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Origin of salinity variations in Florida Bay

Abstract—This note presents a method of distinguishing the source of freshwater that causes reductions in salinity in the coastal environment of South Florida. This technique, which uses the $\delta^{18}O$ and δD of the water, allows for differentiation of the freshwater derived from precipitation as opposed to runoff, because surface waters in the Everglades have been highly evaporated and therefore have elevated $\delta^{18}O$ and δD values relative to precipitation. A time series of monthly $\delta^{18}O$ and δD values of surface waters, collected from stations in Florida Bay between 1993 and 1999, has shown that, during this time, the major source of freshwaters causing depressions in the salinity in the western portion of Florida Bay was derived from precipitation rather than from the runoff of water from the Everglades. In the eastern portion of Florida Bay, close to the boundary between peninsular Florida and the Bay, the proportion of freshwater derived from precipitation drops steadily, reaching <10%. This method not only allows differentiation between the sources of freshwater but can, in a temporal sense, ascertain the effectiveness of water management practices on the salinity of the estuarine ecosystems of South Florida.

Florida Bay is a large triangular body of water located between the Florida Keys and peninsular Florida to the north (Fig. 1). The water in the Bay is composed of a mixture of freshwater derived from the Everglades, through Taylor and Shark Sloughs and directly from precipitation, and seawater that enters from the Gulf of Mexico and the Florida reef tract. This mixture allows salinities to fluctuate between essentially zero, close to the Everglades–Florida Bay interface, to marine values closer to the western and southern margin of Florida Bay. In addition, as a result of the isolation of some of the interior portions of the bay, salinities can attain values as high as 50–70 as a result of evaporation. The amount of groundwater input into Florida Bay is still unknown, but wells that have been drilled indicate that these subsurface fluids are all saline (Bohlke et al. 1999) and have enriched $\delta^{18}O$ and δD values ($\delta^{18}O$ = +1.5–+2.7‰; δD = +13–+20‰). In fact, the saltwater-freshwater interface is located ~10 km inland from the present coastline (Price 2001; Fitterman et al. 1999). Hence, groundwater is not considered at present to be a significant source of freshwater input into Florida Bay.

Over the past 15 yr, there has been growing concern regarding the detrimental role salinity plays in controlling the survivorship of seagrasses and other organisms within Florida Bay (McIvor et al. 1994). This concern reached its peak between 1989 and 1991, when salinities within Florida Bay reached values >60 in some of its interior portions (Boesch et al. 1993). As a result of this concern, extensive monitoring programs were instigated that involved the collection of water samples from a network of stations throughout Florida Bay (Boyer et al. 1999). Initial responsibility for the origin of the high salinity in Florida Bay was believed to be a result of reduced water delivery to Florida Bay caused by anthropogenic management of water flow from the water conservation areas into the Everglades National Park and, ultimately, into Taylor Slough (Boesch et al. 1993). These conclusions resulted in the initiation of a large engineering project that was designed to divert water into Taylor Slough. Several studies were initiated at this time that attempted to address the historical record of salinity in Florida Bay by use of proxy indicators contained within the skeletons of calcareous material such as corals (Swart et al. 1996) and shell material (Halley and Roulier 1999). The results of the study of Swart et al. (1999) indicated that Florida Bay had experienced a long history of salinity variation but that (1) the highest salinities over that past 150 yr had indeed occurred since 1960 and (2) a major influence on the salinity was the construction of the railway between Miami and Key West. These conclusions were based on an analysis of the $\delta^{18}O$ of the skeleton of a massive scleractinian coral growing in Lignumvitae Basin near the Peterson Keys (site 20; Fig. 1) and a correlation with salinity records between 1955 and 1986 (Swart et al. 1996, 1999).

In order to better understand the relationship between salinity and the $\delta^{18}O$ of the water, $\delta^{18}O$ and δD measurements were made on samples collected by Florida International University from a series of stations within Florida Bay (Fig. 1) starting in 1993. These data were used to demonstrate different relationships between salinity and $\delta^{18}O$ for the purposes of the reconstruction of past salinity records from the $\delta^{18}O$ of the skeletons of calcareous organisms (Swart et al. 2001). In this note, we report the results of associations between salinity and the $\delta^{18}O$ on samples from Florida Bay collected between 1993 and 1999 and discuss the implications that these associations have on the origin of salinity reductions in Florida Bay. In addition to the data collected on samples from Florida Bay, we have used data measured on samples from the Taylor and Shark Sloughs (Price 2001; Swart et al. 2001) in the Everglades as well as precipitation samples from four localities in South Miami (Fig. 1).

Methods—Surface water samples were collected on an approximately monthly basis from a network of stations in Florida Bay and the Everglades. The stations in Florida Bay are the same ones analyzed for salinity and other chemical parameters (Boyer et al. 1999). There are 28 stations within Florida Bay. Between November 1994 and August 1996, water samples were only collected from 20 stations. Of the 75 months between October 1993 and January 1999, samples were collected in 56 months. Samples of precipitation were also collected at three locations in south Florida (Fig. 1) between 1995 and 1999 and analyzed for their $\delta^{18}O$ and δD isotopic compositions. Oxygen and hydrogen isotopic measurements were made in the Division of Marine Geology and Geophysics at the University of Miami. Both measurements were made by use of a water equilibration system attached to a Europa GEO (Swart 2000). In the water equil-

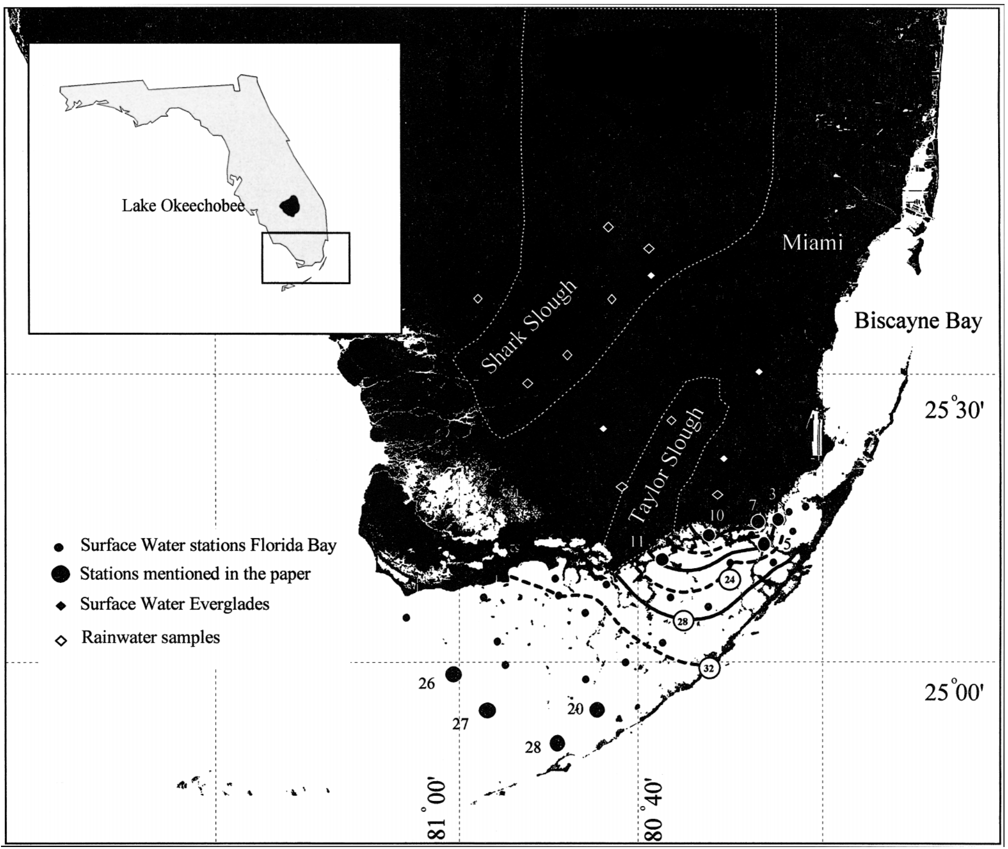

Fig. 1. Map showing location of sites in Florida Bay in addition to sites from which surface waters, Everglades samples, and rainfall samples were collected in the Everglades. Numbers refer to sampling locations, which are listed in Table 1. Contours show mean salinity values in Florida Bay between October 1993 and January 1999. Salinity data are from Boyer et al. (1999).

ibration system, the $\delta^{18}O$ was determined on CO_2 that had been injected into serum bottles at slightly above atmospheric pressure that contained 1 cm^3 of sample. This method is similar to that described by Epstein and Mayeda (1953). The samples are subsequently equilibrated at 35°C for 8 h without shaking. The process is entirely automated, with the CO_2 being injected and retrieved by use of an autosampler and the gas being transferred to a dual-inlet mass spectrometer through a cryogenic trap (−70°C) to remove water. The precision of this method for oxygen, determined by measuring 59 samples of our internal standard, was ±0.08‰ for $\delta^{18}O$. The hydrogen isotopic composition was determined by use of the same device as that used for CO_2. Equilibration with hydrogen gas took place in the presence of a platinum catalyst (Hokko Beads) at 35°C (Coplen et al. 1991). The precision of this method was ±1.5‰. Both oxygen and hydrogen isotopic data were calibrated by use of Vienna Standard Mean Ocean Water (V-SMOW) and are reported in ‰, according to the conventional notation. Salinity measurements were made by Florida International University and have been reported elsewhere in various publications (Boyer et al. 1999).

Florida Bay salinity—During the period for which $\delta^{18}O$ values are reported (1993–1999), the mean salinity of Florida Bay studied varied from 18.1 to 48.3. The lowest salinity recorded was 0.10 in Highway Creek site and the maximum (68.4) in Little Madeira Bay (*see Fig. 1*). Little Madeira Bay also exhibited the largest range in salinity, varying from 3.4 in October 1995 to 68.4 in April 1999. The smallest range in salinity occurred at the Oxfoot Bank site (26.8–38.4). A contour map showing the mean salinity values is shown in Fig. 1.

Florida Bay oxygen—The mean monthly $\delta^{18}O$ values for Florida Bay were positively correlated with the mean salinity (r = 0.68, n = 65) (Fig. 2a). In contrast, there was no correlation if the mean salinities were compared with the mean $\delta^{18}O$ values for the individual sites over the study period (r = 0.0007, n = 28). The range of mean $\delta^{18}O$ values for individual months lay between −1.12‰ and +3.36‰, with the highest and lowest $\delta^{18}O$ values occurring in May 1999 and October 1999, respectively. The range in absolute $\delta^{18}O$ values for individual basins ranged from −3.54‰ to +5.71 ‰. The lowest $\delta^{18}O$ value occurred in Joe Bay in October 1999 and the highest $\delta^{18}O$ value in August 1994 in Manatee Bay. The largest ranges in $\delta^{18}O$ values occurred in Joe Bay (8.37‰), whereas the lowest range occurred at the Sprigger Bank site (2.9‰).

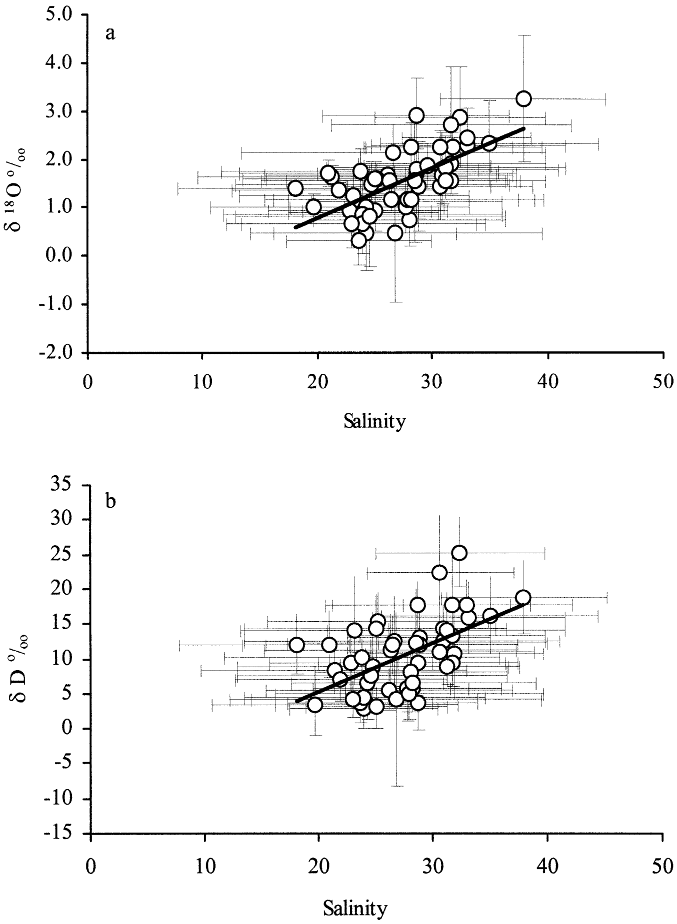

Fig. 2. (a) Correlation between salinity and $\delta^{18}O$ for the entire Florida Bay between 1993 and 1998. The data set shows a correlation coefficient of 0.65 ($n = 56$, $P > 0.01$). Error bars represent ± 1 SD of the samples measured during a particular month. (b) Correlation between salinity and δD for the entire Florida Bay between October 1993 and January 1999. ($r = 0.495$, $n = 56$, $P > 0.01$).

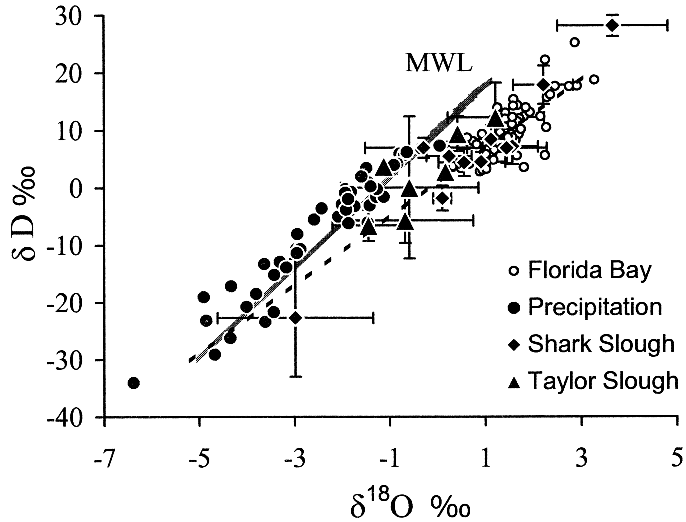

Fig. 3. Plot of mean $\delta^{18}O$ and δD values from Florida Bay, precipitation, and mean monthly surface water samples from Shark and Taylor Slough (see Fig. 1) with respect to the MWL. The error bars on the data from the Everglades represent ±1 SD of the values collected from the stations during a particular month. The intercept of the best-fit line with data from Florida Bay and the Everglades intercepts the MWL at values that are indistinguishable from local precipitation (Meyers et al. 1993; Price 2001; this study). The weighted means for $\delta^{18}O$ and δD of precipitation are −2.8‰ and −10.5‰, respectively.

Florida Bay hydrogen—The δD of the monthly means for Florida Bay were positively correlated with salinity ($r = 0.6$, $n = 65$) (Fig. 2b). The $\delta^{18}O$ and δD values were also correlated ($r = 0.82$). The correlation exhibited a slope of 6, compared with a slope of 8 for the meteoric water line (MWL) (Fig. 3). The mean range of δD values in Florida Bay extended from −5.0 to +25.8‰. The highest values (+70‰) and ranges (71‰) occurred in Little Blackfoot Sound, whereas the lowest ranges occurred in the western portion of Florida Bay at Oxfoot Bank. The $\delta^{18}O$ and δD were positively correlated but deviated from the MWL (Fig. 3).

Florida Bay precipitation—The $\delta^{18}O$ of precipitation measured between 1997 and 1999 ranged from −6.5‰ to 0‰, with a mean weighted value of −2.83‰. This value agrees well with a mean $\delta^{18}O$ of −2.7‰ calculated by Swart et al. (1989). The weighted mean of the δD was −10.59‰. The plot of $\delta^{18}O$ and δD shows that the data plot is indistinguishable from the MWL (Fig. 3).

Everglades—The mean $\delta^{18}O$ value of waters collected from six surface sites in Shark Slough (Fig. 1) was +0.86‰ (δD = +7.1‰) and ranged between −2.98‰ and +3.65‰ (δD = −17 to +23‰) (Fig. 4). This was in contrast to a mean value of +0.16‰ (δD = +4.8‰) and ranged from −2.25‰ to 1.55‰ (δD = −6.6 to +20‰) for three stations from Taylor Slough (Fig. 4). The $\delta^{18}O$ and δD were positively correlated and exhibited a similar slope to that relationship exhibited in Florida Bay (Fig. 3).

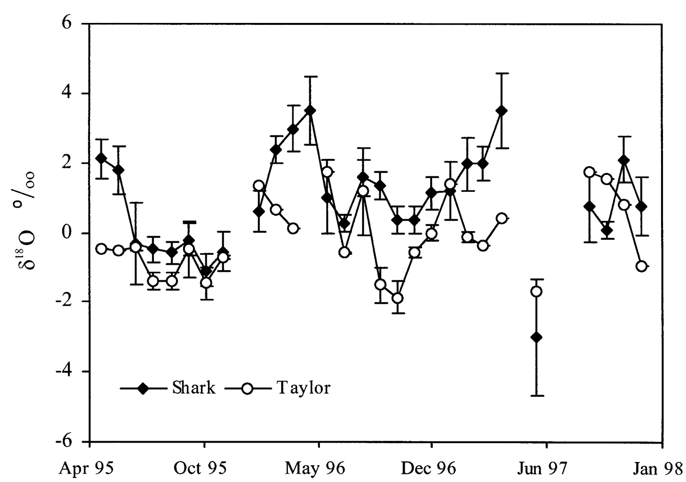

Fig. 4. Time series of the oxygen isotopic composition of surface water samples from the Everglades (Swart et al. 2001). Error bars represent ±1 SD of the stations in either Shark or Taylor Slough (see Fig. 1).

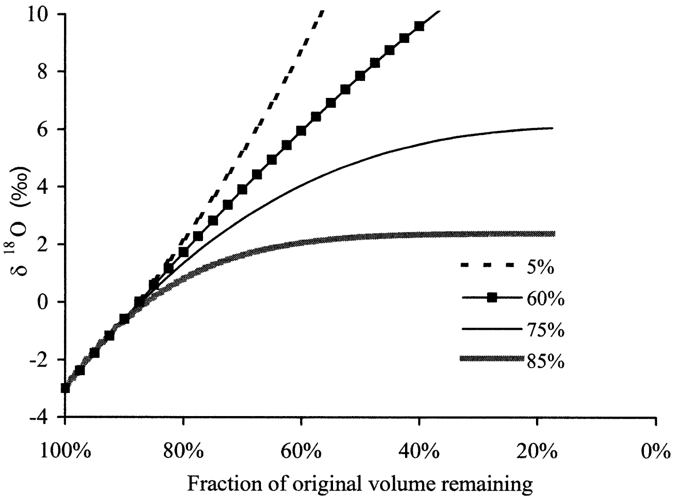

Fig. 5. Model data showing the behavior of oxygen during evaporation (Gonfiantini 1986). The initial oxygen isotopic composition of the evaporating water in this model is −3‰. Under these environmental conditions (temperature, 23.5°C; oxygen isotopic composition of atmospheric water vapor, δa, −8.5), the maximum oxygen isotopic composition that could be attained is approximately +2‰ under a relative humidity of 85%. The mean relative humidity in South Florida is 75%, although, during the summer, when the majority of evaporation occurs, the relative humidity can be significantly higher.

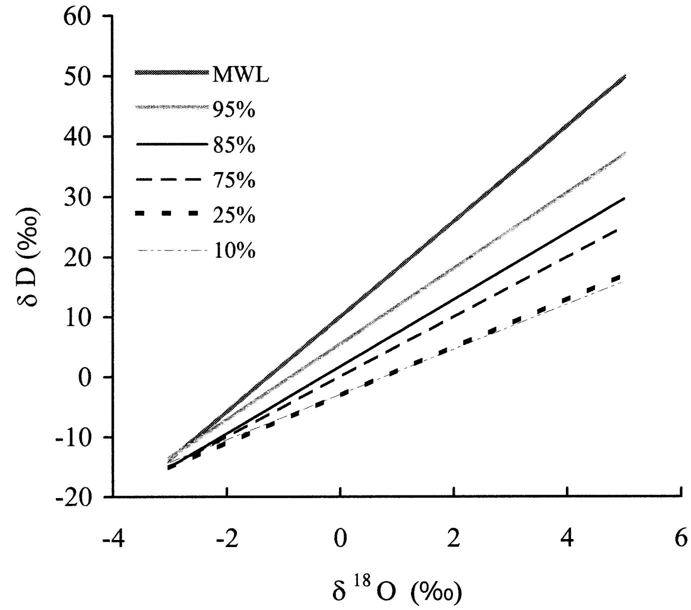

Fig. 6. Model data showing the behavior of $\delta^{18}O$ and δD during evaporation (Gonfiantini 1986) from a initial composition similar to that shown in Fig. 6. With increasing relative humidity, the correlation between oxygen and hydrogen plots closer to the MWL.

Origins of oxygen isotopic variation—The processes that control the $\delta^{18}O$ and δD of surface waters are well known and have been described in a large number of papers (Gonfiantini 1986). In Florida Bay, the inputs of water are precipitation, runoff from the Everglades, inputs from groundwater, and inundation by marine fluids. In addition to these sources, a major influence on the $\delta^{18}O$ and δD is exerted by evaporation. These processes have been described in Florida Bay in papers by Lloyd (1964) and Swart et al. (1989).

Evaporation: As a result of the fractionation of water during evaporation, residual water bodies become enriched in the heavier isotopes of hydrogen and oxygen. The absolute isotopic composition that can be attained by an evaporating body is primary dictated by the relative humidity of the atmosphere and, to a lesser degree, by the temperature of evaporation, the isotopic composition of the atmospheric water vapor, and the salinity of the fluid being evaporated (Gonfiantini 1986). High isotopic values can be attained in environments of low relative humidity, whereas the maximum $\delta^{18}O$ of evaporating waters in South Florida, which has a mean humidity of ~75%, is approximately +4–+5‰ (Fig. 5). Although the behavior of $\delta^{18}O$ and δD during evaporation is similar, slight differences between these elements produces a different relationship between $\delta^{18}O$ and δD when compared with the MWL, the relationship seen in precipitation (Craig and Gordan 1965). Progressive deviations from the MWL occur during the evaporation of fluids into atmospheres of progressively lower relative humidity (Fig. 6). Modeling of the relationship between $\delta^{18}O$ and δD can therefore be used to calculate the relative humidity under the assumption of a knowledge of the temperature of evaporation and the isotopic composition of atmospheric water vapor (Gonfiantini 1986; Swart 1991).

A further complication in the relationship between salinity and isotopic composition can be introduced during the evaporation of saline fluids as a result of interaction between different ions in the solution. As a result of this interaction, during the final stages of evaporation, the $\delta^{18}O$ and δD values can actually decrease producing a different relationship between the $\delta^{18}O$ and δD values (Gonfiantini 1986).

Modeling of the $\delta^{18}O$ and δD data collected in this study is complicated by mixing with saline fluids. However, by coincidence, the $\delta^{18}O$ and δD composition of marine waters falls more or less on the same trend produced by the evaporation of local precipitation, with a $\delta^{18}O$ and δD composition of −2.7‰ and −12‰. Hence, whether by coincidence or by artifact, a best fit of the $\delta^{18}O$ and δD data produced an intercept with the MWL (Fig. 3), which is similar to measurements on the $\delta^{18}O$ and δD for the local rainfall (Meyers et al. 1993; Price 2001).

Everglades—Peninsular Florida is characterized by a low relief and high rainfall (114 cm yr^{-1}, Nuttle et al. 2000). The bedrock is principally composed of porous limestone, which is a major aquifer. Generally, water is considered to flow from north to south along a very slight hydraulic gradient and is accompanied by severe evaporation. The climate in southern Florida is principally subtropical, separated into wet (June–October) and dry seasons. Approximately 70% of the precipitation occurs during the wet season, although the dry season is known to be dominated by cyclicity related to El Niño, during which exceptionally high precipitation can occur. The surface waters in the Everglades are typically considerably enriched in the heavier isotopes of hydrogen and oxygen compared with rainfall. In addition, the mean

$\delta^{18}O$ and δD values of water from Shark Slough are consistently isotopically enriched compared with Taylor Slough. A plot of $\delta^{18}O$ versus δD for all surface water data from the Everglades shows a strong positive correlation ($r = 0.9$, $n = 20$) with a slope of 7, compared with 8 for MWL. The intercept of this line with the MWL indicates a mean $\delta^{18}O$ and δD isotopic composition of rainfall −3‰ and −16‰, respectively (Fig. 3). The slope of the trend between the $\delta^{18}O$ and δD is controlled by a number of factors, as outlined by Gonfiantini (1986) and agrees with the model of $\delta^{18}O$ and δD during evaporation (Gonfiantini 1986) when the mean atmospheric temperature and humidity of South Florida and the atmospheric composition are used in equilibrium with mean isotopic composition of precipitation.

Florida Bay—Florida Bay exhibits wide ranges in salinity. The average amount of rainfall received by Florida Bay varies from 114 cm yr^{-1} in the northeast to 102 cm yr^{-1} in the southwest (Nuttle et al. 2000). Although decreases in salinity of Florida Bay are caused by inundation of freshwaters derived as a result of runoff from the Everglades and/or precipitation, increases in salinity relative to marine values are caused exclusively by evaporation. The oxygen isotopic composition of marine areas outside Florida Bay have been measured previously by various authors and range between 0.5‰ and +1.0‰ (Ortner et al. 1995; Leder et al. 1996). Data presented in this paper and in previous work (Meyers et al. 1993) show that, as a result of evaporation, waters from the Everglades have $\delta^{18}O$ and δD values that are distinctly different from local precipitation (Swart et al. 1986). Therefore, the salinity versus $\delta^{18}O$ relationships found in Florida Bay result from the mixing of marine water, with a relatively positive $\delta^{18}O$ value of between +0.5‰ and +1.0‰, and freshwater derived either from the runoff from the Everglades or from precipitation. Hence, by use of these differences, it is possible to distinguish the source of the freshwater in Florida Bay that causes reductions in salinity. Examples of the trends shown in two basins are exhibited in Fig. 7a,b. These basins, Joe Bay and Lignumvitae Basin (*see Fig. 1*), represent end members of a transition from the freshwater to the marine environment. The $\delta^{18}O$ and δD of the intercept at zero salinity represents the isotopic composition of the freshwater that is principally responsible for causing the salinity variation. Although there are slight differences between the behavior of $\delta^{18}O$ and δD, in the following discussion we will deal with only the $\delta^{18}O$ data, because similar conclusions can be reached by use of the δD data. On the basis of a correlation between the salinity and $\delta^{18}O$ for all of the sites from which samples were collected, the intercepts of the correlation between $\delta^{18}O$ and salinity can be calculated for each of the basins. The results of these calculations, together with the correlation coefficients and statistical significance, are shown in Table 1 and Fig. 8a,b and indicate that sites closer to the Everglades have intercepts that suggest that the principal source of the water causing the lower salinity values was derived from the Everglades. In contrast, sites further away from the Everglades–Florida Bay transition indicate a freshwater component that appears to be dominated by precipitation. The trend from a runoff source toward a precipitation source is progressive

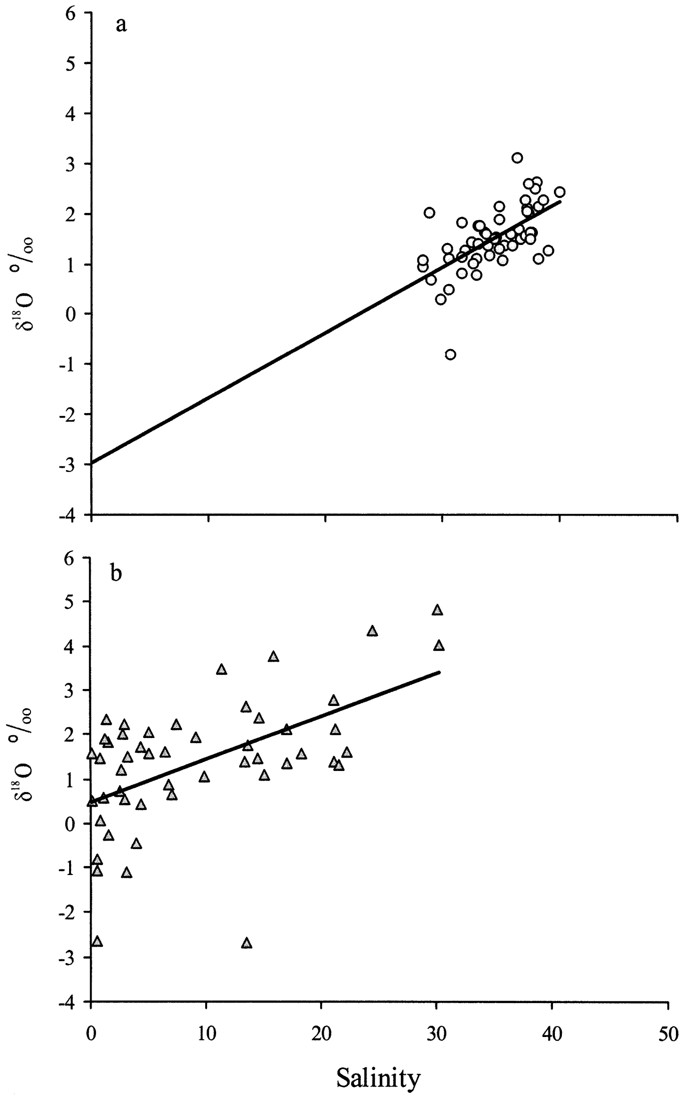

Fig. 7. Plot of the (a) salinity vs. $\delta^{18}O$ from Lignumvitae Basin (Peterson Keys, Sta. 20; see Fig. 1) and (b) Joe Bay site (see Fig. 1). The intercept with the zero salinity yields the oxygen isotopic composition of the zero salinity end member. See Table 1 for values of intercept and regression coefficients.

and agrees with a pattern one would expect intuitively. The application of a simple two-component mixing model to the data presented in Table 1, using Equation 1, enables calculation of the parameter x, the

$$\delta m = x\delta p + (1 - x)\delta e \qquad (1)$$

relative proportion of freshwater derived from precipitation as opposed to the amount of freshwater derived from the Everglades. In this equation, δm is the measured isotopic composition, δp is the isotopic composition of precipitation (−2.7‰), and δe is the isotopic composition of water from the Everglades (+0.2‰). Hence, the data presented in Fig. 8a can be converted into an estimate of the relative proportion derived from the Everglades (Fig. 8c). On the basis of this calculation, >80% of the salinity decreases in large portions of western Florida Bay are a result of dilution by rain-

Table 1. Intercepts, regression coefficients, and minimum and maximum intercepts (at 95% confidence limits) between salinity and oxygen isotopic composition. The regressions coefficients are statistically significant at the 99% confidence, with the exception of Old Dan Bank, which was statistically significant at the 95% confidence limits.

	Station name	Intercept	Minimum	Maximum	*R*
1	Card Sound Bridge	−0.31	−4.2	+1.4	0.37
2	Middle Key	−2.32	−4.0	0.0	0.59
3	Manatee Bay	−1.24	−2.8	−0.2	0.75
4	Barnes Sound	−0.57	−1.8	+0.2	0.58
5	Blackwater Sound	−0.28	−3.0	0.0	0.58
6	Little Blackwater Sound	−0.10	−1.2	+1.0	0.56
7	Highway Creek	0.52	0.0	+1.0	0.75
8	Long Sound	−0.05	−1.0	+0.4	0.71
9	Duck Key	−0.29	−1.1	+0.6	0.61
10	Joe Bay	0.45	0.0	+1.0	0.60
11	Little Madeira Bay	−0.60	−1.2	+0.2	0.65
12	Terrapin Bay	−0.69	−2.2	−0.1	0.61
13	Whipray Basin	−0.66	−2.5	+0.5	0.51
14	Garfield Bight	−0.43	−1.2	+0.6	0.56
15	Rankin Lake	−1.07	−2.0	0.0	0.64
16	Murray Key	−2.22	−3.5	−1.2	0.61
17	Johnson Key Basin	−2.53	−4.0	−1.0	0.57
18	Rabbit Key Basin	−1.73	−3.6	−0.1	0.46
19	Twin Key Basin	−2.91	−4.6	−1.2	0.62
20	Peterson Keys	−2.28	−4.3	−1.2	0.62
21	Porpoise Lake	−1.21	−2.1	+0.3	0.65
22	Captain Key	−1.03	−1.9	0.0	0.67
23	Park Key	−0.29	−1.0	+0.2	0.71
24	Butternut Key	−0.62	−1.1	0.0	0.74
25	East Cape	−1.36	−3.0	+1.0	0.33
26	Oxfoot Bank	−2.18	−3.9	−0.5	0.54
27	Sprigger Bank	−0.44	−3.2	+0.8	0.35
28	Old Dan Bank	−1.81	−4.1	+1.1	0.29

fall rather than by runoff from the Everglades. The estimate in the range of the intercept at zero salinity (95% confidence limits) is included in Table 1. The resultant error arises from a combination of analytical error, seasonal variation in the isotopic composition of the rainfall, and runoff from the Everglades, and the amount of evaporation (see discussion below). Relatively low regression coefficients and narrow ranges of salinity result in a higher range of intercept values (i.e., Old Dan Bank) compared with stations with well-correlated salinity and oxygen isotopic compositions (i.e., Peterson Keys). It is not possible to use these estimate to produce a range in uncertainty of the amount of precipitation, because the minimum and maximum values are in some instances outside the range of the values used as the end members. For example, in the case of the correlation obtained from the Peterson Keys (Fig. 1) station, which shows a range from −4.3‰ to −1‰, the variation in the intercept could be interpreted as reflecting dilution by water with an oxygen isotopic composition of between −4.3‰ and −1‰. This range is well within that expected in precipitation but is significantly more negative than that derived from runoff. Hence, the conclusion based on the use of the intercept from the best fit to the data remains, that a significant proportion of the salinity variations in this particular basin is derived from precipitation rather than runoff. In another example, Old Dan Bank (Fig. 1), there is a relatively poor correlation between salinity and $\delta^{18}O$, combined with a narrow range of salinity values (28–40). These factors combined to produce a large error in the intercept (−4‰ to +1‰). In this case, it is not possible to determine whether salinity variations are a result of either precipitation or runoff, although the best fit intercept of −1.81‰ suggests that the predominant source of freshwater is precipitation. A final example is Joe Bay (Figs. 1, 7b). Here the salinity ranges from 0 to 30, and the $\delta^{18}O$ of the intercept varies from 0 to +1‰. In this situation, most of the salinity variation is a result of inundation by water from the Everglades, although there were instances during which the mean $\delta^{18}O$ of the water was close to that from rainfall.

Influence of evaporation of relationships between salinity and oxygen isotopic composition—On the basis of the work of Gonfianitini (1986), the expected change in $\delta^{18}O$ during evaporation can be calculated and related to expected changes in salinity. Because both the salinity and $\delta^{18}O$ increase during evaporation a positive correlation will arise between these two variables, which will yield an intercept at zero salinity that could be interpretable as reflecting the $\delta^{18}O$ of water with a salinity of zero. To assess whether this artifact is significant in influencing the estimate of the intercept measured during this study, we recalculated the intercepts using only salinity values <36. Hence, we assumed that salinity values >36 were a result of evaporation, whereas salinity values <36 were a result of mixing between a freshwater source and seawater. In reality, of course, there is the likelihood that evolution of the salinity of any water is the complicated product of mixing and evaporation followed by further evaporation and mixing. Although our data do not allow us to understand these complications, eliminating samples with salinity values >36 removes samples that have unequivocally been influenced by evaporation. The results of this calculation reveal that the conclusions based on the entire data set remain essentially unchanged (Fig. 8b). Small differences in the percentage of freshwater derived from the Everglades appear in the central Florida Bay region, but in most cases the results are not significantly different from those calculated when the entire data set was used.

Perhaps the most persuasive argument that the intercept of the relationship between salinity and $\delta^{18}O$ has significance lies in the analysis of the spatial distribution of this intercept as shown in Fig. 8a,b. This figure shows a steady and nonrandom change in the intercept from relatively positive values close to the Everglades–Florida Bay interface in the eastern portion of the Bay toward more negative values in the west. These changes are consistent with the interpretation offered in this note and cannot be produced as a result of differences in evaporation or mixing with marine waters.

The implication of the data presented in this note is that a principal input of freshwater over a major portion of Florida Bay is derived directly from precipitation rather than from runoff. This can be confirmed by use of the estimated input of freshwater into Florida Bay that results from the input from runoff, which is estimated to be 10% of that derived from rainfall (Nuttle et al. 2000), compared with the

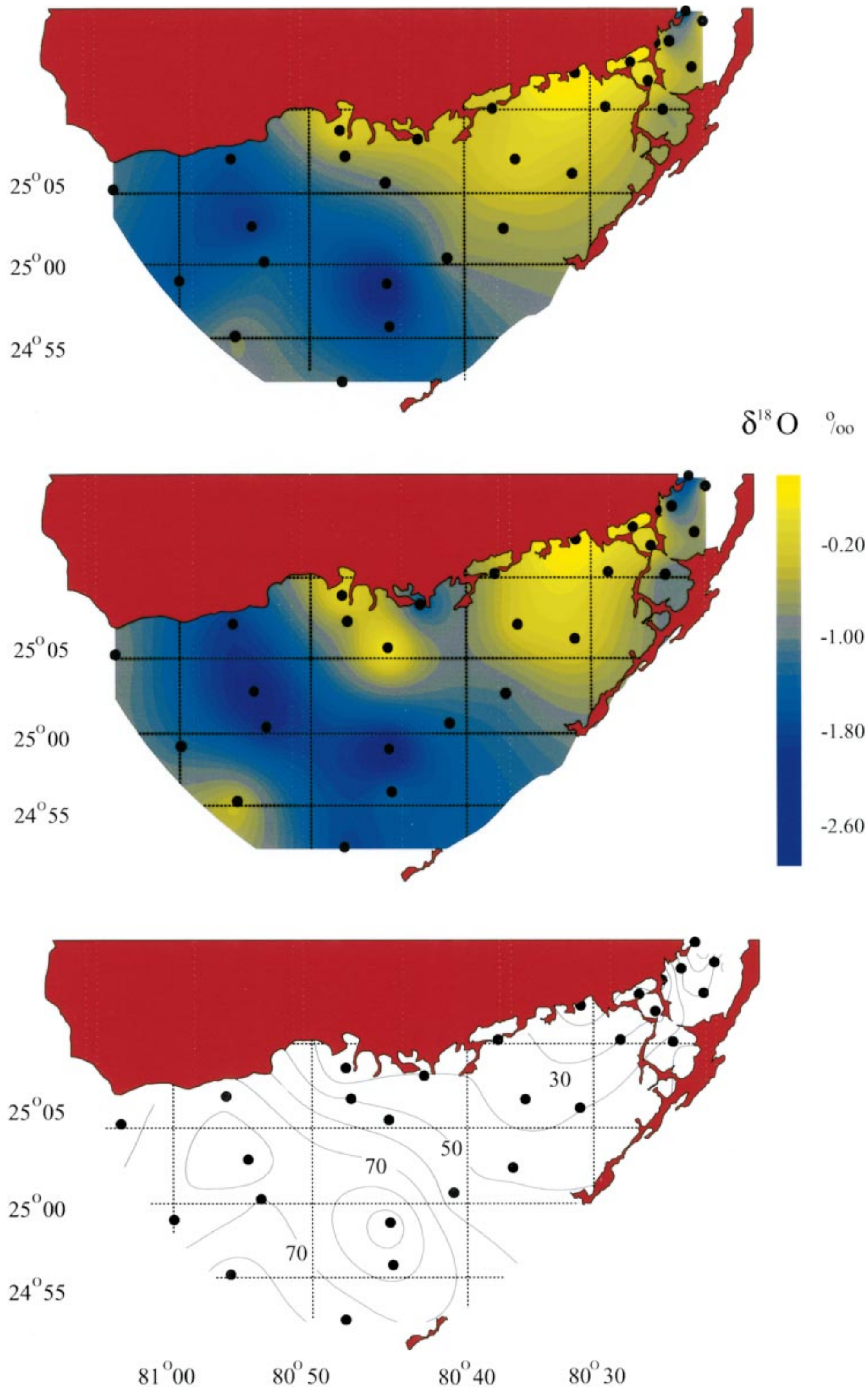

Fig. 8. (a) Color contour map of the intercept between $\delta^{18}O$ and salinity for Florida Bay. (b) Contour map of the intercept between $\delta^{18}O$ and salinity for Florida Bay that used water samples with salinity values $<36‰$ only. (c) Contour map of the solution to Eq. 1 that used contours calculated in (a). Values are shown as percentage of freshwater derived from precipitation.

mean input of water from precipitation. Because most of this runoff passes through Taylor Slough and from wetland areas to the east, its influence is evident on the oxygen isotopic composition of northeastern Florida Bay in this region, despite the low contribution of runoff relative to precipitation.

P. K. Swart and R. Price[1]

Stable Isotope Laboratory
Division of Marine Geology and Geophysics
Rosenstiel School of Marine and Atmospheric Science
University of Miami
4600 Rickenbacker Causeway
Miami, FL 33149

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[1] Current address: Department of Geology, Florida International University, Miami, Florida 33199.

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