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HISTORIC TRENDS IN THE SECCHI DISK TRANSPARENCY OF LAKE PONTCHARTRAIN

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ABSTRACT A major environmental concern about Lake Pontchartrain is an assumed long-term increase in turbidity based on Secchi disk transparency observations. Regression of the available data on Secchi disk transparency versus time (1953 through 1990) reveals a statistically significant decrease in transparency of about 40%. However, the data set is biased in that it does not adequately represent the seasonal effects of salinity and wind speed. Two analytical procedures were undertaken to determine the extent to which the apparent long-term decrease in transparency was dependent on the seasonal bias. One procedure involved seasonal adjustment of the data for the effects of salinity and wind speed. The other procedure was to remove the seasonal bias by constructing unbiased data sets.

Seasonal adjustment for the effects of salinity and wind speed reduced the level of significance for the relationship between Secchi disk transparency and time from about 1% to about 10%. This result indicates that some of the apparent decrease in transparency in the original data is the result of inadequate representation of seasonal effects in the biased data set.

In most years data are not available for all months with the result that the seasonal effects of salinity and wind speed are not adequately represented. When the bias was removed by constructing unbiased data sets, the data no longer supported the conclusion of a statistically significant change in Secchi disk transparency from 1953 to 1990; $p > 0.5$.

INTRODUCTION

Lake Pontchartrain is an embayment in a large estuarine system in southeastern Louisiana. It has a mean salinity of 4 ppt, a mean depth of 3.7 m, and a surface area of 1630 km^2. Saline water enters from adjacent estuaries through tidal passes. Fresh water sources are streams, New Orleans area outfall canals, and the Mississippi River during opening and leakage of the Bonnet Carré Spillway (Barbé and Poirrier, 1991).

Over one million people live on the southern shore of Lake Pontchartrain. With increasing urbanization of the New Orleans area over the last century, concerns have arisen as to possible declines in water quality, fisheries, recreational use and commercial value of the estuary (Houck *et al.*, 1987). Increased turbidity, for example, is regarded as an environmental problem in Lake Pontchartrain. Support for that concern is provided by Stone *et al.* (1980) who plotted four sets of selected Secchi disc transparency data from Lake Pontchartrain and concluded that water clarity had decreased by almost 50% between 1953 and 1978.

Although Stone's report (Stone *et al.*, 1980) is often cited as indicating a major environmental change in Lake Pontchartrain, it did not include all available data or address the seasonal effects of wind and salinity on transparency values. Thompson and Fitzhugh (1985) found a relationship between salinity and lake clarity with Lake Pontchartrain being clearer during periods of higher salinity and more turbid during fresher periods. Swenson (1980), found that winds blowing over Lake Pontchartrain are sufficient to stir and mix bottom sediments throughout the water column about 15% of the time. Thompson and Verret (1980) reported that occasional high winds during frontal passages, and at other times, are capable of resuspending bottom sediments, especially in the winter. Dow and Turner (1980) also stated that turbid conditions may be caused by weather fronts and their wind systems.

Storm-water runoff from the New Orleans area is currently discharged into Lake Pontchartrain without any treatment. Although the potential contribution of urban runoff to the pollution of estuaries has been recognized for some time, few studies have actually documented specific adverse effects (Odum and Hawley, 1987). On an annual basis, pollution from urban runoff can contribute more suspended solids and plant nutrients than any other pollution source (Scheaffer *et al.*, 1982). Urban runoff could affect the Secchi disc transparency of Lake Pontchartrain through the introduction of plant nutrients which increase phytoplankton growth and by the introduction of suspended solids (Mancini and Plummer, 1987; Odum and Hawley, 1987).

It is currently assumed that the turbidity of Lake Pontchartrain has increased by almost 50% between 1953 and 1978 (Stone *et al.*, 1980) due to the activities of man. Our study includes recent data, investigates the effects of salinity, wind and seasonal differences on transparency and tests long-term trends for statistical significance. The study was designed to provide a better understanding of trends and how natural factors affect water clarity. Results of this study will provide realistic goals for the treatment of urban runoff in plans to restore Lake Pontchartrain.

Materials and Methods

Description of the Database

The Secchi disc is widely used to estimate the depth of light penetration in aquatic habitats (Tyler, 1968). All data used in this study were obtained with a 20 cm disc with black and white quadrants. The raw data used in this study consisted of observations of Secchi disk transparency and salinity recorded by several investigators during the periods shown in Table 1. This data set contains Secchi disk transparency and salinity data from July 1953 through December 1990. In some years, data are not available for several months. For most months, data were only collected once a month. Data collected by the Louisiana Department of Environmental Quality from 1985 through 1990 were recorded from the Causeway Bridge, which is about 20 feet above the water surface. Therefore, their transparency values may be lower because of the greater distance between the observer and the water surface. In summary, the data set is incomplete:

- It does not contain data for all years.
- It does not contain data for all months.
- It may not be representative of particular months because data were collected only once or twice a month.
- It is not consistent with regard to station location.

Wind data used in this study were taken at New Orleans International Airport from 1953 through 1990 and published in Local Climatic Data by the National Weather Service Meteorological Observation Office. The elevations at which the wind data were measured were not the same in all years. The data from January, 1953 to July, 1969 were taken at an elevation of 3 feet above the ground, and the others at an elevation of 4 feet.

TABLE 1
Sources of Secchi disk transparency and salinity data.

Investigators	Period	N*
Suttkus *et al.* (1954)	8/19/53 - 6/30/54	155
Stern and Stern (1969)	6/2/69 - 7/22/69	71
Dugas and Tarver (1973)	3/18/70 - 5/18/71	109
Tarver and Savoie (1976)	9/26/72 - 8/22/74	279
Poirrier *et al.* (1975)	7/17/73 - 11/1/73	73
Stone *et al.* (1980)	1/78 - 12/78	219
O'Hara and Capello (1988); Louisiana Department of Environmental Quality (LADEQ) (unpublished data)	3/31/82 - 11/29/82	456
	1/4/83 - 12/7/84	816
	7/8/85 - 8/14/90	311
Steimle and Associates (1985)		
Western lake	1/12/84 - 10/25/84	168
Eastern lake	2/16/84 - 11/1/84	149

*Number of observations

The salinity data set, STORET, obtained from the U.S. Army Corps of Engineers contains data from 1953 through 1980, and from 1986 through 1989. These data were only used in analysis of variance to determine the statistical significance of annual seasonality in salinity.

Statistical Methods

All criteria were met for application of parametric statistical methods. Simple and multiple regression analyses and the analyses of variance were performed according to standard procedures as described in Sokal and Rohlf (1981).

RESULTS

Annual means, standard deviations, standard errors, and coefficients of variation of Secchi disk transparency were calculated for each year in which Secchi disk transparency data were available and are presented in Table 2. The highest values of Secchi disk transparency occurred in 1953 and 1954 (Table 2). The lowest Secchi disk transparencies occurred from 1973 through 1983. This period was affected by Bonnet Carré spillway openings in 1973, 1975, 1979 and 1983. The greatest relative dispersion (coefficient of variation) was recorded in 1974 and 1978 during the period

TABLE 2
Statistics for annual Secchi disk transparency calculated from the original data set.

		Secchi disk transparency (cm)					
Year	N*	Mean	High	Low	SD*	SE*	CV*
1953	62	131.69	431	30	76.36	9.70	59.4
1954	93	133.00	366	30	84.57	8.76	63.2
1969	71	89.31	183	15	39.51	4.69	44.2
1970	72	144.15	304.8	45.72	66.57	7.85	46.2
1971	37	140.87	182.9	91.44	23.88	3.93	17.0
1972	44	114.60	274	15.2	52.40	7.90	45.7
1973	208	79.29	274.3	9.1	41.59	2.88	52.4
1974	100	63.70	243.8	9.1	54.20	5.42	85.1
1978	219	60.60	165	1.5	37.42	2.53	61.7
1982	456	100.71	236.22	30.48	36.36	1.70	36.1
1983	685	55.79	182.88	2.54	30.54	1.17	54.7
1984	448	70.35	347.98	5.08	39.64	1.87	56.3
1985	35	106.80	213.4	14	47.70	8.06	44.7
1986	60	109.50	302.3	30.5	53.10	6.86	48.5
1987	59	68.00	142.24	25	26.00	3.38	38.2
1988	59	79.65	203.2	15.24	40.88	5.32	51.3
1989	59	102.00	182.88	30.48	34.00	4.43	33.3
1990	58	85.57	152.4	30.48	34.81	4.57	40.7

* N = Number of Observations
SD = Standard Deviation
SE = Standard Error
CV = Coefficient of Variation

of spillway openings, although 1953 and 1954 also realized high relative dispersion. The lowest relative dispersion was recorded 1971.

Average annual Secchi disk transparency is plotted as a function time in Figure 1. The period of time represented in the graph is 38 years: 1953 through 1990. Specific years are indicated above each point in the graph. Linear regression analysis was performed on annual means. The slope of the regression line, -1.47 cm/year, is statistically significant; $0.01 < p < 0.02$. The regression line indicates an apparent decrease in Secchi disk transparency from about 130 cm in 1953 and 1954 to about 80 cm in 1990 -- an apparent decrease of about 40%.

The data set is biased in that it does not adequately represent the seasonal effects of salinity and wind speed, two variables that have significant effects on Secchi disk transparency.

Figure 2 shows the annual seasonality in salinity. It is a graph of average monthly salinity versus months of the year. The highest salinities occur in the fall (September, October and November) and the lowest salinities occur in the spring (April, May and June). Monthly means are based on 32 years of data from the STORET data base (U.S. Army Corps of Engineers). That data base was used to test the validity of the apparent seasonality in salinity with analysis of variance. The ANOVA table for two-way analysis of variance without replication is presented in Table 3. The variance ratio, 21.18, exceeds the critical value for the test, 1.8, indicating that highly significant differences exist among monthly mean salinities, producing a highly significant annual seasonality in salinity.

Figure 3 shows the annual seasonality in wind speed. It is a graph of average monthly wind speed versus months of the year. The highest wind speeds occur in February and March and the lowest wind speeds occur in July and August. Monthly means are based on 38 years of data from the National Weather Service. That data base was used to test the validity of the apparent seasonality in wind speed with analysis of variance. The ANOVA table for two-way analysis of variance without replication is presented in Table 4. The variance ratio, 103.42, exceeds the critical value for the test, 1.8, indicating that highly significant

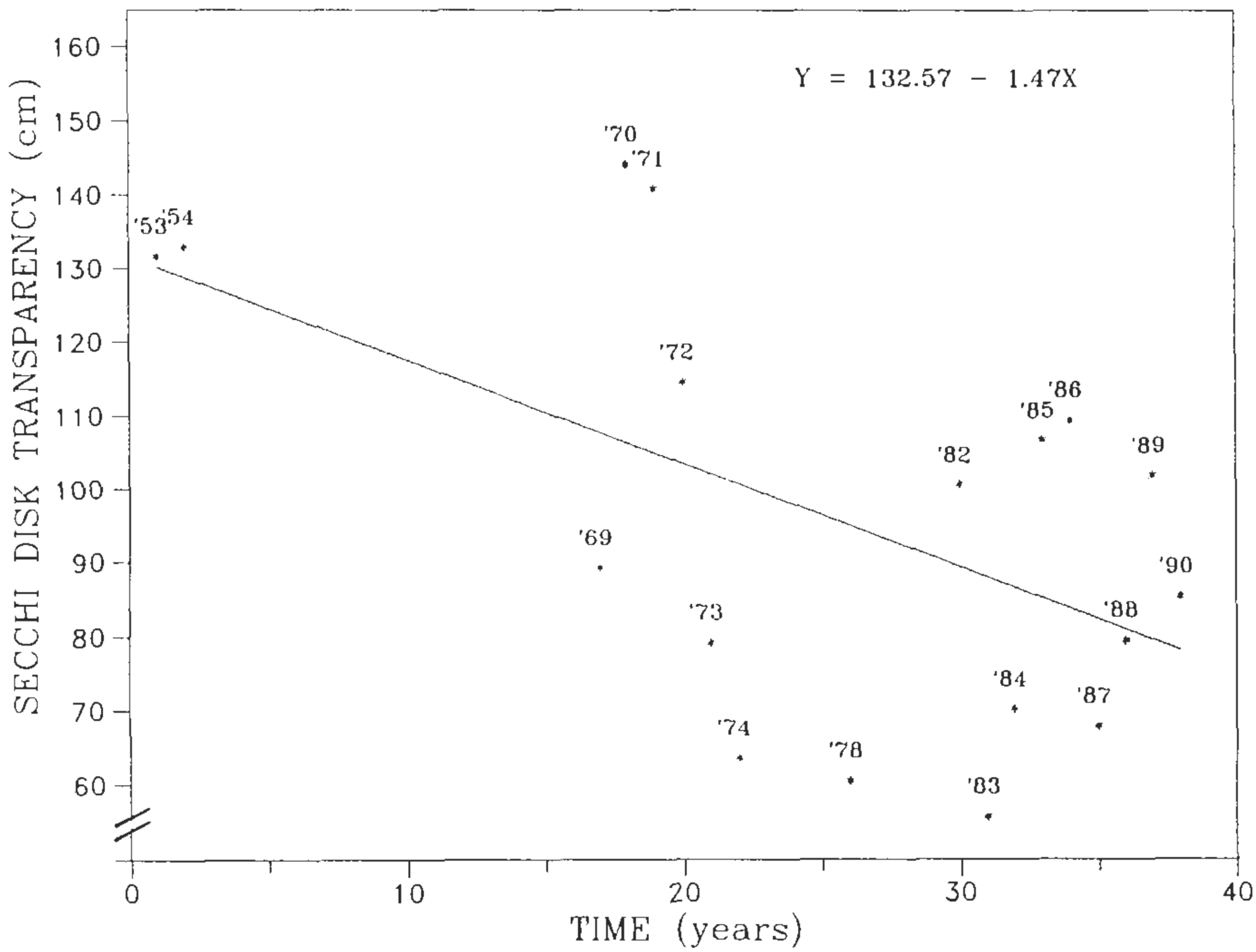

Figure 1. Annual mean Secchi disk transparency of Lake Pontchartrain from 1953 through 1990.

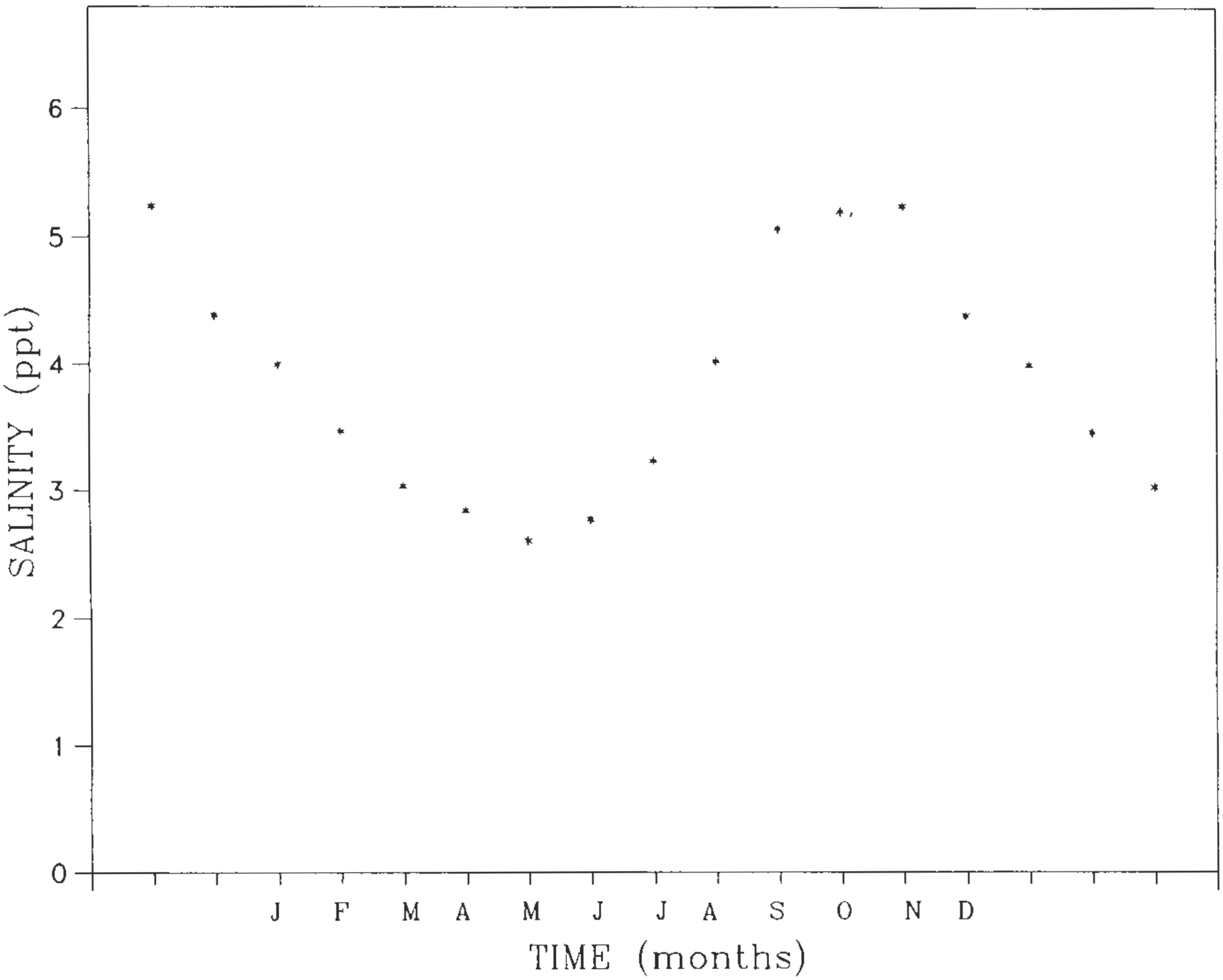

Figure 2. Monthly mean salinity.

TABLE 3
Analysis of variance of monthly mean salinity.

Source	SS	df	MS	F*
Month	333.77	11	30.34	21.28
Year	711.25	31	22.94	
Error	484.79	340	1.43	
Total	1529.81	38		

* F(0.95) = 1.8

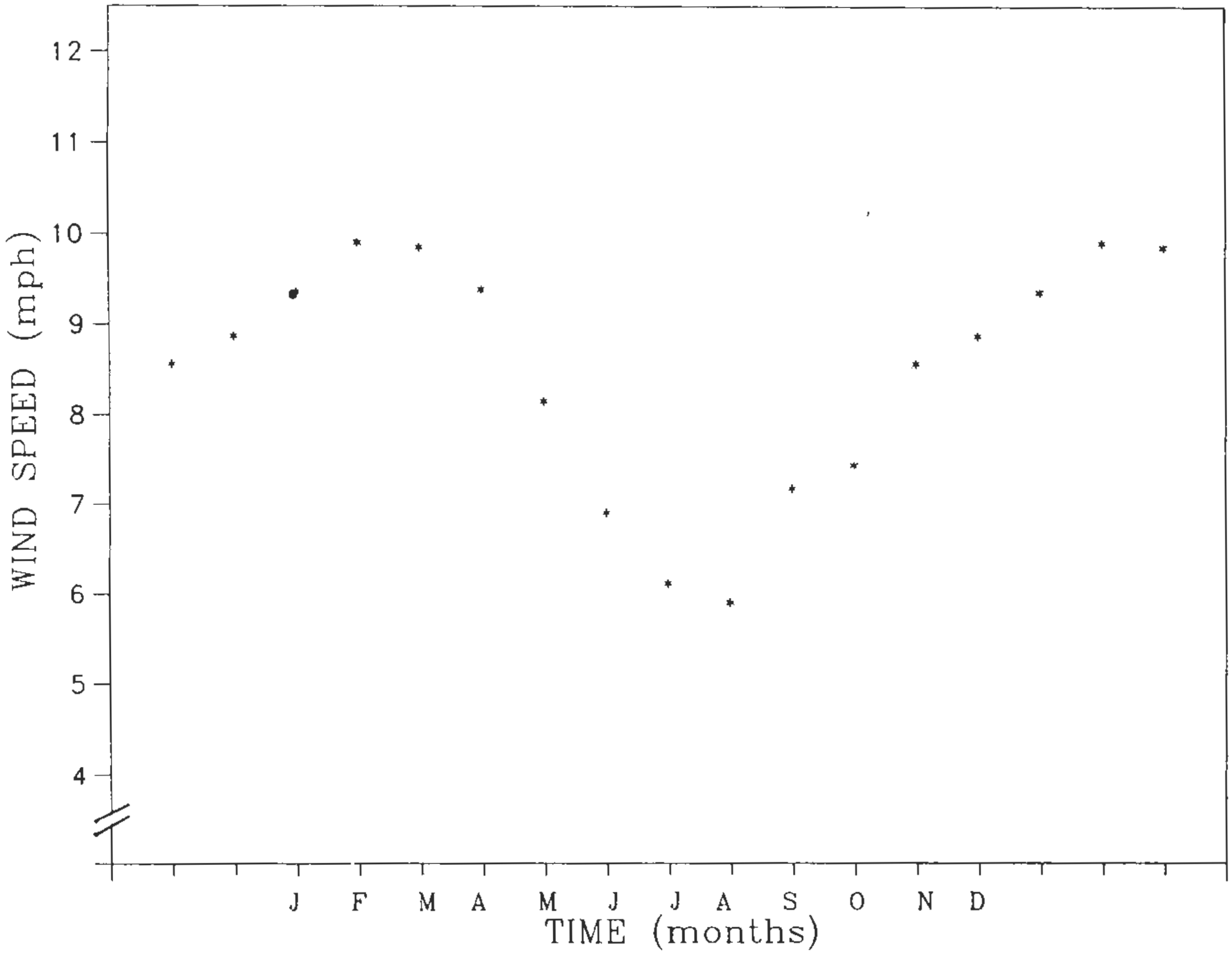

Figure 3. Monthly mean wind speed.

TABLE 4
Analysis of variance of monthly mean wind speed.

Source	SS	df	MS	F*
Month	825.50	11	75.05	103.42
Year	240.54	37	6.50	
Error	295.34	407	0.73	
Total	1361.38	455		

* F(0.95) = 1.8

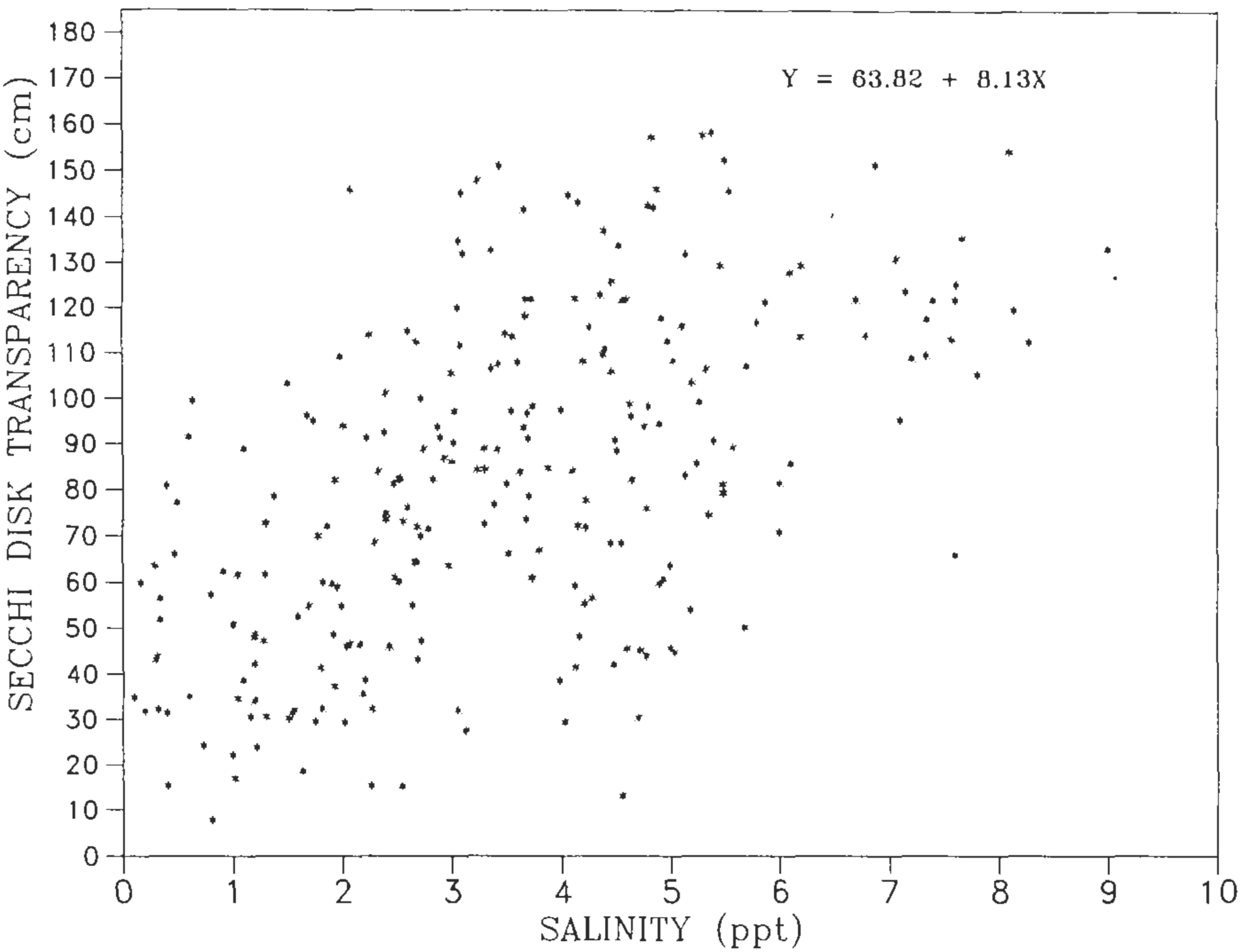

Figure 4. Secchi disk transparency (individual points) versus salinity.

differences exist among monthly mean wind speeds, producing a highly significant annual seasonality in wind speed.

Seasonal adjustment of the Secchi disk transparency data for salinity and wind speed was conducted in an effort to compensate for the seasonal bias in the data set. The adjustment for salinity is presented first.

Secchi disk transparency is plotted as a function of salinity in Figure 4. Salinity data are from the original data set. (Transparency values above 160 cm and salinity values above 10 ppt are not included in the graph.) Linear regression analysis was performed on individual points. The slope of the regression line, 8.13 cm/ppt salinity, is statistically significant; $0.01 < p < 0.02$. Figure 5 is a graph of average annual Secchi disk transparency plotted as a function of salinity.

Figure 6 is a graph of salinity versus time -- the 38-year period 1953 through 1990. Salinity data are from the original data set. Although there is considerable year-to-year variation in salinity, there has been no long-term change in salinity. The slope of the linear regression line, -0.02 cm/year, is not statistically significant. The long-term average salinity, 3.9 ppt, was used as a base for seasonally adjusting the data for salinity.

There are two equivalent ways to seasonally adjust the Secchi disk transparency data. One way is to adjust annual means where annual mean Secchi disk visibilities and annual mean salinities are used in the calculation to provide adjusted annual mean Secchi disk visibilities. An equivalent procedure is to adjust individual points where individual Secchi disk transparency observations and associated salinities are used in the calculation; adjusted annual mean Secchi disk visibilities are then calculated from the adjusted points. Individual points are adjusted in the following example:

The adjustment procedure employed the regression equation presented in Figure 5 of Secchi disk transpar-

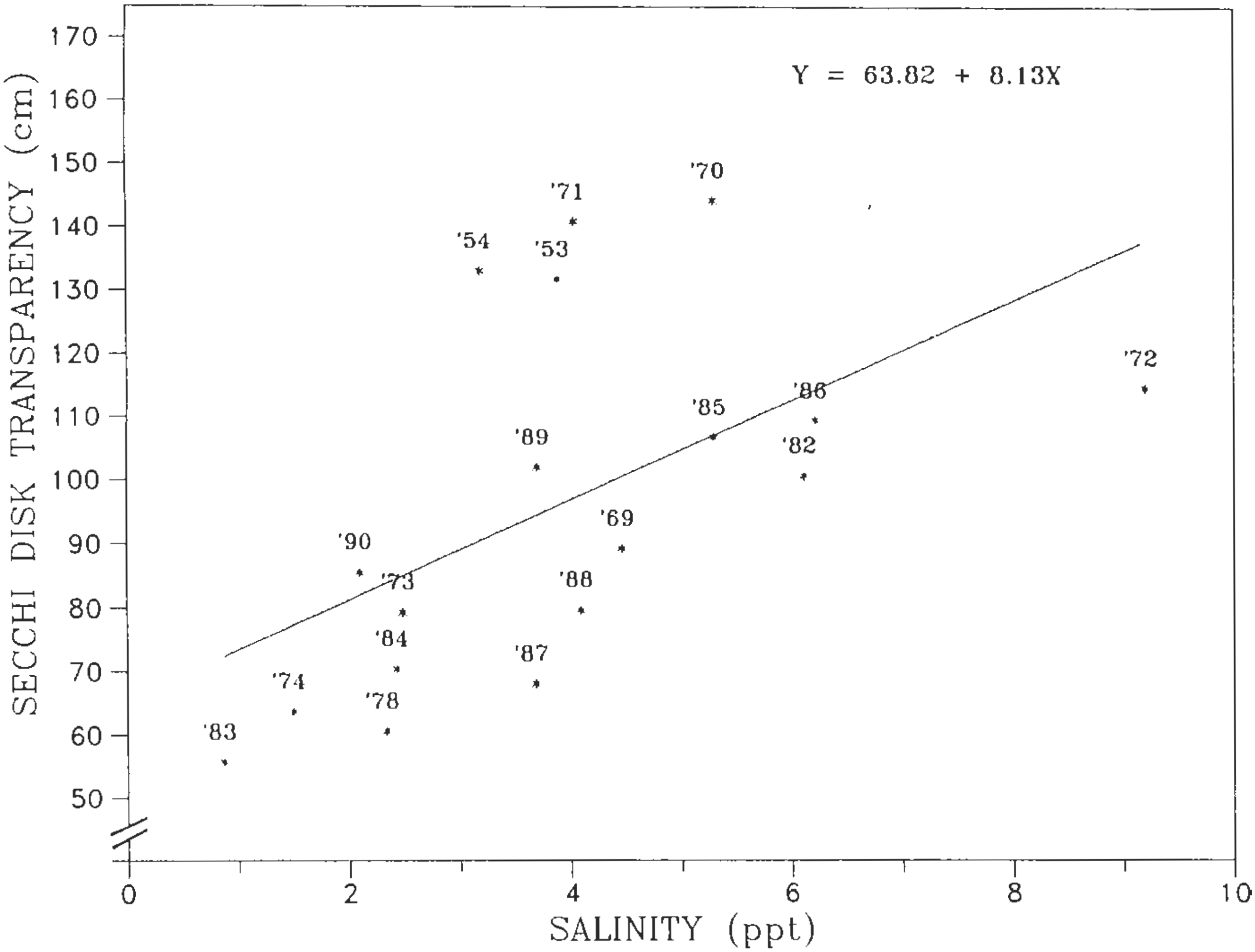

Figure 5. Annual mean Secchi disk transparency as a function of salinity.

ency versus salinity: Y = 63.82 + 8.13X. Two values of Secchi transparency were calculated for each point: (1) Secchi disk transparency using the long-term average salinity, 3.9 ppt; (2) Secchi disk transparency using the salinity associated with the specific point. The difference between those two values was the adjustment factor for that point. The adjustment factor was subtracted from Secchi disk transparency for that point. This operation adjusts the data to the long-term average salinity.

Figure 7 is a graph of annual mean Secchi disk transparency adjusted for salinity versus time. Comparison with Figure 1 reveals that very little change in slope has occurred -- 1.47 cm/year to -1.34 cm/year. The relationship between Secchi disk transparency and time is still significant at the 5% level, indicating that on average the Secchi disk transparency values in the original data set are not associated with unusually high or low salinities because of unequal representation of the seasonal effects of salinity in the data set.

Figure 8 is a graph of Secchi disk transparency versus wind speed. The graph includes Secchi disk transparency points in the original data set. (Transparency values above 160 cm are not included in the graph.) Wind speed is the five-day average of mean wind speed. Data are from the National Weather Service data set. Linear regression was performed on individual points. The slope of the regression line, -4.36 cm/mph, is statistically significant; $p < 0.01$.

Figure 9 is a graph of average annual wind speed versus time -- the 38-year period from 1953 through 1990. Although there is considerable year-to-year variation in wind speed, there has not been a long-term change in wind speed. Regression analysis was performed on annual means. The slope of the linear regression line, -0.02 mph/year, is not statistically significant. The long-term average wind speed, 8.13 mph, was used as a base for seasonally adjusting the data for wind.

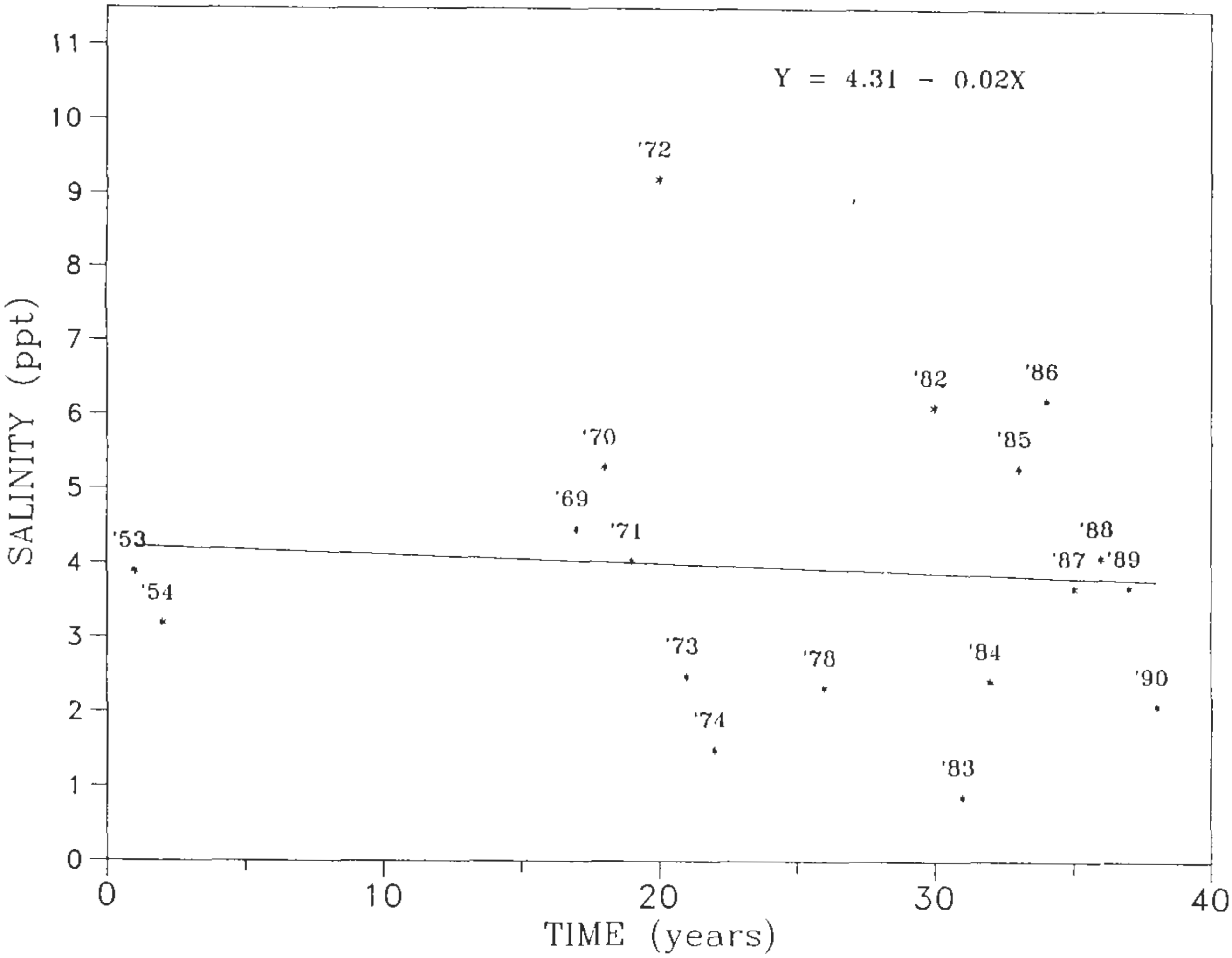

Figure 6. Annual mean salinity of Lake Pontchartrain from 1953 through 1990.

The adjustment procedure was the same as that described above for salinity. It employed the regression equation presented in Figure 7 of Secchi disk transparency versus wind speed: Y = 121.43 - 4.36X.

Figure 10 is a graph of Secchi disk transparency adjusted for wind speed versus time. Comparison with Figure 1 reveals that significant change in slope has occurred -- 1.47 cm/year to -1.06 cm/year. The relationship between Secchi disk transparency and time is no longer significant at the 5% level; $0.05 < p < 0.10$. This analysis determined that on an annual basis some Secchi transparency points were associated with unusually high or low wind speeds because of unequal representation of the seasonal effects of wind speed in the data set.

Multiple regression analysis was conducted with salinity and wind as independent variables and Secchi disk transparency as the dependent variable. Individual points were used in the analysis. The resulting regression equation was:

$$Y = 97.83 + 8.03 X1 - 5.15 X2.$$

Both partial regression coefficients are statistically significant. The long-term average salinity, 3.9 ppt, and the long-term average wind speed, 8.13 mph, were used as the base for seasonally adjusting the data for both salinity and wind speed. The adjustment procedure was the same as that described above for salinity. It employed the multiple regression equation shown above.

Figure 11 is a graph of Secchi disk transparency adjusted for both salinity and wind speed versus time. The relationship between Secchi disk transparency and time is no longer significant at the 5% level, but it is still significant at the 10% level; $0.05 < p < 0.10$. Seasonal adjustment has reduced the level of significance to about 10% (Figure 11). Therefore, one can conclude that some of the apparent decrease in Secchi disk transparency in the original data (Figure 1) is the result of unequal representation of the

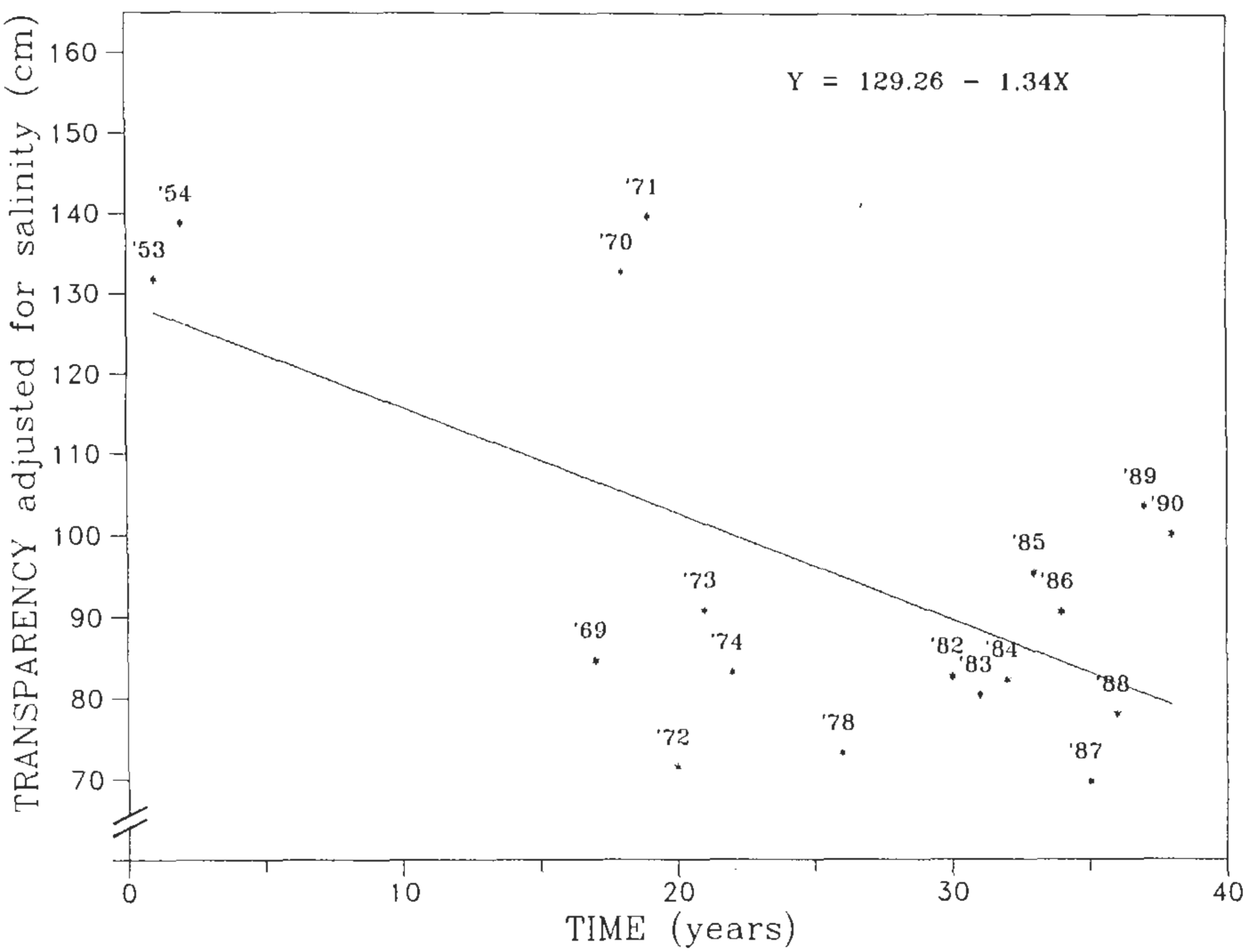

Figure 7. Annual mean Secchi disk transparency from 1953 through 1990 adjusted for salinity.

seasonal effects of salinity and wind speed in the biased data set.

Another analytical procedure undertaken with the original data set was to remove the seasonal bias by constructing unbiased data sets. There is not data in all 12 months of the year in most years represented in the data set. That is especially a problem in the earlier years. Only in the late 1980s are data consistently available for all 12 months of the year.

The Secchi disk transparency data set was, of course, subject to a seasonal bias in those years in which data were not available for all 12 months of the year. When the bias was removed by constructing unbiased data sets, the long-term relationship between Secchi disk transparency and time was no longer statistically significant. Three examples are provided:

Example 1. Table 5 contains Secchi disk transparency values for those years in which continuous data were available from August through December. This period was

TABLE 5
Secchi disk transparency for years in which data are available - August through December.

Year	Time (yr)	Transparency (cm)
1953	1	116.91
1970	18	149.64
1973	21	85.42
1978	26	81.93
1983	31	57.02
1985	33	119.29
1986	34	136.76
1987	35	78.23
1990	38	104.52

Regression transparency vs. time: $Y = 120.05 - 0.64X$
$P > 0.5$

selected because in 1953 Secchi disk transparency readings were available only from August through December. It is not surprising that Secchi disk transparency was high in 1953 when one considers that salinity is highest in October and November (contributing to high transparency values), and that wind speed is lowest in August and September (also contributing to high transparency values). Other years have even higher average Secchi disk transparency values for the August through December period. Annual means in Table 5 were calculated by taking the average of monthly means rather than an average of all data points. Regression of annual Secchi disk transparency versus time produced the following equation:

$$Y = 120.05 - 0.64X.$$

The slope, -0.64 cm/year, is not statistically significant, $p > 0.5$. On the basis of this analysis, it is concluded that there has been no change in Secchi transparency over the 38-year period from 1953 through 1990.

Example 2. Table 6 contains Secchi disk transparency values for those years in which continuous data was available from January through June. This period was selected because in 1954 Secchi disk transparency observations were available only from January through June. The seasonal bias in the original data set was removed by constructing a data set consisting only of years in which Secchi disk transparency observations were recorded from January through June. Annual means in Table 6 were calculated by taking the average of monthly means rather than an average of all data points. Regression of annual Secchi disk transparency versus time produced the following linear regression equation:

$$Y = 75.13 - 0.49X.$$

The slope, -0.49 cm/year, was not statistically significant, $p > 0.4$. On the basis of this analysis, it is concluded that there has been no change in Secchi disk transparency over the 37-year period from 1954 through 1990.

Example 3. The original Secchi disk transparency data set, obtained by combining data from the sources indicated in Table 1, is incomplete. Data are missing for several months in most years. Table 7 includes all years for which there is at least some Secchi disk transparency data. Secchi disk transparency was estimated for those months in which data are not available -- the so-called missing months in the data set.

Missing data points were estimated with the multiple regression equation, $Y = 97.83 + 8.03\,X1 - 5.15\,X2$, and the appropriate monthly average wind speed and monthly average salinity. After estimating values for missing months, annual means for Secchi disk transparency were calculated for 1953 through 1990. Regression of annual

TABLE 6
Secchi disk transparency for years in which data are available - January through June.

Year	Time (yr)	Transparency (cm)
1954	2	97.46
1973	21	57.44
1974	22	47.55
1978	26	38.04
1983	31	29.95
1984	32	47.97
1986	34	80.65
1987	35	57.49
1988	36	65.28
1989	37	87.27
1990	38	64.58

Regression transparency vs. time: $Y = 75.13 - 0.49X$
$P > 0.4$

TABLE 7
Secchi disk transparency with estimated values in missing months.

Year	Time (yr)	Transparency (cm)
1953	1	94.89
1954	2	89.80
1969	17	87.13
1970	18	122.57
1971	19	101.54
1972	20	92.80
1973	21	75.37
1974	22	75.14
1978	26	59.12
1982	30	94.84
1983	31	43.86
1984	32	67.32
1985	33	91.71
1986	34	109.45
1987	35	67.48
1988	36	79.93
1989	37	102.23
1990	38	80.97

Regression transparency vs. time: $Y = 95.52 - 0.42X$
$P > 0.5$

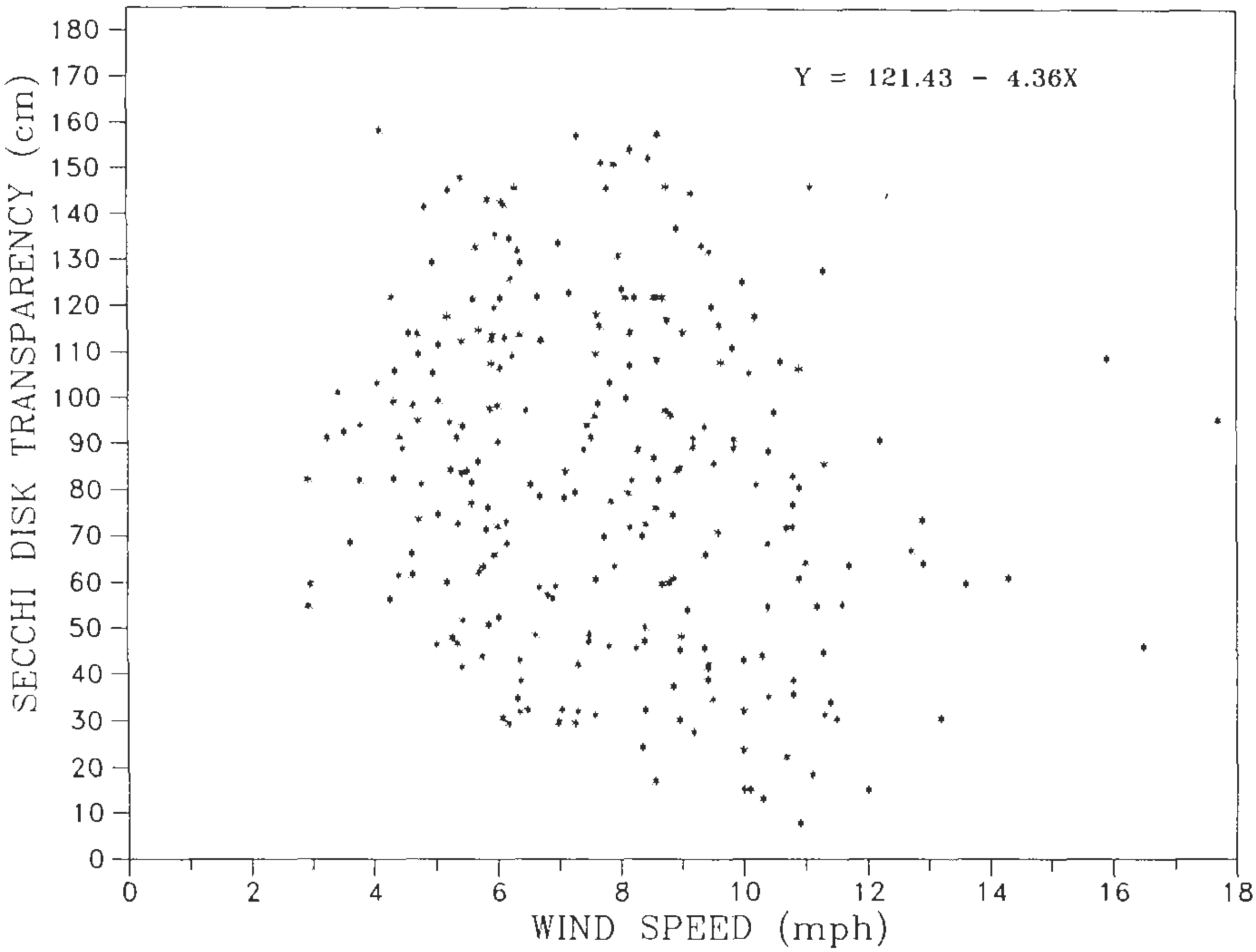

Figure 8. Secchi disk transparency (individual points) versus wind speed.

Secchi disk transparency versus time produced the following linear regression equation:

$$Y = 95.52 - 0.42X.$$

The slope, -0.42 cm/year, is not statistically significant, $p > 0.5$. On the basis of this analysis, it is concluded that there has been no change in Secchi transparency over the 38-year period from 1953 through 1990.

In summary, the historic data set on Secchi disk transparency in Lake Pontchartrain is biased in that it does not adequately represent the seasonal effects of salinity and wind speed. When the seasonal bias is removed from the data, it no longer supports the conclusion of a long-term decrease in Secchi disk transparency.

DISCUSSION

Regression of the original data on Secchi disk transparency versus time (1953 through 1990) reveals a statistically significant decrease in transparency with time. The regression line suggests a decrease in transparency of about 40%. However, the original data set is biased in that it does not adequately represent the seasonal effects of salinity and wind speed. The data set was subjected to two analytical procedures to determine the extent to which the apparent long-term decrease in Secchi disk transparency was dependent on the seasonal bias. One procedure involved seasonal adjustment of the data for the effects of salinity and wind speed. The other procedure was to remove the seasonal bias by constructing unbiased data sets.

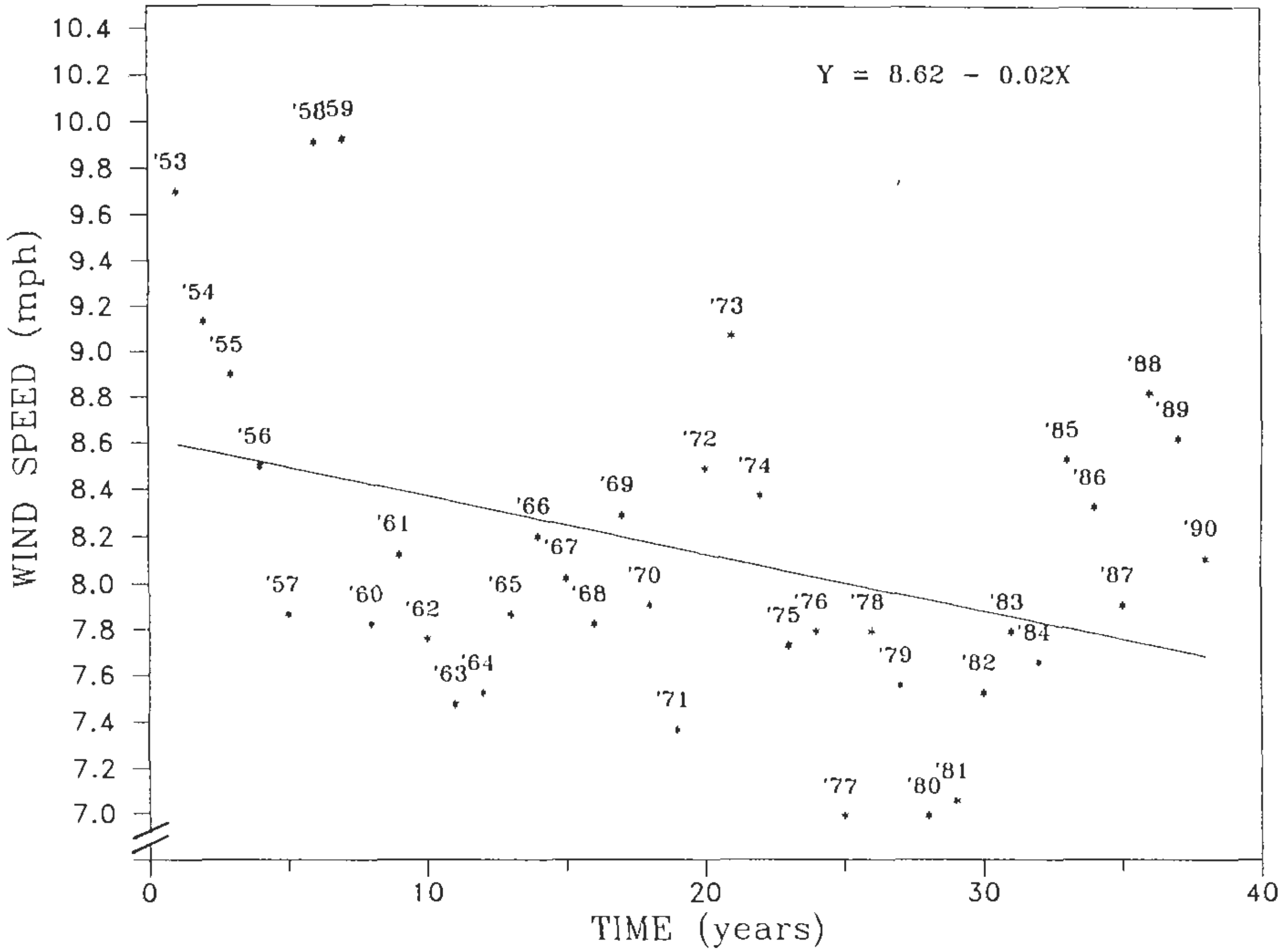

Figure 9. Annual mean wind speed for Lake Pontchartrain area from 1953 through 1990.

Regression analysis revealed a statistically significant, positive relationship between Secchi disk transparency and salinity, and a statistically significant, negative relationship between Secchi disk transparency and wind speed. Further analysis indicated that neither average annual salinity nor average annual wind speed had changed significantly from 1953 through 1990.

Secchi disk transparency data were seasonally adjusted for the effects of salinity and wind speed. The base for adjustment in each case was the long-term average of the variable for which adjustment was being made. Regression of Secchi disk transparency (adjusted for salinity) versus time revealed a statistically significant relationship, indicating that the adjustment procedure had not influenced the statistical significance of the long-term relationship between Secchi disk transparency and time. This result indicates that on average the Secchi disk transparency values in the original data set are not associated with unusually high or low salinities because of unequal representation of the seasonal effects of salinity in the biased data set.

Regression of Secchi disk transparency (adjusted for wind speed) versus time indicated that there was no longer a statistically significant relationship between Secchi disk transparency and time; $0.05 < p < 0.10$. Adjusting the data for the effect of wind speed had reduced the level of significance for the relationship from about 1% to about 10%. This result indicates that some Secchi disk transparency values in the original data set are associated with unusually high or low wind speeds because of the unequal representation of the seasonal effects of wind speed in the biased data set.

Multiple regression of Secchi disk transparency (adjusted for both salinity and wind speed) versus time also

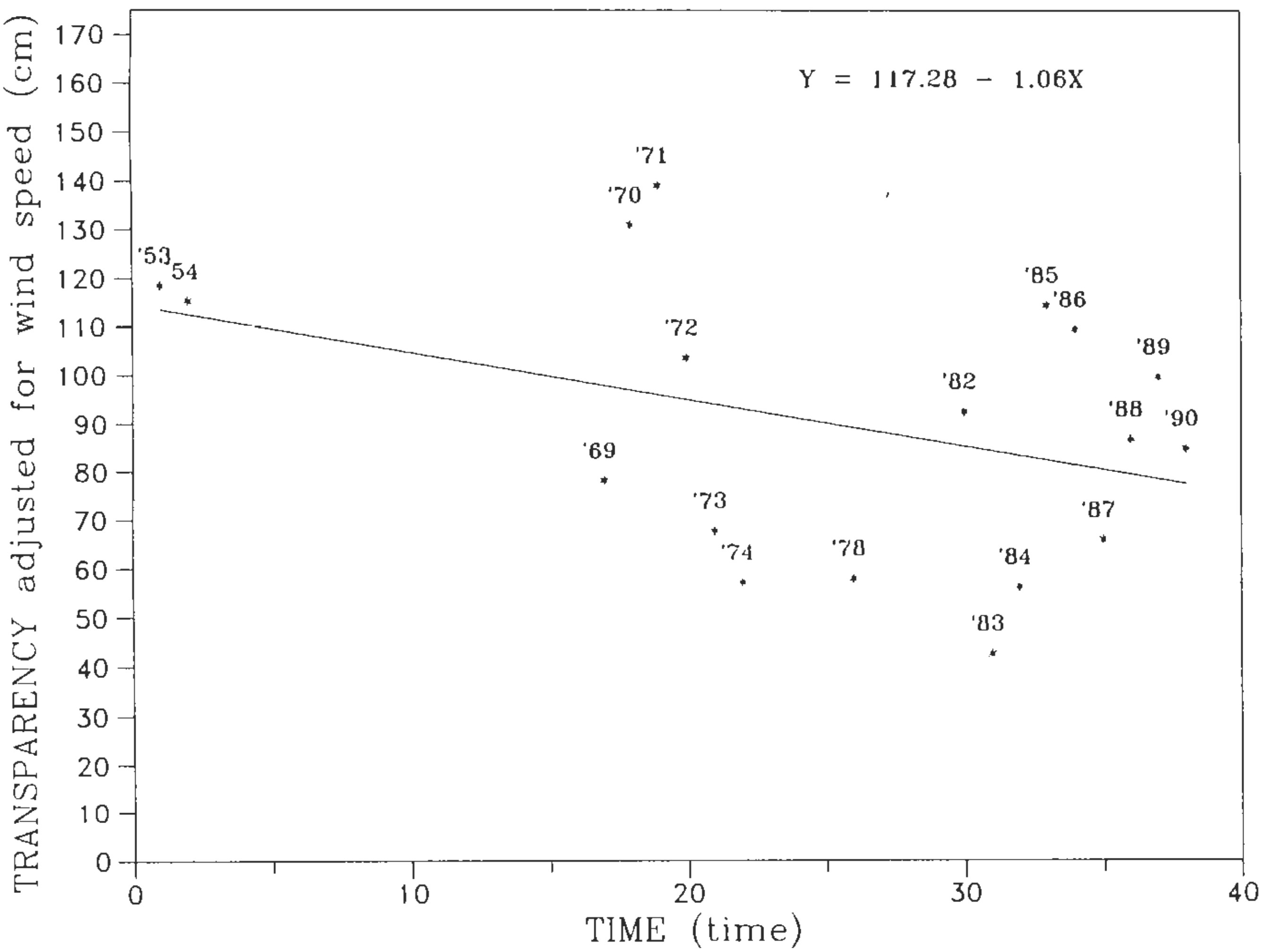

Figure 10. Annual mean Secchi disk transparency from 1953 through 1990 adjusted for wind speed.

indicated that there was no longer a statistically significant relationship between Secchi disk transparency and time; $0.05 < p < 0.10$. Seasonal adjustment had reduced the level of significance to about 10%. One can, therefore, conclude that some of the apparent decrease in Secchi disk transparency in the original data is the result of unusually high and low salinities and wind speeds realized because of unequal representation of the seasonal effects of salinity and wind speed in the biased data set.

Another analytical procedure undertaken with the original data set was to remove the seasonal bias by constructing unbiased data sets. In most of the years represented in the data set, data are not available for all 12 months of the year, especially before 1983. Only in the late 1980s are data consistently available for all 12 months of the year.

Analysis of variance of monthly salinity data from 1953 through 1980, and 1986 through 1989 (32 years) revealed a statistically significant annual seasonality, with the highest values occurring in November and the lowest values occurring in May. Similarly, analysis of variance of monthly wind speed data from 1953 through 1990 (38 years) revealed a statistically significant annual seasonality, with the highest values occurring in February and the lowest values occurring in August. These seasonal effects are not adequately represented in the available data on Secchi disk transparency in Lake Pontchartrain. The seasonal bias was removed from the data by constructing unbiased data sets in three ways: (1) The derived data set contained Secchi disk transparency values for those years in which continuous data were available from August through December; (2) The derived data set contained

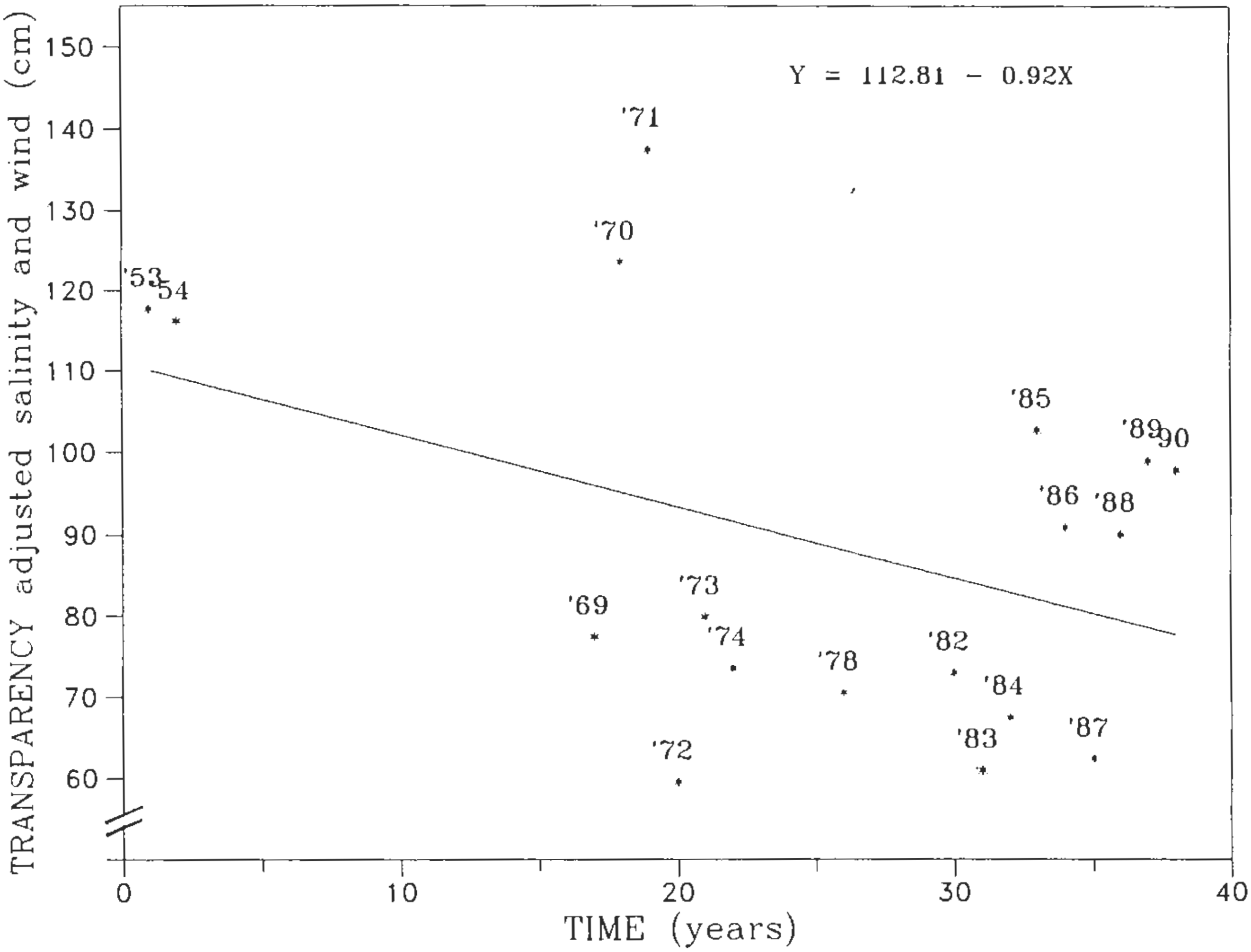

Figure 11. Annual mean Secchi disk transparency from 1953 through 1990 adjusted for salinity and wind speed.

Secchi disk transparency values for those years in which continuous data were available from January through June; (3) The derived data set contained all of the original data on Secchi disk transparency in addition to estimated values for those months in which data was not available. In each case, when the seasonal bias was removed from the original data, it no longer supported the conclusion of a statistically significant change in Secchi disk transparency from 1953 to 1990; $p > 0.4$.

Results of this study do not support the long-term increase in turbidity of almost 50% reported by Stone (1980). Although urban runoff is known to produce short-term increases in water turbidity near outfall canals (Stern and Stern, 1969), data examined in this study do not indicate a long-term, lake-wide increase.

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