MID-HOLOCENE CLIMATE CHANGE IN SOUTHWESTERN DOMINICAN REPUBLIC: PROXY EVIDENCE FROM STABLE ISOTOPE VALUES AND MOLLUSCAN INDICES

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INTRODUCTION

Instrumental climate records span a fraction of Earth history and thus provide an inadequate perspective on variability and evolution of climate. A more complete understanding of past climate derived from proxy evidence is necessary to better understand the driving mechanisms of climate change.

The purpose of this research is to develop a low-resolution record of mid-Holocene climate change in southwestern Dominican Republic by using stable oxygen and carbon isotope values of bivalves in conjunction with population density, diversity, and taphonomic analyses of mollusks. Bivalves and other invertebrates were collected from a subaerially exposed coral reef complex in the Enriquillo Valley (18°30'N, 71º40'W). The $\delta^{18}O$ and $\delta^{13}C$ values of carbonate shells of marine organisms are strong indicators of environmental conditions at the time of carbonate precipitation (Krantz et al., 1987) that include temperature, evaporation and precipitation changes, migration of the intertropical convergence zone (ITCZ) as recognized by Haug et al. (2001), and local marine restriction. This record can be compared to evidence for climate change contemporaneous with the thermal maximum ~6000 years before present (ybp) from Lake Miragoane, Haiti as reported by Curtis and Hodell (1993). Understanding past mechanisms for climate change will lead to a greater understanding of how these mechanisms will affect future climate.

METHODS

Sample Collection

Three vertical transects, sections C (13.40 m below sea level), L (7.14 BSL), and K (1.14 m BSL), were sampled for invertebrate fossils from a preserved in-situ near-shore reef complex near Lago Enriquillo. 1000 cm^3 samples were gathered in vertical succession along each outcrop transect and sieved in the field to obtain mollusks, corals, and echinoid spines.

Preparation

At the University of Washington and Lee, samples were sonicated to remove sediment. Prior to micromilling, bivalves were additionally cleaned, dried, and fixed to glass slides. One shell from each sample, when available, was micromilled with a diamond-tipped drill bit and computer-controlled drilling device along growth-lines at 3-5 evenly spaced increments to obtain at least 20 μg powdered calcium carbonate.

Stable Isotopes

Isotope analyses were conducted at the University of Saskatchewan. Carbonate samples were roasted *in vacuo* at 200°C for one hour to remove water and volatile organic contaminants that might interfere with stable isotope values of carbonate. $\delta^{18}O$ and $\delta^{13}C$

values were obtained using a Finnegan Kiel-III carbonate preparation device, directly coupled to the dual port of a Thermo Finnegan MAT 253 stable isotope ratio mass spectrometer. Twenty to fifty μg of carbonate were reacted with 3 drops of anhydrous phosphoric acid for 240 seconds. Isotope ratios were corrected for acid fractionation and $\delta^{17}O$ contribution and reported in per mil notation relative to the Vienna Pee Dee belemnite (VPDB) standard. Isotopic data are presented in the following standard delta notation (Rye and Sommer, 1980):

$$\delta^{18}O‰ \text{ or } \delta^{13}C‰ = [(R_{sample} / R_{standard}) - 1] \cdot 1000$$

Identification, Biodiversity, Taphonomy

Bivalve and gastropod shells were identified to the species level when possible using Abbott (1974) and Warmke and Abbott (1962). Growth lines were counted under microscopes to determine age at time of death. Several specimens from various samples were submersed in Fiegl's solution to test for aragonite. Taphonomic ratings were assigned to each shell based on fragmentation, boring holes, encrustations, abrasion, and articulation. Shells were rated on a taphonomic scale of 1 to 4, with 1 indicating best preservation (Fig. 1). Species dominance, richness, evenness, and diversity (using the Shannon-Weaver Index) were determined using species identification and number of specimens information.

RESULTS

Growth rings from several bivalves indicate an age of about one year at time of death (assuming one ring per lunar month). Aragonitic shells were deemed diagenentically unaltered. Analysis of adjacent coral transects yielded the following dates: ~9377 through 8457 years before present (ybp) for C (see Jackson, this volume), ~9362 through 8325 ybp for L (see Teneva, this volume), and ~5595 ybp near the top of K (see Dyck, this volume). These dates were used to convert height in section to time; constant accretion through each section was assumed.

Isotope Data

Figures 2a through 4a show the isotopic variation throughout transects. C (~9377-8457 ybp) shows no trend in $\delta^{18}O$ values; values fluctuate between 1.5-2.5‰ and -0.2-0.2‰. L (~9362-8325 yBP) also shows no $\delta^{18}O$ trend; values fluctuate between 1.5-2.5‰ and 0.0-0.5‰. K (~5595 ybp) $\delta^{18}O$ values have a mode of -0.2‰. C and L $\delta^{13}C$ values positively correlate with corresponding $\delta^{18}O$ values.

A) Coral Taphonomy

Class	Condition	Corallites	Tiny ridges	Coral edges
1	pristine	tips intact	clearly defined	not rounded, sharp breaks
2	slightly weathered	tips weathered away	not sharply defined	not rounded, fairly sharp breaks
3	moderately weathered	tips present as bumps	not present	slight rounding
4	weathered	not present	not present	rounded
5	extremely weathered	pockets present where once present	not present	very rounded

Figure 1 A. Coral and mollusk taphonomic scales. Scale used with *Acropora cervicornis* (5 classes based on 4 criteria for each taphonomic level). Data from Dyck, this volume.

B) Mollusk Taphonomy						
Class	**Condition**	**Borings**	**Encrustation**	**Fragment-ation**	**Abrasion**	**Articulation**
1	pristine	none	none	none	none	possible
2	good	one - few	very few	some:	minimal	not necessary
3	decent	several - many	several	moderate	moderate	none
4	poor	many +	many	much	much	none

Figure 1B. Coral and mollusk taphonomic scales. Scale used with all bivalves and gastropods (4 classes based on 5 criteria for each taphonomic level).

Biodiversity Data

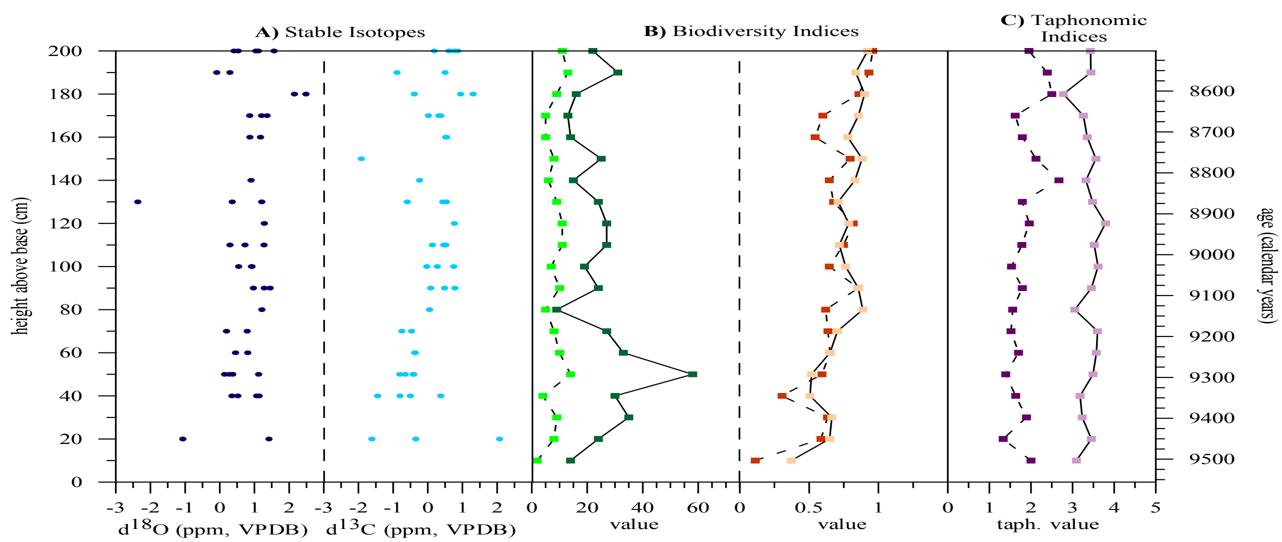
Figures 2b through 4b show the biodiversity variation throughout each transect. There is no overall trend in number of specimens for sections C and L; average number of specimens is about 24 and 18, respectively. Values follow an increasing trend up-section in K followed by a leveling off and decrease in the two uppermost samples; the average number of specimens is about 21. Average species richness is about 8,6, and 8 for C, L, and K, respectively. Richness and number of specimens correlate well in C, L, and K; r values are 1.00, 0.85, and 0.87 respectively. Shannon-Weaver diversity and species-evenness indices progressively increase up-section in C and show reasonable correlation ($r = 0.73$). Diversity decreases while evenness remains constant through L and are therefore more poorly correlated ($r = 0.64$). The two indices show no trend through K, but correlate well ($r = 0.85$).

Cerithium litteratum and *Cerithium algicola* are found in far greater abundances in section K than in C and L. Ten other bivalve and gastropod species are absent in C and L, but present in K as one or two specimens.

Taphonomic Data

Figures 2c through 4c show the taphonomic variation of mollusks relative to corals throughout each transect. The coral taphonomic

Figure 2. Transect DR-C data versus height above base and age. A) Stable isotopic ratios for oxygen (dark) and carbon (light). δ18O values greater than 3 ppm (1) and less than -3 ppm (7) and δ13C values less than -3 ppm (5) have been omitted. B) Biodiversity indices: number of specimens (dark solid), richness (light dashed), Shannon-Weaver diversity (dark dashed), and evenness (light solid). C) Average mollusk (dashed) and coral (solid) taphonomic ratings.



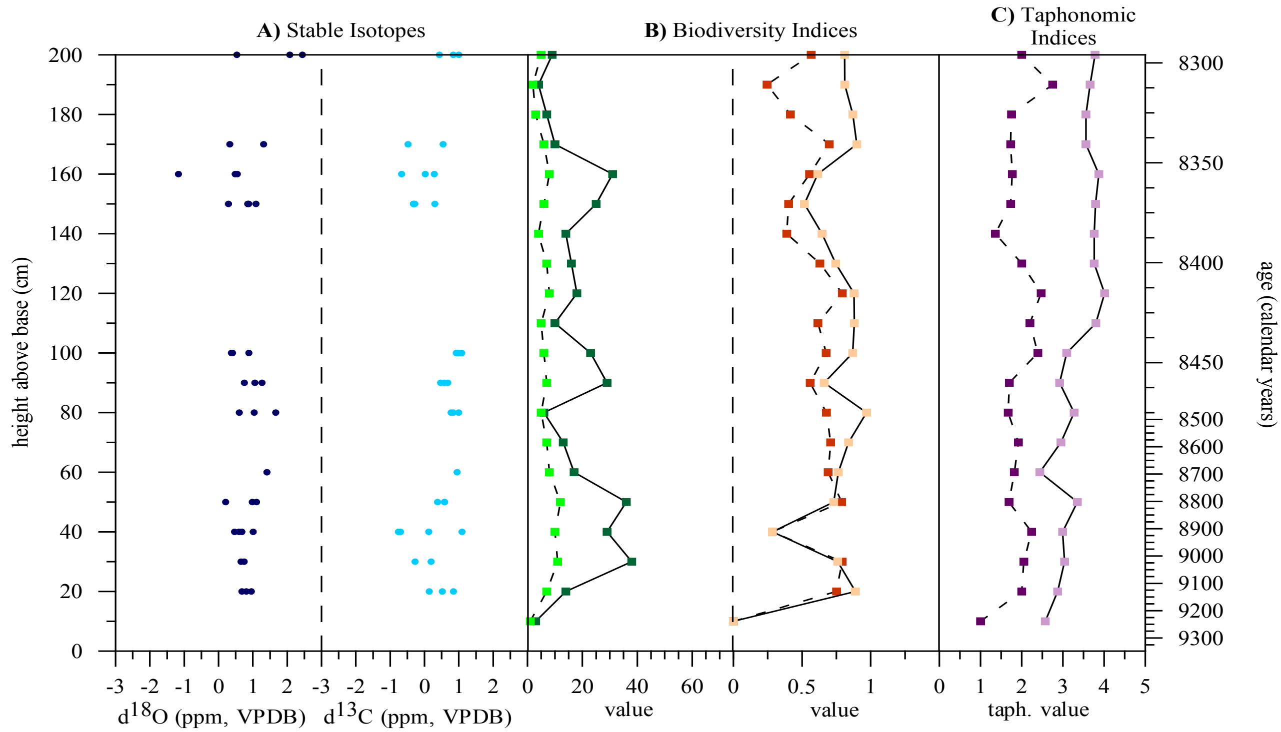


Figure 3. Transect DR-L data versus height above base and age. A) Stable isotopic ratios for oxygen (dark) and carbon (light). B) Biodiversity indices: number of specimens (dark solid), richness (light dashed), Shannon-Weaver diversity (dark dashed), and evenness (light solid). The lowest sample was <1000 cm³, thus reducing the indices' reliability. C) Average mollusk (dashed) and coral taphonomic ratings.

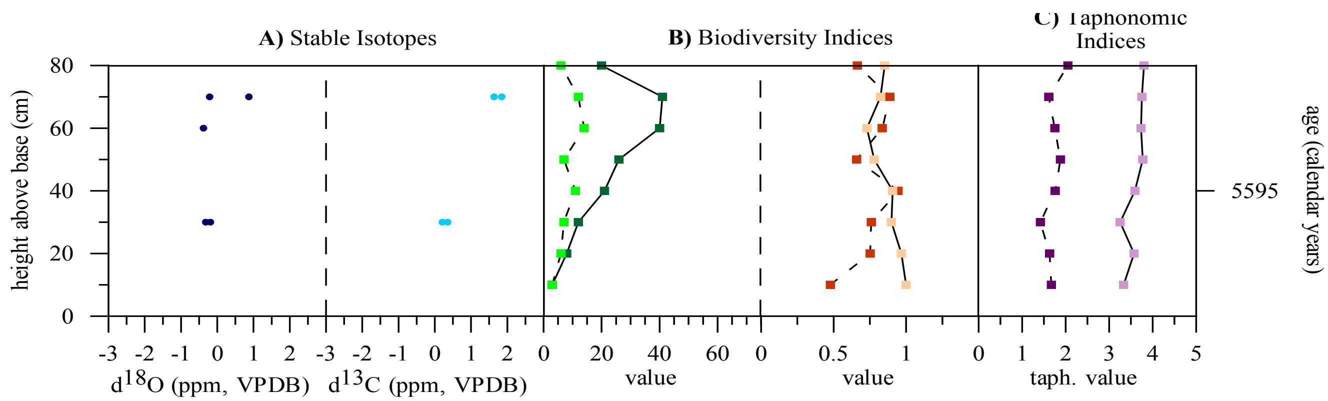


Figure 4. Transect DR-K data versus height above base and age. A) Stable isotopic ratios for oxygen (dark) and carbon (light). One $\delta^{13}C$ value less than -3 ppm has been omitted. B) Biodiversity indices: number of specimens (dark solid), richness (light dashed), Shannon-Weaver diversity (dark dashed), and evenness (light solid). Lowest three samples were <1000 cm³, thus reducing the indices' reliability. C) Average mollusk (dashed) and coral (solid) taphonomic ratings.

values fluctuate and worsen up-section in L, and on average are worse than C. Values fluctuate at moderately high values and plateau at high values through K.

DISCUSSION

The oxygen isotope value of bivalve shells is a function of both temperature and the $\delta^{18}O$ value of the water in which they grew. Higher temperatures have been correlated with seawater with lower $\delta^{18}O$ values, and conversely lower temperatures are associated with higher $\delta^{18}O$ values (Rye and Sommer, 1980). The $\delta^{18}O$ of seawater changes with fluctuations in precipitation and evaporation and provide a proxy for salinity. $\delta^{18}O$ values are depleted during rainy seasons compared to seawater, thus a wetter climate is also correlated with decreasing $\delta^{18}O$ (Rozanski et al., 1993).

Stable $\delta^{18}O$ values from bivalves ~9400-8300 ybp (C and L), prior to the thermal maximum, are enriched (~0.0 to 1.5‰) with respect to depleted values (-0.5 to 0.9‰) at or closer to the thermal maximum, from ~5595 ybp (K). This suggests that higher temperatures and/or higher precipitation peak at the thermal maximum. Temperature changes may be attributed to increased insolation or seaway restriction. Precipitation changes may be driven by increased seasonality at the thermal maximum or northward migration of the ITCZ, which is associated with especially heavy rainfall and therefore greater decreases in $\delta^{18}O$ values.

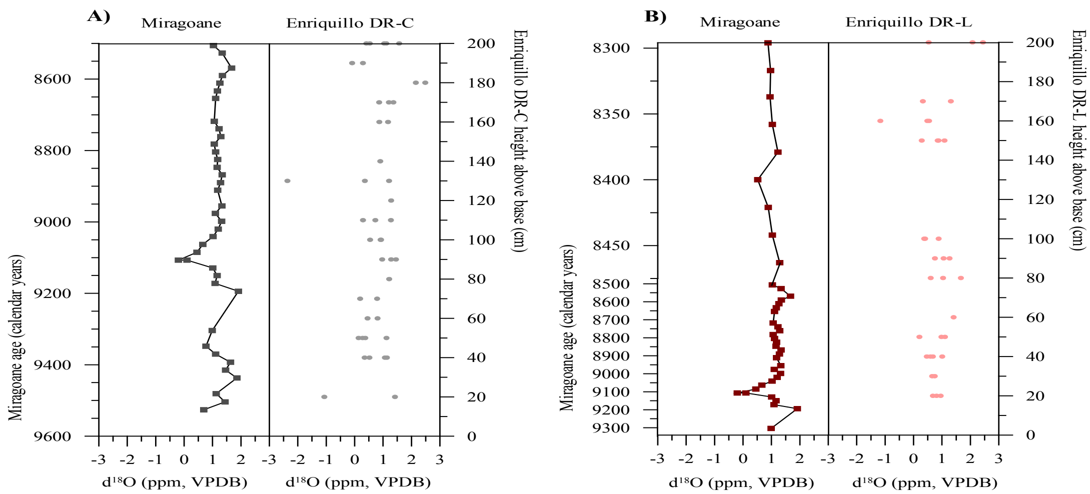
Stable oxygen isotope values from Lake Miragoane, Haiti positively correspond to those from Lago Enriquillo between ~9400-8300 ybp and have similarly lower $\delta^{18}O$ values ~5595 ybp, closer to the thermal maximum (Fig. 5). Curtis and Hodell (1993) attributed the overall $\delta^{18}O$ trends to increasing warm, wet conditions from 10,000-7000 ybp, that persisted from 7000-4000 ybp. The persistent moist period corresponds to increased seasonality resulting from insolation changes associated with the precession cycle of Earth's orbital parameters.

Shannon-Weaver diversity, richness, evenness, number of specimens, and taphonomic data support a changing local environment. C and L (~9400-8300 ybp) provide contemporaneous data and may indicate greater precipitation and/or evaporation through time. It is assumed that L grew closer than C to the paleo-shore and farther up the reef-slope (6 m) based on the geographic relationship to each other. Evenness and diversity increase through time farther down-reef (C), while they decrease farther up-reef (L), at a locality possibly more susceptible to precipitation/evaporation changes. The presence and greater abundance of several mollusk species in K (~5595 ybp), additionally support changing conditions. The lowest three K samples contain <1000 cm^3, hence are unreliable indicators (Figure 4b).

The coral taphonomic index is more reliable than the mollusk taphonomic index due to species consistency and has been selected as the preferred proxy. Peaks in evenness and abundance coincide with poor taphonomic episodes and thereby may be providing false indication of greater diversity. Taphonomic changes may be caused by greater transport prior to burial, thus may provide information about storms and energy. If so, a poorer taphonomic index indicates greater energy and/or storm activity ~5595 ybp, which is consistent with the theory of greater precipitation at this time compared to 9400-8300 ybp.

CONCLUSIONS

Isotopic and population data provide evidence for temperature, evaporation and precipitation changes, migration of the ITCZ, and possible local marine restriction in the Enriquillo Valley leading up to and departing from the thermal maximum, which peaked at 6000 ybp in the Dominican Republic. These trends parallel



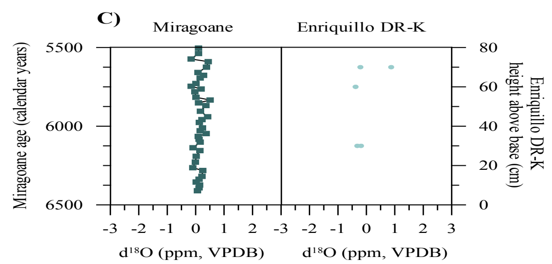


Figure 5. Stable oxygen isotopes from Lake Miragoane, Haiti compared to those from Lago Enriquillo in transects: A) DR-C, B) DR-L, and C) DR-K. Miragoane isotopes are plotted versus age, and Enriquillo isotopes are plotted versus height above base, though are mostly contemporaneous. Outliers greater than 3 ppm and less than -3 ppm have been omitted from graph (see Fig. 2a through 4a).

the climatic trends recognized in previous Caribbean climate studies.

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