ESA 50 YEARS 1969-2019

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memorandum

date	May 10, 2019
to	Mark Alderson, Executive Director, Sarasota Bay Estuary Program
cc	
from	David Tomasko, Ph.D. Emily Keenan, M.S.
subject	Preliminary Assessment of Sarasota Bay Water Quality Trends

Executive Summary

Concerns about the potential degradation of water quality in Sarasota Bay have been complicated by the recognition that the Numeric Nutrient Concentration (NNC) criteria developed for the Sarasota Bay Estuarine Nutrient Region are problematic. Additionally, in the years since the end of the reference period used in the NNC criteria (2001 to 2005) there has been a trend of increased rainfall in the Sarasota Bay / Lemon Bay watershed.

In five regions of Sarasota Bay examined in this report, increases in rainfall have co-occurred with a decline in salinity (on an annual basis). In each system examined, salinity and concentrations of Total Nitrogen (TN) are inversely correlated. Consequently, four of the five regions show a trend of increases in TN since 2006. As chlorophyll-a and TN are correlated in Sarasota Bay increases in chlorophyll-a were found in each bay region examined, except for that portion of Sarasota Bay north of New Pass. Increases in TN in this area (Upper Sarasota Bay) are in-line with expectations based on the TN vs. salinity relationship that existed during the reference period of 2001 to 2005. However, in the southern portions of Sarasota Bay, in the areas of New Pass / Big Pass, Roberts Bay, Little Sarasota Bay and Blackburn Bay, increases in TN concentrations are above and beyond those which can be explained by regional changes in rainfall and its effects on both salinity and nitrogen. Instead, there is an apparent excess of nitrogen that appears to be loaded into local waters in those portions of Sarasota Bay south of New Pass.

As a whole, the portion of Sarasota Bay north of New Pass appears to be healthy in terms of both water quality and seagrass distribution. North of New Pass, seagrass coverage is within 5% of the highest values recorded over the past 30 years, and are well above estimates from 1988. In the areas of New Pass and Big Pass, seagrass coverage is also within 5% of peak values, and well above estimates from 30 years ago. However, recent trends in nitrogen concentrations are higher than expectations based on changes in rainfall alone.

In Roberts Bay, seagrass coverage is similar to values 30 years ago, but recent trends in nitrogen and chlorophyll-a concentrations are greater than can be explained by trends in rainfall. In both Little Sarasota Bay and

Blackburn Bay, seagrass coverage declined by more than 20% between 2016 and 2018. In both these systems, increases in nitrogen and chlorophyll-a are above and beyond that which can be explained by changes in rainfall.

It is more likely than not that anthropogenic nutrient loads have increased to both Little Sarasota Bay, Blackburn Bay, and also to Roberts Bay (to a lesser degree) over the past 13 years. As nutrient concentrations in recent years are above and beyond those which can be attributed to rainfall alone, results suggest increased nutrient loads from sources with nitrogen concentrations higher than stormwater runoff, such as wastewater treatment plants and/or septic tanks. It is recommended that special attention be paid to ensure that wastewater practices meet the intent of the goals spelled out in the Sarasota Bay National Estuary Programs' Comprehensive Conservation and Management Plan, as well as relevant regulatory criteria.

Introduction

Currently, the Florida Department of Environmental Protection (FDEP) lists Numeric Nutrient Concentration (NNC) criteria for Sarasota Bay (FAC 62-302.531) that include equations that attempt to take into account climatic conditions by incorporating values for "color" into the derivation of NNC values for chlorophyll-a, Total Nitrogen (TN) and Total Phosphorus (TP). In an attempt to "normalize" criteria for the regional and seasonal differences in water quality, TN targets for the Sarasota Bay Estuarine Nutrient Region (SBENR) were to be interpreted using an equation that linked TN values to the amount of "color" in the water, with color expressed in Platinum Cobalt Units (PCU). Unfortunately, constraints have been identified which invalidate the application of the criteria as currently codified. For example, if arithmetic mean values of color exceed 40 PCU in the Manatee County portion of the SBENR during the wet season, the derived NNC criterion for TN is a negative number. Alternately, low levels of color (below 17 PCU) in the Sarasota County portion of the SBENR during the dry season also result in negative NNC criteria. Negative values are not valid criteria and cannot be applied to evaluate water quality condition.

The generation – based on color – of problematic NNC criteria has resulted in a determination that existing NNC criteria for Sarasota Bay can no longer be relied upon (Janicki Environmental, Inc. [JEI] 2018). In response, a revised approach to develop NNC criteria was developed, which resulted in a proposed new NNC criteria for TN of 0.49 mg / liter. While this revised criterion avoids the problems inherent in the original criteria, it is not normalized for salinity, and therefore could be expected to result in "false positives" for anthropogenic impairment in wetter than normal years, and "false negatives" for impairment in drier than normal years.

Also, Sarasota County has recently raised concerns related to trends of TN in southern portions of Sarasota Bay (JEI 2018). At the request of the Sarasota Bay Estuary Program (SBEP), ESA was tasked with developing a preliminary and third-party assessment of the reasonableness of the proposed NNC criteria of 0.49 mg TN / liter for the SBENR. This assessment was based on an approach wherein water quality data in recent years (2006-2018) can be explained by potential changes in rainfall, or human activities, or some combination of rainfall and human activities.

Methods

The data set used in these analyses was restricted to data from the years 1998 to 2018, using the latest run of the Impaired Waters Rule (IWR) dataset. Water quality was aggregated at the WBID level, for the following waterbodies:

- Sarasota Bay north of New Pass up to Palma Sola Bay (WBID 1968B)
- Sarasota Bay east of New Pass and Big Pass (WBID 1968C)
- Roberts Bay (WBID 1968D)
- Little Sarasota Bay (WBID 1968E)
- Blackburn Bay (WBID 1968F)

Parameters analyzed included the following: Chlorophyll-a, TN and salinity.

Particular attention was paid to the years of 2006 to 2018, as they represent the years after the reference period of 2001 to 2005 (as established in JEI, 2011). The 2001 to 2005 reference period was one in which seagrass coverage was increasing in Sarasota Bay, which was thought to indicate water quality conditions that should be sufficient to protect the ecological health of the bay and its ecological features. In this way, if water quality was found to be "degrading" in the years after the reference period, one could conclude that more recent years represent a deterioration of conditions.

Within all WBIDs, trend analysis for TN, chlorophyll-a and salinity were conducted as well as relationships between parameters. Statistical analysis was conducted using either linear, exponential, power or polynomial equations. If more than one relationship was found to be statistically significant ($P < 0.05$), the mathematical equation with the highest r-squared value is displayed. Prior to selection, parameters were tested to ensure compliance with the required assumptions of normality and homogeneity of variance. For clarity of interpretation, only those relationships with r-squared values higher than 0.50 are displayed. In this way, if a relationship between two parameters was statistically significant, but such a relationship explained less than half the variability between the two parameters, such relationships were not considered to be overly helpful. Data were evaluated on an annual basis, using annual geometric means.

For each WBID listed above, the relationship between TN and salinity was established through regression analysis, using data from the reference period of 2001 to 2005 . For each WBID, the upper boundary of the TN vs. salinity regression was established using the 80^{th} percentile limit of the relationship. The upper boundary of the 80^{th} percentile limit represents a range of TN concentrations sufficiently high that only 10 percent (approximately) of values would be expected to be higher, for a given salinity.

The number and percentage of salinity-normalized TN values that exceed this upper threshold were then quantified and the results displayed on an annual basis. In addition, annual geometric means of chlorophyll-a, TN and salinity were calculated for each WBID for each year.

In addition, seagrass mapping results clipped to the boundaries of the WBIDs outlined above, for the years of 1996 to 2018. The GIS data used was made available from the Southwest Florida Water Management District (SWFWMD). Finally, annual rainfall amounts for the Sarasota Bay / Lemon Bay watershed were downloaded from SWFWMD and results compared to period-of-record (1918 to 2018) average.

Results

Salinity

Statistically significant trends of declining salinity were found for four of the five WBIDs examined (Figures 1 to 5).

Figure 1 – Trend in salinity in WBID 1968B (Upper Sarasota Bay).

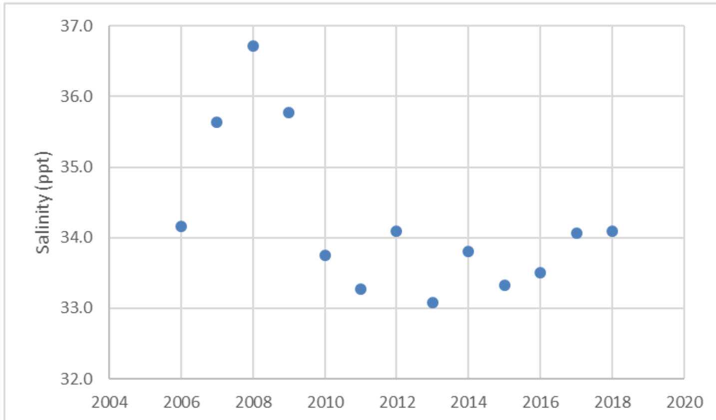


Figure 2 – Trend in salinity in WBID 1968C (New Pass and Big Pass).

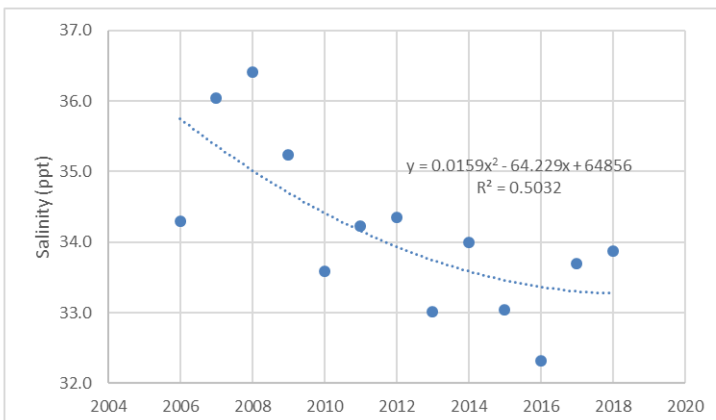


Figure 3 – Trend in salinity in WBID 1968D (Roberts Bay).

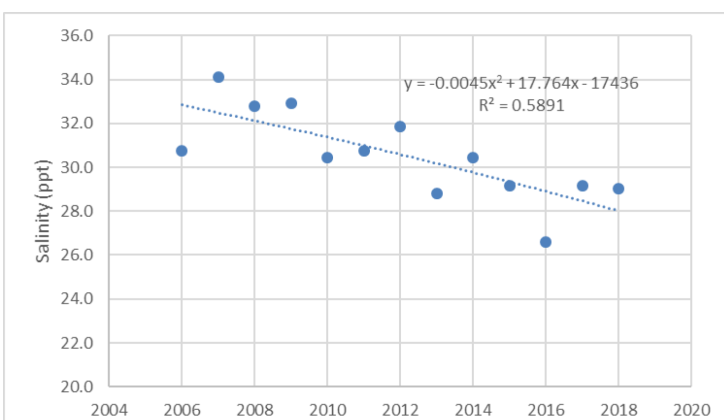


Figure 4 – Trend in salinity in WBID 1968E (Little Sarasota Bay).

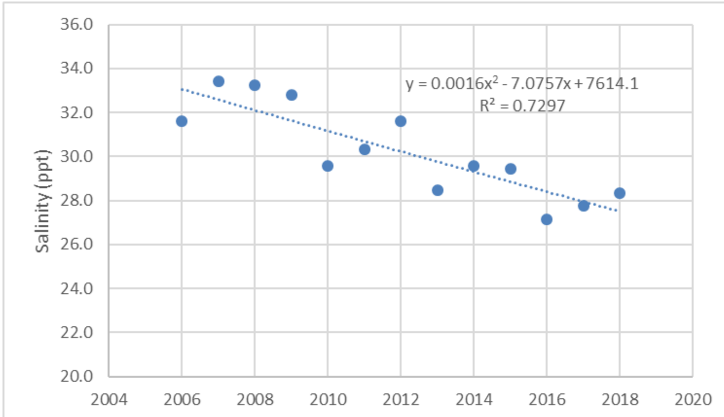
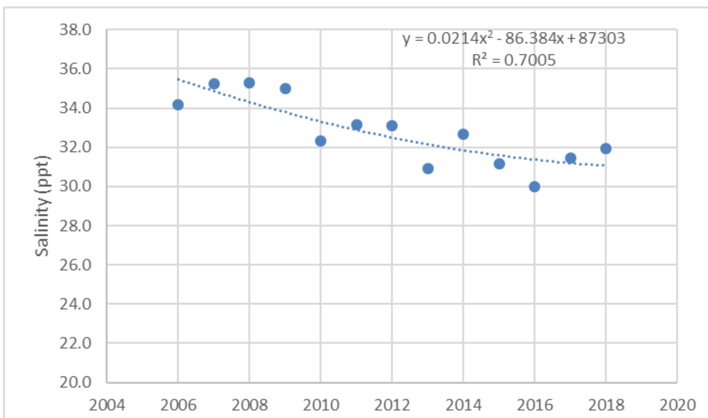
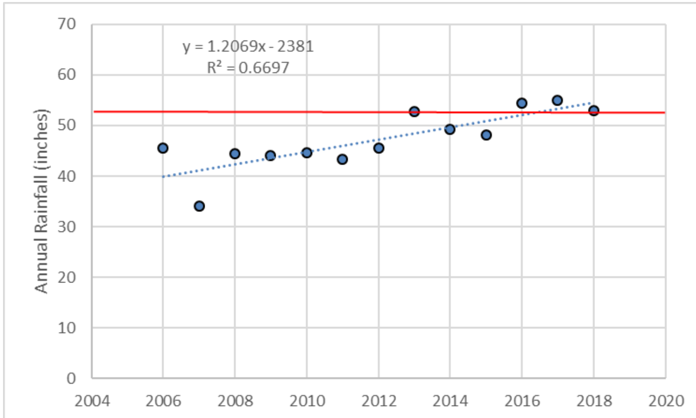


Figure 5 – Trend in salinity in WBID 1968F (Blackburn Bay).



The downward trends in salinity across most of the locations examined correlates with a trend of increased rainfall for the Sarasota Bay / Lemon Bay watershed (Figure 6). Over the past 13 years, which represents the years after the end of the 2001 to 2005 reference period, rainfall has increased. Prior to 2016, rainfall was below the long-term average for 9 of the 10 years. Since 2016, rainfall has been at or above the long-term average.

Figure 6 – Trend in annual rainfall in the Sarasota Bay / Lemon Bay watershed. Rainfall data from SWFWMD. Red line represents period of record (1915 to 2018) annual average of 52 inches.



For each of the WBIDs, the relationship between salinity and TN was examined, as shown in Figures 7 through 11.

Figure 7 – Relationship between TN and salinity in WBID 1968B (Upper Sarasota Bay).

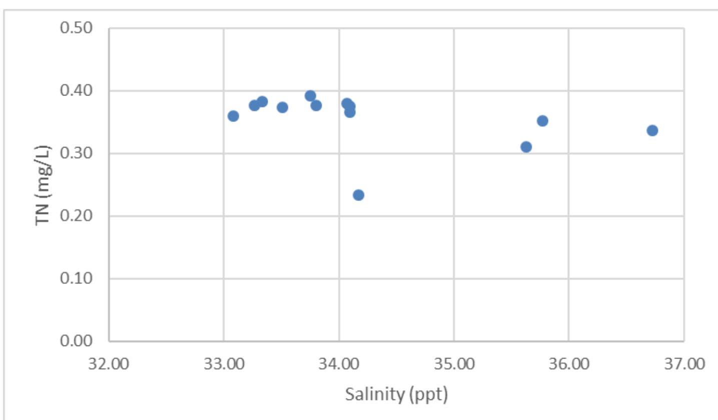


Figure 8 – Relationship between TN and salinity in WBID 1968C (New Pass and Big Pass).

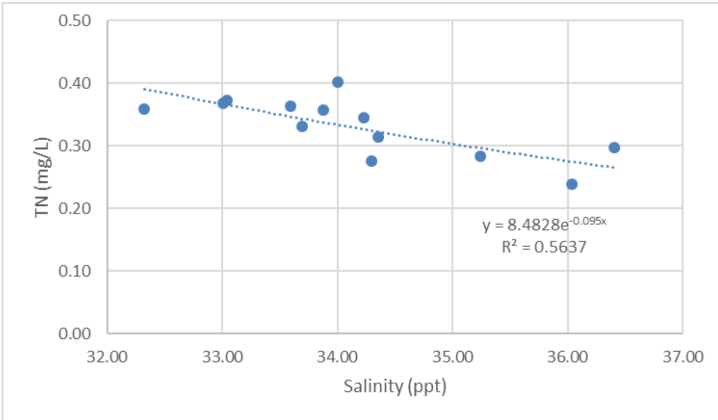


Figure 9 - Relationship between TN and salinity in WBID 1968D (Roberts Bay).

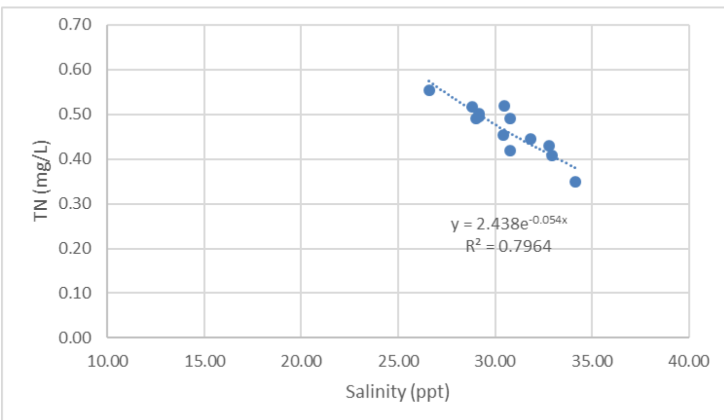


Figure 10 – Relationship between TN and salinity in WBID 1968E (Little Sarasota Bay).

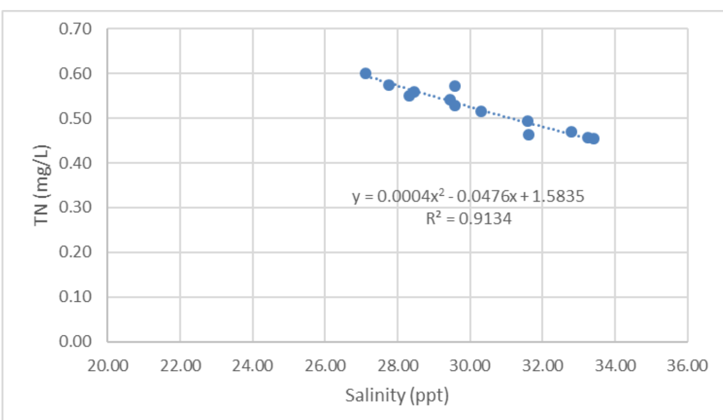
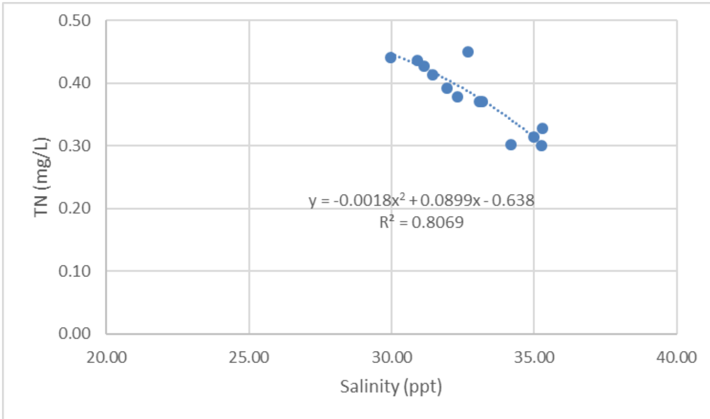


Figure 11 – Relationship between TN and salinity in WBID 1968F (Blackburn Bay).



For those portions of Sarasota Bay south of Big Pass and New Pass, there were statistically significant and inverse relationships between TN and salinity. As rainfall has increased since the end of the 2001 to 2005 reference period (Figure 6) salinities have decreased in those areas south of New Pass / Big Pass. Based on the relationships seen between TN and salinity, increased rainfall alone would be expected to bring about an increase in TN.

Figures 12 through 16 show trends in TN, for the years 2006 to 2018.

Figure 12 – Trend in TN in WBID 1968B (Upper Sarasota Bay).

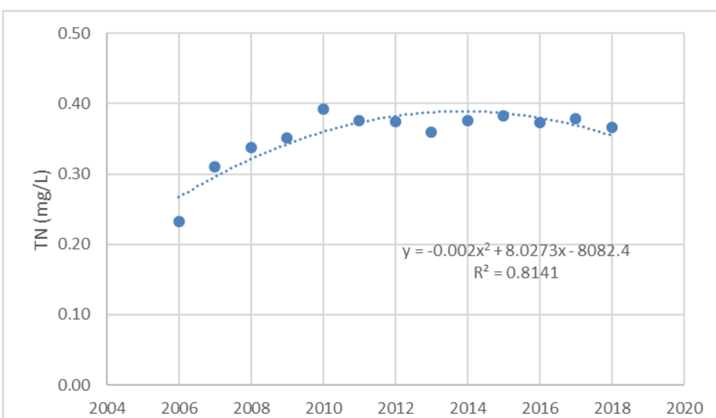


Figure 13 – Trend in TN in WBID 1968C (New Pass / Big Pass).

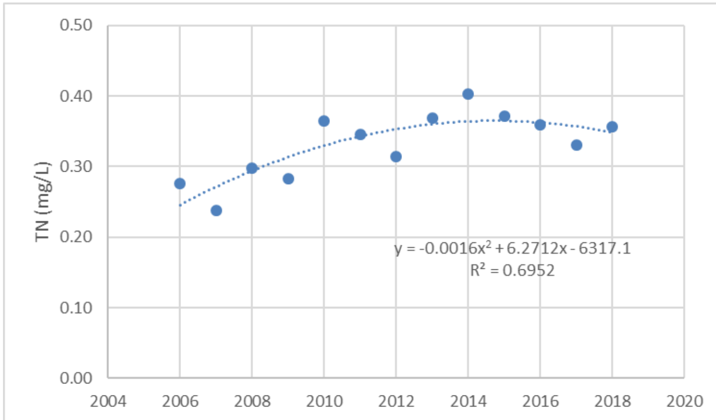


Figure 14 – Trend in TN in WBID 1968D (Roberts Bay).

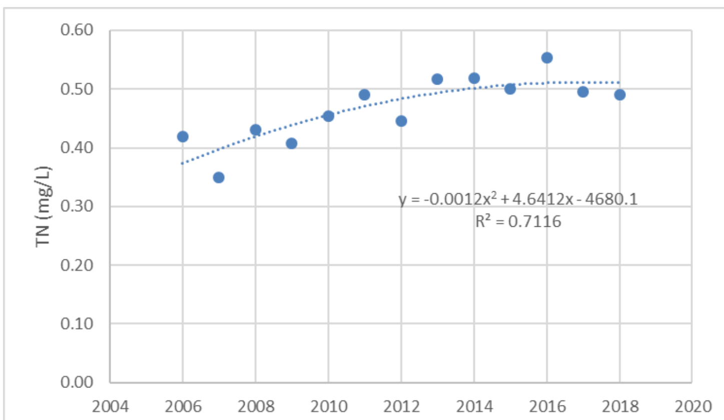


Figure 15 – Trend in TN in WBID 1968E (Little Sarasota Bay).

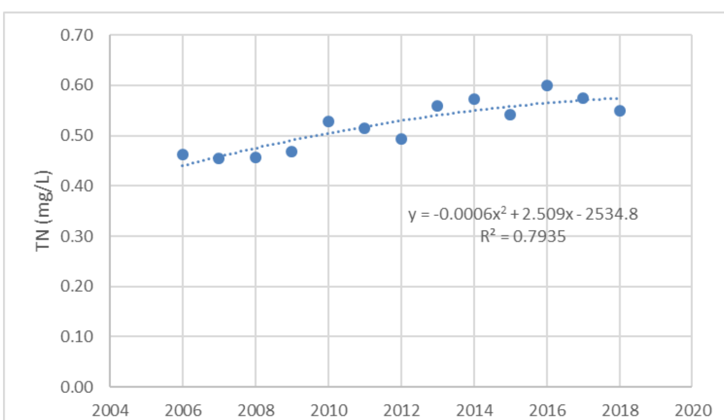
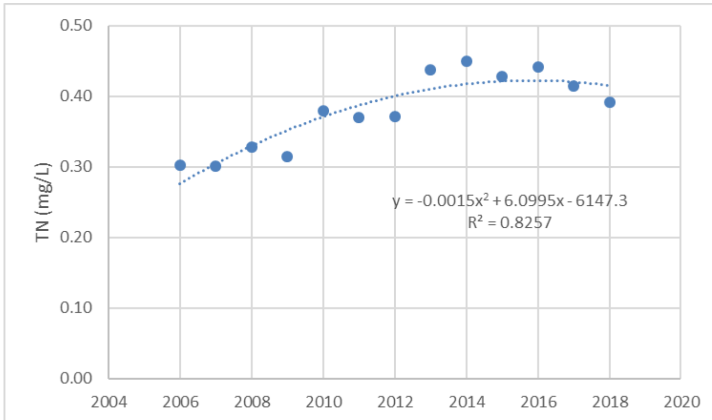


Figure 16 – Trend in TN in WBID 1968F (Blackburn Bay).



Consistent with findings noted more than twenty-five years ago (Tomasko et al. 1992) chlorophyll-a concentrations correlate with TN concentrations in Sarasota Bay. Therefore, trends in chlorophyll-a in Sarasota Bay would be expected to be similar to trends in TN. Trends in chlorophyll-a are displayed in Figures 17 to 21.

Figure 17 – Trend in chlorophyll-a in WBID 1968B (Upper Sarasota Bay).

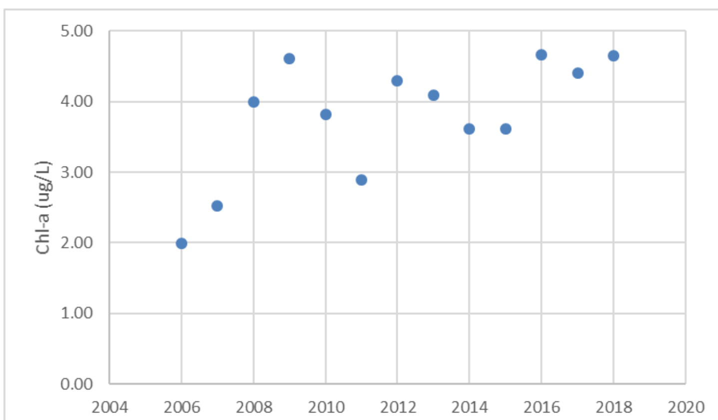


Figure 18 – Trend in chlorophyll-a in WBID 1968C (Big Pass / New Pass).

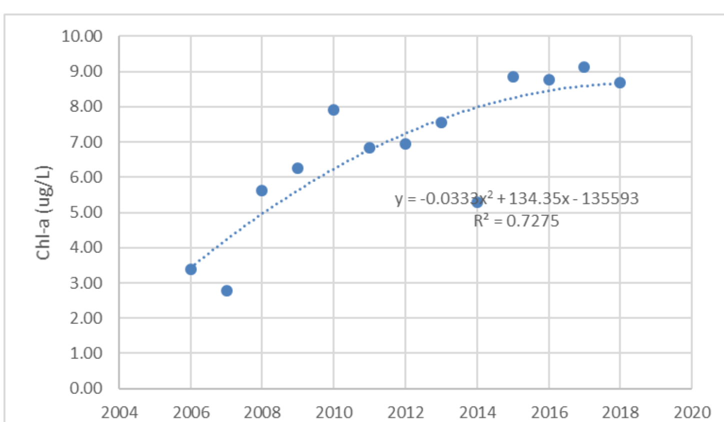


Figure 19 – Trend in chlorophyll-a in WBID 1968D (Roberts Bay).

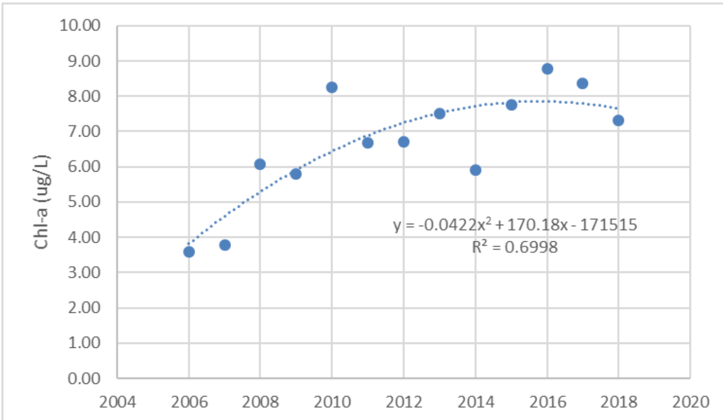


Figure 20- Trend in chlorophyll-a in WBID 1968E (Little Sarasota Bay).

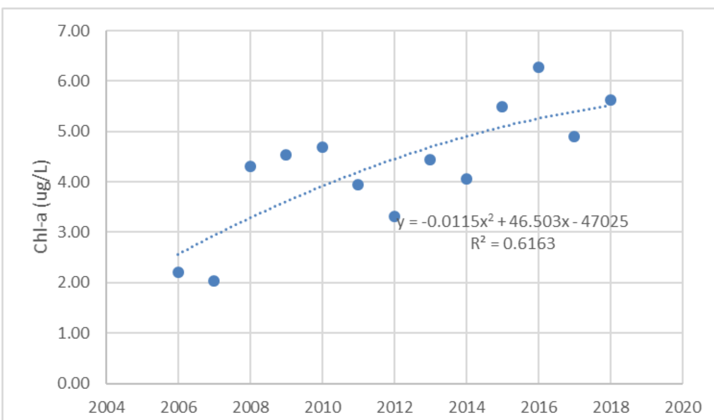
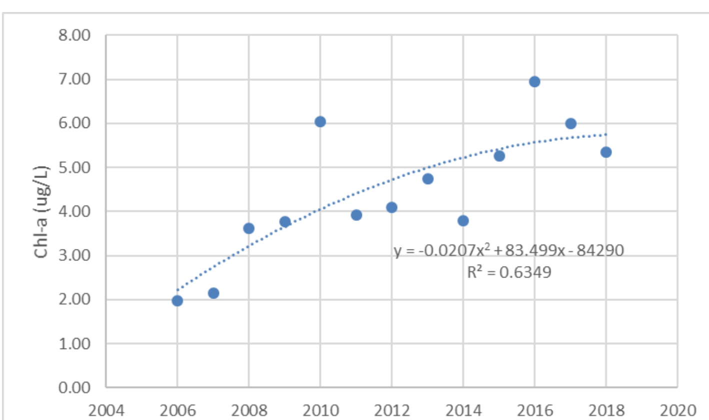


Figure 21 – Trend in chlorophyll-a in WBID 1968F (Blackburn Bay).



The increases in chlorophyll-a shown in most of the sections of Sarasota Bay (Figures 18 to 21) are likely linked to increases in TN, and TN increases are likely related to reduced salinities, as TN and salinity are inversely correlated for most of Sarasota Bay (e.g., Figures 8 to 11).

In its broadest sense, the management of water quality in Sarasota Bay appears to be complicated in recent years by the finding that rainfall has trended higher since the reference period of 2001 to 2005(Figure 6). A more refined question that was addressed in this report was whether or not there was evidence of an increase in TN concentrations above and beyond that which could be explained by salinity and rainfall patterns. Figures 22 to 26 show the regressions of TN vs. salinity for each of the WBIDs examined here during the reference period, and also the upper and lower boundaries of the 80th prediction limit.

Figure 22 – Relationship between TN and salinity during the years 2001 to 2005 for WBID 1968B (Upper Sarasota Bay). Dashed lines represent upper and lower boundaries of 80th prediction limit.

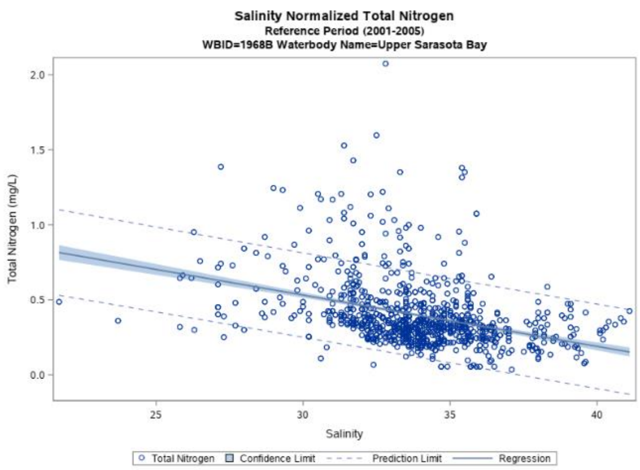


Figure 23 – Relationship between TN and salinity during the years 2001 to 2005 for WBID 1968C (New Pass / Big Pass). Dashed lines represent upper and lower boundaries of the 80th prediction limit.

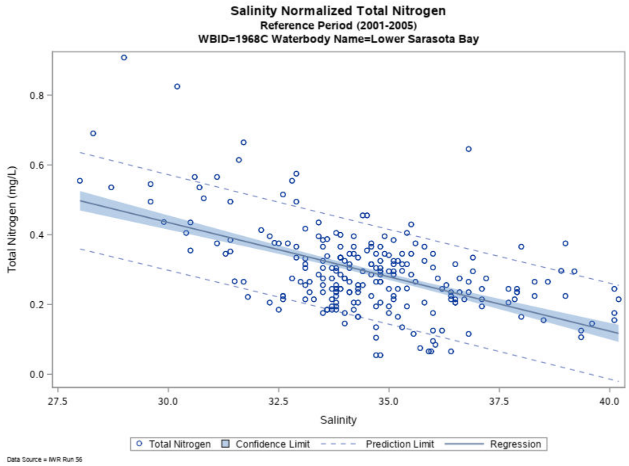


Figure 24 – Relationship between TN and salinity during the years 2001 to 2005 for WBID 1968D (Roberts Bay). Dashed lines represent upper and lower boundaries of the 80th prediction limit.

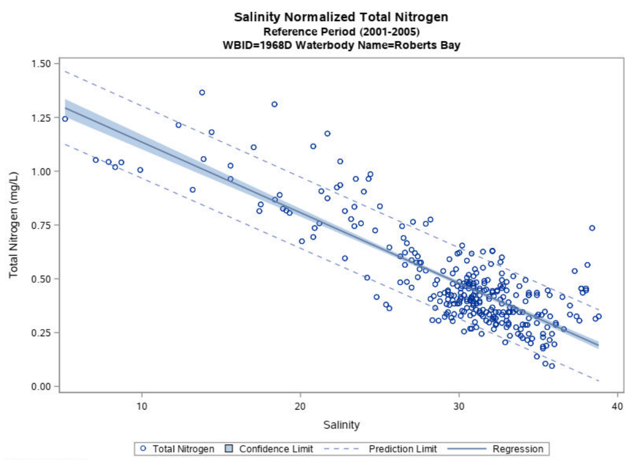


Figure 25 – Relationship between TN and salinity during the years 2001 to 2005 for WBID 1968E (Little Sarasota Bay). Dashed lines represent upper and lower boundaries of the 80th prediction limit.

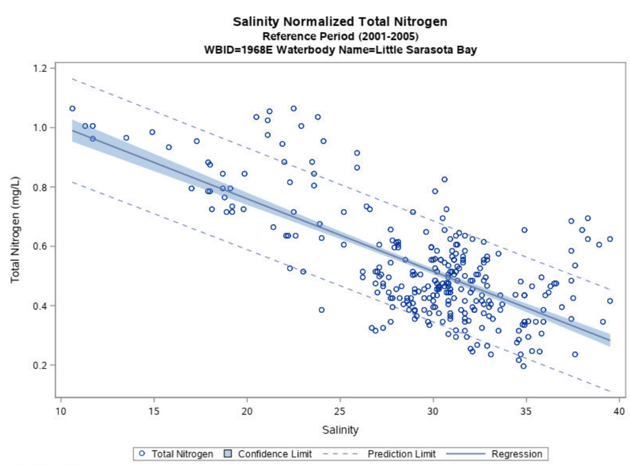
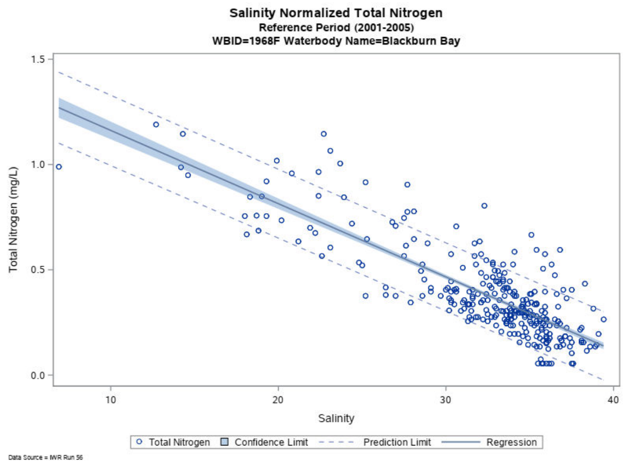


Figure 26 – Relationship between TN and salinity during the years 2001 to 2005 for WBID 1968F (Blackburn Bay). Dashed lines represent upper and lower boundaries of the 80th prediction limit.



As is typical for Florida estuaries, there is a strong inverse relationship between TN concentrations and salinity for each WBID examined in Sarasota Bay. This finding illustrates the limitations of developing NNC criteria that are based on single concentrations, as TN would be expected to increase during wet seasons or wet years, as well as during low tides and at locations farther away from tidal passes. For these reasons, single concentration NNC criteria can result in a false sense of optimism in dry conditions, and a perhaps overly pessimistic view during dry periods. Complicating this issue, rainfall in the Sarasota Bay / Lemon Bay watershed has displayed a trend of increasing values since the reference period for NNC criteria (Figure 6) which has resulted in a pattern of decreasing salinities in four of the five WBIDs examined in Sarasota Bay (Figures 2 through 5).

Rather than simply determining that TN values are higher or lower than a single concentration, an alternative approach to examining water quality conditions in Sarasota Bay is to test whether or not concentrations are higher than would be expected, after normalizing for salinity.

In Southwest Florida's Clam Bay (Collier County) NNC criteria are normalized for salinity, and exceedances are listed only when TN concentrations are higher than would be expected, based on the upper 10th percent boundary of the relationship between TN and conductivity (which is an analog of salinity). As listed in Florida Administrative Code (FAC) 62-302.532(j), the impairment threshold for TN is when 10 percent of TN values exceed the respective TN Upper Limit. The TN Upper Limit is listed in FAC 62-302.532(j) as:

$$\text{TN Upper Limit (mg/L)} = 2.3601 - 0.0000268325 * \text{Conductivity } (\mu S)$$

For the WBIDs examined here, we used a similar approach for each year after the reference period. Results from this analysis were derived for each WBID, based on the TN vs. salinity relationship developed in that WBID during the reference period of 2001 to 2005.

Table 1 – Display of results of TN exceedance rates for each WBID for the years 2006 to 2018. Boxed filled in as green indicate less than 10% of TN values exceeded the upper boundary of the TN vs. salinity relationship derived during the reference period of 2001 to 2005. Boxes filled in as yellow had 10 to 15% of TN values exceeding the upper boundary, and boxes filled in as red had more than 15% of TN values higher than the upper boundary of the TN vs. salinity relationship established during the 2001 to 2005 reference period. The white box refers to insufficient data to conduct the analysis.

Year	Upper Sarasota Bay	New Pass / Big Pass area	Roberts Bay	Little Sarasota Bay	Blackburn Bay
2006	green	white	green	yellow	yellow
2007	yellow	yellow	green	red	red
2008	green	red	yellow	yellow	yellow
2009	green	green	yellow	green	green
2010	green	red	red	red	red
2011	green	red	red	red	green
2012	green	yellow	green	yellow	green
2013	green	yellow	yellow	red	red
2014	green	red	yellow	yellow	red
2015	green	red	yellow	yellow	green
2016	green	green	yellow	red	green
2017	green	green	green	red	green
2018	green	red	red	red	red

The results displayed in Table 1 show that Upper Sarasota Bay (WBID 1968B) has had a non-significant trend in TN concentrations (Figure 12) and that annual TN values are in-line with expectations for a period of increased rainfall (Figure 6) and decreased salinity (Figure 1).

In contrast, the increases in TN concentrations seen in New Pass / Big Pass (WBID 1968C), Roberts Bay (WBID 1968D), Little Sarasota Bay (WBID 1968E) and Blackburn Bay (WBID 1968F) are more than can be explained by trends in both rainfall and salinity. It appears that in the southernmost WBIDs examined here, increases in TN have not only brought about an increase in chlorophyll-a (see Figures 18 to 21) but the increases in TN are above and beyond that which can be explained by trends in rainfall alone.

Too see if the increases in TN and chlorophyll-a had impacted seagrass resources, GIS layers of seagrass maps for the period of 1988 to 2018 were clipped to the same boundaries as the WBIDs used in the water quality analyses. Seagrass data are displayed in terms of the following Florida Land Use Cover Classification System (FLUCCS) categories: patchy seagrass meadows (9113), continuous seagrass meadows (9116) and total seagrass coverage (911). Results are shown in Figures 27 through 31.

Figure 27 – Seagrass coverage for 1988 to 2018 for WBID 1968B (Upper Sarasota Bay). FLUCCS codes displayed are 9113 (patchy), 9116 (continuous) and 911 (total seagrass). Dashed line is statistically significant trend for total seagrass coverage.

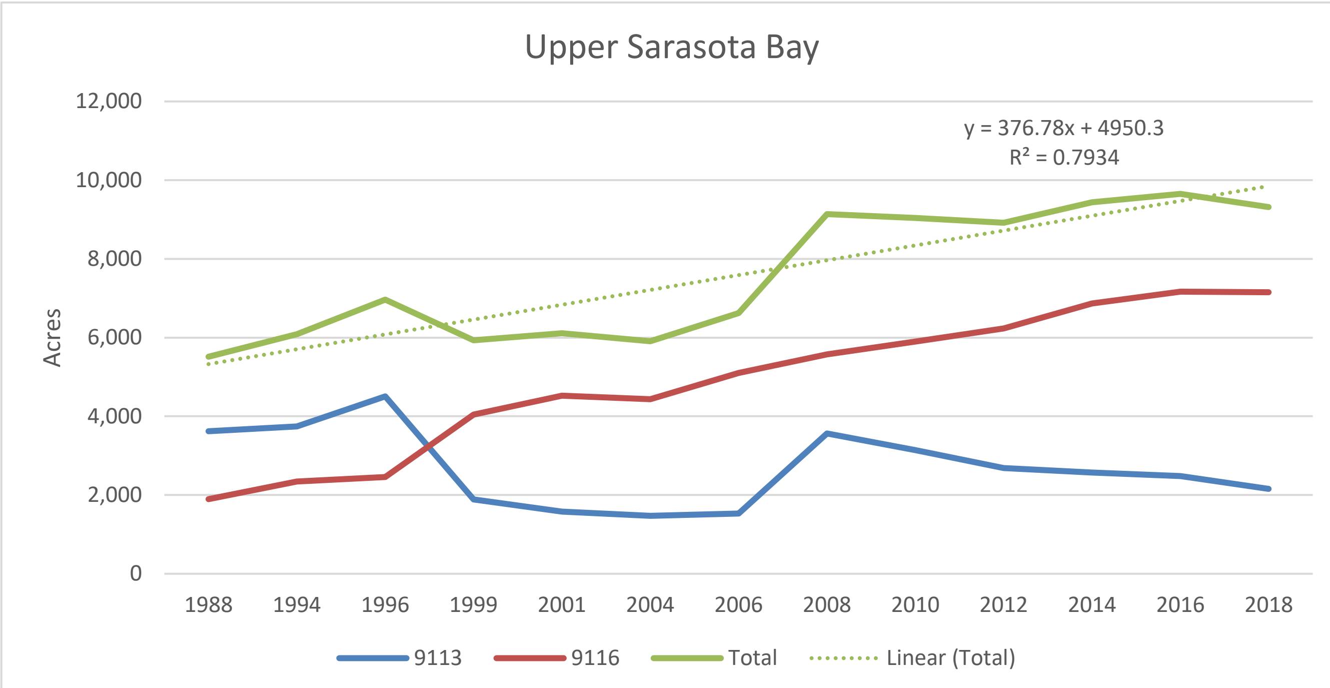


Figure 28 – Seagrass coverage for 1988 to 2018 for WBID 1968C (New Pass / Big Pass). FLUCCS codes displayed are 9113 (patchy), 9116 (continuous) and 911 (total seagrass). Dashed line is statistically significant trend for total seagrass coverage.

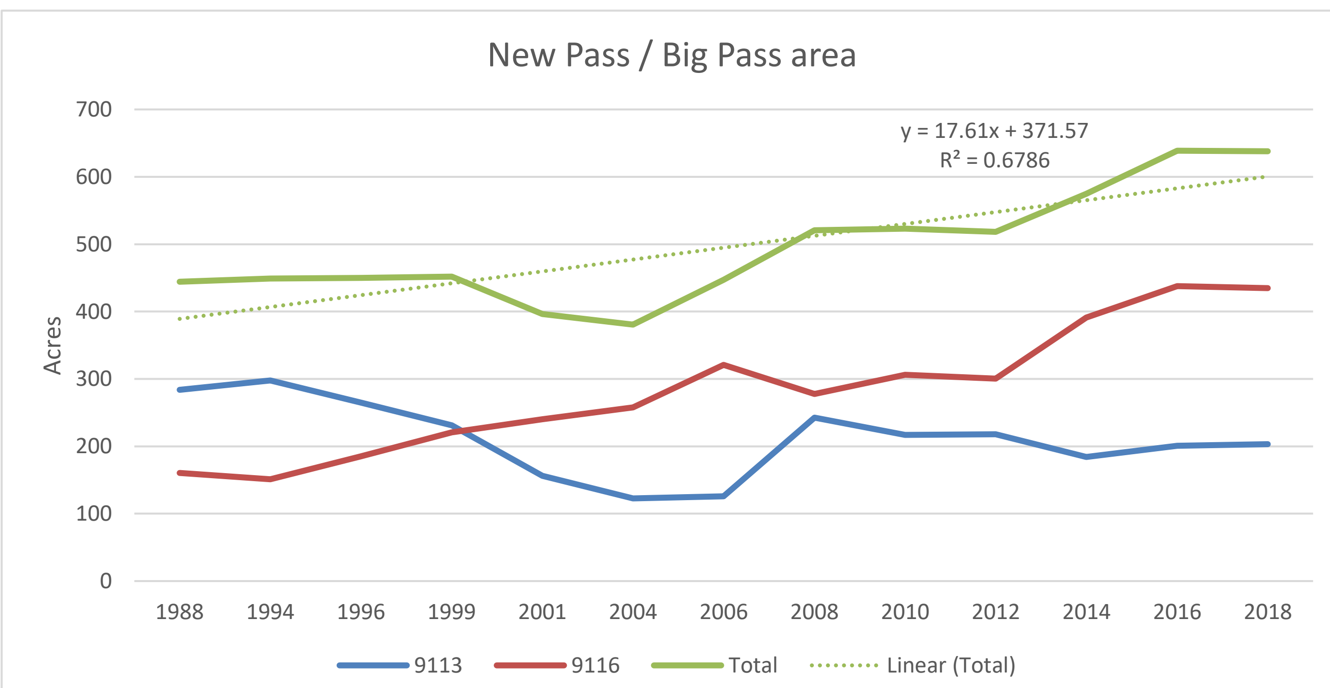


Figure 29 – Seagrass coverage for 1988 to 2018 for WBID 1968D (Roberts Bay). FLUCCS codes displayed are 9113 (patchy), 9116 (continuous) and 911 (total seagrass).

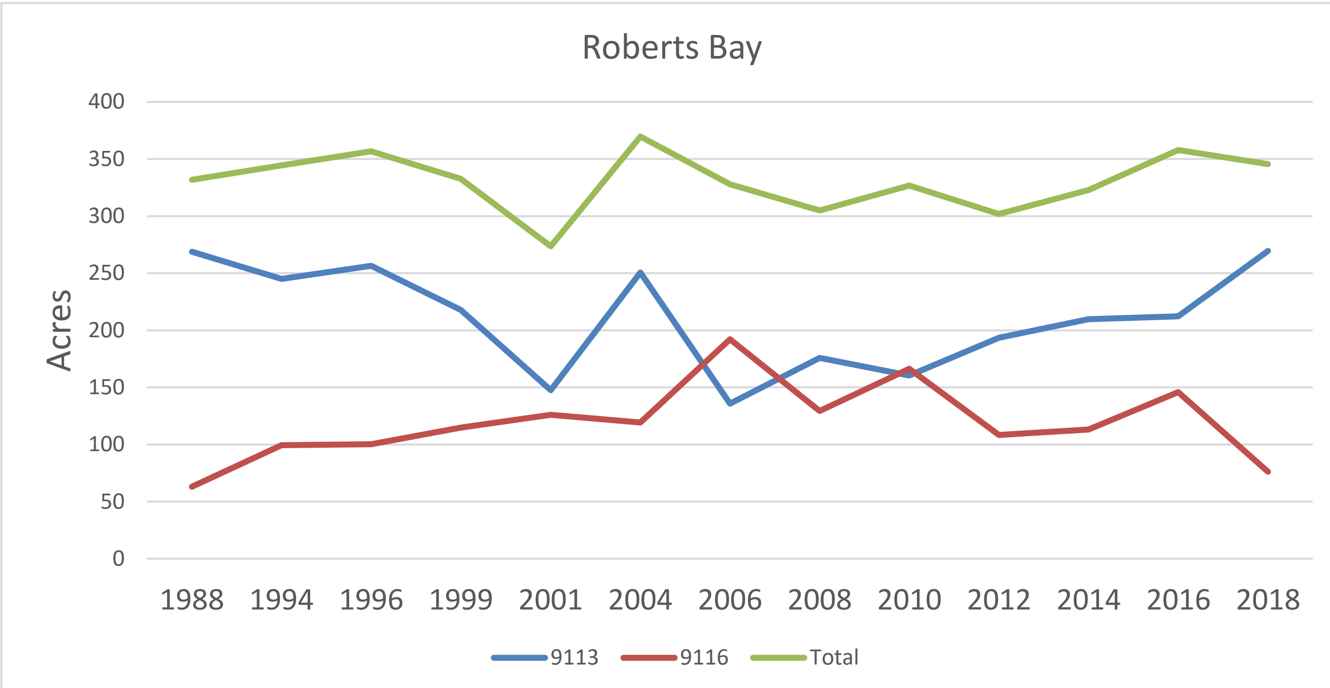


Figure 30 – Seagrass coverage for 1988 to 2018 for WBID 1968E (Little Sarasota Bay). FLUCCS codes displayed are 9113 (patchy), 9116 (continuous) and 911 (total seagrass).

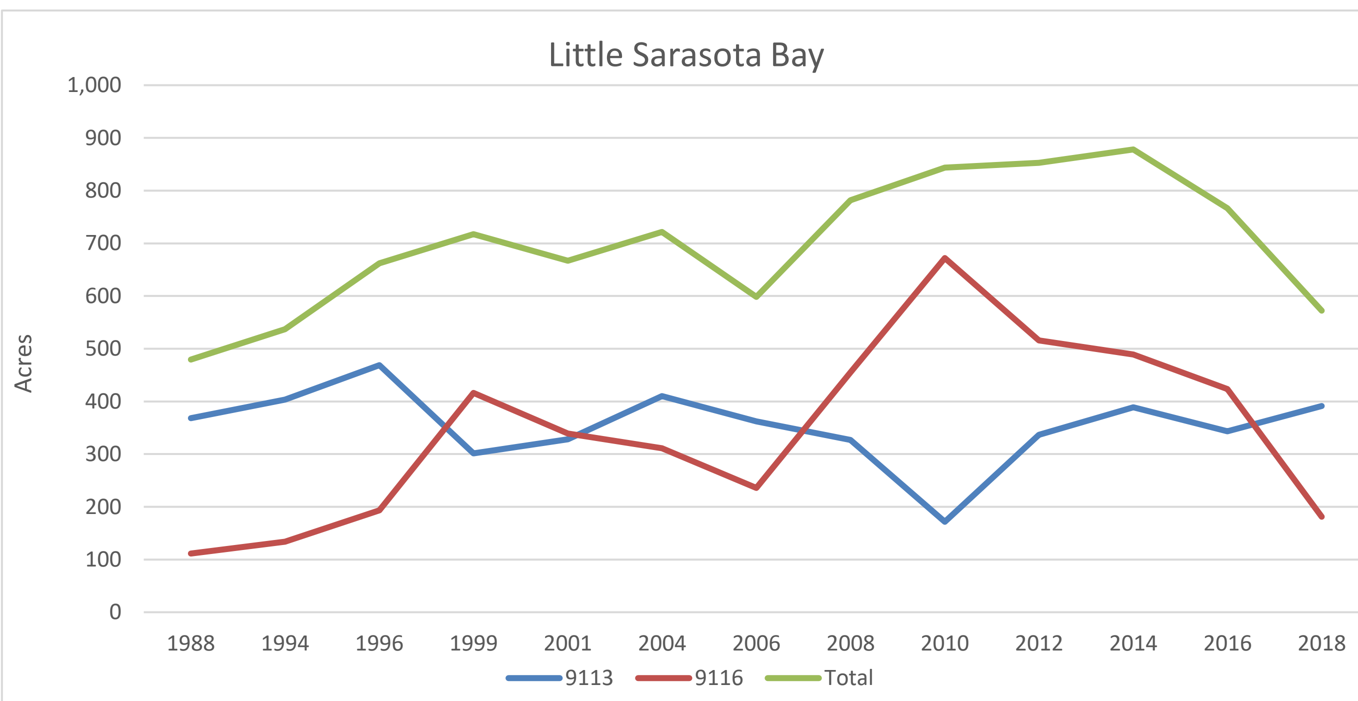
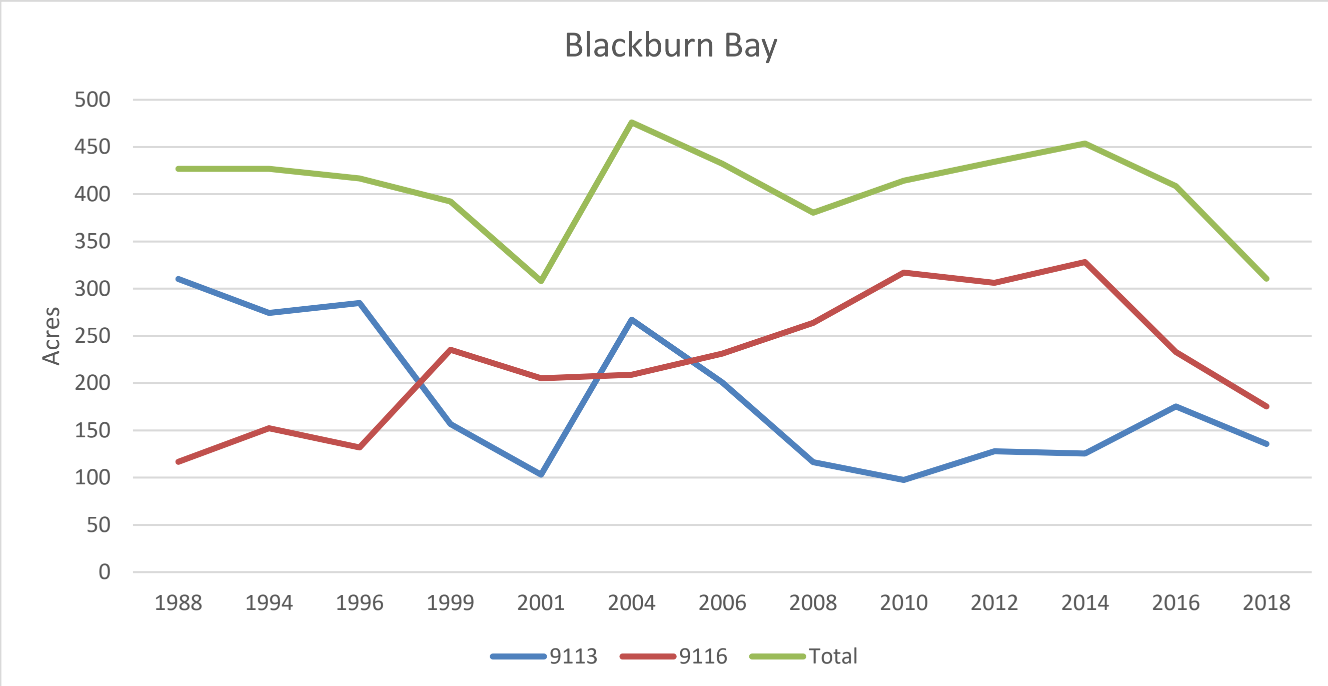


Figure 31 – Seagrass coverage for 1988 to 2018 for WBID 1968F (Blackburn Bay). FLUCCS codes displayed are 9113 (patchy), 9116 (continuous) and 911 (total seagrass).



Seagrass coverage was stable from 2016 to 2018 in the New Pass / Big Pass area (Figure 28) and declined by approximately 4% in Upper Sarasota Bay (Figure 27). From 2016 to 2018, seagrass losses of 3% were recorded in Roberts Bay (Figure 29) while declines 24 and 25% were recorded in Blackburn Bay and Little Sarasota Bay, respectively.

In 2018, seagrass coverage in Upper Sarasota Bay (WBID 1968B) was 69% higher than in 1988, an increase of 3,798 acres, or nearly 6 square miles. In the New Pass / Big Pass area (WBID 1968C) 2018 seagrass coverage was 44% higher than in 1988, an increase of 193 acres.

In contrast, areas south of Siesta Key Drive had more modest patterns of seagrass coverage. In Roberts Bay (WBID 1968D) seagrass coverage in 2018 was only 4% higher than in 1998. In Little Sarasota Bay (WBID 1968E) seagrass coverage in 2016 was 60% higher in 2016 than in 1998, but in 2018 coverage declined by 25% to levels lower than at any time since 1994. In Blackburn Bay, seagrass coverage peaked in 2004, with 2018 values lower by 35% from estimates 14 years prior.

<u>Discussion</u>

Over the past few years, increases in rainfall have been noted in the Sarasota Bay / Lemon Bay watershed. In all the WBIDs examined in this report, this increase in rainfall has co-occurred with a decline in salinity (on an annual basis). In each system examined, salinity and TN are correlated, and so there is little surprise that most of the WBIDs examined show a trend of increases in TN since 2006. As chlorophyll-a and TN are correlated in Sarasota Bay (i.e., Tomasko et al. 1992) increases in chlorophyll-a were found in each WBID, with the exception of Upper Sarasota Bay.

Increases in TN in the northernmost WBID (Upper Sarasota Bay) are in-line with expectations based on the TN vs. salinity relationship that existed during the reference period for existing (or current) NNC criteria development of 2001 to 2005. However, in the areas of New Pass / Big Pass, Roberts Bay, Little Sarasota Bay and Blackburn Bay, increases in TN concentrations are above and beyond those which can be explained by regional changes in rainfall and its effects on salinity. It would appear that there is an excess of TN loaded into local waters in those portions of Sarasota Bay south of New Pass.

As a whole, the water quality and seagrass coverage in the portion of Sarasota Bay north of New Pass appears to be in good shape. Seagrass coverage is within 5% of peak values, and are well above coverage estimates from 30 years ago, and trends in nitrogen and phosphorus are in-line with expectations with recent trends in rainfall. In the areas of New Pass and Big Pass, seagrass coverage is also within 5% of peak values, and well above estimates from 30 years ago. However, recent trends in nitrogen are higher than would be expected based on changes in rainfall alone.

In Roberts Bay, seagrass coverage is similar to values 30 years ago, but recent trends in nitrogen and chlorophyll-a are more than can be explained by trends in rainfall. A more careful examination of anthropogenic nutrient sources should be considered, to prevent Roberts Bay from degrading due to factors other than rainfall.

In both Little Sarasota Bay and Blackburn Bay, seagrass coverage decline by more than 20% between 2016 and 2018. In both these systems, increases in nitrogen and chlorophyll-a are above and beyond that which can be explained by changes in rainfall. It is more likely than not that anthropogenic nutrient loads have increased to both Little Sarasota Bay and Blackburn Bay, and also to Roberts Bay (to a lesser degree) over the past 13 years. As nutrient increases are above and beyond those which can be attributed to rainfall alone, results suggest nutrient loads have increased from sources with nitrogen concentrations higher than stormwater runoff, such as wastewater treatment plants and/or septic tanks. Particular attention should be paid to ensure that wastewater practices meet the intent of the goals spelled out in both the Sarasota Bay National Estuary Programs' Comprehensive Conservation and Management Plan (SBNEP 1995) as well as relevant regulatory criteria (i.e., Florida Statutes 403.086.

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