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Results of the City of Tampa Surface Water Compliance Monitoring Program for the years 1990 and 1991 and examination of long-term water quality and biological indicator trends in Hillsborough Bay

City of Tampa Department of Sanitary Sewers

RESULTS OF THE CITY OF TAMPA SURFACE WATER COMPLIANCE MONITORING PROGRAM FOR THE YEARS 1990 AND 1991, AND EXAMINATION OF LONG-TERM WATER QUALITY AND BIOLOGICAL INDICATOR TRENDS IN HILLSBOROUGH BAY

SUBMITTED TO

THE FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION
SOUTHWEST DISTRICT

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BY

CITY OF TAMPA
DEPARTMENT OF SANITARY SEWERS
BAY STUDY GROUP

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INTRODUCTION

This report is submitted to Florida Department of Environmental Regulation (FDER) to satisfy the requirements set forth in specific condition No. 12 of Hookers Point WWTP permit No. D029-184532A. The report is based on data obtained by the City of Tampa (COT) compliance water quality monitoring program approved under construction permit DC29-152799 and the report also includes examination of long-term trends for water quality parameters and biological indicators collected by the City of Tampa Bay Study Group and the Environmental Protection Commission of Hillsborough County (EPC). Results from these studies are discussed in four sections: 1) Compliance monitoring of Hillsborough Bay water quality by the COT, 2) long-term monitoring of Hillsborough Bay water quality by the EPC, 3) comparison between COT compliance monitoring stations and selected EPC stations in the upper portion of Hillsborough Bay and 4) long-term monitoring of Tampa Bay water quality and biological indicators by the COT.

Results from the compliance monitoring include data collected monthly at three stations in the upper portion of Hillsborough Bay (COT15, COT16 and COT17; Figure 1). Sampling of these stations started in January 1990. The EPC laboratory analyze sub-samples for carbonaceous biological oxygen demand (5-day), total phosphorus, ortho-phosphate, total nitrogen, total Kjeldahl nitrogen, nitrite+nitrate-nitrogen and ammonia-nitrogen. In addition, the COT Bay Study Group laboratory measure chlorophyll-a, dissolved oxygen and several other field measured water quality parameters.

The long-term water quality data base maintained by the EPC is discussed as trends of annual averages for the parameters specified in the study plan. This discussion includes all 14 EPC stations in Hillsborough Bay (Figure 2) and the group of EPC stations close to the COT AWT outfall (EPC2, EPC6, EPC52 and EPC70; Figure 1).

The comparison between COT compliance monitoring stations (COT15, COT16 and COT17; Figure 1) and the group of EPC stations close to the Hookers Point WWTP discharge (EPC2, EPC6, EPC52 and EPC70; Figure 1) includes examination of averages for the two year period 1990 through 1991 for the parameters specified in the study plan.

Examination of the COT, multi-disciplinary, long-term water quality and biological indicator monitoring program includes discussion of annual averages for parameters specified in the study plan. The first part of this section reports on results

from the water quality and phytoplankton monitoring conducted at two stations located in Hillsborough Bay (COT4 and COT12) and one station located in Middle Tampa Bay (COT13; Figure 3). The second part presents results from the drift macro-algae monitoring conducted at five transects in Hillsborough Bay (Figure 4).

METHODS

Field and laboratory methods are described in the compliance monitoring study plan submitted to the FDER Tampa office on November 16, 1989 entitled "City of Tampa Surface Monitoring Plan of Hillsborough Bay." Modifications to the study occurred on January 1992, when a Hydrolab DataSonde 3 probe replaced previous equipment used for measurements of temperature, salinity and dissolved oxygen.

RESULTS

Compliance Water Quality Monitoring in Hillsborough Bay by the COT

Information collected from the COT compliance monitoring stations COT15, COT16 and COT17 (Figure 1) for the period January 1990 through December 1991, are listed in the appendix. This information is also discussed and presented in the graphs below.

Temperature (Figure 5):
There is little variation in water temperatures (mid-depth) between the three stations. The expected seasonal variation is evident.

Salinity (Figure 6):
There is little variation in salinities (mid-depth) between the three stations. Salinity was reduced at all stations for the period July through October 1991.

Secchi Depth (SD; Figure 7):
SD depths show considerable temporal variation. High values occur at all stations during the winter, and low values are generally seen during the summer. Although some variation is noted between the three stations, the difference is small and the same general trend is present for all stations.

Surface Dissolved Oxygen (SDO; Figure 8):
SDO concentrations are similar for the three stations. High concentrations are noted for all stations during the winter and low concentrations are seen during the summer and fall.

Middle Dissolved Oxygen (MDO; Figure 9):
Trends for MDO concentrations are similar to those for SDO, except for a large variation between stations in July 1991.

Bottom Dissolved Oxygen (BDO; Figure 10):
BDO concentrations are dependent on parameters such as depth and substrata. A comparison between stations of varying depths and sediment type is not valid. In general, seasonal trends for the three stations are similar, with peaks during winter and lows during summer and fall.

Total Nitrogen (TN; Figure 11):
TN concentrations are similar for the three station and no seasonal pattern is apparent.

Total Kjeldahl Nitrogen (TKN; Figure 12):
See the comments for TN.

Ammonia Nitrogen (NH3; Figure 13):
There is little variation in NH3 concentration between the three stations, with the exception that values at station COT15 are elevated relative the other stations for the period May through August 1990. No seasonal pattern is apparent.

Nitrite + Nitrate Nitrogen (NO2+NO3; Figure 14):
NO2+NO3 concentrations are slightly higher at station COT17 than at stations COT15 and COT16.

Total Phosphorus (TP; Figure 15):
TP concentrations are similar at the three stations. However, station COT17 has consistently slightly lower values.

Ortho-Phosphorus (PO4; Figure 16):
See comments for TP.

Carbonaceous Biological Oxygen Demand (CBOD5; Figure 17):
CBOD5 is similar for all stations.

Chlorophyll-a (CHLA; Figure 18:)
CHLA concentrations measured at mid-depth are generally similar for the three stations. However, in July 1991 concentrations at stations COT16 and COT17 were near 60 ug/l, while the level at station COT15 was below 20 ug/l. Nevertheless, consistent differences between the stations are not apparent. A seasonal pattern is evident, with peaks during the summer and the lowest concentrations during the winter.

Long-Term Trends of Hillsborough Bay Water Quality Parameters Sampled by the EPC

Long-term trends, shown as annual averages for the parameters specified in the study plan (DO, CBOD5, TP, PO4, TN, TKN and CHLA) for all 14 EPC stations in Hillsborough Bay (Figure 2) and

for the group of EPC stations close to the Hookers Point WWTP outfall (EPC2, EPC6, EPC52 and EPC70; Figure 1) are discussed and presented in the graphs below:

TN (Figure 19):
Excluding 1987, TN concentrations has declined since 1983. There is little difference between the two groups of stations. Nitrogen data generated by the EPC prior to 1980 has been deemed questionable by EPC.

TKN (Figure 20):
See the comments for TN.

TP(Figure 21):
TP concentrations have decreased from approximately 2ppm in 1974 to current concentrations of near 0.5ppm. The "All Stations" group consistently has higher concentrations than the upper Hillsborough Bay station group, reflecting the influence of the Alafia River on the lower and mid portions of Hillsborough Bay. The Alafia River appears to be a major source of TP to the bay (see Figure 31).

PO4 (Figure 22):
See the comments for TP. In addition, PO4 information is based on a much smaller number of samples than TP (see Table 1). The EPC did not start sampling of PO4 at all Tampa Bay stations until December 1990.

CBOD5 (Figure 23):
CBOD5 peaked during the period 1975-1977 at 4.5 to 5mg/l. Values have declined to current levels of less than 2mg/l. There is no consistent difference between groups of stations. However, the influence of Hookers Point WWTP prior to the conversion to AWT in 1979, may be indicated by the higher values for the upper Hillsborough Bay station group during the period 1973 through 1977.

DO (Figures 24-26):
There are no consistent spatial or temporal trends for either SDO, MDO or BDO concentrations, with the exception that SDO was elevated for the "All Stations" group during the years 1976 through 1981.

CHLA (Figure 27):
Based on the EPC CHLA record, Hillsborough Bay had highest CHLA concentrations during the mid-1970's. At that time, values ranged from approximately 25 to 32ug/l. CHLA concentrations have since decreased considerably and current concentrations are near 10ug/l. There is no consistent difference between groups of stations, however the influence of the Hookers Point WWTP, prior to conversion to AWT in 1979, may be indicated by the higher values for the upper Hillsborough Bay station group during the period 1973 through 1977.

Comparison between COT Compliance Monitoring Stations and Selected EPC Stations in the Upper Hillsborough Bay

Average values for the two year period 1990 and 1991 for the parameters specified in the study plan (DO, CBOD5, TP, PO4, TN, TKN and CHLA) for the group of EPC stations close to the Hookers Point WWTP outfall (EPC2, EPC6, EPC52 and EPC70; Figure 1) and from the COT compliance monitoring stations (COT15, COT16 and COT17; Figure 1) are discussed and presented in the graphs below. Summary statistics for each parameter by each station listed above is shown in Table 1.

TN (Figures 28):
The highest mean TN concentration for the two station groups was found at station EPC2, at the mouth of Hillsborough River, and the lowest concentrations at stations EPC52 and EPC70. All COT compliance stations had TN concentrations within one standard error of the mean (1 SE) of the selected EPC stations. Therefore, no impact from the Hookers Point WWTP discharge on the COT compliance stations is apparent for this parameter.

TKN (Figure 29):
See the comments for TN.

TP(Figures 30 and 31):
The highest mean TP concentration for the two station groups were found at stations COT15 and COT16 and the lowest concentrations at station EPC2 (Figure 30). All COT compliance stations had relatively high TP concentrations, suggesting a possible impact on TP from sources located in the upper portion of Hillsborough Bay. However, when comparing TP concentrations for the COT compliance monitoring stations and <u>all</u> EPC stations in Hillsborough Bay (Figure 31) it is evident that station EPC74 at the mouth of the Alafia River has by far the greatest concentrations, suggesting that the Alafia River is a major source of TP to Hillsborough Bay.

PO4 (Figure 32 and 33):
See the comments for TP.

CBOD5 (Figure 34):
The highest mean CBOD5 concentrations for the two station groups were found at stations EPC2 and EPC52 and the lowest concentrations at station COT15. All COT compliance stations had CBOD5 concentrations significantly lower than the selected EPC stations. Therefore, no impact from the Hookers Point WWTP discharge is apparent for this parameter.

DO (Figures 35, 36 and 37):
The highest mean SDO concentration for the two station groups was found at station EPC52 and the lowest concentrations at station EPC2 (Figure 35). The COT

compliance stations had intermediate SDO concentrations. Therefore, no impact from the Hookers Point WWTP discharge is apparent for this parameter.

The comments for SDO also apply for MDO (Figure 36).

BDO concentrations (Figure 37) are not only a function of possible discharges, but are also greatly dependant on water depth and sediment composition. Therefore, no attempt is made to relate this parameter the Hookers Point WWTP discharge.

CHLA (Figure 38):
The highest mean CHLA concentrations for the two station groups were found at stations COT16 and COT17 and the lowest concentrations at station EPC70. All COT compliance stations had relatively high CHLA concentrations, however their values were within 1 SE of station EPC6. Further, CHLA analysis for the COT compliance stations were performed by the COT Bay Study Group laboratory, and for the EPC stations by the EPC laboratory. It is possible that the use of slightly different methodologies may account for much of the difference seen between the two station groups. Therefore, it is difficult to relate this parameter to the Hookers Point WWTP discharge, or any other discharge in this area until a study, which compares results of CHLA analysis on split samples between the two laboratories, has been conducted. However, station COT4 in the central portion of Hillsborough Bay (see Figure 3) has a mean CHLA concentration of 16.3 ug/l for the period 1990-1991, which is very similar to levels found at the upper bay compliance stations. The similarity of CHLA concentrations at the upper bay stations and the mid bay station suggests a lack of detectable impact on CHLA concentrations at the COT compliance stations from the Hookers Point WWTP discharge.

Long-Term Trends of Tampa Bay Water Quality and Biological Indicators Sampled by the COT

Results from the long-term, multi-disciplinary, COT water quality and biological indicator monitoring program are discussed and presented in the graphs below. The parameters SD, DO, CHLA, phytoplankton production rates, Schizothrix calcicola sensu Drouet cell concentrations and total phytoplankton cell concentrations are presented as annual averages for the study period for two stations located in Hillsborough Bay (COT4 and COT12) and one station located in Middle Tampa Bay (COT13; Figure 3). Drift macro-algae biomass is shown as the annual average biomass for each of the five transects in Hillsborough Bay (Figure 4). The growth of submerged seagrasses and the attached benthic alga Caulerpa prolifera in Hillsborough Bay was discussed in the COT report submitted to FDER on March 1, 1992.

SD (Figure 39):

SD depth generally increased gradually between 1982 and 1989, however, after 1989 there has been a reduction in water transparency at the three stations. This reduction does not appear to be related to phytoplankton biomass (CHLA), which has decreased steadily since the mid 1980's (see Figures 27 and 41). The recent SD reduction may have been caused by an increase in sediment resuspension. Possible sources of this resuspension may be dredging and commercial fishing activities.

DO (Figure 40):

SDO and BDO concentrations declined gradually between 1986 and 1990, however, with the exception of BDO values at station COT4, all values increased in 1991.

CHLA (Figure 41):

Surface CHLA decreased sharply between 1982 and 1984. The decline has continued, although more gradual, to current concentrations of 16, 12 and 7ug/l for stations COT4, COT12 and COT13, respectively.

Phytoplankton Production (Figure 42):

Depth integrated primary production has decreased steadily since 1985 at all three stations, indicating reduced eutrophication in these sections of Tampa Bay. In general, the Middle Tampa Bay station has lower primary production rates than the Hillsborough Bay stations.

Schizothrix calcicola sensu Drouet (Figure 43):

The abundance of this blue-green alga has decreased substantially after 1983. Concentrations during the last eight years have been approximately one-third of the pre-1984 levels.

Total Phytoplankton (Figure 44):

No long-term trends of total phytoplankton cell concentrations are apparent. The Hillsborough Bay stations consistently have higher cell concentrations than the middle Tampa Bay station. Peak concentrations of phytoplankton abundance for stations COT4 and COT12 occurred in 1987, the same year TN concentrations, measured by EPC, were high in Hillsborough Bay (see Figure 19).

Macro-Algae (Figure 45):

Long-term spatial trends of drift macro-algae biomass show that two areas, Transect B in northeastern Hillsborough Bay, and Transect E in northwestern Hillsborough Bay, generally have higher average drift macro-algae accumulations than the other three transects. It is also apparent that the current macro-algae abundance is less than earlier years for all transects.

DISCUSSION

There are no indications, either from the compliance monitoring program or from the comparison between the COT compliance monitoring stations and the group of EPC stations close to the discharge site, that the discharge from the Hookers Point WWTP, during the years 1990 and 1991, had a negative impact on water quality and biological indicators in Hillsborough Bay.

The only parameters identified in this study, which show an impact potentially related to sources in the upper portion of Hillsborough Bay are TP and PO4. Possible sources of the these parameters include, among others, the fertilizer loading terminals in East Bay and the Hookers Point WWTP. However, the elevated concentrations of these parameters may be of no consequence to water quality or biological indicators in Hillsborough Bay. It is known that growth of the phytoplankton population in Tampa Bay, and specifically Hillsborough Bay, is limited by the supply of nitrogen. Therefore, it is unlikely that the elevated concentrations of TP and PO4 found at the compliance stations have had a negative impact on water quality parameters or biological indicators in Hillsborough Bay or Tampa Bay.

Long-term trends of water quality and biological indicators monitored in Hillsborough Bay by both the EPC and the COT programs have shown substantial improvements during the last decade. It is apparent that several important indicators of estuarine health, such as CHLA, blue-green alga abundance and seagrass growth (discussed in the report to FDER on March 1, 1992), have improved since the Hookers Point WWTP converted from primary treatment to AWT in 1979. These findings agree with the recently acquired understanding of the nutrient, specifically nitrogen, loading history of Hillsborough Bay (Johansson 1991). Further, statistical relationships have been developed between external nitrogen loading to Hillsborough Bay and the response of phytoplankton biomass (CHLA).

These relationships suggest that the reduction in external nitrogen loading to the bay that occurred when the Hookers Point WWTP converted from primary treatment to AWT, probably would have caused a substantial reduction of phytoplankton biomass in Hillsborough Bay. Therefore, the conversion of the Hookers Point WWTP from primary treatment to AWT has without doubt had a beneficial long-term effect on water quality and biological indicators in Hillsborough Bay. Further, it is not unreasonable to assume that the recent water quality improvements seen in other major sections of Tampa Bay (Boler 1989), such as Middle Tampa Bay and Lower Tampa Bay, may at least partly be related to the conversion of the Hookers Point WWTP.

REFERENCES

Boler, R. 1990. Surface water quality, 1988-1989. Hillsborough County, Florida. Hillsborough County Environmental Protection Commission.

Johansson, J.O.R. 1991. Long-term trends of nitrogen loading, water quality and biological indicators in Hillsborough Bay, Florida. pp. 157-176. In: Treat, S.F. and P.A. Clark (eds.), Proceedings, Tampa Bay Area Scientific Information Symposium 2. 1991 Feb. 27 - March 1; Tampa, FL. Text, Tampa, Fl.

Table 1. Summary statistics for COT compliance monitoring stations and selected EPC monitoring stations in the upper portion of Hillsborough Bay for the period 1990-1991.

STATION	STATISTICS	TN mg/l	TKN mg/l	TP mg/l	PO4 mg/l	SDO mg/l	MDO mg/l	BDO mg/l	CBOD5 mg/l	CHLA ug/l
COT15	N OF CASES	24	24	24	24	24	24	24	23	24
	MINIMUM	0.45	0.43	0.35	0.29	4.40	3.30	0.60	0.24	5.10
	MAXIMUM	1.24	1.22	1.16	0.75	8.10	7.50	7.20	2.20	38.29
	MEAN	0.71	0.68	0.55	0.51	6.23	5.81	4.62	1.18	14.26
	STANDARD DEV	0.22	0.21	0.17	0.11	1.03	1.18	2.04	0.51	7.55
COT16	N OF CASES	24	24	24	24	24	24	24	23	24
	MINIMUM	0.41	0.40	0.32	0.29	4.20	3.90	0.60	0.47	3.66
	MAXIMUM	1.67	1.63	0.84	0.73	7.40	7.40	7.00	2.30	62.85
	MEAN	0.71	0.68	0.55	0.50	6.33	6.13	5.09	1.27	16.77
	STANDARD DEV	0.28	0.27	0.14	0.13	0.84	0.90	1.83	0.49	12.77
COT17	N OF CASES	24	24	24	24	24	24	24	23	24
	MINIMUM	0.31	0.34	0.31	0.29	4.90	4.80	4.70	0.51	2.38
	MAXIMUM	1.30	1.19	1.12	0.84	7.60	7.50	7.30	2.10	58.68
	MEAN	0.67	0.65	0.52	0.48	6.37	6.23	6.07	1.26	16.72
	STANDARD DEV	0.21	0.20	0.16	0.16	0.71	0.70	0.72	0.44	12.52
EPC2	N OF CASES	24	24	24	13	21	23	21	24	24
	MINIMUM	0.46	0.43	0.27	0.27	2.90	2.10	0.10	0.50	2.80
	MAXIMUM	1.38	1.25	0.58	0.49	7.70	8.30	7.20	4.10	38.10
	MEAN	0.76	0.73	0.43	0.34	5.84	5.30	4.56	1.78	10.85
	STANDARD DEV	0.26	0.24	0.08	0.08	1.62	1.66	2.25	0.87	7.71
EPC6	N OF CASES	24	24	24	13	23	23	22	24	24
	MINIMUM	0.43	0.42	0.36	0.29	5.20	5.00	4.20	0.20	2.40
	MAXIMUM	1.24	1.23	0.78	0.67	11.70	9.10	7.60	5.90	78.60
	MEAN	0.71	0.70	0.51	0.36	6.77	6.51	5.78	1.72	13.50
	STANDARD DEV	0.21	0.21	0.09	0.10	1.38	1.05	1.04	1.01	16.43
EPC52	N OF CASES	24	24	24	13	23	23	23	24	24
	MINIMUM	0.37	0.36	0.26	0.25	4.30	4.10	1.70	0.50	2.60
	MAXIMUM	1.41	1.36	1.01	0.83	16.20	12.10	7.90	3.90	36.60
	MEAN	0.84	0.83	0.46	0.38	7.96	7.10	5.57	1.79	12.24
	STANDARD DEV	0.26	0.25	0.15	0.15	2.21	1.71	1.72	0.83	9.04
EPC70	N OF CASES	24	24	24	12	20	23	20	24	24
	MINIMUM	0.32	0.31	0.34	0.26	4.50	2.90	2.50	0.20	2.10
	MAXIMUM	1.13	1.12	0.63	0.64	7.80	11.00	10.40	3.30	22.00
	MEAN	0.63	0.62	0.47	0.40	6.29	6.22	5.52	1.65	9.77
	STANDARD DEV	0.21	0.21	0.09	0.11	0.92	1.49	1.94	0.70	5.44

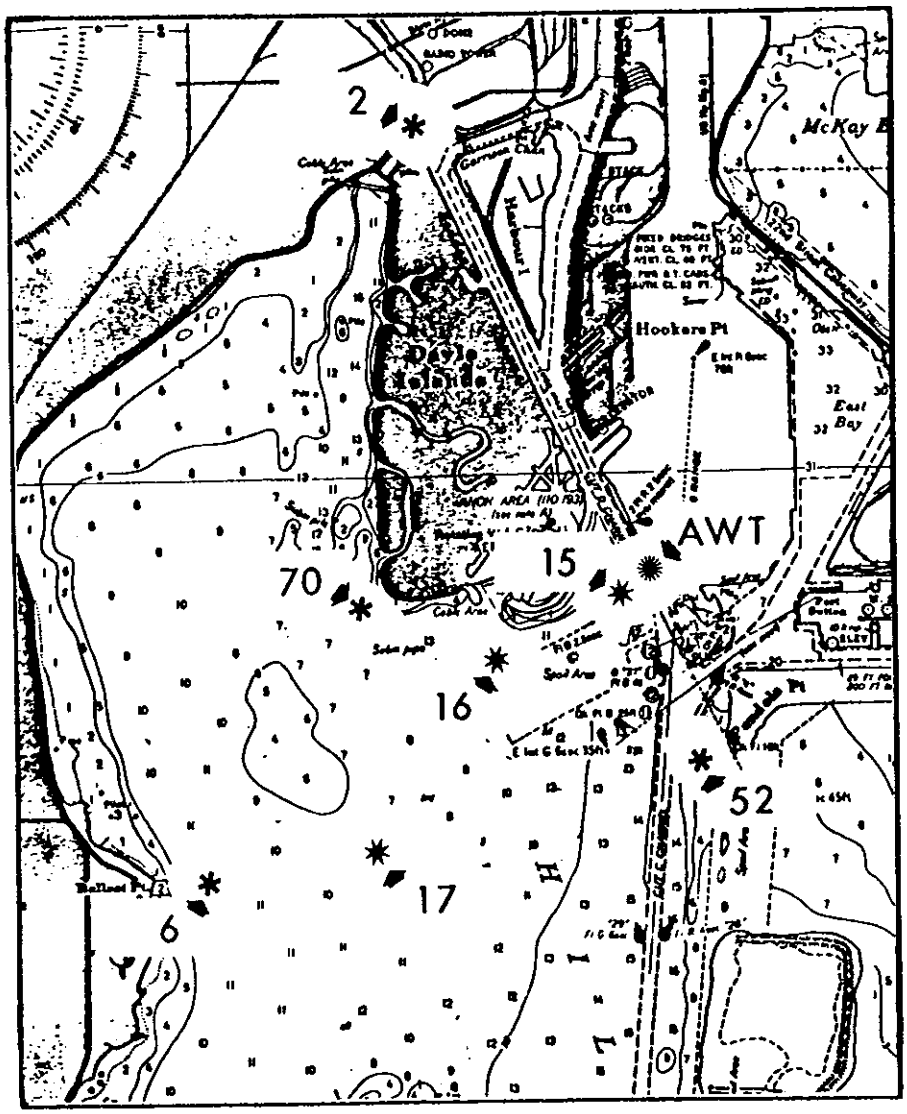

Figure 1. The Hookers Point WWTP discharge site (✺), COT compliance monitoring stations (✱) and nearby EPC stations (✱) in Hillsborough Bay.

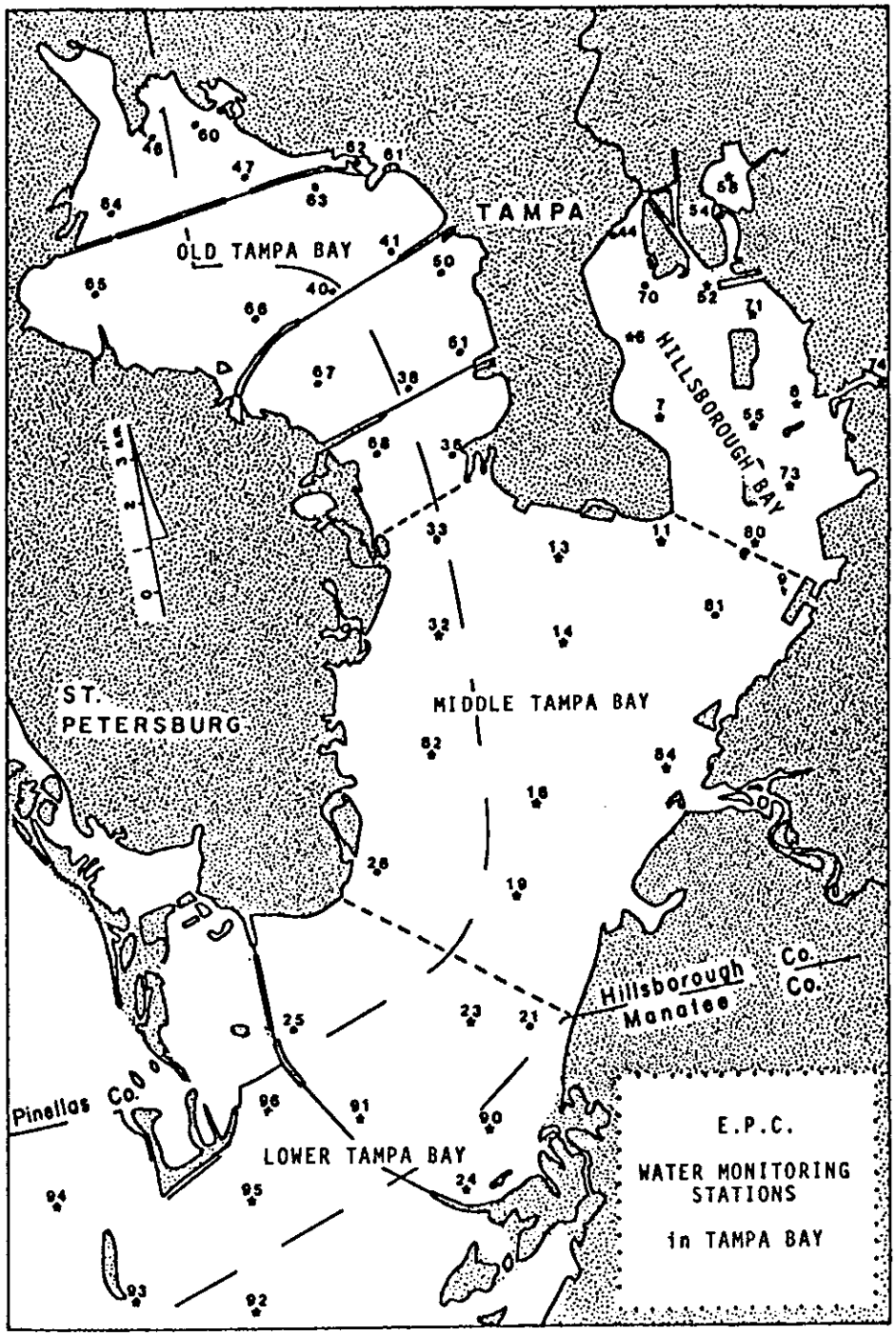

Figure 2. Water quality monitoring stations in Tampa Bay sampled by the EPC (from Boler 1989).

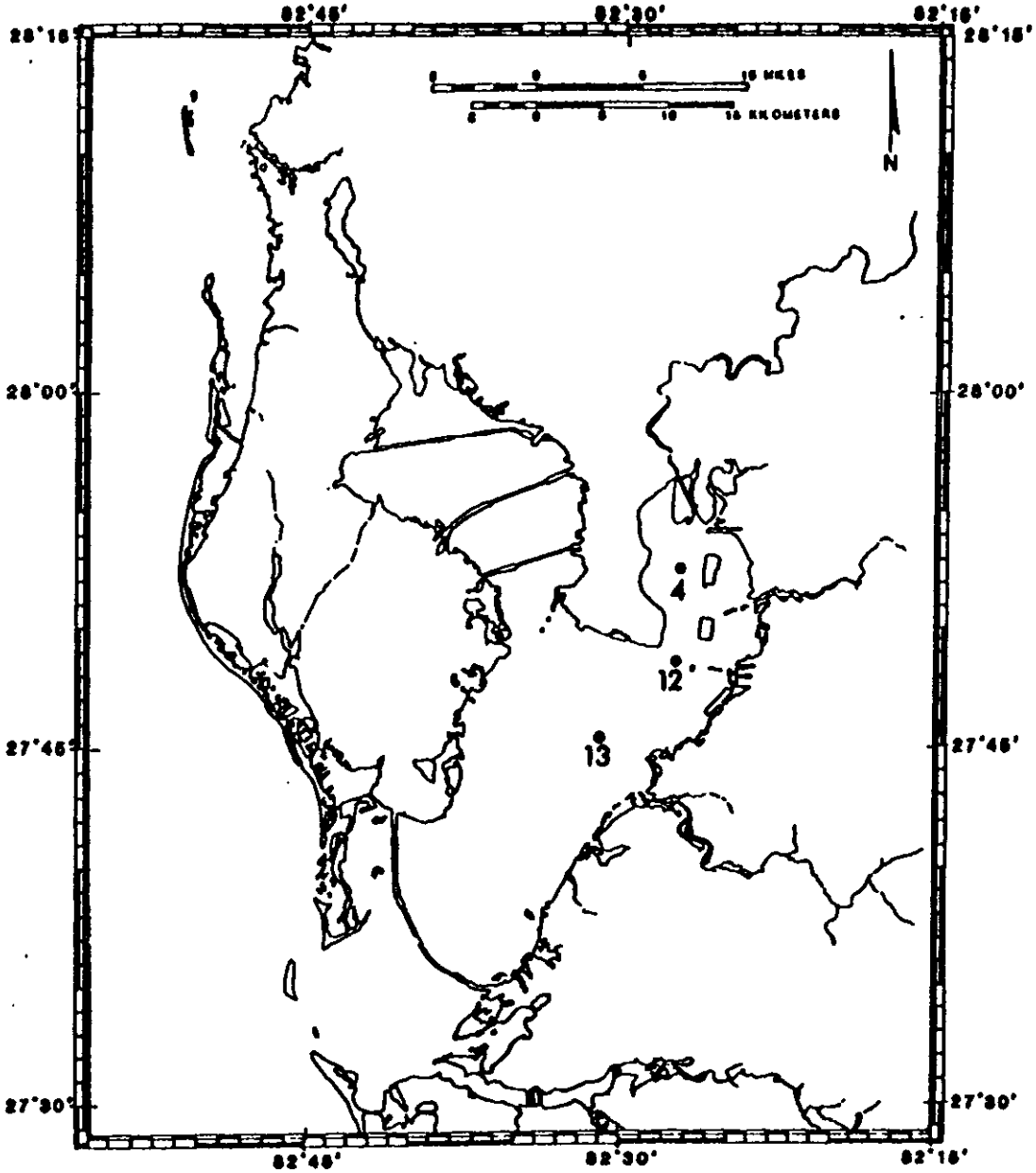

Figure 3. Water quality and phytoplankton monitoring stations in the Tampa Bay sampled by the COT.

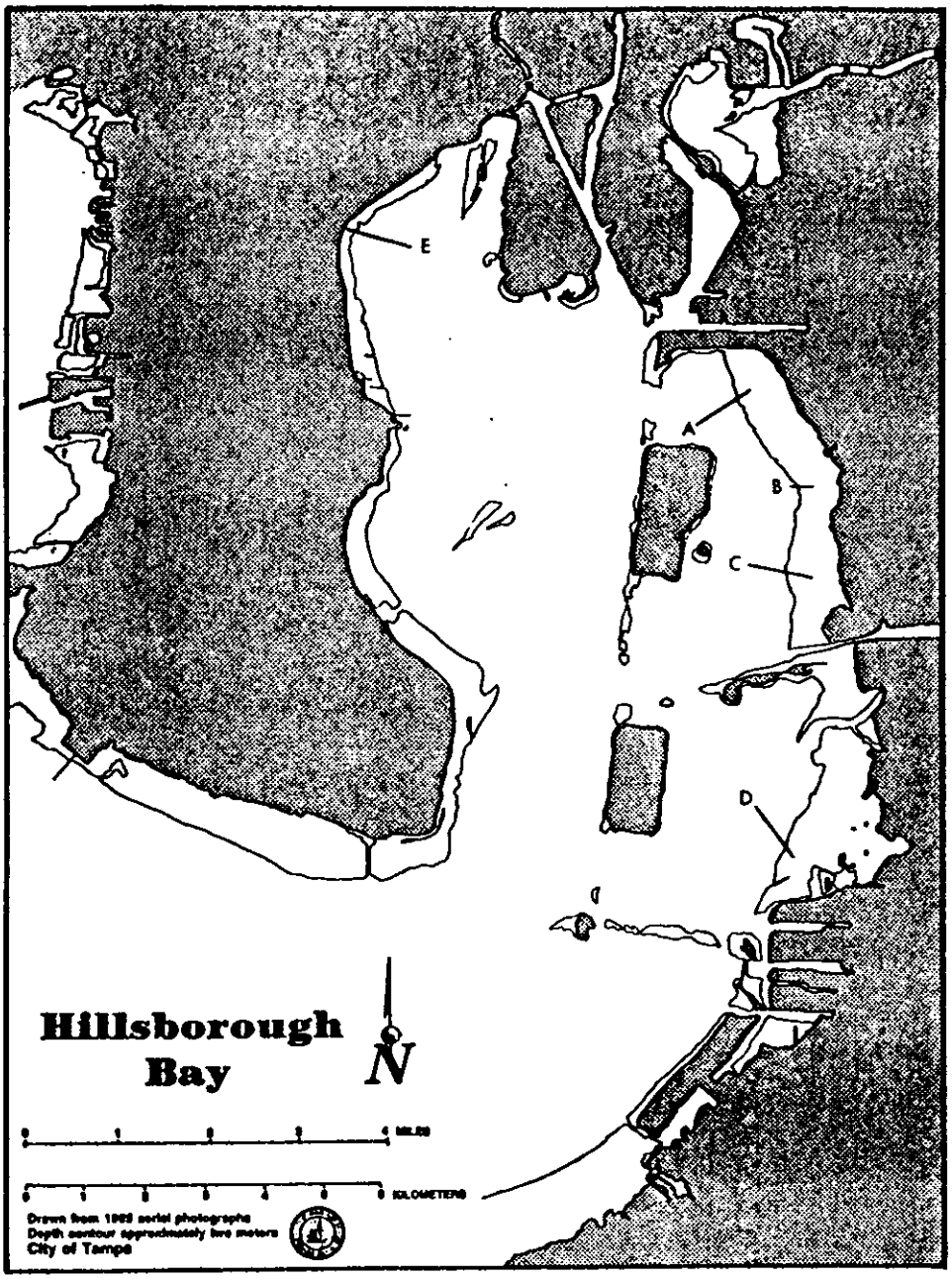

Figure 4. Macro-algae monitoring transects in Hillsborough Bay sampled by the COT.

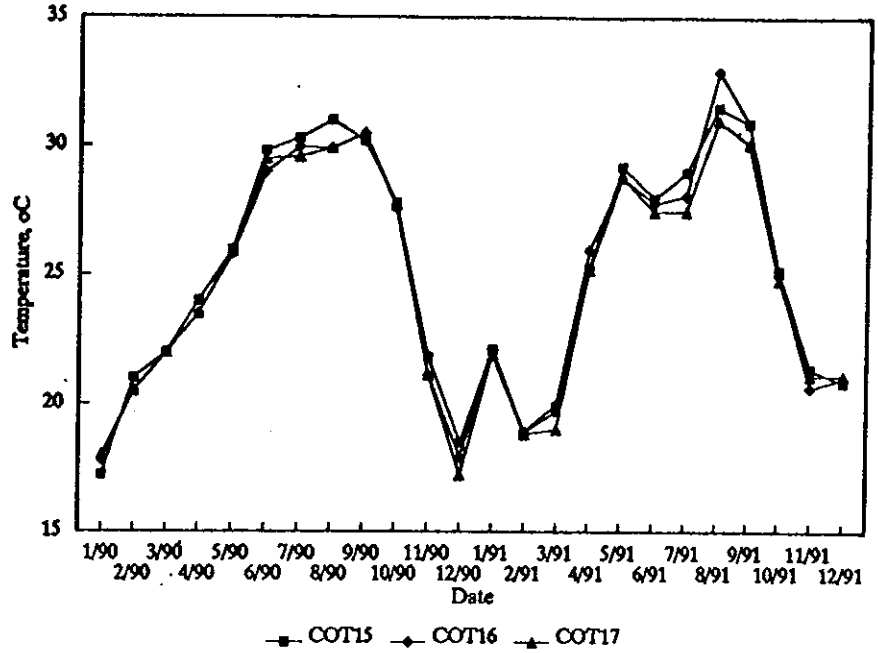

Figure 5. Monthly mid-depth temperatures at the COT compliance monitoring stations.

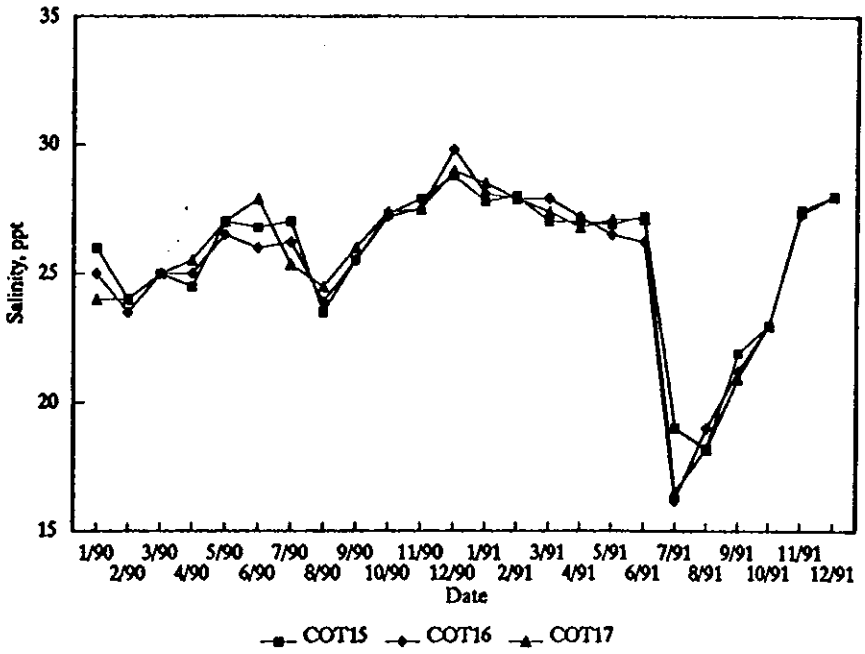

Figure 6. Monthly mid-depth salinities at the COT compliance monitoring stations.

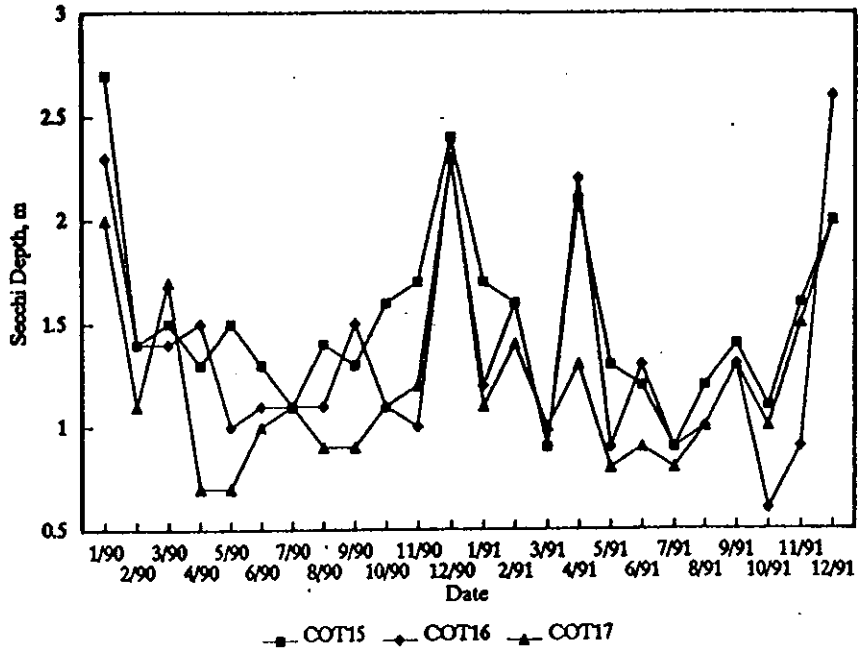

Figure 7. Monthly SD depths at the COT compliance monitoring stations.

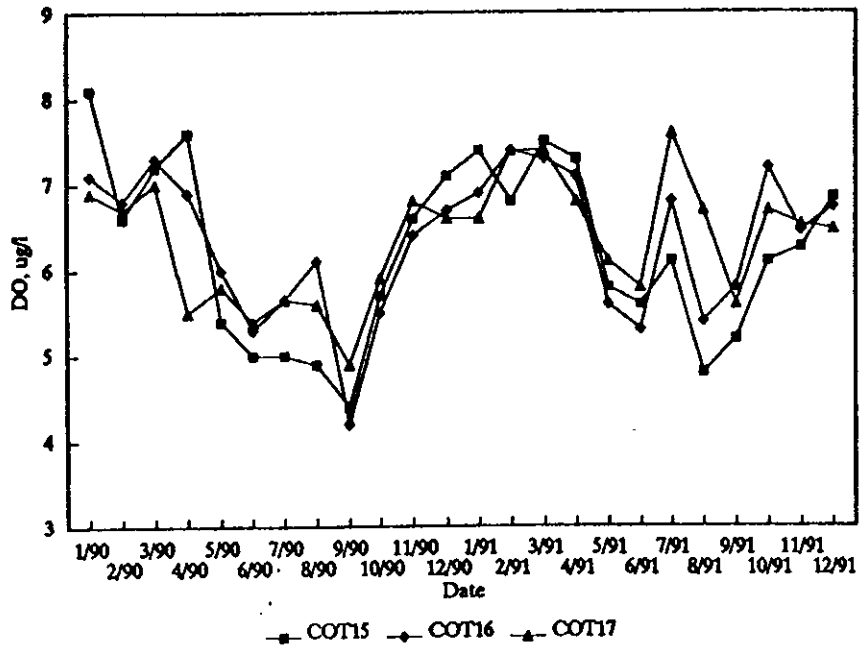

Figure 8. Monthly SDO concentrations at the COT compliance monitoring stations.

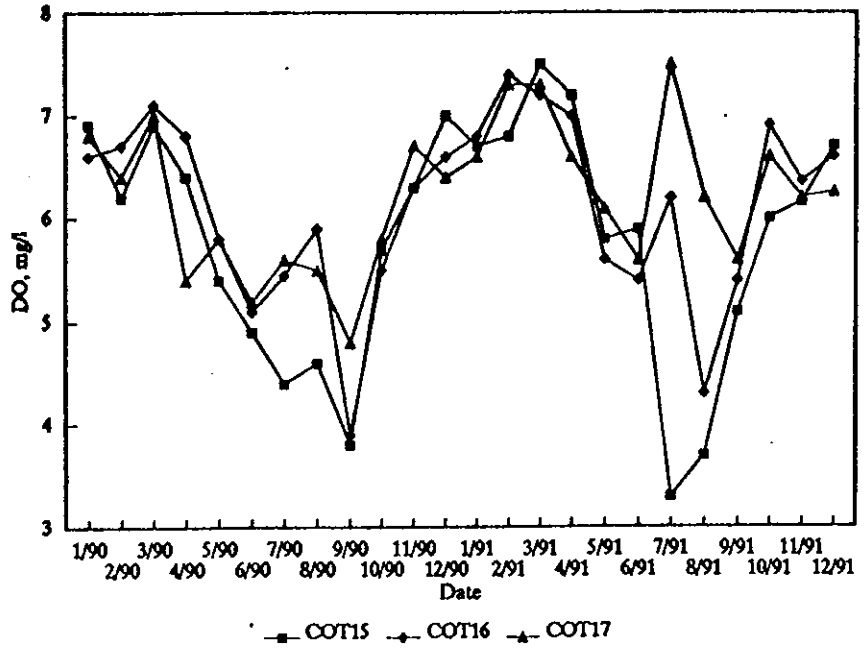

Figure 9. Monthly MDO concentrations at the COT compliance monitoring stations.

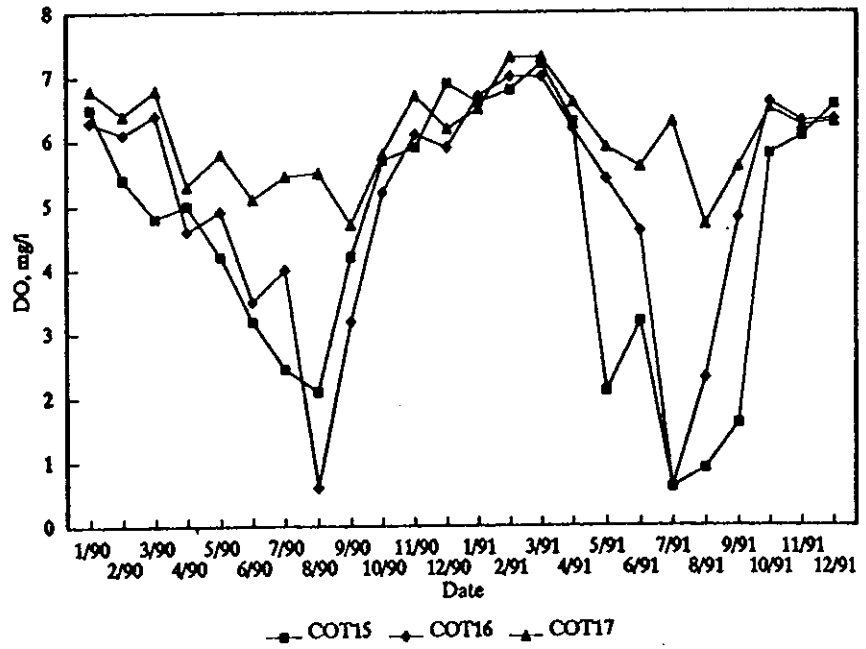

Figure 10. Monthly BDO concentrations at the COT compliance monitoring stations.

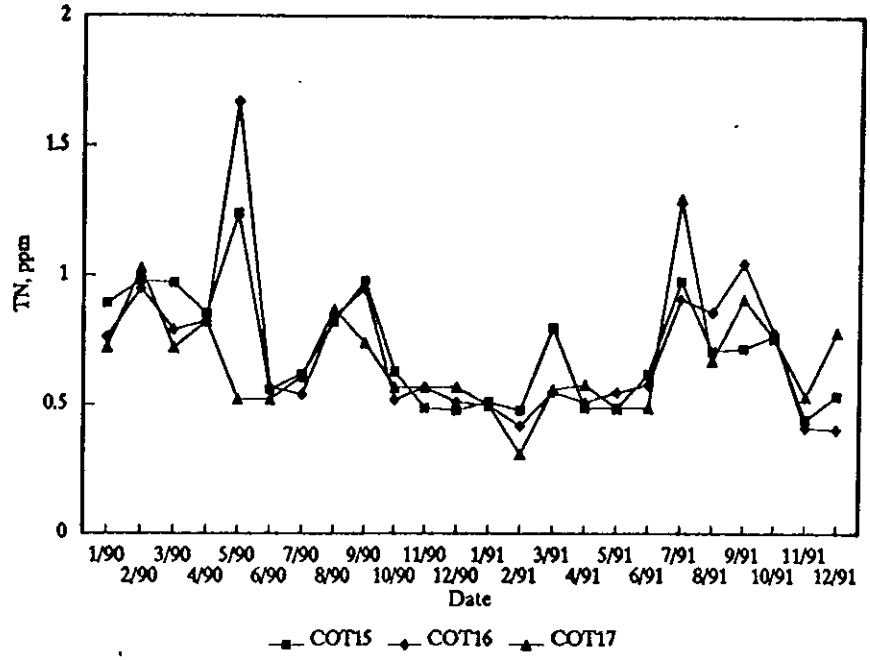

Figure 11. Monthly mid-depth TN concentrations at the COT compliance monitoring stations.

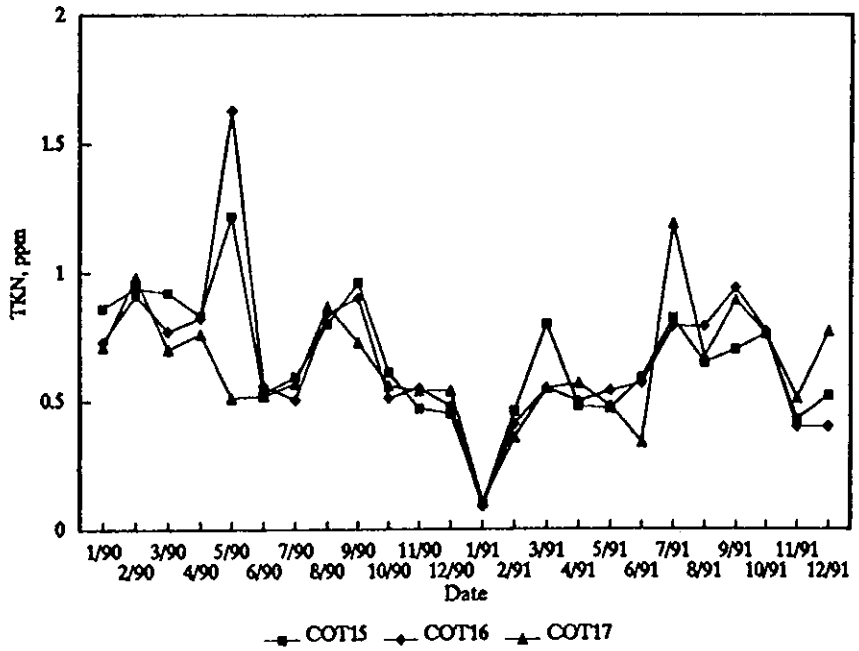

Figure 12. Monthly mid-depth TKN concentrations at the COT compliance monitoring stations.

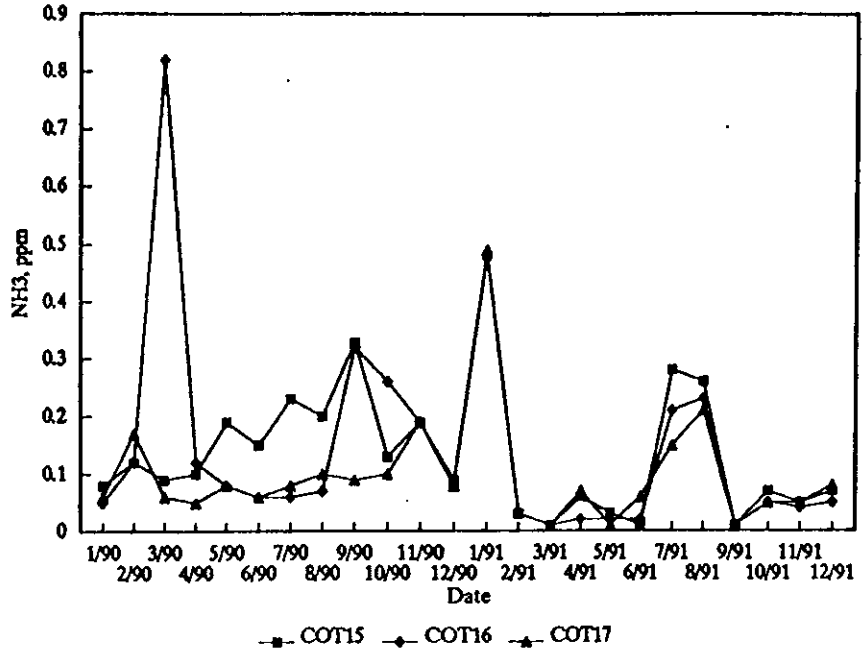

Figure 13. Monthly mid-depth NH3 concentrations at the COT compliance monitoring stations.

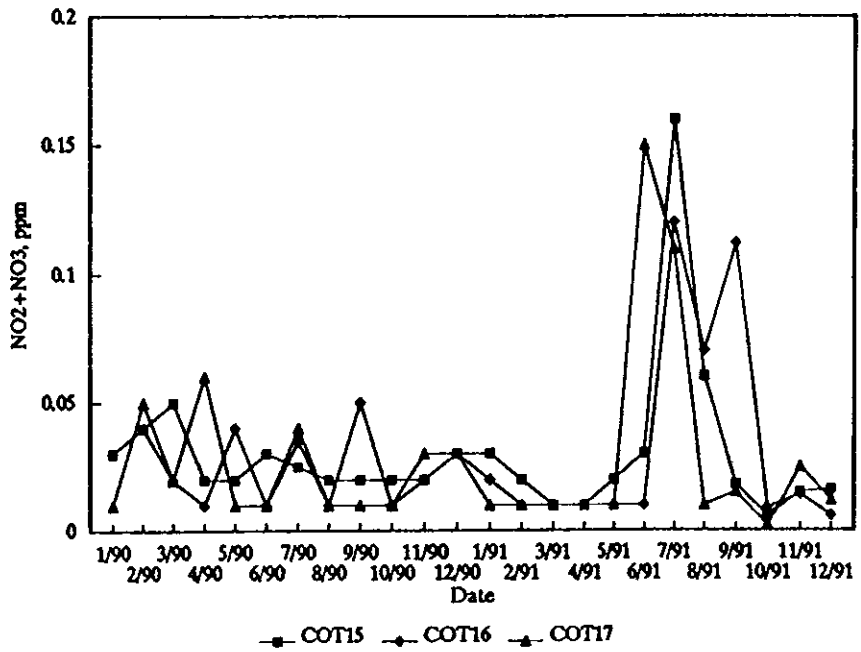

Figure 14. Monthly mid-depth NO2+NO3 concentrations at the COT compliance monitoring stations.

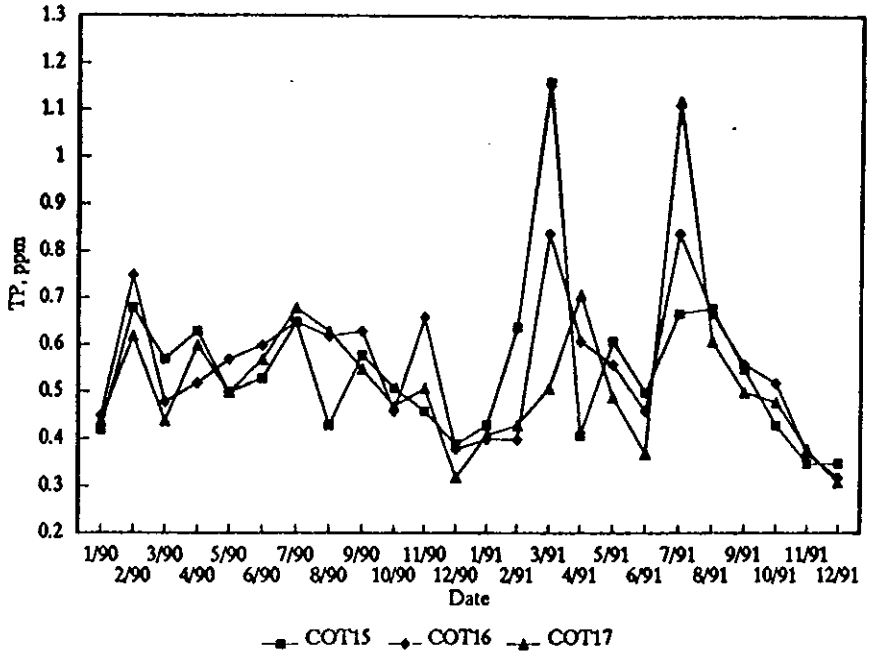

Figure 15. Monthly mid-depth TP concentrations at the COT compliance monitoring stations.

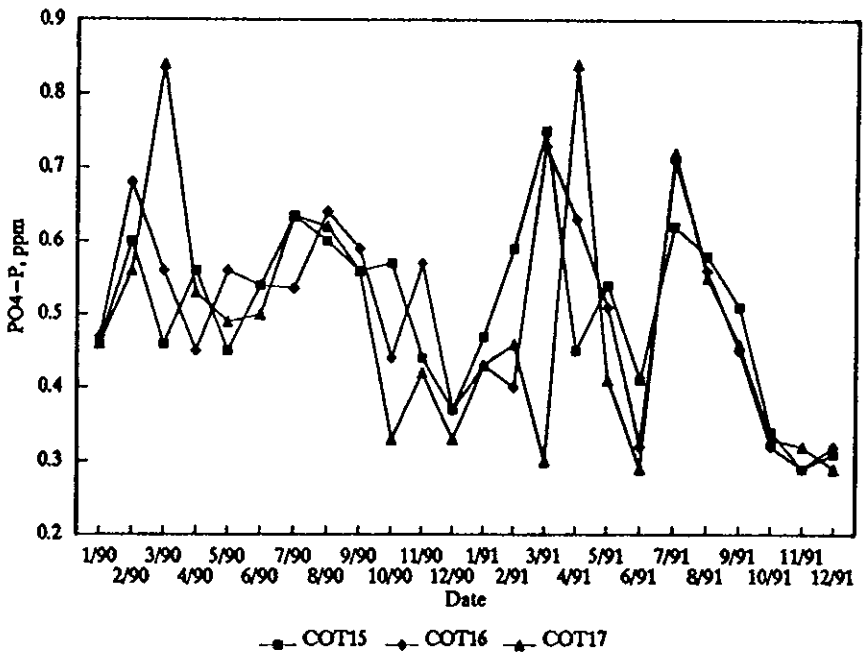

Figure 16. Monthly mid-depth PO4 concentrations at the COT compliance monitoring stations.

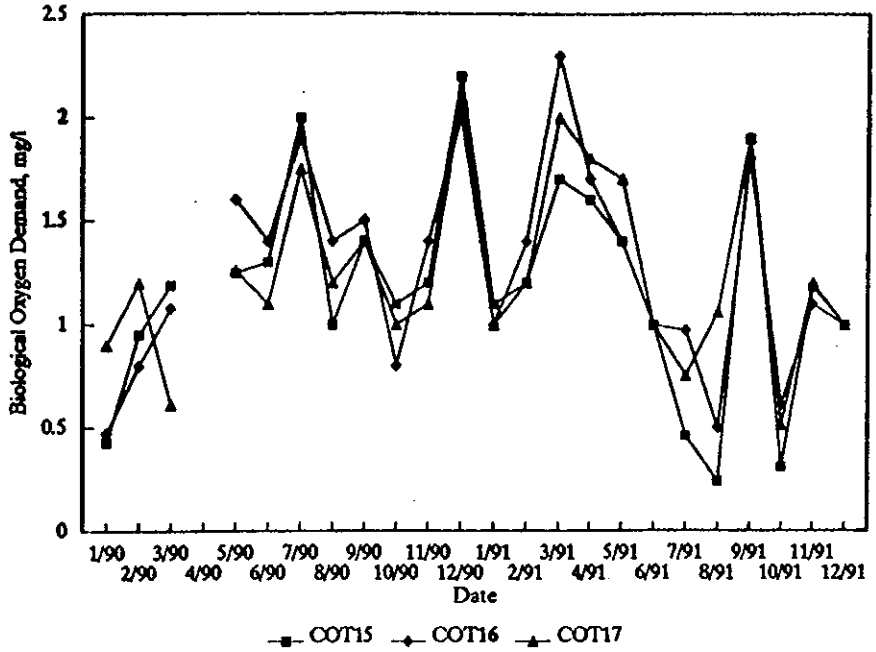

Figure 17. Monthly mid-depth CBOD5 concentrations at the COT compliance monitoring stations.

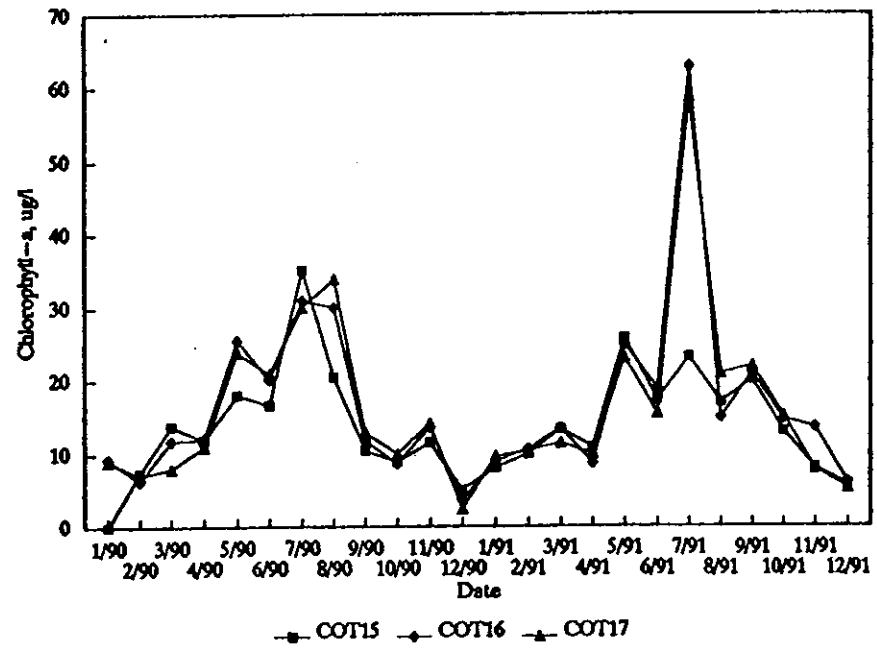

Figure 18. Monthly mid-depth CHLA concentrations at the COT compliance monitoring stations.

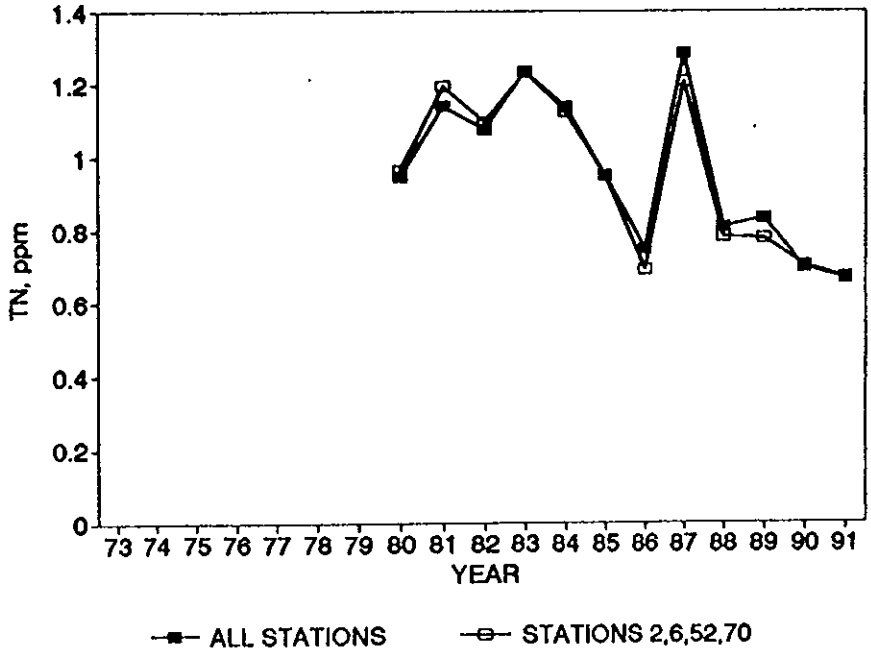

Figure 19. Long-term trend of TN concentrations for stations sampled in Hillsborough Bay by the EPC.

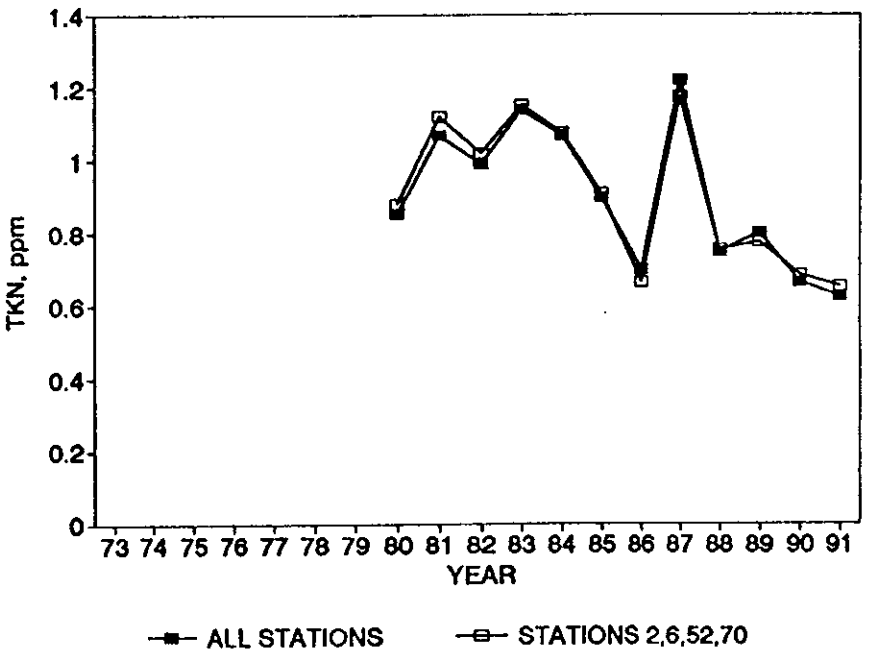

Figure 20. Long-term trend of TKN concentrations for stations sampled in Hillsborough Bay by the EPC.

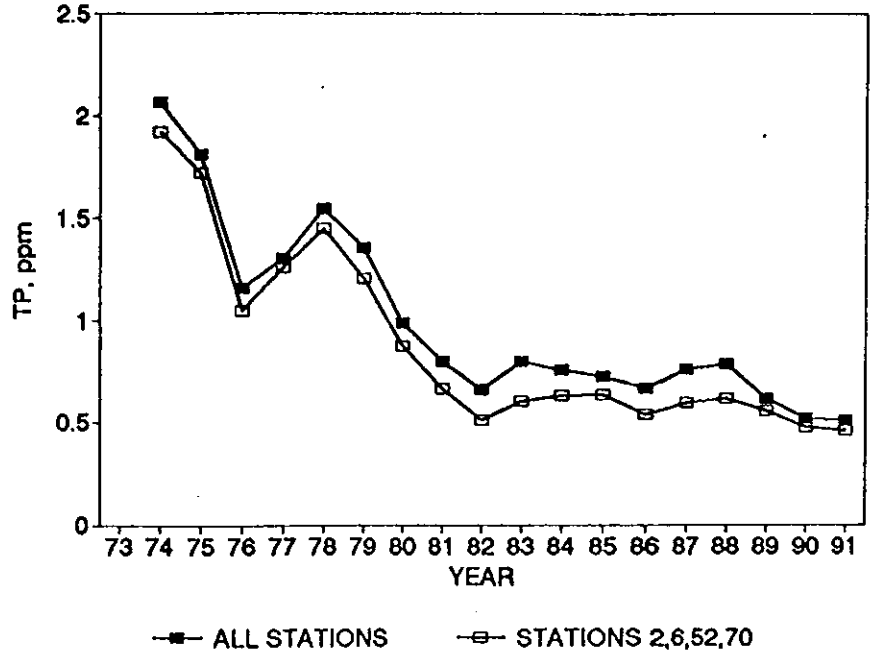

Figure 21. Long-term trend of TP concentrations for stations sampled in Hillsborough Bay by the EPC.

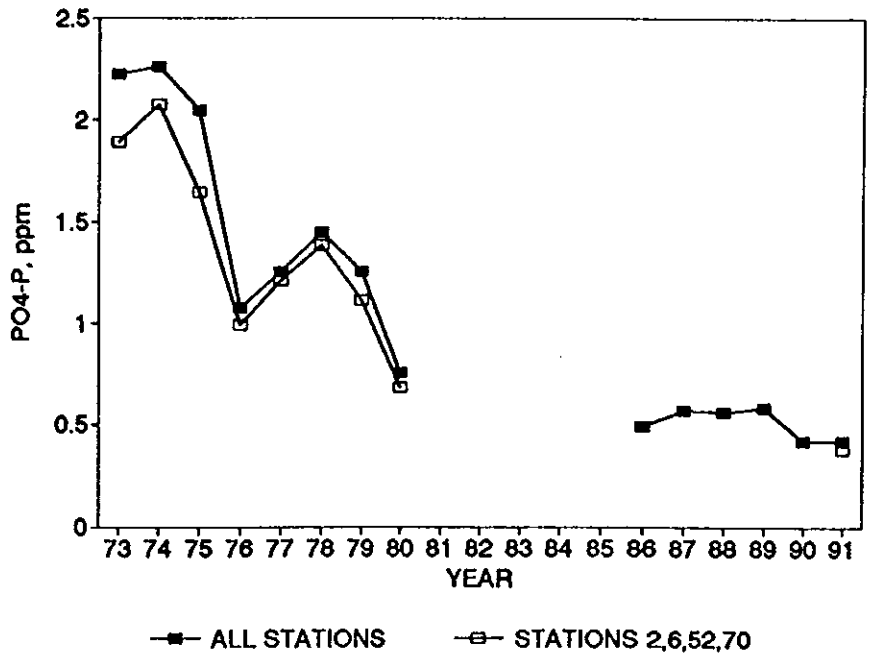

Figure 22. Long-term trend of PO4 concentrations for stations sampled in Hillsborough Bay by the EPC.

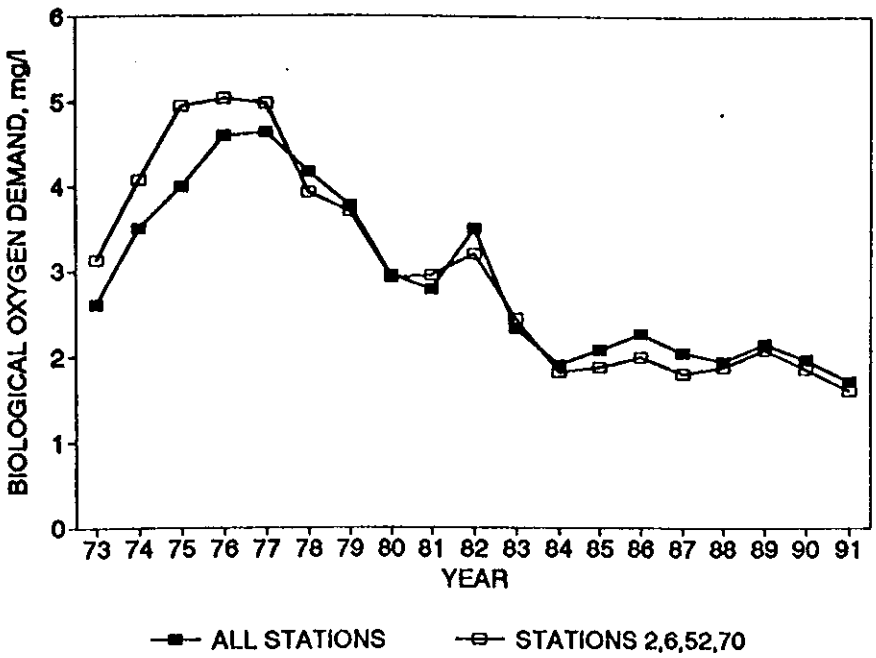

Figure 23. Long-term trend of CBOD5 concentrations for stations sampled in Hillsborough Bay by the EPC.

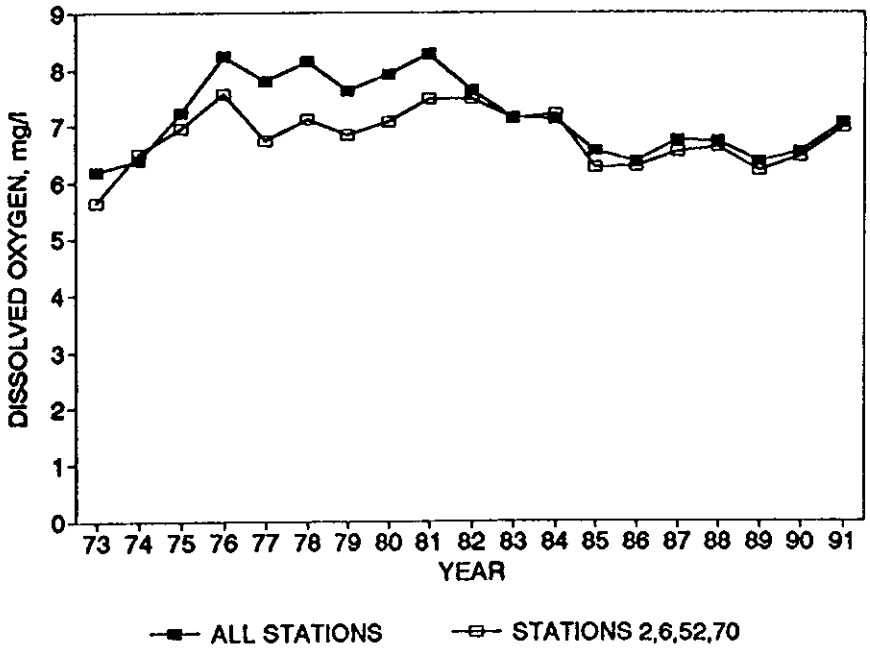

Figure 24. Long-term trend of SDO concentrations for stations sampled in Hillsborough Bay by the EPC.

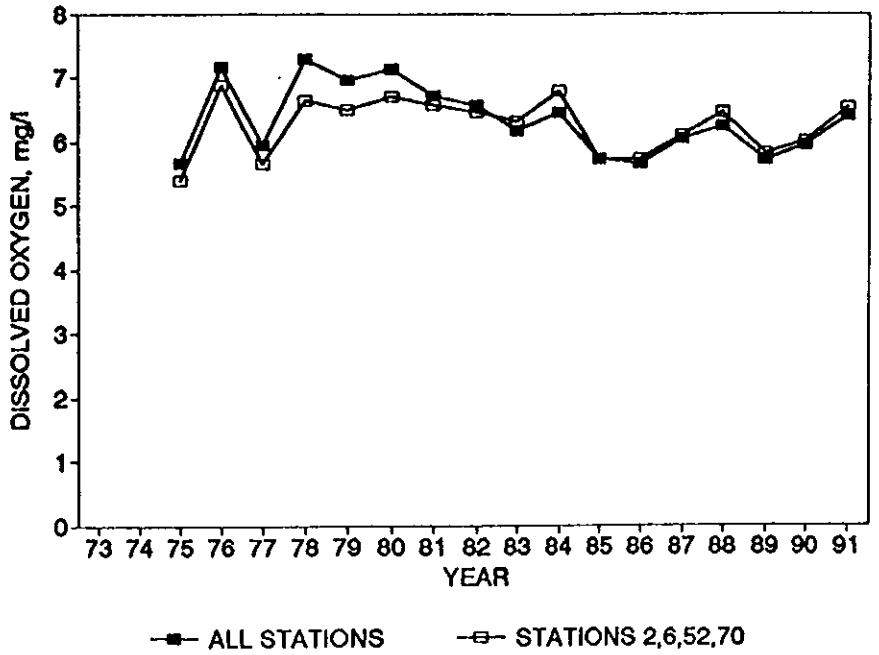

Figure 25. Long-term trend of MDO concentrations for stations sampled in Hillsborough Bay by the EPC.

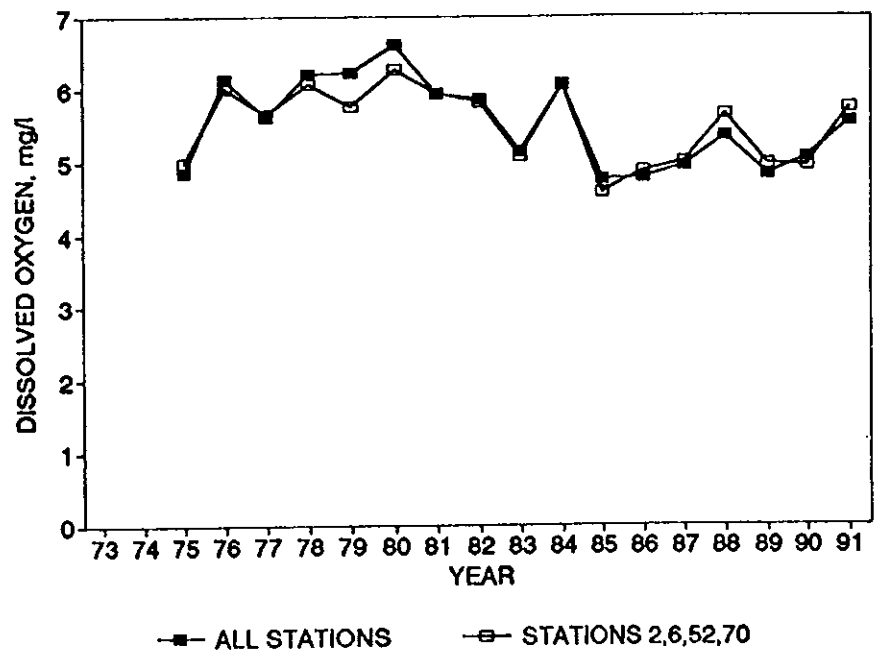

Figure 26. Long-term trend of BDO concentrations for stations sampled in Hillsborough Bay by the EPC.

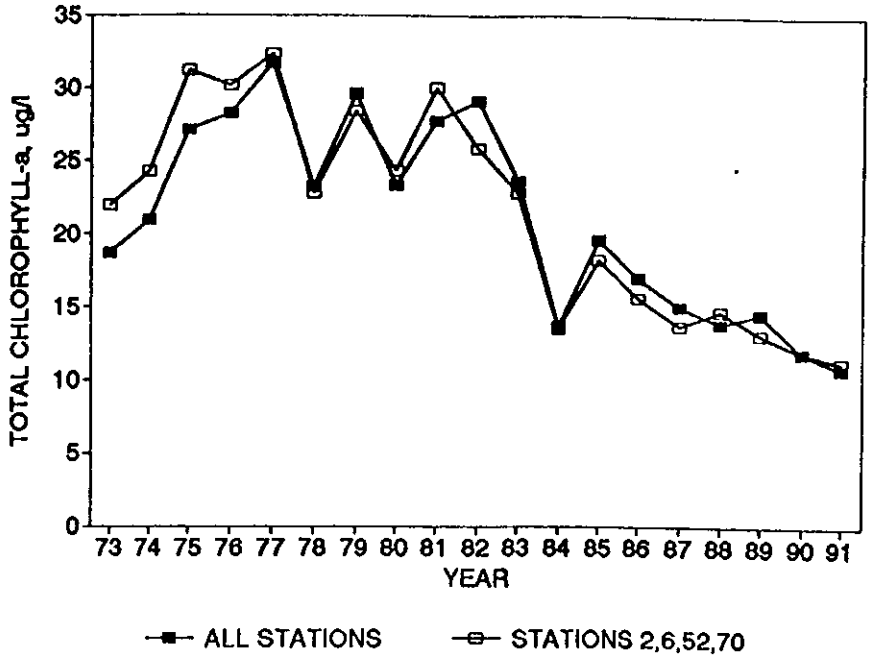

Figure 27. Long-term trend of CHLA concentrations for stations sampled in Hillsborough Bay by the EPC.

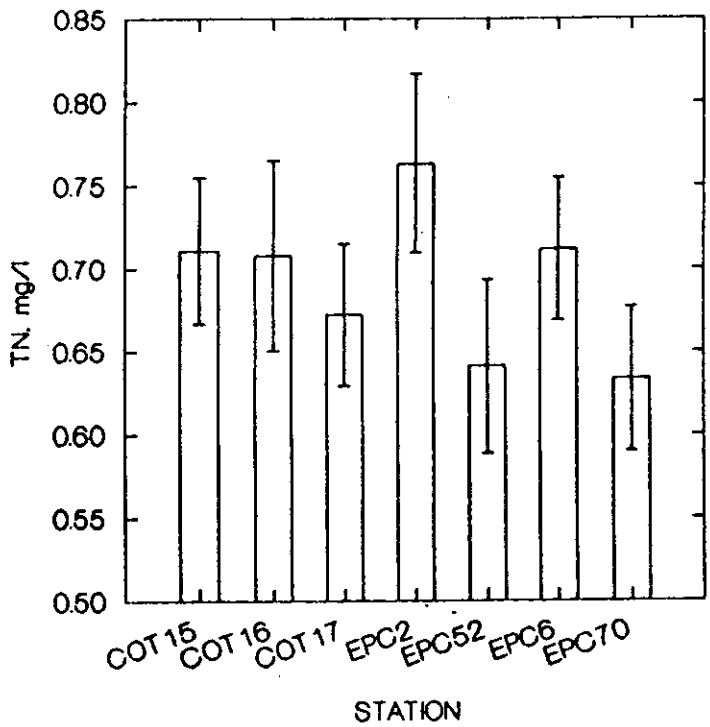

Figure 28. Comparison of mean values and standard errors for TN concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

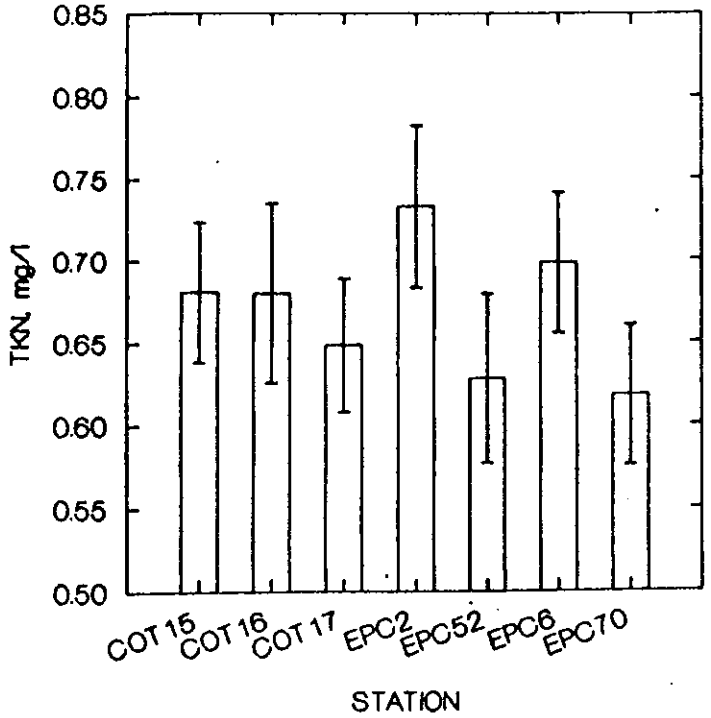

Figure 29. Comparison of mean values and standard errors for TKN concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

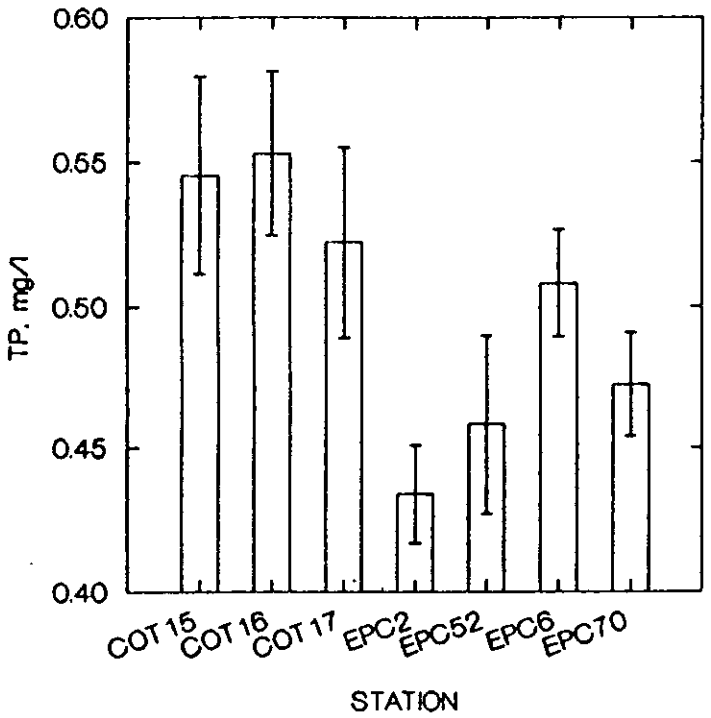

Figure 30. Comparison of mean values and standard errors for TP concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

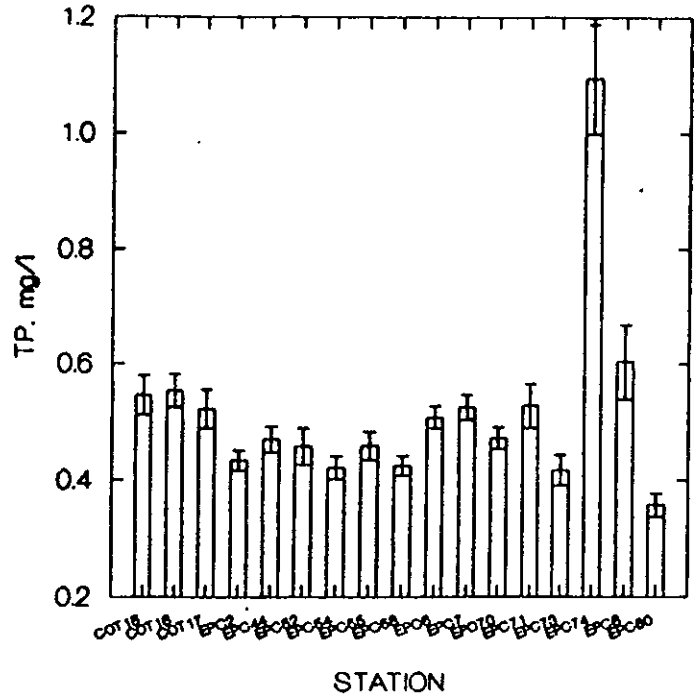

Figure 31. Comparison of mean values and standard errors for TP concentrations measured at the COT compliance monitoring stations and all EPC stations in Hillsborough Bay for the two years 1990 and 1991.

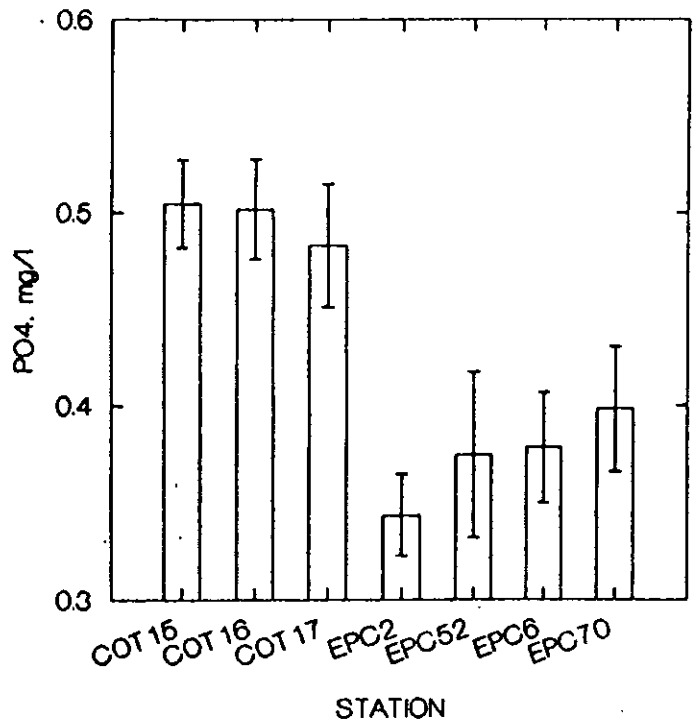

Figure 32. Comparison of mean values and standard errors for PO4 concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

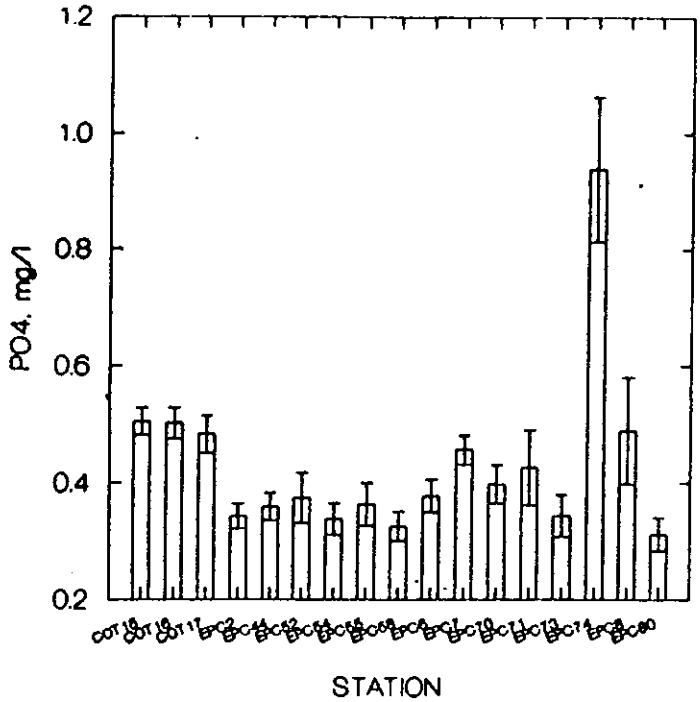

Figure 33. Comparison of mean values and standard errors for PO4 concentrations measured at the COT compliance monitoring stations and all EPC stations in Hillsborough Bay for the two years 1990 and 1991.

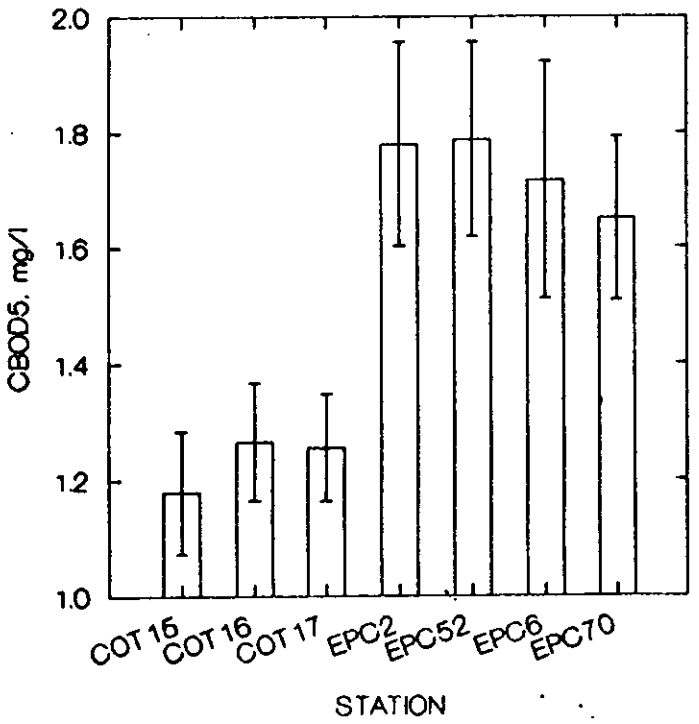

Figure 34. Comparison of mean values and standard errors for CBOD5 concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

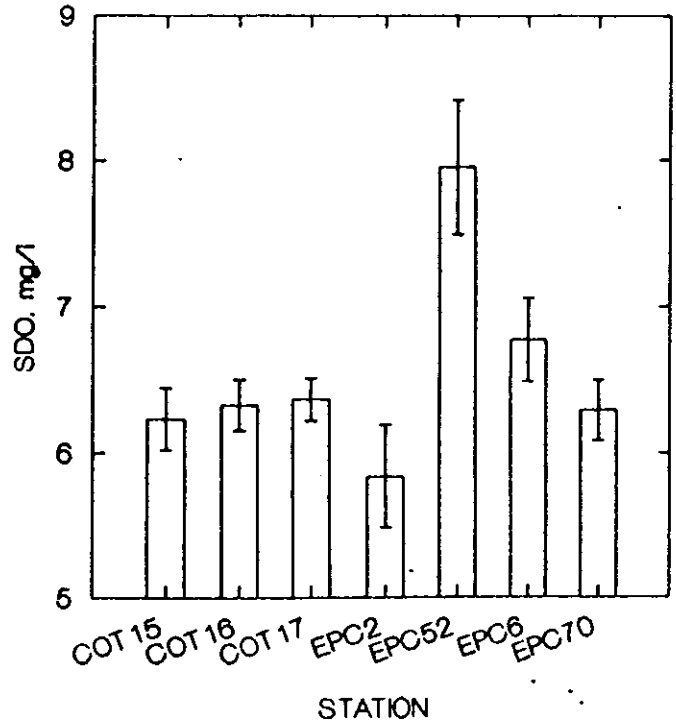

Figure 35. Comparison of mean values and standard errors for SDO concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

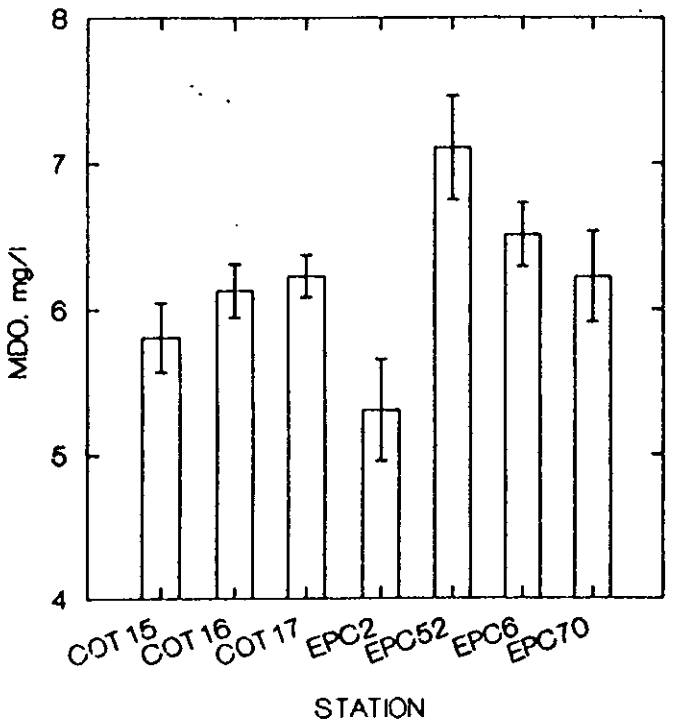

Figure 36. Comparison of mean values and standard errors for MDO concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

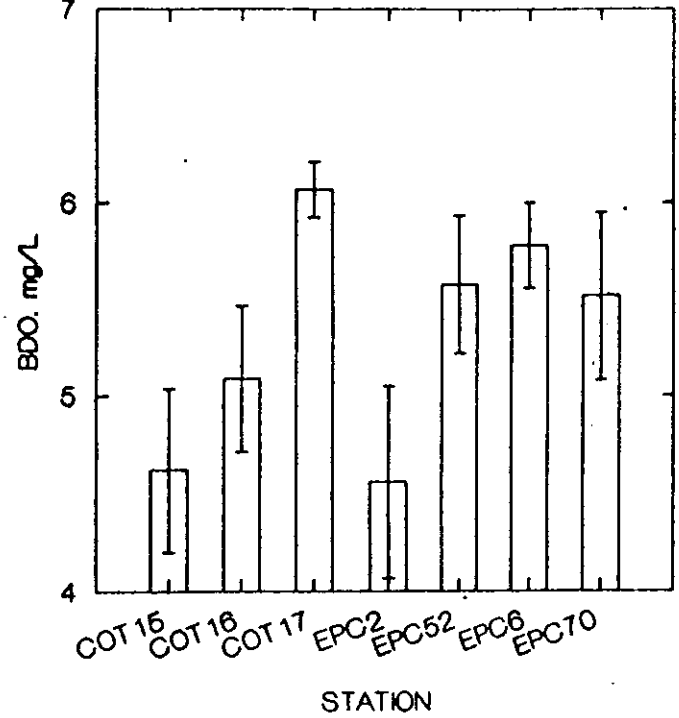

Figure 37. Comparison of mean values and standard errors for BDO concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

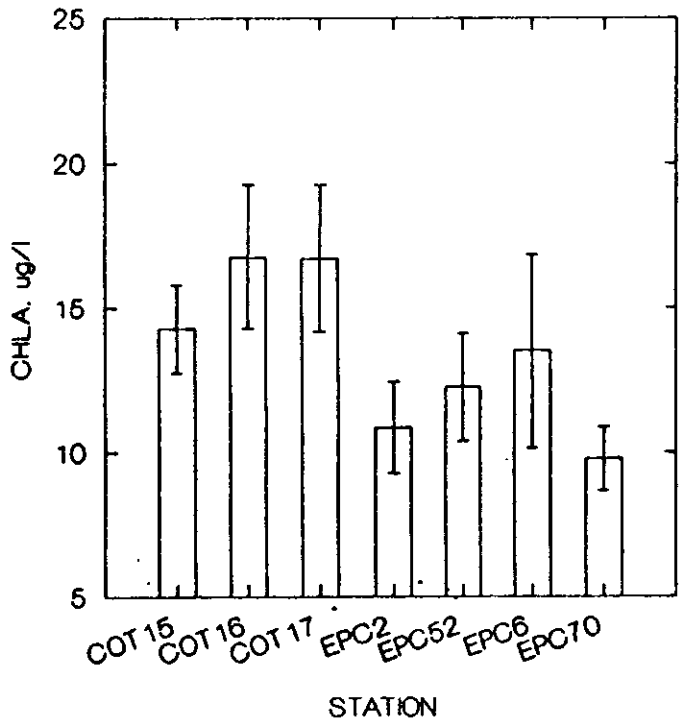

Figure 38. Comparison of mean values and standard errors for CHLA concentrations measured at the COT compliance monitoring stations and the group of EPC stations close to the Hookers Point WWTP discharge site for the two years 1990 and 1991.

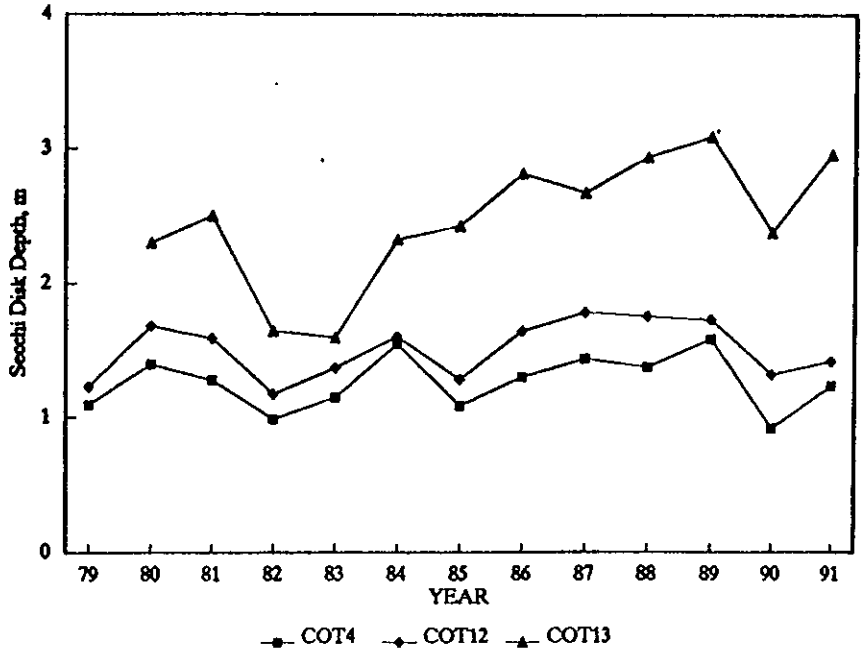

Figure 39. Long-term trend of SD depth measured by the COT in Tampa Bay.

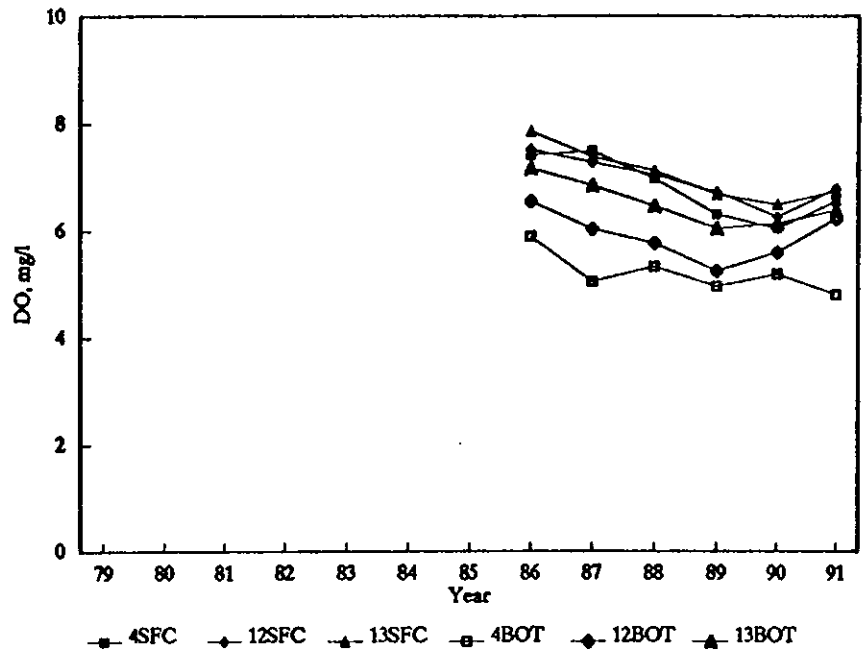

Figure 40. Long-term trend of DO concentrations measured by the COT in Tampa Bay.

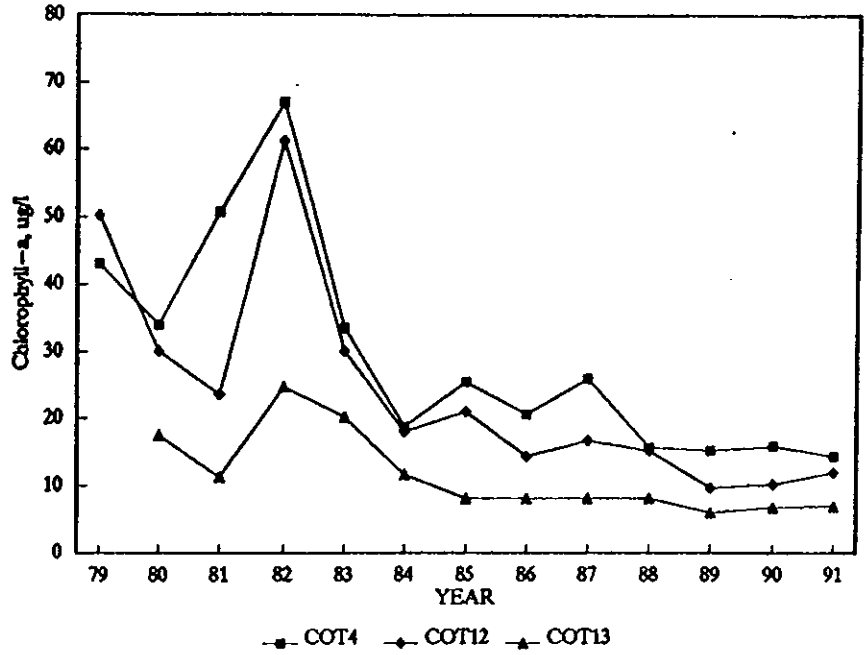

Figure 41. Long-term trend of surface CHLA concentrations measured by the COT in Tampa Bay.

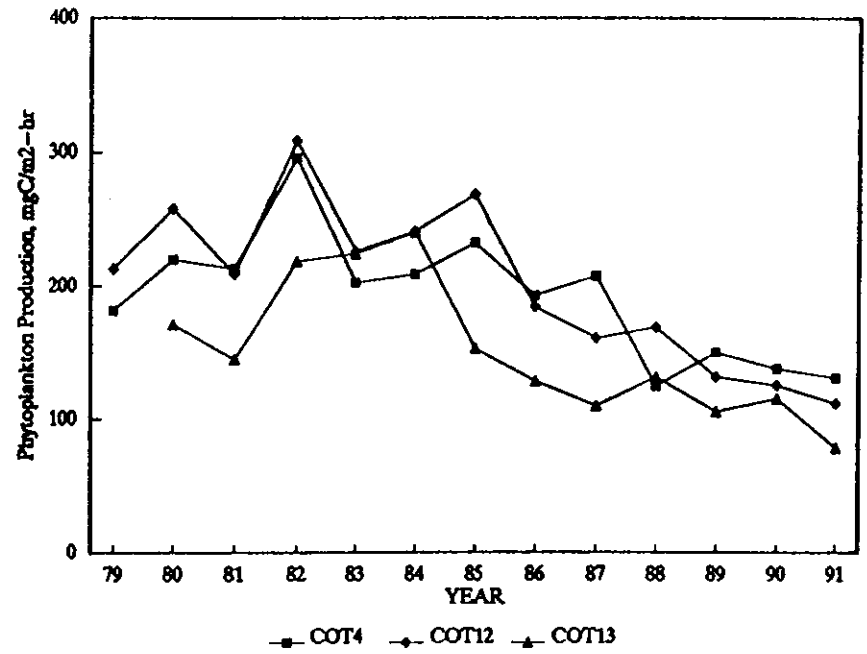

Figure 42. Long-term trend of depth integrated phytoplankton production measured by the COT in Tampa Bay.

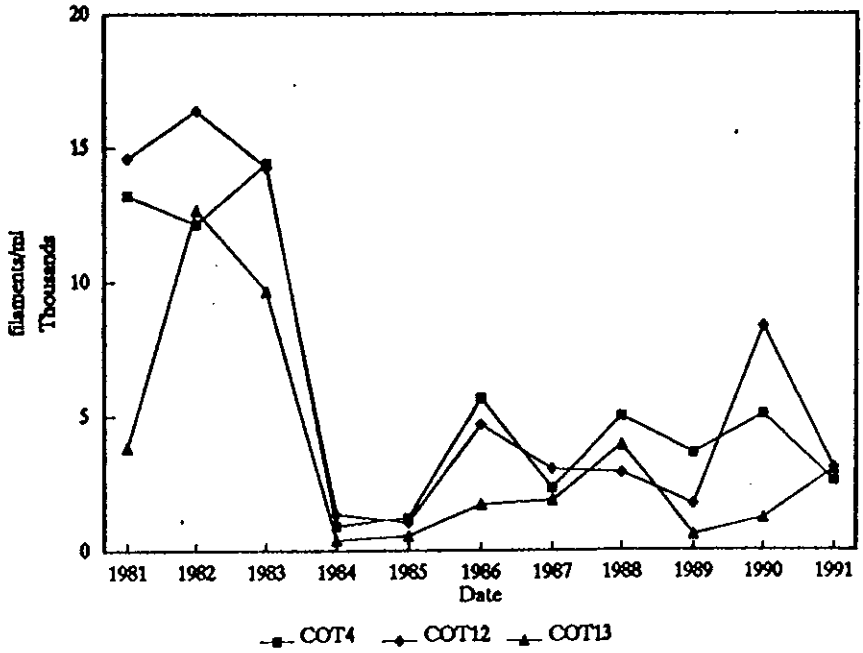

Figure 43. Long-term trend of Schizothrix calcicola sensu Drouet concentrations measured by the COT in Tampa Bay.

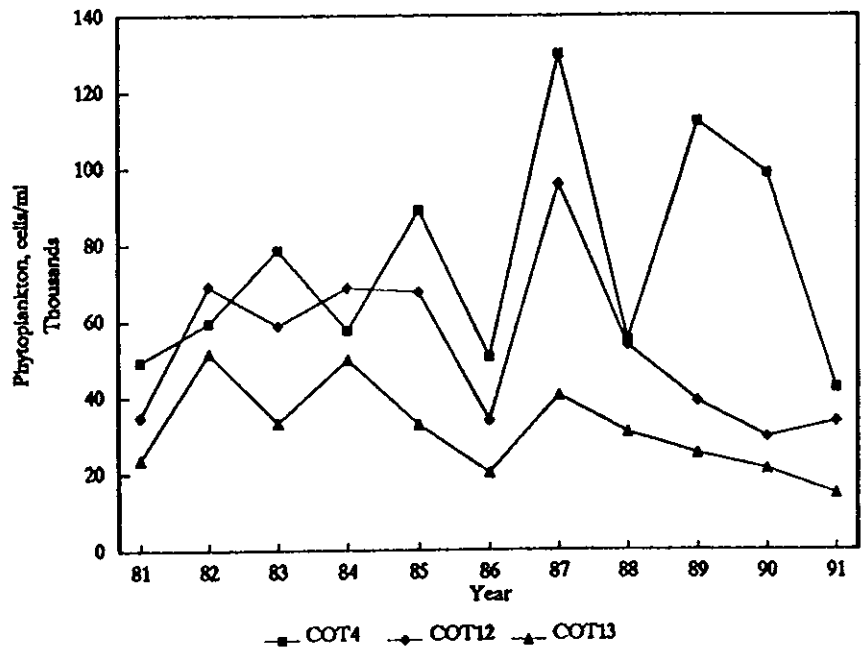

Figure 44. Long-term trend of total phytoplankton concentrations measured by the COT in Tampa Bay.

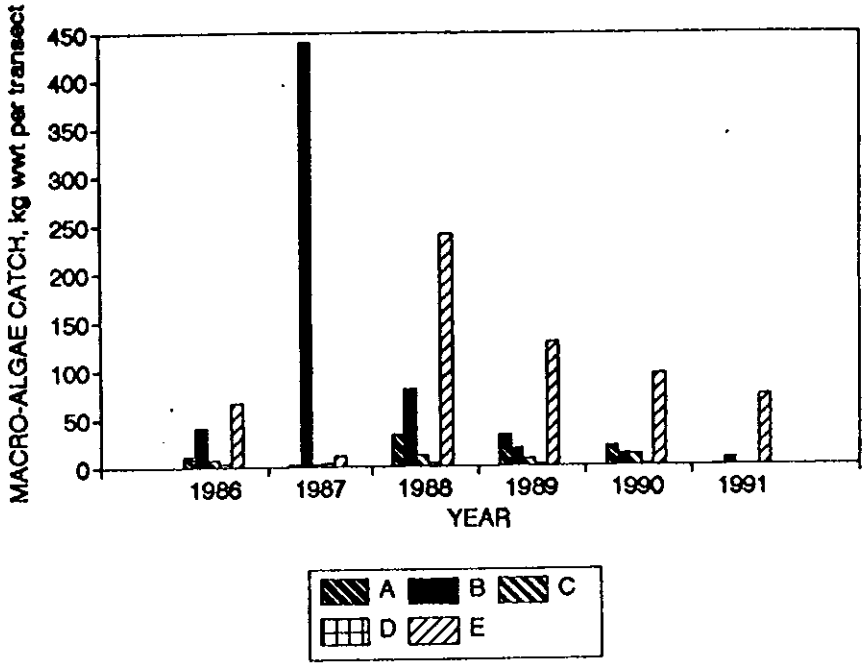

Figure 45. Long-term trend of drift macro-algae biomass measured by the COT in Hillsborough Bay

APPENDIX

Appendix Table A. Results from the City of Tampa compliance monitoring in Hillsborough Bay for station COT15 for the years 1990-1991. Missing values: a CBOD5 sample was collected by the COT in April 11, 1990, but the sample was not analyzed by the EPC.

DATE	STA	MO	YEAR	TN ppm	TKN ppm	TP ppm	PO4 ppm	CBOD5 mg/l	NO2+NO3 ppm	NH3 ppm	CHL-A ug/l	SDO mg/l	MDO mg/l	BDO mg/l
1/10/90	15	1	1990	.89	.86	.42	.46	.43	.03	.08	7.52	8.10	6.90	6.50
2/14/90	15	2	1990	.98	.94	.68	.60	.95	.04	.12	7.43	6.60	6.20	5.40
3/14/90	15	3	1990	.97	.92	.57	.46	1.19	.05	.09	13.78	7.20	6.90	4.80
4/11/90	15	4	1990	.85	.83	.63	.56		.02	.10	11.83	7.60	6.40	5.00
5/09/90	15	5	1990	1.24	1.22	.50	.45	1.25	.02	.19	17.99	5.40	5.40	4.20
6/13/90	15	6	1990	.56	.53	.53	.54	1.30	.03	.15	16.63	5.00	4.90	3.20
7/18/90	15	7	1990	.62	.59	.61	.64	2.00	.03	.41	38.29	5.20	4.40	3.20
8/15/90	15	8	1990	.82	.80	.43	.60	1.00	.02	.20	20.48	4.90	4.60	2.10
9/12/90	15	9	1990	.98	.96	.58	.56	1.40	.02	.33	10.41	4.40	3.80	4.20
10/10/90	15	10	1990	.63	.61	.51	.57	1.10	.02	.13	8.82	5.70	5.70	5.70
11/14/90	15	11	1990	.49	.47	.46	.44	1.20	.02	.19	11.51	6.60	6.30	5.90
12/11/90	15	12	1990	.48	.45	.39	.37	2.20	.03	.09	5.10	7.10	7.00	6.90
1/09/91	15	1	1991	.51	.10	.43	.47	1.10	.03	.48	8.07	7.40	6.70	6.60
2/13/91	15	2	1991	.48	.46	.64	.59	1.20	.02	.03	10.03	6.80	6.80	6.80
3/13/91	15	3	1991	.80	.80	1.16	.75	1.70	.01	.01	13.35	7.50	7.50	7.20
4/09/91	15	4	1991	.49	.48	.41	.45	1.60	.01	.06	10.92	7.30	7.20	6.30
5/08/91	15	5	1991	.49	.47	.61	.54	1.40	.02	.03	25.75	5.80	5.80	2.10
6/12/91	15	6	1991	.62	.59	.50	.41	1.00	.03	.01	17.36	5.60	5.90	3.20
7/16/91	15	7	1991	.98	.82	.67	.62	.46	.16	.28	23.11	6.10	3.30	.60
8/14/91	15	8	1991	.71	.65	.68	.58	.24	.06	.26	17.00	4.80	3.70	.90
9/11/91	15	9	1991	.72	.70	.55	.51	1.90	.02	.01	20.05	5.20	5.10	1.60
10/09/91	15	10	1991	.77	.76	.43	.34	.31	.01	.07	13.01	6.10	6.00	5.80
11/06/91	15	11	1991	.45	.43	.35	.29	1.18	.02	.05	8.04	6.27	6.16	6.07
12/04/91	15	12	1991	.54	.52	.35	.31	1.00	.02	.07	5.86	6.85	6.70	6.57

Appendix Table B. Results from the City of Tampa compliance monitoring in Hillsborough Bay for station COT16 for the years 1990-1991. Missing values: a CBOD5 sample was collected by the COT in April 11, 1990, but the sample was not analyzed by the EPC.

DATE	STA	MO	YEAR	TN ppm	TKN ppm	TP ppm	PO4 ppm	CBOD5 mg/l	NO2+NO3 ppm	NH3 ppm	CHL-A ug/l	SDO mg/l	MDO mg/l	BDO mg/l
1/10/90	16	1	1990	.76	.73	.45	.47	.47	.03	.05	9.33	7.10	6.60	6.30
2/14/90	16	2	1990	.95	.91	.75	.68	.80	.04	.12	6.34	6.80	6.70	6.10
3/14/90	16	3	1990	.79	.77	.48	.56	1.08	.02	.82	11.80	7.30	7.10	6.40
4/11/90	16	4	1990	.82	.82	.52	.45		.01	.12	11.99	6.90	6.80	4.60
5/09/90	16	5	1990	1.67	1.63	.57	.56	1.60	.04	.08	25.54	6.00	5.80	4.90
6/13/90	16	6	1990	.57	.56	.60	.54	1.40	.01	.06	20.14	5.30	5.10	3.50
7/18/90	16	7	1990	.51	.48	.60	.50	1.90	.03	.06	31.07	5.70	5.30	2.60
8/15/90	16	8	1990	.84	.84	.62	.64	1.40	.01	.07	30.01	6.10	5.90	.60
9/12/90	16	9	1990	.95	.90	.63	.59	1.50	.05	.32	11.79	4.20	3.90	3.20
10/10/90	16	10	1990	.52	.51	.46	.44	.80	.01	.26	8.68	5.50	5.50	5.20
11/14/90	16	11	1990	.57	.55	.66	.57	1.40	.02	.19	13.61	6.40	6.30	6.10
12/11/90	16	12	1990	.51	.48	.38	.37	2.00	.03	.08	3.66	6.70	6.60	5.90
1/09/91	16	1	1991	.50	.09	.40	.43	1.00	.02	.48	9.01	6.90	6.80	6.70
2/13/91	16	2	1991	.42	.41	.40	.40	1.40	.01	.03	10.70	7.40	7.40	7.00
3/13/91	16	3	1991	.55	.55	.84	.73	2.30	.01	.01	13.45	7.30	7.20	7.00
4/09/91	16	4	1991	.51	.50	.61	.63	1.70	.01	.02	8.69	7.10	7.00	6.20
5/08/91	16	5	1991	.55	.54	.56	.51	1.40	.01	.02	24.84	5.60	5.60	5.40
6/12/91	16	6	1991	.58	.57	.46	.32	1.00	.01	.02	18.93	5.30	5.40	4.60
7/16/91	16	7	1991	.91	.79	.84	.71	.97	.12	.21	62.85	6.80	6.20	.60
8/14/91	16	8	1991	.86	.79	.67	.56	.50	.07	.23	14.90	5.40	4.30	2.30
9/11/91	16	9	1991	1.05	.94	.56	.45	1.80	.11	.01	21.03	5.80	5.40	4.80
10/09/91	16	10	1991	.78	.77	.52	.32	.61	.01	.05	14.66	7.20	6.90	6.60
11/06/91	16	11	1991	.41	.40	.37	.29	1.10	.01	.04	13.53	6.46	6.36	6.31
12/04/91	16	12	1991	.41	.40	.32	.32	1.00	.01	.05	6.09	6.74	6.60	6.34

Appendix Table C. Results from the City of Tampa compliance monitoring in Hillsborough Bay for station COT17 for the years 1990-1991. Missing values: a CBOD5 sample was collected by the COT in April 11, 1990, but the sample was not analyzed by the EPC.

DATE	STA	MO	YEAR	TN ppm	TKN ppm	TP ppm	PO4 ppm	CBOD5 mg/l	NO2+NO3 ppm	NH3 ppm	CHL-A ug/l	SDO mg/l	MDO mg/l	BDO mg/l
1/10/90	17	1	1990	.72	.71	.44	.46	.90	.01	.06	8.99	6.90	6.80	6.80
2/14/90	17	2	1990	1.03	.98	.62	.56	1.20	.05	.17	7.05	6.70	6.40	6.40
3/14/90	17	3	1990	.72	.70	.44	.84	.61	.02	.06	7.92	7.00	7.00	6.80
4/11/90	17	4	1990	.82	.76	.60	.53		.06	.05	11.02	5.50	5.40	5.30
5/09/90	17	5	1990	.52	.51	.50	.49	1.26	.01	.08	23.83	5.80	5.80	5.80
6/13/90	17	6	1990	.52	.52	.57	.50	1.10	.01	.06	20.89	5.40	5.20	5.10
7/18/90	17	7	1990	.59	.56	.56	.55	1.90	.03	.04	38.79	5.90	5.80	5.60
8/15/90	17	8	1990	.87	.87	.63	.62	1.20	.01	.10	33.83	5.60	5.50	5.50
9/12/90	17	9	1990	.74	.73	.55	.56	1.40	.01	.09	12.85	4.90	4.80	4.70
10/10/90	17	10	1990	.57	.56	.47	.33	1.00	.01	.10	9.96	5.90	5.80	5.80
11/14/90	17	11	1990	.57	.54	.51	.42	1.10	.03	.19	14.10	6.80	6.70	6.70
12/11/90	17	12	1990	.57	.54	.32	.33	2.10	.03	.08	2.38	6.60	6.40	6.20
1/09/91	17	1	1991	.50	.11	.41	.43	1.00	.01	.49	9.67	6.60	6.60	6.50
2/13/91	17	2	1991	.31	.36	.43	.46	1.20	.01	.03	10.40	7.40	7.30	7.30
3/13/91	17	3	1991	.56	.55	.51	.30	2.00	.01	.01	11.42	7.40	7.30	7.30
4/09/91	17	4	1991	.58	.57	.71	.84	1.80	.01	.07	9.99	6.80	6.60	6.60
5/08/91	17	5	1991	.49	.48	.49	.41	1.70	.01	.01	23.07	6.10	6.10	5.90
6/12/91	17	6	1991	.49	.34	.37	.29	1.00	.15	.06	15.43	5.80	5.60	5.60
7/16/91	17	7	1991	1.30	1.19	1.12	.72	.75	.11	.15	58.68	7.60	7.50	6.30
8/14/91	17	8	1991	.67	.67	.61	.55	1.06	.01	.21	20.87	6.70	6.20	4.70
9/11/91	17	9	1991	.91	.89	.50	.46	1.90	.02	.01	21.89	5.60	5.60	5.60
10/09/91	17	10	1991	.76	.76	.48	.33	.51	.00	.05	15.16	6.70	6.60	6.50
11/06/91	17	11	1991	.54	.51	.38	.32	1.20	.03	.05	7.89	6.54	6.21	6.23
12/04/91	17	12	1991	.78	.77	.31	.29	1.00	.01	.08	5.27	6.48	6.26	6.29