Chapter 8C: St. Lucie and Caloosahatchee River Watersheds Annual Report

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SUMMARY

As required by the Northern Everglades and Estuaries Protection Program (NEEPP), the South Florida Water Management District (SFWMD or District), in coordination with the Florida Department of Environmental Protection (FDEP) and Florida Department of Agriculture and Consumer Services (FDACS), continues to implement the comprehensive Research and Water Quality Monitoring Programs (RWQMPs) for the St. Lucie and Caloosahatchee estuaries and their river watersheds in accordance with Subsection 373.4595(6), Florida Statutes (F.S.). Various programs were initiated, completed, or continued in Water Year 2019 (WY2019; May 1, 2018–April 30, 2019). In addition, the St. Lucie River Watersheds' water quality monitoring results for total phosphorus (TP) and total nitrogen (TN) by basin are presented in Appendix 8C-1 of this volume. This chapter, in conjunction with Chapters 8A and 8B of this volume, fulfills reporting requirements outlined in the NEEPP legislation.

St. Lucie Estuary

WY2019 represented an average year relative to the long-term average of the period of record (POR; WY1997–WY2019) for rainfall and freshwater inflow to the St. Lucie Estuary (SLE). The percentage of rainfall recorded by season in WY2019 was similar to the percentage observed in the wet (May–October; 74%) and dry (November–April; 26%) seasons of the long-term average. The total annual freshwater inflow to the SLE in WY2019, 0.87 million acre-feet (ac-ft), was lower than the long-term average of 1.01 million ac-ft. The total inflow and percent contribution from Lake Okeechobee in WY2019 (0.31 million ac-ft, 36%) were greater than the long-term average (0.27 million ac-ft, 27%).

In WY2019, 1,206 metric tons (t) TN and 216 t TP was loaded into to the SLE, which were both lower than the long-term average of 1,759 t TN and 320 t TP. The greatest contribution to TN loading in WY2019 was from Lake Okeechobee (45%) followed by the St. Lucie Watershed (40%), which differed from the relative source contributions of TP loading where the highest contribution was from St. Lucie Watershed (58%) followed by Lake Okeechobee (34%). The magnitude of TN and TP load from the Tidal Basin in WY2019 (179 and 17 t, respectively) was the lowest of the past three water years and less than the long-term average (296 t TN and 44 t TP).

Average chlorophyll *a* (Chla) concentration for WY2019 at stations HR1 (North Fork), SE03 (Roosevelt Bridge), and SE11 (St. Lucie Inlet) were 12.95, 7.55, and 4.87 micrograms per liter (µg/L), respectively, which were similar to the long-term averages. Average annual TN and TP concentrations in WY2019 were lower than the long-term average values for each station. In WY2019, the concentrations of Chla, TN, and TP were greater in the wet season than in the dry season.

Salinity at the Roosevelt Bridge along US 1 was within the > 10 to ≤ 26 salinity envelope for the eastern oyster (*Crassostrea virginica*), for 63% of the days in WY2019, which was greater than the long-term average (61%) and the past two water years: WY2018 (46%) and WY2017 (37%). Average live oyster

density increased in the WY2019 dry season, with an average of 510 live oysters per square meter (m^2) in March 2019, similar to the pre-Hurricane Irma levels of WY2017.

Caloosahatchee River Estuary

The total annual rainfall across the Caloosahatchee River Estuary (CRE) and the Caloosahatchee River Watershed in WY2019 was similar to the long-term average (WY1997–WY2019). The percentage of rainfall recorded in the WY2019 wet season (74%) was slightly lower than the percentage observed in over the long-term (79%). Contributions of total freshwater inflow from Lake Okeechobee, C-43 Basin, and Tidal Basin exceeded long-term averages. The total annual freshwater inflow to the CRE (2.23 million ac-ft) was greater than the long-term average (1.9 million ac-ft).

TN loading to the CRE in WY2019 (3,811 t) was more than the long-term average (3,102 t). The magnitude of TN supplied in WY2019 by the C-43 Basin was 1,852 t (49%) and by the Tidal Basin was 572 t (15%). The input of TN from Lake Okeechobee in WY2019 was 282 t more than the long-term average. However, the percent contribution of TN from Lake Okeechobee in WY2019 (37%) remained consistent with the long-term contribution of 36% to the total flow discharging to the Caloosahatchee River Watershed.

TP loading in WY2019 was 110 t more than the long-term average of 303 t. The greatest contribution of TP loading in WY2019 was from the C-43 Basin at 53%, which was less than the long-term average of 59%. The magnitude and percent contribution of Lake Okeechobee to TP loading in WY2019 (131 t, 32%) were higher than the long-term average loading and percent contribution (76 t, 25%).

The annual average concentrations of TN at stations along the estuary (CES04, CES06, and CES08) in WY2019 were above the long-term average (WY2000–WY2019), while TP was similar to the long-term average. In WY2019, the concentrations of TN and TP were greater in the wet than in the dry season. WY2019 average Chla concentrations at the upper (CES04) and middle (CES06) estuary sites were lower relative to the long-term average.

A salinity envelope of 0 to < 10 has been set for tape grass (*Vallisneria americana*) in the upstream portion of the estuary. Salinity was < 10 at the Ft. Myers monitoring station 94% of the total days of WY2019, more than the previous two water years. Live oyster density at both the Iona Cove (406 live oyster/ m^2) and Bird Island (1,073 live oyster/m^2) stations in the CRE in the WY2019 dry season exhibited similar values to those in the dry season pre-hurricane Irma (WY2017), though numbers were comparatively lower than the previous four water years. At both stations, there was an abnormally high peak in spat settlement in the WY2019 wet season occurring in September 2018, with average spat per shell settlement higher than that of the previous five years.

ST. LUCIE ESTUARY AND RIVER WATERSHED CONDITIONS

BACKGROUND

The SLE and St. Lucie River Watershed are located in southeastern Florida in Martin and St. Lucie counties, and are tributaries to the Southern Indian River Lagoon (**Figure 8C-1**; Ji et al. 2007, SFWMD et al. 2009, Buzzelli et al. 2012). 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 to the Atlantic 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 with semi-diurnal tides of 1.25-foot (ft; 0.38-meter [m]) average tidal amplitude. Total surface area of the estuary is 11.2 square miles (29.0 square kilometers) or 7,168 acres (2,903 hectares) with an average depth of 7.87 ft (2.4 m) (Buzzelli et al. 2013a). The mean flushing time of the SLE is 7 days and it ranges from approximately 2 to 20 days (Ji et al. 2007, Buzzelli et al. 2013b). The SLE is geographically divided into four distinct segments: North Fork, South Fork, Middle Estuary, and Lower Estuary, which is located adjacent to the St. Lucie Inlet.

The SLE receives drainage from a comparatively large watershed area, as the ratio between the St. Lucie Basin area and SLE surface area is approximately 100:1 (e.g., Tampa Bay has a ratio of 5.5:1). To accommodate population growth and coastal development, the St. Lucie Basin has been highly altered from the historical natural wetlands and sloughs into a managed system comprised of eight subbasins. Primary land use type within the St. Lucie Basin based on 2012 land use data is 52% agricultural, 19% urban, 11% wetlands, 7% upland forest, and 5% open water (SFWMD et al. 2018).

The combination of basin modifications, channelized freshwater inflow, and increased coastal population density have created a hydrodynamically and ecologically complex estuary with water quality (e.g., nitrogen and phosphorous loading, and Chla concentrations) and benthic habitat attributes that vary at seasonal, annual, and interannual scales (Cloern 2001, Buzzelli et al. 2013a, b). Previously documented water quality issues include extreme fluctuation in salinity, sedimentation, light reduction, nutrient enrichment, phytoplankton blooms, bottom water hypoxia, and increased prevalence of pathogens (Doering 1996, Millie et al. 2004, Phlips et al. 2012, 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 seagrass (Wilson et al. 2005, Buzzelli et al. 2012, Parker et al. 2013).

A suite of external drivers and ecological responses are monitored in the SLE (**Figure 8C-2**). External driver variables include rainfall, freshwater discharge, and nutrient loads, with patterns of salinity, estuarine nutrient concentrations, and benthic habitat condition as the estuarine ecological responses. Oyster monitoring data are also presented in this chapter. Submerged aquatic vegetation (SAV) is also monitored in the estuary with a newly expanded monitoring program; data are currently undergoing analyses and results will be presented in the next South Florida Environmental Report (SFER).

For inputs of fresh water and nutrients, the watershed was categorized into three basins: Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin (**Table 8C-1**). Each basin is composed of multiple subbasins. There are calculated inputs to the St. Lucie Basin 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; and a combination of measured and modeled inputs from Ten Mile Creek (TMC). Modeled inputs to the Tidal Basin are through the North Fork; Basin 4, 5, 6; and the South Fork (**Figure 8C-1**).

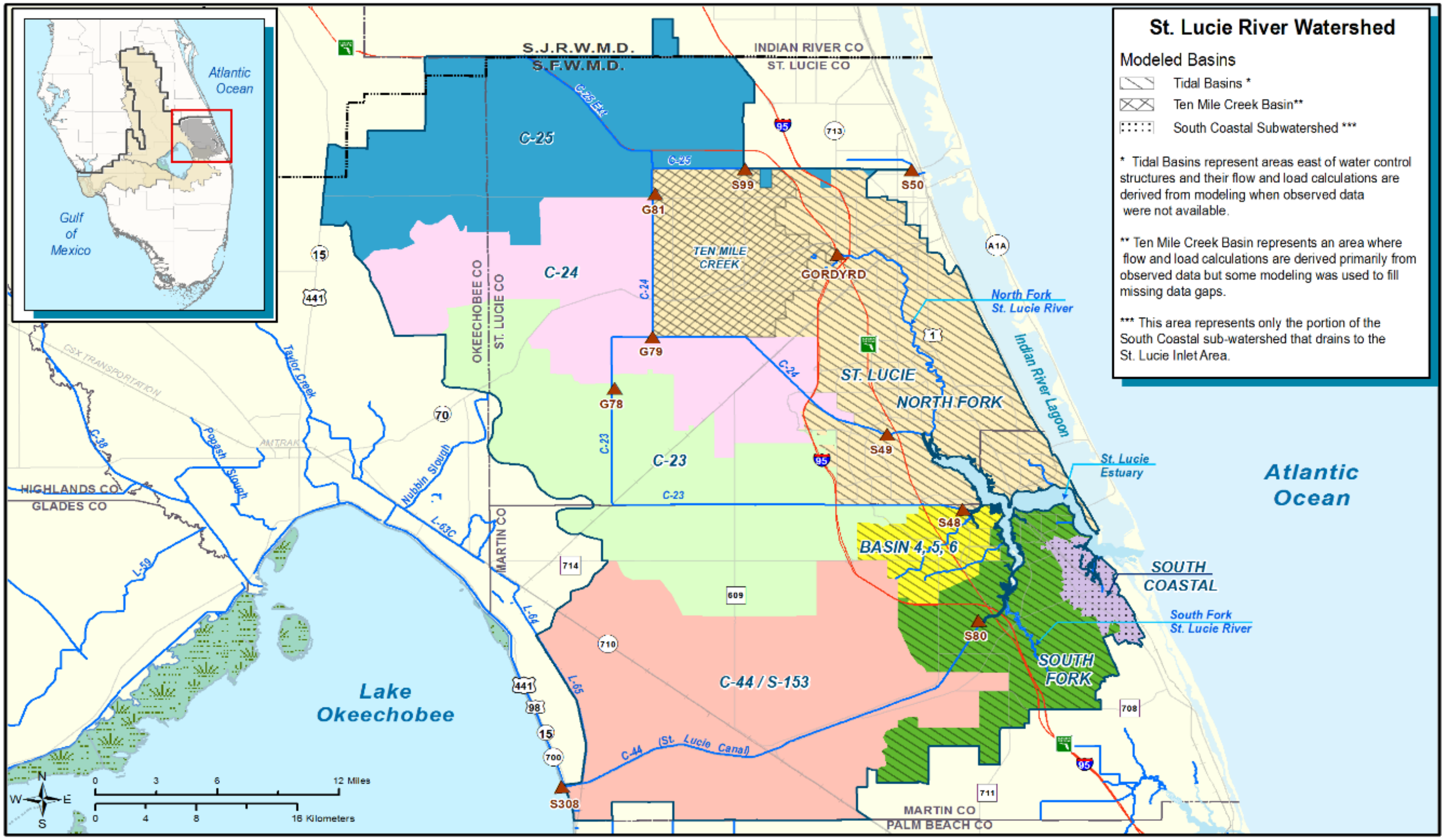

Figure 8C-1. The St. Lucie River Watershed with its basins and major water control structures. Modeled basin areas are also depicted.

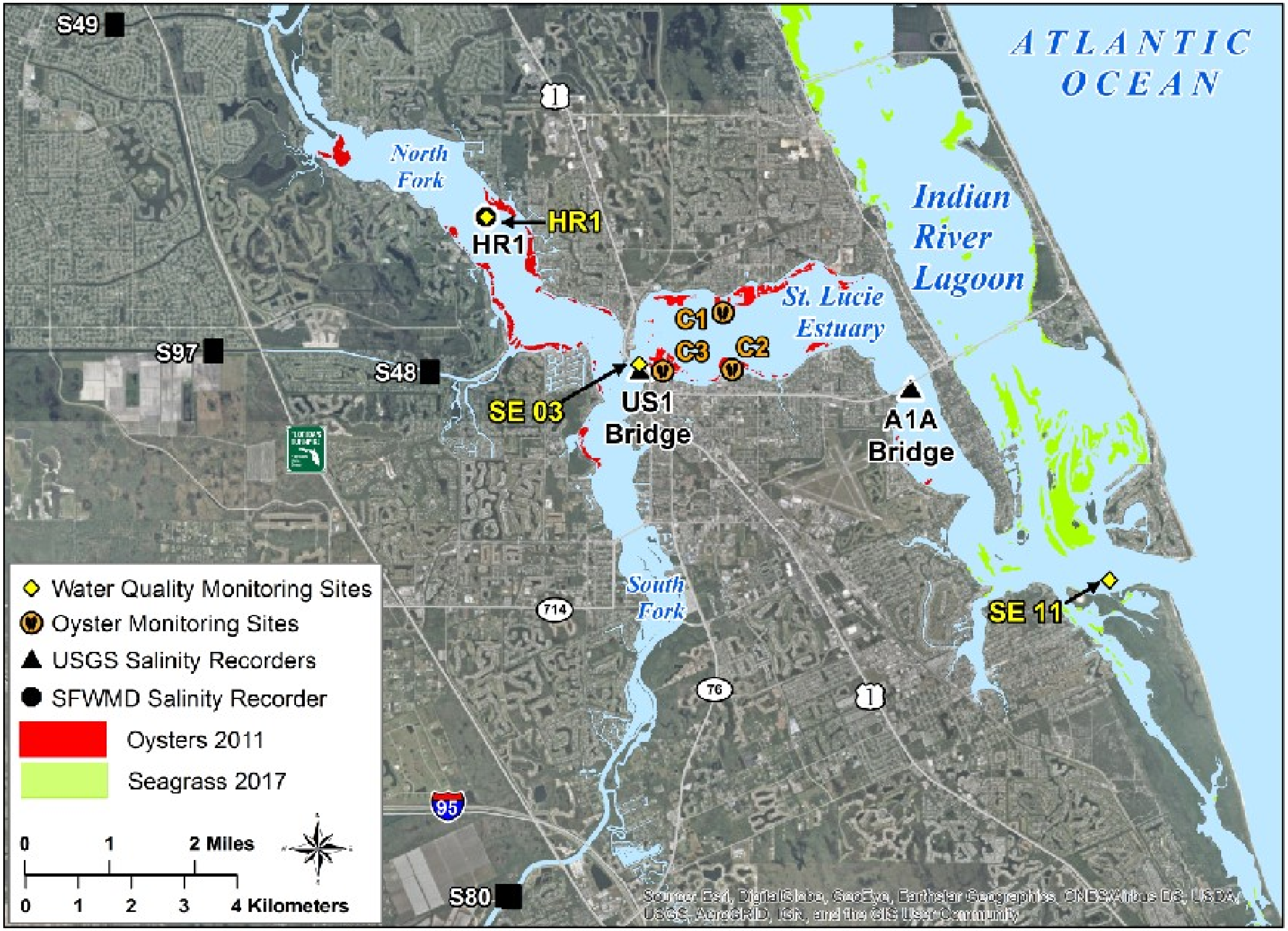

Figure 8C-2. Salinity, water quality, and oyster monitoring sites in the SLE.
The map also depicts distribution of seagrass habitat presence in the lower SLE and Southern Indian River Lagoon.

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

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

HYDROLOGY

Rainfall

Daily next generation radar (NEXRAD) rainfall data from WY1997 through WY2019 (long-term POR) for each subbasin of the St. Lucie River Watershed were downloaded from SFWMD's corporate environmental database, DBHYDRO (http://my.sfwmd.gov/nexrad2/nrdmain.action). The cumulative amount of rainfall was computed using area weighting, which accounts for the different sizes of the subbasins.

The daily rainfall over the past three water years (WY2017–WY2019) across the entire St. Lucie River Watershed is presented in **Figure 8C-3**. During that period, the daily rainfall ranged from 0 to 5.7 inches (0 to 146 millimeters [mm]). The maximum daily rainfall occurred on September 10, 2017, when Hurricane Irma made landfall (NHC 2018; **Figure 8C-3**) and was the second highest daily rainfall during the long-term POR.

In WY2019, total rainfall to the St. Lucie River Watershed was 52.8 inches (1,341 mm), 74% in the wet season and 26% in the dry season, which is similar to that of the long-term average (74% and 26% in the wet and dry season, respectively; **Figure 8C-4**). This was lower than WY2018 (67.3 inches or 1,708 mm), but higher than WY2017 (44.5 inches or 1,129 mm) and the long-term annual average (48.8 inches or 1,239 mm). During WY2019, it rained 261 days (72%), with 8 days having rainfall > 1.0 inch (25 mm). The passing of Hurricane Irma and other tropical storms resulted in WY2018 wet season rainfall (53.8 inches or 1,366 mm) higher than in the wet seasons of WY2017 and WY2019 (37.9 inches or 963 mm and 34.6 inches or 878 mm, respectively) and the long-term wet season average (36.2 inches or 920 mm).

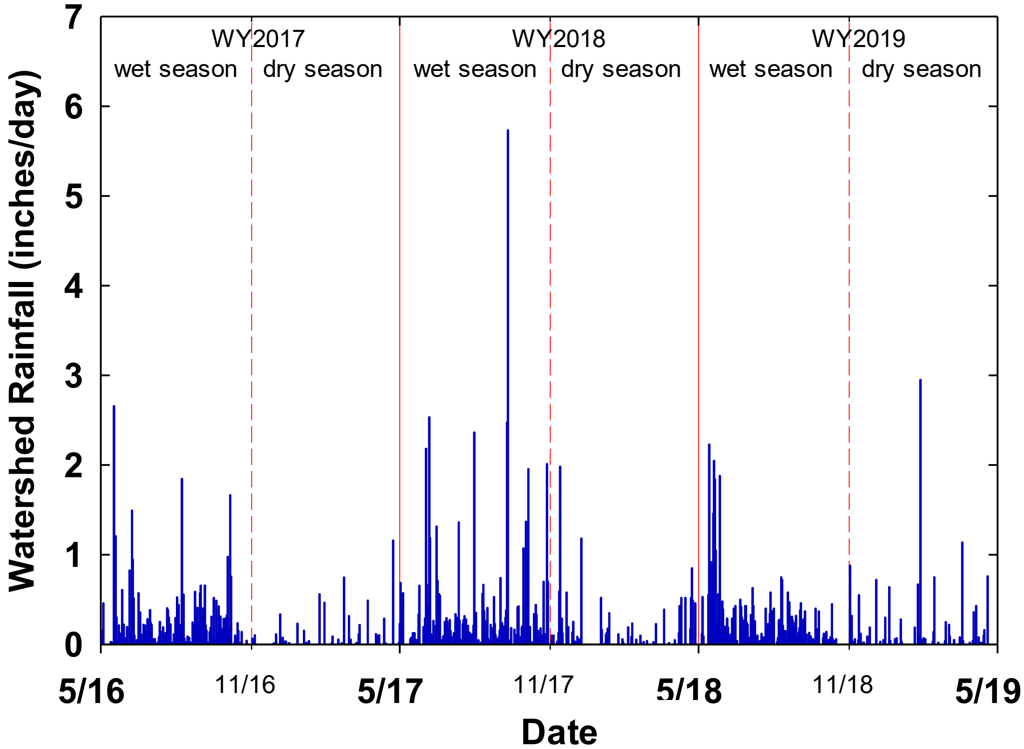

Figure 8C-3. Time series of total daily rainfall to the St. Lucie River Watershed from WY2017 through WY2019. The highest rainfall event during this three-year POR occurred during hurricane Irma on September 10, 2017.

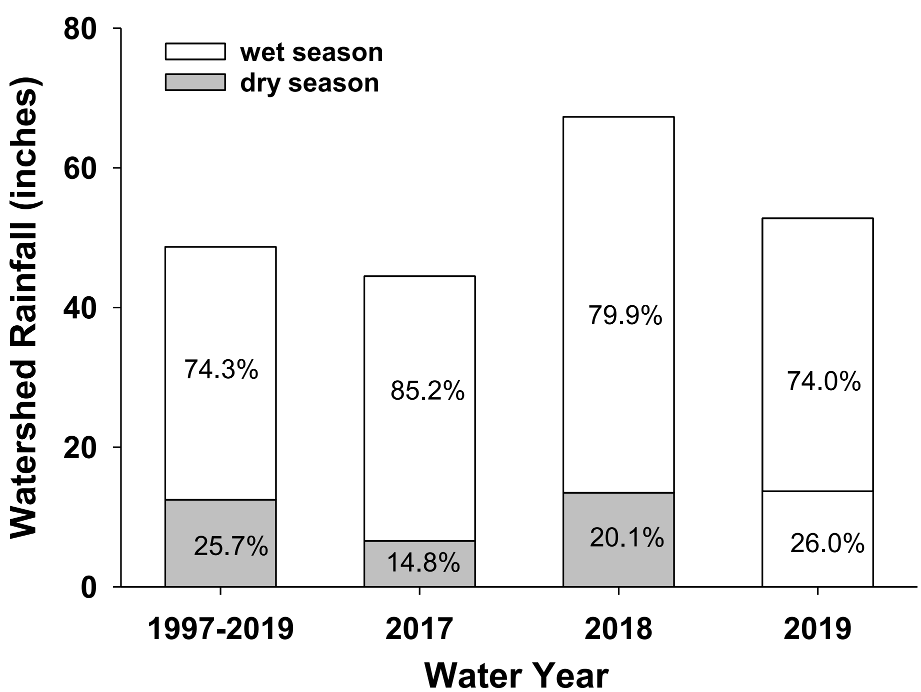

Figure 8C-4. Total rainfall in the St. Lucie River Watershed over the long-term average (WY1997–WY2019) and the past three water years (WY2017, WY2018, and WY2019) by season. The figure shows the percentage of annual total rainfall for each season.

The greatest rainfall in WY2019 occurred in the Tidal Basin (58.6 inches or 1,488 mm) and the least in the C-24 Subbasin (47.3 inches or 1,202 mm; **Figure 8C-5**). The long-term average watershed rainfall showed a different spatial distribution pattern with the most rainfall over the Tidal Basin (49.6 inches or 1,260 mm) and the least over the C-23 Subbasin (47.3 inches or 1,200 mm; **Figure 8C-5**).

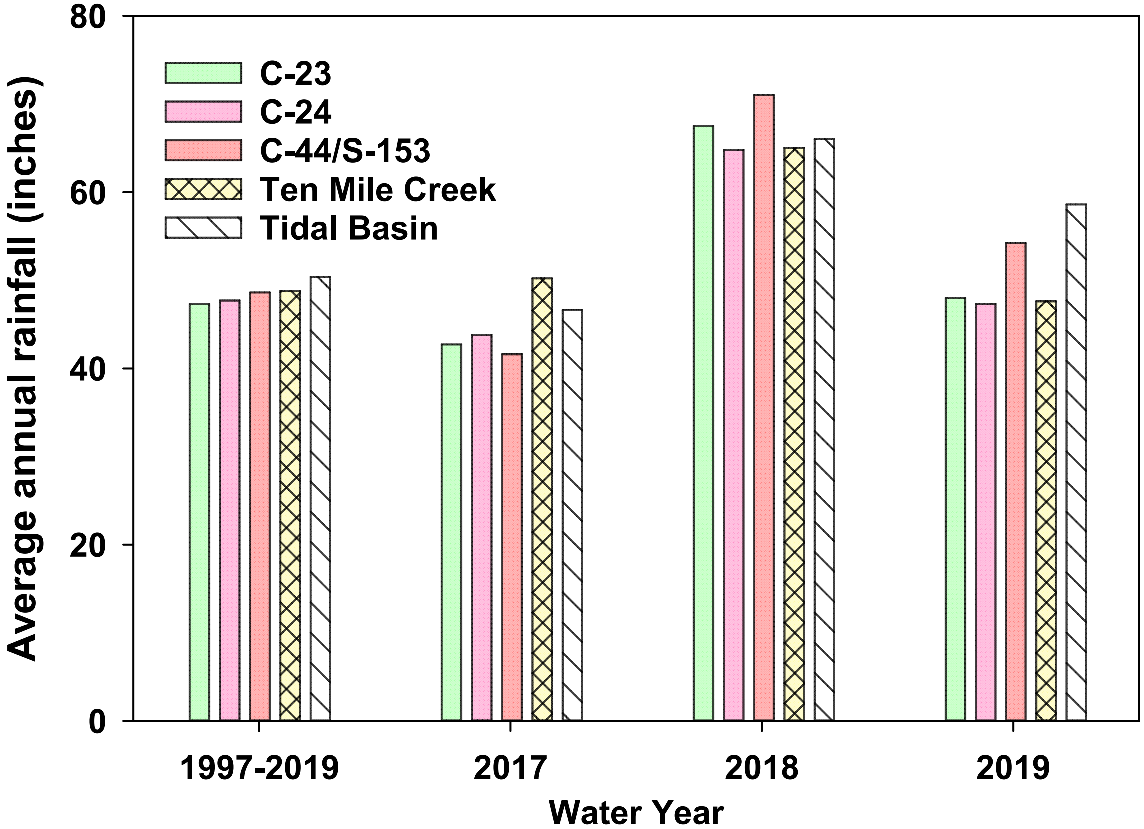

Figure 8C-5. Average annual rainfall in the St. Lucie Watershed Tidal Basin (hatched white bar) and subbasins (colored bars) for the past three water years and the long-term average (WY1997–WY2019). See **Figure 8C-1** for locations of subbasins.

Freshwater Inflow

Freshwater inflow to the SLE is measured at the S-80 (C-44/S-153 Subbasin), S-48 (C-23 Subbasin), S-49 (C-24 Subbasin), and the Gordy Road structures (TMC Subbasin) (**Figure 8C-1** and **Table 8C-1**). These multiple subbasin inflows were assigned to one of three basins: Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin. 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 Linear Reservoir (Lin Res) model calibrated to the SLE Watershed Hydrology Model (WaSH) and data collected in the nearby basins (Wan and Konyha 2015). Total daily inflows during WY1997–WY2019 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 basins from source to total inflow.

Total freshwater inflow in WY2019 was 867.99 thousand ac-ft, of which 308.28 thousand ac-ft (36%) was from Lake Okeechobee, 383.09 thousand ac-ft (44%) from the St. Lucie Basin, and 176.19 thousand ac-ft (20%) from the Tidal Basin (**Table 8C-2** and **Figure 8C-6a**). The contributions from Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin in WY2019 were each approximately 50% less than

WY2018. Inflows in WY2019 were comparable to WY2017 and the long-term inflows, indicating that inflows were high in WY2018, a very wet year. Annual inflow from the three basins (Lake Okeechobee, St. Lucie Basin, and Tidal Basin) from WY1997 to WY2019 fluctuated, with the highest flow occurring in WY2006 (2.25 million) followed by the lowest flow in WY2007 (0.30 million ac-ft, **Figure 8C-7a**).

Table 8C-2. Summary of freshwater inflow in thousand acre-feet per year (10^3 ac-ft/yr) and TN loads and TP loads in metric tons per year (t/yr) from Lake Okeechobee, the St. Lucie Basin (C-23, C-24, C-44, and TMC) and the Tidal Basin (modeled) to the SLE. Shown in the table are the long-term averages (WY1997–WY2019) and values for WY2017, WY2018, and WY2019.

Period	Inflow (10^3 ac-ft/yr)			
	Lake Okeechobee	St. Lucie Basin	Tidal Basin	Total
WY1997–WY2019	266.00	489.18	251.90	**1,007.08**
WY2017	338.21	370.42	236.53	**945.17**
WY2018	585.62	673.51	316.85	**1,575.99**
WY2019	308.28	383.06	176.19	**867.53**

Period	TN load (t/yr)			
	Lake Okeechobee	St. Lucie Basin	Tidal Basin	Total
WY1997–WY2019	554.62	908.60	295.82	**1,759.04**
WY2017	621.26	497.44	257.53	**1,376.23**
WY2018	1,345.53	1,400.00	389.72	**3,135.25**
WY2019	546.05	593.47	179.12	**1,318.64**

Period	TP load (t/yr)			
	Lake Okeechobee	St. Lucie Basin	Tidal Basin	Total
WY1997–WY2019	57.30	220.92	43.57	**321.80**
WY2017	56.83	144.45	28.56	**229.84**
WY2018	160.51	349.96	45.32	**555.79**
WY2019	73.46	157.42	17.34	**248.21**

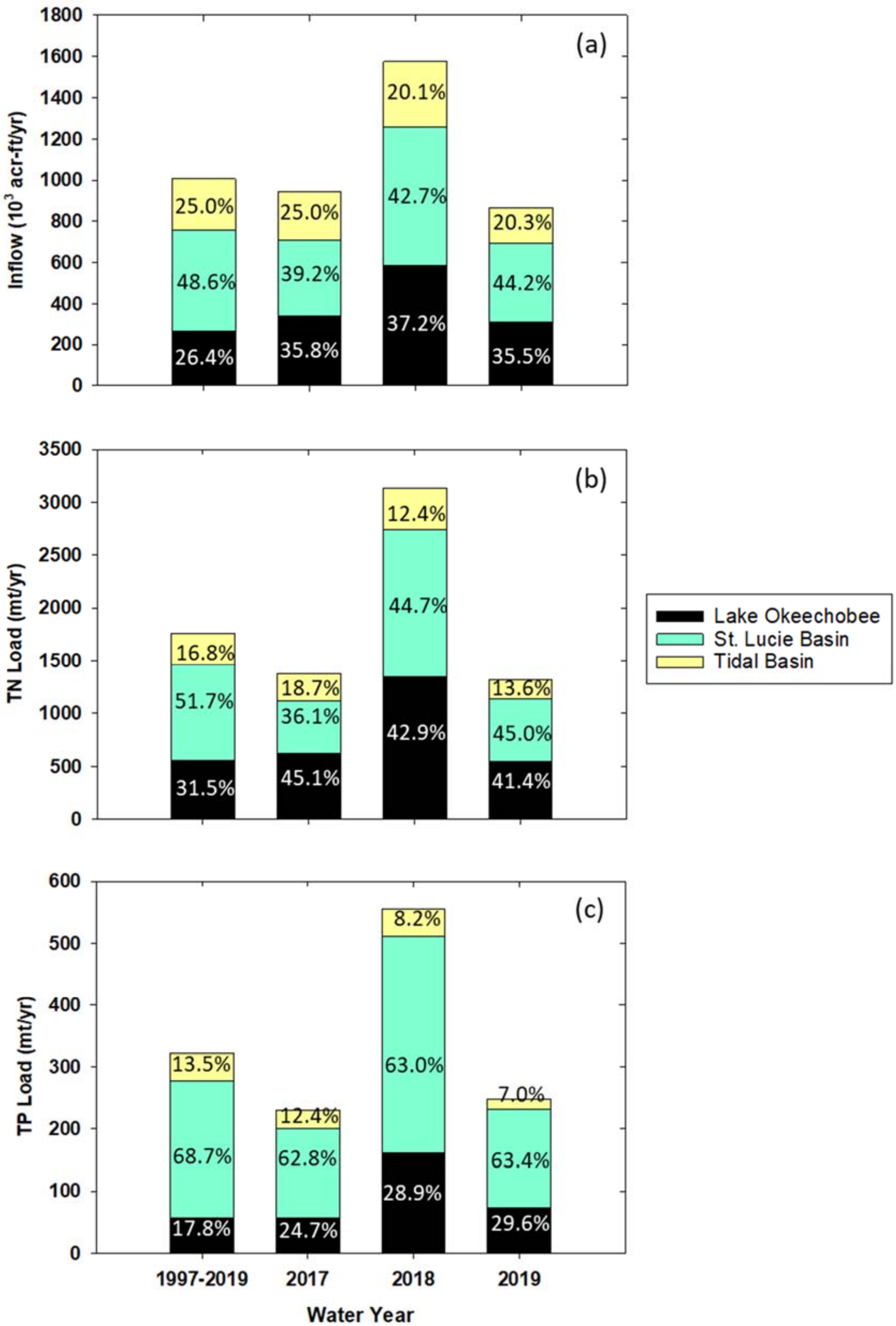

Figure 8C-6. Stacked bar chart for the (a) total freshwater inflow in million acre-feet per year (10^3 ac-ft/yr) and (b) TN load and (c) TP loads in metric tons per year (t/yr) attributable to Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin. Displayed are the long-term average for WY1997–WY2019, WY2017, WY2018, and WY2019.

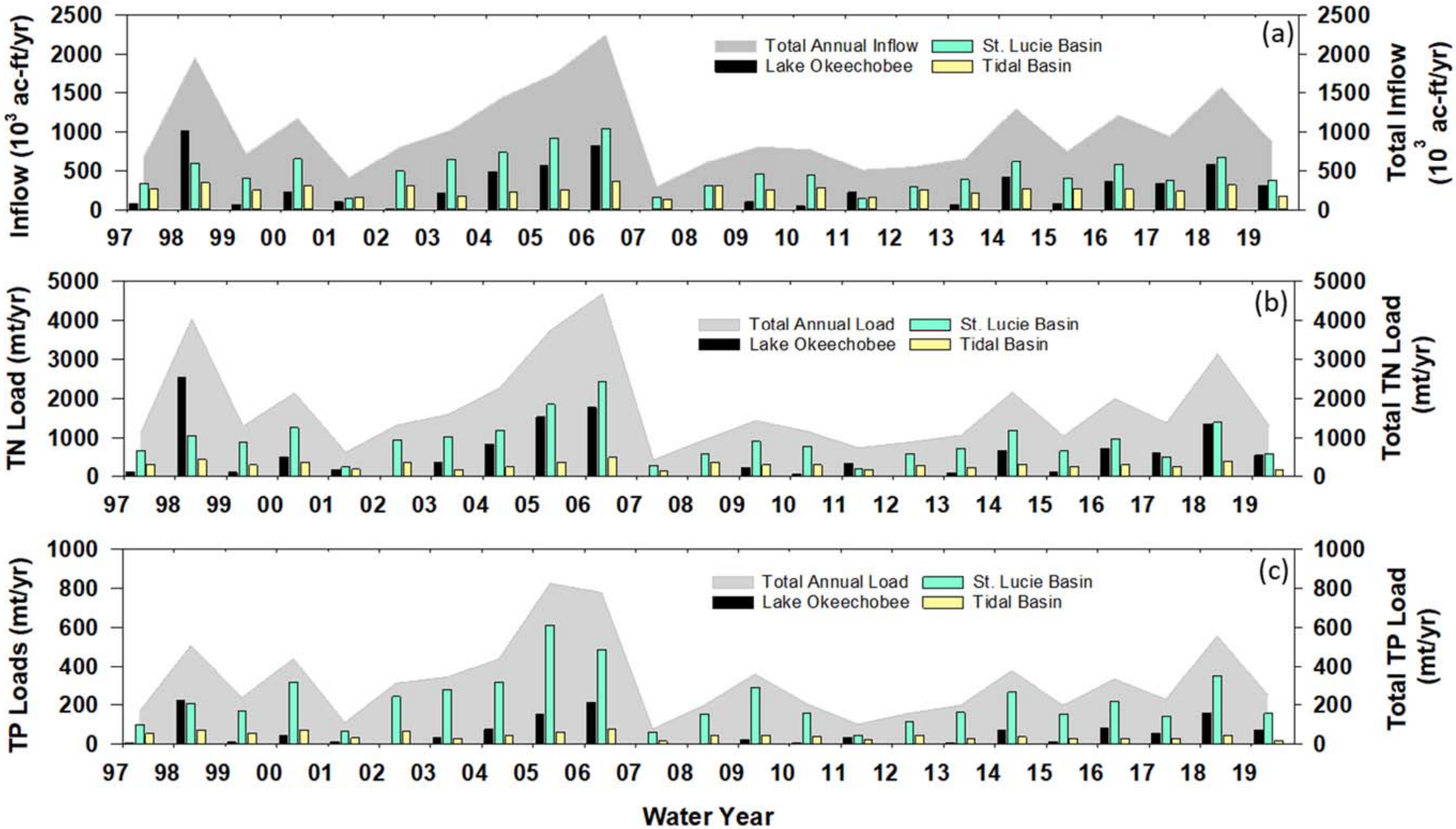

Figure 8C-7 Time series of (a) annual freshwater inflow in million acre-feet per year (10^3 ac-ft/yr or 1.233×10^9 m^3) and (b) TN load, and (c) TP load in metric tons per year (t/yr) into the SLE attributable to Lake Okeechobee, the St. Lucie Basin, and the Tidal Basin for the POR (WY1997–WY2019).

Total Nitrogen and Total Phosphorus Loads to the Estuary

The concentrations of TN and TP are monitored at approximately monthly intervals at the same locations as flow and salinity; TN is monitored via grab samples, TP is monitored by either grab sample or autosampler, depending on sample location (SFWMD 2017; **Figure 8C-2**). Inflows and nutrient load data from TMC for this report were simulated from WY1997 through WY1999 because the data set was incomplete. The daily loads of TN and TP were calculated as the product of the total daily inflow and the computed daily nutrient concentration.

The annual nutrient loading to the SLE fluctuated with total freshwater inflow over the long-term POR, WY1997–WY2019 (**Figures 8C-6** and **8C-7**), confirming that nutrient loading is highly affected by surface flow hydrology, though magnitude of response differs among TN and TP (SFWMD 2009). Long-term average TN load was 1,759.04 metric tons per year (t/yr) and TP 321.80 t/yr (**Table 8C-2**). WY2019 total TN loading was 1.318.64 t, of which 41% was from Lake Okeechobee (546.05 t), 45% from the St. Lucie Basin (593.47 t), and 14% from the Tidal Basin (179.12 t) (**Figure 8C-6b** and **7b**). This TN loading was comparable to WY2017 and the long-term average but was lower than WY2018. Total TP loading in WY2019 was 248.21 t/yr, which was lower than WY2017 (229.84 t/yr) and the long-term average (321.80 t/yr), and 45% of WY2018 loading (555.79 t/yr). The nutrient loads in WY2018 were high due to higher inflow and flow-weighted mean concentrations (FWMCs) of nutrients from the St. Lucie Basin and Lake Okeechobee (**Table 8C-2**). This high nutrient rich freshwater inflow may have been attributed to the above average rainfall and Hurricane Irma (**Figures 8C-3** and **8C-4**). Most TP loading in WY2019 originated from the St. Lucie Basin (157.42 t, 63%), followed by Lake Okeechobee (73.46 t, 30%), with the smallest contribution from the Tidal Basin (17.34 t, 7%; **Table 8C-2** and **Figure 8C-6c**). Relative to the long-term average, the WY2019 percent contribution from Lake Okeechobee was greater, whereas the contributions from the St. Lucie and Tidal Basins were less (**Figure 8C-6c**).

Total Phosphorus and Total Nitrogen Loading Data for the Most Recent Five Years (Water Years 2015–2019)

Table 8C-3 lists tributary basin annual flows, TP load, TP FWMC, TN load, and TN FWMC for the last five water years (WY2015–WY2019) in the St. Lucie River Watershed. Tributary basins of the St. Lucie River Watershed include the C-44, C-23, C-24, Ten Mile Creek, and Tidal subbasins. Flow and nutrient loads from the Tidal Basin were estimated by modeled flow and measured grab sample data from within the basin. Lake Okeechobee contributed 31% of total flow, 38% of TN load, and 25% of TP load during WY2015–WY2019. The Tidal Basin represented the largest contribution of the tributary basins, with 24% of total flow, 16% of TN load, and 10% of TP load, followed by C-24 and C-23 subbasins, with 13% and 11% of total flow, 15% and 13% of TN load, and 18 and 17% of TP load, respectively. The TMC and C-44 subbasins showed similar contributions to the St. Lucie Watershed during this five-year period (11% of total flow, 8% of TN load, and 14% of TP load).

Table 8C-3. St. Lucie River Watershed tributary basin annual flow volumes with TP and TN loads and FWMC for WY2015–WY2019. (Note: mg/L – milligram per liter.)

Water Year	Lake Okeechobee	C-44 Basin	C-23 Basin	C-24 Basin	TMC Basin	Tidal Basin	Total
Flow (10^3 x ac-ft)							
WY2015	80.25	107.99	104.98	104.55	89.46	268.67	755.90
WY2016	369.84	188.56	106.71	176.62	114.42	262.56	1,218.71
WY2017	338.22	78.82	65.88	97.95	127.75	236.53	945.15
WY2018	585.63	79.85	219.68	221.15	152.88	316.85	1,576.04
WY2019	308.28	121.06	92.05	77.02	92.96	176.19	867.56
5-Year Average	336.44	115.26	117.86	135.46	115.49	252.16	1,072.67
5-Year %	31%	11%	11%	13%	11%	24%	100%
TN Load (t/yr)							
WY2015	120.43	170.67	198.49	186.87	96.14	265.42	1,038.03
WY2016	717.23	289.09	204.47	326.51	149.68	303.72	1,990.69
WY2017	621.26	62.18	113.89	162.11	159.27	257.53	1,376.23
WY2018	1,345.53	256.64	457.48	457.19	228.69	389.72	3,135.25
WY2019	546.05	160.63	166.47	153.99	112.39	179.12	1,318.64
5-Year Average	670.10	187.84	228.16	257.33	149.23	279.10	1,771.77
5-Year %	38%	11%	13%	15%	8%	16%	100%
TN FWMC (mg/L)							
WY2015	1.22	1.28	1.53	1.45	0.87	0.80	1.11
WY2016	1.57	1.24	1.55	1.50	1.06	0.94	1.32
WY2017	1.49	0.64	1.40	1.34	1.01	0.88	1.18
WY2018	1.86	2.61	1.69	1.68	1.21	1.00	1.61
WY2019	1.44	1.08	1.47	1.62	0.98	0.82	1.23
5-Year	1.61	1.32	1.57	1.54	1.05	0.90	1.34
TP Load (t/yr)							
WY2015	13.33	37.12	55.37	41.59	21.17	30.61	199.19
WY2016	83.60	63.73	53.50	59.85	41.92	30.58	333.17
WY2017	56.83	30.03	28.49	34.28	51.64	28.56	229.84
WY2018	160.51	68.25	100.03	111.37	70.32	45.32	555.79
WY2019	73.46	51.04	36.66	40.89	28.83	17.34	248.21
5-Year Average	77.54	50.03	54.81	57.60	42.78	30.48	313.24
5-Year %	25%	16%	17%	18%	14%	10%	100%
TP FWMC (mg/L)							
WY2015	0.135	0.279	0.428	0.323	0.192	0.092	0.214
WY2016	0.183	0.274	0.406	0.275	0.297	0.094	0.222
WY2017	0.136	0.309	0.351	0.284	0.328	0.098	0.197
WY2018	0.222	0.693	0.369	0.408	0.373	0.116	0.286
WY2019	0.193	0.342	0.323	0.430	0.251	0.080	0.232
5-Year	0.187	0.352	0.377	0.345	0.300	0.098	0.237

ESTUARY RESPONSES

Water Quality

Water samples are obtained via grab sample mid-depth at 12 stations in the SLE at approximately monthly intervals as part of the RWQMP. Three representative stations were chosen to evaluate water quality conditions in the estuary: HR1 in the North Fork, SE03 in the Middle Estuary at the US1 Roosevelt Bridge, and SE11 near the St. Lucie Inlet (**Figure 8C-2**). Analyses included concentrations of Chla, TN, and TP during WY1997–WY2019 from HR1 and SE03, and during WY1998–WY2019 from SE11 (**Figures 8C-8** and **8C-9**). Long-term and season concentrations are presented as average and standard deviation for the entire POR for each station and the last three water years (WY2017, WY2018, and WY2019; **Table 8C-4**). Measurements of TN and TP were used to compute TN:TP molar ratios. Shapiro-Wilk tests were used to evaluate data normality. Where normality could not be assumed, non-parametric Kruskal-Wallis analyses were conducted. Multiple comparisons were evaluated with Mann-Whitney U tests. Concentrations of Chla, TN, and TP were examined separately for significant spatial differences. Trend analysis for TN and TP concentrations from Seasonal Kendall tests for the period WY2008–WY2017 are also included for reference (FDEP 2018). In addition to statistical analyses, **Figures 8C-8** and **8C-9** present the temporal patterns of Chla, TN, TP, and TN:TP from WY2009 to WY2019 to interpret variations relative to water inflow since the implementation of the current Lake Okeechobee Regulation Schedule, LORS2008 (SFWMD 2010).

The concentrations of Chla ranged from 0.34 to 90 µg/L and varied significantly among the three stations (i.e., along the estuary gradient) and between seasons (**Figure 8C-8**). The gradient between the upstream stations to the St. Lucie Inlet was evident with the highest average value observed at HR1 (12.91 ± 12.02 µg/L), followed by SE03 (8.69 ± 8.10 µg/L), and SE11 (3.62 ± 2.97 µg/L). Comparisons of all stations over the entire POR showed significantly greater concentrations in the wet season (10.60 ± 11.49 µg/L) than in the dry season (6.37 ± 5.76 µg/L) with the highest average values in July and August. In WY2018, SE03 and SE11 showed higher Chla concentrations in the dry than in the wet season. The observed opposite pattern was likely caused by larger than average wet season freshwater inflow into the estuary associated with Hurricane Irma. Annual average Chla concentration at all three stations were comparable to the corresponding long-term average.

The concentration of TN of all stations over the POR ranged from 0.06 to 2.89 milligrams per liter (mg/L) and differed significantly among stations (**Table 8C-4** and **Figure 8C-9**). The average concentrations at HR1 and SE03 (0.96 ± 0.40 mg/L and 0.96 ± 0.43 mg/L, respectively) were similar and significantly higher than at SE11 (0.51 ± 0.37 mg/L; **Table 8C-4** and **Figure 8C-9**). All three stations were affected by seasonality with greater values in the wet season and the highest values occurring in September and October. The average concentrations of WY2017 and WY2019 were similar, and slightly lower than the long-term average concentration (WY1998–WY2019). One (HR1) out of the three stations showed significant decreasing long-term (WY2008–WY2017) trends for TN concentrations (FDEP 2018).

The concentrations of TP ranged from of 0.004 to 1.040 mg/L and varied significantly among the three stations over the POR (**Table 8C-4** and **Figure 8C-9**). Similar to Chla, TP showed a decreasing pattern in the downstream direction, with the highest average value at HR1 (0.20 ± 0.11 mg/L), followed by SE03 (0.18 ± 0.09 mg/L), and SE11 (0.06 ± 0.06 mg/L). Comparisons of all stations over the entire POR showed that the long-term average TP concentration in the wet season (0.20 ± 0.12 mg/L) was significantly higher than in the dry season (0.10 ± 0.06 mg/L), causing lower long-term average TN:TP molar ratios lower in the wet than in the dry season. August and September were the months with the highest average TP concentrations over the POR. The TN:TP molar ratios increased in the downstream direction, with the lowest value at HR1 (11:1), followed by SE03 (12:1), and SE11 (15:1). The concentrations of TP in WY2017 and WY2019 were lower than the long-term average concentration. None of the three stations showed significant long-term (WY2008–WY2017) trends in changes of TP concentrations (FDEP 2018).

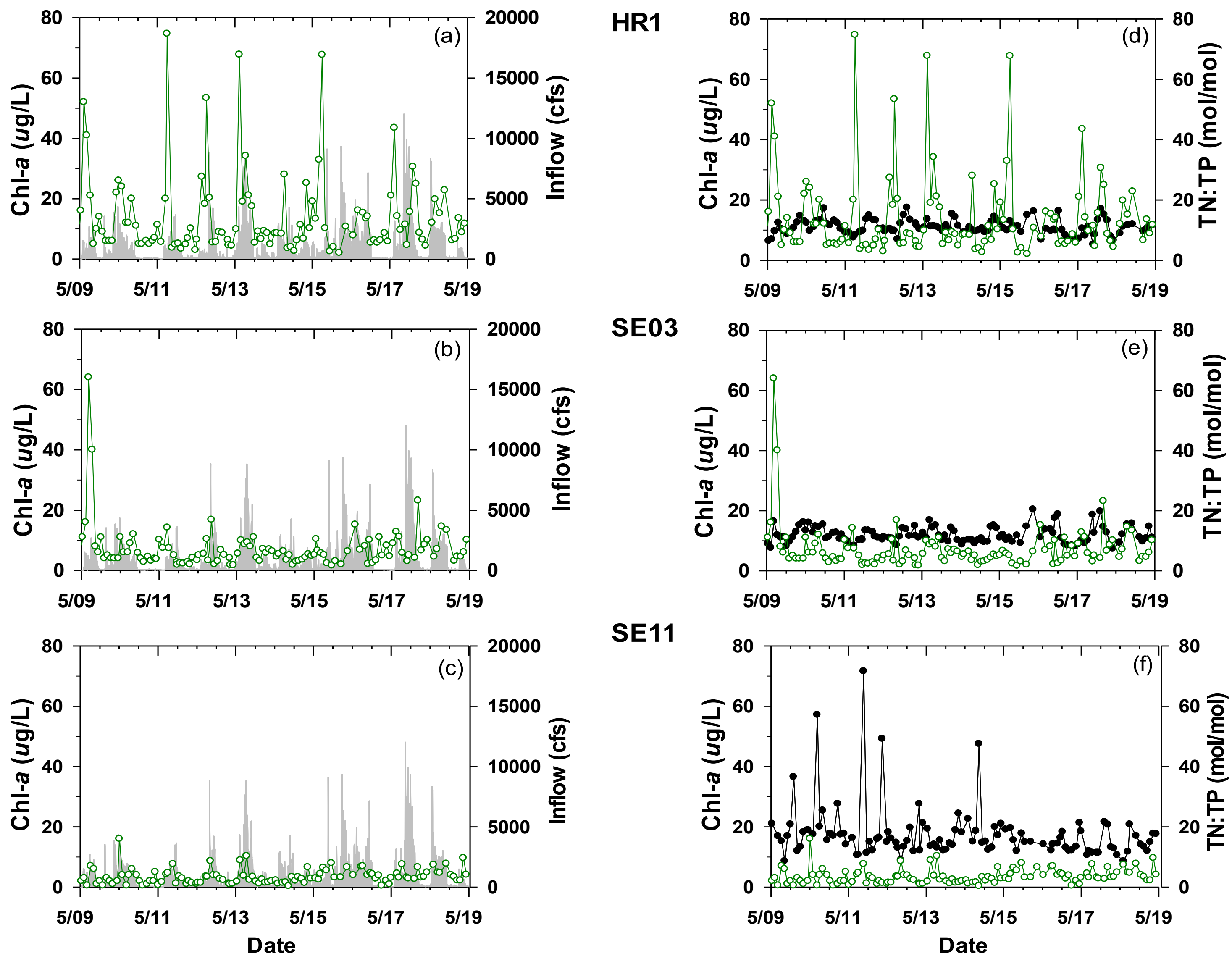

Figure 8C-8. Time series (WY2009–WY2019) of Chla (green line with open circles) and total gauged inflows (gray line in a through c) and TN:TP molar ratios (black line with solid circles in d through f) at stations HR1, SE03, and SE11 in the SLE.

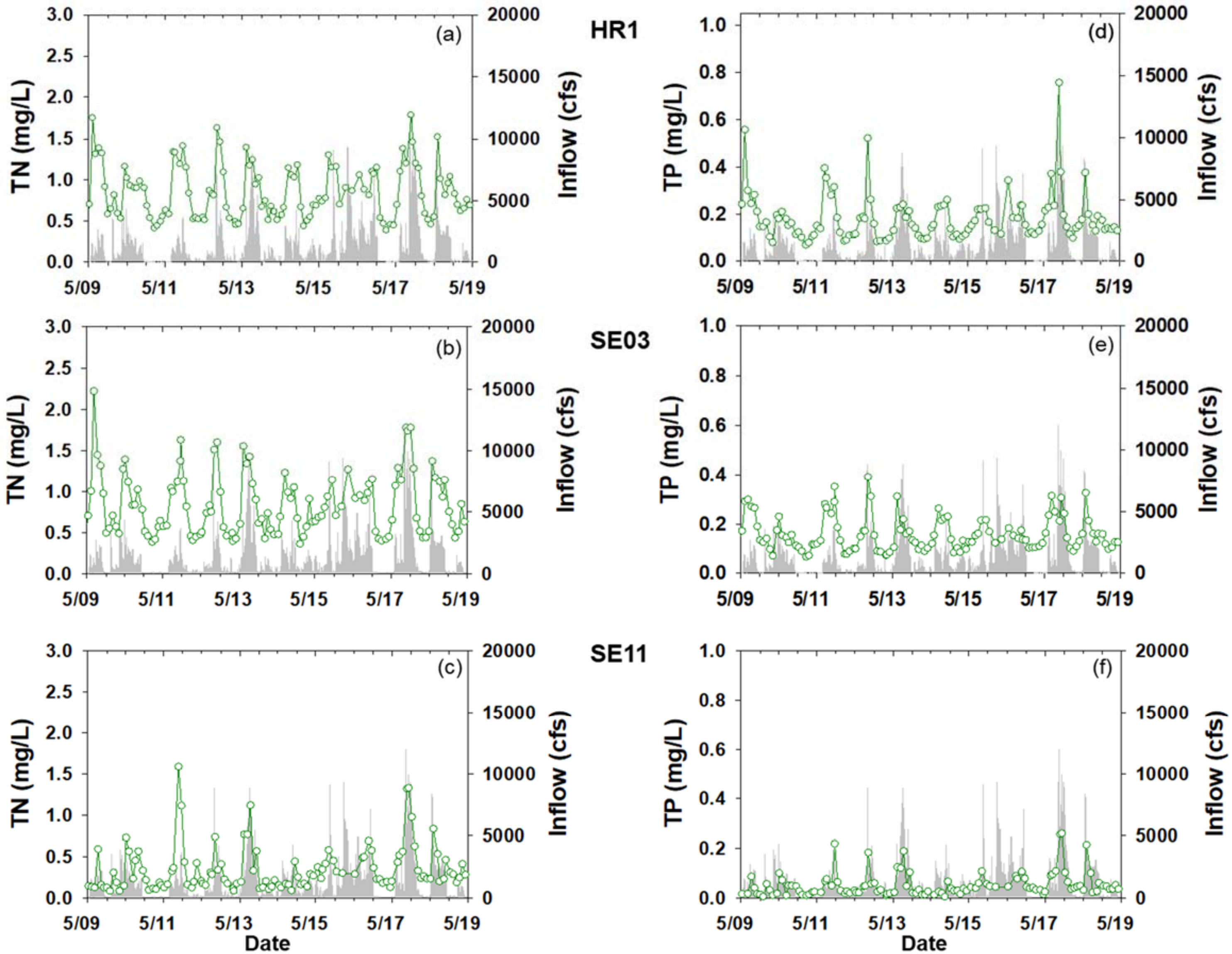

Figure 8C-9. Time series (WY2009–WY2019) of TN (a through c, green line with open circles) and TP (d through f, green line with open circles), and total gauged inflows (gray line) at stations HR1, SE03, and SE11 in the SLE.

Table 8C-4. Water column concentrations of Chla, TN, and TP at three stations (HR1, SE03, and SE11) in the SLE. The table includes wet season (May–October), dry season (November–April), and total annual averages (Avg) and standard deviations (SD) for the period WY1997–WY2019 for HR1 and SE03 and the period WY1998–WY2019 for SE11, and for WY2017, WY2018, and WY2019. Statistically significant differences between wet and dry season of each station are in bold.

Period	Chla (µg/L)																	
	HR1						SE03						SE11					
	Wet		Dry		Total		Wet		Dry		Total		Wet		Dry		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY1997/8–WY2019	**16.1**	14.4	**9.5**	7.4	12.9	12.0	10.8	10.0	6.3	4.2	8.7	8.1	**4.2**	3.3	**3.0**	2.3	3.6	3.0
WY2017	**13.3**	3.3	**6.2**	1.2	9.5	4.3	8.5	4.8	5.8	3.2	7.0	4.0	**5.3**	1.5	**2.4**	1.5	3.7	2.1
WY2018	17.4	13.9	15.1	10.7	16.2	11.9	7.8	3.8	10.5	7.4	9.0	5.6	4.0	1.8	4.1	1.6	4.1	1.6
WY2019	**17.4**	4.8	**9.4**	3.2	12.9	5.6	9.9	4.9	5.7	2.7	7.6	4.2	5.8	2.2	4.3	2.8	4.9	2.5

Period	TN (mg/L)																	
	HR1						SE03						SE11					
	Wet		Dry		Total		Wet		Dry		Total		Wet		Dry		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY1997/8–WY2019	**1.14**	0.38	**0.76**	0.32	0.96	0.40	**1.13**	0.40	**0.77**	0.39	0.96	0.43	**0.61**	0.38	**0.40**	0.33	0.51	0.37
WY2017	0.99	0.13	0.58	0.29	0.76	0.31	0.97	0.08	0.56	0.29	0.74	0.30	**0.51**	0.15	**0.22**	0.08	0.35	0.19
WY2018	**1.27**	0.37	**0.78**	0.32	1.03	0.41	1.28	0.43	0.85	0.55	1.07	0.52	0.73	0.48	0.44	0.30	0.58	0.41
WY2019	0.98	0.32	0.71	0.08	0.85	0.26	**1.04**	0.29	**0.63**	0.15	0.83	0.31	0.41	0.25	0.28	0.07	0.35	0.19

Period	TP (mg/L)																	
	HR1						SE03						SE11					
	Wet		Dry		Total		Wet		Dry		Total		Wet		Dry		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY1997/8–WY2019	**0.26**	0.12	**0.14**	0.05	0.20	0.11	**0.22**	0.09	**0.13**	0.04	0.18	0.09	**0.09**	0.07	**0.04**	0.03	0.06	0.06
WY2017	**0.24**	0.06	**0.13**	0.02	0.18	0.07	**0.16**	0.02	**0.11**	0.01	0.13	0.03	**0.08**	0.02	**0.03**	0.01	0.05	0.03
WY2018	**0.37**	0.21	**0.14**	0.03	0.25	0.18	**0.25**	0.06	**0.14**	0.06	0.19	0.08	0.14	0.10	0.06	0.02	0.10	0.08
WY2019	0.21	0.09	0.15	0.02	0.18	0.07	**0.19**	0.07	**0.12**	0.02	0.16	0.06	0.08	0.07	0.04	0.01	0.06	0.05

Salinity

Salinity is derived from conductivity and temperature field measurements and converted to unitless salinity values per Fofonoff and Millard (1983). Salinity gradients are a conservative property of the water body and therefore are useful in connecting sources of freshwater inflow, circulation, and biological indicators (Wilber 1992, Jassby et al. 1995, Hagy and Murrell 2007, Pollack et al. 2011). In the SLE, a seven-day average salinity envelope of > 10 to ≤ 26 at the US1 Roosevelt Bridge (**Figure 8C-2)** has been determined as beneficial to adult oysters in the Middle Estuary (USACE and SFMWD 2004, Alleman 2012). Systematic analyses of inflows determined that total discharges ranging from approximately 350 to 2,000 cubic feet per second (cfs) can help maintain this salinity envelope (USACE and SFWMD 2004, Wilson et al. 2005).

Surface and bottom salinity observations are recorded every 15 minutes at three stations: HR1, US1 at the Roosevelt Bridge, and the A1A Bridge (**Figure 8C-2**). Data reporting and analyses focus on salinity at the US1 Roosevelt Bridge. Salinity was vertically averaged from surface and bottom measurements to produce a water column average time series over the long-term POR (WY2001–WY2019; based on best available data). The percentages of days for the oyster resource-based salinity criteria were calculated over the POR and for WY2017, WY2018, and WY2019 (**Table 8C-5** and **Figure 8C-10**). The seven-day moving average salinity was calculated using average daily surface and bottom salinity data.

Daily salinity of the water column during WY2019 at the US1 Roosevelt Bridge ranged from 1.12 on August 31, 2018, to 30.82 on January 7, 2019, and showed an inverse pattern to freshwater inflow (**Figure 8C-10**). In WY2019, salinity fell in the preferred envelope for adult eastern oysters more frequently (63.2%) than in the previous two water years. Moreover, WY2019 showed the lowest frequency of salinity out of the favorable envelope < 10 (29.2%) or ≥ 26 (7.5%) (**Table 8C-5**). Most of the high seven-day average salinity values > 26 in WY2019 occurred in January 2019, whereas the low salinity < 10 seven-day average salinity values occurred during the wet season (May 22, 2018, to October 13, 2018) (**Figure 8C-10**).

Table 8C-5. The percentage of days the seven-day moving average water column salinity at the US1 Roosevelt Bridge was categorized below, within, or above the preferred salinity envelope of 10 to 26 for adult eastern oysters.

Period	Days with Salinity < 10 (%)	Days with Salinity ≥ 10 and < 26 (%)	Days with Salinity ≥ 26 (%)
WY2001–WY2019	31.4%	61.2%	8.4%
WY2017	39.2%	36.5%	24.3%
WY2018	39.0%	46.0%	14.0%
WY2019	29.2%	63.2%	7.5%

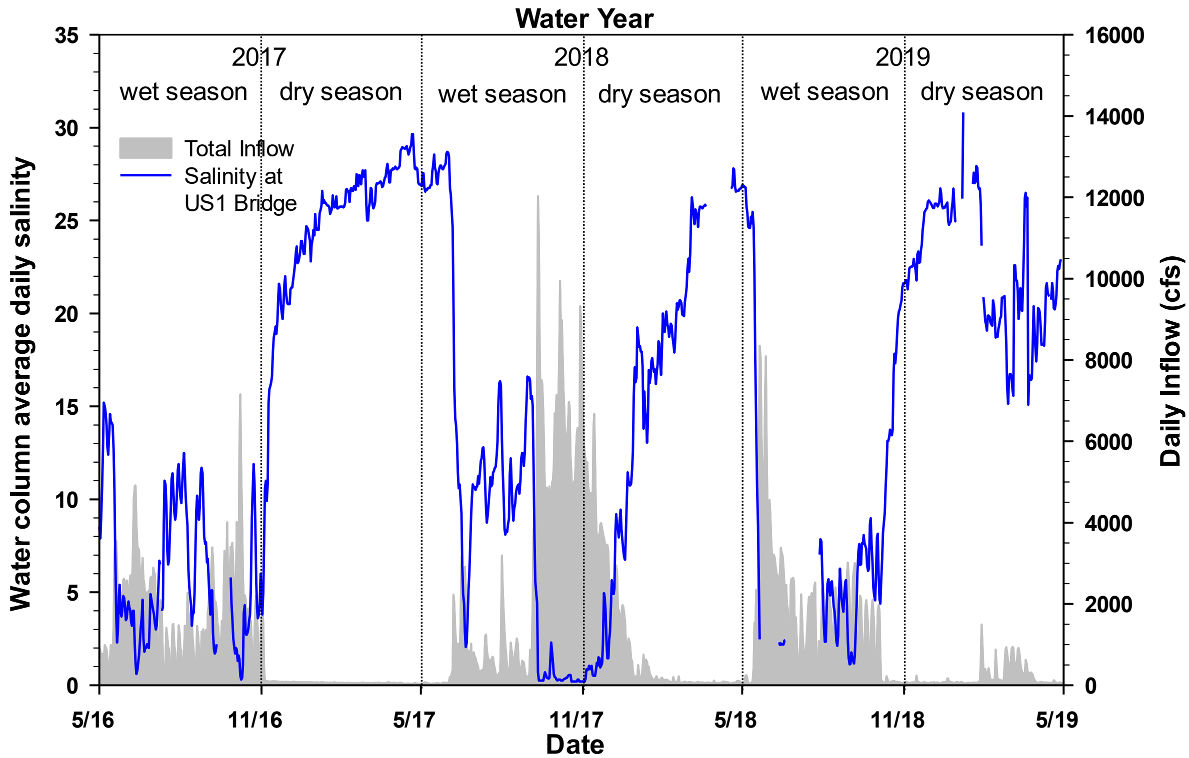

Figure 8C-10. Time series of total freshwater inflow, not including the Tidal Basin, from the St. Lucie Basin and daily average water column salinity at the US1 Roosevelt Bridge in the SLE for WY2016–WY2019.

Oyster Habitat

Oysters are sensitive to salinity and generally thrive best under salinity conditions between 10 and 26 (USACE and SFWMD 2004, Alleman, 2012). Oysters are important to estuarine health because they filter water and suspended solids, couple the water column to the benthos, and provide structure and living aquatic habitat for other organisms (Peterson et al. 2003, Coen et al. 2007, Buzzelli et al. 2012). Oyster monitoring has been ongoing in three segments of the SLE (Middle Estuary, South Fork, and North Fork) since WY2006 (Parker et al. 2013) as a component of the Restoration Coordination and Verification (RECOVER) Program in support of the Comprehensive Everglades Restoration Plan (CERP) (RECOVER 2014). At each site, three stations are sampled. This report analyzes data collected by the Florida Fish and Wildlife Conservation Commission (FWC) from the Middle Estuary at Stations C1, C2, and C3 (**Figure 8C-2**), which are close to the salinity monitoring station at US1 Roosevelt Bridge, over the last five water years.

Oyster density (live oyster/m^2) for this ongoing monitoring program is determined biannually, with quarterly monitoring commencing in 2018 at the C1, C2, and C3 stations, using survey methodology based on methods from Lenihan and Peterson (1998) and Grizzle et al. (2005). At each station, 15 replicate 0.25-m^2 quadrats are monitored for the number of live and dead oysters and up to 10 live oysters are selected from each quadrat for shell height measurements. During WY2019, oyster density at Stations C1, C2, and C3 increased significantly from the wet to the dry season from an average of 194 to 510 live oysters/m^2 (**Figure 8C-11a**). This was a significant recovery from the first dry season sampling event (March 2018) after Hurricane Irma, when only one out of the 45 quadrats monitored at Stations C1, C2, and C3 contained live oysters (8 live oyster/m^2 in that individual quadrat). The quarterly sampling at these stations recorded the density of oysters in June 2017 before the September 2017 storm event; density was 1,047 live oyster/m^2, slightly higher than numbers observed in the WY2017 wet season, when 990 live oysters/m^2 were recorded (data not shown). During the period after Hurricane Irma, salinities at the US1 Roosevelt

Bridge remained below 10 for approximately three months (**Figure 8C-10)**. The percentage of days during WY2019 that salinity at the US1 Roosevelt Bridge was in the preferred envelope of salinity (10 to 26) was higher than occurred over the long-term average, reflecting an improvement in the conditions for adult oysters related to WY2019 inflows. During the WY2019 dry season, average live oyster density at Stations C1, C2, and C3 was similar to densities of the WY2017 dry season, when 599 live oysters/m^2 were recorded (**Figure 8C-11a)**. Salinity during the WY2019 dry season remained in the preferred range for the eastern oyster, which was similar to that of the WY2017 dry season (**Figure 8C-10)**, as were the inflow conditions between these two water years (**Figure 8C-6a).** The mean shell height of oysters present at Stations C1, C2, and C3 in March 2019, was similar to pre-Irma values (average ~40 mm), with an increase in shell height observed between the WY2019 wet (September) and dry (March) season sampling events (**Figure 8C-11b**).

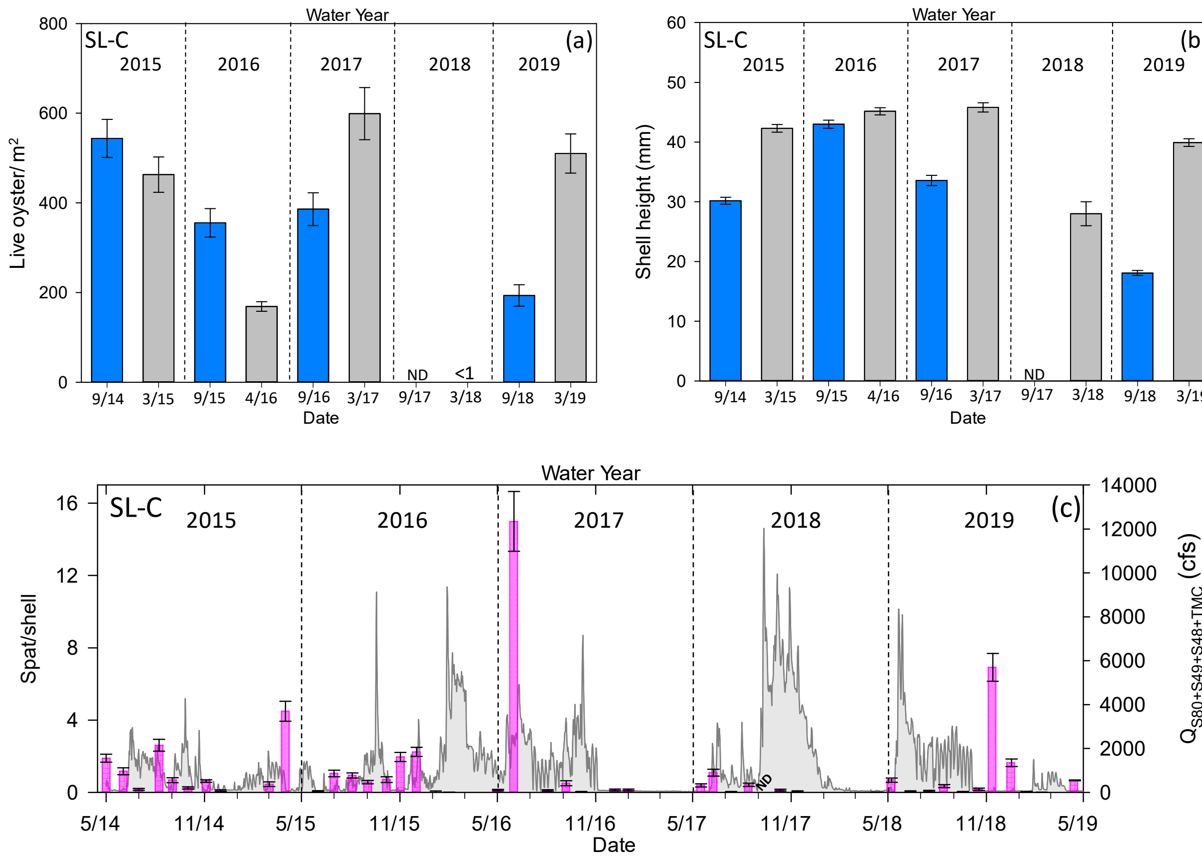

Figure 8C-11. Oyster monitoring data from the SLE Middle Estuary at Stations C1, C2, and C3 (collectively called SL-C) for WY2015–WY2019. Values represent average ± standard error, of the three stations for each sampling date, for (a) density and (b) shell height, where blue bars represent wet season and gray bars represent dry season sampling events, and (c) larval recruitment over a monthly deployment of oyster arrays. In (c), The right y-axis, Q (cfs), depicts daily freshwater inflow rate to the SLE from the S-80, S-48, S-49, and Ten Mile Creek structures (grey-filled area). Tidal Basin flows are not included. Samples were not collected September 2017 (ND).

Five live oysters from each station, a total of 15, are collected monthly to determine the presence in the tissue of the disease dermo caused by the protozoan pathogen *Perkinsus marinus* (Ray 1966). Disease intensity, per the Mackin scale categories 0 to 5 (Mackin 1962), is recorded and prevalence (%) determined as number of oysters infected/total number of oysters collected. The percent prevalence of dermo infection at Stations C1, C2, and C3 was highest in WY2016 and relatively low in WY2019 (**Table 8C-6**). Salinity in the SLE was relatively high in WY2015, when oysters made a comeback from widespread mortalities in 2014, and temperatures were higher than normal. The high values in WY2016 may be associated with a lasting increased dermo disease originated in WY2015 as the result of warmer temperatures along with higher salinities in WY2015. Infection intensity, however has consistently scored in the light infection category (Stage 1 score) or lower on the Mackin scale (0 to 100 cells observed in tissue sample) from WY2015 to WY2019 indicating that disease at the SLE Middle Estuary has likely not been a significant stressor over the last five years.

Table 8C-6. Percent prevalence of dermo in live adult oyster (number infected/total collected) from the SLE Middle Estuary sites (Stations C1, C2, and C3) for WY2015–WY2019 and percent prevalence of infection intensity that was greater than a score of light infection (> 1 stage score) on the Mackin scale (Mackin 1962).

Water Year	Season	Percent Prevalence of Dermo Presence (Average)	Percent Prevalence of Greater Than Light Category of Dermo Intensity
WY2015	Wet	15.6	0
	Dry	25.6	0
WY2016	Wet	34.4	0
	Dry	33.3	0
WY2017	Wet	13.3	0
	Dry	16.7	0
WY2018	Wet	18.3 [a]	0
	Dry	NL [b]	0
WY2019	Wet	2.5 [c]	0
	Dry	15.6	0

a. Values from May through August sampling 2017 as Hurricane Irma prevented September sampling.

b. No live oysters present at age to collect for analyses.

c. Values from June through October 2018.

Oyster larval recruitment is measured from the underside of clean shells suspended on a 12-shell monitoring array (Parker 2013). Three arrays per station are deployed for an average of 31 days. The average number of spat settled per shell is calculated using the spat counts from the middle shells (excluding the top and bottom shells of the arrays). Larval recruitment at Stations C1, C2, and C3 is generally low, with average settlement ranging from 0 to 7 from WY2015 to WY2019, with the exception of a peak in recruitment observed in June 2016 during WY2017 (**Figure 8C-11c**). During this time period, over the month's deployment of the recruitment arrays, salinity increased from 10 to 15, before dropping to just below 5 prior to retrieval (**Figure 8C-10**). An additional peak in settlement was observed in November 2018 during a period of low freshwater inflow conditions and a salinity increase from just above 5 to 22 (**Figures 8C-10** and **11c**). Following Hurricane Irma, dry season WY2018 settlement monitoring observed 0 spat/shell from December 2017 to March 2018, hypothesized to be a result of the reduced number of larval producing adults and prolonged low salinities. There are typically two peaks for oyster spawning; the first in late spring to early summer with an increase in water temperatures and the second in autumn (**Figure 8C-11c)**. Currently research is being conducted using controlled experiments on larvae and adult oysters under various salinity treatments and recovery durations to provide information on the effects of timing and duration of freshwater releases on these estuarine organisms.

SUMMARY

- Average total rainfall across the St. Lucie and Tidal Basins in WY2019 was 52.9 inches (1,341 mm), with 74% occurring in the wet season and 26% in the dry season. This is similar to WY2017 (44.5 inches or 1,129 mm) and the long-term annual average (WY1997–WY2019; 48.8 inches or 1,239 mm) but was lower than WY2018 (67.3 inches or 1, 708 mm), which was unusually high due to Hurricane Irma.
- Total freshwater inflow to the SLE in WY2019 was 0.87 million ac-ft, of which 37% was from Lake Okeechobee, 43% from the St. Lucie Basin, and 20% from the Tidal Basin. Inflows in WY2019 were comparable to WY2017 and the long-term term average (WY1997–WY2019) inflows.
- Nitrogen loading in WY2019 (1,206 t) was lower than the long-term average (1,759 t) with the highest contribution of 481 t (40%) from the St. Lucie Basin.
- Phosphorus loading in WY2019 (216 t) was lower than the long-term average (320 t) with the highest contribution of 125 t (68%) from the St. Lucie Basin.
- There were significant spatial and seasonal variations in the concentrations of Chla. The WY2019 average Chla concentration at all three estuary stations were comparable to the corresponding long-term (WY1997–WY2019) average concentrations.
- The average concentrations of TN and TP in WY2019 were lower than the long-term average concentrations (WY1997–WY2019).
- The percentage of days when salinity was within the preferred envelope for adult eastern oysters (> 10 to ≤ 26) was 63% in WY2019, greater than WY2018 (46%) and WY2017 (36%).
- Oyster density in the WY2019 dry season was an average of 510 live oyster/m^2, which was similar to densities observed in WY2017, indicating recovery after extensive decline following Hurricane Irma in September 2017. Larval recruitment also recovered in WY2019, with a peak spat settlement in November 2018.

CALOOSAHATCHEE RIVER ESTUARY AND WATERSHED CONDITION

BACKGROUND

Historically, the Caloosahatchee River was a winding river from its origin 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 were 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 three water control structures: S-77, S-78, and S-79 (**Figure 8C-12**). The final lock and dam structure at Olga (Franklin Lock and Dam or S-79) was completed in 1966 to prevent upstream saltwater intrusion and assure freshwater supply.

Discharges from Lake Okeechobee and the Caloosahatchee River Watershed between the S-77 and S-79 structures are regulated by the United States Army Corps of Engineers (USACE). Presently, the C-43 canal spans 44 miles (70 km) from S-77 at Lake Okeechobee to S-79, while the Caloosahatchee River Estuary (CRE) begins at S-79 and spans 26 miles (42 km) to Shell Point where it empties into San Carlos Bay (**Figure 8C-12)**. The surface area of the CRE is 21.6 square miles (55.9 square km) with an average depth of 8.9 ft (2.7 m) (Buzzelli et al. 2013a). The flushing time mean is 18.4 days and ranges from 2 to 30 days (Buzzelli et al. 2013b).

The modern Caloosahatchee River Watershed is divided into three contributing basins: C-43 Basin, Tidal Caloosahatchee Basin, and Lake Okeechobee measured via S-77 and S-79 (**Table 8C-7** and **Figure 8C-12**). The C-43 subbasins are East Caloosahatchee/S-4 and West Caloosahatchee (Bertolotti and Balci 2012, Buzzelli et al. 2017). The highest percentage of land use type within the Caloosahatchee River Watershed is agricultural, which comprises 43% according to the Florida Land Use, Cover and Forms Classification System (FLUCCS) Level 1 categories, with urban and built up (18%) and wetlands (14%) as the second and third highest, respectively.

Table 8C-7. Major contributing areas of the Caloosahatchee River Watershed.

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

Both the Caloosahatchee River Watershed and Lake Okeechobee can significantly influence the CRE water quality and biotic resources (Buzzelli et al. 2015). 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 (Bortone and Turpin 2000, Doering and Chamberlin 2000, 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).

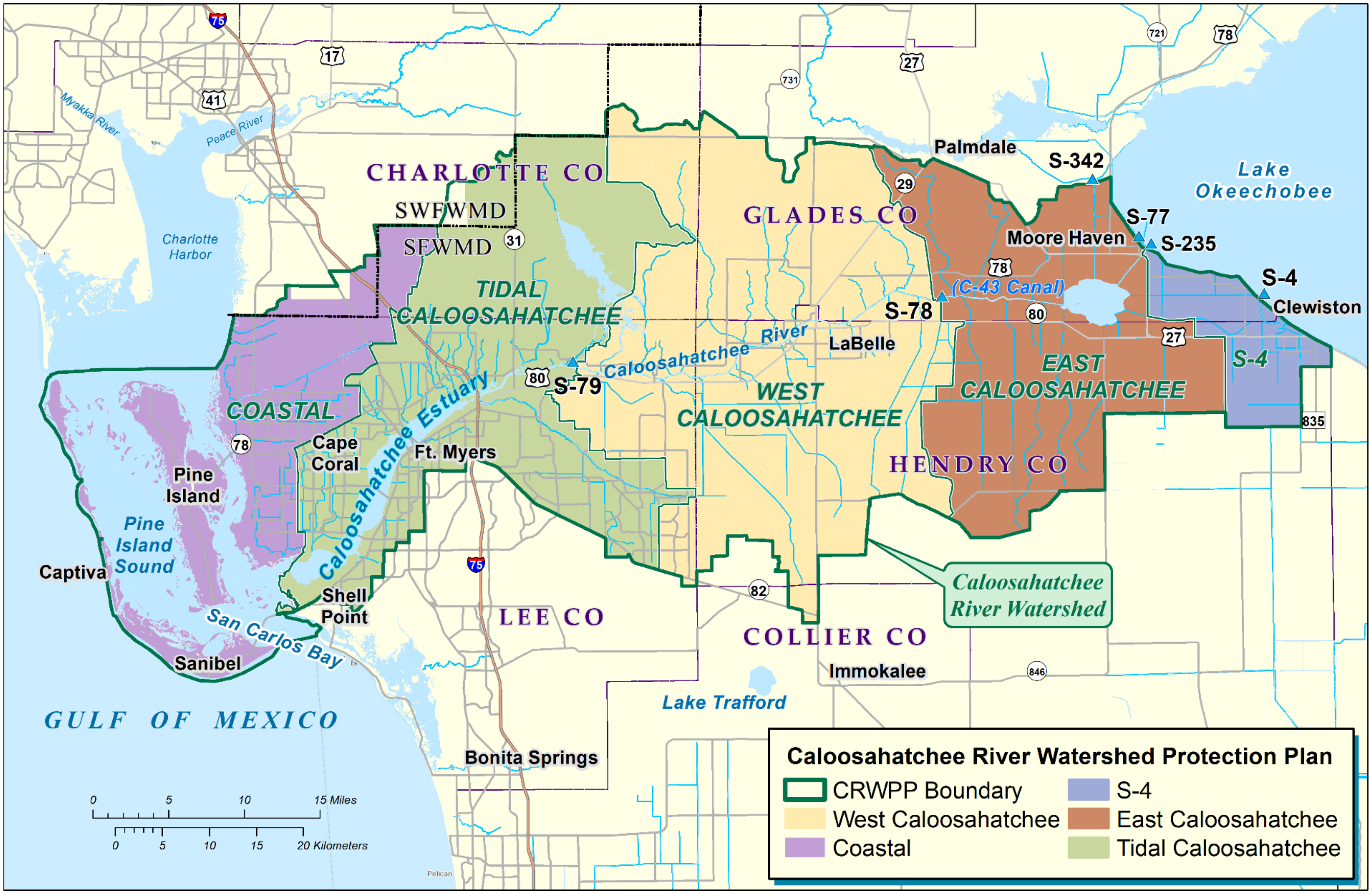

Figure 8C-12. The Caloosahatchee River Watershed with its basins and major water control structures.

A suite of external drivers and ecological responses are monitored in the CRE (**Figure 8C-13**). External drivers include rainfall, freshwater discharge, and nutrient loads, with patterns of salinity, estuarine nutrient concentrations, Chla concentration, and oyster habitat as the ecological responses. Oyster monitoring data will be presented in this report. SAV are also monitored in the estuary with a newly expanded monitoring program, for which the data are currently undergoing analyses and will be presented in the 2021 SFER.

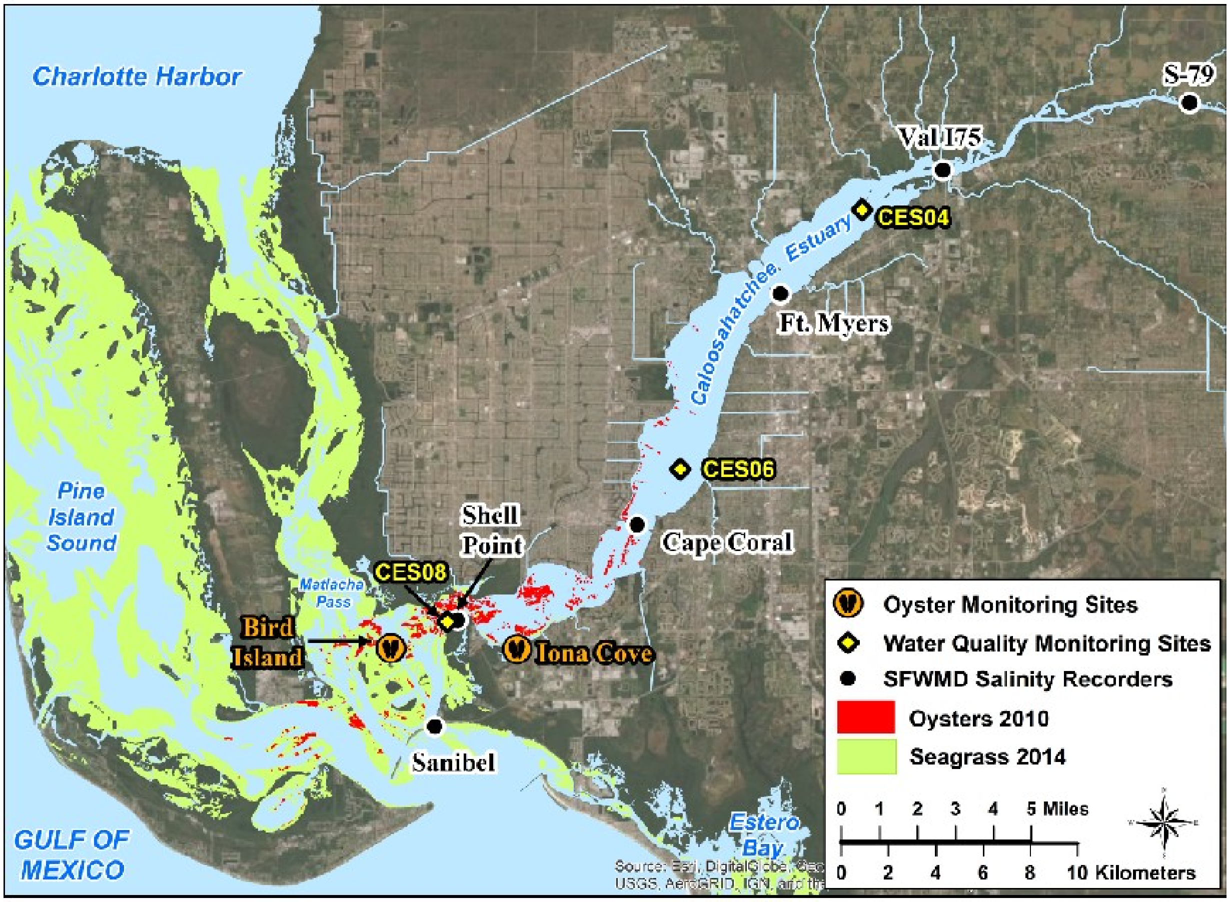

Figure 8C-13. Monitoring locations of salinity, water quality, and living aquatic habitat (oysters) for the CRE. The map includes a depiction of the distribution of seagrass and oyster habitat in the CRE, Matlatcha Pass, and Pine Island Sound.

HYDROLOGY

Rainfall

Daily NEXRAD rainfall data for the long-term POR, WY1997–WY2019, for each basin of the Caloosahatchee River Watershed were downloaded from DBHYDRO, accessible via the District's website at http://my.sfwmd.gov/nexrad2/nrdmain.action. The cumulative amount of rainfall across the watershed was computed using area weighting, which accounts for the different sizes of the basins.

The daily rainfall to the Caloosahatchee River Watershed for the past three water years (WY2017–WY2019) ranged from 0 to 7.4 inches (0 to 188 mm, **Figure 8C-14**), with the maximum occurring on September 10, 2017, when Hurricane Irma made landfall. Total rainfall for the Caloosahatchee River Watershed in WY2019 was 54.0 inches (1,371 mm), with 74% received during the wet season (May–October) (**Figure 8C-15**), comparable to the long-term annual average (52.3 inches or 1,328 mm). During WY2019, it rained 205 days (56%), with 7 days having rainfall > 1.0 inch (25 mm). WY2019 wet season rainfall was lower (39.8 inches or 1,011 mm) than in the wet season of the two previous years (43.2 inches or 1,097 mm in WY2017 and 57.2 inches or 1,453 mm in WY2018). Total rainfall in WY2019 was less than WY2018 (63.0 inches or 1,601 mm) but greater than WY2017 (48.1 inches or 1,222 mm) (**Figure 8C-15)**. Spatial distribution patterns of rainfall across the watershed in WY2019 were similar to those observed in WY2018 and the long-term annual average, with the most rainfall in the Tidal Caloosahatchee Basin and the least rainfall in the Coastal and S-4 basins (**Figure 8C-16**).

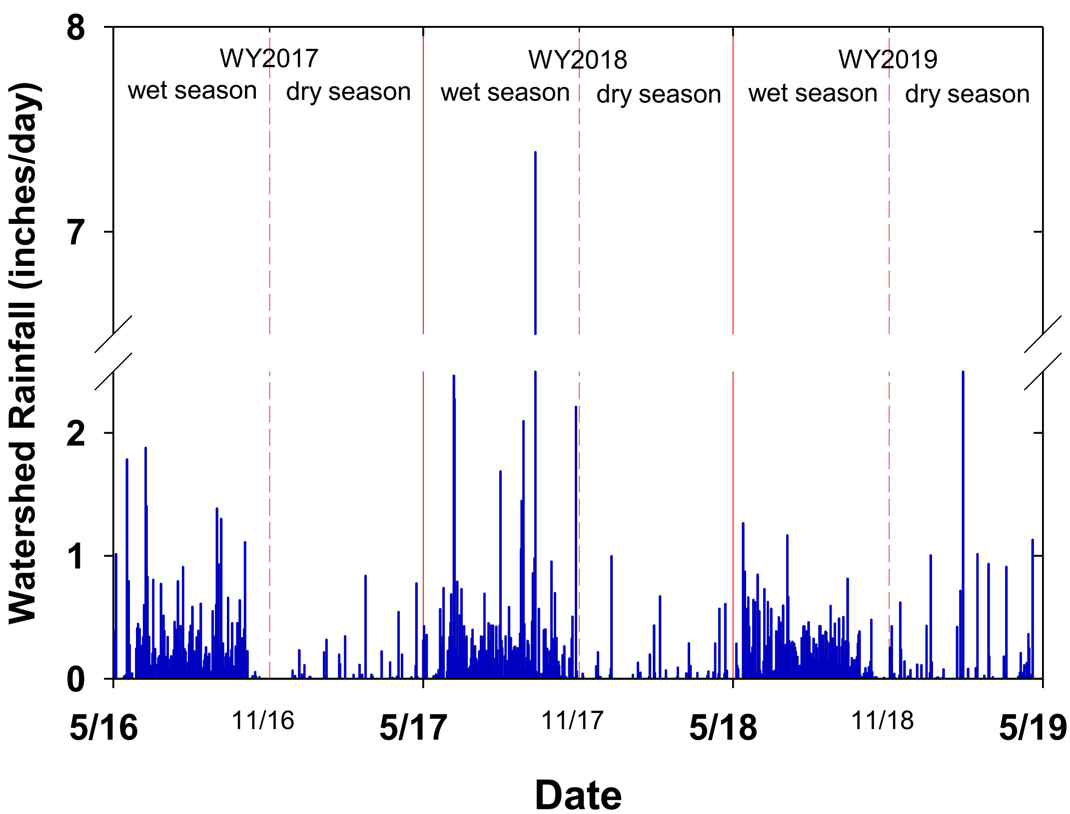

Figure 8C-14. Time series of total daily rainfall to the Caloosahatchee River Watershed for WY2017–WY2019. Maximum rainfall occurred during passage of Hurricane Irma on September 10, 2017.

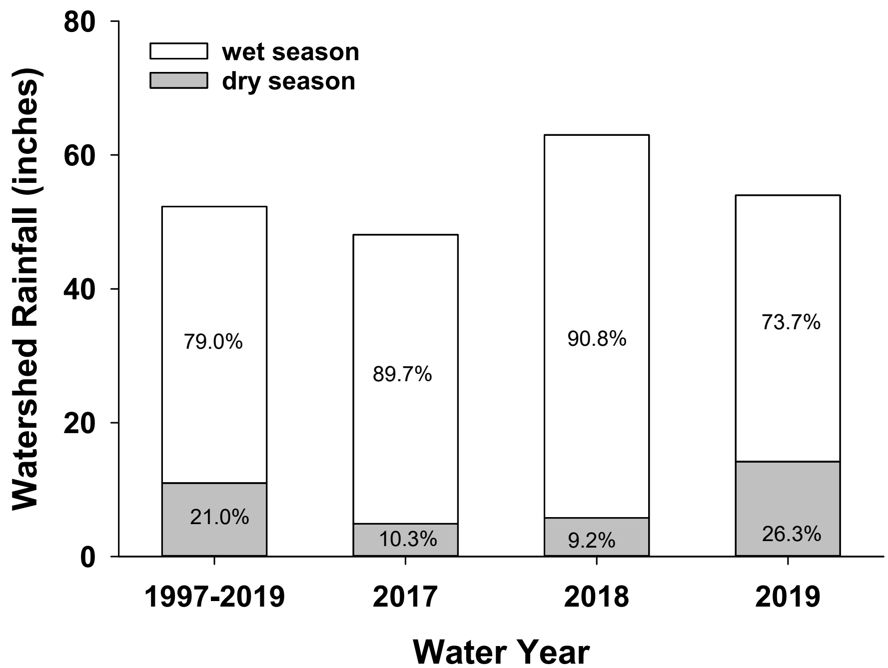

Figure 8C-15. Total rainfall in the Caloosahatchee River Watershed by water year and season including averages from the WY1997–WY2019 period and the past three water years: WY2017, WY2018, and WY2019. The numbers are percentage of annual total rainfall for each season.

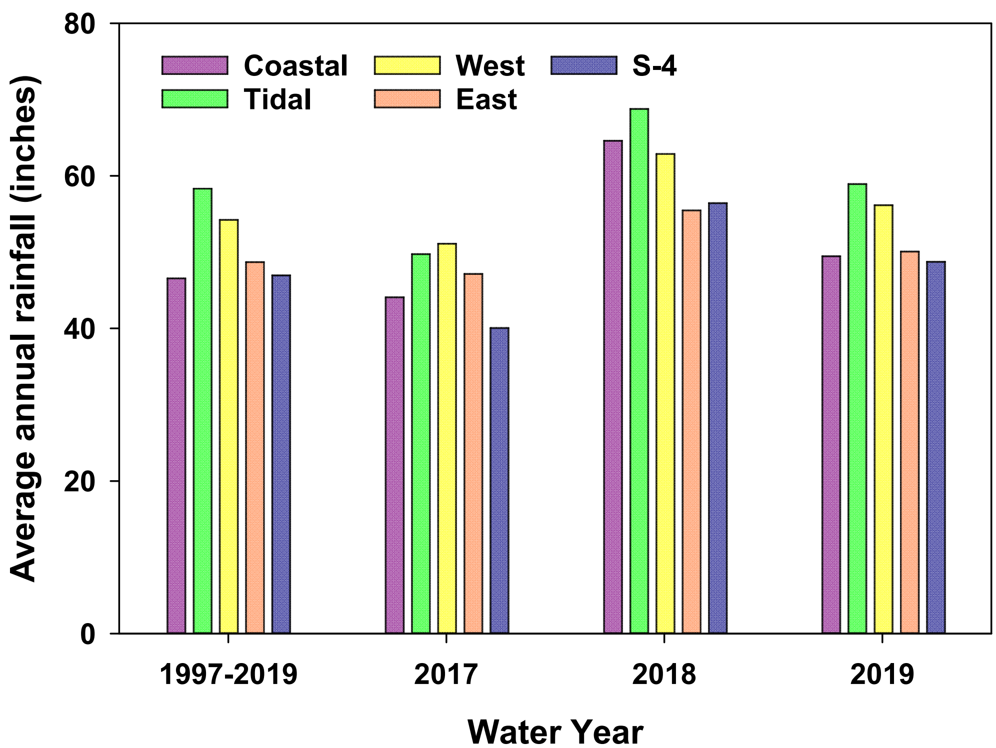

Figure 8C-16. Average annual rainfall to the Caloosahatchee River Watershed contributing areas (Coastal, Tidal Caloosahatchee, West Caloosahatchee, East Caloosahatchee, and S-4), including the long-term average (WY1997–WY2019), and WY2017, WY2018, and WY2019. See Figure **8C-12** for locations of basins.

Freshwater Inflow

The Caloosahatchee River Watershed basins are divided into three main basins (C-43 Basin, Tidal Caloosahatchee Basin, and Lake Okeechobee) and tributaries (**Table 8C-7**). All freshwater flows are measured except those from the Tidal Caloosahatchee Basin where the Linear Reservoir (Lin Res) 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 flow and load calculations, the East Caloosahatchee Basin and the S-4 basin are combined.

Average daily inflows from WY1997 through WY2019 for S-79, S-78, S-77, and the Tidal Caloosahatchee Basin were used to evaluate intra- and interannual variations in inflow, quantify total inflow to the CRE, and estimate the contributions of the basins to total inflow. This included the relative volume contributions from the three basins. Total daily discharges and contributions were categorized by water year and season. As mentioned in the previous paragraph, the contribution of the Tidal Caloosahatchee Basin to freshwater inflow and nutrient loads was estimated using the Lin Res Model. Flows and loads from the Cape Coral Coastal Basin (referred to as Coastal Basin in **Figure 8C-12**) were not estimated as they do not discharge into the CRE.

The total freshwater inflow to the CRE in WY2019 was 2.23 million ac-ft (**Table 8C-8**), of which 45% was from the C-43 Basin, 34% was from Lake Okeechobee, and 21% from the Tidal Caloosahatchee Basin (**Figure 8C-17a**). The total inflow in WY2019 was higher than the long-term average (WY1997–WY2019) inflow (1.90 million ac-ft) but was 38% lower than WY2018 and 5% lower than WY2017 total inflow. High rainfall in WY2018 resulted in high total inflow. The magnitude of each source (Lake Okeechobee, C-43 Basin, and Tidal Caloosahatchee Basin) contribution to inflow fluctuated greatly between WY1997 and WY2019 reflecting seasonal and interannual climatic cycles, such as El Niño events (**Figure 8C-18a**). The highest total flow occurred in WY2006 (4.06 million acre-feet per year [ac-ft/yr]) and the lowest flow occurred in WY2008 (0.29 million ac-ft/yr; **Figure 8C-18a**).

Total Nitrogen and Total Phosphorus Loads to the Estuary

TN and TP loads were calculated using measured daily inflows at S-79 and S-77, and TN and TP concentrations determined from water samples collected approximately monthly under conditions of flow at the structure. The contribution of the Tidal Caloosahatchee Basin was estimated as tidal basin runoff and TN and TP concentrations collected by Lee County and the City of Cape Coral. Data are available from the websites of the Lee County Department of Natural Resources (https://www.leegov.com/naturalresources) and the City of Cape Coral (http://www.capecoral.net/).

The annual TN and TP loads to the CRE fluctuated with total freshwater inflow over the long-term POR, which is WY1997–WY2019 (**Figures 8C-18b** and **8C-18c**). In WY2019, TN load was 3,810.85 t/yr of which 49% was from the C-43 Basin, 36% from Lake Okeechobee, and 15% from Tidal Caloosahatchee Basin (**Figure 8C-17b**). The total TN load in WY2019 was 23% greater than the long-term average and 12% greater than WY2017 (**Table 8C-8**) due to higher load contribution from each source (**Figure 8C-17c**). In WY2019, TP loading was 412.87 t, of which 53% was from the C-43 Basin, 32% from Lake Okeechobee, and 16% from the Tidal Caloosahatchee Basin (**Figure 8C-17c**). This TP load was 36% greater than the long-term average and 30% greater than WY2017 (**Table 8C-8**), due to higher contributions from each of the three sources (**Figure 8C-18c**). WY2019 TP load was 36% lower and TN 28% lower than WY2018, likely due to Hurricane Irma effects on inflow in WY2018. The WY2019 TN:TP loading ratios calculated using TN loads and TP loads in metric tons per year of the major contributors vary with Lake Okeechobee having a ratio of 10.6:1 and C-43 Basin having a ratio of 8.5:1 (**Figure 8C-18c**), indicating water contributed from the two sources provide different nutrient environments to the estuary.

Table 8C-8. Summary of freshwater inflow in thousand acre-feet per year (10^3 ac-ft/yr) and TN loads and TP loads in metric tons per year (t/yr) from Lake Okeechobee, the C-43 Basin, and the Tidal Caloosahatchee Basin (ungauged) to the CRE. Shown in the table are the long-term averages (WY1997–WY2019) and values for WY2017, WY2018, and WY2019.

Period	Inflow (10^3 ac-ft/yr)			
	Lake Okeechobee	C-43 Basin	Tidal Basin	Total
WY1997–WY2019	630.22	885.38	382.49	1,898.09
WY2017	1,010.07	929.41	392.76	2,332.23
WY2018	1,201.05	1,391.91	474.37	3,067.34
WY2019	760.54	998.17	472.45	2,231.16

Period	TN Load (t/yr)			
	Lake Okeechobee	C-43 Basin	Tidal Basin	Total
WY1997–WY2019	1,103.88	1,557.80	440.28	3,101.96
WY2017	1,559.23	1,464.68	392.94	3,416.85
WY2018	2,115.19	2,641.37	572.50	5,329.06
WY2019	1,386.35	1,852.22	572.27	3,810.83

Period	TP Load (t/yr)			
	Lake Okeechobee	C-43 Basin	Tidal Basin	Total
WY1997–WY2019	75.74	179.09	48.14	302.96
WY2017	103.94	175.12	38.38	317.44
WY2018	194.74	372.77	75.55	643.06
WY2019	131.18	217.09	64.60	412.88

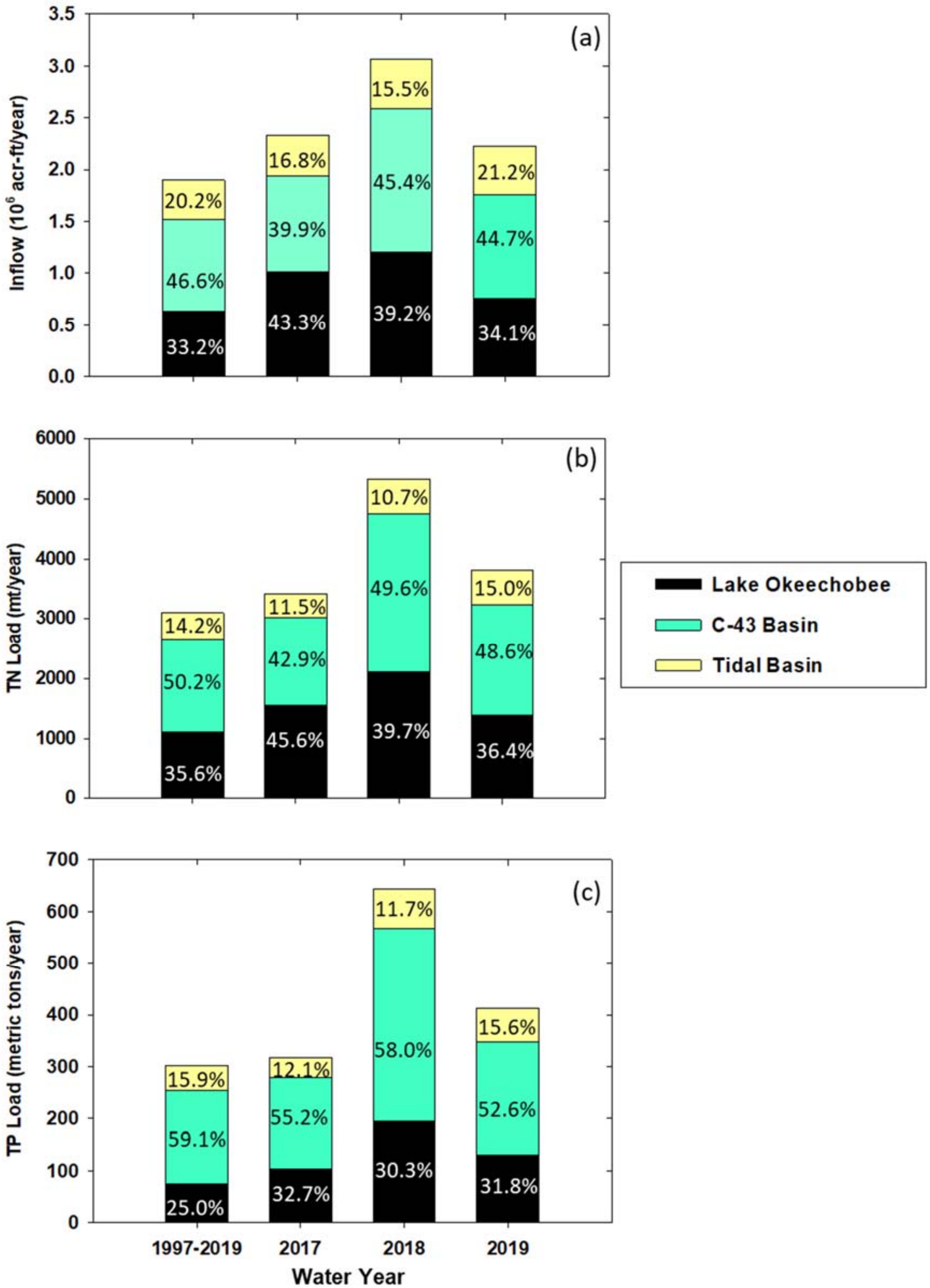

Figure 8C-17. Stacked bar chart for (a) total freshwater inflow in million ac-ft per year (10^3 ac-ft/yr) and (b) TN load and (c) TP load in metric tons per year (t/yr) attributable to Lake Okeechobee, the C-43 Basin, and the Tidal Caloosahatchee Basin. Displayed are the long-term average for WY1997–WY2019, WY2017, WY2018, and WY2019.

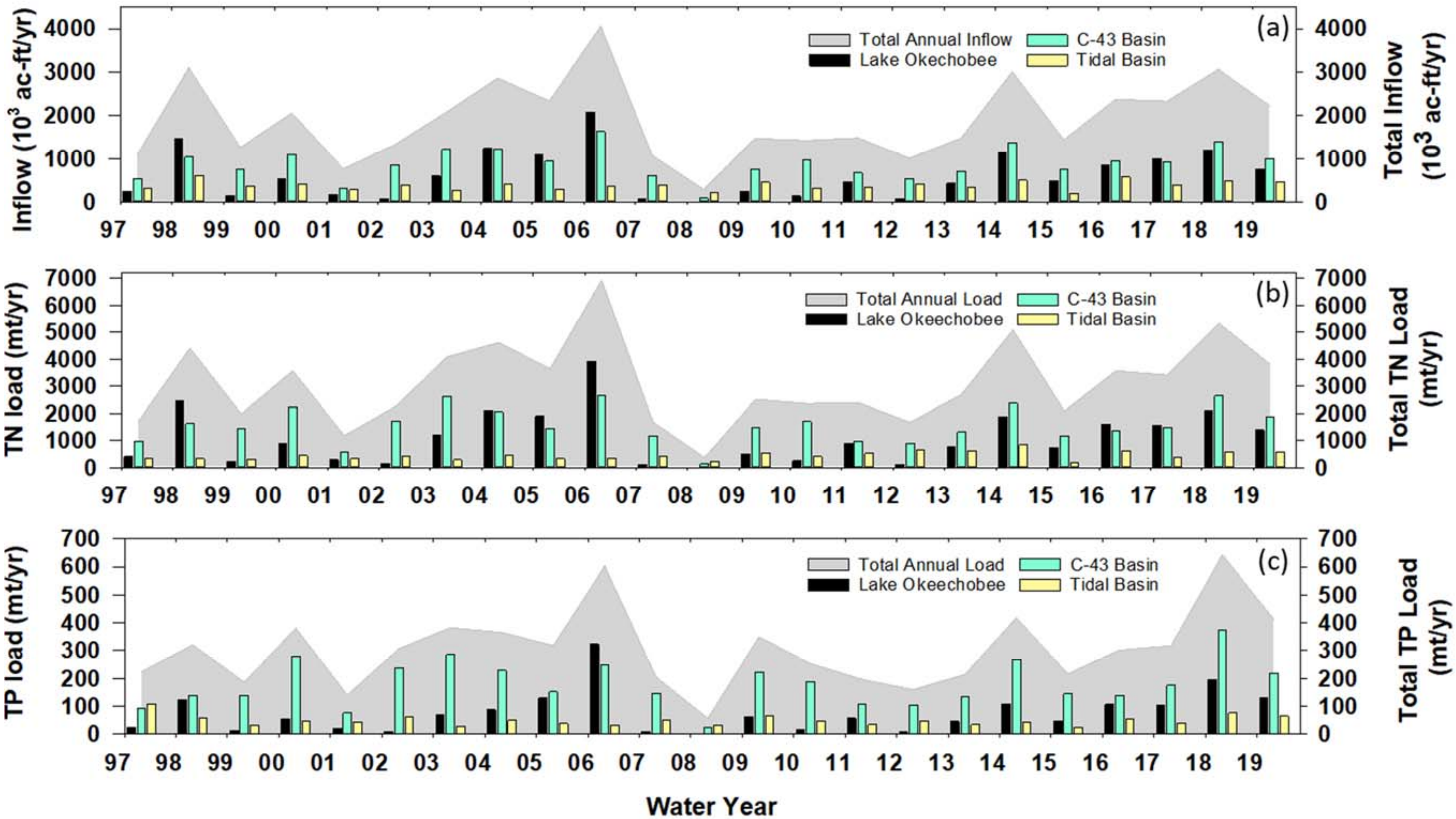

Figure 8C-18. Time series of (a) annual freshwater inflow in million acre-feet per year (10^3 ac-ft/yr or 1.233×10^9 cubic meters [m^3]) and (b) TN loads and (c) TP loads in metric tons per year (t/yr) into the CRE attributable to Lake Okeechobee, the C-43 Basin, and the Tidal Basin for the POR (WY1997–WY2019).

Total Phosphorus and Total Nitrogen Loading Data for the Most Recent Five Years (Water Years 2015–2019)

Table 8C-9 lists the basin annual inflows, TN load, TN FWMC, TP load, and TP FWMC for the last five water years (WY2015–WY2019) in the Caloosahatchee River Watershed. Contributions to the watershed included inflows from Lake Okeechobee, C-43 and S-4 basins combined, and the Tidal Caloosahatchee Basin. The 5-year average contribution from the Tidal Caloosahatchee Basin accounted for 18% total flow, 14% TP load, and 14% TN load. The percent contributions from the C-43 and S-4 basins were 44% of total flow, 56% of TP load, and 47% of TN load. Lake Okeechobee contributed 38% of total flow, 31% of TP load, and 41% of TN load averaged over this five-year period.

Table 8C-9. Caloosahatchee River Watershed tributary basin annual flow volumes with TP and TN loads and FWMCs.

Water Year	Lake Okeechobee	C-43 and S-4 Basins	Tidal Caloosahatchee Basin	Total
		Flow (10^3 x acre-feet)		
WY2015	488.88	748.05	199.58	1,433.75
WY2016	848.67	957.60	570.49	2,376.73
WY2017	1,010.07	929.41	392.76	2,332.23
WY2018	1,201.05	1,391.91	474.37	3,067.33
WY2019	760.54	998.17	472.45	2,231.16
5-Year Average	861.84	1,005.03	421.93	2,288.80
5-Year %	38%	44%	18%	100%
		TN load (t/yr)		
WY2015	734.33	1,162.10	182.53	2,078.95
WY2016	1,594.33	1,344.86	627.33	3,566.52
WY2017	1,559.23	1,464.68	392.94	3,416.85
WY2018	2,115.19	2,641.37	572.50	5,329.06
WY2019	1,386.35	1852.22	572.27	3,810.83
5-Year Average	1,477.89	1,693.05	469.51	3,640.44
5-Year %	41%	47%	14%	100%
		TN FWMC (mg/L)		
WY2015	1.22	1.26	0.74	1.18
WY2016	1.52	1.14	0.89	1.22
WY2017	1.25	1.28	0.81	1.19
WY2018	1.43	1.54	0.98	1.41
WY2019	1.48	1.50	0.98	1.38
5-Year	1.39	1.37	0.90	1.29
		TP load (t/yr)		
WY2015	47.85	144.74	22.90	215.48
WY2016	106.22	139.68	55.77	301.67
WY2017	103.94	175.12	38.38	317.44
WY2018	194.74	372.77	75.55	643.06
WY2019	131.18	217.09	64.60	412.88
5-Year Avgerage	116.78	209.88	51.44	378.11
5-Year %	31%	56%	14%	100%
		TP FWMC (mg/L)		
WY2015	0.079	0.157	0.093	0.122
WY2016	0.101	0.118	0.079	0.103
WY2017	0.083	0.153	0.079	0.110
WY2018	0.131	0.217	0.129	0.170
WY2019	0.140	0.176	0.111	0.150
5-Year	0.110	0.169	0.099	0.134

ESTUARY RESPONSES

Water Quality

Water samples are obtained via grab sample at a depth of 0.5 m at 10 stations in the CRE, San Carlos Bay, and Pine Island Sound at approximately monthly intervals as part of the RWQMP (**Figure 8C-12**). The stations with the most complete records (CES04, CES06, and CES08) were selected to characterize estuarine water quality. Concentrations of Chla, TN, and TP for WY2000–WY2019 were assessed (**Figures 8C-19** and **8C-20**). Long-term and seasonal averages and standard deviations were calculated for the WY2000–WY2019 period and the most recent three water years (WY2017, WY2018, and WY2019) (**Table 8C-10**). Measurements of TN and TP were used to compute TN:TP molar ratios. Shapiro-Wilk tests were used to evaluate data normality. Where normality could not be assumed, non-parametric Kruskal-Wallis analyses were conducted. Multiple comparisons for station means were evaluated with Mann-Whitney U tests. In addition to statistical analyses, **Figures 8C-19** and **8C-20** present the temporal patterns of Chla, TN, TP, and TN:TP for WY2009–WY2019 to interpret variations relative to water inflow since the implementation of the current Lake Okeechobee Regulation Schedule, LORS2008 (SFWMD 2010).

Concentrations of Chla varied from 0.25 to 106 µg/L, with similar long-term average values at CES04 (9.57 ± 13.11 µg/L) and CES06 (9.05 ± 11.19 µg/L), which were significantly higher than at CES08 (3.37 ± 3.16 µg/L) (**Figure 8C-19**). In general, wet season concentrations were greater than those measured during the dry season, with some exceptions in WY2017 at CES06 and WY2018 and WY2019 at CES04 (**Table 8C-10**). The highest average values occurred between June and July in all three stations. The annual concentrations of Chla at CES04 and CES06 from WY2017 through WY2019 were lower than the long-term annual average, with WY2019 concentrations lower in both wet and dry season for each station (**Table 8C-10**). Wet season concentrations at Station CES08 during WY2018 and WY2019 were higher and dry season concentrations lower relative to the long-term average, lending to similar overall annual average concentration values.

Concentrations of TN ranged from 0.03 to 2.54 mg/L and varied significantly among the three stations and seasons (**Figures 8C-20a** through **8C-20c**). The average concentrations decreased along the estuary gradient in the downstream direction, with the highest average value observed at CES04 (1.18 ± 0.33 mg/L), followed by CES06 (0.94 ± 0.36 mg/L), and CES08 (0.53 ± 0.28 mg/L). Comparisons of all stations over the entire POR showed significantly greater concentrations in the wet (1.03 ± 0.44 mg/L) than in the dry (0.82 ± 0.37 mg/L) season with the highest average values occurring between June and July. In WY2019 average concentrations of TN at all three stations were higher than the long-term average and WY2017, but lower than WY2018 averages (**Table 8C-10**). The high values in WY2018, with dry season average values higher than wet season average values, likely reflect the impact of Hurricane Irma.

Concentrations of TP ranged from 0.02 to 0.69 mg/L and varied significantly among the three stations (**Figures 8C-20d** through **8C-20f**). Similar to TN, TP concentrations exhibited a decreasing pattern in the downstream direction, with the highest average value observed at CES04 (0.13 ± 0.07 mg/L), followed by CES06 (0.10 ± 0.06 mg/L), and CES08 (0.07 ± 0.05 mg/L). The nutrient concentrations reflect a common spatial pattern in estuaries resulting from mixing of nutrient-rich headwaters with the downstream ocean water of lower nutrient concentration. Wet season WY2019 TP concentrations (0.13 ± 0.08 mg/L) were significantly higher than dry season concentrations (0.08 ± 0.04 mg/L) and the highest average TP values occurred between July and September. The WY2019 average TP concentrations at the three stations were comparable to the long-term averages and less than WY2018, when intense precipitation and subsequent high inflow from the hurricane increased nutrient concentrations in the estuary (**Table 8C-10**).

The highest average TN:TP molar ratio in WY2019 occurred at CES04 (22:1) followed by CES06 (20:1) and CES08 (20:1), the station that was also the least variable. In general, TN:TP molar ratios were lower in the wet season than in the dry season, indicating that external nutrients carried by inflow can drive seasonal changes in phosphorus and nitrogen within the estuary.

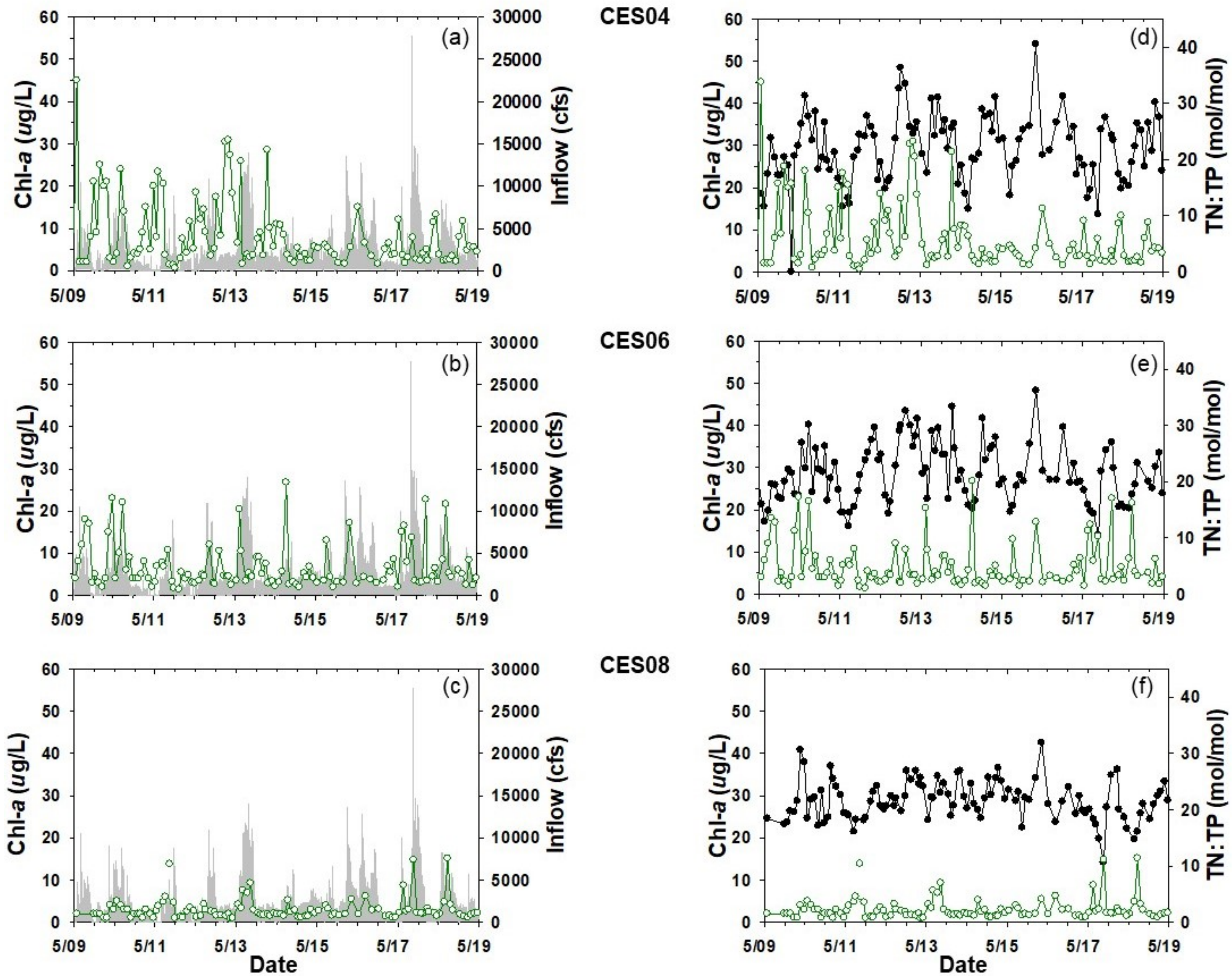

Figure 8C-19. Time series (WY2009-WY2019) of Chla (green line with open circles) and flow at S-79 (gray line in a through c) and TN:TP molar ratios (black line with solid circles in d through f) at stations CES04, CES06 and CES08 in the CRE.

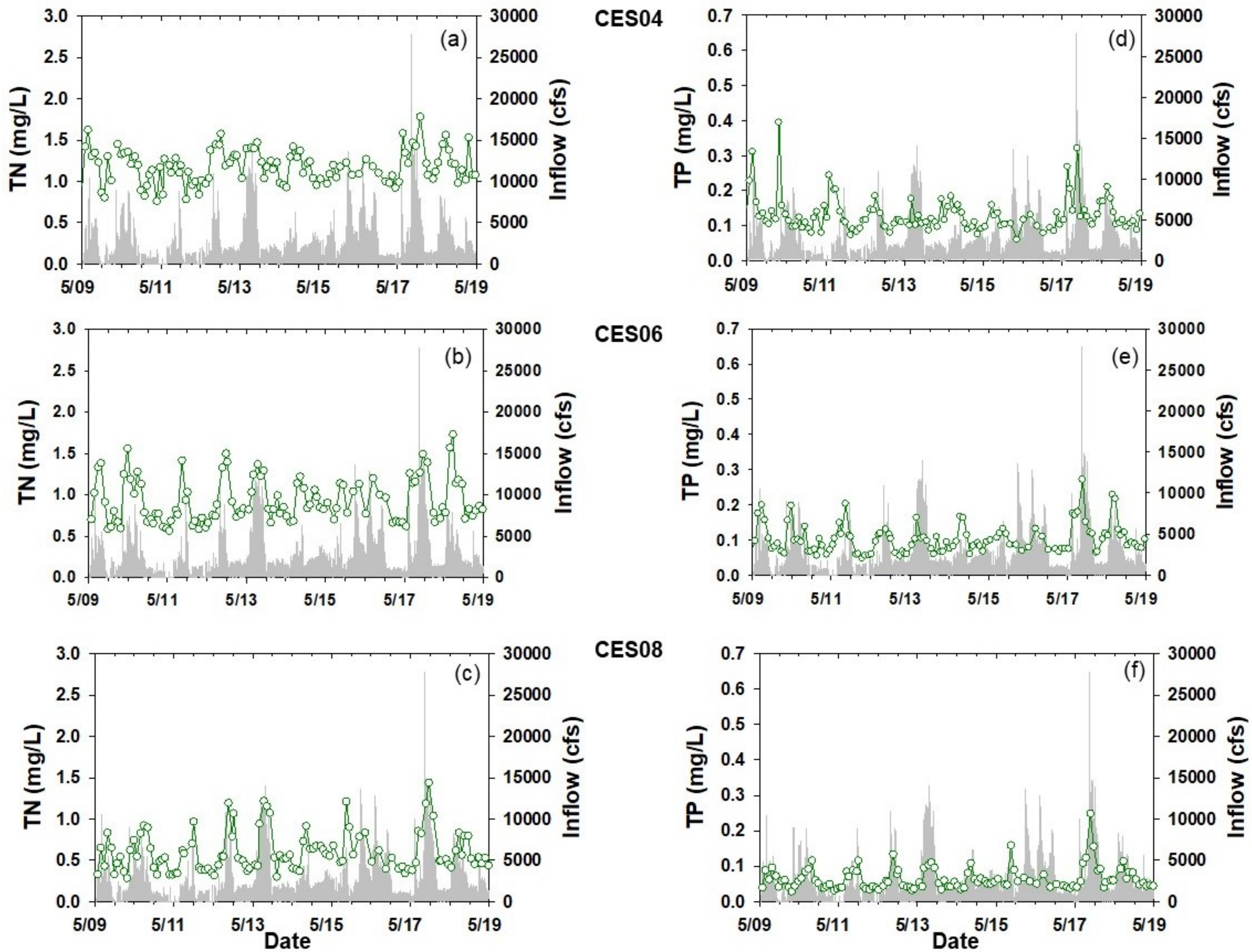

Figure 8C-20. Time series (WY2009-WY2019) of TN (a through c) and TP (d through f) represented by the green line with open circles, and flow at S-79 (gray line) at stations CES04, CES06 and CES08 in the CRE.

Table 8C-10. Water column concentrations of Chla, TN, and TP at three stations (CES04, CES06 and CES08) in the CRE. The table includes wet season (May–October), dry season (November–April), and total annual averages (Avg) with standard deviations (SD) for the WY2000–WY2019 period (except for WY2003–WY2006 and WY2008 for CES08), and for WY2017, WY2018, and WY2019. Statistically significant differences between wet and dry season of each station are in bold.

Period	Chla (µg/L)																	
	CES04						CES06						CES08					
	Wet		Dry		Total		Wet		Dry		Total		Wet		Dry		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY2000-WY2019	10.78	16.94	8.36	7.41	9.57	13.11	**11.20**	13.78	**6.89**	7.17	9.05	11.19	**4.59**	3.81	**2.36**	2.01	3.37	3.16
WY2017	8.33	6.00	4.13	1.82	5.70	4.11	3.61	0.76	5.47	2.31	4.77	2.04	3.65	2.23	1.67	0.84	2.41	1.69
WY2018	5.19	3.98	6.40	4.75	5.79	4.23	9.75	6.21	7.18	7.71	8.46	6.81	5.60	5.16	2.26	0.59	3.93	3.91
WY2019	**2.79**	0.67	**6.70**	2.75	4.75	2.79	8.54	7.56	4.71	2.26	6.45	5.42	5.78	5.32	1.72	0.42	3.57	3.99

Period	TN (mg/L)																	
	CES04						CES06						CES08					
	Wet		Dry		Total		Wet		Dry		Total		Wet		Dry		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY2000-WY2019	**1.26**	0.36	**1.10**	0.28	1.18	0.33	**1.08**	0.38	**0.79**	0.28	0.94	0.36	**0.61**	0.33	**0.45**	0.21	0.53	0.28
WY2017	**1.18**	0.09	**1.01**	0.07	1.08	0.11	0.99	0.21	0.73	0.13	0.83	0.20	0.50	0.11	0.42	0.07	0.45	0.09
WY2018	1.34	0.21	1.25	0.31	1.30	0.25	1.16	0.29	0.88	0.29	1.03	0.31	0.86	0.41	0.60	0.25	0.74	0.36
WY2019	1.34	0.15	1.14	0.20	1.24	0.20	**1.26**	0.34	**0.80**	0.06	1.03	0.33	0.67	0.17	0.49	0.04	0.58	0.15

Period	TP (mg/L)																	
	CES04						CES06						CES08					
	Wet		Dry		Total		Wet		Dry		Total		Wet		Dry		Total	
	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD	Avg	SD
WY2000-WY2019	**0.16**	0.09	**0.11**	0.04	0.13	0.07	**0.13**	0.06	**0.08**	0.03	0.10	0.06	**0.09**	0.07	**0.06**	0.02	0.07	0.05
WY2017	0.11	0.02	0.10	0.02	0.10	0.02	**0.11**	0.03	**0.07**	0.00	0.08	0.02	0.06	0.02	0.04	0.00	0.05	0.01
WY2018	0.20	0.08	0.13	0.02	0.16	0.07	**0.17**	0.06	**0.10**	0.03	0.13	0.06	0.12	0.07	0.07	0.02	0.09	0.06
WY2019	**0.15**	0.04	**0.11**	0.02	0.13	0.04	**0.15**	0.05	**0.09**	0.01	0.12	0.05	**0.09**	0.02	**0.05**	0.01	0.07	0.02

Salinity

Salinity is derived from conductivity and temperature field measurements and converted to unitless salinity values per Fofonoff and Millard (1983). 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). At the estuary-scale, average monthly inflows of 400 to 2,800 cfs at the S-79 structure were determined to be conducive to tape grass in the upstream regions 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).

Surface and bottom salinity observations were recorded every 15 minutes at six stations in the CRE: S-79, ValI75, Ft. Myers, Cape Coral, Shell Point, and Sanibel Island Bridge. Data analyses focused on the long-term average (WY2001–WY2019) and the last three water years at the Ft. Myers station. The Ft. Myers surface salinity data were used to calculate the percentage of days above or below a salinity of 10, the threshold criteria for tape grass (**Table 8C-11** and **Figure 8C-12**). Additional salinity data at the Cape Coral Bridge near the oyster monitoring sites of Bird Island and Iona Cove are also presented and further discussed under the oyster monitoring section of this report.

In WY2019, daily average surface salinity at the Ft. Myers station ranged from 0.19 to 14.82 and showed an inverse relationship to freshwater inflow (**Figure 8C-21**). The percentage of days of salinity < 10 in WY2017 (75.1%) and WY2018 (69.1%) were comparable to the long-term average (73.2%) but was greater in WY2019 (93.7%; **Table 8C-11**). Consequently, WY2019 showed about four times less occurrence of average salinity ≥ 10 relative to the long-term average.

Table 8C-11. Salinity criteria at the Ft. Myers station for WY2001–WY2019, WY2017, WY2018, and WY2019. At the Ft. Myers station, the daily average surface salinity goal is not to exceed the 30-day moving average surface salinity goal of 10 (Section 40E-8.221, Florida Administrative Code).

Period	Days with 30-day Moving Average of Surface Salinity < 10 (%)	Days with 30-day Moving Average of Surface Salinity ≥ 10 (%)
WY2001–WY2019	73.2%	26.8%
WY2017	75.1%	24.9%
WY2018	69.1%	30.9%
WY2019	93.7%	6.3%

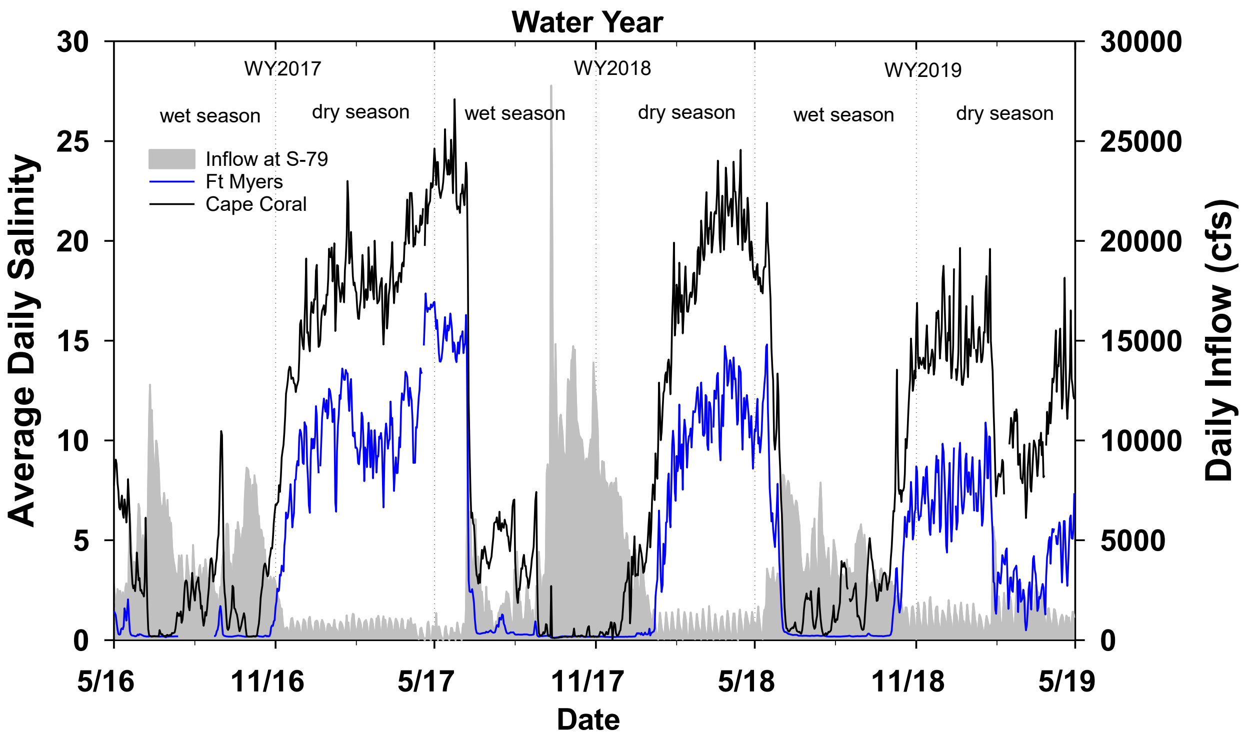

Figure 8C-21. Time series of total freshwater inflow (cfs) at S-79 (grey fill) and daily average surface water salinity at the Ft. Myers (blue line) and Cape Coral (black line) stations in the CRE for WY2016–WY2019.

Oyster Habitat

Oyster monitoring has been ongoing in the lower CRE at several stations since WY2001 as a component of the RECOVER Program in support of CERP (RECOVER 2014). This report presents data from the Bird Island (CR-BI) and Iona Cove (CR-IC) stations (**Figure 8C-12**) over the last five years (WY2015–WY2019). Data were collected by Florida Gulf Coast University during Calendar Year (CY2014)–CY2017 and FWC during CY2017–CY2019).

The ongoing monitoring program determines oyster density using survey methodology based on methods from Lenihan and Peterson (1998) and Grizzle et al. (2005), sampling biannually over this long-term period of record and quarterly at CR-BI and CR-IC beginning in CY2018. At each station, four 0.25-m^2 quadrats are placed haphazardly and all oysters with articulated shells are counted to determine the number of dead versus living. From each quadrat, up to 50 shells are selected for shell height measurements. Live oyster average density at Iona Cove in both WY2019 seasons (wet = 229, dry = 406 live oyster/m^2), were similar to that of WY2017 (wet = 231, dry = 430 live oyster/m^2) (**Figure 8C-22a**). The highest number observed over the last five years at Iona Cove was in the WY2016 dry season when 1,552 live oyster/m^2 were found. This was followed by a significant decline in WY2017, likely due to prolonged low salinity events (salinity ≤ 10 at the Cape Coral monitoring station) during that period that began at the end of the WY2016 dry season and continued through the WY2017 wet season (**Figure 8C-21**). These patterns of decline in population health are also observed in the shell height metrics when these two sampling events are compared (**Figure 8C-22b**). While the numbers are lower than some previous years, the WY2019 density observations indicate a significant recovery from Hurricane Irma effects, following which an average of only 2 live oysters/m^2 was observed in March 2018 (**Figure 8C-22a**). Observed average shell heights were also similar to those before Hurricane Irma (~40 mm) (**Figure 8C-22b**). Average live oyster/m^2 at the Bird Island station, located at the mouth of the estuary, was generally higher than at the CR-IC station over the POR (**Figures 8C-22a** and **23a**), though CR-BI frequently exhibited smaller shell heights (**Figure 8C-22b** and **23b**). At CR-BI, the highest density of live oysters was observed in the WY2017 wet season (2,107 live oysters/m^2), though oysters were smaller in height relative to the previous sampling event (**Figure 8C-23b**), followed by a significant decline in the WY2017 dry season (809 live oyster/m^2) and the June 2017 quarterly sampling event (813 live oyster/m^2). Numbers were reduced to the lowest over this five-year period post Hurricane Irma (587 live oyster/m^2 observed in March 2018) (**Figure 8C-23a**). Shell size at CR-BI has increased during WY2019 to pre-storm values (~30 mm) also indicating recovery in the population (**Figure 8C-23b**).

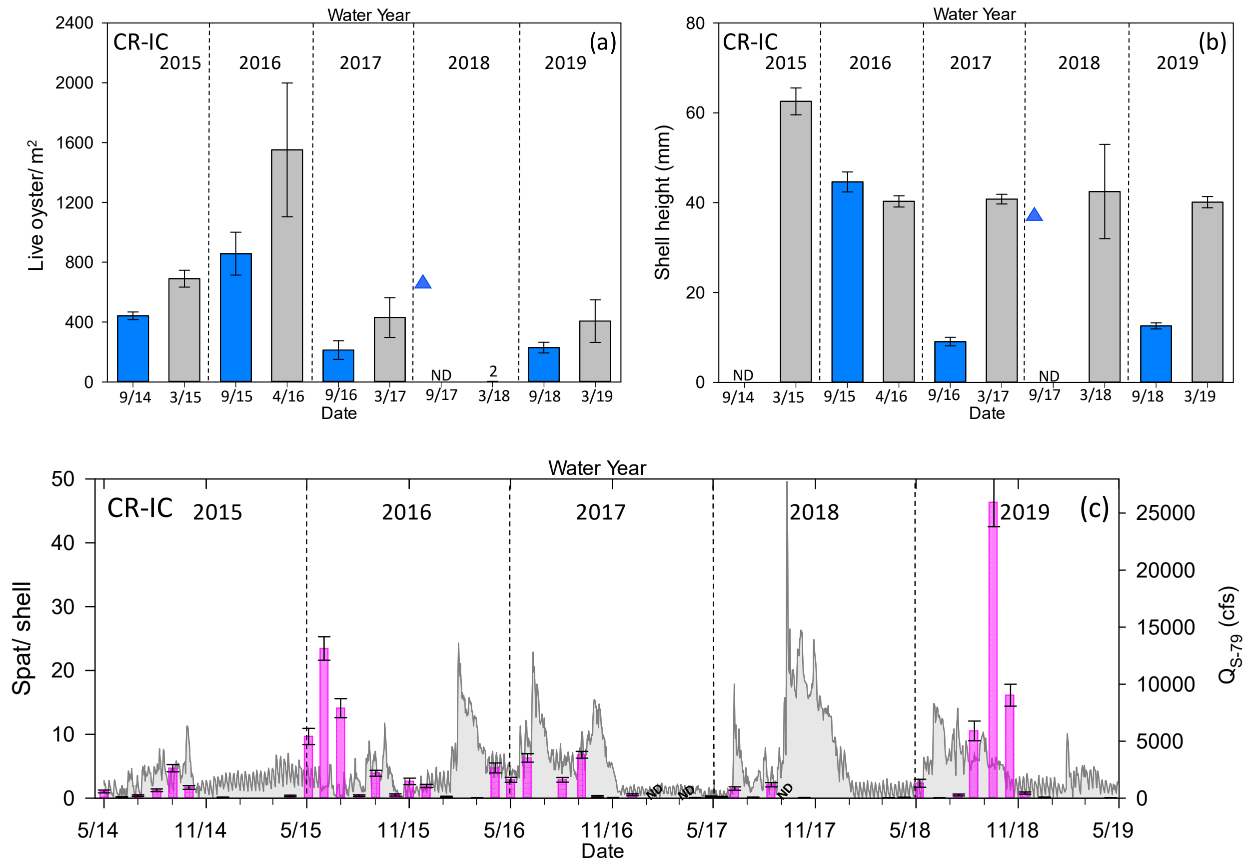

Figure 8C-22. Oyster monitoring metrics from the CRE Iona Cove station (CR-IC) for WY2015–WY2019 include (a) oyster density, (b) shell height, and (c) larval recruitment. The blue triangles in (a) and (b) represent a quarterly sampling event in June 2017 and before the passage of Hurricane Irma on September 10, 2017, affected the area. Blue bars in (a) and (b) indicate wet season sampling and grey bars indicate dry season sampling. The gray filled area in (c) depicts the daily freshwater inflow rate (y-axis) to the CRE from the S-79 structure. New arrays were deployed in January and February 2017 and no samples were collected September 2017 (ND). Density, shell height, and larval recruitment values represent average ± standard error for each sampling date.

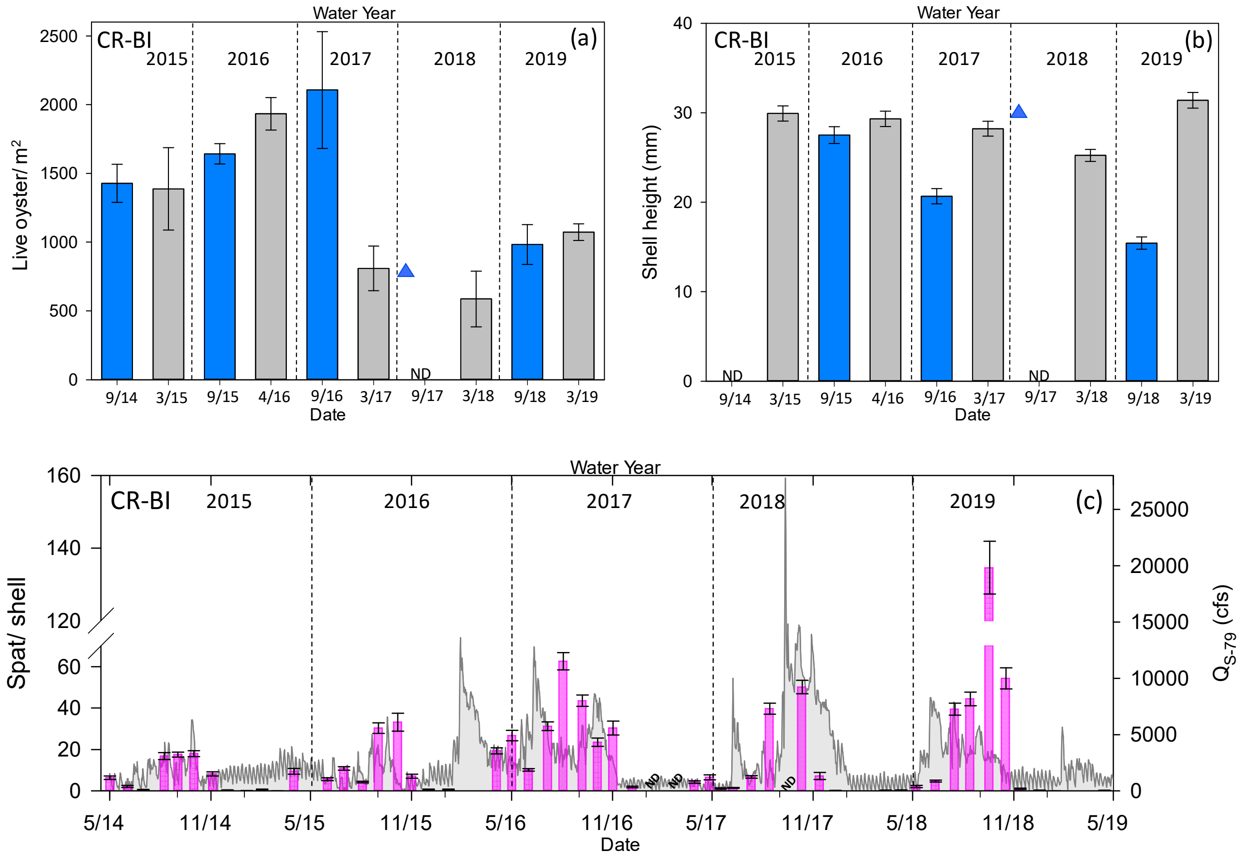

Figure 8C-23. Oyster monitoring metrics from the CRE Bird Island station (CR-BI) for WY2015–WY2019 include (a) oyster density, (b) shell height, and (c) larval recruitment. The blue triangles in (a) and (b) represent a quarterly sampling event at this station on June 2017 and before the passage of Hurricane Irma on September 10, 2017. Blue bars in (a) and (b) represent wet season sampling and grey bars represent dry season sampling. The grey filled area in (c) depicts daily freshwater inflow rate to the CRE from the S-79 structure. New arrays were deployed in January–February 2017 and no samples were collected September 2017 (ND). Values represent average ± standard error for each sampling date.

Five to fifteen live adult oysters are collected monthly from each station to determine the presence of the disease dermo, which is caused by the protozoan pathogen *Perkinsus marinus*, in the oysters' tissue (Ray 1966). Disease intensity, per the Mackin scale categories 0 to 5 (Mackin 1962), is recorded and prevalence is determined as the number of oysters infected/total number of oysters collected. Dermo prevalence and infection intensity of more than a "light infection" (>1 on the Mackin scale) was generally higher at CR-BI than CR-IC, possibly a reflection of the environmental preference of the parasite for higher salinity areas (**Table 8C-12**). The greatest prevalence of dermo at both stations was in WY2016, which could be an artifact of an oyster population already under environmental stress during this period. Percent prevalence of dermo at CR-BI in the WY2019 dry season was 53%, and the percent of infection intensity higher than the light category (> Stage 1 score) on the Mackin scale was 13%.

Table 8C-12. Total percent prevalence of dermo in live adult oyster (number infected/total collected) from the CRE Iona Cove (CR-IC) and Bird Island (CR-BI) stations for WY2015–WY2019 and percent prevalence of infection intensity that was greater than a score of light infection (> 1 Stage score) on the Mackin scale.

Water Year	Season	Average Percent Prevalence of Dermo Presence		Percent Prevalence of > Light Category of Dermo Intensity	
		Iona Cove	Bird Island	Iona Cove	Bird Island
WY2015	Wet	56.7	58.4	0	0
	Dry	78.9	68.6	0	2.0
WY2016	Wet	92.2	88.9	1.1	4.0
	Dry	82.2	88.9	12.4	1.0
WY2017	Wet	66.3	62.2	1.1	4.0
	Dry	29.3	37.8	0	0
WY2018	Wet	60	28.0	10[a]	0
	Dry	NL	28.9	NL[b]	12.2
WY2019	Wet	8	37.8	0	4.4
	Dry	20	53.3	0	13.3

a. Values from May through August 2017 (WY2018) sampling only; Hurricane Irma prevented the September sampling.
b. No live oysters at an age to collect for analyses were present.

Oyster larval recruitment is measured from the underside of clean shells suspended on a 12-shell monitoring array (Parker 2013). Three arrays are deployed at each station for an average of 31 days. The average number of spat settled per shell is calculated using the spat counts from the middle 10 shells (excluding the top and bottom shells of the arrays). Larval recruitment is historically lower at the more upstream site. The average for the WY2015–WY2019 period is 3 and 13 spat/shell for CR-IC and CR-BI, respectively (**Figure 8C-22c** and **8C-23c)**. Larval recruitment was only 0.02 spat/shell at CR-IC in the dry season months following Hurricane Irma in WY2018, because of a high flow, low salinity environment (**Figure 8C-22c**). Both sites exhibited a peak in spat settlement at the end of the WY2019 wet season, which had the highest observed recruitment over the POR (CR-IC = 46 and CR-BI = 135 average spat/shell). This recruitment coincided with a period when daily average salinity was peaking at approximately 5 for short periods at the nearby Cape Coral Bridge salinity monitoring station (**Figure 8C-21**).

SUMMARY

- Average annual rainfall across the C-43 and Tidal Caloosahatchee basins in WY2019 was 54.0 inches (1,371 mm), with 74% occurring in the wet season and 26% occurring in the dry season. This was lower than WY2018 (63.0 inches, or 1,601 mm; WY2018 was unusually high due to Hurricane Irma), but similar to the long-term annual average (WY1997–WY2019; 52.3 inches, or 1,328 mm).
- In WY2019, the total freshwater inflow to the CRE was 2.23 million ac-ft, of which 45% was from the C-43 Basin, 34% was from Lake Okeechobee, and 21% from the Tidal Caloosahatchee Basin. Inflows in WY2019 were comparable to the long-term average (WY1997–WY2019).
- Nitrogen loading to the CRE in WY2019 (3,811 t) was higher than the long-term average (WY1997–WY2019), with the greatest source of loading from the C-43 Basin (1,852 t, 49% of the total).

- Phosphorus loading to the estuary in WY2019 (413 t) was higher than the long-term average (WY1997–WY2019). The largest source was from the C-43 Basin (217 t, 53% of the total).
- The WY2019 average Chla concentrations along the estuary were lower than the long-term average and tended to be higher in the wet season than the dry season, with some exceptions.
- The total average concentrations of TN and TP in WY2019 were higher than the long-term average concentration (WY1997–WY2019). The concentrations of both TN and TP were higher in the wet than in the dry season, whereas the TN:TP molar ratios were lower in the wet than in the dry season.
- The percentage of days with salinity meeting of 30-day moving average of surface salinity < 10 at the Ft. Myers station was 94% in WY2019, which was greater than WY2018 (69%), WY2017 (75%), and the long-term average (73%).
- Oysters density at both Iona Cove and Bird Island returned to pre-Hurricane Irma values in the WY2019 dry season (CR-IC = 406, CR-BI = 1,073 live oyster/m^2). At both sites there was an above average peak in larval recruitment in September 2018 (WY2019; CR-IC = 46 and CR-BI = 135 average spat/shell).

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