much greater in corals such as FB-16 and FB-45 compared to FB-5 which are located in the central Florida Bay. The greater magnitude of change in these corals reflects the higher degree of salinity variable in this portion of the bay. The high salinity event is not as clear in the small coral records from Rabbit Key Basin (FB-14), Arsenicker Keys (FB-7), and even *Lignumvitae* corals (FB-40 and FB-42). This poor correlation is rather puzzling as there is clearly an increase in oxygen in FB-5 which is in the same basin. We believe that the poor correlation is probably a result of salinity stratification in these basins which affects these small corals which grow very close to the bottom and only have a maximum size of approximately 5 cm. In contrast, the FB-5 coral is much larger and less likely to be affected by the stratification. In the north-central bay, the corals are less affected as the water depth is less and the waters are generally well mixed.

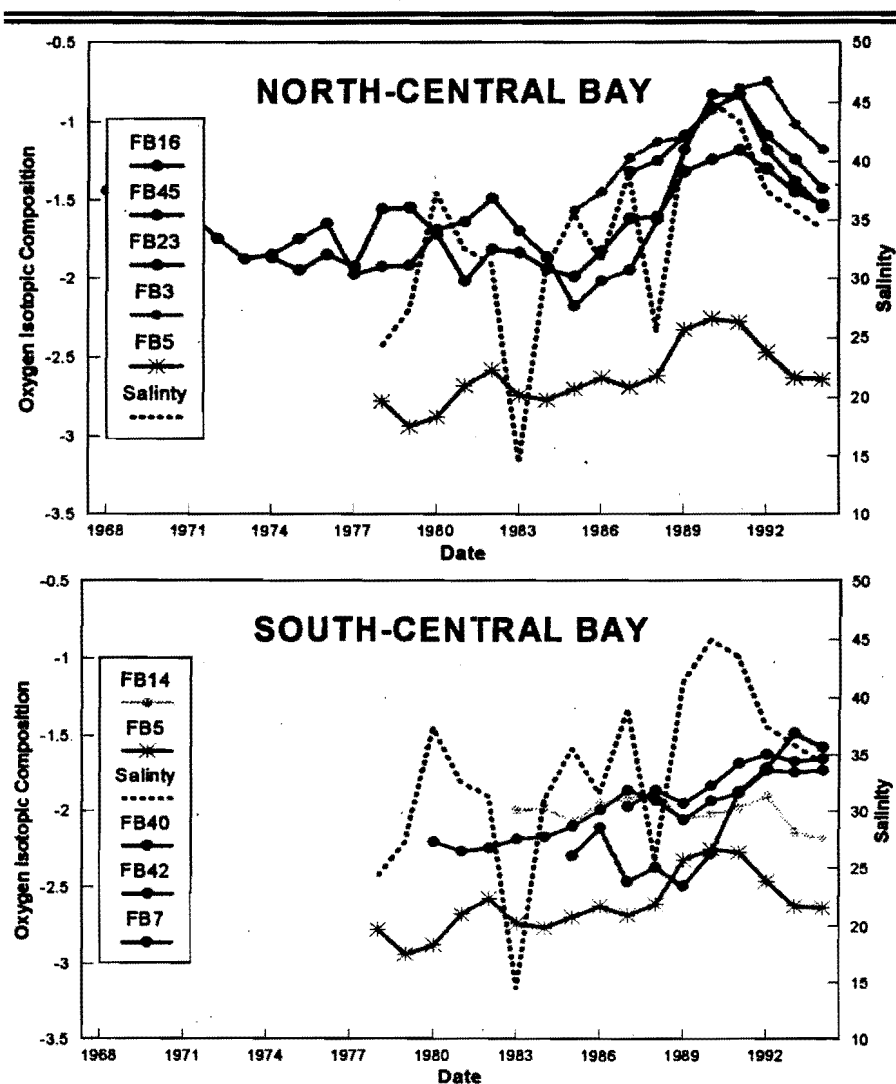


Figure 14. Time-scale comparisons of oxygen isotopic compositions of Florida Bay small corals and averaged baywide salinity. Isotopic compositions of corals in the northeastern portion of the bay mimic the drought of 1990.