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HALOPHYTES OF THE HYPERSALNE LAKES OF SAN SALVADOR, BAHAMAS

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Approximately 80% Of the Earth's surface is covered with a saline solution of about 29-36 ppt. (.5M NaCl). Few higher plants can tolerate such saline conditions. Those that do are collectively known as halophytes. Halophytes are distinguished from glycophytes mainly by growth response to salinity. Growth of glycophytes decreases with increasing salinity whereas growth of halophytes seems to increase to an optimum typical bell-shape curve.

Work by the author in the past at the University of Houston tends to confirm this. Salicornia bigelovii was grown in hydroponic culture with varying concentrations of sea salt added. Maximum growth rates were observed near 29 ppt. whereas growth in lower salinities and higher salinities was increasingly reduced. (Rivers 1969)

Duncan (1974) has prepared a list of species that include some 347 species in 177 genera. However his definition of halophytes includes those that tolerate any sea water, pure or diluted. Considerable variation in salt tolerance is found within the angiosperms. Some families have species with a high salt tolerance, e.g., Potamogetonaceae, Hydrocharitaceae, Chenopodiaceae, Zygophyllaceae, Tamaricaceae, Frankeniaceae Rhizophoraceae, Plumbaginaceae, and the Verbenaceae (Waisel 1974).

Halophytes have evolved a number of adaptive mechanisms to survive and inhabit these areas with such high osmotic potentials. These include eliminating salts, accumulating salts, restricting salt accumulation and mechanisms of isolation of salts in tissues.

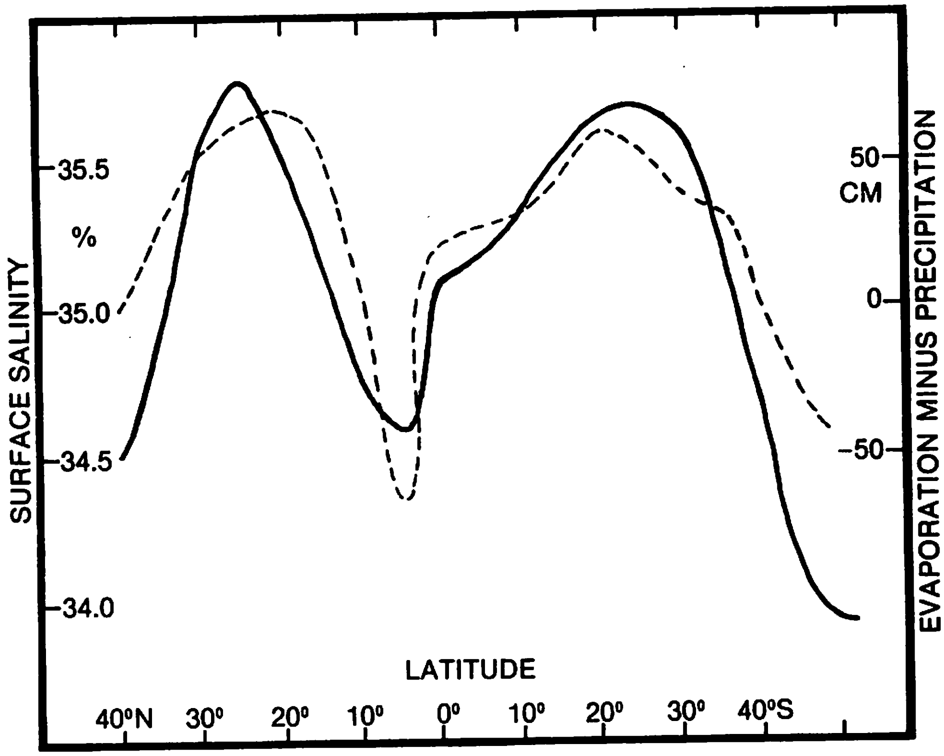

Figure 1. Evaporation minus precipitation (dash curve) and average values of all oceans of surface salinity (heavy curve) plotted against latitude. (Modified from Sverdrup.)

Typically salines have a high osmotic potential with high NaCl content. In addition salines may be further complicated by high concentrations of sulfates, carbonates and bicarbonates and pH.

Some interesting variations exist. The Caspian Sea is the largest enclosed body of water in the world and has a salinity that differs from the normal sea water in that it is low in sodium and chlorine but rich in calcium and sulphates. In the case of the Aral Sea the proportions of the various ions are quite different from "sea water". Here there are more sulphates, calcium and magnesium while the sodium and chlorine content is low (Briggs 1974).

There are at least four very different types of inland bodies of water on San Salvador. They are (1) a large system of inter-connecting lakes extending virtually the length of the island. (2) Isolated lakes of varying size and shape, some shallow and subject to periodic drying. This includes the misnamed Fresh Lake. (It was almost dry in March of 1985 with the remaining water more than 25 percent salt.) (3) the "blue holes" which are vertical, somewhat cavernous features produced as a result of solution activity of the past. These are influenced by the tide and show daily tidal fluctuation. Some of these are topped with a lens of less saline water. And (4) Pigeon Creek, a tidal lagoon on the southeast of the island with extensive shallow flats that extend in two arms, a southwest branch with an extensive growth of mangroves, and a large north branch with shallow flats of mangroves in the southeast section.

Reports by previous investigators indicate salinities from 38% to 53% of the inland lakes (Marshall 1982, Teeter 1982, Eberhad and Lang 1974, Gerace 1973). With the exception of Gerace (1973) chloride ion titration was used to determine salinity.

Although precipitation rate is a respectable 33 to 51 inches as reported by Teeter (1982) considerable seasonal variation exists. High temperatures and strong trade winds combine to produce evaporation rates at these latitudes that greatly exceed precipitation. See Figure 1.

Results

During the months of February and March 1985 visits were made by canoe and on foot to most of the inland lakes of San Salvador. Collections of plants and water sample collections were made. Specific gravity and density determinations at 15 degrees centigrade were made by hydrometer and converted to salinity ppt. Efforts were made to correlate water salinity and halophytic plant communities. Species that were most euhalophytic were noted.

The interconnecting lakes are made up of several relatively large bodies of water. They make up most of the inland waters of San Salvador. Beginning on the east and by order of connection these are Little Lake, Great Lake, Long Lake, Northwest Arm and Northeast Arm. Little Lake lies just east of Cockburn Town and Northeast Arm extends to the foot of the lighthouse.

A conduit was observed in Little Lake as evidenced by a voluminous boil of water that occurred during periods of high tide. This conduit is located off the point in the lake about half way across. It can be seen by its conspicuous water movement at times of high tide. Measurement of the hole indicates a size of about 3 x 5 meters at the mouth. It is obvious that a considerable flux of water through this conduit occurs between tide changes. An attempt was made to determine a tide level variation within Little Lake. Because of the shallowness of the lake and local winds of varying strength no reliable measurements were made. However, a variation of water level of approximately 10 cm was noted.

Figure 2. Salinity Determinations

Date	Location	Salinity ppt (0/00)
	a. Interconnected Lakes	
2/28/85	Long Lake	68
3/7/85	Little Lake - Dock	60
3/8/85	Grand Lake - Westside	71
"	Little Lake - conduit site, slack tide	58
3/11/85	Little Lake - South end	58
"	Little Lake - conduit site, incoming tide	54
3/19/85	Little Lake - Dock	56
3/22/85	Long Lake - North end	72
3/" /85	North west Arm - near Victoria Hill	75
"	North East Arm - Narrows	73
"	Little Lake - conduit site, incoming tide	51
3/29/85	N. E. Arm - Lighthouse boathouse	81
3/" /85	N. E. shallow lake North end	89
3/" /85	Near Inagua Island	83
	b. Tidal Lagoon-Pigeon Creek	
3/17/85	Dock - Southwest Fork	41.2
"	Near S. W. fork end	44.5
"	First bend of channel - North Fork	38.8
"	Mid point - North Fork	42
"	North of school - North Fork	39.2
"	Dock - upper end- North Fork	41.2
	c. Isolated Lakes	
3/12/85	Clear Pond (near Grotto Beach)	37.4
3/15/85	Granny Lake - shallow end	94.5
3/17/85	Storr's Lake - South end	74
3/19/85	Roadside Pond - Cockburn Town (24 hrs. after rainfall)	13
"	N. Granny Lake	65
"	Storr's Lake - North end	75
3/29/85	Finger Lake	74
"	Fresh Lake	252
"	United Estate Lake - West of road	59
"	Granny Lake	97.5
"	Between CCFL base and Coast Guard	63
	d. "Blue Holes"	

3/14/85	Bernie's Blue Hole	33.5
"	East of Granny Lake	34
"	Watling's Castle	25.5
3/15/85	Lighthouse Cave	33.5
3/21/85	Watling7s Castle - surface	25.5
3/21/85	Watling's Castle - bottom	25.5
"	Blue Hole # 2	25
3/29/85	Blue Hole # 2	25.5
"	East of Granny Lake	34.5

d. <u>Ocean</u>

3/7/85	Graham's Harbor	36.
3/29/85	Columbus Monument	35.1
"	East Beach	35.2

Salinities of 58 to 60 ppt. were found in Little Lake. At high tide a salinity of 54 ppt was noted in the incoming water of the conduit. This indicates that the lake water has been diluted slightly by water from some other source. It is likely that a connection exists between the sea and the lake through solution connections. It is unlikely that flushing of the connection takes place but rather an oscillation of the resident water with some addition from the sea to replace water evaporated from the lake surface.

Little Lake is connected, by a narrow and shallow man-made channel of ancient origin, to Great Lake. Observations of water movement through this channel were inconclusive as a wind driven oscillation of water in the channel was continuous.

Salinities of these interconnecting bodies of water increased with increasing distance from Little Lake and they were found to be: Great Lake - 71 ppt., Long Lake- 71 ppt., N.W. Arm -73 ppt., N.E. Arm -81 ppt.

Only very euhalophytic vegetation could tolerate such salinities. The vegetation pattern differs remarkably from typical estuarine vegetation patterns where these plants would normally occur. Zonation, while obvious on the extreme periphery of the lake, does not occur near the lake front. Pioneer vegetation in these areas was observed to be Sesuvium portulacastrum with the decumbent glasswort, Salicornia perennis, and the saltwort, Batis maritima. Extremes of succulence was observed in all of these species. S. portulacastrum was most numerous and successful. Woody vegetation included the black mangrove, Avicenna germinans, buttonwood, Conocarpus erectus, and Rhizophora mangle, the red mangrove. A. germinans was most successful and each plant was invariably surrounded by large numbers of pneumatophores. Its position was frequently shared with R. mangle which appeared to be somewhat stunted.

The silver buttonwood, C. erectus, was found with "dry feet" growing above the small beach berms. It was quite conspicuous and thriving. Further from the beach 3 to 20 meters on flats that infrequently existed behind the berms was found more typical estuarine zonation. This was dominated by B. maritima, S. perennis and frequently, Sporobolus virginicus. Conspicuous by its absence was the annual glasswort, Salicornia bigelovii. (It is hypothesized that salinity levels may be consistently too high for annual germination of the seed of S. bigelovii).

Of the common sea grasses of San Salvador only Halodule beaudettei Den Hartog was observed growing in the inland lakes. It was collected from Little Lake and found growing extensively in 1 meter of water on the East side.

There are a number of isolated lakes on the island. Many of these are located around the periphery of the island. Most of them are shallow, small and subject to substantial or complete loss of water during the dry season. Salinity in these lakes is directly related to rainfall.

Some of the lakes are larger and deeper. Isolated in the interior of the island is Granny Lake and North Granny Lake. N. Granny Lake is the most attractive of the inland lakes. It contains deeper (>3m) clear, bluish-green water. Salinity was 65 ppt. Granny Lake located just to the south but separted by a high ridge had a similar salinity of 63 ppt. Storr's Lake, located near the eastern shore, had an average salinity of 75 ppt. Vegetation surrounding all of these lakes was mostly woody. It included R. mangle, C. erectus and A. germinans ,with C. erectus most vigorous. In some areas a flourishing mat of B. maritima was found growing beneath A. germinans at the water's edge. A long finger-like lake is at the end of Jake Jones' road. The lake was surrounded by jungle-like, very vigorous growth of R. mangle, similar to a forest and almost impenetrable.

A number of "blue holes" or small bodies of water that have these aspects are found on the island. These are characteristically lower in salinity and are tidal influenced. Those visited include several on the south east end of the island, Blue Hole Watlings and Blue Hole 2, one lying east of Granny Lake and Bernie's Blue Hole and the lighthouse cave. The two located near Watling's Castle had salinities of 25.5 ppt., and had a tidal range of 61 cm, March 21,1985. The lighthouse cave and Bernie's Blue Hole both had salinities of 33.5 ppt. This gives an indication of unity in this water. These pools were generally surrounded with a rim-like margin that precluded

Figure 3: Aerial view of North Granny Lake in foreground. Turbidity of N. Granny Lake is greatly reduced as compared to Granny Lake (adjacent and above).

Figure 4: Shallow pools of highly saline water at the east end of Granny Lake. Struggling euhalophytes among the karst crust are Avicenna germinans, Sporobolus virginicus in potholes, and decumbent Sesuvium portulacastrum.

Figure 5: Vegetation of the flats surround the "blue holes" east of Granny Lake. Sporobolus virginicus in foreground, darker Salicornia perennis near midline, and woody Conocarpus erectus and Avicenna germinans surrounding water.

Figure 6: Rim-like margin surrounding blue hole #2 near Watling's Castle. Less than 4 meters depth with cavernous hole at bottom of 2.3 x 3.4 meters. Surface and bottom water are both 25 ppt. 3/19/85.

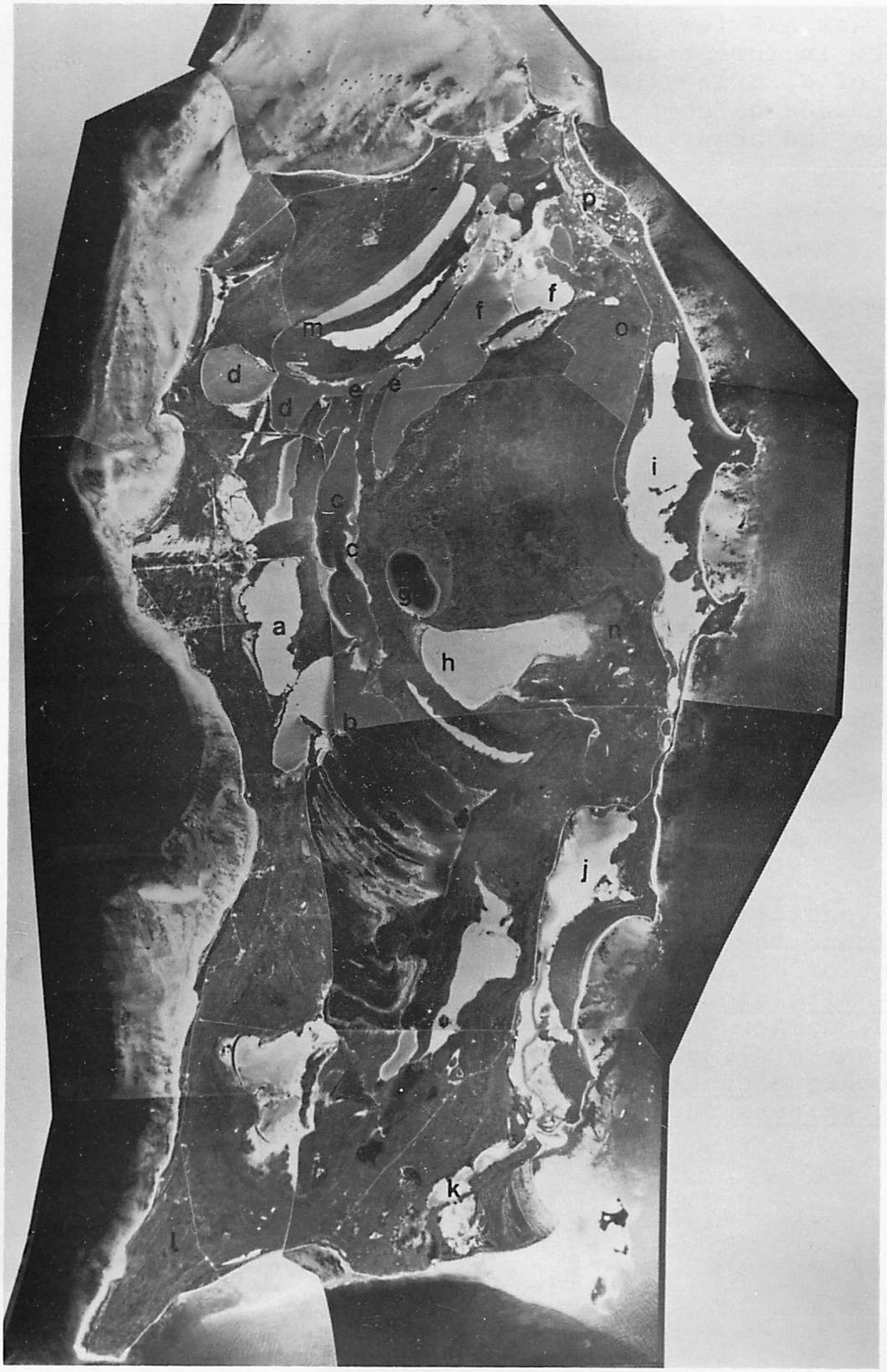

Figure 7: Aerial photograph of San Salvador Island, Bahamas. a. Little Lake; b. Grand Lake; c. Long Lake; d. Northwest Arm and Victoria Hill Lake; e. the Narrows; f. Northeast Arm and Lighthouse Lake; g. North Granny Lake; h. Granny Lake; i. Storr's Lake; j. Pigeon Creek Lagoon, North Arm; k. South Arm; l. Watling's and Blue Hole #2; m. Finger Lake; n. Blue hole east of Granny Lake; o. Bernie's Blue Hole; p. Fresh Lake.

the growth of truly euhalophytic species.

The Blue Hole east of Granny Lake lacked the funnel-like cavernouos feature but had topography slightly similar to a tidal flat. An extensive growth of Sporobolus virginicus, Salicornia perennis and B.maritima was found here.

Avicenna germinans and Conocarpus erectus were growing in the periphery of the pool flat. The salinity of the water was 34 ppt.

The final inland water feature of the island is the tidal lagoon known as Pigeon Creek that opens to the sea at Snow Bay. The southwest branch is populated in the extensive shallow flats with R. mangle and A. germinans. The water salinity was 44.5 ppt. The North Arm was populated on the periphery with C. erectus and A. germinans frequently with B. maritima beneath these plants. There is an extensive growth of R.mangle and A. germinans in the shallow water of the east side of this area.

Salinities are influenced by the shallow flats that promote heating and evaporation of the water. Water is removed and mixed with each tide change. Salinities at slack tide varied from 44.1 ppt. in the North and to 35.5 ppt. in outer Snow Bay.

It is apparent that most of the inland bodies of water are directly under the influence of the rainfall on the island. It would be of interest to correlate rainfall with salinity in the interconnected lakes on a monthly basis for several years. Evaporation is very high and in some years may exceed 3 times the annual rainfall. In the inland lakes replacement sea water probably enters these inland lakes through at least one conduit. This coupled with evaporation has combined to produce high salinities in these waters. The most unstable bodies of water are the small shallow lakes of the periphery of the island. These may dry up during periods of low rainfall and the exposed lake bottom is covered with salt crystals. Vegetation is very sparse in these areas.

The most euhalophytic species in descending order were determined to be Sesuvium portulacastrum, Batis maritima, Salicornia perennis, Sporobolus virginicus, Avicenna germinans, Rhizophora mangle and Conocarpus erectus. The only sea grass found was Halodule beaudetti and its presence indicates a high degree of salt tolerance.

Acknowledgments

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References

Briggs, John C. 1974. Marine Zoogeography, p. 212-214. New York: McGraw-Hill.

Duncan, W. 1974. Vascular Halophytes of the Atlantic and Gulf Coasts of North America North of Mexico. In Ecology of Halophytes edited by Robert Reimold and William Queen.

Gerace, D., 1973. Ecology of Inland Lakes and Pigeon Creek Bay. Island Environmental Studies, San Salvador, Bahamas: CCFL Field Station. Unpublished field research project.

Lang, Karen and Anatol Eberhard. 1974 Chloriniy of Pond and Well Waters. Environmental Chemistry. San Salvador, Bahamas: CCFL Field Station. Unpublished field research project.

Marshall, Harold. 1982. Phytoplankton composition from two saline lakes on San Salvador, Bahamas: Bull. Marine Science 32:351-353.

Rivers, W. Guy. 1969. The Physiology of Salt Tolerance of the Salt Marsh Halophyte, Salicornia Bigelovii. Houston, Tx: University of Houston Doctoral Dissertation.

Sverdrup, H. V., Johns M. W., and Fleming,.R. H. 1942. The Oceans, p. 124. Englewood Cliffs, N.J.: Prentice-Hall.

Teeter, James W. 1982. The Topographic, hydrographic and sedimentologic setting of Little Lake, San Salvador Island, Bahamas. Occasional Papers 1983 No.1. San Salvador, Bahamas: CCFL Field Station.

Waisel, Yoav. 1972, Biology of Halophytes, p. xii. New York: Academic Press.