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DEVELOPMENT OF A CONCEPTUAL DESIGN FOR A BAY QUALITY INDEX FOR TAMPA BAY, FLORIDA

FINAL REPORT

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DEVELOPMENT OF A CONCEPTUAL DESIGN FOR A BAY QUALITY INDEX FOR TAMPA BAY, FLORIDA

Prepared for:

Tampa Bay National Estuary Program
111 7th Avenue South
St. Petersburg, Fl 33701

Prepared by:

Coastal Environmental, Inc.
9800 4th Street North
Suite 108
St. Petersburg, FL 33702

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency, through the Urban Institute, and in cooperation with the Tampa Bay National Estuary Program (TBNEP), has sponsored this project to investigate the technical feasibility of developing a Bay Quality Index (BQI) for Tampa Bay. The BQI was intended for a non-technical audience as a public information and education tool. The project objective was to develop a framework, or conceptual design, for a BQI that includes components for a variety of bay attributes, including physical, chemical, and biological characteristics of the bay.

The conceptual design of the Tampa Bay BQI was approached through a stepped process. Initially, consultation with the Urban Institute and TBNEP staff resulted in the development of the general form and content of the index. Examples of other BQI's from Buzzards Bay and Chesapeake Bay, as well as the Environmental Protection Commission (EPC) of Hillsborough County's water quality index were reviewed. Secondly, a workshop was held at which it was suggested that the index be composed of three major components or attributes: Water Quality, Living Resources, and Impaired Uses. The workshop participants made further recommendations regarding specific variables to be considered for inclusion in each bay attribute.

Based on the input from the workshop and previous discussions with the Urban Institute and TBNEP staff, potential data sources for use in developing a BQI were identified and acquired if possible. The conceptual approach to calculating a BQI includes four steps: 1) ranking data for each variable into classes ranging from very poor to excellent, whereby each was assigned a value from 1 (very poor) to 5 (excellent); 2) combining class values for each bay attribute into a Score; 3) calculating a sub-index from 0 (worst) to 10 (best) based on the Score for each bay attribute; and 4) combining sub-indices calculated for all bay attributes into a single BQI representative of overall bay quality.

Three methods for ranking variables were examined: 1) a Subjective method through use of professional judgement; 2) an Objective method based on the frequency distributions of the existing data; and 3) a Mixed method based on state water quality standards and frequency distributions of existing data. Example calculations of water quality index values were compared to reported EPC water quality index values and were found to be consistent with respect to trends with time for each bay segment.

The state of data availability for living resources and impaired uses was not adequate to perform example calculations of a composite BQI for Tampa Bay. Nevertheless, available data for water quality did indicate that a Subjective approach to calculating attribute indices of the BQI may be feasible and reflective of bay quality conditions as perceived by the scientific community of Tampa Bay.

In order for a BQI that incorporates attributes of Water Quality, Living Resources, and Impaired Uses to be realized, input would be necessary from a variety of individuals with expertise that can be grouped into each identified bay attribute. It may be extremely difficult to reach a consensus among experts when attempting to assign classes (poor, good, excellent) to numbers of manatees, nesting pairs of birds, fish and seagrass acreage. Additional complexities may arise when deciding if each data variable of an attribute, or each attribute of the BQI, deserves equal weight with respect to other variables and attributes.

The following recommendations are offered in order to calculate a composite BQI:

1. Given the strengths and weaknesses of the Subjective and Objective methods to assigning variable values to classes, a Subjective approach may be more appropriate for incorporating a wide variety of bay attributes as is intended for the BQI.

2. A group of experts, specific to each bay attribute, should be convened to identify the appropriate data variables to use as indicators of bay quality.

3. The identified data for each attribute should be compiled to ensure that those data are available in an appropriate form for inclusion in a BQI calculation.

4. Upon reviewing available data for each variable, each group of experts should assign ranges of variable values to classes from very poor to excellent (1-5). State standards, representative data from Tampa Bay, and representative data from estuaries other than Tampa Bay, should be used when deciding how variable values are assigned to each class.

5. Test calculations should be performed to evaluate the sensitivity of each attribute index, and to assess if reasonable and informative judgements can be made from each attribute index value and from the overall Bay Quality Index value.

1.0 INTRODUCTION

1.1 BACKGROUND INFORMATION

The U.S. Environmental Protection Agency, through the Urban Institute, and in cooperation with the Tampa Bay National Estuary Program (TBNEP), has sponsored this project to investigate the technical feasibility of developing a Bay Quality Index (BQI) for Tampa Bay. The intent of the proposed index is to provide a sound, reliable composite indicator of overall quality of Tampa Bay and its major components. The index should capture the major characteristics of the bay in a straightforward, simplified manner that can easily be interpreted by public and private officials as well as the general public at large.

A need has been recognized to communicate the status of Tampa Bay in simple terms, to a non-technical audience. It is also recognized that estuaries are complex systems and it can be difficult for a non-technical audience to understand system status in regard to ecological health. Furthermore, the implementation of sound management options are often dependent on the ability of the scientific community to convey information to decision and policy makers that may lack a scientific background. Developing an index that reflects the overall quality of the bay as perceived by the scientific community, would constitute an important tool used to convey the condition of a complex system in simple terms to a lay audience. The Bay Quality Index, therefore, is intended to reflect the relative quality (e.g., poor or good) of the bay as perceived by the local scientific community.

Using an index to convey the quality of an ecological system is not a new idea. The Environmental Protection Commission of Hillsborough County (EPC) in Tampa, Florida has been using a water quality index calculated from seven water quality parameters that are collected monthly in Tampa Bay. The Maryland Department of the Environment has developed two environmental indices that evaluate nutrient reduction strategies under implementation in Chesapeake Bay, Maryland (MDE, 1992). The first index is a nutrient load index that quantifies point and non-point source loads of nitrogen and phosphorus. The second environmental index depicts water quality trends from the parameters of total nitrogen, total phosphorus, chlorophyll-a, dissolved oxygen, and Secchi depth. The Eutrophication index, used by the Buzzards Bay Citizens' Water Quality Monitoring Program, in Massachusetts (Coalition for Buzzards Bay, 1992), was modeled after the EPC water quality index currently used in Tampa Bay.

The project objective, as supported by the Urban Institute, was to develop a framework, or conceptual design, for a BQI that include multiple components encompassing a variety of bay attributes that are reflective of the quality of Tampa

Bay. Ideally, the BQI would incorporate physical, chemical, and biological characteristics of the bay, and allow for periodic re-calculations over time (seasonally and annually). An acceptable BQI would enable non-technical people to assess the relative "quality" among bay segments, and to follow changes in "quality" of bay segments over time.

The index was also intended to incorporate quality attributes which affect many users of the bay (e.g., boating, fishing, commercial, swimming, aesthetics, ecological health) and be computable for the bay as a whole as well as for identified bay segments. In addition, the BQI was also intended to include a provision for reporting sub-indices on key attributes (e.g., Water Quality, Living Resources, Impaired Uses).

There are several points regarding development of this index that should be recognized at the outset:

- Computations of the index are not expected to replace expert opinion of bay quality, but rather to be generally consistent with expert opinion.

- This index is not proposed to replace the Environmental Protection Commission of Hillsborough County (EPC) water quality index.

- The biases of the group that may set the ranges of variable (data) values regarded as "poor" or "good" will be reflected in this index. This is necessarily true since value judgements are required to set these ranges.

- The ranges of variable values classified from "very poor" to "excellent" are arbitrary and that adjustment of these ranges can be made. The values presented in this report are an initial attempt at setting these ranges and can be adjusted as desired by the TBNEP and its advisors.

- It is difficult to capture in one index all relevant components of "bay quality," and thus, the BQI is not likely to satisfy all factions of the scientific community. The goal of developing the index is, however, to facilitate communication of the changing health of the bay to a non-scientific audience (i.e., elected officials, decision-makers, and the general public), and is intended to foster public awareness of general trends in bay quality.

The conceptual design of the Tampa Bay BQI was approached through a stepped process. Through consultation with TBNEP staff and Urban Institute representatives, the general content and form of the index were developed. A TBNEP sponsored workshop was subsequently held June 22, 1993, to provide direction for further development of the BQI design. Shown below is a list of individuals that attended the workshop. A summary of the workshop is provided in Appendix A.

- Holly Greening, TBNEP
- Andy Squires, Coastal Environmental, Inc.
- Doug Heimbuch, Coastal Environmental, Inc.
- Roger Johansson, City of Tampa
- Richard Boler, EPC
- Peter Clark, TBRPC Agency on Bay Management
- Jim Culter, Mote Marine Laboratory
- Joe O'Hop, FDEP Marine Research Institute

Throughout this report, the following terms are used to describe various components of the BQI conceptual design:

- Attribute: a category of bay quality (e.g., Water Quality, Living Resources, Impaired Uses);

- Variable: a measured quantity used as an indicator of quality that is associated with a specific attribute;

- Class: a range of values for each variable assigned to each level of quality from very poor to excellent.

- Class Value: an integer, assigned to each class from very poor (1) to excellent (5).

- Score: the sum of all class values for a given attribute.

The following bay attributes for possible inclusion into a BQI, created from a "brainstorming" approach, were presented and discussed at the workshop:

- Water Quality,
- Sediment Quality,
- Living Resources,
- Pollutant Loading,
- Watershed Characteristics,
- Regulatory Activities.

The workshop participants expressed the viewpoint that a BQI should not address variables that may be causing an observed condition in the bay (e.g., ambient nutrient concentrations). Rather, a BQI should focus on those variables reflective of the actual condition of the bay itself (e.g., chlorophyll-a concentrations). Consequently, the group agreed to eliminate three potential attributes that were discussed for possible inclusion in the index: Pollutant Loadings, Watershed Characteristics, and Regulatory Activities. The group did recognize that some of the variables of the eliminated attributes may be relevant to factors reflective of bay quality. Some of those variables, were in turn, placed in a newly created bay attribute called "Impaired Uses."

Each of the remaining bay attributes that are addressed below was discussed separately at the workshop to determine the appropriate variables that should be considered for a BQI. The group was informed that as the BQI was currently conceptualized, a separate sub-index would be calculated for each attribute, and then all attribute indices could be combined to calculate an overall BQI.

1.2 WATER QUALITY

Water quality data variables agreed upon by the group that warranted further consideration for use in a "Water Quality Index" (WQI) component of the BQI included:

- dissolved oxygen,
- chlorophyll-a,
- water clarity (Secchi disc depth or photosynthetically active radiation),
- total suspended solids.

Most participants felt that dissolved oxygen was important because it supports living resources. The current and past sampling methods used in Tampa Bay by the EPC, however, may not sample at the most appropriate time to characterize worst case conditions (i.e., at dawn) when concentrations may be the lowest. It is very difficult to distinguish degraded habitats from healthy habitats using dissolved oxygen information collected at mid-day. Consequently, the participants felt that the incorporation of dissolved oxygen into a WQI component of the BQI may not be appropriate to "back" calculate an index (i.e., calculate an index for a historical period) using the available data collected by EPC. It could, however, be used in the future if the current monitoring practices are modified.

Chlorophyll-a, a measurement of phytoplankton biomass, is an excellent indicator of water quality. High phytoplankton biomass often results from excess nutrient input to a system, and the existence of phytoplankton, along with water color, turbidity, and suspended solids, are significant variables affecting water column light attenuation or water clarity.

The use of Secchi Disappearance Depth (SDD), or Photosynthetically Active Radiation (PAR) measurements were agreed upon by the workshop participants, as the most appropriate water clarity variables to include in the WQI. The SDD is a simple measure of how deep in the water column a black and white disc can be seen by an observer at the surface. The technique provides a simple and reliable means to assess water clarity, and the method has been widely used for many years in aquatic research. Unfortunately, if the SDD is greater than the water depth, no relative measure of water clarity can be determined since the Secchi disc would be visible while resting on the bottom. For this reason, SDD is not appropriate for shallow areas, those areas where water clarity is most meaningful in regard to light availability to seagrasses. An alternative measure of water clarity is to measure PAR. PAR measurements are made with a light meter and PAR measures the attenuation of light within the water column. In areas where water clarity is considered good, accurate PAR measurements can often be made at much shallower depths compared to SDD. PAR measurements have not been widely used in Tampa Bay monitoring programs to date, but their use has been strongly recommended for future assessments of Tampa Bay water clarity.

The inclusion of other water clarity variables into the WQI, such as color and turbidity, were also discussed. Participants thought that color would be adequately represented in SDD or PAR measurements, and thus it would be redundant to add color to the WQI. Turbidity is a measure of the optical property of a sample which causes light to be scattered or absorbed instead of transmitted through the water column (Boler, 1992). Properties affecting turbidity include suspended particles such as bottom sediments, other inorganic particulate debris, or microscopic plankton. Factors affecting turbidity in the water column may also influence SDD or PAR measurements to some degree, and turbidity was also viewed as being somewhat redundant to the total suspended solids (TSS) present in the water column.

TSS were agreed upon by the group to be the fourth and final variable for possible use in the WQI. TSS may partially be accounted for in chlorophyll-a and SDD or PAR measurements. However, TSS is a measure of the amount of particulate material in the water column, whereas turbidity measures how such materials affect properties of light absorption and scatter. Heavy particulate loads can have adverse affects on filter feeding organisms by clogging their feeding apparatus or on fish by clogging their gills.

The group also agreed that ambient concentrations and nutrients were not necessary or desired as a WQI variable. Particulate fractions of nutrients that have affected actual water clarity conditions are included in the chlorophyll-a (phytoplankton biomass) and total suspended solids data variables. Dissolved inorganic nutrient concentrations could be representative of potential phytoplankton growth, however, their concentrations would be more reflective of causative agents of water quality rather than a measurement of actual water quality. For example, if dissolved inorganic nitrogen (ammonia and nitrite-nitrate nitrogen) concentrations were extremely high in a water body, but other environmental conditions were not conducive to phytoplankton growth (e.g., water temperature and/or light), then the phytoplankton biomass (measured as chlorophyll-a) would remain low, and the resultant water quality would be favorable. Using total nitrogen and phosphorus would not add any new relevant information to a WQI that is not already included in the other variables recommended for inclusion.

Overall, the group was in favor of limiting the number of variables in the bay attribute of water quality to dissolved oxygen, chlorophyll-a, TSS, and SDD or PAR, to adequately characterize and simplify the determination of a WQI.

1.3 SEDIMENTS

Potential sediment variables considered for inclusion in the calculation of a "Sediment Quality Index" (SQI) of the BQI included sediment metal concentrations and sediment toxicity. Since no periodic monitoring of these variables have been performed in Tampa Bay, and since the monitoring of sediment variables that may be appropriate for a SQI are not planned, the group agreed to eliminate the attribute of "Sediments" from consideration at this time.

A few of the variables originally included with the "Sediment" attribute, as well as other variables deemed inappropriate for the bay attributes previously identified, were combined into a new attribute called "Impaired Uses," which is subsequently discussed.

1.4 LIVING RESOURCES

Variables agreed upon by the group that warranted further consideration for possible inclusion into a "Living Resource Quality Index" (LRQI) included:

- seagrass acreage,
- mangrove acreage,
- saltmarsh acreage,
- juvenile fish,
- recreational fish (catch per unit effort),
- crab/shrimp catch (FDEP),
- benthic index,

- marine mammals (manatees/dolphins),
- colonial nesting birds, and
- scallop counts.

The vegetative habitat acreage for seagrasses, saltmarshes, and mangroves can be obtained from the periodic assessments performed by SWFWMD SWIM. Fish population data are collected by the Florida Department of Environmental Protection, Marine Research Institute (MRI) in St. Petersburg, Florida. A bay-wide benthic monitoring program for Tampa Bay, using methods patterned after the U.S. EPA EMAP-E program, was initiated in September 1993. Work is underway to develop a "benthic index" with data collected from EMAP-E programs, and thus, a "benthic index" for Tampa Bay may be available in the near future. Marine mammal and nesting bird information should be investigated further to determine if quantitative density data are available and if they can be related to the quality of living resources in Tampa Bay with a reasonable degree of confidence. In addition, the TBNEP initiated a citizen's scallop monitoring program during the summer of 1993, and thus, scallop densities may be available on a periodic basis in the future.

1.5 IMPAIRED USES

"Impaired Uses" provided an attribute for several variables previously grouped in other attributes. Workshop participants had little input regarding the actual application of data for several of these variables. It was suggested that the types of data that are available for these variables be investigated, and depending on what is available, a recommendation of what further use each variable can provide in developing an "Impaired Uses Index" (IUI) should be presented.

Variables agreed upon by the group that warrant further consideration included:

- shellfish bed closures,
- sediment toxicity,
- sediment metals,
- coliform counts,
- red tide counts,
- number of fish kills, and
- blue-green algae blooms.

1.6 CONCLUDING REMARKS

The data available for the variables listed under each of the agreed upon bay attributes that were developed during this workshop (water quality, impaired uses, living resources) were compiled. Based on the available information, a conceptual design and some potential alternatives for calculating a BQI were developed.

2.0 METHODS

2.1 COMPILATION OF AVAILABLE DATA

Available data were compiled from the sources identified below. Water quality data, collected monthly, were readily available from the EPC. In other cases, such as variables for living resources, only some data were readily available, and many of those data have only been collected at a frequency of once every one or two years. A very limited amount of data collected periodically was readily available for the Impaired Uses attribute. Given the limited effort allowable to acquire data for identified variables, and the anticipated difficulty in assigning variable value ranges to classes (very poor to excellent), all potentially useful data were not obtained. As a consequence, an overall BQI incorporating all bay attributes, was not calculated, however, historical data were available for example Water Quality Index (WQI) calculations to characterize conditions since the mid 1970's.

2.1.1 Water Quality

Bay water quality data were readily available from the EPC for the variables chlorophyll-a, water clarity (SDD), bottom dissolved oxygen, total suspended solids and turbidity. Photosynthetically Active Radiation (PAR) data were recommended for inclusion in the WQI as an alternative for SDD, however, PAR data are not periodically collected by the EPC. The City of Tampa currently collects PAR information, but their data are not collected bay-wide.

Data from sites located in Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, and Lower Tampa Bay segments, as delineated by Lewis and Whitman (1985), for the water quality variables of chlorophyll-a, SDD, total suspended solids, bottom dissolved oxygen, and turbidity, were retrieved from the EPC data records. Only the existing EPC stations in these four bay segments that were recommended for inclusion in the TBNEP water quality monitoring program (Coastal Environmental, Inc., 1993), were used. These site locations were assessed as being chosen at random (i.e., without significant bias) and serve as being reflective of the overall areal conditions of each bay segment. The EPC sites that were not included, were located near areas of special concern (e.g., point sources), or possibly for convenience (e.g., near channel markers). Since some of the older data include more than one measurement per month at a given site, monthly mean values were calculated for each parameter at each bay site. In order to generate tables of data for WQI calculations, mean annual values for each variable were determined for the entire bay as well as for each bay segment.

It was discovered that the ongoing monitoring program conducted by EPC only provides total suspended solids (TSS) data at a few sites (e.g., six in 1990) bay-wide, and thus, the use of TSS data will not be adequate for inclusion into example calculations of the WQI. As a possible alternative indicator of suspended solids, available turbidity data, which provides good long-term spatial coverage at all EPC sampling sites, were retrieved from the EPC data for use in demonstration calculations.

Available water quality data from 1974 through 1990 are listed in Appendix B.

2.1.2 Living Resources

Living resource data were available for seagrasses, mangroves, and marine mammals. Much of the living resource data were not easily obtainable. Data for variables that were available were often collected during different time periods and at different frequencies, and thus, are difficult to incorporate into an index calculation. Information for several other suggested variables, (fisheries, benthic indices, colonial nesting birds), were not readily available; suggested sources of these data are discussed below.

2.1.2.1 Vegetative Habitats

The seagrass habitat areal coverage values used for 1982 were those values reported by Lewis et al. (1991), from data originally interpreted through a cooperative study between the U.S. Fish and Wildlife Service and the Florida Department of Natural Resources (Haddad 1989), and by the SWFWMD SWIM program, respectively. The 1988 and 1990 seagrass habitat areal coverage values were those determined by the SWFWMD SWIM program as part of their periodic mapping of seagrasses in Tampa Bay. Areal seagrass coverages were compiled for each bay segment for the years 1950, 1982, 1988, and 1990.

Areal coverage data for mangroves and marshes by bay segment in 1990 were compiled from SWFWMD data. Mangrove and marsh coverage data for other years were not readily available.

Existing information on seagrasses, mangroves, and saltmarshes will only yield areal estimates, which may not reflect the quality or functionality of these habitats. If vegetative data variables are to be included in a Living Resource Quality Index (LRQI), it is recommended that an areal estimate of "functionally healthy" vegetative habitats for each vegetative type be used. In such a case, the term "functionally healthy" should be carefully defined.

Compiled seagrass, mangrove and marsh data, as described above, are listed in Appendix C. Each of these data sets could potentially be used as variables for inclusion in a LRQI.

2.1.2.2 Marine Mammals

Marine mammal information, also collected by the FDEP at the Marine Research Institute (MRI) in St. Petersburg, Florida and by Reynolds et al. (1991), were obtained for possible inclusion as variables in the LRQI. Biweekly (1987-1989) and monthly (1989-1990) bottlenose dolphin and manatee counts were reported by Weigle et al. (1991) and Reynolds et al. (1991), respectively. These data are listed in Appendix D.

2.1.2.3 Fisheries

Fishery data are available from the MRI in St. Petersburg, Florida. Seasonal estimates of juvenile fish population densities are available from the Fisheries Independent Monitoring Program (FIMP). These data have been obtained from the MRI, however, the choice of representative species for inclusion into the LRQI, as well as the ranking criteria to determine appropriate classes for each chosen species has not been developed to date. The possible use of these data into the LRQI would require a considerable level of effort and additional discussion. The MRI also has information on commercial landings of shellfish and finfish for counties that fall into the Tampa Bay estuary. These data represent the fishery landings that are reported (brought to shore) for each county. Trip ticket information used to collect fisheries landing data includes a category for where fish are caught. Although Tampa Bay is listed as a possible area where fish are caught, information for this category is only provided on a voluntary basis, and thus it is often not provided. Nevertheless, these fishery landing data could provide useful information for further development of a LRQI

A description of the database containing juvenile fish data collected by the MRI are listed in Appendix E.

2.1.2.4 Birds

Bird count data from Tampa Bay are available from publications and from local organizations affiliated with the National Audubon Society. Bird count information from 1988 through 1992 is available from data published in the annual Christmas Bird Count volumes of *American Birds (1988, 1989, 1990, 1991, and 1992).* Bird counts of the following species, for example, are listed in *American Birds*.

- Brown Pelican
- Double-crested Cormorant
- Anhinga
- Laughing Gull
- Great Blue Heron
- Great White Heron
- Little Blue Heron
- Roseate Spoonbill
- Great Egret
- Reddish Egret
- Belted Kingfisher
- Black Skimmer

The development of a digital data set from information available in *American Birds*, will entail a high level of effort. It is recommended that other data sources that may be more relevant to bay quality be considered. The Tampa Bay Sanctuary of the National Audubon Society performs periodic counts of nesting pairs of colonial birds that inhabit islands within the Tampa Bay area. Although information from the Tampa Bay Sanctuary of the National Audubon Society could not be obtained for this report, it may be the most relevant bird data for inclusions into a LRQI.

2.1.3 Impaired Uses

Data for the Impaired Uses attribute for possible use in an "Impaired Uses Quality Index" (IUQI) have not been compiled. Data associated with at least two variables; shellfish bed closures, and total coliform bacteria counts, should be available from the FDEP and the EPC, respectively. Information on shellfish bed closures in Tampa Bay is available from the FDEP in Port Charlotte, Florida (James Seagle). Total coliform bacteria data are available from the EPC. Appropriate data for other variables (toxicity, sediment metals, red tide counts, fish kills, algae blooms) suggested by workshop participants for consideration in the IUQI have not been obtained to date. It is unlikely that monthly or quarterly bay-wide measurements of red tide and blue-green algae bloom cell counts exist for the entire Tampa Bay system. Information on fish kills, red tides, and algae blooms may be available for limited time periods from the MRI in St. Petersburg, Florida. The City of Tampa examines samples for phytoplankton taxonomic analyses monthly at one station in Middle Tampa Bay and at two stations in Hillsborough Bay.

2.2 DESIGN OF BAY QUALITY INDEX

The conceptual design will allow for the calculation of an index (or sub-index) for each bay attribute (Water Quality, Living Resources, Impaired Uses) as well as an index (the BQI) that include all attributes. The design as presented gives equal weight to each variable and to each bay attribute, however, it could easily be modified to include unequal weighting factors to data variables and/or bay attributes. In addition, it incorporates an ordinal component (ranking of each variable value into a class) into the calculation of the index. An ordinal approach is appropriate for the Living Resource and Impaired Uses attributes since they contain biological population variables that typically are not normally distributed. In order to combine Living Resource, Impaired Uses, and Water Quality attribute indices into a BQI, an ordinal approach was chosen for all three attribute index calculations.

A four step process is used to determine a BQI:

1) for each attribute, variable values are **classified** from very poor (1) to excellent (5);

2) for each attribute, a **score** is determined from the sum of all class values for a given attribute;

3) for each attribute, a **Water Quality Index (WQI)** from 0-10 is calculated from the score;

4) all attribute index values are combined to calculate a **Bay Quality Index (BQI).**

Figure 2.1 illustrates the conceptual approach for the development of a BQI. The approach developed for a BQI, as outlined above, is based on a classification of variable values for each respective attribute (Water Quality, Living Resources, Impaired Uses) into one of five possible class values, 1-5, representing very poor, poor, medium, good, and excellent quality, respectively. The sum of class values for all variables within a given attribute will result in a "score." The highest possible score will occur when all variables classes are excellent (class 5). The score for a given attribute can then be converted to an attribute quality index value from 0 (worst) to 10 (best) by the following equation:

$$\textit{ATTRIBUTE QUALITY INDEX} = \frac{\left(\left(\frac{10}{MSP} \times Score\right) - 2\right)}{8 \times 10} x100 \qquad \text{Equation 1}$$

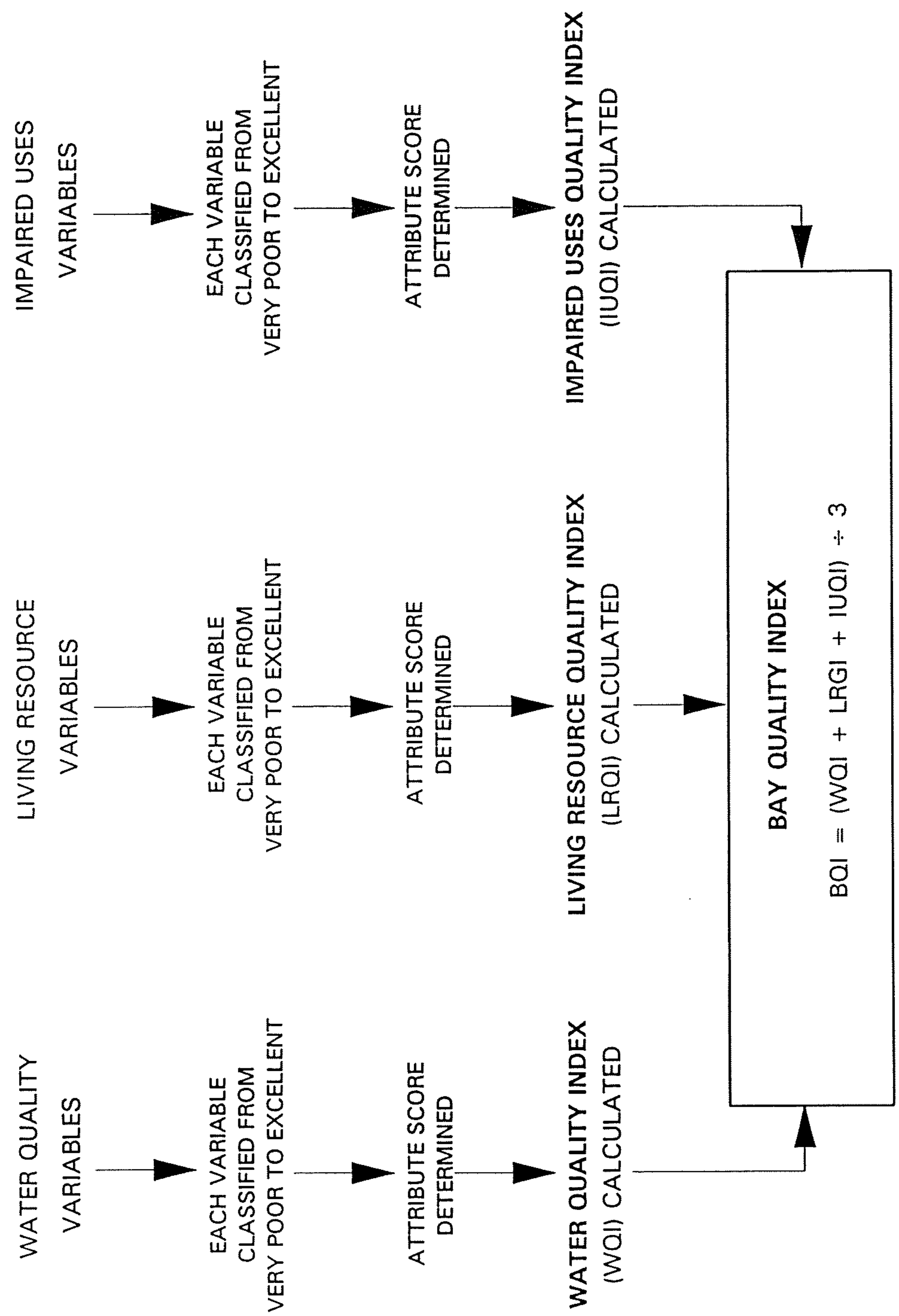


Figure 2.1 Conceptual approach for a BQI.

where,

MSP = Maximum Score Possible; for example, if 4 variables are ranked into five classes from 1-5, then the MSP would occur when all variables are in class 5, thus the MSP = 4 x 5, or 20.

Score = the sum of class values from all variables of a given attribute.

The coefficients (-2, 8, and 10) in equation 1 are specific to the number of variables for each attribute and the number of possible class values. They are essentially used to scale the index value to fall in a range from 0 (worst) to 10 (best). The mean value of all three attribute index values, as shown in Figure 2.1, is equal to the BQI which will also range from 0 to 10.

The following example is offered to demonstrate the calculation of a WQI. If the water quality attribute was comprised of four variables, as discussed, the data for these variables could be classified, as they relate to bay quality, from very poor to excellent. Chlorophyll-a, for example, might be ranked as follows:

Chlorophyll-a (μg/L)	Class	Class Value
>30	very poor	1
20-30	poor	2
10-20	medium	3
5-10	good	4
< 5	excellent	5

The other water quality variables of SDD, turbidity, and bottom dissolved oxygen, can also be classified in a similar manner. Thus, for any given point in space and time, the following WQI classification could result.

Variable	Class	Class Value
chlorophyll-a	good	4
Secchi disc	medium	3
turbidity	excellent	5
dissolved oxygen	medium	3

A score can be determined by summing the class values, thus, for these data the score is equal to 15 (SCORE = 4+3+5+3 = 15).

A calculated WQI value of 6.875 results from equation 1 given the MSP is 20 (four variables all with class values of 5), and the score is 15.

Following this procedure, attribute index values could be determined for each of the attributes. A BQI is the sum of attribute indices divided by three, which results in an overall index ranging from 0 (worst) to 10 (best).

2.2.1 RANKING CRITERIA

An appropriate number of possible classes was determined from a series of test calculations using water quality variable data to examine the sensitivity of resultant index values. Example indices were originally calculated based on three possible classes. Index values based on only three classes, however, were not sensitive enough to reflect changes in variable values. Subsequent calculations using five possible classes did yield index values with acceptable sensitivity to changing variable values of water quality. Consequently, the conceptual design of a BQI incorporates a ranking of all possible values for each variable into one of five possible classes from very poor to excellent.

Ranking of variable values can be controversial and can impart a high degree of subjectivity. At this stage in the process it is very important to clearly define how the ranking can be conducted. The following are offered as three potential methods for ranking variable values into classes:

Subjective - the use of "professional judgement" by "experts" to set variable ranges for each class;

Objective - the use of historical data to determine frequency distributions into quantiles, for example 0-20%, 20-40% and 40-60%, 60-80%, and 80-100%; and

Mixed - the use of state standards in combination with quantiles of historical data for data components lacking state standard criteria.

Each method was examined to determine the manner in which they could be used.

The following is an example of the Subjective method to set ranges of variable values into classes. It is recognized that an acceptable WQI would require further development of these classes from a consensus building process with a committee of "experts." The proposed variable ranges for each class are shown in Table 2.1.

Table 2.1 Classes for water quality variables determined by a Subjective method.					
VARIABLE	CLASS				
	1	**2**	**3**	**4**	**5**
Chlorophyll-a (μg/l)	>30	>20 - 30	>10 - 20	>5 - 10	≤5
Secchi Disk (in.)	≤30	>30 - 40	>40 - 60	>60 - 90	>96
Turbidity (NTU)	>9	>7 - 9	>5 - 7	>3 - 5	≤3
Bottom Dissolved Oxygen (mg/l)	≤4.5 >8	>4.5 - 5 >7.5 - 8	>5 - 5.5 >7 - 7.5	>5.5 - 6 >6.5 - 7	>6 - 6.5

For each variable, the frequency distribution of existing Tampa Bay data and knowledge of which values were deemed very poor, poor, medium, good, and excellent, with respect to water quality, were carefully taken into consideration. This task was undertaken so different methods of determining class assignments could be compared. The ranges of variable values for each class are not to be considered as final classifications, but simply preliminary classifications to enable initial testing of the conceptual design of the BQI.

The following discussion summarizes the values for each variable that were assigned to the extreme classes (very poor and excellent). Ranges of variable values used for the intermediate classes (poor, medium, good) can be viewed in Table 2.1. Chlorophyll-a values greater than 30 μg/l are classed as very poor, while those of 5 μg/l or less were considered representative of excellent water quality. SDD of 30 inches or less were considered very poor; SDD of more than 96 inches were classed as excellent. Turbidity values in Tampa Bay have occurred in a relatively narrow range overall, and the resultant ranges were set with narrow intervals. As a result, turbidities less than 9 NTU are classed as very poor, while values of 3 or less are considered excellent. Classification of bottom dissolved oxygen concentrations presented the greatest difficulty compared to other variables. Low concentrations are indicative of anoxic conditions, and thus, poor water quality. Highly eutrophic conditions with high phytoplankton biomass are also indicative of poor water quality, but those conditions can result in highly oxygenated waters (high dissolved oxygen) from excessive phytoplankton production. In order to account for these possibilities, a high and a low range of dissolved oxygen concentrations were assigned to most classes. Concentrations greater than 6 mg/l and as high as 6.5 mg/l are classed as excellent. Concentrations greater than 8 mg/l or concentrations of 4.5 mg/l or less are classed as very poor.

The second alternative method to ranking is an Objective approach. This approach utilized the existing water quality data (monthly means, 1974-1990) from the EPC surface water sampling program. More than 8,000 data points were available for each variable. The frequency distribution of these historical data in the areas of interest was used in assigning classes. Classes from very poor to excellent were assigned to parameter values falling into the 0 -20th, 20th-40th, 40th-60th, 60th-80th, and 80th-100th percentiles of all data values, respectively. The ranking criteria for classes based on quantiles are shown below in Table 2.2.

Table 2.2 Classes of water quality variables determined by an Objective method.

VARIABLE	CLASS				
	1	**2**	**3**	**4**	**5**
Chlorophyll-a (μg/l)	>18.7	>11.6 - 18.7	>7.5 - 11.6	>4.3 - 7.5	≤4.3
Secchi Disk (in.)	≤36	>36 - 48	>48 - 60	>60 - 84	>84
Turbidity (NTU)	>7	>5 - 7	>4 - 5	>2.5 - 4	≤2.5
Bottom Dissolved Oxygen (mg/l)	≤5.1	>5.1 - 6	>6 - 6.8	>6.8 - 7.7	>7.7

In the third alternative to ranking, state standards were only applicable to dissolved oxygen indicative of "low" water quality. State water quality standards for turbidity in all surface water quality classifications (F.A.C. 17-302.530), require values not to exceed 29 NTU above background levels. The existing data in Tampa Bay shows that turbidity has not exceeded 29 NTU. The use of the turbidity state standard also requires that background conditions be defined, a complication that is difficult to incorporate into the ranking process under the existing approaches. For these reasons, the state water quality standard for turbidity was not used. State water quality standards for dissolved oxygen in Class III waters require concentrations of at least 5 mg/l. Thus, dissolved oxygen concentrations <5 mg/l would be classified as "very poor" (Class 1). Since the concentration cut-off of the 0-20th percentile by frequency distribution (5.1 mg/l, see above) is nearly identical to the state standard, and since there is no other state standard applicable to the range of values observed for the identified water quality variables, the creation of a separate and significantly different set of class criteria by state standards was not possible.

2.3 CALCULATIONS OF EXAMPLE WATER QUALITY INDICES

Example WQI values were calculated from annual mean values for all stations in the bay and annual mean values for the bay segments of Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, and Lower Tampa Bay. Separate Water Quality Indices were generated using the Subjective and Objective ranking alternatives to set classes of variable values. In addition, comparisons to WQI values that have been calculated by the EPC since 1981 were made.

3.0 RESULTS

3.1 WATER QUALITY INDEX

As previously discussed, mean annual water quality values amenable for use in the WQI are shown in Appendix B. Mean annual values for each parameter of interest are listed for Tampa Bay (bay-wide values) and for each of four bay segments (Old Tampa Bay, Hillsborough Bay, Middle Tampa Bay, and Lower Tampa Bay). Example WQI values were calculated utilizing the two ranking methods (Subjective and Objective).

3.1.1 Comparison of Subjective and Objective Ranking Methods

Example WQI values calculated from mean annual data collected bay-wide utilizing the Subjective and Objective Ranking Methods are shown in Figures 3.1a and 3.1b. As illustrated in Figure 3.1b, the Subjective method resulted in a WQI showing a long-term improving bay-wide trend with time (r^2 = 0.2109). The improving trend with time is consistent with the perception of the scientific community that water quality has been improving in Tampa Bay. The Objective method yielded a very slight increase in WQI with time, with a low proportion of the variation in index values accounted for by the fitted least squares regression (r^2 = 0.0479). The Objective method resulted in a WQI showing virtually no change with time, and therefore, is not consistent with the perception of the scientific community in Tampa Bay. It should also be recognized that the Objective approach must rely on the frequency distribution of existing data. Updates of the existing data will eventually change the frequency distribution of the data, and thus, the cut-off points of variable values that are set to specific classes will also change. Therefore, the same specific variable value that is classed as "good" today, may be classed as "excellent" or "medium" tomorrow. Consequently, long-term trends with time could be distorted to some degree.

Since calculated WQI values developed by using the Subjective approach were consistent with perceived water quality trends in Tampa Bay, for demonstration purposes further development of the WQI will be based on the Subjective method to determining class ranks. **The WQI determined using the Subjective method will subsequently be referred to as the Subjective WQI.**

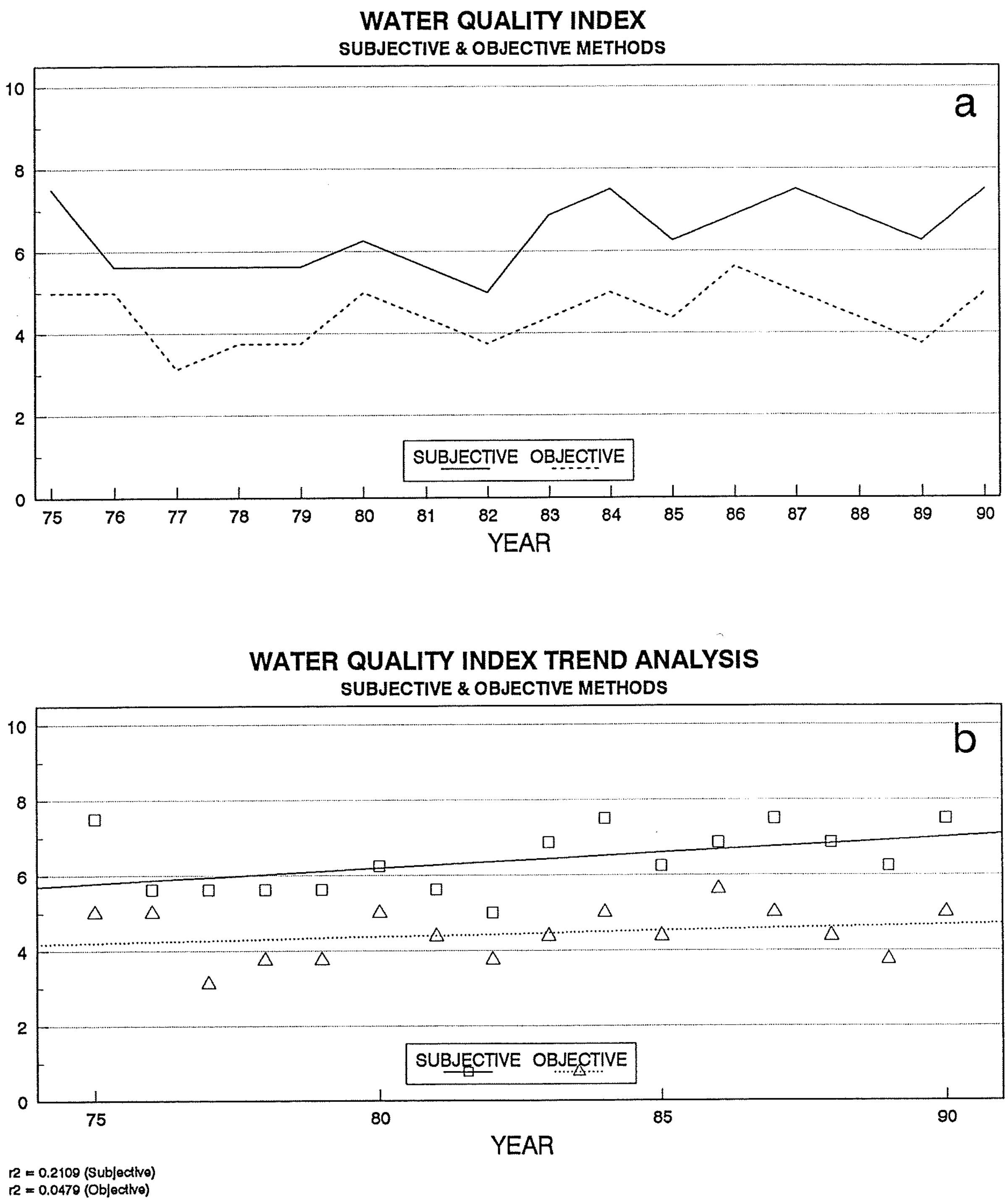


Figure 3.1 Bay-wide mean annual WQI values (1975-1990) calculated by Subjective and Objective methods. a) WQI values. b) Best fit least squares regressions.

3.1.2 Comparison of the Subjective WQI and EPC WQI

The workshop participants requested that a different approach from what the EPC was using to derive their WQI be used in the WQI component of the BQI. Some participants believed that a few of the EPC WQI variables were not appropriate (e.g., total nitrogen, total phosphorus, SDD), and that the index could be improved to better reflect water quality. Nevertheless, since the EPC WQI has generally followed the perceived water conditions occurring in Tampa Bay, consistency between the Subjective WQI and the EPC WQI was examined.

The WQI constructed by the EPC (Boler, 1992) utilizes empirical data from seven parameters (or variables). Parameters were chosen based on data availability and on the representation of the impairment considerations of Tampa Bay. Each parameter value was converted to a point value from 0 (lowest quality) to 100 (highest quality) by application of a parameter transformation scale (PTS). Each PTS consists of a graph relating relative "quality" with measured parameter values based on "knowledge" of what measured parameter value constitutes high or low water quality. Thus the EPC WQI also uses a "subjective" method to determine relative ranges of "quality" for each variable. Except for total coliform and dissolved oxygen, parameter values were derived from samples taken at mid-depth in the water column. Total coliform samples were collected from the surface. Percent saturation of dissolved oxygen measured near the surface, at mid-depth, and near the bottom were each transformed to "quality" points. The mean point value for these three depths at each site per sampling event was used as part of the calculation of the WQI (personal communication, December 1993, Richard Boler, EPC). Parameters were also weighted depending on their importance to ecosystem health and public use. The total of all weighting factors is equal to one. The parameters used to construct the EPC WQI and their respective weights as reported by the EPC are shown below.

Parameter	
% Saturation Dissolved Oxygen	0.212
Chlorophyll-a	0.167
Total Coliform	0.167
Effective Light Penetration (Secchi)	0.111
Total Phosphorus	0.111
Total Kjeldahl Nitrogen	0.111
Biochemical Oxygen Demand	0.111
Total	1.000

For ease of comparison to the Subjective WQI, the EPC WQI values were converted to a 0-10 scale by dividing by 10.

The WQI classified Subjectively was examined by bay segment during a ten year period (1981-1990) in which Tampa Bay has reportedly shown considerable improvement in water quality (Figure 3.2). The example calculations of the WQI (Figure 3.2a), as constructed with four variables, shows best conditions in Lower Tampa Bay (7-10 index points), intermediate conditions in Old and Middle Tampa Bays (4-8 index points), and the worst conditions in Hillsborough Bay (2-6 index points). The trend is towards improvement in all segments except Hillsborough Bay (Figure 3.2b). The lack of improvement exhibited by the WQI values in Hillsborough Bay does not reflect the perceived conditions of improving water quality that have occurred in that bay segment.

Bay-wide averaged WQI values (1981-1990) from the example WQI calculations and from EPC WQI values were consistent (Figure 3.3). The example WQI values exhibit greater interannual variability compared to EPC WQI values (Figure 3.3a). This difference may be due to the ordinal component (ranking of variable values) by which the Subjective WQI values are calculated and that the Subjective WQI uses fewer variables (4) relative to the EPC WQI (7). An examination of the least squares regression lines (Figure 3.3b) shows both indices have trends with similar slopes, suggesting that both indices measure the same amount of "quality" improvement from 1981 to 1990. The greater interannual variability in the Subjective WQI is reflected in the lower coefficient of determination (r^2) of the fitted regression line compared to the EPC WQI.

Trends between the Subjective and EPC WQI were compared by bay segment in Figure 3.4. In contrast to the Subjective WQI (Figure 3.4a) where an improving trend was not observed for Hillsborough Bay, the EPC WQI values (Figure 3.4b) result in trends showing water quality improvements in all bay segments.

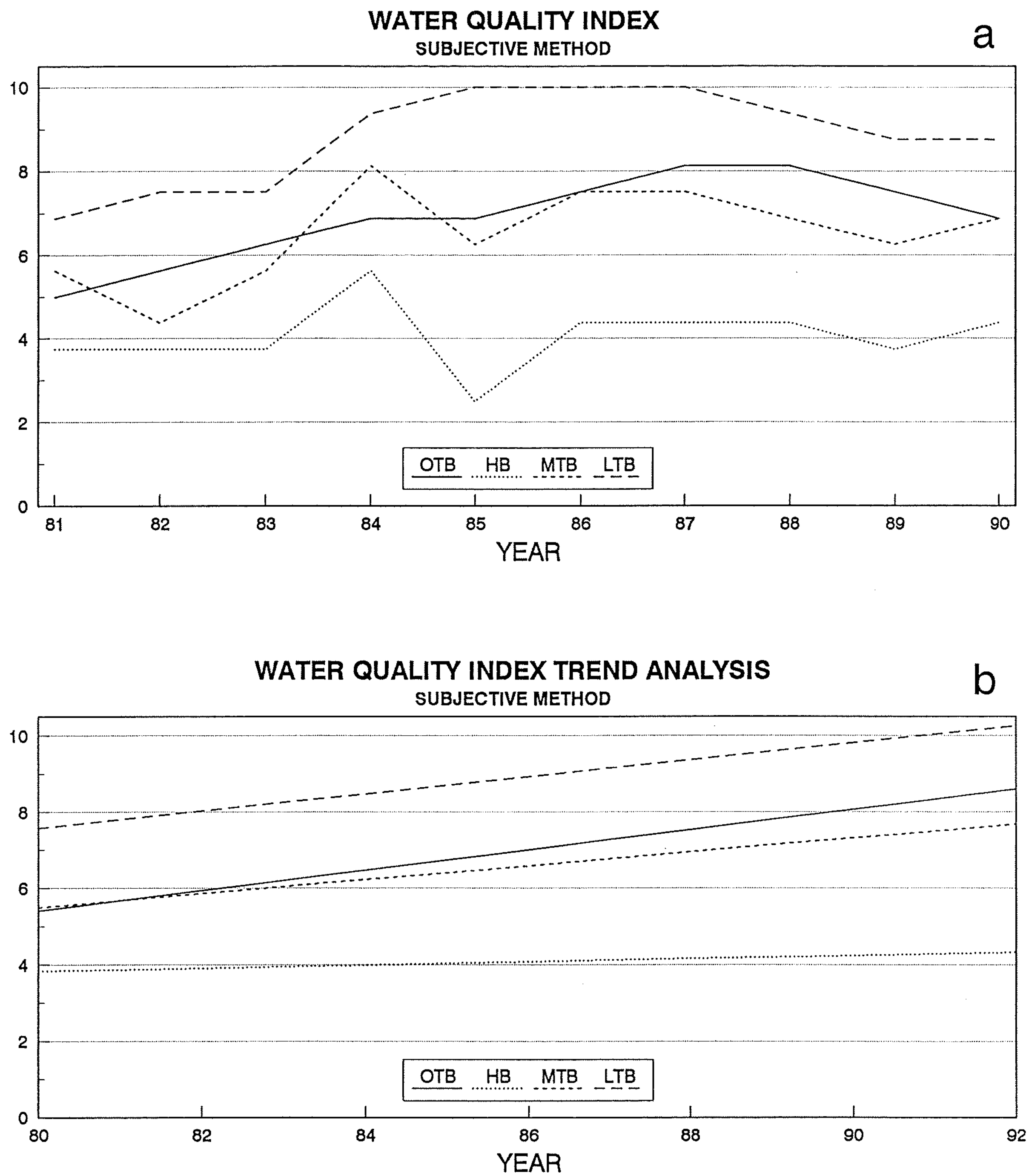
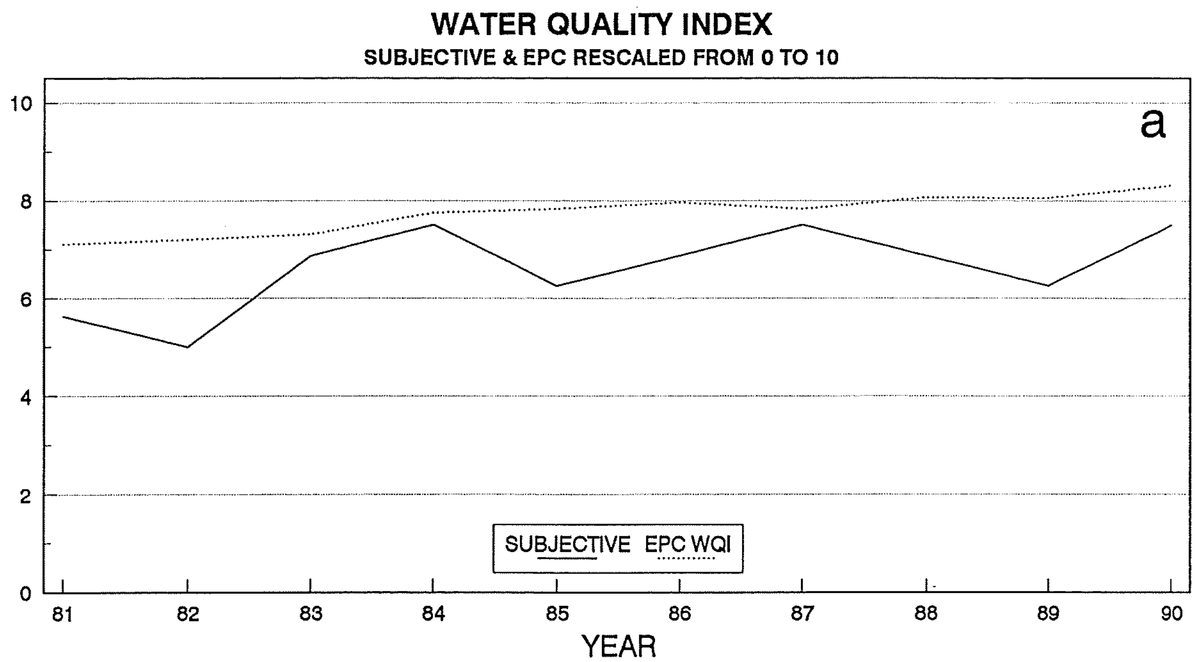


Figure 3.2 Mean annual WQI values (1981-1990) by bay segment determined using the Subjective method. a) WQI values. b) Best fit least squares regressions.



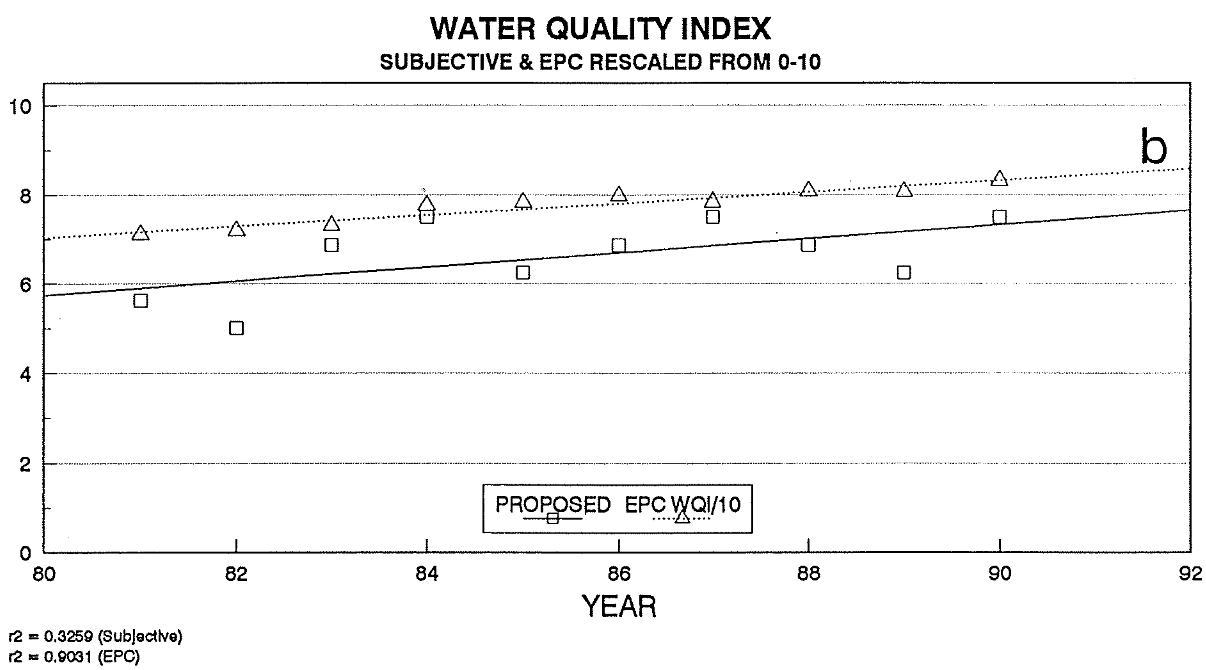


Figure 3.3 Mean annual values (1981-1990) of the Subjective WQI compared to the EPC WQI. a) WQI values. b) Best fit least squares regressions.

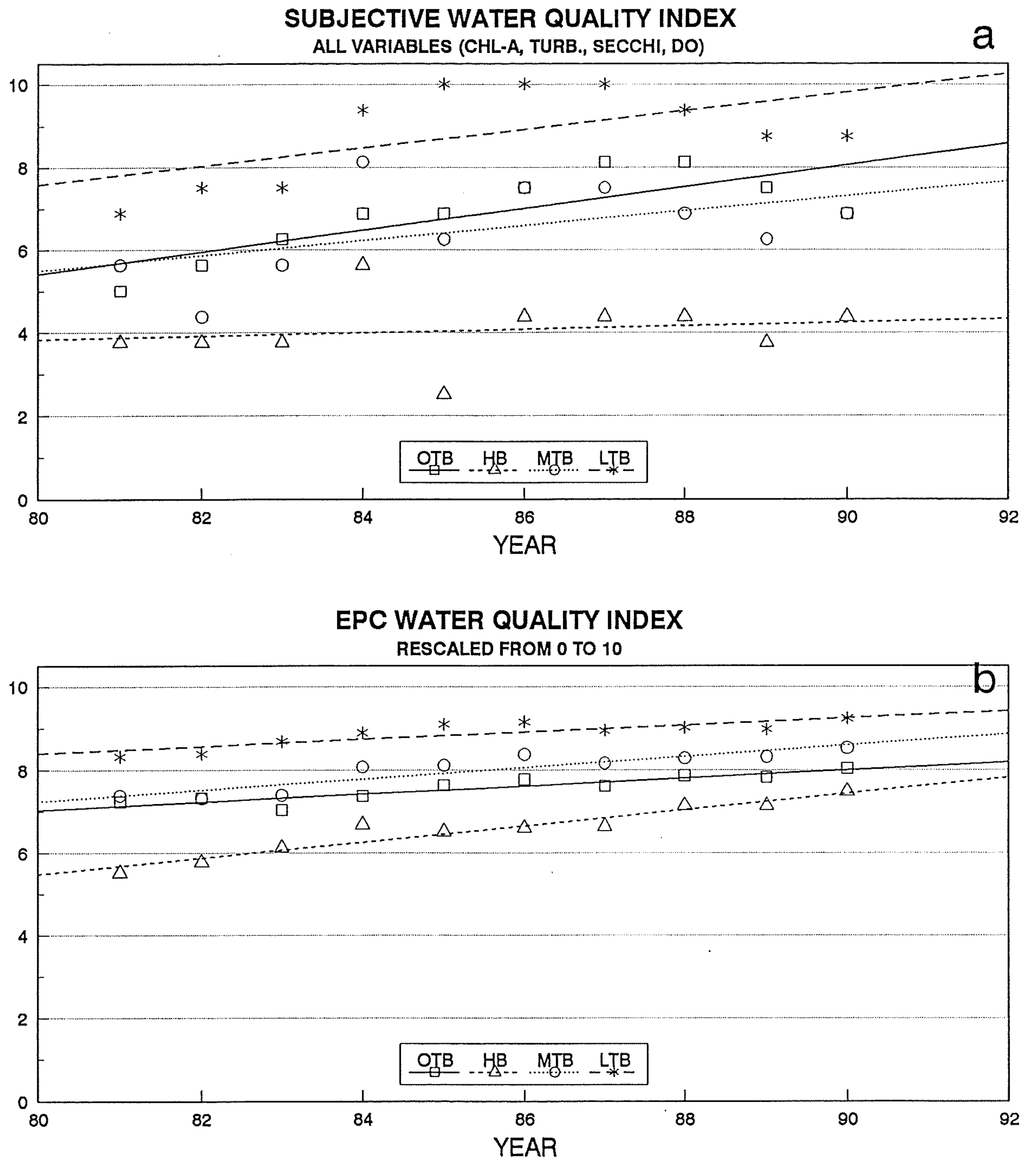


Figure 3.4 Best fit least squares regressions of mean annual values of the Subjective WQI and the EPC WQI calculated by bay segment. a) Subjective WQI. b) EPC WQI.

The classification of each data variable in Hillsborough Bay was examined to determine if any particular variable class was inconsistent relative to other variables. It was determined, as illustrated in Figure 3.5a, that the class values of bottom dissolved oxygen during 1981 and 1982 were not consistent with classes for other variables, thereby resulting in WQI values showing no improvement with time in Hillsborough Bay. Figure 3.5b illustrates the difference between WQI values calculated with and without the variable of dissolved oxygen. WQI values are 2 index points lower in 1981 and 1982, and show the greatest water quality improvement between 1982 and 1984 if the dissolved oxygen variable is not used. This is consistent with empirical data from Hillsborough Bay that resulted in greater SDD and a marked reduction in the duration and magnitude of blue-green algae blooms (*Schizothrix calcicola sensu* Drouet) during those years, both of which were interpreted by the local scientific community as significant water quality improvements (Johansson, 1991). Furthermore, when the bottom dissolved oxygen variable is removed from the Subjective WQI equation, the slope of the long-term trend of the Subjective WQI is similar to the slope resulting from the EPC WQI (Figure 3.5c).

The ranges of variable values used to classify bottom dissolved oxygen concentrations that were chosen by the Subjective method may not be appropriate. Existing dissolved oxygen data were collected after dawn, however, bottom dissolved oxygen concentrations may be more meaningful with respect to water quality if measured when they are typically lowest during the course of a 24 hour period (i.e., at or near dawn). The classes chosen for dissolved oxygen, when applied to the WQI calculation, apparently do not accurately reflect the perceived water quality conditions in Hillsborough Bay. Consequently, it is recommended that the example WQI calculations exclude the use of the dissolved oxygen variable. The incorporation of dissolved oxygen into the WQI should be reconsidered and tested when a set of data exist with dissolved oxygen concentrations measured at dawn.

The Subjective WQI was recalculated without the bottom dissolved oxygen variable to ensure reasonable results were produced for the entire bay and for each of the other bay segments. Annual averaged bay-wide values of the Subjective WQI, although somewhat more variable from year to year, are very consistent, and slightly lower, relative to the EPC WQI (Figure 3.6a). Trend analysis by linear regression (Figure 3.6b) indicate that both the Subjective and EPC WQI values have increased with time, and the Subjective WQI values have increased at a greater rate from 1981 to 1990. Interestingly, both WQI values in 1990 are nearly identical (8.3).

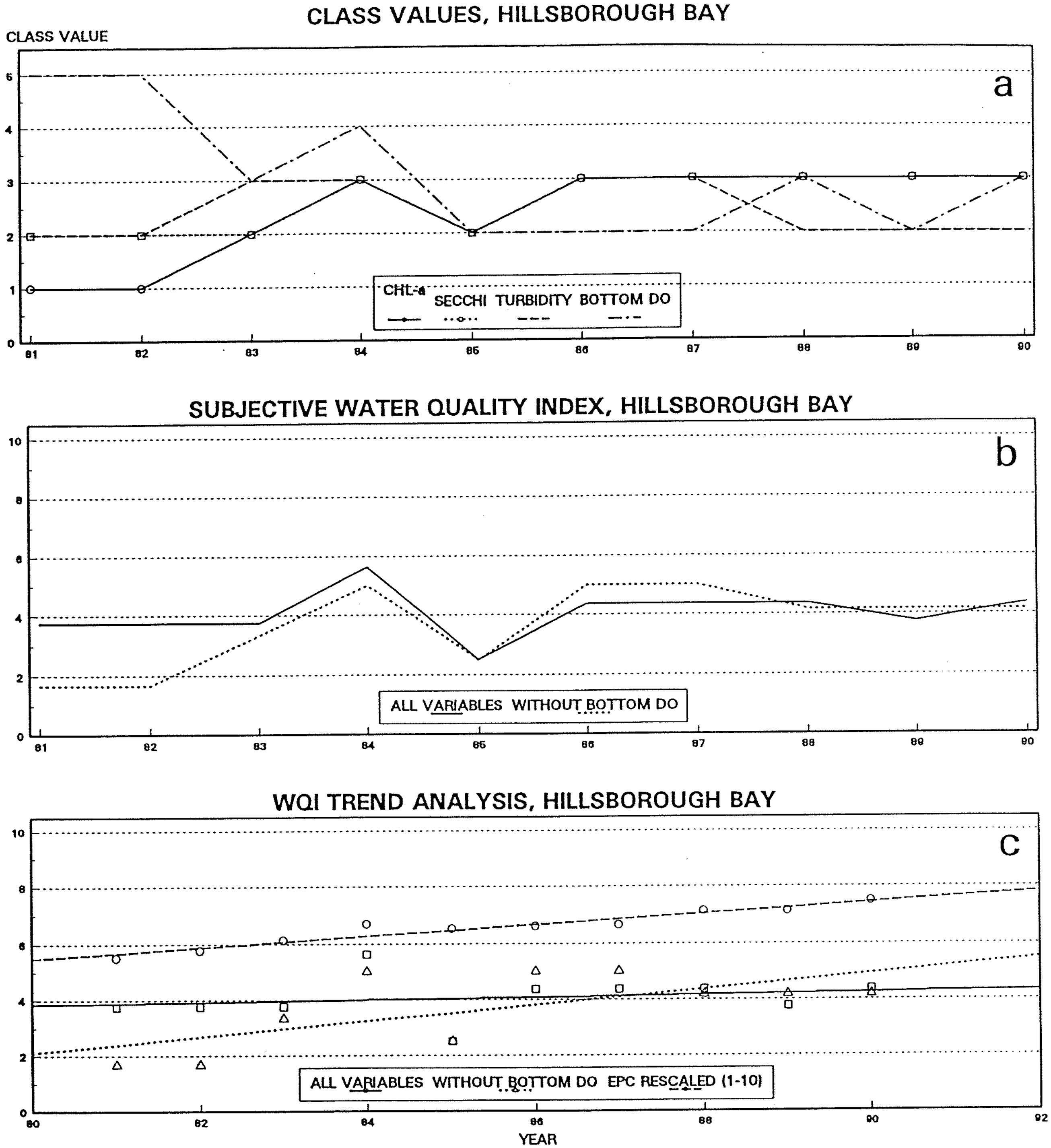
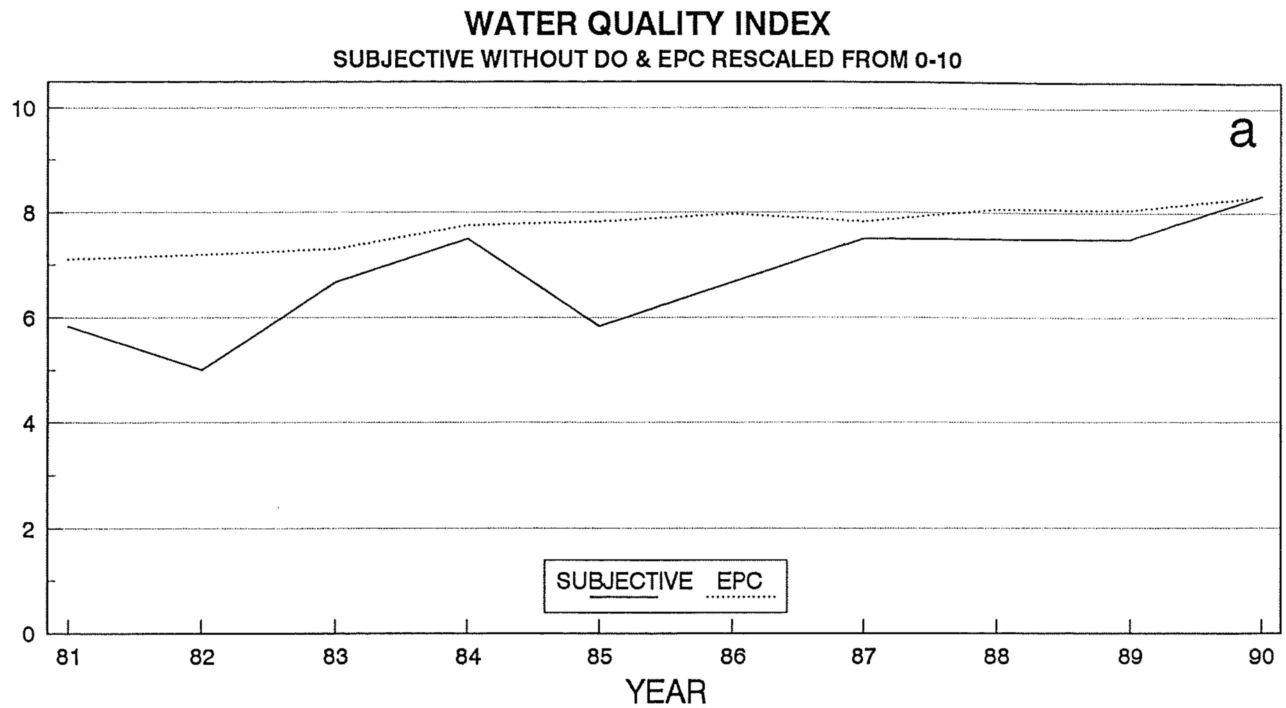


Figure 3.5 a) Mean annual class values (1981-1990) for all variables of the Subjective WQI in Hillsborough Bay. b) Mean annual values (1981-1990) of the Subjective WQI for all variables and for all variables except bottom dissolved oxygen. c) Best fit least squares regression comparisons between mean annual values of the Subjective WQI with and without bottom dissolved oxygen, and with the EPC WQI.



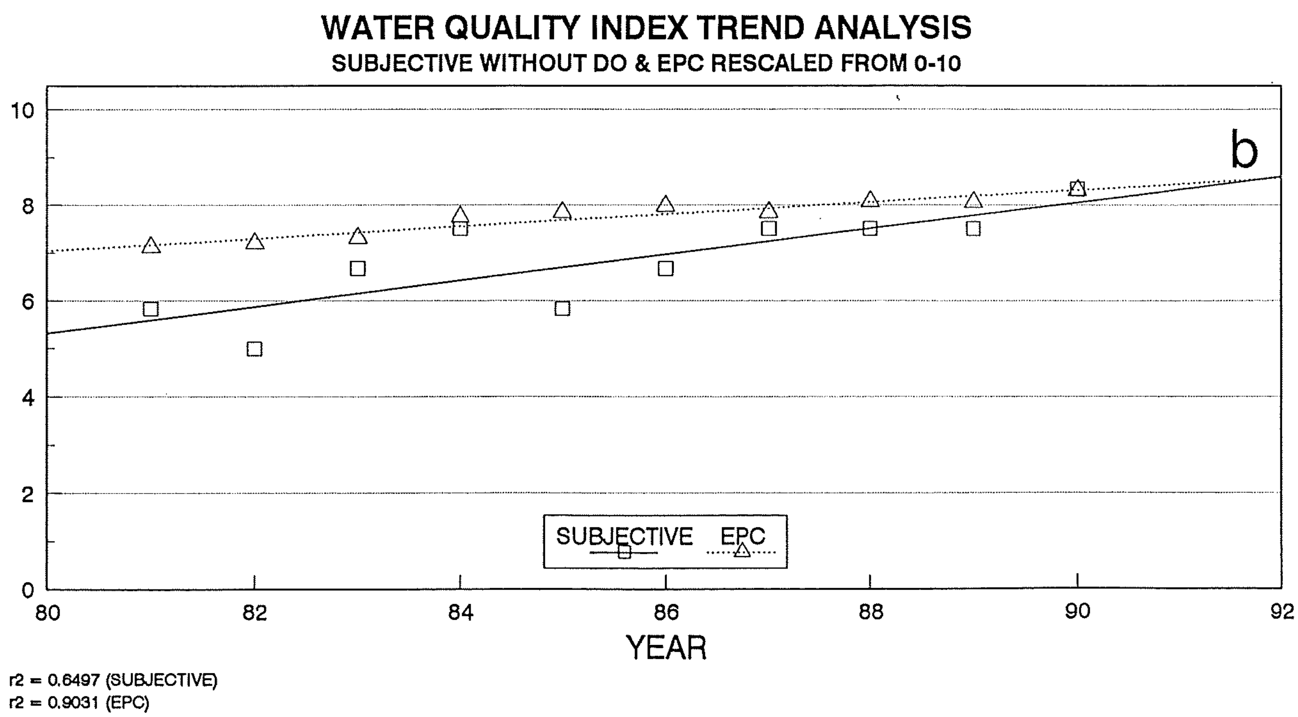


Figure 3.6 Bay-wide mean annual values (1981-1990) of the Subjective WQI without bottom dissolved oxygen compared to the EPC Water Qualtiy Index. a) WQI values. b) Best fit least squares regressions.

WQI values from 1975 through 1990 both with (Figure 3.7a) and without (Figure 3.7b) dissolved oxygen shows that the greatest effect of removing dissolved oxygen is exhibited in Hillsborough Bay. Without dissolved oxygen, the Subjective WQI in all bay segments shows an increasing trend with time (Figure 3.7c). Overall during the period of record (1975-1990, Figure 3.7b), the Subjective WQI indicates best water conditions in Lower Tampa Bay (7.5-10.0 index points), intermediate conditions in Old Tampa Bay and Middle Tampa Bay (4.2-7.5 index points), and worst water quality conditions in Hillsborough Bay (1.7-5.0 index points).

The Subjective WQI using the variables of chlorophyll-a, Secchi depth, and turbidity, exhibits trends in water quality that are consistent with the WQI calculated by the EPC (Figures 3.8a and 3.8b). The Subjective index using three variables, as was true when based on four variables, shows more year to year variability compared to the EPC index. Because the Subjective WQI utilizes a ranking procedure to characterize the relative quality of variable values, and uses only three data variables, a change in one variable will have more of an influence on the WQI value relative to a WQI based on more data variables. The EPC index may have less interannual variability since it utilizes more variables (7) and is constructed using empirical data values transformed by an equation (not ranked) to index points that are intended to be reflective of water quality.

3.2 LIVING RESOURCE DATA

Due to the time and effort required to properly acquire and classify living resource data, these data variables were not ranked, and as a consequence, example LRQI calculations were not made. Alternatively, readily available data were compiled for vegetative habitats (seagrasses, mangroves, marshes), marine mammals (manatees and bottlenose dolphins), and juvenile fishes. These data, as previously identified, are presented in Appendices C, D, and E, respectively. Other identified Living Resource data components were not readily available.

These data were reviewed, and their classification with respect to "bay quality" was addressed with individuals ("experts") from the MRI in St. Petersburg, Florida, who were responsible for interpreting the data. Upon discussing how variables values (e.g., manatee counts, dolphin counts, fish abundance) may relate to "bay quality," with these individuals, it was clear that the ranking of variable values into classes from very poor to excellent would be extremely difficult, possibly controversial, and beyond the level of effort intended for this project.

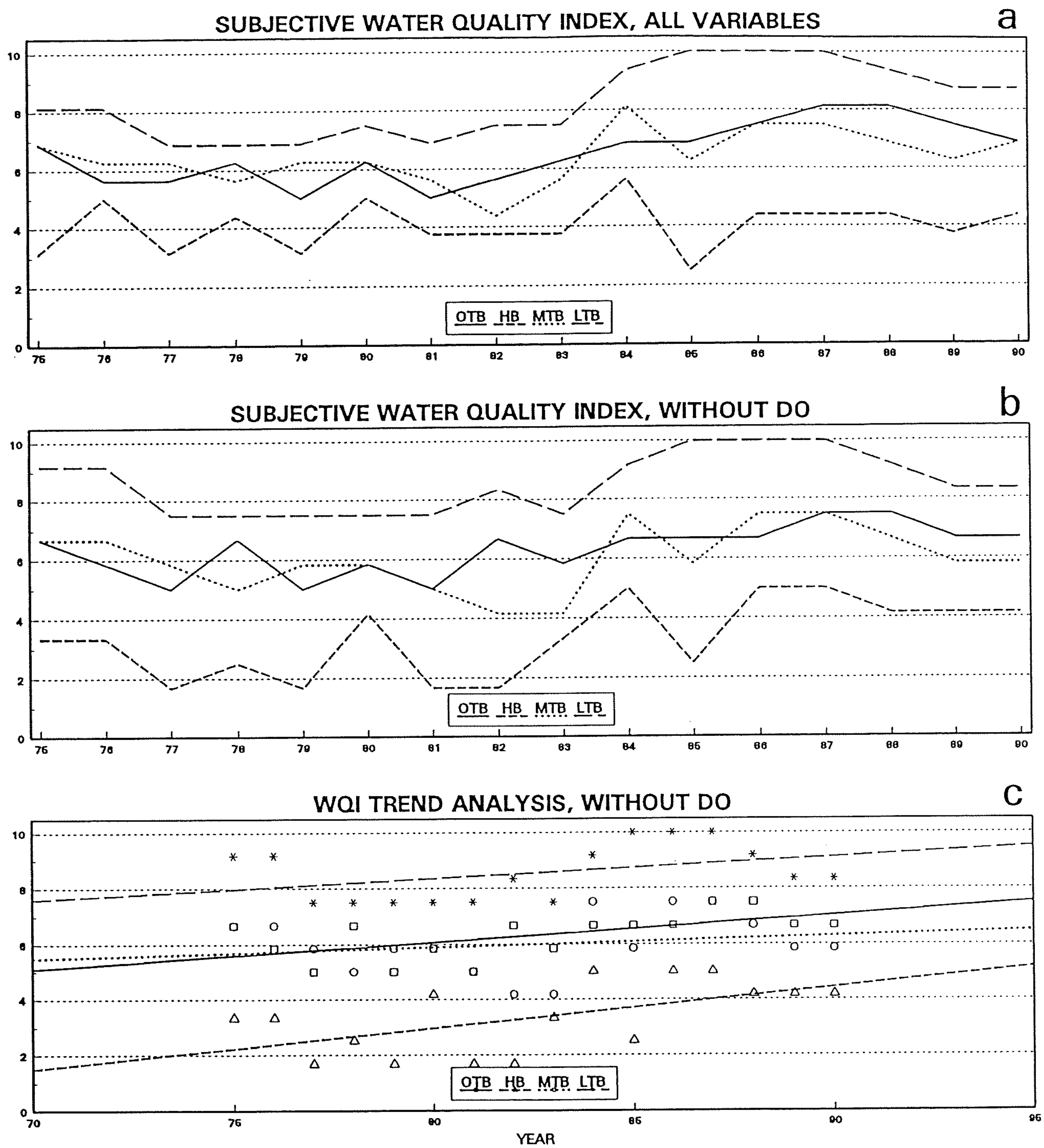


Figure 3.7 Mean annual values (1975-1990) by bay segment of the Subjective Water Qualtiy Index. a) All variables. b) All variables except bottom dissolved oxygen. c) Best fit least squares regressons with all variables except bottom dissolved oxygen.

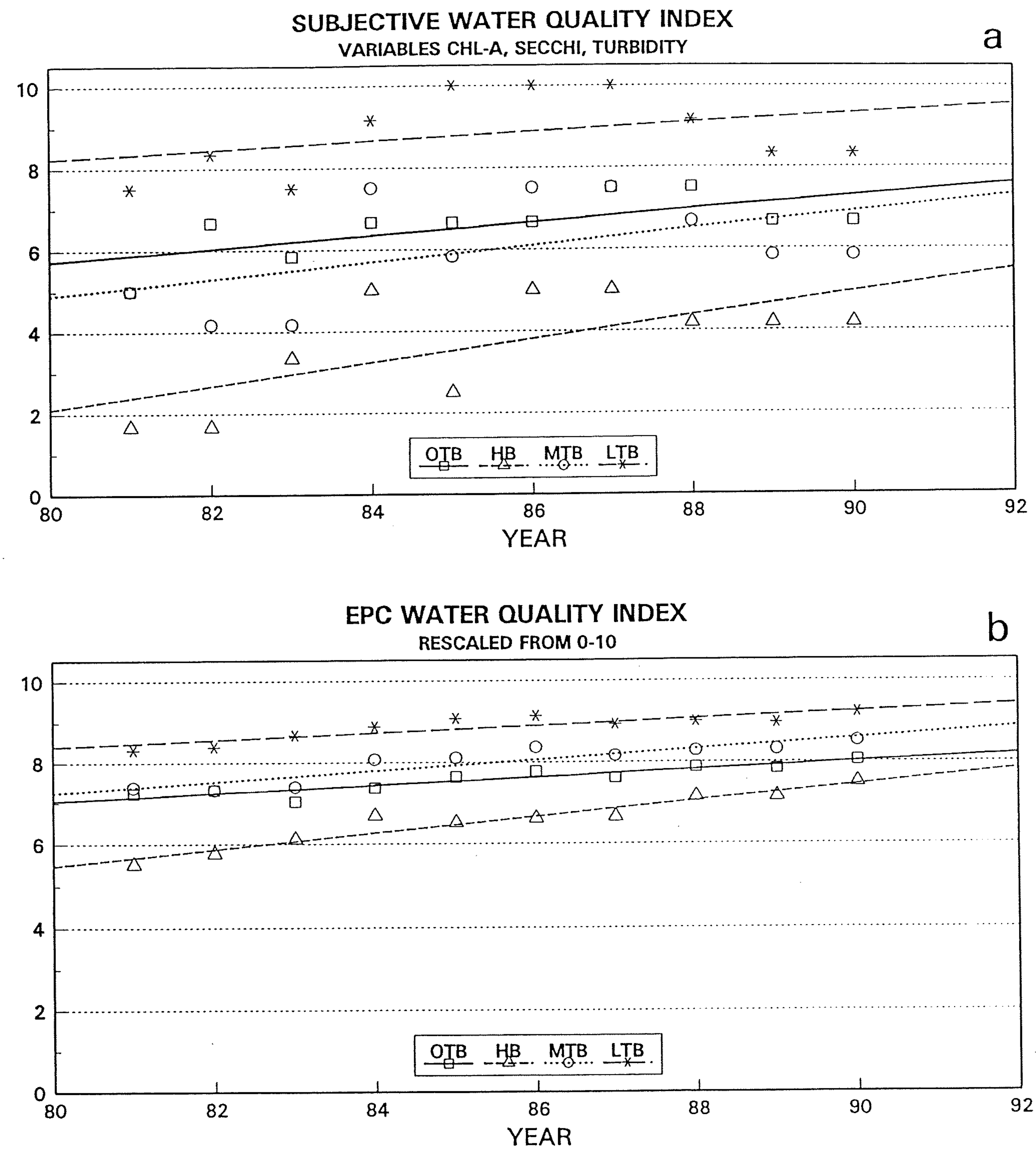


Figure 3.8 Best fit least squares regressions of mean annual values (1981-1990) by bay segment of the Subjective Water Qualtiy Index without bottom dissolved oxygen and the EPC Water Qualtiy Index. a) Subjective WQI without bottom dissolved oxygen. b) EPC WQI.

3.3 IMPAIRED USES

No data for impaired uses were readily available.

4.0 SUMMARY AND CONCLUSIONS

The current state of readily available information in characterizing the identified bay attributes was not adequate to calculate a Bay Quality Index that incorporates components of each attribute. A conceptual design, however was developed that would allow the combining of indices of dissimilar bay attributes, such as Water Quality, Living Resources, and Impaired Uses, into a single index of "Bay Quality," when the appropriate data become available.

4.1 DATA AVAILABILITY

As recommended by workshop participants, available data were compiled for the attributes of Water Quality, Living Resources, and Impaired Uses. Several data variables for each attribute were identified by workshop participants for possible inclusion into a BQI. An attempt was made to acquire available information and make recommendations as to how the acquired empirical data could be used to construct a BQI, however, varying degrees of success were encountered.

Adequate information was available to calculate a Water Quality Index (WQI) of the BQI using the proposed framework. In general, water quality data were readily available on a monthly basis for each bay segment from EPC. However, the temporal and spatial frequencies in which total suspended solid data were collected, were inadequate for use in calculating a WQI. As a result, turbidity measurements were used as a proxy for TSS data during the testing of example calculations of a WQI.

Information was readily available for many of the Living Resource data variables, however, the frequency that data were collected does not allow for the calculation of seasonal or annual BQI values. Seagrass habitat areal coverage data were found by bay segment for four different years, 1950, 1982, 1988, and 1990. Marsh and mangrove areal coverage data by bay segment, were only available for 1990. Monthly counts of both manatees and dolphins were available from 1987 through 1990. Juvenile fish data are also available from the MRI in St. Petersburg, Florida, although a meaningful compilation of appropriate data was beyond the level of effort intended for this project. Unpublished information on the number of colonial nesting bird pairs inhabiting islands in the Tampa Bay area each year is recorded locally, however, these data were not readily available.

Although information on shellfish bed closures and coliform counts are recorded by local sources, no other information for variables of Impaired Uses were readily available.

4.2 CONCEPTUAL DESIGN OF A BQI

The conceptual design of the BQI incorporates an ordinal approach by ranking empirical data to five classes from very poor (1) to excellent (5). Class values (from 1-5) for variables within a bay attribute are summed and the resultant value is scaled to an index number from 0 (worst) to 10 (best). The mean of all attributes is equal to a BQI from 0-10. This approach provides a simple way to create indices constructed in a similar manner for a wide variety of attribute data. The critical step for calculating a BQI reflective of "bay quality" is the appropriate assignment of variable values to each of five possible classes.

4.3 EXAMPLE CALCULATIONS OF WQI VALUES

Example calculations of a Water Quality Index (WQI) were performed using water quality attribute variables in order to test the feasibility and potential usefulness of the conceptual design. It should be recognized that the conceptual design presented herein for water quality could also be used for other attributes of bay quality for incorporation into a BQI. Since EPC WQI values are generally consistent with perceived water quality conditions in Tampa Bay, example calculations of WQI values of a BQI were compared to previously calculated EPC WQI values. It should also be recognized that the perception of the scientific community on trends in Tampa Bay water quality have not been quantitatively tested or scientifically evaluated. Nevertheless, given the above limitations, three conclusions were reached regarding the application of the proposed approach to water quality data.

1. The Subjective (professional judgement) method in determining ranges of variable values for each class, rather than the Objective (frequency distribution of empirical data) method, yielded results more consistent with perceived water quality conditions in Tampa Bay.

2. The use of existing bottom dissolved oxygen data as one of the four water quality variables, did not yield WQI values consistent with perceived water quality conditions in Hillsborough Bay. WQI values calculated using the variables of chlorophyll-a, Secchi disappearance depth, and turbidity, were in general agreement with perceived water quality conditions in the four main segments of Tampa Bay from 1975 through 1990.

3. The Subjective WQI values are consistent with WQI values calculated by the Environmental Protection Commission of Hillsborough County (EPC) in regard to overall long-term trends and relative quality among segments of Tampa Bay.

Several other inferences regarding the representativeness of data variables were uncovered. Of the four variables identified, chlorophyll-a concentrations and Secchi disappearance depths (SDD) were most reflective of perceived water quality conditions. Bottom dissolved oxygen (DO) concentrations caused conflicting results, especially in Hillsborough Bay. The range of turbidity values recorded for Tampa Bay may be below values that influence water quality as currently perceived.

Chlorophyll-a is important since its concentrations are reflective of algal biomass, and as such, it integrates the effect of nutrient inputs and light availability on the ecological condition of the water column.

SDD data were consistently reflective of perceived water quality conditions in Tampa Bay. The widespread use of Secchi disc measurements in aquatic research makes its use attractive and convenient when characterizing and comparing systems based on existing data. Unfortunately, informative SDD measurements are not possible in shallow waters where SDD exceeds the water column depth. A more useful indicator of water clarity in Tampa Bay in shallow and deep waters alike, would be the use of Photosynthetically Active Radiation (PAR) measurements with a light meter capable of measuring the attenuation of light within the water column.

DO should also be very important to water column biota, however, existing empirical data may not have been measured at the best time of day to accurately reflect water quality. The EPC utilizes the percent saturation of DO, collected at surface, middle, and bottom depths between mid-morning and mid-afternoon, as a variable of their WQI. The Subjective WQI originally used DO, instead of percent DO saturation, since the actual concentration of oxygen in the water column, and not its percent saturation, was deemed more important to an organisms' survival. It is recognized, however, that there may be other benefits in using the percent DO saturation as an indicator of overall system health. DO is unquestionably an important variable indicative of system health. Although not used in the example WQI calculations using existing data, appropriately measured DO concentrations and/or percent saturation values should be tested and used if possible in future calculations of a water quality index.

Under the assumption that higher turbidity values between 0 and 10 NTU equate to poorer water quality, the use of turbidity in the WQI is difficult to interpret. For example, a comparison of SDD and turbidity values in Hillsborough Bay (Figure 4.1), shows that both variables increase from 1975 to 1990. SDD shows an overall increase in water clarity, however, turbidity values indicate the opposite may be occurring. It is apparent that SDD and turbidity are not assessing water quality in a consistent manner under the current assumptions. The use of total suspended solids data, if it becomes available, may yield more useful and interpretable results. Based on this present analysis, a reasonable assumption may be that turbidity values below

10 NTU are not degrading water quality as currently perceived. Such an assumption lends some support to the state water quality standard set not to exceed 29 NTU turbidity above background levels.

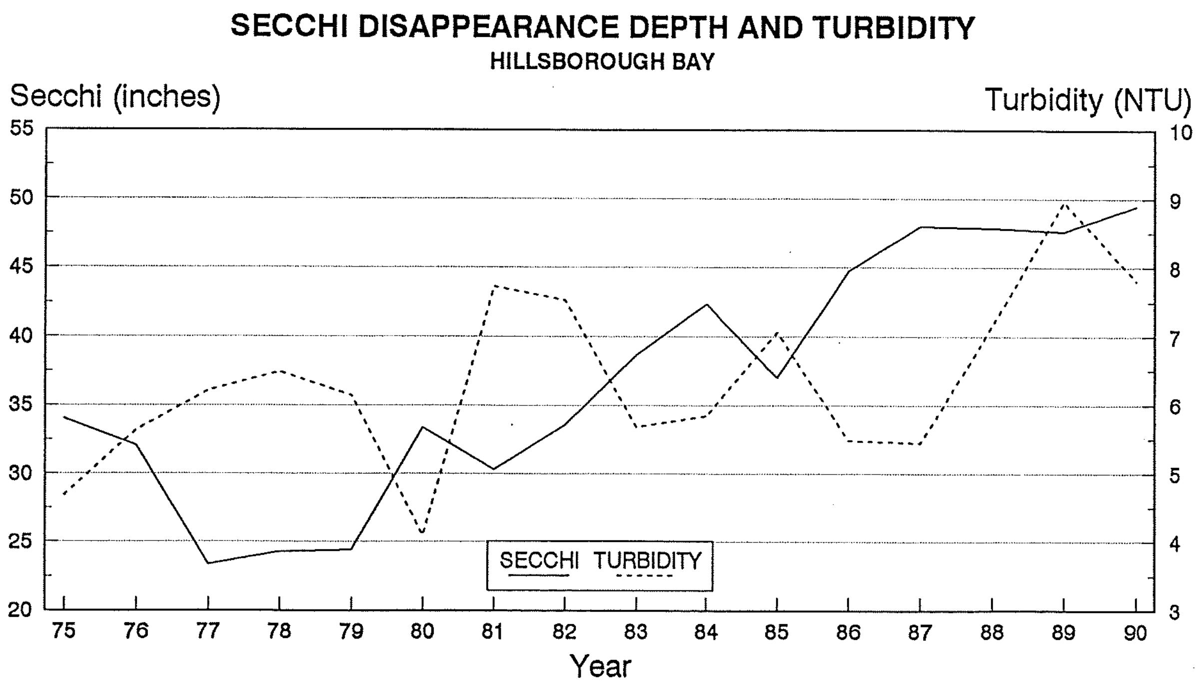


Figure 4.1 Secchi disappearance depth and turbidity values (1975-1990) in Hillsborough Bay.

4.4 CONCLUSIONS

A conceptual design of a BQI was developed that included three bay attributes, Water Quality, Living Resources, and Impaired Uses. Variables for possible inclusion into the BQI were identified for each bay attribute. Available data for water quality were adequate for example calculation of Water Quality Index values. Available data for other bay attributes were compiled, however, those data could not be readily used in example calculations of separate attribute indices. Available data for water quality did indicate that the calculation of an attribute index to be incorporated into an overall calculation of a BQI may be feasible and reflective of bay quality conditions as perceived by the scientific community of Tampa Bay.

The WQI calculated by the EPC already provides an adequate assessment of perceived water quality in Tampa Bay, and is, in its current form, appropriate as an indicator of overall water quality. Some adjustments in the EPC WQI calculations could easily be made to improve upon its utility and representativeness of bay water quality. For example, a replacement of SDD with PAR values expressed as light attenuation (extinction coefficients), and the use of bottom DO or percent DO saturation data collected at dawn, when and if such data become available. Further review and refinement of parameter weights may also provide more representative WQI values.

In order for a BQI that incorporates attributes of Water Quality, Living Resources, and Impaired Uses to be realized, input would be necessary from a variety of individuals with expertise that can be grouped into each identified bay attribute. It may be extremely difficult to reach a consensus among experts when attempting to assign classes (poor, good, excellent) to numbers of manatees, nesting pairs of birds, fish and seagrass acreage. Additional complexities may arise when deciding if each data variable of an attribute, or each attribute of the BQI, deserves equal weight with respect to other variables and attributes.

4.5 RECOMMENDATIONS

The following recommendations are offered in order to calculate a composite BQI:

1. Given the strengths and weaknesses of the Subjective and Objective methods to assigning variable values to classes, a Subjective approach may be more appropriate for incorporating a wide variety of bay attibutes as is intended for the BQI.

2. A group of experts, specific to each bay attribute, should be convened to identify the appropriate data variables to use as indicators of bay quality.

3. The identified data for each attribute should be compiled to ensure that those data are available in an appropriate form for inclusion in a BQI calculation.

4. Upon reviewing available data for each variable, each group of experts should assign ranges of variable values to classes from very poor to excellent (1-5). State standards, representative data from Tampa Bay, and representative data from estuaries other than Tampa Bay, should be used when deciding how variable values are assigned to each class.

5. Test calculations should be performed to evaluate the sensitivity of each index, and to assess if reasonable and informative judgements can be made from each attribute index value and the overall Bay Quality Index value.

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APPENDIX A

SUMMARY OF WORKSHOP

HELD ON JUNE 22, 1993

BAY QUALITY INDEX

REVIEW OF WORKSHOP HELD JUNE 22, 1993

Attendance:
Holly Greening, TBNEP
Andy Squires, Coastal
Doug Heimbuch, Coastal
Roger Johansson, City of Tampa
Richard Boler, Env. Prot. Comm. of Hillsb. Co.
Peter Clark, TBRPC Agency on Bay Management
Jim Culter, Mote Marine Laboratory
Joe O'Hop, FDNR Marine Research Institute

Holly Greening of the TBNEP and Coastal representatives reviewed the background information previously mailed to individuals that were invited to the workshop summarized herein on the development of the conceptual design of a Bay Quality Index (BQI) for Tampa Bay .

The following categories for subsequent index development were presented and discussed:

- Water Quality
- Sediment Quality
- Living Resources
- Pollutant Loading
- Watershed Characteristics
- Regulatory Activities

The participants expressed the viewpoint that a BQI should not address components that may be causing the observed condition in the bay, but rather, a BQI should focus on those components reflective of the actual condition of the bay itself. Consequently, the group agreed to eliminate three potential BQI categories that were presented in the mail-out: Pollutant Loadings, Watershed Characteristics, and Regulatory Activities. The group did recognize that some of the data components of the eliminated categories may be relevant to factors reflective of bay quality. Some of those components, by the end of the workshop, were placed in a newly created category called "Impaired Uses."

Each category was discussed separately to determine the appropriate data components that should be considered for a BQI.

WATER QUALITY

Data components agreed upon by the group that warrant further consideration included:

- chlorophyll-a
- water clarity (Secchi or PAR)
- total suspended solids
- dissolved oxygen

Most participants felt dissolved oxygen was important, but that the current methods used in Tampa Bay did not sample at the most appropriate time (ie., during dawn) when concentrations are usually the lowest. Consequently, the incorporation of dissolved oxygen into the BQI may not be appropriate unless the current monitoring practices are modified.

Other water clarity components, such as color and turbidity, were discussed, but individuals present thought that Secchi disk depth or PAR measurements along with chlorophyll-a and total suspended solids values were adequate to assess water clarity.

The group was also in favor of limiting the number of data components in the "Water Quality" category in order to minimize the potential complexity of the final BQI calculation.

SEDIMENTS

Potential sediment components discussed for BQI use included metal concentrations and sediment toxicity testing.

Since no periodic monitoring of sediments have been performed in Tampa Bay, and since the monitoring of components that may be appropriate for a BQI are not planned, the group agreed to eliminate the category of "Sediments" from consideration.

A few of the data components originally included with the "Sediment" category, as well as other components deemed inappropriate for the BQI categories previously identified, were combined into an additional category called "Impaired Uses."

IMPAIRED USES

"Impaired Uses" provided a category for several components previously grouped in other categories. Participants had little input regarding the actual application of data for several of these components. Coastal will investigate the types of data that are available for these components and, depending on what is available, recommend what further use each component can provide in developing a BQI.

Data components agreed upon by the group that warrant further consideration included:

- shellfish bed closures
- toxicity
- sediment metals
- beach closures?
- bacteria counts
- red tide counts
- number of fish kills
- blue-green algae blooms

LIVING RESOURCES

Data components agreed upon by the group that warrant further consideration included:

- seagrass acreage
- mangrove acreage
- saltmarsh acreage
- juvenile fish
- recreational fish (catch per unit effort)
- crab/shrimp catch (FDEP)
- benthic index?
- marine mammals (manatees/dolphins)
- colonial nesting birds
- scallop counts

The vegetative habitat acreage could be obtained from periodic assessments performed by the SWFWMD. Fishery population data is collected by the Florida Dept. of Protection. Marine mammal and nesting bird information will be investigated further to determine if their densities can be related to bay quality with a reasonable degree of confidence. In addition, the TBNEP will be beginning a citizen's scallop monitoring program this summer, and thus, scallop densities may be available on a periodic basis in the future.

DEVELOPMENT OF BAY QUALITY INDICES

Coastal will compile the available data for the components listed under each of the agreed upon categories that were developed during this workshop. These categories include:

- Water Quality
- Impaired Uses
- Living Resources

Each data component identified above as warranting further investigation will be examined as to whether or not it is an appropriate indicator of "bay quality." Sample BQI calculations will be developed and subsequently presented to the TBNEP staff and to those invited to the workshop for comment and review.

APPENDIX B

ANNUAL MEANS FOR SELECTED WATER QUALITY PARAMETERS COLLECTED BY THE ENVIRONMENTAL PROTECTION COMMISSION OF HILLSBOROUGH COUNTY (1974-1990)

EPC annual mean water quality values for Tampa Bay

OBS	YEAR	CHL-A (µg/l)	SECCHI (inches)	TURBIDITY (NTU)	DISSOLVED OXYGEN (mg/l)	SALINITY (ppt)
1	74	12.2172	70.9091	4.56336	.	.
2	75	15.3809	66.9216	4.30323	6.35727	.
3	76	13.6304	58.9277	4.68396	7.18628	25.7159
4	77	17.2081	45.5785	5.35831	6.56235	30.1513
5	78	13.5965	43.2893	5.52830	6.96177	25.9330
6	79	19.2149	39.1588	4.97170	6.95000	25.2338
7	80	14.6901	46.6956	3.95110	6.89606	26.5329
8	81	16.6724	53.1818	5.96708	6.88833	28.7279
9	82	19.1541	57.4640	5.32914	7.09341	26.9145
10	83	18.6153	55.2696	4.69436	6.17441	23.2922
11	84	9.3707	59.4080	4.37540	6.25640	25.8954
12	85	12.6762	63.0092	4.98620	5.48804	29.0815
13	86	10.4971	71.2286	3.87460	5.76759	27.1749
14	87	9.8210	72.0297	4.21131	5.88803	26.5906
15	88	8.8385	71.5230	5.41667	5.87902	27.2575
16	89	9.5807	65.3793	7.20977	5.62477	28.0403
17	90	8.4916	68.8448	6.97612	6.16565	29.2020

EPC annual mean water quality values by bay segment

OTB = 1 MTB = 3
HB = 2 LTB = 4

OBS	YEAR	SEGMENT	CHL-A (μg/l)	SECCHI (inches)	TURBIDITY (NTU)	OXYGEN (mg/l)	SALINITY (ppt)
1	74	1	9.4650	71.280	3.95960	.	.
2	75	1	12.4625	62.650	4.70417	6.75179	.
3	76	1	10.5092	49.783	4.67500	7.44583	24.5462
4	77	1	10.9105	46.300	5.69000	6.98586	29.7429
5	78	1	9.4891	45.700	4.95909	7.26330	24.5956
6	79	1	17.3355	32.841	4.69725	7.22727	22.7391
7	80	1	13.5245	42.700	3.56364	6.82273	24.4845
8	81	1	11.8186	55.882	5.10455	7.21091	27.0828
9	82	1	12.1850	60.533	3.92778	7.64833	24.9493
10	83	1	17.1173	52.391	3.86818	6.60519	20.1990
11	84	1	8.8445	50.580	3.59000	6.54625	22.6715
12	85	1	10.5365	63.900	4.04000	5.77571	27.4544
13	86	1	10.0715	65.430	3.40000	6.19611	25.3470
14	87	1	8.7932	66.573	4.00909	6.39070	23.7629
15	88	1	7.8000	65.300	4.95000	6.13820	25.0193
16	89	1	8.9150	61.150	6.00833	6.16887	25.7415
17	90	1	8.2986	67.091	6.80455	6.92439	27.2591
18	74	2	23.1688	37.948	5.52027	.	.
19	75	2	30.2143	34.052	4.68571	4.53868	.
20	76	2	29.3542	32.056	5.63889	6.49792	22.6198
21	77	2	35.2667	23.396	6.22340	5.65937	27.1303
22	78	2	24.8000	24.307	6.49432	6.34756	22.8068
23	79	2	30.1011	24.460	6.14773	6.52299	22.1225
24	80	2	23.2425	33.369	4.10000	6.94813	23.8275
25	81	2	30.8636	30.330	7.72727	6.29477	26.5346
26	82	2	34.5772	33.570	7.53165	6.11645	24.5250
27	83	2	25.7899	38.693	5.68750	5.35625	21.1210
28	84	2	13.5371	42.407	5.84270	5.99844	24.5431
29	85	2	20.6594	37.031	7.06250	4.66508	27.9577
30	86	2	17.3309	44.798	5.48876	4.87333	25.5697
31	87	2	15.7750	48.021	5.44792	4.84179	24.4017
32	88	2	14.5417	47.885	7.16667	5.28765	25.5057
33	89	2	14.4189	47.625	8.95833	4.73263	25.9660
34	90	2	12.2365	49.458	7.81250	5.09494	27.7711
35	74	3	10.2462	74.862	4.75000	.	.
36	75	3	12.3731	68.955	3.84615	6.63413	.
37	76	3	10.1492	73.621	4.20455	7.19385	26.0750
38	77	3	12.5862	49.696	4.39683	6.70870	30.7113
39	78	3	13.0000	44.955	5.91667	6.90077	26.6580
40	79	3	17.9136	43.258	4.79545	6.74924	26.4578
41	80	3	14.3022	48.403	4.02239	6.93731	27.7405
42	81	3	14.4962	54.606	6.17424	6.78030	29.5691
43	82	3	20.1449	55.271	5.50000	7.28190	27.6117
44	83	3	20.9462	56.000	5.13636	6.21557	24.4903
45	84	3	9.3538	64.619	4.19231	6.13983	26.4875
46	85	3	12.3057	62.914	5.20714	5.62404	29.2675
47	86	3	8.1364	78.000	3.53731	5.85000	27.3129
48	87	3	8.6486	77.282	4.12857	5.97895	27.0453
49	88	3	7.6833	77.597	5.08333	5.90937	27.8228
50	89	3	8.3625	70.333	7.27778	5.63380	29.0803
51	90	3	7.6556	73.225	7.20423	6.28359	29.5484
52	74	4	4.2182	111.709	4.14545	.	.
53	75	4	4.6455	119.782	3.48182	7.00093	.
54	76	4	4.6847	93.300	4.08333	7.48500	31.3580
55	77	4	5.0283	75.133	4.28000	7.14000	35.1833
56	78	4	5.0463	67.278	4.63889	7.35926	33.2275
57	79	4	7.1173	70.127	3.84545	7.31182	33.3245
58	80	4	5.8567	69.883	4.38333	6.91500	34.7933
59	81	4	6.2855	82.636	4.62727	7.30091	34.6333
60	82	4	6.1610	92.280	4.17000	7.36633	33.1188
61	83	4	7.2045	86.673	4.22727	6.52000	31.5100
62	84	4	3.6055	94.527	3.64545	6.26000	32.0840
63	85	4	3.9017	103.200	2.98333	6.03556	33.6867
64	86	4	3.5508	113.237	2.62712	6.15847	32.2327
65	87	4	3.5467	114.233	2.70000	6.33061	32.5878
66	88	4	3.1767	114.500	3.95000	6.31923	33.7886
67	89	4	4.7133	96.300	6.73333	6.07288	34.2237
68	90	4	3.6828	98.897	5.63793	6.44528	33.8415

APPENDIX C

SEAGRASS, MANGROVE, AND MARSH AREAL COVERAGES

FROM TAMPA BAY

Seagrass Areal Coverage Data (hectares) From Tampa Bay

1950 data: cooperative study between the Florida Dept. of Natural Resources (FDNR) and the U.S. Fish and Wildlife Service (USFWS) as reported by Lewis et al. (1991)

1982/88 data: cooperative study between USFWS, FDNR, and Southwest Florida Water Management District (SWFWMD) SWIM Department as reported by Lewis et al. (1991)

1990 data: from SWFWMD SWIM photointerpretations and groundtruthing

OBSERVATION	YEAR	OTB	HB	MTB	LTB	TCB	MR	BCB	TOTAL SEAGRASS
1	1950	4393	1110	3844	2471	297	51	4282	16448
2	1982	2405	0	1636	2030	304	53	2335	8763
3	1988	2119	25	2287	2272	399	99	2482	9683
4	1990	2248	18	2143	2489	405	146	2734	10184

Areal Coverage (hectares) of Mangrove and Marshes by bay Segment for Tampa Bay (from SWFWMD photointerpretations, 1990).

TYPE	YEAR	OTB	HB	MTB	LTB	TCB	MR	BCB	TOTAL SEAGRASS
MANGROVE	1990	1150	499	905	221	84	6.0	1252	4117
MARSH	1990	3452	751	5061	2174	1122	711	493	13766

APPENDIX D

MANATEE AND BOTTLENOSE DOLPHIN COUNTS

FROM TAMPA BAY (1987-1990)

Manatee Count Data From Tampa Bay
(from Weigle, 1991)

OBS	DAY	MONTH	YEAR	SEASON	QTR	GROUPS	ADULTS	CALVES	TOT_CT
1	13	11	87	W	4	12	54	6	60
2	28	11	87	W	4	29	63	8	71
3	18	12	87	C	1	9	44	3	47
4	31	12	87	C	1	5	35	3	38
5	18	1	88	C	1	13	52	4	56
6	29	1	88	C	1	8	34	8	42
7	15	2	88	C	1	5	25	3	28
8	29	2	88	C	1	9	76	12	88
9	14	3	88	W	2	19	44	4	48
10	25	3	88	W	2	24	71	3	74
11	6	4	88	W	2	28	60	6	66
12	18	4	88	W	2	24	55	2	57
13	5	5	88	W	2	34	63	3	66
14	17	5	88	W	2	33	64	9	73
15	7	6	88	W	3	14	29	4	33
16	20	6	88	W	3	26	59	7	66
17	12	7	88	W	3	27	40	3	43
18	22	7	88	W	3	21	41	2	43
19	4	8	88	W	3	13	21	5	26
20	23	8	88	W	3	14	30	4	34
21	19	9	88	W	4	8	32	3	35
22	30	9	88	W	4	13	40	3	43
23	26	10	88	W	4	19	36	2	38
24	16	11	88	W	4	20	55	4	59
25	9	12	88	C	1	25	66	4	70
26	20	12	88	C	1	6	48	8	56
27	11	1	89	C	1	31	60	3	63
28	26	1	89	C	1	12	29	2	31
29	11	2	89	C	1	16	74	7	81
30	25	2	89	C	1	3	46	5	51
31	28	3	89	W	2	17	39	4	43
32	26	4	89	W	2	10	24	2	26
33	24	5	89	W	2	20	44	2	46
34	20	6	89	W	3	11	16	1	17
35	20	7	89	W	3	12	16	1	17
36	25	8	89	W	3	14	24	4	28
37	29	9	89	W	4	10	26	4	30
38	27	10	89	W	4	21	27	4	31
39	29	12	89	C	1	28	84	5	89
40	10	1	90	C	1	29	63	6	69
41	9	2	90	C	1	30	65	6	71
42	2	3	90	W	2	32	58	5	63
43	18	4	90	W	2	38	75	6	81
44	11	5	90	W	2	18	33	2	35
45	22	6	90	W	3	13	24	1	25
46	26	7	90	W	3	27	48	3	51
47	8	8	90	W	3	9	13	2	15
48	21	9	90	W	4	22	44	5	49
49	29	10	90	W	4	21	61	2	63
50	3	12	90	C	4	21	37	3	40
51	17	12	90	C	4	53	95	6	101

Bottlenose Dolphin Count Data From Tampa Bay
(from Reynolds et al., 1991)

OBS	DAY	MONTH	YEAR	SEASON	QTR	GROUPS	ADULTS	CALVES	TOT_CT
1	13	11	87	W	4	33	105	3	108
2	28	11	87	W	4	27	136	6	142
3	18	12	87	C	1	45	220	12	232
4	31	12	87	C	1	30	95	4	99
5	18	1	88	C	1	34	112	3	115
6	29	1	88	C	1	21	67	2	69
7	15	2	88	C	1	13	28	0	28
8	29	2	88	C	1	45	151	2	153
9	14	3	88	W	2	11	22	0	22
10	25	3	88	W	2	34	123	2	125
11	6	4	88	W	2	49	172	8	180
12	18	4	88	W	2	7	32	0	32
13	5	5	88	W	2	11	26	1	27
14	17	5	88	W	2	43	153	2	155
15	7	6	88	W	3	31	96	3	99
16	20	6	88	W	3	29	72	2	74
17	12	7	88	W	3	39	134	4	138
18	22	7	88	W	3	15	42	0	42
19	4	8	88	W	3	37	98	5	103
20	23	8	88	W	3	36	103	4	107
21	19	9	88	W	4	33	126	5	131
22	30	9	88	W	4	30	87	3	90
23	26	10	88	W	4	40	85	1	86
24	16	11	88	W	4	29	87	1	88
25	9	12	88	C	1	34	113	7	120
26	20	12	88	C	1	27	99	6	105
27	11	1	89	C	1	16	65	1	66
28	26	1	89	C	1	29	56	2	58
29	11	2	89	C	1	21	60	5	65
30	25	2	89	C	1	19	44	2	46
31	28	3	89	W	2	23	66	2	68
32	26	4	89	W	2	21	42	3	45
33	24	5	89	W	2	30	101	2	103
34	20	6	89	W	3	18	37	2	39
35	20	7	89	W	3	16	28	3	31
36	25	8	89	W	3	35	72	3	75
37	29	9	89	W	4	15	57	2	59
38	27	10	89	W	4	31	77	1	78
39	29	12	89	C	1	20	79	3	82
40	10	1	90	C	1	38	103	3	106
41	9	2	90	C	1	18	45	1	46
42	2	3	90	W	2	18	34	0	34
43	18	4	90	W	2	32	102	3	105
44	11	5	90	W	2	13	29	1	30
45	22	6	90	W	3	21	52	4	56
46	26	7	90	W	3	34	93	3	96
47	8	8	90	W	3	20	27	4	41
48	21	9	90	W	4	34	120	6	126
49	20	10	90	W	4	27	101	11	112
50	3	12	90	C	4	13	33	2	35
51	17	12	90	C	4	36	111	7	118

APPENDIX E

DATABASE FORMAT OF JUVENILE FISH DATA COLLECTED UNDER THE FLORIDA DEPARTMENT OF PROTECTION, MARINE RESEARCH INSTITUTE'S FISHERIES INDEPENDENT MONITORING PROGRAM

Enclosure 1.

SAS INPUT STATEMENTS FOR THE LENGTH DATABASE

```
INPUT FIELD_NO $ 1-10 SPLTTYPE 11 SPLTNUM 12-13 SPLITS 14-15 CELLS 16-17
      CELLNUM 18-19 SPECIES $ 20-29 NUMFISH 30-35 TAGTYPE $ 36 SEX
      $ 37 (L1-L20) (4.);
```

VARIABLE DESCRIPTIONS FOR THE LENGTH DATABASE

VARIABLE NAME	LOCATION	DATA TYPE	VARIABLE DESCRIPTION
FIELD_NO	1 - 10	CHARACTER	A ten digit code identifying each sample.
SPLTTYPE	11	NUMERIC	Type of splitter used.
SPLTNUM	12 - 13	NUMERIC	Number of the splitter used.
SPLITS	14 - 15	NUMERIC	Number of times the sample was split.
CELLS	16 - 17	NUMERIC	The number of cells counted from the splitter.
CELLNUM	18 - 19	NUMERIC	The cell number of the counted cells.
SPECIES	20 - 29	CHARACTER	NODC code identifying the species caught.
NUMFISH	30 - 35	NUMERIC	The number of that species caught.
TAGTYPE	36	CHARACTER	The type of tag (if any) found in the species caught.
SEX	37	CHARACTER	The sex of the species caught.
L1 - L20	38 - 117 (4.)	NUMERIC	Twenty length measurements of the species caught.

Enclosure 2.

SAS INPUT STATEMENTS FOR THE FIELD DATABASE

```
INPUT FIELD_NO $ 1-10 DATE $ 11-18 GEAR 19-21 REP 22-23 STTN 24-26 LAT 27-32
      LONG 33-38 ZONE $ 39 GRID 40-42 MCGRID 43-45 MOON 46-47 BOTTOM $
      48-49 PERIOD 50 SHORVEG $ 51-54 CURRELAT 55-58 WINRELAT 59-62
      BOTT_VEG $ 63-64 BYCATCH $ 65-68 QUANTITY 69-73 SOAKHR 74-75
      SOAKCOL $ 76 SOAKMIN 77-78 SPEED 79-82 SHORORNT 83-86 BEARING 87-90
      BOAT $ 91 SFST_DO 92-95 BTST_DO 96-99 SFE_DO 100-103 BTE_DO 104-107
      SFST_PH 108-111 BTST_PH 112-115 SFE_PH 116-119 BTE_PH 120-123
      SFSTTEMP 124-127 BTSTTEMP 128-131 SFETEMP 132-135 BTETEMP 136-139
      SFSTSALN 140-143 BTSTSALN 144-147 SFESALN 148-151 BTESALN 152-155
      SFSTCOND 156-159 BTSTCOND 160-163 SFECOND 164-167 BTECOND 168-171
      STHR 172-173 STCOL $ 174 STMIN 175-176 EHR 177-178 ECOL $ 179 EMIN 180-
      181 STTIDE $ 182-183 ETIDE $ 184-185 STDEPTH 186-189 EDEPTH 190-193
      STWINDDR $ 194-195 STWINDSP 196-198 EWINDDR $ 199-200 EWINDSP
      201-203 STCLOUDS 204-207 ECLOUDS 208-211 STCURRNT 212-215 ECURRNT
      216-219 DIST_TOW 220-223 BNET_WID 224-228 BNET_DIS 229-232 RISEHR
      233-234 RCOLON $ 235 RISEMIN 236-237 SETHR 238-239 SETCOLON $ 240
      SETMIN 241-242 P_COVER 243-245 BANK $ 247;
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VARIABLE DESCRIPTIONS FOR THE FIELD DATABASE

VARIABLE NAME	LOCATION	DATA TYPE	VARIABLE DESCRIPTION
FIELD_NO	1-10	CHARACTER	A ten digit code identifying each sample.
DATE	11-18	CHARACTER	Date (Month/Day/Year) that the sample was taken.
GEAR	19-21	NUMERIC	Gear that was used to collect that sample.
REP	22-23	NUMERIC	Repetition number of the sample.
STTN	24-26	NUMERIC	Station where the sample was taken.
LAT	27-32	NUMERIC	Latitude where the sample was taken.
LONG	33-38	NUMERIC	Longitude where the sample was taken.
ZONE	39	CHARACTER	Zone where the sample was taken.
GRID	40-42	NUMERIC	Grid where the sample was taken.
MCGRID	43-45	NUMERIC	McGrid where the sample was taken.
MOON	46-47	NUMERIC	Days past full moon when the sample was taken.
BOTTOM	48-49	CHARACTER	Bottom type over which the sample was taken.
(Continued)			

PERIOD	50	NUMERIC	Period during which the sample was taken.
SHORVEG	51-54	CHARACTER	Shore vegetation at the sample site.
CURRELAT	55-58	NUMERIC	Current direction in relation to direction gear was pulled.
WINRELAT	59-62	NUMERIC	Wind direction in relation to direction gear was pulled.
BOTT_VEG	63-64	CHARACTER	Bottom vegetation over which the sample was taken.
BYCATCH	65-68	CHARACTER	Type of bycatch collected in the sample.
QUANTITY	69-73	NUMERIC	Amount of bycatch collected in the sample.
SOAKHR	74-75	NUMERIC	Number of hours that the gear was set.
SOAKCOL	76	CHARACTER	Colon separating soakhr and soakmin.
SOAKMIN	77-78	NUMERIC	Number of minutes past the hour that the gear was set.
SPEED	79-82	NUMERIC	Engine RPM at which the gear was pulled.
SHORORNT	83-86	NUMERIC	Orientation to the shore where the sample was taken.
BEARING	87-90	NUMERIC	The compass direction in which the gear was pulled.
BOAT	91	CHARACTER	The boat from which the sample was collected.
SFST_DO	92-95	NUMERIC	Surface start dissolved oxygen.
BTST_DO	96-99	NUMERIC	Bottom start dissolved oxygen.
SFE_DO	100-103	NUMERIC	Surface end dissolved oxygen.
BTE_DO	104-107	NUMERIC	Bottom end dissolved oxygen.
SFST_PH	108-111	NUMERIC	Surface start pH.
BTST_PH	112-115	NUMERIC	Bottom start pH.
SFE_PH	116-119	NUMERIC	Surface end pH.
BTE_PH	120-123	NUMERIC	Bottom end pH.
SFSTTEMP	124-127	NUMERIC	Surface start temperature.
BTSTTEMP	128-131	NUMERIC	Bottom start temperature.
SFETEMP	132-135	NUMERIC	Surface end temperature.
BTETEMP	136-139	NUMERIC	Bottom end temperature.
SFSTSALN	140-143	NUMERIC	Surface start salinity.
BTSTSALN	144-147	NUMERIC	Bottom start salinity.
SFESALN	148-151	NUMERIC	Surface end salinity.
BTESALN	152-155	NUMERIC	Bottom end salinity.
SFSTCOND	156-159	NUMERIC	Surface start conductivity.
BTSTCOND	160-163	NUMERIC	Bottom start conductivity.
SFECOND	164-167	NUMERIC	Surface end conductivity.
BTECOND	168-171	NUMERIC	Bottom end conductivity.

(Continued)

STHR	172-173	NUMERIC	Hour that the gear began sampling.
STCOL	174	CHARACTER	Colon separating STHR and STMIN.
STMIN	175-176	NUMERIC	Minutes past the hour that the gear began sampling.
EHR	177-178	NUMERIC	Hour that the gear stopped sampling.
ECOL	179	CHARACTER	Colon separating EHR and EMIN.
EMIN	180-181	NUMERIC	Minutes past the hour that the gear stopped sampling.
STTIDE	182-183	CHARACTER	Tidal phase when the sampling began.
ETIDE	184-185	CHARACTER	Tidal phase when the sampling ceased.
STDEPTH	186-189	NUMERIC	Depth where the sample was taken when sampling began.
EDEPTH	190-193	NUMERIC	Depth where the sample was taken when sampling ceased.
STWINDDR	194-195	CHARACTER	Wind direction when sampling began.
STWINDSP	196-198	NUMERIC	Wind speed when sampling began.
EWINDDR	199-200	CHARACTER	Wind direction when sampling ceased.
EWINDSP	201-203	NUMERIC	Wind speed when sampling ceased.
STCLOUDS	204-207	NUMERIC	Percentage of cloud cover when sampling began.
ECLOUDS	208-211	NUMERIC	Percentage of cloud cover when sampling ceased.
STCURRNT	212-215	NUMERIC	Rate of current flow when sampling began.
ECURRNT	216-219	NUMERIC	Rate of current flow when sampling ceased.
DIST_TOW	220-223	NUMERIC	Distance which the gear was towed.
BNET_WID	224-228	NUMERIC	Net end - Net end distance for Blocknets.
BNET_WID	229-232	NUMERIC	Bag - Shore distance for Blocknets.
RISEHR	233-234	NUMERIC	Hour that the sun rose.
RCOL	235	CHARACTER	Colon separating RISEHR and RISEMIN.
RISEMIN	236-237	NUMERIC	Minutes past the hour that the sun rose.
SETHR	238-239	NUMERIC	Hour that the sun set.
SETCOL	240	CHARACTER	Colon separating SETHR and SETMIN.
SETMIN	241-242	NUMERIC	Minutes past the hour that the sun set.
P_COVER	243-245	NUMERIC	Percentage of the bottom covered by the bottom vegetation.
BANK	247	CHARACTER	The type of shoreline where the seine was set.

Enclosure 3. **VALUES AVAILABLE FOR EACH VARIABLE.**

BAY

Bay system and associated lab designations

AP	-----	Apalachicola
TB	-----	Tampa Bay
CH	-----	Charlotte Harbor
CK	-----	Cedar Key
FW	-----	Fort Walton
IR	-----	Indian River

TRIP TYPE

C	-----	Cryptic Mortality
F	-----	Fixed Station Sampling
G	-----	Gear Testing
H	-----	Hatchery Release Sampling
M	-----	Monitoring

GEAR CODES

1 ------ 20' Seine w/o bag, 1/8" mesh.
10 ------ 70' Center-bag seine, 1/8" mesh, onshore, deployed from boat (boat set). 12" lead spacing
11 ------ 70' Seine, 1/8" mesh offshore - circular w/ center-bag. 12" lead spacing
12 ------ 70' Seine, 1/8" mesh, on shore w/o boat, center-bag seine (beach set). 12" lead spacing
13 ------ 70' Terminal-bag seine,1/8" mesh, leads spaced every 12". Offshore-circular.
* 20 ------ 70' Center-bag seine, 1/8" mesh, leads spaced every 6". Offshore-circular.
21 ------ 70' Terminal-bag seine, 1/8" mesh, leads spaced every 6". Offshore-circular.
* 22 ------ 70' Center-bag seine, 1/8" mesh, leads spaced every 6". On shore w/o boat (Beach set).
* 23 ------ 70' Center-bag seine, 1/8" mesh, leads spaced every 6" (Boat Set).

- Continued -

24 ------ 70' Center-bag seine, 1/8" mesh, leads spaced every 6", w/many ends line. On shore w/o boat (Beach set).

25 ------ 70' Center-bag seine, 1/8" mesh, leads spaced every 6", w/ many ends line. Offshore-circular.

100 ------ 70' Terminal-bag seine, offshore-circular done in association with mangrove blocknets. 12" lead spacing.

101 ------ 70' Seine, offshore-circular w/ terminal bag, done in association with seawall blocknets. 12" lead spacing.

102 ------ 70' Terminal-bag seine, leads spaced every 6". Used in association w/ seawall block nets.

103 ------ 70' Terminal-bag seine, leads spaced every 6". Used in association w/ mangrove block nets.

104 ------ 70' Seine, offshore center seine w/ 6" lead spacing. Done in association w/ seawall blocknets.

105 ------ 70' Seine, offshore center seine w/ 6" lead spacing. Done in association w/ mangrove block nets.

106 ------ 70' Seine, offshore-circular w/ terminal bag, done in association w/ dropnets.

107 ------ 70' Center-bag seine, 1/8" mesh, leads spaced every 6". Offshore-circular, done in association w/1m^2 dropnets.

150 ------ 200' Seine, when used as a drag seine on poles and deployed from a boat.

151 ------ 400' Pull through seine, 1/8" mesh, w/ terminal-bag

152 ------ 400' Purse net, 1/8" mesh, w/ terminal bag

153 ------ 200' Blocknets, when used in association with mangroves. 12" lead spacing.

154 ------ 200' Block nets, when used in association with seawall. 12" lead spacing.

155 ------ 600' Center-bag seine 1 $^1/_2$" stretch mesh ($^3/_4$" bar mesh), set from skiff on-shore (Boat Set), 6" lead spacing.

200 ------ Small mesh gillnet (5-panel)

201 ------ Small mesh gillnet (3-panel = 250') 50'(50 mm) - 100'(75 mm) - 100'(100mm).

202 ------ Small mesh gillnet (3-panel = 350') 50'(50 mm) - 150'(75 mm) - 150'(100mm)

203 ------ Small mesh gillnet (3-panel = 450') 50'(50 mm) - 200'(75 mm) - 200'(100mm)

204 ------ 600' Large mesh gillnet (4-panel) - 150'; 3",4", 5",6" mesh - NORMAL SET: Small mesh to shore.

205 ------ 600' Large mesh gillnet (4-panel) - 150'; 3",4", 5",6" mesh, set an association w/ NORMAL gillnet set - REVERSE SET: Large mesh to shore.

206 ------ 600' Large mesh gillnet (4-panel) - 150'; 3",4", 5",6" mesh, set in association with REVERSE gillnet set. NORMAL SET: Small mesh towards shore.

- Continued -

250 ------ 600 yrd. Trammel net
300 ------ 20' Otter trawl w/ 1/8" liner & tickler chain straight tow.
301 ------ 20' Otter trawl w/ 1/8" liner & tickler chain arc tow.
302 ------ 20' Otter trawl w/o liner w/tickler chain straight tow.
303 ------ 12' Otter trawl w/ 1/8" liner & w/o tickler chain straight tow.
304 ------ 12' Otter trawl w/o liner & w/o tickler chain straight tow.
305 ------ 12' Otter trawl w/ 1/8" liner & w/o tickler chain arc tow.
306 ------ 20' Otter trawl w/ 1/8" liner & tickler chain combination tow (straight trawl/arc boat)
349 ------ Roller frame trawl
350 ------ Roving dropnet, 1 m^2, from skiffs
351 ------ Stationary dropnet, 1 m^2
352 ------ Stationary dropnet, 2 m^2
353 ------ Stationary dropnet, 4 m^2
354 ------ Roving dropnet (w/17' whaler)
400 ------ Plexiglass traps
401 ------ Pound net
402 ------ Stop nets, e.g. Alafia canal
403 ------ 600' 4 Panel gillnet(3",4",5",6" stretch mesh), Normal set, set in association w/5 Panel gillnet
404 ------ 600' 4 Panel gillnet(3",4",5",6" stretch mesh), Reverse set, set in association w/5 Panel gillnet
405 ------ 650' 5 Panel gillnet(2"'3",4",5",6" stretch mesh), Normal set, set in association w/4 Panel gillnet
406 ------ 650' 5 Panel gillnet(2"'3",4",5",6" stretch mesh), Reverse set, set in association w/4 Panel gillnet
407 ------ 300' Center bag seine, $^3/_4$" stretch mesh, lead spaced 6". Boat set.

MOON

Number of days past full moon

BOTTOM TYPE

D ------ Detritus
H ------ Shell
M ------ Mud
O ------ Oysters
P ------ Sponge
R ------ Rocks
S ------ Sand
T ------ Tunicates
U ------ Unknown

BOATS

-	------	no boat used (line through field)
B	------	20' mullet skiff (Minnow)
C	------	23' mullet skiff (CZM)
E	------	E C & P 23' mullet skiff
F	------	24' Tremblay (Fort Walton)
J	------	22' Tremblay #0130 (Miss Joan)
M	------	small mullet boat (Vertebrate)
R	------	22' Tremblay (Road Warrior)
S	------	23' mullet skiff (Lightning Rod)
T	------	22' Tremblay #0131 (Sea Neb)
W	------	17' Whaler

BANK

A	------	Gentle sloping bank inundated
B	------	Gentle sloping bank not inundated
C	------	Steep bank inundated
D	------	Steep bank not inundated

SHORE VEGETATION TYPE

AP	------	Australian Pines
AV	------	Aquatic Vegetation; mixed
*BM	------	Black Mangrove
BP	------	Brazilian Pepper
BW	------	Button Wood
CS	------	Cattails
*JU	------	Juncus
*MA	------	Mangrove
MG	------	Marsh Grasses
MU	------	Mud
NO	------	None
OS	------	Overhanging shrubs/trees
OY	------	Oysters
PA	------	Palmetto
*RM	------	Red Mangrove
RO	------	Rocks
RR	------	Rip Rap

- Continued -

*SA	------	Sand
SH	------	Shell
SN	------	Spartina
SW	------	Seawall
TG	------	Terrestrial Grasses
TO	------	Trees: Oak
TP	------	Trees: Pine
TV	------	Terrestrial Vegetation
WM	------	White Mangrove
WR	------	Algal mat (Wrack)
WX	------	Wax Myrtle

Note: Shore vegetation includes whatever is the predominant or distinguishing feature on shore.

CURRENT RELATION

* degrees from facing current *

0°	-----	into (against)
90°	-----	perpendicular (across)
180°	-----	away (with)

BOTTOM VEG.

A	------	Acanthophora
B	------	Acetabularia
C	------	Caulerpa
F	------	Algae: Filamentous red
G	------	Algae: Filamentous green
*2	------	Algae: Mixed
3	------	Algae: Unidentified
*4	------	Grasses: Mixed
5	------	Grasses: Unidentified
*H	------	Halodule
I	------	Halophila
*N	------	None
R	------	Ruppia
S	------	Syringodium
*T	------	Thalassia
*U	------	Unknown

BY-CATCH

AB	------	Acetabularia
AD	------	Algae: Drift
AF	------	Algae: Floating Mat
AG	------	Algae: Filamentous green
*AM	------	Algae: Mixed
AR	------	Algae: Filamentous red
AT	------	Acanthophora
AU	------	Algae: Unknown
BR	------	Bryozoans
CA	------	Caulerpa
CB	------	Cattails/Marsh grasses
CG	------	Corals: Gorgonian
CH	------	Crabs: Horseshoe
CI	------	Crabs: Spider
CL	------	Clay
CM	------	Crabs: Mixed
CP	------	Crabs: portunid
CS	------	Grasses: Cattails/Marsh
*CT	------	Ctenophores
*DT	------	Detritus
EM	------	Egg mass: gelatinous
ES	------	Egg cases: snail
*GM	------	Grasses: Mixed
GO	------	Gorgonian corals
GR	------	Gracilaria
GU	------	Grasses: Unknown
*HA	------	Halodule
HI	------	Halophila
JF	------	Jellyfish
JU	------	Juncus
*LL	------	Leaf Litter
MI	------	Mixed Invertebrates
MS	------	Mangrove seeds/propogules
MU	------	Mud
NO	------	None
NU	------	Nudibranch
OY	------	Oysters
PC	------	Pine Cones
PN	------	Pine Needles
PR	------	Palm Root
QH	------	Quahogs
RO	------	Rocks

- Continued -

RU	------	Ruppia
SA	------	Sand
SD	------	Sand Dollars
SN	------	Shrimp; noncommercial
UR	------	Sea Urchins
*SF	------	Starfish
SH	------	Shell
SN	------	Spartina
SP	------	Sponges
ST	------	Sticks and branches
SY	------	Syringodium
*TH	------	Thalassia
TU	------	Tunicates
UL	------	Ulva
*UU	------	Unknown
WT	------	Worm Tubes

QUANTITY

Estimation of the amount of by-catch in gallons.

SOAK TIME

* real time values in HOURS:MINUTES *

SPEED

RPM reading from tachometer (X 100)

SHORE ORIENTATION

* degrees from facing shore - for gillnets

0°	-----	opening facing shore
90°	-----	opening perpendicular to shore
180°	-----	opening opposite shore

DISSOLVED OXYGEN

mg/l --- milligrams per liter (round off to 1/10th)

TEMPERATURE

°C --- degrees Celsius (round off to 1/10th)

SALINITY

0/00 --- parts per thousand (round off to 1/10th)

TIME

HH:MM --- 24 hour time clock

TIDE

HF ------ high & falling
HR ------ high & rising
HS ------ high & slack
LF ------ low & falling
LR ------ low & rising
LS ------ low & slack
MF ------ mid & falling
MR ------ mid & rising
NG ------ negligible tide fluctuation

DEPTH

Measured ------ in meters

WIND DIRECTION

N/S/E/W	------	north / south / east / west
NE/SE	------	northeast / southeast
NW/SW	------	northwest / southwest

WIND SPEED

MPH ------ estimated speed in miles per hour

% CLOUD COVER

0	------	No clouds (clear)
1-100	------	Visual estimation
101	------	Fog
102	------	Rain

CURRENT

cm/s ------ in centimeters per second, # beeps/min. x 0.425

DISTANCE TOWED

nm ------ in nautical miles, calculated w/LORAN

SPLITTER

2	------	Two-way splitter
3	------	Three-way splitter
5	------	Twenty-five-way splitter
6	------	Six-way splitter

WIND RELATION

Degrees designating angle of wind relative to the bow of the boat

0 ------ Into
90 ------ Off starboard bow
180 ------ Off stern
270 ------ Off port bow

CORING DEVICE

1 ------ Post hole digger
2 ------ 4" PVC corer
* 3 ------ 6" PVC corer

TAGGED OR MARKED FISH RECAPTURE

1 ------ Fluorescent pigment mark
2 ------ Internal anchor tag
3 ------ Coded wire tag
4 ------ Pit tag
5 ------ Dart tag
6 ------ Fin clipped
7 ------ Australian dart tag
8 ------ PDX Small Australian dart tag
9 ------ IEX Small belly tag
38 ------ Coded wire w/PDX tag
39 ------ Coded wire w/IEX tag

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* = Frequently used codes.