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Recent improvements of water quality and biological indicators in Hillsborough Bay, the northeastern section of Tampa Bay, Florida

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RECENT IMPROVEMENTS OF WATER QUALITY AND BIOLOGICAL INDICATORS IN HILLSBOROUGH BAY, THE NORTHEASTERN SECTION OF TAMPA BAY, FLORIDA.

SUBMITTED TO
AMSA

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INTRODUCTION

Hillsborough Bay (105 km^2 or 40 $miles^2$) is the eastern uppermost section of the Tampa Bay system (907 km^2 or 350 $miles^2$), which is one of the largest estuaries in the southeastern United States (Figures 1 and 2).* Hillsborough Bay is surrounded by a large metropolitan complex and supports extensive industrial activity (and serves as a major shipping port.

During the late 1960's, Hillsborough Bay was determined highly eutrophic and anoxic conditions were reported along its western edge by FWPCA (1969). The City of Tampa was implicated as a major point source polluter of Hillsborough Bay based on its release since 1951 of primary treated wastewater effluent into the bay. To alleviate nutrient loads to Hillsborough Bay, the City of Tampa upgraded its Hooker's Point facility to advanced wastewater treatment (AWT) with a 60 MGD capacity. The transformation from primary treatment to advanced was successive. Secondary treatment was achieved in January 1978 followed by AWT in January 1979. In July 1979, a variance for the AWT phosphorus removal requirement was issued by the Florida Department of Environmental Regulation (FDER) and secondary treatment phosphorus concentrations have been released since then. The variance was issued because earlier bioassay experiments, both by the City of Tampa and the FDER, had indicated nitrogen as the most limiting nutrient for algal growth in Hillsborough Bay.

In 1976 the City of Tampa created the Bay Study Group to initiate a comprehensive study of phytoplankton productivity and standing crop to monitor the effects of sewage pollution abatement in Hillsborough Bay. Numerous studies have shown that phytoplankton are well suited as monitors of trophic state due to their high growth rates and rapid response to changing environmental conditions. As the study has progressed other important indicators of water quality have been included in the study effort, such as submerged vegetation monitoring and test plantings of seagrasses. In addition, water quality information collected by the Environmental Protection Commission of Hillsborough County (HCEPC) will also be used in the discussion of recent water quality improvements.

Most of the information from these two long-term and independent environmental monitoring studies of Hillsborough

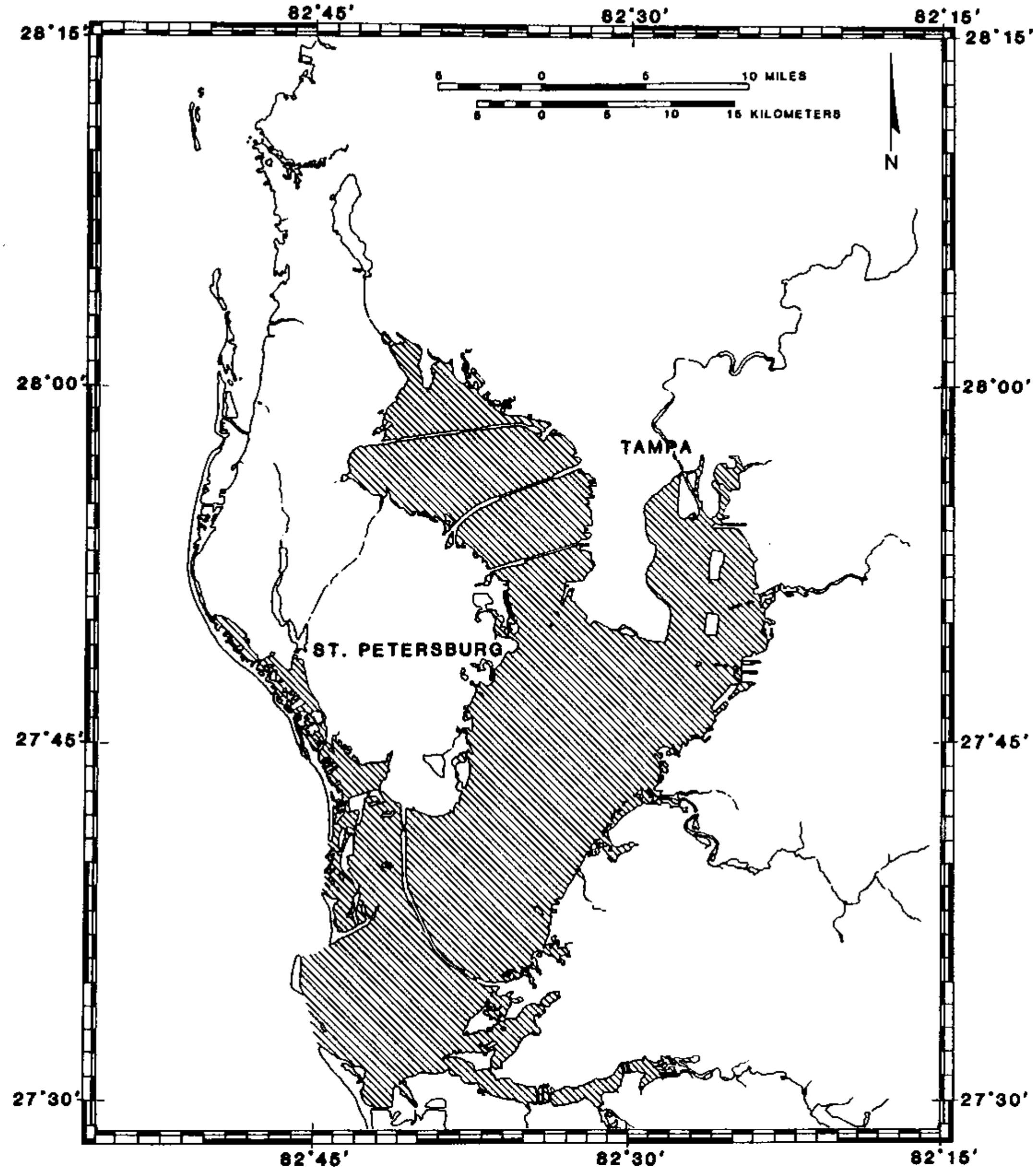

Figure 1. Tampa Bay, Florida

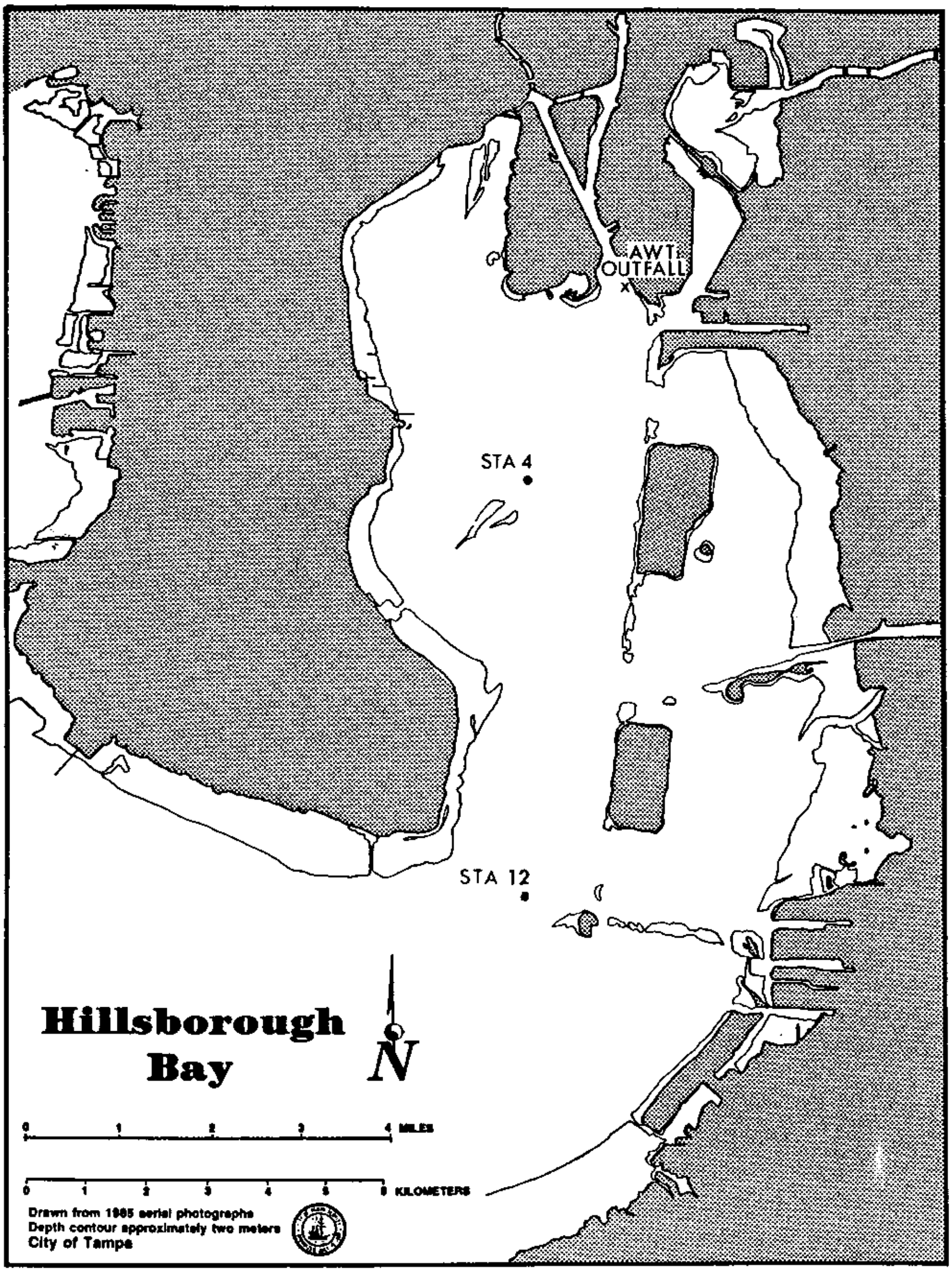

Figure 2. Hillsborough Bay and the locations of the Hooker's Point discharge and the BSG water quality stations.

Bay is not directly related to the composition of wastewater effluent. Instead, mainly indirect relationships between effluent loadings and the water quality parameters of interest may be assumed. Since comprehensive statistical analyses of the data have not yet been attempted, simple trends will be used to show that water quality conditions in Hillsborough Bay have improved since nutrient loadings were reduced in 1979.

HOOKER'S POINT EFFLUENT CHARACTERISTICS

Loadings of biochemical oxygen demand (BOD), suspended solids, total nitrogen and total phosphorus to Hillsborough Bay from the Hooker's Point AWT facility drastically decreased as the plant converted from primary to advanced treatment (Figure 3). For example, loadings of BOD, suspended solids and total nitrogen were reduced an order of magnitude or more. In addition, discharges of fecal coliform bacteria were virtually eliminated at this time. The fecal coliform bacteria count and loadings of BOD, suspended solids and total nitrogen have remained at the low AWT levels since 1979. Total phosphorus loadings have been maintained at secondary treatment levels due to the phosphorus variance. The variance was issued by FDER after the City of Tampa demonstrated that secondary releases of phosphorus from Hooker's Point were small compared to natural and industrial inputs. Further, algal bioassay experiments conducted by both the Bay Study Group and FDER indicated that nitrogen appeared to be the most limiting nutrient for algal growth in Hillsborough Bay (COT 1983; FDER 1983).

AMBIENT NUTRIENT CONCENTRATIONS IN HILLSBOROUGH BAY

Ambient concentrations of total phosphorus in Hillsborough Bay have decreased during the last 10 years (Figure 4). This trend correlates poorly with discharge levels from Hooker's Point. Considering that loadings from Hooker's Point are small relative to natural and industrial sources and that industrial discharges of phosphorus have decreased recently, this decreasing trend of ambient phosphorus concentrations can be explained (Estevez and Upchurch 1985; Fanning and Bell 1985).

There are several independent records of ambient nitrogen concentrations for Hillsborough Bay, however, reliable data do not exist prior to 1980. Therefore, since Hooker's Point started to discharge low AWT levels of total nitrogen in mid 1979, there is no record to show possible decreases in ambient nitrogen concentrations caused by the transformation to AWT. Further, nitrogen appears to be the most important nutrient to sustain the primary production of the bay, and a

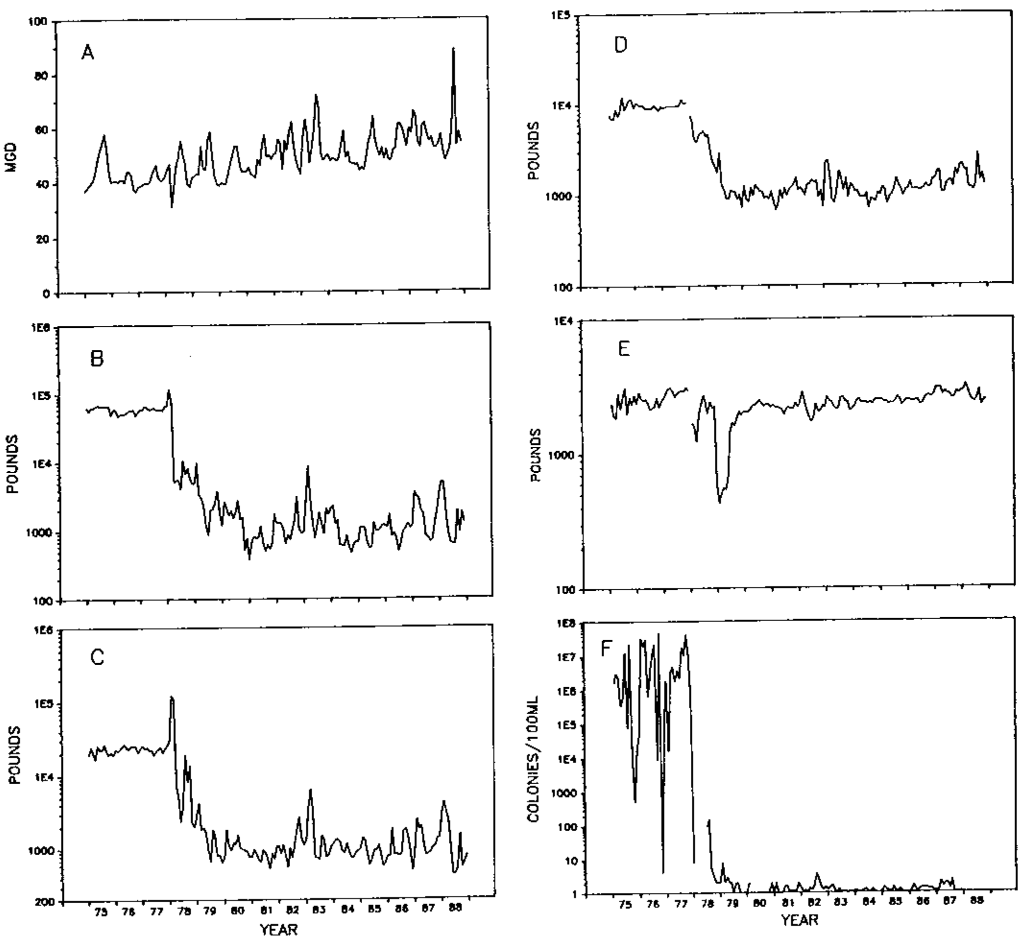

Figure 3. Hooker's Point effluent characteristics. A. Average daily flow; B. Average daily loading of BOD; C. Average daily loading of suspended solids; D. Average daily loading of total nitrogen; E. Average daily loading of total phosporus; F. Average daily loading of fecal coliform bacteria.

close relationship between ambient and discharge concentrations of nitrogen may not be expected. Dissolved species of nitrogen contained in the effluent would rapidly be converted to particulate fractions by biological activity and these particulate forms of nitrogen would not be accounted for during routine measurements of dissolved nitrogen concentrations.

Nevertheless, the importance of Hooker's Point nitrogen discharges, before and after AWT, can be theoretically assessed relative to the nitrogen demand of the water column primary production. Annual Hillsborough Bay phytoplankton production is $620 gCm^{-2}yr^{-1}$ based on ^{14}C measurements from 1978 to 1983 (Johansson et al. 1985). Water column demands are estimated by assuming that phytoplankton production accounts for nearly all of primary production and that phytoplankton assimilate nitrogen in proportion to the Redfield C:N ratio of 106:16. It is also assumed that ammonia is the nitrogen form most readily assimilated by the phytoplankton (Pennock 1987) and that pre-AWT discharges of nitrogen consisted mostly of ammonia (Pickard, Hooker's Point plant manager, personal comm.). Based on these calculations the annual phytoplankton need of ammonia is 7.8 moles m^2-yr. Primary treated discharges from the Hooker's Point plant, prior to 1979, supplied 0.4 moles m^2-yr or approximately 15 percent of the phytoplankton ammonia demand. Advanced wastewater treatment greatly reduced the amount of ammonia discharged and the plant now only supplies 0.005 moles m^2-yr or 0.06 percent of the phytoplankton ammonia demand in Hillsborough Bay. In addition, see Johansson and Squires (1989) for a detailed discussion of other important nutrient sources in Hillsborough Bay.

PHYTOPLANKTON BIOMASS AND TAXONOMIC COMPOSITION

Assuming that nutrients (mainly nitrogen) discharged from Hooker's Point significantly affect the phytoplankton biomass of Hillsborough Bay, then changes in phytoplankton parameters would be expected after AWT was initiated in 1979. Chlorophyll a concentrations, which are estimates of phytoplankton biomass, show a decreasing trend since the early 1980's (Figure 5). Levels have remained relatively constant and low since 1984. Rainfall and associated runoff have been suggested as driving forces of Hillsborough Bay water quality and it appears that a general short-term trend exists between annual averaged rainfall and chlorophyll-a concentrations (Figure 5). However, the decreasing trend of chlorophyll-a over the study period is not reflected in the trend of annual rainfall. Possibly, rainfall has immediate and short-term effects on water quality, while large and long-term changes in nutrient loadings to the bay, determine the long-term trend of water quality.

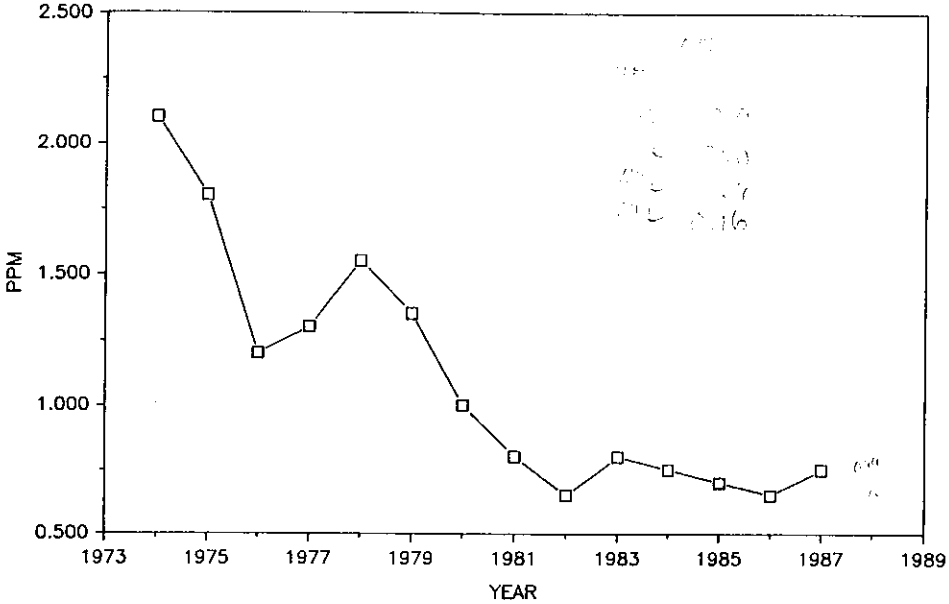

Figure 4. Ambient concentrations of total phosphorus in Hillsborough Bay. Data from HCEPC 1988.

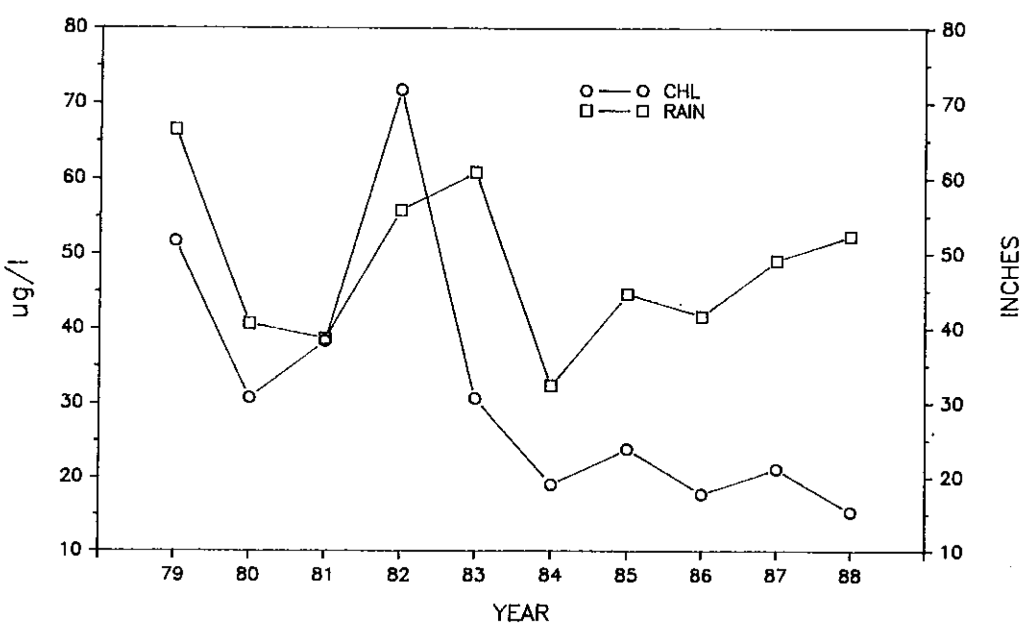

Figure 5. Annual average chlorophyll-a concentrations in Hillsborough Bay and yearly total rainfall at Tampa. Rainfall data from USCOMM (1987).

The substantial decrease of chlorophyll-a in Hillsborough Bay correlates with the loss of a planktonic filamentous blue-green alga (Schizothrix calcicola sensu Drouet), which prior to 1984 dominated the phytoplankton population from late summer to early winter (Figure 6). This alga has been present in the bay since 1984, but in much reduced concentrations. Blue-green algae are considered nuisance species and are often indicators of poor water quality (Paerl 1987). In highly eutrophic areas, they appear to outcompete more desirable phytoplankton with higher food value, such as diatoms (Hecky and Kilham 1987; Pearl 1987). Therefore, if blue-greens replace better food species such as small diatoms, less particulate organic carbon will be available to secondary production. More fixed carbon will be lost to export, the sediments, and bacterial remineralization processes, and as a result the ecological efficiency of the system will be lowered. It is difficult to demonstrate the response of the Hillsborough Bay ecosystem to the change in phytoplankton composition with the limited data available. Nevertheless, it is possible to determine an increase in efficiency of organic carbon production by the dominant primary producers (phytoplankton) of the system. The ratio, organic carbon produced by the phytoplankton per unit chlorophyll a and time (productivity index), measures how efficient the phytoplankton convert inorganic carbon to organic carbon. Increasing index values indicate a more efficient phytoplankton population. The ratio has increased severalfold in Hillsborough Bay since 1984, when the blue-greens became scarce and were replaced with a "typical" estuarine phytoplankton population consisting of highly efficient small photosynthetic flagellates and diatoms with a high food value (Figure 7). The trend of the index clearly shows that the phytoplankton of Hillsborough Bay have become more efficient producers of organic carbon during the last ten years. Consequently, it may also be assumed that the total ecosystem efficiency has increased as a response to the change in the phytoplankton population.

WATER COLUMN LIGHT TRANSPARENCY AND SEAGRASS PERSISTENCE

Phytoplankton biomass is an important factor affecting water column light penetration in phytoplankton dominated estuaries similar to Hillsborough Bay. Further, the dense concentrations of the blue-green alga S. calcicola found in the bay prior to 1984 may have magnified reductions in light penetration. Kirk (1977) found that blue-green algae reduce light to a greater degree than other phytoplankton types. Water column light penetration is an important factor limiting the survival of submerged seagrasses in estuaries. Seagrass meadows are vitally important to estuarine systems by stabilizing sediments and providing habitat for fish, shellfish, and many crustacean species. Seagrasses also

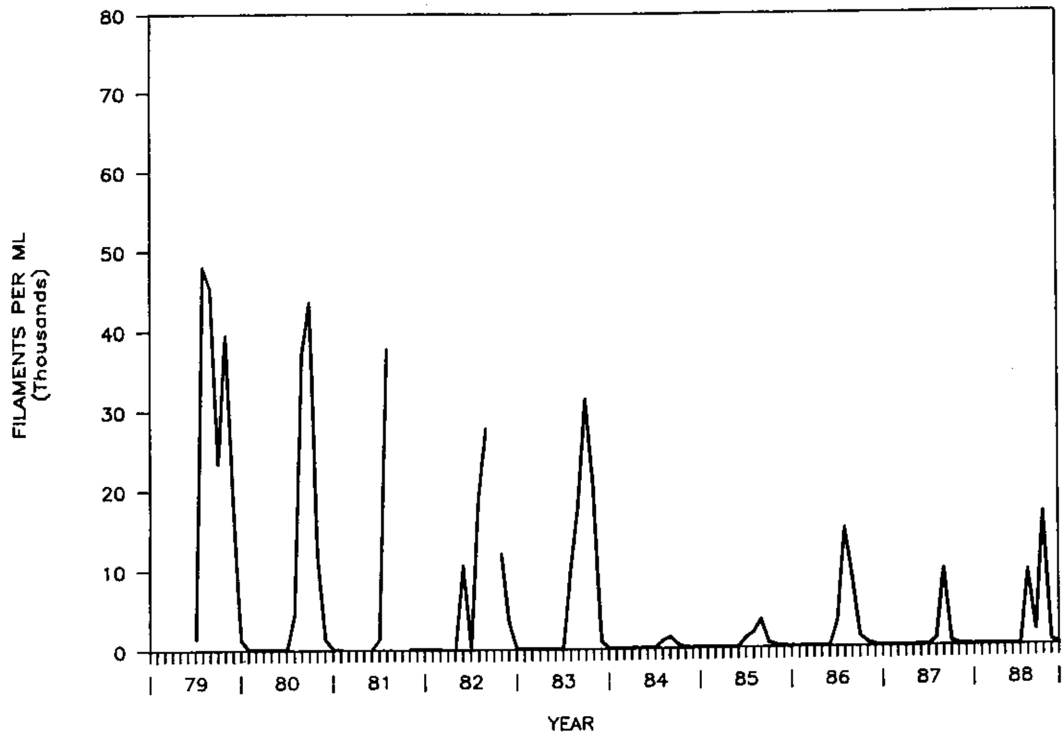

Figure 6. Monthly concentrations of Schizothrix calcicola sensu Drouet in Hillsborough Bay.

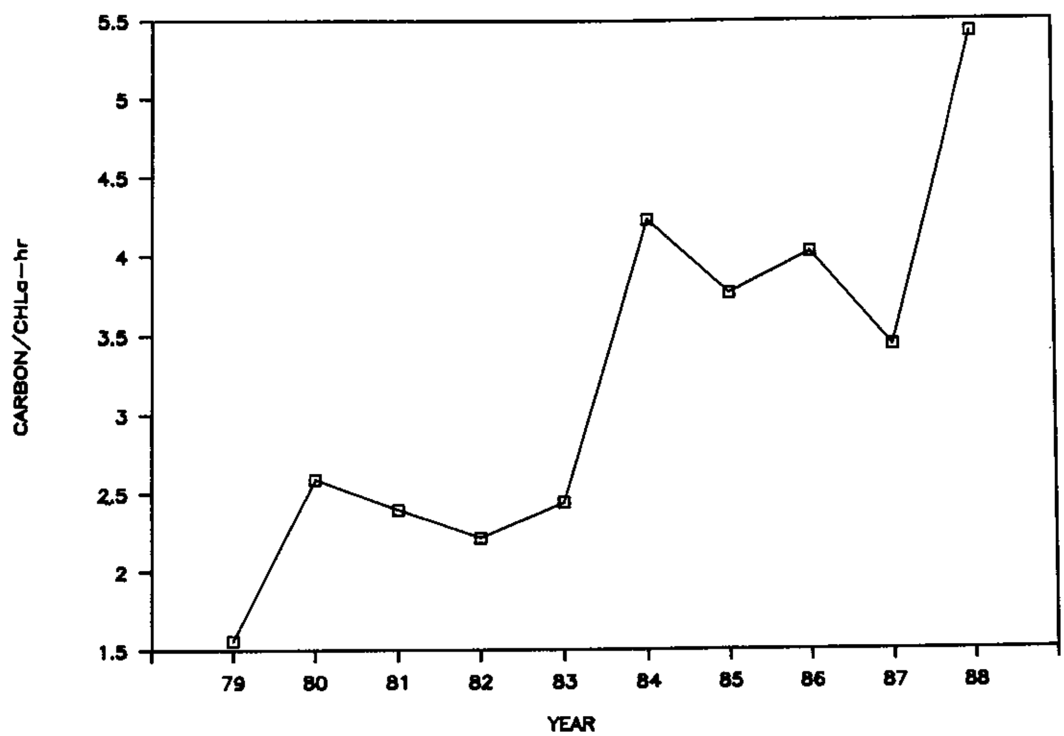

Figure 7. Annual average Hillsborough Bay productivity index.

represent a significant component of the detrital food chains.

Hillsborough Bay, and Tampa Bay as a whole, have had serious losses of seagrass. Historic records show that the areal coverage of Tampa Bay seagrasses has decreased dramatically during the last one hundred years. In 1982, approximately 20 percent of the originally estimated seagrass coverage still remained (Lewis et al. 1985). In Hillsborough Bay, the subsection of Tampa Bay which has received the heaviest impact from urbanization and which has historically had the highest levels of chlorophyll-a, all seagrasses were lost between 1950 and 1984. However, subsequent to the substantial decrease in Hillsborough Bay chlorophyll-a concentrations in 1984, and increased water column light penetration (Figure 8), modest seagrass recolonization was observed in 1985 (Lewis, Housel & Associates Inc., personal comm.). An extensive inventory of Hillsborough Bay seagrass coverage in 1986 (COT 1988) found 0.5acres of the shallow sandbars at the perimeter of the bay covered by Halodule wrightii (shoalgrass). In 1988 this coverage had doubled and in addition, deeper portions of the sandbar had been covered extensively by the rhizophytic macroalga Caulerpa prolifera. The habitat created by this alga resemble a seagrass habitat in many ways. Further, test plantings conducted by the Bay Study Group of the seagrass H. wrightii in 1987, have been successful at several locations in Hillsborough Bay, which indicate that large areas of the intertidal and shallow subtidal bottom of Hillsborough Bay may now be available for seagrass colonization.

WATER QUALITY INDEX

A general water quality index is calculated annually for each major section of Tampa Bay by the HEPC (Figure 9). The index, which includes the parameters dissolved oxygen, chlorophyll a, total coliform, biochemical oxygen demand, total phosphorus, total Kjeldahl nitrogen, and effective light penetration, produces a relative trend of water quality. Increasing index values indicate improving water quality. Reliable TKN concentrations are not available prior to 1981, however the index indicates that water quality has improved in Hillsborough Bay during the period 1981 - 1987.

CONCLUSION

Hillsborough Bay water quality has improved since 1979, when AWT discharges from the Hooker's Point facility commenced. These improvements have also been documented by HEPC (1988) and observed by FDER district personnel (Palmer and McClelland 1988). The reduced loadings of nitrogen from the

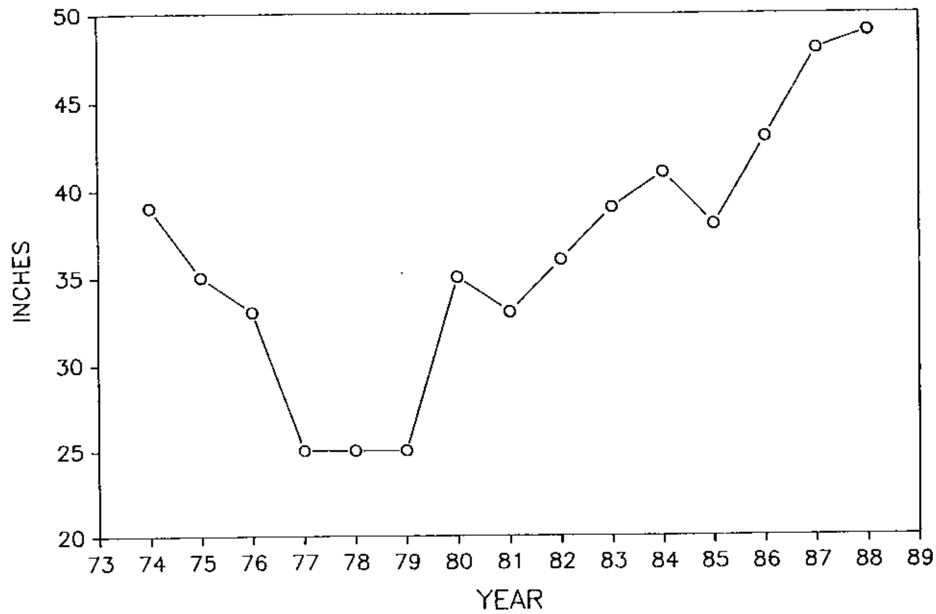

Figure 8. Annual average Hillsborough Bay Secchi disk transparency. Data from HCEPC (1988).

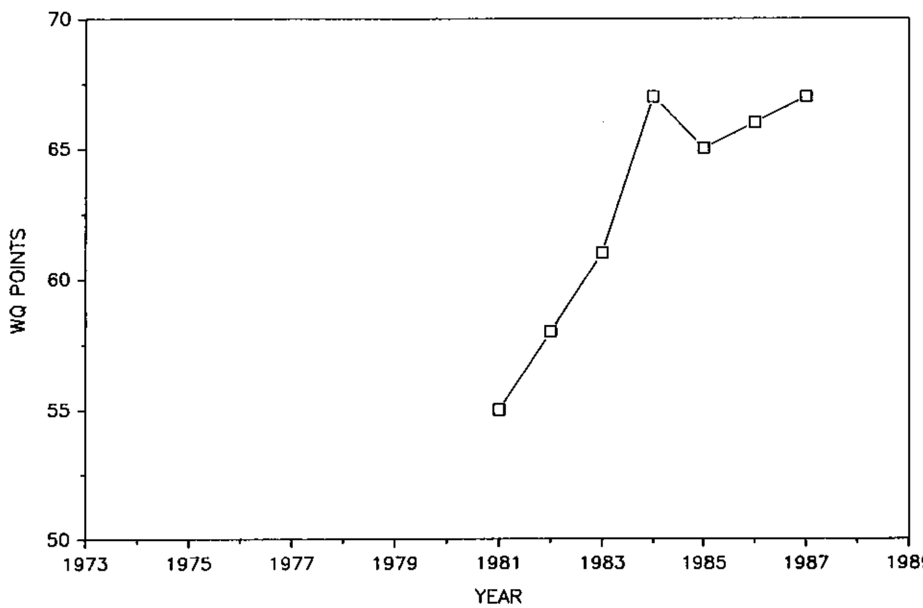

Figure 9. Annual average Hillsborough Bay water quality index. Data from HCEPC (1988).

Hooker's Point AWT facility have helped to lower the nutrient loadings to Hillsborough Bay. Therefore, less nutrients have become available for phytoplankton growth, which has apparently allowed for greater water column light penetration. Seagrasses and the attached macroalgae Caulerpa have seemingly responded to the increased light penetration by colonizing shallow areas of Hillsborough Bay. The return of seagrass meadows to the shallow bottom of Hillsborough Bay is an obvious and easy to observe phenomenon, and is considered by many local environmentally concerned organizations and individuals as an important sign of improving water quality in Hillsborough Bay.

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HILLSBOROUGH BAY PRODUCTIVITY INDEX

ANNUAL AVERAGES OF STATIONS 4 & 12