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AN ANALYSIS OF LONG-TERM SALINITY PATTERNS IN THE LOUISIANA COASTAL ZONE[1]

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ABSTRACT: Saltwater intrusion is believed to be one of the greatest threats to Louisiana's fishery and wildlife resources. The Louisiana Department of Wildlife and Fisheries has maintained salinity recording stations throughout the state's coastal marshes since the 1960's. We applied several different analytical approaches to the salinity data from 17 stations to determine whether this data base could be used to detect and quantify long-term salinity trends in coastal Louisiana.

We did not detect a large-scale, consistent trend over time in coastal salinities across the state. Problems that hindered the detection of long-term trends included short periods of record and the placement of the recording stations in salt and brackish marsh areas, where we would not expect to find great changes in salinity. For the data to be useful in monitoring salinity trends in coastal marshes, especially with respect to saltwater intrusion, stations should be added in fresh and intermediate marshes. In addition, the relationships our study revealed between short- and long-term data indicate that records covering less than a decade are insufficient to denote long-term salinity changes, barring some major modification of the hydrologic regime.

Saltwater intrusion and wetland loss remain two of the greatest threats to Louisiana's fishery and wildlife resources. Although the causes of wetland loss remain poorly understood, freshwater marshes invaded by salt water are believed to sustain the greatest losses. Researchers have recently studied patterns of vegetational changes and wetland loss (Craig *et al.* 1979; Chabreck 1982; Chabreck and Linscombe 1982; Scaife *et al.* 1983), but relatively few studies have been made of long-term coastal salinity patterns.

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Several studies have, however, contributed to our knowledge of salinity regimes in coastal Louisiana. Barrett (1971) characterized salinity regimes in the state's coastal zone as varying primarily with seasonal changes in tides, rainfall, river discharge, and evaporation rates. Gagliano *et al.* (1970) compiled an atlas of coastal Louisiana salinities using data from the U.S. Army Corps of Engineers and the Louisiana Department of Wildlife and Fisheries (LDWF). Later, Gagliano *et al.* (1972) used salinity measurements and such variables as river discharge and rainfall to statistically model salinities in Lake Pontchartrain and Barataria Bay. Van Sickle *et al.*'s (1976) work in Barataria Bay, Sikora and Kjerfve's (1985) work in Lake Pontchartrain, and Wiseman and Swenson's (1987) work statewide represent the few studies that have attempted to quantify long-term salinity trends in Louisiana's estuaries.

This study is a natural outgrowth of Van Sickle *et al.*'s (1976) findings in that we apply many of their techniques to a statewide salinity data base maintained by LDWF since the 1960's. Our objective is to determine if these data can be used to detect and quantify long-term salinity trends in coastal Louisiana.

MATERIALS AND METHODS

LDWF Salinity Data

LDWF maintains more than 25 continuously recording salinity stations across Louisiana's coastal zone. We obtained salinity records from 17 of these stations (Table 1), all originally located in brackish or salt marshes from the nearshore waters of the Gulf of Mexico inland to such places as St. Mary's Point in upper Barataria Bay (Fig. 1; Chabreck *et al.* 1968). Most stations recorded data during the 1970's, and some have records extending back to the 1960's.

Over the years, various types of equipment have been used to collect data. All devices recorded conductivity, which was later converted to salinity in parts per thousand (ppt). In the 1960's, data were collected with chart recorders which recorded onto paper disks. In the mid-1970's, these devices were replaced with what are generically called "continuous recorders"; these recorded conductivity on paper or magnetic tape. Byrne *et al.* (1976) describe, in detail, how data from the chart and continuous recorders were collected and salinities calculated. Chart recorder data were determined to the nearest 0.1 ppt. We have used one additional decimal place to calculate averages for all the data.

Analyses

Our initial examination of the data revealed that salinity records for stations are not complete. Gaps in the data range from a few hours or a few days to whole months and occasionally whole years.

Table 1. Locations and sample dates for LDWF salinity measurement stations.

Station	Location	Years chart	Years continuous	Marsh type[1]
102	Rigolets	1972-74	1974-79	B
117	Grand Pass	—	1975-79	S
118	Chef Menteur	1967-72	—	B
221	Bay Gardene	1967-73	1972-79	S
251	Long Bay	—	1972-76	S
252	California Pt.	—	1972-75	S
253	Sable Is.	—	1973-77	S
315	Marine Lab	1959-75	1975-80	S
317	St. Mary's Pt.	—	1973-80	S
416	Cocodrie	1967-74	1974-80	S
518	Sister Lake	1967-73	1974-80	S
619	Cypremort Pt.	1974-76	1976-80	B
620	Southwest Pass	—	1978-80	S
701	Rockefeller (above weir)	—	1975-78	S
702	Rockefeller (below weir)	—	1974-79	S
719	Cameron, north	—	1975-80	B
721	Cameron, south	1967-74	—	B - S

[1]Based on vegetation map from Chabreck *et al.* (1968).

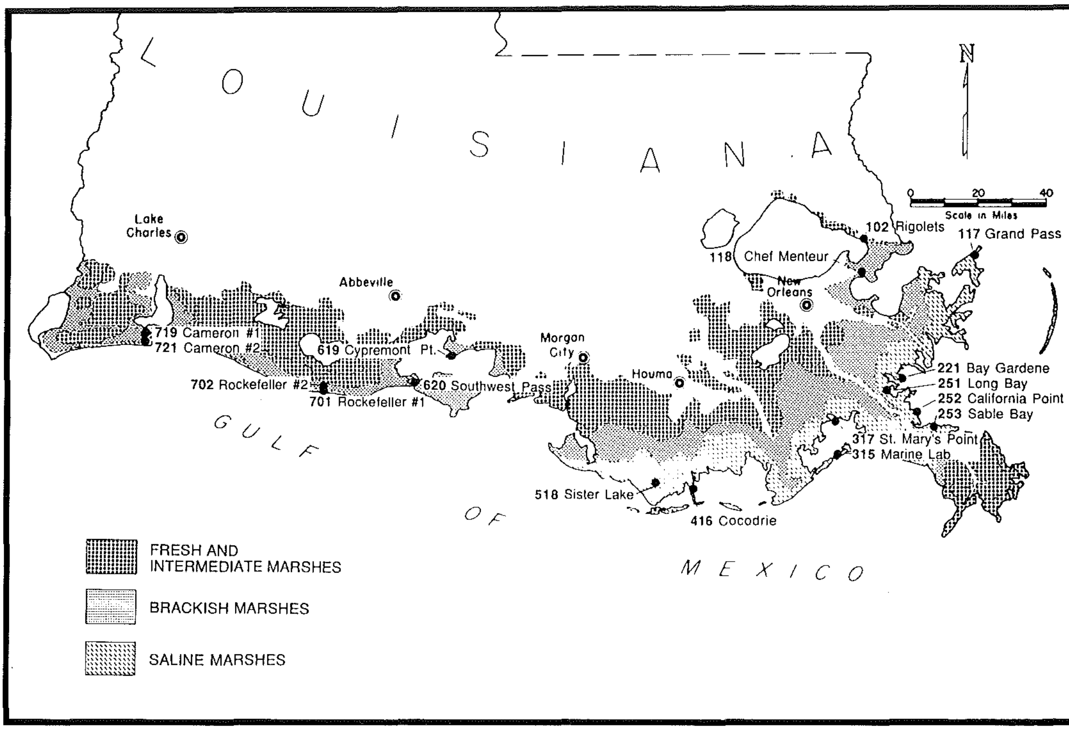

Figure 1. Map of the study area showing locations of the Louisiana Department of Wildlife and Fisheries salinity measurement stations overlain on vegetative type map by Chabreck *et al.* (1968).

Many stations across the state did not have salinity records for common time periods. Approximately one-half of the stations had five years or less of salinity records (Table 1).

We conducted preliminary analyses to determine how various data gaps affected daily, weekly, and monthly averages. Days that had less than 75% of the hourly readings were excluded from the analyses. We used monthly averages (calculated as the monthly averages of daily averages) to reduce the impact of missing values and minimize the effects of short-term variations in river discharge and rainfall.

To test for salinity trends we initially developed a broad-scale model that would incorporate differences due to station locations, time of year, and yearly trends. Simple linear regression techniques were used to test for trends in average monthly salinity and average variance of monthly salinity over time on a station-by-station basis. For those stations with data from both chart and continuous recorders, we conducted analyses of covariance to test for differences in long-term trends due to recorder types. Because most of these stations were converted from one device to another without ovelapping time periods of data collection, any differences between the two recorder types are confounded with differences between the two time periods. To detect relationships between stations, we constructed correlation matrices for mean monthly salinities and variances.

RESULTS AND DISCUSSION

We did not detect a large-scale trend over time in coastal salinities across the state. The results of our broad-scale statistical model and of our correlation analysis were not readily interpretable because of gaps in the data, the lack of ovelapping salinity records for most of the stations, and the frequent lack of long-term records. Therefore, the results of these analyses are not presented here.

We did not detect a significant difference between the long-term salinities measured by chart and continuous recorders for those stations where both devices were used.

One of the most limiting factors in testing for a long-term relationship was that only one-half of the stations had more than five years of data. This is not long enough to test for trends in a system where environmental conditions can cause large fluctuations in salinity to occur in annual, biannual or longer cycles. We initially expected that many of the stations would have significant positive salinity trends, suggestive of continuing saltwater intrusion. Van Sickle *et al.* (1976) found an increasing trend in salinity at the St. Mary's Point station during their study (1961-1974). However, we did not detect a significant increasing or decreasing trend at this station in our study, which included data for 1973-1980. Our data covered a shorter period, during which a rise in salinity from 1973 to 1977 and a decrease from 1978 to 1980 averaged out to no significant change in salinities. Of the 17 stations for which we had data, only 6 had statistically significant trends in average monthly salinity over time (Table 2). We felt that the presence of serial correlation in the monthly salinity data with respect to annual variations limited our ability to detect salinity trends. So, in order to determine whether these trends were due to short-term fluctuations, we overlaid the mean annual salinities for each of these stations with our longest salinity record (Marine Lab) (Figure 2). One station, Sable Island, showed a positive trend in salinity, but the brevity of the record (five years) made it difficult to attach much meaning to this finding. The trends in all five remaining stations were negative, indicating that salinities decreased over time. However, two of these stations, Grand Pass and Cameron, appeared to reflect short-term fluctuations in salinity (Figure 2). The Bay Gardene, Marine Lab, and Cocodrie Stations each had record lengths of greater than six years. The rate of decrease in salinities at these stations ranged from −0.02 to −0.04 ppt per month.

Table 2. Number of monthly values (n), probabilities (p), and estimates of slope for LDWF stations recording a significant trend in salinity over time.

Station	Location	n	p[1]	Slope[2]
117	Grand Pass	34	0.002	−0.19
221	Bay Gardene	85	0.002	−0.04
253	Sable Is.	32	0.010	0.18
315	Marine Lab	237	0.000	−0.02
416	Cocodrie	140	0.005	−0.27
719	Cameron	64	0.000	−0.12

[1]The probability that the slope is not significantly different from zero.

[2]Change in salinity (ppt) per change in time of one month.

The lengthy record for the Marine Lab yielded results similar to those of Van Sickle *et al.* (1976) who found that salinities decreased (−0.007 ppt per month) from 1961 to 1974. They attributed much of this decrease to increased discharge from the Mississippi River. We feel that this and possibly long-term increases in rainfall and local freshwater flow were partly responsible for the negative trends we found at these three stations.

Overall, even considering the obvious changes in coastal vegetation over the years, the lack of any statistically significant increasing trend for most of the data is not surprising because, based on Chabreck's (1968) marsh type designation, most stations are located in salt or brackish marshes. This could affect our ability to detect a trend in two ways: (1) these areas are likely to have already

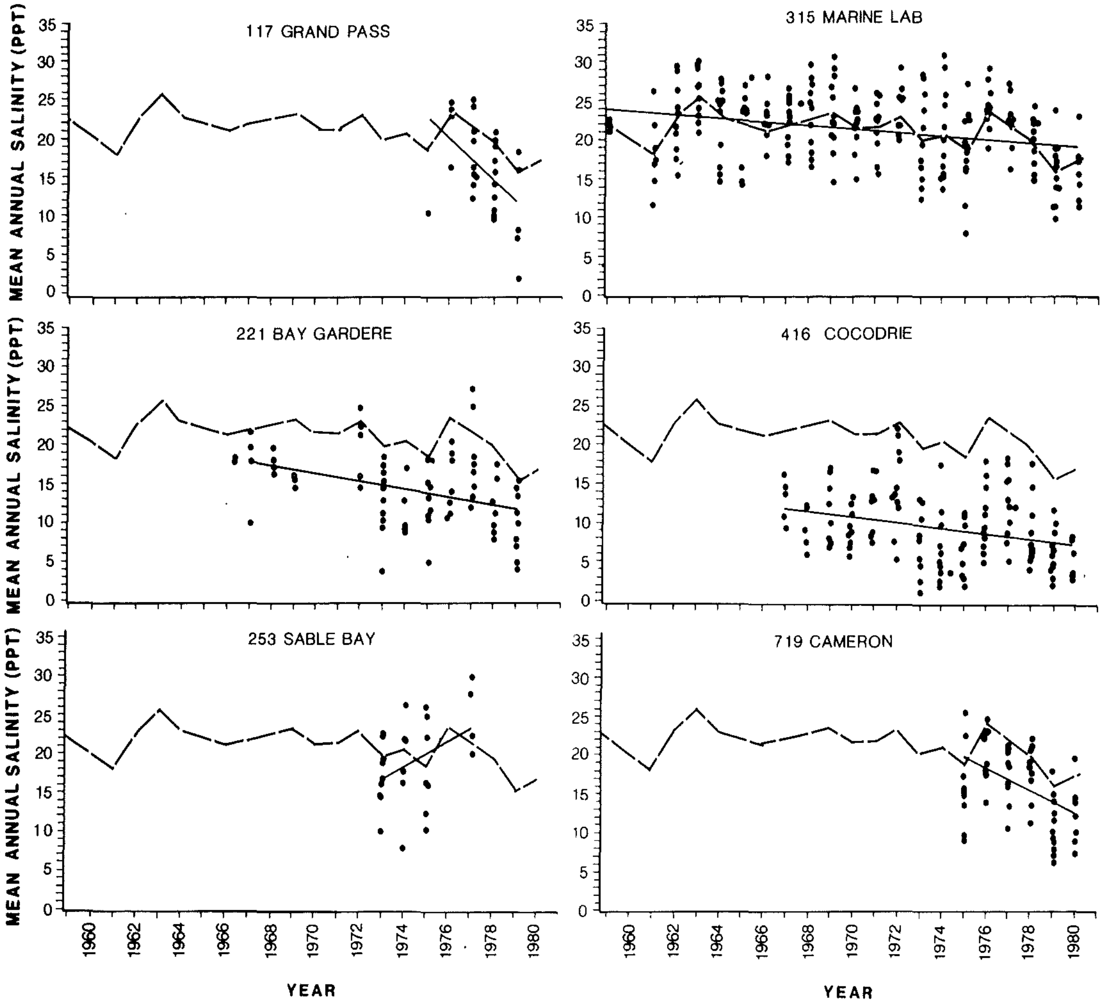

Figure 2. Mean annual salinities for the Marine Lab Station (dashed line) overlain with the mean monthly salinities (points) and their regression line (solid line) for the Grand Pass, Bay Gardene, Sable Island, Marine Lab, Cocodrie, and Cameron Stations.

been subject to saltwater intrusion. In that case, we are then measuring normal variation around a given salinity, or (2) it may be more difficult to detect a trend in salinity at stations in salt or brackish marshes. An increase in salinity due to saltwater intrusion cannot continue indefinitely but should eventually level off at a value similar to that for Gulf waters. As salinity approaches the maximum, its rate of change will decrease. Normal variations due to environmental influences, however, will remain the same and thus will mask the effect of increasing salinity.

After reinspecting the salinity patterns for the remaining stations, we felt that the patterns at most stations generally coincided with fluctuations noted for the stations with longer records. Specifically, in a nonquantitative, nonstatistical sense, these six stations, Grand Pass, Bay Gardene, Sable Island, Marine Lab, St. Mary's Point, and Cocodrie, appear to exhibit salinities that generally decreased from about 1971 to 1974, increased from about 1974 to 1977, and decreased from about 1977 to 1980 (Figure 2). Indeed, the significant trends noted at the Sable Island and north Cameron stations were in the same directions as those noted in the long-term stations for the periods of overlap, 1975 to 1979 and 1973 to 1977 (Figure 2). This suggests to us that salinity records shorter than a decade may not reflect long-term salinity changes, barring some major modification of the hydrologic regime. This tends to be supported by Sikora and Kjerfve (1985) who found an 11-year periodicity in their salinity data. If our speculation is valid, the records from a series of Endeco meters LDWF deployed in 1980 are now approaching a useful length. It may also be that saltwater intrusion is not a broad phenomenon, but is rather localized. None of our salinity stations were placed near recently built dikes or canals where change in the flow patterns could be measured.

CONCLUSIONS

Initially, we hypothesized a broad-scale pattern of increasing salinities indicative of Louisiana's continuing and rapid rates of wetland loss. However, those significant long-term trends detected were negative. These findings are probably attributable to a combination of short periods of record and large annual fluctuations in salinities due to environmental factors, such as annual rainfall or increased discharge from the Mississippi River. Wiseman and Swenson (1987) were also unable to detect a consistent, long-term pattern in salinities. In addition, ancillary information such as that reported by Van Sickle *et al.* (1976) and Byrne *et al.* (1976) suggests that saltwater intrusion may have already occurred in these areas where most of our data were collected. If it had, we would not expect to observe a trend in salinities over time. Instead, we would be measuring changes in some overall salinity as influenced by environmental conditions. If however, a gradual change in salinity is occurring in these areas, we will have a poor ability to detect that change in light of the larger, environmentally-caused fluctuations. In either case, only long-term measurements of salinity in areas that are currently of fresh or intermediate salinity, or areas where the hydrologic regime has been recently modified should reflect changes such as saltwater intrusion and related alterations in the environment.

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