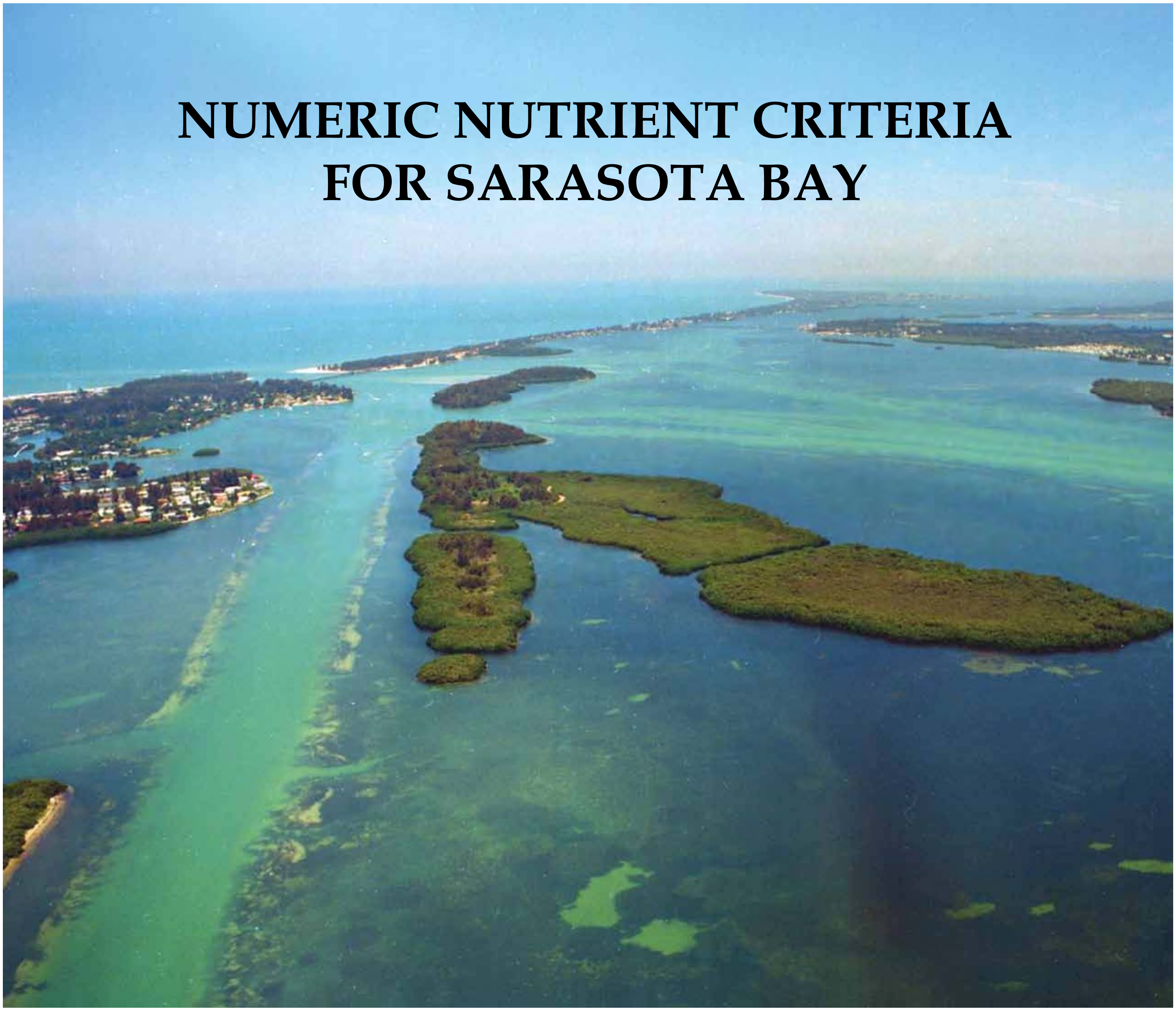
NUMERIC NUTRIENT CRITERIA FOR SARASOTA BAY



SARASOTA BAY
ESTUARY PROGRAM
Restoring Our Bays

Prepared for:
Sarasota Bay Estuary Program

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EXECUTIVE SUMMARY

One of the major objectives of the Clean Water Act (CWA) is to restore and maintain the chemical, physical and biological integrity of the Nation's waters to provide "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water". On January 14, 2009 the U.S. Environmental Protection Agency (USEPA) determined under the CWA section 303(4)(B) that new or revised water quality standards expressed as numeric nutrient criteria (NNC) are necessary to meet the requirements of the CWA in the State of Florida. These criteria are numeric limits on the amount of phosphorus and nitrogen that would be allowed in Florida's waters. NNC will provide baselines against which to measure environmental progress, to facilitate the writing of protective NPDES permits, and to develop defensible TMDLs.

The original USEPA schedule for proposed estuarine and coastal water criteria was January 2011. This schedule has been recently modified and now requires USEPA to propose estuarine and coastal waters nutrient criteria and downstream protective values in Florida by November 14, 2011. This revised schedule will allow more time for peer review by the Science Advisory Board (SAB) as well as an extended public comment period.

In October 2009, the Sarasota Bay Estuary Program (SBEP) Policy and Management boards directed the Technical Advisory Committee (TAC) to develop numeric nutrient criteria for the estuarine waters of the Sarasota Bay system. The primary objectives of this project were to:

- develop a data base of water quality and nutrient loads for each of the major bay segments;
- define the chlorophyll *a* thresholds that meet light attenuation and seagrass targets in each bay segment;
- define the quantitative relationships between nutrient concentrations or loading and chlorophyll *a* concentrations in each bay segment; and
- estimate the numeric nutrient criteria, i.e., the nutrient concentrations or loading consistent with the chlorophyll *a* thresholds, for each bay segment.

This effort would fulfill the need for establishing NNC based on the best available data for the following SBEP estuarine segments:

- Palma Sola Bay
- Sarasota Bay
- Roberts Bay
- Little Sarasota Bay
- Blackburn Bay

A water quality subcommittee of the TAC began the NNC development process by reviewing existing seagrass and chlorophyll *a* data and proposing a set of chlorophyll *a* targets to support the development of the NNC. This review confirmed that the recent extents of seagrasses are meeting the established targets; the subcommittee thus determined that the recent chlorophyll *a* concentrations and resultant water clarity must be protective of the seagrasses in each of the segments. Upon review of the chlorophyll *a* concentration data, it was deemed appropriate to include not only the data from the 2004-2005 time frame but also data from several antecedent years (2001-2003). **The resultant mean chlorophyll a concentrations from this overall period (2001-2005) were established as the targets for each segment.** These targets are:

- Palma Sola Bay – 8.5 μg/L
- Sarasota Bay – 5.2 μg/L
- Roberts Bay – 8.2 μg/L
- Little Sarasota Bay – 8.2 μg/L
- Blackburn Bay – 6.0 μg/L

The subcommittee further recognized that there may be years in which these targets may be exceeded without causing significant reductions in seagrass cover. This means that there is some allowable, or acceptable, amount of variation that should not elicit a significant degradation in water quality and therefore seagrass coverage. The subcommittee defined this level of variation as "the standard deviation around the mean annual chlorophyll *a* concentrations in each segment for the entire period of record". Therefore, a distinction is made between a **target**, i.e., a desired chlorophyll *a* concentration and a **threshold**, i.e., a chlorophyll *a* concentration above which undesirable chlorophyll *a* concentrations exist and should not be exceeded. The chlorophyll *a* threshold for each segment is "the sum of the target and the standard deviation around the mean annual chlorophyll *a* concentrations for that segment". **Therefore, the sum of the mean chlorophyll a concentrations for 2001-2005 and the standard deviation around the mean annual chlorophyll a concentrations for that segment are the thresholds that were used in the development of the numeric nutrient criteria in the SBEP estuarine waters.** They are:

- Palma Sola Bay – 11.8 μg/L
- Sarasota Bay – 6.1 μg/L
- Roberts Bay – 11.0 μg/L
- Little Sarasota Bay – 10.4 μg/L
- Blackburn Bay – 8.2 μg/L

The water quality data used in these analyses were provided by Sarasota and Manatee counties. These data included monthly chlorophyll *a*, TN, TP, salinity, color, turbidity, and other variables. The nutrient and hydrologic loading estimates were developed by applying the Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) which was designed and calibrated by Jones Edmunds & Associates, Inc. for Sarasota County. In addition to the water quality and nutrient loading data, estimates of residence times for each segment were derived based on the physical features and hydrologic loads for each segment.

A linear regression model approach was used to develop statistically defensible relationships between potential stressors and water quality responses. The independent variables used in the model building process included nutrient loadings, nutrient concentrations, and estimates of residence time. The loadings data included monthly hydrologic, TN, and TP loads as well as cumulative total loads extending from two to six months (e.g., 2-month cumulative TN load = TN load current month + TN load one- month prior). The water quality constituents included TN and TP concentrations along with numerous other constituents.

The stressor-response relationships for Roberts Bay, Little Sarasota Bay, and Blackburn Bay indicated very similar responses in chlorophyll *a* concentrations to changes in nutrient concentrations. Specifically, two terms, TN concentration and season, explained more than 60% of the variation in the chlorophyll *a* data. These results indicate that there are significant relationships between chlorophyll *a* and TN concentrations in each of these segments and that these relationships vary between the wet and dry seasons. The relationship between chlorophyll *a* and TN concentrations in Sarasota Bay is more complex. This relationship depends upon location within the segment (north vs. south) and the ambient water color.

Based on the quantitative relationships between chlorophyll *a* and TN concentrations in each of these segments and the chlorophyll *a* thresholds, the NNC expressed as mean annual TN concentrations were determined for each segment. These criteria are:

- Roberts Bay – 0.54 mg/L,
- Little Sarasota Bay – 0.60 mg/L,
- Blackburn Bay – 0.43 mg/L, and
- Sarasota Bay – 0.28-1.34 mg/L (based on ambient water color for the period 1998-2009).

No significant relationship was found between chlorophyll a concentrations and either nutrient (TN or TP) concentrations or loadings in Palma Sola Bay. Given this result, an alternative method for proposing NNC for Palma Sola Bay was necessary.

The SBEP water quality subcommittee of the TAC considered three potential candidate methods for estimating the TN criterion for Palma Sola Bay. These methods included a logistic regression approach, a changepoint analysis approach, and an approach similar to that used to define the chlorophyll *a* thresholds. All three potential candidate methods give relatively similar results**. The subcommittee recommended the third option – i.e., that based on the 2001-2005 ambient TN data.** The proposed NNC for Palma Sola Bay is:

- a mean annual TN concentration of 0.93 mg/L.

The full TAC concurred with the subcommittee's recommendation on 23 July 2010.

I. Introduction

The Sarasota Bay Estuary Program (SBEP) began in June 1989 when Sarasota Bay was designated an "estuary of national significance" by the U.S. Congress as part of the Water Quality Act of 1987. SBEP is one of 28 National Estuary Programs (www.epa.gov/nep/) in the United States. The Sarasota Bay Estuary Program is a member of the Association of National Estuary Programs (www.nationalestuaries.org/).

The SBEP partners include:

- Sarasota County,
- Manatee County,
- City of Sarasota,
- City of Bradenton,
- Town of Longboat Key,
- Florida Department of Environmental Protection,
- Southwest Florida Water Management District, and
- U.S. Environmental Protection Agency.

SBEP was initially tasked with characterizing the environmental conditions of Sarasota Bay and formulating a comprehensive restoration and protection plan based upon this analysis. The resulting plan was the Comprehensive Conservation and Management Plan (CCMP).

The CCMP recommends specific actions to be taken by local governments as well as state and federal agencies to restore and protect Sarasota Bay. The CCMP was formally approved by the Governor of Florida and the Administrator of the U.S. Environmental Protection Agency in 1995.

SBEP has been a focal point for the local government agencies and assists them in their efforts to protect water quality in the estuarine waters of the area. To this end, SBEP has provided a forum for the establishment of critical environmental endpoints to assure increasingly difficult funding opportunities are being effectively applied.

II. Objectives

The primary objectives of this project are:

- To develop a data base of water quality and nutrient loads for each of the major bay segments;

- To define the chlorophyll *a* thresholds that meet light attenuation and seagrass targets in each bay segment;

- To define the quantitative relationships between nutrient concentrations or loading and chlorophyll *a* concentrations in each bay segment; and

- To estimate the numeric nutrient criteria, i.e., the nutrient concentrations or loading consistent with the chlorophyll *a* thresholds, for each bay segment.

III. SBEP Goals and Targets

Sarasota Bay is a coastal lagoonal system formed by a necklace of barrier islands to the west and the mainland of Manatee and Sarasota Counties to the east (Figure III-1). This coastal lagoon, with its unique ecological character of small embayments, tidal tributaries and small creeks, coves, inlets and passes, is bounded by Anna Maria Sound to the north and stretches all the way to just north of the Venice Inlet, which serves as its southern boundary. The overall watershed is approximately 455 square miles. The bay itself is approximately 56 miles long and has an average depth of 6.5 feet.

Sarasota Bay is made of a series of smaller bays or segments. Each of these segments are unique from one another. They differ in overall size, shape and water depth, shoreline features, habitat and sediment characteristics. These unique characteristics lead to differences in water circulation, freshwater inputs, nutrient loads, as well as other consequences for health and vitality. Because of these differences, each embayment must be analyzed and managed independently from the others at the same time recognizing their connectivity.

The Sarasota Bay Estuary Program recognizes the following segments as having their own unique set of conditions and influences: Palma Sola Bay, Sarasota Bay proper, Roberts Bay, Little Sarasota Bay, and Blackburn Bay.

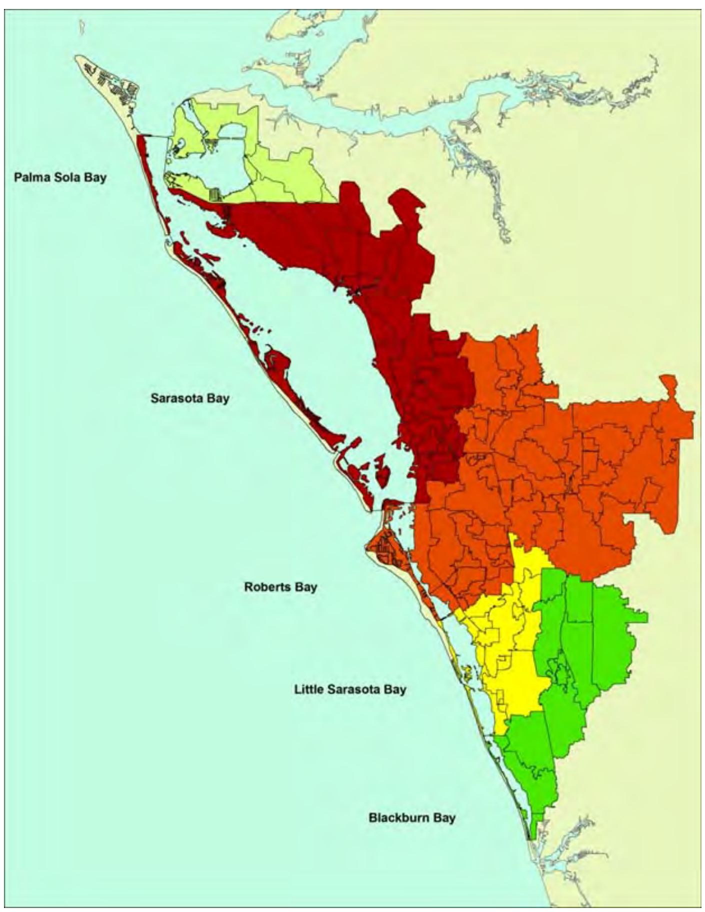

Figure III-1. - Sarasota Bay Estuary Program segments and their watersheds.

Sarasota Bay was named an estuary of "national significance" in 1987 which led to its designation as a National Estuary Program by the EPA two years later. The Sarasota Bay Estuary Program is dedicated to improving and protecting the area's greatest and most important natural asset - Sarasota Bay. The SBEP strives to improve water quality, increase habitat and enhance the natural resources of the area for use and enjoyment by the public.

A Management Conference was formed comprising federal, state, regional and local officials who oversaw the development and implementation of a Comprehensive Conservation and Management Plan (CCMP) for Sarasota Bay. The Policy Committee established the goals, objectives, budgets and work plans for the conference.

Several priority concerns were identified:

- Declines in water and sediment quality
- Loss of wetlands and other coastal habitats
- Loss of seagrasses
- Declines in finfish and shellfish populations
- Overuse

The Management Conference also developed plans of action to address these concerns through technical studies and citizen action plans which resulted in the development of the CCMP in 1995. Progress in the implementation of the CCMP has been documented. A State of the Bay report (SBEP, 2010) has been recently completed and a summary of these accomplishments is given in Appendix 1.

In addition to other goals, the SBEP has established quantitative targets for the restoration and protection of seagrasses (Janicki et al., 2009) and for water quality, specifically chlorophyll *a* concentrations (Janicki Environmental, 2010a).

III-1. Seagrass Targets

One of the primary SBEP goals is to maintain and/or restore seagrass coverage to its historic extent. The seagrass target project provided technically-defensible quantitative seagrass targets for the Sarasota Bay ecosystem. Establishment of seagrass targets provides a necessary basis for management decisions regarding water quality and other issues that can influence the distribution and persistence of this resource. Targets were defined through an analysis of historic and recent aerial surveys of the study area.

The historic aerial photos used to establish the baseline extent of seagrass in the study area were dated circa 1950. Recent trends in and persistence of seagrass throughout the SBEP were determined through analysis of GIS shapefiles based on aerial surveys executed biannually by the Southwest Florida Water Management District since 1988. Due to anthropogenic modifications in the estuary such as shoreline build-out and the dredging of the Intracoastal Waterway (ICW), certain areas have been altered to the extent that they have no reasonable potential for restoration; these so-called non-restorable areas have been identified and removed from the analyses.

The trend analyses show that Sarasota Bay proper is currently at its highest seagrass level since 1950 and exceeds the baseline extent (Figures III-2 – III-65). The seagrass coverage in Roberts Bay and Blackburn bays also increased since the baseline period. In Palma Sola Bay, the seagrass coverage has remained very similar over the entire period of record. In contrast, Little Sarasota Bay has shown a decline in seagrasses since 1950.

The definition of the most appropriate seagrass targets was reached with input from the Technical Advisory Committee (TAC). The TAC recommended that the greater of either the historic or recent (2004-2006) seagrass coverages be established as the target in each segment. The sole exception to this rule was Little Sarasota Bay. Since 1984, the direct connection to the Gulf of Mexico (Midnight Pass) has been closed. This physical alteration may have contributed to the difference in seagrass coverage between the historic and current coverages. However, a recent FDEP decision precludes re-opening of this pass. Therefore, the recent coverage in Little Sarasota Bay has been established as the target. Table III-1 presents the seagrass targets that were adopted by the SBEP Management and Policy boards.

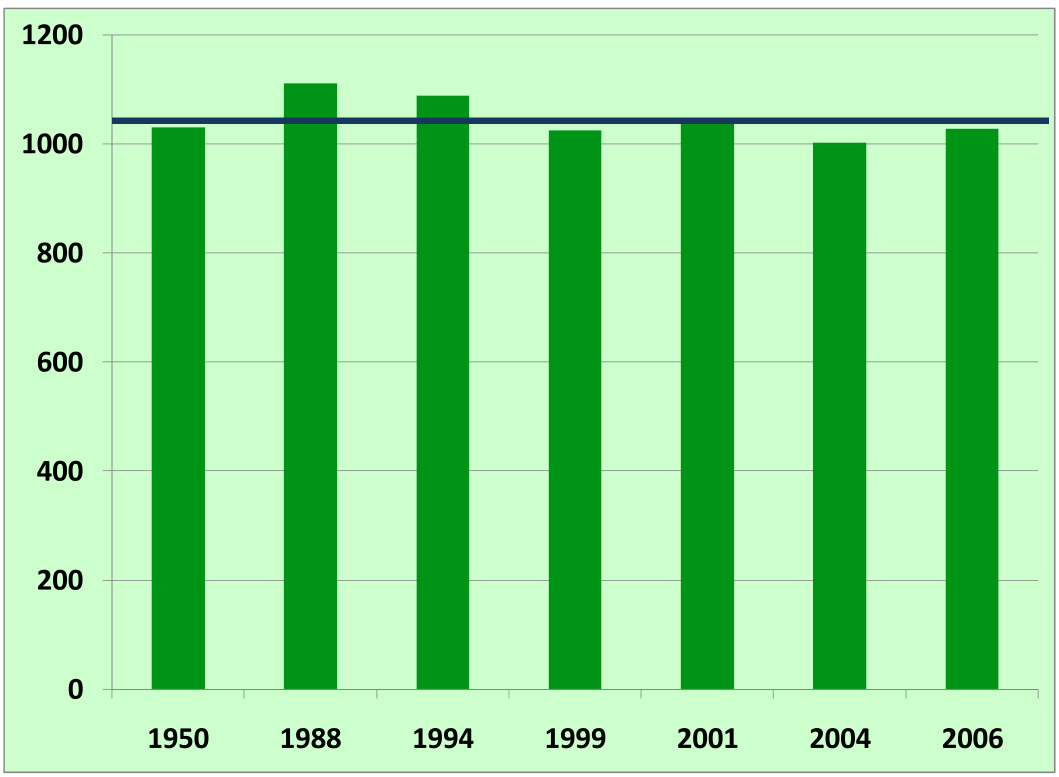

Figure III-2. Annual seagrass acreages in Palma Sola Bay. Horizontal line = seagrass target.

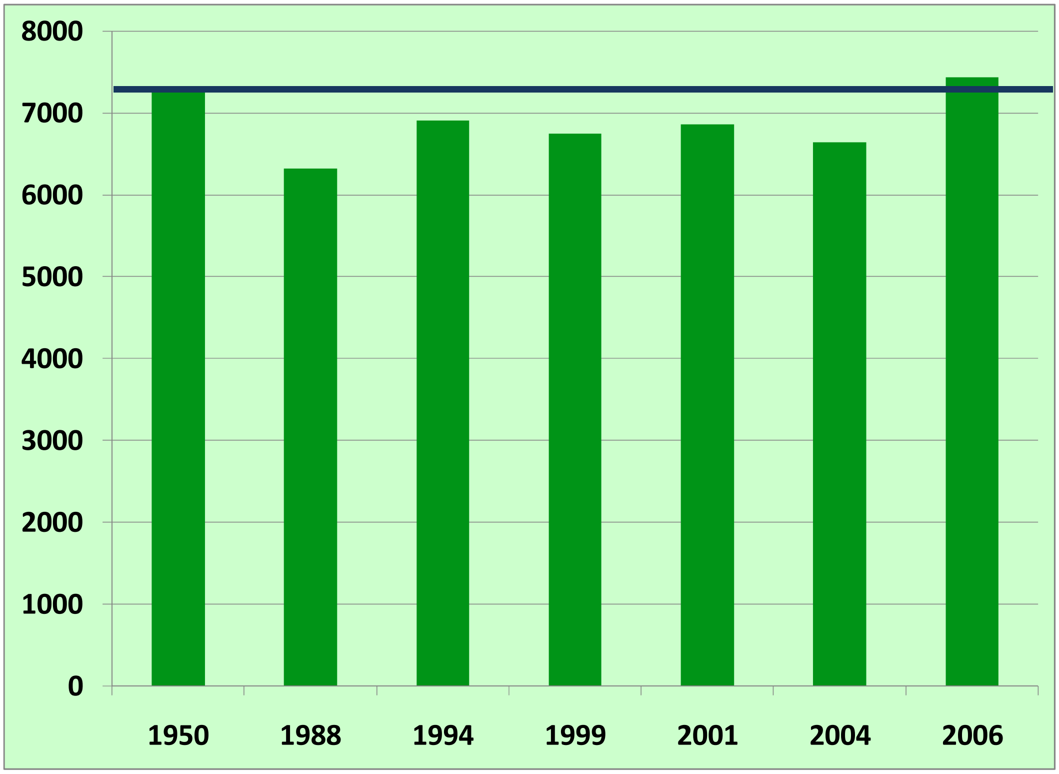

Figure III-3. Annual seagrass acreages in Sarasota Bay. Horizontal line = seagrass target.

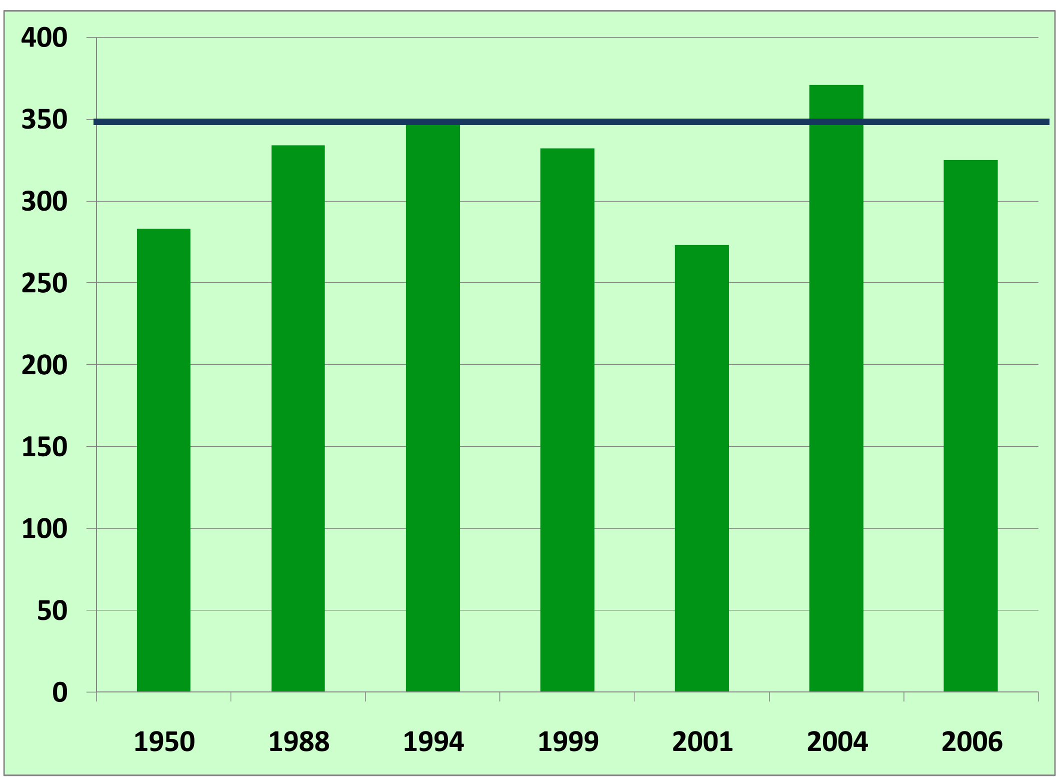

Figure III-4. Annual seagrass acreages in Roberts Bay. Horizontal line = seagrass target.

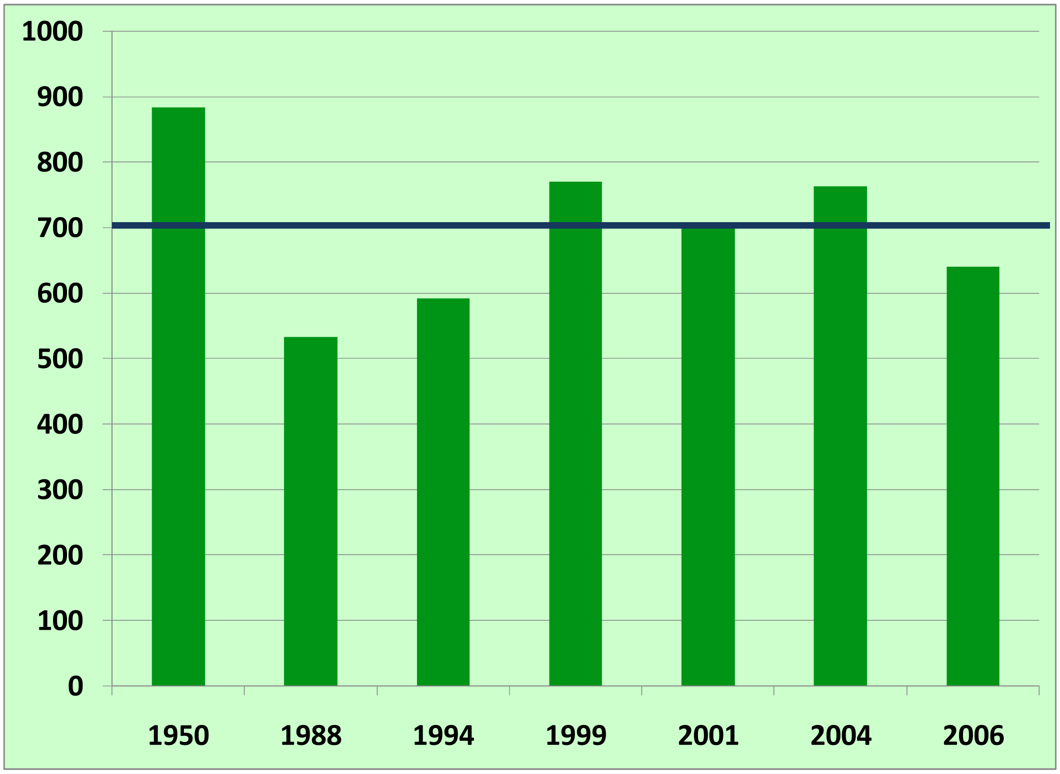

Figure III-5. Annual seagrass acreages in Little Sarasota Bay. Horizontal line = seagrass target.

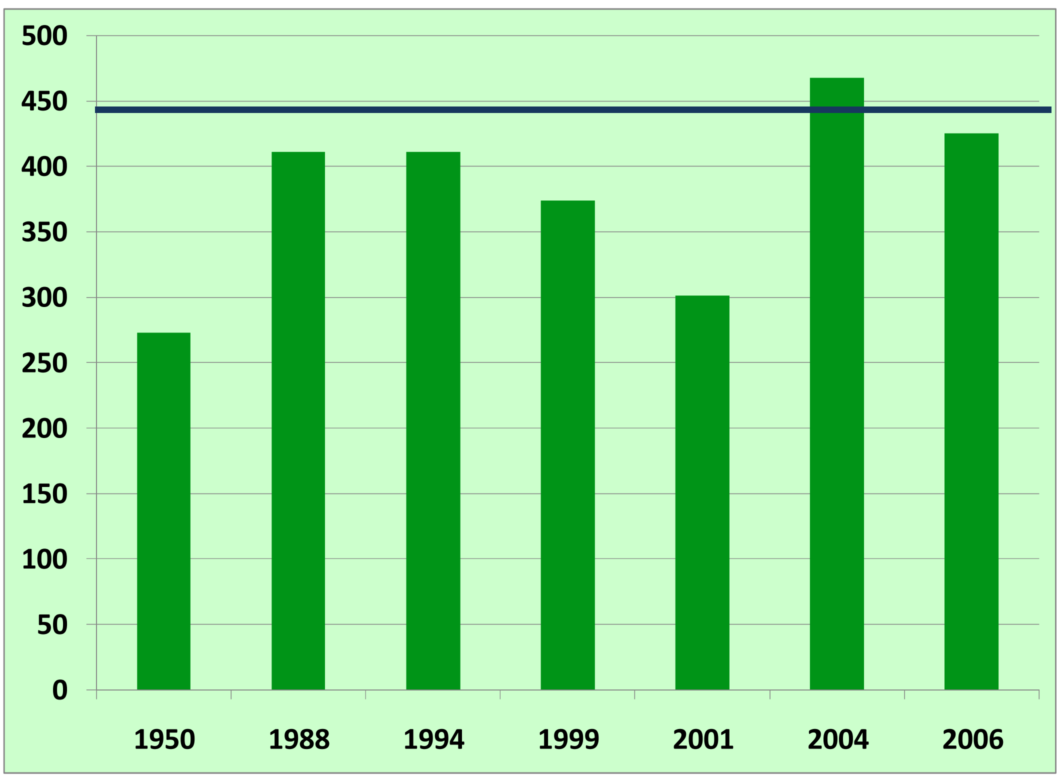

Figure III-6. Annual seagrass acreages in Blackburn Bay. Horizontal line = seagrass target.

Table III-1. SBEP seagrass coverage and targets. Unit of measure = acres.			
Bay Segment	**Historical (1950)**	**Current 2004-2006 Average**	**Seagrass Target**
Palma Sola	1,031	1,015	1,031
Sarasota	7,269	7,041	7,269
Roberts	283	348	348
Little Sarasota	883	702	702
Blackburn	273	447	447
Total	9,739	9,552	9,997

III-2. Chlorophyll *a* Targets and Thresholds

In October 2009, the SBEP Policy and Management boards directed the TAC to develop numeric nutrient criteria for the estuarine waters of the area. A subcommittee of the TAC began the process by reviewing the existing seagrass and chlorophyll *a* data and proposing a set of chlorophyll *a* targets to support the development of the numeric nutrient criteria (Janicki Environmental, 2010).

Given that the recent extents of seagrasses are meeting the established targets, the subcommittee determined that the recent chlorophyll *a* concentrations and resultant water clarity are protective of the seagrasses in each of the SBEP segments. Upon review of the chlorophyll *a* concentration data, it was deemed appropriate to include not only the data from the 2004-2005 period but also from several antecedent years (2001-2003). The resultant mean chlorophyll a concentrations from this overall period (2001-2005) were established as the targets for each segment (Table III-2). The subcommittee further recognized that there may be years in which these targets may be exceeded without causing significant reductions in seagrass cover. This means that there is some allowable amount of variation that should not elicit a significant degradation in water quality and therefore seagrass coverage. The subcommittee defined this level of variation as the standard deviation around the mean annual chlorophyll *a* concentrations in each segment for the entire period of record. Therefore, a distinction is made between a **target**, i.e., a desired chlorophyll *a* concentration and a **threshold**, i.e., a chlorophyll *a* concentration above which undesirable chlorophyll *a* concentrations exist. The chlorophyll *a* threshold for each segment is the sum of the target and the standard deviation around the mean annual chlorophyll *a* concentrations in each segment. The thresholds shown in Table III-1 are used in later sections of this report in the development of the numeric nutrient criteria in the SBEP estuarine waters.

Table III-2. Recommended chlorophyll *a* targets and thresholds (µg/L).			
Bay Segment	**Target Chlorophyll *a* (µg/L)**	**Inter-annual Variability (1 SD of Annual Means)**	**Threshold Chlorophyll *a* (µg/L)**
Palma Sola	8.5	3.3	11.8
Sarasota	5.2	0.9	6.1
Roberts	8.2	2.8	11.0
Little Sarasota	8.2	2.2	10.4
Blackburn	6.0	2.2	8.2

IV. Recent Water Quality Assessments

This section provides an examination of water quality data for total nitrogen (TN), total phosphorus (TP), chlorophyll *a*, and salinity within the SBEP estuarine area to identify any spatial and temporal trends. Bay segments in the SBEP area include Palma Sola Bay, Sarasota Bay, Roberts Bay, Little Sarasota Bay, and Blackburn Bay (Figure IV-1). This summary will be used to assist in setting locally-appropriate numeric nutrient criteria for estuaries in the SBEP system.

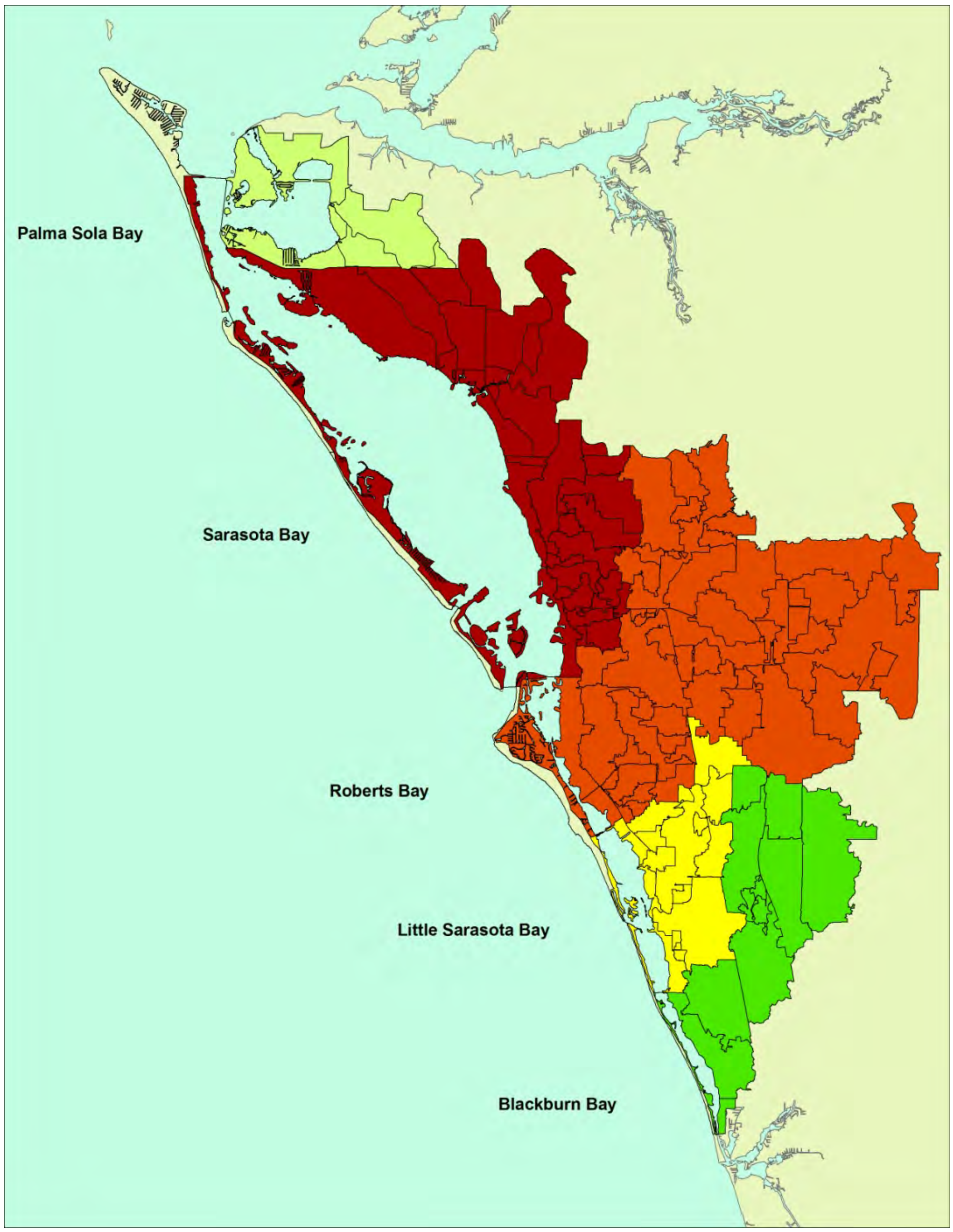

Figure IV-1. - Sarasota Bay Estuary Program segments and their watersheds.

IV-1.0 Ambient Water Quality Sampling Programs in the SBEP Area

Both Sarasota County and Manatee County collect water quality data within the SBEP area. The two monitoring programs are briefly described below. Maps showing the sampling sites from both programs are presented in Appendix 2.

The Sarasota County ambient water quality monitoring program was initiated in 1998. Sarasota Bay was divided into 12 segments, each with multiple randomly chosen sampling sites. Samples are collected on a monthly basis from each segment. All sample locations are sampled once every year. Each sampling location is also re-sampled every year in the same month as the preceding years. This stratified random monitoring program characterizes overall estuarine health by describing entire bay segments rather than isolated locations in each water body.

The Manatee County Environmental Management Department (EMD) ambient water quality monitoring program for Manatee County's estuarine waters is the Regional Ambient Monitoring Program (RAMP). The Manatee County RAMP program divides the County's estuarine area into two segments of 24,356 km^2 hexagonal sampling areas each. The south segment includes Palma Sola Bay and Sarasota Bay north of the county line, both of which are within the SBEP area.

Sampling points were randomly located within each hexagon at the start of the program. A hexagonal sampling area was included in the program if the randomly generated sampling point was at least 4ft deep by the nautical chart and verified during program reconnaissance. One-third of the sampling points in each segment, eight points, are sampled monthly. All sampling points in a segment are visited within each calendar quarter. In bay segments where both Sarasota and Manatee counties collected data, these data were averaged.

Times series of monthly mean values for each bay segment were produced to allow visual inspection of trends over time and to allow a comparison between bay segments. Trends in chlorophyll *a*, TN, or TP concentrations were assessed using graphical plots and the seasonal Kendall Tau trend test (Hirsch et al., 1982; Hirsch and Slack, 1984; Reckhow, 1993). The seasonal Kendall Tau is a nonparametric test that estimates the median slope from all pair-wise comparisons in a timeseries of data. The statistical test accounts for seasonality and serial autocorrelation prior to evaluating the statistical significance of the trend in the time series. Therefore, the seasonal Kendall Tau is a sophisticated and robust method to evaluate trends in water quality data that often do not fit the assumptions necessary for the use of parametric statistics (e.g. linear regression).

In addition to the examination of inter-annual variability, box and whisker plots were generated to examine within-year variability in water quality in each of the bay segments.

Besides tidal action, rainfall provides a driver for changes to surface water quality. Both direct rainfall on a water body and stormwater runoff from the watershed cause nonpoint source loadings to be a major factor in most receiving waters' quality. Annual rainfall for the 1998 though 2009 period is summarized in Table IV-1. The rainfall data are described in Chapter V below. It may be expected that years with high rainfall would cause changes to water quality, such as lower salinity, in segments with larger watersheds, while segments with smaller watersheds that contribute runoff would show less of an effect.

Table IV-1. Annual rainfall in the SBEP area sorted by rainfall.

Year	Rainfall (inches)
2000	32.8
2007	34.2
2009	43.4
2008	44.2
2006	45.3
2001	46.9
1999	49.7
2004	51.9
2002	53.4
1998	57.3
2003	60.3
2005	61.2

IV-2.0 Ambient Water Quality Assessment

The following summarizes annual and seasonal trends in salinity, TN, TP, and chlorophyll *a* for each SBEP bay segment. Results are based on a review of data for the period January 1998 through December 2009, except Palma Sola Bay that had data available only through December 2008.

IV-2.1 Palma Sola Bay

IV-2.1.1 Salinity

Mean annual salinity for the 1998 through 2008 period in Palma Sola Bay averaged 29.8 parts per thousand (ppt) (Figure IV-2). The lowest annual value, 22.3 ppt occurred in 2008 and the highest annual value, 34.8 ppt, occurred in 2000, a very dry year (Table IV-1). There was no significant trend in salinity in Palma Sola Bay over this time period ($p > 0.05$; Appendix 2).

The box-and-whisker plots for salinity show values lower in the summer wet season than in the dry season, as would be expected (Figure IV-3). Monthly means range from 32.1ppt (May) to 25.0 ppt (October).

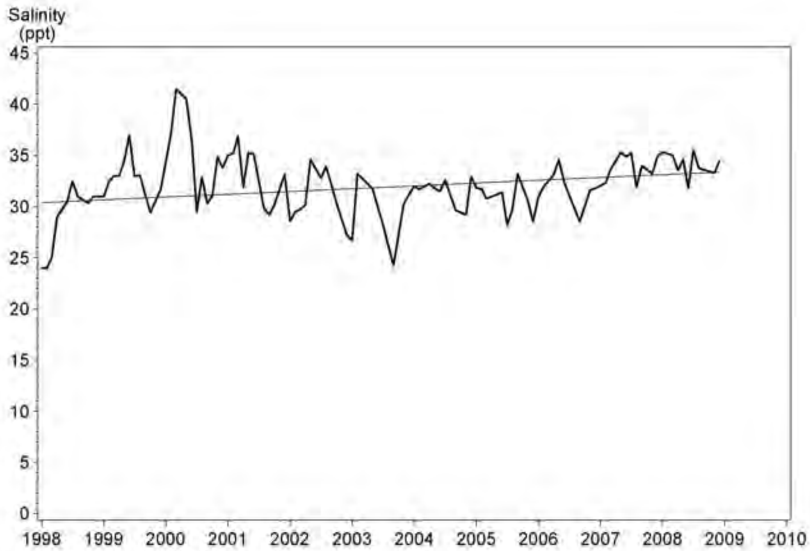

Figure IV-2. Mean monthly salinity (ppt) observed in Palma Sola Bay. The line is a least squares fit to the data.

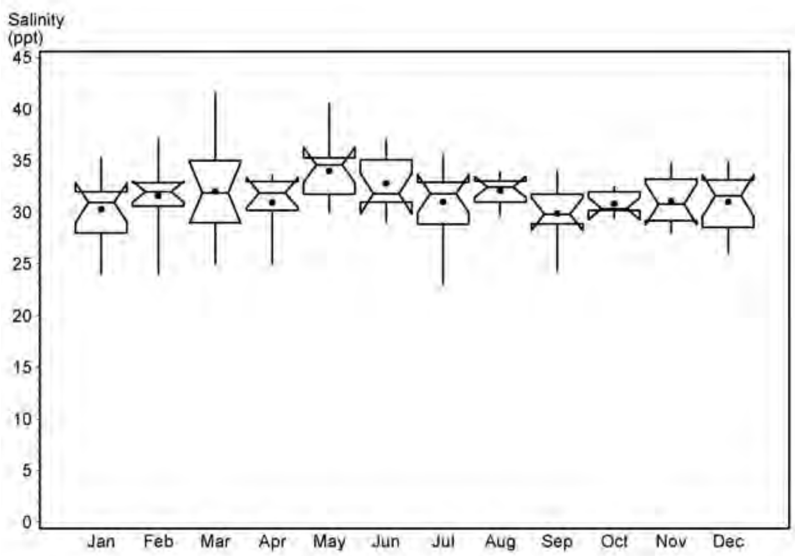

Figure IV-3. Box-and-whisker plots of the mean monthly salinity (ppt) observed in Palma Sola Bay.

IV-2.1.2 Chlorophyll *a*

Mean annual chlorophyll *a* concentrations for the 1998-2008 period in Palma Sola Bay averaged 8.25 μg/L (Figure IV-4). The lowest annual value of 4.89 μg/L occurred in 2005, a significantly wet year (Table IV-1). Lower chlorophyll concentrations may be expected if higher volumes of freshwater are reducing residence time on an annual basis. The highest annual value, 11.3 μg/L, occurred in 1998, also a wet year. A significant decreasing trend in chlorophyll *a* concentrations was observed during the 1998-2008 period ($p<0.0001$, Appendix 3).

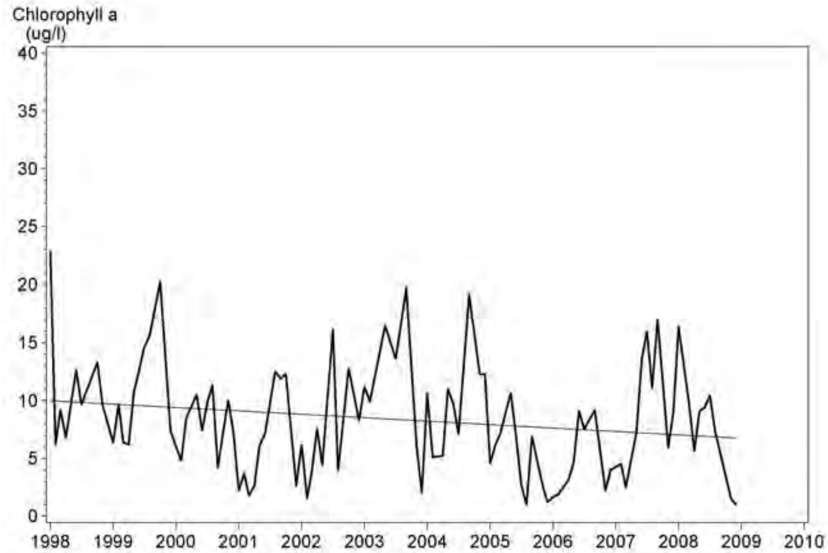

Figure IV-4. Mean monthly chlorophyll *a* concentrations (μg/L) observed in Palma Sola Bay.

Chlorophyll *a* monthly box-and-whisker plots show a definite seasonal signal (Figure IV-5). During the warmer summer months when nutrient loading is typically greatest and day length increases, the mean monthly chlorophyll *a* concentrations are much higher than those observed in the dry, cooler period of the year. Monthly means range from 12.4 μg/L (July) to 5.26 μg/L (November).

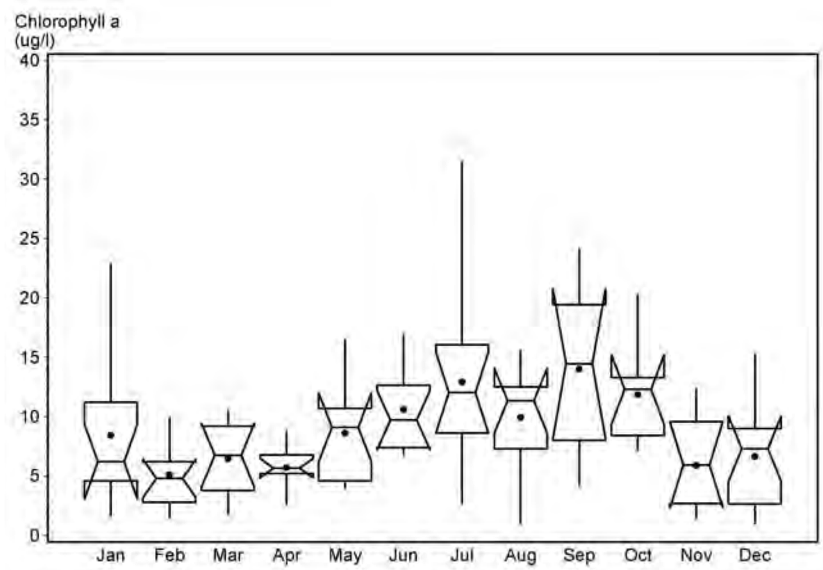

Figure IV-5. Box-and-whisker plots of the mean monthly chlorophyll *a* concentrations (μg/L) observed in Palma Sola Bay.

IV-2.1.3 Total Nitrogen

The mean annual TN concentrations for the 1998-2008 period in Palma Sola Bay averaged 0.77 mg/L (Figure IV-6). The lowest annual concentration (0.59 mg/L) occurred in 2004; the highest annual value of 1.09 mg/L occurred in the drought year of 2001. There was no significant trend in TN concentrations in Palma Sola Bay over this time period ($p > 0.05$; Appendix 3).

The box-and-whisker plot for TN suggests some intra-annual trend in TN concentrations (Figure IV-7). Values are somewhat higher in the late summer months. Monthly means range from 1.03 mg/L (September) to 0.59 mg/L (April). Higher monthly values during the summer are likely the result of increased TN loading during the wetter summer months.

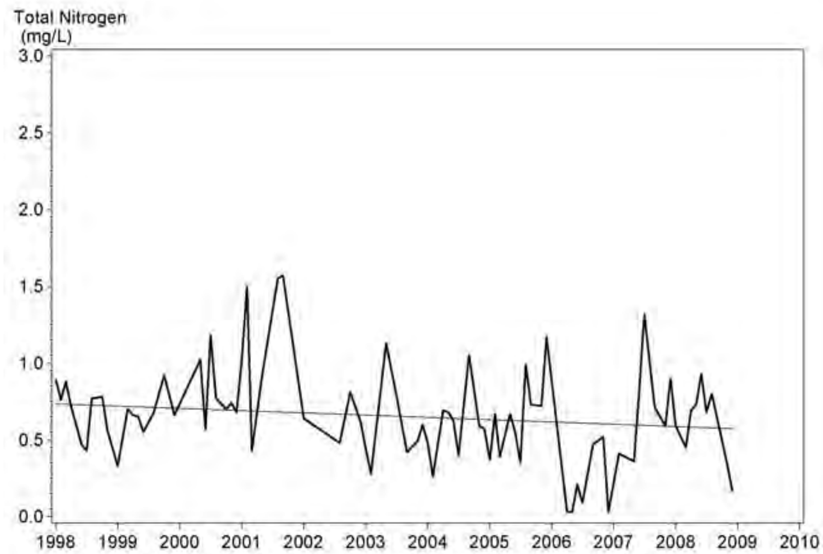

Figure IV-6. Mean monthly TN concentrations (mg/L) observed in Palma Sola Bay.

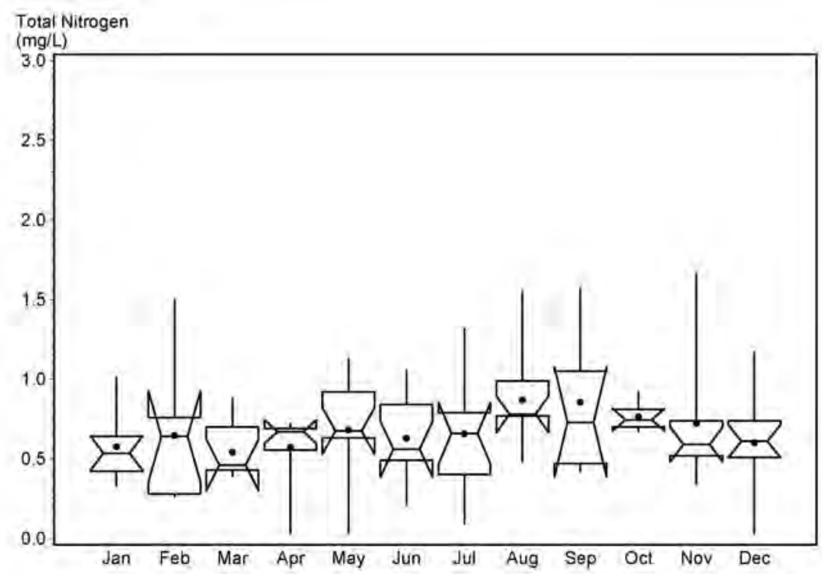

Figure IV-7. Box-and-whisker plots of the mean monthly TN concentrations (mg/L) observed in Palma Sola Bay.

IV-2.1.4 Total Phosphorus

Mean annual TP for the 1998-2008 period in Palma Sola Bay averaged 0.16 mg/L. The lowest annual value (0.07 mg/L) occurred in 2004, a moderately wet year (Table IV-1). The highest annual value (0.33 mg/L) occurred in 2008. A statistically significant, but slight increasing trend in TP concentrations was observed during the 1998-2008 period ($p<0.0001$, Appendix 3).

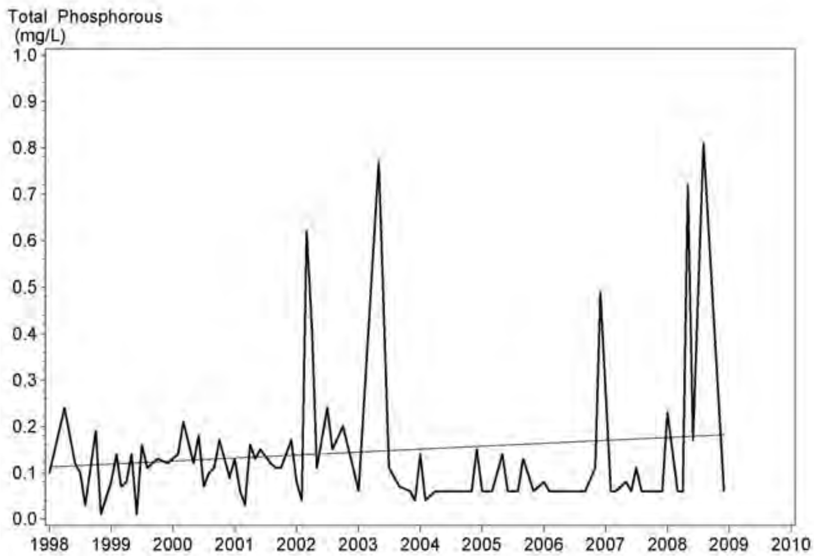

Figure IV-8. Mean monthly TP concentrations (mg/L) observed in Palma Sola Bay.

Unlike TN, there was very little within-year variability in TP concentrations (Figure IV-9). Monthly means for March, April, and May are as high as summer month values. Monthly means range from 0.22 mg/L (May) to 0.10 mg/L (November).

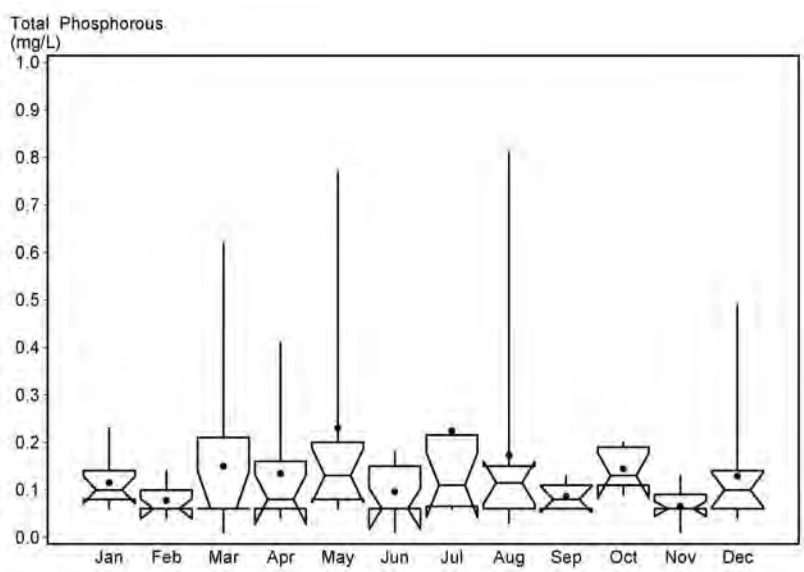

Figure IV-9. Box-and-whisker plots of the mean monthly TP concentrations (mg/L) observed in Palma Sola Bay.

IV-2.2 Sarasota Bay

IV-2.2.1 Salinity

Mean annual salinity for the 1998 through 2009 period in Sarasota Bay averaged 34.5 ppt (Figure IV-10). The lowest annual value, 31.9 ppt, occurred in 1998, a wet year as shown in Table IV-1. The highest mean annual salinity, 36.3 ppt, occurred in 2008, a dry year. There was a significant increasing trend in salinity in Sarasota Bay over this time period ($p<0.01$; Appendix 3).

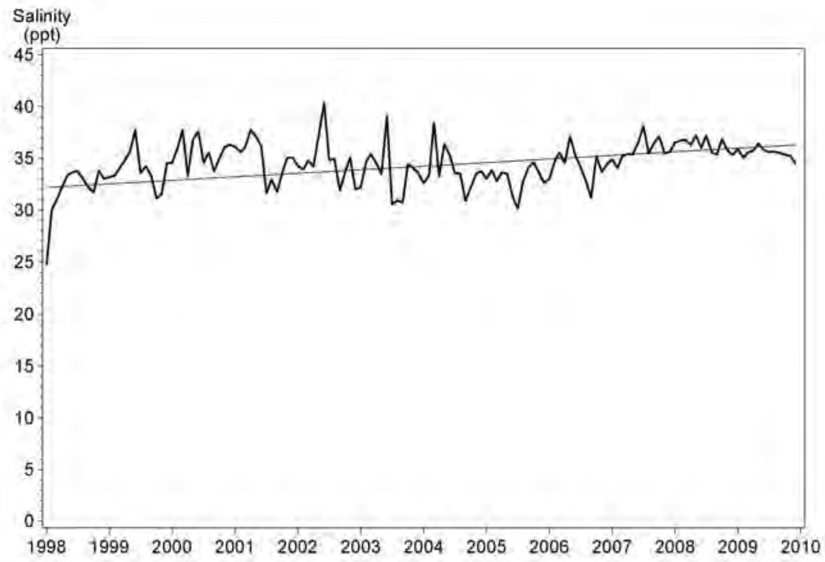

Figure IV-10. Mean monthly salinity (ppt) observed in Sarasota Bay.

The salinity box-and-whisker plots show values somewhat lower in the summer wet season than in the dry season, as would be expected, but the within-year variation is not great with monthly means varying less than 3 ppt. Monthly means range from 35.3 ppt (June) to 32.8 ppt (January).

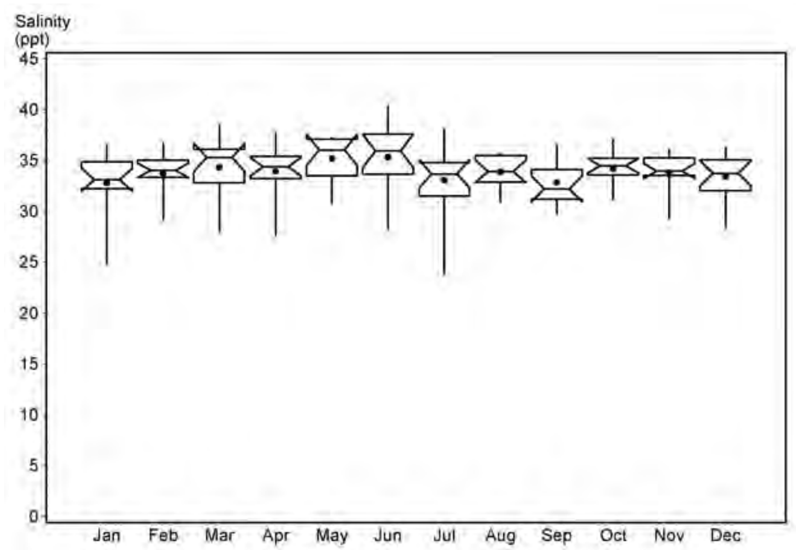

Figure IV-11. Box-and-whisker plots of the mean monthly salinity (ppt) observed in Sarasota Bay.

IV-2.2.2 Chlorophyll *a*

Mean annual chlorophyll *a* for the 1998 through 2009 period in Sarasota Bay averaged 5.0 μg/L (Figure IV-12). The lowest annual value of 3.3 μg/L occurred in 2006, a year of moderate rainfall (Table IV-1). The highest annual value, 6.0 μg/L, occurred in 2009, a dry year. There was a statistically significant but slight decreasing trend in chlorophyll a concentrations in Sarasota Bay during this period ($p < 0.03$, Appendix 3).

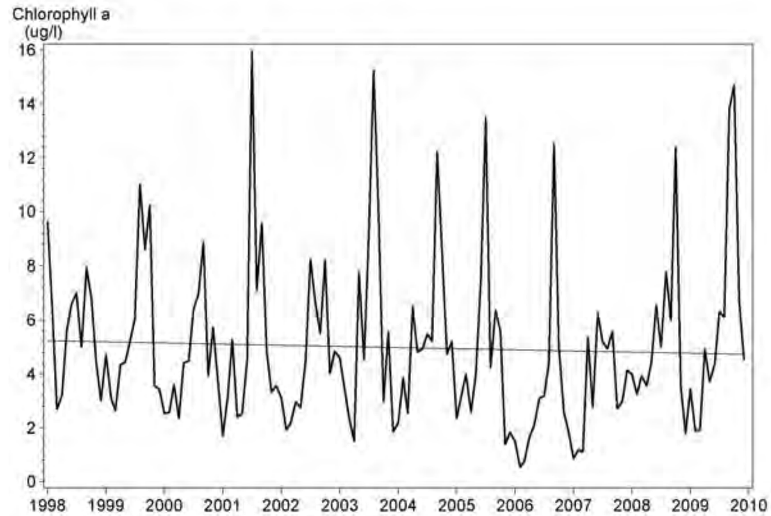

Figure IV-12. Mean monthly chlorophyll *a* concentrations (μg/L) observed in Sarasota Bay.

Box-and-whisker plots of the mean monthly chlorophyll *a* concentrations show a definite seasonal signal (Figure IV-13). During the warmer summer months the mean monthly chlorophyll a concentrations were approximately 3X higher than those observed in the dry period. Monthly means range from 9.3 μg/L (September) to 2.8 μg/L (February)."

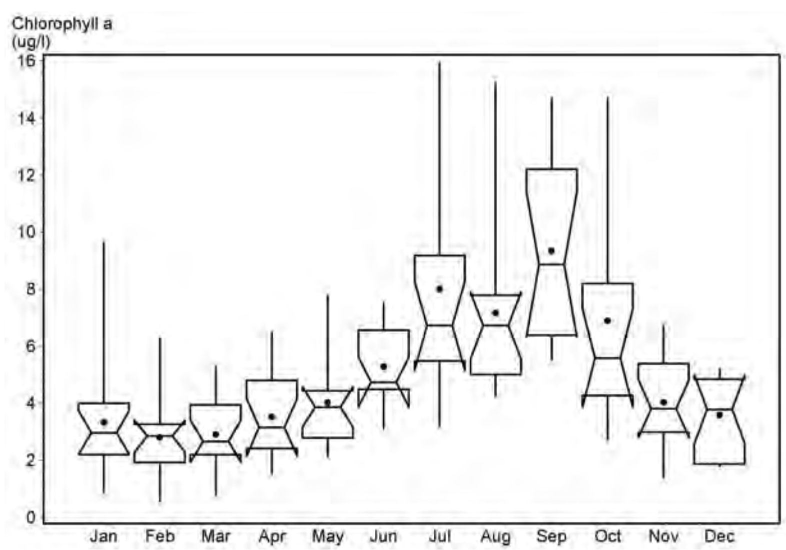

Figure IV-13. Box-and-whisker plots of the mean monthly chlorophyll *a* concentrations (μg/L) observed in Sarasota Bay.

IV-2.2.3 Total Nitrogen

The mean annual TN concentrations for the 1998 through 2009 period in Sarasota Bay averaged 0.35 mg/L (Figure IV-14). The lowest annual value of 0.28 mg/L occurred in 2006, a moderately dry year (Table IV-1). The highest mean annual concentration of 0.41 mg/L occurred in 2004, a somewhat wetter year. There was no statistically significant trend in TN concentrations in Sarasota Bay during this period ($p > 0.05$, Appendix 3).

The box-and-whisker plot for mean monthly TN concentrations suggests some within-year variation with somewhat higher concentrations in the late summer months (Figure IV-15). Monthly means range from 0.49 mg/L (September) to 0.29 mg/L (February).

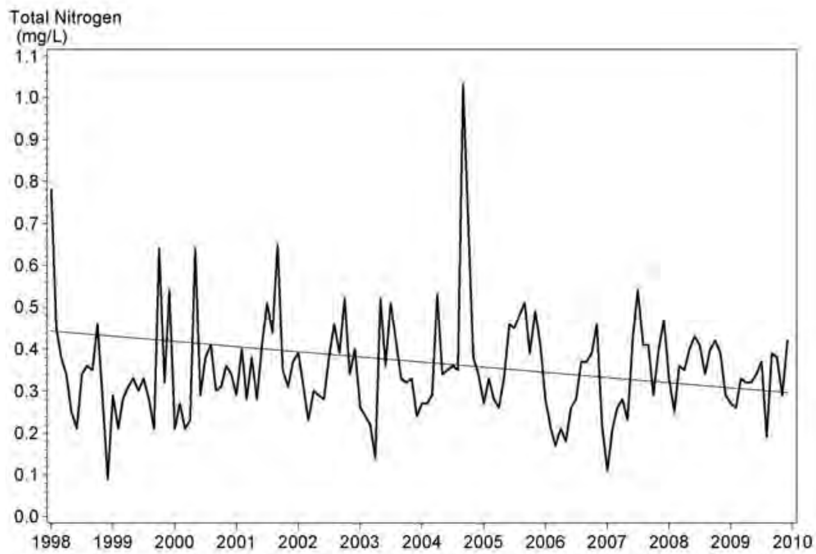

Figure IV-14. Mean monthly TN concentrations (mg/L) observed in Sarasota Bay.

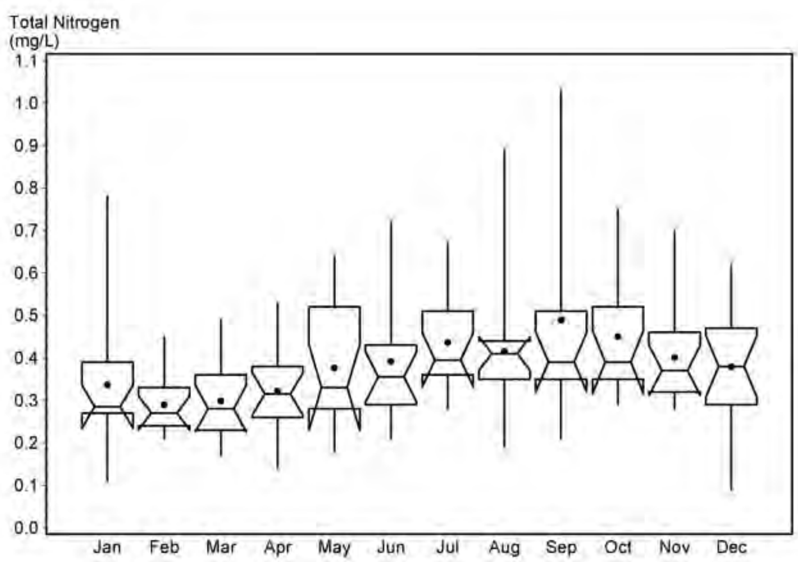

Figure IV-15. Box-and-whisker plots of the mean monthly TN concentrations (mg/L) observed in Sarasota Bay.

IV-2.2.4 Total Phosphorus

Mean annual TP concentrations for the 1998-2009 period in Sarasota Bay averaged 0.13 mg/L (Figure IV-16). The lowest mean annual concentration of 0.06 mg/L occurred in 2009, while the highest annual value, 0.22 mg/L, occurred in 2002. There was a statistically significant but slight decreasing trend in Sarasota Bay TP concentrations during this period ($p<0.03$, Appendix 3).

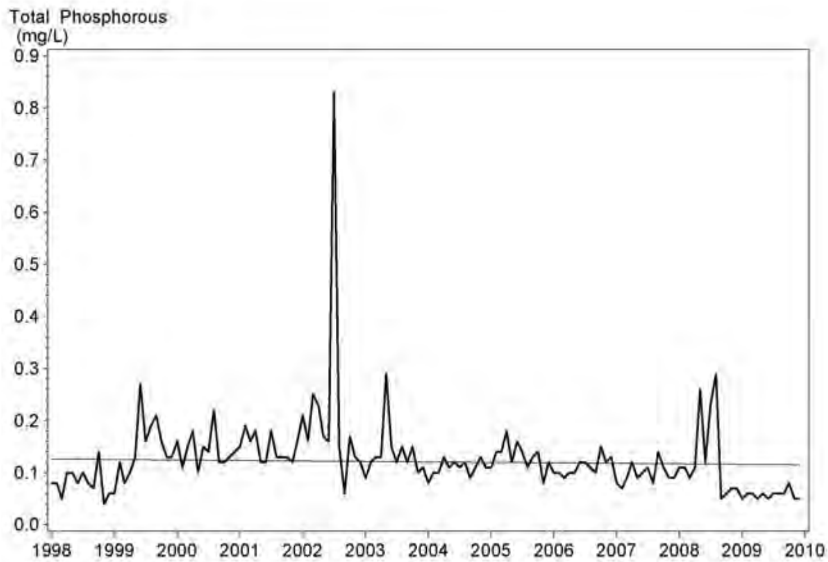

Figure IV-16. Mean monthly TP concentrations (mg/L) observed in Sarasota Bay.

The box-and-whisker plot of mean monthly TP concentrations shows higher concentrations more likely during the summer months (Figure IV-17). Monthly means range from 0.18 mg/L (July) to 0.09 mg/L (November), a two-fold difference.

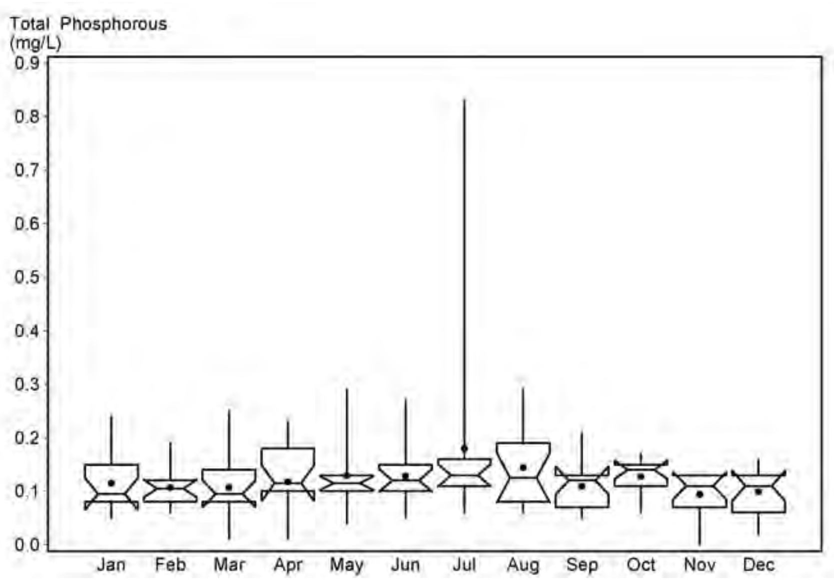

Figure IV-17. Box-and-whisker plots of the mean monthly TP concentrations (mg/L) observed in Sarasota Bay.

IV-2.3 Roberts Bay

IV-2.3.1 Salinity

Mean annual salinity for the 1998-2009 period in Roberts Bay averaged 31.3 pp (Figure IV-18). The lowest annual value, 28.6 ppt, occurred in 2003, a wet year (Table IV-1). The highest annual value, 33.6 ppt, occurred in the 2000 drought year. There was no statistically significant trend in salinity in Roberts Bay during this period (p>0.05, Appendix 2).

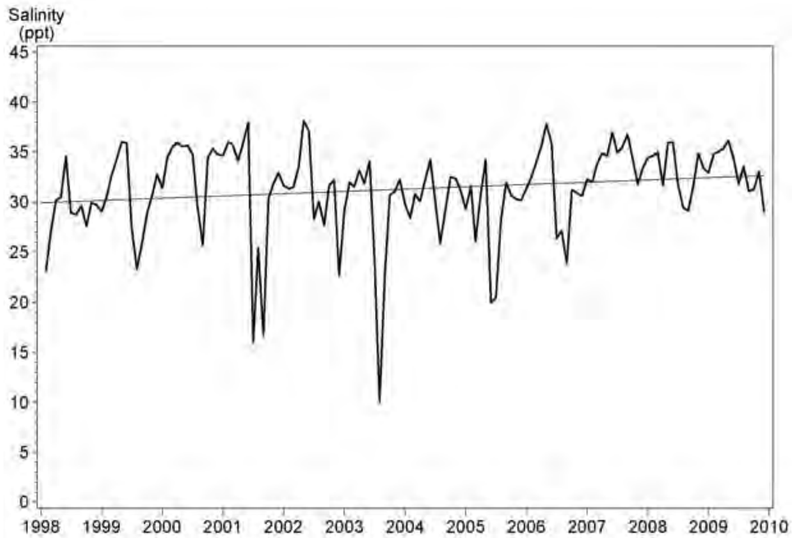

Figure IV-18. Mean monthly salinity (ppt) observed in Roberts Bay.

The salinity box-and-whisker plots for salinity show the most distinct seasonal pattern among the SBEP segments, with summer wet season salinities much lower than in the dry season as would be expected (Figure IV-19). Roberts Bay exhibits this wide within-year variation due to the significant freshwater inputs delivered by Phillippi Creek. Monthly means range from 34.9 ppt to 27.2 ppt.

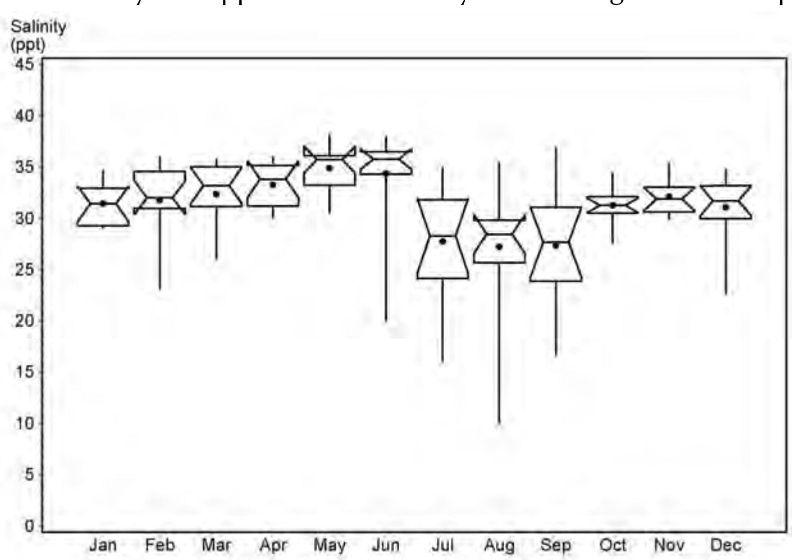

Figure IV-19. Box-and-whisker plots of the mean monthly salinity (ppt) observed in Roberts Bay.

IV-2.3.2 Chlorophyll *a*

Mean annual chlorophyll *a* concentrations for the 1998-2009 period in Roberts Bay averaged 7.3 μg/L (Figure IV-20). The lowest mean annual concentration of 3.6 μg/L occurred in 2007, a dry year (Table IV-1). The highest mean annual concentration, 11.6 μg/L, occurred in the drought year of 2001. There was no statistically significant trend in chlorophyll *a* concentrations in Roberts Bay during this period ($p > 0.05$, Appendix 3).

The box-and-whisker plot of mean monthly chlorophyll *a* concentrations shows significant within-year variation (Figure IV-21), with values during the hotter summer months over five times as high as the cooler period of the year. Monthly means range from 16.8 μg/L to 2.97 μg/L.

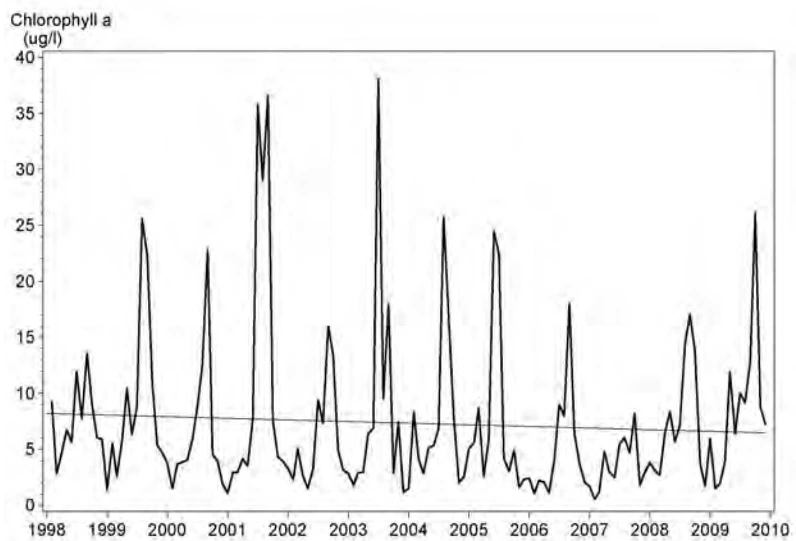

Figure IV-20. Mean monthly chlorophyll *a* concentrations (μg/L) observed in Roberts Bay.

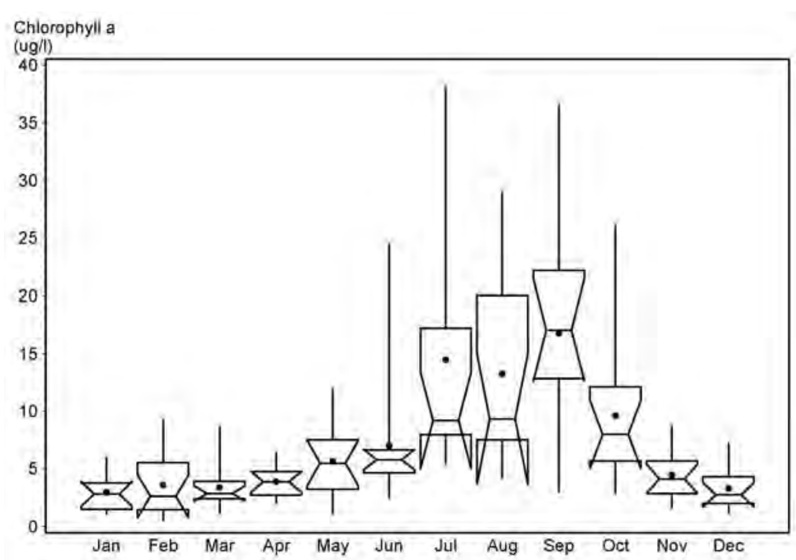

Figure IV-21. Box-and-whisker plots of the mean monthly chlorophyll *a* concentrations (μg/L) observed in Roberts Bay.

IV-2.3.3 Total Nitrogen

The mean annual TN concentrations for the 1998 through 2009 period in Roberts Bay North averaged 0.43 mg/L (Figure IV-22). There was very little inter-annual variation in TN concentrations. The lowest annual value of 0.36 mg/L occurred in 2007 with the highest mean annual TN concentration of 0.48 mg/L observed in 2002. There was no statistically significant trend in TN concentrations in Roberts Bay during this period (p > 0.05, Appendix 3).

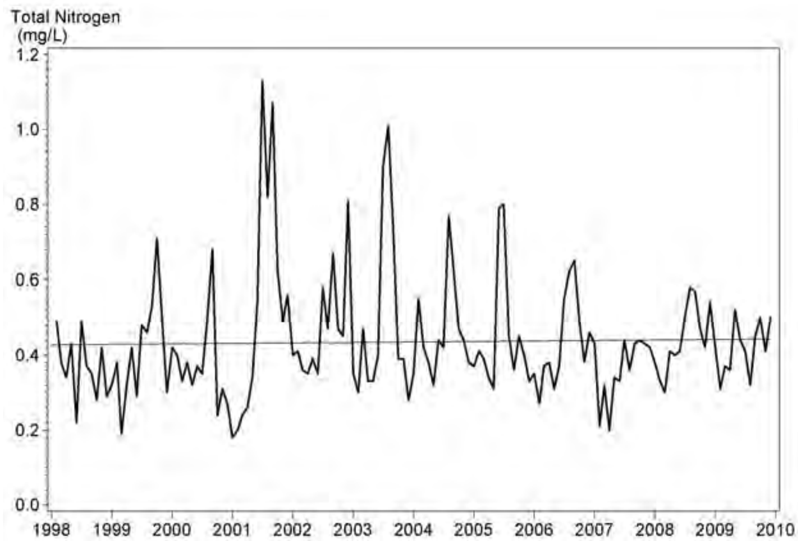

Figure IV-22. Mean monthly TN concentrations (mg/L) observed in Roberts Bay.

The box-and-whisker plot for TN presents a distinct seasonal trend in TN concentrations (Figure IV-23). The highest TN concentrations were observed in the late summer months (July, August, and September) and lowest during the winter months. Monthly means range from 0.59 mg/L (September) to 0.34 mg/L (April).

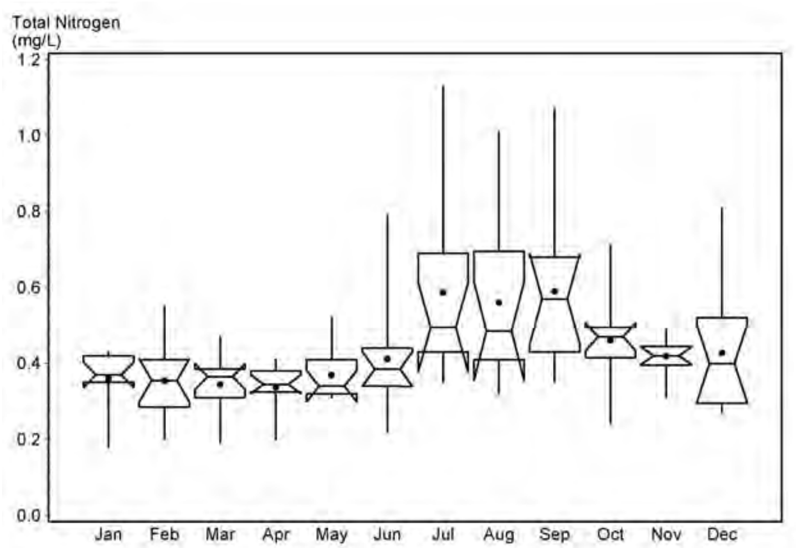

Figure IV-23. Box-and-whisker plots of the mean monthly TN concentrations (mg/L) observed in Roberts Bay.

IV-2.3.4 Total Phosphorus

Mean annual TP concentrations for the 1998 through 2009 period in Roberts Bay averaged 0.17 mg/L (Figure IV-24). The lowest mean annual TP concentration (0.09 mg/L) occurred in 2009 and the highest annual mean annual (0.22 mg/L) was observed in 2001. There was a significant decreasing trend in Roberts Bay TP concentrations during this period ($p<0.0001$, Appendix 3).

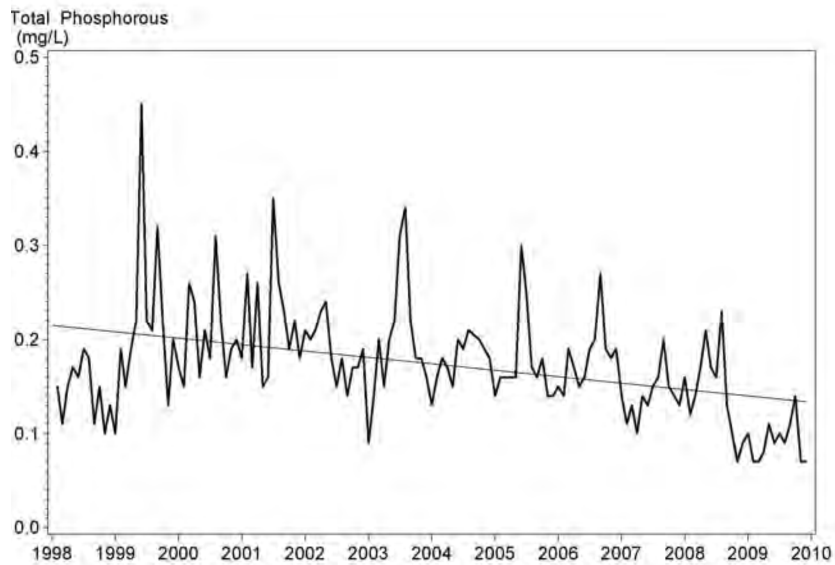

Figure IV-24. Mean monthly TP concentrations (mg/L) observed in Roberts Bay.

There was an appreciable within-year variation in Roberts Bay TP concentrations (Figure IV-25). Mean monthly TN concentrations ranged from 0.21 mg/L (August) to 0.14 mg/L (January).

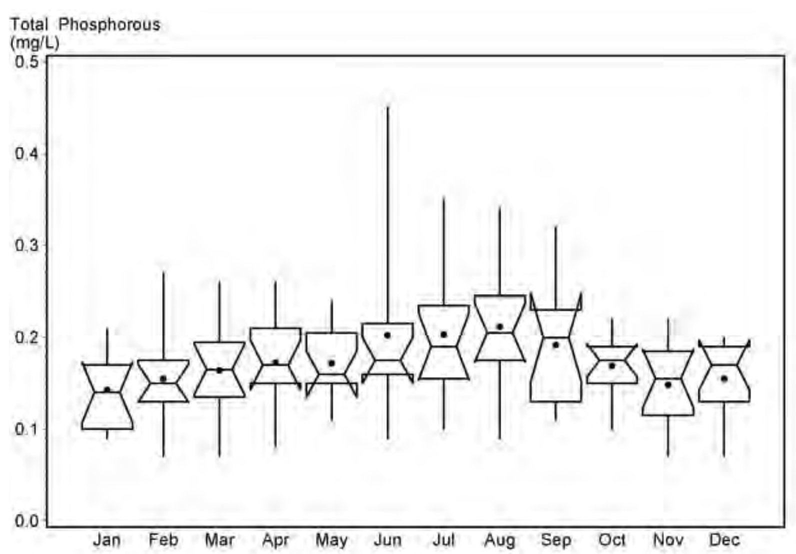

Figure IV-25. Box-and-whisker plots of the mean monthly TP concentrations (mg/L) observed in Roberts Bay.

IV-2.4 Little Sarasota Bay

IV-2.4.1 Salinity

Mean annual salinity for the 1998-2009 period in Little Sarasota Bay averaged 30.8 ppt (Figure IV-26). The lowest annual value, 27.3 ppt, occurred in 2005, a wet year (Table IV-1). The highest mean annual salinity, 33.6 ppt, was observed 2007. There was no statistically significant trend in salinity in Little Sarasota Bay during this period ($p > 0.05$, Appendix 3).

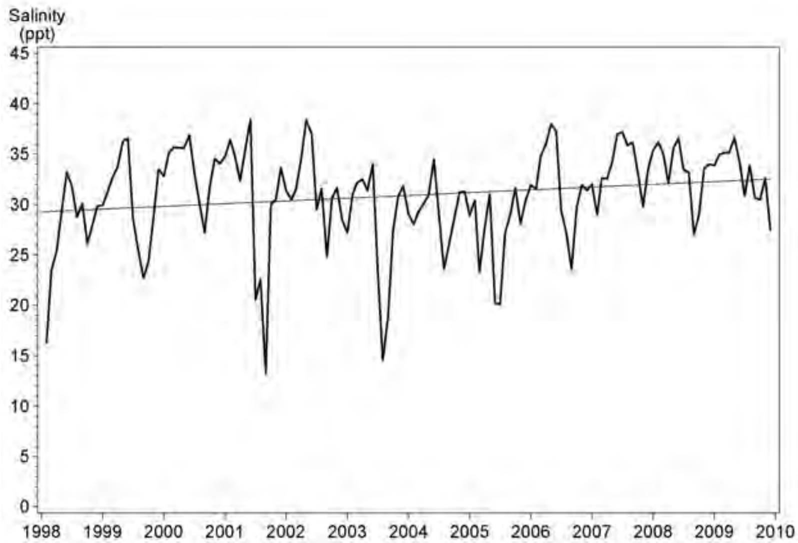

Figure IV-26. Mean monthly salinity (ppt) observed in Little Sarasota Bay.

The box-and-whisker plots for the mean monthly salinity in Little Sarasota Bay show a clear seasonal pattern, with summer wet season salinities much lower than those observed in the dry season (Figure IV-27). Monthly mean salinity ranged from 34.6 ppt (June) to 25.8 ppt (September).

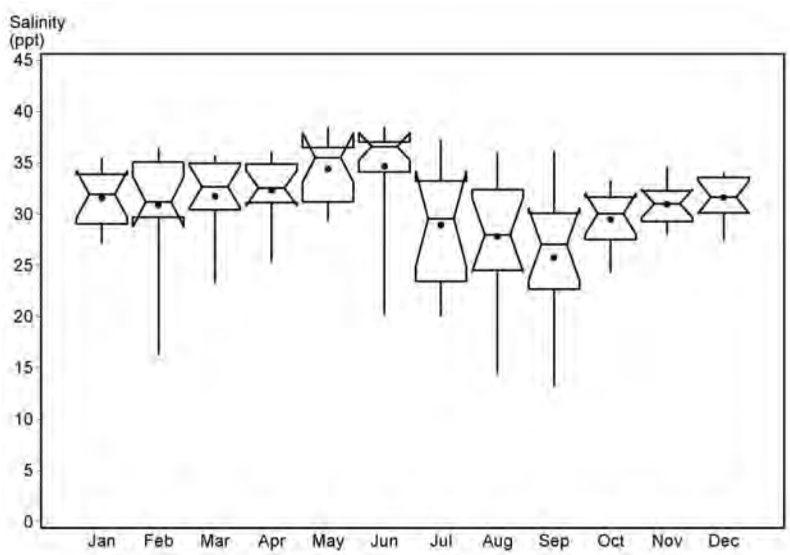

Figure IV-27. Box-and-whisker plots of the mean monthly salinity (ppt) observed in Little Sarasota Bay.

IV-2.4.2 Chlorophyll *a*

Mean annual chlorophyll *a* concentrations averaged 7.3 μg/L in Little Sarasota Bay during the 1998-2009 period (Figure IV-28). The lowest mean annual chlorophyll *a* concentration of 4.9 μg/L occurred in 2007 and the highest mean annual chlorophyll *a* concentration, 11.2 μg/L, occurred in 2007. There was a statistically significant but slight decreasing trend in chlorophyll a concentrations in Little Sarasota Bay during this period ($p < 0.05$, Appendix 3).

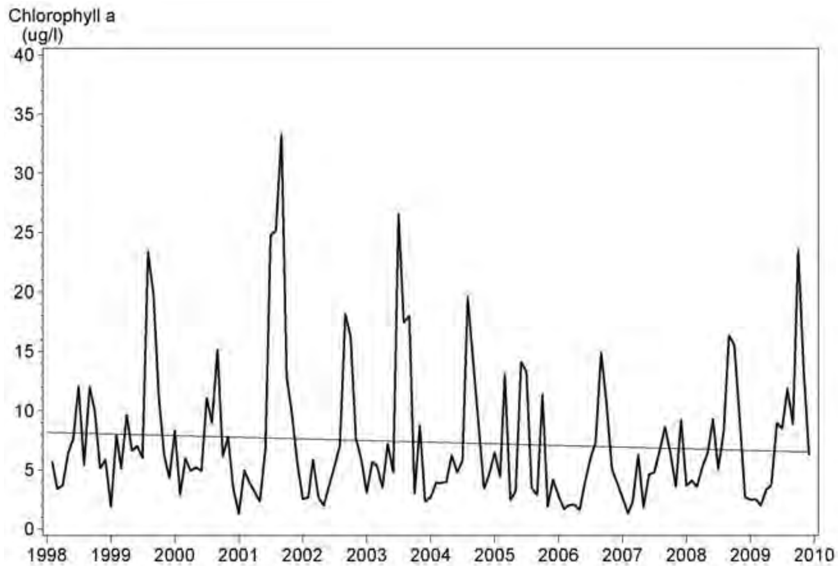

Figure IV-28. Mean monthly chlorophyll *a* concentrations (μg/L) observed in Little Sarasota Bay.

The mean monthly chlorophyll *a* concentrations exhibited a distinct seasonal signal (Figure IV-29). Monthly means ranged from 15.3 μg/L (September) to 3.4 μg/L (January).

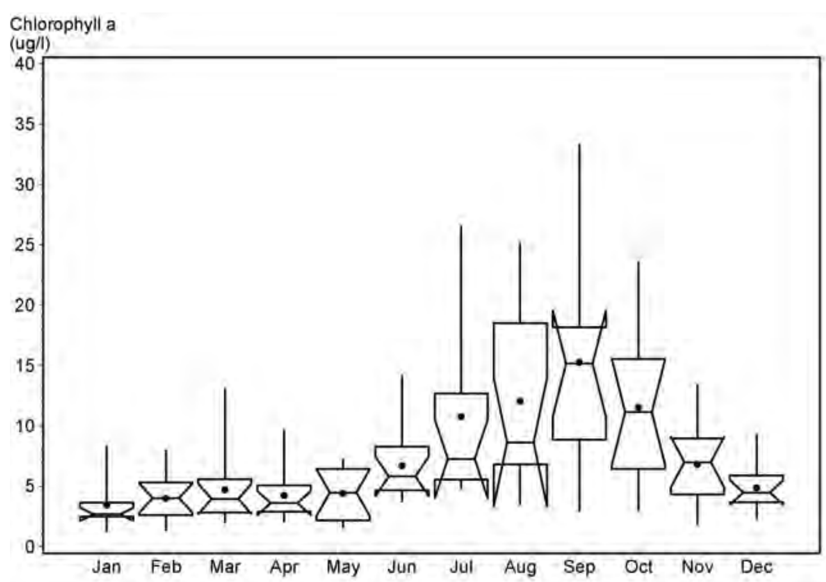

Figure IV-29. Box-and-whisker plots of the mean monthly chlorophyll *a* concentrations (μg/L) observed in Little Sarasota Bay.

IV-2.4.3 Total Nitrogen

The mean annual TN concentrations in Little Sarasota Bay for the 1998 through 2009 period averaged 0.49 mg/L (Figure IV-30). The lowest mean annual TN concentration of 0.43 mg/L was observed in 1998 while the highest mean annual TN concentration was 0.56 mg/L found in 2001. There was no statistically significant trend in Little Sarasota Bay TN concentrations during this period ($p > 0.05$, Appendix 3).

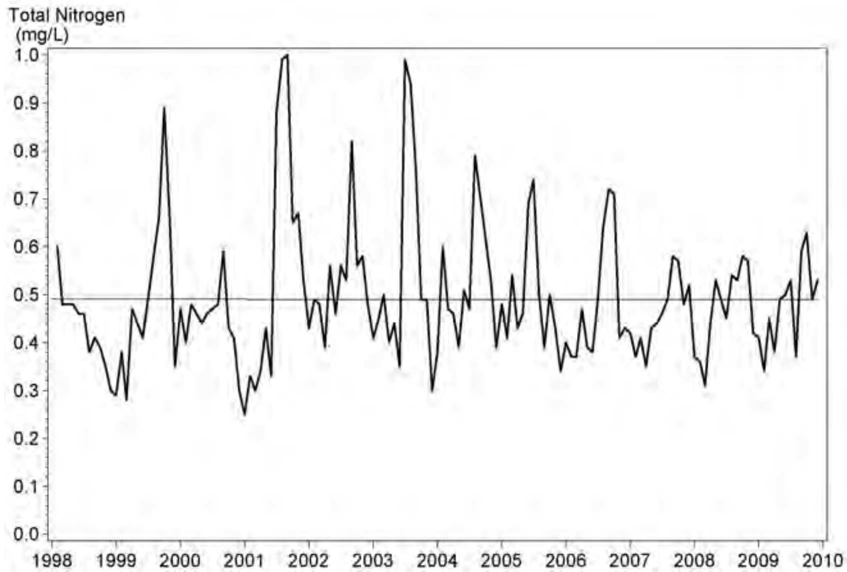

Figure IV-30. Mean monthly TN concentrations (mg/L) observed in Little Sarasota Bay.

The TN concentrations in Little Sarasota Bay were higher in the late summer months (Figure IV-31). Monthly mean TN concentrations ranged from 0.64 mg/L (September) to 0.39 mg/L (January).

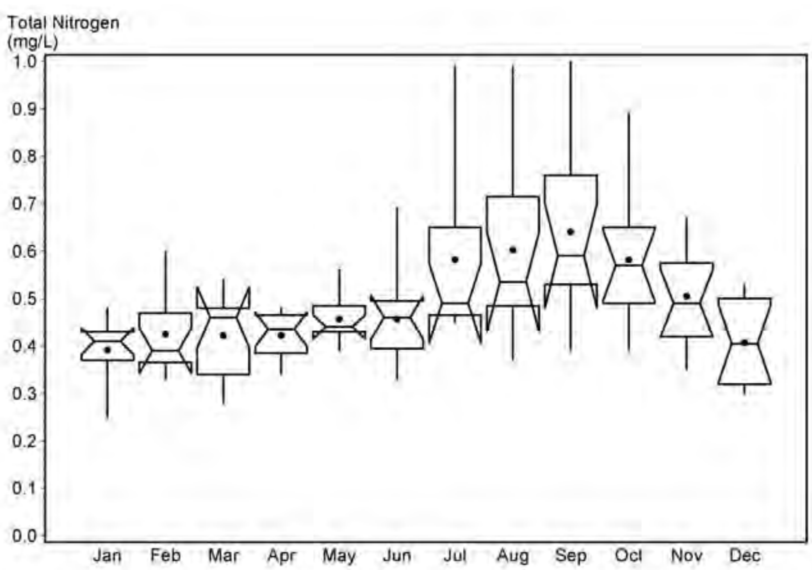

Figure IV-31. Box-and-whisker plots of the mean monthly TN concentrations (mg/L) observed in Little Sarasota Bay.

IV-2.4.4 Total Phosphorus

Mean annual TP concentrations in Little Sarasota Bay averaged 0.17 mg/L during the 1998-2009 period (Figure IV-32). The lowest mean annual TP concentration was 0.09 mg/L in 2009; while the highest mean annual concentration was 0.22 mg/L in 1999. There was a statistically significant decreasing trend in Little Sarasota Bay TP concentrations during this period ($p < 0.02$, Appendix 3).

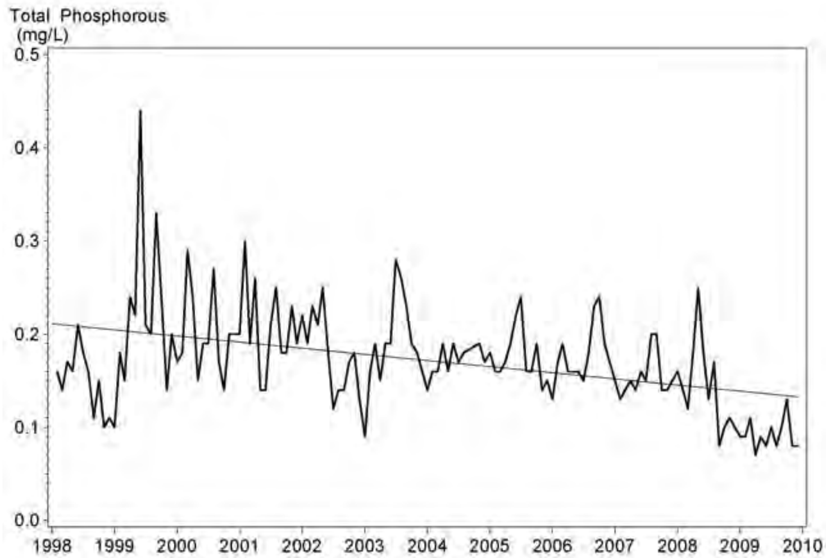

Figure IV-32. Mean monthly TP concentrations (mg/L) observed in Little Sarasota Bay.

There was little within-year variation in TP concentrations in Little Sarasota Bay during this period (Figure IV-33).

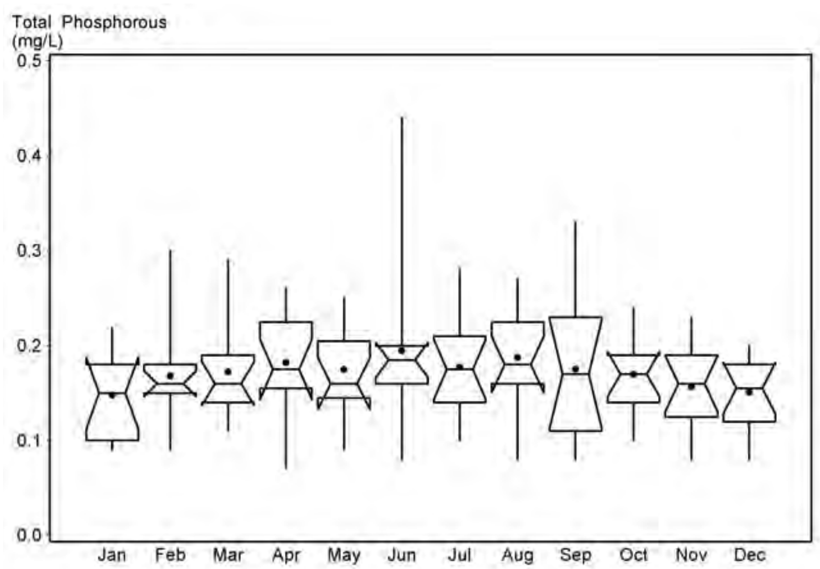

Figure IV-33. Box-and-whisker plots of the mean monthly TP concentrations (mg/L) observed in Little Sarasota Bay.

IV-2.5 Blackburn Bay

IV-2.5.1 Salinity

Mean annual salinity in Blackburn Bay in the 1998-2009 period averaged 33.5 ppt (Figure IV-34). The lowest mean annual salinity was 30.3 ppt which occurred in 2005, a relatively wet year (Table IV-1). The highest annual mean salinity was 35.7 ppt and occurred in 2000. There was no statistically significant trend in Blackburn Bay salinity during this period ($p > 0.05$, Appendix 3).

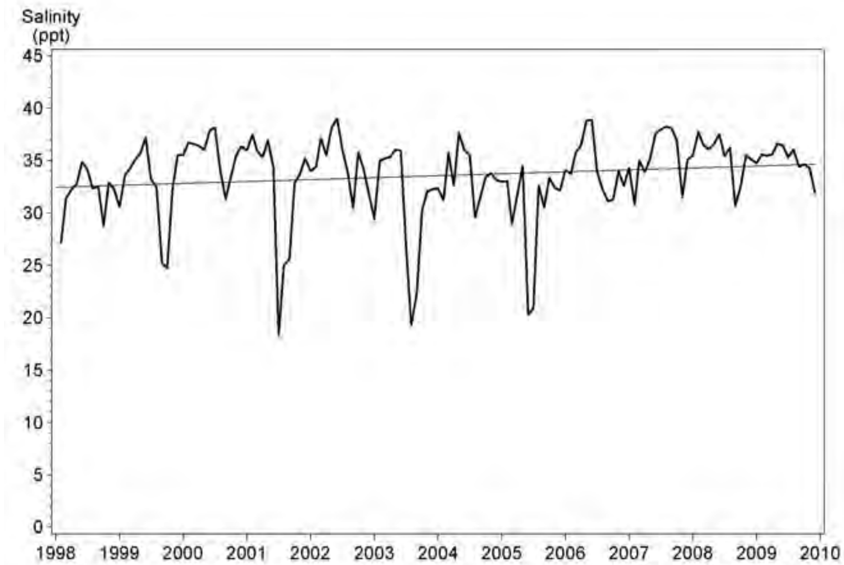

Figure IV-34. Mean monthly salinity (ppt) observed in Blackburn Bay.

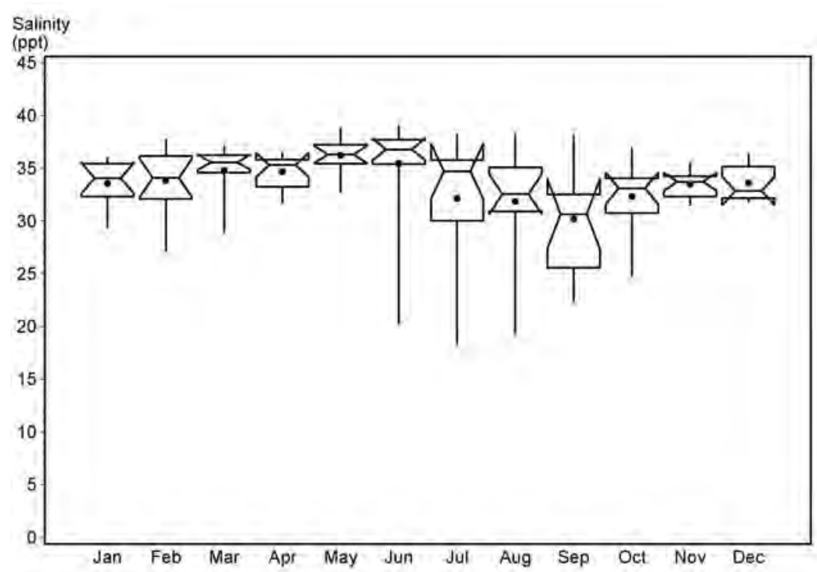

Figure IV-35. Box-and-whisker plots of the mean monthly salinity (ppt) observed in Blackburn Bay.

IV-2.5.2 Chlorophyll *a*

Mean annual chlorophyll *a* concentrations for the 1998-2009 period in Blackburn Bay averaged 5.3 μg/L (Figure IV-36). The lowest annual mean chlorophyll *a* concentration was 3.0 μg/L and occurred in 2007. The highest annual mean chlorophyll *a* concentration was 9.3 μg/L and was observed in 2001. There was a significant decreasing trend in chlorophyll a concentrations in Blackburn Bay during this period ($p < 0.0001$, Appendix 3).

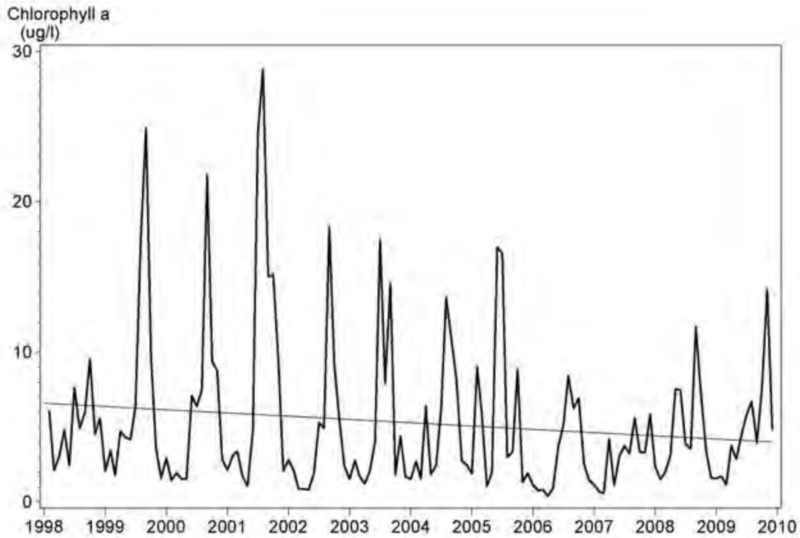

Figure IV-36. Mean monthly chlorophyll *a* concentrations (μg/L) observed in Blackburn Bay.

The mean monthly chlorophyll *a* concentrations show a definite seasonal signal, with the highest concentrations observed during the summer months (Figure IV-37). Monthly mean concentrations ranged from 11.9 μg/L (September) to 1.9 μg/L (January).

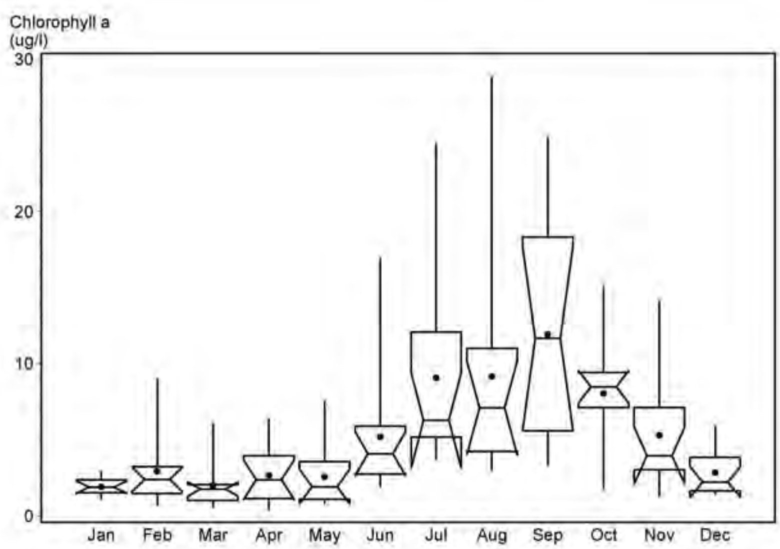

Figure IV-37. Box-and-whisker plots of the mean monthly chlorophyll *a* concentrations (μg/L) observed in Blackburn Bay.

IV-2.5.3 Total Nitrogen

The mean annual TN concentrations during the 1998-2009 period in averaged 0.34 mg/L (Figure IV-38). The lowest annual mean TN concentration of 0.26 mg/L occurred in 1998. The highest annual mean concentration of 0.41 mg/L was observed in 2005. There was a statistically significant increasing trend in TN concentrations in Blackburn Bay during this period ($p<0.05$, Appendix 3).

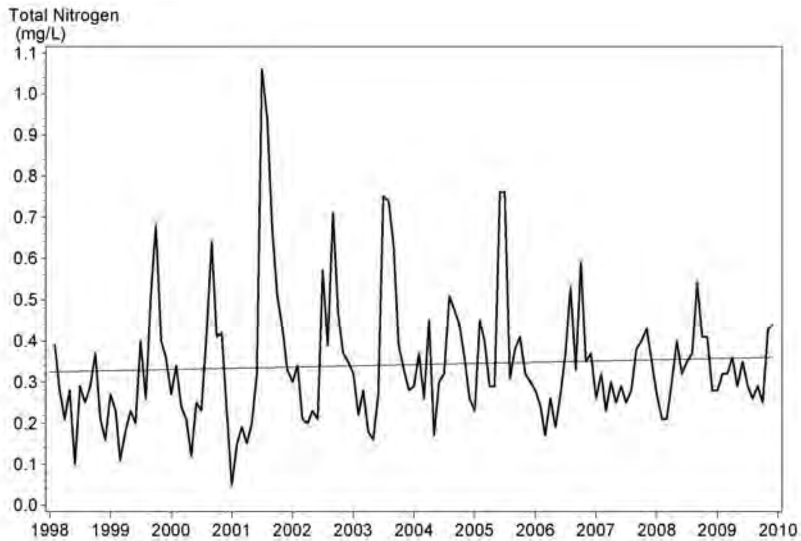

Figure IV-38. Mean monthly TN concentrations (mg/L) observed in Blackburn Bay.

The box-and-whisker plot for mean monthly TN concentrations show a distinct pattern with the highest TN concentrations observed from July through October (Figure IV-39). The monthly mean TN concentrations ranged from 0.49 mg/L (September) to 0.23 mg/L (May).

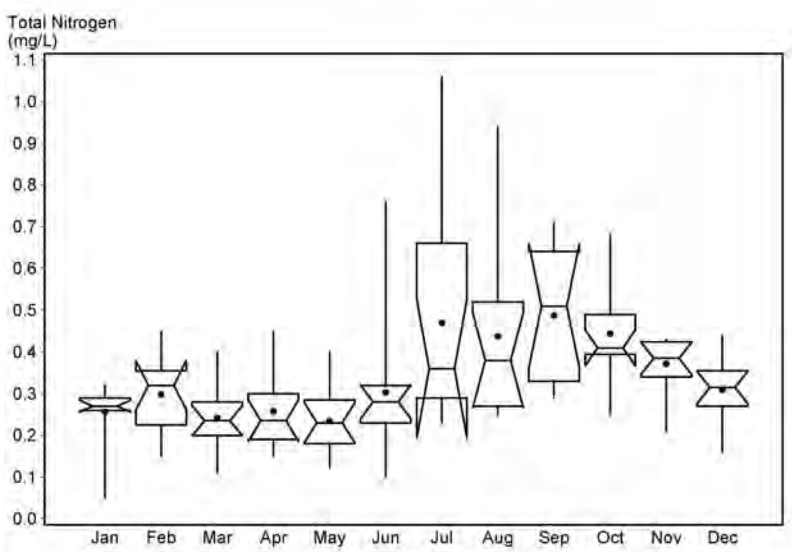

Figure IV-39. Box-and-whisker plots of the mean monthly TN concentrations (mg/L) observed in Blackburn Bay.

IV-2.5.4 Total Phosphorus

The annual mean TP concentrations in Blackburn Bay averaged 0.15 mg/L during the 1998-2009 period (Figure IV-40). The lowest annual mean of 0.06 mg/L occurred in 2009. The highest annual mean TP concentration was 0.21 mg/L and was observed in 2001. There was no statistically significant trend in Blackburn Bay TP concentrations during this period ($p > 0.05$, Appendix 3).

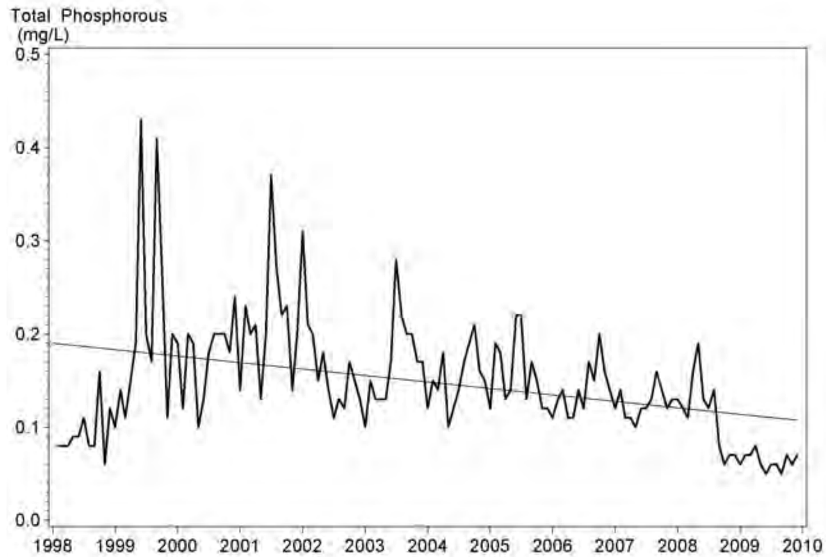

Figure IV-40. Mean monthly TP concentrations (mg/L) observed in Blackburn Bay.

There was a slight seasonal trend in TP concentrations with slightly higher concentrations observed during the summer months (Figure IV-41). Monthly mean TP concentrations ranged from 0.17 mg/L (October) to 0.12 mg/L (November).

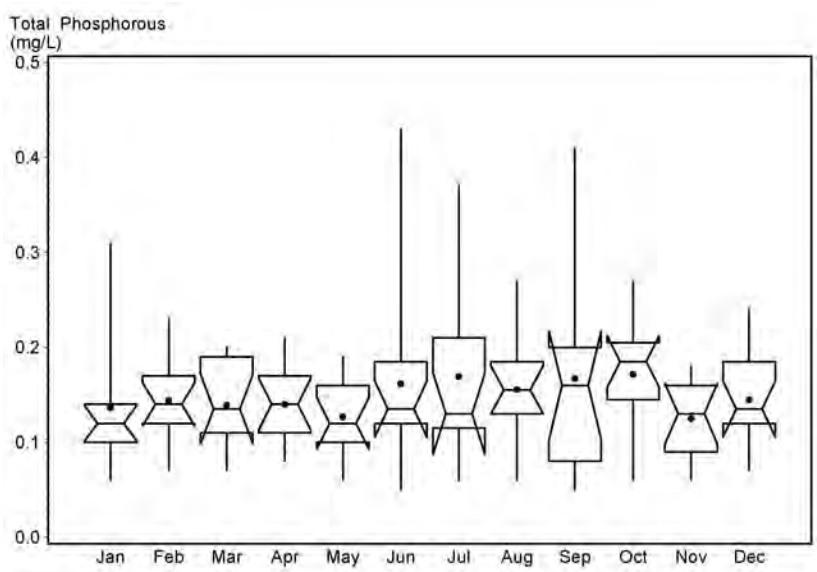

Figure IV-41. Box-and-whisker plots of the mean monthly TP concentrations (mg/L) observed in Blackburn Bay.

IV-3 Summary

The five SBEP bay segments exhibit a range of water quality characteristics based on watershed size, tributaries, estuary shape and size, and flushing rate and circulation. Because of the limited size and similar land use of most of the watersheds, flushing and tidal exchange appears to be a critical factor in water quality in the bay segments.

Sarasota Bay and Blackburn Bay have the best tidal exchange with the Gulf of Mexico. These two segments have the highest average annual salinity and lowest average annual TN, TP, and chlorophyll *a* concentrations of the SBEP segments.

Palma Sola Bay and Little Sarasota Bay have the most restricted tidal exchange, and have the lowest salinity and highest TN, TP, and chlorophyll *a* concentrations of the segments. Roberts Bay receives significant nonpoint source loading from Phillippi Creek but has tidal exchange with the Gulf of Mexico via Big Sarasota Pass.

Temporal trends in the four parameters varied significantly. Salinity showed an increasing trend in all segments except Palma Sola which had a slight downward trend. Trends in TN varied from slightly increasing (Palma Sola Bay) to strongly decreasing (Sarasota Bay). TP trends were strongly decreasing except for Palma Sola Bay which had a slightly increasing trend, and Sarasota Bay which had a very slight decreasing trend. Chlorophyll a trends decreased in all five segments.

Seasonality also varied by parameter. Salinity seasonal variation was largest in Roberts and Little Sarasota Bays, moderate in Sarasota and Blackburn Bays, and lowest in Palma Sola Bay. TN showed a strong to moderate seasonal variation in all segments. TP seasonality was evident but much more muted that TN. Chlorophyll a seasonality was the most distinct, with large differences in wet/summer and dry/winter concentrations in all segments. Palma Sola Bay showed the least difference.

V. Characterization of Nutrient Loadings to the Sarasota Bay Estuary Segments

This section provides a brief summary of the model used to develop hydrologic and nutrient loading estimates for each segment within the SBEP area and a discussion of the temporal trends in these loadings.

V-1. Nutrient Loading Estimates for Sarasota Bay

Nutrient and hydrologic loads were estimated for the period 1988-2008 for five bay segments within the greater Sarasota Bay watershed (from north to south): Palma Sola Bay, Sarasota Bay, Roberts Bay, Little Sarasota Bay and Blackburn Bay (Figure III-1). Drainage basins for each bay segment were delineated based on drainage boundaries provided by Manatee and Sarasota counties and are the same basins used to develop loading estimates for Roberts Bay for the time period 1994-2008 (2009 RBay WMP). Nutrient loading estimates were derived for each of the 114 drainage basins using the Spatially Integrated Model for Pollutant Loading Estimates (SIMPLE) which was designed and calibrated by Jones Edmunds & Associates, Inc (JEA 2009 SIMPLE design report).

The SIMPLE model consists of six modules that produce pollutant loading estimates for the primary point and non-point sources within a watershed: 1) Direct Runoff, 2) Baseflow, 3) Irrigation, 4) Point Source, 5) Septic Tanks, and 6) Atmospheric Deposition. We used the SIMPLE model to estimate nutrient loads for the first five sources, but calculated atmospheric deposition externally (see below for more detail). Nutrient loads from the SIMPLE model were combined with loads from atmospheric deposition to estimate Total Nutrient Loads to each bay segment.

Rainwater runoff and groundwater flow, both tightly coupled to precipitation, are the primary mechanisms by which nutrients are transported from the watershed to Sarasota Bay. In order to estimate nonpoint source nutrient loads related to these hydrologic processes, the Direct Runoff and Baseflow modules reference an externally generated table of monthly hydrologic values that estimate rainfall, runoff and baseflow for all combinations of land use and soil type in the Sarasota Bay watershed. Below, we describe the external hydrologic engine that estimates these hydrologic values. Then, we briefly outline the modules that estimate nutrient loads from runoff and baseflow. Finally, we outline the modules that estimate non-point source contributions from irrigation and point source contributions from wastewater treatment facilities and septic tanks.

V-1.1 Estimation of Hydrologic Values

The hydrologic engine used to estimate rainfall, runoff and baseflow was provided by Jones Edmunds and Associates, Inc. (JEA) as a continuous simulation spreadsheet model and was recoded to run using the Statistical Analysis Software package (SAS version 9.2). Parameter estimates derived from the original spreadsheet model, which was run by JEA for Sarasota County (1994-2008), were compared with estimates derived from the recoded SAS engine to ensure identical model outputs prior to estimating hydrologic parameters for the pre-NEXRAD time period and for the Manatee County portion of the Sarasota Bay watershed.

Precipitation and evapotranspiration data were the inputs required to run the hydrologic engine. Monthly rainfall estimates were made using NEXRAD rainfall data for 1994-2008 and data from SWFWMD and National Weather Service rain gauges for the pre-NEXRAD period from 1989-1993. Rainfall for the pre-NEXRAD period was estimated for each 2km x 2km NEXRAD pixel using the inverse-distance squared method to interpolate rainfall between gauges. Losses of water to evapotranspiration were modeled as a function of water table level, soil moisture, and land use with potential evapotranspiration data provided by the U.S. Geological Survey.

Runoff and baseflow were estimated on a daily time-step for each combination of NEXRAD pixel, land use and soil type and were then summed to obtain monthly values. Runoff estimates were based on those of the Natural Resource Conservation Service (NRCS, 1986) and accounted for antecedent moisture conditions as well as differences in runoff volume from pervious and impervious surfaces, and as a result of changes in soil saturation as a function of rainfall. Baseflow was calculated using the Dupuit-Forcheimer equation which is a function of the horizontal and vertical distances travelled by groundwater and hydraulic conductivity for each soil type.

Estimates of monthly rainfall, runoff and groundwater were produced by the hydrologic engine and exported to a geodatabase table that was referenced by the Direct Runoff and Baseflow modules during execution of the SIMPLE model.

V-1.2 Direct Runoff

Monthly nutrient loads (lbs/month) and hydrologic loads (ft^3/month) from runoff were estimated for each drainage basin. Runoff volumes and nutrient concentrations were a function of the relative proportions of each land use and hydrologic soil type within each basin and were adjusted for land use changes over time using a time-stamped land use coverage for Sarasota county provided by JEA. The time-stamped land use coverage for Manatee county was created following the same procedure used to create the Sarasota coverage. Briefly, each land use polygon was time-stamped by intersecting historic (1990) and current (2004 for Sarasota county, 2007 for Manatee county) land use coverages obtained from the Southwest Florida Water Management District and then intersecting the resulting coverage with the parcel database retrieved from Manatee and Sarasota county Property Appraisers to create a land use coverage that described historic and current land uses and the year in which land uses changed over time. The soil coverage was retrieved from the USDA's Natural Resources Conservation Service. The spatial coverage for lands treated by best management practices (BMPs) was created for Manatee County by subsetting from the land use coverage all polygons classified as reservoirs, golf courses, open lands, and medium/high-density residential lands and lands permitted by SWFWMD's Environmental Resource Permit. SWFWMD aerial photography from 2008 was used to identify and digitize any additional BMPs. All BMPs were considered to be wet detention for the purposes of estimating pollutant removal efficiencies.

V-1.3 Baseflow

As with runoff, nutrient loads (lbs/month) and hydrologic loads (ft^3/month) from baseflow were estimated for each drainage basin as a function of land use and soil type within the basin. Event mean concentrations for baseflow were held constant across land uses and soil types and were derived from literature values and used previously in other southwest Florida estuaries.

V-1.4 Irrigation

The spatial coverage for irrigated lands in Manatee County consisted of residential, commercial and agricultural lands, and golf courses. The source of irrigated water was assumed to be groundwater unless otherwise indicated by the coverage of areas with access to reuse water as provided by the Counties. Irrigation rate was assigned for lands in both Sarasota and Manatee Counties using a relationship between average parcel age and market value and was calibrated through field observations of lawn health by Jones-Edmunds. Healthier lawns on golf courses and residential lands were assumed to receive a higher rate of irrigation than less healthy lawns. Medium irrigation rates were assumed for agricultural lands. Nutrient loads from irrigation were corrected for irrigation of impervious areas and infiltration to groundwater so as not to overestimate irrigation loadings.

V-1.5 Point Sources

Daily water quality data including nutrient concentrations and flows were obtained from Florida Department of Environmental Protection, Sarasota County and Manatee County for the major point sources (> 0.1 MGD) for the model period, including 1989-1993 and 2008 to expand the existing water quality dataset for Sarasota County provided by Jones-Edmunds. Smaller non-delegated facilities treating <0.05 MGD were included in Sarasota County dataset but were not obtained for Manatee County. When data were not available for a given time period, monthly averages were calculated using existing data for that point source. Improvements to the existing dataset were made by replacing previously averaged values with newly acquired data for the major point sources and by correcting total effluent volumes for the City of Sarasota plant to account for surface water discharge as well as reuse. The only major point source in Manatee County, the Southwest Wastewater Treatment Plant, was converted to advanced wastewater treatment prior to 1989 with effluent being disposed via deep injection well and into the reuse system rather than being discharged directly to surface waters. Therefore, flows for this point source were considered to be 0 MGD.

Non-compliant effluent (i.e., sewage spills, reuse spills) was accounted for in the point source module by referencing tables containing information on the location, volume and concentrations of non-compliant spills. Spill data were obtained from Manatee and Sarasota Counties.

V-1.6 Septic Tanks

The spatial coverage for septic tanks throughout the bayshed was estimated by first assigning points representing septic tanks to each developed parcel and then by removing points from parcels that intersected the central sewer coverage provided by the Counties. A concentration of low, medium or high corresponding to literature values was then assigned to each septic tank based on the hydrologic soil group, presence or absence of BMPs and distance from each tank to the nearest surface water as estimated using GIS. Failure rate was assigned as a percentage of tanks based on hydrologic soil group and tank age.

V-1.7 Atmospheric Deposition

Total atmospheric deposition is defined as the sum of wet deposition (rainfall) and dry deposition (gaseous constituent interaction and dust fallout) directly to the surface of the bay. Deposition of pollutants to the watershed of the bay is incorporated into nonpoint source loading estimates.

Three types of data were used to estimate total atmospheric deposition:

- an estimate of the hydrologic load directly to the surface of the bay via precipitation;
- an estimate of the pollutant concentration in that precipitation; and
- an estimate of dry deposition, either from empirical data or model-based estimates.

Precipitation-derived hydrologic loads to the bay surface were estimated as the total monthly rainfall using the rainfall dataset used to generate hydrologic loads to the watershed (described above).

Mean monthly pollutant concentrations for total nitrogen (TN) in rainfall were obtained from the National Atmospheric Deposition Program (NADP) Verna Wellfield site in Sarasota County. This site represents the nearest long-term site measuring precipitation concentration data. TN loadings from precipitation were estimated by multiplying the monthly precipitation-weighted mean TN concentrations from the Verna site and the monthly bay surface hydrologic loads to estimate monthly wet TN loads to the bay. Estimates of wet deposition for nitrogen were calculated as follows:

$$Nwet_m = [N]_m * H_m,$$

$Nwet_m$ = wet deposition of nitrogen (kg/month) for each month *m*,

$[N]_m$ = mean precipitation-weighted nitrogen concentration (g/m^3) in the rainfall measured at the Verna Wellfield for each month *m*, and

H_m = estimated hydrologic load (m^3/month) from rainfall for each month *m* to the bay surface.

Concentrations for total phosphorus (TP) in rainfall were unavailable from the Verna site and had to be estimated from a relationship between rainfall concentrations of nitrogen and phosphorus which were based on data collected by the Tampa Bay Atmospheric Deposition Study (TBADS) were utilized (Poor, 2000). This program, running from 1996 to 2006, included sampling elements for both wet and dry deposition at an intensive monitoring site located on the Gandy Bridge Causeway. The data available from TBADS include concentrations for nitrogen and phosphorus, wet and dry deposition rates, and an estimate of the ratio of dry:wet deposition, and have been used to estimate atmospheric deposition to Tampa Bay (Pribble et al., 2001).

Estimates of dry deposition for both nitrogen and phosphorus were based on data collected at the TBADS site. Dry deposition was estimated using the TBADS-derived seasonal dry:wet deposition ratio, which was 1.05 for the dry season (months 1-6 and 11-12) and 0.66 for the wet season (months 7-10), as follows:

$$Ndry_m = \text{Seasonal Deposition Ratio} * Nwet_m,$$

$Ndry_m$ = dry deposition of nitrogen (kg/month) for each month *m*, and

$Nwet_m$ = wet deposition of nitrogen (kg/month) for each month *m*.

Total atmospheric deposition to a surface of the bay was given as the sum of the wet and dry deposition, as follows:

$$Ntot_m = Nwet_m + Ndry_m,$$

$Ntot_m$ = total atmospheric deposition of nitrogen (kg/month) for each month *m* to the surface of the bay.

V-2. Temporal Trends in Hydrologic and Nutrient Loadings by Bay Segment

Hydrologic and nutrient loads were estimated for the period 1989-2008 for five bay segments within the SBEP area (from north to south): Palma Sola Bay, Sarasota Bay, Roberts Bay, Little Sarasota Bay, and Blackburn Bay (Figure V-1).

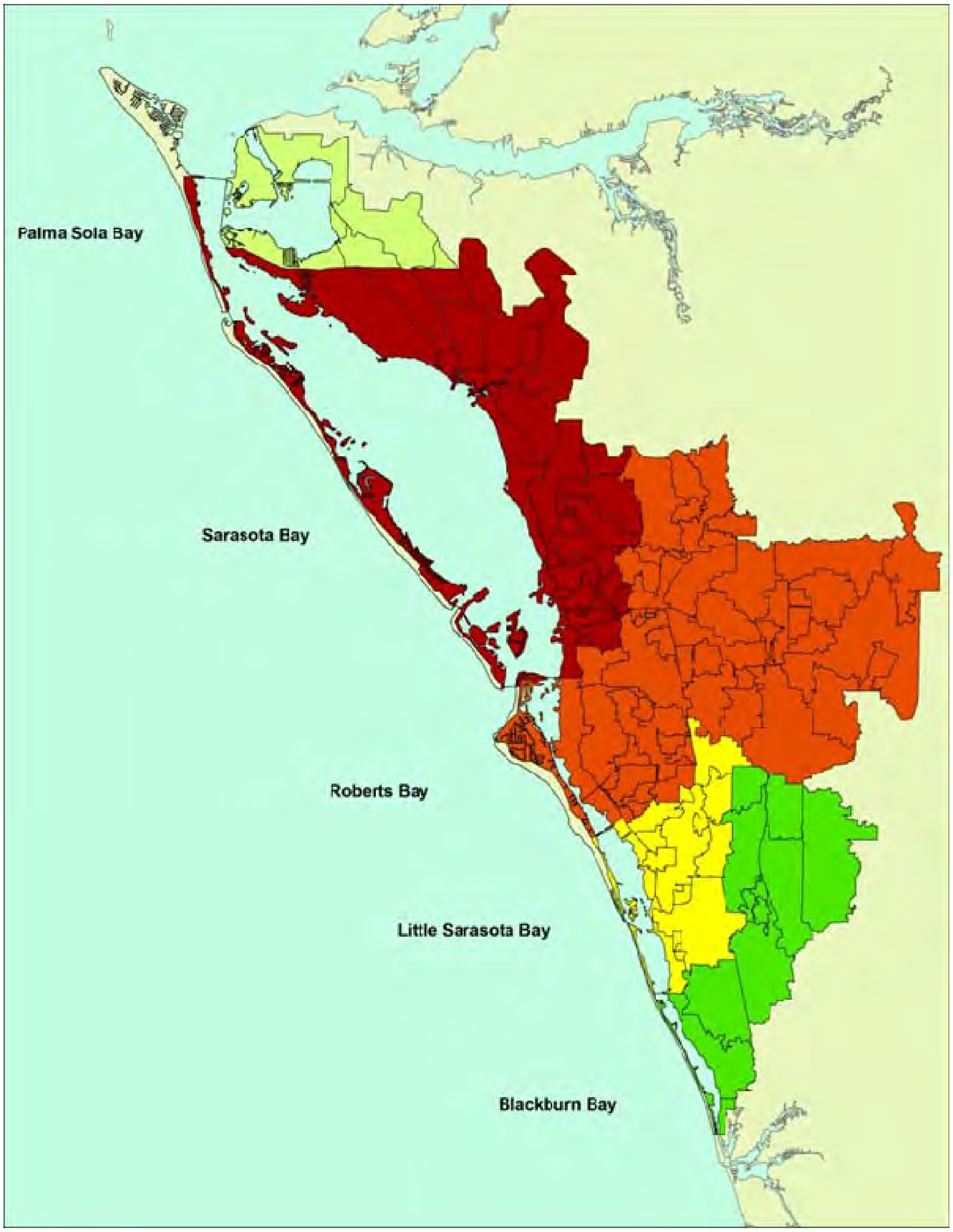

Figure V-1. - Sarasota Bay Estuary Program segments and their watersheds.

The total annual hydrologic, TN, and TP loads to each bay segment are presented in Figure V-2 through V-4 and are discussed in the following sections

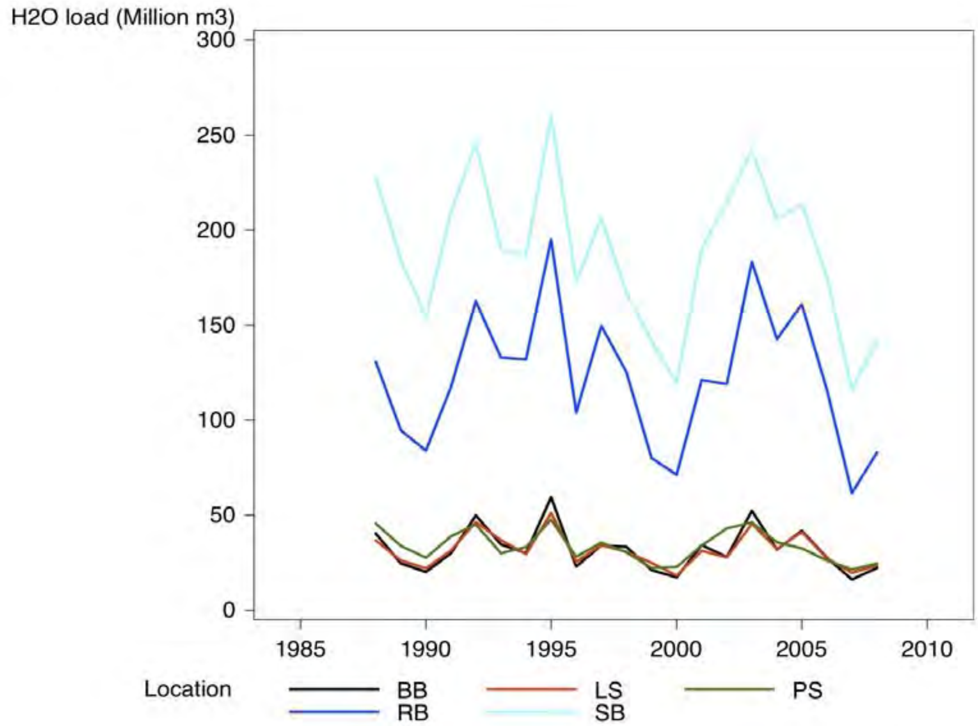

Figure V-2. – Annual hydrologic loads by bay segment. BB = Blackburn Bay, LS = Little Sarasota Bay, PS = Palma Sola Bay, RB = Roberts Bay, SB = Sarasota Bay.

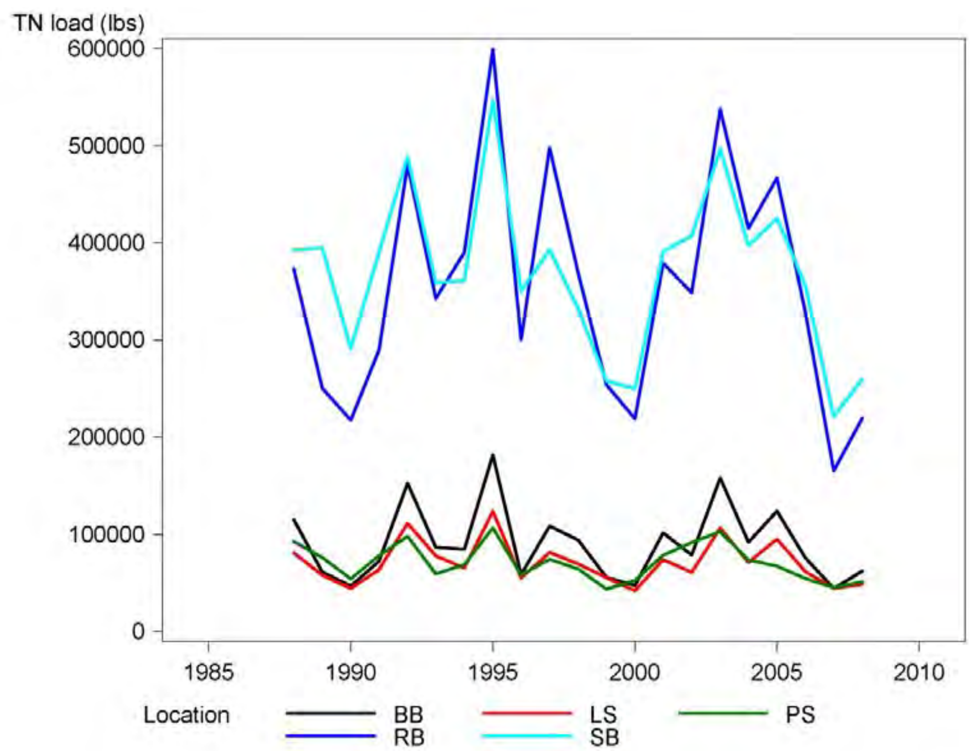

Figure V-3. – Annual TN loadings by bay segment. BB = Blackburn Bay, LS = Little Sarasota Bay, PS = Palma Sola Bay, RB = Roberts Bay, SB = Sarasota Bay.

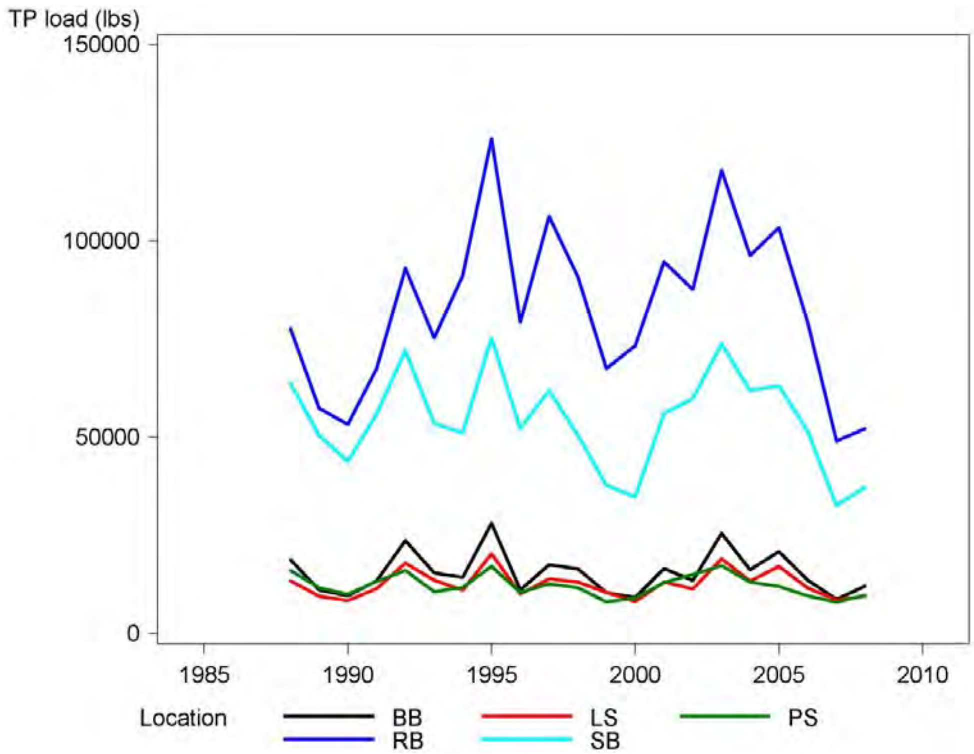

Figure V-4. – Annual TP loadings by bay segment. BB = Blackburn Bay, LS = Little Sarasota Bay, PS = Palma Sola Bay, RB = Roberts Bay, SB = Sarasota Bay.

Table V-1 presents the relative contribution to the recent (2008) loads to each bay segment. The contributions from direct runoff and base flow exceed 50% for each segment. Atmospheric deposition is relatively more important in Sarasota and Palma Sola bays, i.e., those segments with the greatest surface area.

Table V-1. Relative contribution (%) for each load type to the 2008 loads to each bay segment.

Load Type	BB	LSB	PSB	RB	SB
Atmospheric Deposition	4.0	15.6	20.4	2.3	31.7
Base Flow	21.9	25.0	19.4	27.6	15.3
Direct Runoff	59.8	56.0	49.5	59.2	42.5
Irrigation	1.7	2.3	2.3	2.5	1.3
Septic	12.6	1.1	8.4	4.1	4.3
Point Source	0.0	0.0	0.0	4.3	4.8

V-2.1 Palma Sola Bay

The highest annual hydrologic loads to Palma Sola Bay were observed during wetter years (generally > 55 inches) of 1992, 1995, and 2003 (Figure V-2). Drier years, in terms of total rainfall (< 40 inches), occurred in 1990, 1999, 2000, and 2007 and corresponded to the lowest observed hydrologic loads during those years. As expected, the highest annual nutrient loadings for TN and TP were observed during years of peak hydrologic loads in 1988, 1992, 1995, 2003, and 2005 (Figures V-3 and V-4).

Box-and-whisker plots of the hydrologic and nutrient loadings for Palma Sola Bay are presented in Figures V-5-V-7. The bars represent the range of observations, while the upper and lower margins of the box indicate the 25th and 75th percentiles. The solid line is the median value and the dot is the mean value. Mean hydrologic loads for Palma Sola Bay were highest during the wet season between June and October when average monthly loads ranged from 2.6 – 4.6 million cubic meters (Figure V-5). September had the highest average hydrologic loads in all bay segments, with October dropping sharply. During the dry season from November to May, average hydrologic loads to Palma Sola Bay ranged from 1.0 – 1.8 million cubic meters per month. For all bay segments, May had the lowest hydrologic loads. Interestingly, March consistently had the highest hydrologic loads observed during the dry season. As a rule, the average monthly hydrologic load to each of the bay segments during the wet season was 2.5 times greater than that during the dry season.

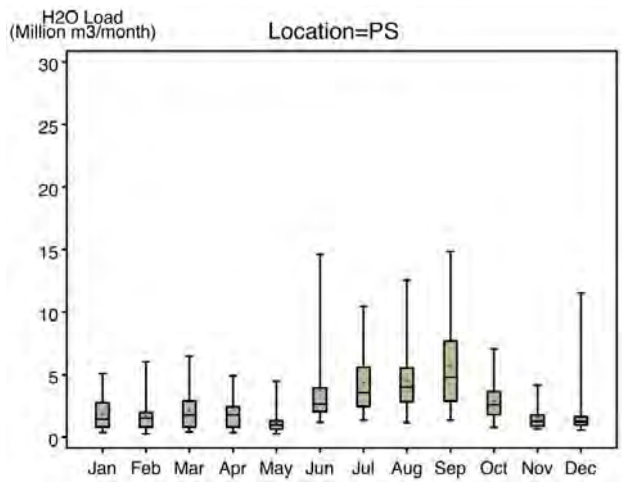

Figure V-5. – Average monthly hydrologic loads to Palma Sola Bay (1989-2008).

Average monthly loads for TN and TP were highest during the wet season (June-October) as expected from trends in rainfall and hydrologic loadings, and peaked in September (Figures V-6 and V-7). TN loads to Palma Sola ranged from 8.002 to 10,089 lbs/month between June-September and declined to 2,494 to 43,982 lbs/month during the dry season. TP loads displayed the same seasonal trends with the highest loads at 1,736 lbs in September at the end of the wet season and 485 lbs in May at the end of the dry season. As with hydrologic loads, wet- season nutrient loads were consistently greater than dry-season loads for TN (2.5 X greater) and TP (2 X greater).

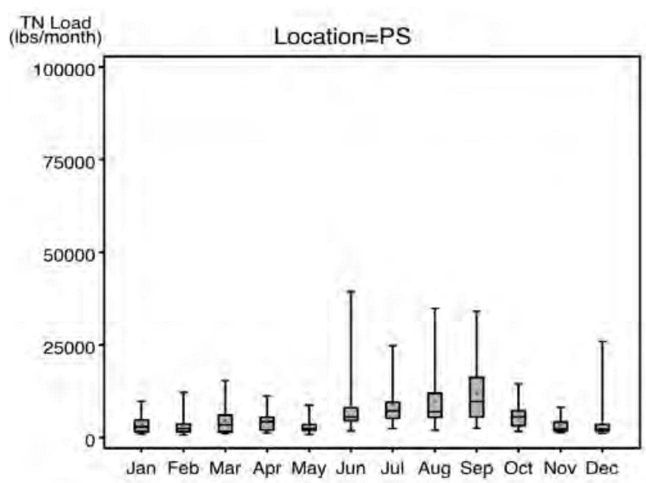

Figure V-6. – Average monthly TN loads to Palma Sola Bay (1989-2008).

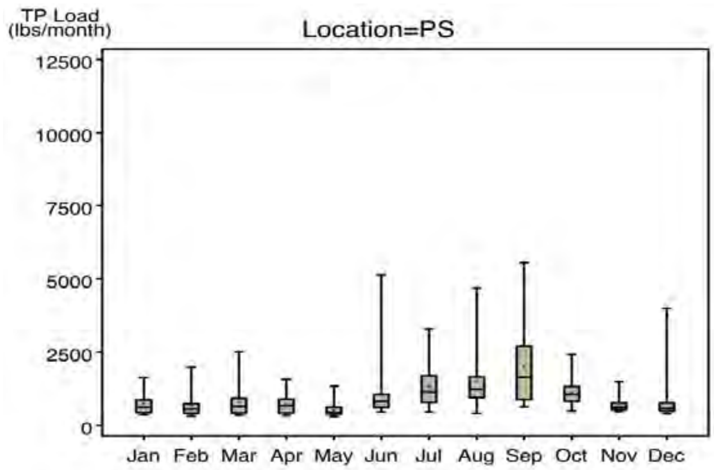

Figure V-7. – Average monthly TP loads to Palma Sola Bay (1989-2008).

V-2.2 Sarasota Bay

As with Palma Sola Bay, higher-than-average annual hydrologic loads to Sarasota Bay were observed during wetter years of 1992, 1995, and 2003, as well as 2005 (Figure V-2). Drier years occurred in 1990, 1999, 2000, and 2007 and corresponded to the lowest observed hydrologic loads during those years. The highest annual nutrient loadings for TN and TP were observed during years of peak hydrologic loads in 1992, 1995, 2003, and 2005 (Figures V-3 and V-4). Sarasota Bay also had noticeably higher than average TN in 1989 despite an average hydrologic load that year.

Monthly hydrologic loads to Sarasota Bay were highest during the wet season between June and October when average loads ranged from 17.2 – 28.5 million cubic meters (Figure V-8). The highest hydrologic loads were observed in September. Average hydrologic loads were lowest to Sarasota Bay from November to May, with May consistently having the lowest monthly loads. Dry season loads ranged from 7.8 – 11.8 million cubic meters per month. Average monthly hydrologic loads during the wet season were 2.5 times greater than those during the dry season.

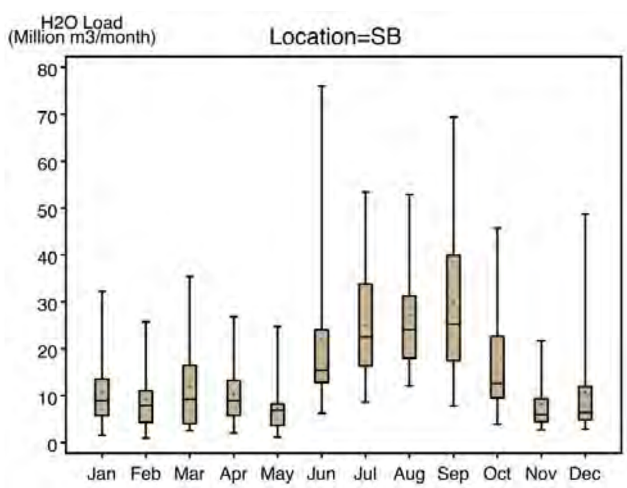

Figure V-8. – Average monthly hydrologic loads to Sarasota Bay (1989-2008).

Peak nutrient loads were observed between June-October with the highest monthly loads observed in September (Figures V-9 and V-10). Sarasota Bay received between 30,465 and 54,704 lbs TN/month between June-October but only one-third those amounts during the dry season, 14,180 to 25,437 lbs/month. Sarasota Bay also received higher TP loads during the wet season peaking at

8,187 lbs/month, but only one-fourth the TP load during the dry season at 2,256 lbs/month in May. As with hydrologic loads, wet- season nutrient loads were consistently greater than dry-season loads for TN (2 times greater) and TP (2 times greater).

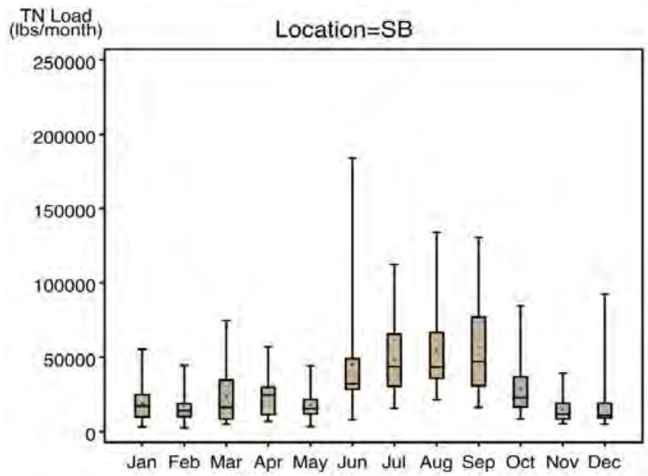

Figure V-9. – Average monthly TN loads to Sarasota Bay (1989-2008).

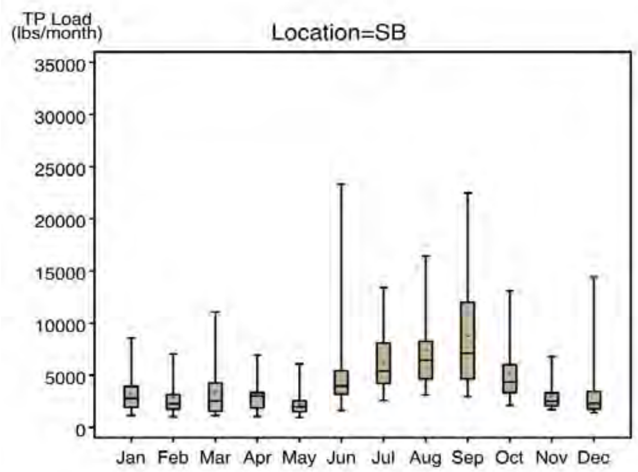

Figure V-10. – Average monthly TP loads to Sarasota Bay (1989-2008).

V-2.3 Roberts Bay

The highest annual hydrologic loads to Roberts Bay were observed during wetter years of 1992, 1995, 2003, and 2005 (Figure V-2). Drier years occurred in 1990, 1999, 2000, and 2007 and corresponded to the lowest observed hydrologic loads during those years. The highest annual nutrient loadings for TN and TP were observed in 1992, 1995, 2003, and 2005 during years of peak hydrologic loads (Figures V-3 and V-4). Higher than average annual nutrient loads were also observed during 1997 for Roberts Bay.

Mean hydrologic loads for Roberts Bay were highest between June and October when average monthly loads ranged between 12.3 – 19.7 million cubic meters (Figure V-11). September had the highest average hydrologic loads. The lowest hydrologic loads were observed between November and May when average loads to Roberts Bay ranged from 5.1 – 7.4 million cubic meters per month. As a rule, the average monthly hydrologic load to Roberts Bay during the wet season was 2.5 times greater than that during the dry season.

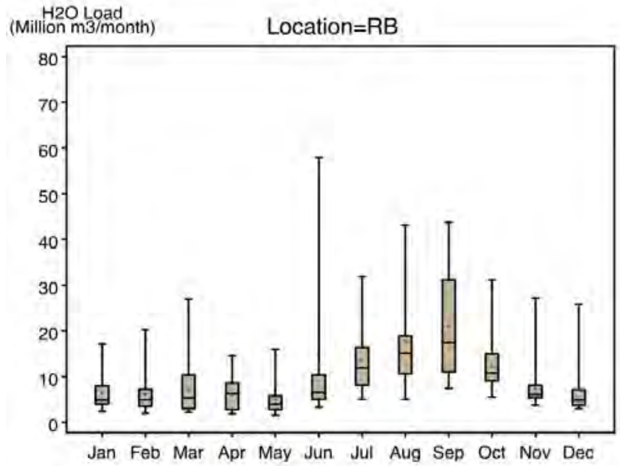

Figure V-11. – Average monthly hydrologic loads to Roberts Bay (1989-2008).

TN and TP loads were also highest from June-October, peaking in September (Figures V-12 and V-13). Roberts Bay received between 41,177 and 57,156 lbs TN/month between June-September while only one-third those amounts during the dry season, 15,622 to 21,585 lbs/month. Higher TP loads were observed for Roberts Bay during the wet season at 11,955 lbs/month compared to 4,620 lbs/month during the dry season. As with hydrologic loads, wet- season nutrient loads were consistently 3X greater than dry-season loads for TN and TP.

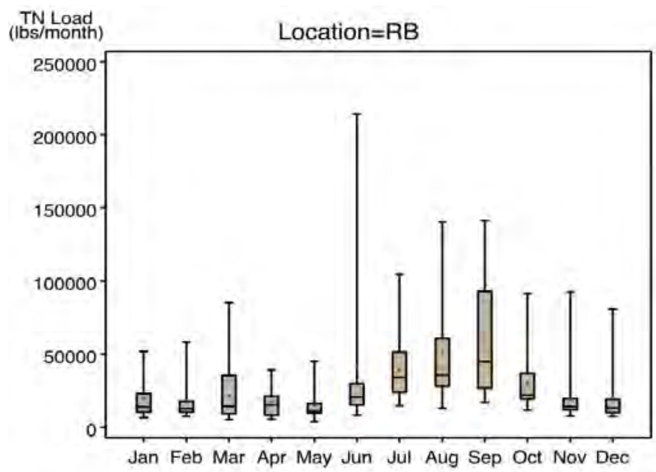

Figure V-12. – Average monthly TN loads to Roberts Bay (1989-2008).

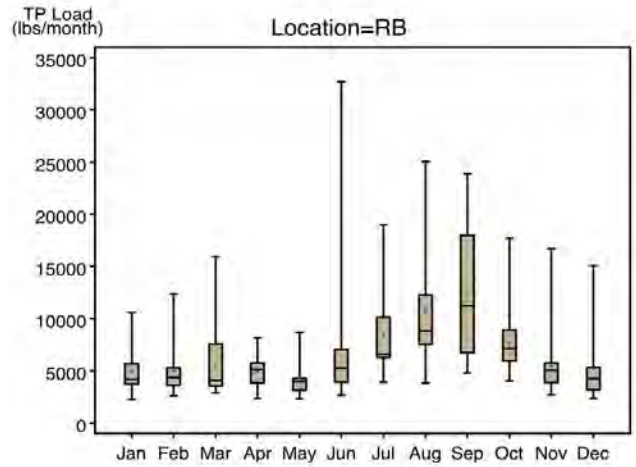

Figure V-13. – Average monthly TP loads to Roberts Bay (1989-2008).

V-2.4 Little Sarasota Bay

Little Sarasota Bay received the highest annual hydrologic loads during 1992, 1995, 2003, and 2005 (Figure V-2). The highest TN and TP loads were observed during the same years (Figures V-3 and V-4). Lowest hydrologic loads occurred in 1990, 1999, 2000, and 2007.

Mean hydrologic loads for Little Sarasota Bay were highest between June and October when average monthly loads ranged from 3.0 – 5.0 million cubic meters (Figure V-14). The highest loads occurred in September and dropped off in October at the end of the wet season. Between November and May, average hydrologic loads to Little Sarasota Bays ranged from 1.3 – 1.9 million cubic meters per month, with May having the lowest hydrologic loads. The average monthly hydrologic load to Little Sarasota Bay was 2.5 times greater during the wet season than during the dry season.

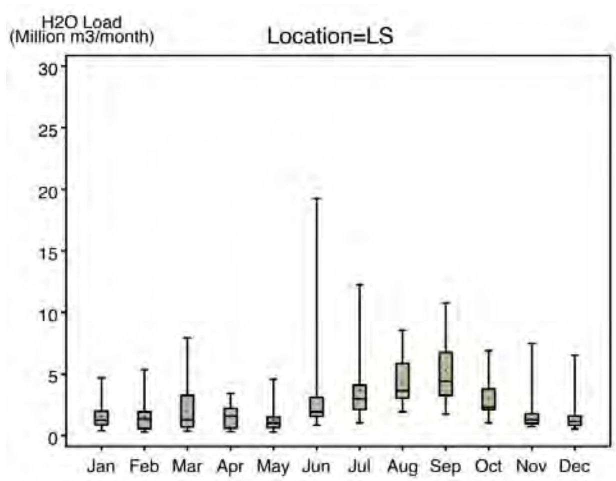

Figure V-14. – Average monthly hydrologic loads to Little Sarasota Bay (1989-2008).

Average monthly loads for TN and TP (Figure V-15 and V-16) were highest during the wet season (June-October) as expected from trends in rainfall and hydrologic loadings, and peaked in September and TN loads to Little Sarasota Bay ranged from 6,253 to 11,380 lbs/month between June-September and dropped to 3,013 to 4,408 lbs/month during the dry season. Monthly TP averages during the wet season were between 1,260 and 1,948 lbs/month, but dropped to between 561 and 805 lbs/month during the dry season. Average wet- season nutrient loads were consistently greater than dry-season loads for TN (2.5 times greater) and TP (2 times greater).

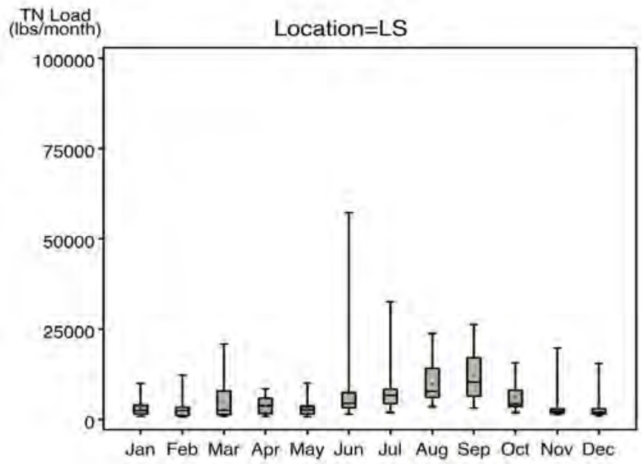

Figure V-15. – Average monthly TN loads to Little Sarasota Bay (1989-2008).

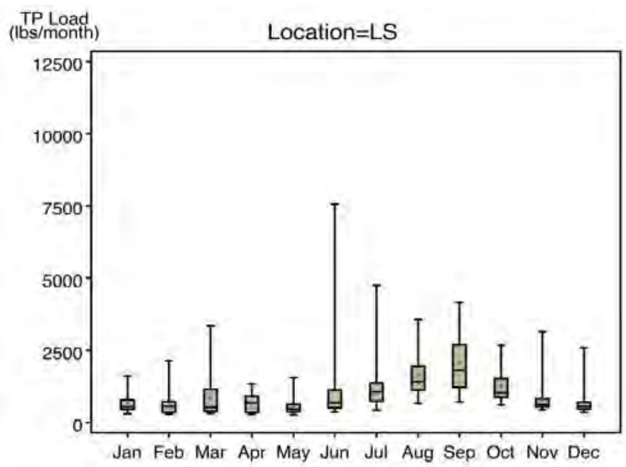

Figure V-16. – Average monthly TP loads to Little Sarasota Bay (1989-2008).

V-2.5 Blackburn Bay

Blackburn Bay received the highest annual hydrologic loads during 1992, 1995, 2003, and 2005 (Figure V-2). As was the case throughout the greater Sarasota Bay watershed, the lowest hydrologic loads to Blackburn Bay were observed in 1990, 1999, 2000, and 2007. The highest annual loadings for TN and TP were observed in 1992, 1995, 2003, and 2005 (Figures V-3 and V-4). Higher than average annual nutrient loads were also observed during 1997 for Blackburn Bay.

As was true for all bay segments within the Sarasota Bay watershed, Blackburn Bay experienced the highest monthly hydrologic loads during the wet season between June and October when loads were between 3.1 – 5.1 million cubic meters (Figure V-17). Hydrologic loads were highest in September averaging 5.1 million cubic meters. The lowest monthly hydrologic loads were observed in May during the end of the dry season (November to May) when average hydrologic loads to Blackburn Bay ranged from 1.1 – 1.9 million cubic meters per month. Average hydrologic loads to Blackburn Bay during the wet season were 2.5 times greater than that during the dry season.

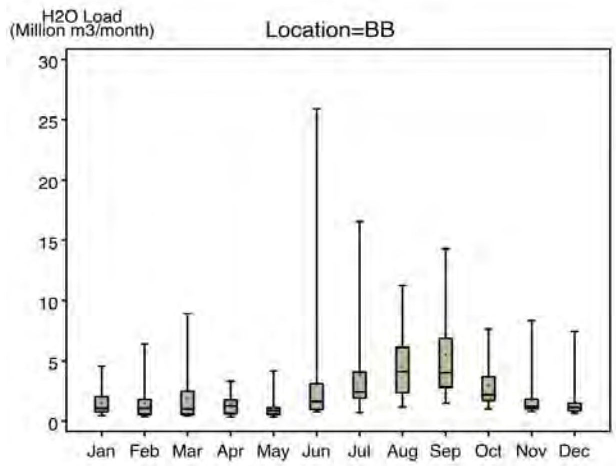

Figure V-17. – Average monthly hydrologic loads to Blackburn Bay (1989-2008).

The highest average monthly nutrient loads were observed during the wet season from June-October, with a peak loading in September, corresponding to higher than average hydrologic loadings during those months (Figures V-18 and V-19). TN loads to Blackburn Bay ranged from 11,699 to 15,048 lbs/month between June-September and dropped to between 2,782 to 5,008 lbs/month during the dry season. TP loads were also highest in September at 2,406 lbs/month and lowest in May at 592 lbs/month. As with hydrologic loads, wet- season nutrient loads were consistently greater than dry-season loads for TN (2.5 times greater) and TP (2 times greater).

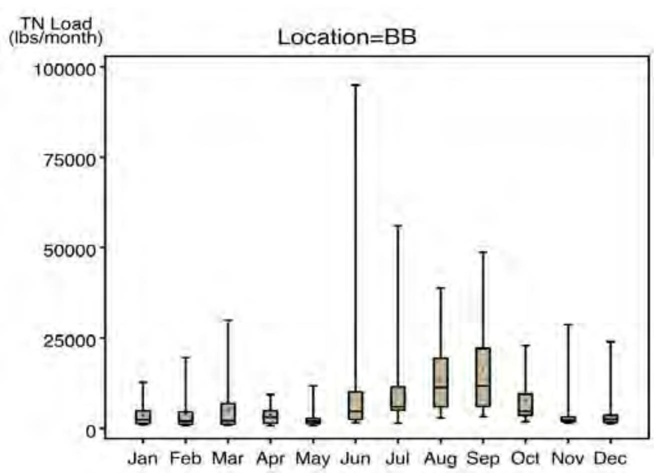

Figure V-18. – Average monthly TN loads to Blackburn Bay (1989-2008).

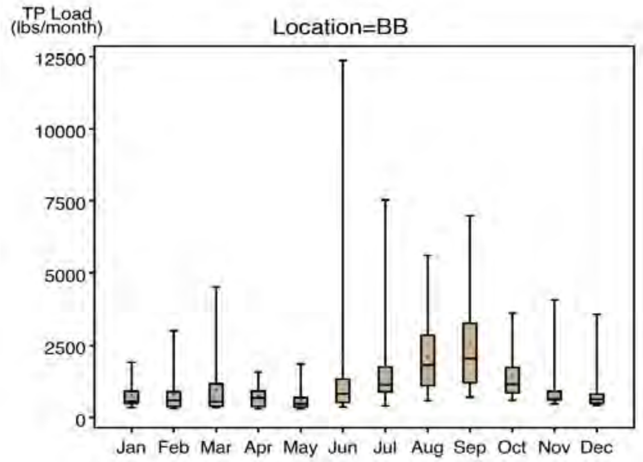

Figure V-19. – Average monthly TP loads to Blackburn Bay (1989-2008).

V-3. Temporal Trends in Residence Times by Bay Segment

A box model was developed to estimate the hydraulic residence times within the SBEP segments. The box model was based on observed salinity distributions within the system and estimated freshwater inflows from the SIMPLE model to the system. Methods were similar to those described by Hagy et al. (2000), with the exception that the SBEP system was assumed to be well mixed vertically, so that all transport was horizontal. Hydraulic residence time is also named the pulse residence time (PRT), as residence times are dependent upon introducing a pulse of tracer into a selected segment at the beginning of the box model simulation and tracking the time necessary for the concentration of this tracer to decrease to a certain level.

The specific method used to estimate the pulse residence times for each segment is given in Appendix 4.

The box model iterations resulted in segment- and monthly-specific estimates of PRT. For each segment, the median PRT for each year was calculated, and then the median PRT of the annual values for each segment were calculated. These segment-specific PRTs are provided in Table V-2, and represent the median hydraulic residence time within each segment given the observed conditions of 1994-2007.

Table V-2. Median annual pulse residence time for each segment based on 1994-2007 conditions.

Segment	Pulse Residence Time (days)
Palma Sola Bay	35.8
Sarasota Bay	28.8
Roberts Bay	2.8
Little Sarasota Bay	19.2
Blackburn Bay	3.0

A time series plot of the annual PRTs for each segment for the 1994-2007 period is provided in Figure V-20. As show in Table V-2, the PRTs are in units of days, so that a shorter PRT indicates more rapid exchange between the segment and the Gulf, and a longer PRT indicates slower exchange. Not surprisingly, the smaller segments with large freshwater inflows relative to the segment size (Roberts Bay, Blackburn Bay) have much shorter residence times (on the order of 10 times shorter) than do those with smaller inflows and relatively larger segment volumes (Sarasota Bay, Little Sarasota Bay). As can be seen from Figure V-20, the interannual variability in PRT is small for all segments, with only about 10% variability in PRT in those segments with longer residence times, and almost no variability in PRT in those segments with shorter residence times.

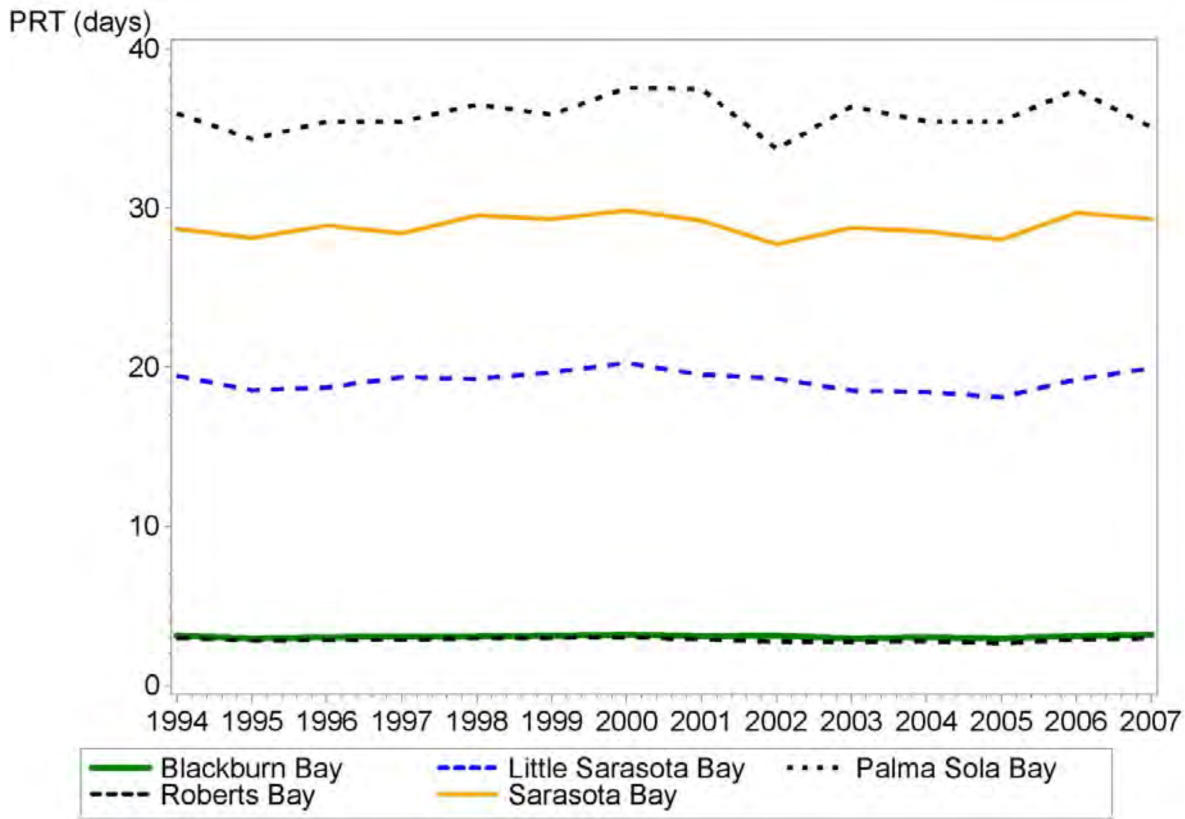

Figure V-20. Median annual PRTs (days) for each segment, based on monthly PRTs for each years.

VI. Relationships between Chlorophyll and Nutrient Loads and Concentrations

The objective of this section is to present the methods and results obtained in the development of quantifiable relationships between chlorophyll *a* and nutrient loadings and/or concentrations for each bay segment in the SBEP area. A summary of the potential empirical approaches to establish NNC was recently completed for the three National Estuary Programs on the Florida Gulf Coast (Janicki Environmental, 2010b).

In most estuarine ecosystems N is the most limiting nutrient (a nutrient whose concentration in the environment of an organism determines the growth and productivity of that organism) (Boynton et., 1982; Howarth, 1988; Chapra, 1997; National Research Council, 2000; Pennock et al., 2000). Aquatic ecosystems are commonly characterized by their N:P ratios. Receiving waters with ratios less than 10:1 are considered nitrogen limited, while ratios higher than 10:1 are assumed to be phosphorus limited (FDEP, 2000). In Sarasota Bay, ratios between total nitrogen (TN) and total phosphorus (TP) are typically well below 10 (Lowrey, 1992), which is consistent with presumed nitrogen limitation. In Roberts Bay, FDEP (2005) calculated a median TN:TP ratio of 2.4, indicating strong nitrogen limitation of phytoplankton growth. In addition, empirically derived relationships also point to the primary role of nitrogen in the eutrophication processes in Sarasota Bay (i.e., Tomasko et al. 1992 and 1996), as was found in the earliest studies in Tampa Bay (i.e., Johansson 1991). More recent assessments also support the finding of nitrogen-limitation of macroalgae in Sarasota Bay (Dillon and Chanton, 2008).

VI-1 Data Sources

The water quality data used in these analyses are described in Section IV. The estimates of hydrologic, TN, and TP loadings used are described in Section V. Residence times used in these analyses are also described in Section V.

VI-2 Analytical Approach

A linear regression approach was used to develop statistically defensible relationships. Linear regression is a parametric statistical technique that is used to explore the relationship between two or more variables. In ordinary least-squares regression, the relationship between the dependent variable (y-axis) and independent variable (x-axis) is developed. This is done by fitting a straight line through the set of points such that the sum of squared residuals of the model is as small as possible. That is to say, the vertical distances between the individual points and the fitted line are minimized.

In linear regression, it is assumed that the data are independent samples from the population that is being sampled. For example, the data should come from samples that are representative of the spatial and temporal variability of the system. Another important assumption of linear regression is that the error term of the model is normally distributed, with constant variance. Often times, one or more of the variables exhibits a non-linear relationship with the other variables. While there are non-linear regression techniques that can be employed, one should attempt to transform the data before resorting to nonlinear methods. Often, linear relationships can be developed using transformed data and these models will satisfy the assumptions of linear regression.

The stepwise regression procedure (SAS 9.2, 2010) was used to identify the independent variables that have a significant relationship with chlorophyll *a*. In the stepwise procedure, the independent variables are added to the model one at a time and the F statistic for the variable must be significant in order for the variable to be included in the model. Unlike the forward procedure which only adds additional variables to the model, the stepwise procedure examines the F statistic for all variables already included in the model after each step. Variables that are no longer significant based on the F statistic are removed. The result is a ranked list of significantly contributing variables.

Diagnostic statistics and plots are commonly used to determine if the regression model meets the assumptions of linear regression. The most commonly used statistics are the statistical significance of the model parameters and the coefficient of determination (R^2). The statistical significance of the model parameters tests whether the slope and intercept of the model are significantly different from zero. The coefficient of determination is a measure of the variance in the dependent variable that is explained by the model. A plot of the residuals versus the independent variable can be used to judge if the assumption of constant variance is met. Additional plots of residuals versus other variables can also be instructive. For example, a time-series plot of the residuals can be used to assess whether or not the residuals vary seasonally. Additional diagnostics can be run to identify outliers and test for leverage or influential points. Data points that are identified by these additional diagnostics should be further investigated to determine if they are the result of a data entry error or other problems that merit removing them from the analysis.

The independent variables used in the model building process included loadings, concentrations, and estimates of residence time. The loadings data included monthly hydrologic, TN, and TP loads as well as cumulative total loads extending from two to six months (e.g., 2-month cumulative TN load = TN load current month + TN load one- month prior). The water quality constituents included TN and TP concentrations along with numerous other constituents. The results of the analyses for each segment are presented below.

VI-3 Roberts Bay

A series of bivariate plots were examined to investigate relationships between chlorophyll *a* and other potential explanatory variables. TN concentration was identified as the variable that makes that greatest contribution to explaining the variability in chlorophyll *a* concentrations in Roberts Bay. As can be seen in Figure VI-1, there is a pattern of increasing chlorophyll *a* concentrations with increasing TN concentrations.

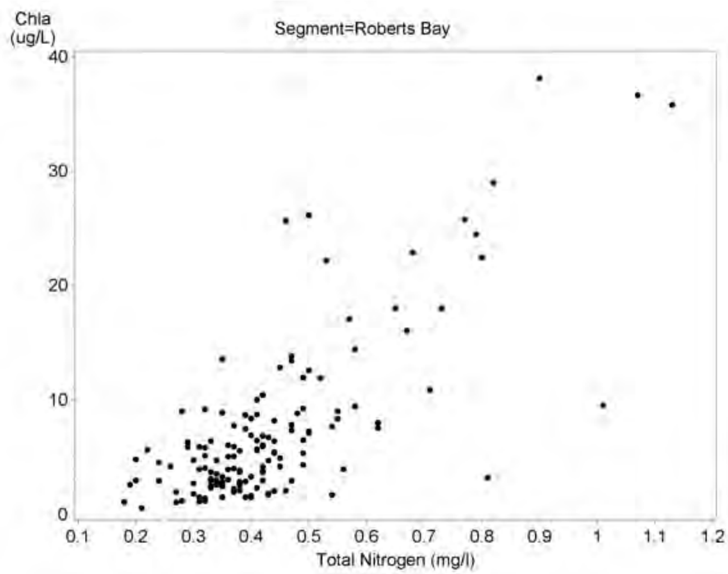

Figure VI-1. Relationship between monthly average chlorophyll *a* and TN concentrations in Roberts Bay.

A regression model between chlorophyll *a* and TN concentrations was developed and the residuals from this model were examined to identify any other explanatory variables that might contribute to the overall variance accounted for by the model. The residual analysis revealed a seasonal difference in residuals. Specifically, given the same TN concentrations, higher chlorophyll a concentrations can be expected during the wetter, warmer summer months (July-October) than during the remainder of the year. Therefore, a seasonal term was added to the regression equation. The season term is a dummy variable which equals one during July-October and zero other months of the year. The final regression equation is:

[Chlorophyll *a*] = -5.73 + (27.07 * [TN]) + (3.41 * season)

The model was fit with 133 observations and resulted in an R^2 value of 0.62. The regression was highly significant with a probability of a greater |F| value of < 0.0001. The slope and parameter coefficients were also highly significant. A plot of predicted versus observed chlorophyll *a* concentrations is presented in Figure VI-2. The fit is generally good with some overestimation at low concentrations and underestimation at hogher levels. Residual plots for the Roberts Bay chlorophyll *a* regression model are presented in Appendix 5.

VI-4 Little Sarasota Bay

A series of bivariate plots were examined to investigate relationships between chlorophyll *a* and other potential explanatory variables in Little Sarasota Bay. TN concentration was identified as the variable that makes that greatest contribution to explaining the variability in chlorophyll *a* concentration. As can be seen in Figure VI-3 there is a pattern of increasing chlorophyll *a* concentrations with increasing TN concentrations.

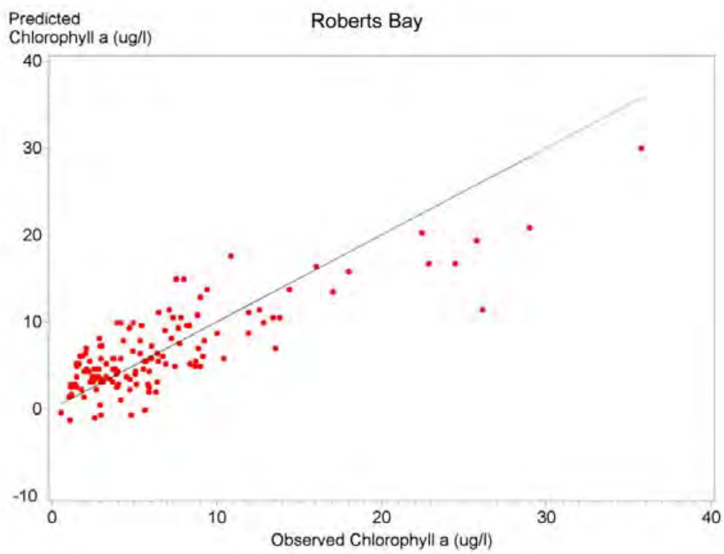

Figure VI-2. Predicted versus observed chlorophyll *a* concentrations for Roberts Bay ($R^2 = 0.62$).

A regression model between chlorophyll *a* and TN concentrations was developed and the residuals from this model were examined to identify any other explanatory variables that might contribute to the overall variance accounted for by the model. As was found in Roberts Bay, the residual analysis revealed a seasonal difference in residuals. Specifically, given the same TN concentrations, chlorophyll a concentrations can be expected to be higher in Little Sarasota Bay during the wetter, warmer summer months (July-October) than during the remainder of the year. Therefore, a seasonal term was added to the regression equation. The season term is a dummy variable which equals one during July-October and zero other months of the year. The final regression equation is:

[Chlorophyll *a*] = -4.48 + (21.59 * [TN]) + (2.97 * season)

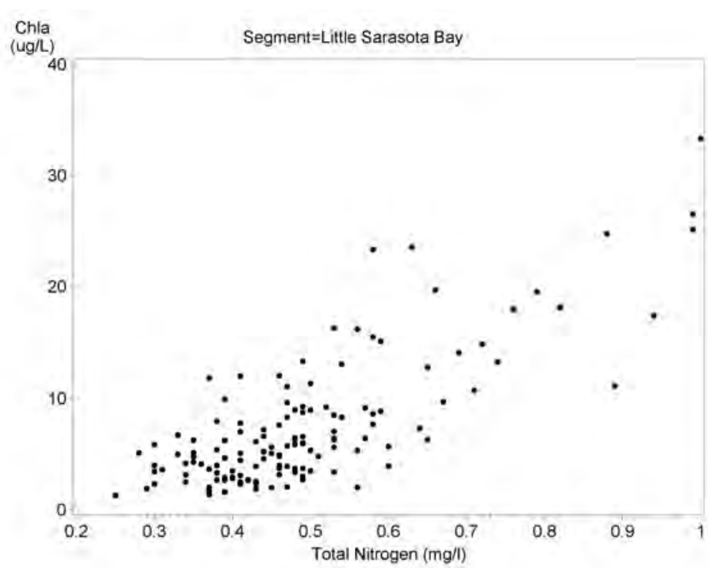

Figure VI-3. Relationship between monthly average chlorophyll *a* and TN concentrations in Little Sarasota Bay.

The model was fit with 133 observations and resulted in an R^2 value of 0.57. The regression was highly significant with a probability of a greater |F| value of < 0.0001. The slope and parameter coefficients were also highly significant. A plot of predicted versus observed chlorophyll *a* concentrations is presented in Figure VI-4. Residual plots for the Little Sarasota Bay chlorophyll *a* regression model are presented in Appendix 5.

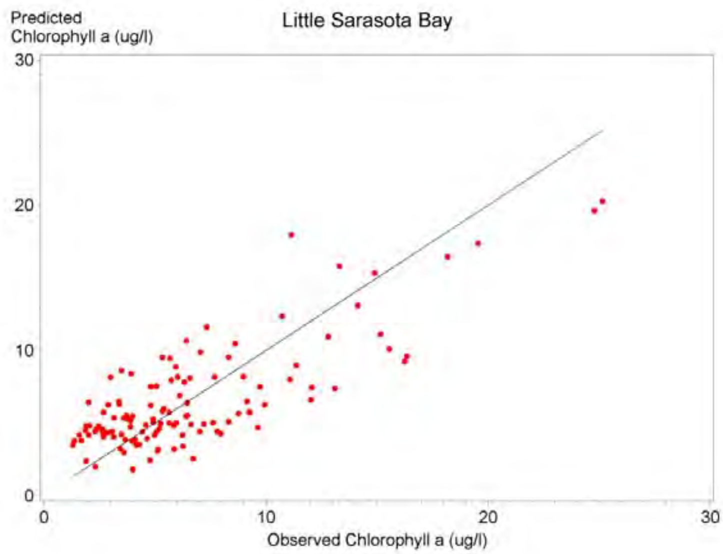

Figure VI-4. Predicted versus observed chlorophyll *a* concentrations in Little Sarasota Bay (R^2=0.57).

VI-5 Blackburn Bay

A series of bivariate plots were examined to investigate relationships between chlorophyll *a* and other potential explanatory variables. TN concentration was identified as the variable that makes that greatest contribution to explaining the variability in chlorophyll *a* concentration. As can be seen in Figure VI-5, there is a pattern of increasing chlorophyll *a* concentrations with increasing TN concentrations.

A regression model between chlorophyll *a* and TN concentrations was developed and the residuals from this model were examined to identify any other explanatory variables that might contribute to the overall variance accounted for by the model. Similar to both Roberts Bay and Little Sarasota Bay, this analysis revealed a seasonal difference in residuals. Specifically, given the same TN concentrations, chlorophyll a concentrations can be expected to be higher in Blackburn Bay during the wetter, warmer summer months (July-October) than during the remainder of the year. Therefore, a seasonal term was added to the regression equation. The season term is a dummy variable which equals one during July-October and zero other months of the year. The final regression equation is:

[Chlorophyll *a*] = -3.55 + (23.72 * [TN]) + (1.73 * season)

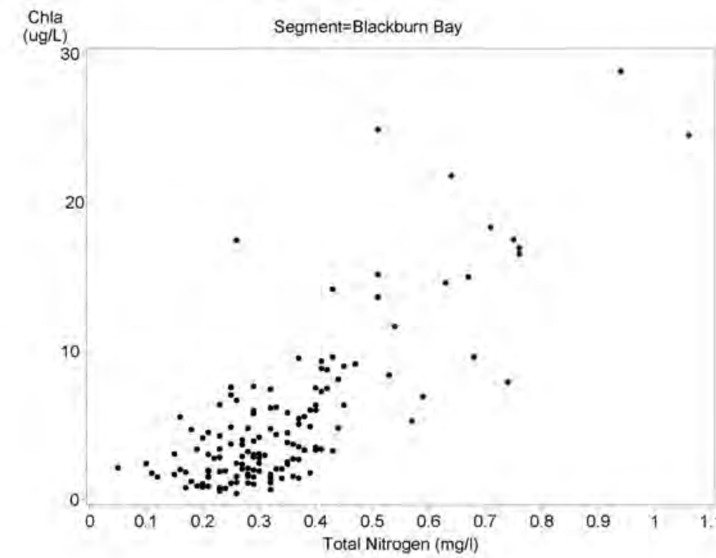

Figure VI-5. Relationship between monthly average chlorophyll *a* and TN concentrations in Blackburn Bay.

The model was fit with 133 observations and resulted in an R^2 value of 0.73. The regression was highly significant with a probability of a greater |F| value of < 0.0001. The slope and parameter coefficients were also highly significant. A plot of predicted versus observed chlorophyll *a* concentrations is presented in Figure VI-6. Residual plots for the Blackburn Bay chlorophyll *a* regression model are presented in Appendix 5.

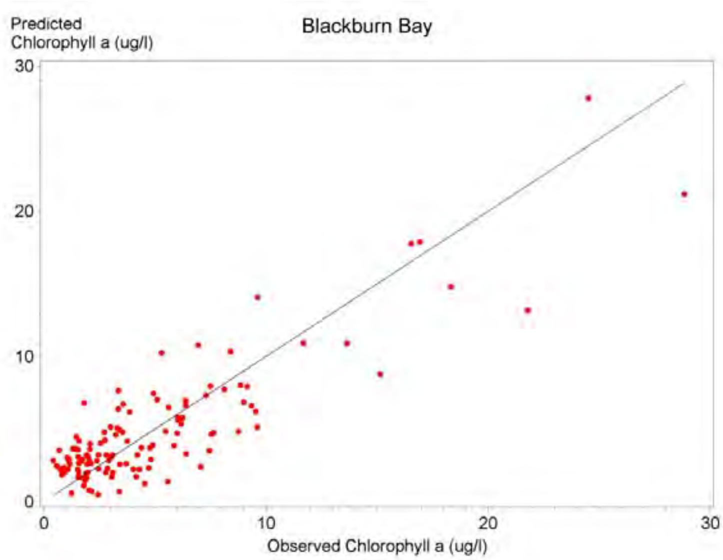

Figure VI-6. Predicted versus observed chlorophyll *a* concentrations in Blackburn Bay ($R^2 = 0.73$).

VI-6 Sarasota Bay

In order to investigate potential relationships between chlorophyll *a* and explanatory variables in Sarasota Bay, a series of bivariate plots were examined. TN concentration was identified as the variable that makes the greatest contribution to explaining the variability in chlorophyll *a* concentrations in Sarasota Bay. As expected, there is a pattern of increasing chlorophyll *a* concentrations with increasing TN concentrations (Figure VI-7). As in the regressions developed for Roberts Bay, Little Sarasota Bay, and Blackburn Bay, initial efforts revealed a seasonal difference in residuals. This indicates that given the same TN concentration, higher chlorophyll *a* concentrations are expected during the summer months. Therefore, a seasonal term was added to the regression equation. The season term is a dummy variable which equals one during the wet season (June-October) and zero other months of the year.

Unlike Roberts Bay, Little Sarasota Bay, and Blackburn Bay, Sarasota Bay is a substantially larger system with greater spatial variability in TN concentrations. Specifically, TN concentrations in the northern portion of the bay (Figure VI-8) are greater than those in the southern portion (Table VI-1). In contrast, there is less spatial variability in the chlorophyll a concentrations. As a result, given the same TN concentrations, higher chlorophyll *a* concentrations are found in the southern portion of the bay. Therefore, a region term was added to the regression equation to account for the spatial differences in TN and chlorophyll *a* concentrations in Sarasota Bay.

Further analysis of the residuals from the regression model revealed that color also contributed to explaining the variation in chlorophyll *a* and was added to the regression equation. The final regression equation obtained is:

[Chlorophyll *a*] = -1.06 + (3.58 * [TN]) + (0.32 * color) + (2.03 * season) – (4.84 * region)

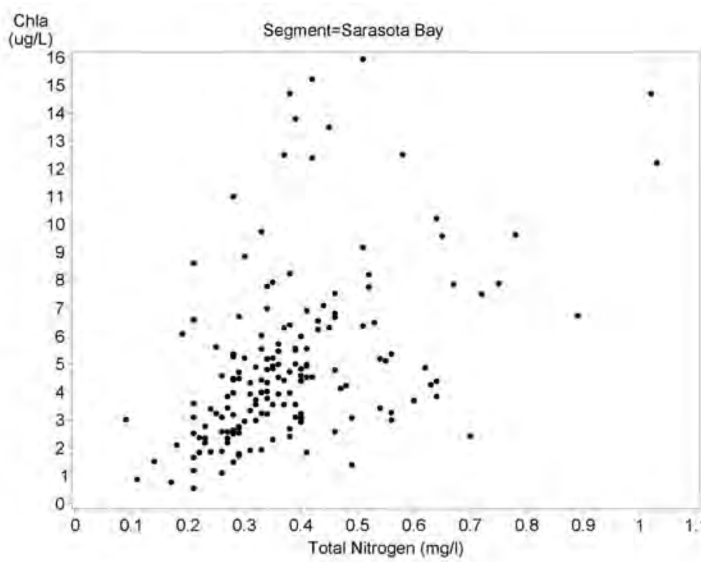

Figure VI-7. Relationship between monthly average chlorophyll *a* and TN concentrations in Sarasota Bay.

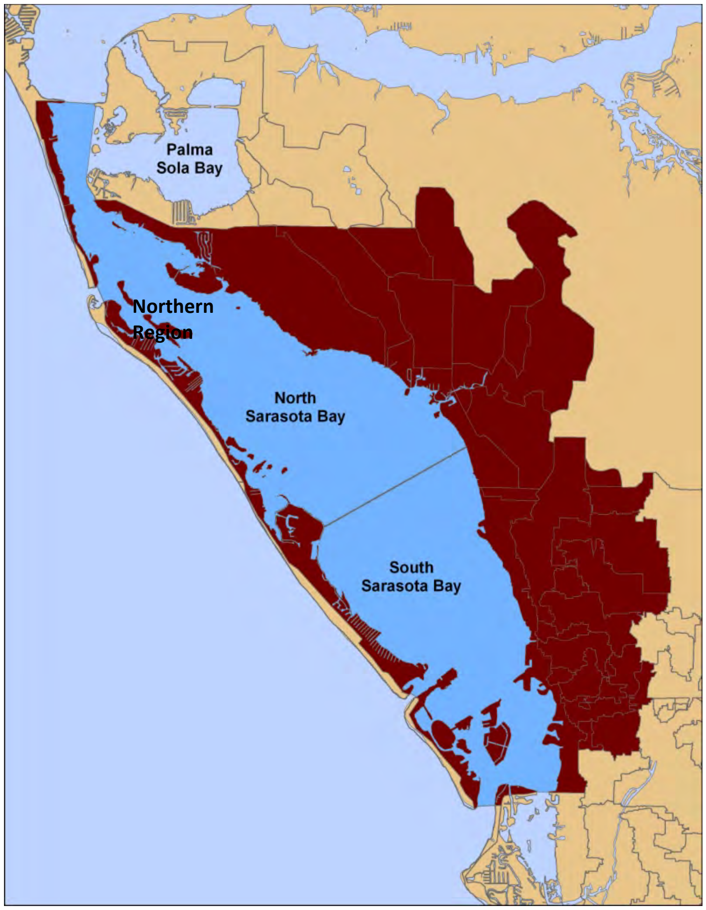

Figure VI-8. Northern and southern portions of the Sarasota Bay segment.

Table VI-1. Comparison of water quality within Northern and Southern Sarasota Bay. Values represent medians for the period 1998-2009.		
Variable	Northern Sarasota Bay	Southern Sarasota Bay
Chlorophyll a (μg/l)	5.2	3.4
TN (mg/l)	0.56	0.28
Color (PtCo units)	20	10

The model was fit with 156 observations and resulted in an R^2 value of 0.67. The regression was highly significant with a probability of a greater $|F|$ value of < 0.0001. The slope and parameter coefficients were also significant. A plot of predicted versus observed chlorophyll *a* concentrations is presented in Figure VI-8. Residual plots for the Sarasota Bay chlorophyll *a* regression model are presented in Appendix 5.

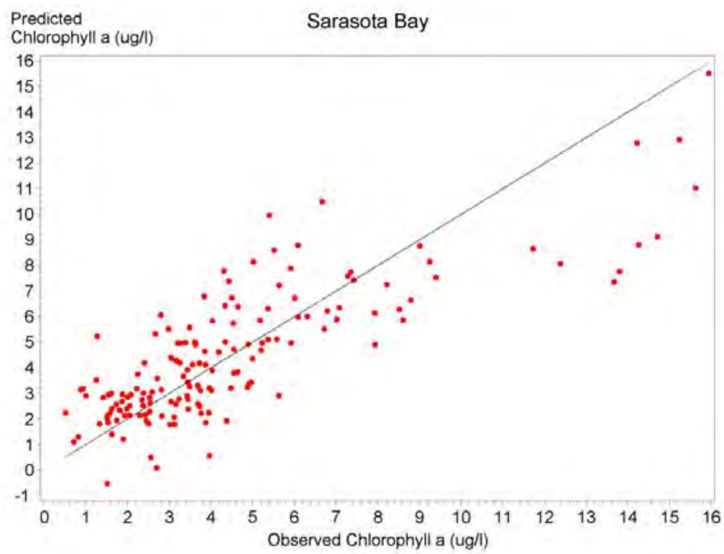

Figure VI-8. Predicted versus observed chlorophyll *a* concentrations in Sarasota Bay ($R^2 = 0.67$).

VI-7 Palma Sola Bay

A series of bivariate plots were examined to investigate relationships between chlorophyll *a* and other potential explanatory variables in Palma Sola Bay. Specifically, examination of the relationship between chlorophyll *a* concentrations and both TN concentrations and loads were examined. As can be seen in Figures VI-9 and VI-10, there is no apparent relationship between chlorophyll *a* concentrations and either TN concentrations or loads. A similar lack of relationships was found for TP concentrations and loads, as well as a series of cumulative loading.

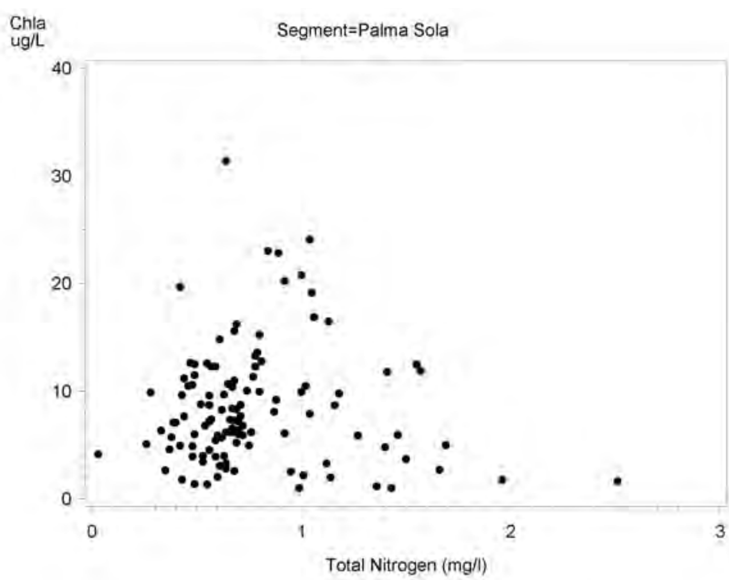

Figure VI-9. Relationship between monthly average chlorophyll *a* and TN concentrations in Palma Sola Bay.

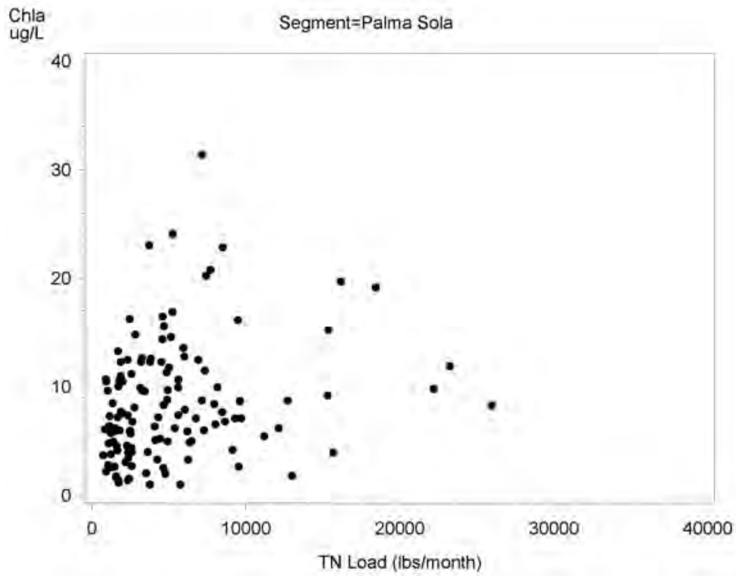

Figure VI-10. Relationship between monthly average chlorophyll *a* and TN loading in Palma Sola Bay.

Several other analytical tools were applied to discern if a quantitative relationship between chlorophyll *a* concentrations and either TN concentrations or loads could be found. Specifically, various applications of both logistic regression techniques and changepoint analyses were investigated.

Logistic regression was used to predict the probability of a chlorophyll *a* concentration greater than the threshold value of 11.8 μg/l for Palma Sola Bay as a function of TN concentration. A season term was incorporated to account for the differential effects of TN concentration on phytoplankton production depending on water temperature and photoperiod. One hundred and seventy-one observations were used in the regression and 49 chlorophyll exceedances (i.e., chlorophyll *a* > 11.8 μg/l) occurred in the dataset. The resulting logistic regression equation was:

$$LOG\left(\frac{p_{(y=1|x)}}{1-p_{(y=1|x)}}\right) = -2.1521 + 2.0486 * TN + 0.74 * 1(Wet)$$

The model R^2 was 0.24 and suggested that the odds of a value exceeding the threshold during the wet season was more than twice [i.e., $e^{(0.74)}$] that of the dry season (Figure V-11). In order to use logistic regression for prediction, one must assign a probability cutpoint from which to define an exceedance. The SAS program (SAS, 2010) uses a jackknife routine to estimate the probability cutpoint that results in the highest predictive accuracy of the model and therefore confidence in "making the right call".

Applying this jackknife procedure to the TN and chlorophyll *a* concentration data for Palma Sola Bay identified a probability cutpoint of 0.45 which resulted in 76% classification success (sensitivity=47% and specificity=87%). Based on these results, a TN concentration that is predicted to result in a chlorophyll *a* concentration exceedance in the wet season is 0.57 mg/l and in the dry season 1.31 mg/l. Using these values and calculating a weighted mean TN concentration results in an annual average annual TN concentration of 1.06 mg/l. It is important to note that these estimates do not include uncertainty in the model estimates which may be substantial, therefore the results should be applied with a degree of caution.

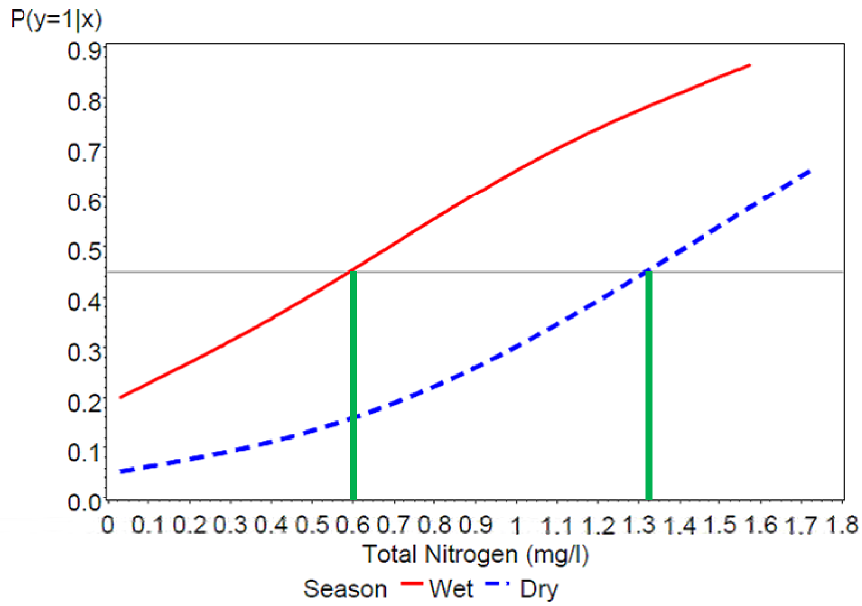

Figure V-11. Predicted probabilities of a chlorophyll *a* value greater than 11.8 in wet and dry season in Palma Sola Bay. Horizontal line indicates cutpoint probability for assigning a predicted value as an exceedance.

Changepoint analysis was performed to identify a potential threshold TN value that was associated with a non-linear increase in chlorophyll a concentrations. Changepoint analysis performs an iterative search through the data sorted in increasing order of TN values to identify a "changepoint" in the relationship that maximizes the difference in chlorophyll concentrations between two groups of data. In this way a threshold value for TN is identified. No *a priori* threshold is specified. The decision tree approach defines the breakpoint as that which maximizes the difference by minimizing the *p* value associated with the F test. The point in the covariate (TN concentration) at which the *p* value is minimized, after adjustment for multiple comparisons, is assigned as the breakpoint defining the split of the chlorophyll data into 2 groups. Once the first split is made the process continues to test for subsequent splits that are conditional on the first split. This is called "conditional inference" or "conditional probability analysis" which has been popularized recently by the USEPA as a potential approach for establishing numeric nutrient criteria.

For this analysis, the state threshold for chlorophyll-a in marine waters (11 μg/l) was used as a criterion value for evaluating the potential of the identified changepoint value of TN to serve as a potential numeric nutrient criterion. That is, if the identified changepoint resulted in a group of chlorophyll data with an average value above 11 μg/l then the TN changepoint was deemed as a potential value for numeric nutrient criterion development.

The results of changepoint analysis for Palma Sola Bay is provided in Figure V-12. A statistically significant TN changepoint value of 0.756 mg/l was identified as the value that maximized the difference in the distribution of chlorophyll *a* concentrations between two groups. The average chlorophyll *a* concentration when TN concentrations were below 0.756 mg/l was 7.69 μg/l and the average chlorophyll *a* concentration when TN concentrations were above 0.756 g/l was 11.6 μg/l. Since the average chlorophyll *a* concentration in the high TN group was above the state threshold, we consider this TN value to be potentially meaningful in allowing Palma Sola Bay to continue to meet its designated uses.

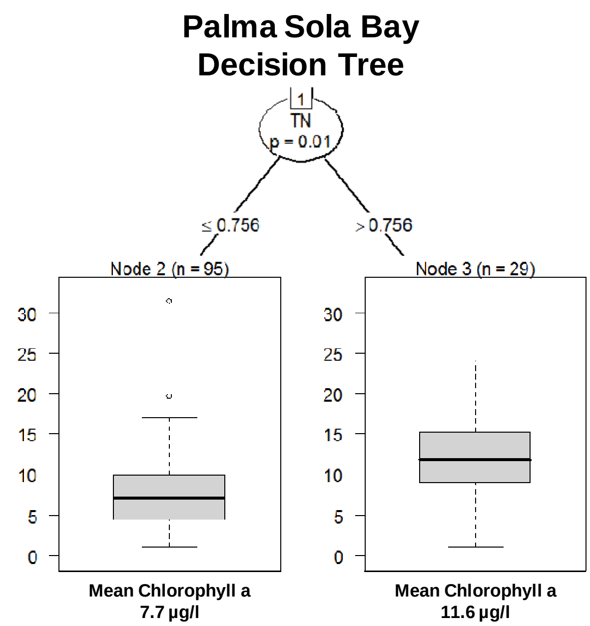

Figure V-12. Results of changepoint analysis in Palma Sola Bay with distribution of chlorophyll *a* values displayed in boxplots and the TN changepoint identified as 0.75.

VII. Recommended SBEP Numeric Nutrient Criteria

We have applied the stressor-response relationships described in Section VI to estimate draft numeric nutrient criteria for each SBEP segment. The strategy for developing the numeric nutrient criteria is based on the chlorophyll *a* thresholds identified in Section III and the quantitative relationships between chlorophyll *a* and nutrients derived in Section VI. The following describes the approach used.

VII-1 Roberts, Little Sarasota, and Blackburn Bays

The stressor-response relationships for Roberts Bay, Little Sarasota Bay, and Blackburn Bay that were identified in Section VI indicated very similar responses in chlorophyll *a* concentrations to changes in nutrients. Specifically, two terms, TN concentration and season, explained more than 60% of the variation in the chlorophyll *a* data.

For each of these segments, the regression was used to estimate the TN concentrations that correspond to the chlorophyll *a* thresholds identified in Section III. This resulted in an estimated TN concentration for each season. The annual mean of the seasonally-specific TN concentrations was calculated by weighting for the number of months in each season. This weighted annual mean TN concentration is that TN concentration that corresponds to the chlorophyll *a* threshold concentration, and therefore is the proposed numeric nutrient criterion for each segment.

Figures VII-1 – VII-3 present comparisons of the proposed numeric criteria for Roberts Bay, Little Sarasota Bay, and Blackburn Bay, expressed as an annual geometric mean TN concentration, to the recent ambient geometric mean TN concentrations measured in each segment. The geometric means are used to achieve consistency with the approach used by EPA in the proposed freshwater numeric nutrient criteria.

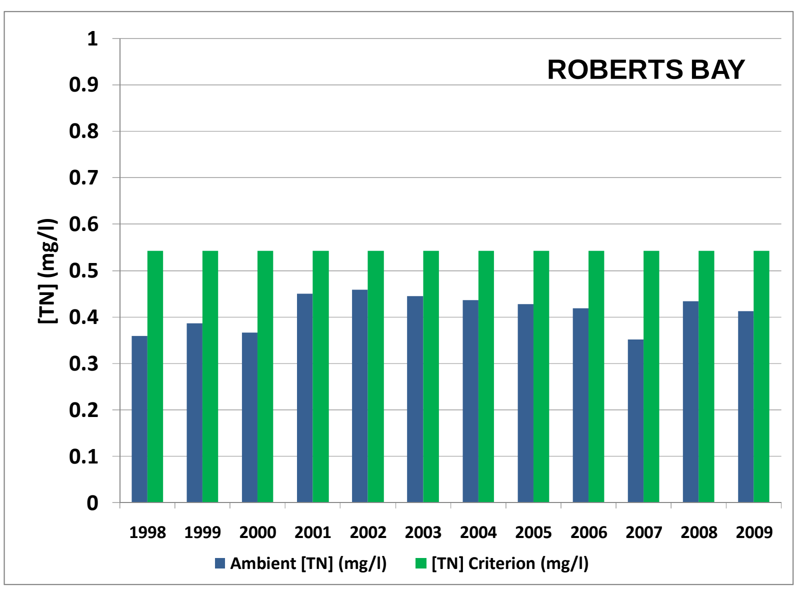

Figure VII-1. Comparison of the proposed TN criterion to observed TN concentrations (expressed as geometric means) in Roberts Bay.

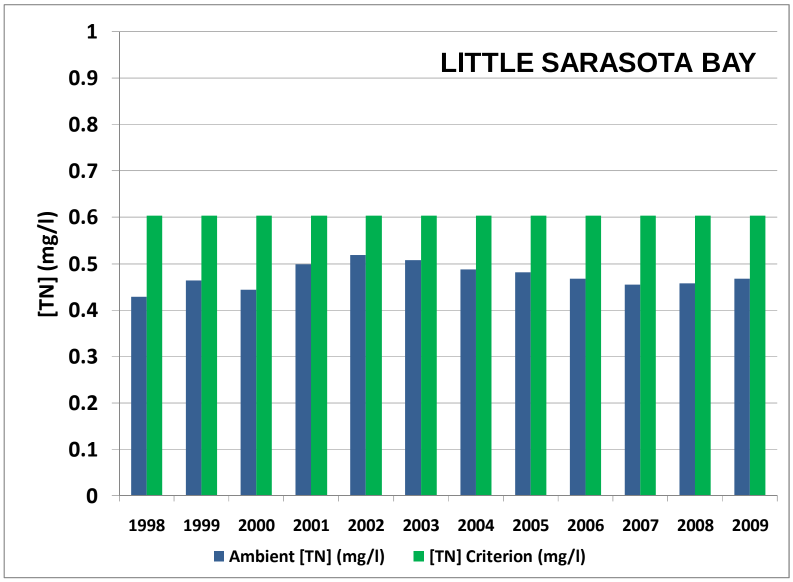

Figure VII-2. Comparison of the proposed TN criterion to observed TN concentrations (expressed as geometric means) in Little Sarasota Bay.

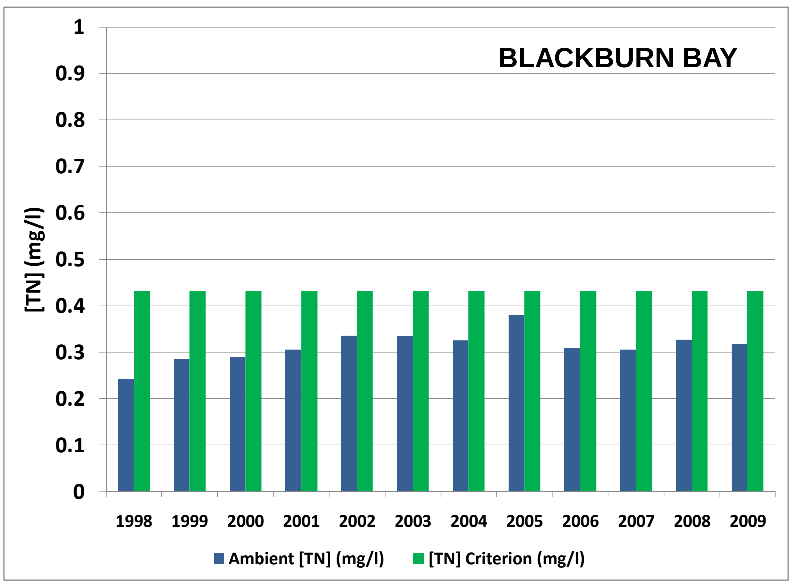

Figure VII-3. Comparison of the proposed TN criterion to observed TN concentrations (expressed as geometric means) in Blackburn Bay.

VII-2 Sarasota Bay

As shown in Section VI, the relationship between chlorophyll a concentrations and nutrients in Sarasota were more complex than those observed in Roberts Bay, Little Sarasota Bay, or Blackburn Bay. This resulted from the spatial variability within Sarasota Bay and the influence of color on the relationship between chlorophyll a concentrations and TN concentrations in that segment. Therefore, application of the regression derived for Sarasota Bay to estimate the proposed numeric nutrient criterion is more complex. Since color influences the relationship between chlorophyll a concentrations and TN concentrations, the TN concentration that corresponds to the threshold chlorophyll a concentrations for Sarasota Bay will vary from year-to-year depending upon the ambient color observed in a year.

To estimate the TN concentration that corresponds to the threshold chlorophyll a concentrations for Sarasota Bay, the mean color for each region and season was calculated for a given year. This mean color was used to calculate the TN concentration for each region and season. The annual mean of these TN concentrations was calculated by weighting for the number of months in each season, as was done for Roberts Bay, Little Sarasota Bay, or Blackburn Bay. This weighted annual mean TN concentration is that TN concentration that corresponds to the chlorophyll *a* threshold concentration for a given year. These mean annual TN concentrations are the proposed numeric nutrient criterion for Sarasota Bay.

Figures VII-4 presents a comparison of the proposed numeric criteria for Sarasota Bay expressed as an annual mean TN concentration, to the recent ambient geometric mean TN concentrations measured in Sarasota Bay.

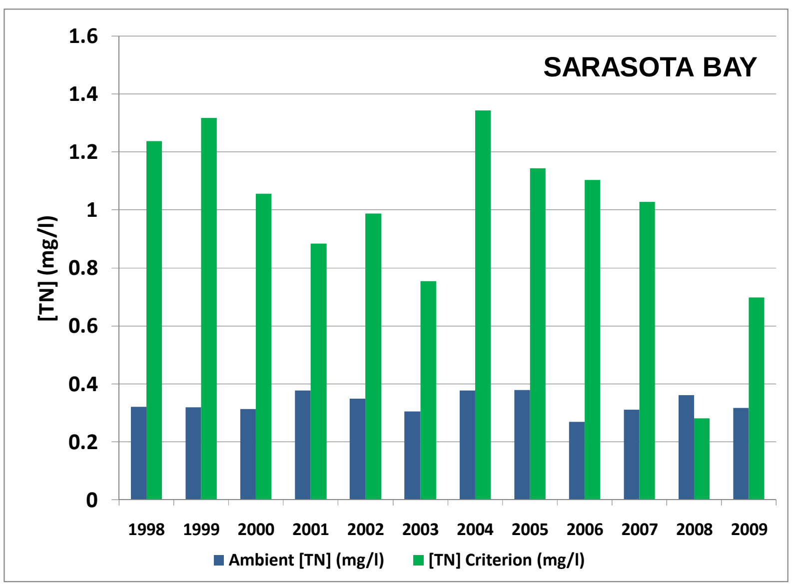

Figure VII-4. Comparison of the proposed TN criterion to observed TN concentrations (expressed as geometric means) in Sarasota Bay.

VII-3 Palma Sola Bay

No significant quantitative relationship was found between chlorophyll a concentrations and either the TN or TP concentrations or loadings in Palma Sola Bay. Therefore, the approach to derive a numeric nutrient criterion for Palma Sola Bay will necessarily differ from that used for the other SBEP segments.

The SBEP water quality subcommittee of the TAC considered three potential candidate methods for estimating the TN criterion for Palma Sola Bay:

- The logistic regression results suggested wet and dry season TN concentrations of 0.57 mg/l and 1.31 mg/l, respectively. The annual mean, weighting for season, gives a result of 1.06 mg/l as a candidate TN criterion. Note that the logistic model fit was weak – $r^2 = 0.25$.

- The changepoint analysis identified a breakpoint in the TN concentrations of approximately 0.76 mg/l.

- Following the logic used by the subcommittee to establish chlorophyll a concentrations for the SBEP segments

    - the mean TN concentration for the 2001-2005 period was 0.74 mg/l
    - the standard deviation of the annual mean TN concentrations for the period of record was 0.19 mg/l
    - therefore, this method results in a candidate TN criterion of 0.93 mg/l.

All three potential candidate methods give relatively similar results.

The subcommittee recommended the third option – i.e., that based on the 2001-2005 ambient TN data. The full TAC concurred with the subcommittee's recommendation on 23 July 2010.

Figures VII-5 presents a comparison of the proposed numeric criteria for Palma Sola Bay expressed as an annual mean TN concentration, to the recent ambient geometric mean TN concentrations measured in Palma Sola Bay.

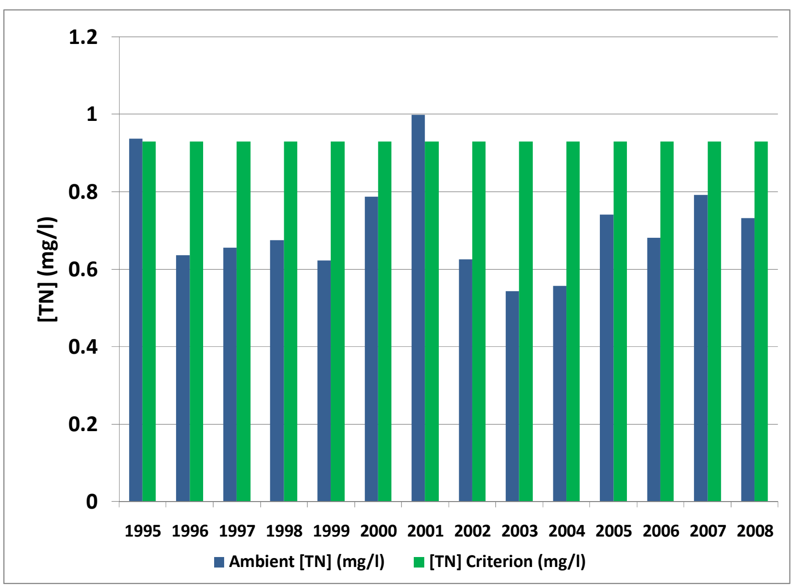

Figure VII-5. Comparison of the proposed TN criterion to observed TN concentrations (expressed as geometric means) in Palma Sola Bay.

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Appendix 1.
Sarasota Bay Estuary Program
Comments on EPA Proposed Freshwater
Numeric Nutrient Criteria

Sarasota Bay Estuary Program (SBEP) response to the EPA's Proposed Water Quality Standards for the State of Florida's Lakes and Flowing Waters and Methodology for Deriving Downstream Protection Values for Sarasota Bay, FL

These comments are provided for EPA's review and use in developing the Sarasota Bay Estuary Program's (SBEP) numeric nutrient criteria for Sarasota Bay. Additional comments and recommendations will be provided through the Florida Department of Environmental Protection (FDEP) in June 2010.

Background

Sarasota Bay is a fifty mile long coastal lagoon on the southwest coast of Florida (Figure 1). It is comprised of one large bay segment (Big Sarasota Bay) and several smaller embayments including Palma Sola Bay in the north and a series of three contiguous embayments (Roberts Bay, Little Sarasota Bay, and Blackburn Bay) to the south. The Bay has four inlets or passes (Venice Inlet, Big Sarasota Pass, New Pass and Longboat Pass). The SBEP area is bounded to the north by Anna Maria Sound, which opens into Tampa Bay and to the south by Venice Inlet. There are numerous, small tidal creeks that enter the bay along the eastern shoreline, ranging in size from the largest (Phillippi Creek: drainage area of 36,417 acres) to the smallest (Palma Sola Creek: drainage area of 900 acres). The watershed is highly developed and consists of agricultural, residential, commercial and light industrial land uses.

Circulation is primarily driven by tidal exchange with the Gulf of Mexico. Big Sarasota Bay circulation is forced by the tides at Anna Maria Sound, Longboat Pass, New Pass and Big Pass. Tidal circulation in Little Sarasota Bay is forced by tides at Venice Inlet and the Intracoastal Waterway running through the middle of the bay. The closing of Midnight Pass in Little Sarasota Bay in 1983 permanently altered the circulation in the three lower embayments.

History of Nutrient Management in Sarasota Bay

Sarasota Bay was named an "Estuary of National Significance" in the Water Quality Act of 1987 and was formally designated as a National Estuary Program (NEP) in 1989. The Program's Comprehensive Conservation and Management Plan (CCMP), which provides specific actions to be implemented by the community to reduce pollutants (including nutrients) and restore lost habitat, was signed in 1995. In 2004, the SBEP became an independent State Agency with authority to oversee water quality management and protection.

Sarasota Bay is a nitrogen limited system (Lowrey, 1992; FDEP, 2005). Ratios between total nitrogen (TN) and total phosphorus (TP) in Sarasota Bay are typically well below 10 (i.e., Lowrey, 1992), which is consistent with presumed nitrogen limitation. Roberts Bay (a segment of Sarasota Bay- see Figure 1) had a median TN:TP ratio of 2.4, which also indicates strong nitrogen limitation of phytoplankton growth (FDEP, 2005).

From its inception, the SBEP recognized that wastewater and stormwater were the primary sources of anthropogenic nitrogen input (the other source being atmospheric deposition) entering the bay. As such, wastewater treatment and reclamation and stormwater treatment and prevention became the two most important action items in the CCMP with the goal of reducing nitrogen inputs to the bay by 48%. Each of these action items contained a number of specific elements designed to reach this nutrient reduction goal (CCMP, 1995).

Figure 1. Map of Sarasota Bay, its watershed and tributaries.

Through the cooperation of SBEP partners - local municipal and county governments, the Southwest Florida Water Management District (SWFWMD), the Florida Department of Environmental Protection (DEP) and the Environmental Protection Agency (EPA) - in implementing these action items, we have documented significant improvements in water quality and the resultant recovery of seagrass throughout the estuary over the past twenty years. The highlights of these improvements and recovery are:

1. Nitrogen loads- using the EPA approved Watershed Management Model- to Sarasota Bay have been reduced by 46% since 1988 (Tomasko *et al*., 2005). *Author's note: recent estimates of TN load reduction using WMM approximate 64% (Tomasko et al, 2009, Estuarine Research and Coastal Federation Conference, Portland Oregon) - this information has not been published.*

2. As of 2008, seagrass acreage is 24% higher than 1950 acreage. (Figure 2).

3. Total seagrass acreage (2008) has increased 46% since 1988 (Figure 2).

4. Continuous seagrass beds have increased 180% since 1988 (Figure 2).

5. Sarasota Bay is meeting designated uses with respect to nutrients. Bay scallops returned to Sarasota Bay seagrass beds in 2008. Fisheries data show high abundances of juvenile fish within seagrass beds in all bay segments (Serviss and Sauers, 2003). These findings support the attainment of full aquatic life support and use.

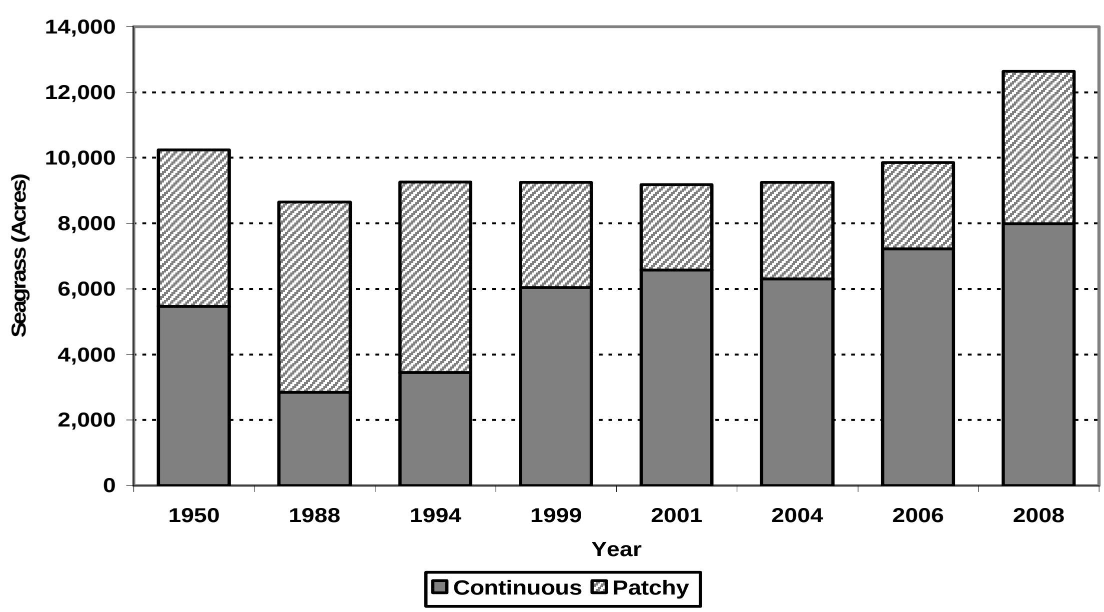

Figure 2. Total seagrass cover (in acres) for Sarasota Bay. (SWFWMD, 2008).

Nitrogen Reduction Measures

Declines in total nitrogen (TN) concentrations and loads are a result of extensive capital improvement projects undertaken by our partners ($375 million). Pollution reduction efforts have focused on three major tributaries and coastal areas: Phillippi Creek; Whitaker Bayou, and Manatee County (coastal wastewater seepage from agriculture reuse and Bowlees Creek).

Phillippi Creek- South Bay

Phillippi Creek drains 38% of the Sarasota Bay watershed. Annual TN concentrations averaged 3.12 mg/l from 1970 through 1988 (Figure 3). Nitrogen loading from Phillippi Creek has decreased approximately 60% since that time. These nitrogen load reductions are the result of three major infrastructure programs: 1) the construction of a major watershed stormwater treatment facility, 2) construction of an AWWTP, allowing for the removal of nineteen ineffective WWTPs, and 3) a major septic tank replacement program within the watershed.

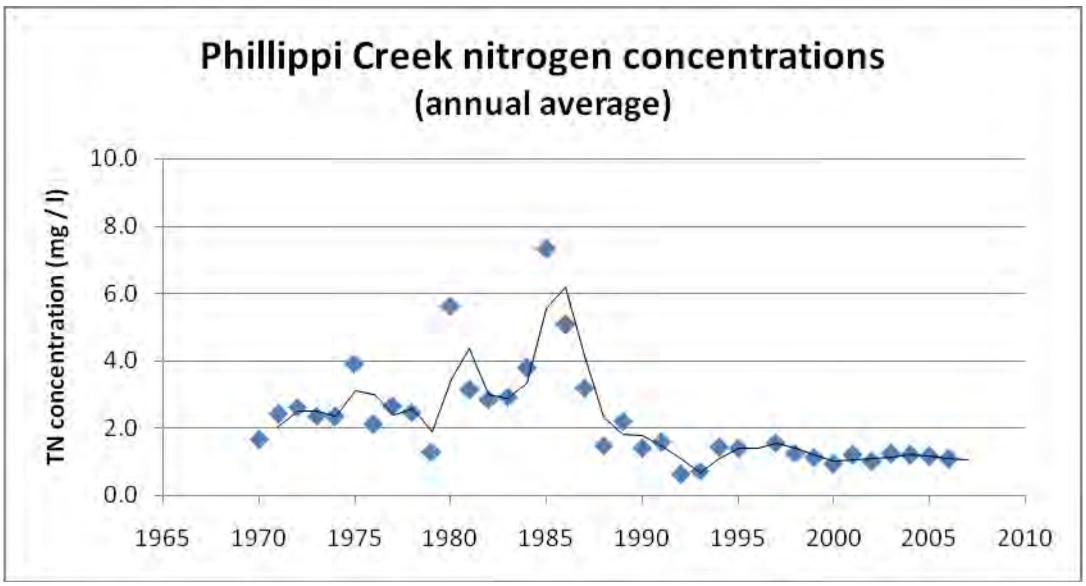

Figure 3. Nitrogen concentrations in Phillippi Creek, the main tributary to Sarasota Bay. (PBSJ, 2009).

Whitaker Bayou- Central Bay

Whitaker Bayou, a tributary which was once the largest anthropogenic contributor of nitrogen to Sarasota Bay (Figure 4), has seen a ten-fold reduction in nitrogen loads due to the following improvements: 1) upgrading the City of Sarasota wastewater treatment plant to AWT standards, 2) expansion of the City's reclaimed water system, 3) converting remaining areas of Whitaker Bayou from septic systems to central sewer, and 4) consolidation of the remaning WWTPs in the watershed. In 2016, the City is expected to cease discharging wastewater into Whitaker Bayou.

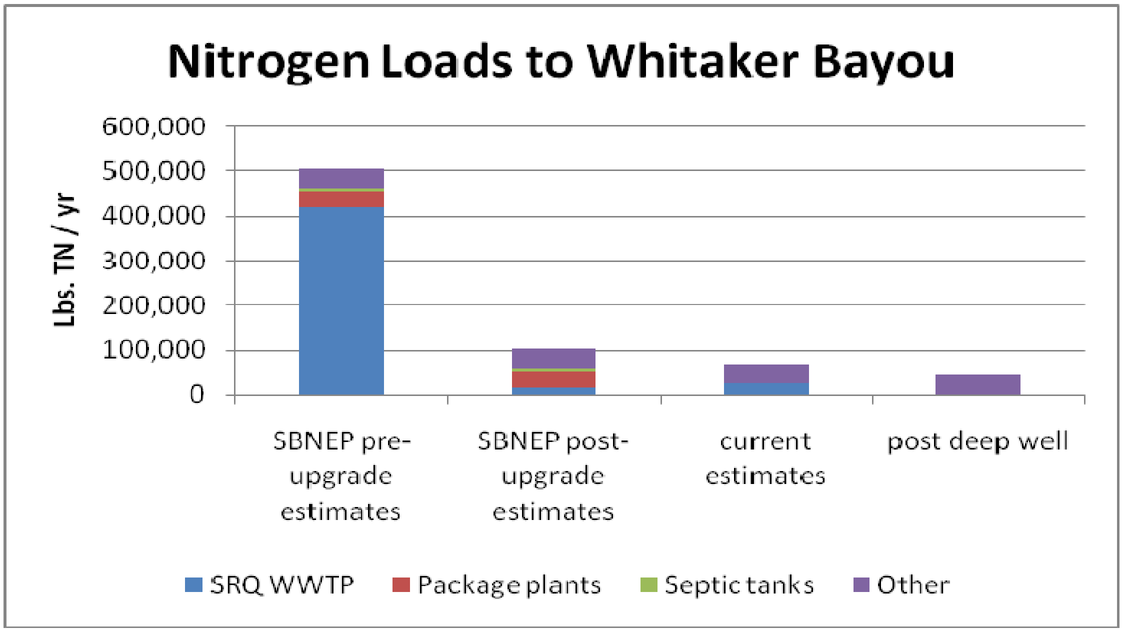

Figure 4. Nitrogen loads to Whitaker Bayou. (Tomasko *et al*., 2005).

Manatee County- North Bay

Manatee County's southwest regional WWTP (15 mgd) in north Sarasota Bay no longer discharges to the surface waters of the state. This was accomplished through 1) construction of a tail water recovery system in 1980, 2) permitting deep well injection of wastewater in 1991, and 3) wastewater reuse. No septic tanks or package plants remain in service in the Sarasota Bay watershed portion of Manatee County and there is no direct discharge of wastewater in the northern Bay.

The Bowlees Creek watershed has seen significant water quality improvements as a result of several wastewater and stormwater treatment projects. First, Lake Brennan was expanded into a regional stormwater treatment system. Second, the stormwater drainage system at the Sarasota/Bradenton Airport was reconstructed utilizing modern water quality treatment technologies. Finally, sewer systems were replaced or upgraded in the lower portions of the watershed.

Educational Programs

The SBEP and partners have developed broad scale adult and in-school educational programs to promote pollution prevention and stewardship including: Florida Friendly Landscaping, Neighborhood Environmental Stewardship Teams and Water Wise initiatives. Local water use has been reduced to 80 gallons/per person/day.

Florida Yards are required in all new development in approximately 80% of the watershed. Substantial public relations initiatives have been aimed at reducing water consumption and pollution abatement.

Adoption of Local Fertilizer Ordinances

Finally, Sarasota County and the Cities of Sarasota and Longboat Key recently adopted fertilizer ordinances which prohibit, among other things, fertilizer application during the summer (wet) months. This ordinance covers 80% of the Sarasota Bay watershed.

Numeric Nutrient Criteria Setting in Sarasota Bay: Role of the Sarasota Bay Estuary Program

For the past several years, the SBEP has been working with its partners to establish local water quality targets for the maintenance and restoration of seagrasses. To date, we have held a number of technical advisory committee meetings specifically to address this issue not only as a response to the impending criteria being developed by the EPA, but also for our partners and stakeholders as a framework to better understand the local response of seagrasses to nutrient loads so that we may better manage our estuary and its watershed. The specific role of the SBEP is to facilitate information exchange, modeling and technical data in support of EPA's rule making process. The SBEP supports third party review.

We recognize the timeliness for completing this task as it relates to the ongoing development of numeric nutrient criteria for estuarine and coastal waters in Florida by the EPA and FDEP. Their schedule calls for draft criteria to be established by January 2011. We have set an aggressive timetable in order to provide preliminary results by early June, 2010, for consideration by the EPA as site-specific criteria based on the best local data and knowledge.

The basic strategy for establishing water quality and loading criteria follows that utilized over the past 13 years by the Tampa Bay Estuary Program (TBEP) and the Nitrogen Management Consortium. The paradigm depends upon knowledge of the quantitative relationships between light attenuation and ambient water quality (e.g., chlorophyll *a*) and between chlorophyll concentrations and nutrient loading. Empirical modeling techniques are being used to identify these quantitative relationships.

The objectives of the project for setting nutrient criteria are:

- To develop a database of nutrient loads and concentrations for each major bay segment for the period 1989-2008 and for a future scenario and updating load estimates based on a new watershed loading model.
- To define the quantitative relationships between chlorophyll *a* concentrations and light attenuation for each bay segment;
- To estimate the chlorophyll thresholds to meet the light attenuation and seagrass targets for each bay segment;
- To define the quantitative relationships between nutrient loading and chlorophyll *a* concentrations for each bay segment; and

- To estimate the numeric nutrient criteria, i.e., the nutrient loading consistent with the chlorophyll *a* thresholds, for each bay segment. These estimates will incorporate additional hydrological factors, including circulation and residence time, and water clarity parameters.

Our initial efforts have resulted in establishing seagrass targets for each of the main bay segments (Table 1). Seagrass targets were based on either historical (1950) coverage or the average of the two most recent surveys (2004 - 2006). These targets will be re-evaluated every five years. This process was vetted at the technical and management levels of the program; in May 2009, the SBEP policy board formally approved and adopted the seagrass acreages as restoration goals.

The SBEP has also established and approved interim chlorophyll *a* targets (also Table 1). The period 2001 – 2005 was selected as the performance window to include multiyear conditions antecedent to the most recent seagrass surveys. This time period also included years that had a wide range in annual rainfall. Since the average seagrass coverage from 2004 – 2006 for all bay segments are at or above 1950 coverage, water quality conditions from our performance window must be sufficient for seagrass to meet the designated target acreages.

Historic chlorophyll thresholds (FAC 62-303) were established in 2004 by FDEP to evaluate nutrient impairment by major bay segment as identified in the EPA 1998 303d report. FDEP evaluated impairment in 2005, 2007 and 2009 using these historic chlorophyll thresholds. **All Sarasota Bay segments have been de-listed by the FDEP for nutrients (chlorophyll *a*).**

Table 1. Sarasota Bay Seagrass and Chlorophyll *a* Targets by Bay Segment. Chlorophyll *a* Values Represent the Average of the Annual Means for the Period 2001 – 2005.

Sarasota Bay Segment	**Seagrass Target (Acres)**	**Chlorophyll *a* Target (µg/L)**
Palma Sola	1,031	8.3
Sarasota Bay	7,269	5.0
Roberts Bay	348	7.6
Little Sarasota Bay	702	7.2
Blackburn Bay	447	5.6
TOTAL	9,997	

<u>SBEP Concerns with the Proposed Rule</u>

The SBEP has concerns regarding the draft rule for numeric nutrient criteria for lakes and streams within the Sarasota Bay watershed. This rule is based on the initial premise that

Sarasota Bay loads are above its assimilative capacity. However, Sarasota Bay is below the chlorophyll thresholds in each of its bay segments and no segment has been deemed "impaired" for nutrients by the FDEP. Additionally, seagrass acreages are at or above their targets.

The SBEP approach to establishing the approved loading targets is similar to the approach used in Tampa Bay (Greening and Janicki, 2006; Janicki and Wade, 1996) and follows EPA's technical guidance which states that quantifying stressor-response relationships is the preferred approach in establishing numeric nutrient criteria. Specifically, the SBEP will be defining these quantitative relationships between nutrient loads and chlorophyll levels in all Sarasota Bay segments. There is considerable evidence to demonstrate that existing loads to Sarasota Bay are providing for the full aquatic life protection and support for all designated uses related to nutrients in the estuary.

There are other concerns that deal specifically with the application of the USGS Spatially Referenced Regression on Watershed Attributes (SPARROW) model for the southeastern US. This model was used to calculate both existing and baseline loads for Sarasota Bay that were used to estimate protective loads for Sarasota Bay. While the SPARROW model may work well for its expressed purpose, i.e., to examine landscape characteristics that influence delivery of nitrogen from sources within the watersheds in the southeastern US, its application to the Sarasota Bay watershed is questionable. The Sarasota Bay load estimates that are being developed are driven by <u>local</u> data sources (particularly point sources, atmospheric deposition, and fertilizer shipping), while the SPARROW coefficients are based on regional (southeastern US) data. Thus, the scaling of SPARROW to such a small basin as Sarasota Bay needs to be validated.

Estimates using SPARROW do not fully reflect the time-varying loads to an estuary and its resulting response to those loads. Rather, the downstream load is based on a load normalized to the hydrologic conditions experienced in 2002. The proposed DPV for TN (.54 mg/l) is less than the natural concentrations cited in the Lemon Bay model by EPA.

Finally, the SBEP has concerns with the methodology for proposed downstream protection value (DPV) for estuarine protection for Sarasota Bay. The proposed DPV is inappropriate based on the fact that current nutrient loadings to the bay <u>*are not*</u> above their assimilative capacity based on recent trends and current acreages of seagrass, the primary response variable. The proposed TN concentration- 0.54 mg/L- for downstream protection is less than the concentration from natural areas derived by the EPA using the Lemon Bay Watershed Model. The SBEP will propose an alternative quantitative methodology based on scientifically defensible approaches, to derive and quantify the protective load to Sarasota Bay and its tributary streams.

SBEP Recommendations

In conclusion, we have summarized the site-specific work that has been completed for Sarasota Bay, including the establishment of seagrass and chlorophyll *a* targets, the ongoing development of quantitative relationships among seagrasses, light, chlorophyll and nutrients, and the development of a new locally based nutrient loading model. This process has given us a comprehensive understanding of the relationships between nutrient loading and water quality responses in the Bay.

Specifically, we recommend that the **EPA consider adopting the downstream protective loads that will be established by the SBEP for the estuarine and coastal waters rule. The SBEP will present draft criteria to the FDEP and EPA by June, 2010.**

Thank you for your advanced consideration of this information regarding numeric nutrient criteria developed by the SBEP in the water quality standards rule making process.

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Appendix 2.
Water Quality Sampling Programs

Ambient Water Quality Sampling Programs in the SBEP Area

Both Sarasota County and Manatee County collect water quality data within the SBEP area. The two monitoring programs are briefly described below.

This Sarasota County ambient water quality monitoring program was initiated in 1995. Sarasota Bay was divided into 12 segments, each with multiple randomly chosen sampling sites. The Sarasota County Ambient Water Quality Monitoring Network segmentation scheme is shown in Figure 1. All program sample locations are sampled once every year. Each site is re-sampled every year in the same month as the preceding years. This randomized, stratified monitoring program characterizes overall estuarine health by describing entire bay segments rather than isolated locations in each water body.

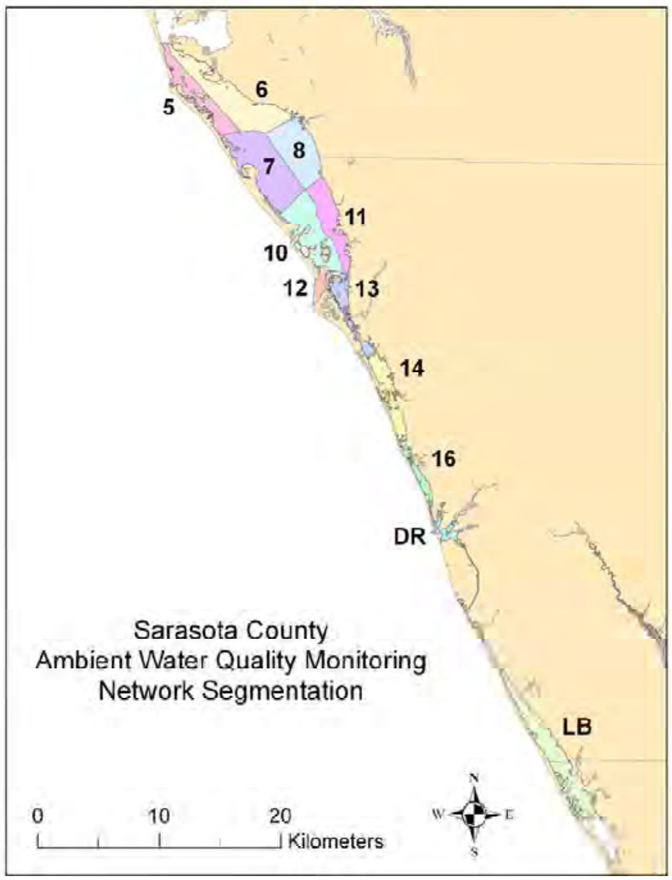


Figure 1. Sarasota County Ambient Water Quality Segments.

Aqueous samples are taken from mid-depth from the entire coastal estuarine system in Sarasota County, including Sarasota Bay, Roberts Bay (Sarasota), Little Sarasota Bay, Blackburn Bay, Lyons Bay, Dona Bay, Roberts Bay (Venice), Lemon Bay and the estuarine portion of the Myakka River.

Dataloggers are deployed at the same stations defined by the sampling program. Datalogger site selection produces a balanced distribution of data from throughout the study area. Two dataloggers are deployed monthly to measure temperature, salinity, dissolved oxygen concentration, percent oxygen concentration, pH, and specific conductance at 15 minute intervals for at least one complete 24-hour period. Field meter readings are taken at top, middle and bottom depths.

The Manatee County Environmental Management Department (EMD) ambient water quality monitoring program for Manatee County's estuarine waters is the Regional Ambient Monitoring Program. RAMP began in November, 1995 and is the successor to EMD's old AWP station network that had operated since 1988. RAMP evolved from a series of Tampa Bay Estuary Program sponsored workshops on the methods, variables and field techniques of estuarine water quality monitoring to improve data compatibility among the water quality monitoring programs of the different jurisdictions. All RAMP implementations use the same sampling design and include the same set of core measurements. The RAMP concept has been endorsed by the Tampa Bay, Sarasota Bay, and Charlotte Harbor National Estuary Programs.

The Manatee County RAMP program divides the County's estuarine area into two segments of 24, 3.56km^2 hexagonal sampling areas each. The south segment includes Palma Sola Bay, and Sarasota Bay north of the county line, both of which are within the SBEP area.

Sampling points were randomly located within each hexagon at the start of the program. A hexagonal sampling area was included in the program if the randomly generated sampling point was at least 4ft deep by the nautical chart and verified during program reconnaissance. The statistical basis of the RAMP design allows for the addition of pre-selected stations if there was no overriding physical reason for the station's geographic placement at a particular point. One-third of the sampling points in each segment, eight points, are sampled monthly. All sampling points in a segment are visited within each calendar quarter.

In bay segments where both Sarasota and Manatee counties sample, averaged data from both programs are presented. Also, based on discussions with representatives of the sampling programs, it was decided to exclude data from segment 12 from the analysis. Segment 12 is in Big Sarasota Pass and likely reflects Gulf of Mexico water quality characteristics as much or more so than bay water characteristics, especially during flood tide sampling events.

Maps of the sampling locations in Sarasota Bay are provided below in Figure 2. It should be noted that the rotating sampling schedule for Sarasota County's sites are regular (monthly), and are shown for each month. Manatee County's sampling rotation is not as regular so symbols representing each sampling grid cell are illustrated.

Figure 2a. Sarasota Bay Sampling Sites - January

Figure 2c. Sarasota Bay Sampling Sites – March.

Figure 2b. Sarasota Bay Sampling Sites - February

Figure 2d. Sarasota Bay Sampling Sites – April.

Figure 2e. Sarasota Bay Sampling Sites - May

Figure 2f. Sarasota Bay Sampling Sites - June

Figure 2g. Sarasota Bay Sampling Sites – July.

Figure 2h. Sarasota Bay Sampling Sites - August

Figure 2i. Sarasota Bay sampling sites – September.

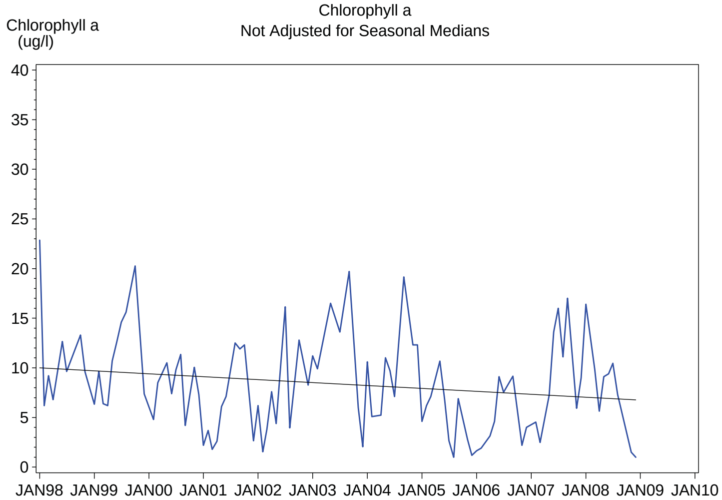
Figure 2j. Sarasota Bay sampling sites – October.

Figure 2k. Sarasota Bay sampling sites - November

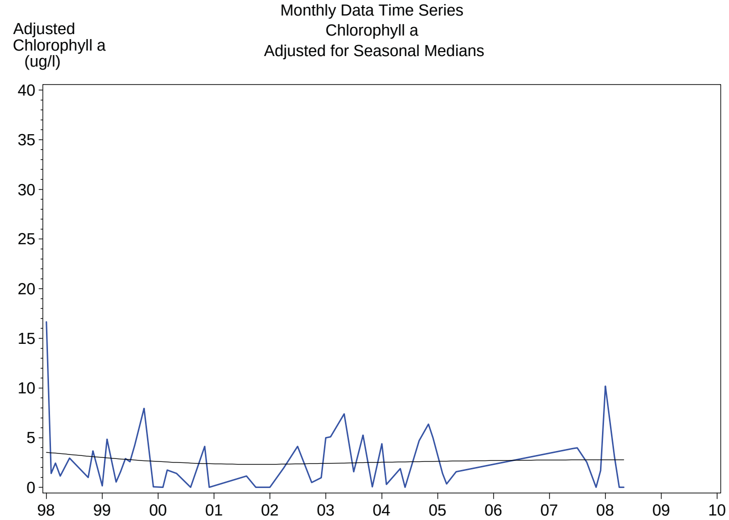
Figure 2l. Sarasota Bay sampling sites – December.

Appendix 3.
Water Quality Trend Tests

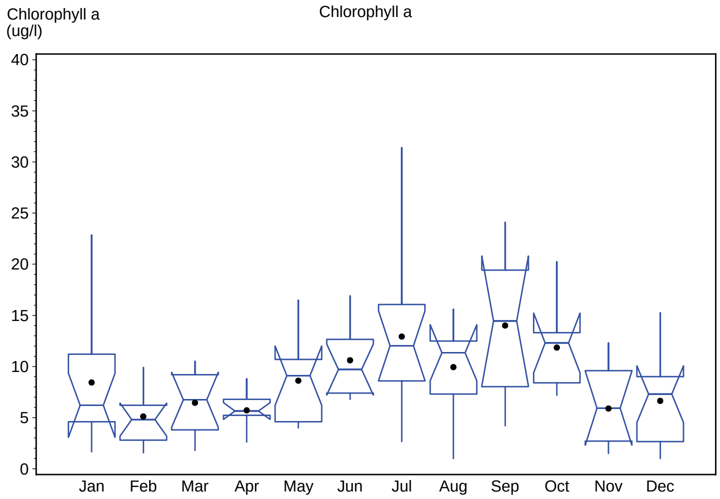
Palma Sola Bay Trends Appendix - Display 1
Monthly Data Time Series
Chlorophyll a
Not Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 2
Monthly Data Time Series
Chlorophyll a
Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 3
Seasonal Univariate Statistics
Chlorophyll a



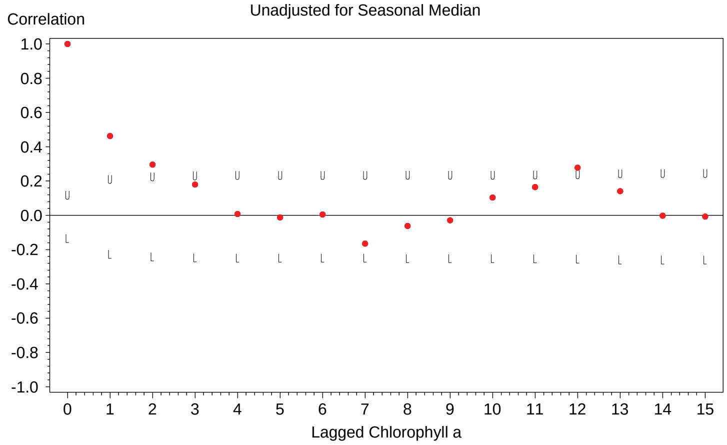
Palma Sola Bay Trends Appendix - Display 4
Autocorrelation Statistics for Chlorophyll a

Unadjusted for Seasonal Medians

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.463	0.109	0.218	-0.218
2	0.296	0.117	0.233	-0.233
3	0.180	0.120	0.239	-0.239
4	0.008	0.121	0.241	-0.241
5	-0.012	0.121	0.241	-0.241
6	0.005	0.121	0.241	-0.241
7	-0.165	0.121	0.241	-0.241
8	-0.062	0.122	0.243	-0.243
9	-0.029	0.122	0.243	-0.243
10	0.104	0.122	0.243	-0.243
11	0.165	0.122	0.244	-0.244
12	0.278	0.123	0.246	-0.246
13	0.141	0.125	0.251	-0.251
14	-0.002	0.126	0.252	-0.252
15	-0.007	0.126	0.252	-0.252

Palma Sola Bay Trends Appendix - Display 5
Correlogram for Chlorophyll a

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 6
Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.207	.004	0.079	-0.3

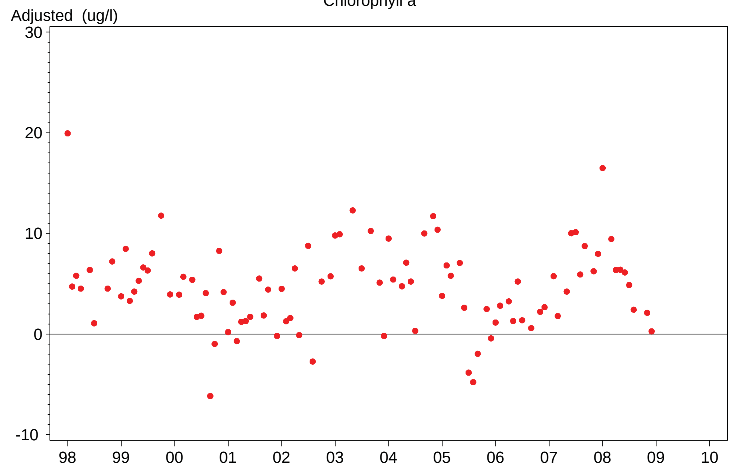
Palma Sola Bay Trends Appendix - Display 7

Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.20671	.00430537	0.079404	-0.3

Palma Sola Bay Trends Appendix - Display 8
Time Series Plot of Data Adjusted for Season and Detrended
Chlorophyll a



Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 9

Autocorrelation Statistics for Chlorophyll a

Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.302	0.109	0.218	-0.218
2	0.185	0.112	0.225	-0.225
3	0.195	0.114	0.227	-0.227
4	0.100	0.115	0.230	-0.230
5	0.177	0.115	0.231	-0.231
6	0.148	0.116	0.233	-0.233
7	-0.016	0.117	0.234	-0.234
8	0.088	0.117	0.234	-0.234
9	-0.046	0.117	0.235	-0.235
10	-0.036	0.117	0.235	-0.235
11	0.004	0.117	0.235	-0.235
12	-0.029	0.117	0.235	-0.235
13	-0.064	0.117	0.235	-0.235

Palma Sola Bay Trends Appendix - Display 9

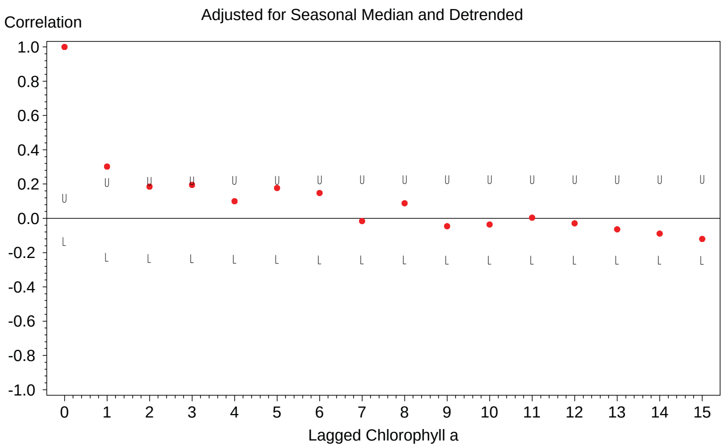
Autocorrelation Statistics for Chlorophyll a

X

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
14	-0.089	0.118	0.235	-0.235
15	-0.120	0.118	0.236	-0.236

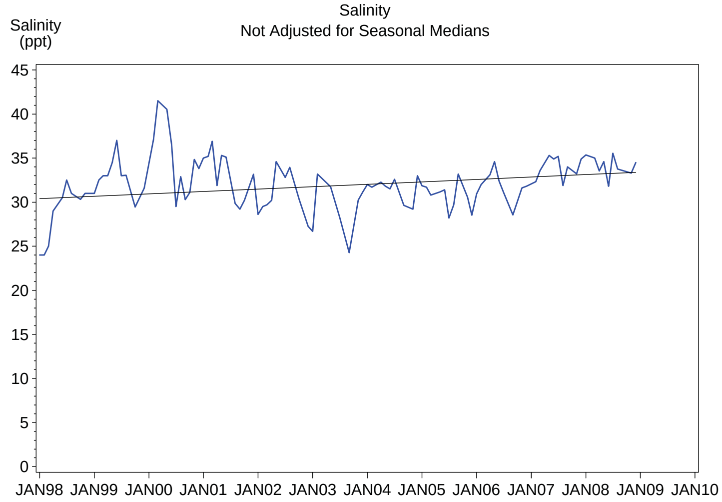
Palma Sola Bay Trends Appendix - Display 10
Correlogram for Chlorophyll a

Adjusted for Seasonal Median and Detrended

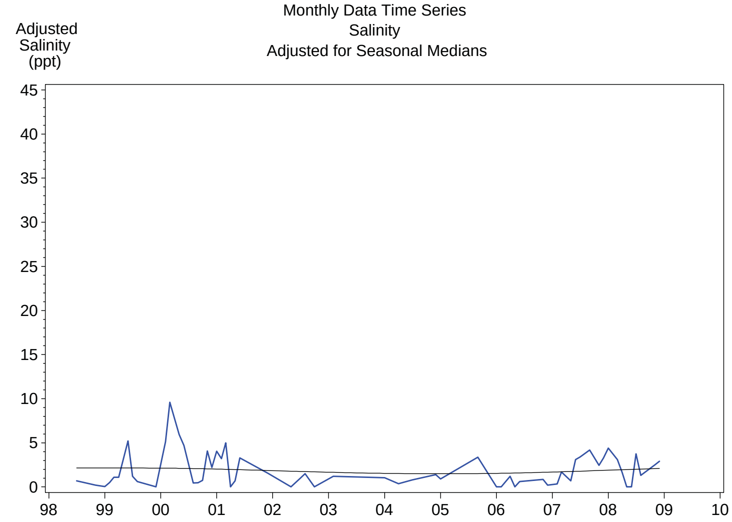


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

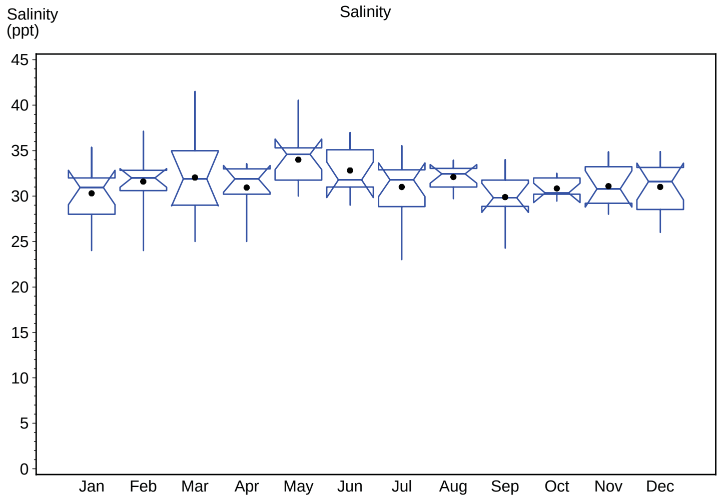
Palma Sola Bay Trends Appendix - Display 11
Monthly Data Time Series
Salinity
Not Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 12
Monthly Data Time Series
Salinity
Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 13
Seasonal Univariate Statistics
Salinity



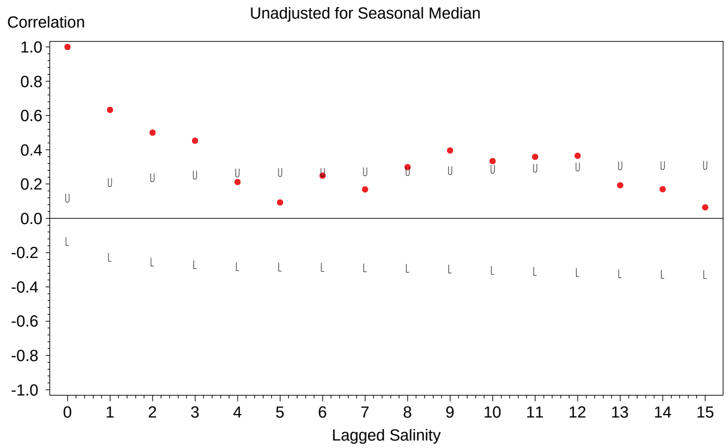
Palma Sola Bay Trends Appendix - Display 14
Autocorrelation Statistics for Salinity

Unadjusted for Seasonal Medians

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.633	0.109	0.218	-0.218
2	0.500	0.123	0.246	-0.246
3	0.453	0.131	0.261	-0.261
4	0.212	0.137	0.273	-0.273
5	0.093	0.138	0.276	-0.276
6	0.249	0.138	0.277	-0.277
7	0.169	0.140	0.280	-0.280
8	0.299	0.141	0.282	-0.282
9	0.396	0.143	0.287	-0.287
10	0.334	0.148	0.295	-0.295
11	0.359	0.151	0.301	-0.301
12	0.365	0.154	0.308	-0.308
13	0.193	0.157	0.315	-0.315
14	0.170	0.158	0.317	-0.317
15	0.064	0.159	0.318	-0.318

Palma Sola Bay Trends Appendix - Display 15
Correlogram for Salinity

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 16
Seasonal Kendall Tau Trend Test Statistics
Salinity

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.276	0	0.052	0.267

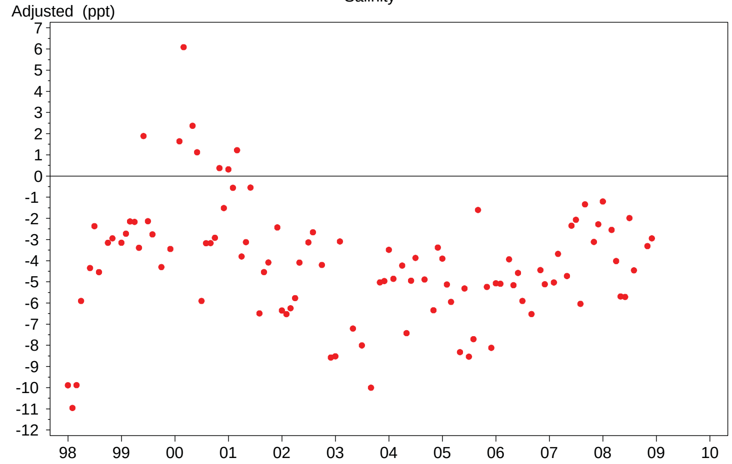
Palma Sola Bay Trends Appendix - Display 17

Seasonal Kendall Tau Trend Test Statistics
Salinity

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.27563	.000101447	0.051933	0.26667

Palma Sola Bay Trends Appendix - Display 18
Time Series Plot of Data Adjusted for Season and Detrended
Salinity



Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 19

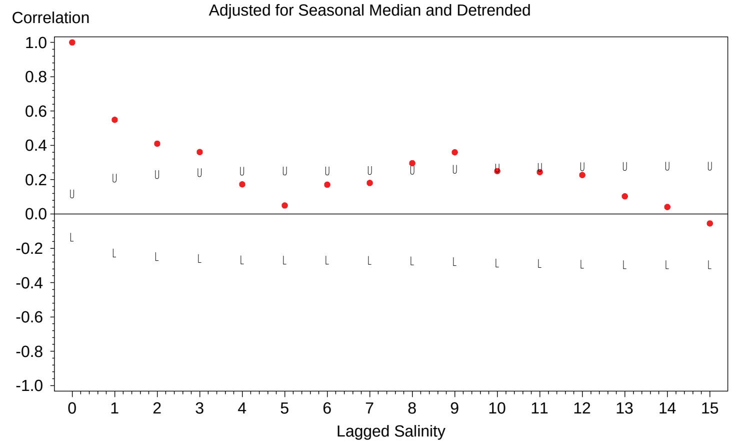
Autocorrelation Statistics for Salinity

Adjusted for Seasonal Median and Detrended

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.549	0.109	0.218	-0.218
2	0.410	0.120	0.239	-0.239
3	0.361	0.125	0.250	-0.250
4	0.173	0.129	0.258	-0.258
5	0.050	0.130	0.260	-0.260
6	0.171	0.130	0.260	-0.260
7	0.181	0.131	0.262	-0.262
8	0.296	0.132	0.264	-0.264
9	0.360	0.135	0.269	-0.269
10	0.250	0.138	0.277	-0.277
11	0.244	0.140	0.280	-0.280
12	0.227	0.142	0.284	-0.284
13	0.103	0.143	0.286	-0.286
14	0.041	0.144	0.287	-0.287
15	-0.055	0.144	0.287	-0.287

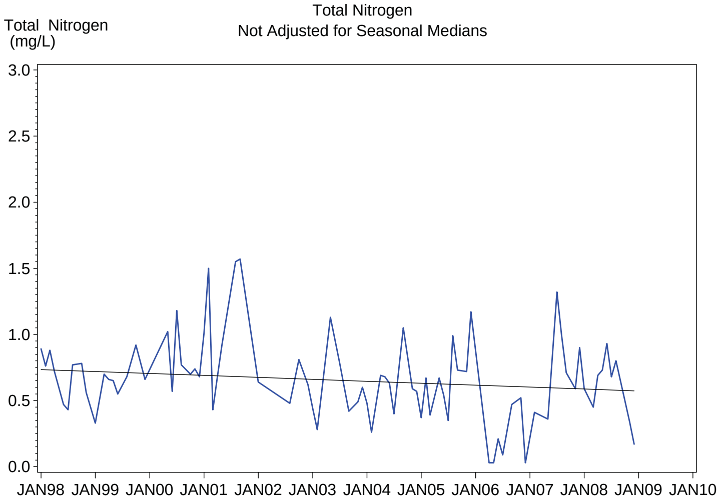
Palma Sola Bay Trends Appendix - Display 20
Correlogram for Salinity

Adjusted for Seasonal Median and Detrended

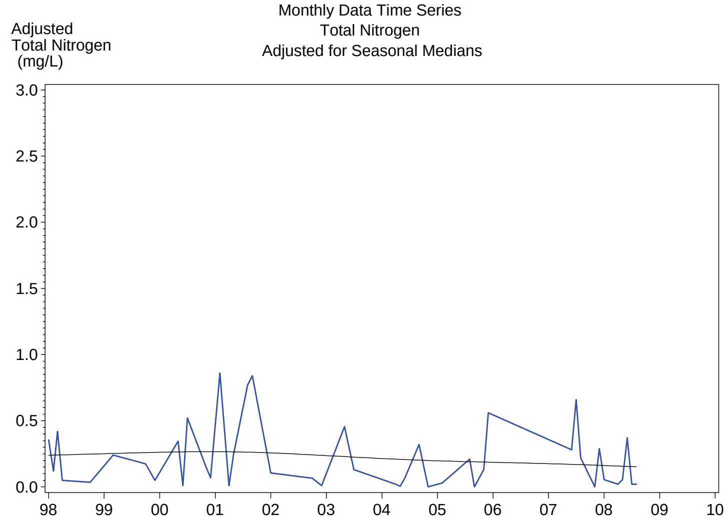


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

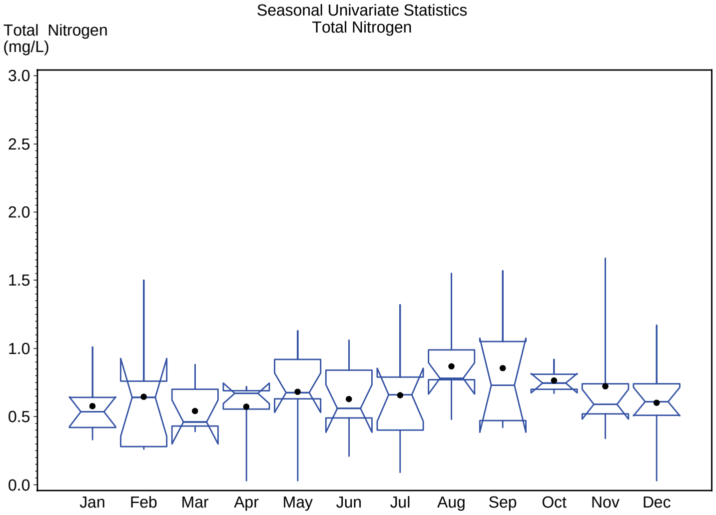
Palma Sola Bay Trends Appendix - Display 21
Monthly Data Time Series
Total Nitrogen
Not Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 22
Monthly Data Time Series
Total Nitrogen
Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 23
Seasonal Univariate Statistics
Total Nitrogen



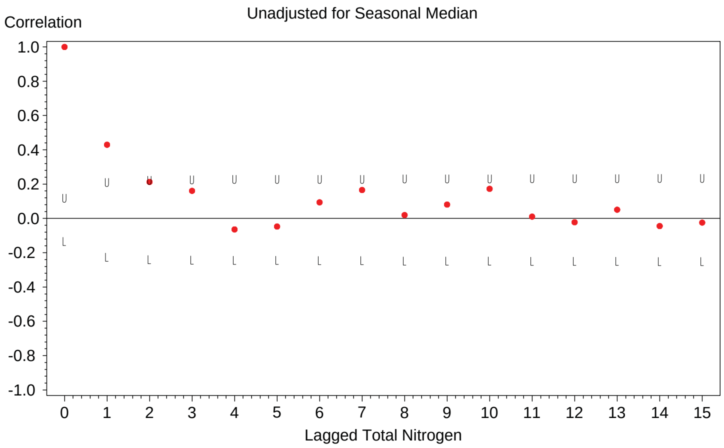
Palma Sola Bay Trends Appendix - Display 24
Autocorrelation Statistics for Total Nitrogen

Unadjusted for Seasonal Medians

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.430	0.109	0.218	-0.218
2	0.213	0.116	0.231	-0.231
3	0.161	0.117	0.234	-0.234
4	-0.064	0.118	0.236	-0.236
5	-0.047	0.118	0.236	-0.236
6	0.094	0.118	0.237	-0.237
7	0.166	0.119	0.237	-0.237
8	0.020	0.119	0.239	-0.239
9	0.081	0.119	0.239	-0.239
10	0.173	0.120	0.239	-0.239
11	0.011	0.121	0.241	-0.241
12	-0.022	0.121	0.241	-0.241
13	0.051	0.121	0.241	-0.241
14	-0.044	0.121	0.242	-0.242
15	-0.024	0.121	0.242	-0.242

Palma Sola Bay Trends Appendix - Display 25
Correlogram for Total Nitrogen

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 26
Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.083	0.303	0.415	-.009

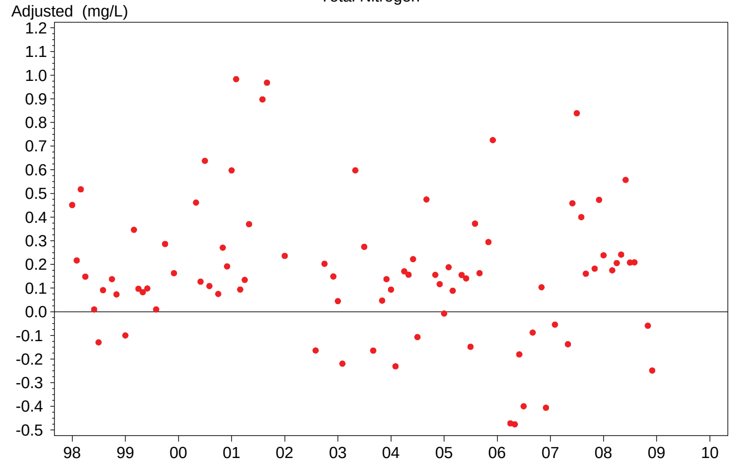
Palma Sola Bay Trends Appendix - Display 27

Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.083141	0.30273	0.41546	-.00875

Palma Sola Bay Trends Appendix - Display 28
Time Series Plot of Data Adjusted for Season and Detrended
Total Nitrogen



Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 29

Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.387	0.109	0.218	-0.218
2	0.195	0.114	0.229	-0.229
3	0.197	0.116	0.231	-0.231
4	-0.065	0.117	0.234	-0.234
5	-0.042	0.117	0.234	-0.234
6	0.114	0.117	0.235	-0.235
7	0.167	0.118	0.235	-0.235
8	0.088	0.119	0.237	-0.237
9	0.068	0.119	0.238	-0.238
10	0.135	0.119	0.238	-0.238
11	-0.128	0.120	0.239	-0.239
12	-0.096	0.120	0.240	-0.240
13	-0.096	0.121	0.241	-0.241

Palma Sola Bay Trends Appendix - Display 29

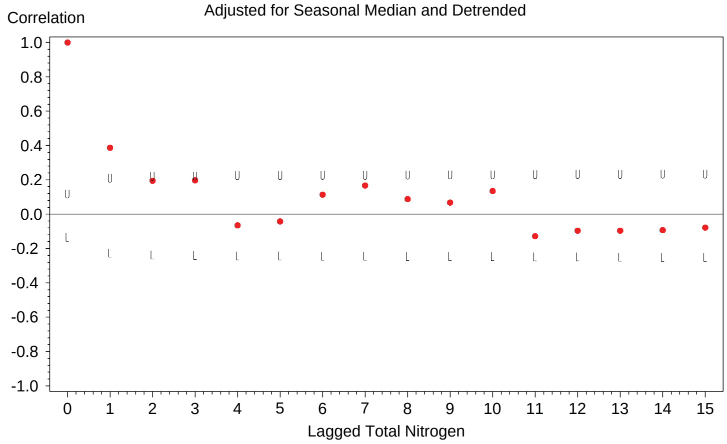
Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
14	-0.093	0.121	0.242	-0.242
15	-0.078	0.121	0.242	-0.242

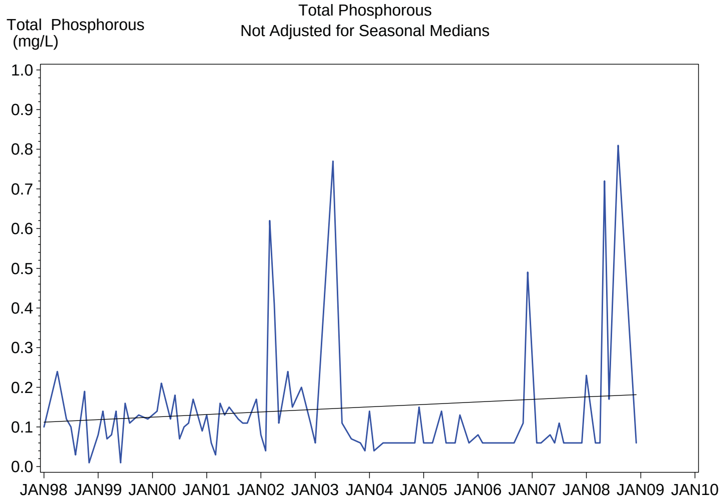
Palma Sola Bay Trends Appendix - Display 30
Correlogram for Total Nitrogen

Adjusted for Seasonal Median and Detrended

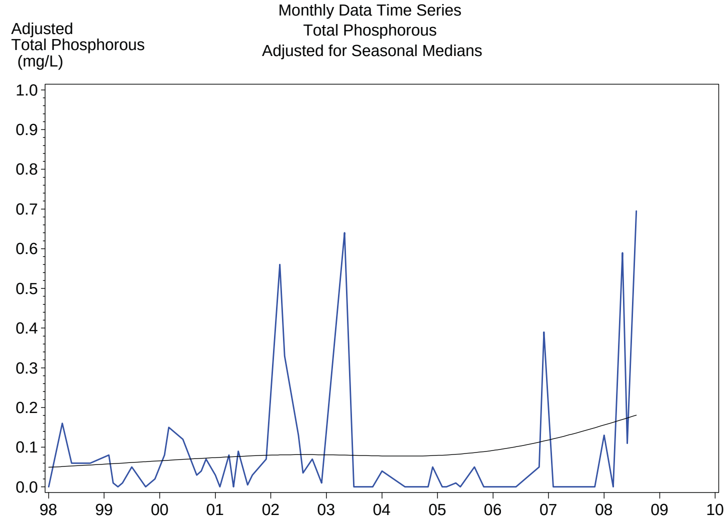


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

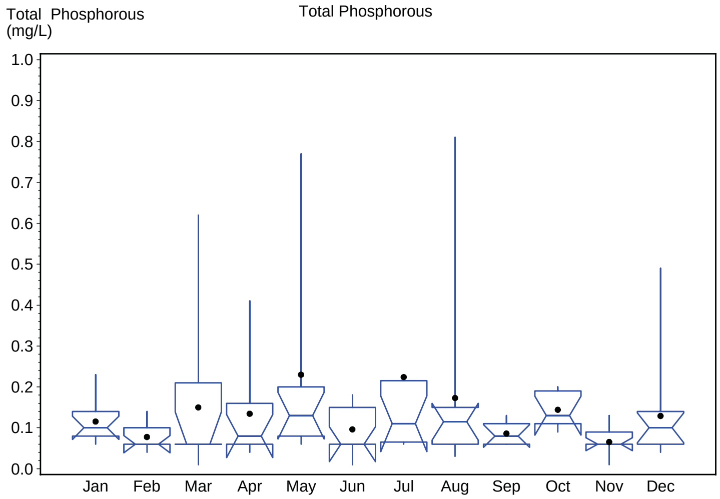
Palma Sola Bay Trends Appendix - Display 31
Monthly Data Time Series
Total Phosphorous
Not Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 32
Monthly Data Time Series
Total Phosphorous
Adjusted for Seasonal Medians



Palma Sola Bay Trends Appendix - Display 33
Seasonal Univariate Statistics
Total Phosphorous



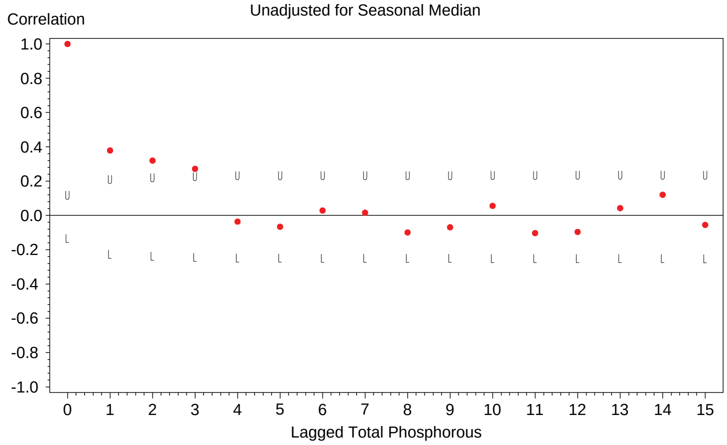
Palma Sola Bay Trends Appendix - Display 34
Autocorrelation Statistics for Total Phosphorous

Unadjusted for Seasonal Medians

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.379	0.109	0.218	-0.218
2	0.320	0.114	0.228	-0.228
3	0.272	0.118	0.235	-0.235
4	-0.036	0.120	0.240	-0.240
5	-0.066	0.120	0.240	-0.240
6	0.029	0.120	0.241	-0.241
7	0.016	0.120	0.241	-0.241
8	-0.099	0.120	0.241	-0.241
9	-0.069	0.121	0.241	-0.241
10	0.056	0.121	0.242	-0.242
11	-0.103	0.121	0.242	-0.242
12	-0.096	0.121	0.243	-0.243
13	0.043	0.122	0.243	-0.243
14	0.121	0.122	0.243	-0.243
15	-0.055	0.122	0.244	-0.244

Palma Sola Bay Trends Appendix - Display 35
Correlogram for Total Phosphorous

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Palma Sola Bay Trends Appendix - Display 36
Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.097	0.182	0.268	-.001

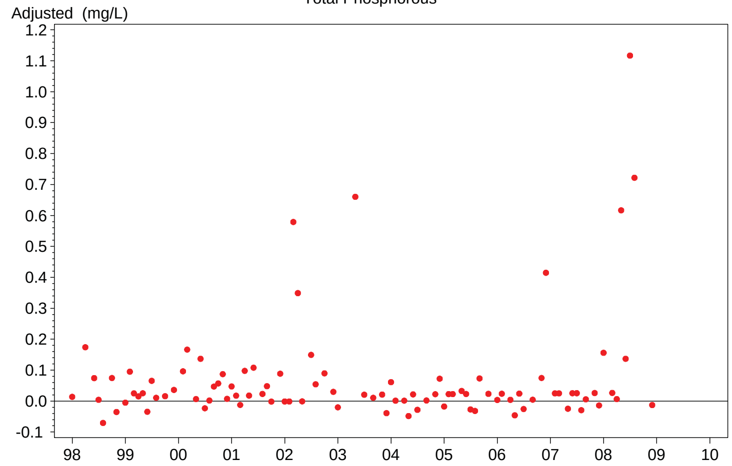
Palma Sola Bay Trends Appendix - Display 37

Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.097196	0.18177	0.26846	-.00125

Palma Sola Bay Trends Appendix - Display 38
Time Series Plot of Data Adjusted for Season and Detrended
Total Phosphorous



Zero Reference Line Shown

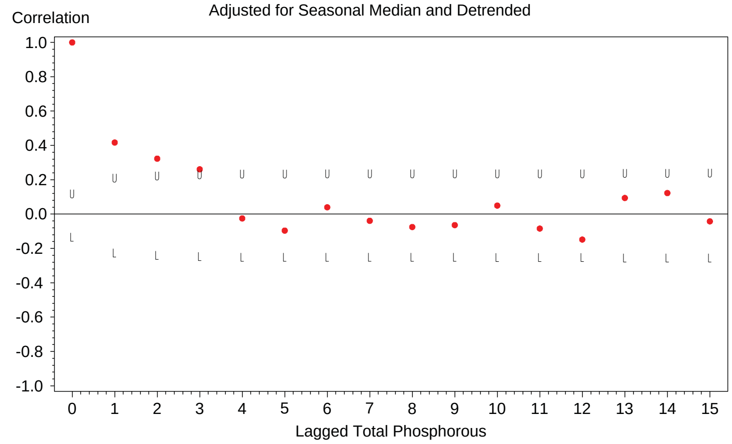
Palma Sola Bay Trends Appendix - Display 39
Autocorrelation Statistics for Total Phosphorous

Adjusted for Seasonal Median and Detrended

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.063	0.126	-0.126
1	0.417	0.109	0.218	-0.218
2	0.323	0.115	0.231	-0.231
3	0.261	0.119	0.238	-0.238
4	-0.025	0.121	0.242	-0.242
5	-0.096	0.121	0.242	-0.242
6	0.040	0.121	0.243	-0.243
7	-0.039	0.121	0.243	-0.243
8	-0.075	0.121	0.243	-0.243
9	-0.064	0.122	0.243	-0.243
10	0.050	0.122	0.244	-0.244
11	-0.084	0.122	0.244	-0.244
12	-0.148	0.122	0.244	-0.244
13	0.094	0.123	0.246	-0.246
14	0.123	0.123	0.246	-0.246
15	-0.042	0.124	0.247	-0.247

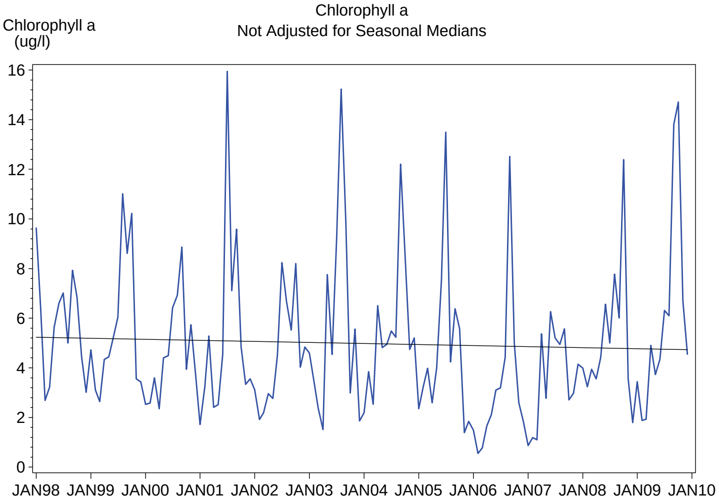
Palma Sola Bay Trends Appendix - Display 40
Correlogram for Total Phosphorous

Adjusted for Seasonal Median and Detrended

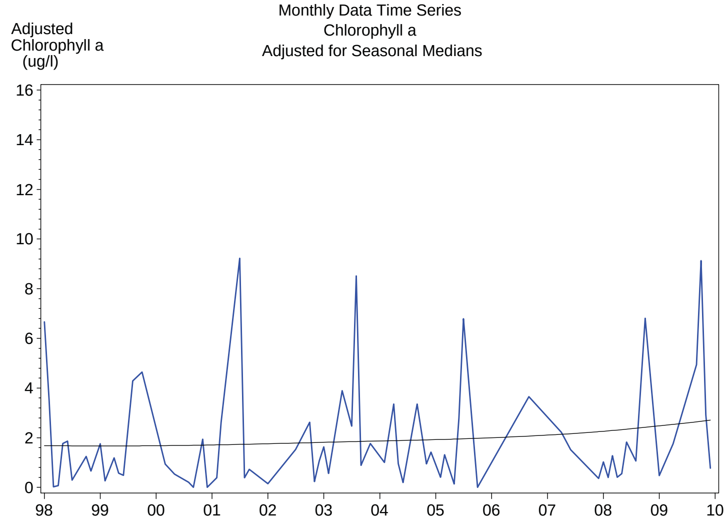


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

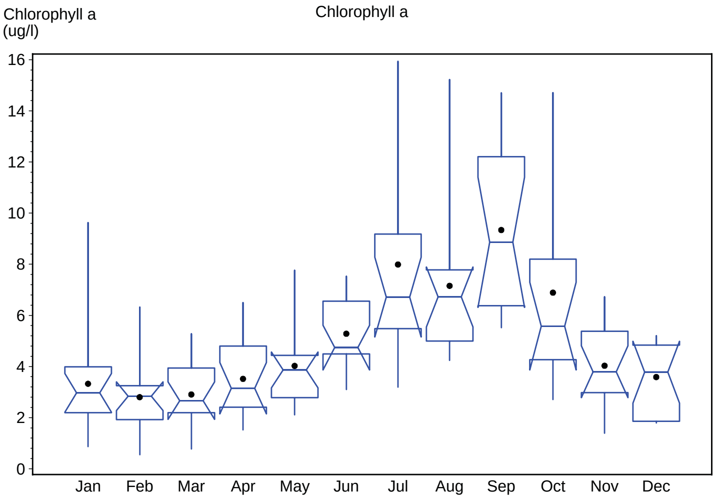
Sarasota Bay Trends Appendix - Display 1
Monthly Data Time Series
Chlorophyll a
Not Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 2
Monthly Data Time Series
Chlorophyll a
Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 3
Seasonal Univariate Statistics
Chlorophyll a



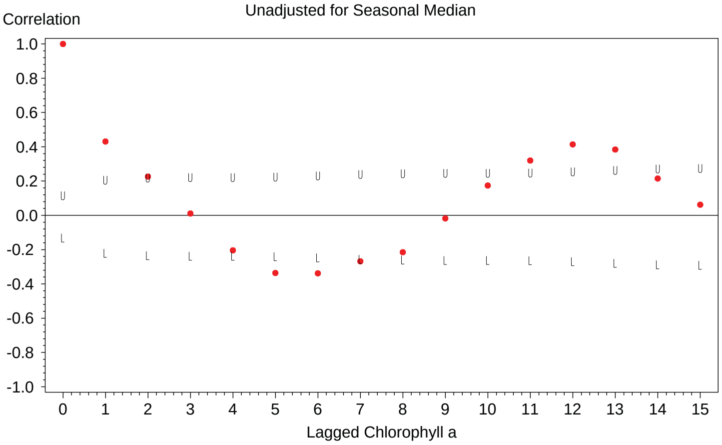
Sarasota Bay Trends Appendix - Display 4
Autocorrelation Statistics for Chlorophyll a

Unadjusted for Seasonal Medians

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.431	0.107	0.213	-0.213
2	0.226	0.113	0.226	-0.226
3	0.011	0.115	0.229	-0.229
4	-0.204	0.115	0.229	-0.229
5	-0.336	0.116	0.232	-0.232
6	-0.338	0.120	0.239	-0.239
7	-0.268	0.123	0.247	-0.247
8	-0.215	0.125	0.251	-0.251
9	-0.018	0.127	0.254	-0.254
10	0.174	0.127	0.254	-0.254
11	0.320	0.128	0.256	-0.256
12	0.414	0.131	0.262	-0.262
13	0.384	0.136	0.271	-0.271
14	0.215	0.140	0.279	-0.279
15	0.062	0.141	0.282	-0.282

Sarasota Bay Trends Appendix - Display 5
Correlogram for Chlorophyll a

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 6
Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.127	0.03	0.152	-0.077

Sarasota Bay Trends Appendix - Display 7

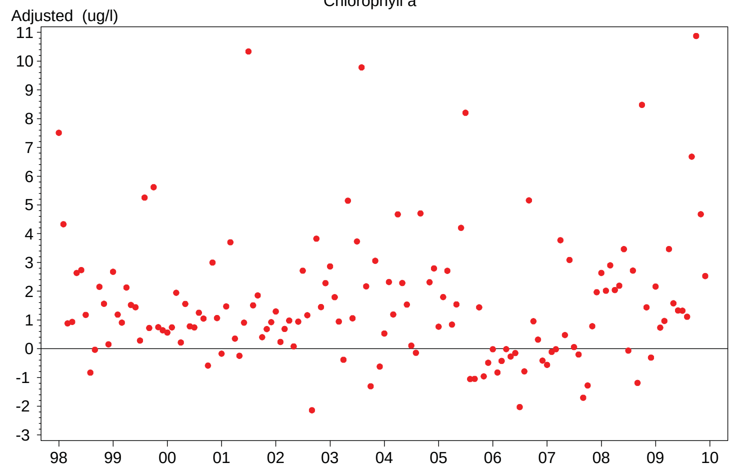
Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.12685	0.030380	0.15161	-0.07675

Sarasota Bay Trends Appendix - Display 8

Time Series Plot of Data Adjusted for Season and Detrended
Chlorophyll a



Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 9

Autocorrelation Statistics for Chlorophyll a

Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.135	0.107	0.213	-0.213
2	0.034	0.107	0.214	-0.214
3	0.030	0.107	0.215	-0.215
4	0.004	0.107	0.215	-0.215
5	-0.030	0.107	0.215	-0.215
6	0.035	0.107	0.215	-0.215
7	0.090	0.107	0.215	-0.215
8	0.005	0.108	0.215	-0.215
9	0.043	0.108	0.215	-0.215
10	0.011	0.108	0.215	-0.215
11	-0.050	0.108	0.216	-0.216
12	-0.075	0.108	0.216	-0.216
13	0.002	0.108	0.216	-0.216

Sarasota Bay Trends Appendix - Display 9

Autocorrelation Statistics for Chlorophyll a

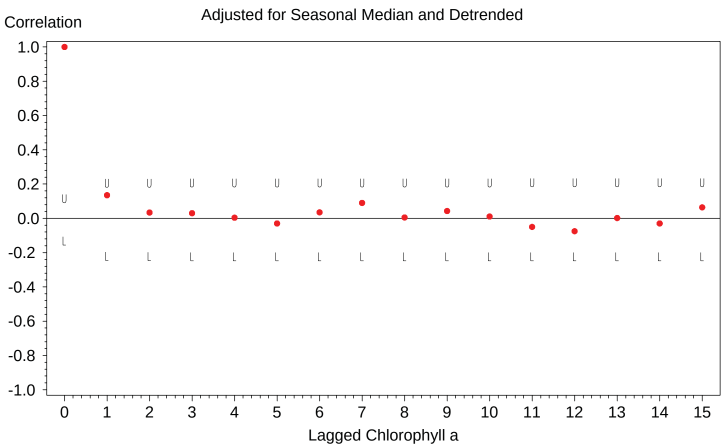
X

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
14	-0.030	0.108	0.216	-0.216
15	0.064	0.108	0.216	-0.216

Sarasota Bay Trends Appendix - Display 10

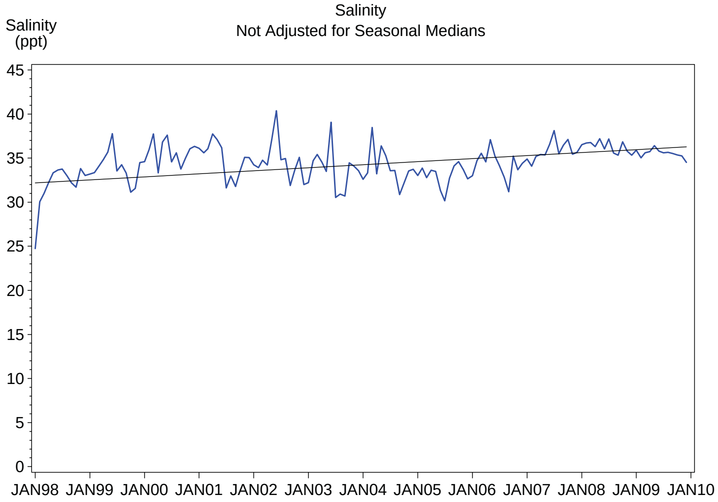
Correlogram for Chlorophyll a

Adjusted for Seasonal Median and Detrended

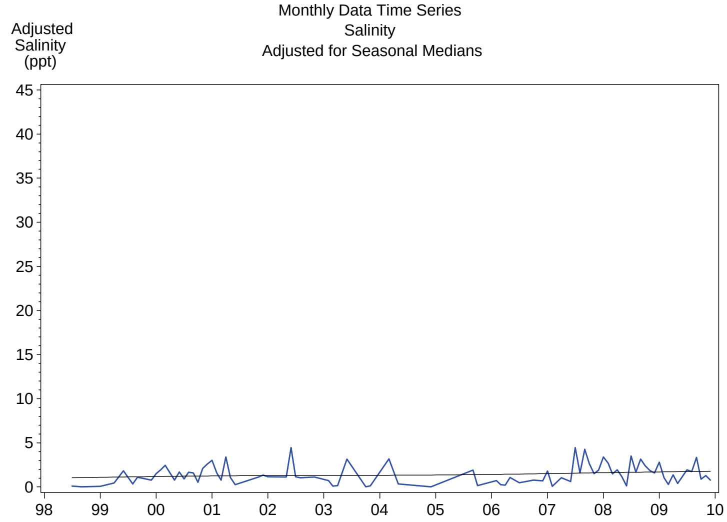


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

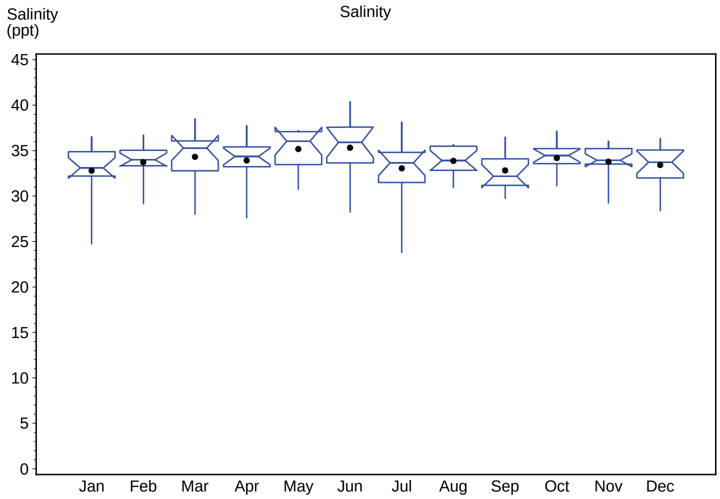
Sarasota Bay Trends Appendix - Display 11
Monthly Data Time Series
Salinity
Not Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 12
Monthly Data Time Series
Salinity
Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 13
Seasonal Univariate Statistics
Salinity



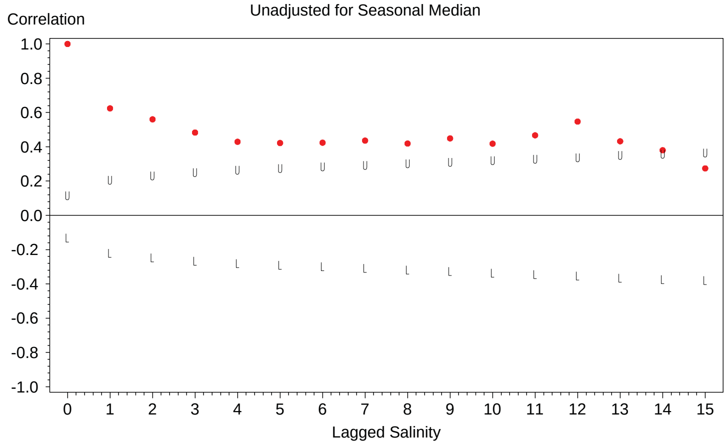
Sarasota Bay Trends Appendix - Display 14
Autocorrelation Statistics for Salinity

Unadjusted for Seasonal Medians

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.624	0.107	0.213	-0.213
2	0.560	0.120	0.239	-0.239
3	0.483	0.129	0.258	-0.258
4	0.429	0.136	0.272	-0.272
5	0.422	0.141	0.282	-0.282
6	0.424	0.146	0.291	-0.291
7	0.436	0.150	0.300	-0.300
8	0.419	0.155	0.310	-0.310
9	0.449	0.159	0.318	-0.318
10	0.418	0.164	0.328	-0.328
11	0.467	0.168	0.336	-0.336
12	0.547	0.173	0.345	-0.345
13	0.432	0.179	0.358	-0.358
14	0.380	0.183	0.366	-0.366
15	0.274	0.186	0.372	-0.372

Sarasota Bay Trends Appendix - Display 15
Correlogram for Salinity

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 16
Seasonal Kendall Tau Trend Test Statistics
Salinity

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.421	0	.005	0.322

Sarasota Bay Trends Appendix - Display 17

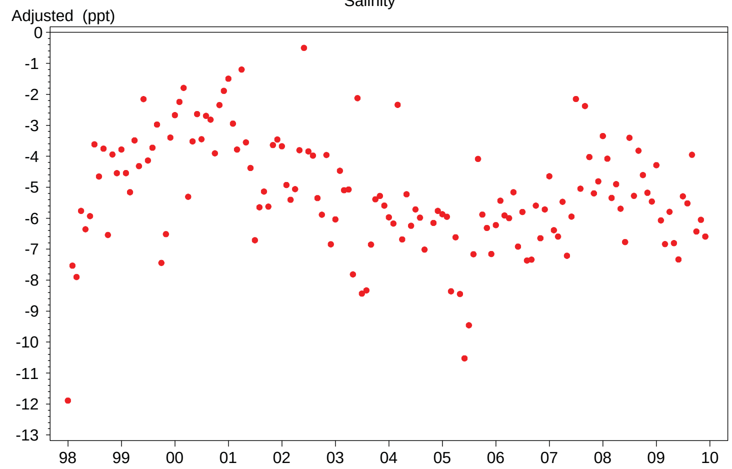
Seasonal Kendall Tau Trend Test Statistics
Salinity

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.42130	0	.00498998	0.32167

Sarasota Bay Trends Appendix - Display 18

Time Series Plot of Data Adjusted for Season and Detrended
Salinity



Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 19

Autocorrelation Statistics for Salinity

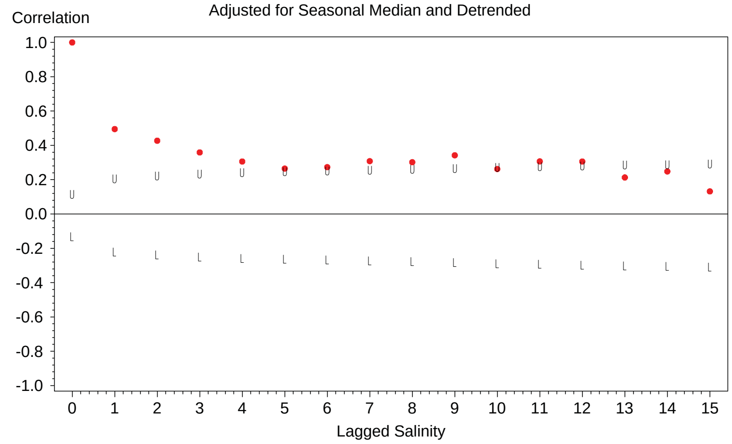
Adjusted for Seasonal Median and Detrended

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.495	0.107	0.213	-0.213
2	0.427	0.115	0.230	-0.230
3	0.359	0.121	0.242	-0.242
4	0.306	0.125	0.250	-0.250
5	0.265	0.128	0.255	-0.255
6	0.273	0.130	0.259	-0.259
7	0.308	0.132	0.264	-0.264
8	0.302	0.135	0.269	-0.269
9	0.342	0.137	0.274	-0.274
10	0.262	0.140	0.281	-0.281
11	0.307	0.142	0.284	-0.284
12	0.306	0.145	0.289	-0.289
13	0.213	0.147	0.294	-0.294
14	0.248	0.148	0.296	-0.296
15	0.132	0.150	0.300	-0.300

Sarasota Bay Trends Appendix - Display 20

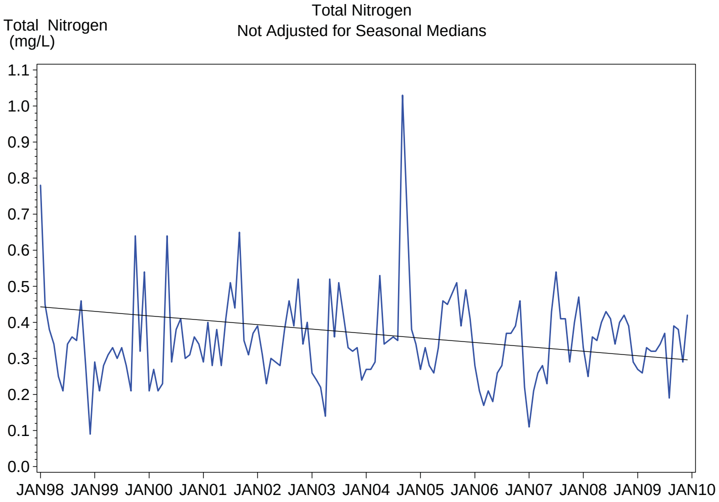
Correlogram for Salinity

Adjusted for Seasonal Median and Detrended

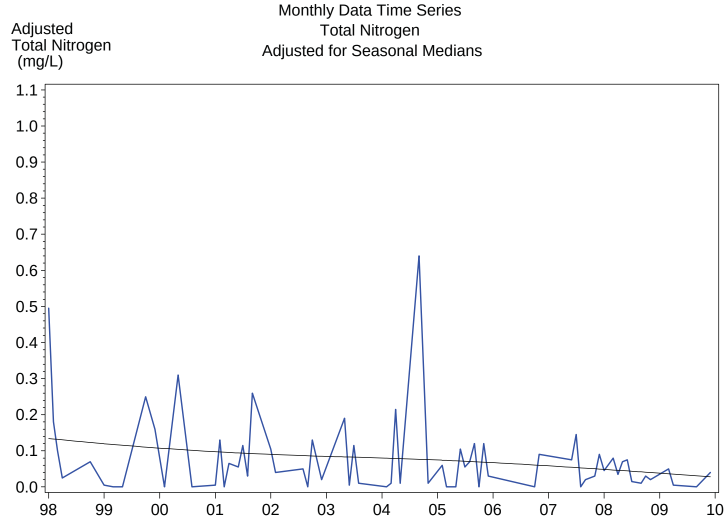


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

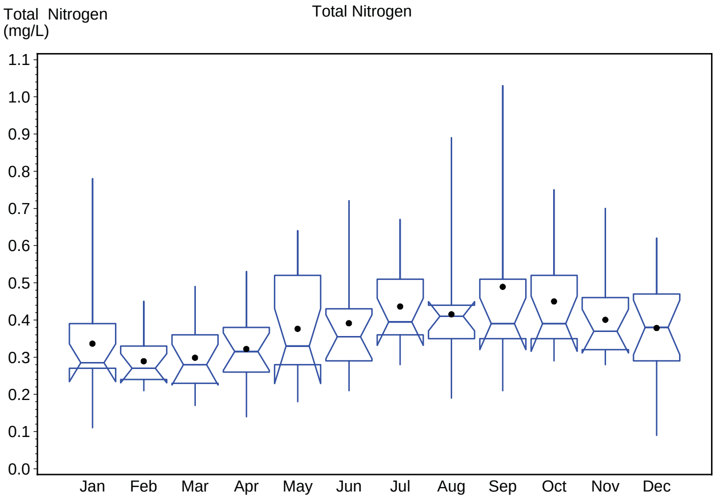
Sarasota Bay Trends Appendix - Display 21
Monthly Data Time Series
Total Nitrogen
Not Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 22
Monthly Data Time Series
Total Nitrogen
Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 23
Seasonal Univariate Statistics
Total Nitrogen



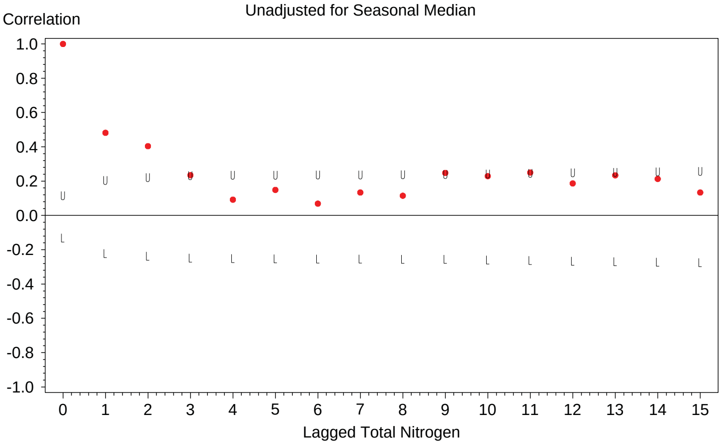
Sarasota Bay Trends Appendix - Display 24
Autocorrelation Statistics for Total Nitrogen

Unadjusted for Seasonal Medians

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.482	0.107	0.213	-0.213
2	0.404	0.115	0.229	-0.229
3	0.235	0.120	0.240	-0.240
4	0.092	0.122	0.243	-0.243
5	0.149	0.122	0.244	-0.244
6	0.069	0.123	0.245	-0.245
7	0.134	0.123	0.245	-0.245
8	0.115	0.123	0.246	-0.246
9	0.248	0.124	0.247	-0.247
10	0.229	0.125	0.251	-0.251
11	0.250	0.127	0.254	-0.254
12	0.187	0.129	0.258	-0.258
13	0.234	0.130	0.260	-0.260
14	0.213	0.132	0.263	-0.263
15	0.134	0.133	0.266	-0.266

Sarasota Bay Trends Appendix - Display 25
Correlogram for Total Nitrogen

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 26

Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.193	.001	0.09	-.009

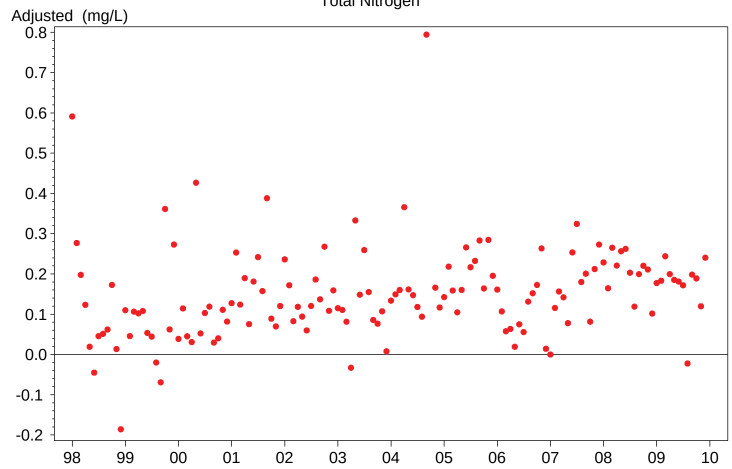
Sarasota Bay Trends Appendix - Display 27

Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.1926	.00104595	0.090172	-.00875

Sarasota Bay Trends Appendix - Display 28
Time Series Plot of Data Adjusted for Season and Detrended
Total Nitrogen



Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 29

Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.344	0.107	0.213	-0.213
2	0.322	0.111	0.221	-0.221
3	0.208	0.114	0.228	-0.228
4	0.145	0.116	0.231	-0.231
5	0.253	0.116	0.233	-0.233
6	0.159	0.118	0.237	-0.237
7	0.217	0.119	0.238	-0.238
8	0.160	0.121	0.241	-0.241
9	0.207	0.122	0.243	-0.243
10	0.089	0.123	0.246	-0.246
11	0.060	0.123	0.246	-0.246
12	-0.011	0.123	0.246	-0.246
13	0.044	0.123	0.246	-0.246

Sarasota Bay Trends Appendix - Display 29

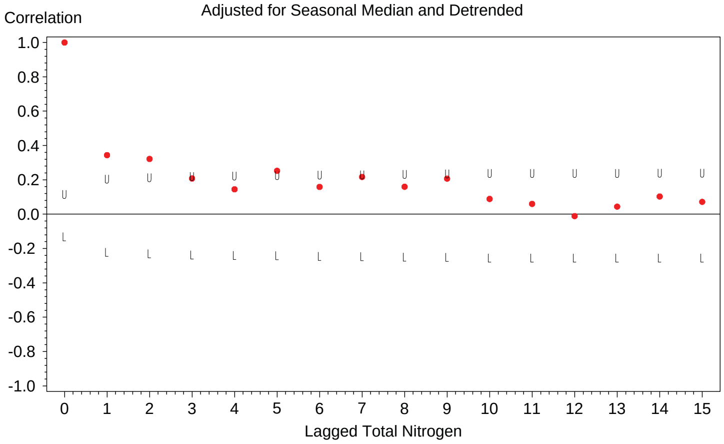
Autocorrelation Statistics for Total Nitrogen

X

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
14	0.103	0.123	0.247	-0.247
15	0.072	0.124	0.247	-0.247

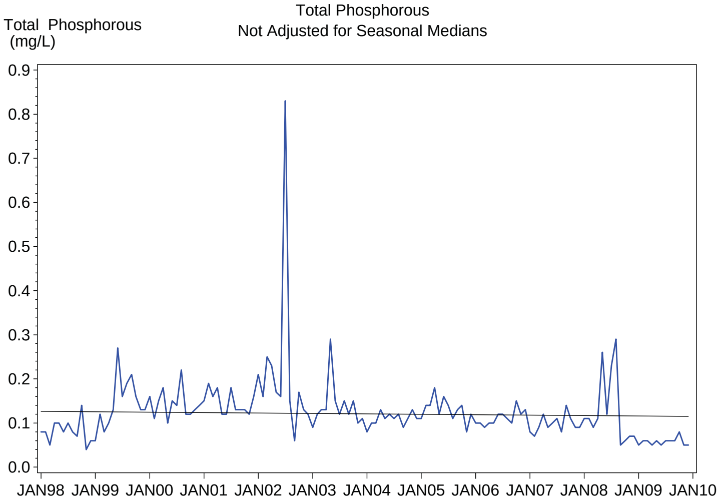
Sarasota Bay Trends Appendix - Display 30
Correlogram for Total Nitrogen

Adjusted for Seasonal Median and Detrended

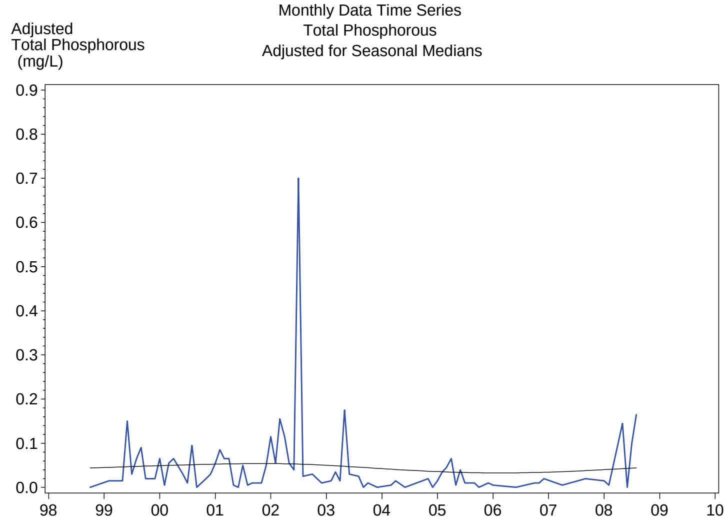


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

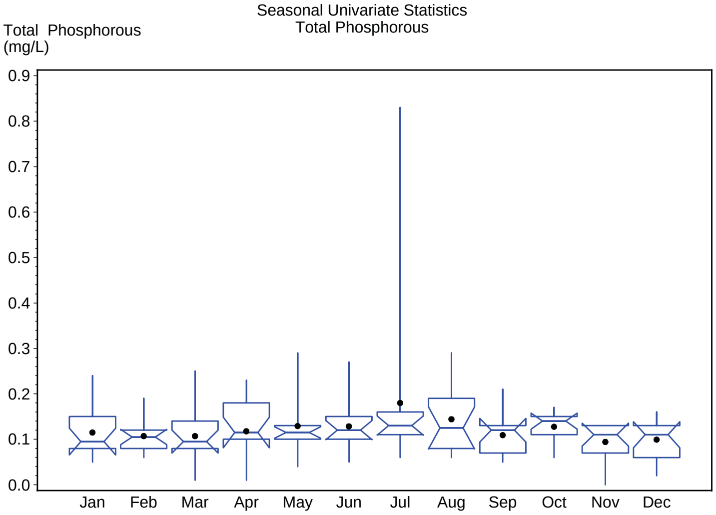
Sarasota Bay Trends Appendix - Display 31
Monthly Data Time Series
Total Phosphorous
Not Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 32
Monthly Data Time Series
Total Phosphorous
Adjusted for Seasonal Medians



Sarasota Bay Trends Appendix - Display 33
Seasonal Univariate Statistics
Total Phosphorous



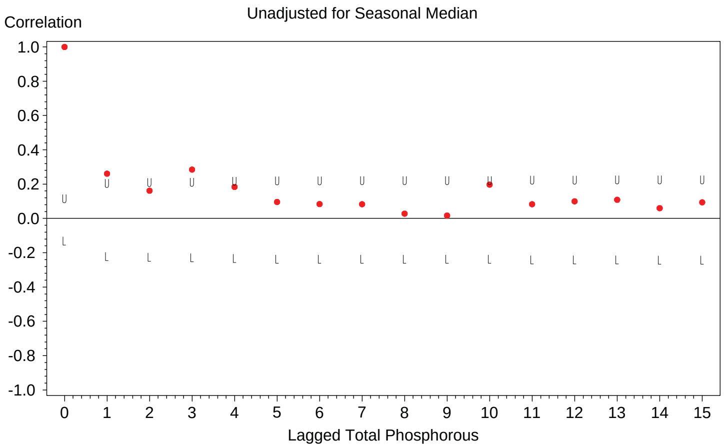
Sarasota Bay Trends Appendix - Display 34
Autocorrelation Statistics for Total Phosphorous

Unadjusted for Seasonal Medians

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.261	0.107	0.213	-0.213
2	0.162	0.109	0.218	-0.218
3	0.285	0.110	0.220	-0.220
4	0.184	0.113	0.225	-0.225
5	0.096	0.114	0.228	-0.228
6	0.084	0.114	0.228	-0.228
7	0.083	0.114	0.229	-0.229
8	0.028	0.115	0.229	-0.229
9	0.017	0.115	0.229	-0.229
10	0.197	0.115	0.229	-0.229
11	0.083	0.116	0.232	-0.232
12	0.100	0.116	0.232	-0.232
13	0.109	0.116	0.233	-0.233
14	0.060	0.117	0.234	-0.234
15	0.094	0.117	0.234	-0.234

Sarasota Bay Trends Appendix - Display 35
Correlogram for Total Phosphorous

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 36
Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.122	0.035	0.382	-.002

Sarasota Bay Trends Appendix - Display 37

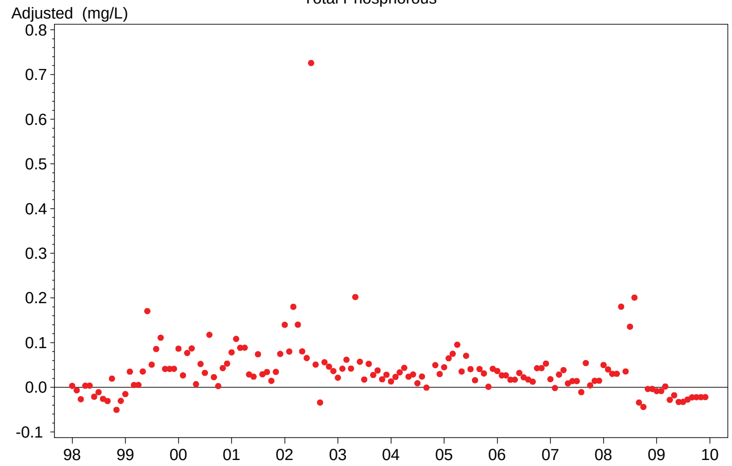
Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.12222	0.035065	0.38163	-.00166667

Sarasota Bay Trends Appendix - Display 38

Time Series Plot of Data Adjusted for Season and Detrended
Total Phosphorous



Zero Reference Line Shown

Sarasota Bay Trends Appendix - Display 39

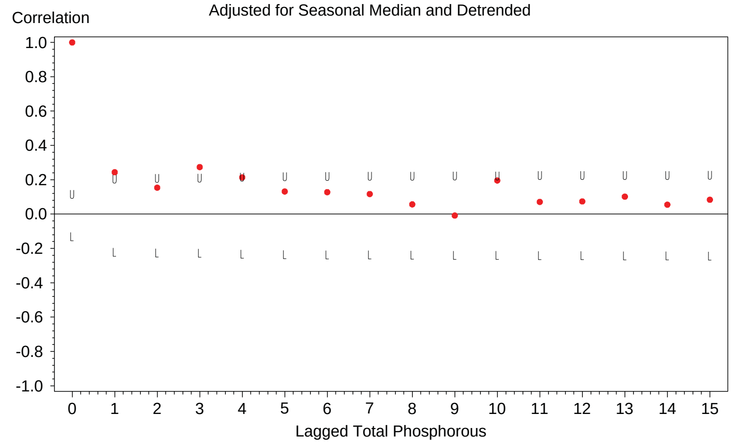
Autocorrelation Statistics for Total Phosphorous

Adjusted for Seasonal Median and Detrended

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.244	0.107	0.213	-0.213
2	0.154	0.109	0.217	-0.217
3	0.274	0.110	0.219	-0.219
4	0.214	0.112	0.224	-0.224
5	0.132	0.114	0.227	-0.227
6	0.128	0.114	0.228	-0.228
7	0.117	0.115	0.229	-0.229
8	0.057	0.115	0.230	-0.230
9	-0.008	0.115	0.231	-0.231
10	0.196	0.115	0.231	-0.231
11	0.071	0.117	0.233	-0.233
12	0.074	0.117	0.233	-0.233
13	0.102	0.117	0.234	-0.234
14	0.055	0.117	0.234	-0.234
15	0.084	0.117	0.235	-0.235

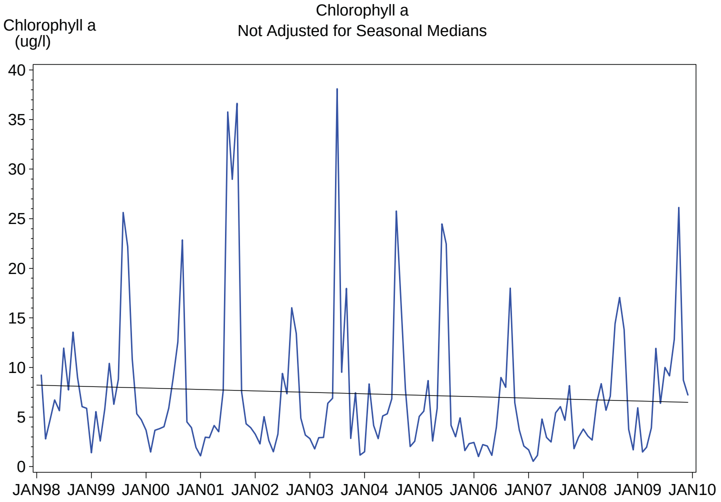
Sarasota Bay Trends Appendix - Display 40
Correlogram for Total Phosphorous

Adjusted for Seasonal Median and Detrended

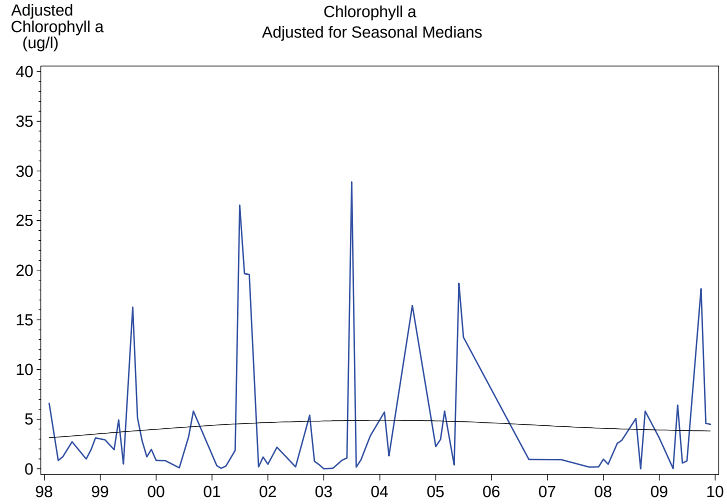


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

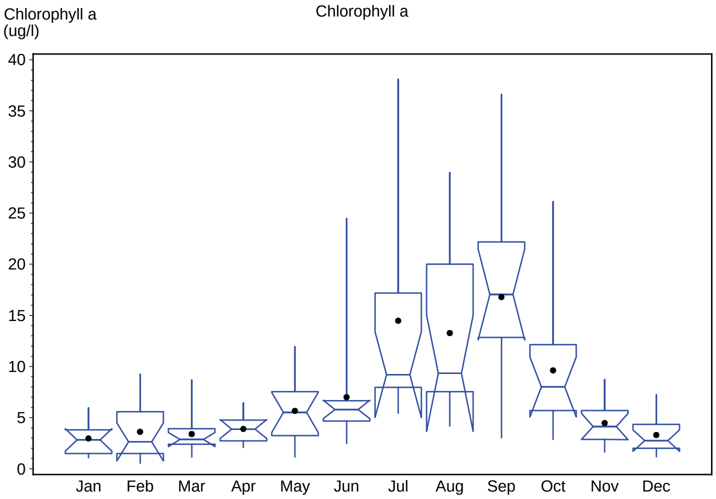
Roberts Bay Trends Appendix - Display 1
Monthly Data Time Series
Chlorophyll a
Not Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 2
Monthly Data Time Series
Chlorophyll a
Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 3
Seasonal Univariate Statistics
Chlorophyll a



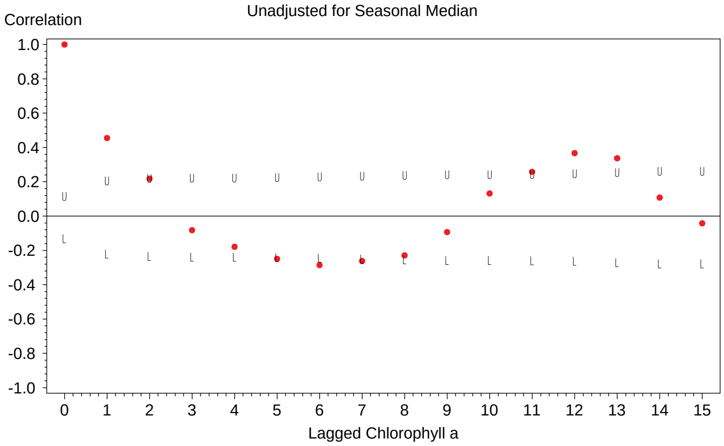
Roberts Bay Trends Appendix - Display 4
Autocorrelation Statistics for Chlorophyll a

Unadjusted for Seasonal Medians

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.455	0.107	0.213	-0.213
2	0.218	0.114	0.227	-0.227
3	-0.082	0.115	0.231	-0.231
4	-0.179	0.116	0.231	-0.231
5	-0.249	0.117	0.233	-0.233
6	-0.285	0.119	0.237	-0.237
7	-0.262	0.121	0.242	-0.242
8	-0.229	0.123	0.246	-0.246
9	-0.093	0.125	0.250	-0.250
10	0.132	0.125	0.250	-0.250
11	0.258	0.126	0.251	-0.251
12	0.367	0.128	0.255	-0.255
13	0.337	0.132	0.263	-0.263
14	0.108	0.135	0.270	-0.270
15	-0.042	0.135	0.270	-0.270

Roberts Bay Trends Appendix - Display 5
Correlogram for Chlorophyll a

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 6
Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.104	0.111	0.285	-0.132

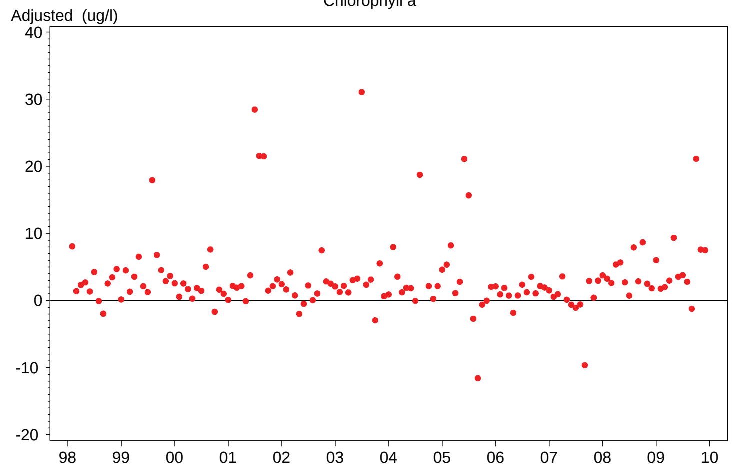
Roberts Bay Trends Appendix - Display 7

Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.10390	0.11082	0.28539	-0.13214

Roberts Bay Trends Appendix - Display 8
Time Series Plot of Data Adjusted for Season and Detrended
Chlorophyll a



Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 9
Autocorrelation Statistics for Chlorophyll a

Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.281	0.107	0.213	-0.213
2	0.058	0.109	0.219	-0.219
3	-0.092	0.109	0.219	-0.219
4	-0.006	0.110	0.220	-0.220
5	0.003	0.110	0.220	-0.220
6	-0.012	0.110	0.220	-0.220
7	-0.012	0.110	0.220	-0.220
8	-0.090	0.110	0.220	-0.220
9	-0.037	0.110	0.220	-0.220
10	-0.019	0.110	0.220	-0.220
11	-0.068	0.110	0.220	-0.220
12	-0.052	0.110	0.221	-0.221
13	0.032	0.110	0.221	-0.221

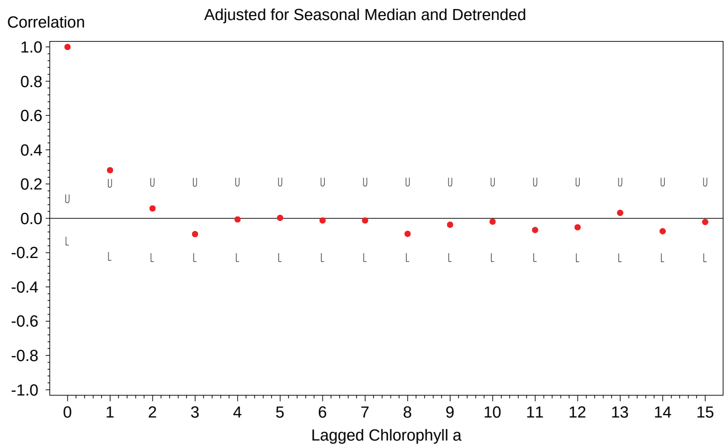
Roberts Bay Trends Appendix - Display 9
X

X
Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
14	-0.075	0.110	0.221	-0.221
15	-0.021	0.111	0.221	-0.221

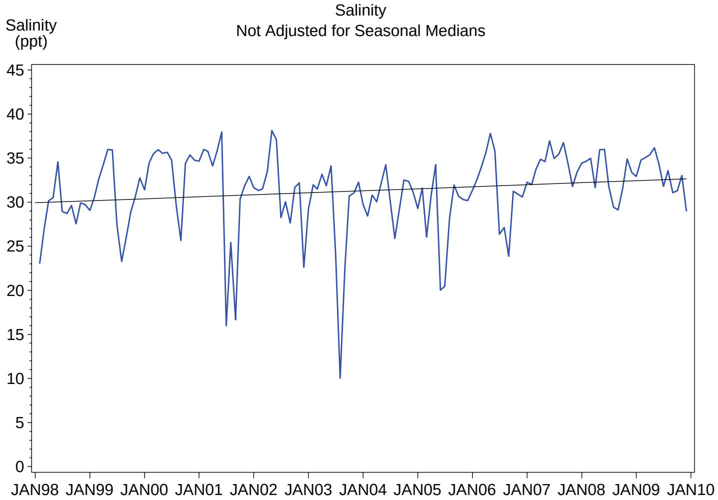
Roberts Bay Trends Appendix - Display 10
Correlogram for Chlorophyll a

Adjusted for Seasonal Median and Detrended

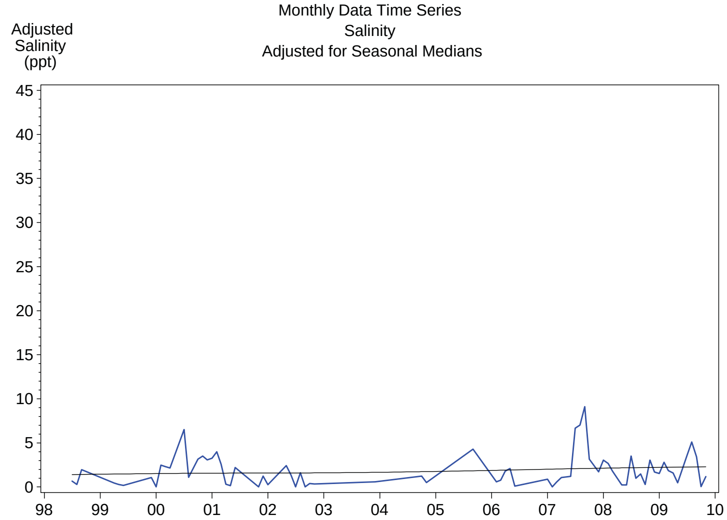


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

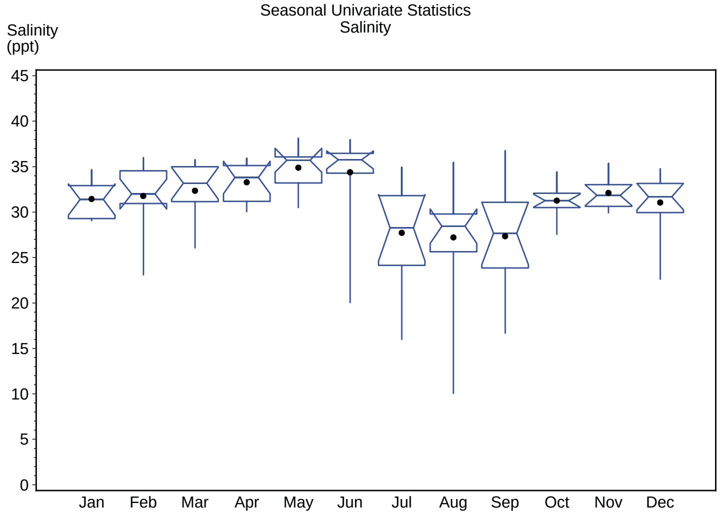
Roberts Bay Trends Appendix - Display 11
Monthly Data Time Series
Salinity
Not Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 12
Monthly Data Time Series
Salinity
Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 13
Seasonal Univariate Statistics
Salinity



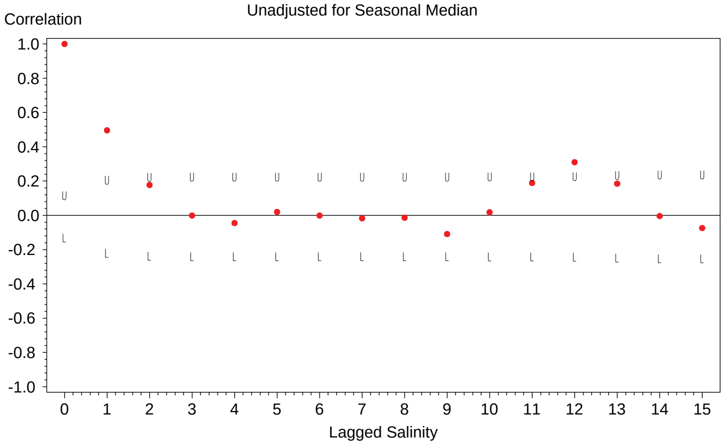
Roberts Bay Trends Appendix - Display 14
Autocorrelation Statistics for Salinity

Unadjusted for Seasonal Medians

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.496	0.107	0.213	-0.213
2	0.177	0.115	0.230	-0.230
3	-0.001	0.116	0.232	-0.232
4	-0.045	0.116	0.232	-0.232
5	0.020	0.116	0.232	-0.232
6	-0.001	0.116	0.232	-0.232
7	-0.017	0.116	0.232	-0.232
8	-0.014	0.116	0.232	-0.232
9	-0.109	0.116	0.232	-0.232
10	0.018	0.117	0.233	-0.233
11	0.189	0.117	0.233	-0.233
12	0.310	0.118	0.235	-0.235
13	0.185	0.121	0.241	-0.241
14	-0.004	0.122	0.244	-0.244
15	-0.074	0.122	0.244	-0.244

Roberts Bay Trends Appendix - Display 15
Correlogram for Salinity

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 16
Seasonal Kendall Tau Trend Test Statistics
Salinity

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.202	.002	0.14	0.192

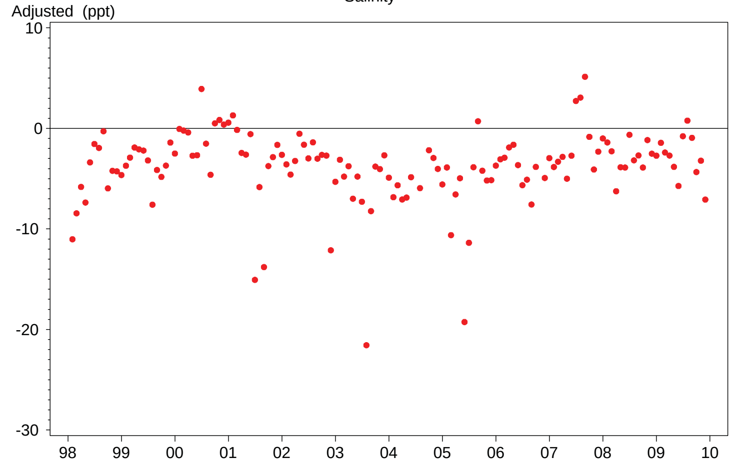
Roberts Bay Trends Appendix - Display 17

Seasonal Kendall Tau Trend Test Statistics
Salinity

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.20187	.00201845	0.13981	0.19214

Roberts Bay Trends Appendix - Display 18
Time Series Plot of Data Adjusted for Season and Detrended
Salinity



Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 19

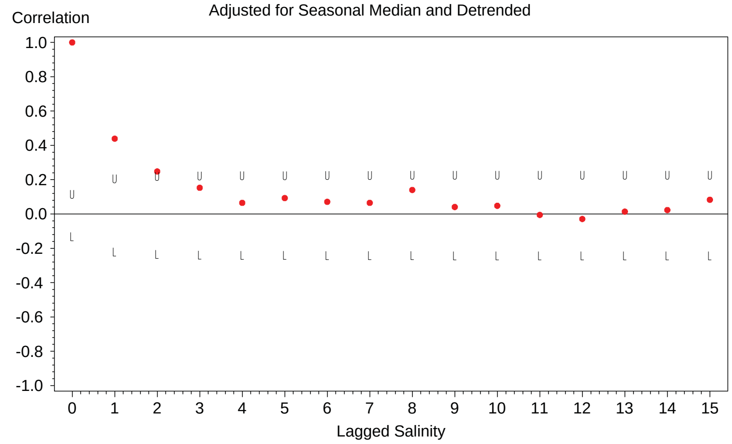
Autocorrelation Statistics for Salinity

Adjusted for Seasonal Median and Detrended

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.439	0.107	0.213	-0.213
2	0.248	0.113	0.227	-0.227
3	0.153	0.115	0.231	-0.231
4	0.065	0.116	0.232	-0.232
5	0.093	0.116	0.232	-0.232
6	0.071	0.116	0.233	-0.233
7	0.065	0.117	0.233	-0.233
8	0.140	0.117	0.234	-0.234
9	0.041	0.117	0.235	-0.235
10	0.048	0.117	0.235	-0.235
11	-0.005	0.118	0.235	-0.235
12	-0.029	0.118	0.235	-0.235
13	0.014	0.118	0.235	-0.235
14	0.023	0.118	0.235	-0.235
15	0.083	0.118	0.235	-0.235

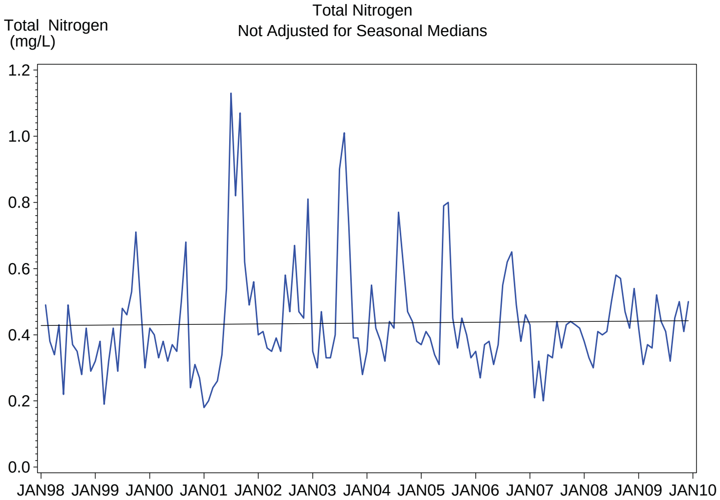
Roberts Bay Trends Appendix - Display 20
Correlogram for Salinity

Adjusted for Seasonal Median and Detrended

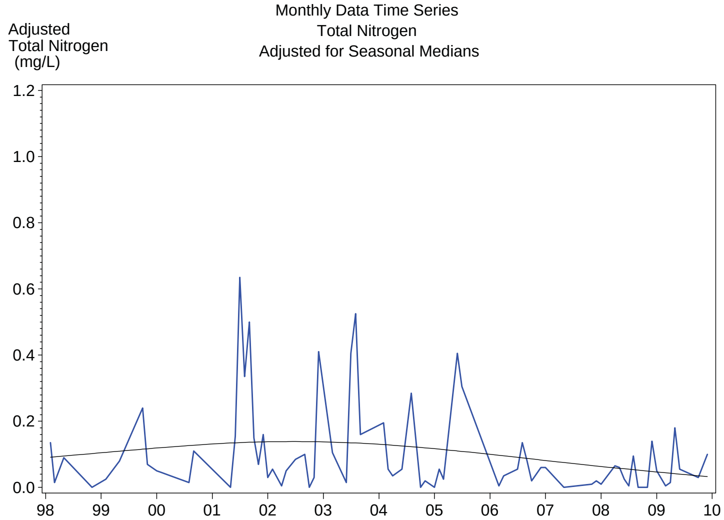


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

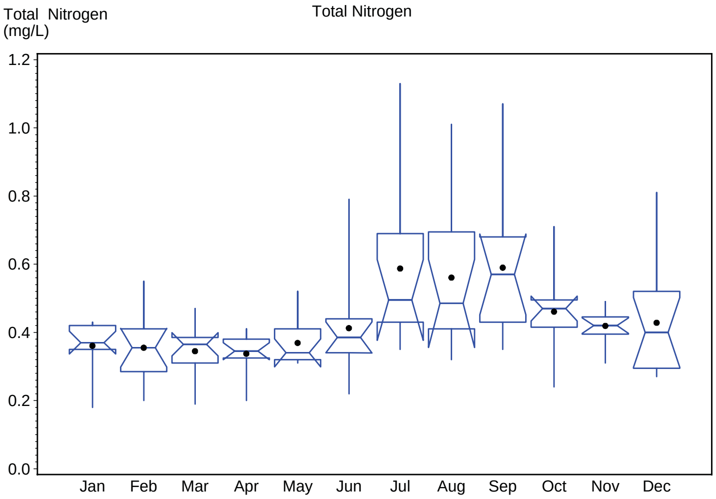
Roberts Bay Trends Appendix - Display 21
Monthly Data Time Series
Total Nitrogen
Not Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 22
Monthly Data Time Series
Total Nitrogen
Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 23
Seasonal Univariate Statistics
Total Nitrogen



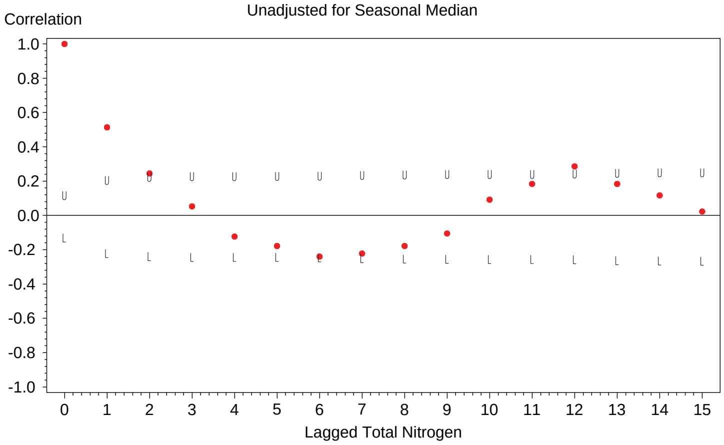
Roberts Bay Trends Appendix - Display 24
Autocorrelation Statistics for Total Nitrogen

Unadjusted for Seasonal Medians

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.514	0.107	0.213	-0.213
2	0.245	0.116	0.231	-0.231
3	0.053	0.118	0.235	-0.235
4	-0.123	0.118	0.235	-0.235
5	-0.178	0.118	0.236	-0.236
6	-0.240	0.119	0.238	-0.238
7	-0.222	0.121	0.242	-0.242
8	-0.178	0.122	0.245	-0.245
9	-0.105	0.123	0.247	-0.247
10	0.092	0.124	0.248	-0.248
11	0.184	0.124	0.248	-0.248
12	0.286	0.125	0.250	-0.250
13	0.184	0.128	0.255	-0.255
14	0.117	0.129	0.257	-0.257
15	0.023	0.129	0.258	-0.258

Roberts Bay Trends Appendix - Display 25
Correlogram for Total Nitrogen

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 26
Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.044	0.504	0.527	.002

Roberts Bay Trends Appendix - Display 27

Seasonal Kendall Tau Trend Test Statistics

Total Nitrogen

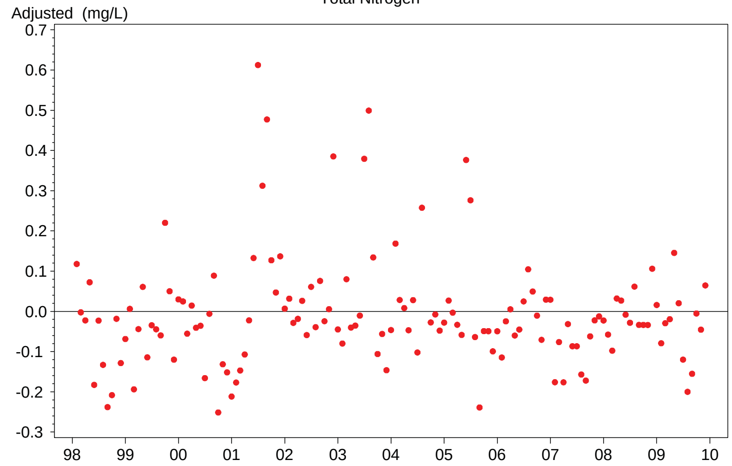
Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.044156	0.50363	0.52685	.00154762

Roberts Bay Trends Appendix - Display 28

Time Series Plot of Data Adjusted for Season and Detrended

Total Nitrogen



Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 29

Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.442	0.107	0.213	-0.213
2	0.180	0.113	0.227	-0.227
3	0.104	0.114	0.229	-0.229
4	-0.002	0.115	0.230	-0.230
5	0.021	0.115	0.230	-0.230
6	-0.024	0.115	0.230	-0.230
7	-0.036	0.115	0.230	-0.230
8	-0.075	0.115	0.230	-0.230
9	-0.100	0.115	0.230	-0.230
10	-0.017	0.115	0.231	-0.231
11	-0.048	0.115	0.231	-0.231
12	-0.005	0.115	0.231	-0.231
13	-0.033	0.115	0.231	-0.231

Roberts Bay Trends Appendix - Display 29

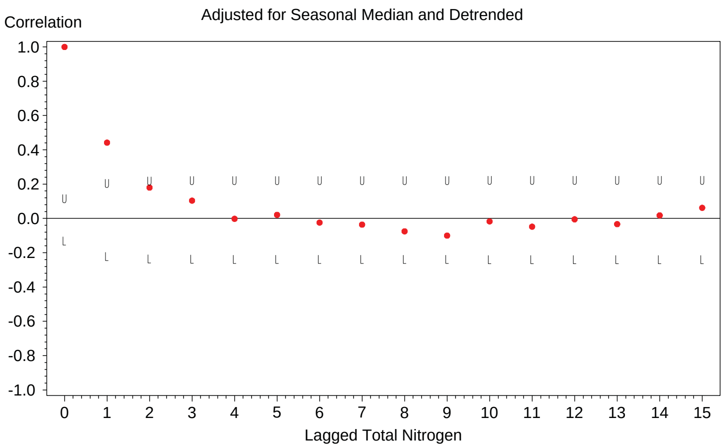
Autocorrelation Statistics for Total Nitrogen

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
14	0.018	0.115	0.231	-0.231
15	0.062	0.115	0.231	-0.231

Roberts Bay Trends Appendix - Display 30

Correlogram for Total Nitrogen

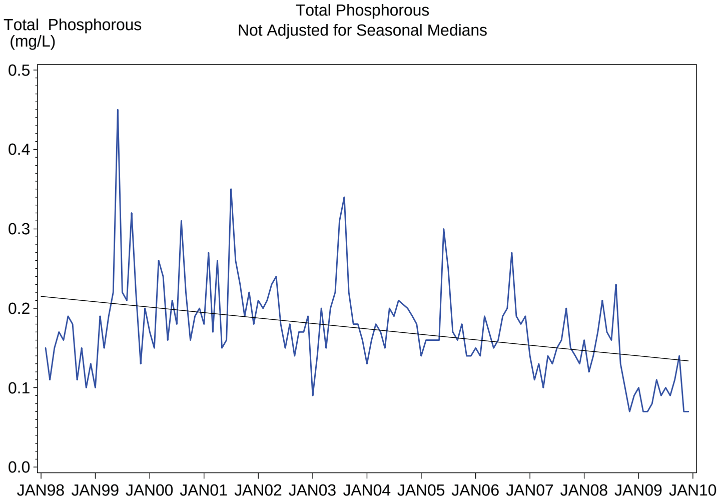
Adjusted for Seasonal Median and Detrended



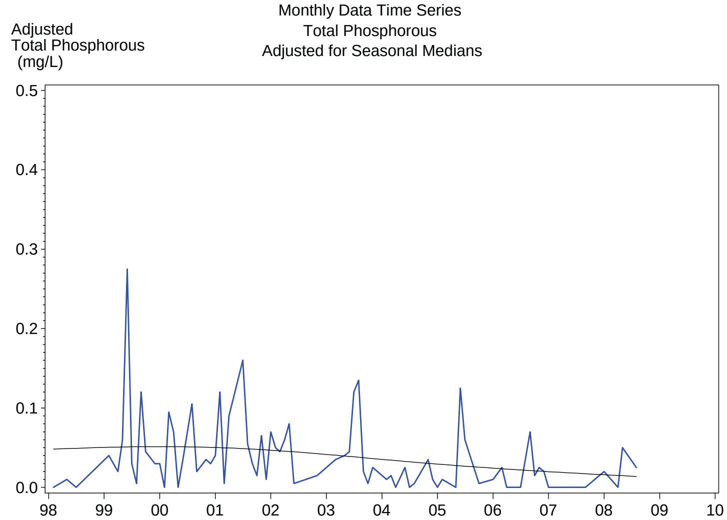
U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit

Zero Reference Line Shown

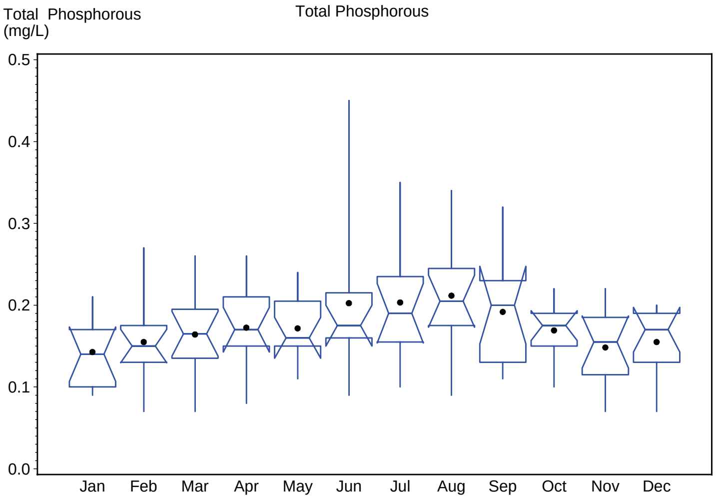
Roberts Bay Trends Appendix - Display 31
Monthly Data Time Series
Total Phosphorous
Not Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 32
Monthly Data Time Series
Total Phosphorous
Adjusted for Seasonal Medians



Roberts Bay Trends Appendix - Display 33
Seasonal Univariate Statistics
Total Phosphorous



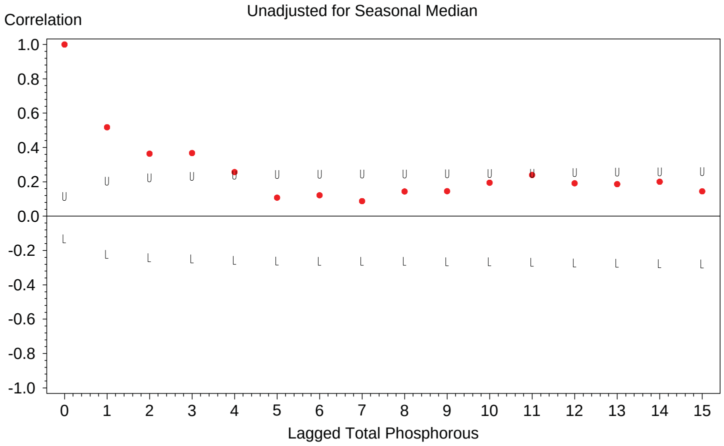
Roberts Bay Trends Appendix - Display 34
Autocorrelation Statistics for Total Phosphorous

Unadjusted for Seasonal Medians

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.518	0.107	0.213	-0.213
2	0.364	0.116	0.232	-0.232
3	0.368	0.120	0.240	-0.240
4	0.257	0.124	0.248	-0.248
5	0.108	0.126	0.252	-0.252
6	0.122	0.127	0.253	-0.253
7	0.088	0.127	0.254	-0.254
8	0.144	0.127	0.254	-0.254
9	0.146	0.128	0.256	-0.256
10	0.195	0.128	0.257	-0.257
11	0.240	0.130	0.259	-0.259
12	0.192	0.131	0.263	-0.263
13	0.187	0.132	0.265	-0.265
14	0.201	0.133	0.267	-0.267
15	0.145	0.134	0.269	-0.269

Roberts Bay Trends Appendix - Display 35
Correlogram for Total Phosphorous

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 36
Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.329	0	0.031	-.007

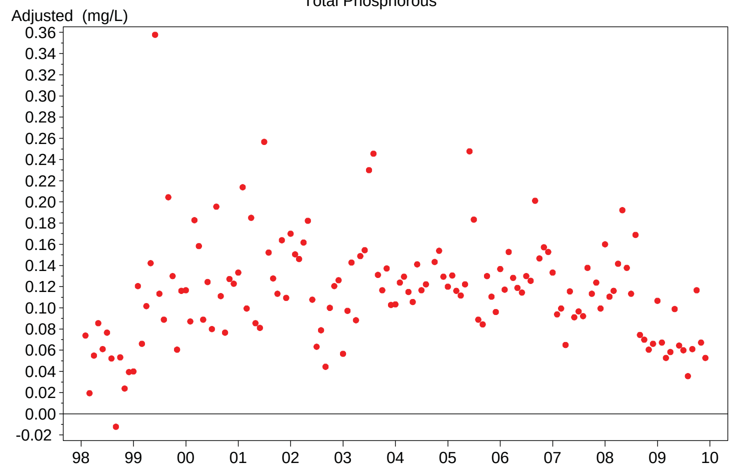
Roberts Bay Trends Appendix - Display 37

Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.32857	.000000318	0.031076	-.00666667

Roberts Bay Trends Appendix - Display 38
Time Series Plot of Data Adjusted for Season and Detrended
Total Phosphorous



Zero Reference Line Shown

Roberts Bay Trends Appendix - Display 39

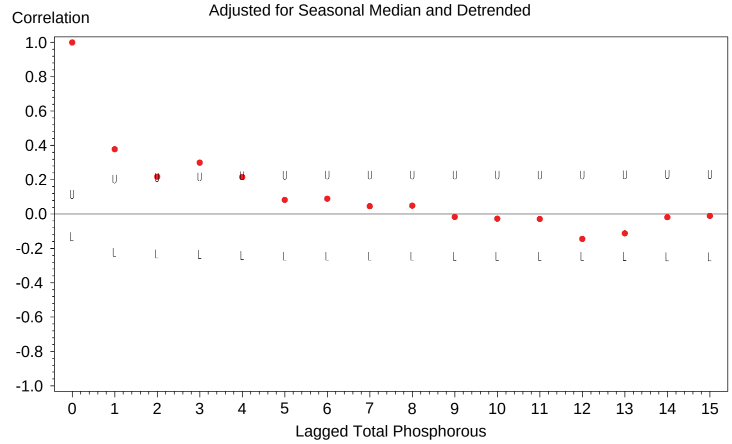
Autocorrelation Statistics for Total Phosphorous

Adjusted for Seasonal Median and Detrended

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.378	0.107	0.213	-0.213
2	0.218	0.112	0.223	-0.223
3	0.300	0.113	0.226	-0.226
4	0.216	0.116	0.232	-0.232
5	0.083	0.118	0.235	-0.235
6	0.090	0.118	0.236	-0.236
7	0.046	0.118	0.236	-0.236
8	0.050	0.118	0.236	-0.236
9	-0.016	0.118	0.237	-0.237
10	-0.026	0.118	0.237	-0.237
11	-0.028	0.118	0.237	-0.237
12	-0.144	0.118	0.237	-0.237
13	-0.112	0.119	0.238	-0.238
14	-0.018	0.119	0.239	-0.239
15	-0.010	0.119	0.239	-0.239

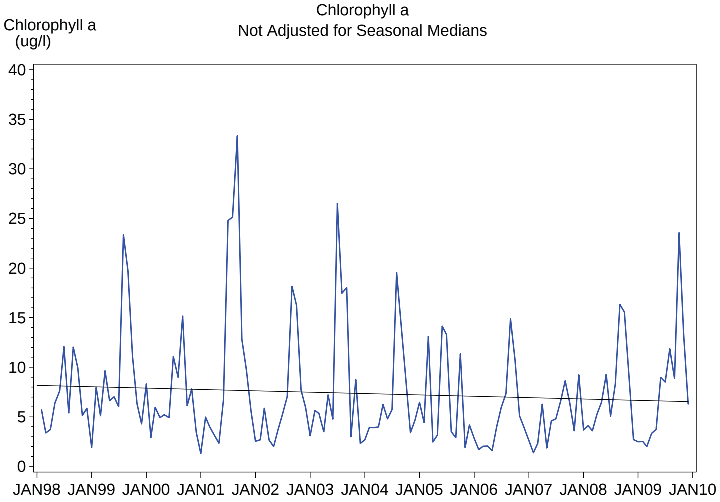
Roberts Bay Trends Appendix - Display 40
Correlogram for Total Phosphorous

Adjusted for Seasonal Median and Detrended

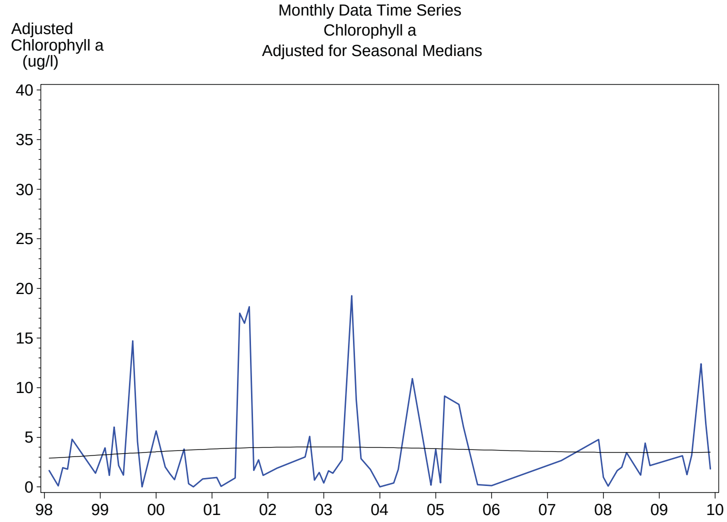


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

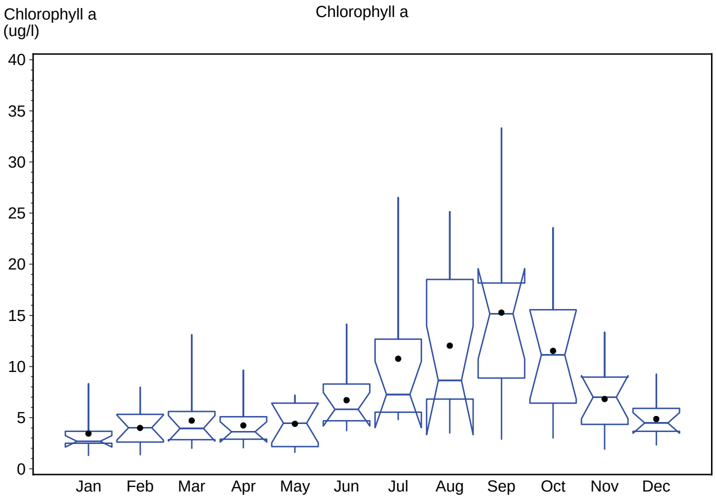
Little Sarasota Bay Trends Appendix - Display 1
Monthly Data Time Series
Chlorophyll a
Not Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 2
Monthly Data Time Series
Chlorophyll a
Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 3
Seasonal Univariate Statistics
Chlorophyll a



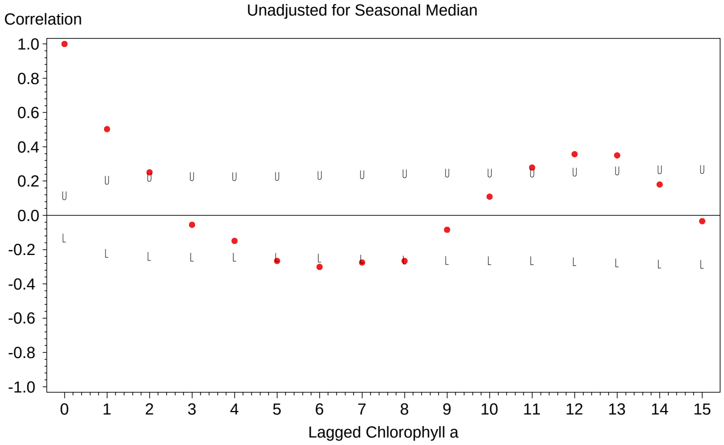
Little Sarasota Bay Trends Appendix - Display 4
Autocorrelation Statistics for Chlorophyll a

Unadjusted for Seasonal Medians

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.503	0.107	0.213	-0.213
2	0.251	0.115	0.231	-0.231
3	-0.055	0.117	0.235	-0.235
4	-0.149	0.117	0.235	-0.235
5	-0.266	0.118	0.236	-0.236
6	-0.301	0.120	0.241	-0.241
7	-0.275	0.123	0.246	-0.246
8	-0.266	0.125	0.251	-0.251
9	-0.084	0.128	0.255	-0.255
10	0.109	0.128	0.256	-0.256
11	0.279	0.128	0.256	-0.256
12	0.357	0.130	0.261	-0.261
13	0.350	0.134	0.268	-0.268
14	0.180	0.138	0.275	-0.275
15	-0.034	0.138	0.277	-0.277

Little Sarasota Bay Trends Appendix - Display 5
Correlogram for Chlorophyll a

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 6
Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.128	0.05	0.151	-0.115

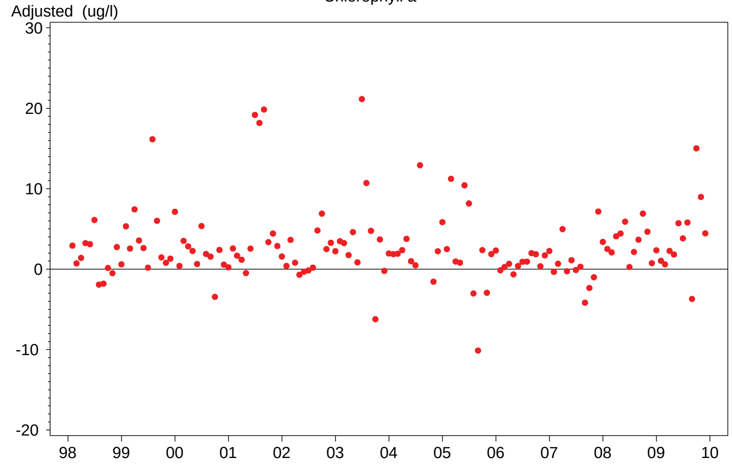
Little Sarasota Bay Trends Appendix - Display 7

Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.1278	0.050474	0.15075	-0.115

Little Sarasota Bay Trends Appendix - Display 8
Time Series Plot of Data Adjusted for Season and Detrended
Chlorophyll a



Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 9

Autocorrelation Statistics for Chlorophyll a

Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.308	0.107	0.213	-0.213
2	0.114	0.110	0.220	-0.220
3	-0.077	0.110	0.221	-0.221
4	0.064	0.111	0.221	-0.221
5	-0.005	0.111	0.221	-0.221
6	-0.041	0.111	0.221	-0.221
7	-0.042	0.111	0.222	-0.222
8	-0.119	0.111	0.222	-0.222
9	-0.058	0.111	0.223	-0.223
10	-0.068	0.111	0.223	-0.223
11	-0.105	0.112	0.223	-0.223
12	-0.087	0.112	0.224	-0.224
13	0.040	0.112	0.224	-0.224

Little Sarasota Bay Trends Appendix - Display 9

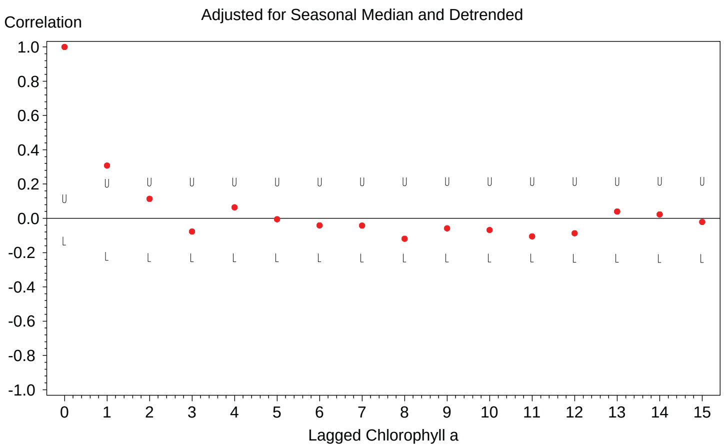
Autocorrelation Statistics for Chlorophyll a

Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
14	0.023	0.112	0.225	-0.225
15	-0.021	0.112	0.225	-0.225

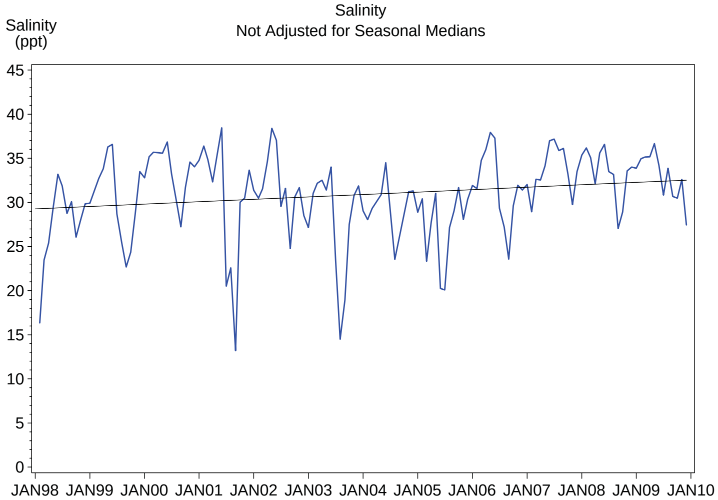
Little Sarasota Bay Trends Appendix - Display 10
Correlogram for Chlorophyll a

Adjusted for Seasonal Median and Detrended

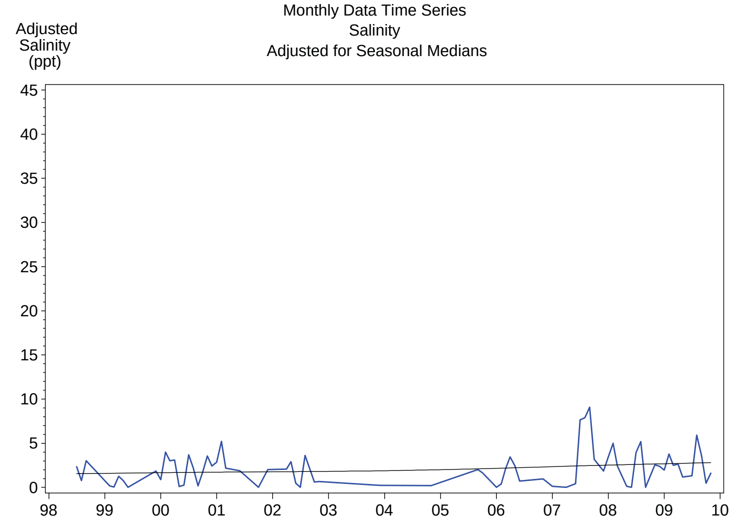


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

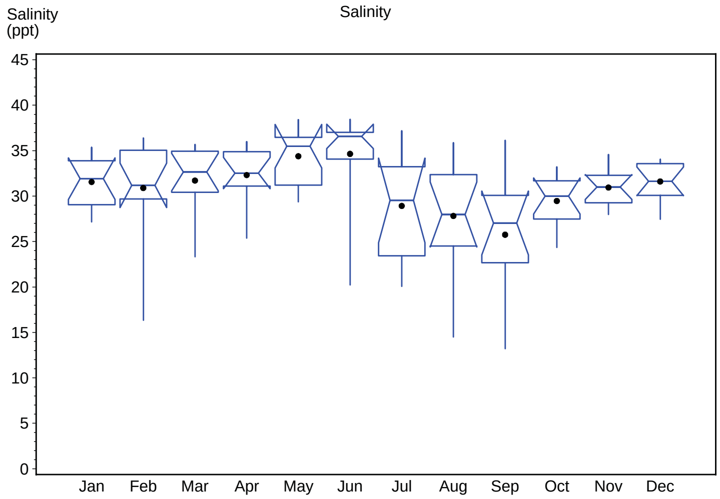
Little Sarasota Bay Trends Appendix - Display 11
Monthly Data Time Series
Salinity
Not Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 12
Monthly Data Time Series
Salinity
Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 13
Seasonal Univariate Statistics
Salinity



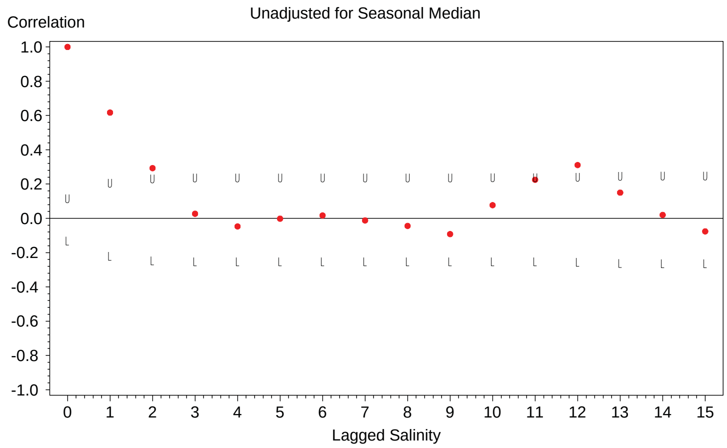
Little Sarasota Bay Trends Appendix - Display 14
Autocorrelation Statistics for Salinity

Unadjusted for Seasonal Medians

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.617	0.107	0.213	-0.213
2	0.293	0.119	0.239	-0.239
3	0.027	0.122	0.244	-0.244
4	-0.047	0.122	0.244	-0.244
5	-0.002	0.122	0.244	-0.244
6	0.017	0.122	0.244	-0.244
7	-0.012	0.122	0.244	-0.244
8	-0.044	0.122	0.244	-0.244
9	-0.092	0.122	0.244	-0.244
10	0.077	0.122	0.245	-0.245
11	0.225	0.123	0.245	-0.245
12	0.311	0.124	0.248	-0.248
13	0.150	0.127	0.254	-0.254
14	0.020	0.128	0.256	-0.256
15	-0.076	0.128	0.256	-0.256

Little Sarasota Bay Trends Appendix - Display 15
Correlogram for Salinity

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 16
Seasonal Kendall Tau Trend Test Statistics
Salinity

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.163	0.013	0.236	0.217

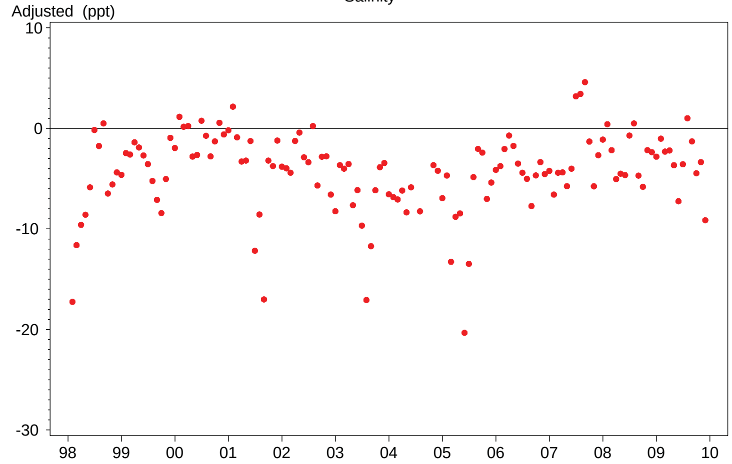
Little Sarasota Bay Trends Appendix - Display 17

Seasonal Kendall Tau Trend Test Statistics
Salinity

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.16310	0.012735	0.23566	0.21667

Little Sarasota Bay Trends Appendix - Display 18
Time Series Plot of Data Adjusted for Season and Detrended
Salinity



Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 19

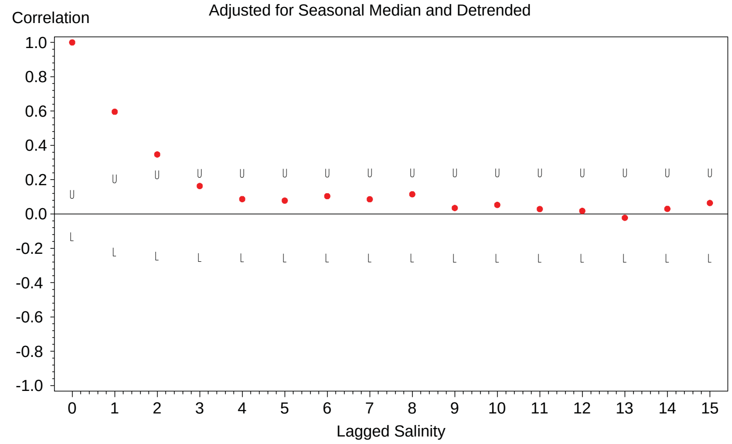
Autocorrelation Statistics for Salinity

Adjusted for Seasonal Median and Detrended

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.596	0.107	0.213	-0.213
2	0.347	0.119	0.237	-0.237
3	0.163	0.122	0.245	-0.245
4	0.087	0.123	0.246	-0.246
5	0.078	0.123	0.247	-0.247
6	0.104	0.124	0.247	-0.247
7	0.086	0.124	0.248	-0.248
8	0.115	0.124	0.248	-0.248
9	0.035	0.125	0.249	-0.249
10	0.053	0.125	0.249	-0.249
11	0.029	0.125	0.249	-0.249
12	0.018	0.125	0.249	-0.249
13	-0.022	0.125	0.249	-0.249
14	0.030	0.125	0.249	-0.249
15	0.064	0.125	0.249	-0.249

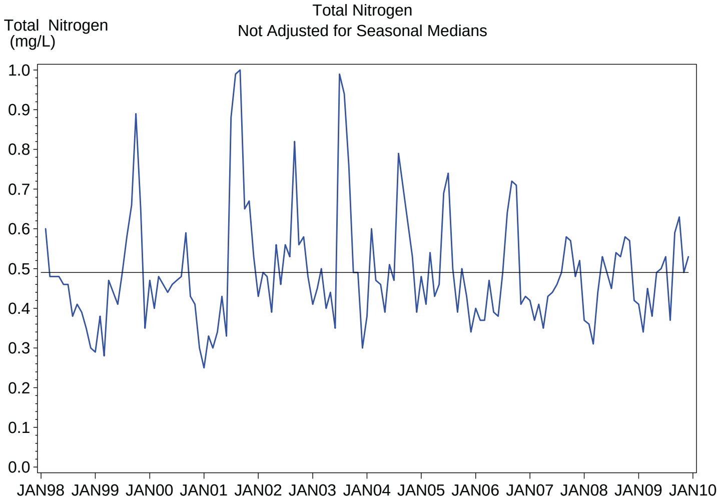
Little Sarasota Bay Trends Appendix - Display 20
Correlogram for Salinity

Adjusted for Seasonal Median and Detrended

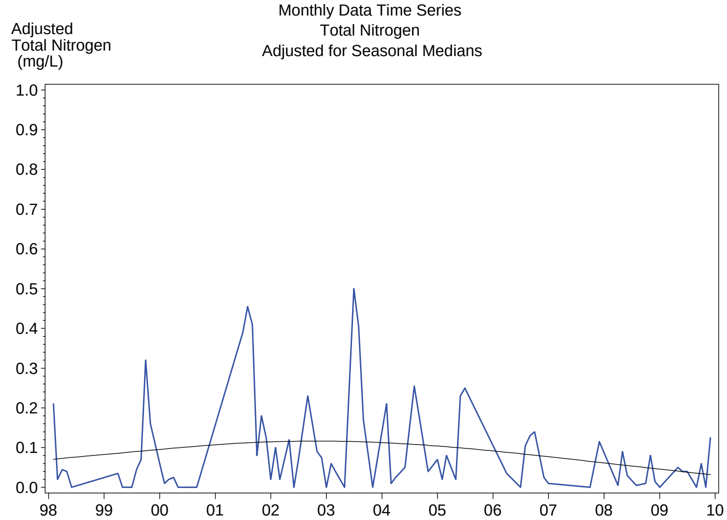


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

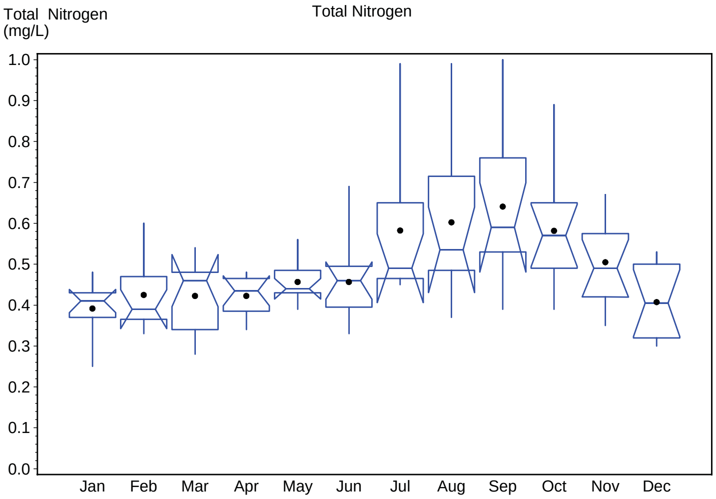
Little Sarasota Bay Trends Appendix - Display 21
Monthly Data Time Series
Total Nitrogen
Not Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 22
Monthly Data Time Series
Total Nitrogen
Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 23
Seasonal Univariate Statistics
Total Nitrogen



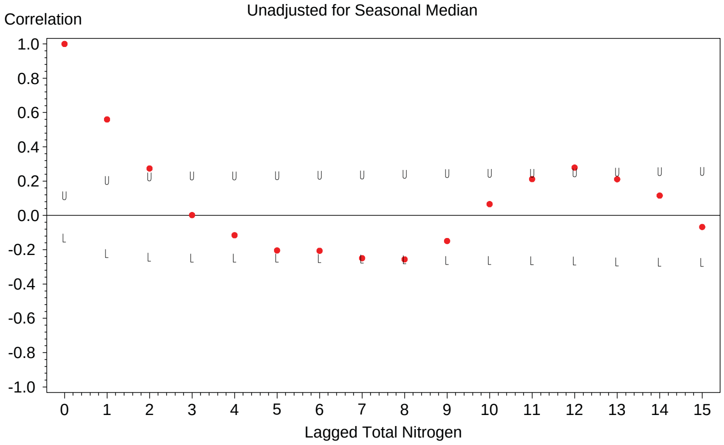
Little Sarasota Bay Trends Appendix - Display 24
Autocorrelation Statistics for Total Nitrogen

Unadjusted for Seasonal Medians

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.560	0.107	0.213	-0.213
2	0.274	0.117	0.234	-0.234
3	0.002	0.120	0.239	-0.239
4	-0.115	0.120	0.239	-0.239
5	-0.204	0.120	0.240	-0.240
6	-0.206	0.121	0.243	-0.243
7	-0.249	0.123	0.245	-0.245
8	-0.256	0.125	0.249	-0.249
9	-0.149	0.127	0.253	-0.253
10	0.066	0.127	0.254	-0.254
11	0.212	0.127	0.255	-0.255
12	0.279	0.129	0.257	-0.257
13	0.211	0.131	0.262	-0.262
14	0.116	0.132	0.264	-0.264
15	-0.067	0.133	0.265	-0.265

Little Sarasota Bay Trends Appendix - Display 25
Correlogram for Total Nitrogen

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 26
Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.014	0.838	0.82	0

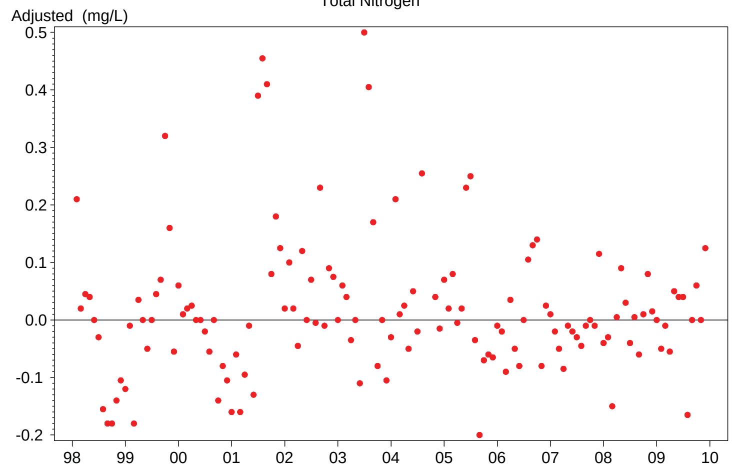
Little Sarasota Bay Trends Appendix - Display 27

Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.014493	0.83760	0.82029	0

Little Sarasota Bay Trends Appendix - Display 28
Time Series Plot of Data Adjusted for Season and Detrended
Total Nitrogen



Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 29

Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.446	0.107	0.213	-0.213
2	0.216	0.113	0.227	-0.227
3	0.048	0.115	0.230	-0.230
4	0.020	0.115	0.230	-0.230
5	0.028	0.115	0.230	-0.230
6	0.039	0.115	0.230	-0.230
7	-0.031	0.115	0.230	-0.230
8	-0.151	0.115	0.230	-0.230
9	-0.137	0.116	0.232	-0.232
10	-0.068	0.117	0.233	-0.233
11	-0.068	0.117	0.233	-0.233
12	-0.029	0.117	0.234	-0.234
13	-0.068	0.117	0.234	-0.234

Little Sarasota Bay Trends Appendix - Display 29

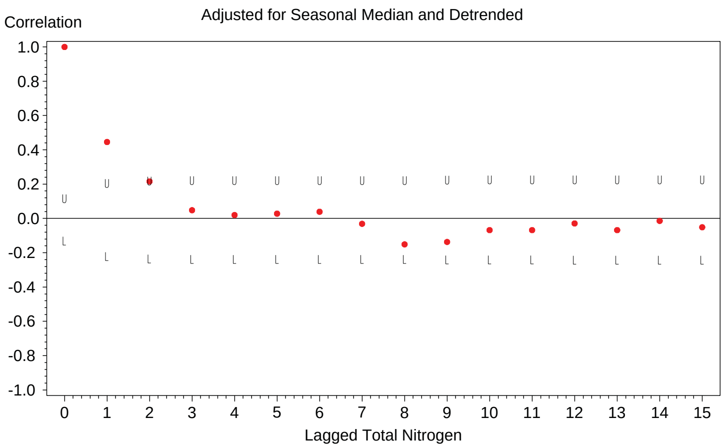
Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
14	-0.014	0.117	0.234	-0.234
15	-0.051	0.117	0.234	-0.234

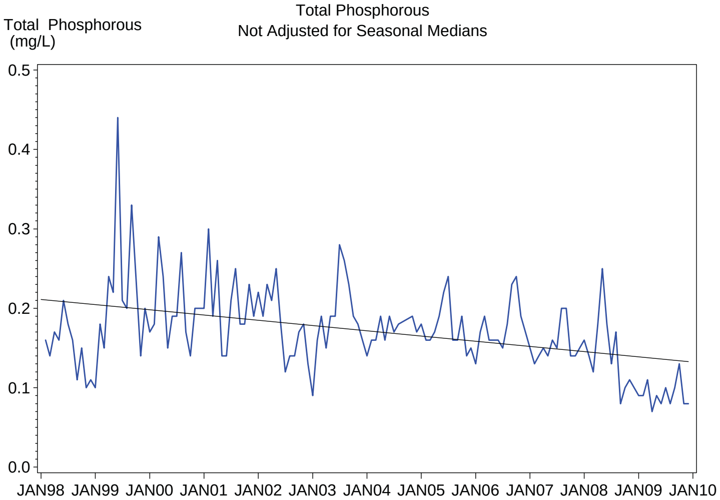
Little Sarasota Bay Trends Appendix - Display 30
Correlogram for Total Nitrogen

Adjusted for Seasonal Median and Detrended

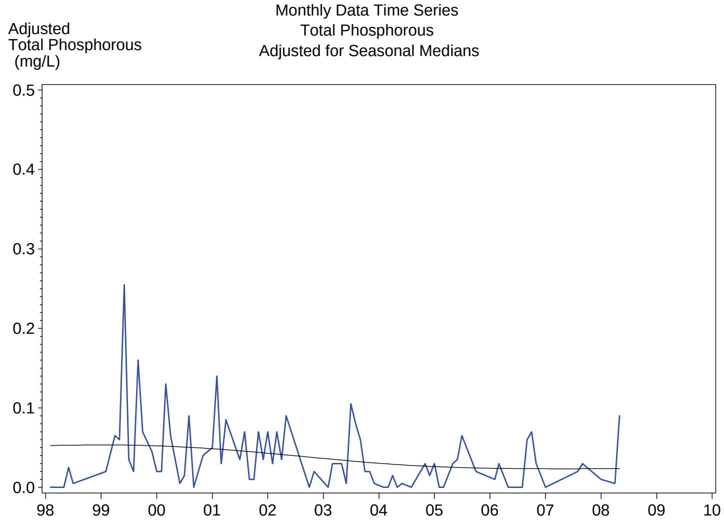


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

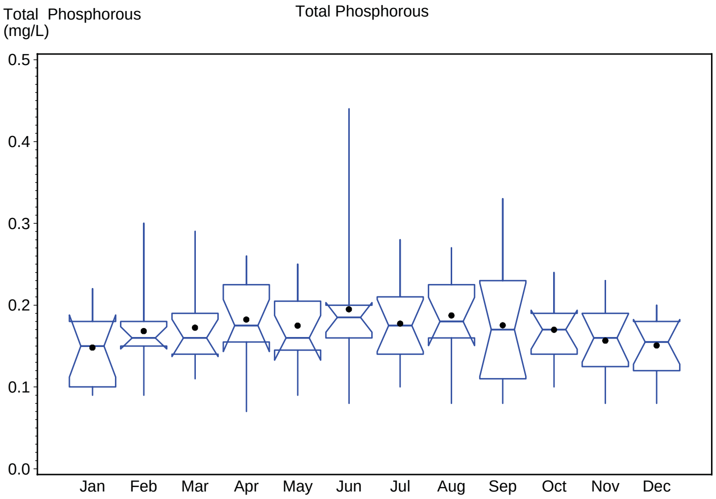
Little Sarasota Bay Trends Appendix - Display 31
Monthly Data Time Series
Total Phosphorous
Not Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 32
Monthly Data Time Series
Total Phosphorous
Adjusted for Seasonal Medians



Little Sarasota Bay Trends Appendix - Display 33
Seasonal Univariate Statistics
Total Phosphorous



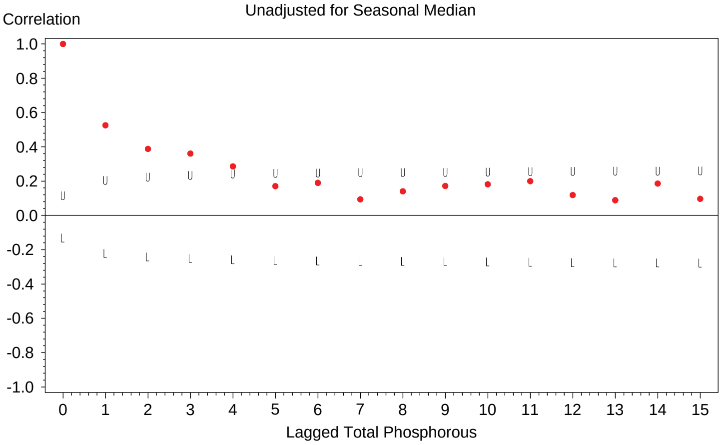
Little Sarasota Bay Trends Appendix - Display 34
Autocorrelation Statistics for Total Phosphorous

Unadjusted for Seasonal Medians

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.526	0.107	0.213	-0.213
2	0.388	0.116	0.232	-0.232
3	0.361	0.121	0.242	-0.242
4	0.286	0.125	0.250	-0.250
5	0.171	0.127	0.255	-0.255
6	0.190	0.128	0.256	-0.256
7	0.094	0.129	0.259	-0.259
8	0.141	0.130	0.259	-0.259
9	0.172	0.130	0.260	-0.260
10	0.182	0.131	0.262	-0.262
11	0.200	0.132	0.264	-0.264
12	0.119	0.133	0.266	-0.266
13	0.089	0.133	0.267	-0.267
14	0.186	0.134	0.267	-0.267
15	0.097	0.135	0.269	-0.269

Little Sarasota Bay Trends Appendix - Display 35
Correlogram for Total Phosphorous

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 36
Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.325	0	0.022	-.007

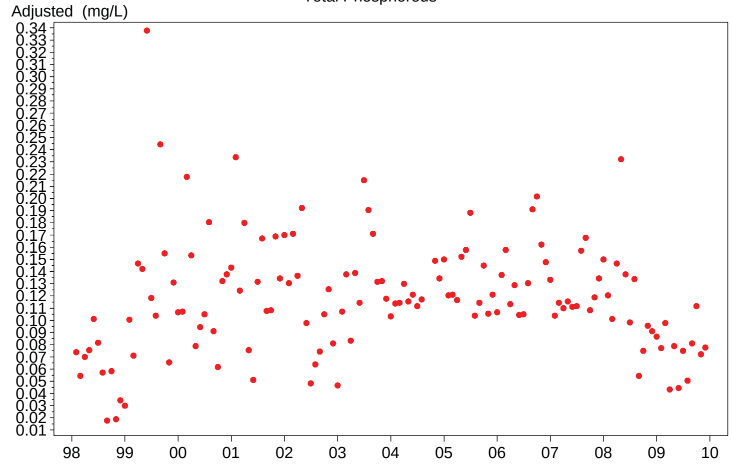
Little Sarasota Bay Trends Appendix - Display 37

Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.32543	.000000432	0.022159	-.00666667

Little Sarasota Bay Trends Appendix - Display 38
Time Series Plot of Data Adjusted for Season and Detrended
Total Phosphorous



Zero Reference Line Shown

Little Sarasota Bay Trends Appendix - Display 39

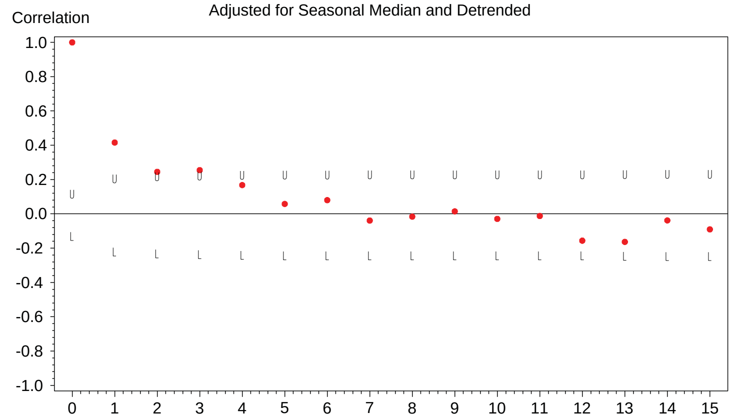
Autocorrelation Statistics for Total Phosphorous

Adjusted for Seasonal Median and Detrended

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.416	0.107	0.213	-0.213
2	0.245	0.113	0.225	-0.225
3	0.255	0.115	0.229	-0.229
4	0.168	0.117	0.233	-0.233
5	0.058	0.118	0.235	-0.235
6	0.080	0.118	0.235	-0.235
7	-0.039	0.118	0.236	-0.236
8	-0.016	0.118	0.236	-0.236
9	0.015	0.118	0.236	-0.236
10	-0.029	0.118	0.236	-0.236
11	-0.012	0.118	0.236	-0.236
12	-0.156	0.118	0.236	-0.236
13	-0.163	0.119	0.238	-0.238
14	-0.038	0.120	0.239	-0.239
15	-0.090	0.120	0.239	-0.239

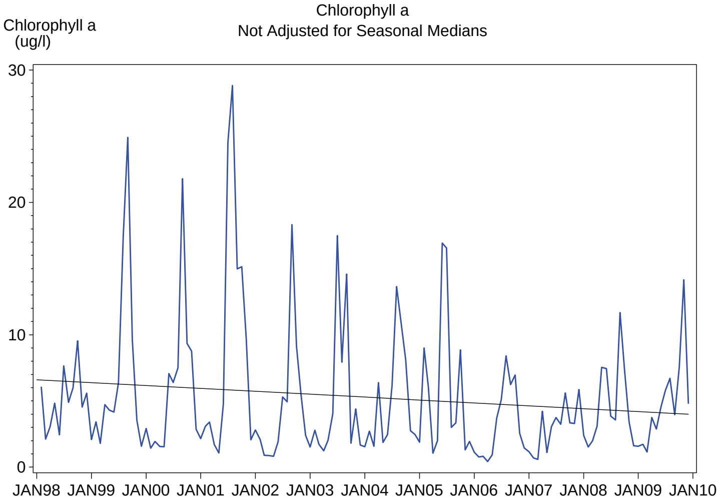
Little Sarasota Bay Trends Appendix - Display 40
Correlogram for Total Phosphorous

Adjusted for Seasonal Median and Detrended

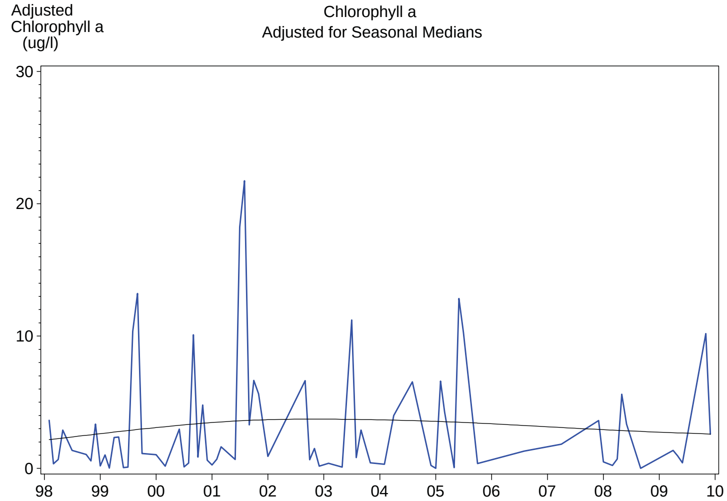


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

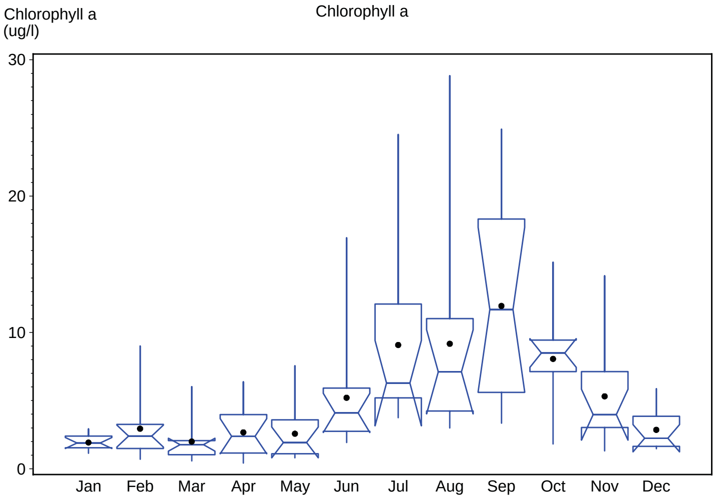
Blackburn Bay Trends Appendix - Display 1
Monthly Data Time Series
Chlorophyll a
Not Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 2
Monthly Data Time Series
Chlorophyll a
Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 3
Seasonal Univariate Statistics
Chlorophyll a



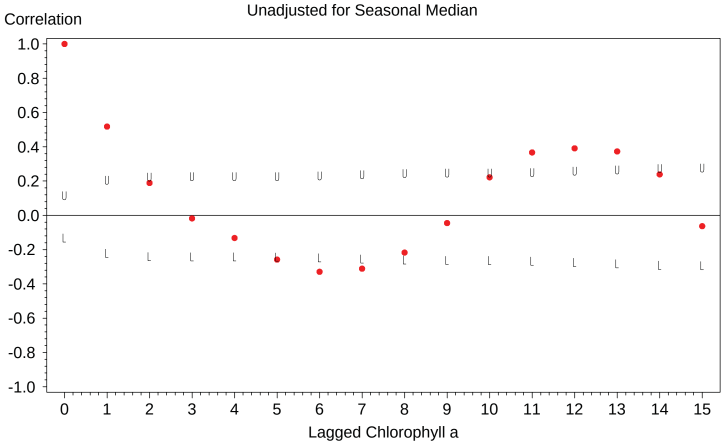
Blackburn Bay Trends Appendix - Display 4
Autocorrelation Statistics for Chlorophyll a

Unadjusted for Seasonal Medians

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.518	0.107	0.213	-0.213
2	0.189	0.116	0.232	-0.232
3	-0.018	0.117	0.234	-0.234
4	-0.132	0.117	0.234	-0.234
5	-0.258	0.117	0.235	-0.235
6	-0.329	0.120	0.239	-0.239
7	-0.311	0.123	0.246	-0.246
8	-0.217	0.126	0.252	-0.252
9	-0.045	0.127	0.255	-0.255
10	0.222	0.127	0.255	-0.255
11	0.367	0.129	0.258	-0.258
12	0.391	0.133	0.266	-0.266
13	0.373	0.137	0.274	-0.274
14	0.239	0.141	0.282	-0.282
15	-0.063	0.142	0.285	-0.285

Blackburn Bay Trends Appendix - Display 5
Correlogram for Chlorophyll a

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 6
Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.229	0	0.037	-0.141

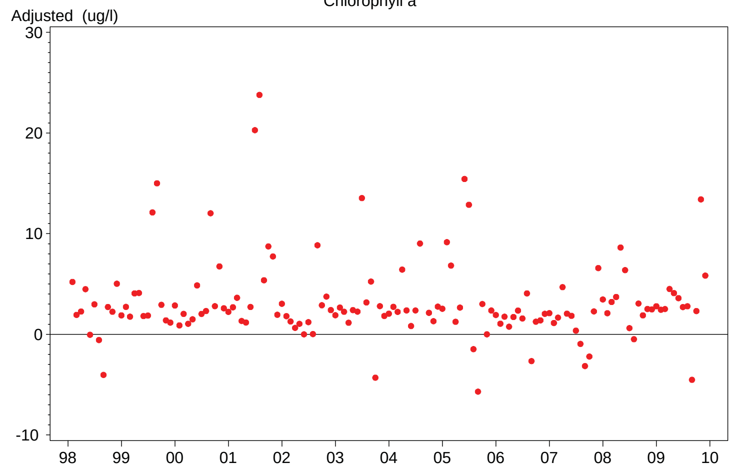
Blackburn Bay Trends Appendix - Display 7

Seasonal Kendall Tau Trend Test Statistics
Chlorophyll a

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.22857	.000414614	0.037203	-0.14143

Blackburn Bay Trends Appendix - Display 8
Time Series Plot of Data Adjusted for Season and Detrended
Chlorophyll a



Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 9

Autocorrelation Statistics for Chlorophyll a

Adjusted for Seasonal Median and Detrended

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.350	0.107	0.213	-0.213
2	-0.021	0.111	0.222	-0.222
3	-0.040	0.111	0.222	-0.222
4	0.051	0.111	0.222	-0.222
5	-0.001	0.111	0.222	-0.222
6	-0.076	0.111	0.222	-0.222
7	-0.124	0.111	0.222	-0.222
8	-0.079	0.112	0.223	-0.223
9	-0.026	0.112	0.224	-0.224
10	0.107	0.112	0.224	-0.224
11	0.054	0.112	0.225	-0.225
12	-0.028	0.112	0.225	-0.225
13	0.089	0.112	0.225	-0.225

Blackburn Bay Trends Appendix - Display 9

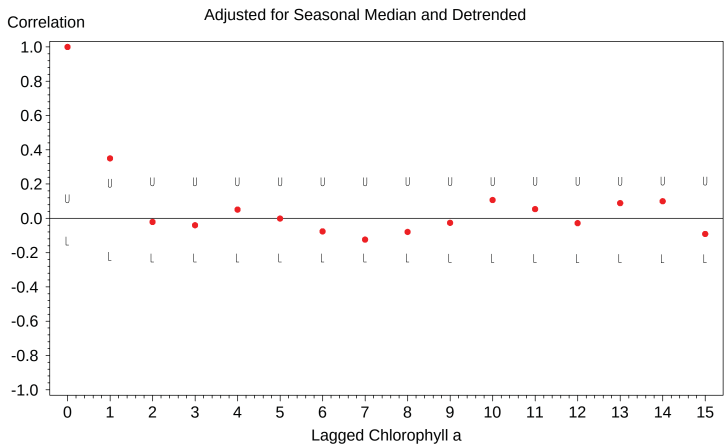
Autocorrelation Statistics for Chlorophyll a

X

Lagged Chlorophyll a	Correlation	Standard Error	Upper Limit	Lower Limit
14	0.100	0.113	0.226	-0.226
15	-0.091	0.113	0.226	-0.226

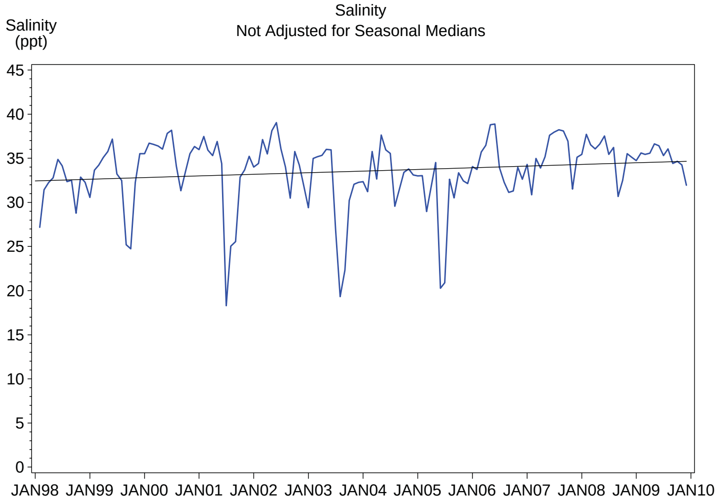
Blackburn Bay Trends Appendix - Display 10
Correlogram for Chlorophyll a

Adjusted for Seasonal Median and Detrended

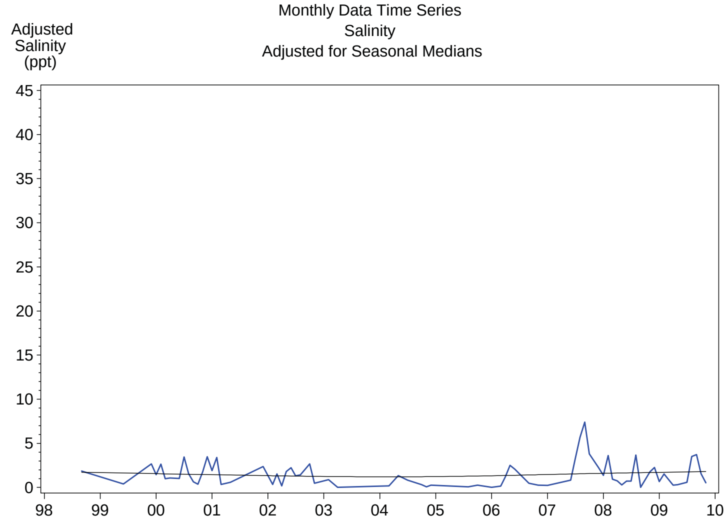


U=Upper 95% Confidence Limit   L=Lower 95% Confidence Limit
Zero Reference Line Shown

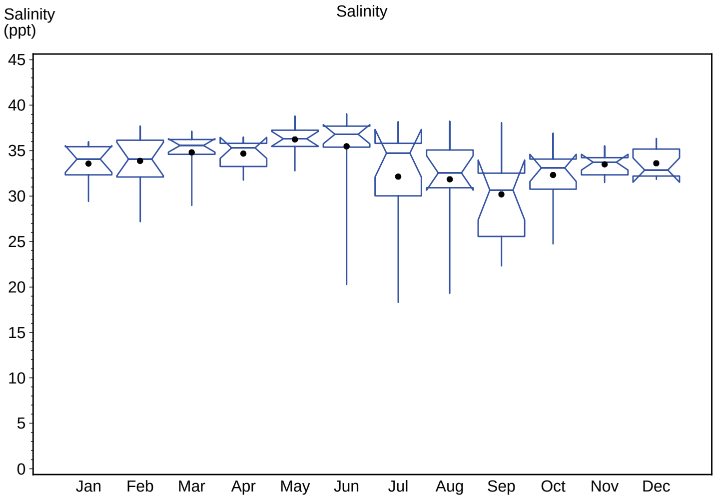
Blackburn Bay Trends Appendix - Display 11
Monthly Data Time Series
Salinity
Not Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 12
Monthly Data Time Series
Salinity
Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 13
Seasonal Univariate Statistics
Salinity



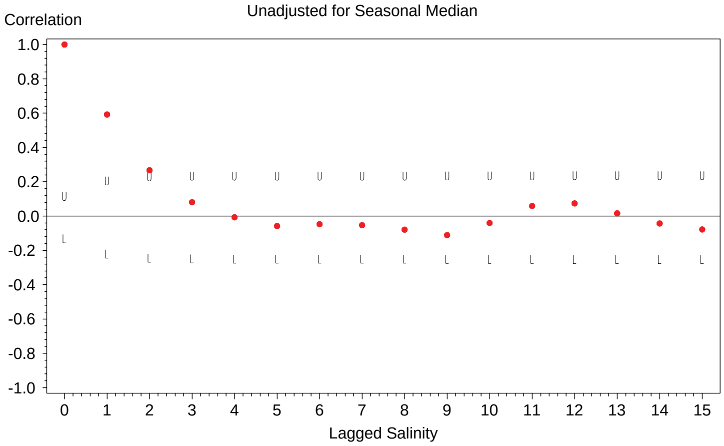
Blackburn Bay Trends Appendix - Display 14
Autocorrelation Statistics for Salinity

Unadjusted for Seasonal Medians

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.592	0.107	0.213	-0.213
2	0.267	0.118	0.237	-0.237
3	0.081	0.121	0.241	-0.241
4	-0.007	0.121	0.242	-0.242
5	-0.058	0.121	0.242	-0.242
6	-0.047	0.121	0.242	-0.242
7	-0.053	0.121	0.242	-0.242
8	-0.079	0.121	0.242	-0.242
9	-0.111	0.121	0.243	-0.243
10	-0.040	0.122	0.243	-0.243
11	0.059	0.122	0.243	-0.243
12	0.074	0.122	0.244	-0.244
13	0.016	0.122	0.244	-0.244
14	-0.043	0.122	0.244	-0.244
15	-0.078	0.122	0.244	-0.244

Blackburn Bay Trends Appendix - Display 15
Correlogram for Salinity

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 16
Seasonal Kendall Tau Trend Test Statistics
Salinity

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.147	0.024	0.284	0.123

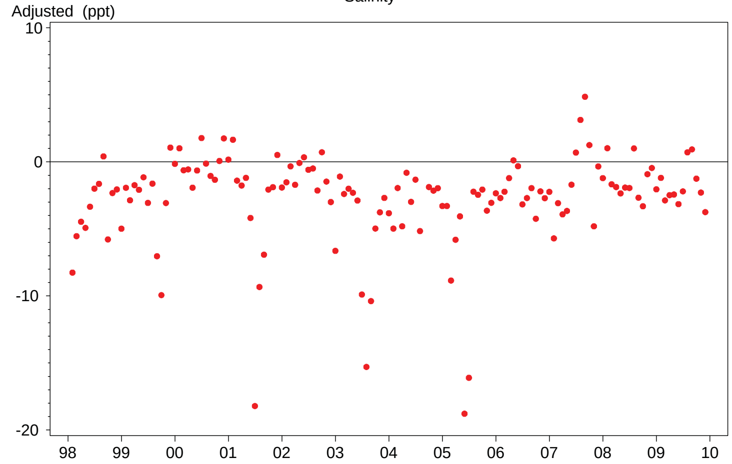
Blackburn Bay Trends Appendix - Display 17

Seasonal Kendall Tau Trend Test Statistics
Salinity

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.14675	0.023813	0.28355	0.12313

Blackburn Bay Trends Appendix - Display 18
Time Series Plot of Data Adjusted for Season and Detrended
Salinity



Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 19

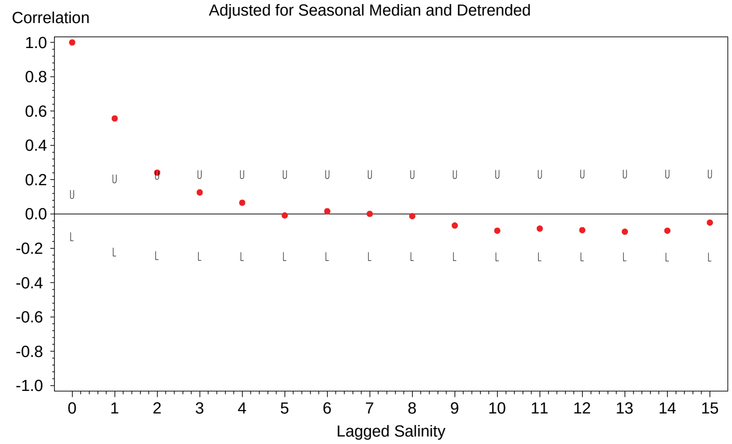
Autocorrelation Statistics for Salinity

Adjusted for Seasonal Median and Detrended

Lagged Salinity	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.557	0.107	0.213	-0.213
2	0.241	0.117	0.234	-0.234
3	0.126	0.119	0.238	-0.238
4	0.066	0.119	0.239	-0.239
5	-0.008	0.120	0.239	-0.239
6	0.016	0.120	0.239	-0.239
7	0.001	0.120	0.239	-0.239
8	-0.012	0.120	0.239	-0.239
9	-0.067	0.120	0.239	-0.239
10	-0.097	0.120	0.240	-0.240
11	-0.085	0.120	0.240	-0.240
12	-0.094	0.120	0.241	-0.241
13	-0.103	0.121	0.241	-0.241
14	-0.097	0.121	0.242	-0.242
15	-0.050	0.121	0.242	-0.242

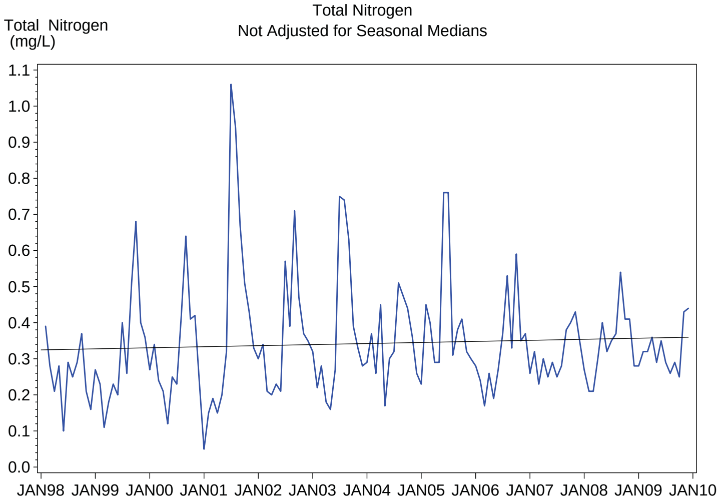
Blackburn Bay Trends Appendix - Display 20
Correlogram for Salinity

Adjusted for Seasonal Median and Detrended

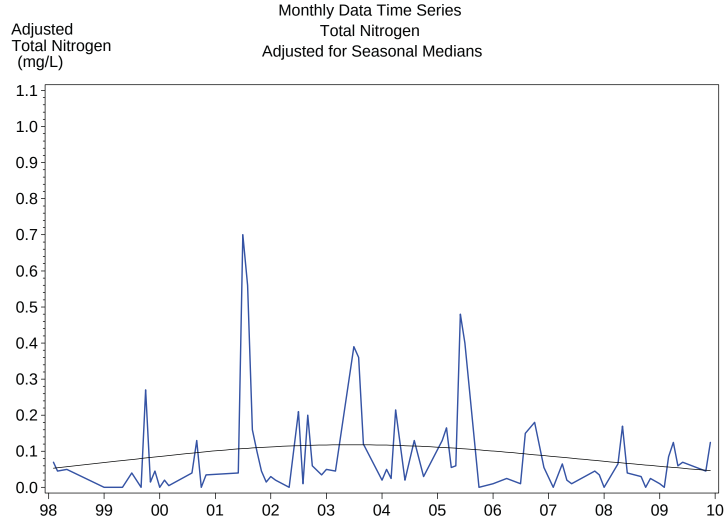


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

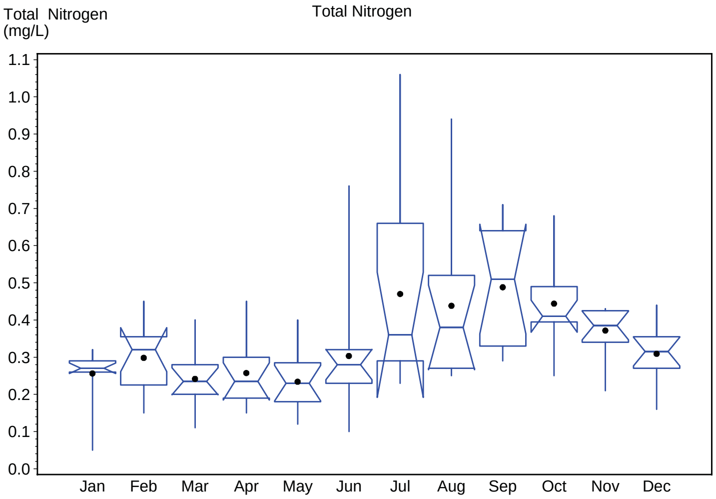
Blackburn Bay Trends Appendix - Display 21
Monthly Data Time Series
Total Nitrogen
Not Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 22
Monthly Data Time Series
Total Nitrogen
Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 23
Seasonal Univariate Statistics
Total Nitrogen



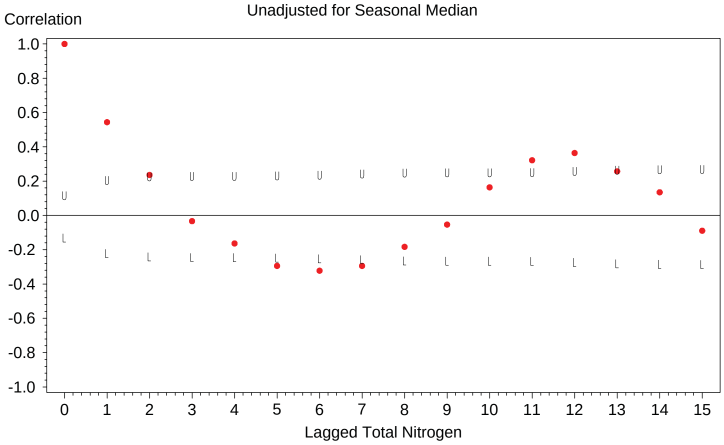
Blackburn Bay Trends Appendix - Display 24
Autocorrelation Statistics for Total Nitrogen

Unadjusted for Seasonal Medians

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.544	0.107	0.213	-0.213
2	0.236	0.117	0.233	-0.233
3	-0.033	0.118	0.237	-0.237
4	-0.163	0.118	0.237	-0.237
5	-0.294	0.119	0.239	-0.239
6	-0.322	0.122	0.244	-0.244
7	-0.294	0.125	0.250	-0.250
8	-0.183	0.128	0.256	-0.256
9	-0.053	0.129	0.258	-0.258
10	0.164	0.129	0.258	-0.258
11	0.322	0.130	0.259	-0.259
12	0.364	0.133	0.265	-0.265
13	0.257	0.136	0.273	-0.273
14	0.135	0.138	0.276	-0.276
15	-0.089	0.139	0.277	-0.277

Blackburn Bay Trends Appendix - Display 25
Correlogram for Total Nitrogen

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 26

Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.126	0.051	0.039	.005

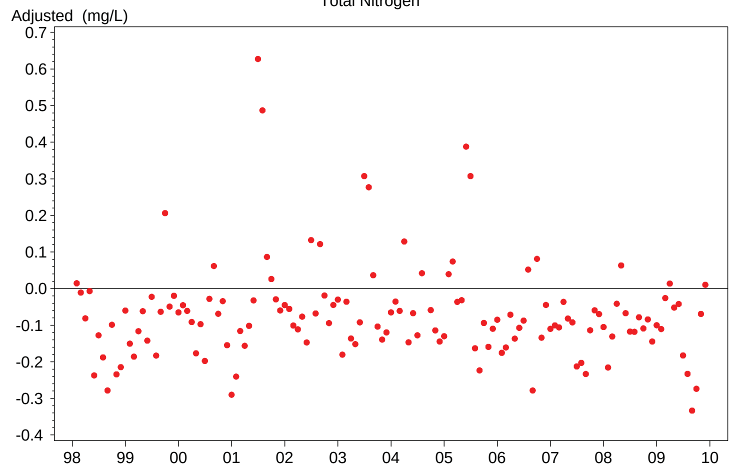
Blackburn Bay Trends Appendix - Display 27

Seasonal Kendall Tau Trend Test Statistics
Total Nitrogen

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
0.12597	0.051368	0.038672	.005

Blackburn Bay Trends Appendix - Display 28
Time Series Plot of Data Adjusted for Season and Detrended
Total Nitrogen



Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 29

Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.450	0.107	0.213	-0.213
2	0.145	0.114	0.227	-0.227
3	-0.008	0.114	0.229	-0.229
4	-0.042	0.114	0.229	-0.229
5	-0.107	0.114	0.229	-0.229
6	-0.090	0.115	0.229	-0.229
7	-0.126	0.115	0.230	-0.230
8	-0.042	0.115	0.231	-0.231
9	-0.006	0.116	0.231	-0.231
10	0.070	0.116	0.231	-0.231
11	0.108	0.116	0.231	-0.231
12	0.100	0.116	0.232	-0.232
13	0.044	0.116	0.233	-0.233

Blackburn Bay Trends Appendix - Display 29

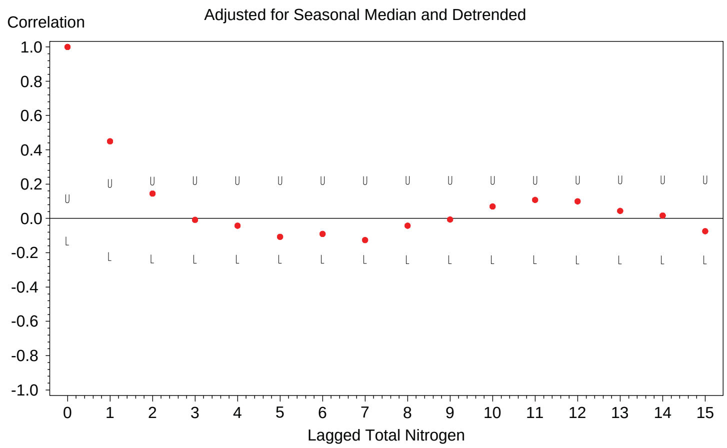
Autocorrelation Statistics for Total Nitrogen

Adjusted for Seasonal Median and Detrended

Lagged Total Nitrogen	Correlation	Standard Error	Upper Limit	Lower Limit
14	0.017	0.116	0.233	-0.233
15	-0.074	0.116	0.233	-0.233

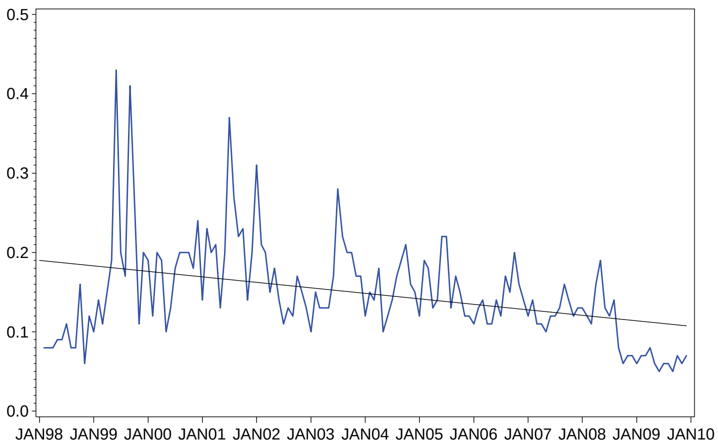
Blackburn Bay Trends Appendix - Display 30
Correlogram for Total Nitrogen

Adjusted for Seasonal Median and Detrended

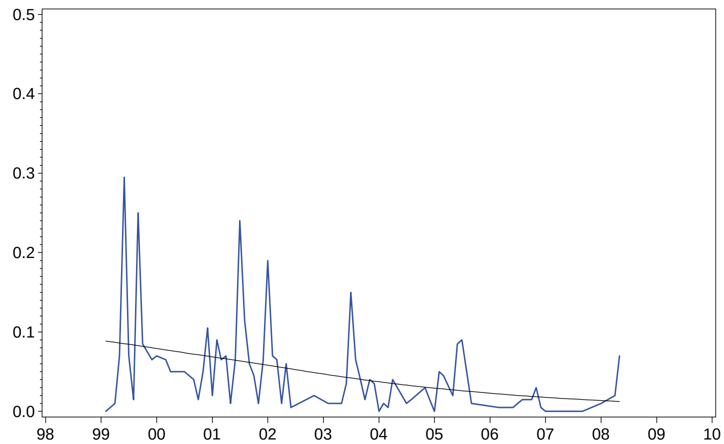


U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

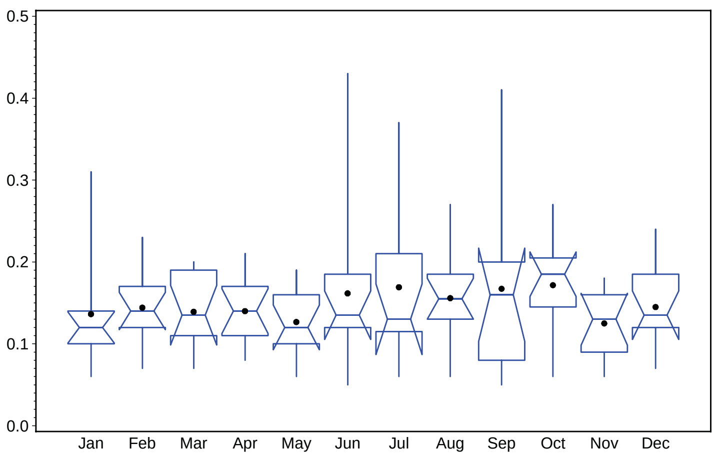
Blackburn Bay Trends Appendix - Display 31
Monthly Data Time Series
Total Phosphorous
Not Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 32
Monthly Data Time Series
Total Phosphorous
Adjusted for Seasonal Medians



Blackburn Bay Trends Appendix - Display 33
Seasonal Univariate Statistics
Total Phosphorous



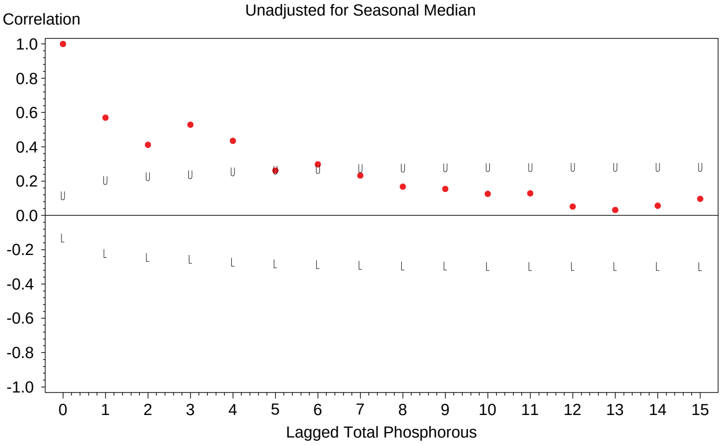
Blackburn Bay Trends Appendix - Display 34
Autocorrelation Statistics for Total Phosphorous

Unadjusted for Seasonal Medians

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.570	0.107	0.213	-0.213
2	0.412	0.118	0.235	-0.235
3	0.529	0.123	0.246	-0.246
4	0.435	0.131	0.263	-0.263
5	0.262	0.137	0.273	-0.273
6	0.298	0.139	0.277	-0.277
7	0.233	0.141	0.282	-0.282
8	0.168	0.142	0.285	-0.285
9	0.155	0.143	0.286	-0.286
10	0.126	0.144	0.288	-0.288
11	0.129	0.144	0.288	-0.288
12	0.052	0.145	0.289	-0.289
13	0.032	0.145	0.289	-0.289
14	0.057	0.145	0.289	-0.289
15	0.097	0.145	0.290	-0.290

Blackburn Bay Trends Appendix - Display 35
Correlogram for Total Phosphorous

Unadjusted for Seasonal Median



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Blackburn Bay Trends Appendix - Display 36
Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Unadjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.283	0	0.082	-.007

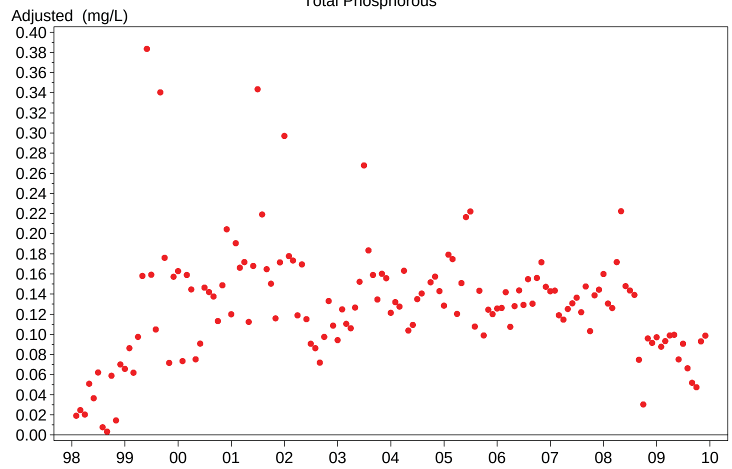
Blackburn Bay Trends Appendix - Display 37

Seasonal Kendall Tau Trend Test Statistics
Total Phosphorous

Adjusted for Seasonal Medians

Tau Statistic	P-Value Without Serial Correlation	P-Value With Serial Correlation	Slope Statistic
-0.28312	.000009705	0.081598	-.00714286

Blackburn Bay Trends Appendix - Display 38
Time Series Plot of Data Adjusted for Season and Detrended
Total Phosphorous



Zero Reference Line Shown

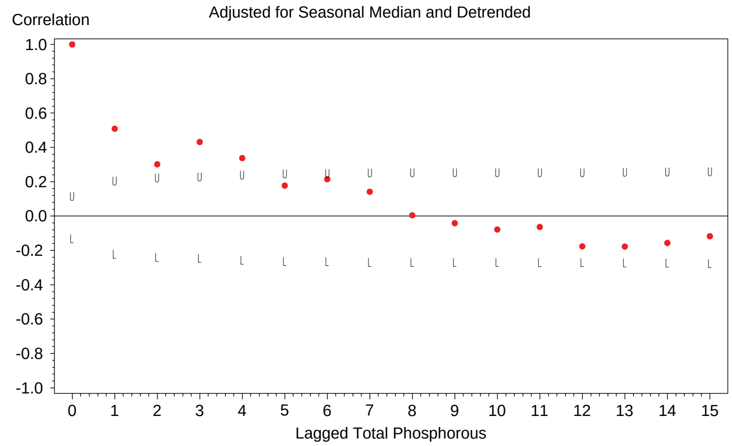
Blackburn Bay Trends Appendix - Display 39
Autocorrelation Statistics for Total Phosphorous

Adjusted for Seasonal Median and Detrended

Lagged Total Phosphorous	Correlation	Standard Error	Upper Limit	Lower Limit
0	1.000	0.062	0.123	-0.123
1	0.509	0.107	0.213	-0.213
2	0.302	0.115	0.231	-0.231
3	0.432	0.118	0.237	-0.237
4	0.338	0.124	0.248	-0.248
5	0.178	0.128	0.255	-0.255
6	0.215	0.129	0.257	-0.257
7	0.142	0.130	0.260	-0.260
8	0.005	0.131	0.261	-0.261
9	-0.041	0.131	0.261	-0.261
10	-0.078	0.131	0.261	-0.261
11	-0.063	0.131	0.262	-0.262
12	-0.176	0.131	0.262	-0.262
13	-0.177	0.132	0.264	-0.264
14	-0.156	0.133	0.265	-0.265
15	-0.117	0.133	0.267	-0.267

Blackburn Bay Trends Appendix - Display 40
Correlogram for Total Phosphorous

Adjusted for Seasonal Median and Detrended



U=Upper 95% Confidence Limit L=Lower 95% Confidence Limit
Zero Reference Line Shown

Appendix 4.

Residence Time Calculations

The method used in this effort is predicated on a well-defined flow path for freshwater beginning at the head of an estuary. For a lagoonal system, it is necessary to define the flow path for freshwater entering the estuary at a given point. For the Sarasota Bay Estuary system, two segment groupings were used to represent separate freshwater flow paths, defined as follows for each grouping (Figure V-9):

- Northern: Palma Sola Bay flows downstream to Sarasota Bay. The northern half of Little Sarasota Bay flows downstream to Roberts Bay, which in turn flows downstream to Sarasota Bay. Sarasota Bay flows downstream to the Gulf of Mexico.

- Southern: Southern half of Little Sarasota Bay flows downstream to Blackburn Bay. Blackburn Bay flows downstream to Dona and Roberts Bay.

For each of the segments in these groupings, non-advective transports were estimated based on observed salinity. Exchange coefficients for non-advective transport were estimated using mean water column salinity data, obtained from the FDEP IWR database. The algorithm for exchange coefficients estimation was based on the salinity mass balance equations developed for each segment of the Sarasota Bay Estuary system. The salinity mass balance equations are provided below for each segment, based on the assumption that for a given month, the mass of salinity coming into the segment is balanced by the mass of salinity leaving the segment. Here, as in Figure 1, Q is the freshwater inflow to the segment from its watershed, C is the salinity in the segment, and E is the non-advective exchange rate between two segments.

Northern Grouping
Palma Sola Bay:
$0 = -Q_{PSB}C_{PSB} + E_{SB,PSB}(C_{SB}-C_{PSB})$

Little Sarasota Bay North:
$0 = -0.5Q_{LSB}C_{LSB} + E_{RB,LSB}(C_{RB}-C_{LSB})$

Roberts Bay:
$0 = -(0.5Q_{LSB}+Q_{RB})C_{RB} + 0.5Q_{LSB}C_{LSB} + E_{SB,RB}(C_{SB}-C_{RB}) - E_{RB,LSB}(C_{RB}-C_{LSB})$

Sarasota Bay:
$$0 = -(0.5Q_{LSB}+Q_{RB}+Q_{SB}+Q_{PSB})C_{SB} + (0.5Q_{LSB}+Q_{RB})C_{RB} + Q_{PSB}C_{PSB} - E_{SB,RB}(C_{SB}-C_{RB}) - E_{SB,PSB}(C_{SB}-C_{PSB}) + E_{GOM,SB}(C_{GOM}-C_{SB})$$

Southern Grouping
Little Sarasota Bay South:
$0 = -0.5Q_{LSB}C_{LSB} + E_{BB,LSB}(C_{BB}-C_{LSB})$

Blackburn Bay:
$0 = -(0.5Q_{LSB}+Q_{BB})C_{BB} + 0.5Q_{LSB}C_{LSB} - E_{BB,LSB}(C_{BB}-C_{LSB}) + E_{DARB,BB}(C_{DARB}-C_{BB})$

For the northern grouping, there are four equations and four unknowns, so that the equations can be solved for the non-advective exchange rates (E-values) as follows:

Sarasota Bay/Palma Sola Bay:
$E_{SB,PSB} = Q_{PSB}C_{PSB}/(C_{SB}-C_{PSB})$

Roberts Bay/Little Sarasota Bay North:
$E_{RB,LSB} = 0.5Q_{LSB}C_{LSB}/(C_{RB}-C_{LSB})$

Sarasota Bay/Roberts Bay:
$E_{SB,RB} = (0.5Q_{LSB} + Q_{RB})C_{RB}/(C_{SB}-C_{RB})$

Gulf of Mexico/Sarasota Bay:
$E_{GOM,SB} = (0.5Q_{LSB} + Q_{RB} + Q_{SB} + Q_{PSB})C_{SB}/(C_{GOM}-C_{SB})$

For the southern grouping, there are two equations and two unknowns, so that the equations can be solved for the non-advective exchange rates (E-values) as follows:

Blackburn Bay/Little Sarasota Bay South:
$E_{BB,LSB} = 0.5Q_{LSB}C_{LSB}/(C_{BB}-C_{LSB})$

Dona and Roberts Bay/Blackburn Bay:
$E_{DARB,BB} = (0.5Q_{LSB} + Q_{BB})C_{BB}/(C_{DARB}-C_{BB})$

Monthly exchange coefficients were calculated using hydrologic loading data and salinity concentration data for 1994-2007. The median exchange coefficients over all months for a given boundary were determined, and used for calculation of the PRTs, described below.

Equations for dilution of a simulated conservative tracer were developed based on the methods of Hagy et al. (2000). The PRT was defined as the length of time required to reduce the mass of a tracer in a given segment to e^{-1} times the initial mass. This calculation was performed using the monthly inflows for each month of the 1994-2007 period, so that a segment-specific PRT was calculated for each month's inflows.

The box model equations for mass balance provided above were used to estimate the change in mass of tracer (ΔM) present in each box (segment) of the model for relatively small time increments ($\Delta t = 1$ hour). The equation for Palma Sola Bay is provided below:

Palma Sola Bay:
$\Delta M_{PSB} = -Q_{PSB}C_{PSB}\Delta t + E_{SB,PSB}(C_{SB}-C_{PSB})\Delta t,$

with C_{PSB} and C_{SB} updated after each time step until the mass of the tracer in Palma Sola Bay declines to e^{-1} of its original value. Similar equations were used for each of the segments, modifying the mass balance equations provided above to provide tracking of conservative tracer masses in each segment. For the boundary conditions, the salinity values in the Gulf of Mexico and Dona and Roberts Bay were set to 36 ppt, and the tracer mass was set to 0.

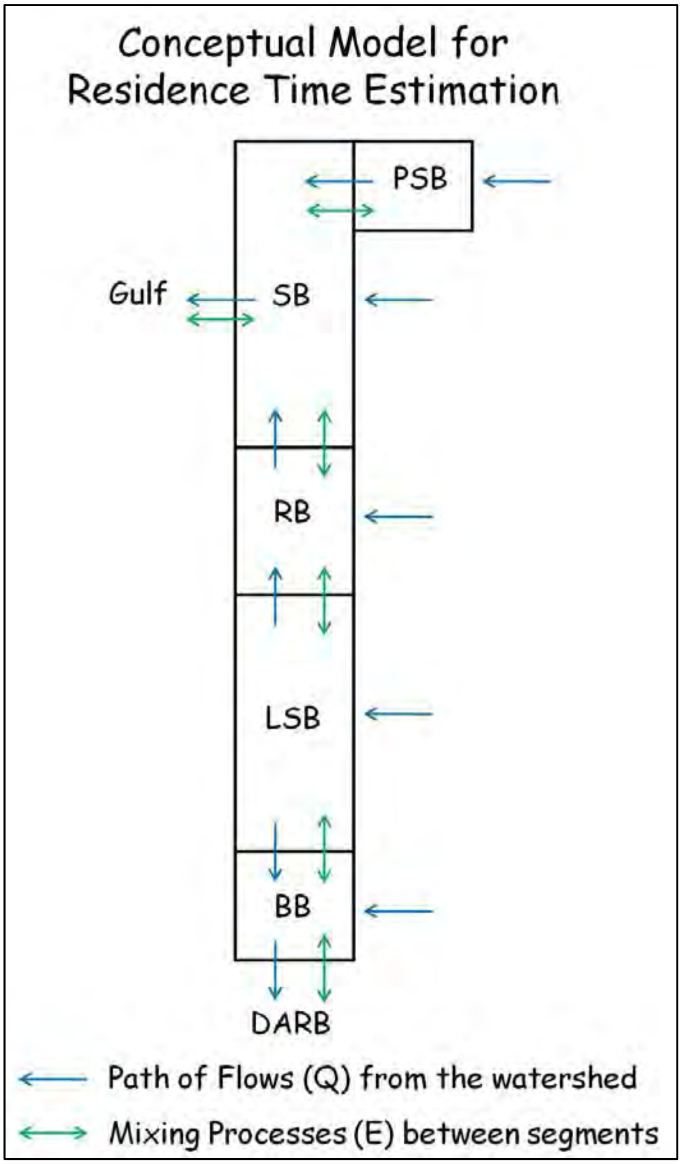
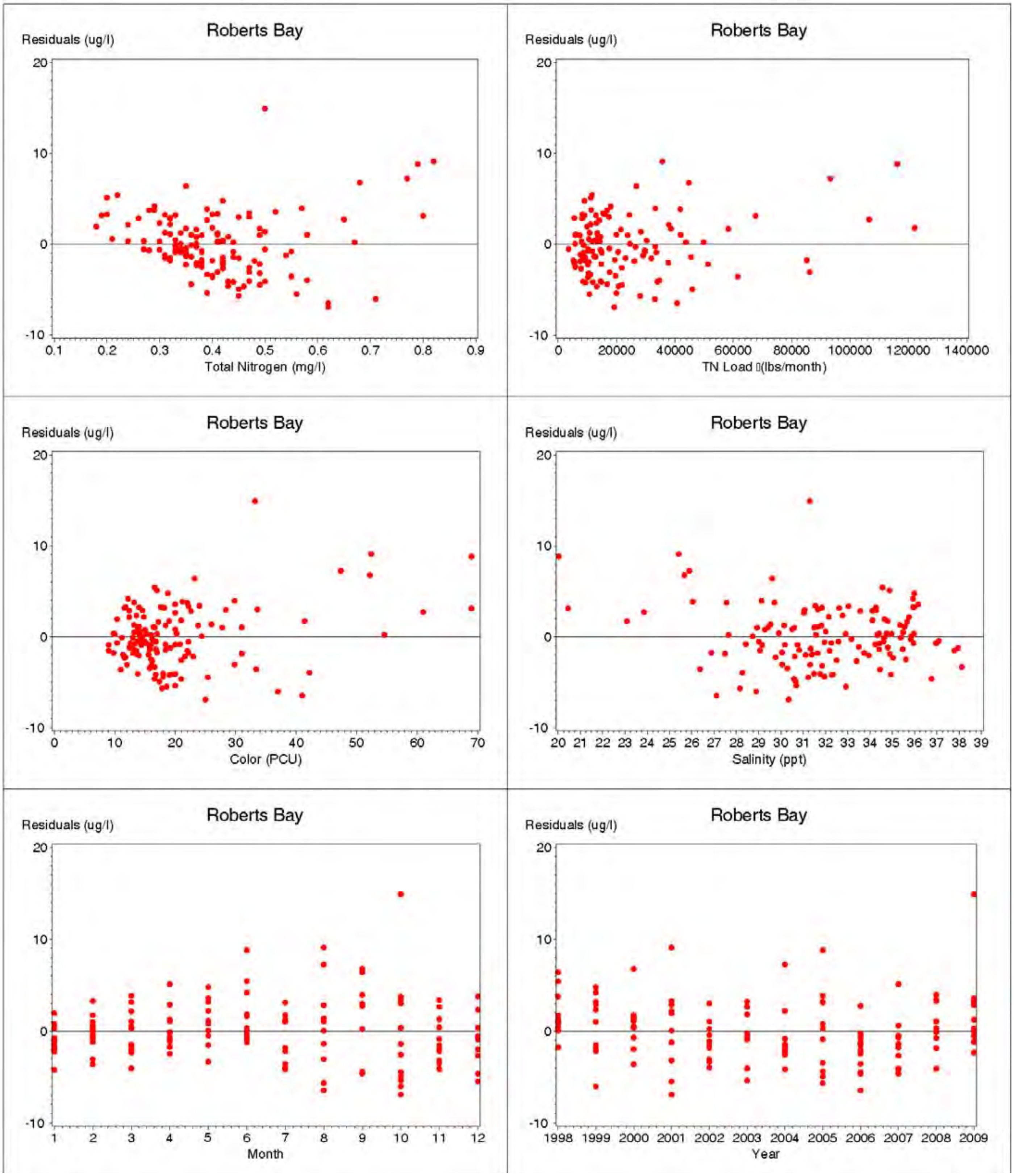


Figure 2-1. Box model schematic for Sarasota Bay Estuary Program. PSB - Palma Sola Bay; SB - Sarasota Bay; RB - Roberts Bay; LSB - Little Sarasota Bay; BB - Blackburn Bay; DARB – Dona and Roberts Bay.

Appendix 5.
Regression Analysis Results


Roberts Bay
Residuals (ug/l)
20
10
0
-10
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Total Nitrogen (mg/l)
Roberts Bay
Residuals (ug/l)
20
10
0
-10
0 20000 40000 60000 80000 100000 120000 140000
TN Load (lbs/month)
Roberts Bay
Residuals (ug/l)
20
10
0
-10
0 10 20 30 40 50 60 70
Color (PCU)
Roberts Bay
Residuals (ug/l)
20
10
0
-10
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39
Salinity (ppt)
Roberts Bay
Residuals (ug/l)
20
10
0
-10
1 2 3 4 5 6 7 8 9 10 11 12
Month
Roberts Bay
Residuals (ug/l)
20
10
0
-10
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Year

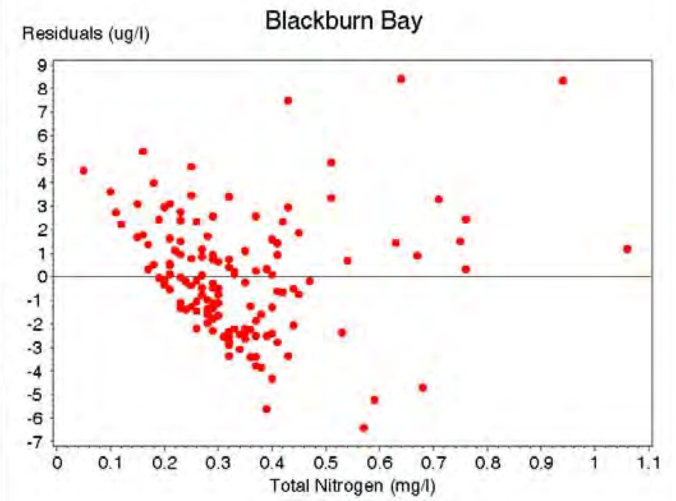
Roberts Bay

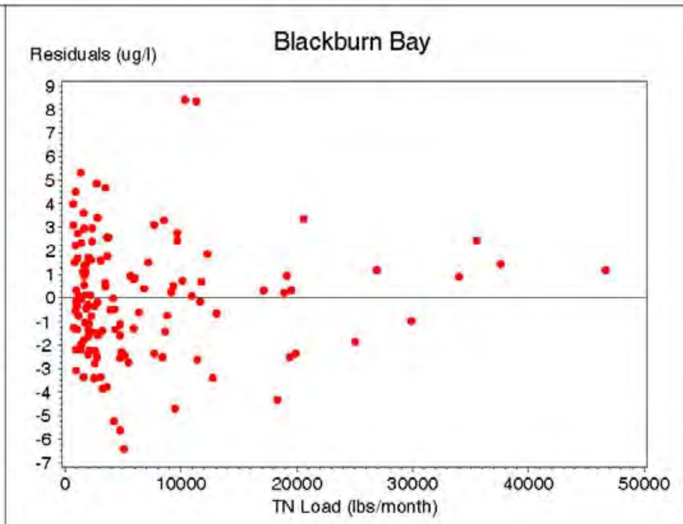
The REG Procedure
Model: MODEL1
Dependent Variable: CHLA Observed Chlorophyll a (ug/l)

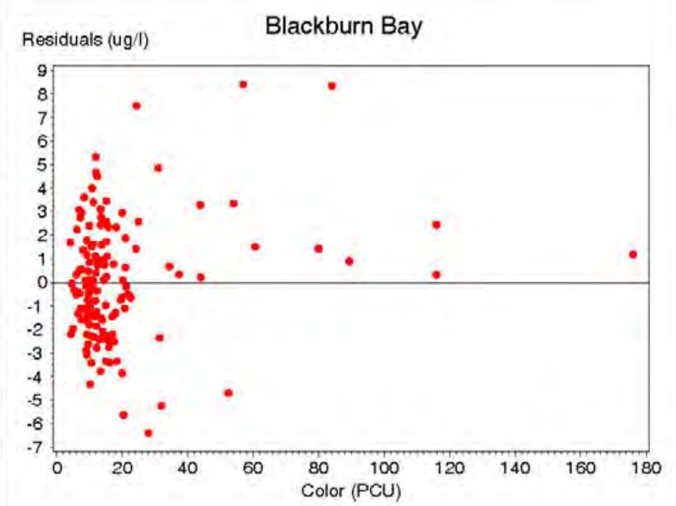
Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	2396.41915	1198.20957	104.07	<.0001
Error	130	1496.69700	11.51305		
Corrected Total	132	3893.11614			

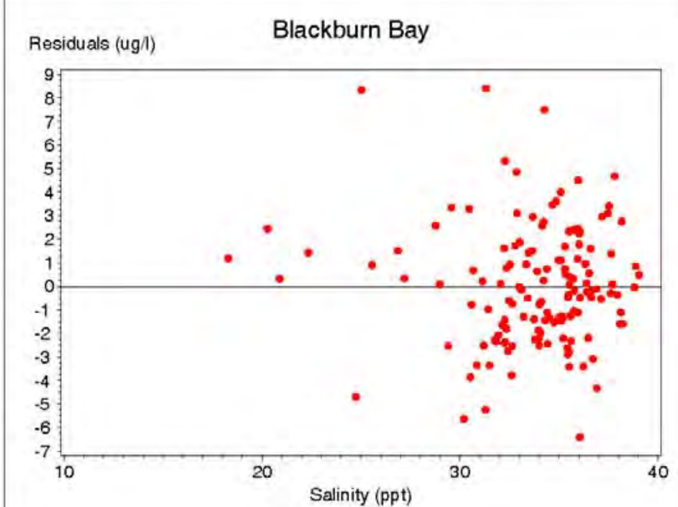
Root MSE	3.39309	**R-Square**	0.6156
Dependent Mean	6.40383	**Adj R-Sq**	0.6096
Coeff Var	52.98527		

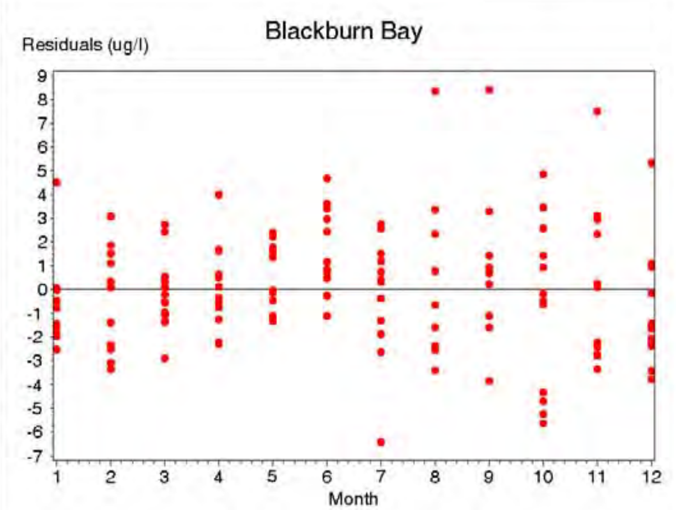
Parameter Estimates						
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	Intercept	1	-5.73163	1.09583	-5.23	<.0001
TN	Total Nitrogen (mg/l)	1	27.06822	2.78787	9.71	<.0001
season	Season	1	3.40907	0.73278	4.65	<.0001

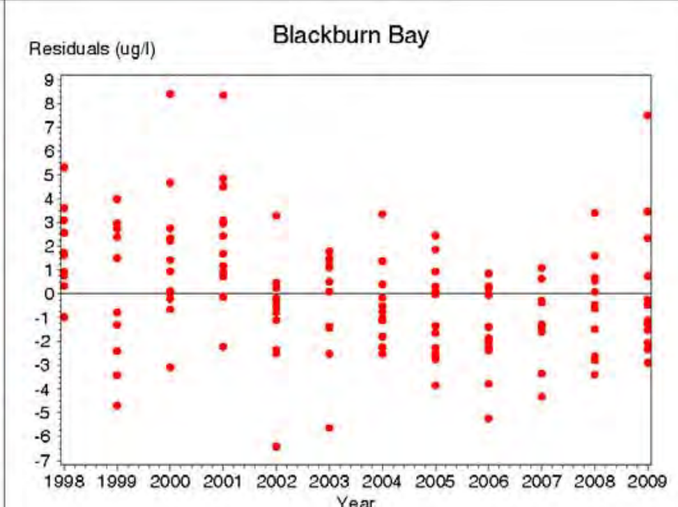

Blackburn Bay
Residuals (ug/l)
Total Nitrogen (mg/l)


Blackburn Bay
Residuals (ug/l)
TN Load (lbs/month)


Blackburn Bay
Residuals (ug/l)
Color (PCU)


Blackburn Bay
Residuals (ug/l)
Salinity (ppt)


Blackburn Bay
Residuals (ug/l)
Month


Blackburn Bay
Residuals (ug/l)
Year

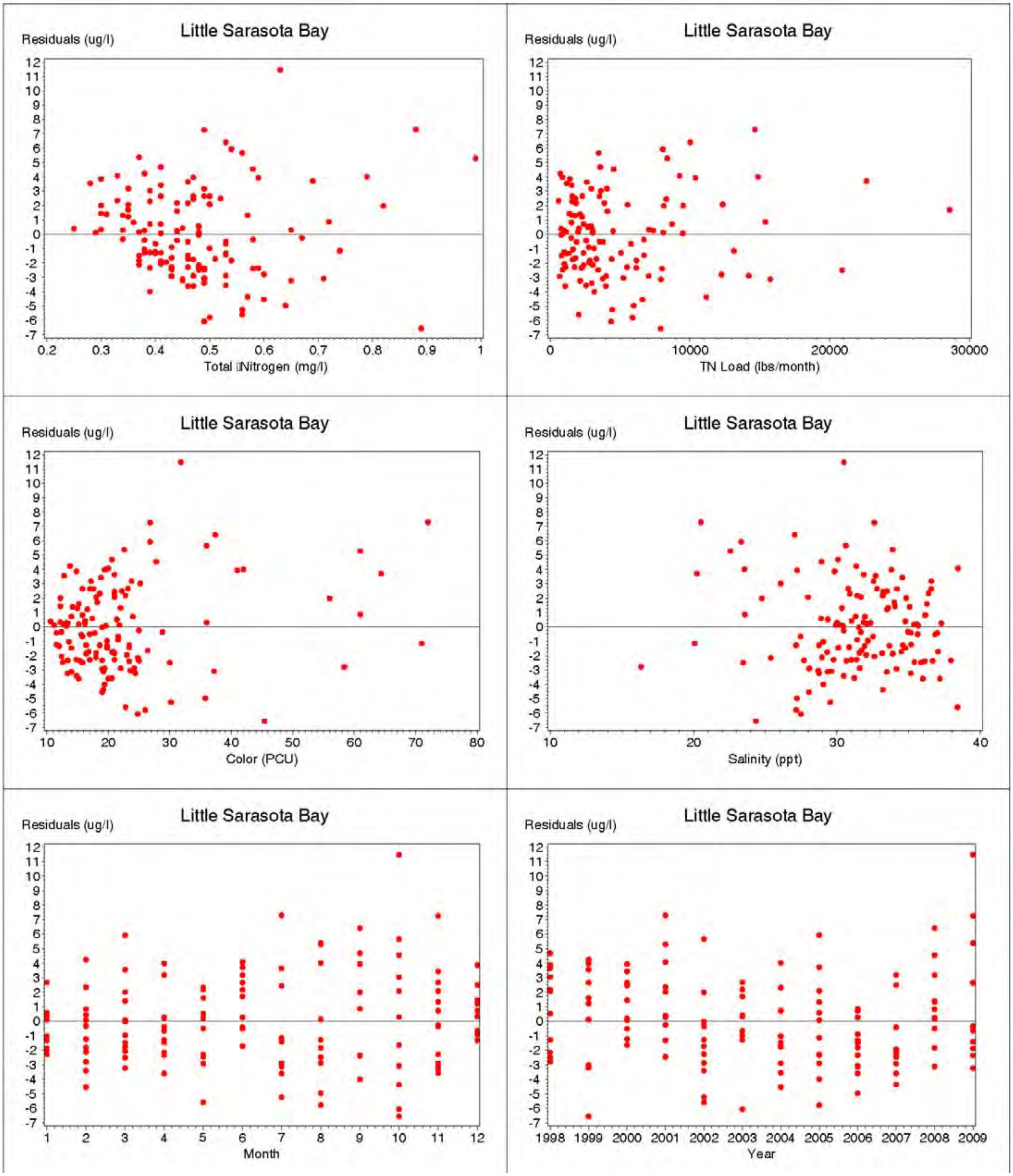
Blackburn Bay

The REG Procedure
Model: MODEL1
Dependent Variable: CHLA Observed Chlorophyll a (ug/l)

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	2389.97234	1194.98617	181.92	<.0001
Error	136	893.33918	6.56867		
Corrected Total	138	3283.31152			

Root MSE	2.56294	**R-Square**	0.7279
Dependent Mean	5.04266	**Adj R-Sq**	0.7239
Coeff Var	50.82518		

Parameter Estimates						
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	Intercept	1	-3.54519	0.53584	-6.62	<.0001
TN	Total Nitrogen (mg/l)	1	23.72468	1.64213	14.45	<.0001
season	Season	1	1.73363	0.54632	3.17	0.0019



Little Sarasota Bay
Residuals (ug/l)
Total Nitrogen (mg/l)
Little Sarasota Bay
Residuals (ug/l)
TN Load (lbs/month)
Little Sarasota Bay
Residuals (ug/l)
Color (PCU)
Little Sarasota Bay
Residuals (ug/l)
Salinity (ppt)
Little Sarasota Bay
Residuals (ug/l)
Month
Little Sarasota Bay
Residuals (ug/l)
Year

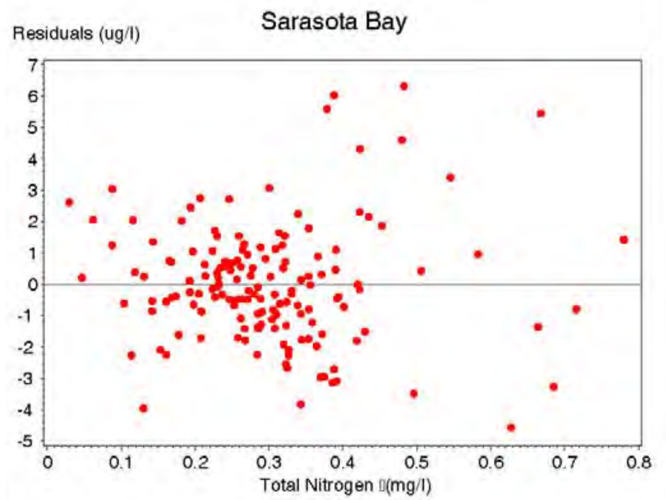
Little Sarasota Bay

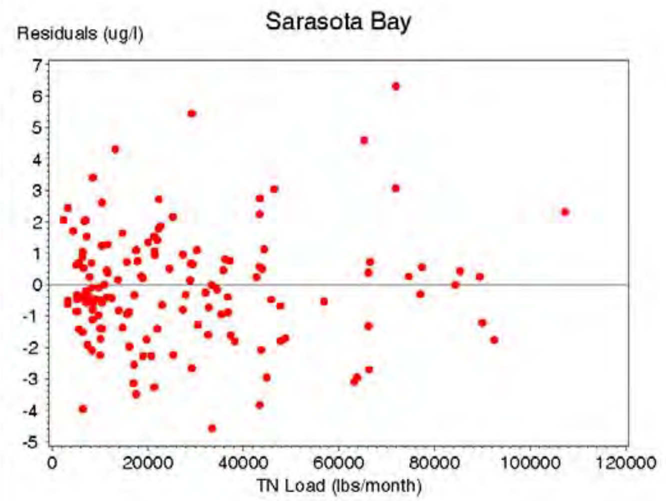
The REG Procedure
Model: MODEL1
Dependent Variable: CHLA Observed Chlorophyll a (ug/l)

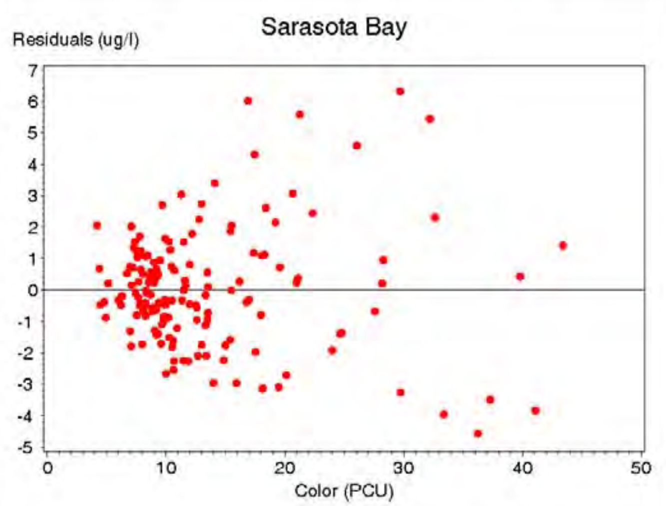
Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	2	1669.40227	834.70113	87.09	<.0001
Error	130	1245.98827	9.58453		
Corrected Total	132	2915.39053			

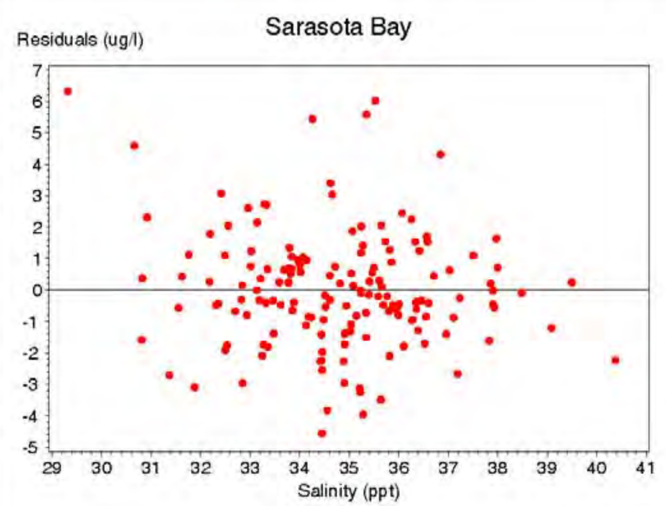
Root MSE	3.09589	**R-Square**	0.5726
Dependent Mean	6.68113	**Adj R-Sq**	0.5660
Coeff Var	46.33781		

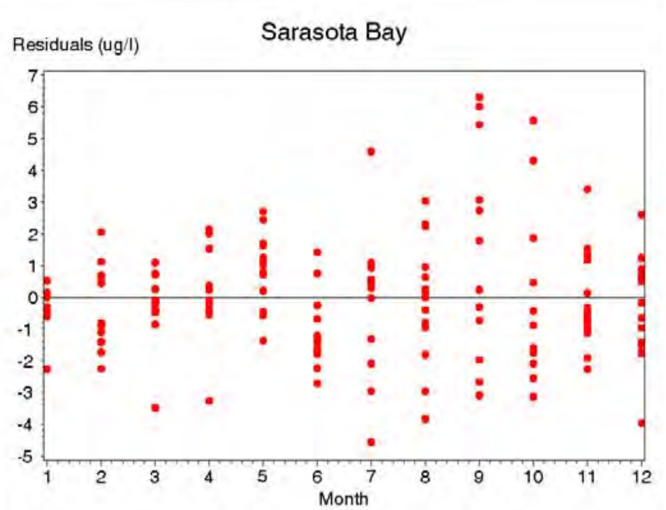
Parameter Estimates						
Variable	**Label**	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	Intercept	1	-4.48471	1.13227	-3.96	0.0001
TN	Total Nitrogen (mg/l)	1	21.58550	2.48964	8.67	<.0001
season	Season	1	2.96735	0.67177	4.42	<.0001

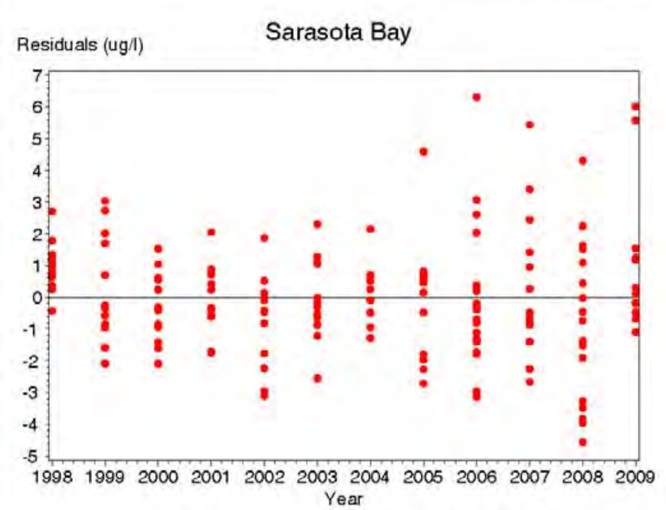

Sarasota Bay
Residuals (ug/l)
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
Total Nitrogen (mg/l)


Sarasota Bay
Residuals (ug/l)
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
0 20000 40000 60000 80000 100000 120000
TN Load (lbs/month)


Sarasota Bay
Residuals (ug/l)
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
0 10 20 30 40 50
Color (PCU)


Sarasota Bay
Residuals (ug/l)
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
29 30 31 32 33 34 35 36 37 38 39 40 41
Salinity (ppt)


Sarasota Bay
Residuals (ug/l)
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
1 2 3 4 5 6 7 8 9 10 11 12
Month


Sarasota Bay
Residuals (ug/l)
7 6 5 4 3 2 1 0 -1 -2 -3 -4 -5
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009
Year

Sarasota Bay

The REG Procedure
Model: MODEL1
Dependent Variable: CHLA

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1062.55690	265.63923	75.19	<.0001
Error	151	533.45239	3.53280		
Corrected Total	155	1596.00929			

Root MSE	1.87957	R-Square	0.6658
Dependent Mean	4.48567	Adj R-Sq	0.6569
Coeff Var	41.90177		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Intercept	1	-1.06229	0.42843	-2.48	0.0143
TN	Total Nitrogen (mg/l)	1	3.58453	1.46053	2.45	0.0153
COLOR	Color (PCU)	1	0.31971	0.03240	9.87	<.0001
season	Season	1	2.03386	0.34301	5.93	<.0001
region	Region	1	-4.84376	0.66331	-7.30	<.0001