Chapter 8C: St. Lucie and Caloosahatchee River Watershed Research and Water Quality Monitoring Results and Activities

Christopher Buzzelli, Anna Wachnicka, Fawen Zheng,
Zhiqiang Chen, Lucia Baldwin, and Amanda Kahn-Dickens

SUMMARY

In 2007, the Northern Everglades and Estuaries Protection Program (NEEPP) was authorized under Section 373.4595, Florida Statutes (F.S.), in response to legislative findings that the Lake Okeechobee, Caloosahatchee River, and St. Lucie River basins are critical water resources that have been and continue to be adversely affected from changes to hydrology and water quality. The NEEPP legislation specifically called for the development of the three northern watershed protection plans: Lake Okeechobee, St. Lucie River, and Caloosahatchee River. In 2009, the St. Lucie River Watershed Protection Plan (SFWMD et al. 2009b) and the Caloosahatchee River Watershed Protection Plan (SFWMD et al. 2009a) were developed by the South Florida Water Management District (SFWMD or District), Florida Department of Environmental Protection (FDEP), and Florida Department of Agriculture and Consumer Services (FDACS), collectively known as the coordinating agencies, with extensive stakeholder input. These plans aim to minimize the undesirable inflows and improve the quality of water delivered to the St. Lucie and Caloosahatchee river estuaries through implementation of the respective river watershed construction projects and research and water quality monitoring programs (RWQMPs) (Paragraphs 373.4595(4)(a) and (c), F.S., respectively). Key to these projects and programs are the FDEP basin management action plans (BMAPs), which are the blueprint to meet FDEP's total maximum daily loads (TMDLs) and are the overarching water quality restoration plans for the Northern Everglades.

In addition to annual NEEPP reporting, three-year updates were previously submitted in 2012 and 2015 for both estuaries as part of the annual *South Florida Environmental Reports (SFERs) – Volume I* (Bertolotti and Balci 2012, Balci and Bertolotti 2012, Buzzelli et al. 2015) in accordance with NEEPP requirements at that time. The previous (Water Year 2016 [WY2016; May 1, 2015–April 30, 2016]), RWQMP annual progress report is provided in the 2017 SFER – Volume I, Chapter 8C (Zheng et al. 2017). In accordance with NEEPP (which was amended in 2016), this chapter fulfills the RWQMP annual progress report for the WY2017 reporting period. In conjunction with Chapter 8A (NEEPP Annual Progress Report) and Chapter 8B (Lake Okeechobee Watershed Research and Water Quality Monitoring Results and Activities), this chapter fulfills the specific reporting requirements outlined in NEEPP for the annual progress report.

This report starts with a description of the estuaries and the river watersheds to set the stage for the rest of the chapter. This is followed by a summary of the conditions of the hydrology (rainfall, inflow, and salinity), water quality (nitrogen [N], phosphorus [P], and chlorophyll), and aquatic habitat (oysters and submerged aquatic vegetation [SAV]) based on results of the RWQMPs. Finally, the St. Lucie and

Caloosahatchee River watershed water quality monitoring results for total phosphorus (TP) and total nitrogen (TN) by basin are presented in Appendix 8C-1 of this volume as supplemental information.

ST. LUCIE ESTUARY

Total annual rainfall across the Tier 1 Contributing Areas (Lake Okeechobee, St. Lucie Basin, and Tidal Basin) to the St. Lucie Estuary (SLE) was less than the long-term average from WY1997–WY2017. Although the 73.9% of the annual rainfall usually occurs in the wet season, this value increased to 85% in WY2017. The relatively high amount of wet season rain was the driver for increased discharge to the SLE. The total annual freshwater inflow to the SLE in WY2017 (0.945 million acre-feet [ac-ft]) was close to the long-term average of ~1.0 million ac-ft. The inflow and contribution from Lake Okeechobee in WY2017 (0.34 million ac-ft and 35.8%, respectively) were greater than the long-term average values (0.25 million ac-ft and 20.0%, respectively). However, as rainfall declined leading into the dry season (November–April), inflow decreased considerably and salinity at the US1 Roosevelt Bridge increased to > 25 rendering only 34.8% of the days in WY2017 within the oyster salinity envelope of 10 to 26.

TN loading to the SLE in WY2017 (1,376.2 metric tons [t]) was less than that in WY2016 (1,990.7 t) and the long-term average from WY1997–WY2017 (1,714.0 t). The magnitude and percentage of TN supplied by the St. Lucie Basin in WY2017 (497.4 t and 36.1%, respectively) were less than the long-term averages (882.8 t and 51.5%, respectively). In contrast, TN input and contribution from Lake Okeechobee in WY2017 increased to 621.3 t and 45.1%, respectively, compared to long-term averages of 535.0 t and 31.2%, respectively. Overall, TP loads in WY2017 (229.8 t) were 37% less than the long-term average (314.1 t). While TP loading from Lake Okeechobee in WY2017 was similar to the long-term average (56.8 t versus 54.8 t), the relative contribution of the lake increased to 24.7%.

The average TN and TP concentrations at stations HR1 (North Fork), SE03 (Roosevelt Bridge), and SE11 (St. Lucie Inlet) in WY2017 were less than the long-term values from the period WY1997–WY2017. While the WY2017 chlorophyll *a* (Chla) concentration at HR1 and SE03, 9.5 and 7.0 micrograms per liter (µg/L), respectively, was less than the long-term averages, 12.3 and 8.8 µg/L, respectively, the concentration at SE11 approximated the long-term average (3.6 µg/L). It is important to note that the average and standard deviation of Chla at HR1 in the wet season (May–October) WY2017 (24.3 ± 23.6 µg/L) were higher than the long-term averages (12.3 ± 11.7 µg/L).

The estimated total SAV coverage at the Willoughby Creek monitoring location just upstream of the St. Lucie Inlet ranged from approximately 5 to 25% between WY2013 and WY2017. The relative cover of the seagrass *Halodule wrightii* (shoal grass) was low (~1 to 5%) but consistent during this period of record. *Halophila johnsonii* (Johnson's grass) was widespread as it approached 5 to 25% cover but it was also more variable at this site. The total SAV coverage at the Boy Scout Island monitoring location has declined since November 2015. This decline has largely been driven by a decrease in the relative cover of *Syringodium filiforme* (manatee grass), although cover values for Johnson's grass have also declined. Almost no *S. filimorme* was observed late in 2016.

Oyster density reached the maximum in the dry season of WY2015 (~1,000 oysters per square meter [oysters/m^2]) before decreasing to 300 to 600 oysters/m^2 in WY2016 and WY2017. Overall, oyster density was greater in the dry season than the wet. The monthly average rate of oyster larval settlement ranged from 0 to 11 spat per shell per month (spat/shell/month) from WY2006 to WY2017. The increase in freshwater inflow late in WY2016 coincided with very low recruitment of oyster larvae. Finally, the weighted prevalence of the oyster marine parasite (dermo) was generally low (< 0.2) from WY2014 to WY2017.

CALOOSAHATCHEE RIVER ESTUARY

The total annual rainfall across the Tier 1 Contributing Areas (Lake Okeechobee, C-43 basin, and Tidal Basin) to the Caloosahatchee River Estuary (CRE) was less than the long-term average from the period WY1997–WY2017.

Although 78.6% of the annual rainfall usually occurs in the wet season, this value increased to 90% in WY2017. The relatively high amount of rain during this time was the driver for increased discharge to the CRE. The total annual freshwater inflow to the CRE in WY2017 (2.9 million ac-ft) was greater than the long-term average (1.9 million ac-ft). The inflow and contribution from Lake Okeechobee in WY2017 (1.0 million ac-ft and 34.9%, respectively) were greater than the long-term values (0.59 million ac-ft and 25.9%, respectively). As rainfall declined leading in the dry season, inflow decreased considerably and salinity at the Ft. Myers monitoring station increased to > 15 rendering only 70% of the days in WY2017 within the target *Vallisneria americana* (tape grass) salinity of less than 10.

TN loading to the CRE in WY2017 (3416.8 t) was less than that in WY2016 (3,566.5 t) but in excess of the long-term average from the period WY1997–WY2017 (3,000.6 t). The magnitude and percentage of TN supplied by the C-43 basin in WY2017 (1,464.7 t and 42.9%, respectively) were less than the long-term averages (1516.9 t and 50.5%, respectively). In contrast, TN input and contribution from Lake Okeechobee in WY2017 increased to 1,559.2 t and 45.6%, respectively, compared to long-term averages of 1,044.2 t and 34.7%. TP loading from the C-43 basin in WY2017 was similar to the long-term value (~175 t) although the relative contribution decreased from an average of 61.0 to 55.2%. The magnitude and contribution of Lake Okeechobee to TP loading in WY2017 (103.9 t and 32.7%, respectively) were higher than the long-term averages (69.6 t and 24.2%, respectively).

The average concentrations of TN, TP, and Chla at stations CES04, CES06, and CES08 in WY2017 were less than the long-term values from the period WY2000–WY2017. In particular, average Chla concentrations at CES04 (5.7 µg/L) and CES06 (4.8 µg/L) were approximately half of the long-term averages. It appeared that TN at downstream station CES08 responded to freshwater inflow with a comparatively high average TN concentration in both seasons of WY2017 (0.74 ± 0.25 mg/L).

Based on Braun-Blanquet scores, total SAV coverage at Site 2 in the upper CRE varied from the period WY2013–WY2017 reaching a maximum of ~5% in WY2017. *Ruppia maritima* (widgeon grass) and *V. americana* had approximately equal spatial cover estimates although the density was low (1 to 5% cover category). *V. americana* has exhibited modest increases in cover since May 2014 (WY2015) as freshwater inflow increased. SAV monitoring site 8 in the lower CRE had a combination of *H. wrightii* and *Thalassia testudinum* (turtle grass). Seagrass cover at his location declined slightly in the wet seasons of WY2015 and WY2016 but appeared to stabilize in WY2017.

Oyster density reached the maximum in the dry season of WY2013 (~3,000 oysters/m^2) before decreasing to ~1,500 oysters/m^2 in WY2015 and WY2016. There appeared to be a slight increase in average live oyster density in WY2017 (> 2,000 oysters/m^2). The monthly average rate of oyster larval settlement ranged from 0 to 150 spat/shell/month at Bird Island from WY2006 to WY2017. Spat settlement appeared to increase from the end of WY2016 into WY2017.

The weighted prevalence for the marine oyster parasite dermo ranged from 1.0 to 3.0 between WY2006 and WY2017. The metric was generally low (< 1.0) except during the drought conditions of WY2012–WY2013. It was at a comparatively low level (< 0.5) in WY2017.

INTRODUCTION

The St. Lucie and Caloosahatchee river basins and estuaries are located on the southern peninsula of Florida. Together with the Lake Okeechobee Basin, they comprise a major overall region known as the Northern Everglades (see Figure 8A-1 in Chapter 8A of this volume). The St. Lucie River Basin lies to the east of Lake Okeechobee and the Caloosahatchee River Basin to the west. Overall, the Northern Everglades is a highly modified system as it is part of the larger overall Central and Southern Florida Flood Control Project (USACE and SFWMD 1999). Importantly, the western part of the St. Lucie River Basin (C-44/S-153) and the eastern portion of the Caloosahatchee River Basin (C-43 East) can discharge either into Lake Okeechobee or into their respective estuaries.

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In addition to annual NEEPP reporting, three-year updates were previously submitted in 2012 and 2015 for both estuaries as part of the annual SFER – Volume I (Bertolotti and Balci 2012, Balci and Bertolotti 2012, Buzzelli et al. 2015) in accordance with NEEPP requirements at that time. The previous (WY2016) RWQMP annual progress report is provided in the 2017 SFER – Volume I, Chapter 8C (Zheng et al. 2017). In accordance with NEEPP (which was amended in 2016), this chapter fulfills the RWQMP annual progress report for the WY2017 reporting period. In conjunction with Chapter 8A (NEEPP Annual Progress Report) and Chapter 8B (Lake Okeechobee Watershed Research and Water Quality Monitoring Results and Activities), this chapter fulfills the specific reporting requirements outlined in NEEPP for the annual progress report.

This report starts with a description of the estuaries and the river basins to set the stage for the rest of the chapter. This is followed by a summary of the conditions of the hydrology (rainfall and freshwater inflow), water quality (salinity, phosphorus, and nitrogen), and aquatic habitat (oysters and SAV) based on results of the RWQMPs. Following the summary for each estuary, significant findings during the WY2017 reporting period are highlighted. In addition, the St. Lucie and Caloosahatchee river watershed water quality monitoring results for TP and TN by basin are presented in Appendix 8C-1 of this volume as supplemental information.

ESTUARINE HABITATS AS INDICATORS OF INFLOW

Freshwater inflow and nutrient loading from the upstream basin are the major external drivers of abiotic and biotic conditions in an estuary (Alber 2002). Knowledge of the causative mechanisms underlying the relationships between inflow patterns and estuarine condition plays a crucial scientific role in establishing freshwater inflow standards for better decision making and management of estuarine resources (Alber 2002, Doering et al. 2002, Wolanski et al. 2004, Adams et al. 2009, Volety et al. 2009). This concept is being applied particularly to water management in coastal Texas, Australia, South Africa, and South Florida.

Estuarine habitats, such as seagrass meadows or oyster reefs are widely used as indicators to evaluate effects of freshwater inflows (Alber 2002, Flannery et al. 2002, Mattson 2002, Montagna et al. 2002). To evaluate the ecological conditions of the SLE and CRE, SAV and oysters are routinely monitored. SAV is commonly monitored to gauge the health of estuarine systems (Tomasko et al. 1996, Duarte et al. 2008), and their environmental requirements can form the basis for water quality goals (Dennison et al. 1993). Different species of SAV have different tolerances for environmental variables including temperature, submarine light penetration, inorganic nutrient availability, and salinity (Short et al. 1993, Lirman and Cropper 2003, Duarte et al. 2007, Lee et al. 2007). While all these variables are important and interrelated, salinity is oftentimes a useful variable to help interpret ecological responses to changes in freshwater inflow (Lirman et al. 2008, Buzzelli et al. 2012). In the case of the CRE, the freshwater SAV *V. americana* provides a good indicator of the habitat to help prescribe freshwater delivery through the S-79 structure (Doering et al. 2002). *V. americana* is very sensitive to both increased salinity and decreased submarine light availability (Bortone and Turpin 2000, French and Moore 2003).

Oyster beds provide an indicator of estuarine condition because the distribution and abundance of the eastern oyster (*Crassostrea virginica*) have ecosystem-scale implications. Oyster beds filter water and suspended solids, couple the water column to the benthos, and provide living aquatic habitat (Peterson et al. 2003, Coen et al. 2007).

To protect valuable resources, the District has conducted comprehensive research supporting its reevaluation of the Caloosahatchee River Minimum Flows and Minimum Water Levels (MFL) Rule (Subsection 40E-8.221(2), Florida Administrative Code [F.A.C.]; SFWMD 2000, 2003). The related technical publication was finalized in January 2018 and associated rule development will also occur in 2018. The Ft. Myers location has two salinity criteria: (1) maintaining daily salinity averages of less than 20, and (2) 30-day salinity averages of less than 10, while the critical salinity criteria at I-75 is less than 5. At the estuary-scale, average monthly inflows of 300 to 2,800 cubic feet per second (cfs) at the S-79 structure are conducive to *V. americana* and favorable for seagrass and oyster habitats in the polyhaline CRE (Chamberlain and Doering 1998, Doering et al. 2002, SFWMD 2003, Volety et al. 2009).

In contrast to the CRE, the SLE has different inflow and salinity targets given the differences in estuarine geomorphology, volume, flushing, and inflow characteristics (Buzzelli et al. 2013b). Oyster habitat provides the biotic indicator of salinity and freshwater discharge in the SLE (USACE and SFWMD 2004, Buzzelli et al. 2013d). The suitable salinity envelope for oysters is an average water column salinity of 10 to 26 at the US1 Bridge. Systematic analyses of inflows determined that discharge ranging from approximately 350 to 2,000 cfs can help to maintain a salinity range favorable for oysters in the SLE (USACE and SFWMD 2004, Buzzelli et al. 2013d, Parker et al. 2013).

ST. LUCIE RIVER ESTUARY AND BASIN CONDITIONS

BACKGROUND

Located in southeastern Florida in Martin and St. Lucie counties, the SLE comprises a major tributary to the Southern Indian River Lagoon (SIRL) (Sime 2005, Ji et al. 2007, Buzzelli et al. 2012; see Figure 8A-1 in Chapter 8A of this volume). Historically, the SLE was a freshwater system exposed to the coastal ocean only through ephemeral passes in the barrier islands. The St. Lucie Inlet was permanently opened in 1892 to provide a connection between the SLE and the coastal ocean. The C-44 canal linking Lake Okeechobee to the South Fork of the SLE was completed in 1924. The SLE is now a partially mixed micro-tidal estuary having a semi-diurnal tide with an amplitude of 1.25 feet (ft; 0.38 meters [m]). The SLE is geographically divided into four distinct segments: North Fork, South Fork, Middle Estuary, and Lower Estuary located near the St. Lucie Inlet. Total surface area of the estuary is 11.2 square miles (29.0 sqaure kilometers or 7,168 acres [2,903 hectares]) with an average depth of 7.87 ft (2.4 m) (Buzzelli et al. 2013a). The flushing time of the SLE ranges from approximately 2 to 20 days (Ji et al. 2007, Buzzelli et al. 2013b).

To accommodate population growth and coastal development, the St. Lucie River Basin has been highly altered from natural sloughs and wetlands into a system of subbasins, which make up the eight basins of the St. Lucie River Basin. The SLE receives drainage from a comparatively large area, as the ratio between basin area and SLE surface area is approximately 100:1 (i.e., Tampa Bay has a ratio of 5.5:1). The primary land use type within the St. Lucie Basin today is agricultural, which comprises 52%. Urban land use comprises 19%, wetlands are 11%, with 7 and 5% occupied by the upland forest and open water types, respectively.

The combination of basin modifications, channelized freshwater inflow, and increased coastal population density has created a hydrodynamically and ecologically complex estuary with variable water quality and benthic habitat attributes at seasonal, annual, and interannual scales (Cloern 2001, Buzzelli et al. 2013a, b). Previously documented water quality issues include allochthonous and autochthonous phytoplankton blooms, bottom water hypoxia, and increased prevalence of pathogens (Doering 1996, Millie et al. 2004, Phlips et al. 2011, LaPointe et al. 2012, Rosen et al. 2017). Changes in inflow and water quality can greatly influence the distribution, composition, and density of benthic habitats such as oyster beds and SAV (Wilson et al. 2005, Buzzelli et al. 2012, Parker et al. 2013).

The inputs of fresh water and nutrients were categorized into three Tier 1 Contributing Areas consisting of Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin (**Table 8C-1**). Each of these Tier 1 categories is composed of multiple Tier 2 Contributing Areas, eight of which discharge directly to the SLE (**Figure 8C-1)**. These eight include calculated inputs from Lake Okeechobee via the S-308 and S-80 structures; measured inflows and nutrient loads at the C-44/S-153, C-23, and C-24 structures; a combination of measured and modeled inputs from Ten Mile Creek for inclusion in the St. Lucie Contributing Area; and modeled inputs from the Tidal Basin through the North Fork, Basin 4-5-6, and the South Fork.

Table 8C-1. Major contributing areas of the St. Lucie River Watershed.

Tier 1 Basins	Tier 2 Basins	Flows and Loads
Tidal Basin	North Fork	Modeled
	Basin 4, 5, 6	Modeled
	South Fork	Modeled
St. Lucie Basin	C-44/S-153	Measured
	C-23	Measured
	C-24	Measured
	Ten Mile Creek	Measured and Modeled
Lake Okeechobee	S-80 and S-308	Calculated

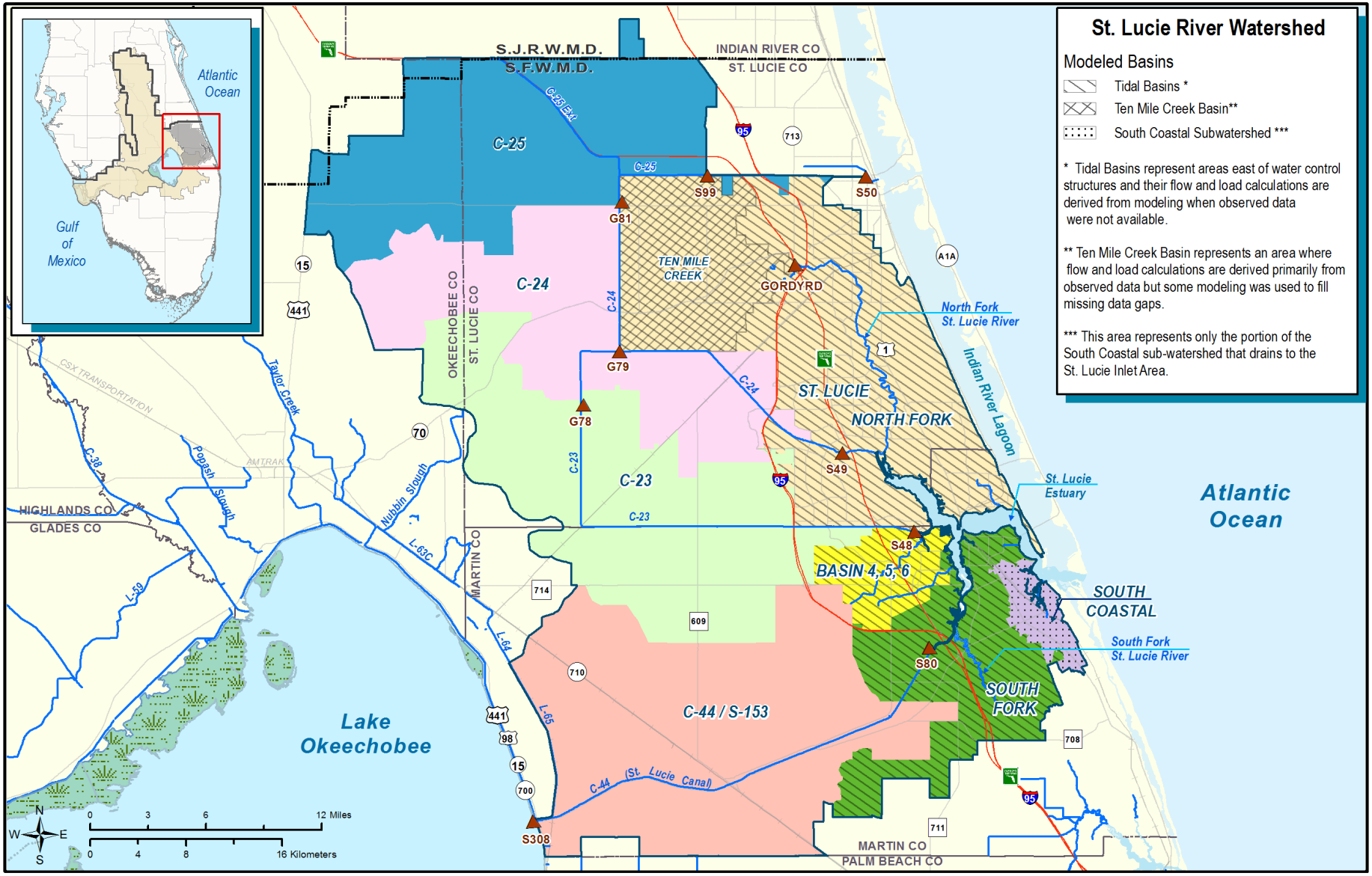

Figure 8C-1. The St. Lucie Watershed with its subbasins and major water control. See text for details of gauged and ungauged freshwater inflows.

HYDROLOGY, WATER QUALITY, AND AQUATIC HABITAT

Methods

A suite of external drivers and ecological responses are monitored in the St. Lucie River Basin and Estuary. These variables include rainfall, freshwater discharge, and nutrient loads as external drivers, and patterns of salinity, estuarine nutrient concentrations, oyster habitat status, and SAV community composition as the estuarine ecological responses. Salinity gradients are a conservative property of the water body and therefore are useful to connect the sources of freshwater inflow, circulation, and biological indicators (Wilber 1992, Jassby et al. 1995, Hagy and Murrell 2007, Pollack et al. 2011).

Daily next generation radar (NEXRAD) rainfall data from WY1997 to WY2017 for each subbasin of the St. Lucie River Basin were downloaded from the District's corporate environmental database, DBHYDRO, on the District's website at http://my.sfwmd.gov/nexrad2/nrdmain.action. The cumulative amount of rainfall across the basin was computed using area-weighting, which accounts for the different sizes of the subbasins.

Freshwater inflow to the SLE is measured at S-80 (C-44/S-153 basin), S-48 (C-23 basin), S-49 (C-24 basin), and the Gordy Road Structure (Ten Mile Creek [TMC] Basin; **Figure 8C-1** and **Table 8C-1**). These multiple inflows can be assigned to one of three Tier 1 Basins or "Contributing Areas" of Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin. The concentrations of TN and TP are monitored at each of these locations. Water for the determination of TP concentration was obtained either using an autosampler or grab sample. Water for TN analyses were from grab samples (SFWMD 2015, 2017). The daily loads of TN and TP were calculated as the product of the total daily inflow and the computed daily nutrient concentration. The drainage area downstream of these major structures comprises the SLE Tidal Basin. The Tidal Basin inflow and nutrient loads were simulated using the SLE Tidal Basin Lin-Res Model calibrated to the SLE Watershed Hydrology Model (WaSH) and data collected in the nearby basins (Wan and Konyha 2015). Inflows and nutrient loads from TMC were simulated from WY1997 through WY1999 because the data set was incomplete. Total daily inflows during WY1997–WY2017 from Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin were organized by month and used to quantify total inflow to the SLE each water year, evaluate intra- and interannual variations in inflow, and estimate the contributions of the Tier 1 Basins from source to total inflow.

Surface and bottom salinity observations were recorded every 30 minutes at three stations in the SLE: HR1, US1 at the Roosevelt Bridge, and the A1A Bridge (**Figure 8C-2**). Salinity was vertically averaged to produce a time series over the long-term period of record (POR; WY2001–WY2017). The percentages of days for the oyster resource-based salinity criteria were calculated over the POR and for WY2015, WY2016, and WY2017.

Water was sampled at mid-depth at 12 stations in the SLE at approximately monthly intervals with three stations featured in this report: HR1 in the North Fork, SE03 in the Middle Estuary at the US1 or Roosevelt Bridge, and SE11 near the St. Lucie Inlet (**Figure 8C-2**). Concentrations of TN, TP, and Chla during WY1997–WY2017 from each of the stations were included in the analyses.

SAV in the SIRL and SLE were monitored monthly during the wet season (May–October) and bimonthly during the dry season (December, February, April) at two sites: Boy Scout Island and Willoughby Creek (**Figure 8C-2**). At each site, a ~2-acre (0.81-hectare) polygon was delineated and for each sampling event, 30 random points within the polygon were sampled. The Braun-Blanquet cover and abundance assesses percent cover of the bottom by the SAV using a scale ranging from 0 to 5 representing values of ~5% to 75 to 100% cover (Fourqurean et al. 2003).

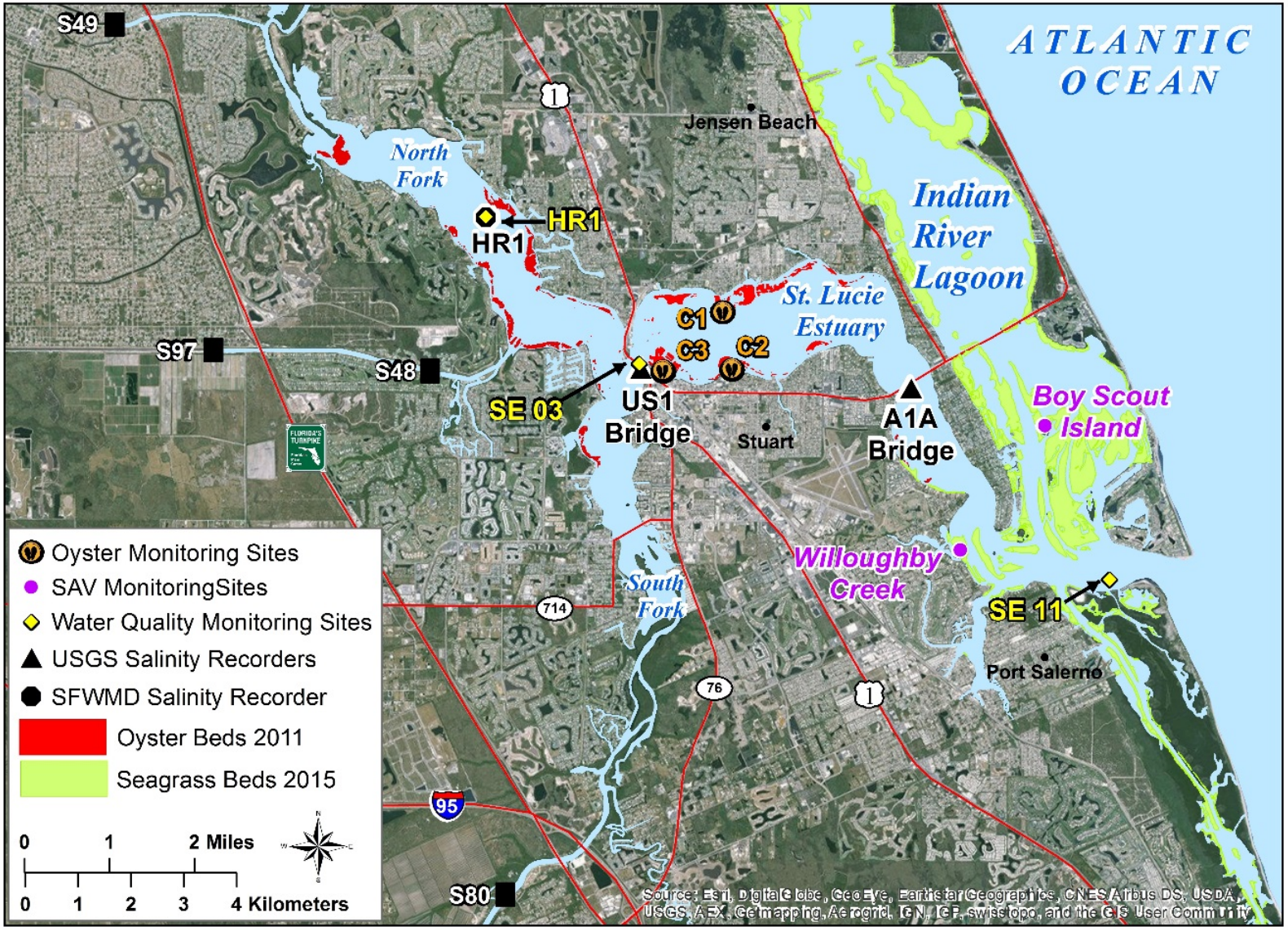

Figure 8C-2. Monitoring locations of salinity, water quality, and living aquatic habitat (oysters and seagrass) for the SLE. Map also depicts distribution of SAV habitat in the St. Lucie Inlet and SIRL. (Note: USGS – United States Geological Survey.)

Oyster monitoring has been ongoing in three segments of the SLE (Middle Estuary, South Fork, and North Fork) since WY2006 (**Figure 8C-2**; Buzzelli et al. 2013d, Parker et al. 2013). There are three sampling sites within each of the three segments. This report features data from the Middle Estuary or the St. Lucie Central segment. The oyster response variables include live oyster density (number per square meter [/m^2), larval recruitment (e.g. "spat fall"), and a combined metric for the prevalence and intensity of the marine oyster parasite *Perkinsus marinus* (dermo).

Live oyster density was determined biannually at each site using methods based on those of Lenihan and Peterson (1998) and Grizzle et al. (2005). Larval recruitment was determined at monthly intervals by counting settled spat on replicated, vertical strings of sterilized oyster shells at each site and expressed as spat/shell/month (Parker et al. 2013). Tissue from a subset of live adult oysters was collected monthly to determine prevalence (number infected divided by total collected) and intensity of the protozoan pathogen, *Perkinsus marinus* (Ray 1966). The Mackin scale infection index was used to assess each tissue sample and the infection intensity calculated for each sampling event. From these metrics, the weighted prevalence was calculated as prevalence times infection intensity (Powell and Kim 2015). Weighted prevalence data were averaged to each water year season for reporting.

Results and Discussion

Rainfall

Daily rainfall amount ranged up 2.0 inches (5.08 centimeters [cm]) with 85.2% of the total annual rainfall occurring in the WY2017 wet season (**Figures 8C-3** and **8C-4**). The long-term average contribution of the wet season to total annual rainfall from the period WY1997–WY2017 was 73.9% although this value decreased to 54.4% in WY2016 when El Niño conditions elevated dry season rainfall (SFWMD 2016). In WY2017, the total annual rainfall to the St. Lucie River Basin was 44.5 inches (113.0 cm), which was lower than in WY2016 (54.1 inches or 137.4 cm), WY2015 (49.2 inches or 125.0 cm) and the long-term average from WY1997 to WY2017 (47.7 inches or 121.2 cm) (**Figures 8C-4**). Spatially, the highest rainfall in WY2017 occurred in the TMC basin (50.2 inches or 127.5 cm) and the lowest in the C-44/S-153 basin (41.6 inches or 105.7 cm), which differed from the long-term (WY1997–WY2017) average rainfall patterns that indicate highest rainfall over the Tidal Basin (49.2 inches or 125 cm) and the lowest over the C-23 basin (46.2 inches or 117.3 cm) (**Figure 8C-5**).

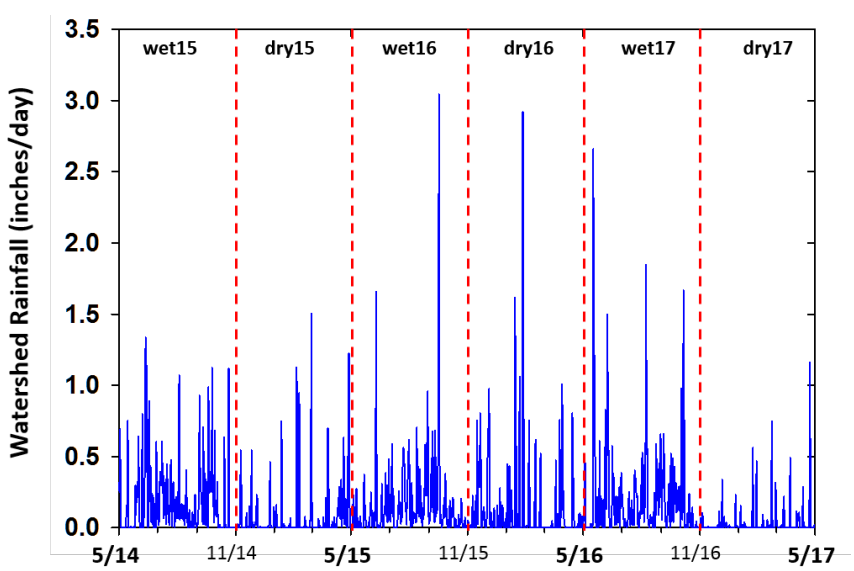

Figure 8C-3. Time series of total daily rainfall to the St. Lucie River Watershed from WY2015 through WY2017. See text for calculation details.

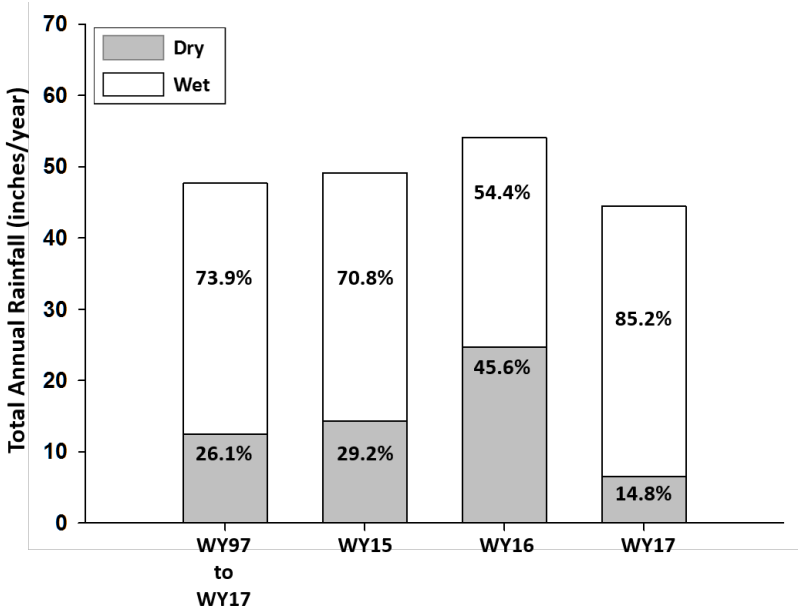

Figure 8C-4. Total rainfall to the St. Lucie River Watershed by water year and season including averages from the period WY1997–WY2017 and those for WY2015, WY2016, and WY2017. Bold numbers are percentage of annual total rainfall for dry versus wet seasons.

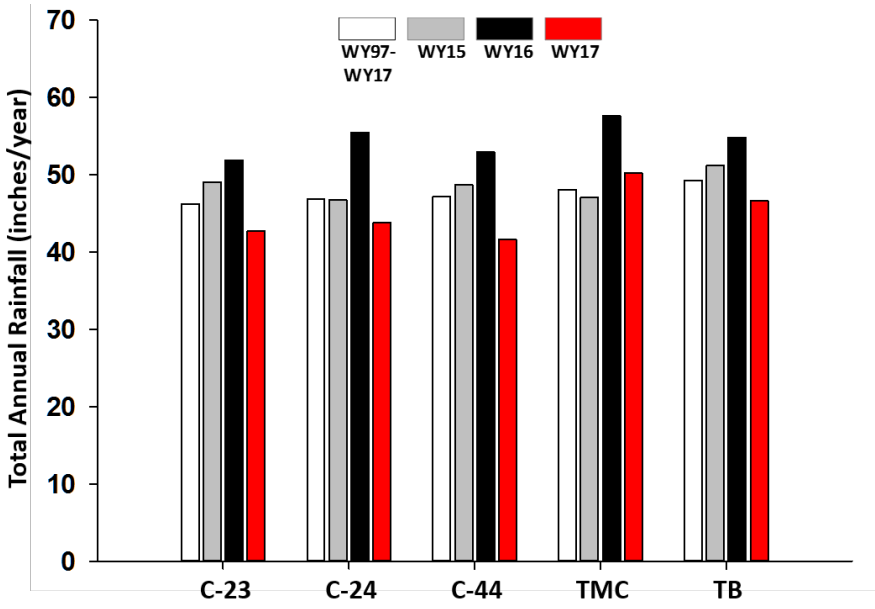

Figure 8C-5. Average annual rainfall to the St. Lucie subbasins, including the long-term average (WY1997–WY2017), WY2015, WY2016, and WY2017.

Freshwater Inflow and Salinity

Freshwater inflow to the SLE was proportional to the total rainfall across the St. Lucie Basin and Tidal Basin (**Figure 8C-6**). Thus, the relatively high percentage of annual rainfall that fell in the WY2017 wet season (85.2%; May–November 2016) was the driver for increased discharge to the SLE. However, as rainfall declined leading into the dry season (November 2016–April 2017), inflow decreased considerably and salinity at the US1 Roosevelt Bridge increased to > 25 (**Figure 8C-6**).

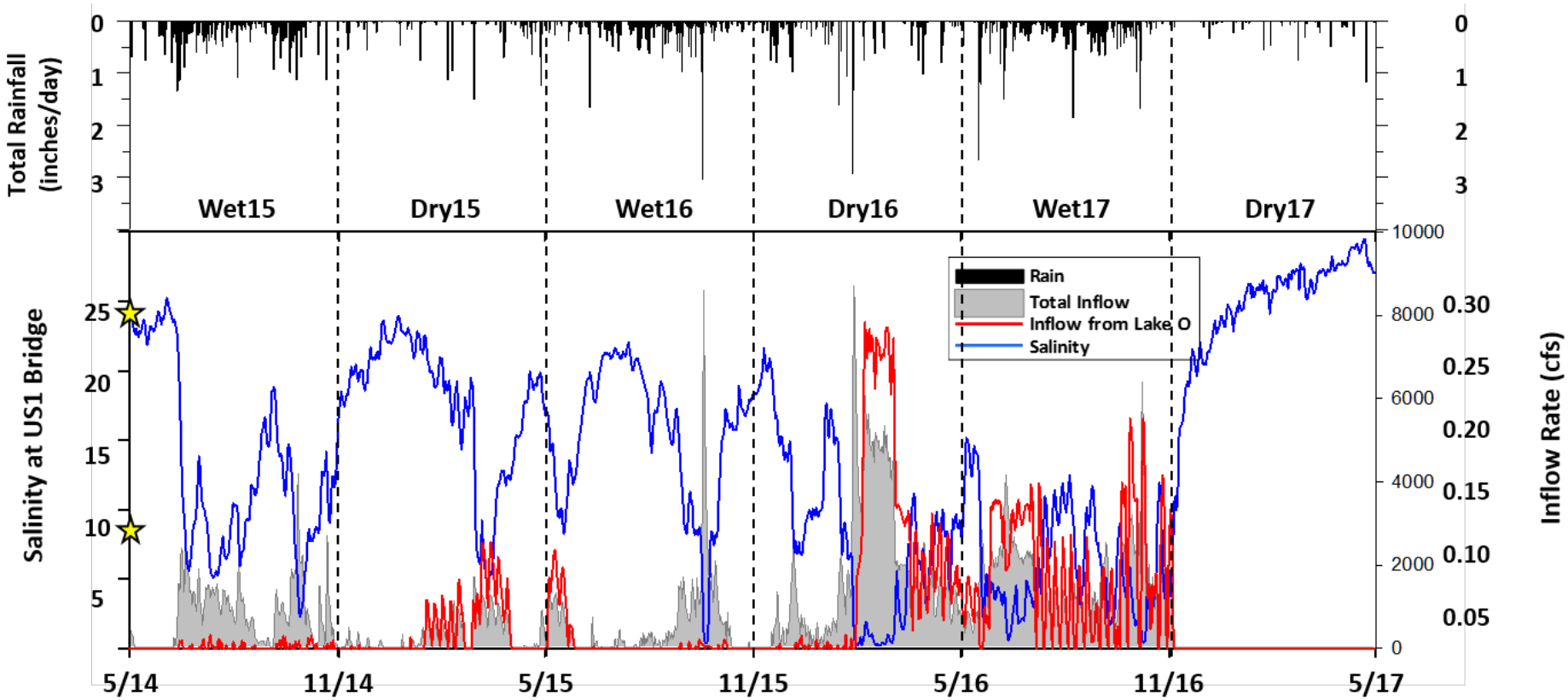

Figure 8C-6. Time series of rainfall (top panel; black bars; inches per day), total gauged freshwater inflow rate (grey fill; cfs), inflow rate from Lake Okeechobee (red; cfs), and salinity at US1 Roosevelt Bridge (blue) from WY2015 through WY2017. The yellow stars mark the target salinity range of 10 to 26. The black dashed lines separate dry and wet seasons for each water year.

The average daily average salinity at the US1 Roosevelt Bridge was less than 10 on 30.6% of days, between 10 to 26 for 60.7% of the total days, and greater than 26 on 8.3% of the days from WY2001 through WY2017 (**Table 8C-2**). While salinity was within the suitable envelope for oysters (10 to 26) for 75.1% of the time in WY2015, this value decreased to 56.8% in WY2016 and 34.8% in WY2017. Based on a suitable salinity of envelope of 10 to 26 the percentages of days where salinity was less than 10 were similar in WY2016 and WY2017 (43.2 and 41.6%, respectively). The dry season increase accounted for most of the 23.6% of days where salinity was greater than 26 in WY2017.

Table 8C-2. Summary of daily average salinity at the US1 Roosevelt Bridge (S_{US1}) categorized based on a salinity envelope of 10 to 26 for the eastern oyster. Shown are the percentage of days where S_{US1} was less than 10 (<10), between 10 and 26 (≥10 and <26), and greater than 26 (≥26) for the long-term POR WY2001–WY2017 relative to values from WY2015, WY2016, and WY2017.

Period	$\%S_{US1} < 10$	$\%S_{US1} \geq 10$ and < 26	$\%S_{US1} \geq 26$
WY2001–WY2017	30.6%	60.7%	8.3%
WY2015	24.9%	75.1%	-
WY2016	43.2%	56.8%	-
WY2017	41.6%	34.8%	23.6%

Total annual freshwater inflow to the SLE ranged from ~0.8 to 1.2 million ac-ft in WY2015, WY2016, and WY2017 (**Table 8C-3** and **Figure 8C-7A**). The long-term average is ~1.0 million ac-ft with 49.9% of the inflow contributed by the St. Lucie Basin (**Figure 8C-8A**). The total inflow of 0.945 million ac-ft in WY2017 was very close to the long-term average although the St. Lucie Basin accounted for only 39.2% of the total. Inflow from Lake Okeechobee was greater in WY2017 compared to the long-term average (0.338 million ac-ft versus 0.249 million ac-ft; **Table 8C-3**). This increased the relative contribution of the lake from 20.0 to 35.8% in WY2017 (**Figure 8C-8A**). While the magnitude of discharge from the Tidal Basin was similar to the long-term average, the relative contribution of the Tidal Basin decreased slightly from a long-term value of 30.1 to 25.0% in WY2017.

Table 8C-3. Summary of freshwater inflow), TN loads (metric tons per year), and TP loads from Lake Okeechobee, the St. Lucie Basin (C-23, C-24, C-44, and TMC), and Tidal Basin (ungauged) to SLE. Data categorized by the for the long-term averages (WY1997–WY2017) and values for WY2015, WY2016, and WY2017.

Parameter	Area	WY1997–2017	WY2015	WY2016	WY2017
Inflow (10 million ac-ft)	**Total**	**0.986**	**0.751**	**1.219**	**0.945**
	Lake Okeechobee	0.249	0.080	0.370	0.338
	St. Lucie Basin	0.485	0.402	0.586	0.370
	Tidal Basin	0.252	0.269	0.263	0.237
TN Load (t per year)	**Total**	**1,714.0**	**1,049.2**	**1,990.7**	**1,376.2**
	Lake Okeechobee	535.0	124.7	717.2	621.3
	St. Lucie Basin	882.8	659.1	969.7	497.4
	Tidal Basin	296.9	265.4	303.7	257.5
TP Load (t per year)	**Total**	**314.1**	**199.1**	**333.2**	**229.8**
	Lake Okeechobee	54.8	13.3	83.6	56.8
	St. Lucie Basin	214.6	155.2	219.0	144.4
	Tidal Basin	44.7	30.6	30.6	28.6

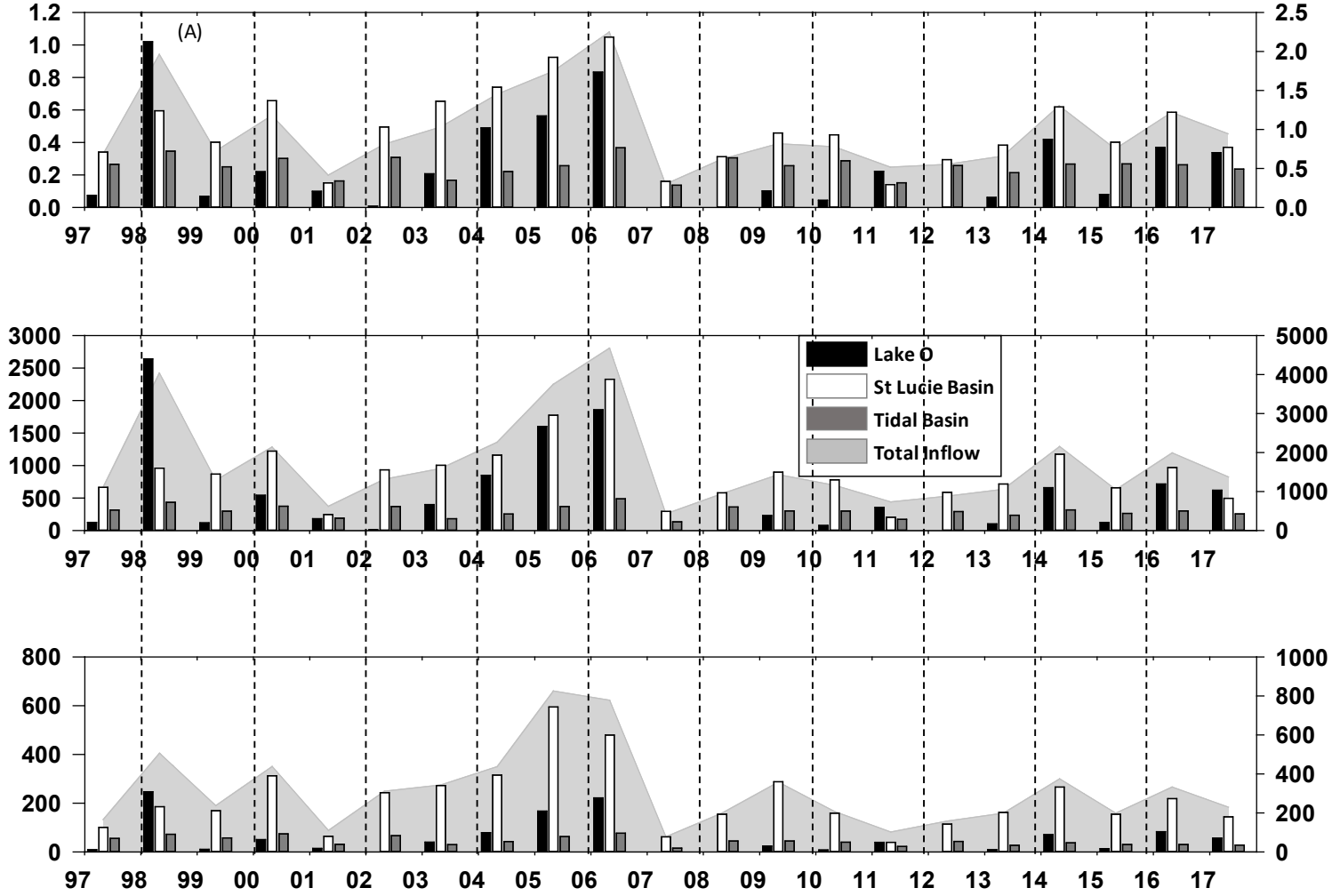

Figure 8C-7. Time series of (A) annual freshwater inflow, (B) TN loading, and (C) TP loading to the SLE for the POR WY1997–WY2017. The left y-axis in each panel corresponds to the annually grouped bars categorizing the inflow among the Lake Okeechobee (black fill), St. Lucie Basin (white fill), and Tidal Basin (dark grey fill) Contributing Areas. The right y-axis is the total annual inflow or nutrient loads (light grey area fill).

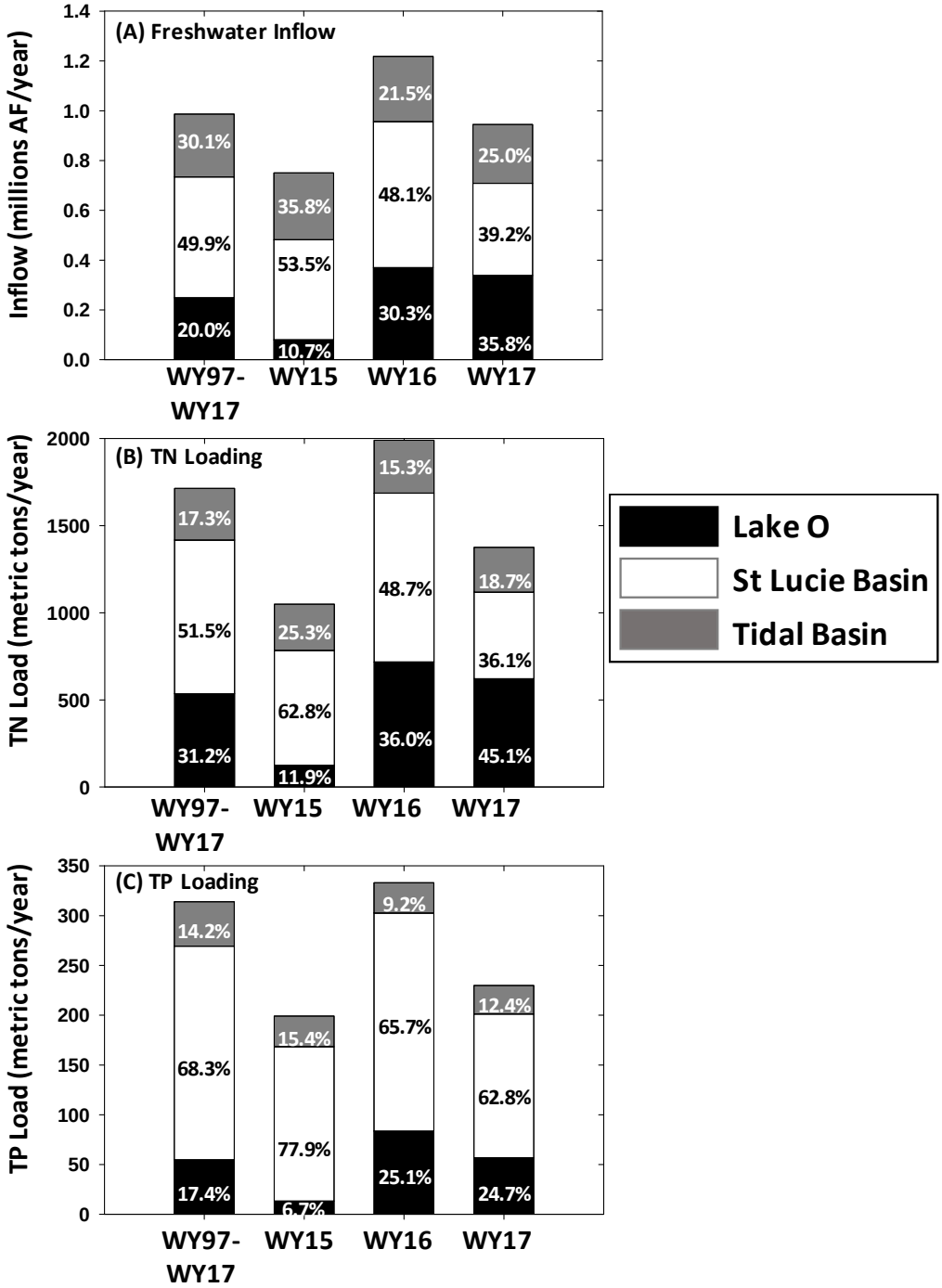

Figure 8C-8. Stacked bar chart for the (A) total freshwater inflow (in million ac-ft [AF]/year), (B) TN loading (t/year), and (C) TP loading (t/year) attributable to Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin. It includes the long-term average from the POR WY1997–WY2017, and WY2015, WY2016, and WY2017.

TN and TP Loads

The annual loading of TN and TP to the SLE fluctuated with total freshwater inflow for the POR, WY1997–WY2017 (**Figure 8C-7B** and **C**). TN loads averaged 1,714 metric tons per year (t/yr) during that period with values of 1,049.2 t, 1,990.7 t, and 1,376.2 t in WY2015, WY2016, and WY2017, respectively (**Table 8C-3** and **Figure 8C-7B**). The magnitude and percentage of TN supplied by the St. Lucie Basin Tier 1 Contributing Area in WY2017 (497.4 t and 36.1%, respectively) were less than the long-term averages (882.8 t and 51.5%, respectively). In contrast, TN loading from Lake Okeechobee in WY2017 increased to 621.3 t compared to the long-term average of 535.0 t. This level of TN loading increased the relative contribution of the lake from 31.2 to 45.1%. The Tidal Basin accounted for slightly less TN in WY2017 (257.7 versus 296.9 t) but a larger percentage of the total (18.7 t versus 17.3%; **Table 8C-3** and **Figure 8C-8B**). These results suggest that under certain conditions Lake Okeechobee can be a significant source of TN to the SLE.

TP loads averaged 314.1 t/yr for the POR, WY1997–WY2017, with values of 199.1 t, 333.2 t, and 229.8 t in WY2015, WY2016, and WY2017, respectively (**Table 8C-3** and **Figure 8C-7C**). The magnitude and percentage of TP supplied by the St. Lucie Basin Tier 1 Contributing Area in WY2017 (144.4 t and 62.8%, respectively) were less than the long-term averages (214.6 t and 68.3%, respectively). TP loading from Lake Okeechobee in WY2017 was similar to the long-term average (56.8 t versus 54.8 t) although the relative contribution of the lake increased from 17.4 to 24.7%. The magnitude and percentage of TP loading from the Tidal Basin decreased in WY2017 (28.6 t and 12.4%, respectively) compared to the long-term values (44.7 and 14.2%, respectively). Overall, WY2017 TP loads to the SLE were 37% less than the long-term average (**Table 8C-3** and **Figure 8C-8C**).

Estuary Water Quality

TN concentrations ranged from < 0.5 milligrams per liter (mg/L) to > 2.5 mg/L at stations HR1, SE03, and SE11 (**Figure 8C-9**). The long-term average concentrations were 0.98 (HR1), 0.98 (SE03), and 0.51 mg/L (SE11; **Table 8C-4**). Concentrations were generally higher in the wet season except at SE03 in WY2016 where the average dry season TN concentration was 0.93 ± 0.30 mg/L versus 0.82 ± 0.19 mg/L from May to November 2016. TN concentrations at all three stations were less than the long-term average in WY2015, WY2016, and WY2017 (**Table 8C-4**). While TN concentrations at stations SE03 and SE11 appeared to follow increases in the freshwater inflow in WY2016, the relationships between gauged discharge to the SLE and estuary water quality conditions are difficult to discern (**Figure 8C-9**). Efforts are under way to quantify these relationships using the long-term data set and a suite of parametric and non-parametric statistics (Buzzelli, Wachnicka, Chen, and Doering, SFWMD, unpublished data).

TP concentrations ranged from < 0.1 to 1.0 mg/L at stations HR1, SE03, and SE11 (**Figure 8C-9**). The long-term average concentrations were 0.20 (HR1), 0.18 (SE03), and 0.06 (SE11; **Table 8C-4**). Concentrations were generally higher in the wet season except at SE03 in WY2016 where the average dry season TP concentration was closer to that from May to November 2016 (0.14 ± 0.02. versus 0.17 ± 0.04). TP concentrations at all three stations were less than the long-term averages in WY2015, WY2016, and WY2017 (**Table 8C-4**). The magnitude and variance in TP concentrations were greater at stations HR1 and SE03 compared to SE11 near the St. Lucie Inlet (**Figure 8C-9**). While TP concentrations at HR1 appeared to respond to freshwater inflow in WY2016, the relationships between gauged discharge to the SLE and estuary water quality conditions are variable and difficult to discern (**Figure 8C-9**, Buzzelli et al. 2013b).

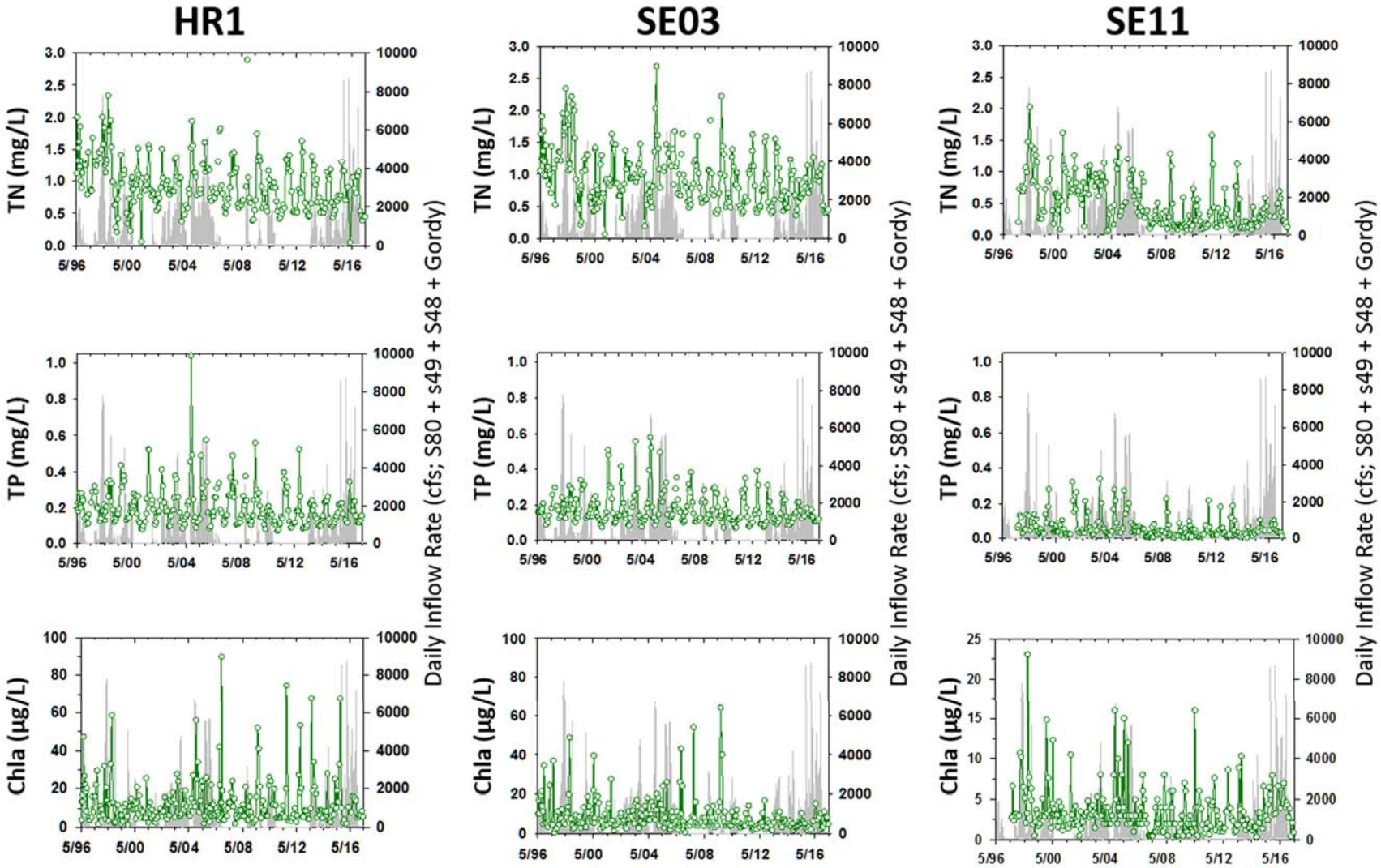

Figure 8C-9. Time series of Chla, TN, and TP (green line with open circle) at stations HR1, SE03, and SE11 in the SLE from WY1997 through WY2017. The grey fill is total gauged inflowshown on right y-axis.

Table 8C-4. Summary of water column concentrations of Chla, TN, and TP at three stations (HR1, SE03, and SE11) in the SLE. The table includes dry season (November–April), wet season (May–October), and total averages and standard deviations (average ± SD) from WY1997 through WY2017 and average values for WY2015, WY2016, and WY2017.

HR1									
	Chla (µg/L)			TN (mg/L)			TP (mg/L)		
	Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Average ± SD	9.1 ± 7.1	15.3 ± 14.1	12.3 ± 11.7	0.82 ± 0.36	1.13 ± 0.37	0.98 ± 0.40	0.14 ± 0.05	0.26 ± 0.11	0.20 ± 0.11
WY2015	10.4 ± 7.9	10.2 ± 9.0	10.3 ± 8.1	0.59 ± 0.11	0.94 ± 0.26	0.77 ± 0.26	0.11 ± 0.02	0.21 ± 0.05	0.16 ± 0.06
WY2016	5.6 ± 4.5	24.3 ± 23.6	18.1 ± 21.0	0.55 ± 0.45	0.98 ± 0.25	0.84 ± 0.37	0.14 ± 0.03	0.19 ± 0.04	0.17 ± 0.04
WY2017	6.2 ± 1.2	13.3 ± 3.3	9.5 ± 4.3	0.58 ± 0.29	0.99 ± 0.13	0.76 ± 0.31	0.13 ± 0.02	0.24 ± 0.06	0.18 ± 0.07

SE03									
	Chla (µg/L)			TN (mg/L)			TP (mg/L)		
	Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Average ± SD	6.6 ± 4.3	10.9 ± 9.9	8.8 ± 8.0	0.86 ± 0.44	1.11 ± 0.40	0.98 ± 0.44	0.13 ± 0.04	0.23 ± 0.09	0.18 ± 0.09
WY2015	4.0 ± 1.0	4.5 ± 1.6	4.2 ± 1.3	0.60 ± 0.19	0.89 ± 0.27	0.74 ± 0.27	0.11 ± 0.02	0.21 ± 0.05	0.15 ± 0.06
WY2016	3.8 ± 2.3	5.3 ± 2.9	4.8 ± 2.7	0.93 ± 0.30	0.82 ± 0.19	0.85 ± 0.22	0.14 ± 0.02	0.17 ± 0.04	0.16 ± 0.04
WY2017	5.8 ± 3.2	8.5 ± 4.8	7.0 ± 4.0	0.56 ± 0.29	0.97 ± 0.08	0.74 ± 0.30	0.11 ± 0.01	0.16 ± 0.02	0.13 ± 0.03

SE11									
	Chla (µg/L)			TN (mg/L)			TP (mg/L)		
	Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Average ± SD	2.9 ± 2.3	4.2 ± 3.4	3.6 ± 3.0	0.40 ± 0.34	0.61 ± 0.38	0.51 ± 0.38	0.04 ± 0.03	0.09 ± 0.07	0.06 ± 0.06
WY2015	3.2 ± 1.8	1.7 ± 1.0	2.4 ± 1.6	0.21 ± 0.06	0.19 ± 0.03	0.20 ± 0.10	0.03 ± 0.01	0.03 ± 0.02	0.03 ± 0.02
WY2016	4.3 ± 2.0	5.0 ± 2.1	4.7 ± 2.0	0.31 ± 0.01	0.40 ± 0.11	0.38 ± 0.11	0.05 ± 0.01	0.06 ± 0.03	0.06 ± 0.02
WY2017	2.4 ± 1.5	5.3 ± 1.5	3.7 ± 2.1	0.22 ± 0.08	0.51 ± 0.15	0.35 ± 0.19	0.03 ± 0.01	0.08 ± 0.02	0.05 ± 0.03

Chla concentrations ranged from 1.0 to 90.0 µg/L at HR1, 1.0 to 60.0 µg/L at SE03, and 1.0 to 25.0 µg/L at SE11 from WY1996 through WY2017 (**Figure 8C-9**). The long-term average and standard deviation (Avg ± SD) concentrations were 12.3 ± 11.7 (HR1), 8.8 ± 8.0 (SE03), and 3.6 ± 3.0 µg/L (SE11; **Table 8C-4**). While these averages decreased in the downstream direction, Chla concentrations were highly variable at all three locations. Because of this variability, the average Chla concentrations were not always higher in the wet season among the three stations. The average and standard deviation of Chla at HR1 in the WY2016 wet season (24.3 ± 23.6 µg/L) were higher than the long-term averages (12.3 ± 11.7 µg/L).

SAV

Halophila johnsonii (Johnson's seagrass) and *Halodule wrightii* (shoal grass) were the two dominant SAV species during the POR of WY2013–WY2017 at Willoughby Creek inside the St. Lucie Inlet (**Figure 8C-10**). These two species are adapted to a broad salinity range (Doering et al. 2002, Kahn et al. 2013). Thus, their coverage and abundance can vary with fluctuations in freshwater discharge and downstream salinity conditions. However, nearshore sediment resuspension, submarine light climate, and inorganic nutrient supply can greatly influence the distribution and density of seagrasses (Lee et al. 2007, Herbert et al. 2011).

Based on Braun-Blanquet scores, total SAV coverage at the Willoughby Creek monitoring location just upstream of the St. Lucie Inlet ranged approximately from 5 to 25% between WY2013 and WY2017 (**Figure 8C-10A**). The relative cover of the seagrass *Halodule wrightii* was low (~1 to 5%) but consistent over the POR. In contrast, *Halophila johnsonii* was more variable with values 5 to 25% in May 2015 and May 2016 and 1 to 5% in November 2015 and November 2016 (**Figure 8C-10A**).

The Boy Scout Island SAV monitoring location within the SIRL is historically dominated by the seagrass *Syringodium filiforme* (manatee grass). The survival and distribution of *Syringodium filiforme* decrease with decreasing salinity (Lirman and Cropper 2003, Herbert et al. 2011, Buzzelli et al. 2012). Based on Braun-Blanquet scores, total SAV coverage at the Boy Scout Island monitoring location has declined since November 2015 (**Figure 8C-10B**). Total seagrass decreased from 5 to 25% cover at the start of WY2016 to 1 to 5% in WY2017 (**Figure 8C-10B**). This decline has largely been driven by a decrease in the relative cover of *Syringodium filiforme*, although cover values for *Halophila johnsonii* have also declined. Almost no *Syringodium filiforme* was observed late in 2016.

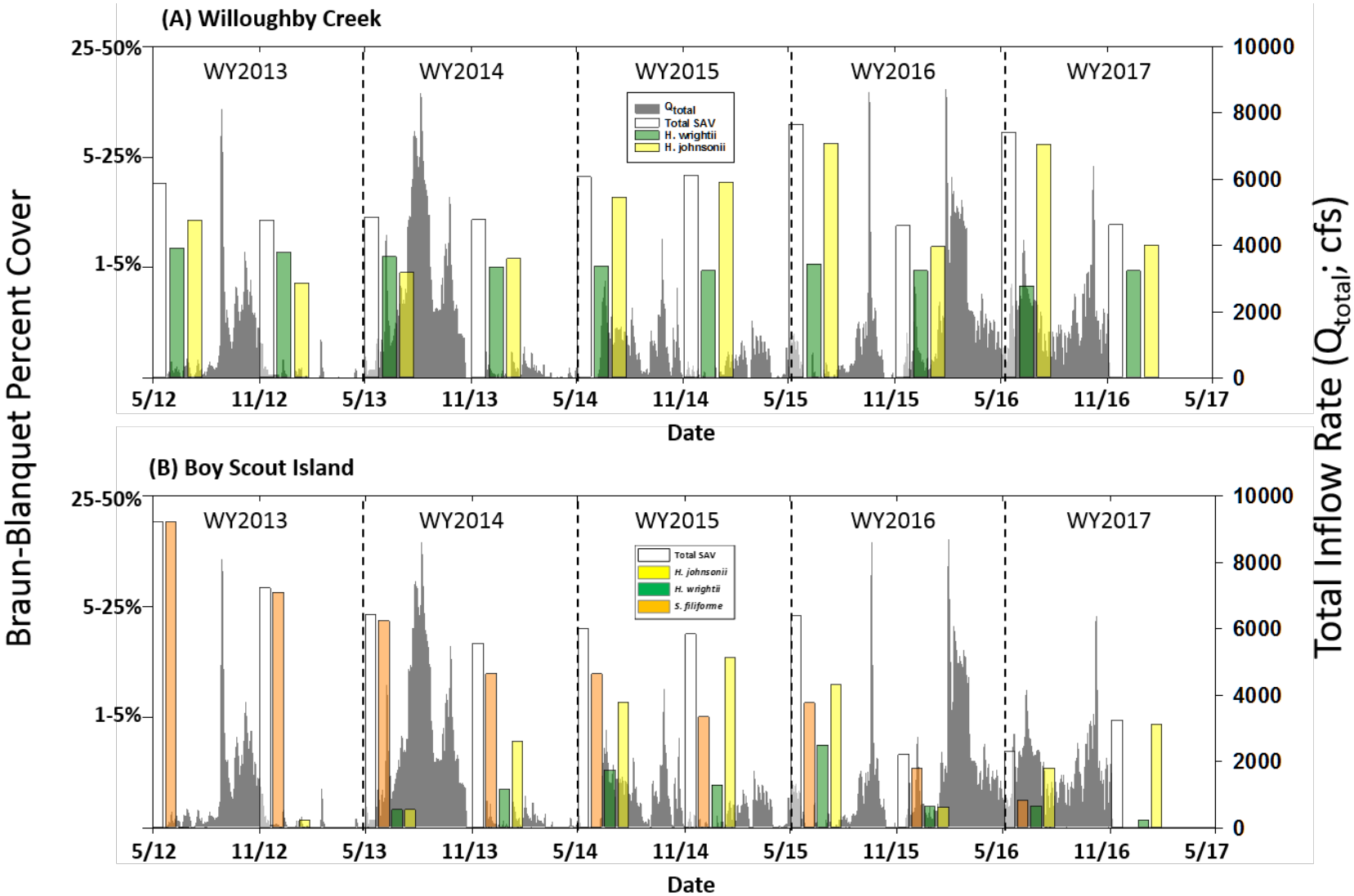

Figure 8C-10. Time series of Braun-Blanquet cover estimates for SAV at (A) Willoughby Creek and (B) Boy Scout Island from WY2013 through WY2017. Seasonal estimates provided for total SAV cover (white fill) and individual species (colored fill). The right y-axis depicts daily freshwater inflow rate to the SLE (grey area fill).

Oyster Habitat

Seasonally averaged live oyster density in the Central Segment of the SLE varied from 0 to 1,000 oysters/m^2 from WY2006 to WY2017 (**Figure 8C-11A**). Oyster density reached the maximum in the WY2015 dry season before decreasing to 300 to 600 oysters/m^2 in WY2016 and WY2017 (**Figure 8C-11A**). Overall, oyster density was greater in the dry season than the wet.

The monthly average rate of oyster larval settlement ranged from 0 to 11 spat/shell/month in the Central Segment of the SLE from WY2006 to WY2017 (**Figure 8C-11B**). Maximum rates of spat fall usually occur in the late wet season. Spat settlement was consistent at this location from May 2014 to October 2015. However, the increase in freshwater inflow late in WY2016 coincided with very low spat fall. Recruitment appeared to increase following this time period.

The intensity and prevalence of the oyster marine parasite dermo were combined into a single unitless metric (weighted prevalence) and averaged seasonally (**Figure 8C-11C**). This value was generally low (< 0.2) for the periods WY2006–WY2011 and WY2014–WY2017. However, values were much higher during the drought of WY2012–WY2013.

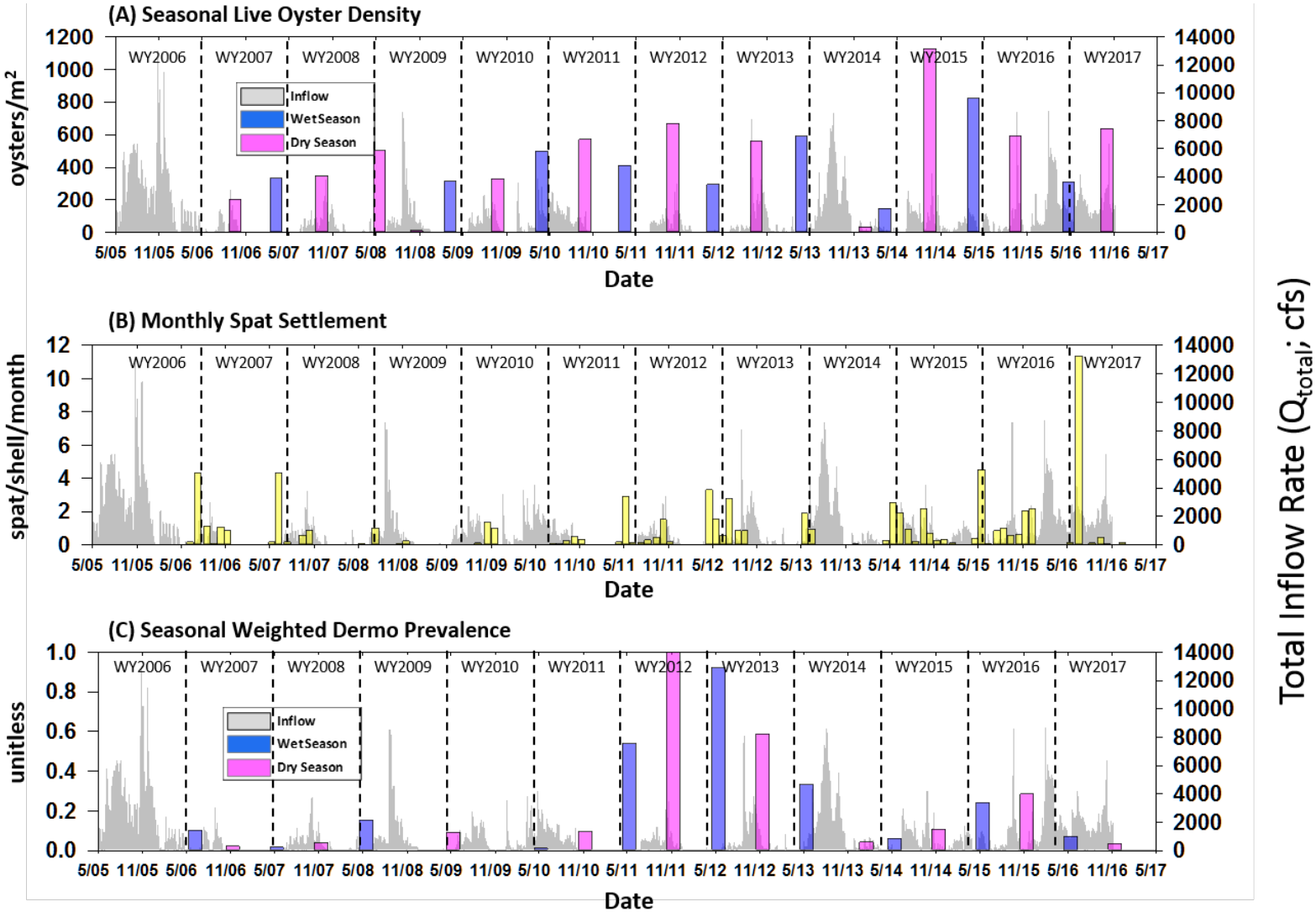

Figure 8C-11. Time series of oyster monitoring metrics from the Central Segment of the SLE for the period WY2006–WY2017. (A) Seasonal average of live oyster density. (B) Monthly spat settlement rate (spat/shell/month). (C) Seasonal average of weighted Dermo prevalence (see *Methods* subsection for details). The right y-axis depicts daily freshwater inflow rate to the SLE (grey area fill).

SUMMARY

- Rainfall across the St. Lucie Watershed and Tidal Basin in WY2017 was less than the average from WY1997 to WY2017 with 85% occurring in the wet season from May to November 2016.
- Freshwater inflow to the SLE in WY2017 was similar to the long-term average of ~1.0 million acre-feet. However, the contribution from Lake Okeechobee in WY2017 (0.34 million acre-feet and 35.8% of the total) was greater than the long-term values (0.25 million acre-feet and 20.0%)
- Nitrogen loading to the SLE in WY2017 (1,376.2 t) was less than the long-term average from WY1997 to WY2017 (1,714 t). The annual contribution from Lake Okeechobee increased from a long-term average of 535.0 to 621.3 t in WY2017.
- Phosphorus loading in WY2017 (229.8 t) was 37% less than the long-term average although the Lake Okeechobee contribution was similar in magnitude (56.8 versus 54.8 t).
- TN and TP concentrations at stations in the North Fork, at the Roosevelt Bridge, and near St. Lucie Inlet in WY2017 were less than the long-term values from WY1997 to WY2017.
- The average Chla concentration was less than or equal to the long-term seasonal averages at all three SLE locations. Elevated chlorophyll values observed in the North Fork from May through July 2016.
- The SAV community at Willoughby Creek inside St. Lucie Inlet was composed of *Halodule wrightii* (shoal grass) and *Halophila johnsonii* (Johnson's grass) with total coverage ranging 5 to 25% in WY2017. Coverage at the Boy Scout Island in the Southern Indian River Lagoon has declined due to a decrease in *Syringodium filiforme* (manatee grass).
- Oyster density ranged from 300 to 600 oysters/m^2 in WY2017 with higher density in the dry season. While increased freshwater inflow in the WY2016 wet season was associated with increased oyster larval recruitment, the weighted prevalence of the oyster marine parasite (Dermo) was comparatively low in WY2017.

CALOOSAHATCHEE RIVER ESTUARY AND WATERSHED CONDITION

BACKGROUND

Historically, the Caloosahatchee River was sinuous as it originated near Lake Flirt ~2 miles (3.2 kilometers [km]) east of La Belle at Fort Thompson. Beginning in the 1880s, the river channel was straightened, deepened, and connected to Lake Okeechobee. This resulted in a loss of 76 river bends and 8.2 miles (13.2 km) of river length (Antonini et al. 2002). Dredging alterations continued and, by 1918, three combination lock and spillway structures had been constructed at Moore Haven, Citrus Center, and Fort Thompson (USACE 1957, Section 6.B.6). Flows within the historic Caloosahatchee River (now the C-43 canal) are controlled through the operation of multiple water control structures (S-77, S-78, and S-79) as these structures regulate downstream freshwater transport. The final lock and dam structure (Franklin Lock and Dam or S-79) was completed in 1966 at Olga to assure freshwater supply and prevent upstream saltwater intrusion. Discharges from Lake Okeechobee and the Caloosahatchee Basin (between the S-77 and S-79 structures) are regulated by USACE. Presently, the C-43 canal spans 70 km from S-77 at Lake Okeechobee to S-79.

The modern Caloosahatchee River Basin is a series of linked regional subbasins and includes the S-4 basin adjacent to Lake Okeechobee, the East Caloosahatchee Basin, the West Caloosahatchee Basin, the Tidal Basin located downstream of S-79, and the Cape Coral Coastal Basin to the north of the CRE (**Figure 8C-12**; Balci and Bertolotti 2012, Buzzelli et al. 2017). The primary land use type within the Caloosahatchee Basin today is agricultural, which comprises 44%. Urban land use comprises 14% and open water comprises 12%. The Franklin Lock and Dam represents the head of the CRE that extends 26.1 miles (42 km) downstream to Shell Point where it empties into San Carlos Bay. The surface area of the CRE is 21.6 square miles (55.9 square kilometers or 13,824 acres [5,599 hectares]) with an average depth of 8.86 ft (2.7 m) (Buzzelli et al. 2013a). The flushing time ranges from 2 to 30 days (Buzzelli et al. 2013b).

Fluctuations in freshwater inflows over time scales ranging from weeks to years have altered salinity regimes and impacted the ecology of the CRE (Chamberlain and Doering 1998, Barnes 2005). Changes in freshwater inflows and salinity have been shown to affect the distribution and dynamics of many taxa and communities including phytoplankton and zooplankton (Tolley et al. 2010, Radabaugh and Peebles 2012), SAV (Doering et al. 2001, 2002, Lauer et al. 2011), oysters and pathogens (La Peyre et al. 2003, Barnes et al. 2007, Volety et al. 2009), fauna inhabiting oyster reefs (Tolley et al. 2005, 2006), and fishes (Collins et al. 2008, Heupel and Simpfendorfer 2008, Simpfendorfer et al. 2011, Poulakis et al. 2013, Stevens et al. 2013).

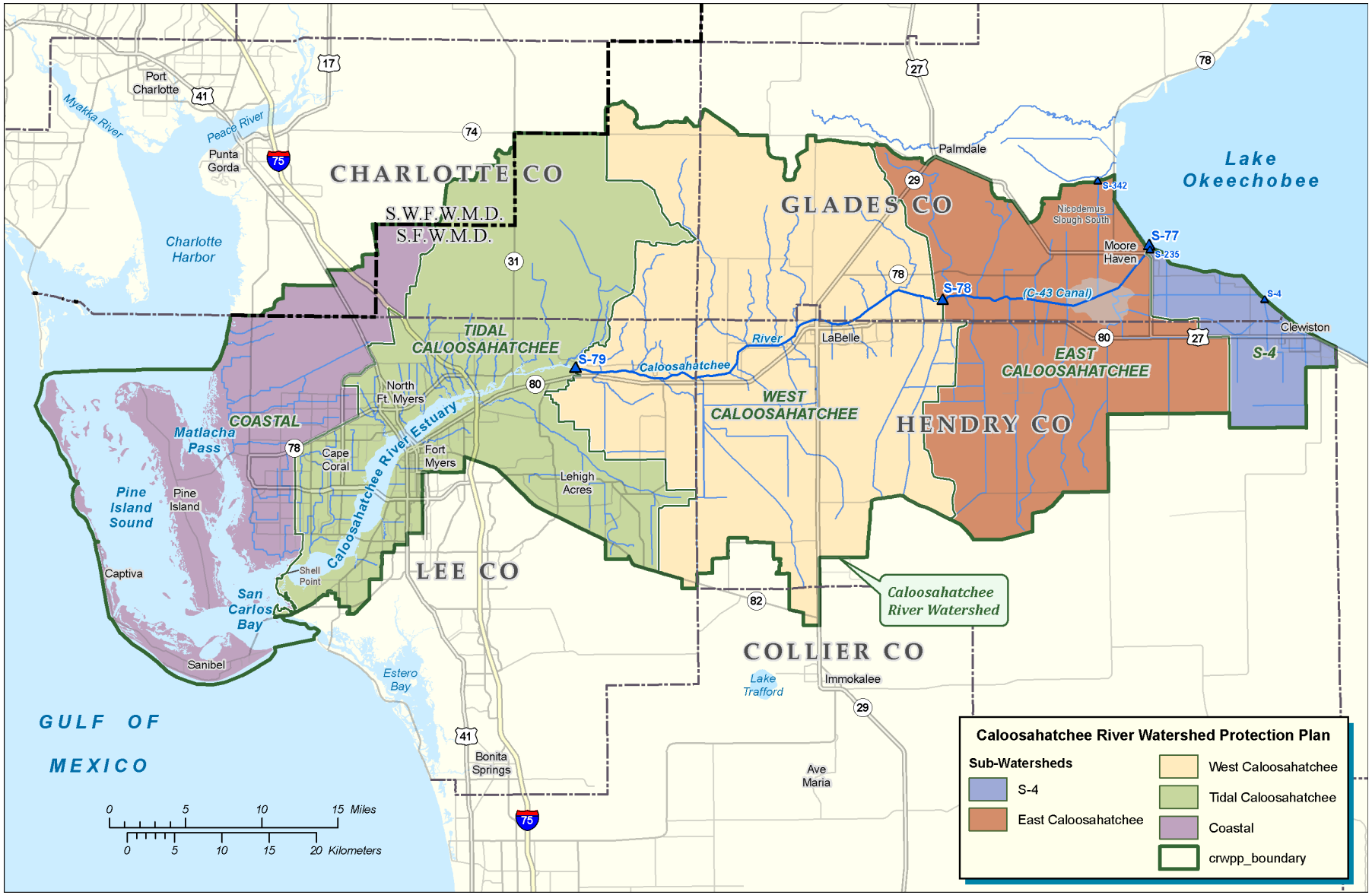

Figure 8C-12. The Caloosahatchee River Watershed with its subbasins and major water control structures.

HYDROLOGY, WATER QUALITY, AND AQUATIC HABITAT

Methods

A suite of external drivers and ecological responses are monitored in the Caloosahatchee River Basin and Estuary. These variables include rainfall, freshwater discharge, and nutrient loads as external drivers, and patterns of salinity, estuarine nutrient concentrations, oyster habitat status, and SAV community composition as the estuarine ecological responses. Salinity gradients are a conservative property of the water body and therefore are useful to connect the sources of freshwater inflow, circulation, and biological indicators (Wilber 1992, Jassby et al. 1995, Hagy and Murrell 2007, Pollack et al. 2011).

Daily NEXRAD rainfall data from WY1997 to WY2017 for each subbasin of the Caloosahatchee River Basin were downloaded from the District's corporate environmental database, DBHYDRO, on the District's website at http://my.sfwmd.gov/nexrad2/nrdmain.action. The cumulative amount of rainfall across the basin was computed using area-weighting, which accounts for the different sizes of the subbasins.

The Caloosahatchee basins and subbasins are categorized into Contributing Areas, or, Tier 1 and 2 levels of organization (**Table 8C-5**). The Tier 1 Contributing Areas are the C-43 basin, Lake Okeechobee, and the Tidal Basin. All freshwater flows and nutrient loads are measured except those from the Tidal Basin where the WaSH model is used to simulate inputs (Wan and Konyha 2015). Freshwater discharge is monitored at S-77 at Lake Okeechobee, S-78 near the City of LaBelle, and S-79 at the upstream boundary of the CRE (**Figure 8C-12**). For the purposes of this report, the East Caloosahatchee Basin and the S-4 basin were combined.

Table 8C-5. Major contributing areas of the Caloosahatchee River Watershed.

Tier 1 Basins	Tier 2 Basins	Flows and Loads
C-43 Basin	East Caloosahatchee/S-4	Measured
	West Caloosahatchee	Measured
Tidal Basin	Tidal Basin	Modeled
Lake Okeechobee	Lake Okeechobee via S-77 and S-79	Measured

Average daily inflows from WY2000 through WY2017 for S-79, S-78, S-77, and the Tidal Basin were used to evaluate intra- and interannual variations in inflow, quantify total inflow to the CRE, and estimate the contributions of the subbasins to total inflow. This included the relative volume contributions from the three Tier 1 Contributing Areas (Lake Okeechobee, C-43 basin, and Tidal Basin). Total daily discharges and contributions were categorized by water year and season. Daily TN and TP loads were calculated using measured daily inflows at S-79 and S-77, and TN and TP concentrations were determined from water samples at the structure. The contribution of the Tidal Basin to freshwater inflow and nutrient loads was estimated using a linear reservoir modeling approach. Flows and loads from the Coastal Subbasin were not estimated as they do not discharge into the CRE.

The concentrations of TN and TP in the tributaries of the CRE were monitored at 16 stations in the Tidal Basin by Lee County and the City of Cape Coral from WY2000 through WY2017. These data are available from the Lee County Department of Natural Resources and City of Cape Coral. The monitoring data from the 16 stations along with the estimated freshwater inflows from the Tidal Basin were used to derive monthly time series of TN and TP loading to the CRE. These data were used to compute monthly nutrient loads from the Tidal Basin.

Surface and bottom salinity observations were recorded every 30 minutes at six stations in the CRE: S-79, Bridge 31, Ft. Myers, Cape Coral, Shell Point, and Sanibel Island Bridge (**Figure 8C-13**). The station at I-75 (ValI75) was temporarily removed due to bridge construction and, therefore, measurements at it were not collected in WY2016. Daily surface and bottom salinity values were averaged together to visualize temporal variations. These data were used to calculate the percentage of days above or below the specified critical criteria.

Water column properties were determined from sampling at a depth of 0.5 m at 10 stations in the CRE, San Carlos Bay, and Pine Island Sound at approximately monthly intervals (**Figure 8C-13**). Three stations (CES04, CES06, and CES08) with the most complete records were selected to characterize estuarine water quality. Concentrations of TN, TP, and Chla from WY2000 through WY2017 were assessed for this report.

SAV were monitored monthly during the wet season (May–October) and bimonthly during the dry season (December, February, April) at seven sites ranging from 1.0 to 2.0 acres (0.4 to 0.8 hectares) in the CRE and San Carlos Bay since 1998 (Sites 1, 2, 4, 5, 6, 7, and 8; **Figure 8C-13**). At each site, a ~2-acre polygon was delineated and for each sampling event, 30 random points within the polygon were sampled. The Braun-Blanquet cover and abundance assesses percent cover of the bottom by the SAV using a scale ranging from 0 to 5 representing values of ~5 to 75–100% cover (Fourqurean et al. 2003). Results from upstream Site 2 and downstream Site 8 were summarized for this report.

Oyster monitoring has been ongoing at multiple sites in the lower CRE since WY2001 (**Figure 8C-13**). The primary site for this report is Bird Island near Shell Point (Volety et al. 2009, Balci and Bertolotti 2012). The Bird Island site was selected for its central location in the lower CRE and data set completeness. The oyster response variables include live oyster density (number per square meter), larval recruitment (e.g., "spat fall"), and the prevalence and intensity of the marine oyster parasite *Perkinsus marinus* (dermo).

Live oyster density was determined biannually at each site using methods based on those of Lenihan and Peterson (1998) and Grizzle et al. (2005). Larval recruitment was determined at monthly intervals by counting settled spat on replicated, vertical strings of sterilized oyster shells at each site and expressed as spat/shell/month (Parker et al. 2013). Tissue from a subset of live adult oysters was collected monthly to determine prevalence (number infected divided by total collected) and intensity of the protozoan pathogen *Perkinsus marinus* (Ray 1966). The Mackin scale infection index was used to assess each tissue sample and the infection intensity calculated for each sampling event. From these metrics, the weighted prevalence was calculated as prevalence times infection intensity (Powell and Kim 2015). Weighted prevalence data were averaged to each water year season for reporting.

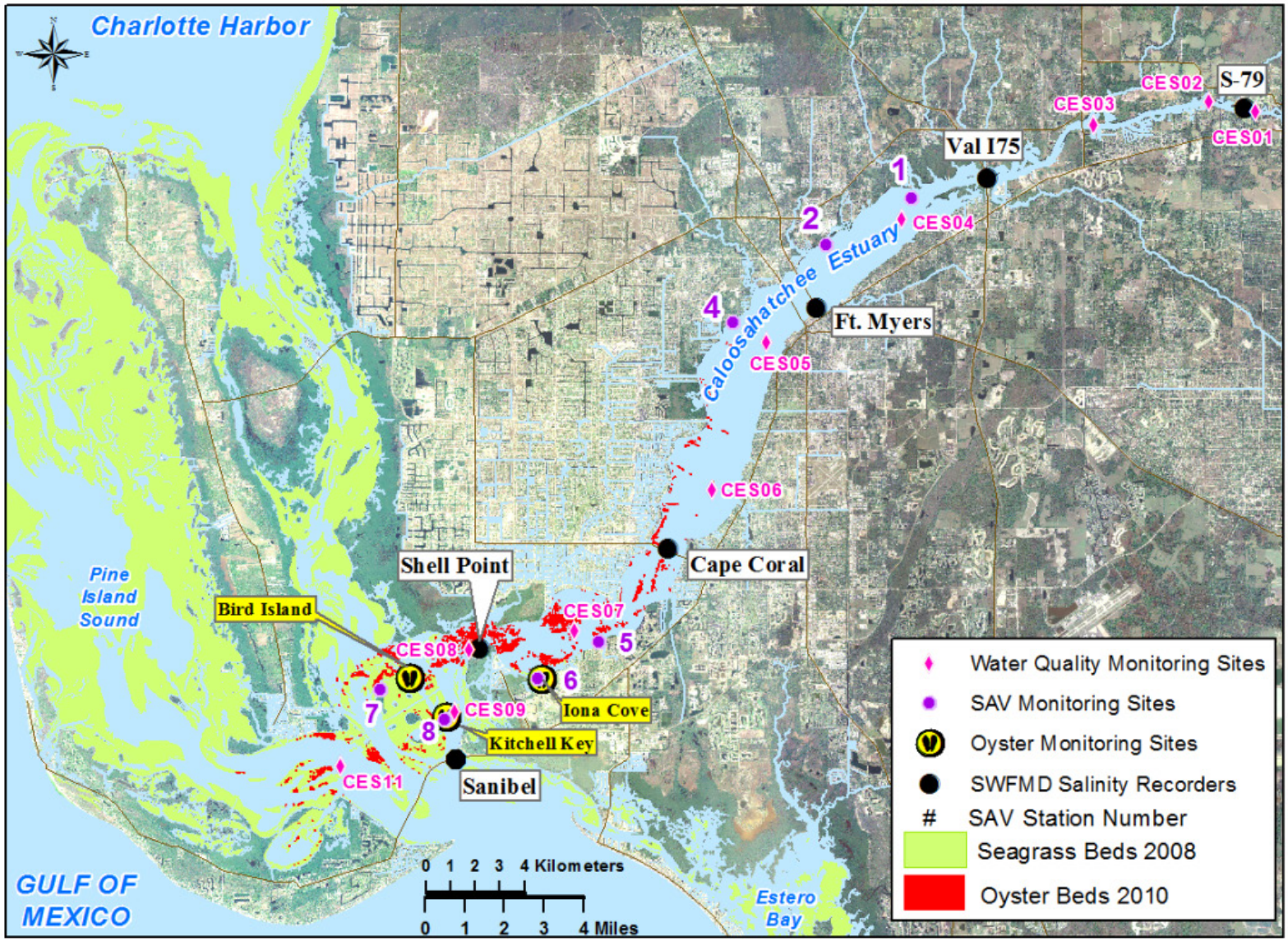

Figure 8C-13. Salinity, water quality, and living aquatic habitat (oysters and seagrass) monitoring sites for the CRE including Pine Island Sound.

Results and Discussion

Rainfall

Daily rainfall amount ranged up 2.0 inches (5.08 cm) with 89.7% of the total annual rainfall occurring in the WY2017 wet season (**Figures 8C-14** and **8C-15**). The long-term average contribution of the wet season to total annual rainfall for the period WY1997–WY2017 was 78.6% although this value was reduced to 66.1% in WY2016 when El Niño conditions elevated dry season rainfall (SFWMD 2016). In WY2017, the total annual rainfall to the Caloosahatchee River Basin was 48.1 inches (122.2 cm), which was the same as WY2015 but lower than WY2016 (62.3 inches or 158.2 cm) or the long-term average for WY1997–WY2017 (51.7 inches or 131.3 cm; **Figure 8C-15**). Spatial patterns in WY2017 differed from those observed in the preceding WY2016 and WY2015, when the greatest rainfall was recorded in Tidal Caloosahatchee Basin (72.1 inches or 183.1 cm) and West Caloosahatchee Basin (50.9 inches or 129.3 cm) and the lowest in the S-4 basin (46.1 inches or 117.1 cm) and the Coastal Basin (43.7 inches or 111.0 cm) (**Figure 8C-16**). The highest rainfall in WY2017 occurred in the West Caloosahatchee Basin (51.1 inches or 129.8 cm) and the lowest in the S-4 basin (40.1 inches or 101.9 cm), which differed from the long-term (WY1997–WY2017) average rainfall pattern that indicate highest rainfall over the Tidal Caloosahatchee Basin (57.8 inches or 146.8 cm) and lowest over the Coastal Basin (45.6 inches or 115.8 cm; **Figure 8C-17**).

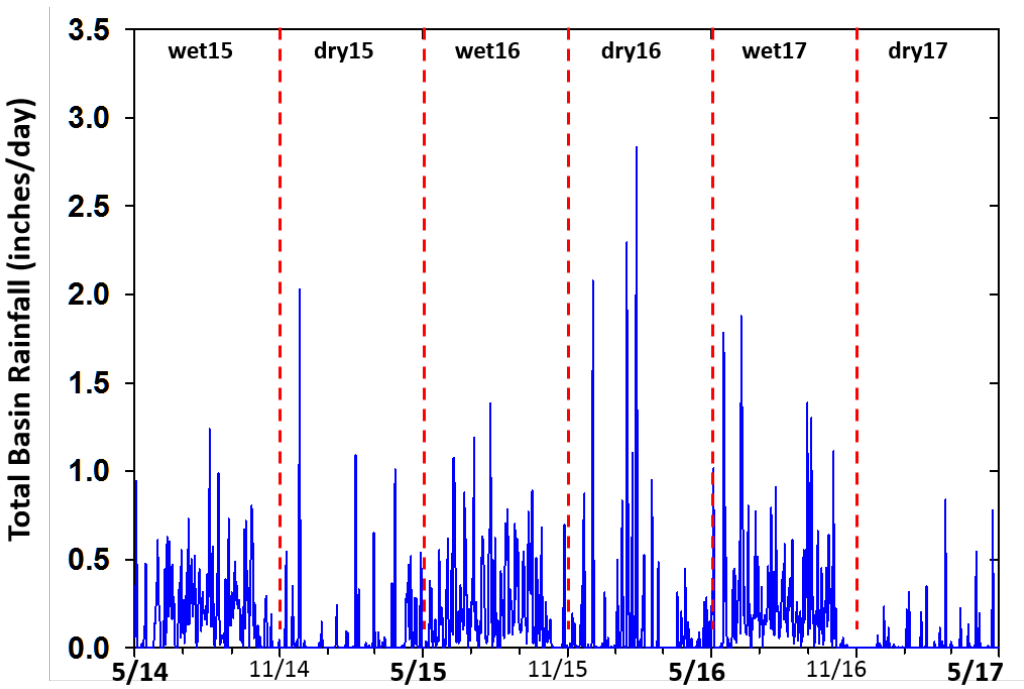

Figure 8C-14. Time series of total daily rainfall to the Caloosahatchee River Watershed from WY2015 through WY2017. See text for calculation details.

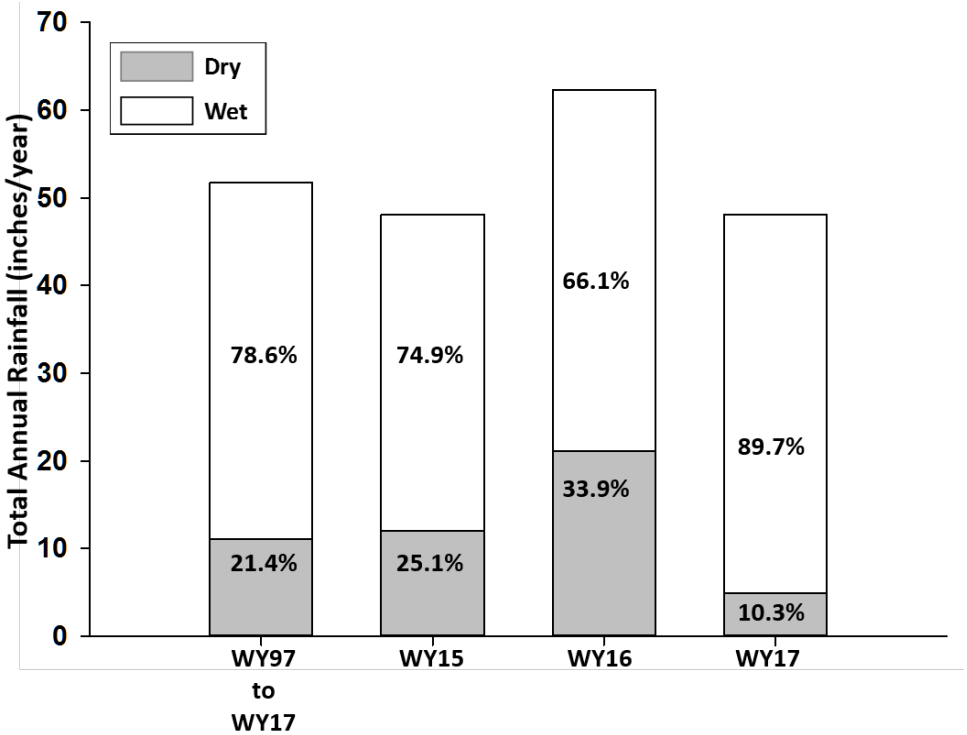

Figure 8C-15. Total rainfall to the Caloosahatchee River Watershed by water year and season including averages from the period WY1997–WY2017 and those for WY2015, WY2016, and WY2017. Bold numbers are percentage of annual total rainfall for dry versus wet seasons.

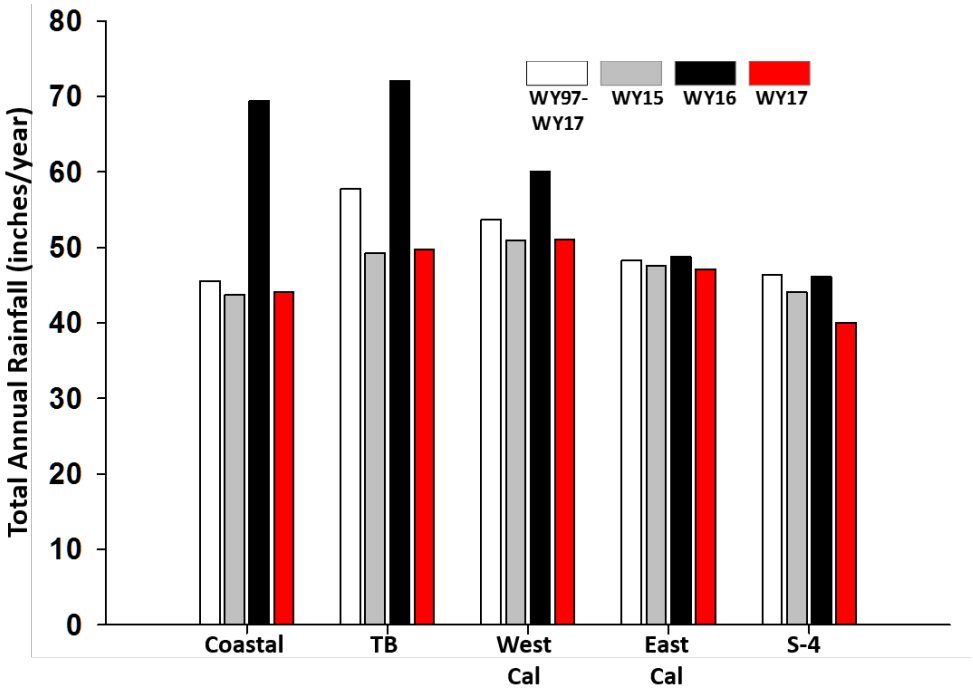

Figure 8C-16. Average annual rainfall to the Caloosahatchee Tier 2 Contributing Areas, including the long-term average (WY1997–WY2017), and WY2015, WY2016, and WY2017.

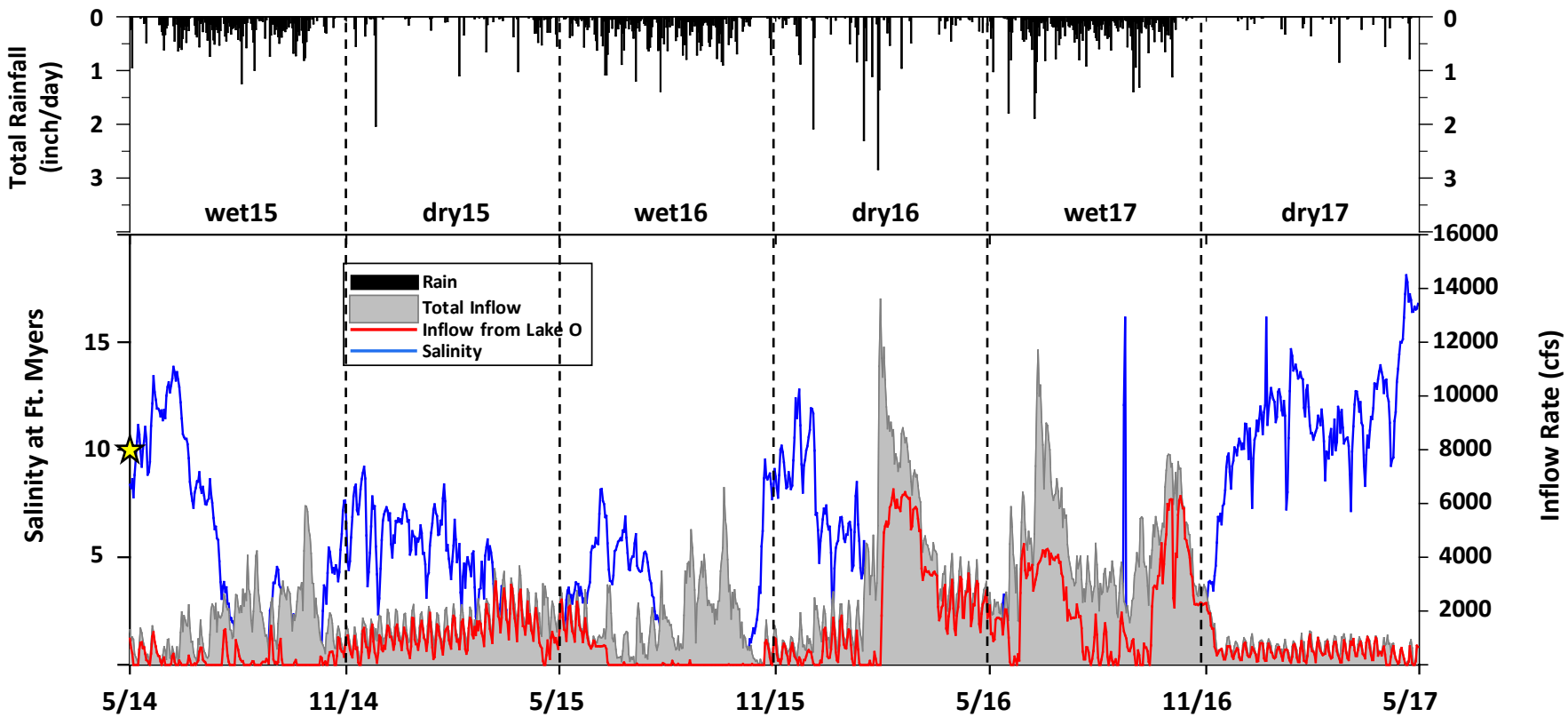

Figure 8C-17. Time series of rainfall (top panel; black bars), total daily freshwater inflow rate (grey fill), inflow rate from Lake Okeechobee (red), and salinity at Ft. Myers (blue) from WY2015 through WY2017. The yellow star marks the target salinity of 10. The black dashed lines separate dry and wet seasons for each water year.

Freshwater Inflow and Salinity

Freshwater inflow to the CRE was proportional to the total rainfall across the C-43 basin and Tidal Basin (**Figure 8C-17**). Thus, the relatively high percentage of annual rainfall that fell in the WY2017 wet season (89.7%) was the driver for increased discharge to the CRE. However, as rainfall declined from November 2016 to May 2017, inflow decreased considerably and salinity at the Ft. Myers station increased to > 15 (**Figure 8C-17**).

The average daily average salinity at the Ft. Myers station was less than 10 on 70.0% of days, and greater than 10 on 30.0% of the days for the period WY2001–WY2017 (**Table 8C-6**). Although these were the same values as observed in WY2017, salinity was less than 10 or within the suitable envelope for *V. americana* requires (< 10) for 92.6% of the time in WY2015 and 99.2% of the time I WY2016.

Table 8C-6. Summary of daily average surface salinity at the Ft. Myers station (S_{FtM}) categorized based on a salinity target of 10 for American *V. americana*. Shown are the percentage of days (%) where S_{FtM} was less or greater than 10 for the long-term POR WY2001–WY2017, and WY2015, WY2016, and WY2017.

Period	% S_{FtM} < 10	% S_{FtM} ≥ 10
WY2001–WY2017	70.0%	30.0%
WY2015	92.6%	7.4%
WY2016	99.2%	0.8%
WY2017	70.0%	30.0%

Total annual freshwater inflow to the CRE ranged from ~1.5 to 3.0 million ac-ft in WY2015, WY2016, and WY2017 (**Table 8C-7** and **Figure 8C-18A**). The long-term average for the period WY2000–WY2017 was ~1.9 million ac-ft with 47.9% of the inflow contributed by the C-43 basin (**Figure 8C-19A**). The total inflow of 2.9 million ac-ft in WY2017 was the highest since WY2014 with only 32.1% derived from the C-43 basin (**Table 8C-7** and **Figure 8C-19A**). Approximately equal freshwater input from Lake Okeechobee and the Tidal Basin (~1.0 million ac-ft) increased the relative contributions of those two Tier 1 Contributing Areas in WY2017 to 34.9 and 33.1%, respectively. The percentage from Lake Okeechobee was higher in WY2017 (34.9%) compared to the long-term average of 25.9% with most of the regulatory releases occurring in the wet season (**Figure 8C-19A**).

Table 8C-7. Summary of freshwater inflow, TN loads, and TP loads from Lake Okeechobee, the C-43 basin, and the Tidal Basin (ungauged) to the CRE. Data categorized by the long-term averages (WY2000–WY2017) and values for WY2015, WY2016, and WY2017.

		WY 2000-2017	WY2015	WY2016	WY2017
Inflow (10 million ac-ft)	**Total**	**1.859**	**1.437**	**2.377**	**2.897**
	Lake Okeechobee	0.594	0.489	0.846	1.010
	C-43 Basin	0.869	0.748	0.960	0.929
	Tidal Basin	0.395	0.200	0.570	0.958
TN Load (t)	**Total**	**3,006.4**	**2,078.9**	**3,566.5**	**3,416.8**
	Lake Okeechobee	1,044.2	725.2	1,589.5	1,559.2
	C-43 Basin	1,516.9	1,171.2	1,349.7	1,464.7
	Tidal Basin	445.3	182.5	627.3	392.9
TP Load (t)	**Total**	**287.9**	**215.5**	**301.7**	**317.4**
	Lake Okeechobee	69.6	47.7	105.9	103.9
	C-43 Basin	175.6	144.9	140.0	175.1
	Tidal Basin	42.7	22.9	55.8	38.4

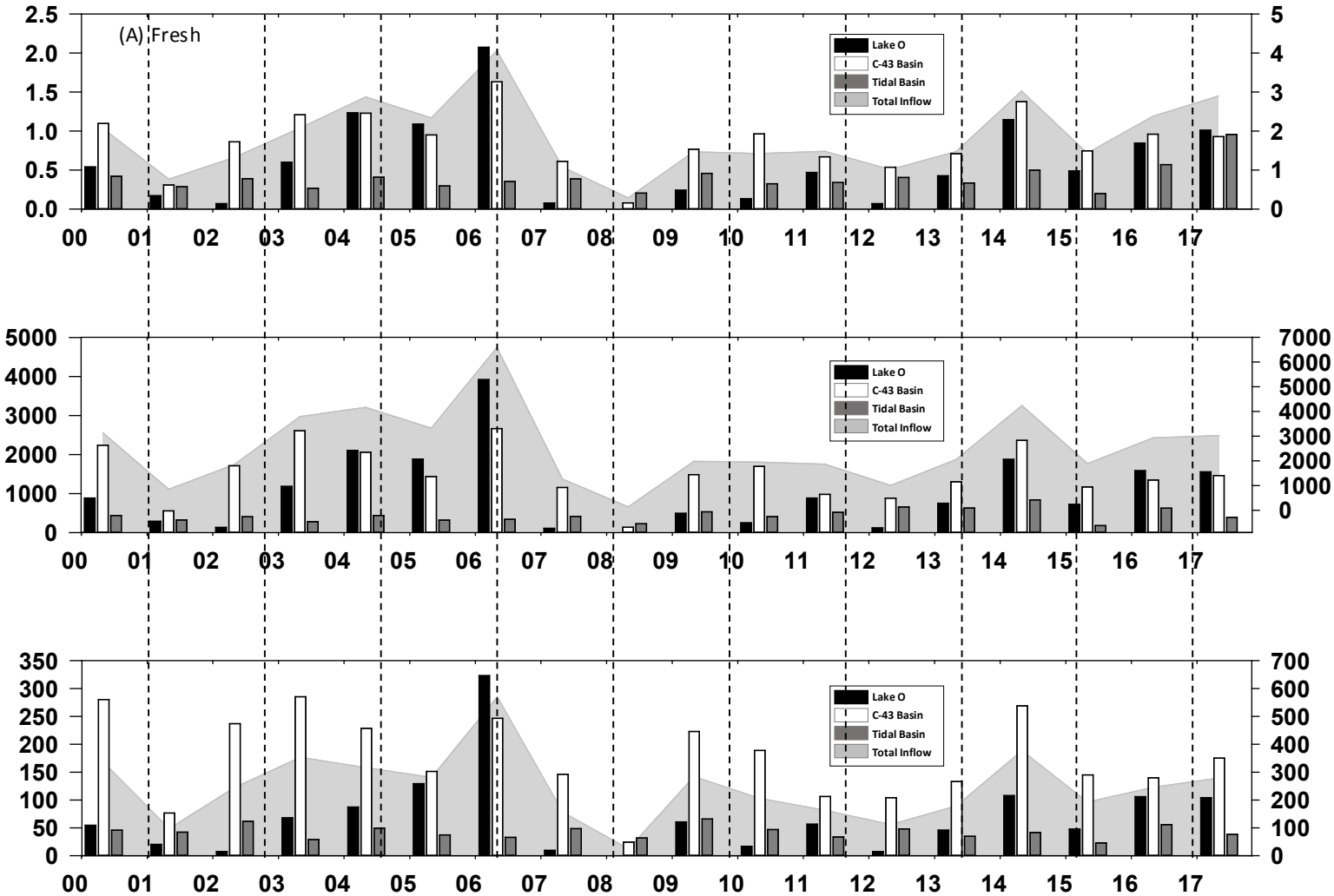

Figure 8C-18. Time series of (A) annual freshwater inflow, (B) TN loading, and (C) TP loading to the CRE for the period WY2000–WY2017. The left y-axis in each corresponds to the annually grouped bars categorizing the inflow among the Lake Okeechobee (black fill), St. Lucie Basin (white fill), and Tidal Basin (dark grey fill) Contributing Areas. The right y-axis is the total annual inflow or nutrient loads (light grey area fill).

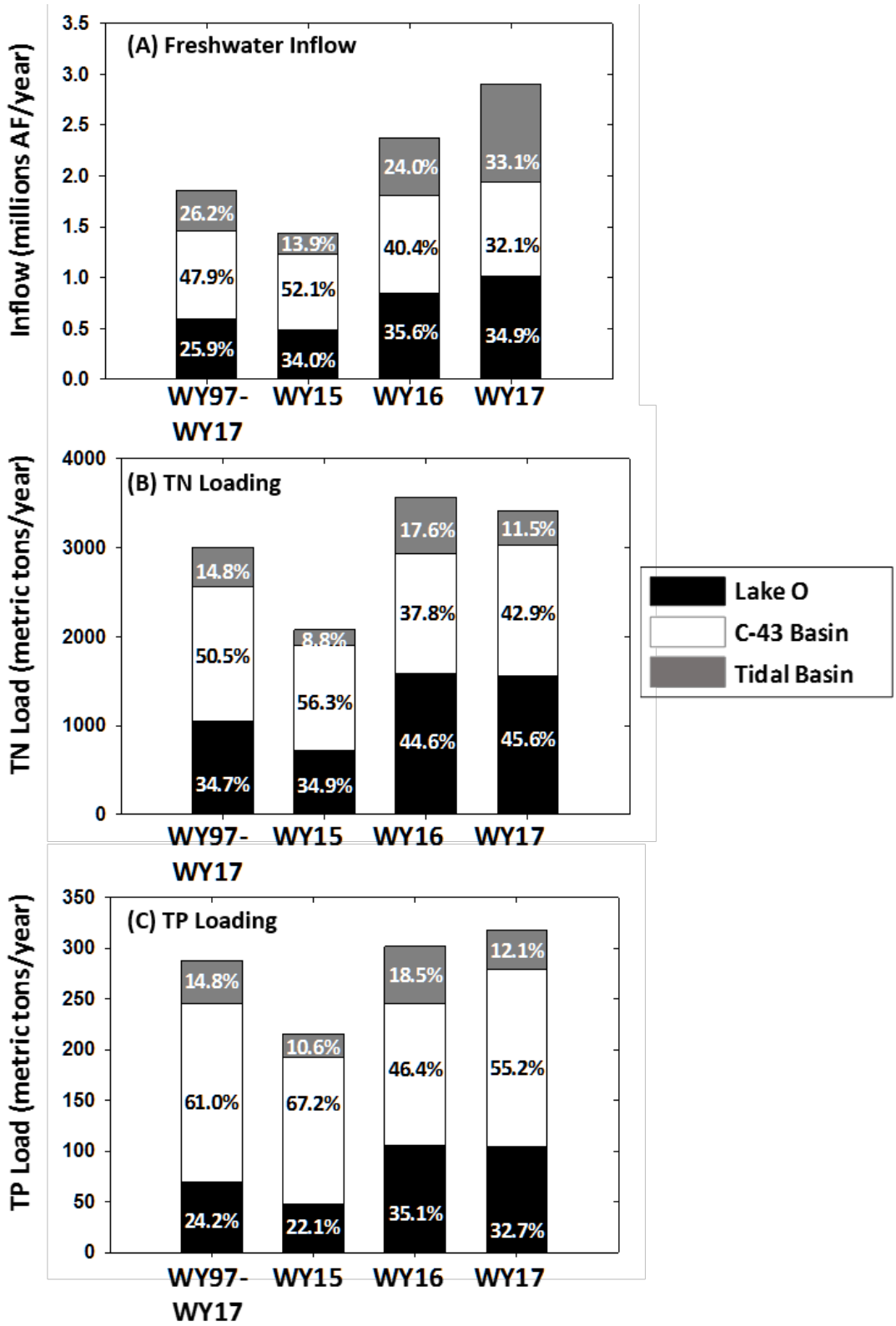

Figure 8C-19. Stacked bar chart for the (A) total freshwater inflow, (B) TN loading, and (C) TP loading attributable to Lake Okeechobee, the C-43 basin, and the Tidal Basin. It includes the long-term average for the period WY2000–WY2017, and WY2015, WY2016, and WY2017.

TN and TP Loads

The annual loading of TN and TP to the CRE fluctuated with total freshwater inflow for the period WY2000–WY2017 (**Figure 8C-18B**). TN loads averaged 3,000.6 t/yr during that period with values of 2078.9 t, 3566.5 t, and 3416.8 t in WY2015, WY2016, and WY2017, respectively (**Figure 8C-19B** and **Table 8C-7**). Although annual TN supplied by the C-43 basin in WY2017 was similar to the long-term average (1,516.9 versus 1,464.7 t; **Table 8C-7**), the relative percentage from this Tier 1 Contributing Area was less (50.5 versus 42.9%; **Figure 8C-19B**). In contrast, TN loading from Lake Okeechobee in WY2017 increased to 1,559.2 t compared to the long-term average of 1,044.2 t. This level of TN loading increased the relative contribution of the lake from 34.7 to 45.6%. Despite the increased freshwater inflow from the Tidal Basin, it accounted for less than the average mass and percentage of the TN loading to the estuary. These results suggest that under certain conditions Lake Okeechobee can be a significant source of TN to the CRE.

TP loads averaged 287.9 t/yr for the period WY2000–WY2017 with values of 215.5 t, 301.7 t, and 317.4 t in WY2015, WY2016, and WY2017, respectively (**Figure 8C-18C** and **Table 8C-7**). Although annual TP supplied by the C-43 basin in WY2017 was similar to the long-term average (175.6 versus 175.1 t; **Table 8C-7**), the relative percentage from the Tier 1 Contributing Area was less (61.0 versus 55.2%; **Figure 8C-19C**). In contrast, TP loading from Lake Okeechobee in WY2017 increased to 103.9 t compared to the long-term average of 69.6 t. This level of TP loading increased the relative contribution of the lake from 24.2 to 32.7%. Despite the increased freshwater inflow from the Tidal Basin, it accounted for less than the average mass and percentage of the TP loading to the estuary. These results suggest that, under certain conditions, Lake Okeechobee can be a significant source of TP to the CRE. However, the ecosystem metabolism of the CRE does not demonstrate strong sensitivity to increased P loading (Buzzelli et al. 2013b).

Estuary Water Quality

TN concentrations ranged from < 1.0 to 4-5 mg/L at stations CES04 and CES06 and from < 0.5 to 1.5 mg/L at station CES08 in the CRE (**Figure 8C-20**). The long-term average concentrations were 1.19 mg/L (CES04), 0.93 mg/L (CES06), and 0.50 mg/L (CES08; **Table 8C-8**). The long-term seasonal averages indicated that TN concentrations were greater in the wet season at all three stations. However, this was not always the case in WY2015, WY2016, or WY2017. TN concentrations in WY2017 were similar to the long-term averages at all three stations. It appeared that TN at downstream station CES08 responded to freshwater inflow (**Figure 8C-20**; Buzzelli et al. 2013b). This response was evident in the a comparatively high average TN concentration in both seasons of WY2016 (0.74 ± 0.25 mg/L; **Table 8C-8**).

TP concentrations ranged from < 0.1 to 0.7 mg/L at stations CES04 and CES06 and from < 0.1 to 0.45 mg/L at station CES08 in the CRE (**Figure 8C-20**). The long-term average concentrations were 0.13 mg/L (CES04), 0.10 mg/L (CES06), and 0.07 mg/L (CES08; **Table 8C-8**). TP concentrations were greater in the wet season than the dry season at all three stations. TP concentrations in WY2017 were slightly less than the long-term averages at all three stations. Overall, while TP concentrations are reduced in the lower CRE (e.g., station CES08), TP exhibits little intra- and interannual variability in the CRE (Buzzelli et al. 2013b).

Chla concentrations ranged from 1.0 to 100.0 µg/L at stations CES04 and CES06 and from 1.0 to 20.0 µg/L at station CES08 in the CRE from WY2000 through WY2017 (**Figure 8C-20**). The long-term average concentrations were 10.0 ± 13.6 µg/L (CES04), 9.1 ± 11.5 µg/L (CES06), and 3.4 ± 3.1 µg/L (CES08; **Table 8C-8**). Chla concentrations were greater in the wet season than the dry season at all three stations except at stations CES06 and CES08 in WY2016. Despite this reversal in seasonality at the two lower stations, the average seasonal concentrations in WY2017 were much less than the long-term averages at all three stations.

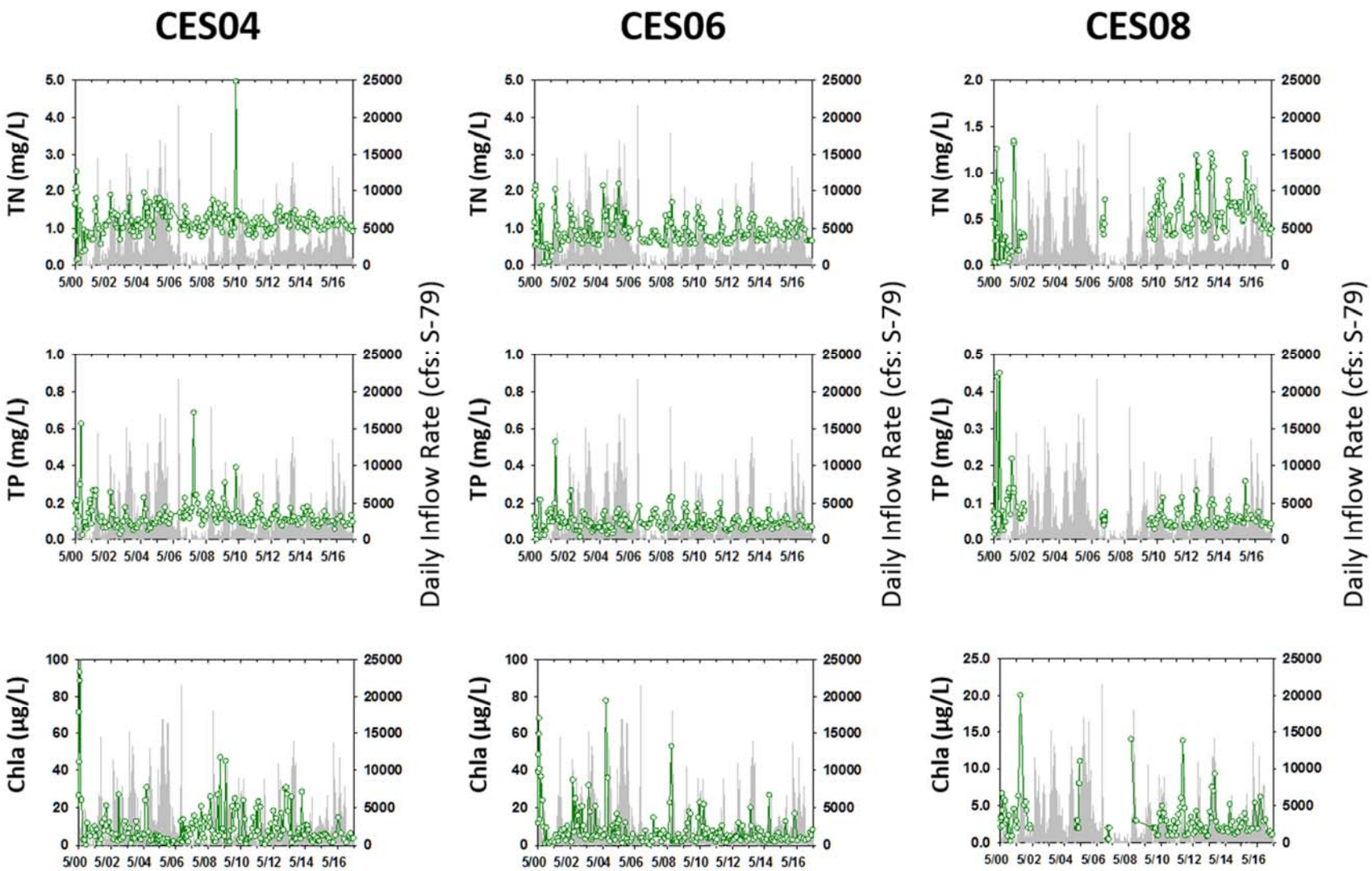

Figure 8C-20. Time series of Chla, TN, and TP (green lines with open circles) at stations CES04, CES06, and CES08 in the CRE for the period WY2000–WY2017. The grey fill is total gauged inflow shown on right y-axis. Chlorophyll *a* concentrations were not determined for some sampling dates at station CES08.

Table 8C-8. Summary of water column concentrations Chla, TN, and TP at three stations (CES04, CES06, and CES08) in the CRE; includes dry season (November–April), wet season (May–October), and total averages and standard deviations (average ± SD) from WY2000 through WY2017 and average values for WY2015, WY2016, and WY2017.

CES04									
	Chla (µg/L)			TN (mg/L)			TP (mg/L)		
	Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Average ± SD	8.5 ± 7.7	11.5 ± 17.6	10.0 ± 13.6	1.13 ± 0.47	1.25 ± 0.37	1.19 ± 0.43	0.11 ± 0.05	0.16 ± 0.09	0.13 ± 0.08
WY2015	3.8 ± 1.5	6.4 ± 4.2	5.1 ± 3.3	1.15 ± 0.15	1.15 ± 0.21	1.15 ± 0.18	0.09 ± 0.01	0.15 ± 0.02	0.12 ± 0.03
WY2016	3.0 ± 2.2	4.9 ± 1.0	4.2 ± 1.7	1.16 ± 0.08	1.07 ± 0.08	1.10 ± 0.09	0.09 ± 0.03	0.12 ± 0.03	0.11 ± 0.03
WY2017	4.1 ± 1.8	8.3 ± 6.0	5.7 ± 4.1	1.01 ± 0.07	1.18 ± 0.09	1.08 ± 0.11	0.10 ± 0.02	0.11 ± 0.02	0.10 ± 0.02

CES06									
	Chla (µg/L)			TN (mg/L)			TP (mg/L)		
	Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Average ± SD	6.9 ± 7.2	11.4 ± 14.3	9.1 ± 11.5	0.78 ± 0.28	1.08 ± 0.38	0.93 ± 0.37	0.08 ± 0.03	0.12 ± 0.06	0.10 ± 0.06
WY2015	4.1 ± 1.7	7.2 ± 9.7	5.7 ± 6.8	0.90 ± 0.09	0.92 ± 0.25	0.91 ± 0.18	0.08 ± 0.01	0.12 ± 0.04	0.10 ± 0.03
WY2016	7.7 ± 8.1	5.1 ± 4.5	6.1 ± 5.7	0.98 ± 0.18	0.94 ± 0.19	0.96 ± 0.17	0.08 ± 0.01	0.11 ± 0.01	0.10 ± 0.02
WY2017	5.5 ± 2.3	3.6 ± 0.8	4.8 ± 2.0	0.73 ± 0.13	0.99 ± 0.21	0.83 ± 0.20	0.07 ± 0.00	0.11 ± 0.03	0.08 ± 0.02

CES08									
	Chla (µg/L)			TN (mg/L)			TP (mg/L)		
	Dry	Wet	Total	Dry	Wet	Total	Dry	Wet	Total
Average ± SD	2.5 ± 2.2	4.6 ± 3.7	3.4 ± 3.1	0.43 ± 0.21	0.58 ± 0.34	0.50 ± 0.29	0.06 ± 0.03	0.08 ± 0.08	0.07 ± 0.06
WY2015	-	-	-	-	-	-	-	-	-
WY2016	3.0 ± 2.1	2.7 ± 1.0	2.8 ± 1.4	0.73 ± 0.14	0.75 ± 0.31	0.74 ± 0.25	0.06 ± 0.01	0.08 ± 0.05	0.07 ± 0.04
WY2017	1.7 ± 0.8	3.7 ± 2.0	2.4 ± 1.7	0.42 ± 0.07	0.50 ± 0.11	0.45 ± 0.09	0.04 ± 0.00	0.06 ± 0.02	0.05 ± 0.01

SAV

SAV monitoring Site 2 in the upper CRE had a combination of *Ruppia maritima* (widgeon grass) and *Vallisneria americana* (tape grass). Widgeon grass can withstand a broad salinity range from 0 to 70 but survives best when salinity is 10 to 20 (Murphy et al. 2003, Strazisar et al. 2015). In contrast, as a freshwater and oligohaline SAV salinity values greater than 10.0 can be damaging to the survival of *V. americana*. Bourn (1932, 1934) reported that growth stopped at 8.4, while Boustany et al. (2010) found limited growth at 8.0. Haller (1974) reported growth at 10.0 but death at 13.3. While growth was minimal or zero when salinities ranged from 10.0 to 15.0, values > 15.0 caused mortality (Haller 1974, Doering et al. 2001, 2002, French and Moore 2003, Frazier et al. 2006, Boustany et al. 2010, Lauer et al. 2011).

The total seagrass cover varied at Site 2 reaching a maximum of ~5% (Braun-Blanquet score of 1.5) from WY2015 to WY2017 (**Figure 8C-21A**). Widgeon and *V. americana* had approximately equal spatial cover estimates although the density was low (1 to 5% cover category). *V. americana* has exhibited modest increases in cover since May 2014 (WY2015) as freshwater inflow increased.

SAV monitoring Site 8 in the lower CRE had a combination of *Halodule wrightii* (shoal grass) and *Thalassia testudinum* (turtle grass). Shoal grass is adapted to a broad salinity range (Doering et al. 2002; Buzzelli et al. 2014). In contrast, turtle grass survives best with oceanic salinity and submarine light levels (Doering and Chamberlain 2000). Overall, the SAV community is much denser at Site 8 than the upstream Site 2 (**Figure 8C-21B**). Peak seagrass cover at Site 8 from WY2012 to WY2017 occurred during the WY2014 and WY2015 wet seasons with turtle grass as the dominant species. Seagrass cover declined slightly in the WY2015 and WY2016 wet seasons but appeared to stabilize in WY2017.

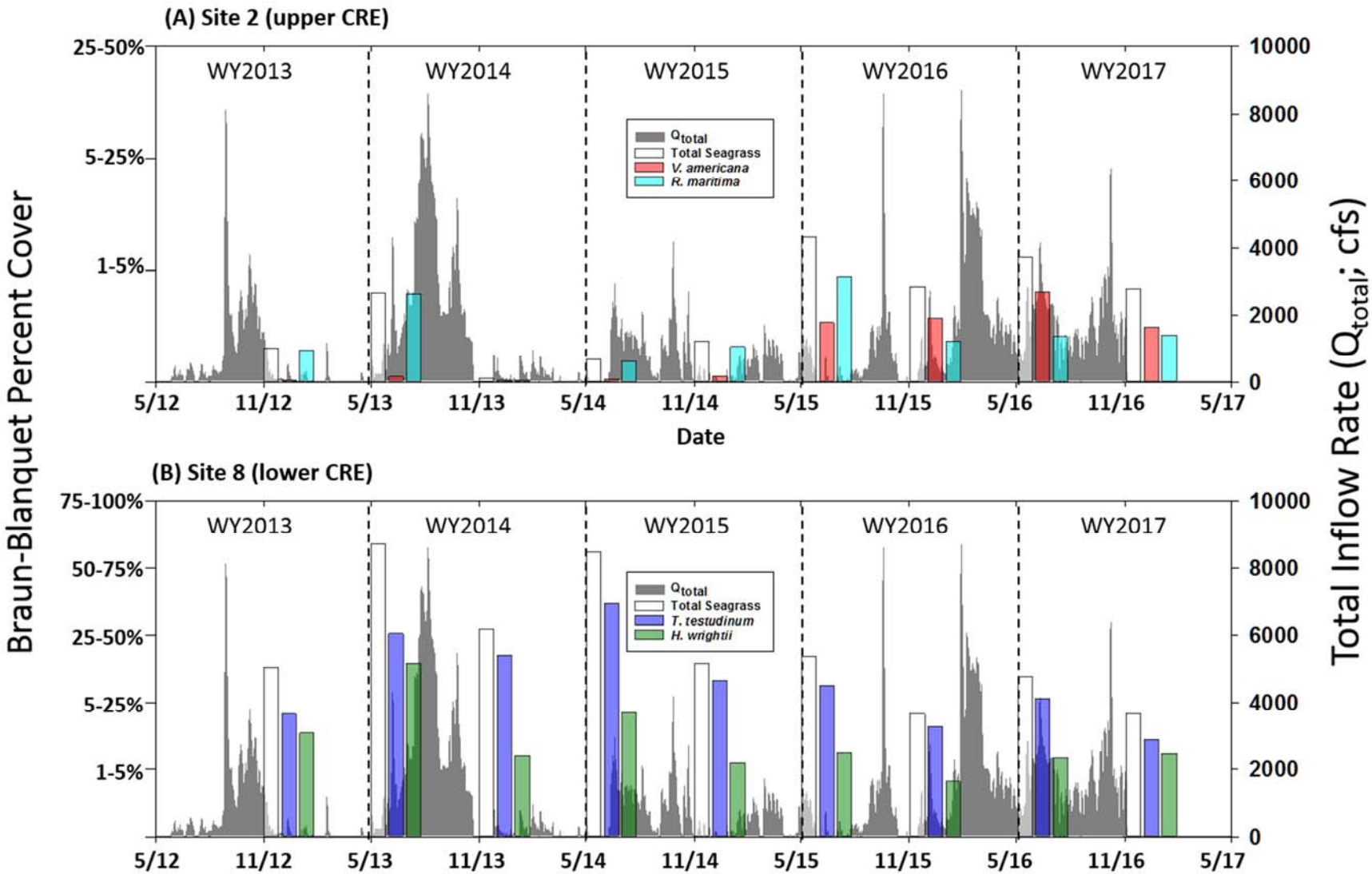

Figure 8C-21. Time series of Braun-Blanquet cover estimates for SAV at (A) Site 2 and (B) Site 8 from the period WY2013–WY2017. Seasonal estimates provided for total SAV cover (white fill) and individual species (colored fill). The right y-axis depicts daily freshwater inflow rate to the CRE (grey area fill).

Oyster Habitat

Seasonally averaged live oyster density at Bird Island near the mouth of the CRE varied from 500 to 3,500 oysters/m^2 from WY2006 to WY2017 (**Figure 8C-22A**). Oyster density reached the maximum in the WY2013 dry season before decreasing to ~1,500 oysters/m^2 in WY2015 and WY2016 (**Figure 8C-22A**). There appeared to be a slight increase in average live oyster density in WY2017 (> 2,000 oysters/m^2). Overall, oyster density was similar between the dry and wet seasons.

The monthly average rate of oyster larval settlement ranged from 0 to 150 spat/shell/month at Bird Island from WY2006 to WY2017 (**Figure 8C-22B**). Maximum rates of spat fall usually occur in the late wet season with values in the range of 20 to 70 spat/shell/month typical from WY2014 to WY2017. Spat settlement appeared to increase from the end of WY2016 into WY2017.

The intensity and prevalence of the oyster marine parasite dermo were combined into a single unitless metric (weighted prevalence) and averaged seasonally (**Figure 8C-22C**). This value ranged from 1.0 to 3.0 from WY2006 to WY2017. The metric was generally low (≤ 1.0) except during the drought conditions of WY2012–WY2013. It was at a comparatively low level (< 0.5) into WY2017.

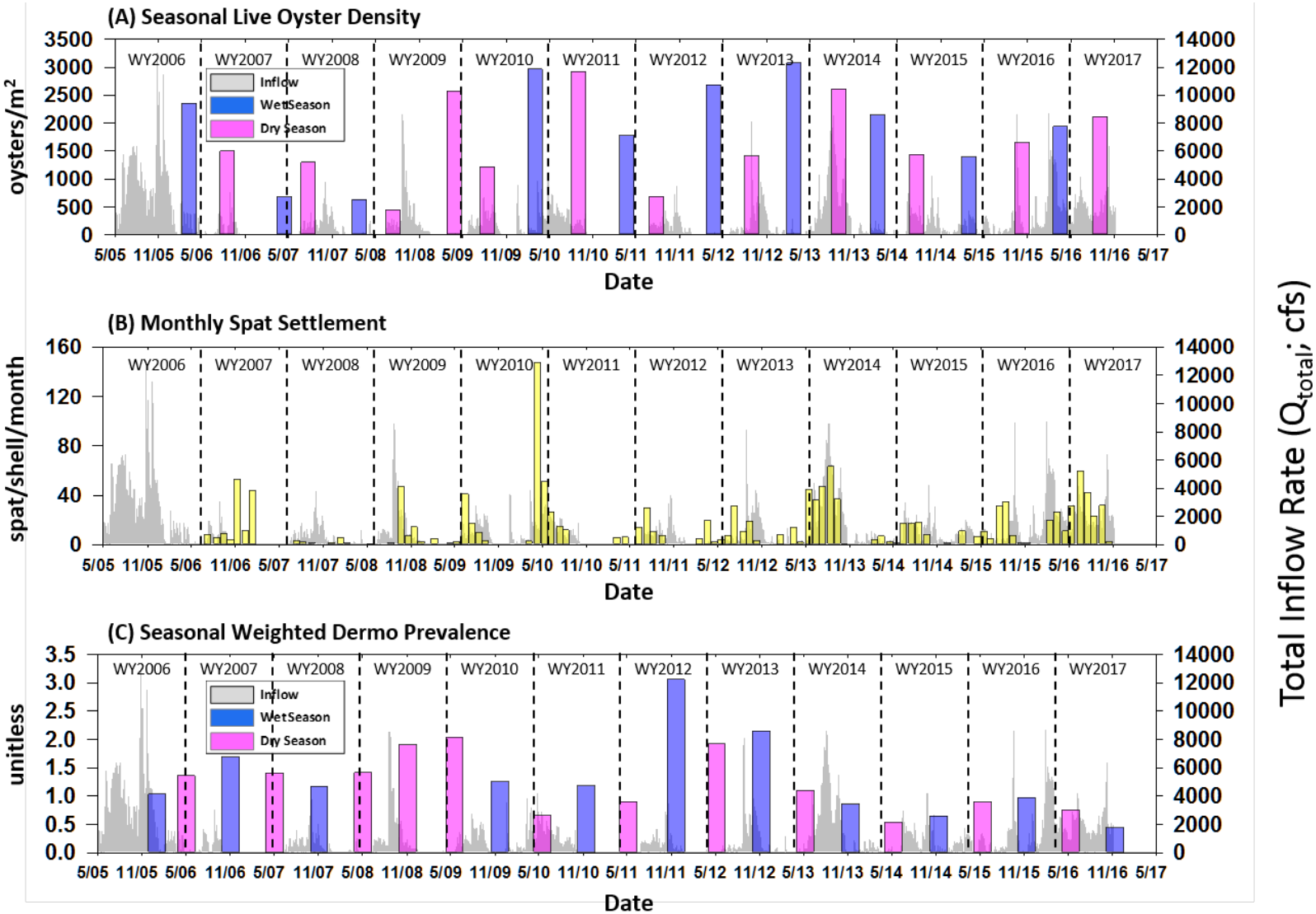

Figure 8C-22. Time series of oyster monitoring metrics from the Bird Island in the lower CRE from the period WY2006–WY2017. (A) Seasonal average of live oyster density. (B) Monthly spat settlement rate. (C) Seasonal average of weighted dermo prevalence (see Methods for details). The right y-axis depicts daily freshwater inflow rate to the CRE (grey area fill).

SUMMARY

- Rainfall across the C-43 Watershed and Tidal Basin in WY2017 was less than the average from WY1997 to WY2017 with 90% occurring in the wet season from May to November 2016.
- Freshwater inflow to the CRE in WY2017 (2.9 million acre-feet) was greater than the long-term average from WY2000 to WY2017 (1.9 million acre-feet). However, the contribution from Lake Okeechobee (1.0 million acre-feet and 34.9% of the total) was greater than the long-term values (0.59 million acre-feet and 25.9%)
- TN loading to the CRE in WY2017 (3,416.8 t) was greater than the long-term average from WY2000 to WY2017 (3,006.4 t). The annual TN contribution from Lake Okeechobee increased from a long-term average of 1,044.2 t to 1,559.2 t in WY2017.
- TP loading in WY2017 (317.4 t) was slightly greater than the long-term average (287.9 t) although the contribution of Lake Okeechobee was greater (103.9 t versus 69.6 t).
- The average concentrations of TN, TP, and Chla in WY2017 at three stations along the length of the CRE were less than the long-term values from WY2000 to WY2017. Dry and wet season average Chla concentrations at the two upper stations were approximately half of the long-term averages.
- The SAV community at Site 2 in the upper CRE was composed of *Ruppia maritima* (widgeon grass) and *V. americana* (tape grass) with a total coverage of ~5% of the bottom in WY2017. Although sparse, *V. americana* cover has increased with freshwater inflow since WY2015. SAV monitoring Site 8 in the lower CRE continued to be vegetated by stable communities of *Halodule wrightii* (shoal grass) and *Thalassia testudinum* (turtle grass)
- There were ~2,000 oysters/m^2 at Bird Island in the lower CRE in WY2017 with higher density in the dry season. While larval recruitment (e.g., "spat settlement") appeared to increase, the weighted prevalence of the oyster marine parasite (Dermo) was comparatively low in WY2017.

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