PROPOSED
NUMERIC NUTRIENT CRITERIA
FOR THE
CHARLOTTE HARBOR NATIONAL ESTUARY PROGRAM
ESTUARINE SYSTEM

DRAFT

Prepared for:

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1.0 Introduction

The Florida Department of Environmental Protection (FDEP) is currently developing a rule to establish numeric nutrient criteria for a number of water body types (FDEP website, 2011). The following summarizes the FDEP view on the development of numeric nutrient criteria in Florida.

The overarching FDEP goal is to "manage nutrients in surface water (and groundwater) at loadings or concentrations that result in protection and maintenance of healthy, well-balanced aquatic communities". Absent site-specific analyses, water quality criteria should be based on a quantifiable linkage between anthropogenic nutrient enrichment and a biological response (such as seagrass growth) that can be used to numerically interpret the narrative nutrient criteria. There is value in knowing whether nutrient concentrations are elevated to potentially environmentally harmful levels, but, conversely, it is equally important to identify adverse biological effects and determine if they are linked to nutrients before deciding that nutrient reduction strategies should be pursued.

The Department recognizes the role of site-specific factors that affect nutrient responses and proposes to base new standards on establishing a systematic numeric interpretation of the existing narrative criteria. This concept is intended to implement Rule 62-302.530 (47)(b), FAC which states, "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna."

As envisioned by FDEP, the narrative nutrient criteria would continue to apply to all waterbodies, and numeric interpretations would be applied when adequate scientific information is available. The narrative would be implemented using a systematic structure that numerically interprets the narrative nutrient criteria for each waterbody in a hierarchical manner.

Numeric interpretations are most accurate when determined as a site-specific function. Therefore, nutrient Total Maximum Daily Loads (TMDLs), Site Specific Alternative Criteria (SSAC), and other site specific actions written to achieve the narrative nutrient criteria should be given preference over more broadly applicable interpretations.

The first tier of the hierarchical approach entails an evaluation of previously established site-specific numeric interpretations of the narrative criteria (including TMDLs, SSACs, and other interpretations embodied in an official Department action). This would be the primary interpretation of the narrative nutrient criteria. Currently, the Charlotte Harbor National Estuary Program (CHNEP) Policy Board has approved a series of segment-specific numeric nutrient criteria. FDEP is represented on the CHNEP Policy Board; therefore, the CHNEP estuarine area is presumably a candidate for inclusion in the first tier of the hierarchical approach.

FDEP has also stated nutrient TMDLs may be expressed as concentrations or loads, and that loads do not have to be translated into concentrations to be deemed the numeric interpretation of the narrative nutrient criteria. This document presents concentration-based numeric nutrient criteria for the segments of the CHNEP.

Finally, FDEP recognizes that future TMDL rules may include a response target (chlorophyll *a*, for example) designed to implement the narrative nutrient criterion. Currently, the recommended assessment of the proposed numeric nutrient criteria for the CHNEP estuarine segments is built on assessing the achievement of a series of segment-specific chlorophyll *a* targets.

Over the past several years, the CHNEP has conducted a series of tasks with the ultimate goal of establishing estuarine numeric nutrient criteria for the CHNEP segments. This document summarizes these efforts. The first part of this document provides background information concerning the CHNEP estuarine system, including a brief physical characterization of the system and a summary of previous work completed with respect to CHNEP estuarine targets. The second part of this document provides the data and methodology utilized for developing estuarine numeric nutrient criteria for the CHNEP estuarine segments, the targets resulting from application of the methodology, the proposed numeric nutrient criteria, and the proposed methodology for implementation and compliance of the CHNEP estuarine numeric nutrient criteria.

The Charlotte Harbor National Estuary Program Area and Its Watershed

The CHNEP area encompasses 11 interconnected estuaries and their watersheds in southwest Florida along the eastern Gulf of Mexico (Figure 1-1). The CHNEP watershed extends over 100 miles from the river headwaters to the estuaries and includes 8 subwatersheds. The estuaries total over 284 square miles, which, for management purposes, are divided into 14 estuarine segments with distinctive resource management conditions.

From north to south, the CHNEP estuarine complex stretches from Dona and Roberts Bay in Sarasota County, through Lemon Bay to the main body of Charlotte Harbor in Charlotte County, fed by the Tidal Myakka and Tidal Peace Rivers, to Pine Island Sound and Matlacha Pass in Lee County, joining San Carlos Bay which is fed by the Tidal Caloosahatchee River, and finally to Estero Bay.

Charlotte Harbor is the largest and deepest of the estuaries, extending over 22 miles from river mouth to Gulf pass and reaching 20 feet deep in the harbor and over 70 feet deep at Boca Grande Pass. The smallest, shallowest bays are Dona and Roberts and Estero bays, which are, respectively, 1 mile and 13 miles long and generally less than 6 feet deep. Lemon Bay is the narrowest estuary, about ¾ of a mile wide. Pine Island Sound has the most extensive coverage of seagrasses (over 26,000 acres) and Matlacha Pass is the tidal node between Charlotte Harbor and Caloosahatchee River waters.

Circulation in the CHNEP is primarily driven by tidal exchange between the Gulf of Mexico and the freshwater inflows from three major rivers and numerous smaller tidal creeks. Dona and Roberts and Lemon bays are separated from the Gulf of Mexico by a series of barrier islands with passes at Venice Inlet, Stump Pass, and Gasparilla Pass. Freshwater inflows include three major rivers (Myakka, Peace, and Caloosahatchee rivers) and numerous smaller creeks. Daily exchange of water is greatest through Boca Grande Pass, which serves as the conduit between the Gulf of Mexico and Charlotte Harbor. Pine Island Sound has the most stable salinities due to passes at Boca Grande, Captiva, Redfish and San Carlos Bay, with little direct watershed inflow. Matlacha Pass has highly altered inflows from the urban areas of Cape Coral and Fort Myers and is connected indirectly to the Gulf in the south through San Carlos Bay. San Carlos Bay provides a direct connection between the Gulf of Mexico and the Caloosahatchee River. The Caloosahatchee River is a highly managed system that includes a series of locks between Lake Okeechobee and the lower portion of the Caloosahatchee River. Estero Bay has 3 moderate sized passes (Matanzas, Big

Carlos, and Little Carlos) and drains a relatively small but highly urbanized watershed through Hendry Creek, Mullock Creek, Spring Creek, Estero River, and Imperial River.

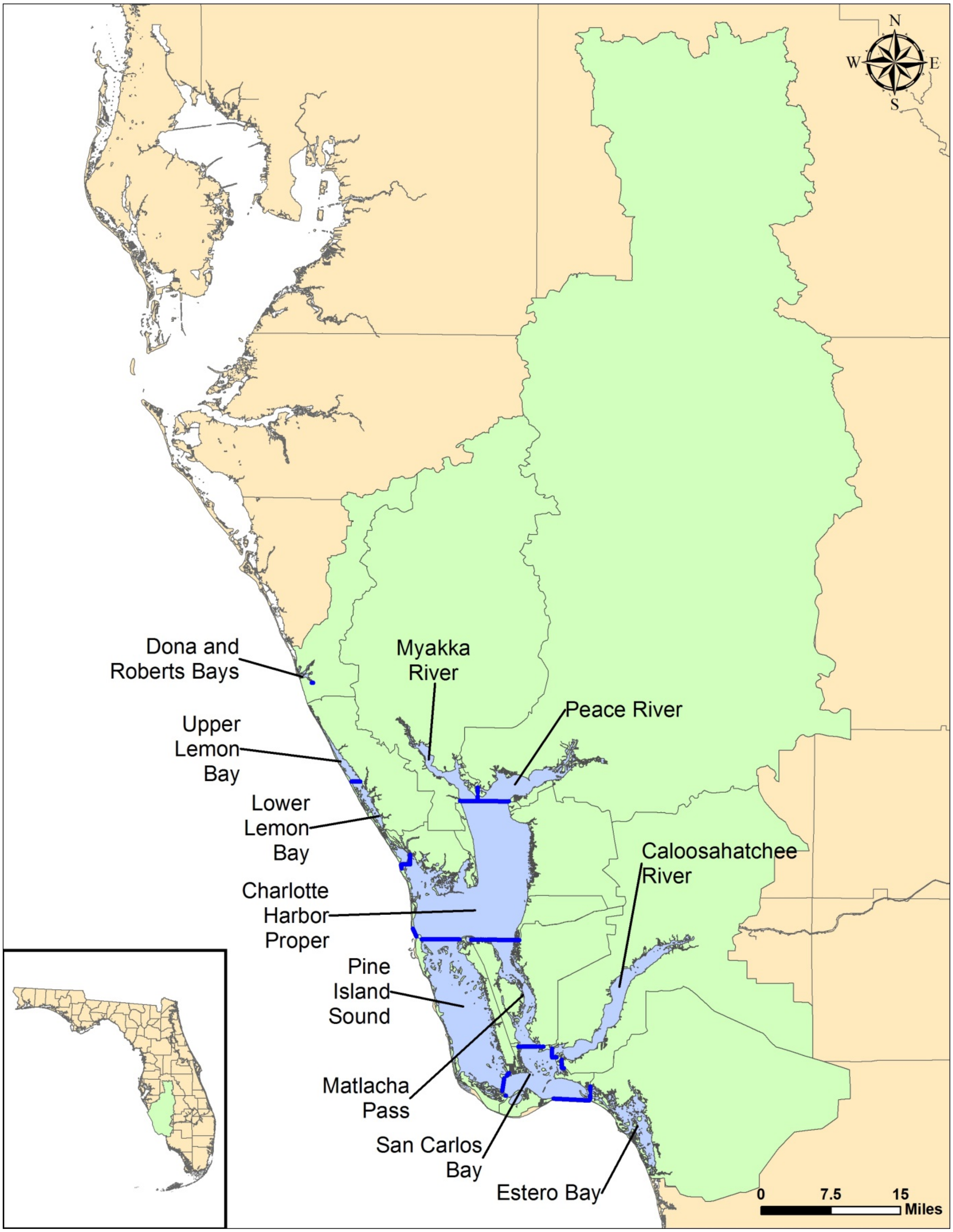

Figure 1-1. Charlotte Harbor National Estuary Program segments.

2.0 Objective

The objective of this document is to propose estuarine numeric nutrient criteria specific to the segments of the CHNEP: Dona and Roberts Bay, Upper Lemon Bay, Lower Lemon Bay, Tidal Myakka, Tidal Peace, Charlotte Harbor Proper (composed of East Wall, West Wall, Bokeelia, and Cape Haze), Matlacha Pass, Pine Island Sound, San Carlos Bay, Tidal Caloosahatchee, and Estero Bay. These criteria are expressed as TN concentrations in these segments.

3.0 Development of Seagrass, Light Attenuation, and Chlorophyll *a* Targets

This section provides a summary of work previously completed by the CHNEP in the establishment of segment-specific seagrass targets and their associated water quality targets.

3.1 Background and Rationale

Charlotte Harbor was designated as an "estuary of national significance" and the CHNEP was established in 1995. CHNEP is a partnership of citizens, elected officials, resource managers and commercial and recreational resource users who are working together to improve the water quality and ecological integrity of the CHNEP's diverse estuaries. A cooperative decision making process is used to address diverse resource management concerns throughout the 4,700 square mile watershed.

CHNEP management actions are guided by the Comprehensive Conservation and Management Plan (CCMP), which identifies four priority problems including water quality degradation, hydrologic alterations, fish and wildlife habitat loss, and stewardship gaps. Fifteen quantifiable objectives and 64 priority actions have been established in order to effectively address the priority problems identified in the CCMP. While not explicitly stated, the CHNEP CCMP recognized the linkages between nutrient enrichment, algal productivity, light attenuation, and seagrass growth and reproduction in a similar fashion to the Tampa Bay Estuary Program nutrient loading-chlorophyll-seagrass paradigm. Technically sound, consensus based resource decisions are made through the CHNEP Management Conference which consists of the Technical Advisory, Citizens Advisory, Management and Policy Committees.

Seagrass acreages throughout the CHNEP have been relatively stable since the 1950s but show significant spatial and temporal variability. Between 1950 and 1988, an estimated 5% of the seagrass acreage in the CHNEP was lost, with the highest losses in Pine Island Sound, Matlacha Pass and San Carlos Bay. Seagrass losses are attributed to physical alterations from dredge and fill activities, primarily the Intracoastal Waterway and Sanibel Causeway, and changes in freshwater inflows, especially in the major rivers.

Seagrasses are used as a living resource basis for developing water quality targets for the CHNEP estuaries. Initial water quality targets were developed in 2005 based on seagrass light requirements at the maximum growth depth and the relationship of water clarity to key light attenuators: color dissolved organic matter (CDOM), chlorophyll *a*, and turbidity. Subsequently, beginning in 2009, CHNEP began the process of refining the water quality targets based on updated light availability and water quality data based on seagrass acreage and a reference period approach (2003-2007).

The refined water quality targets were developed and adopted by the CHNEP Management Conference through a series of tasks and reports, which include: validation of estuary segment scheme, seagrass targets, water clarity targets, nutrient loads, and total nitrogen (TN) and total phosphorus (TP) concentration and load targets.

3.2 Development of Seagrass Targets

One of the primary CHNEP 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 CHNEP ecosystem. Seagrass targets were developed and approved as a CHNEP management tool in August 2009 in order to track changes in an important ecological indicator over time (Janicki Environmental, 2009). 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 CHNEP were determined through analysis of GIS shapefiles based on aerial surveys executed biannually by the South and Southwest Florida Water Management Districts since 1988 (Appendix A provides time series plots of segment-specific seagrass acreages). 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 definition of the most appropriate seagrass targets was reached with input from the Technical Advisory Committee (TAC). The TAC recommended that targets be established as the greater of either the adjusted baseline acreage or the mean of all recent seagrass surveys (Janicki Environmental, 2009). Application of this definition provided the targets identified for each harbor segment in Table 3-1.

In addition to defining these targets, an appropriate definition of a target range, i.e., the range of acceptable seagrass area, was also desired. The target range for each segment is also presented in Table 3-1.

Table 3-1. CHNEP Seagrass targets (from Janicki Environmental, 2009). Unit of measure = acres.

Harbor Segment	Adjusted Baseline	Mean Annual Extent (all years)	Protection Target	Restoration Target	Total Target	Target Range
Dona and Roberts Bay*	112	91	91	21	112	70-124
Upper Lemon Bay	880	1,009	1,009		1,009	949-1,175
Lower Lemon Bay	2,882	2,502	2,502	380	2,882	2,396-2,597
Tidal Myakka River*	344	456	456		456	331-539
Tidal Peace River*	975	384	384	591	975	295-573
Charlotte Harbor Proper						
West Wall	2,106	1,907	1,907	199	2,106	1,676-2,121

Table 3-1. CHNEP Seagrass targets (from Janicki Environmental, 2009). Unit of measure=acres.

East Wall	3,898	3,465	3,465	433	3,898	3,275-3,591
Cape Haze	5,670	6,998	6,998		6,998	6,709-7,464
Bokeelia	2,964	3,342	3,342		3,342	3,101-3,520
Pine Island Sound	23,757	26,837	26,837		26,837	25,941-29,204
Matlacha Pass	9,315	7,582	7,582	1,733	9,315	6,055-7,619
Tidal Caloosahatchee River*	93	87	87	6	93	2-103
San Carlos Bay	3,118	4,372	4,372		4,372	3,709-5,376
Estero Bay	3,662	3,071	3,071	591	3,662	2,393-3,409

* These riverine segments may have underreported seagrass acreages, due to difficulty in delineating seagrass in highly colored waters. These numbers are presented for completeness only and should not be used for reporting of seagrass loss or gain over time.

3.3 Development of Chlorophyll *a* Targets

Establishment of defensible, protective environmental endpoints largely depends upon the definition of a defensible baseline. CHNEP considered three candidate methods for defining chlorophyll *a* thresholds (Janicki Environmental, 2011a). These methods were:

- Regulatory-based Method,
- Optical Model Method, and
- Reference Period Method.

Seagrass and water clarity targets have been established for the segments of the CHNEP area. Given that the recent extents of seagrasses in some segments are meeting their established targets, it logically follows that recent water clarity and chlorophyll *a* concentrations are protective of the seagrasses in those segments that are meeting established targets. It was determined that the reference period approach was most appropriate for target setting. However, for the segments that are not meeting their targets, the same assumption is not valid. This was considered when developing chlorophyll *a* targets for the system utilizing the reference period approach. A description of the data used for target development is provided in Appendix A.

The Tampa Bay Estuary Program (TBEP) (Janicki and Wade, 1996) and Sarasota Bay Estuary Program (SBEP) (Janicki Environmental, 2010c) used a similar reference period approach to define chlorophyll *a* targets. Both programs recognized that there may be years in which chlorophyll *a* targets may be exceeded without causing significant reductions in seagrass cover. Therefore, there is some allowable amount of variation that should not elicit a significant degradation in water quality and therefore seagrass coverage. The SBEP 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. The target was defined as the annual mean of the reference period, i.e., the period that was deemed to be protective on seagrass and water clarity. 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**.

Given the experience of the neighboring estuary programs, the CHNEP TAC decided to use a similar approach, but with different thresholds depending on whether or not a segment was classified as "restoration" or "protection" for seagrass. If a segment is classified as "protection", it logically follows that water clarity and chlorophyll *a* concentrations are protective of seagrasses. Therefore, the chlorophyll *a* threshold for segments that are classified as "protection" is calculated by summing the mean plus one standard deviation. This is the same strategy that was employed by the SBEP in criteria development for the SBEP segments. However, if the segment is under "restoration", the chlorophyll target is calculated by summing the mean plus one-half standard deviation. This provides a threshold that is more stringent than for segments that are classified as "protection" because the "restoration" segments have not achieved the desired levels of seagrass coverage. The reference period used to establish the chlorophyll *a* targets was 2003-2007. This corresponds to the time period used in establishing the water clarity targets for CHNEP (Janicki Environmental, 2010a). The mean chlorophyll *a* concentrations for the reference period (targets), along with the standard deviation (for the period of record) and the thresholds are presented for each segment in Table 3-2.

Table 3-2. Recommended chlorophyll *a* targets and thresholds (µg/L) developed based on reference period (2003-2007).

Segment	Restoration/ Protection	Target Chlorophyll *a* (µg/L)	Standard Deviation of Annual Means (µg/L)	Threshold Chlorophyll *a* (µg/L)
Dona and Roberts Bays	Restoration	4.3	1.2	4.9
Upper Lemon Bay	Protection	6.7	2.2	8.9
Lower Lemon Bay	Restoration	5.1	2.0	6.1
Tidal Myakka	Protection	8.9	2.8	11.7
Tidal Peace	Restoration	10.6	4.0	12.6
Charlotte Harbor Proper (EW+WW+BK+CH)	Restoration/ Protection	4.9	2.4	7.3/6.1
Matlacha Pass	Restoration	4.0	4.1	6.1
Pine Island Sound	Protection	5.1	1.4	6.5
San Carlos Bay	Protection	2.8	0.7	3.5
Tidal Caloosahatchee	Restoration	9.0	n/a	6.9 (TMDL)
Estero Bay	Restoration	4.9	2.0	5.9

Since establishing seagrass targets for tidal rivers is questionable due to issues with color and visibility (Janicki Environmental, 2009), the chlorophyll thresholds for the Tidal Myakka, Tidal Peace, and Tidal Caloosahatchee rivers were not used in criteria development. Instead, the chlorophyll targets for the downstream areas, Charlotte Harbor Proper for the Tidal Peace and Tidal Myakka and San Carlos Bay for Tidal Caloosahatchee, were used. Please note that a proposed Total Maximum Daily Load (TMDL) has been developed for the Tidal Caloosahatchee River as a result of the system being identified as impaired. In the proposed TMDL, a target chlorophyll *a* concentration of 6.9 µg/L was identified for the Tidal Caloosahatchee.

4.0 Proposed Numeric Nutrient Criteria

The CHNEP employed evaluation of stressor-response relationships in a similar manner to that proposed by Janicki Environmental (2010b) and EPA (2010). This approach involves the development of a quantitative relationship (i.e., model) between chlorophyll *a* and some measure of nutrient condition. In this case, the independent variables used in the model-building process included loadings, concentrations, and estimates of residence time. The loadings data (Janicki Environmental, 2010d) 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.

A flowchart of the overall process used to develop numeric nutrient criteria for the segments of the CHNEP area is presented in Figure 4-1. Following this flowchart, numeric nutrient criteria in terms of TN concentrations were developed for each segment.

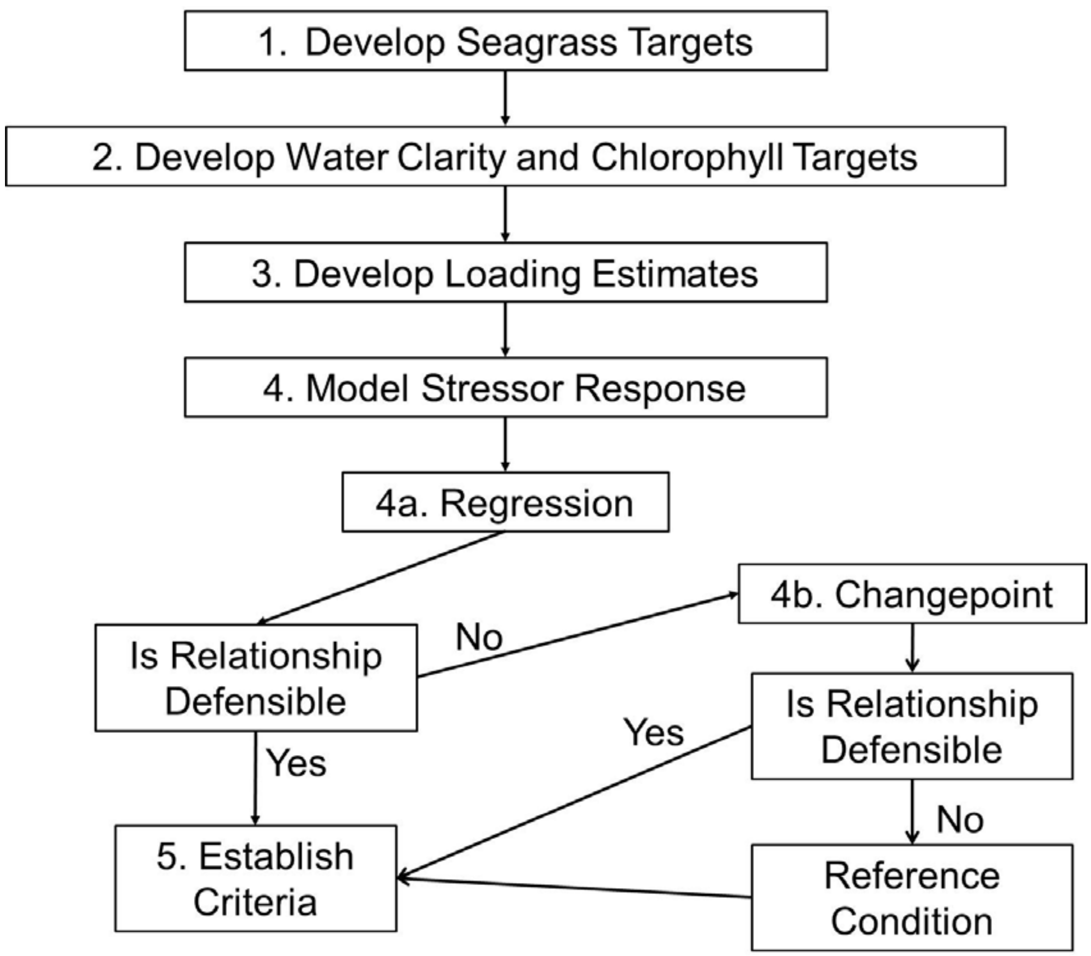

Figure 4-1. Flowchart of Process Used to Develop Numeric Nutrient Criteria.

A complete presentation of the process followed to develop the proposed criteria for CHNEP can be found in Janicki Environmental (2011a). A description of the data utilized is provided in Appendix A.

The CHNEP Management and Policy committees approved the TAC recommendations for the TN concentration-based numeric criteria (Table 4-1) based on the Reference Period approach, as no appropriate stressor-response relationships were found that could be used to develop defensible numeric nutrient criteria. For further description of the numeric nutrient criteria development and comparison to observed conditions, see Janicki Environmental (2011a) and Appendix B.

Table 4-1. Recommended numeric nutrient criteria based on the reference period approach for TN concentration.

Segment	Candidate Criterion
Dona and Roberts Bays	0.42 mg/L
Upper Lemon Bay	0.56 mg/L
Lower Lemon Bay	0.62 mg/L
Tidal Myakka	1.02 mg/L
Tidal Peace	1.08 mg/L
Charlotte Harbor Proper	0.67 mg/L
Matlacha Pass	0.58 mg/L
Pine Island Sound	0.57 mg/L
Tidal Caloosahatchee	TBD
San Carlos Bay	0.56 mg/L
Estero Bay	0.63 mg/L

Additionally, criteria were developed in terms of TP concentration and TN and TP loads (Janicki Environmental, 2011b), based on the reference period approach as for TN concentrations. These criteria are provided in Table 4-2 for use if needed. Description of the derivation of these alternative criteria and comparison to observed conditions are provided in Appendix B.

Table 4-2. Alternative numeric nutrient criteria expressed as TP concentrations and TN and TP loads derived using the Reference Period Approach. The reference period was 2003-2007.

Segment	TP Concentration (mg/L)	TN Load (tons/yr)	TP Load (tons/yr)
Dona and Roberts Bay	0.18	250	48
Upper Lemon Bay	0.26	102	18
Lower Lemon Bay	0.17	136	21
Charlotte Harbor Proper[1]	0.19	5,987	2,281
Pine Island Sound	0.06	190	8
San Carlos Bay	0.07	TBD	TBD
Tidal Myakka River	0.31	1,407	351
Tidal Peace River	0.50	4,343	1,960
Matlacha Pass	0.08	216	24
Tidal Caloosahatchee River	TBD	TBD	TBD
Estero Bay	0.07	587	61

[1]Loads are sum of Charlotte Harbor Proper and the Tidal Peace and Myakka Rivers.

5.0 Implementation

The proposed compliance assessment strategy involves two steps. The initial step is the comparison of the mean annual chlorophyll *a* concentrations in each bay segment to the established chlorophyll *a* thresholds. Compliance is achieved if the threshold is met in that year. If the chlorophyll *a* threshold is exceeded in more than two years during any five-year period, the second step would be an assessment of nitrogen concentrations during that period. The justification for this "2-in-5 year" compliance assessment has been developed (Janicki Environmental, 2011c) and summarized in Appendix C.

The recommendation for compliance assessment also hinges on the availability of the appropriate data for a defensible assessment. Thus, how the specific spatial and temporal averaging has been conducted in the development of the targets and thresholds as well as the compliance assessment is critical. The following discusses this aspect of the implementation of the proposed numeric nutrient criteria for the CHNEP estuarine segments.

From the initial efforts to establish defensible water quality targets, ambient water quality data have been obtained from the following agencies and programs:

- Southwest Florida Water Management District,
- South Florida Water Management District,
- Sarasota County,
- Lee County,
- Peace River Manasota Regional Water Supply Authority,
- Coastal Charlotte Harbor Monitoring Network,
- Charlotte Harbor Volunteer Monitoring Network,
- Charlotte Harbor Aquatic Preserves,
- City of Cape Coral, and
- Florida International University.

Maps showing the locations of these sites are presented in Appendix D.

Defensible compliance assessment will depend upon continued monitoring to ensure that the annual assessment can be completed for attainment of the proposed chlorophyll *a* thresholds and TN criteria. Consideration must also be given to the temporal averaging. The mean annual chlorophyll *a* concentrations have been calculated by first calculating the segment-specific arithmetic monthly means and subsequently calculating an arithmetic annual mean. The compliance would be assessed by calculating the chlorophyll a threshold i.e., the sum of the arithmetic annual mean and the estimate of the interannual variability (see Table 3-2). The TN compliance would be based on the arithmetic annual mean for each bay segment, with the concentration criteria as provided in Table 4-1.

6.0 References

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Janicki Environmental, Inc. 2011c. Charlotte Harbor Numeric Nutrient Criteria: Task 9 - Implementation Issues. Interim Report 6. Prepared for Charlotte Harbor Estuary Program. Ft. Myers, FL.

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APPENDIX A.
Data Description and
Assessment of Seagrass, Water Quality, and Loadings

1.0 Data Description

This appendix provides identification and description of the seagrass, water quality, and loadings data utilized for establishing numeric nutrient criteria in the Charlotte Harbor National Estuary Program estuarine system.

1.1 Seagrasses

Seagrass targets were developed and approved as a CHNEP management tool in August 2009 in order to track changes in an important ecological indicator over time (Janicki Environmental, 2009). Baseline seagrass coverage was determined through photo-interpretation of aerial photos of the study area from circa 1950 obtained from the National Archives in Washington, DC. The CHNEP contracted Photo Science, experts in photo-interpretation services, which provided electronic data coverage of the area of interest for the CHNEP using ArcGIS9. This coverage served as a historic baseline from which to compare recent surveys conducted by the South and Southwest Florida Water Management Districts (Janicki Environmental, 2009). Historic (1950) and recent (1988 to present) surveyed seagrass acreages were compared to establish seagrass targets. These seagrass targets were designed to maintain and/or restore seagrass acreage to its historical extent. While the extent of seagrass in the CHNEP area may be governed by a variety of processes including erosion, salinity changes, biological perturbations, prop scarring and sedimentation, water clarity is thought to be the principal controlling factor in the long-term health of seagrasses in the study area. Therefore, management-level water clarity targets that are related to the light requirements of seagrass were developed to allow managers to correlate changes in water clarity conditions and seagrass conditions over time.

The CHNEP seagrass target for each harbor segment is the greater of either the adjusted baseline acreage or the mean of all recent seagrass surveys (Janicki Environmental, 2009). Application of this definition provided the targets identified for each harbor segment in Table 1-1.

Table 1-1. CHNEP Seagrass targets (from Janicki Environmental, Inc., 2009). Unit of measure = acres.						
Harbor Segment	**Adjusted Baseline**	**Mean Annual Extent (all years)**	**Protection Target**	**Restoration Target**	**Total Target**	**Target Range**
Dona and Roberts Bay*	112	91	91	21	112	70-124
Upper Lemon Bay	880	1,009	1,009		1,009	949-1,175
Lower Lemon Bay	2,882	2,502	2,502	380	2,882	2,396-2,597
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Tidal Peace River*	975	384	384	591	975	295-573
West Wall	2,106	1,907	1,907	199	2,106	1,676-2,121
East Wall	3,898	3,465	3,465	433	3,898	3,275-3,591
Cape Haze	5,670	6,998	6,998		6,998	6,709-7,464
Bokeelia	2,964	3,342	3,342		3,342	3,101-3,520
Pine Island Sound	23,757	26,837	26,837		26,837	25,941-29,204
Matlacha Pass	9,315	7,582	7,582	1,733	9,315	6,055-7,619
Tidal Caloosahatchee River*	93	87	87	6	93	2-103
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* These riverine segments may have underreported seagrass acreages, due to difficulty in delineating seagrass in highly colored waters. These numbers are presented for completeness only and should not be used for reporting of seagrass loss or gain over time.

1.2 Water Quality and Loadings

A number of data sources were used to develop the data base used to determine numeric nutrient criteria for the estuarine waters of the CHNEP. These included ambient water quality data, hydrologic and nutrient loading estimates, seagrass coverage, and bathymetry. These data sources are described in the following subsections.

Ambient water quality data were obtained from the following agencies and programs:

- Southwest Florida Water Management District,
- South Florida Water Management District,
- Sarasota County,
- Lee County,
- Peace River Manasota Regional Water Supply Authority,
- Coastal Charlotte Harbor Monitoring Network,
- Charlotte Harbor Volunteer Monitoring Network,
- Charlotte Harbor Aquatic Preserves,
- City of Cape Coral, and
- Florida International University.

Estimates of hydrologic, TN, and TP loadings have recently been developed for Charlotte Harbor (Janicki Environmental, 2010). The loading sources include:

- atmospheric deposition directly to the surface of the estuary,
- nonpoint sources,
- septic tanks (on-site sewage treatment and disposal systems), and
- domestic and industrial point sources (wastewater treatment facilities and industrial facility discharges).

Monthly loading estimates for each CHNEP segment are reported.

2.0 Assessment of Conditions

The following sections provide segment-specific comparisons of observed conditions to the seagrass targets, and summaries of TN, TP, and chlorophyll *a* concentrations and hydrologic, TN, and TP loadings for each CHNEP. 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.

2.1 Seagrass

The following provides the segment-specific seagrass targets, and acreage estimates in Figures 2-1 through 2-8.

- Dona and Roberts Bay (Figure 2-1)
  - The seagrass target for this segment is 112 acres (Janicki Environmental, 2009).
  - Dona and Roberts Bay is classified as a seagrass "restoration" segment.

- Upper and Lower Lemon Bay (Figure 2-2)
  - The seagrass targets are 1,009 acres for Upper Lemon Bay and 2,882 acres for Lower Lemon Bay (Janicki Environmental, 2009).
  - Upper Lemon Bay is classified as a seagrass "protection" segment, while Lower Lemon Bay is classified as a seagrass "restoration" segment.

- Charlotte Harbor Proper (Figure 2-3)
  - The seagrass target is 16,344 acres (West Wall = 2,106 acres, East Wall = 3,898 acres, Cape Haze = 6,998, Bokeelia = 3,342 acres) (Janicki Environmental, 2009).
  - Cape Haze and Bokeelia are classified as seagrass "protection" segments, while West Wall and East Wall are classified as seagrass "restoration" segments. In order to be conservative, Charlotte Harbor Proper was classified as seagrass "restoration.

- Tidal Myakka (Figure 2-4)
  - The seagrass target for this segment is 456 acres (Janicki Environmental, 2009).
  - Tidal Myakka is classified as a seagrass "protection" segment.

- Tidal Peace (Figure 2-5)
  - The seagrass target for this segment is 975 acres (Janicki Environmental, 2009).
  - Tidal Peace is classified as a seagrass "restoration" segment.

- Pine Island Sound and Matlacha Pass (Figure 2-6)
  - The seagrass targets are 26,837 acres for Pine Island Sound and 9,315 acres for Matlacha Pass (Janicki Environmental, 2009).
  - Pine Island Sound is classified as a seagrass "protection" segment, while Matlacha Pass is classified as a seagrass "restoration" segment.

- San Carlos Bay (Figure 2-7) and Tidal Caloosahatchee
  - The seagrass targets are 4,372 acres for San Carlos Bay and 93 acres for Tidal Caloosahatchee (Janicki Environmental, 2009).
  - San Carlos Bay is classified as a seagrass "protection" segment, while Tidal Caloosahatchee is classified as a seagrass "restoration" segment.

- Estero Bay (Figure 2-8)
  - The seagrass target for this segment is 3,662 acres (Janicki Environmental, 2009).
  - Estero Bay is classified as a seagrass "restoration" segment.

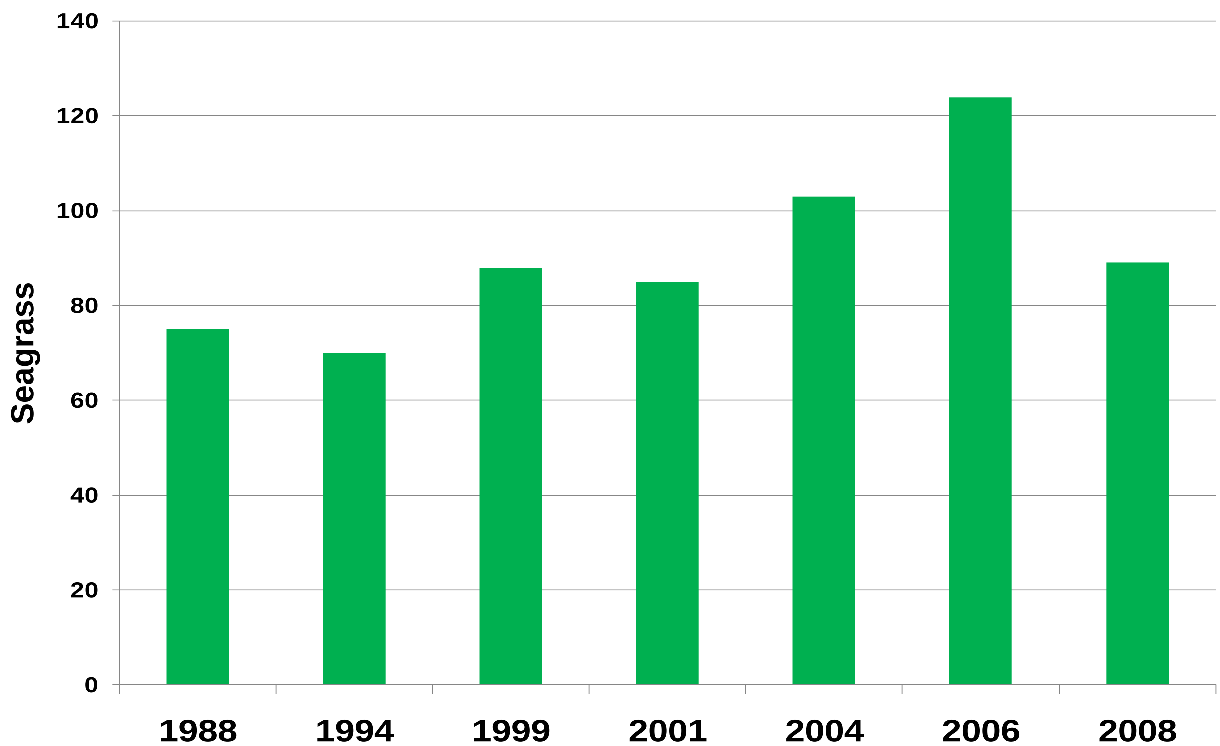


Figure 2-1. Annual seagrass acreages in Dona and Roberts Bays.

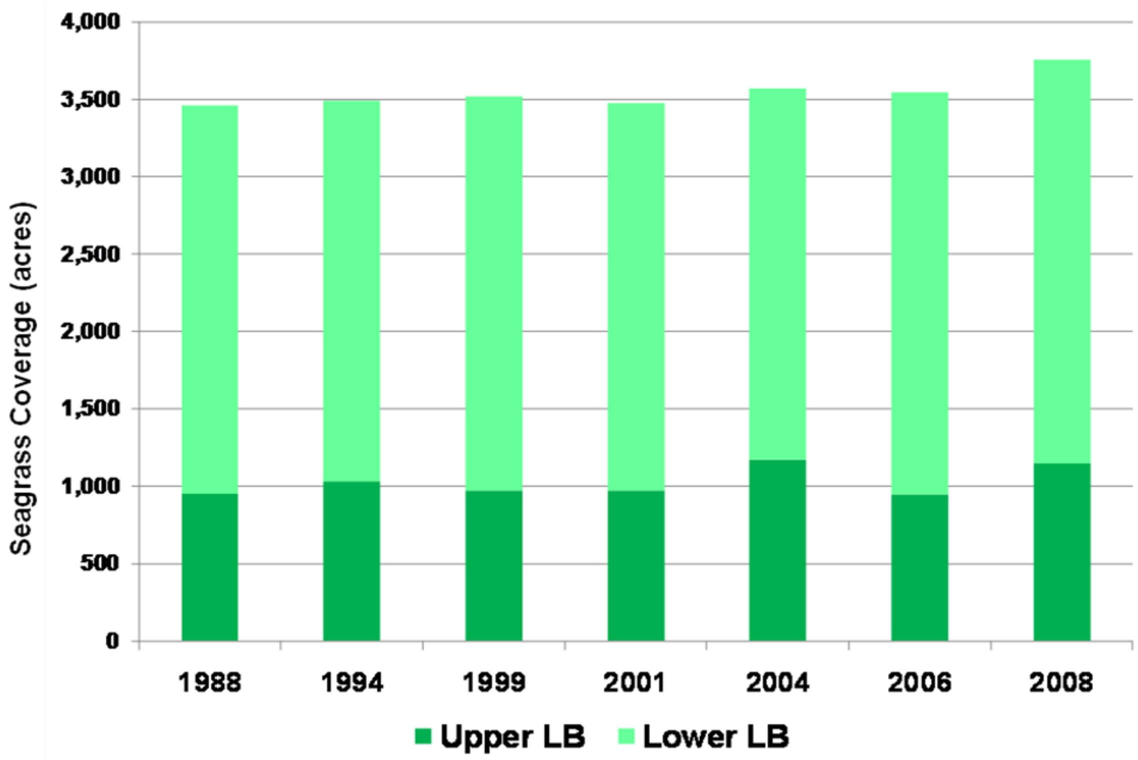


Figure 2-2. Annual seagrass acreages in Upper and Lower Lemon Bay.

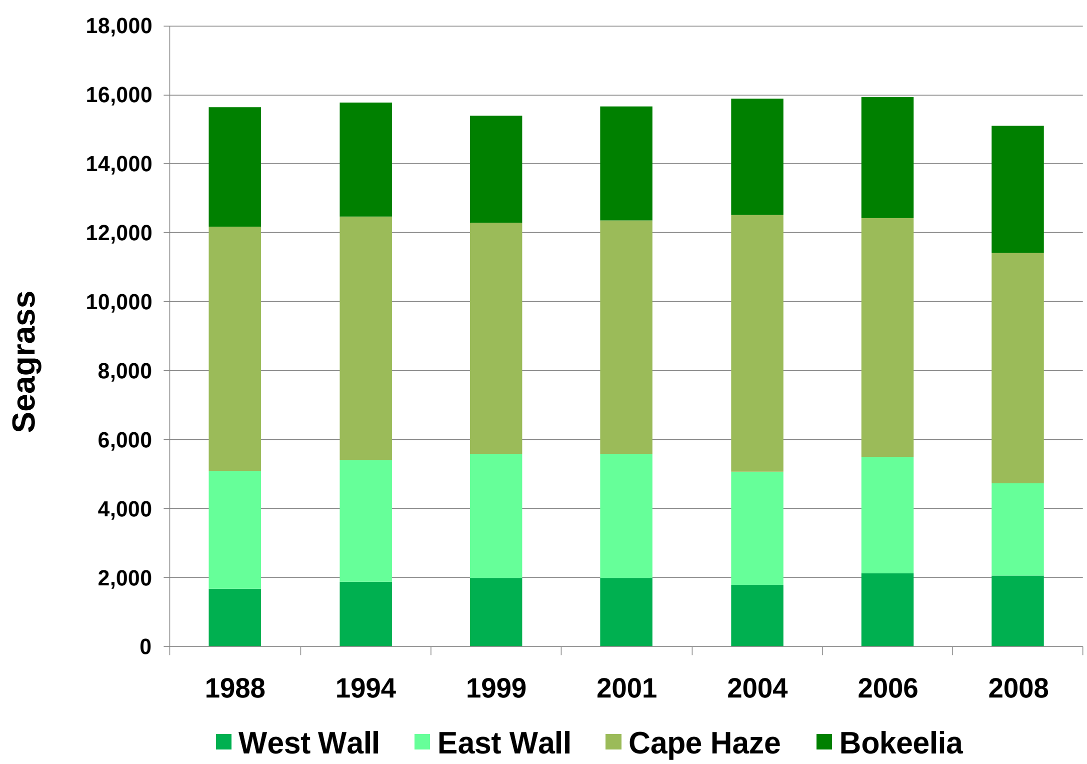


Figure 2-3. Annual seagrass acreages in Charlotte Harbor Proper.

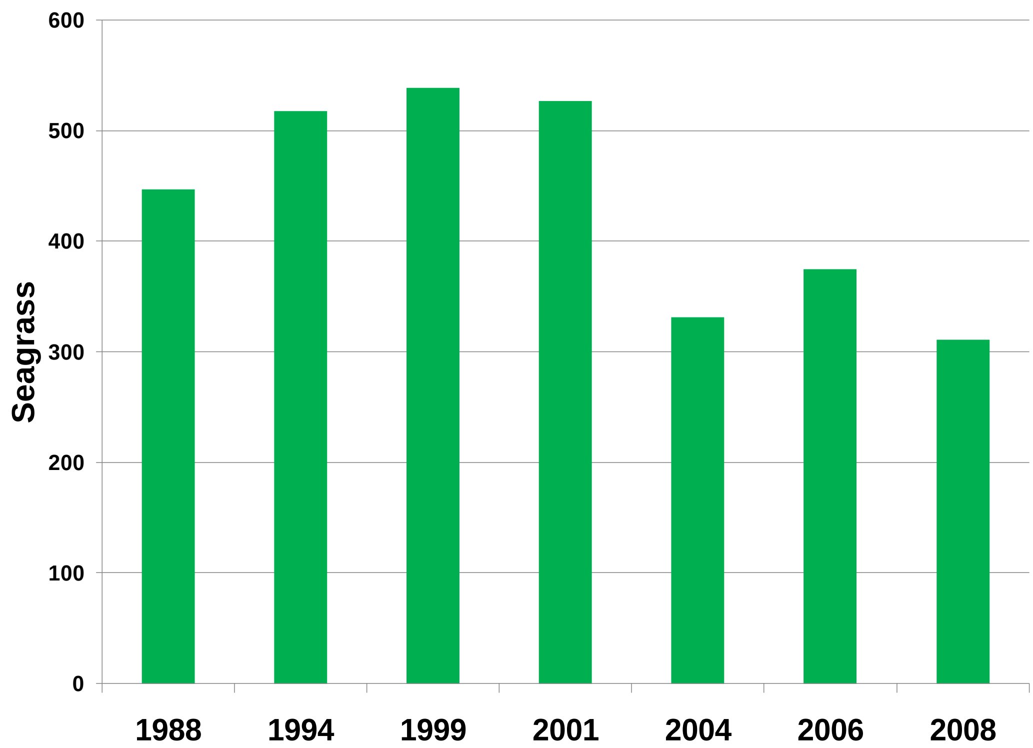


Figure 2-4. Annual seagrass acreages in Tidal Myakka.

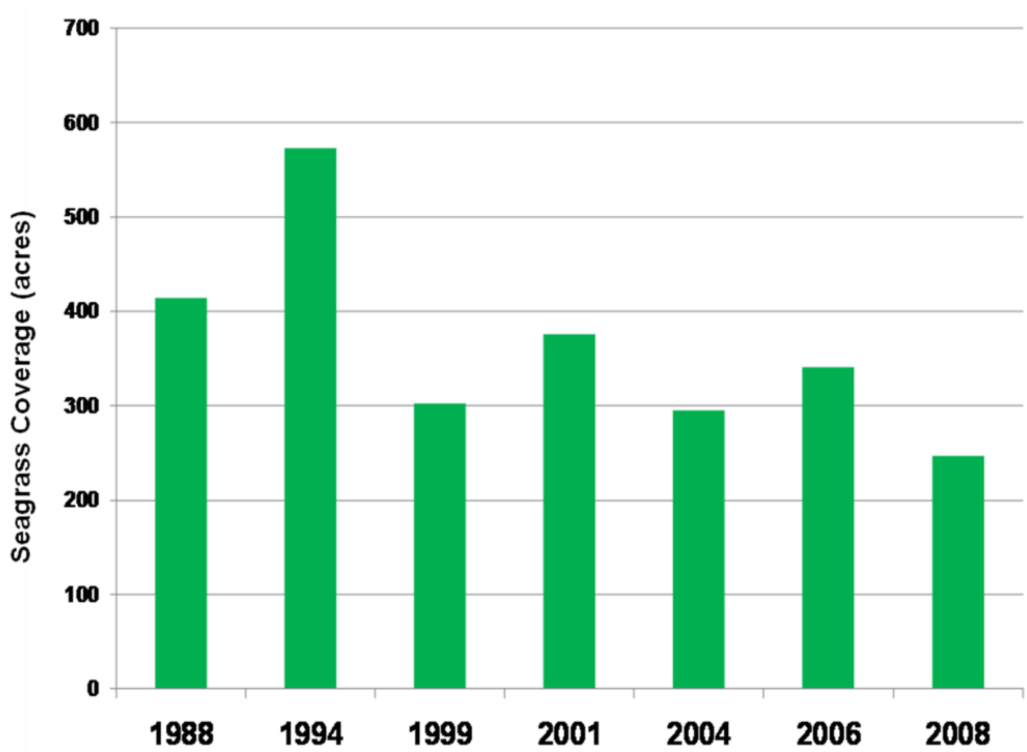


Figure 2-5. Annual seagrass acreages in Tidal Peace.

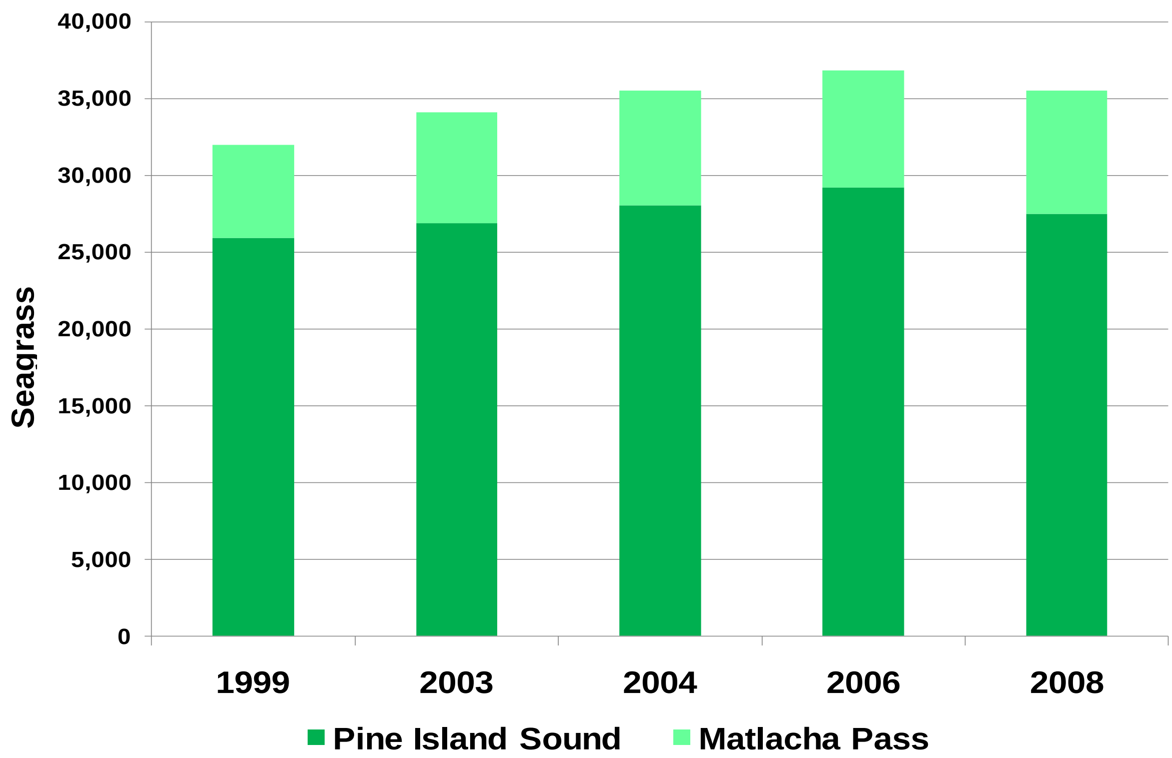


Figure 2-6. Annual seagrass acreages in Pine Island Sound and Matlacha Pass.

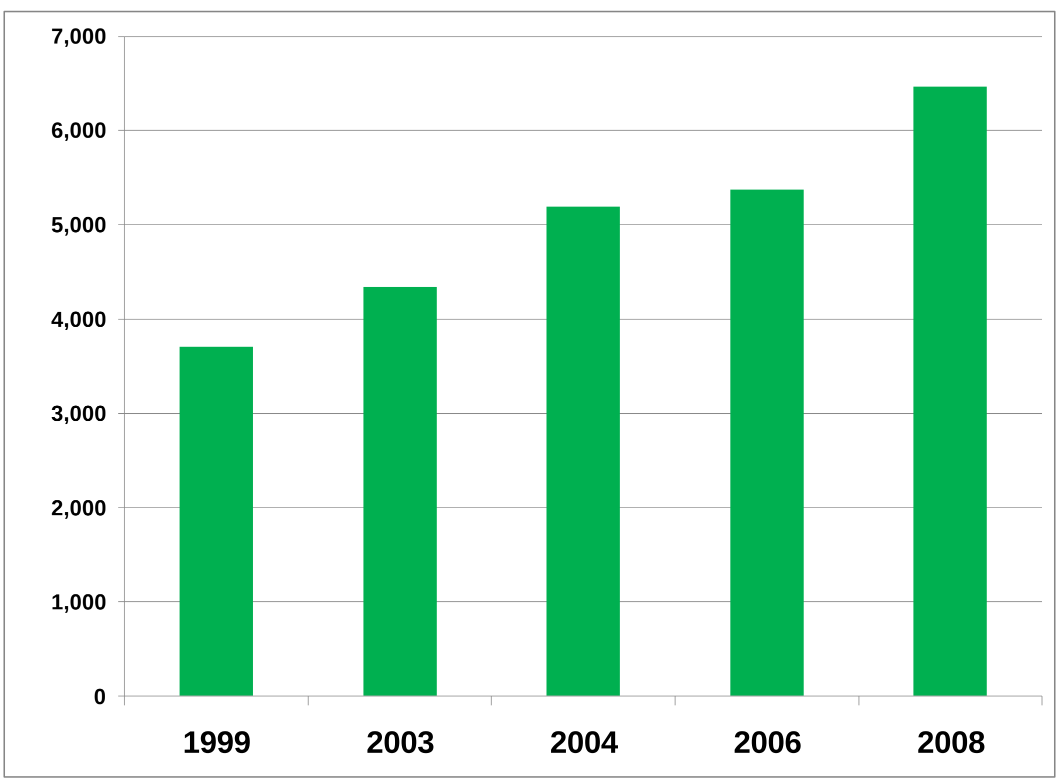


Figure 2-7. Annual seagrass acreages in San Carlos Bay.

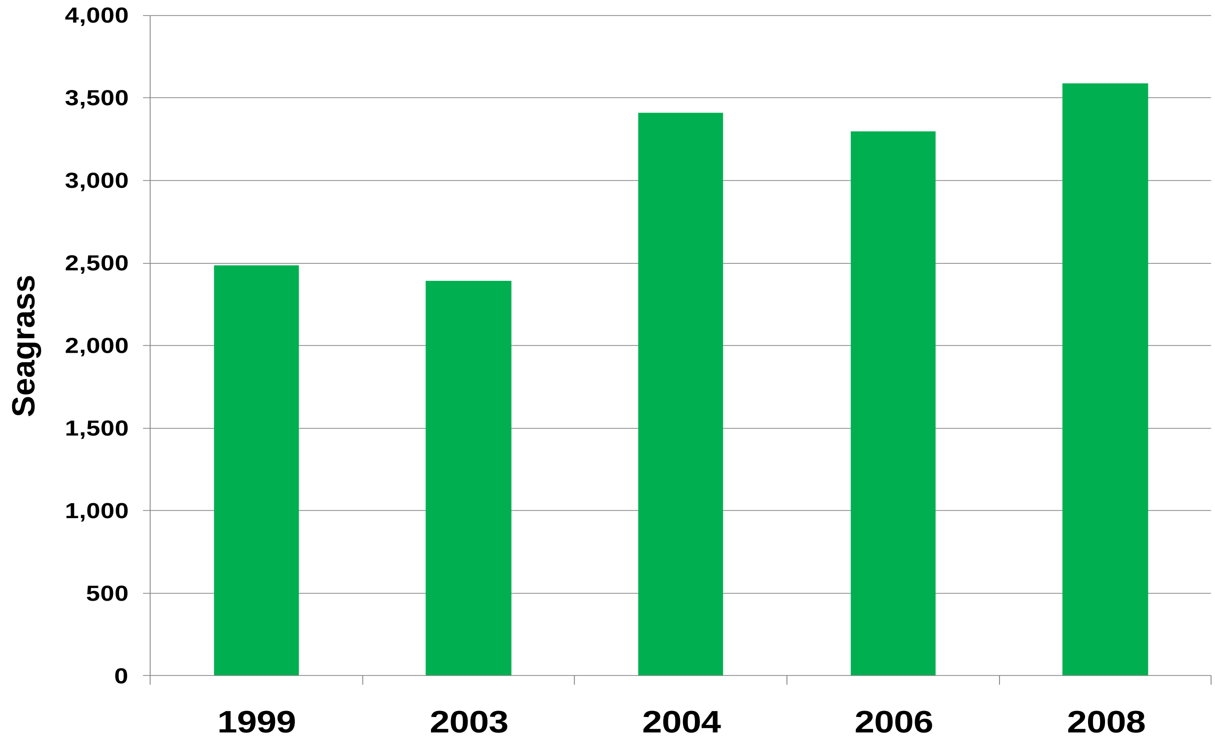


Figure 2-8. Annual seagrass acreages in Estero Bay.

2.2 Total Nitrogen Concentrations

Times series of monthly mean values for each segment were produced to allow visual inspection of trends over time and to allow a comparison between bay segments. Time series plots of monthly TN concentrations are provided for each segment in Figures 2-9 through 2-18.

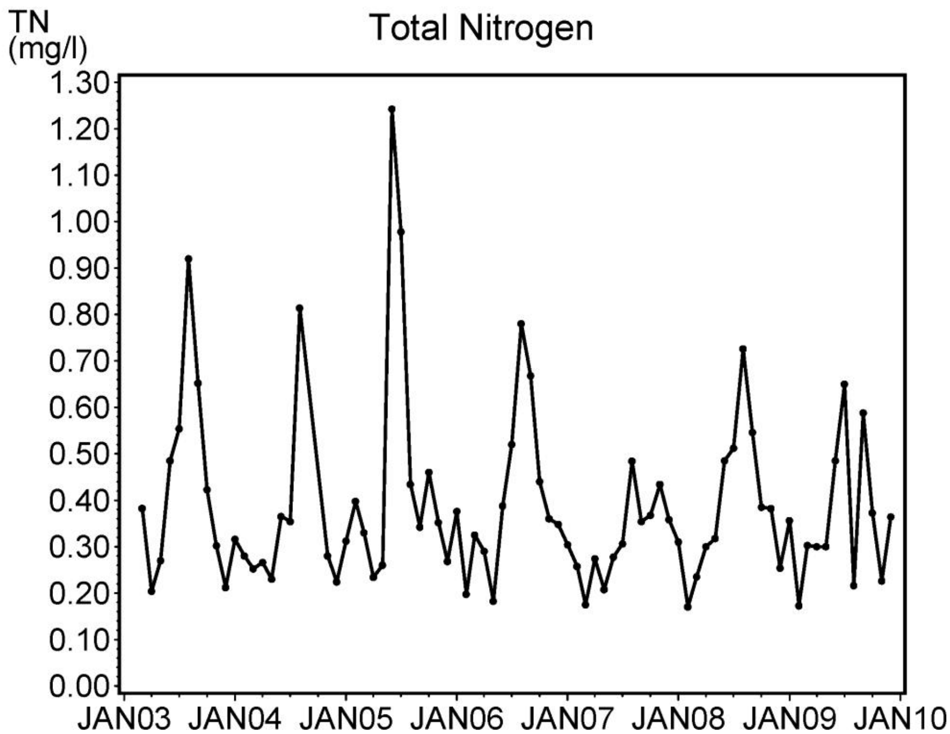


Figure 2-9. Monthly TN concentrations (mg/L) in Dona and Roberts Bays.

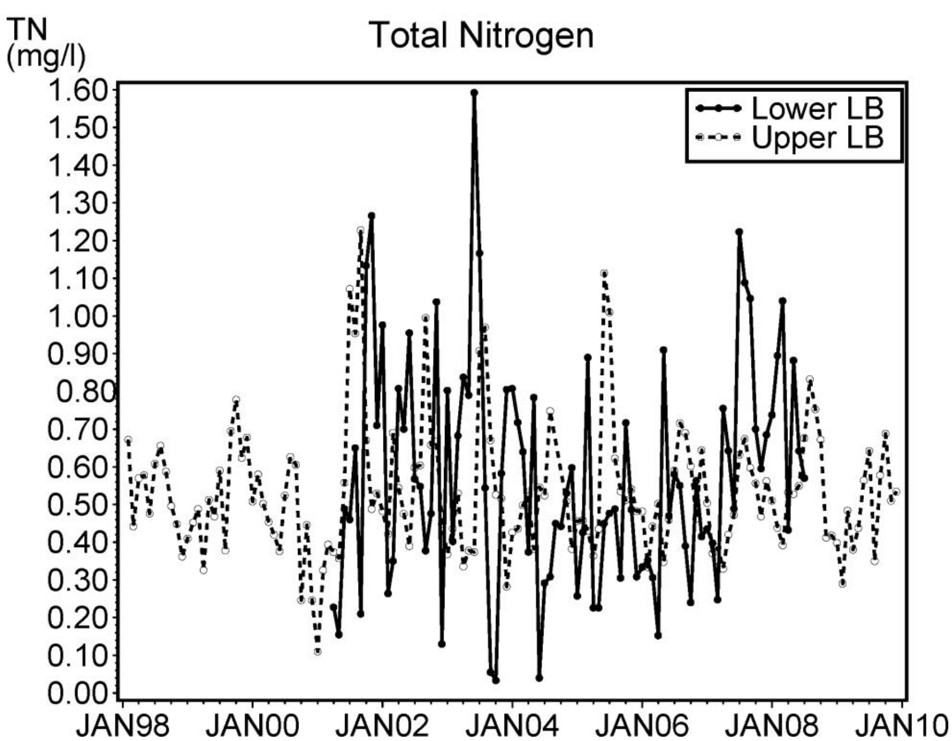


Figure 2-10. Monthly TN concentrations (mg/L) in Upper and Lower Lemon Bay.

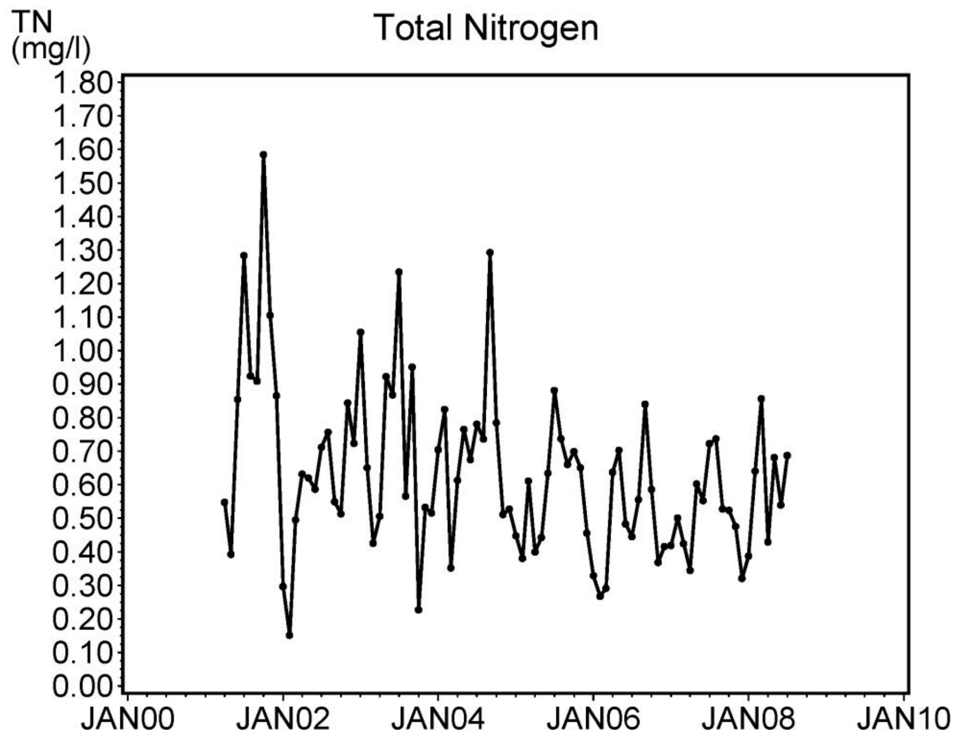


Figure 2-11. Monthly TN concentrations (mg/L) in Charlotte Harbor Proper.

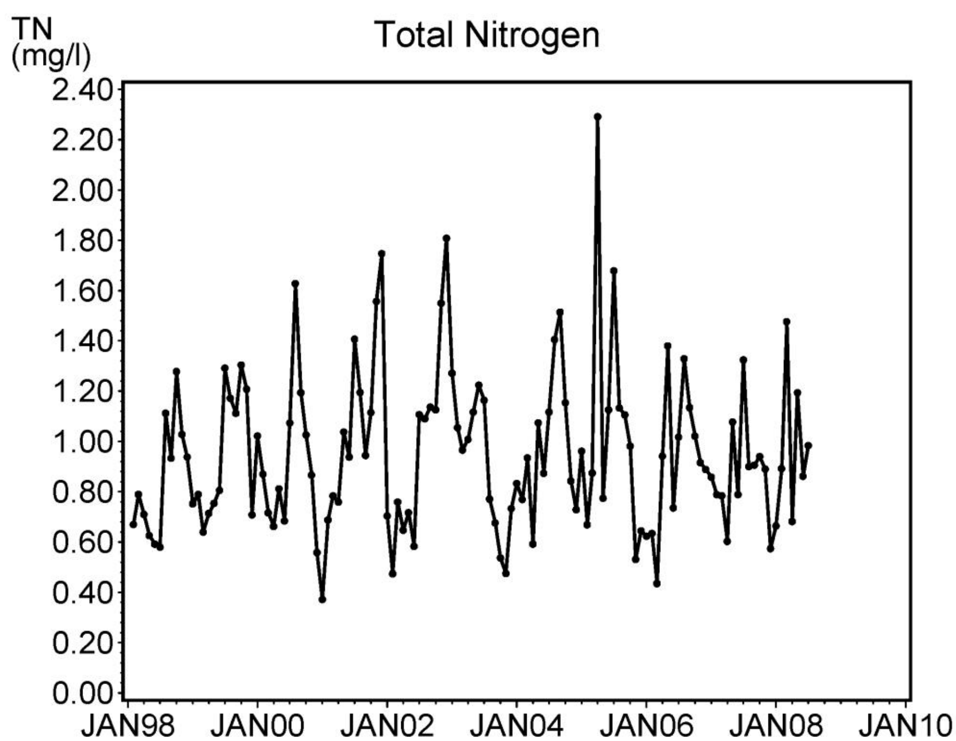


Figure 2-12. Monthly TN concentrations (mg/L) in Tidal Myakka.

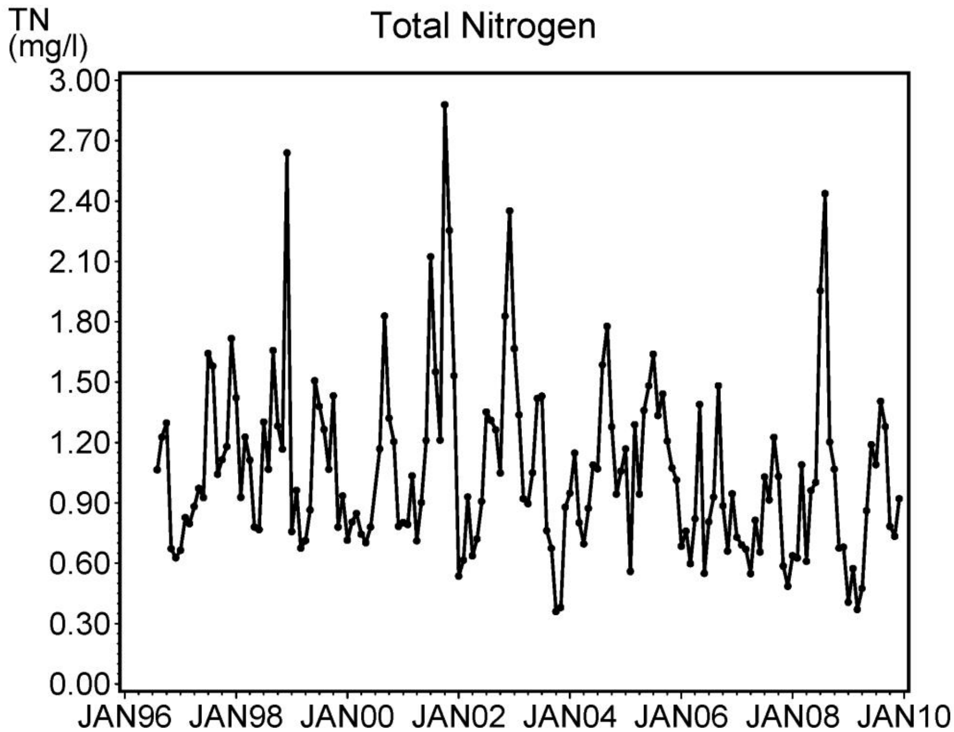


Figure 2-13. Monthly TN concentrations (mg/L) in Tidal Peace.

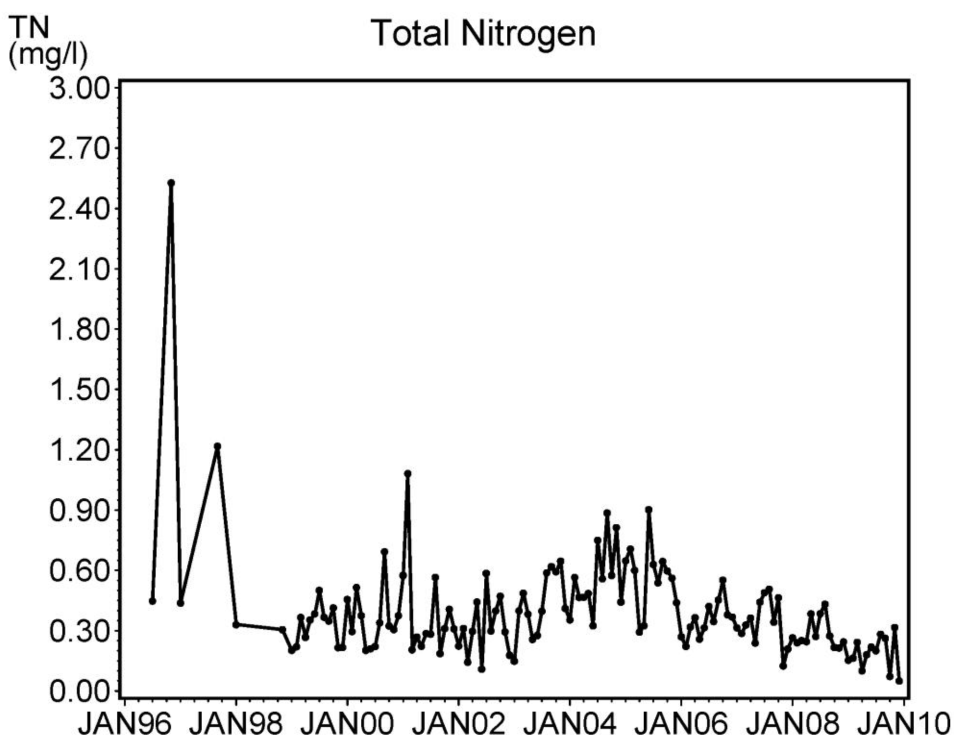


Figure 2-14. Monthly TN concentrations (mg/L) in Pine Island Sound.

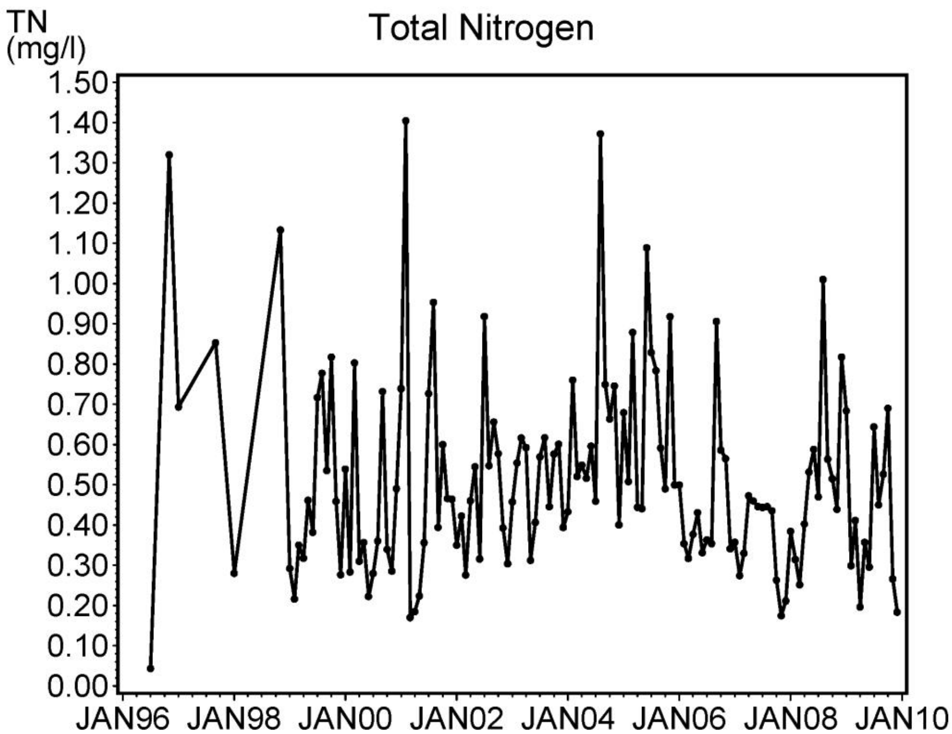


Figure 2-15. Monthly TN concentrations (mg/L) in Matlacha Pass.

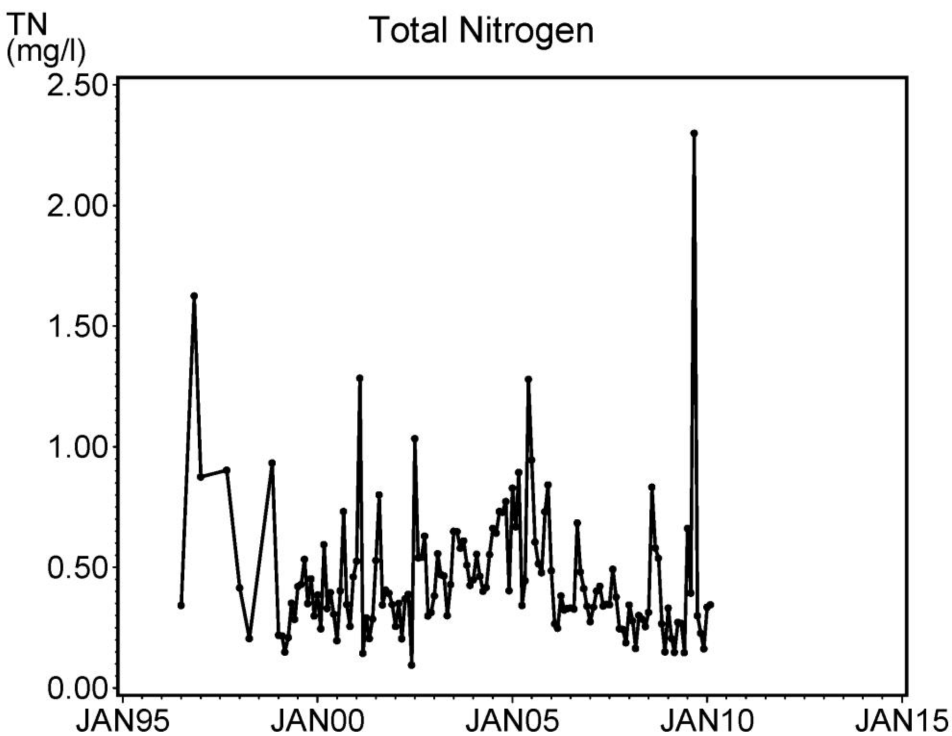


Figure 2-16. Monthly TN concentrations (mg/L) in San Carlos Bay.

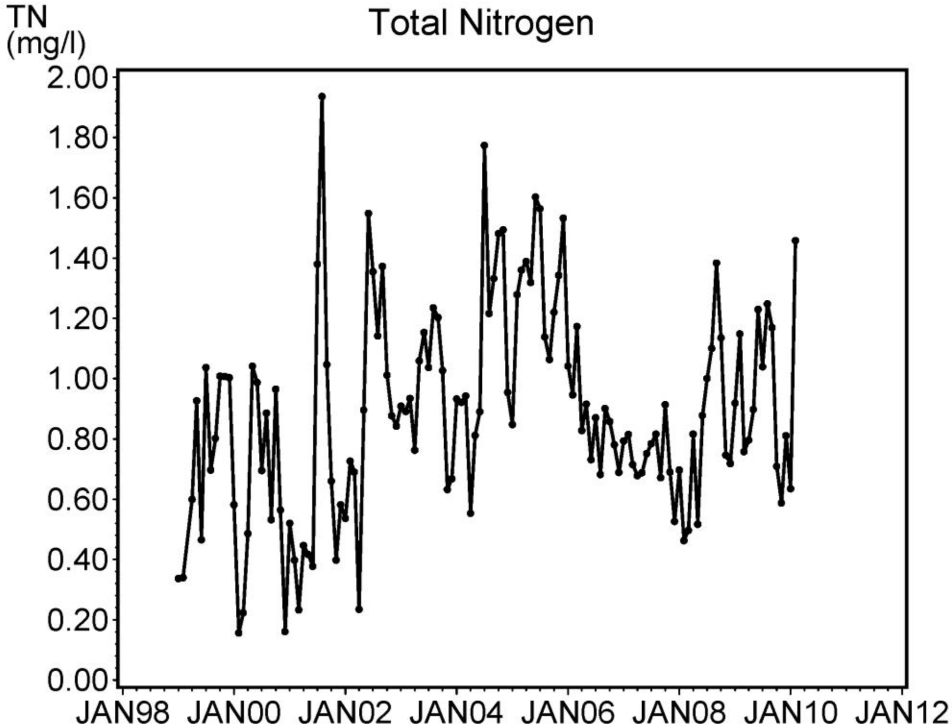


Figure 2-17. Monthly TN concentrations (mg/L) in Tidal Caloosahatchee.

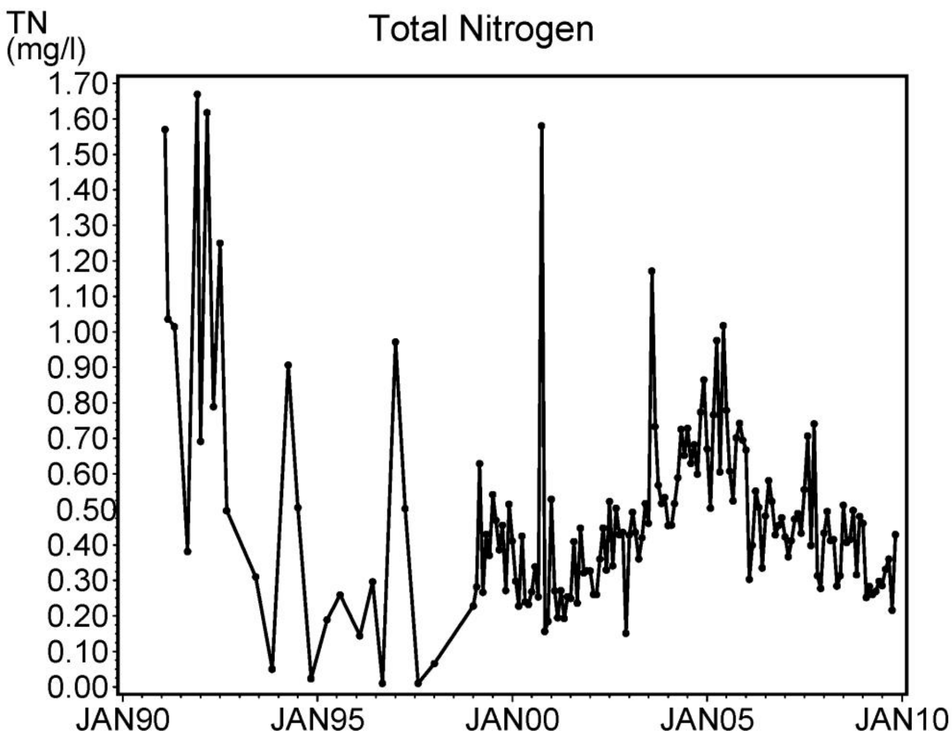


Figure 2-18. Monthly TN concentrations (mg/L) in Estero Bay.

2.3 Total Phosphorus Concentrations

As for TN concentrations, times series of monthly mean TP values for each segment were produced to allow visual inspection of trends over time and to allow a comparison between bay segments. Time series plots of monthly TP concentrations are provided for each segment in Figures 2-19 through 2-28.

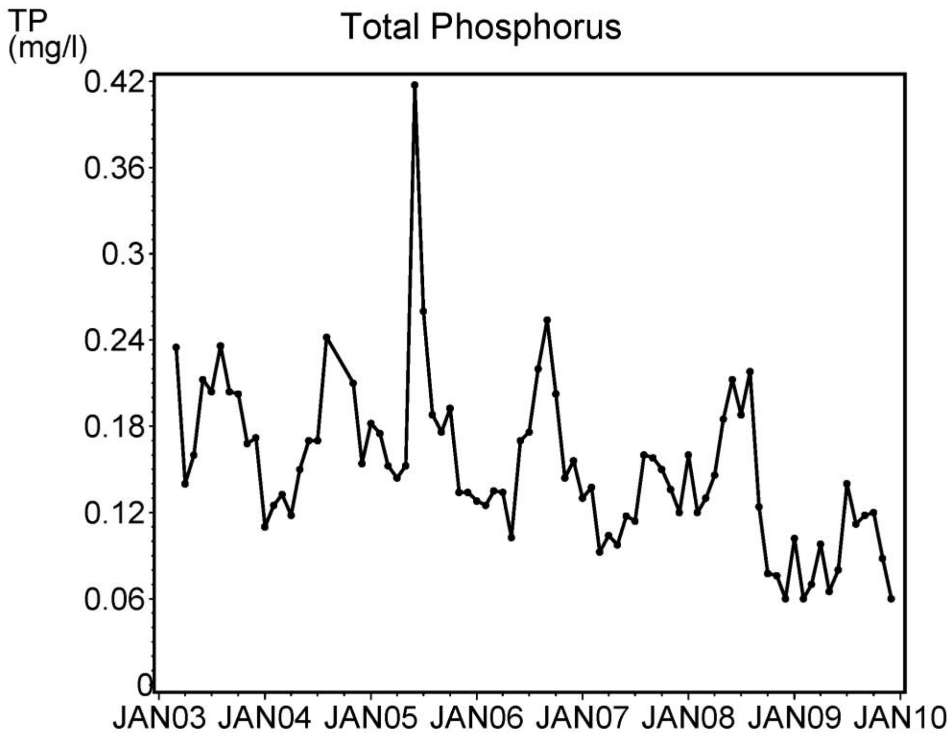


Figure 2-19. Monthly TP concentrations (mg/L) in Dona and Roberts Bays.

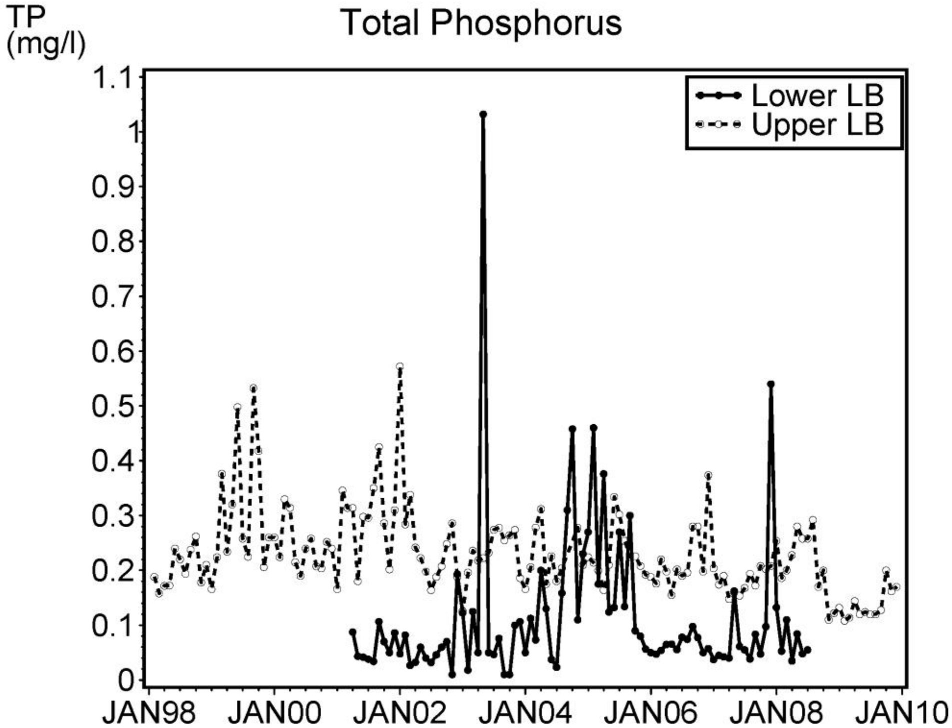


Figure 2-20. Monthly TP concentrations (mg/L) in Upper and Lower Lemon Bay.

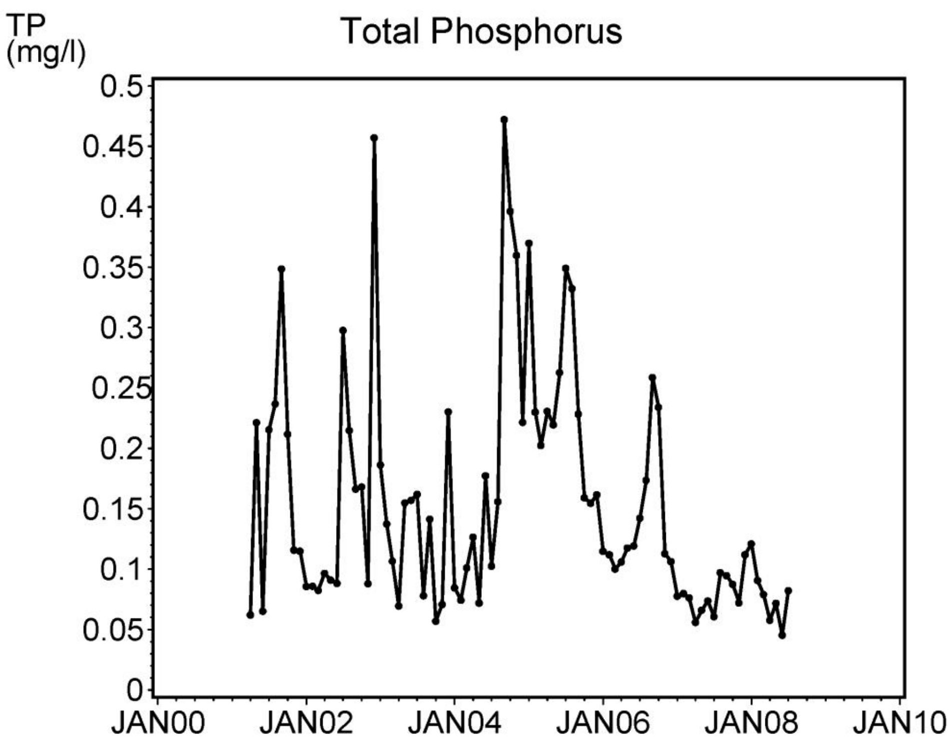


Figure 2-21. Monthly TP concentrations (mg/L) in Charlotte Harbor Proper.

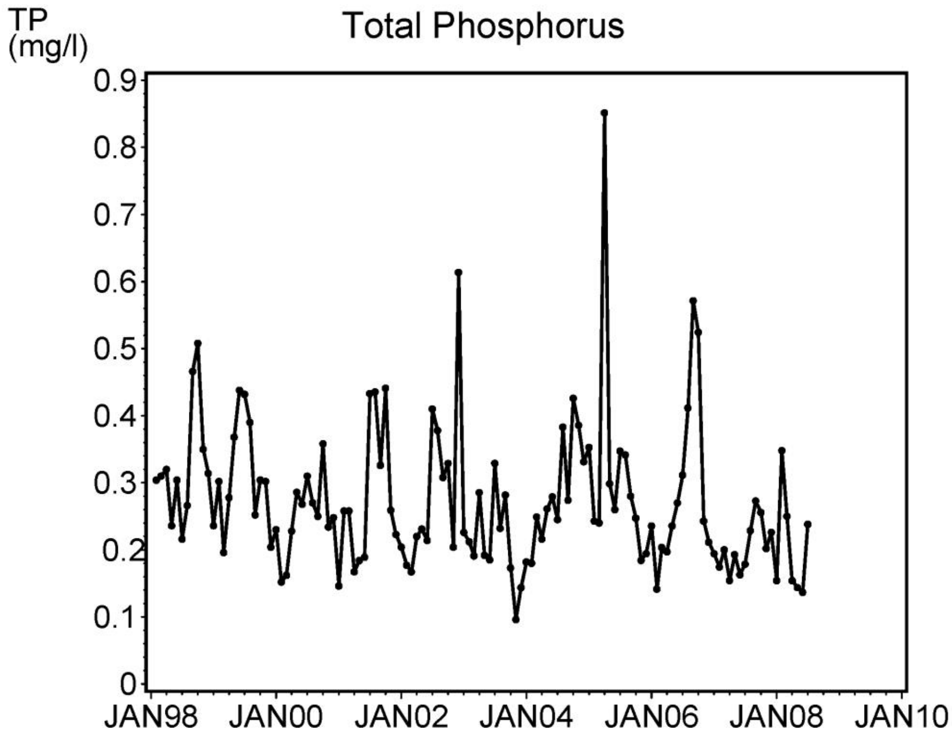


Figure 2-22. Monthly TP concentrations (mg/L) in Tidal Myakka.

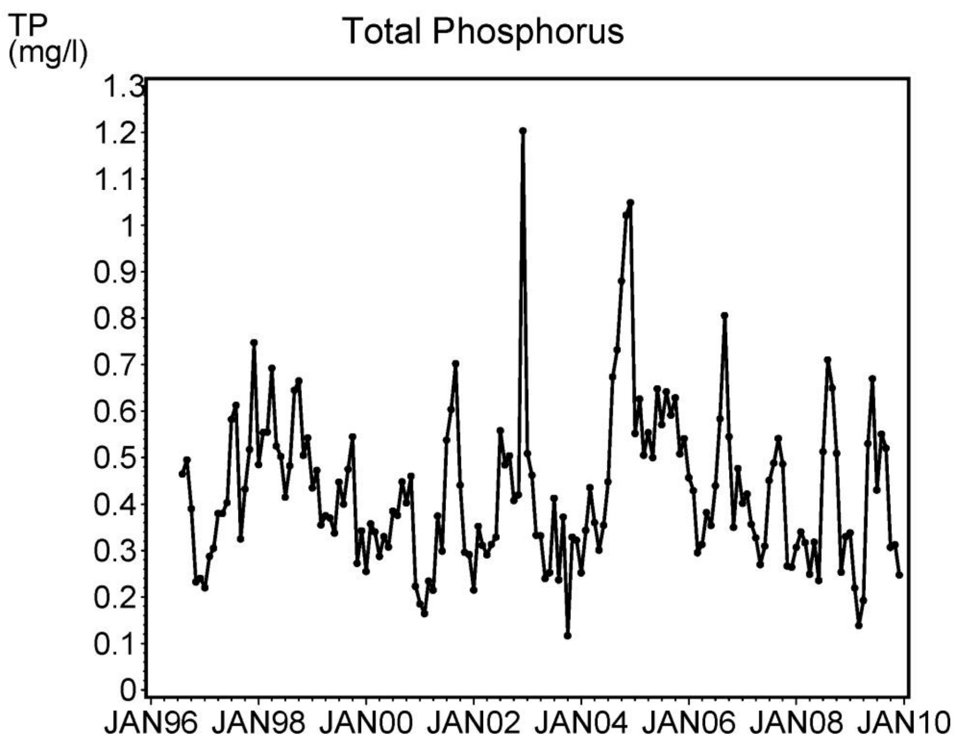


Figure 2-23. Monthly TP concentrations (mg/L) in Tidal Peace.

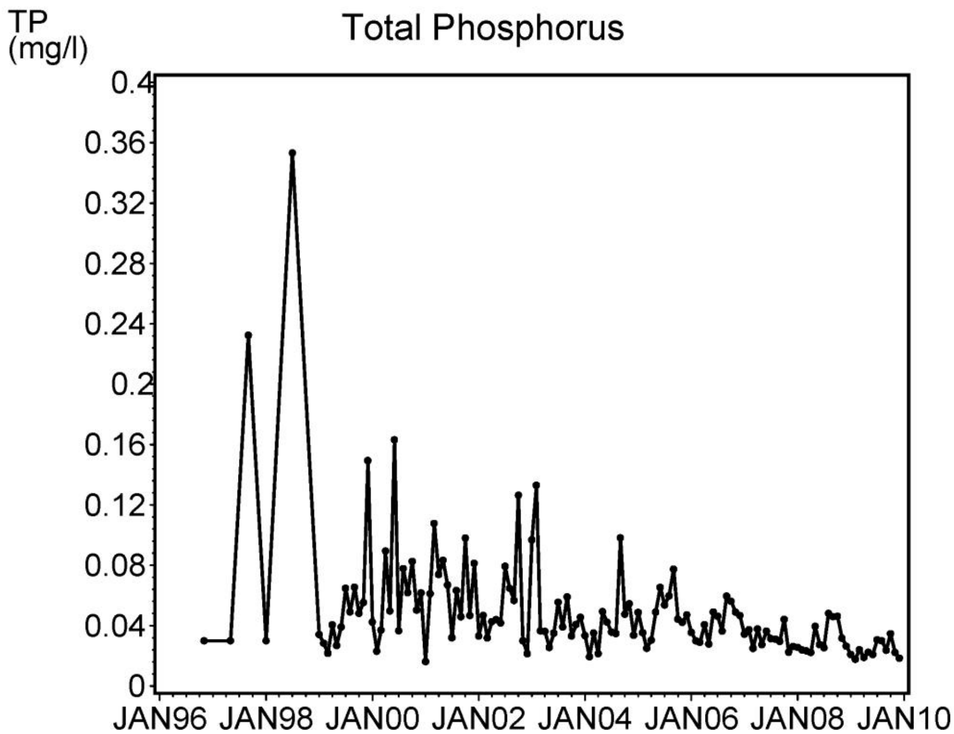


Figure 2-24. Monthly TP concentrations (mg/L) in Pine Island Sound.

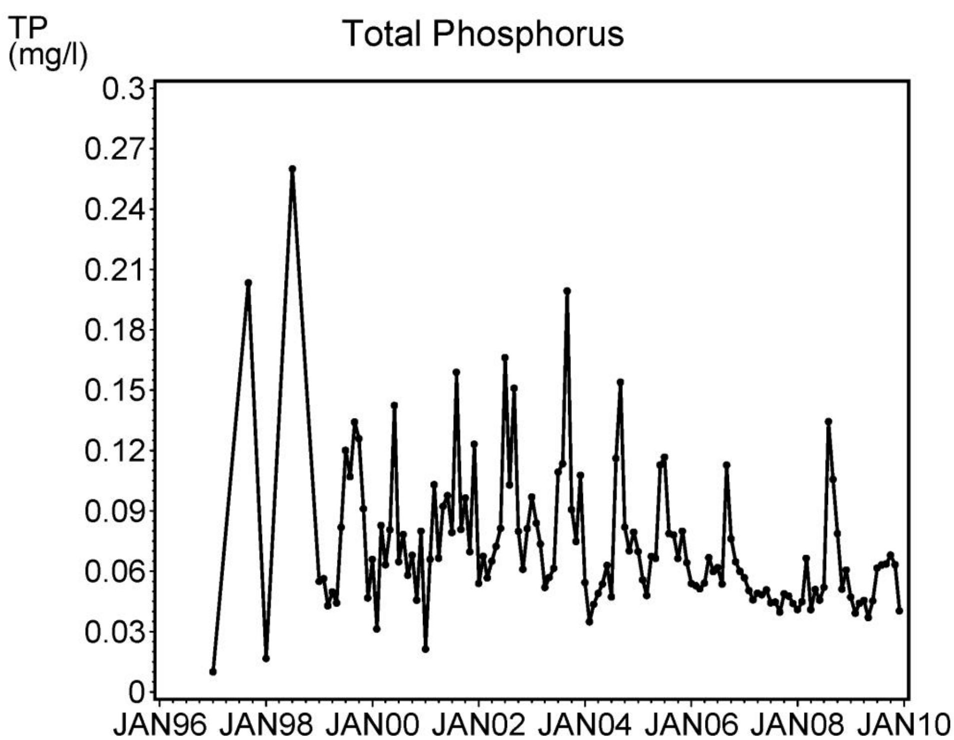


Figure 2-25. Monthly TP concentrations (mg/L) in Matlacha Pass.

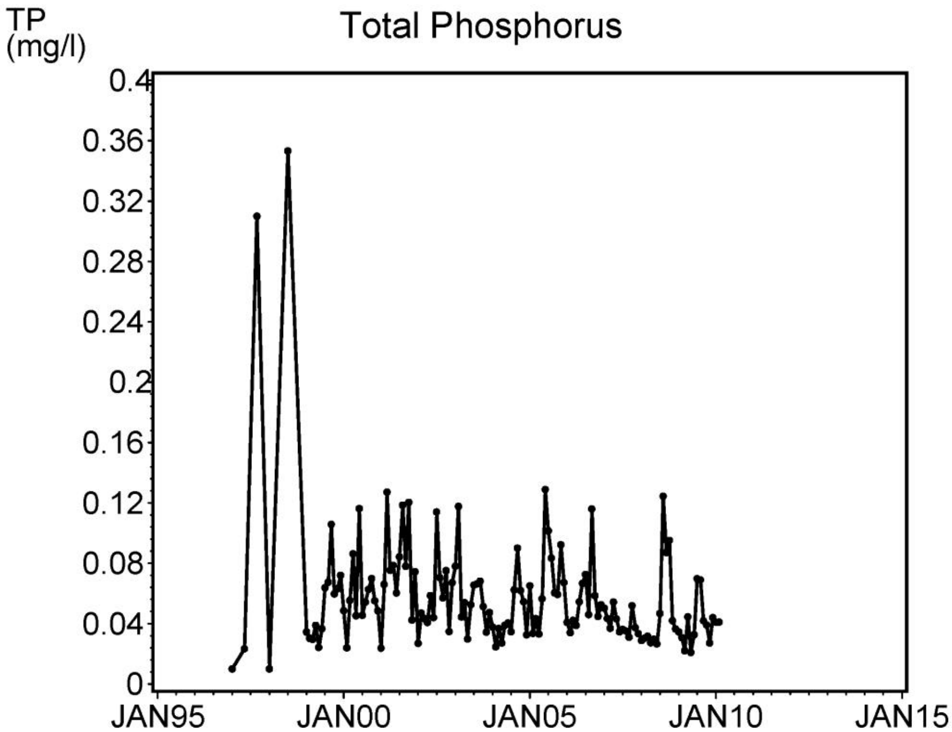


Figure 2-26. Monthly TP concentrations (mg/L) in San Carlos Bay.

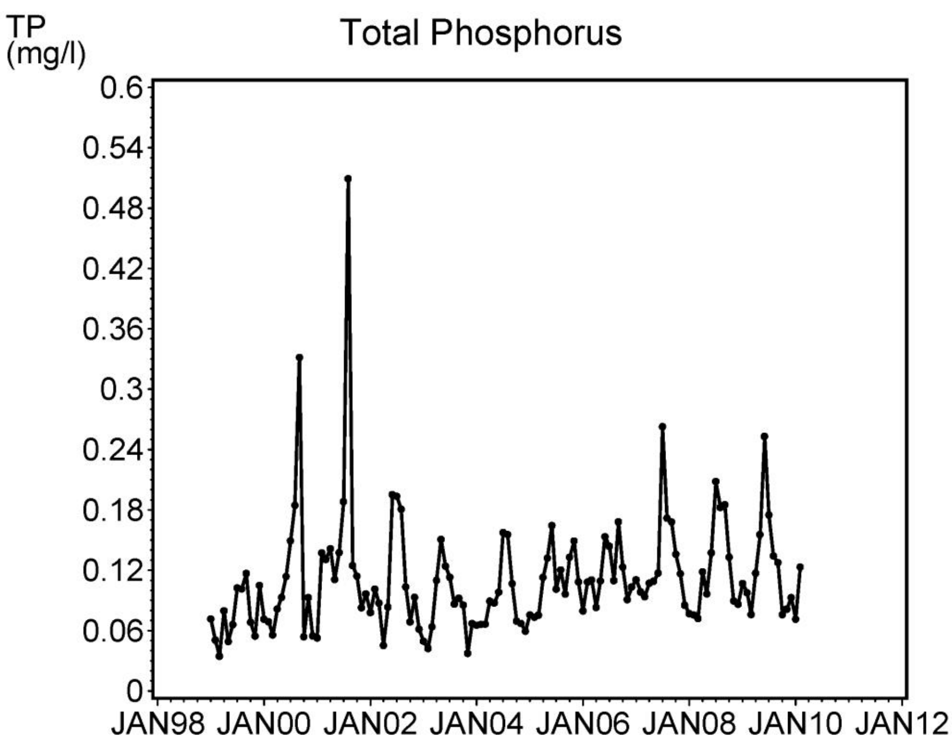


Figure 2-27. Monthly TP concentrations (mg/L) in Tidal Caloosahatchee.

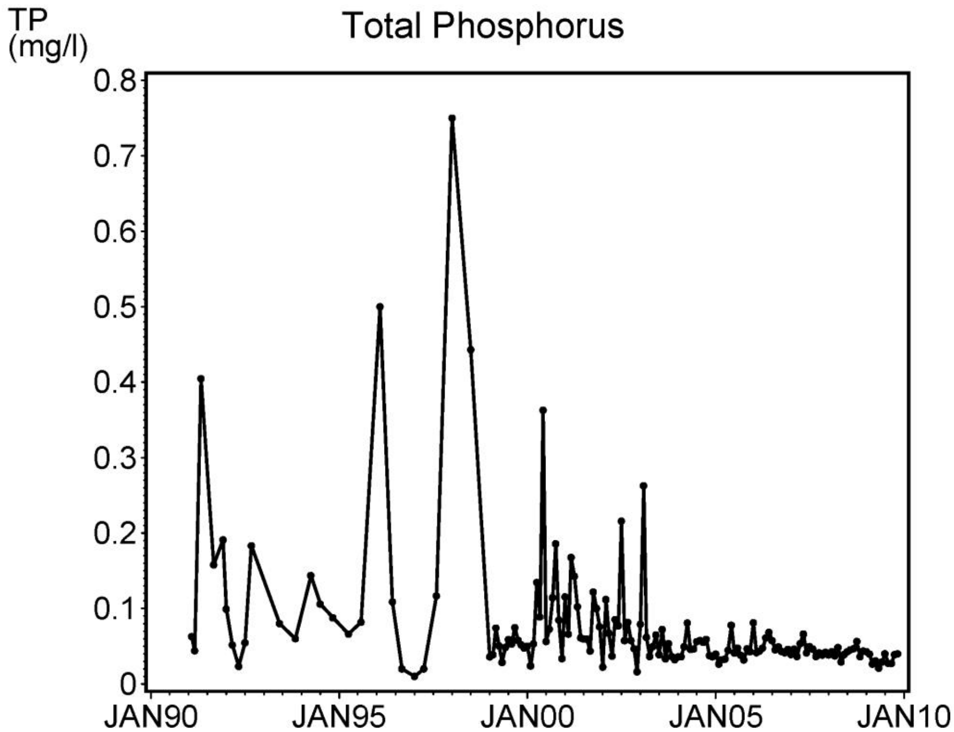


Figure 2-28. Monthly TP concentrations (mg/L) in Estero Bay.

2.4 Chlorophyll *a*

As for nutrient concentrations, times series of monthly mean chlorophyll *a* values for each segment were produced to allow visual inspection of trends over time and to allow a comparison between bay segments. Time series plots of monthly TP concentrations are provided for each segment in Figures 2-29 through 2-38.

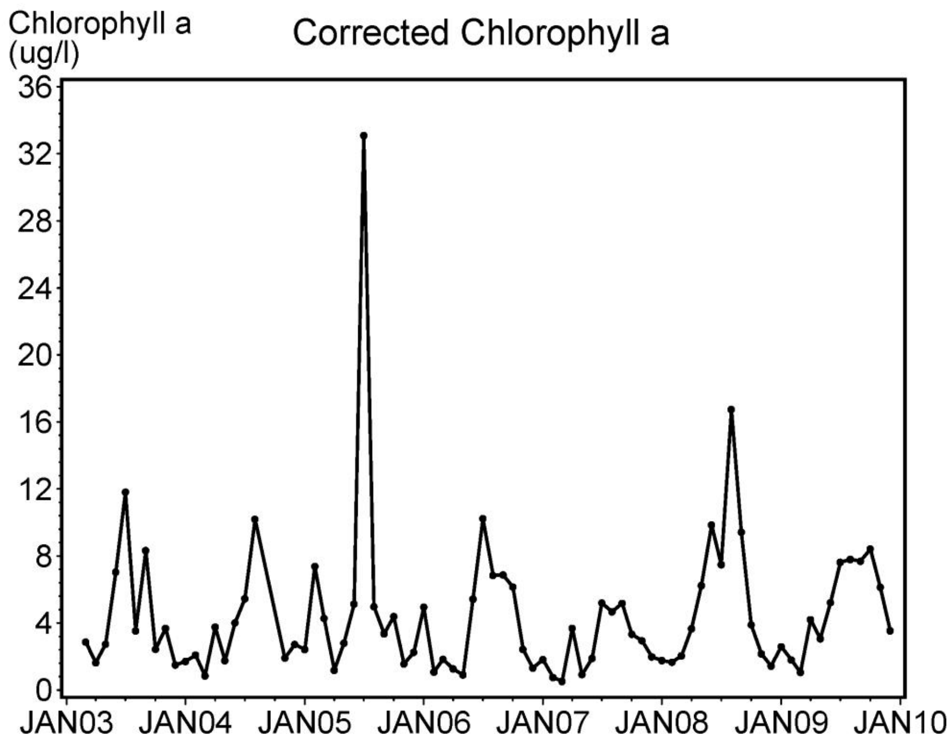


Figure 2-29. Monthly chlorophyll *a* concentrations (μg/L) in Dona and Roberts Bays.

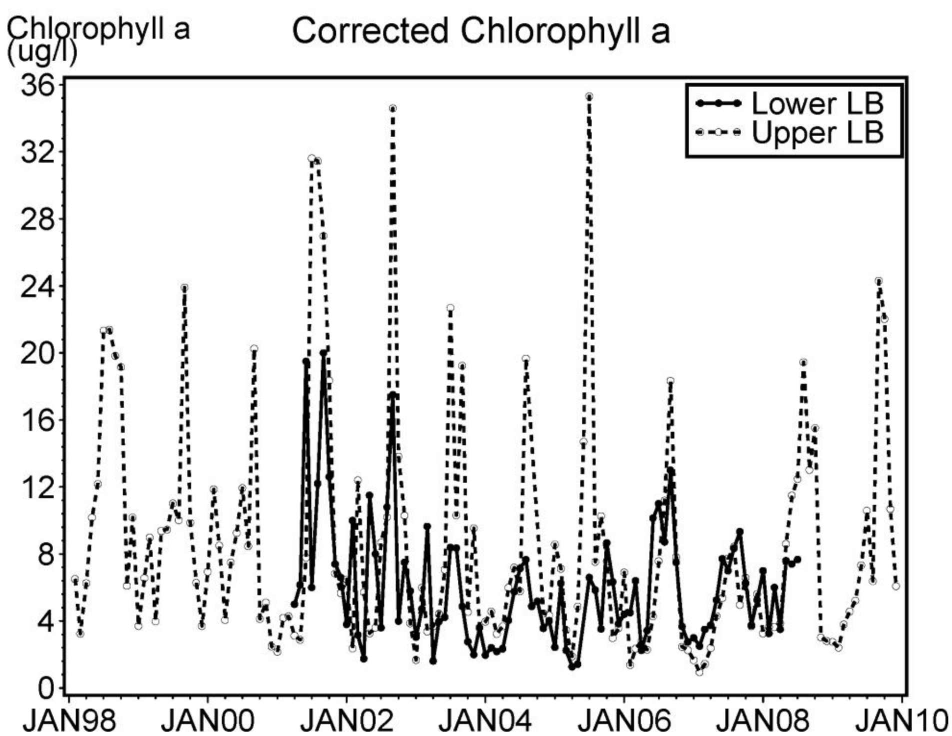


Figure 2-30. Monthly chlorophyll *a* concentrations (μg/L) in Upper and Lower Lemon Bay.

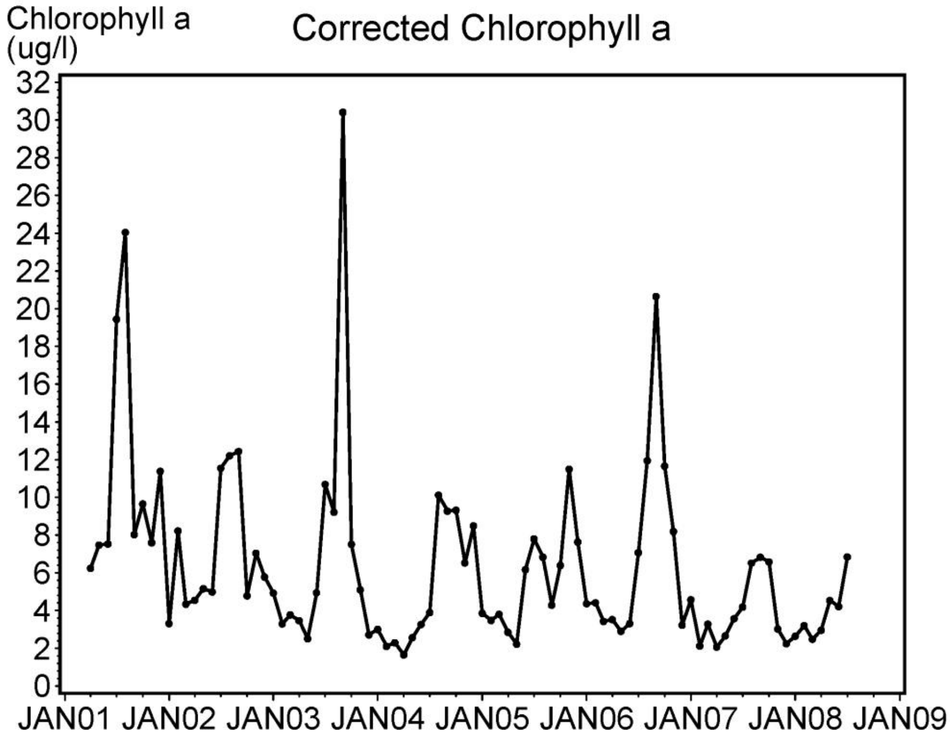


Figure 2-31. Monthly chlorophyll *a* concentrations (μg/L) in Charlotte Harbor Proper.

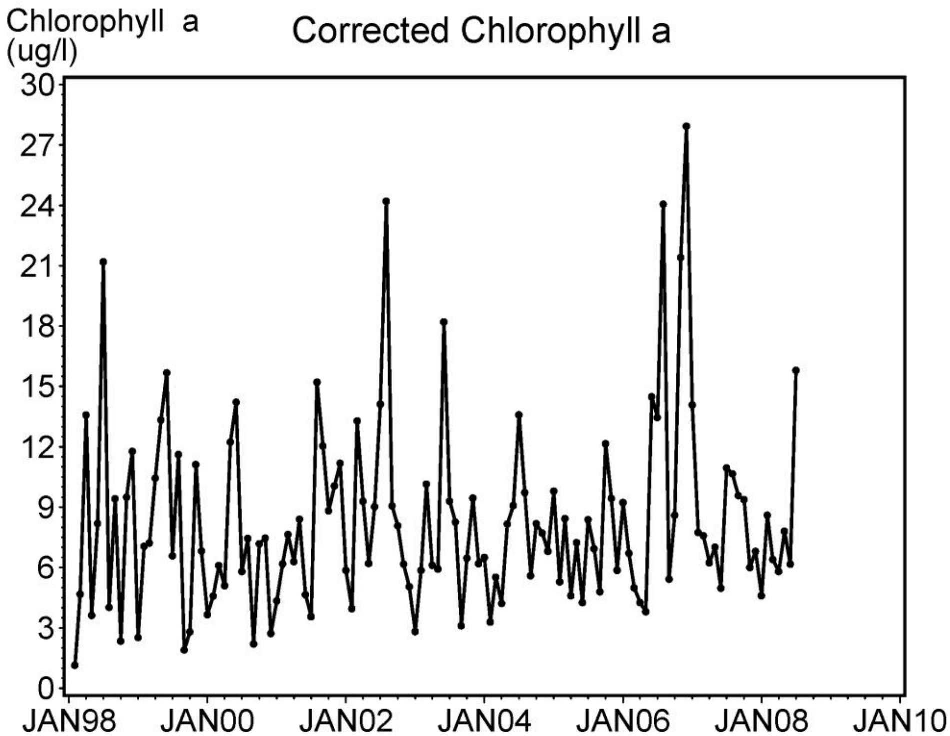


Figure 2-32. Monthly chlorophyll *a* concentrations (μg/L) in Tidal Myakka.

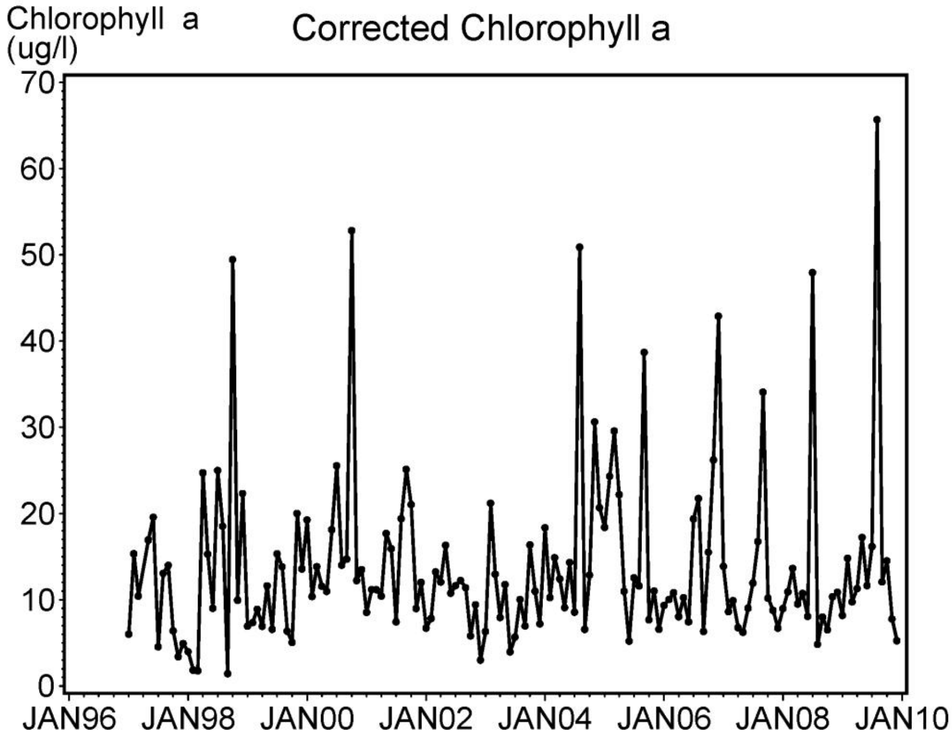


Figure 2-33. Monthly chlorophyll *a* concentrations (μg/L) in Tidal Peace.

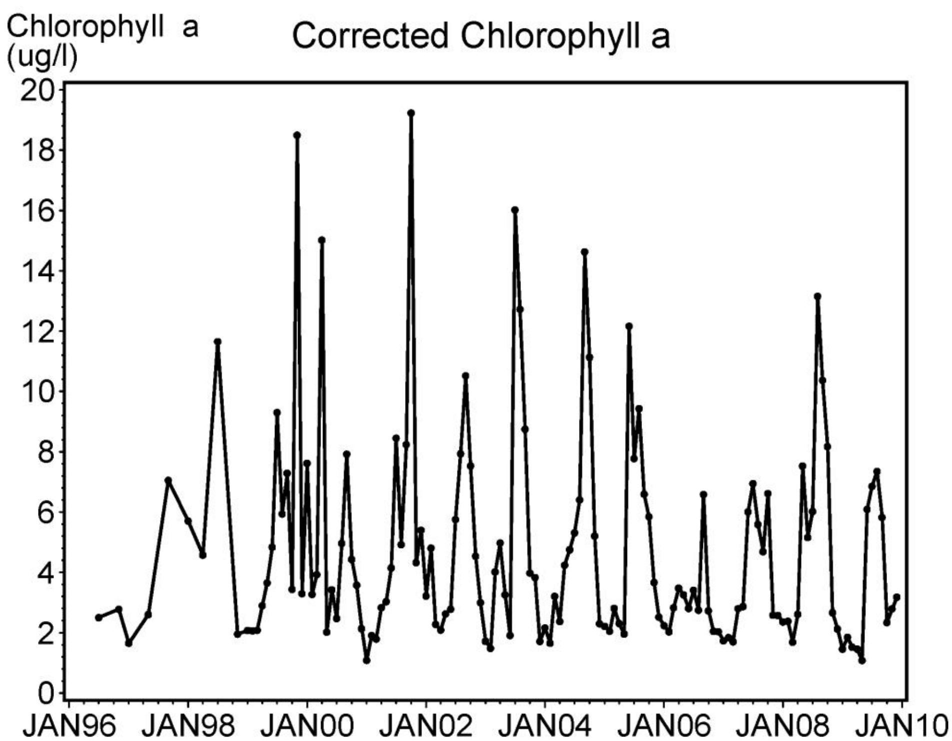


Figure 2-34. Monthly chlorophyll *a* concentrations (μg/L) in Pine Island Sound.

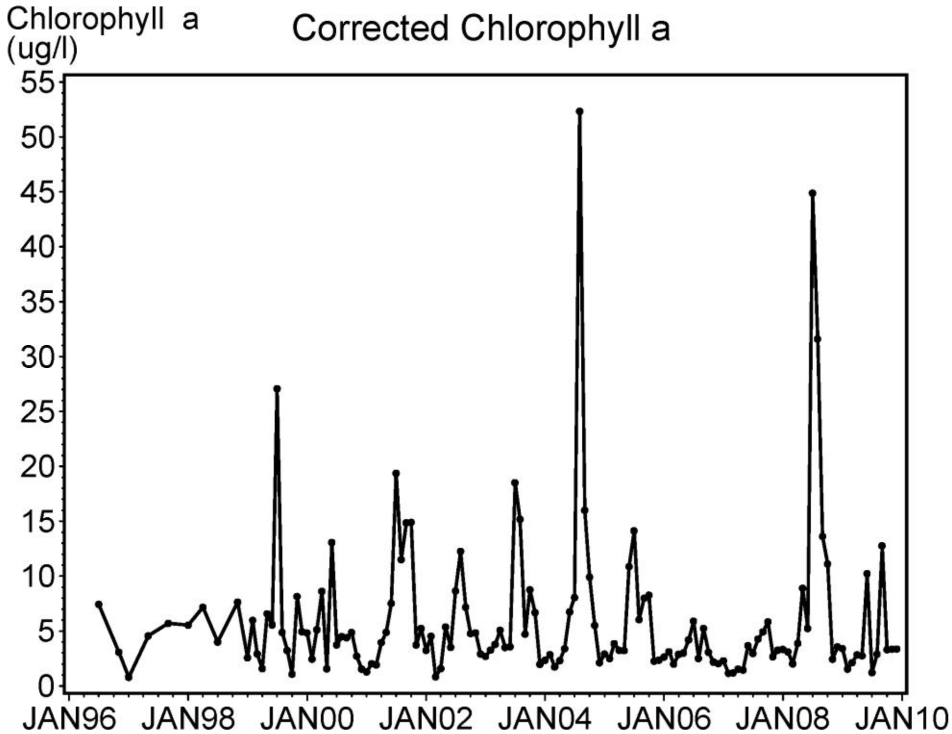


Figure 2-35. Monthly chlorophyll *a* concentrations (μg/L) in Matlacha Pass.

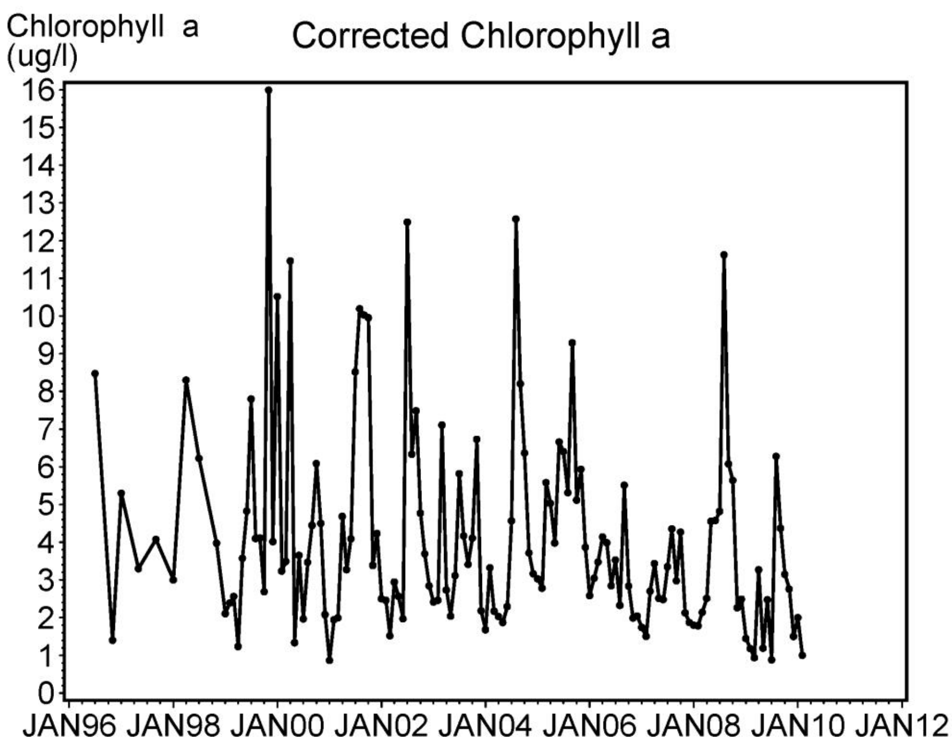


Figure 2-36. Monthly chlorophyll *a* concentrations (μg/L) in San Carlos Bay.

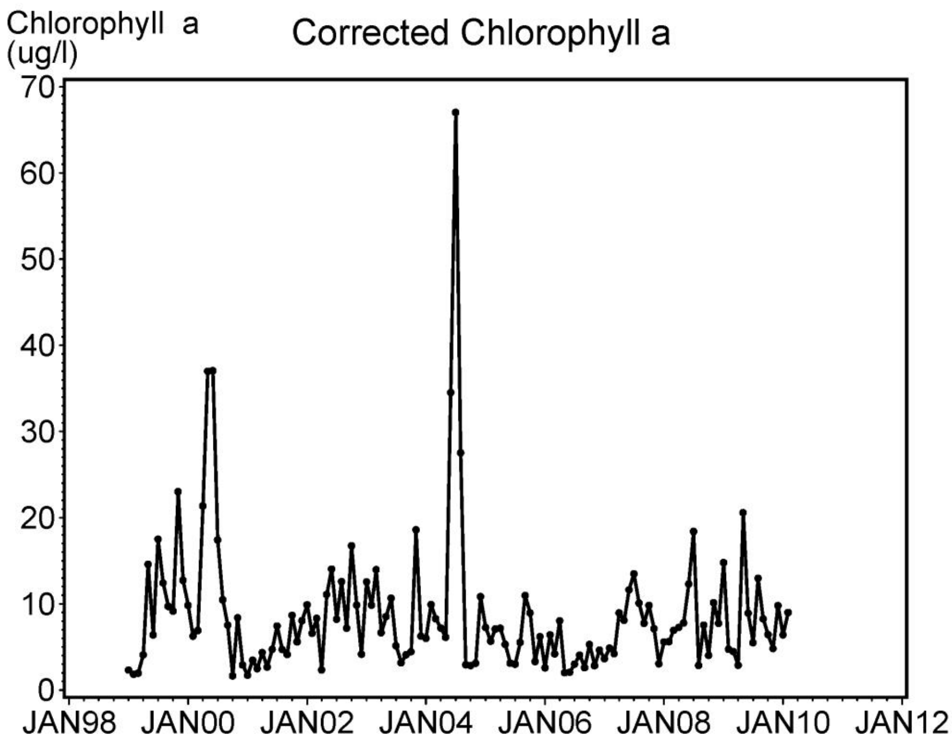


Figure 2-37. Monthly chlorophyll *a* concentrations (μg/L) in Tidal Caloosahatchee.

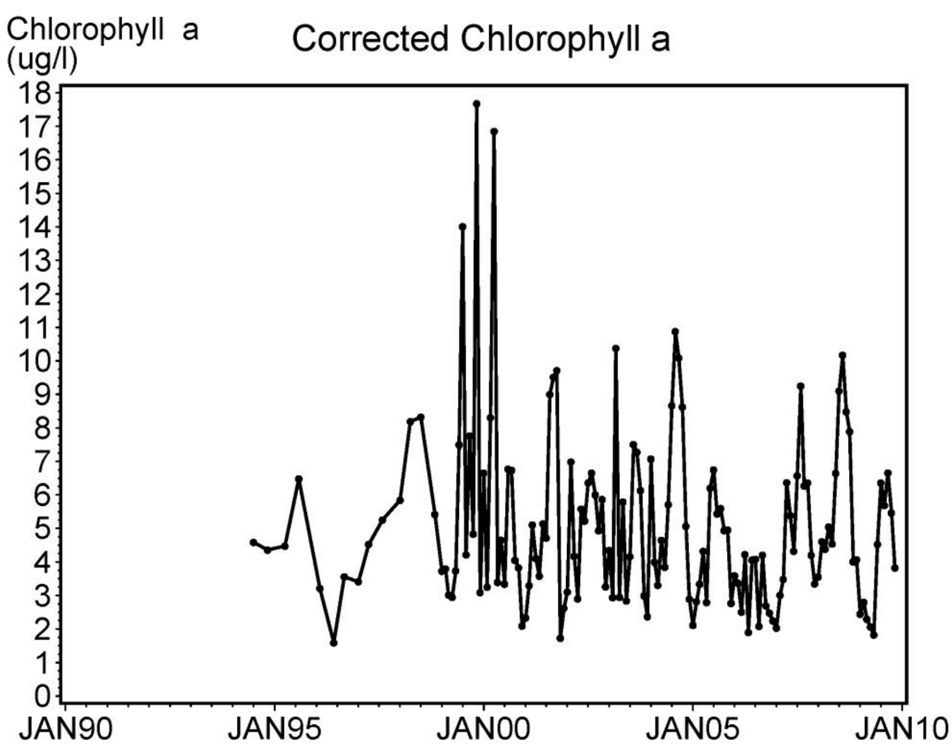


Figure 2-38. Monthly chlorophyll *a* concentrations (μg/L) in Estero Bay.

2.5 Hydrologic, Total Nitrogen, and Total Phosphorus Loadings

Hydrologic and nutrient loads were estimated for the period 1995-2007 for the segments of the CHNEP area. The total annual hydrologic, TN, and TP loads to each bay segment are presented in Figures 2-39 through 2-48.

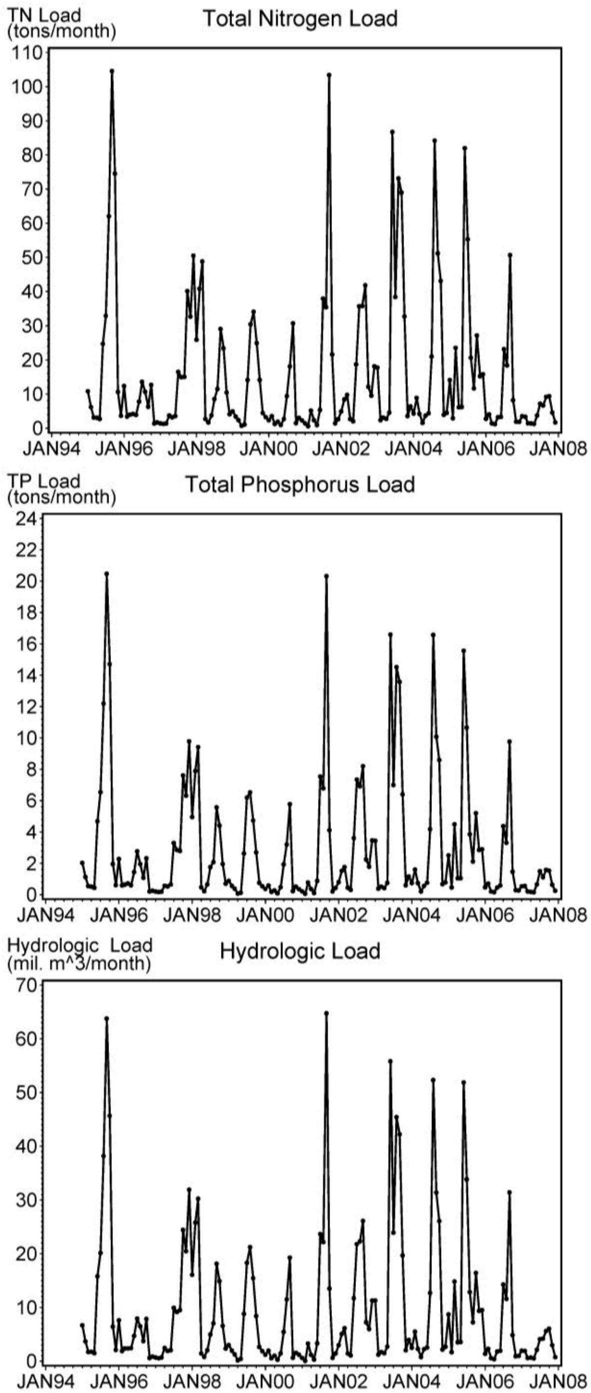


Figure 2-39. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Dona and Roberts Bays.

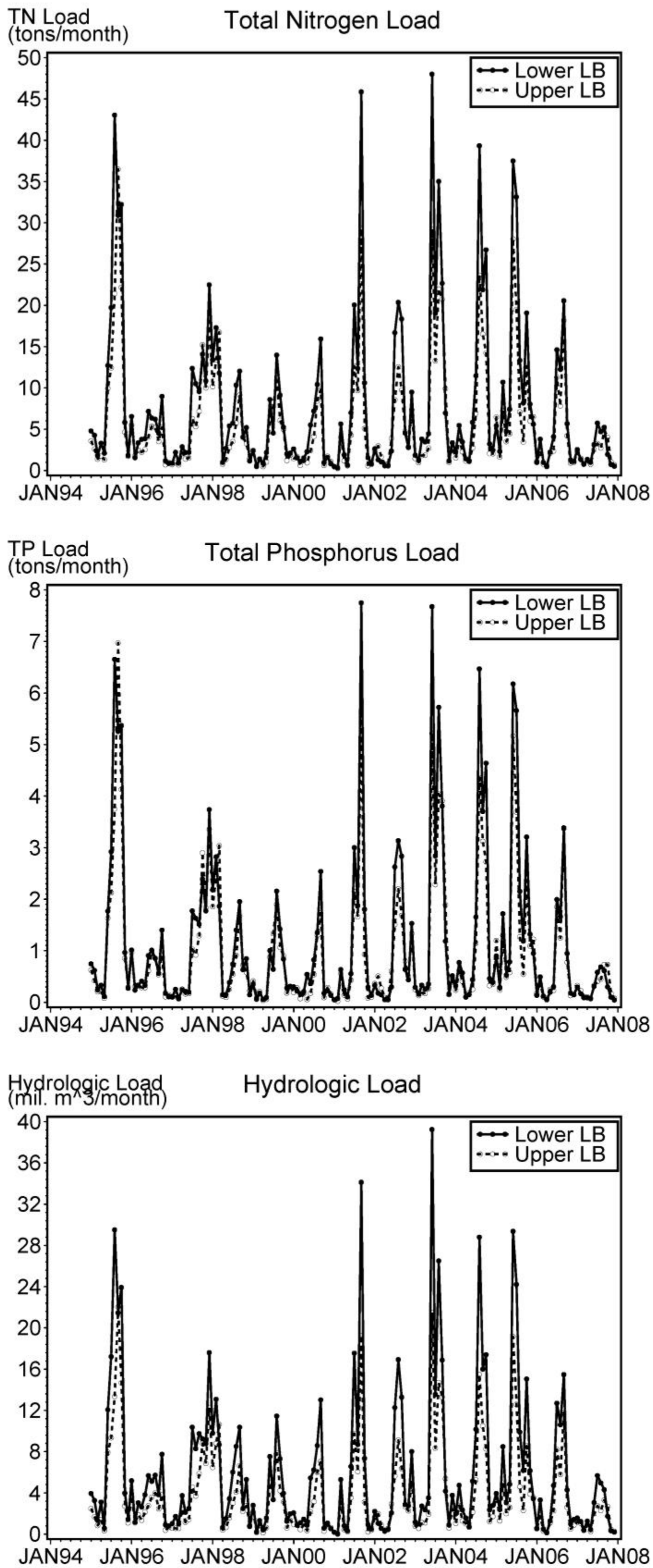


Figure 2-40. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Lemon Bay.

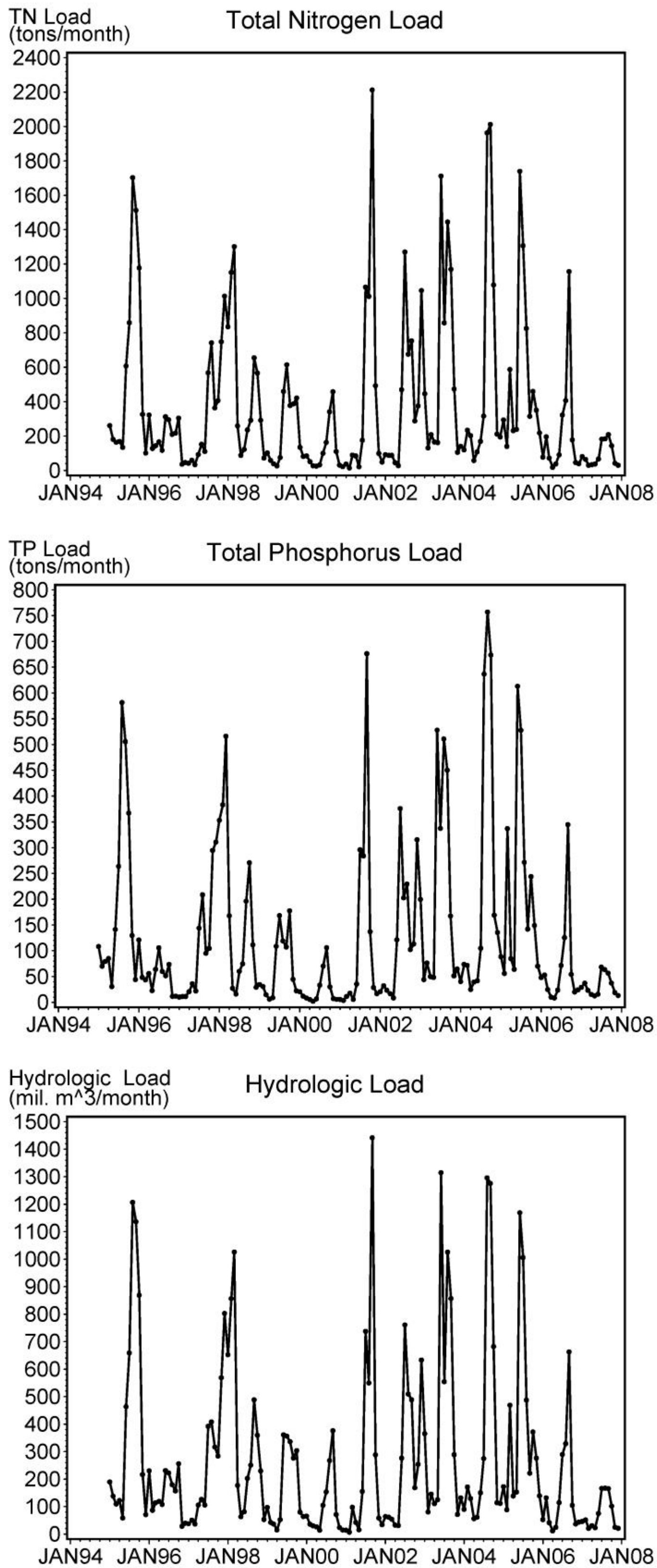


Figure 2-41. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Charlotte Harbor Proper.

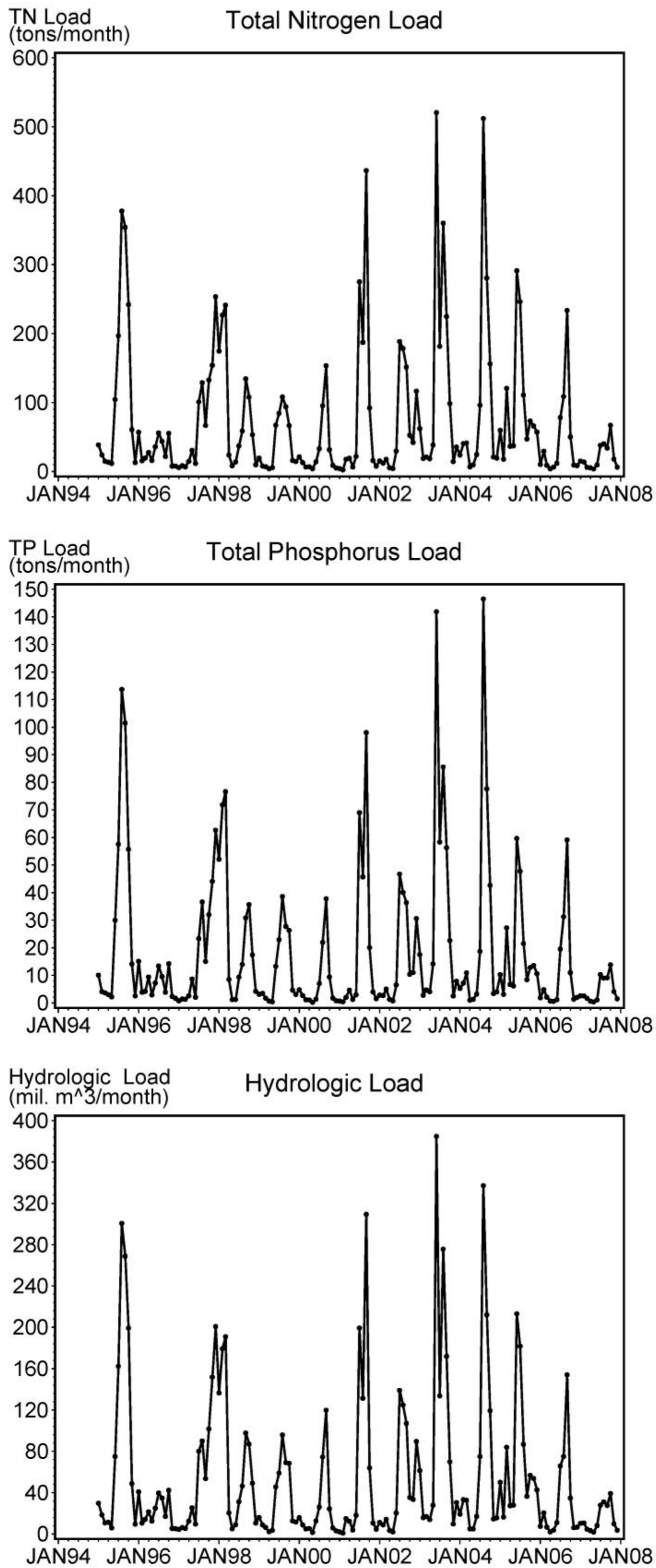


Figure 2-42. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Tidal Myakka.

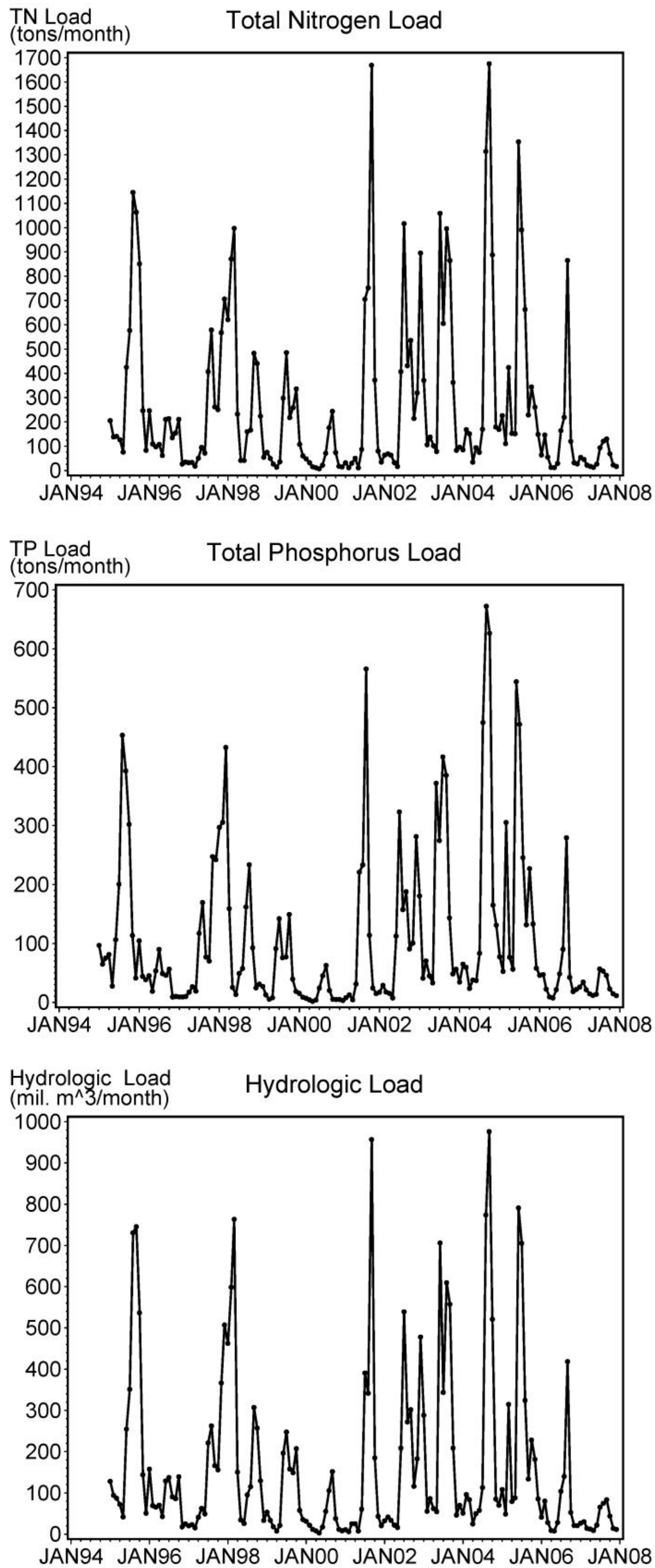


Figure 2-43. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Tidal Peace.

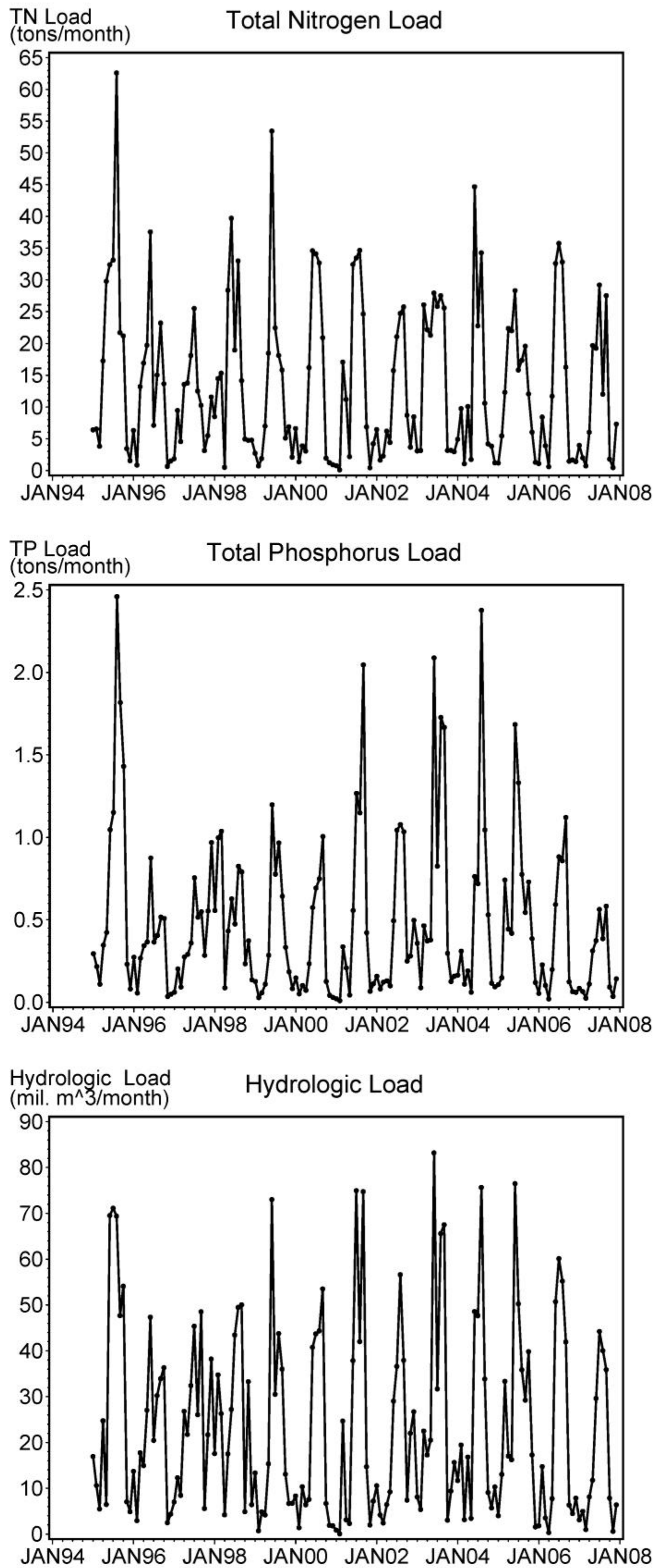


Figure 2-44. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Pine Island Sound.

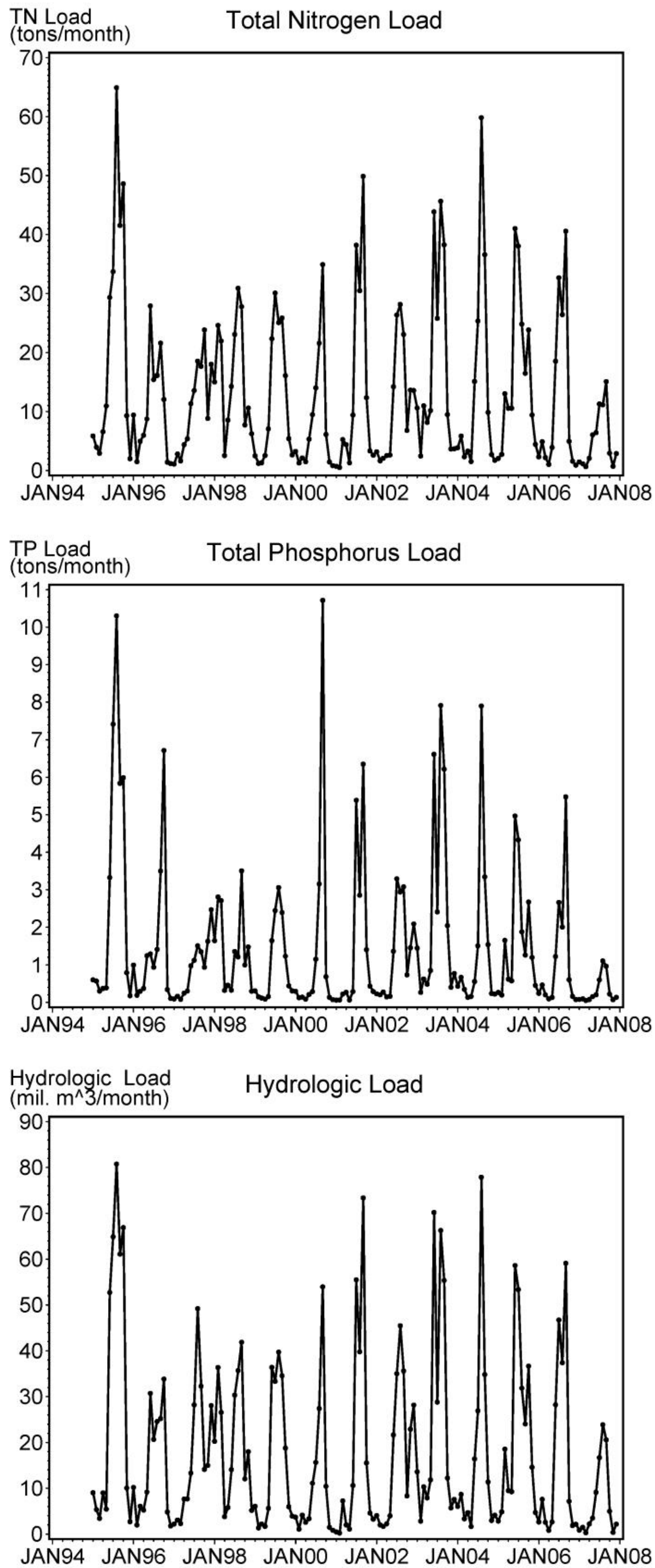


Figure 2-45. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Matlacha Pass.

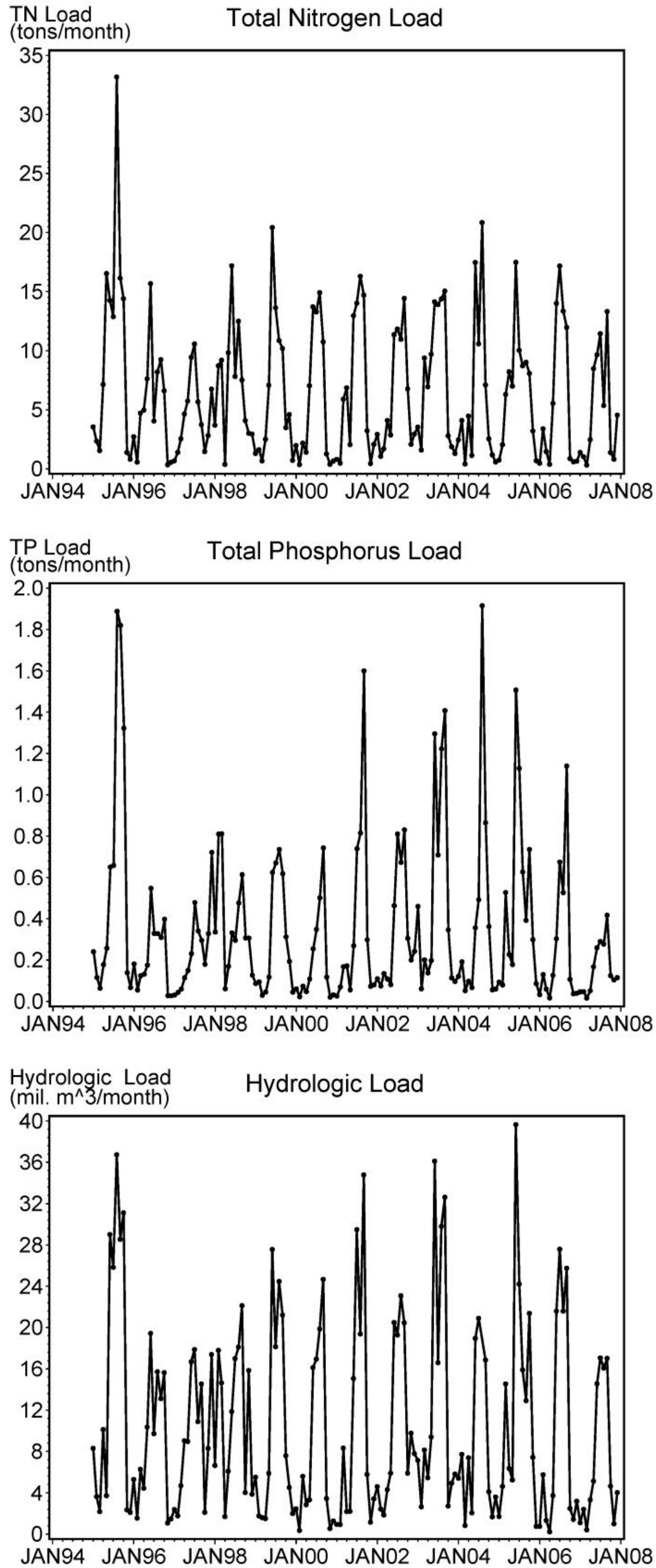


Figure 2-46. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for San Carlos Bay.

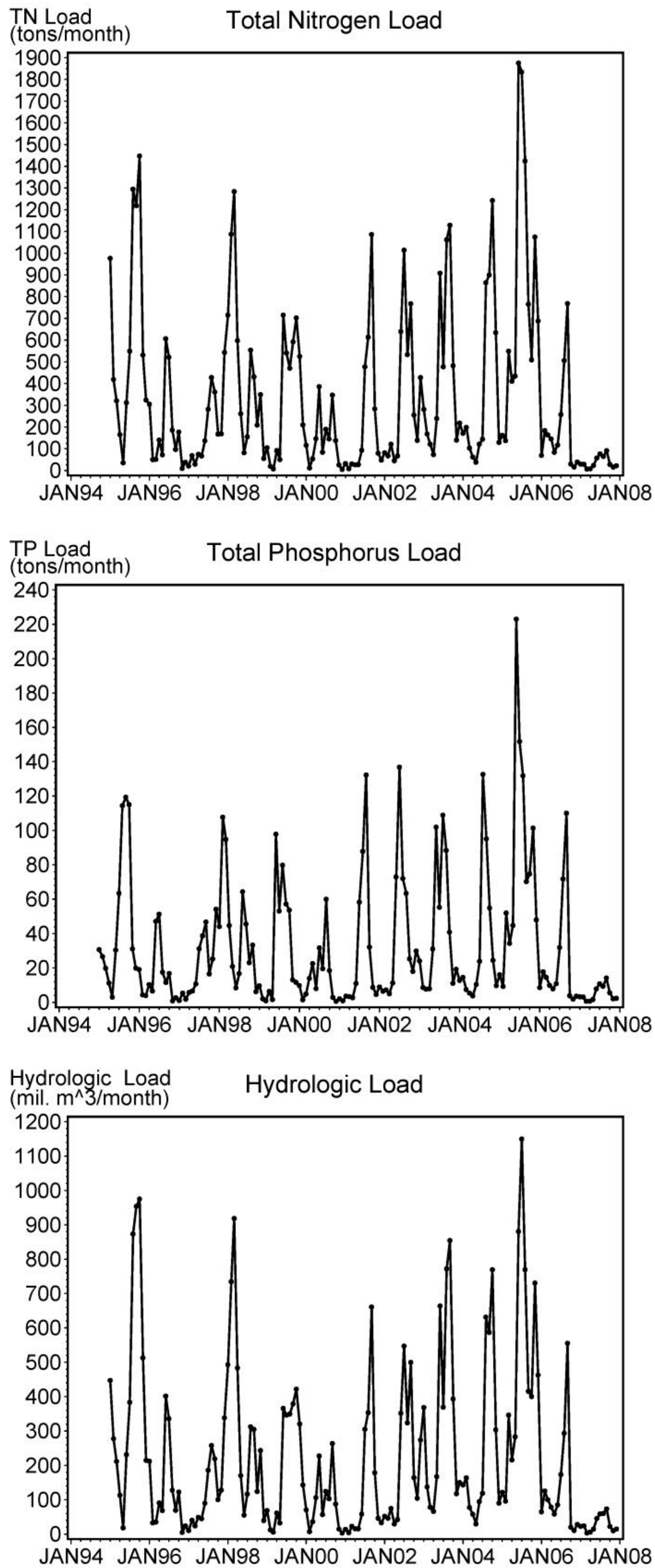


Figure 2-47. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Tidal Caloosahatchee.

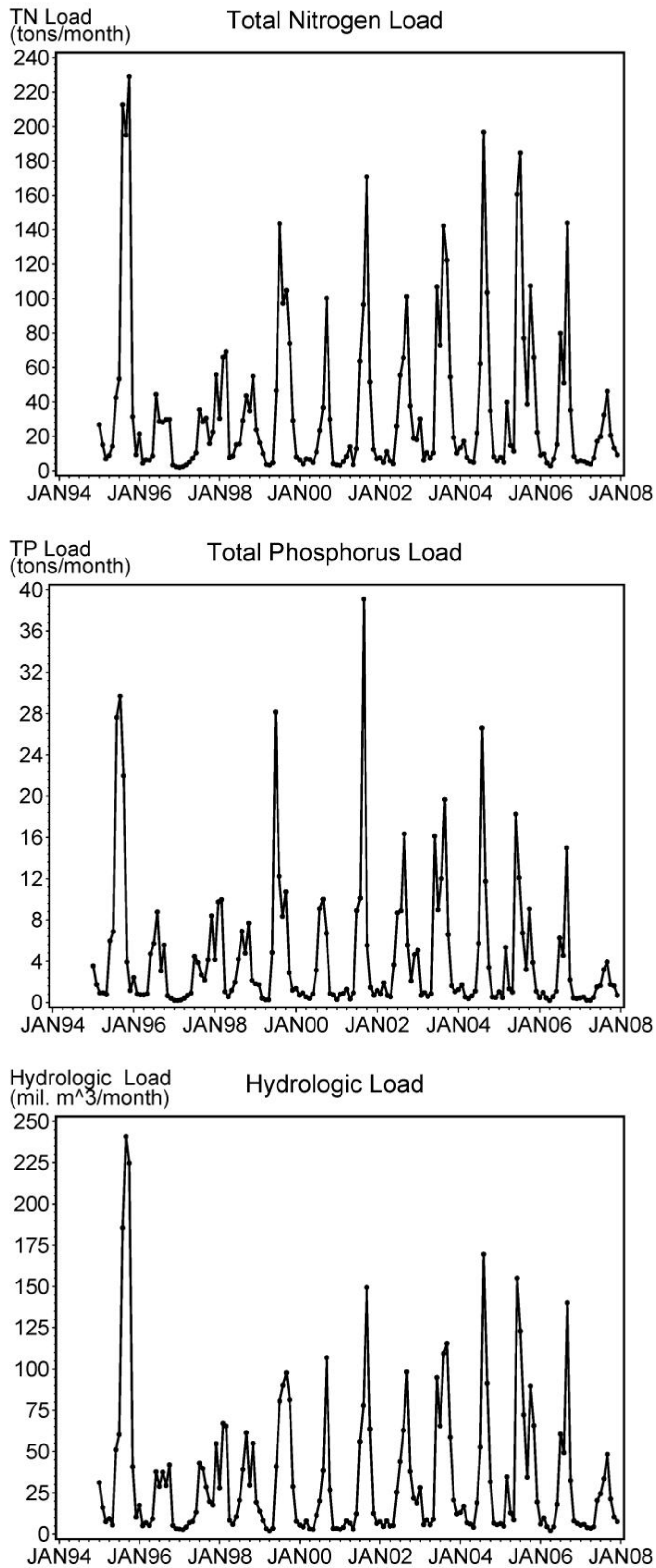


Figure 2-48. Time series of TN loads (top plot), TP loads (middle plot), and hydrologic loads (bottom plot) for Estero Bay.

3.0 References

Janicki Environmental, Inc. 2009. Water Quality Target Refinement Project – Task 2: Seagrass target development. Interim Report 2. Prepared for Charlotte Harbor National Estuary Program, Ft. Myers, FL. Authors: Janicki, A., M. Dema, and M. Wessel.

Janicki Environmental, Inc. 2010. Water Quality Target Refinement Project, Task 4: Pollutant Loading Estimates Development, Interim Report 4. Prepared for Charlotte Harbor National Estuary Program. Ft. Myers, FL.

APPENDIX B.
Criteria Expressed as TN and TP Concentrations, and as TN and TP Loads

1.0 Introduction

This appendix provides summaries of the derivation and application of the recommended numeric nutrient criteria for the CHNEP. Segment-specific stressor-response relationships between chlorophyll a and nitrogen concentrations were developed, but left a considerable amount of variability unexplained. Therefore, the Policy Committee agreed to develop TN concentration criteria based on the reference period approach. The same approach was utilized for developing criteria in terms of TP concentrations and TN and TP loads, should these be necessary.

2.0 Total Nitrogen Concentrations

The CHNEP has developed recommended numeric nutrient criteria as segment-specific mean annual total nitrogen concentrations (Janicki Environmental, 2011a). The strategy for developing the numeric nutrient criteria is based on the chlorophyll *a* thresholds (Table 2-1) (Janicki Environmental, 2011a). The following describes the approach used.

Table 2-1. Recommended chlorophyll *a* targets and thresholds (μg/L) developed based on reference period (2003-2007).

Segment	Restoration/ Protection	Target Chlorophyll *a* (μg/L)	Standard Deviation of Annual Means (μg/L)	Threshold Chlorophyll *a* (μg/L)
Dona and Roberts Bays	Restoration	4.3	1.2	4.9
Upper Lemon Bay	Protection	6.7	2.2	8.9
Lower Lemon Bay	Restoration	5.1	2.0	6.1
Tidal Myakka	Protection	8.9	2.8	11.7
Tidal Peace	Restoration	10.6	4.0	12.6
Charlotte Harbor Proper (EW+WW+BK+CH)	Restoration/ Protection	4.9	2.4	7.3/6.1
Matlacha Pass	Restoration	4.0	4.1	6.1
Pine Island Sound	Protection	5.1	1.4	6.5
San Carlos Bay	Protection	2.8	0.7	3.5
Tidal Caloosahatchee	Restoration	9.0	n/a	6.9 (TMDL)
Estero Bay	Restoration	4.9	2.0	5.9

A data analysis plan developed previously by Janicki Environmental (2010) identified a series of techniques that could be used to estimate statistically defensible relationships between chlorophyll *a* concentrations and nutrient concentrations and/or loadings, including linear regression, logistic regression, and change point analysis. A flowchart of the overall process used to develop numeric criteria for the segments of the CHNEP area is presented in Figure 2-1. Following this flowchart, numeric nutrient criteria in terms of TN concentrations were developed for each segment.

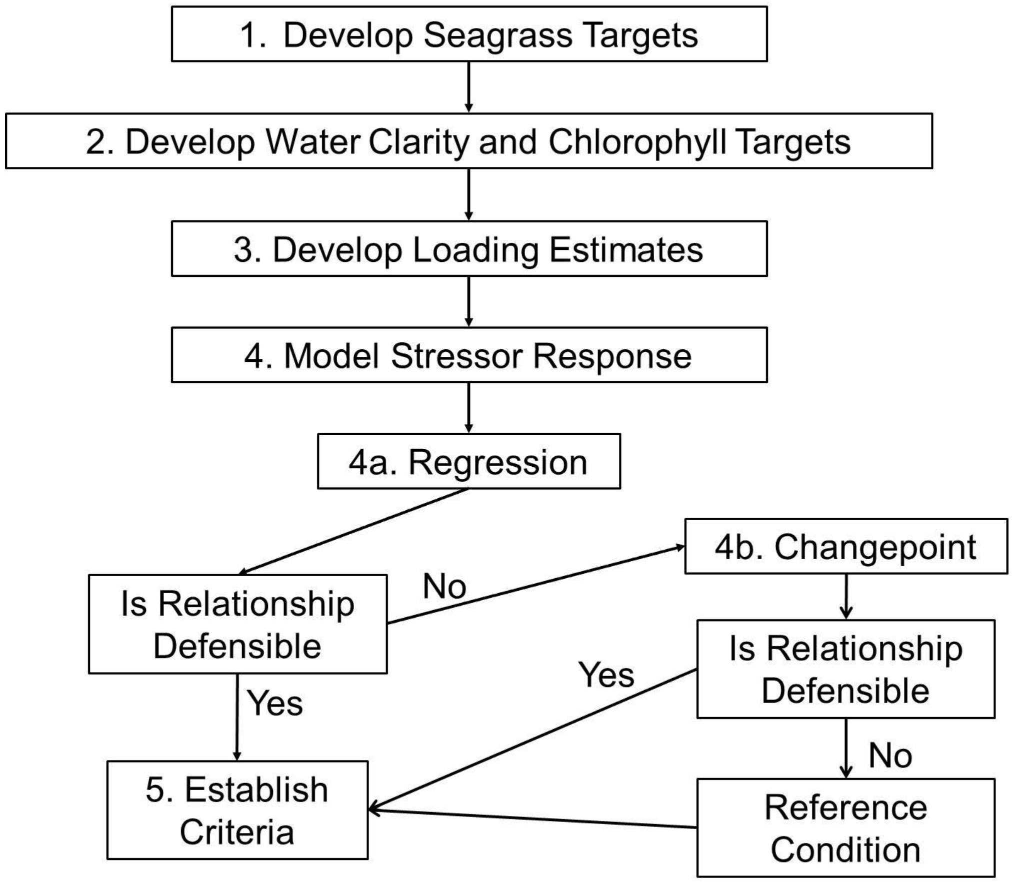


Figure 2-1. Flowchart of Process Used to Develop Numeric Nutrient Criteria.

2.1 Dona and Roberts Bays

While a statistically significant relationship was identified between chlorophyll a and TN concentration for Dona and Roberts Bays, a considerable amount of variability was left unexplained by this relationship. Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the use of this regression to develop defensible numeric nutrient criterion due to the amount of variability left unexplained by the regression. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing a TN concentration criterion for Dona and Roberts Bays. As Dona and Roberts Bays is classified as a seagrass "restoration" segment, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record). This results in the following TN concentration criterion for Dona and Roberts Bays:

TN criterion = 0.40 mg/l (mean) + ½ * 0.04 (SD) = 0.42 mg/l

A comparison of the candidate numeric TN concentration criterion based on the Reference Period method is presented in Figure 2-2.

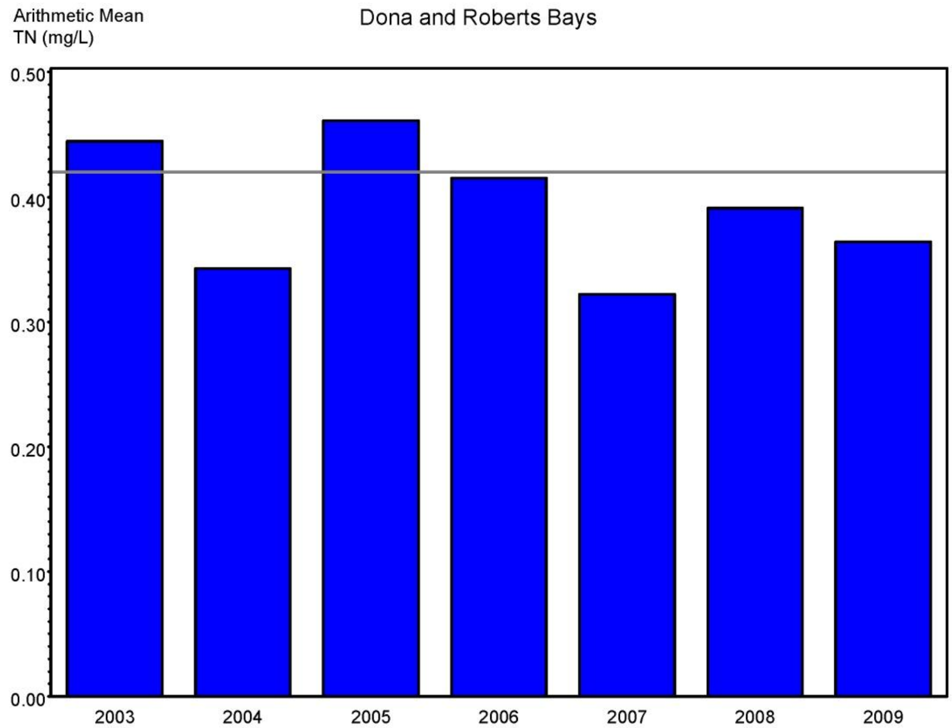


Figure 2-2. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Dona and Roberts Bays.

2.2 Lemon Bay

Lemon Bay has been divided into the Upper and Lower Lemon Bay segments for previous work performed by the CHNEP (Janicki Environmental, 2009). Because the reference period divided Lemon Bay into Upper and Lower Lemon Bay segments and light and seagrass targets were developed individually for Upper and Lower Lemon Bay, an attempt was made to develop numeric nutrient criteria that are specific to the Upper and Lower Lemon Bay segments.

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the Upper Lemon Bay regression to develop defensible numeric nutrient criterion due to the amount of variability left unexplained by the regression. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing TN concentration criteria for Upper and Lower Lemon bays. As Upper Lemon Bay is classified as "protection" for seagrass, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus one standard deviation (for the period of record):

TN criterion = 0.52 mg/l (mean) + 0.04 (SD) = 0.56 mg/l

Lower Lemon Bay is classified as a seagrass "restoration" segment, therefore the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record):

TN criterion = 0.56 mg/l (mean) + ½ * 0.12 (SD) = 0.62 mg/l

A comparison of the candidate numeric TN concentration criteria for Upper and Lower Lemon bays based on the Reference Period method are presented in Figure 2-3 and Figure 2-4, respectively.

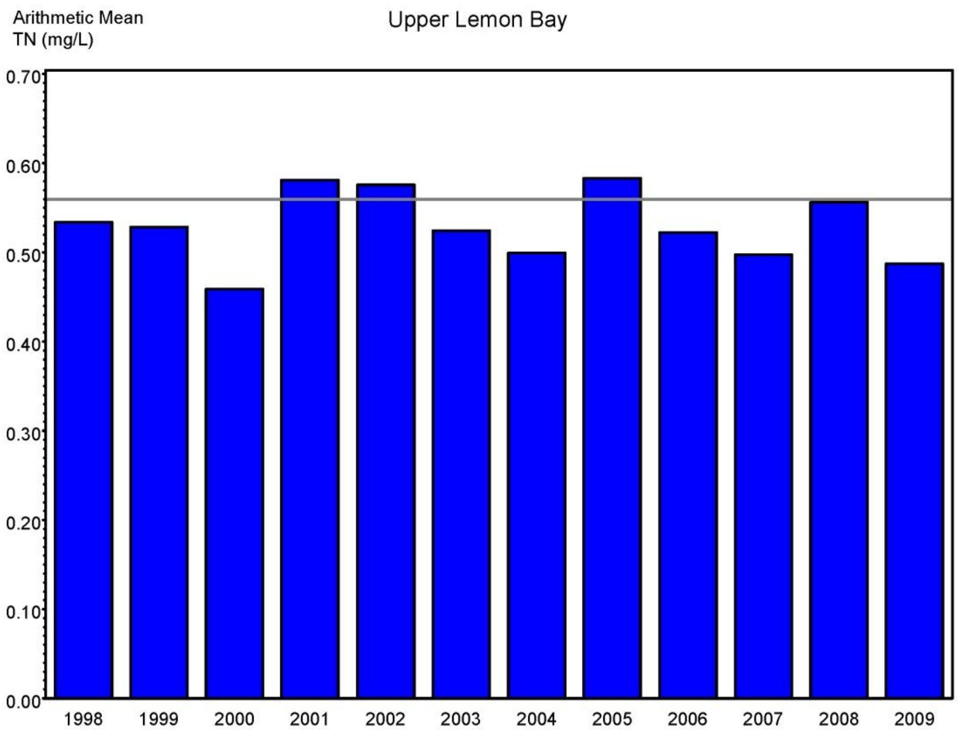


Figure 2-3. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Upper Lemon Bay.

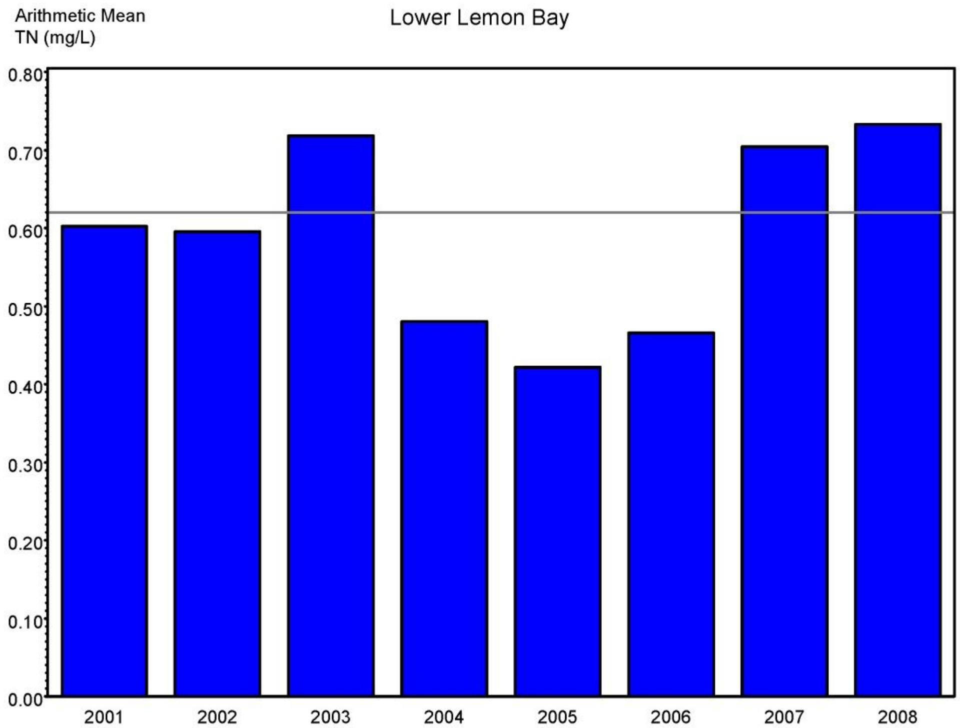


Figure 2-4. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Lower Lemon Bay.

2.3 Charlotte Harbor Proper

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the Charlotte Harbor Proper regression or changepoint analysis to develop a defensible numeric nutrient criterion. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing a TN concentration criterion for Charlotte Harbor Proper. As Charlotte Harbor Proper is classified as "restoration" for seagrass, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record):

TN criterion = 0.60 mg/l (mean) + ½ * 0.14 (SD) = 0.67 mg/l

A comparison of the candidate numeric TN concentration criteria for Charlotte Harbor Proper based on the Reference Period method is presented in Figure 2-5.

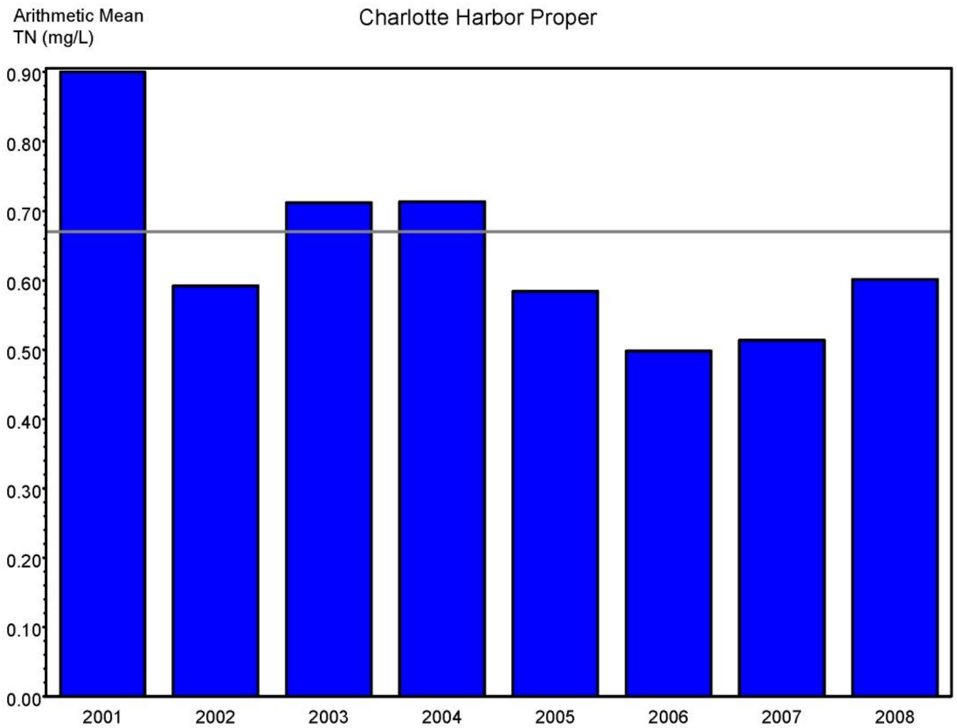


Figure 2-5. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Charlotte Harbor Proper.

2.4 Tidal Myakka

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the Tidal Myakka changepoint analysis to develop a defensible numeric nutrient criterion. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing a TN concentration criterion for Tidal Myakka. As the segment is classified as "protection" for seagrass, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus one standard deviation (for the period of record):

TN criterion = 0.95 mg/l (mean) + 0.07 (SD) = 1.02 mg/l

A comparison of the candidate numeric TN concentration criteria for Tidal Myakka based on the Reference Period method is presented in Figure 2-6.

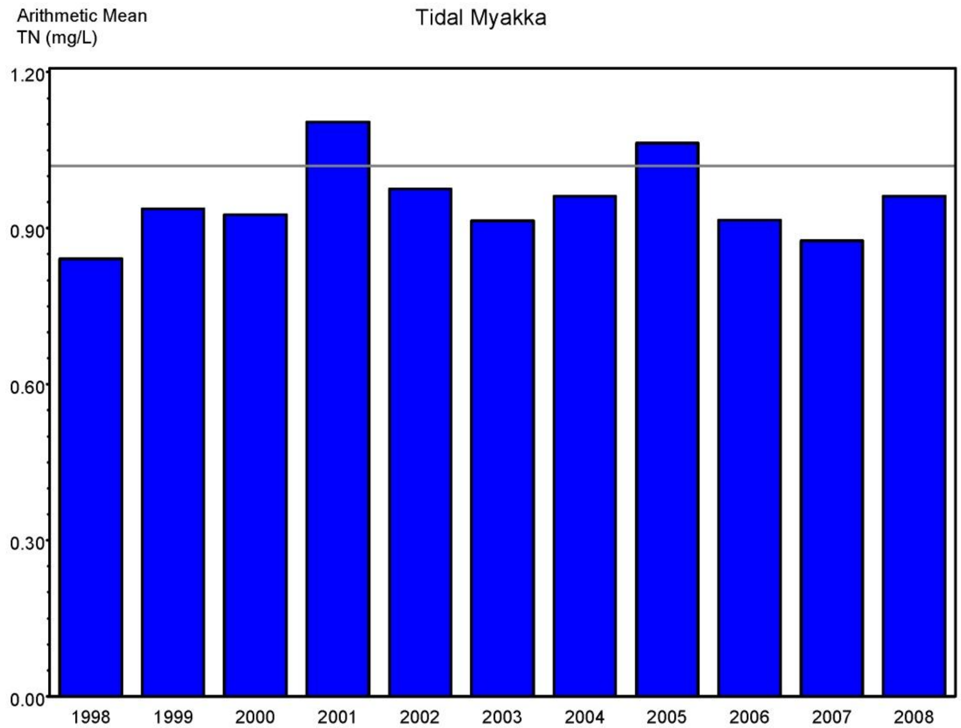


Figure 2-6. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Tidal Myakka.

2.5 Tidal Peace

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the Tidal Peace changepoint analysis to develop a defensible numeric nutrient criterion. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing a TN concentration criterion for Tidal Peace. As the segment is classified as "restoration" for seagrass, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record):

TN criterion = 0.99 mg/l (mean) + ½ * 0.18 (SD) = 1.08 mg/l

A comparison of the candidate numeric TN concentration criteria for Tidal Peace based on the Reference Period method is presented in Figure 2-7.

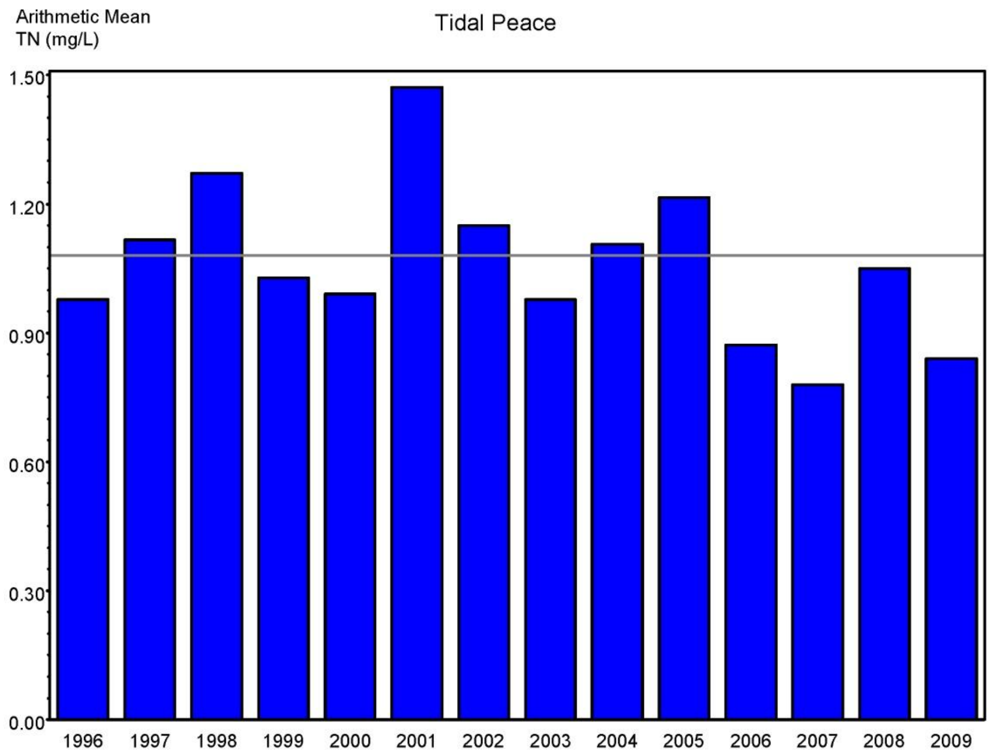


Figure 2-7. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Tidal Peace.

2.6 Pine Island Sound and Matlacha Pass

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the Pine Island Sound and Matlacha Pass regressions to develop defensible numeric nutrient criteria due to the amount of variability left unexplained by the regressions. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing TN concentration criteria for Pine Island Sound and Matlacha Pass. As Pine Island Sound is classified as a seagrass "protection" segment, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus one standard deviation (for the period of record):

TN criterion = 0.46 mg/l (mean) + 0.11 (SD) = 0.57 mg/l

Matlacha Pass is classified as a seagrass "restoration" segment, therefore the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record):

TN criterion = 0.53 mg/l (mean) + ½ * 0.10 (SD) = 0.58 mg/l

A comparison of the candidate numeric TN concentration criteria for Pine Island Sound and Matlacha Pass based on the Reference Period method are presented in Figure 2-8 and Figure 2-9, respectively.

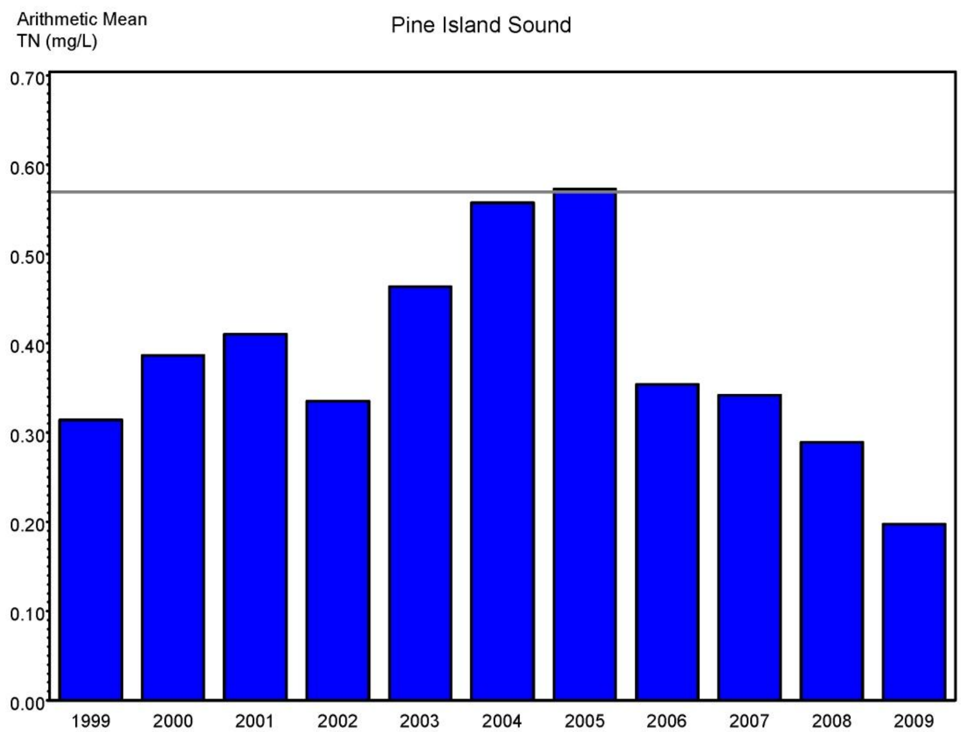


Figure 2-8. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Pine Island Sound.

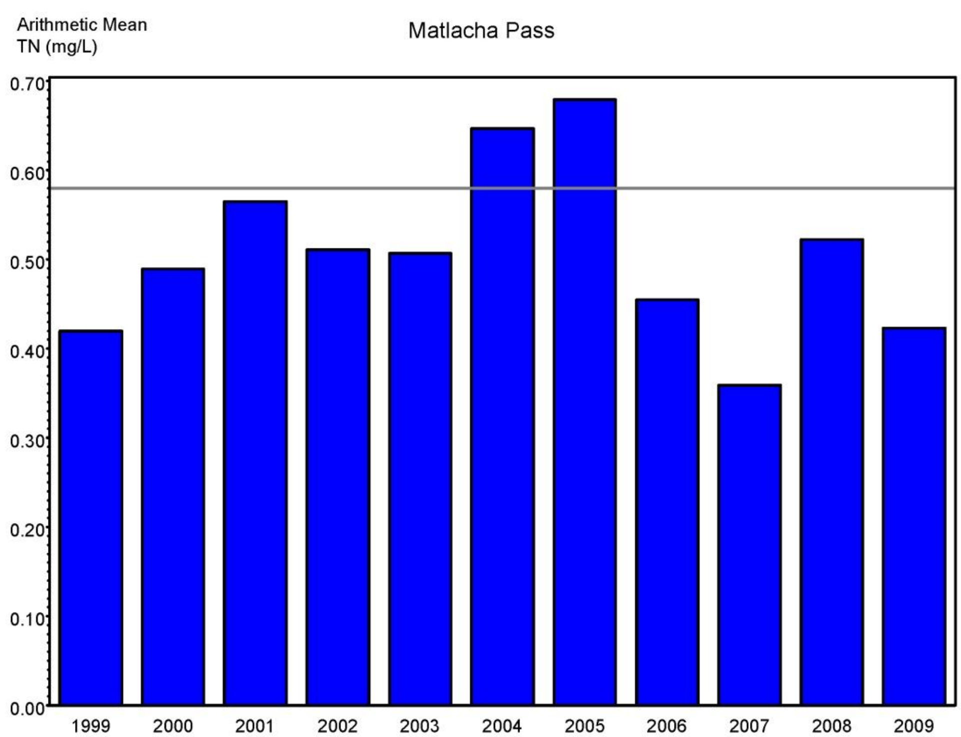


Figure 2-9. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Matlacha Pass.

2.7 San Carlos Bay and Tidal Caloosahatchee

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the Tidal Caloosahatchee regression to develop a defensible numeric nutrient criterion due to the amount of variability left unexplained by the regression. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing TN concentration criteria for Tidal Caloosahatchee. As San Carlos Bay is classified as "protection" for seagrass, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus one standard deviation (for the period of record):

TN criterion = 0.46 mg/l (mean) + 0.10 (SD) = 0.56 mg/l

Tidal Caloosahatchee is classified as a seagrass "restoration" segment, therefore the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record):

TN criterion = 1.00 mg/l (mean) + ½ * 0.18 (SD) = 1.09 mg/l

A comparison of the candidate numeric TN concentration criteria for San Carlos Bay and Tidal Caloosahatchee based on the Reference Period method are presented in Figure 2-10 and Figure 2-11, respectively.

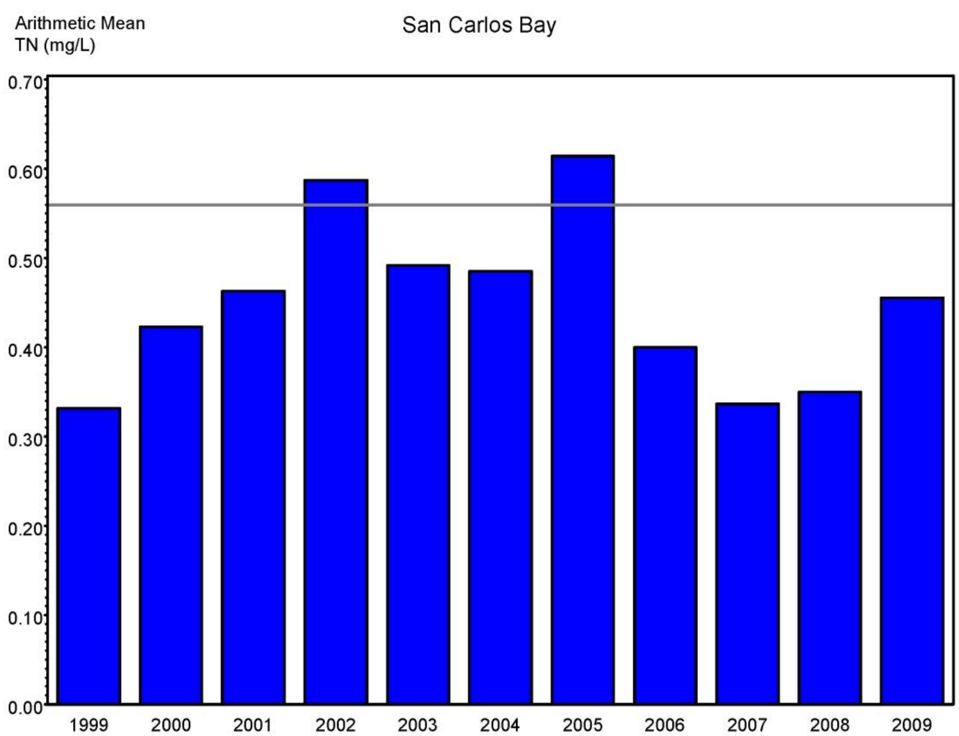


Figure 2-10. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in San Carlos Bay.

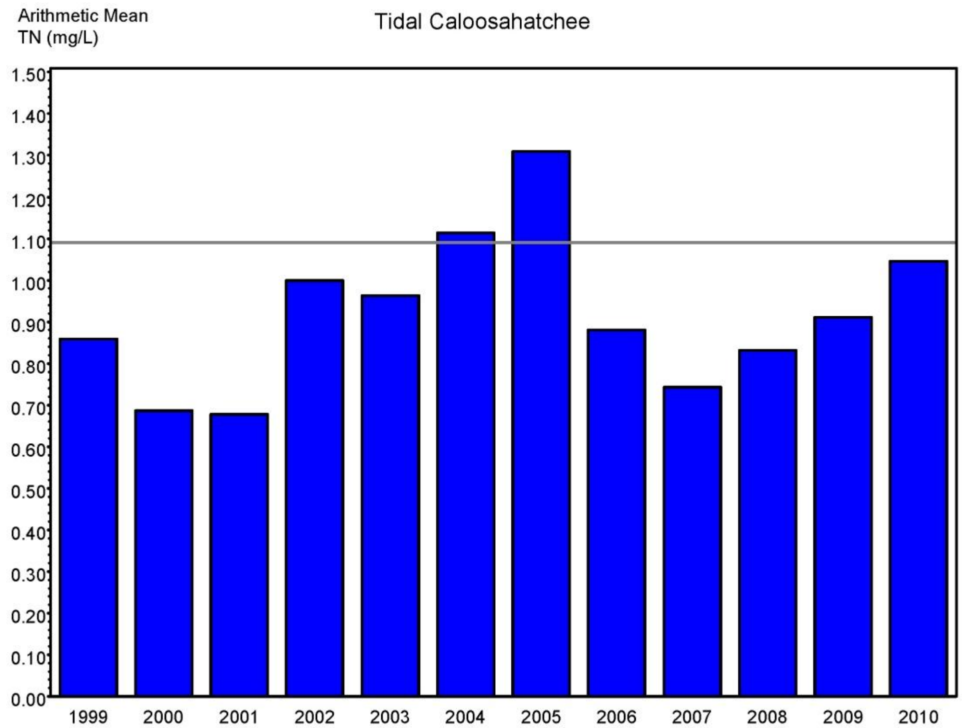


Figure 2-11. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Tidal Caloosahatchee.

Tidal Caloosahatchee has been identified as impaired and a TMDL has been drafted. However, due to concerns raised with the draft TMDL for the Tidal Caloosahatchee, the TMDL is currently being revised. Therefore, it was decided to list the nutrient criteria for Tidal Caloosahatchee as "to be determined" (TBD) until the revision to the draft TMDL is completed.

2.8 Estero Bay

Based on discussions with the CHNEP Technical Advisory Committee, there is not sufficient confidence in the use of the changepoint analysis to develop a defensible numeric nutrient criterion. Therefore, as described in Figure 2-1, the reference period approach was recommended for developing a TN concentration criterion for Estero Bay. As Estero Bay is classified as "restoration" for seagrass, the TN concentration criterion is calculated by summing the annual mean from the reference period (2003-2007) plus ½ standard deviation (for the period of record). This results in the following TN concentration criterion for Estero Bay:

TN criterion = 0.57 mg/l (mean) + ½ * 0.12 (SD) = 0.63 mg/l

A comparison of the candidate numeric TN concentration criterion based on the Reference Period method is presented in Figure 2-12.

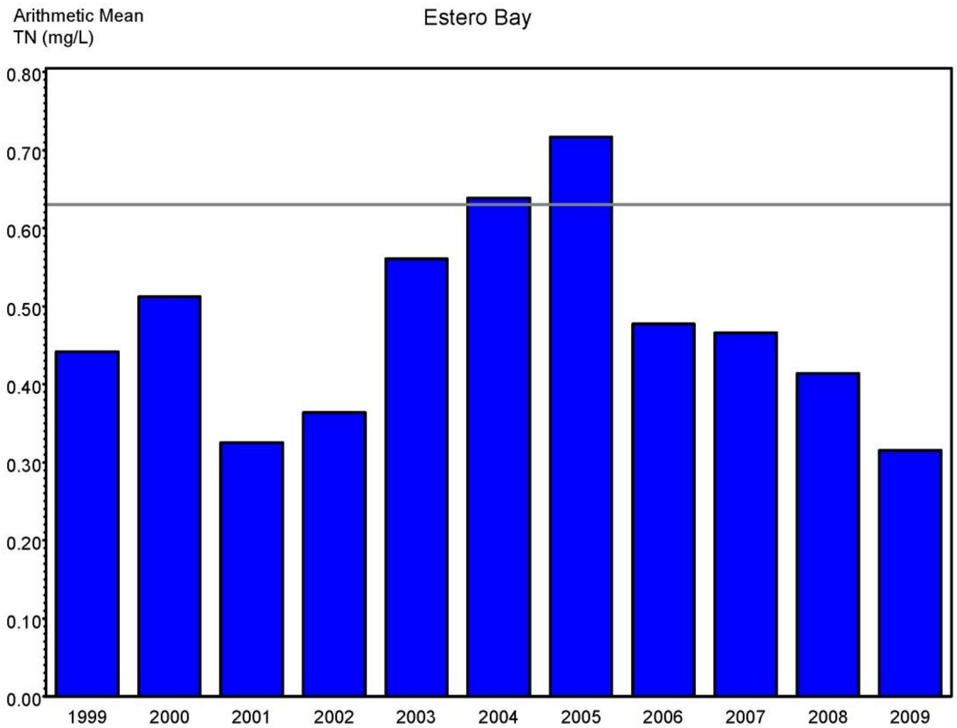


Figure 2-12. Comparison of the candidate TN criterion to observed TN concentrations (expressed as arithmetic means) in Estero Bay.

2.9 Recommended Numeric Nutrient Criteria as TN Concentrations

Based on the results presented above, Table 2-2 provides the recommended numeric nutrient criteria as TN concentrations for the CHNEP.

Table 2-2. Candidate numeric nutrient criteria based on the reference period approach for TN concentration.

Segment	Candidate Criterion
Dona and Roberts Bays	0.42 mg/l
Upper Lemon Bay	0.56 mg/l
Lower Lemon Bay	0.62 mg/l
Tidal Myakka	1.02 mg/l
Tidal Peace	1.08 mg/l
Charlotte Harbor Proper	0.67 mg/l
Matlacha Pass	0.58 mg/l
Pine Island Sound	0.57 mg/l
Tidal Caloosahatchee	TBD
San Carlos Bay	0.56 mg/l
Estero Bay	0.63 mg/l

3.0 Total Phosphorus Concentrations

As described in Janicki Environmental (2011b), multiple analyses were completed in the evaluation of potential TP criteria expressed as in-bay concentrations. The first set of analyses was performed to evaluate potential methods of deriving TP concentration criteria commensurate with the recommended TN concentration criteria and/or chlorophyll *a* thresholds. These included:

- examination of the relationships between TN and TP concentrations within each segment, following the rationale that the recommended TN concentration criteria had already been developed (Janicki Environmental, 2011a) and relationships between TN and TP concentrations could provided TP concentration criteria;
- examination of relationships between monthly TP concentrations with chlorophyll *a* concentrations, with the potential to derive TP concentration criteria based on chlorophyll *a* thresholds; and
- application of a reference period approach to establishing TP concentration criteria.

The most appropriate method was determined to be the Reference Period approach. Relationships between segment TN concentrations and segment TP concentrations are not transparent, and thus could not be used to translate the recommended TN concentration criteria to TP concentration criteria. Stressor-response relationships between chlorophyll *a* and TP concentrations were not sufficient to derive TP concentration criteria based on established chlorophyll *a* thresholds (Janicki Environmental, 2011b). It was determined that the Reference Period Approach (2003-2007) provided the most suitable and internally consistent method for establishing TN and TP concentration criteria for the CHNEP segments, with the exception of the Tidal Caloosahatchee. The Tidal Caloosahatchee has been determined to be impaired for nutrients and a draft TMDL has been developed. However, the TMDL is being revised due to concerns raised by stakeholders. The criteria for Tidal Caloosahatchee are "to be determined" until the TMDL revision is completed.

Following this approach, numeric nutrient criteria expressed as TP concentrations for the bay segments were derived. Targets were based on 2003-2007 reference period data, and the standard deviations in each segment were based on the annual means. The recommended TP concentration threshold for each segment is provided in Table 3-1. The proposed TP concentration criteria are compared to the observed arithmetic mean annual TP concentrations in Figures 3-1 through 3-10, for all segments except the Tidal Caloosahatchee, as criteria for this segment are "to be determined", as described above. The horizontal lines on the figures represent the recommended criteria.

Table 3-1. TP concentration criteria derived using the Reference Period Approach. The reference period was 2003-2007.	
Segment	**TP concentration criterion (mg/L)**
Dona and Roberts Bay	0.18
Upper Lemon Bay	0.26
Lower Lemon Bay	0.17
Charlotte Harbor Proper	0.19
Pine Island Sound	0.06
San Carlos Bay	0.07
Tidal Myakka River	0.31
Tidal Peace River	0.50
Matlacha Pass	0.08
Tidal Caloosahatchee River	TBD
Estero Bay	0.07

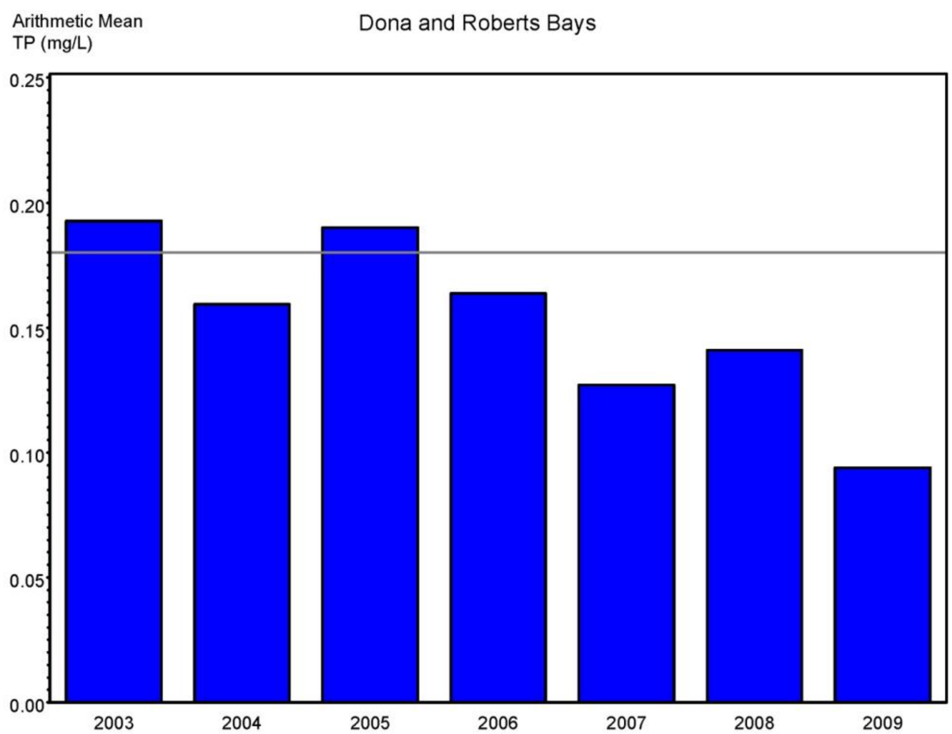


Figure 3-1. Comparison of proposed TP concentration criterion for Dona and Roberts Bay to the annual arithmetic mean TP concentrations.

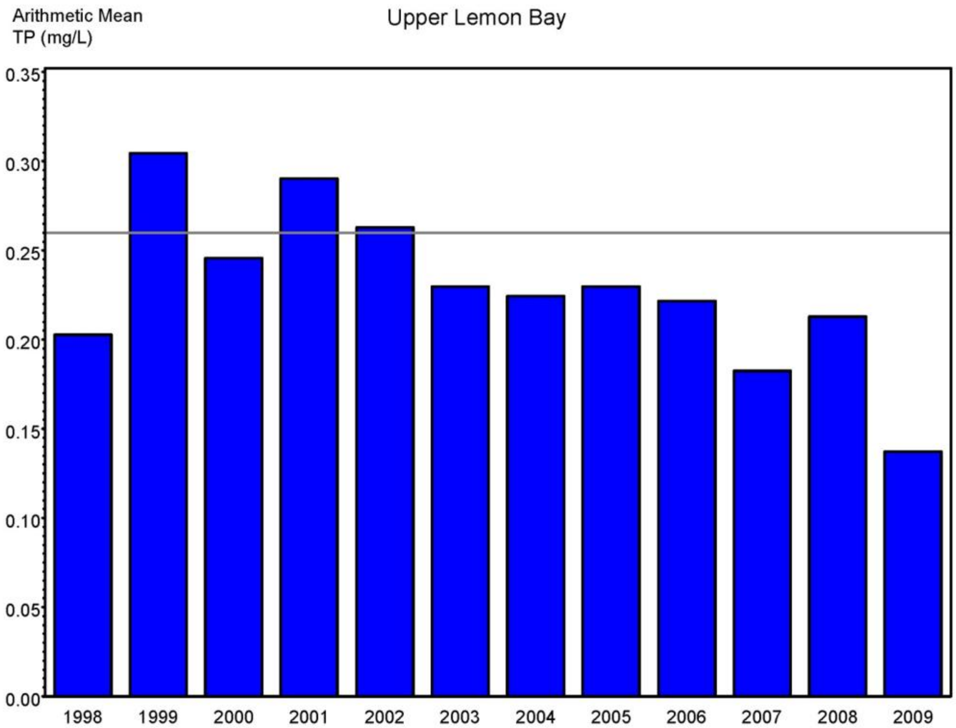


Figure 3-2. Comparison of proposed TP concentration criterion for Upper Lemon Bay to the annual arithmetic mean TP concentrations.

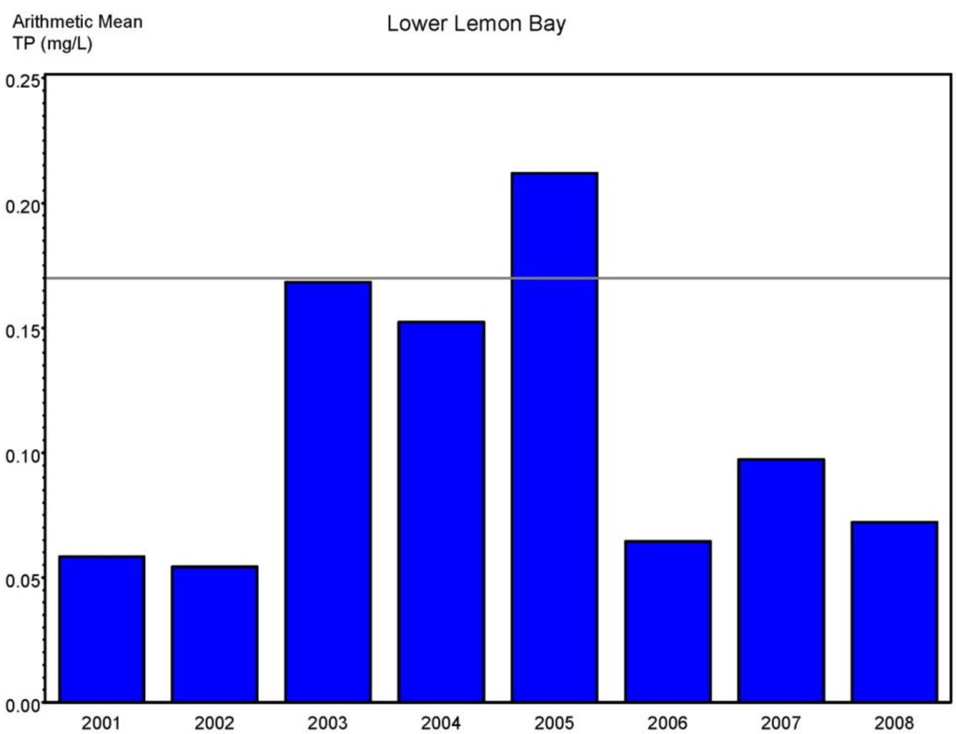


Figure 3-3. Comparison of proposed TP concentration criterion for Lower Lemon Bay to the annual arithmetic mean TP concentrations.

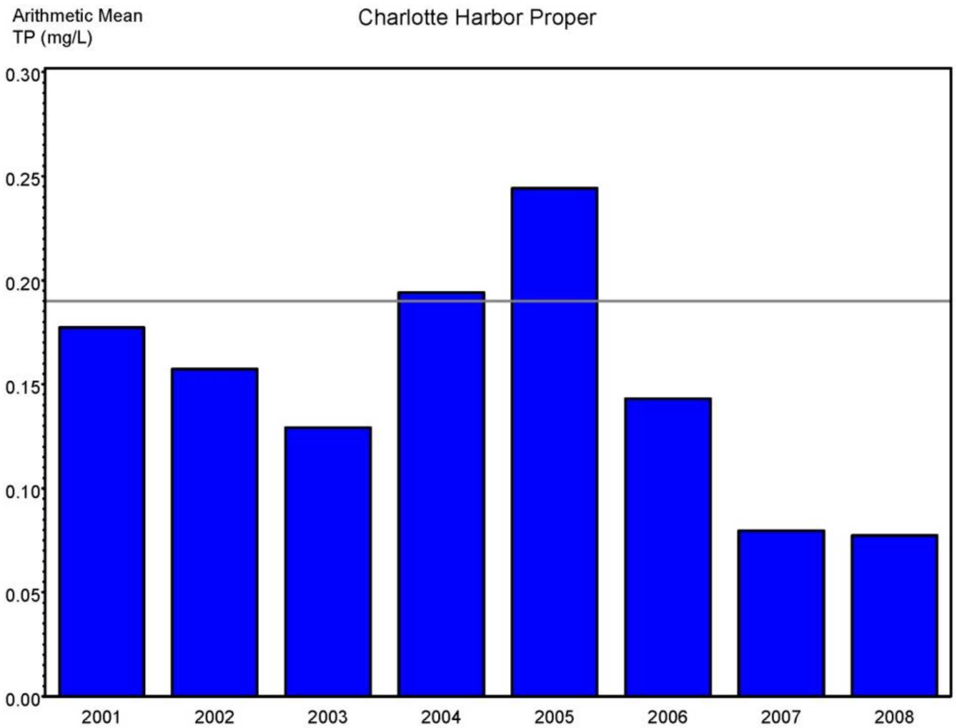


Figure 3-4. Comparison of proposed TP concentration criterion for Charlotte Harbor Proper to the annual arithmetic mean TP concentrations.

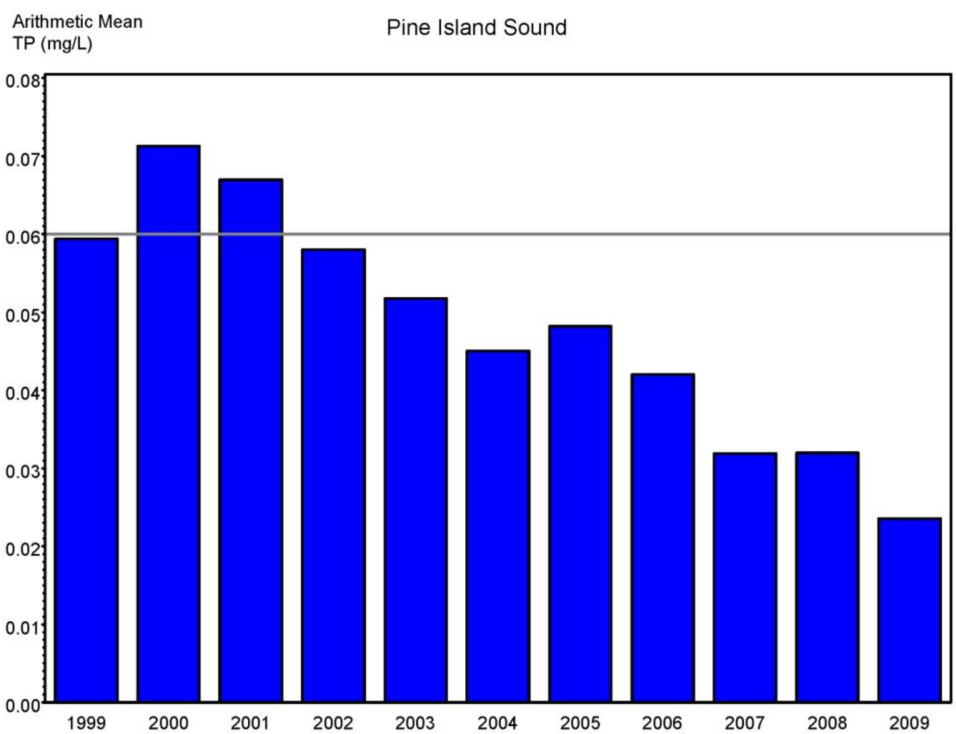


Figure 3-5. Comparison of proposed TP concentration criterion for Pine Island Sound to the annual arithmetic mean TP concentrations.

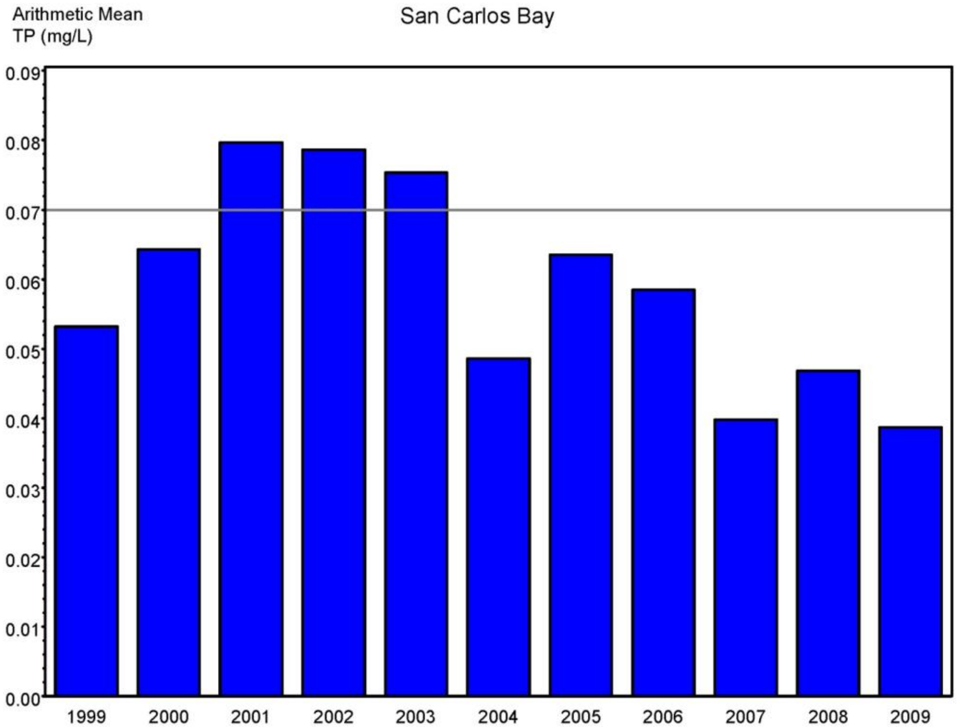


Figure 3-6. Comparison of proposed TP concentration criterion for San Carlos Bay to the annual arithmetic mean TP concentrations.

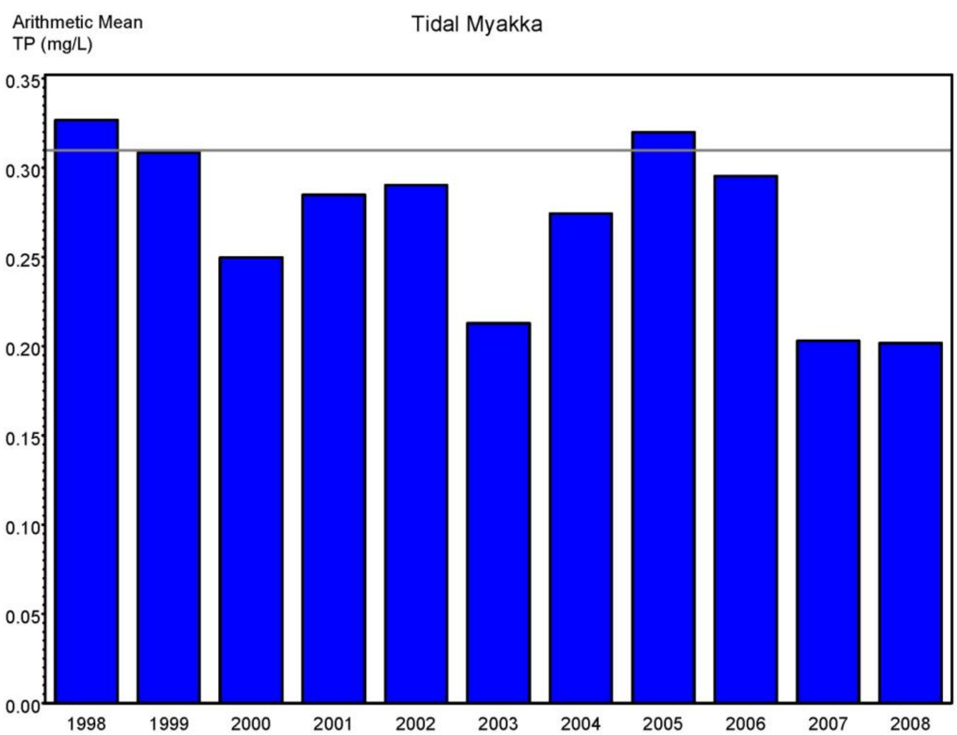


Figure 3-7. Comparison of proposed TP concentration criterion for Tidal Myakka River to the annual arithmetic mean TP concentrations.

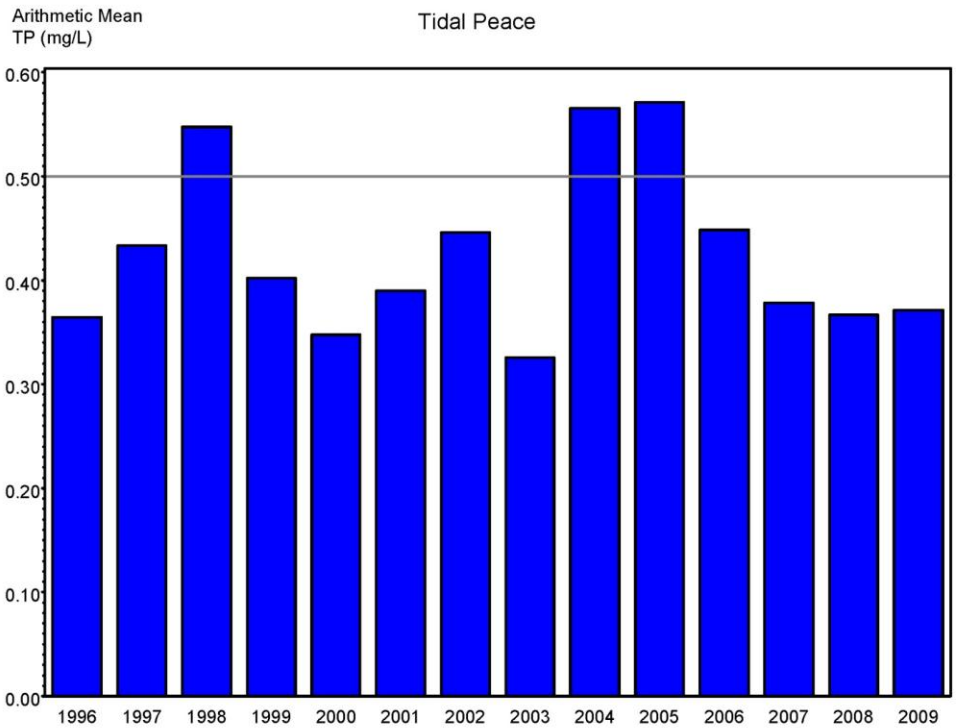


Figure 3-8. Comparison of proposed TP concentration criterion for Tidal Peace River to the annual arithmetic mean TP concentrations.

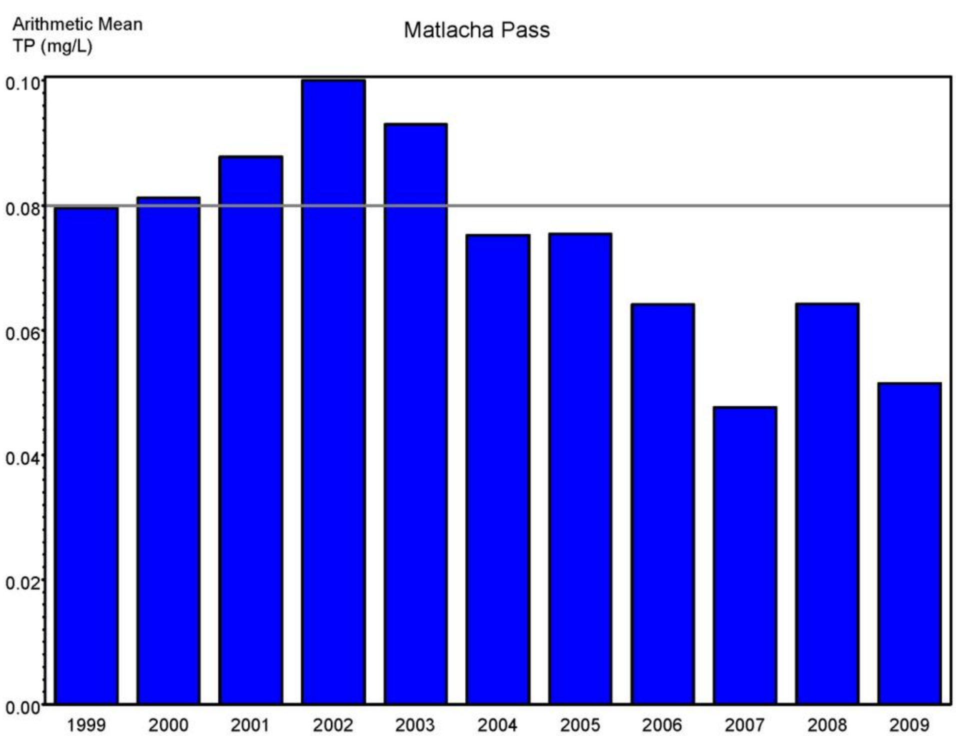


Figure 3-9. Comparison of proposed TP concentration criterion for Matlacha Pass to the annual arithmetic mean TP concentrations.

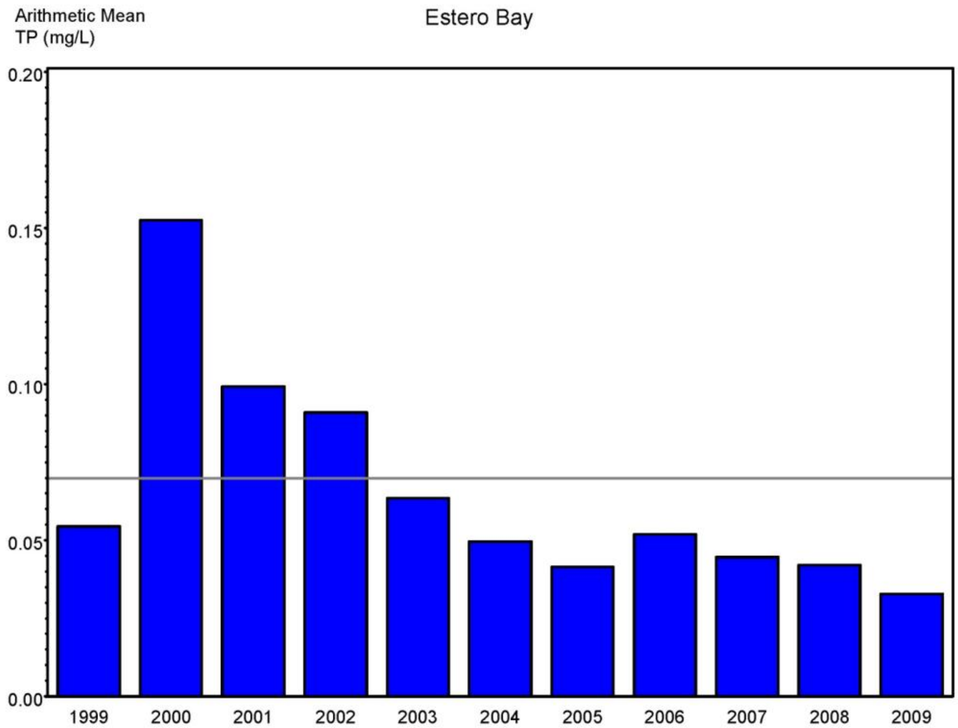


Figure 3-10. Comparison of proposed TP concentration criterion for Estero Bay to the annual arithmetic mean TP concentrations.

4.0 Total Nitrogen and Total Phosphorus Loadings

As described in Janicki Environmental (2011b), the simplest method to propose criteria expressed as loadings to bay segments is based on relationships between segment TN and TP concentrations and TN and TP loadings delivered to each segment. The recommended TN concentration criteria and TP concentration criteria described above can be compared to TN and TP loadings to the segments. If significant relationships are found between the nutrient loads and their respective segment concentrations, then the proposed numeric nutrient criteria could be expressed as loadings. However, based on the limited relationships found between the nutrient concentrations and nutrient loads to those segments, the results of these analyses do not provide adequate evidence to support recommendations for TN and TP loading criteria.

A second method evaluated to provide potential TN and TP criteria expressed as loadings to bay segments is based on relationships between segment chlorophyll *a* concentrations and TN and TP loads delivered to each segment. Chlorophyll *a* thresholds have been developed for the SBEP (Janicki Environmental, 2011a), and may be used to derive loading criteria if appropriate relationships exist. The results of these analyses did not provide adequate evidence to support recommendations for TN and TP loading criteria based on the relationships between chlorophyll *a* concentrations and TN and TP loadings in the bay segments.

Establishment of loading-based nutrient criteria should be consistent with the chlorophyll *a* threshold and concentration-based TN and TP criteria already recommended for the Charlotte Harbor National Estuary Program area. The third approach to developing loadings-based numeric nutrient criteria for both TN and TP is the reference period approach. Based on the methods used for development of the chlorophyll *a* threshold and the recommended TN and TP concentration criteria, loading targets and thresholds were developed. As with nutrient concentrations, the reference period was 2003-2007. Because loading data are available through 2007, the period used to calculate the standard deviation was 1995-2007. These loading criteria (thresholds) are the sum of the 2003-2007 mean and one standard deviation. These criteria are considered to be commensurate with reference period TN and TP concentrations, and with the reference period chlorophyll a thresholds developed previously (Janicki Environmental, 2011a). The loading criteria for TN and TP are presented in Table 4-1. The proposed TN and TP loading criteria are compared to the observed annual TN and TP loadings in Figures 4-1 through 4-10 for all segments except Tidal Caloosahatchee. The horizontal lines represent the proposed criteria.

Table 4-1. TN and TP loading criteria based on the Reference Period Approach. The reference period was 2003-2007.

Segment	TN Load (tons/yr)	TP Load (tons/yr)
Dona and Roberts Bay	250	48
Upper Lemon Bay	102	18
Lower Lemon Bay	136	21
Charlotte Harbor Proper[1]	5,987	2,281
Pine Island Sound	190	8
San Carlos Bay	TBD	TBD
Tidal Myakka River	1,407	351
Tidal Peace River	4,343	1,960
Matlacha Pass	216	24
Tidal Caloosahatchee River	TBD	TBD
Estero Bay	587	61

[1]Loads are sum of Charlotte Harbor Proper and the Tidal Peace and Myakka Rivers.

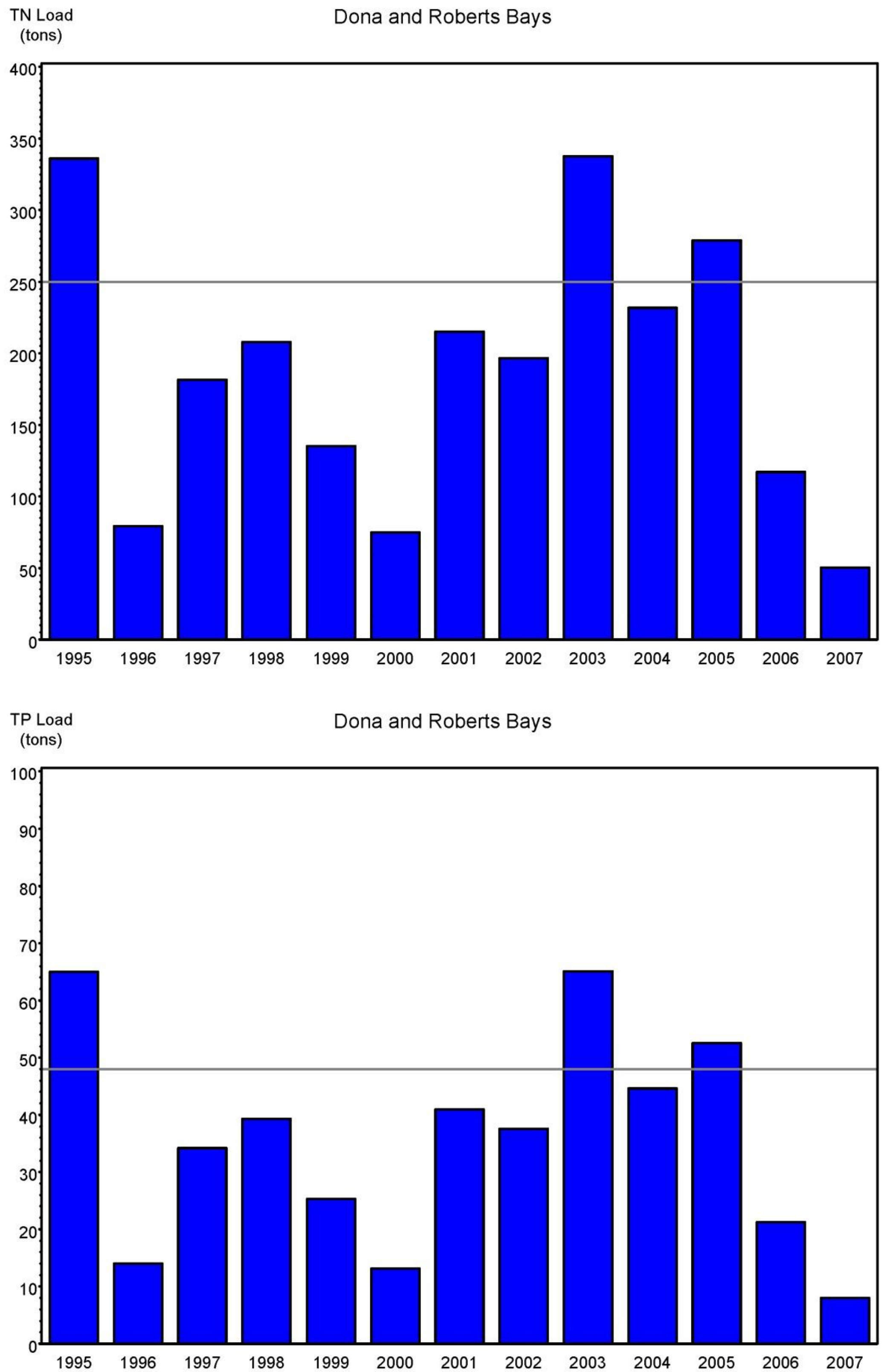
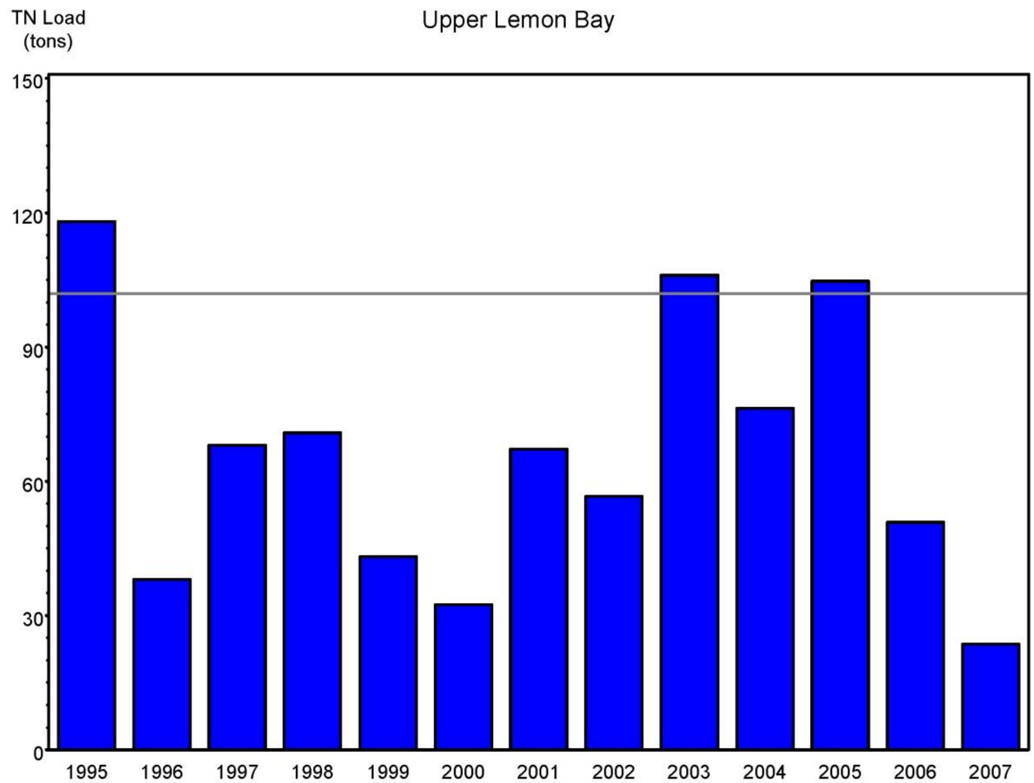


Figure 4-1. Comparison of proposed TN and TP load criteria for Dona and Roberts Bay to annual loads.



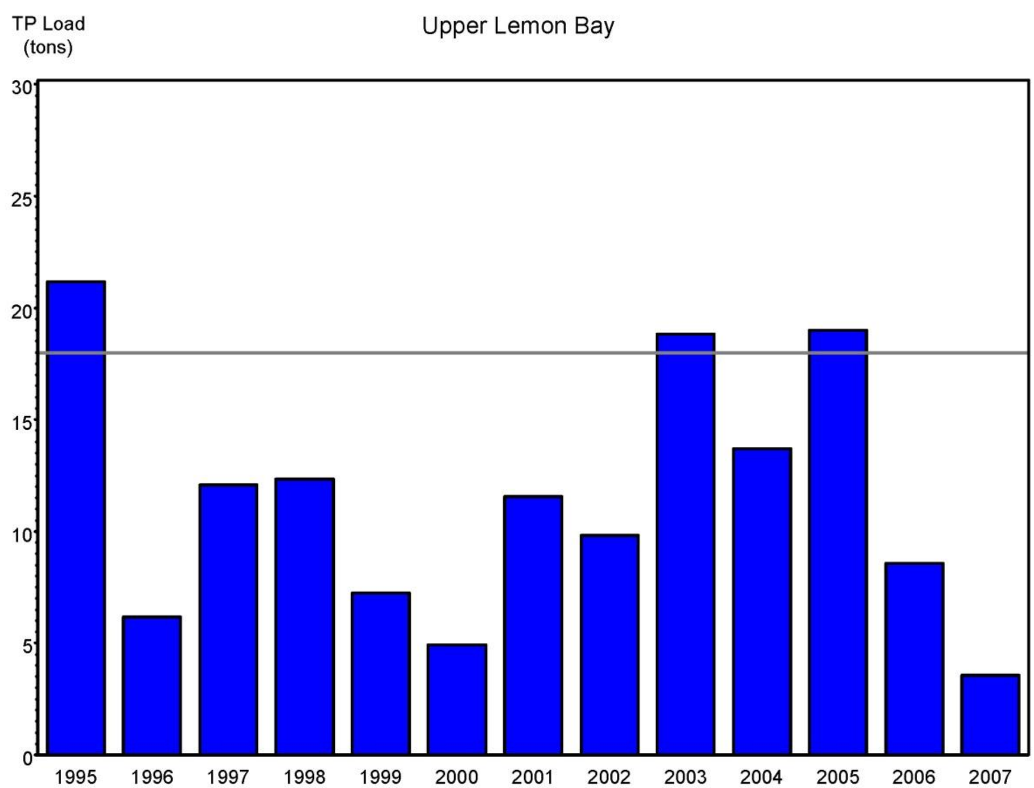


Figure 4-2. Comparison of proposed TN and TP load criteria for Upper Lemon Bay to annual loads.

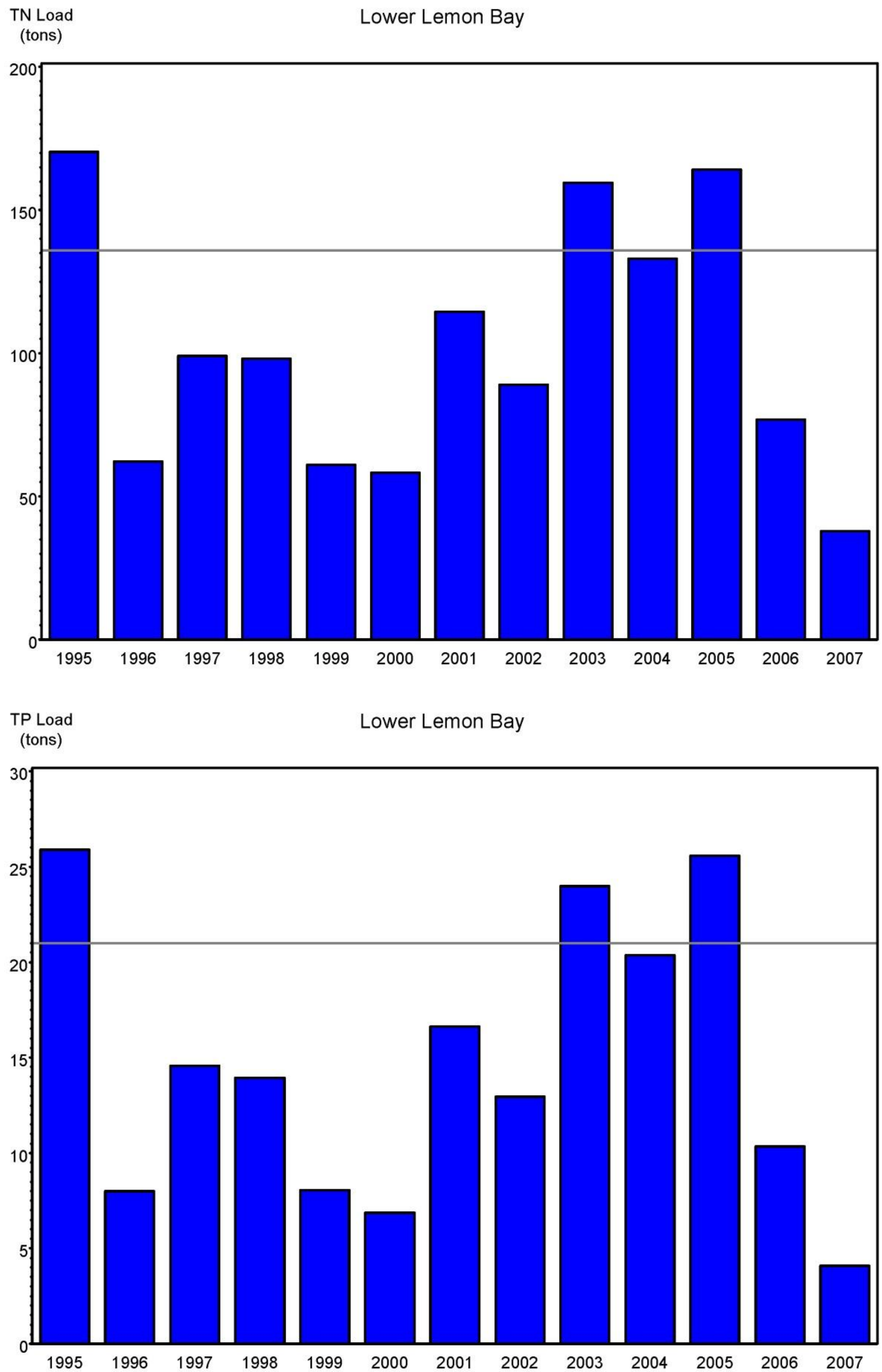
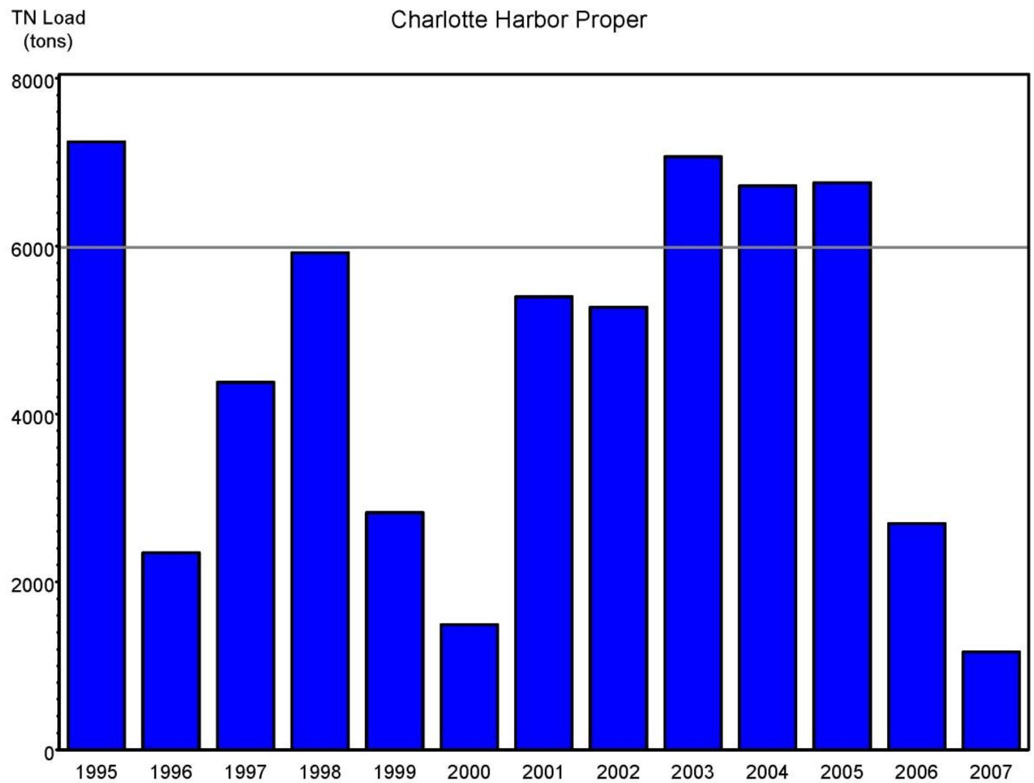


Figure 4-3. Comparison of proposed TN and TP load criteria for Lower Lemon Bay to annual loads.



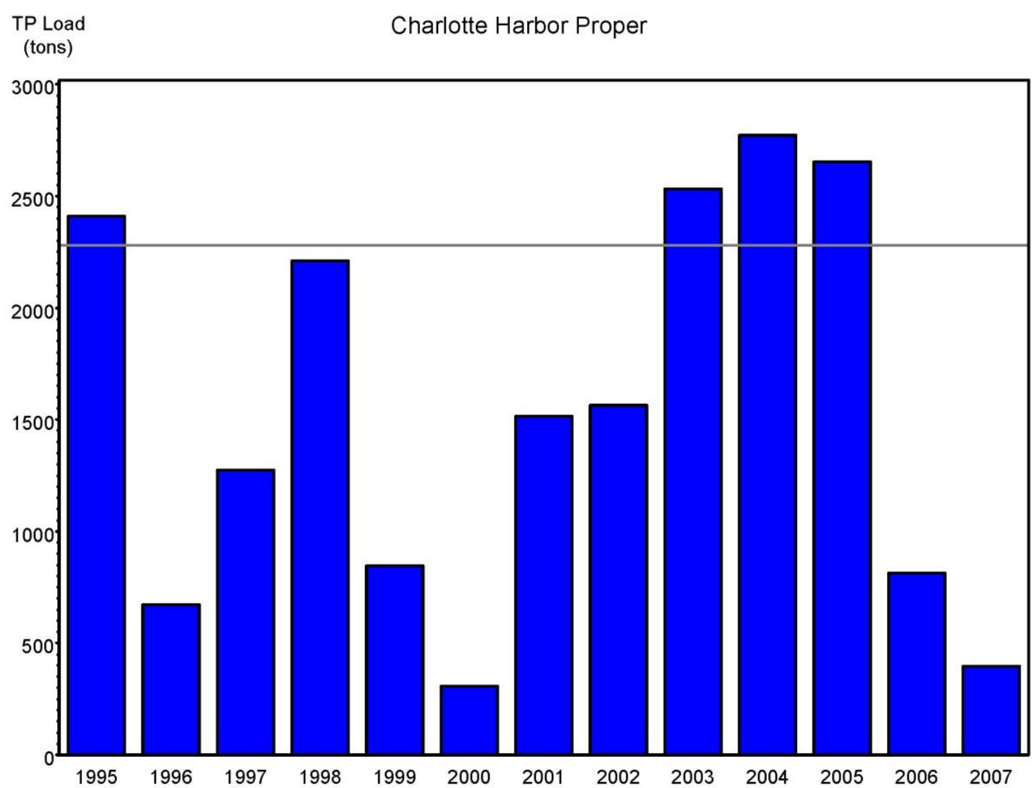


Figure 4-4. Comparison of proposed TN and TP load criteria for Charlotte Harbor to annual loads.

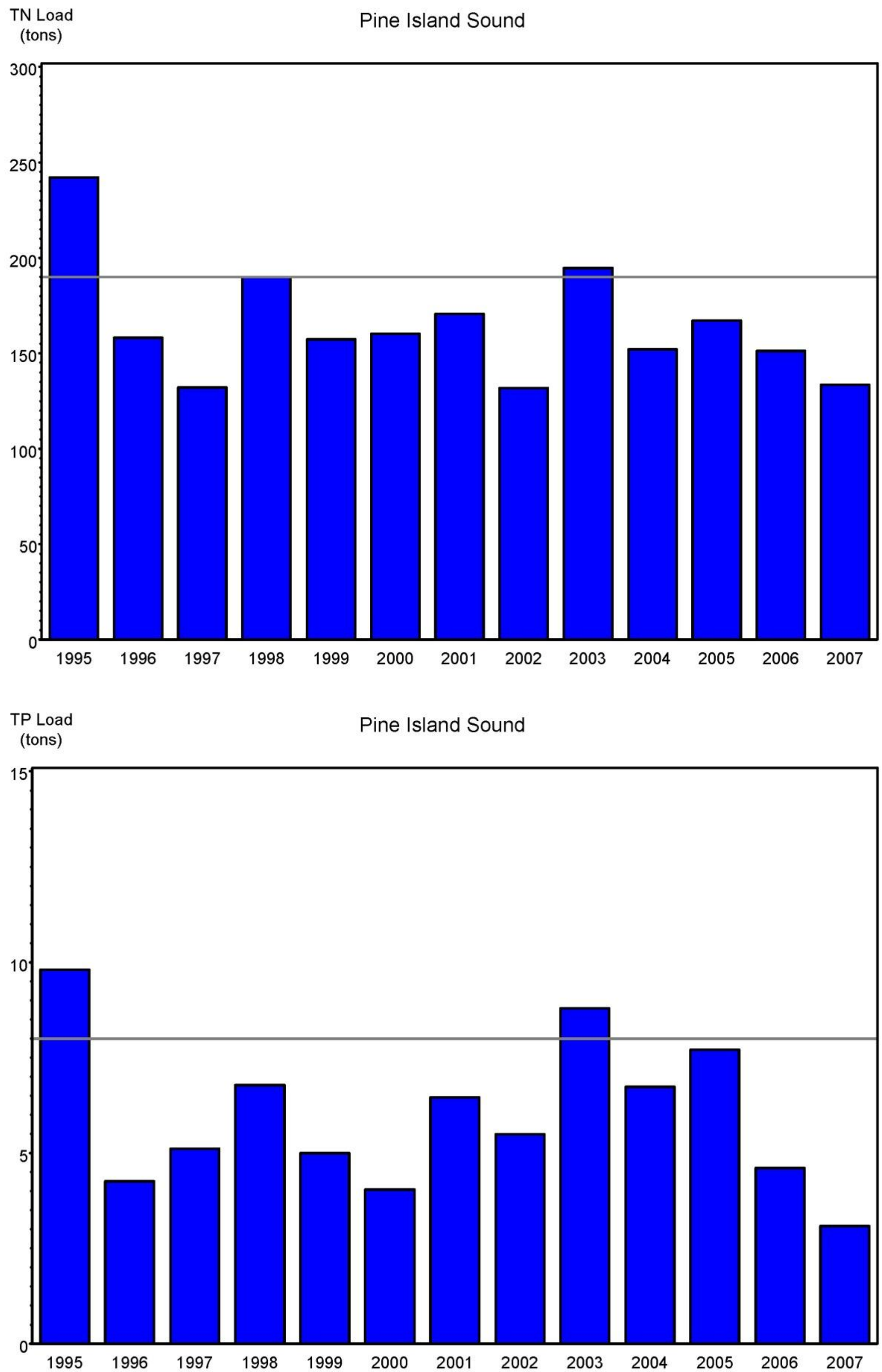


Figure 4-5. Comparison of proposed TN and TP load criteria for Pine Island Sound to annual loads.

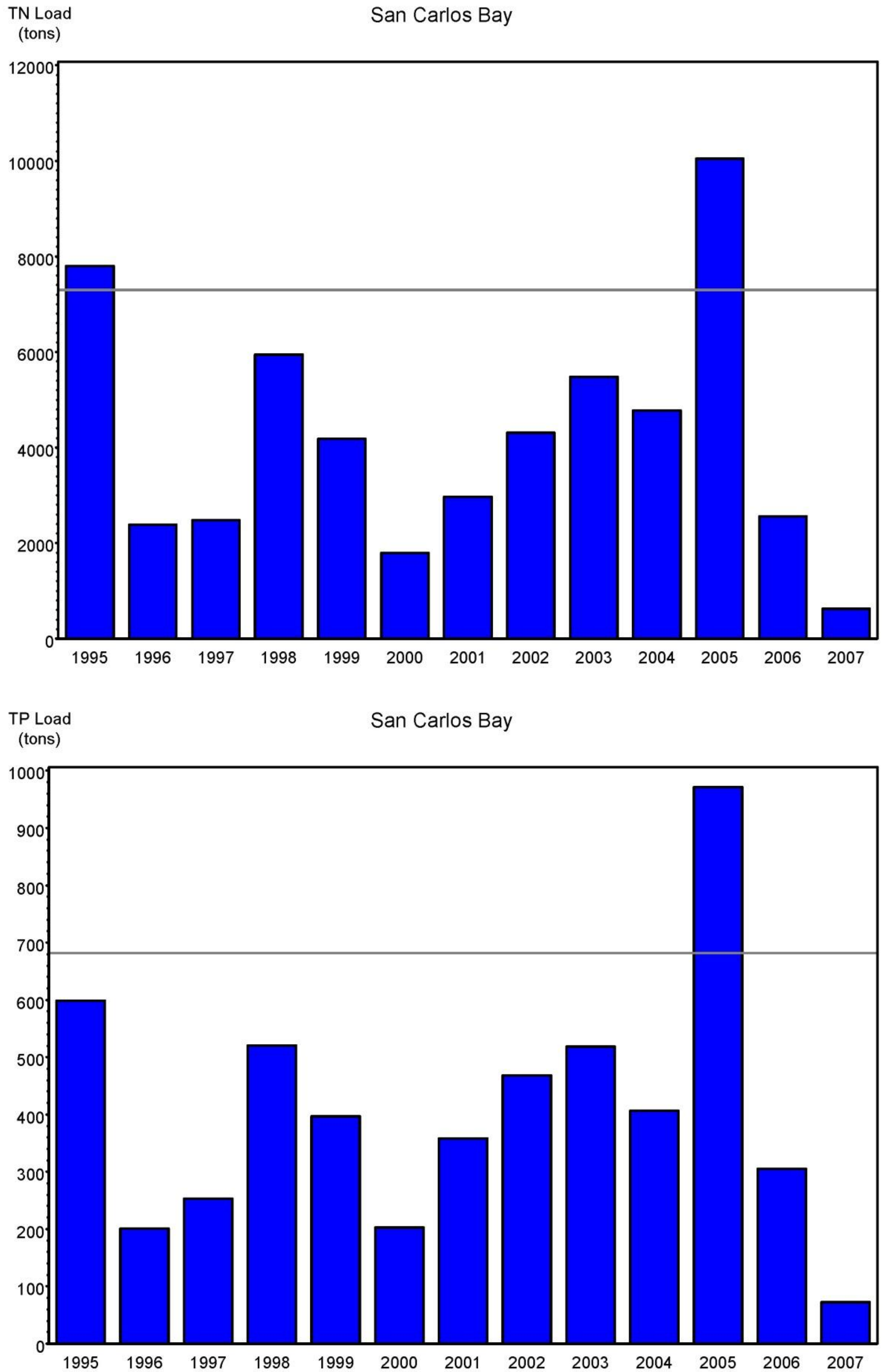


Figure 4-6. Comparison of proposed TN and TP load criteria for San Carlos Bay to annual loads.

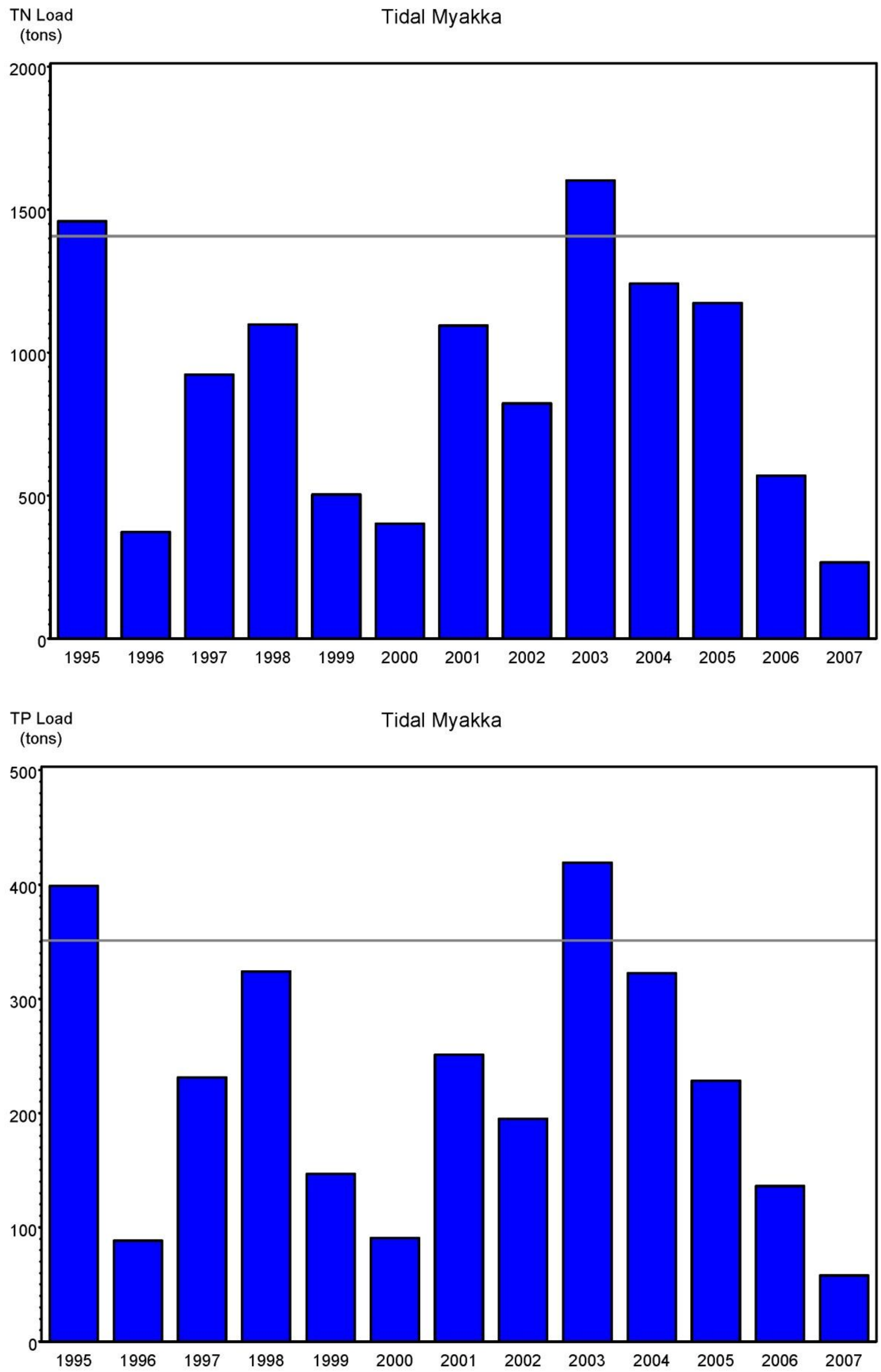
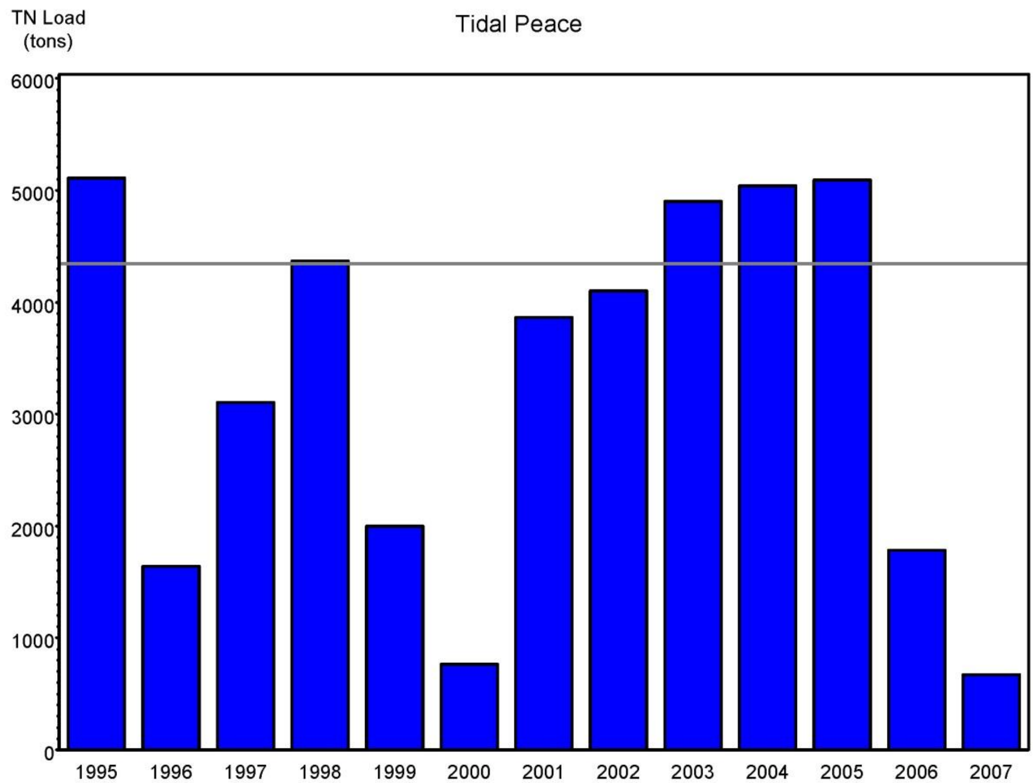


Figure 4-7. Comparison of proposed TN and TP load criteria for Tidal Myakka to annual loads.



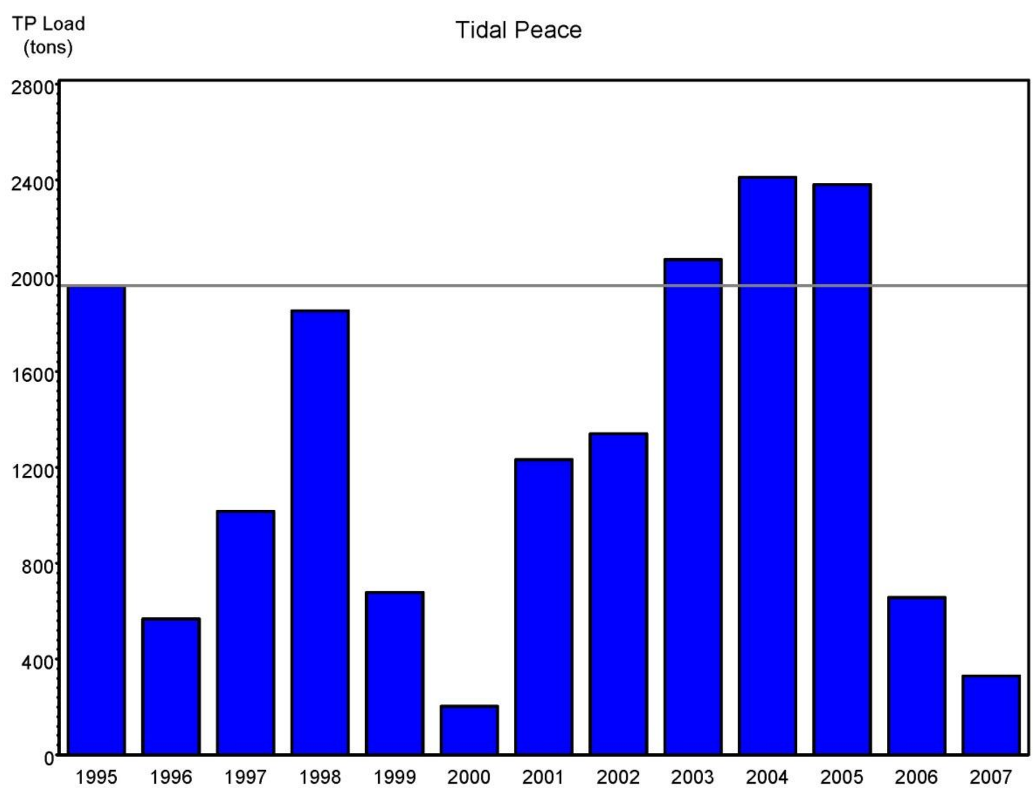
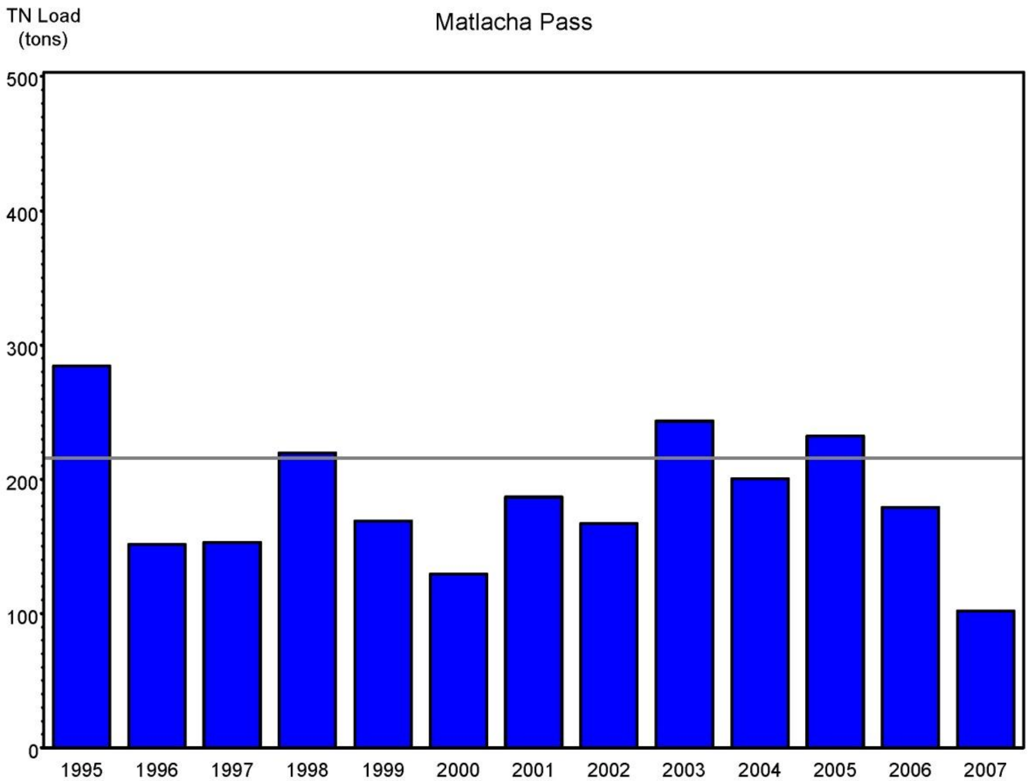


Figure 4-8. Comparison of proposed TN and TP load criteria for Tidal Peace to annual loads.



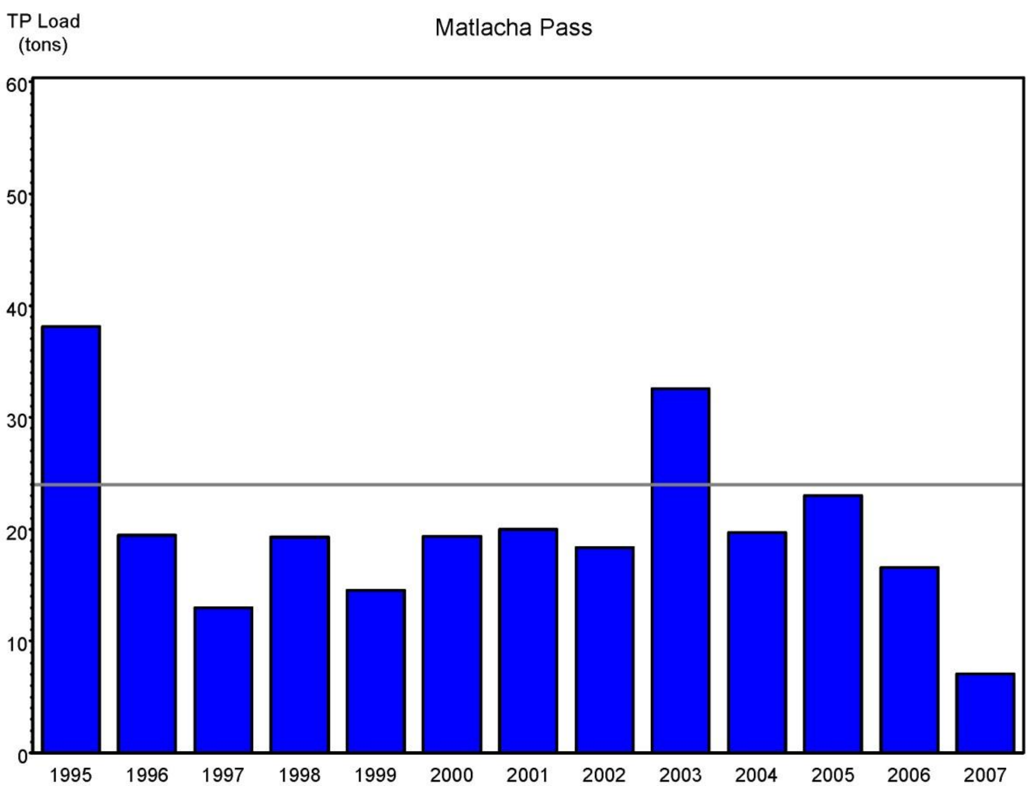


Figure 4-9. Comparison of proposed TN and TP load criteria for Matlacha Pass to annual loads.

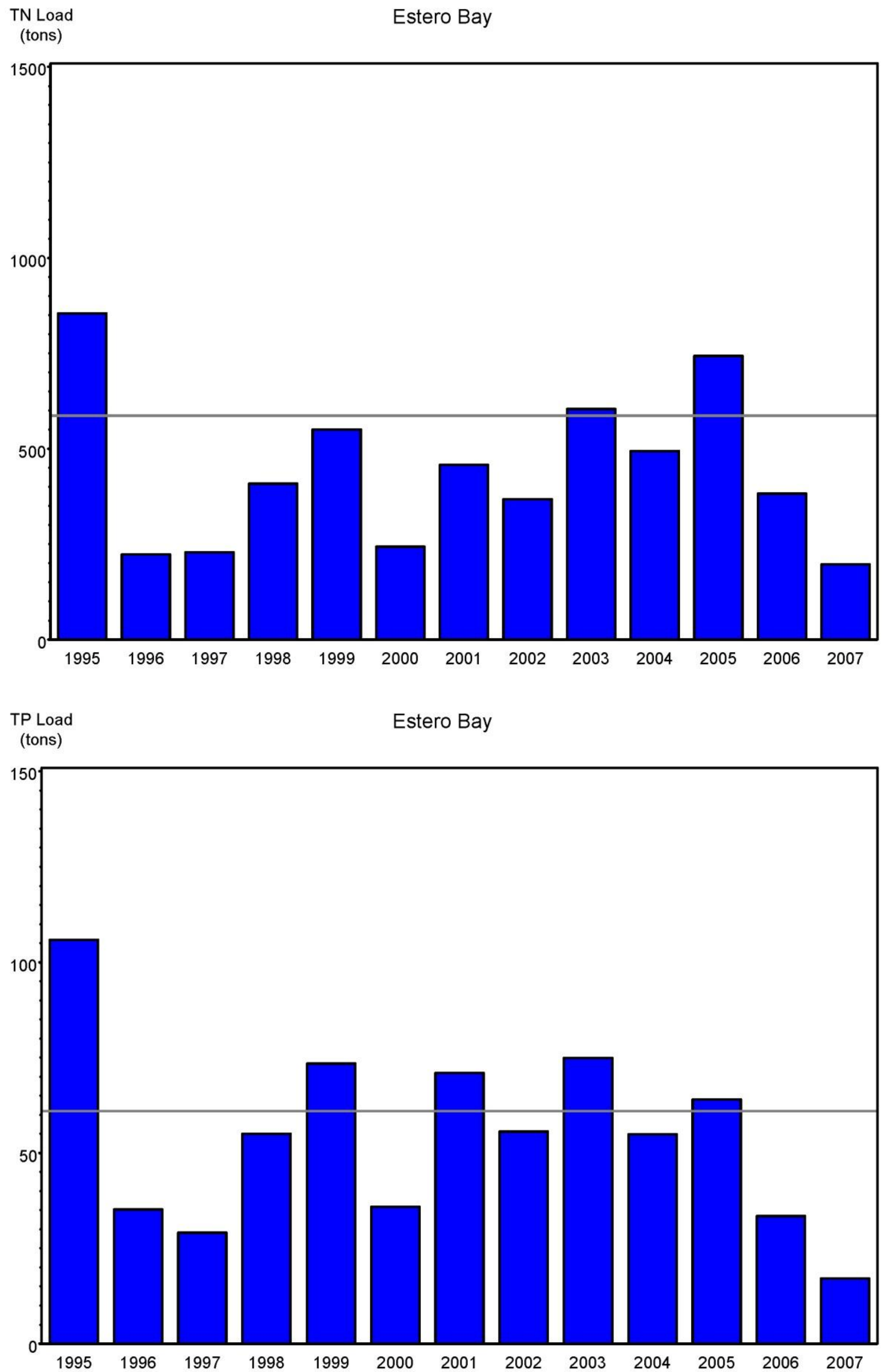


Figure 4-10. Comparison of proposed TN and TP load criteria for Estero Bay to annual loads.

5.0 References

Janicki Environmental, Inc. 2009. Water Quality Target Refinement Project – Task 2: Seagrass target development. Interim Report 2. Prepared for Charlotte Harbor National Estuary Program, Ft. Myers, FL. Authors: Janicki, A., M. Dema, and M. Wessel.

Janicki Environmental, Inc. 2010. Empirical Approaches to Establishing Numeric Nutrient Criteria for Southwest Florida Estuaries. Prepared for Tampa Bay Estuary Program, Sarasota Bay Estuary Program, and Charlotte Harbor National Estuary Program.

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APPENDIX C.
Implementation Issues:
Targets, Thresholds, Type I Error and
Compliance Assessment for Numeric Nutrient Criteria
Using the Reference Period Approach

Background

Site specific numeric nutrient criteria for individual estuarine water bodies in southwest Florida from Saint Joseph Sound in Clearwater, Florida through Estero Bay, Florida are being proposed as alternatives to the application of regional or state wide model based standards. These site specific criteria rely on the identification of a response endpoint and the endpoint defined for these estuaries has been defined as a threshold chlorophyll *a* concentration in all cases. The temporal scale has been defined as yearly; therefore, the assessment statistic is an annual average chlorophyll *a* concentration. Generally, the geometric annual average is used; however, in cases where the data are first averaged monthly, a simple arithmetic average is used. These threshold chlorophyll *a* concentrations for all estuaries have been identified using a reference period approach. Subsequent numeric nutrient criteria have been developed either by applying a stressor response relationship between nutrients and chlorophyll *a* concentrations, or by simply calculating an average of the annual averages of the reference period.

The reference period approach relies on the identification of a period in time when these estuarine water bodies were sufficient to support full aquatic life uses. The overarching logic is that, provided a reliable stressor response model cannot be developed to accurately predict that point at which a system would no longer meet its full aquatic life use, water quality conditions during of a period in time when that waterbody was meeting its designated use would be protective of full aquatic life uses. For example, the estuarine open water segment of Saint Joseph Sound has been meeting full aquatic life uses according to FDEP water quality standards and the Impaired Waters Rule since 2003. This means that chlorophyll *a* concentrations (Chla) have been below an annual average of 11 μg/L and dissolved oxygen concentrations (DO) have been above 4 mg/L in at least 90% of the samples. These “endpoints” (i.e., Chla and DO) are typical indicators used to assess the health of estuarine waters. The period of time between 2003 and 2007 was therefore chosen as the reference period for the CHNEP.

To establish numeric nutrient criteria using the reference period approach, a period of time would be identified when the waterbody was meeting its designated use, parameters would be defined to characterize the population of water quality values for chlorophyll *a*, total nitrogen (TN) and total phosphorus (TP) during that time, and then threshold values would be defined to represent a deviation from the expected condition of the reference period. The following paragraphs provide an example of how targets, thresholds and the type I error, and compliance assessment procedures have been established using the reference period approach.

Reference Period Example

To begin this example, a hypothetical reference period distribution of chlorophyll *a* concentrations was generated. Chlorophyll *a* concentrations in estuaries typically exhibit “lognormal” distribution characteristics. This implies that when a natural log transformation is applied to the distribution, it becomes normally distributed which conforms to most parametric statistical tests. Therefore, a lognormal distribution of chlorophyll *a* concentrations was simulated using a mean of 6.75 μg/L and a standard deviation of 4.49 μg/L. This distribution composed of 10000 observations is shown in Figure 1. Once the data are natural log transformed, the distribution becomes bell shaped corresponding to the normal distribution (Figure 2). Since the Florida Department of Environmental Protection (FDEP) and the Environmental Protection Agency (EPA) have proposed using annual geometric means as regulatory statistics for parameters with lognormal distributions such as chlorophyll *a*, we now consider the log transformed values to represent the data underlying this hypothetical evaluation and back transform the averages to obtain the geometric means.

Given the theoretical distribution of Figure 2, we can generate annual averages to simulate the product of a typical monitoring program. For example, we can randomly select 12 observations from the distribution of log values, and calculate an average and back transform that average to obtain the geometric mean. Further, we can repeat this experiment many times, each time selecting 12 samples and calculating the average of the log values. We expect each average to be close to the overall average of the reference period since it is a random sub-sample, however, we know that variability will exist due to sampling. For example, in Figure 3, we have generated 100 annual averages from the reference period distribution. As can be seen in Figure 3, the distribution of annual averages is centered on a value very close to the overall average in Figure 2 which is expected.

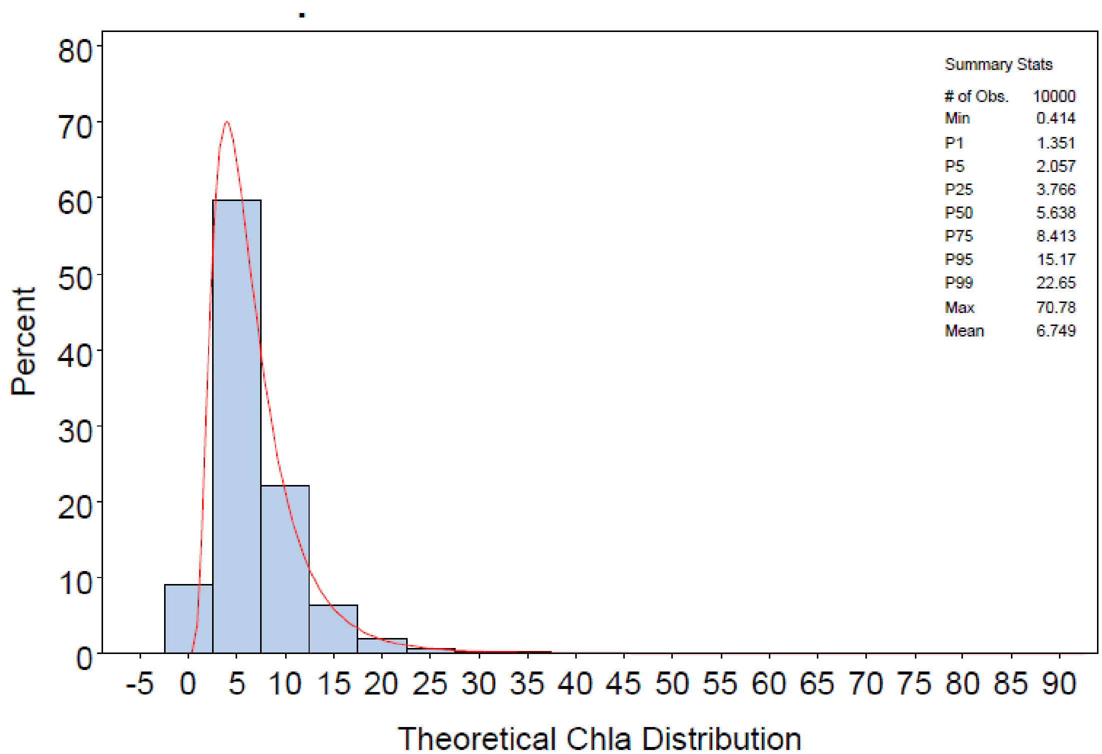

Figure 1. Simulated distribution of chlorophyll *a* concentrations.

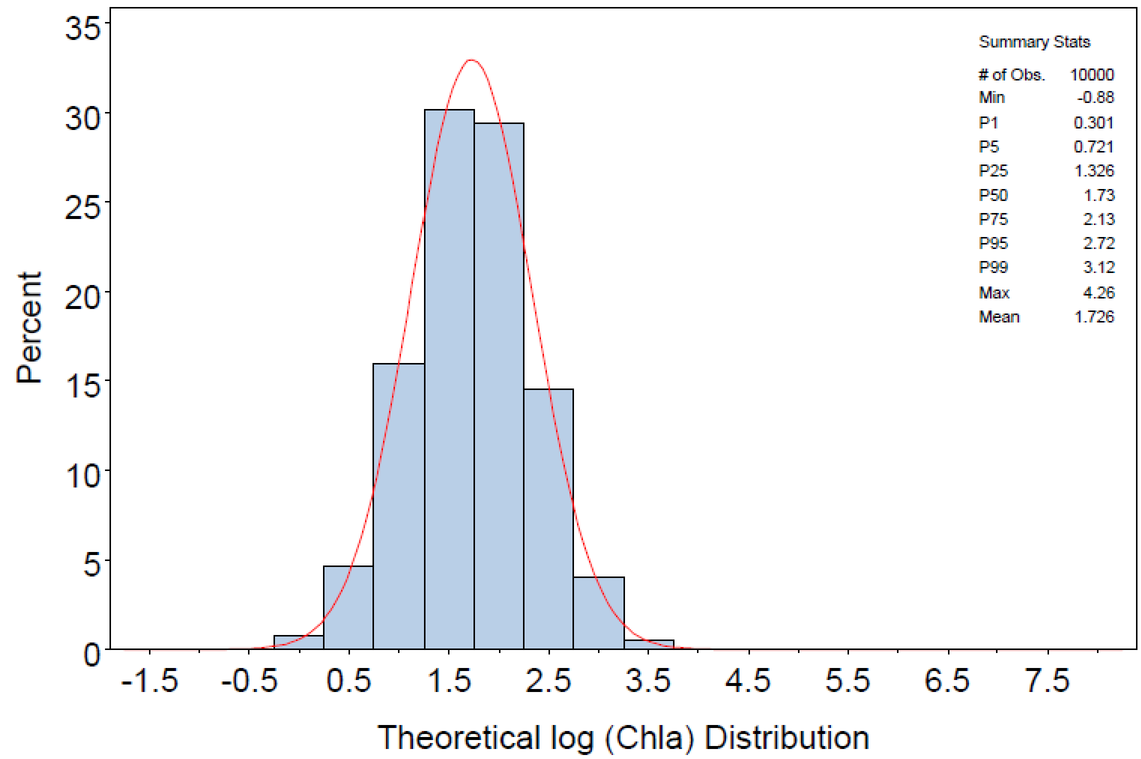

Figure 2. Distribution of the natural log transformed values of the simulated distribution above.

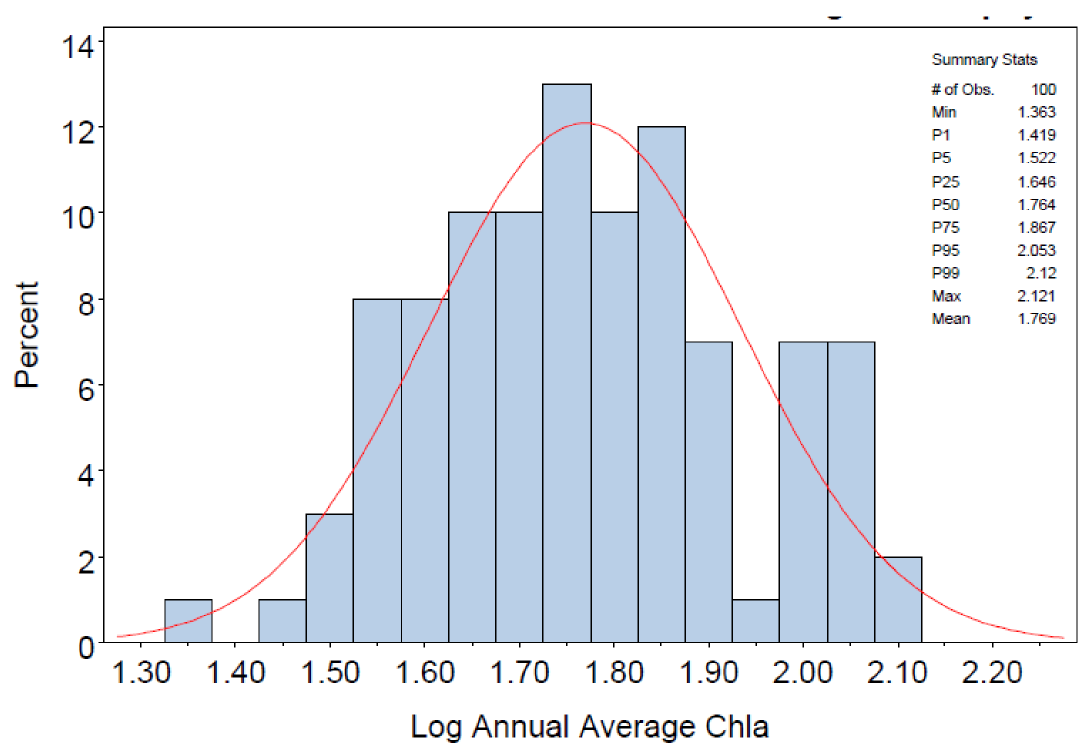

Figure 3. Distribution of 100 annual averages of the log transformed chlorophyll values using 12 samples per year.

To derive the geometric annual averages, we simply back transform the annual averages of Figure 3. This distribution is shown in Figure 4.

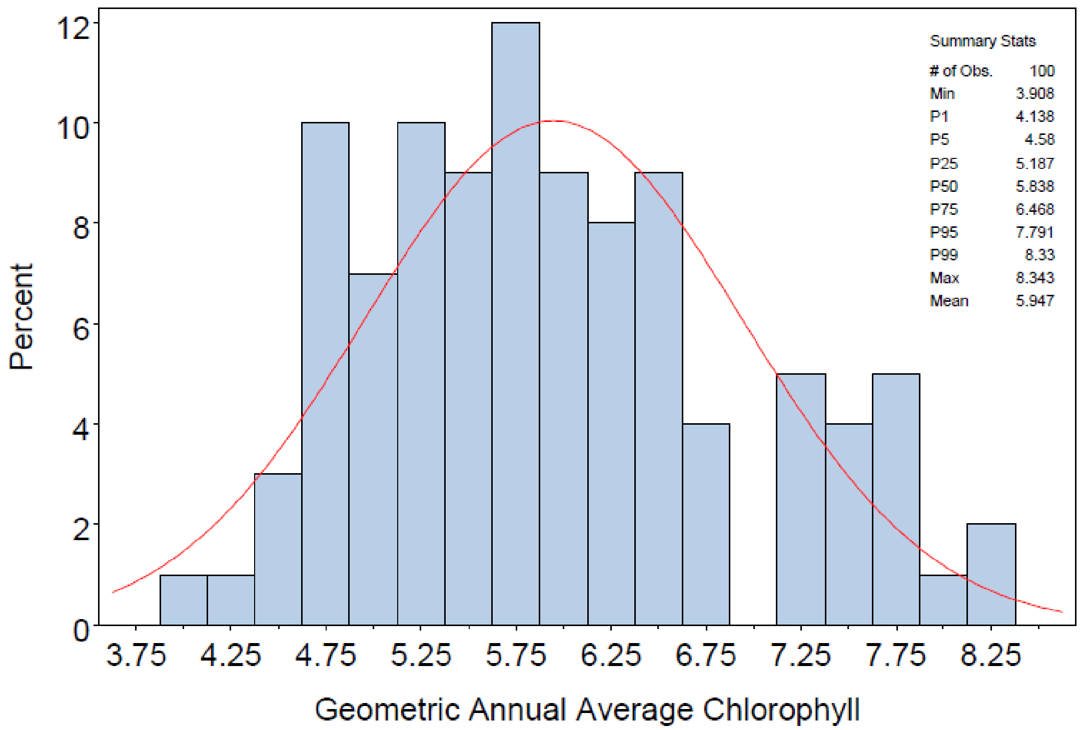

Figure 4. Geometric means taken from the simulated chlorophyll concentrations above.

Targets and Thresholds

Once the geometric means have been calculated we have all the information necessary to develop **targets** and **thresholds** for this theoretical reference period distribution.

The **reference period target** for this distribution can be defined as the overall average of all the geometric means. That is, 5.947 μg/L is our goal for the water body to ensure that it remains similar to the reference period condition we identified as being indicative of full aquatic life support. However, it can be seen from Figure 4 that the distribution of annual geometric means for this population ranges between 3.9 μg/L and 8.3 μg/L. Therefore, the distribution of geometric means can be considered a population of values that represent the expected distribution of annual averages of the reference period. Based on normal distribution theory, we can assign a **threshold** value to represent an annual average above which we would reject the hypothesis that the value was from the same population as the reference period distribution of annual geometric means. Using the z table of standard statistical tests, only 5% of a normal distribution with a mean and standard deviation of the distribution in Figure 4 would lie above the mean+1.65*the standard deviation of the population of geometric means. Therefore, a **threshold** can be constructed for this distribution that defines with 95% confidence what value a given geometric mean would need to exceed to reject the hypothesis that it belonged to the reference period distribution. For this distribution that **threshold** value equals 7.59 μg/L.

The threshold value provides a level of certainty that a future single geometric mean value (i.e. a sample) is not declared to exceed the reference distribution simply due to sampling. As was demonstrated above, we know that some portion of the reference distribution values will be above the **target** value. In fact, nearly 50% of the annual geometric means will be higher than the **target**. However, only 5% of the values will be higher than the **threshold** value of 7.59 μg/L due to chance. This construct defines what is known as the **Type I error rate** or False Positive rate**.** That is, we are willing to accept that 1 in 20 times we may get a value that is higher than 7.59 μg/L that still belongs to the reference period distribution. As was seen in Figure 4, 5% of the values did exceed 7.59 μg/L even though we know the entire population of values.

Therefore, the type I error rate is a value that is selected based on judgment and while 5% is typically used, there is no definitive rationale for 5% versus 1% or 10%. If we wish to be more conservative, we would select a lower type I error rate by choosing a larger value (e.g., 1.96) to multiple against the standard deviation to minimize the potential for falsely declaring that a value was different from the reference distribution. If we have reason to believe that the water body may not fully meet its designated use at values at the higher end of the reference distribution, one could select a higher type I error rate which in turn would equate to a smaller z score to multiply by the standard deviation (e.g., 1). For example, selecting 1 standard deviation equates to a type 1 error rate of 16%. However, the type 1 error rate does have implications on the compliance assessment.

Compliance Assessment

Now that the definition of targets, thresholds, and type 1 error has been identified, there is another consideration that must be taken into account when evaluating criteria exceedances. The exceedance frequency for an exceedance due to chance is defined by the type 1 error rate as described above. However, the exceedance frequency and duration component also must be established to allow for some anomalous condition unrelated to anthropogenic activity such as an El Niño, or La Niña cycles. There is substantial evidence that these meteorological anomalies can result in higher chlorophyll *a* concentrations (e.g., Morrison et al. 2006, Sherwood 2010). Therefore, this type of exceedance is different from the type I error described above. Since we have previously defined the type I error rate, we have already made the choice as to the false positive rate we are willing to accept. The implementation question is now posed to ask "what is the frequency of exceedances and assessment cycle that allows for occurrences unrelated to local anthropogenic activities but remains sensitive to capturing population deviations from the reference period due indicative of human adverse effects?"

To address this question the Multivariate ENSO Index calculated by Klaus Wolter of the National Oceanic and Atmospheric Administration (see Wolter and Timlin 1993) was used as described in several implementation documents produced by Janicki Environmental regarding implementation of numeric nutrient criteria (Janicki Environmental, Inc. 2011a-c). It is easy to see in Figure 5 that when El Niño or La Niña events occur they tend to last more than a single year. In fact, it's quite possible for many of the single events to cross a calendar year. Further information on the frequency and duration of ENSO events can be found at: http://www.esrl.noaa.gov/psd/enso/mei/

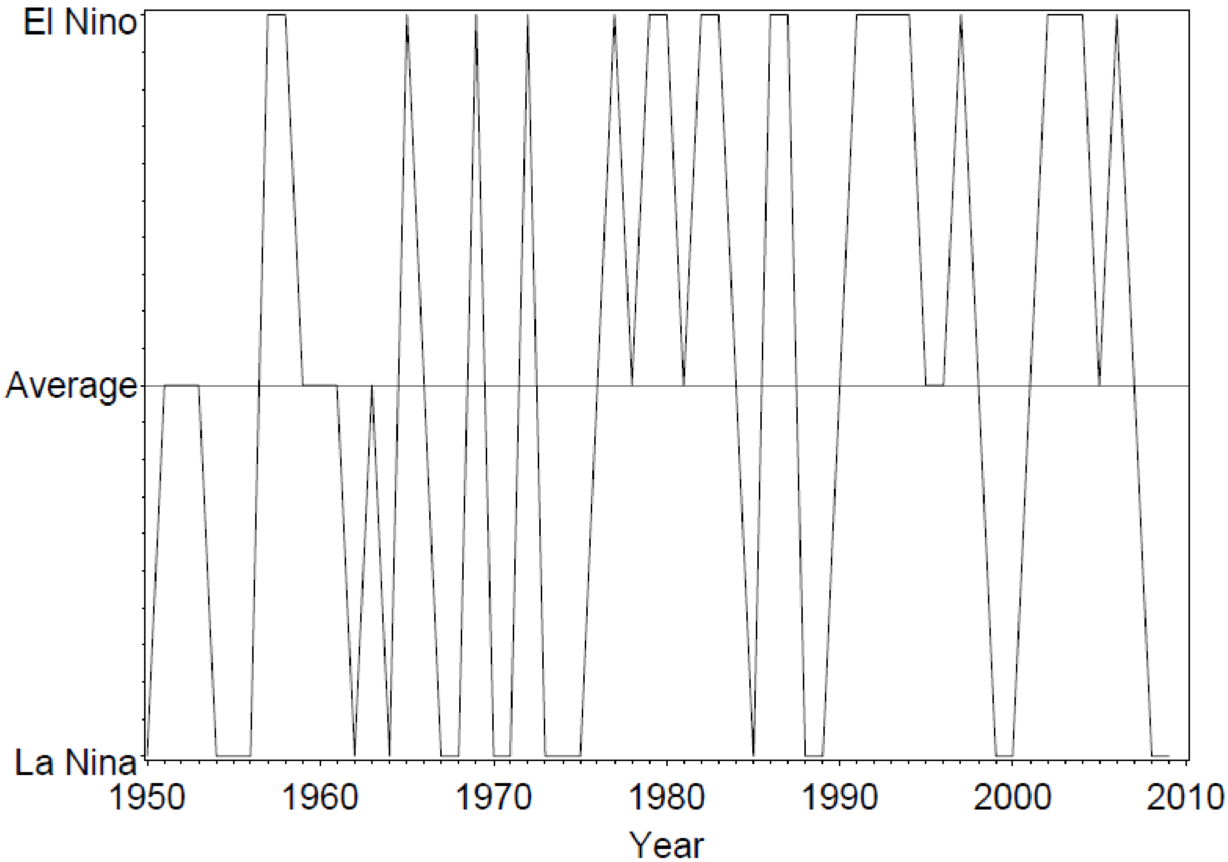

Figure 5. Classification of El Niño and La Niña events as described in Janicki Environmental 2011a.

Based on this analysis, it makes sense to allow for the potential that an anomalous event could result in higher annual geometric average than the reference period threshold value in more than one year in a 5 year cycle as is currently proposed by FDEP. Therefore the recommended allowance as an exceedance frequency in a five year assessment cycle is to allow for no more than 2 exceedances in a 5 year assessment cycle.

It is possible that the type I error rate and the probability of an anomalous event can be calculated such that both the probability of an exceedance occurring by chance and the probability that an exceedance occurs due to anomalous conditions could be integrated. That is, over a 5 year cycle one might calculate the union probability of an exceedance due to chance and an exceedance due to a natural anomaly. This was beyond the scope of this memorandum but one that might be pursued as the implementation process is refined. Because the proposed criteria are based on threshold values with known type 1 error rates, the criteria and the 2 in 5 year implementation criteria are inextricably linked and should not be separated. Further information supporting the use of the 2 in 5 implementation rule is provided in Janicki Environmental (2011a-c).

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Morrison, G., E.T. Sherwood, R. Boler, and J. Barron. 2006. Variations in water clarity and chlorophyll *a* in Tampa Bay, Florida, in response to annual rainfall, 1985-2004. Estuaries and Coasts. 29:926-931.

Sherwood, E.T. 2010. 2009 Tampa Bay Water Quality Assessment. 2010. Technical Report #02-10 of the Tampa Bay Estuary Program. Prepared by the Tampa Bay Estuary Program.

Wolter, K., and M.S. Timlin, 1993: Monitoring ENSO in COADS with a seasonally adjusted principal component index. *Proc. of the 17th Climate Diagnostics Workshop*, Norman, OK, NOAA/NMC/CAC, NSSL, Oklahoma Clim. Survey, CIMMS and the School of Meteor., Univ. of Oklahoma, 52-57.
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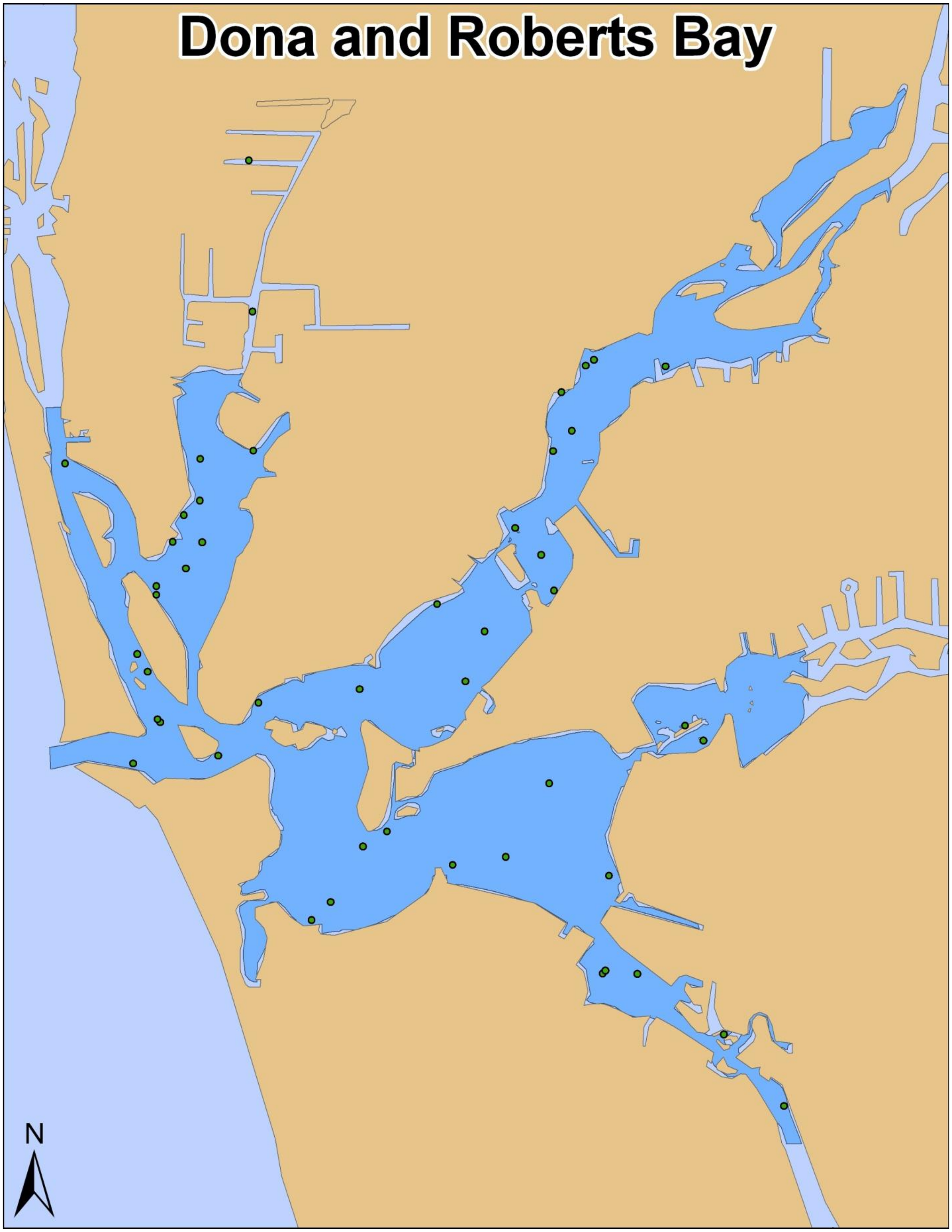
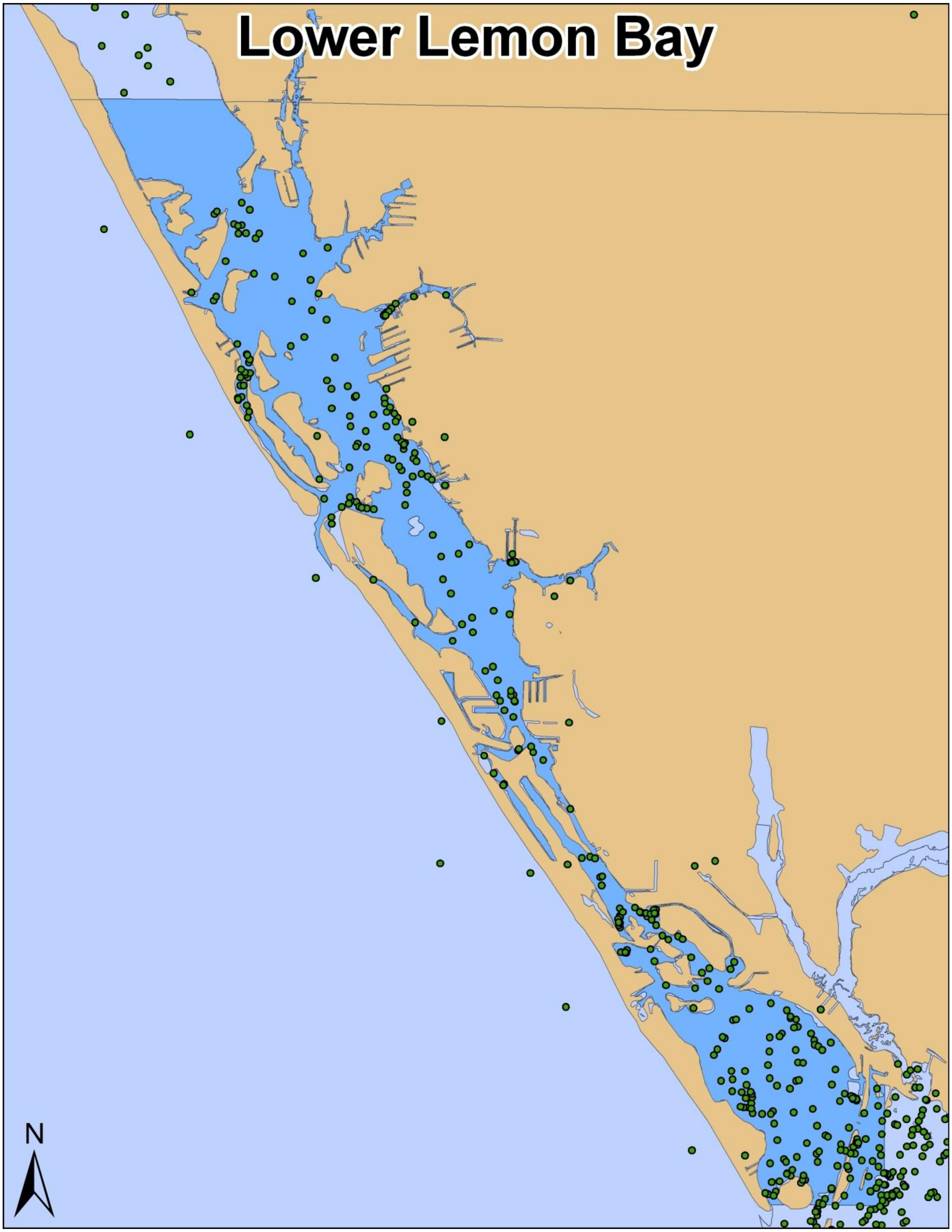
APPENDIX D.
Maps of Monitoring Sites Utilized For Water Quality Assessment In Each Segment


Dona and Roberts Bay
N


Upper Lemon Bay
N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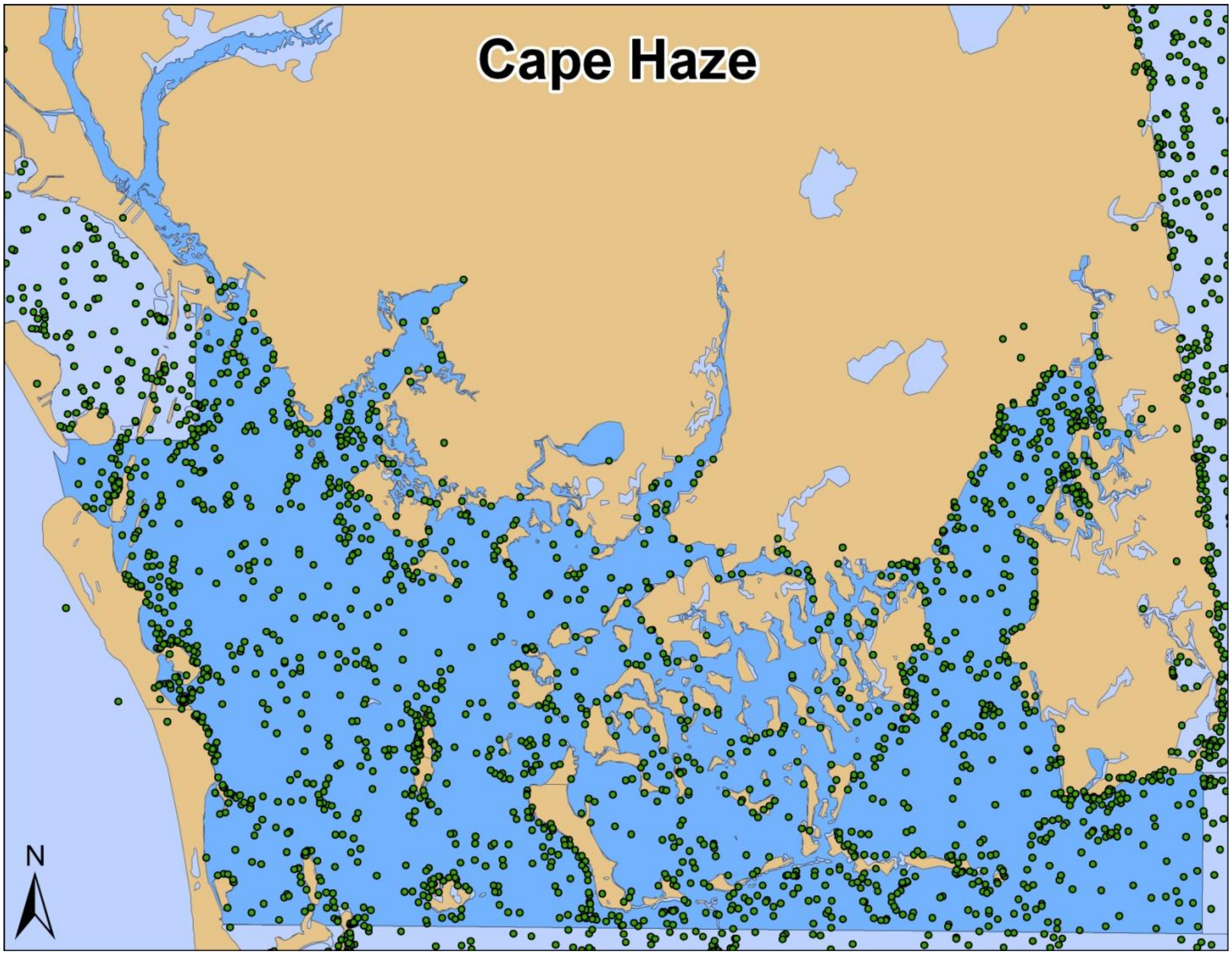
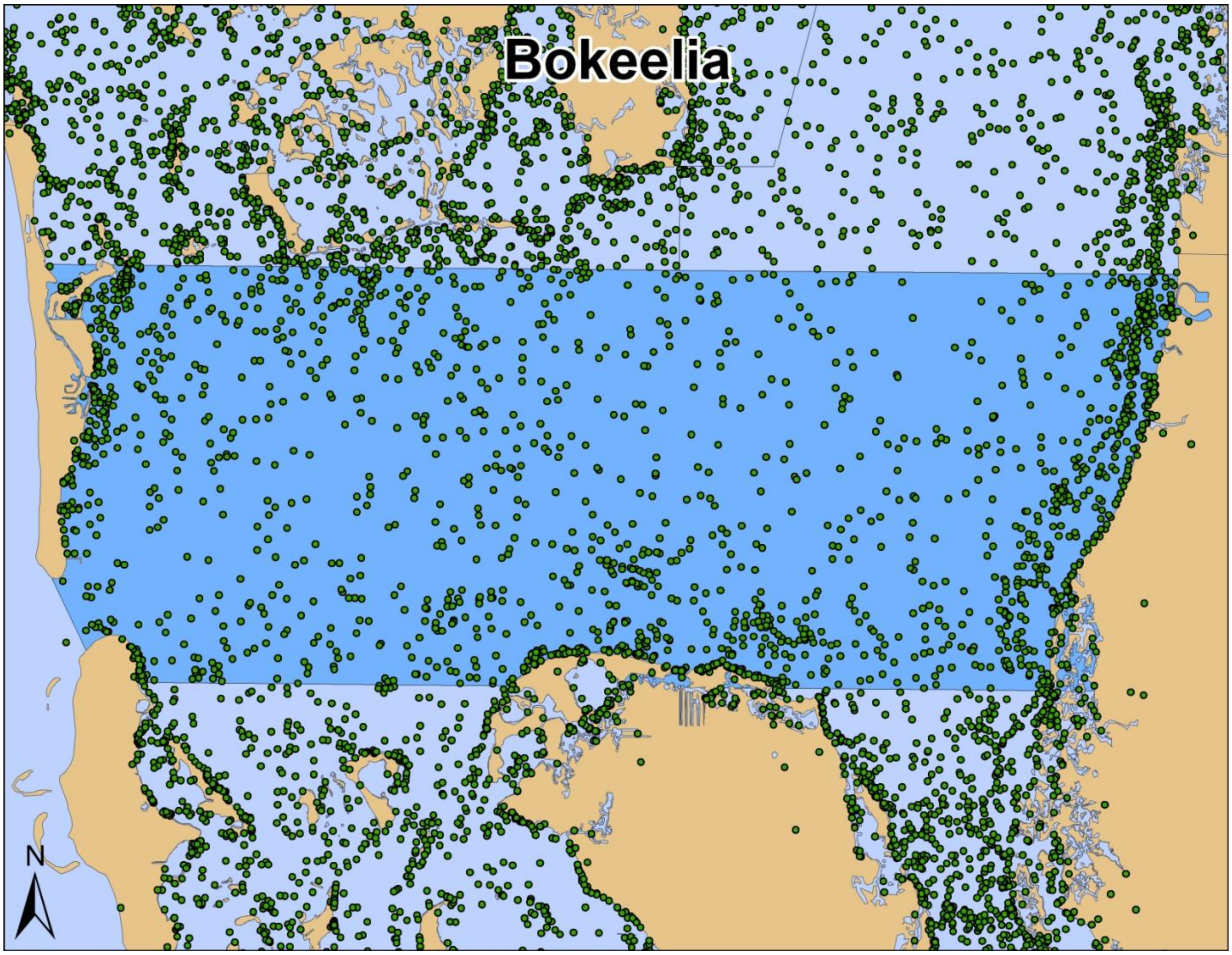
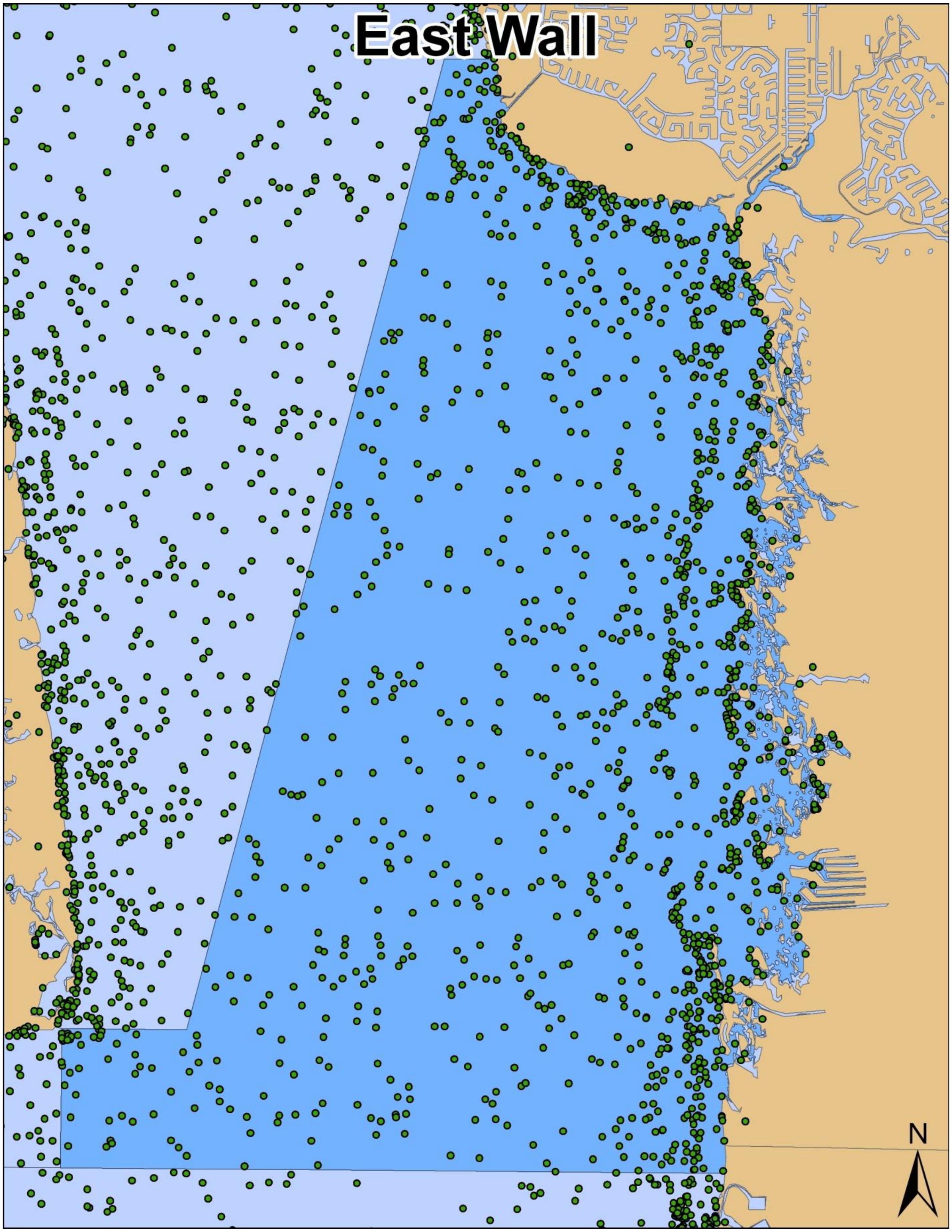
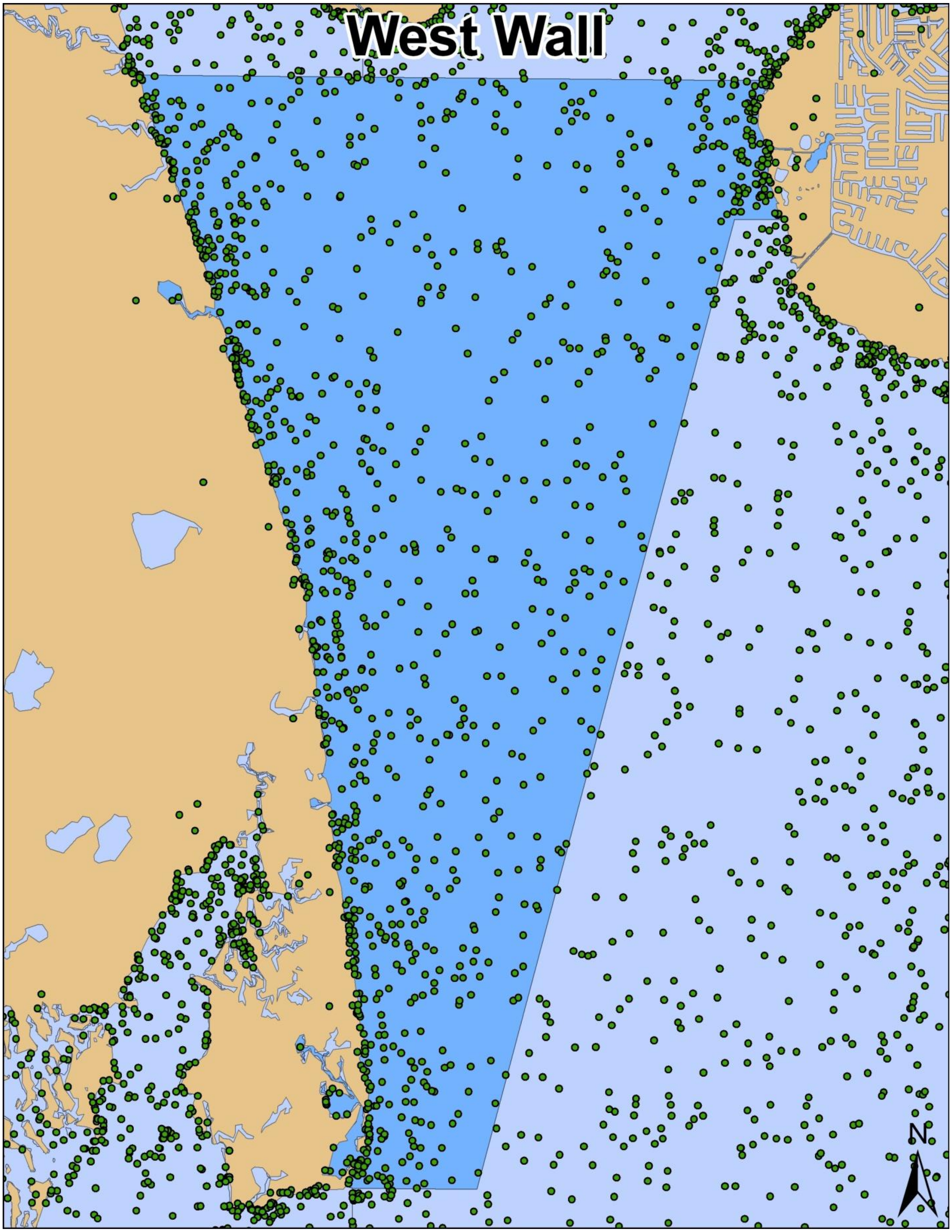

Cape Haze
N


Bokeelia
N


East Wall
N


West Wall
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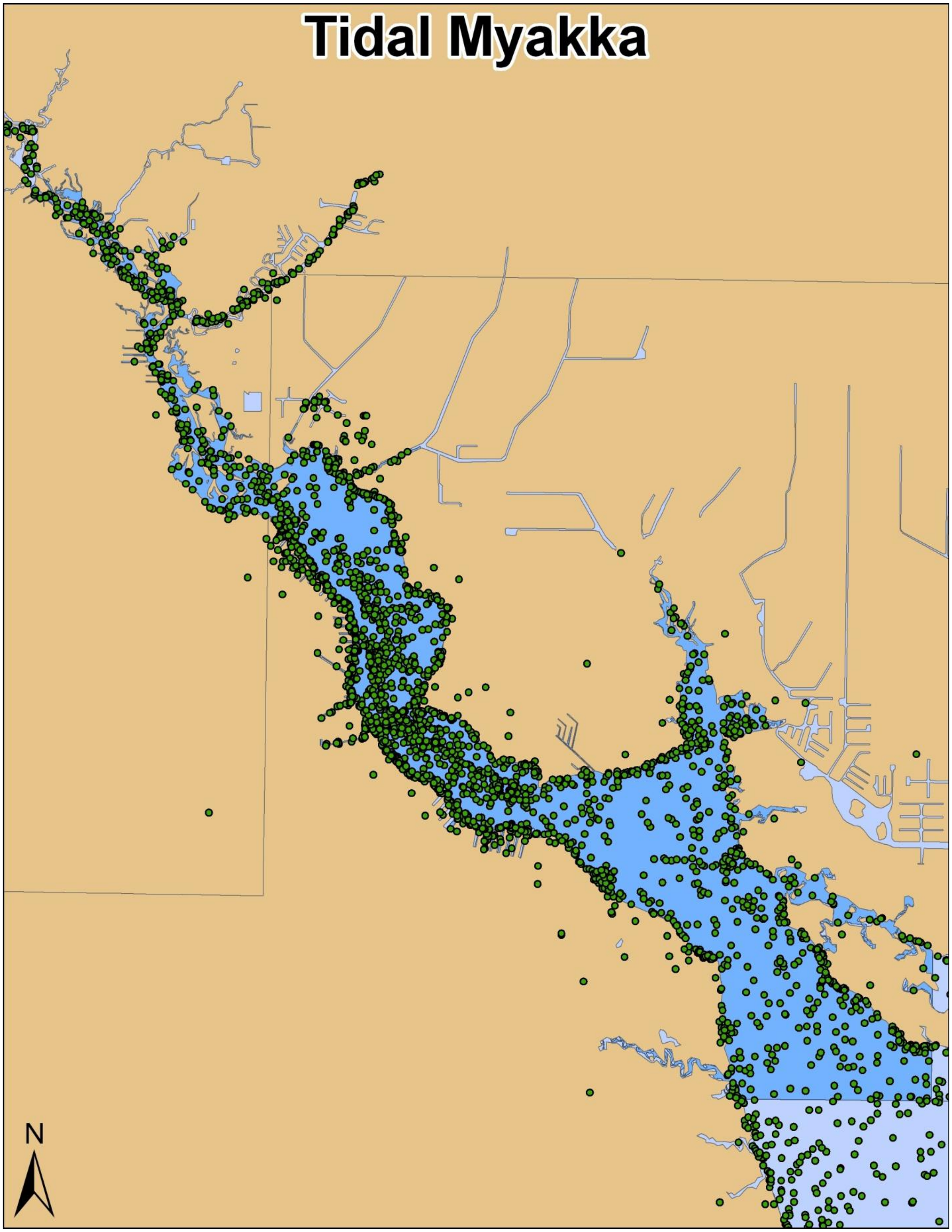
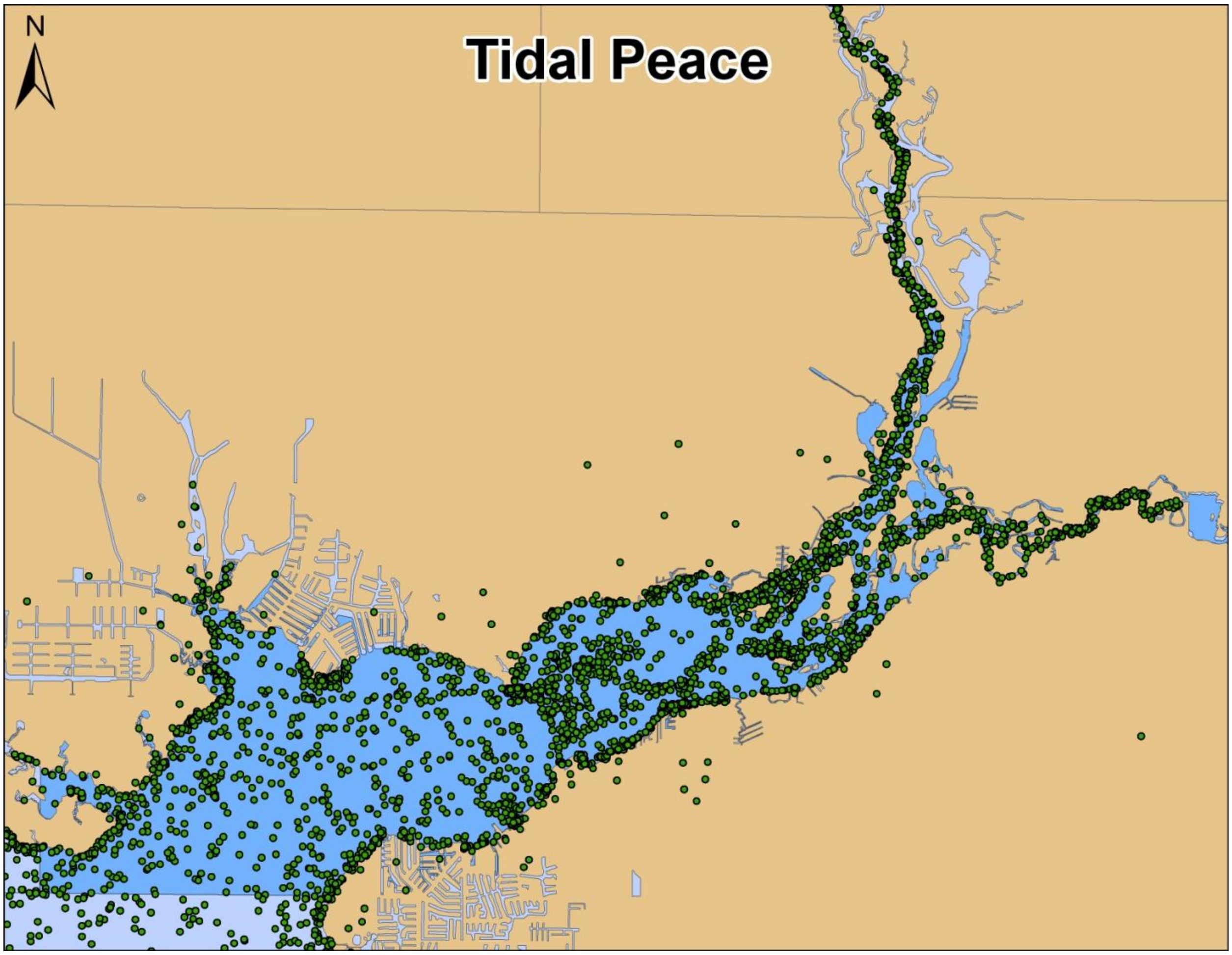
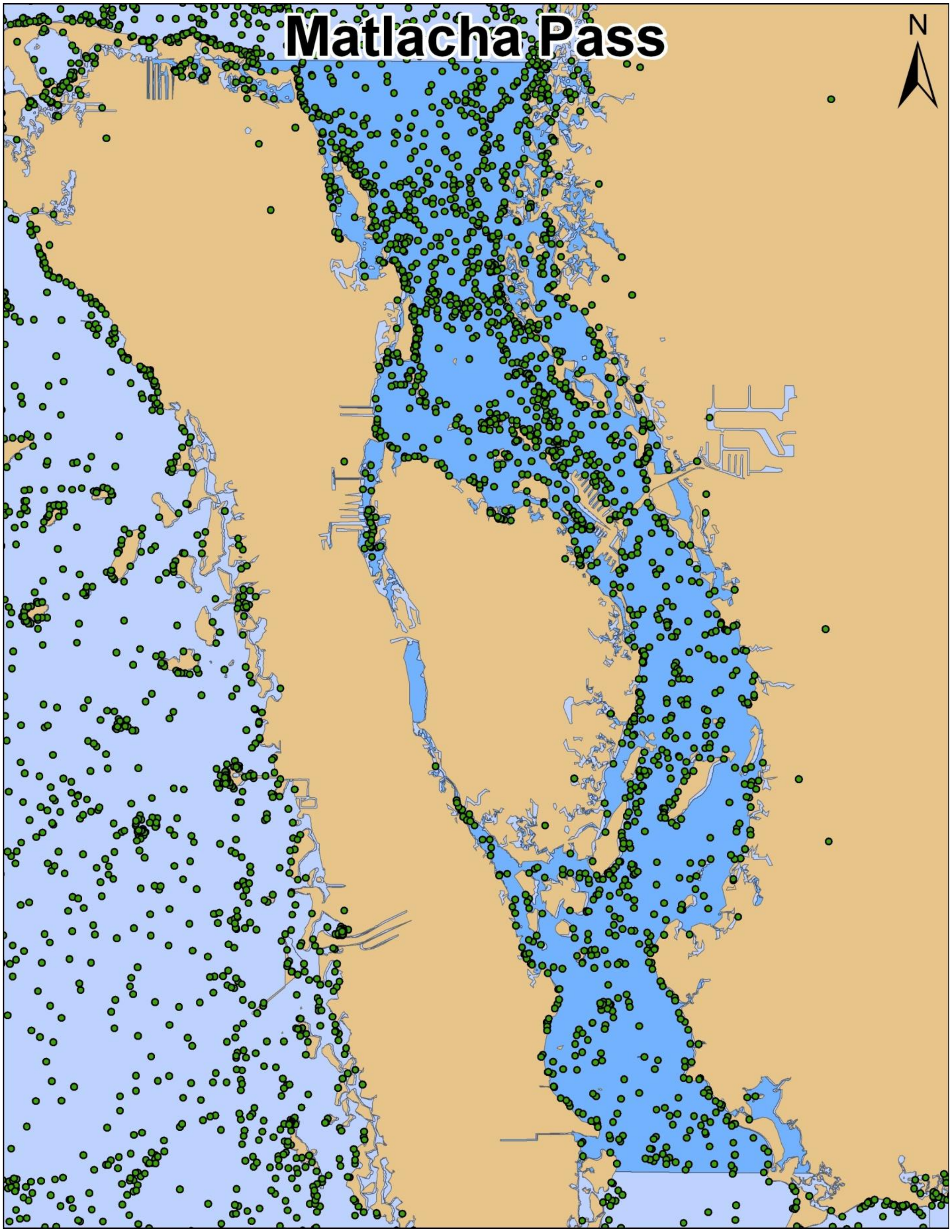
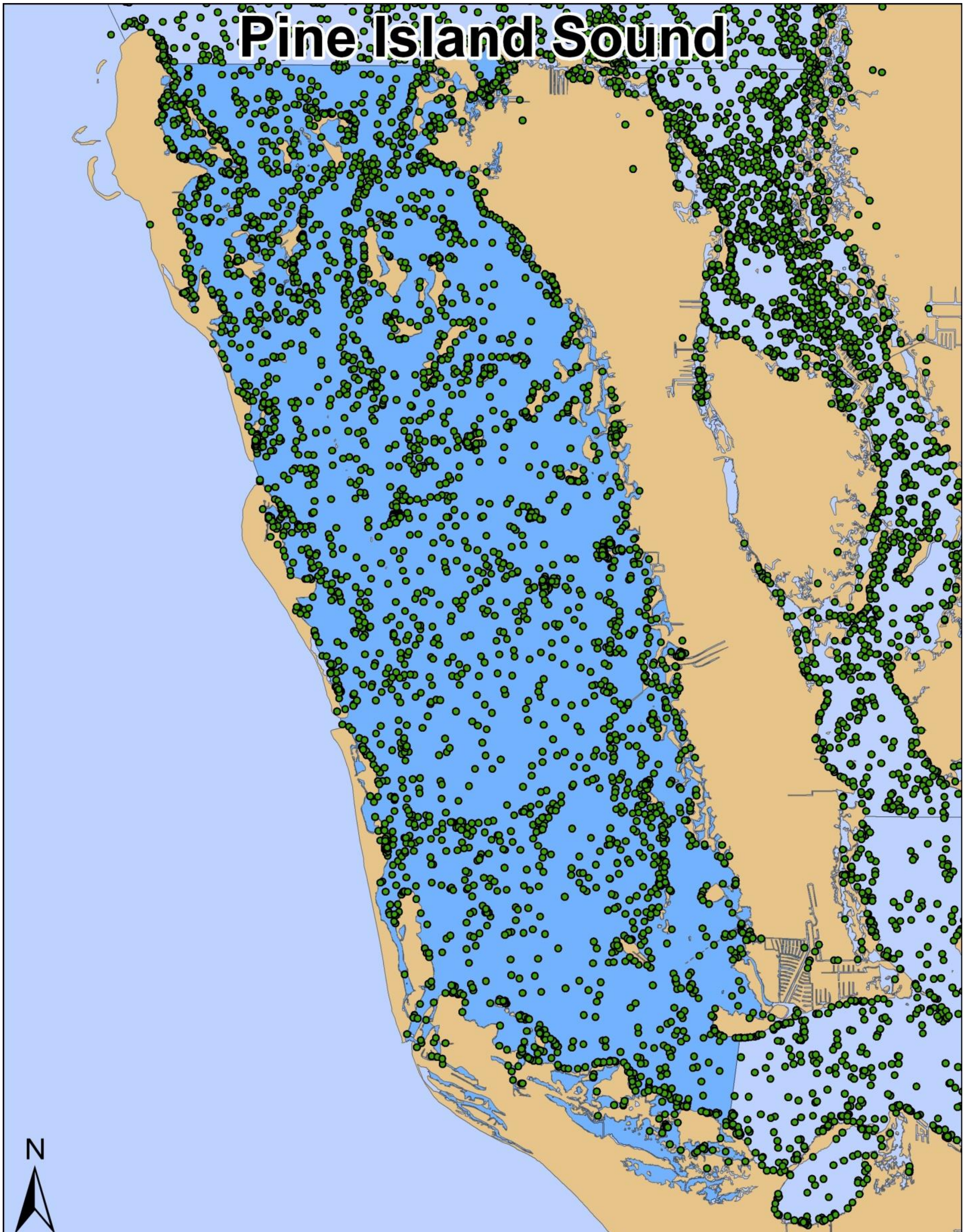
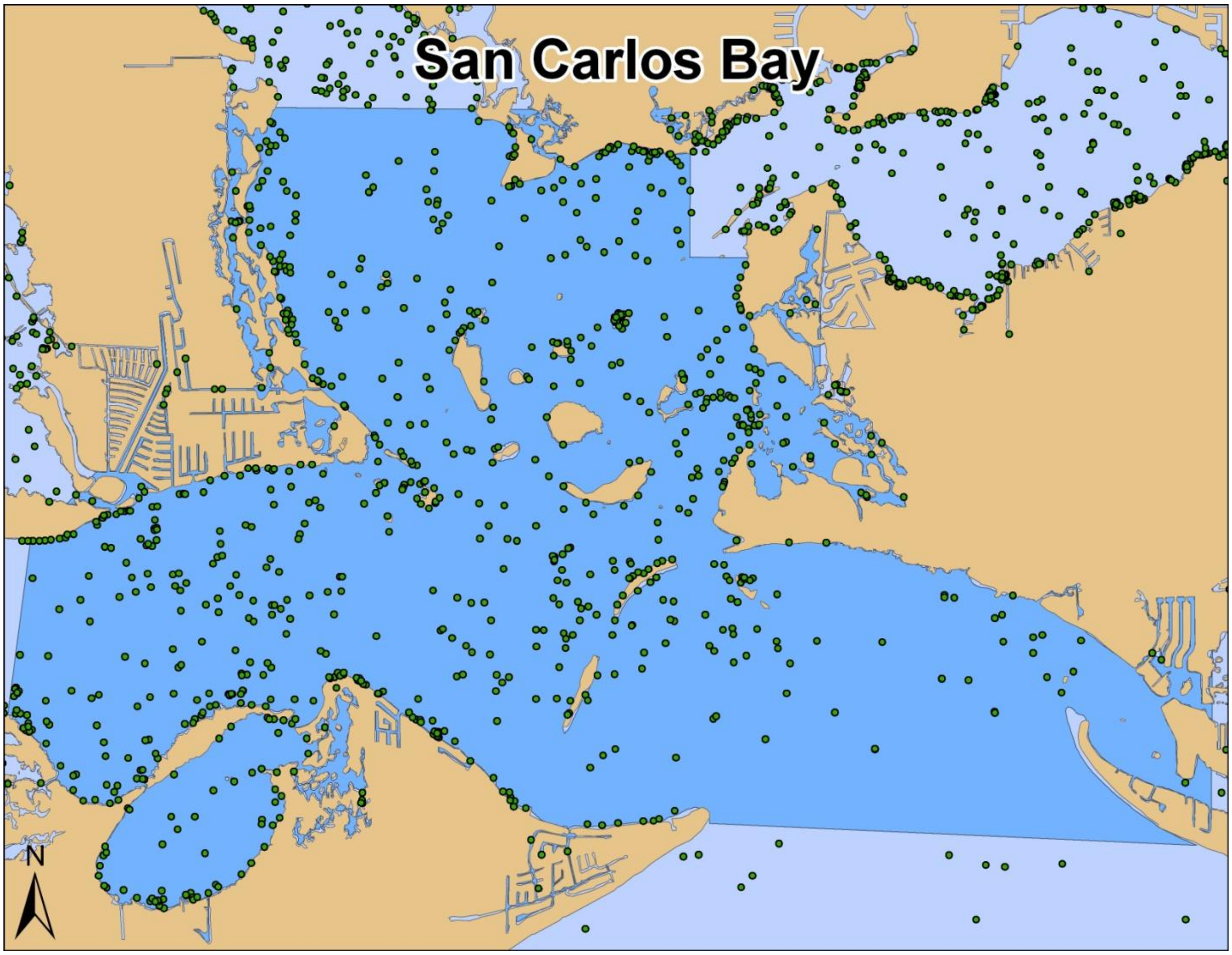
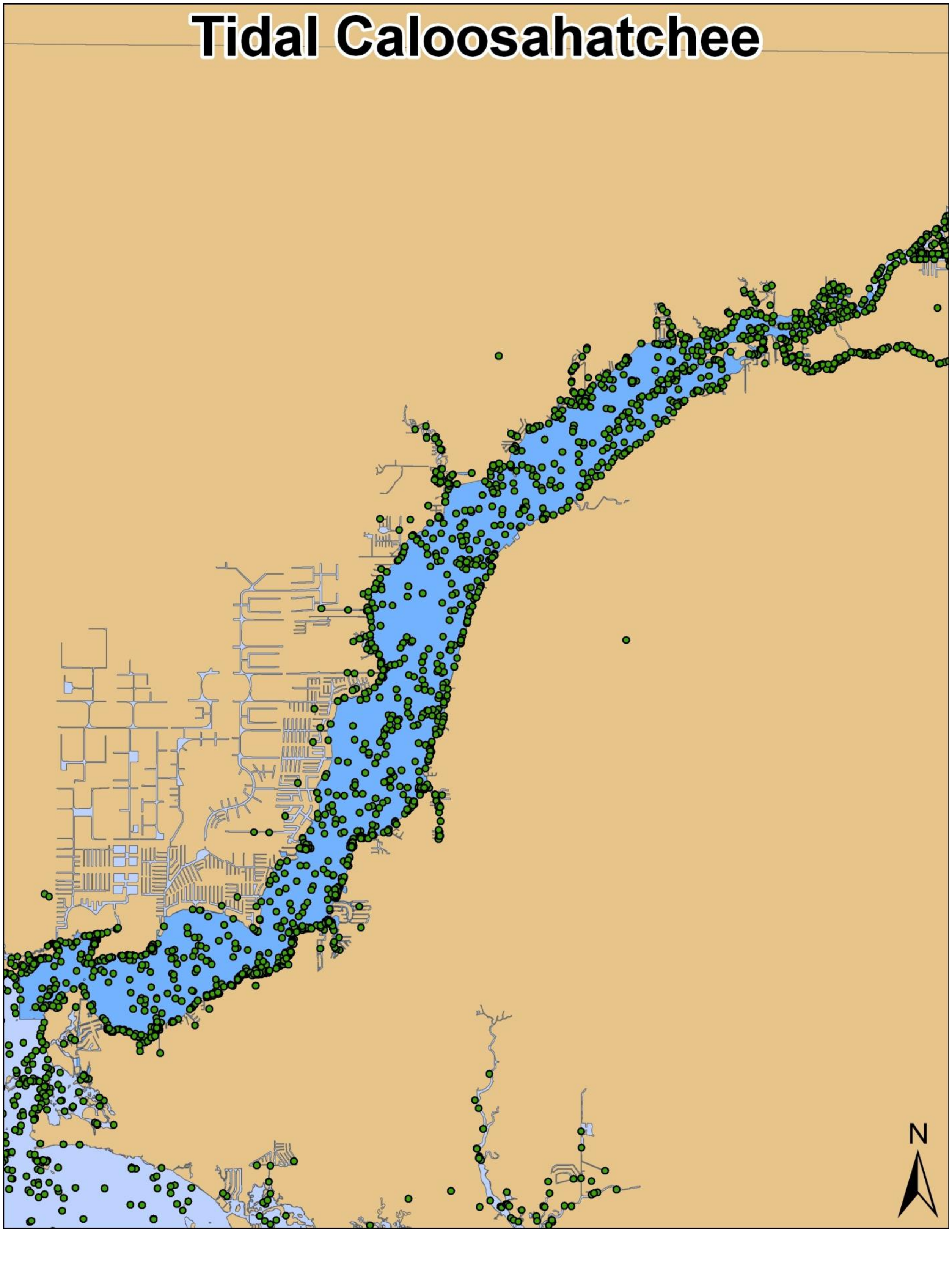

Tidal Myakka
N

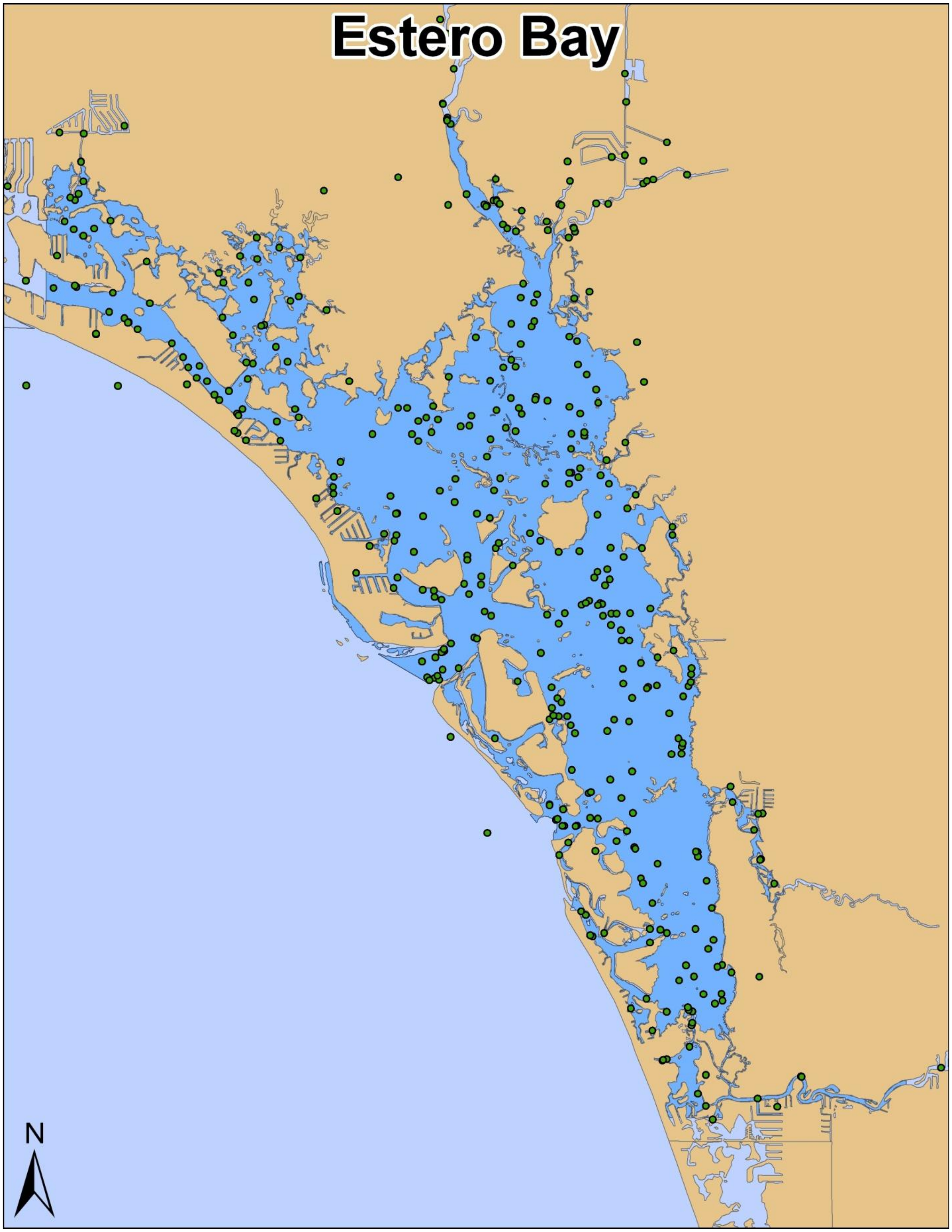

N
Tidal Peace


Matlacha Pass
N


Pine Island Sound
N


San Carlos Bay
N


Tidal Caloosahatchee
N



Estero Bay
N