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RECENT TRENDS IN WATER CLARITY OF LAKE PONTCHARTRAIN

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ABSTRACT An analysis of Secchi disk transparency observations from 3 sites on the Lake Pontchartrain Causeway indicates that water clarity has increased at the north shore and mid-lake sites, but has not changed at the south shore site. Louisiana Department of Environmental Quality data from 1986 through 1995 were used in the analysis. Further analysis indicates that the increased transparency was not caused by changes in salinity or wind speed. The best explanation for the observed increase is the cessation of shell dredging in 1990.

INTRODUCTION

Lake Pontchartrain is an estuarine embayment located in southeastern Louisiana, north of metropolitan New Orleans. The lake has a mean salinity of about 4%, mean depth of 3.7 m and surface area of 1,630 km^2 (Sikora and Kjerfve 1985). Several factors have contributed to the environmental degradation of Lake Pontchartrain including urban and agricultural runoff, shell dredging, saltwater intrusion, operation of the Bonnet Carre Spillway and industrial discharges (Houck et al. 1987). A major environmental concern has been an assumed long-term increase in turbidity based on Secchi disk transparency observations (Stone et al. 1980).

Stone (1980) analyzed 4 sets of Secchi disk transparency data and concluded that water clarity had decreased almost 50% between 1953 and 1978. Francis et al. (1994) also found that regression of the available transparency data on time (1953 through 1990) suggested a statistically significant decrease in transparency of about 40%. The 1953 to 1990 data, however, were biased in that they did not adequately represent the seasonal effects of salinity and wind speed. There are strong correlations between water clarity and salinity and wind speed in Lake Pontchartrain, and both variables vary with season. When the transparency data were adjusted for the seasonal effects of salinity and wind speed or when unbiased data sets were constructed, the data did not support the hypothesis of a change in transparency from 1953 to 1990.

Shell dredging was discontinued during the summer of 1990. It was known to have produced short-term, local increases in turbidity, but may have had more widespread and lasting effects due to the production of unconsolidated bottom sediments that could be more easily resuspended by wind (USACOE 1987). If shell dredging had long-term, widespread effects on water clarity, then a comparison of transparency data from the 1986-90 and 1991-95 periods might reveal an increase in transparency that would be indicative of recovery. Such evidence of recovery would also suggest that a significant impact from shell dredging had occurred.

The present study was conducted to determine whether changes in water clarity as measured by Secchi disk transparency had occurred since 1990, and thereby provide a sequel to our earlier work (Francis et al. 1994), and also to determine whether any observed changes could be attributed to the cessation of shell dredging in the lake.

MATERIALS AND METHODS

Description of the Data Set

Secchi disk transparency, salinity, and turbidity data for the 1986 to 1995 period were obtained from the Louisiana Department of Environmental Quality (LADEQ). The data were collected as part of an ongoing monitoring program which includes monthly measurements at 3 stations on the Lake Pontchartrain Causeway located approximately 4 miles (6.4 km) from the north shore, at mid-lake, and approximately 4 miles from the south shore (Figure 1). A few data points are missing in the 1986 through 1995 data set because measurements were not taken in some months. The missing data points were estimated by distance weighted least squares.

Wind speed data for the 1986 to 1995 period were recorded daily at the New Orleans International Airport. The data set constructed for this study contains the average wind speed for a 5-day period including the day of transparency measurement and the 4 preceeding days.

Regional Effects of Wind

Wind probably has the same effect on transparency in all regions of the lake. It is not possible, however, to conduct a rigorous statistical test of that premise with the available data. Multiple regression analysis was used only to provide some support for the idea. Data were selected from the LADEQ data sets for transparency and salinity and from the wind speed data set recorded at the New Orleans International Airport. The combined data set

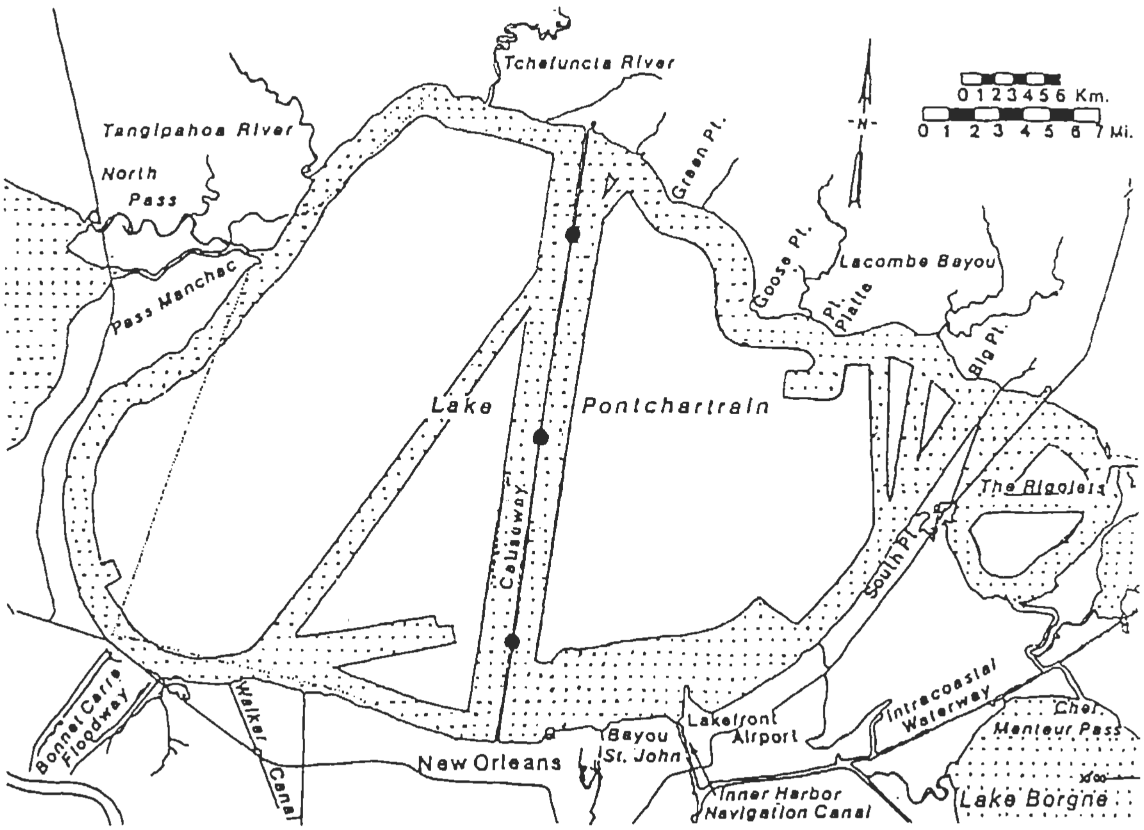

Figure 1. Map of Lake Pontchartrain, Louisiana. The stippled area indicates areas where shell dredging was prohibited (USACOE 1987). The three LADEQ monitoring sites on the Lake Pontchartrain Causeway are indicated by large dots.

has measurements of transparency, salinity and wind speed for 119 months from 1986 through 1995. In 53 months salinity was sufficiently similar at the 3 sampling sites to realize a coefficient of variation of 25 or less. These data were chosen for analysis. The selection procedure was intended to remove salinity as a significant variable in the regression. The selection limit of 25 was an arbitrary choice. There was no autocorrelation in these data.

In regressions of transparency on salinity and wind speed one would expect the partial regression coefficients for salinity not to be significant because of the data selection procedure, and those for wind speed to be significant. If wind speed has the same effect on transparency at the 3 sampling sites, then one would expect 3 parallel regressions with different constants and slopes determined largely by wind. One would expect further that the ratios of constant to slope would be the same if the regressions are parallel.

When transparency was regressed on salinity and wind speed, the partial regression coefficients for salinity were not significant as expected, and those for wind speed were significant at all 3 sites. Ratios of constant to slope were 13.16, 13.51, and 11.40 for the south shore, mid-lake and north shore sampling stations, respectively, suggesting that a given wind speed produced approximately the same percentage decrease in transparency at the 3 sites, or that wind speed had approximately the same effect in the different regions of the lake.

Transparency and Turbidity

Secchi disk transparency measurements were obtained with a 20 cm disk with black and white quadrants. Transparency data were used in the present analysis to facilitate comparison with historic data. Because Secchi disk observations are somewhat subjective, the association between transparency and turbidity data sets was analyzed to corroborate results. Pearson correlation coefficients for transparency and turbidity were greater than 0.8 ($p < 0.001$) for the 3 sampling sites.

Statistical Methods

The 4 time-series data sets used in statistical analyses (transparency, turbidity, salinity and wind speed) possess low but statistically significant first order autocorrelation. Autocorrelation was reduced to non-significance in each data set by differencing with one period lag. Each data set thus fits a first order autoregressive model.

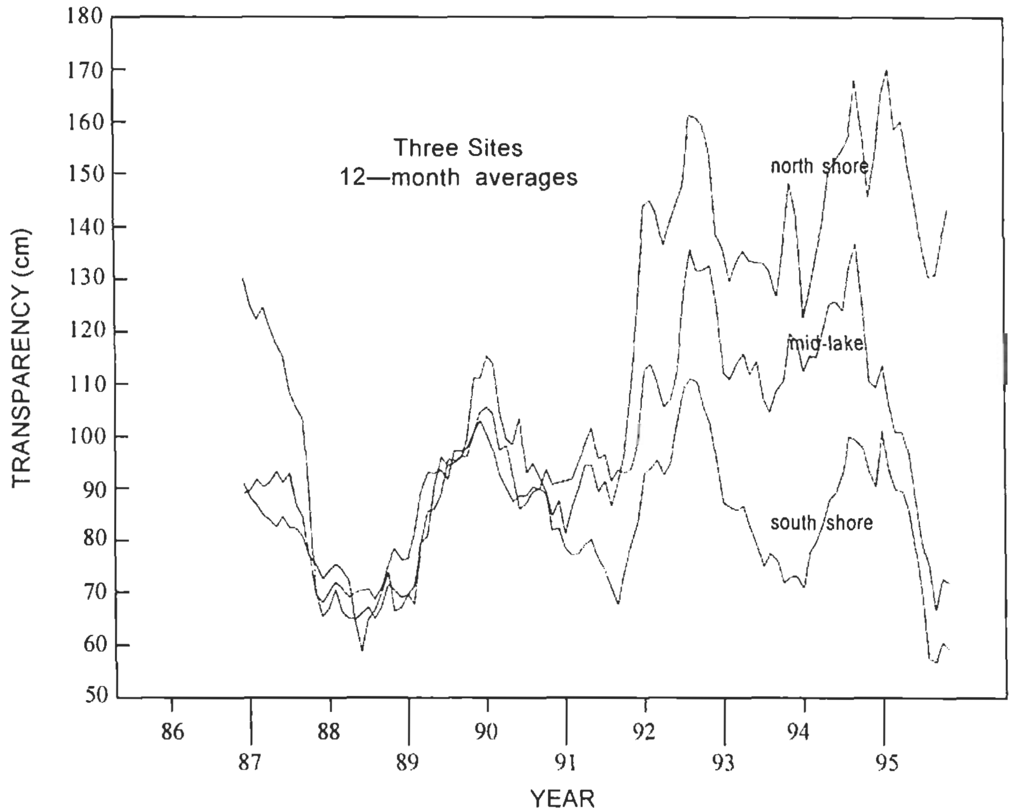

Figure 2. Twelve-month moving averages of monthly Secchi disk transparency at the 3 sampling sites from 1986 through 1995.

Significance tests in analysis of variance and regression analyses were performed with lagged data. Residuals were analyzed to test for normality, homogeneity of variance and independence.

Standardized partial regression coefficients may be obtained with data transformed to standard normal form. Standardized coefficients are useful for comparative purposes because they are independent of scale.

RESULTS

Twelve-month moving averages of monthly Secchi disk transparency measurements from the south shore, mid-lake and north shore sampling sites are presented in Figure 2. Approximately the same transparency was realized at all 3 sites through 1990. After 1990, transparency increased at the north shore and mid-lake sampling sites, but not at the south shore site. One-way analysis of variance indicated that mean transparencies for the 3 sites in the 1986-90 period were not significantly different, $p > 0.5$. In the 1991-95 period, however, mean transparencies for the 3 sites were significantly different from each other, $p < 0.05$.

Lake-wide mean salinities were 3.98% and 3.17% in the 1986-90 and 1991-95 periods, respectively. The 95% confidence intervals for these means overlap, indicating that the higher transparencies measured in the 1991-95 period were not associated with a significant lake-wide change in salinity. Twelve-month moving averages of monthly salinity measurements from the south shore, mid-lake and north shore sampling sites are presented in Figure 3. Consistently lower salinities occurred at the north shore throughout the 1986-95 period. The 95% confidence interval for north shore mean salinity in the 1991-95 period does not overlap the 95% confidence intervals for mid-lake and south shore mean salinities. The higher transparencies observed at the north shore in the 1991-95 period (Figure 2) were thus associated with salinities lower (Figure 3) than were measured at other regions of the lake.

Lake-wide mean wind speeds were 7.76 mph and 8.13 mph in the 1986-90 and 1991-95 periods, respectively. The 95% confidence intervals for these means overlap, indicating that the higher transparencies measured at the north shore in the 1991-95 period (Figure 2) were not associated with a significant lake-wide change in wind speed.

Multiple regression analysis was used to assess the relative effects of salinity and wind speed on transparency between the 1986-90 and 1991-95 periods for the south shore and north shore sampling sites (Table 1). At the south shore, the partial regression coefficient for salinity

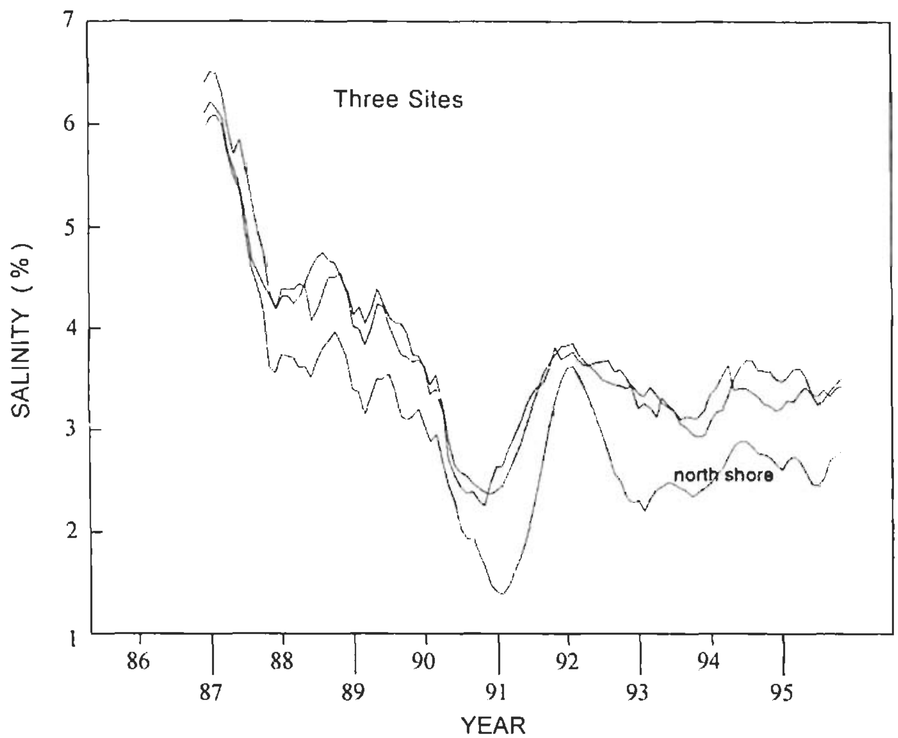

Figure 3. Twelve-month moving averages of monthly salinity at the 3 sampling sites from 1986 through 1995.

was not statistically significant in both periods, suggesting that the negative effect of wind speed was the more prominent factor in determining transparencies. Standardized regression coefficients for salinity at the south shore had overlapping 30% confidence intervals as did standardized coefficients for wind speed. At the north shore, both partial regression coefficients were significant in both periods (Table 1). Standardized regression coefficients for salinity at the north shore had overlapping 30% confidence intervals as did standardized coefficients for wind speed. These results indicate that the relative effects of salinity and wind speed on transparency were different at the 2 sampling sites. More importantly for the purpose of this paper, the results also indicate that the effects of salinity and wind speed were approximately the same in both periods at a given sampling site.

DISCUSSION

The similarity of standardized regression coefficients in the 1986-90 and 1991-95 periods at the south shore and north shore sampling sites (Table 1) indicate that the higher transparencies measured at the north shore in the 1991-95 period (Figure 2) cannot be explained by changes in salinity or wind speed.

Salinity has a statistically significant positive effect on transparency, and wind speed has a statistically significant negative effect on transparency (Francis et al. 1994). Higher transparencies, therefore, are usually associated with higher salinities and lower wind speeds. An unusual feature of the reported results is that the higher transparencies observed at the north shore in the 1991-95 period were not associated with higher salinities or lower wind speeds, but rather with lower salinities than those measured at the mid-lake and south shore sampling sites and with wind speeds that were the same at the 3 sites.

The higher transparencies (Figure 2) and higher regression constant (Table 1) at the north shore during the 1991-95 period may be explained by the positive effect on transparency realized through cessation of shell dredging. Sediment disruption produced by shell dredging probably had a greater negative effect on transparency in the lower-salinity waters of the north shore (Figure 3) because of the tendency for lower-salinity waters to retain particles in suspension longer (Francis et al. 1994). By reducing transparencies at the north shore in the 1986-90 period, shell dredging probably was responsible for the lower regression constant for that period (Table 1). Shell dredging was not present in the 1991-95 period resulting in higher transparencies and a higher regression constant.

Higher transparency peaks were apparent at the north shore and mid-lake sampling sites by the fall of 1991 (Figure 2). This observation is consistent with expectation because an immediate increase in transparency was not anticipated. Unconsolidated sediments that are more

TABLE 1

Regression analyses of transparency vs. salinity and wind speed for south shore and north shore sites in 1986 through 1990 and 1991 through 1995.

Site and Period	Coefficient	Standardized Coefficient	p
South Shore 1986-90			
Constant	153.57		
Salinity	5.55	0.25	0.213
Wind speed	-11.13	-0.54	0.021
South Shore 1991-95			
Constant	163.84		
Salinity	7.42	0.18	0.389
Wind speed	-13.93	0.61	<0.001
North Shore 1986-90			
Constant	92.11		
Salinity	14.12	0.55	0.006
Wind speed	-6.01	-0.23	0.091
North Shore 1991-95			
Constant	155.63		
Salinity	34.02	0.57	0.003
Wind speed	13.94	-0.37	0.006

susceptible to resuspension by wind (USACOE 1987) would persist for a period of time following dredging and have a longer-term effect on turbidity. In addition, an earlier expression of higher transparency may have been mitigated by lower lake-wide salinities in 1990 and early 1991 (Figure 3) that would have lowered transparency.

Transparency remained essentially unchanged at the south shore after shell dredging was stopped. Several factors may have contributed to this outcome. Dredging was prohibited within 3 miles of the south shore extending from the Lake Pontchartrain Causeway east to Paris Road in Orleans Parish, and near oil and gas facilities in Jefferson Parish west of the causeway (Figure 1). Consequently, dredging and its effects on transparency may have been less intense near the south shore site. The south shore is subject to urban runoff from metropolitan New Orleans, and it has a highly modified shore line with no exchange with natural streams and wetlands. Runoff introduces nutrients that can promote algal growth with the result that turbidity from phytoplankton growth may have replaced turbidity from resuspended sediments.

Shell dredging began in 1933 and probably affected transparency prior to the first transparency measurements in 1953. The cessation of shell dredging in 1990 reestablished conditions favoring higher transparencies in some regions of the lake. The change to higher transparencies cannot be attributed to changes in salinity or wind speed.

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