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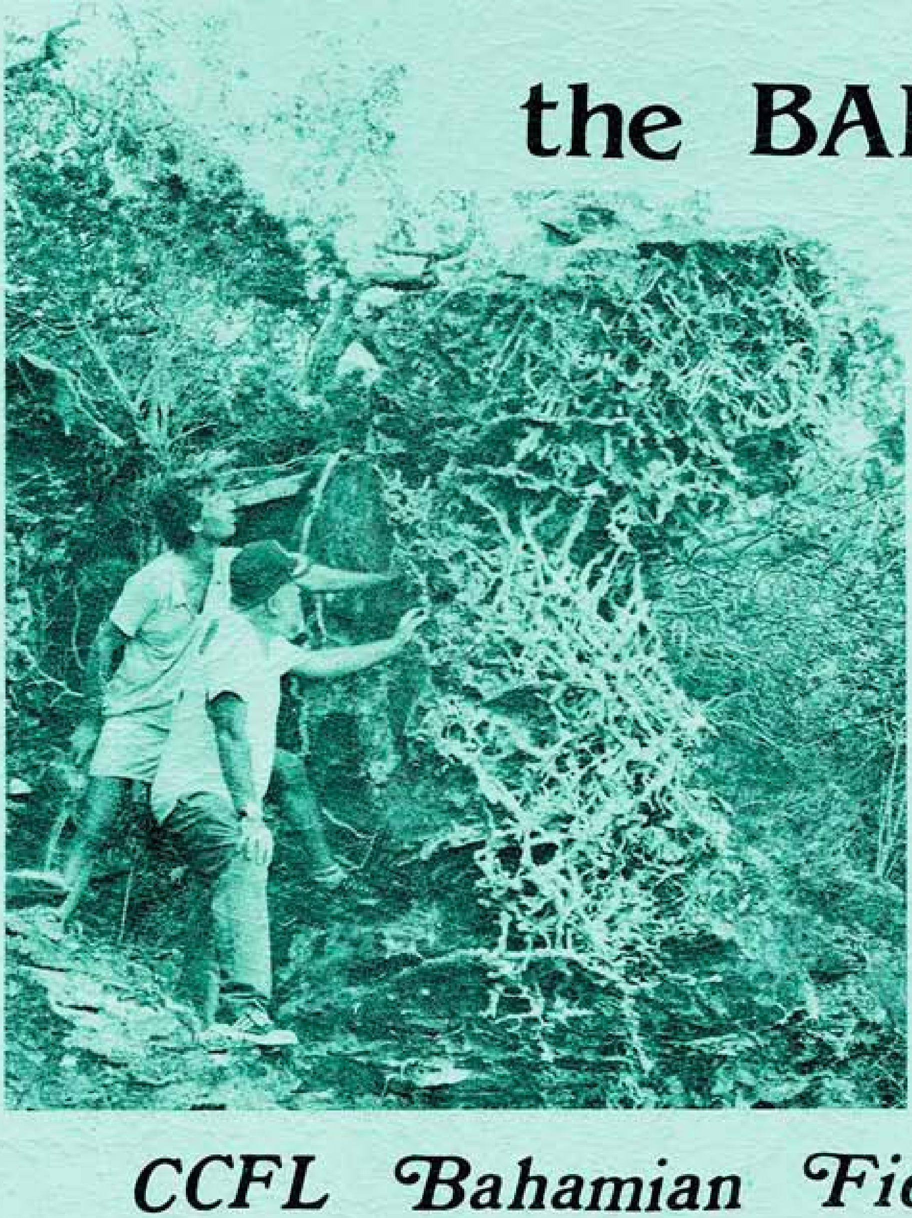
of the

2nd Symposium on the GEOLOGY of the BAHAMAS



June 1984

CCFL Bahamian Field Station

POST PLEISTOCENE SALINITY VARIATIONS IN A BLUE HOLE, SAN SALVADOR ISLAND, BAHAMAS, AS INTERPRETED FROM THE OSTRACODE FAUNA

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Abstract

Core samples through the unconsolidated post Pleistocene sediment in Watling's Blue Hole, a tidally-influenced sinkhole lake on San Salvador Island, Bahamas, reveal four sequential ostracode faunal zones reflecting changing salinity. From most recent to oldest, the zones are the *Perissocytheridea bicelliforma* zone, the *Hemicyprideis setipunctata* zone, the pitted *Cyprideis americana* zone, and the *Cyprideis americana* zone.

Extant *P. bicelliforma* in Watling's Blue Hole and previously reported occurrences suggest that the youngest zone was deposited at a prevailing salinity in the high teens to low twenties. The *H. setipunctata* zone is characterized by the most diverse and numerous ostracode fauna relative to other zones. Prevailing salinities near normal marine (greater than 25 ppt.) are interpreted for this interval. In contrast, the pitted *C. americana* zone is characterized by a paucity of fauna, as well as the marked pitting of the *C. americana* carapace which is unique to this zone. The pitted specimens also exhibit an approximate 10% reduction in carapace thickness in this interval. The zone is interpreted as one of salinities in the low teens. The earliest sediments recovered are also dominated by *C. americana*, but without the above-mentioned pitting. Prevailing salinities in the low twenties are interpreted for this interval.

Introduction

Since 1977 several individuals, including Patricia Bowman, Peter Cooke, Bert Corwin, Cathy Hodges, Daniel Sanger, Chuck Luginbill and the present writers, have focused their attention on the depositional history of the saline lakes of San Salvador Island. Most of the lakes studied to date have been isolated from direct marine contact, at least since post Pleistocene rise in sea level. The lakes currently lie approximately at sea level and their salinity is controlled by seepage of sea water through porous carbonate bedrock and seasonal rainfall and evaporation.

For working conditions the lakes certainly do not have the appeal of the open marine shelf surrounding San Salvador, with its diverse and abundant biota. However, the lakes do offer the advantage of a more complete record by virtue of their internal drainage and apparent slow rates of sedimentation. During presumed slightly lower stands of sea level the lakes appear to have persisted, becoming brackish or fresh. On the other hand, the depositional record of the open shelf has been interrupted by storms, currents and fluctuating sea level.

Field Work and Lab Methods

The field work in Watling's Blue Hole (see index map of San Salvador) was conducted during January 10 and 11, 1981. Subsequently, the blue hole has been revisited several times, usually in January, in order to check the salinity. Initial field work consisted of 4 phases.

Bathymetry and Bedrock Topography: The initial phase of field work consisted of an accurate survey of Watling's Blue Hole, including sounding water depths and probing sediment thickness to bedrock. The blue hole displays a semidiurnal tide with a range of approximately 1 m. The bathymetry (Figure 1a) reveals a shallow platform, broader on the east, extending from

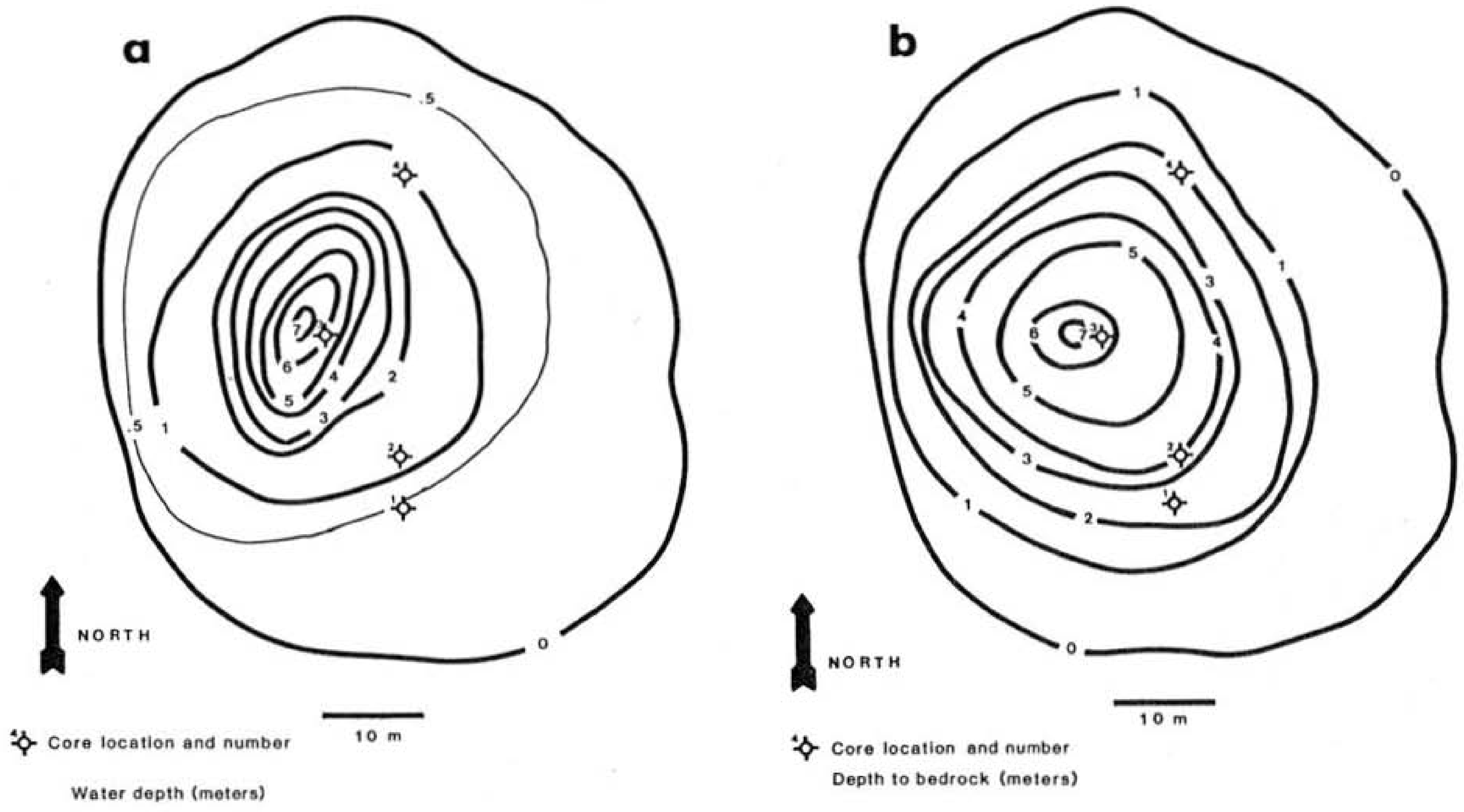

Figure 1. Watling's Blue Hole. (a) Bathymetry; (b) Bedrock Topography

shoreline to water depths of 1 to 2 m. Below 2 m the bottom is steeply funnel-shaped to a maximum depth of 7 m where a bedrock-lined conduit is exposed. Probing through the unconsolidated post-Pleistocene sediments revealed (Figure 1b) a funnel-shaped bedrock surface. The maximum post Pleistocene sediment thickness of 2 to 3 m lies approximately at 1 to 2 m water depth.

DEPTH (m)	TEMPERATURE (°C)	DISSOLVED OXYGEN (ml/L)	SALINITY (ppt)
.3	24.0	16.0	17.2
2	25.3	6.0	20.3
3	25.5	5.9	20.3
4	25.0	5.5	21.0
5	25.2	1.6	20.3
6	25.8	1.5	21.1
7	25.9	1.7	22.6

Table 1: Water chemistry data, Watling's Blue Hole, January 10, 1981

<u>Water Chemistry</u>: In the second phase of the field work water samples were collected using a Nansen bottle. Water temperature was measured immediately and dissolved oxygen and salinity were determined by titration on the day of collection.

Water chemistry is recorded in Table 1.

At the time of measurement, as on several other occasions, the surface water to a depth of 1 to 2 m was noticeably cooler than deeper water, with a sharp thermocline between. On the other occasions, the surface water has been warmer, although no temperatures were measured directly.

Also, at the time of measurement the surface water to a depth of 1 to 2 m was less saline than the water at depth. Similar observations have been recorded on some subsequent visits. At other times, particularly when the surface waters are warmer, the salinity at the surface is greater than that at depth. Clearly, the temperature-salinity relationship reflects density stratification. The maximum salinity recorded on subsequent visits has been 27 ppt.

Dissolved oxygen content on January 10, 1981 was relatively high to depths of 4 m. Below this depth, the oxygen content was much lower and the water gave off hydrogen sulphide gas when poured from the Nansen bottle.

Surface Sediment and Plant Sampling: Modern sediments in Watling's Blue Hole consist of soft, sticky mud which supports a restricted biota consisting principally of the green alga *Batophora*, a salt water grass, the pelecypods *Anomalocardia cuneimeris* and *Pseudocyrena floridana* and the gastropod *Batillaria minima*. In the third phase of the field work several constant volume (126 cm^3) samples of the surface sediment were collected to a depth of 1 cm. These and several samples of the major plants were preserved in buffered formalin for later determination of ostracodes living at time of collection. Subsequent examination revealed no ostracodes living at water depths greater than 4 m, probably a result of the low oxygen values at these depths.

Core Sampling: The final phase of field work involved the recovery of three piston cores (core locations 1, 2 and 4 in Figure 1) and one hand driven core (location 3 in Figure 1). Core 2 was the longest, measuring just under 2 m, and cores 1 and 4 measured approximately 1 m each. These three cores were extruded and described in the lab and subdivided into 2 cm intervals for later processing and examination. Core 3 was extremely short and was not examined further.

Ostracodes as Environmental Indicators

The major problem in using ostracodes as environmental indicators is the lack of ecological data. Few studies of modern ostracodes record the presence of live ostracodes or the specific conditions in which they occur. This is probably a result of the rather random distribution of living ostracodes in the sediment and methods which retrieve inadequate sized surface sediment samples. Noteworthy exceptions to the above criticisms are the studies by King and Kornicker (1970) and Garbett and Maddocks(1979).

In most studies of modern ostracodes, the environmental variables most frequently recorded are water temperature, water depth and salinity. As temperature and depth have probably exhibited little change during the deposition of the post

Pleistocene sediments of Watling's Blue Hole, we have ignored these and have concentrated on the interpretation of salinity changes that occured throughout the section.

Examination of the cores in this study reveals the domination of four ostracode species. Table 2, summarized from the literature and from a series of continuing ecology studies on the living ostracodes of San Salvador, records salinity data and, where possible, abundance data for these four principle ostracode species.

Ostracode Distributions and Paleosalinity Interpretations

Selected intervals from cores 1, 2 and 4 were processed and ostracode abundances were determined by counting. Where sufficiently abundant, a minimum of 300 ostracodes per interval was counted. Otherwise, all ostracodes present were recorded. Varying abundances within core 2, the longest core, revealed four zones based primarily on ostracode dominance. The two shorter cores, 1 and 4, exhibited only the three uppermost ostracode zones and are therefore not considered further.

Prevailing salinities are interpreted primarily on the dominant ostracode in each of the four zones, although the presence of other, less abundant species suggest that salinities must have fluctuated. Whether this fluctuation was seasonal or longer term is unknown. The four ostracode zones in core 2, and interpreted prevailing salinities, are recorded in Figure 2 and discussed below.

SPECIES	SALINITY^{o}/oo	(Date)	SPECIES ABUNDANCE	REFERENCE
Perissocytheridea bicelliforma	8.1		63%	Krutak, 1971
	18.8	(1/25/80)	20%	Teeter, 1980
	17.2-20.3	(1/10/81)	13%	Crotty, 1982
	21.0	(1/ 6/82)	82%	Luginbill, 1982
	Typically 10-20			Garbett & Maddocks, 1979
Cyprideis americana	17.2-20.3	(1/10/81)	45%	Crotty, 1982
	18.8	(1/25/80)	10%	Teeter, 1980
	37.1	(1/12/81)	3%	Sanger, 1983
	64.5-70.5	(1/ 9/82)	minor?	Arnold, 1982
	10.2-50 (least abundant at 30-40)			King & Kornicker, 1970
Dolerocypria inopinata	17.2-20.3	(1/10/81)	41%	Crotty, 1982
	18.8	(1/25/80)	65%	Teeter, 1980
	35.9-37.4	(1/12/81)	41%	Sanger, 1983
	35.7	(1/ 7/82)	100%	Luginbill, 1982
	38.4	(1/28/80)	very minor	Teeter, 1980
	10-20;45-76			Klie, 1939 a;b
Hemicyprideis septipunctata	17.2-20/3	(1/10/81)	1%	Crotty, 1982
	30^{+}			Swain & Kraft, 1975
	35.9-37.4	(1/12/81)	14%	Sanger, 1983
	$11-30^{+}$			Keyser, 1977
	11.3-50 (abundant at 25-35 more so 40-50)			King & Kornicker, 1970

Table 2. Ostracode salinity tolerances.

Cyprideis americana Zone

The initial zone of Watling's Blue Hole is dominated by C. americana and subdominated by Hemicyprideis setipunctata. Alhough both species exhibit a considerable and overlapping salinity range (Table 2) C. americana appears most abundant at less than approximately 30 ppt. and H. setipunctata at greater than 25 ppt. We therefore interpret the prevailing salinity of the C. americana zone as approximately 25 ppt.

Pitted Cyprideis americana Zone

This zone is characterized by the near absence of H. setipunctata and the codominance of Perissocytheridea bicelliforma, Dolerocypria inopinata and a distinctive coarsely pitted variant of C. americana. This variant has not previously been reported and, as it occurs only in the subsurface at Watling's Blue Hole, there is no direct ecological information. Addressing this problem, we compared the wall thickness at a consistently developed pore canal in the typical smooth to punctuate individuals with that in the pitted variant of C. americana. The wall thickness of the pitted variant averaged 10 percent less. We suggest that this variant may have been adapted to living at relatively low salinities, perhaps as low as 10 ppt., where calcium carbonate would have been less readily available. The pitting would have realized an economy of shell material, whereas the ridges, acting as buttresses between the pits, would have provided strength for the shell.

The abundance of P. bicelliforma suggests salinities

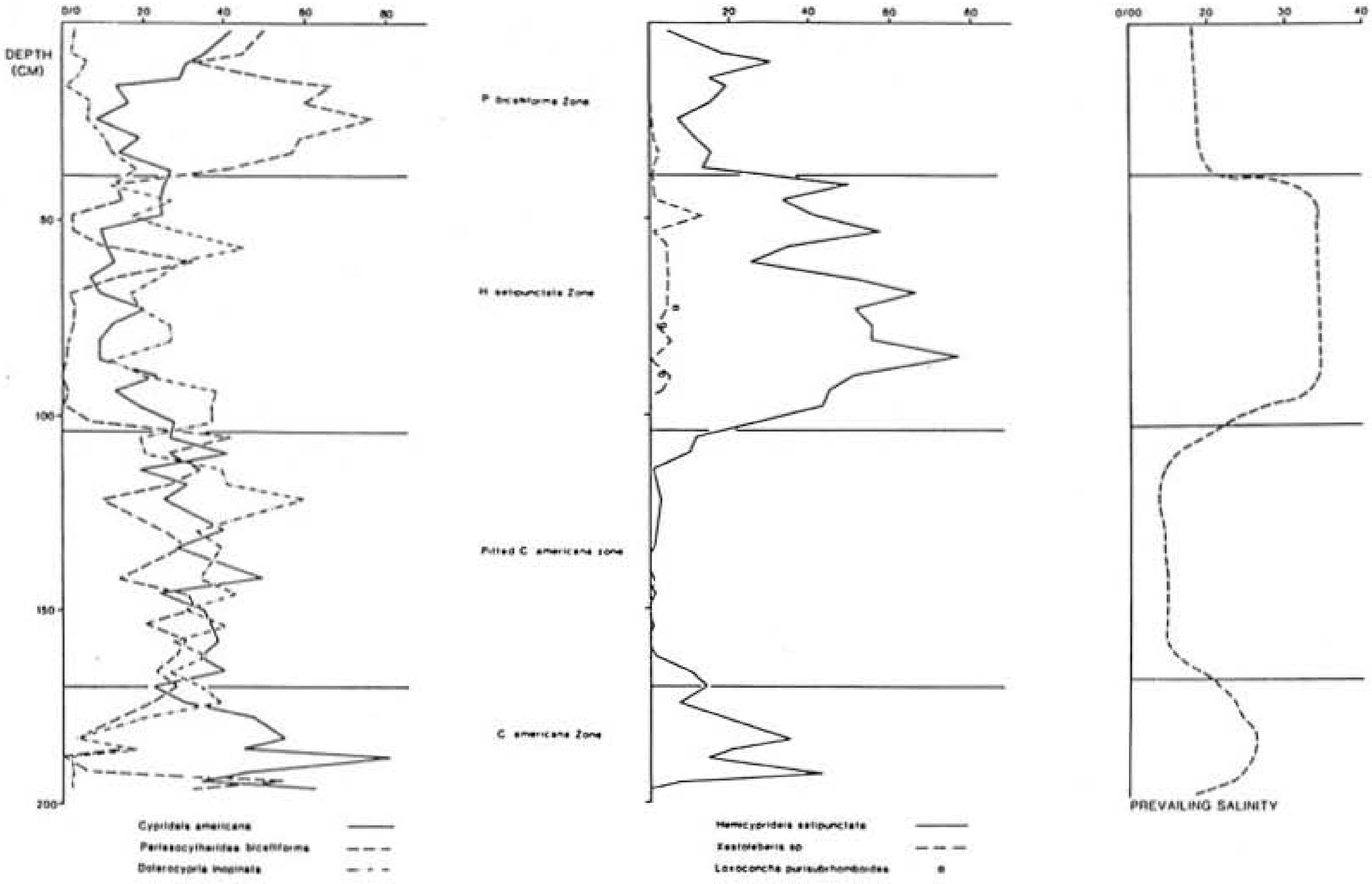

Figure 2. Ostracode Distribution and Prevailing Salinity, Core 2, Watling's Blue Hole.

ranging from 10 to 20 ppt., which would account for the diminished presence of H. setipunctata (Table 2). Considering the above environmental interpretation of the significance of the pitted carapace of C. americana, we propose prevailing salinities for this zone in the low to mid teens.

Hemicyprideis setipunctata Zone

This zone is distinguished by the dominance of H. setipunctata and the reduced abundance of P. bicelliforma especially. Although minor consituents, Loxoconcha purisubrhomboidea is restricted to this zone and Xestoleberis sp., probably a new taxon, is almost so restricted.

H. setipunctata attains its greatest abundance above 25 ppt., at salinities unfavorable for P. bicelliforma. Although L. purisubrhomboidea exhibits an observed salinity range of 10-50 ppt., analysis of abundance data in King and Kornicker (1970) suggests that it is most common at 20-35 ppt. The genus Xestoleberis is usually marine, but some species can tolerate brackish water. Therefore, we suggest prevailing salinities for this zone in excess of 25 ppt., possibly around 35 ppt.

Perissocytheridea bicelliforma Zone

The youngest zone in Watling's Blue Hole is dominated by P. bicelliforma, with C. americana and H. setipunctata as the principle subdominants. Based on the relative abundance of these species we interpret the prevailing salinity as being in the high teens, much as it is presently.

Discussion

The interpreted prevailing salinity values of Figure 2 are probably accurate to within a few parts per thousand. The varying salinity from zone to zone however, appears to be an accurate reflection of the trend through time in Watling's Blue Hole. Although at higher salinities, similar trends have been observed by Sanger and Teeter (1982) in Little Lake and by Luginbill (1983) in Reckley Hill Pond. To date the contemporaneity of the fluctuations in these lakes has not been established.

Such similar trends in widely separated lakes of San Salvador suggest a regional control. Crotty (1982) proposed primarily a sea level control, whereby slightly higher sea level stands would coincide with higher salinity (eg. the _Hemicyprideis setipunctata_ Zone) and slightly lower sea level stands would coincide with lower salinity (eg. the Pitted _Cyprideis americana_ Zone). The fluctuations may also be in response to climatic changes, where more saline intervals represent more arid conditions, and less saline intervals represent periods of higher precipitation. It is also quite possible that sea level and climatic changes have been coordinated and together have controlled the trends observed in the lake sequences. Continuing research is directed at answering these questions.

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