Sanibel Communities for Clean Water Project

2023 Water Quality Monitoring Report

Post Hurricane Ian Monitoring

SCCF
SANIBEL-CAPTIVA
CONSERVATION FOUNDATION

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For The City of Sanibel Natural Resources Department

Submitted by: Mark Thompson, M.S., Research Associate

Eric Milbrandt, Ph.D., Director

900A Tarpon Bay Rd, Sanibel, FL 33957

Description of the Project

Community-owned lakes and stormwater collection systems are the receiving waterbodies for much of Sanibel's stormwater runoff. These systems are designed to retain large volumes of stormwater runoff before discharging offsite. Through this process, stormwater is effectively dissipated through evapotranspiration or directed through the soil and into the groundwater system. Factors such as rainfall, tides, irrigation, insufficient vegetation, and poor system design can allow discharges to surrounding surface water. When discharges from these systems occur, stormwater is conveyed to the Sanibel Slough, a waterbody designated as impaired for nutrients by the Florida Department of Environmental Protection (FDEP), or to the estuarine and gulf waters surrounding Sanibel. The surficial groundwater aquifer on Sanibel is very shallow and effectively connected to most stormwater ponds through porous soils. In this way, groundwater quality and flow is affected by community stormwater systems and lakes. The discharge of groundwater from Sanibel into the estuary and Gulf is estimated to be of nearly equal or greater total annual volume than stormwater runoff. Knowledge of nutrient concentrations and potential loadings from community stormwater systems and lakes is essential for effective management of nutrient loading sources. Poor water quality can negatively impact our environment, wildlife, human health, property values, and overall quality of life; therefore, it is imperative that we educate citizens of Sanibel on the importance of improving water quality at the local scale.

Hurricane Ian and its storm surge inundated Sanibel in September 2022. As a result, the freshwater systems on Sanibel instantly changed on September 28^{th}, 2022, to marine/estuarine systems. This study was initiated to track water quality changes in the former freshwater lakes on Sanibel as they transition from post-Ian conditions. SCCF Marine Laboratory personnel have estimated it may take years for some of the lakes on Sanibel to transition back to freshwater systems with salinity below 3 PSU. This study tracks the first year of that transition for 25 formerly freshwater sites.

The information obtained in this monitoring effort will be used by the City of Sanibel to update their Communities for Clean Water website, which provides water quality data for each individual community and a recommended list of Best Management Practices (BMPs) to improve water quality.

Methods

Surface water samples were taken at 25 unique sites around Sanibel (Table 1; Figure 1). Sites included public and privately owned stormwater systems, ponds, lakes, and reservoirs which have possible interaction with Sanibel's surface water or groundwater.

For this study sampling events were conducted for the 25 sites in December 2022, February 2023, April 2023, June 2023 and August 2023. To get a better idea of short-term change, supplemental sampling at a fewer number of sites was undertaken in October 2022 and May 2023. Samples were analyzed for orthophosphate (OP), total phosphate (TP), nitrate-nitrite (NOx), ammonia (NH3), and total Kjeldahl nitrogen (TKN) using NELAC certified methods by Benchmark Laboratories in Palmetto Florida. In addition to the nutrient sampling, dissolved oxygen (DO), turbidity, colored dissolved organic matter (CDOM), chlorophyll *a*, pH, salinity and temperature data were collected at each sampling site. Chlorophyll *a* analyses were performed using EPA approved methodology at the SCCF Marine Laboratory.

After uploading all data into the SCCF water quality database, it was aggregated within an excel spreadsheet and manipulated for input to Minitab13® software for statistical analyses. Descriptive statistics were produced for each site. Median parameter values were compared between post-Ian data and pre-Ian data using the nonparametric Kruskal-Wallis test. A significance level of 0.05 was used in all comparative analyses.

Sample sites were ranked based upon combined mean inorganic phosphorus, inorganic nitrogen, chlorophyll *a* concentrations and TSI scores from both sampling events. The mean value of each of these four parameters was used to assign a rank score to each sample site with rank 1 indicating the poorest score for each parameter. The four rank scores were then added together to produce a total rank for each site. Total scores were listed from lowest to highest with lowest scoring site having overall poorest water quality condition.

Trophic State Index (TSI) scores are based on lake chlorophyll *a*, total nitrogen, and total phosphorus levels, and were calculated for each of these study lakes following the procedures outlined on pages 86 and 87 of the Florida's 1996 305(b) report. Each waterbody was assigned a water quality grade based upon this study period's TSI values; values above 80 = F, 70-80 = D, 60-70 = C, 50-60 = B, and under 50 = A (Excellent). The grades are based upon TSI values ranging from oligotrophic (good) to hypereutrophic (bad) waterbodies (Carlson and Simpson 1996). Trends in TSI were evaluated for each site for 2016 through August 2023. If the trend in TSI was significantly increasing, the site was listed as having declining water quality while a decreasing TSI trend was identified as improving water quality (Table 2).

Hurricane Ian drastically changed the characteristics of all Sanibel Lakes. The most immediate change was the increase of salinity from near freshwater (0-2 PSU) to near Gulf water concentration (30-35 PSU). To better understand the difference between lakes, the change in salinity, pH, chlorophyll a and nutrients after hurricane Ian was compared between shallow lakes (<5 feet), deep lakes (9-12 feet), and lakes which directly receive treated wastewater (reclaimed water).

Results and Discussion

After the storm surge of Hurricane Ian, salinity is likely to be the main factor controlling lake habitat condition. Mean salinity of lakes after hurricane Ian were significantly greater than those before hurricane Ian (Kruskal Wallis, $p < 0.01$, Figure 2). Salinity ranged from a mean of 32 PSU at the City Hall (SCL27) and South Murex Lakes (SCL48) to 2.4 PSU at the lake adjacent the Tipsy Turtle (SCL82). Twenty one of the 25 lakes had mean salinity greater than 10 PSU after hurricane Ian, suggesting a predominance of highly estuarine water in what was once freshwater systems (Table 2). Over the 11 months of monitoring after hurricane Ian, salinity remained higher in the deeper lakes compared to shallow lakes and lakes which receive reclaimed water (Figure 3). During the dry season from October 2022 through May 2023 all lakes which were not artificially irrigated experienced increasing salinity due to evaporation and a lack of rain. During the wet season of 2023, all lakes showed decreasing salinity, however the deeper lakes had a much lower rate of decrease (Figure 4) than shallow lakes (Figure 5) or reclaimed water lakes (Figure 6). Most of the deeper lakes on Sanibel were man made and hold a relatively larger volume of water even though they may have small watersheds. The large volume of high salinity water in deep lakes coupled with small watersheds results in a longer period before they become fresh again. The deep lakes also interact more significantly with the shallow water aquifer. The surge which inundated Sanibel during hurricane Ian replaced the freshwater in the shallow aquifer with higher salinity water. In general, groundwater flows towards lakes and the lakes which interact more significantly with the (now) high-salinity groundwater will be slow to return to freshwater conditions.

The mean pH of lakes sampled in this study was significantly lower after hurricane Ian compared to before (Kruskal Wallis, $p = 0.011$, Figure 7). The pH has steadily risen since the storm and is now back to seasonal normal pH.

The mean chlorophyll *a* (Chla) concentration ranged from 21.7 ug/l at Sand Pointe (SCL36), to 242 ug/l at The Dunes Lake 4 (SCL08) (Table 2). When compared to pre-Ian chlorophyll a, the concentrations after Ian were significantly greater over the 25 sites (Kruskal-Wallis, $p=0.01$, Figure 8). Immediately after Ian, chlorophyll *a* values were generally as low or lower than before Ian. As new phytoplankton communities became established in the now higher salinity lakes, the greater amounts of carbon and nutrients from hurricane runoff cultivated an increase in the chlorophyll *a*. The Florida DEP general chlorophyll *a* water quality criteria for lakes is 20 ug/l while it is 11 ug/l for estuaries (which these lakes more closely resemble due to salinity). All lakes monitored for this report have mean chlorophyll *a* values above water quality criteria, and are dealing with significant phytoplanktonic blooms.

The median total phosphorus (TP) values for the period after Hurricane Ian compared to before could not be found to differ significantly (Kruskal Wallis, $p = 0.756$, Figure 9). Mean TP in the sampled lakes ranged from 0.034 mg/l at Gumbo Limbo east (SCL11; medium density residential) to 0.853 mg/l in the City's Reclaimed water pond at Pond Apples Park (SCL05;

WWTP) (Table 2). Mean TP values at 92% of the lakes were above the FDEP water quality criteria (0.05 mg/l, Figure 2). Sixty percent (60%) were greater than the 90th percentile (0.092 mg/l) of Florida lakes (Hand 2008).

The median total nitrogen (TN) values for the period after Hurricane Ian compared to before were found to be significantly lower after the hurricane (Kruskal Wallis, $p = 0.036$, Figure 10). The mean TN concentration in lakes ranged from 1.52 mg/l at Gumbo Limbo East (SCL11, medium density LU) to 8.1 mg/l at Dunes Lake 4 (SCL08, Golf Course LU) (Table 2). All of the sites had mean TN values above the Florida criteria for lakes (1.27 mg/l, Figure 4). About 84% of sites had mean TN above the 90^{th} percentile of all lakes in Florida (1.72 mg/l). During this project period, IN made up an average of 11% of the TN value. This is greater than 2022 (3.6%), 2020 (5%), 2018 (7%) and 2016 (5%).

TSI scores are meant to be an integrated look at the magnitude of eutrophication in a lake. Phosphorus, nitrogen and chlorophyll *a* are factors included in the calculated TSI value, so it is a good initial estimation of a lake's overall eutrophic condition. FDEP considers scores over 60 to indicate poor water quality and scores greater than 60 trigger evaluation of waterbodies for impairment. TSI scores ranged from 63 at the Gumbo Limbo east (SCL11, land use = medium density) to 99.5 at the City of Sanibel reclaimed water pond (SCL77, disturbed land use type) (Table 2). The overall mean TSI score for lakes in this study was 77.5, similar to previous monitoring periods. No significant difference could be found in TSI values after the hurricane compared to before (Kruskal Wallis, $p = 0.512$).

The median turbidity and FDOM values for the period after Hurricane Ian compared to before were found to be significantly greater (Kruskal Wallis, $p < 0.01$ and, Figure 12 and 13).

Grading Sanibel waterbodies based upon the TSI score found that no waterbodies received a water quality grade of better than a C; 6 received a C, 13 received a D and 6 received a grade of F (Table 2). Regardless of how an individual lake was ranked relative to other lakes on Sanibel, the water quality grade will give a better indication of its actual current health. If a lake has an F or D water quality grade – its water quality is very poor. A majority of Sanibel's formerly fresh waterbodies are eutrophic, and nutrient-enriched with high primary production leading to algal blooms.

Ranking the sampled lakes following procedures described in the methods section produced a prioritized list of lakes on Sanibel with water quality concerns (Table 2). The current rank results are in a table with results from 2022, 2020, 2018 and 2016 (Table 2) to provide a sense of how water quality has changed in relationship to other Sanibel Lakes.

The characteristics of Sanibel's lakes changed dramatically after Ian with significant changes in salinity and pH. During the 2023 wet season, the shallow lakes have fallen in salinity to under 5 PSU while the deeper lakes have salinity near the concentration in the Gulf of Mexico. Lakes which receive reclaimed water or freshwater will certainly become fresh more quickly than those lakes having little freshwater irrigation in their watershed. The Sanctuary Lake 7 is a large deep lake which has become seen its salinity fall much more quickly than other deep lakes on Sanibel. Since the sanctuary has several sources of freshwater to irrigate their golf course, it can be assumed that freshwater from those irrigation sources is responsible for this lake's lower salinity.

An interpolated map of lake salinity concentrations shows that the lakes across the entire island have salinities greater than (0-2 PSU) freshwater. Due to the storm surge associated with the hurricane, current interpolations are not good indicators of environmental conditions found in specific areas of Sanibel. A Lake's salinity has been found to be closely associated with its depth, and outside inputs of freshwater from reclaimed water or other sources.

Conclusions

Hurricane Ian had significant water quality impacts on the community lakes of Sanibel. On September 28, 2022, the fresh lakes, wetlands and ponds of Sanibel were instantaneously converted to saline waterbodies. Freshwater ecosystems were destroyed, and transient saline-water ecosystems have now developed. Some lakes and ponds are showing significant decrease in salinity due to the precipitation during the 2023 rainy season, however it may be many years before the deeper lakes and the central Sanibel wetland system (Sanibel Slough) can support freshwater flora and fauna. The lakes which receive inputs of reclaimed wastewater directly or through irrigation have seen the biggest decrease in salinity. Deep lakes without reclaimed water input and which interact with saline groundwater are slow to change and continue to have salinities closer to the Gulf of Mexico than to freshwater lakes.

Lakes were ranked from poorest (ranked 1) overall water quality to those with the least impairment (ranked 27). The lakes with poorest water quality can be targeted for lake management plan development and other pertinent BMPs once the source of poor water quality is identified.

In general, lakes on Sanibel are eutrophic to hyper-eutrophic with relatively high nitrogen and phosphorus concentrations and abundant phytoplankton. The storm surge from hurricane Ian may have changed the salinity characteristics of the lakes, but the persistent phytoplankton blooms and low dissolved oxygen problems during cloudy days continues. The lakes are now populated by estuarine fish which have replaced the cichlids, bass and sunfish which were there pre-hurricane. Salinity tolerant killifish and gambusia are the most common fish currently seen. Low dissolved oxygen conditions which occasionally develop in Sanibel lakes due to their eutrophic state, will be more likely to kill the estuarine fish now in these lakes due to low tolerance to oxygen deficiency.

Attached file: ComLakesDat_PostIan_2023.xlsx

Figures and Tables

Table 1. Location of 25 sampling sites used in this project.

SiteID	Site	Lat	Long	Description
SCL02	BeachRdVillasPnd	26.44554	-82.04058	Pond Behind Beach Rd Villas (end_Beach_Rd)
SCL05	CityReclaimDschrge	26.44571	-82.04570	SmallPondatCityReclaimPonds
SCL07	DunesLake5	26.45300	-82.04227	Access tennis court area off Sand Castle
SCL08	DunesLake4	26.45515	-82.05254	Access from GC path Dunes Weir
SCL11	GumboLimboEast	26.44465	-82.05816	Eastern_Lake_GumboLimbo 1565 Bunting
SCL13	SanGolfReclmPnd	26.43910	-82.05151	AccessThru717BirdieView
SCL15	PanamaCanal	26.42978	-82.05942	AtTrailBridge
SCL26	CasaYbel	26.42493	-82.07111	LargePondAdjW.Gulf
SCL27	CityHall	26.44124	-82.07408	FromGazebo
SCL30	Pointe Santos	26.42268	-82.07734	WestGulf just east of Tarpon Bay Rd
SCL31	BaileysPond	26.43361	-82.07880	SW Pond Behind Baileys Sample on Point
SCL36	SandPointe	26.42337	-82.08674	SWPond Sand PointeCondo West Gulf
SCL37	SmithLkBaileyTrct	26.43112	-82.08708	North_lake_Bailey Tract_adj_Island_Inn Rd
SCL43	PalmLake	26.42626	-82.09312	Access behind 215 Palm Lake
SCL48	SLakeMurex	26.43137	-82.09683	Access from 493 Lake Murex Circle
SCL50	StIsabelCathChrch	26.44117	-82.10718	Access Behind St Isabel Church
SCL55	ERockWestEndCoquina	26.43773	-82.11592	East Dead End Coquina Dr
SCL56	WRockEastEndCoquina	26.43802	-82.11892	Access behind 3702 Coquina Dr.
SCL62	ChateauSurMerLake	26.45264	-82.13939	Near discharge culvert under roadway
SCL64	TradewindsNLake	26.45389	-82.14111	Access frm N 1339 Tahiti
SCL71	SanctuaryLake7	26.49135	-82.17098	AccessFrom Golf Cart Path
SCL 74	Herons Landing Lake	26.47001	-82.15974	Access from City Park near Hollys Pond west
SCL82	Behind Jacaranda	26.44404	-82.04640	Pond Behind Former Jacaranda
Devitt01	Pond at SCCF Homestead	26.44440	-82.04939	Access at East end of lake near deck
JM02	Jordan Marsh Effluent	26.44440	-82.04939	Jordan Marsh Effluent Station

Figure 1. Sampling locations for this study. In 2023, 25 sites were sampled in wet and dry season post hurricane Ian.

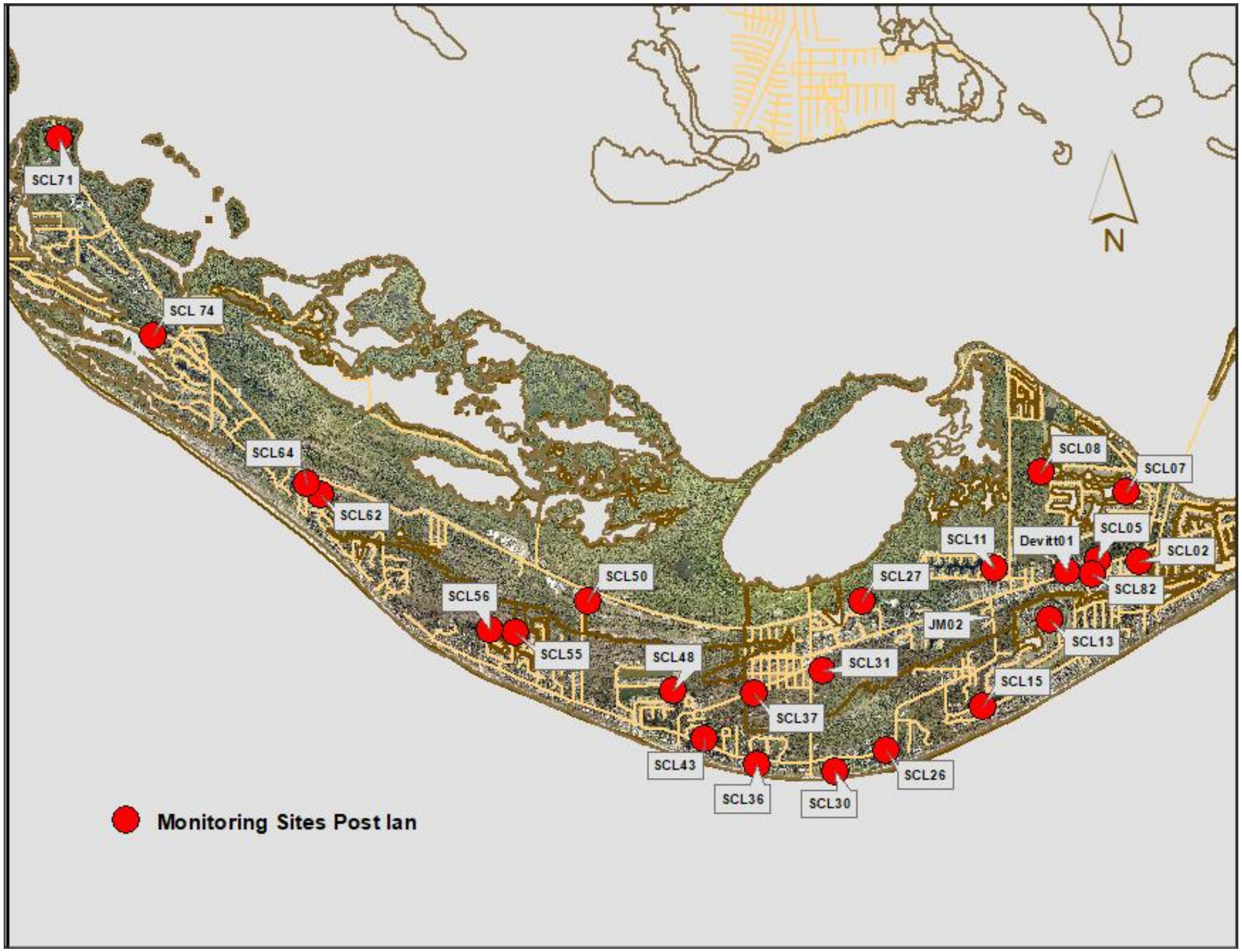


Table 2. Priority problem ranking of sample sites plus east and west basin of Sanibel Slough with associated water quality data 2023. All parameter values shown are averages of wet and dry season results. Ranked from worst to best water quality.

Prority Rank		Description	IN (mg/l)	TN (mg/l)	OP (mg/l)	TP (mg/l)	Chla_Cor ug/l	TSI	Salinity (PSU)	pH	LU	IN Rank	OP Rank	Chla Rank	TSI Rank	Total Rank Score	WQ Trend	WQ Grade	2020 Grade	2018 Grade	2016 Grade
1	SCL05	CityReclaimPond	1.360	3.918	0.714	0.853	136.7	99	7.7	8.92	Comm	1	1	5	1	8	None	F	F	F	F
2	SCL74	Herons Landing Lake	0.860	2.880	0.490	0.481	199.5	88	26.1	7.84	Low	3	3	2	3	11	None	F	F	F	NR
3	SCL08	Dunes Lake 4	0.444	8.100	0.344	0.691	241.5	86	30.8	8.19	GlfCrse	6	4	1	4	15	None	F	D	F	D
4		West Basin Sanibel Slough monthly data	0.587	3.643	0.113	0.147	116.3	83	19.5	7.7	Mixed	4	7	7	6	24	None	F	NR	NR	NR
5		East Basin Sanibel Slough monthly data	0.353	3.261	0.110	0.226	147.3	85	17.9	7.8		9	8	4	5	26	None	F	NR	NR	NR
6	SCL13	SanGolfReclmPnd	0.928	2.783	0.596	0.694	48.5	90	8.9	8.86	GlfCrse	2	2	22	2	28	Improving	F	F	F	F
7	SCL27	CityHall	0.317	2.783	0.087	0.121	99.4	78	32.1	7.80	Comm	11	12	10	11	44	None	D	C	C	C
8	Devitt01	Pond at SCCF Homestead	0.0954	2.915	0.1395	0.1485	69.5	82	14.8	8.20	Disturb	21	5	14	7	47	None	F	D	D	C
9	SCL07	DunesLake5	0.409	1.998	0.053	0.116	78.7	80	28.0	8.31	GlfCrse	7	18	13	10	48	None	D	F	D	D
10	SCL71	SanctuaryLake7	0.023	2.033	0.131	0.169	151.5	76	12.5	8.39	GlfCrse	26	6	3	14	49	Improving	D	F	F	F
11	SCL50	StIsabelCathChrch	0.167	3.140	0.052	0.076	112.6	82	19.6	8.38	Comm	15	19	8	8	50	None	F	F	F	D
12	SCL56	WRockEastEndCoquina	0.205	2.270	0.049	0.062	102.2	76	21.6	8.34	Medium	13	20	9	16	58	None	D	C	D	C
13	JM02	Jordan Marsh Effluent	0.223	4.59	0.08025	0.1298	48.1	81	19.5	8.3		12	15	23	9	59	Declining	D	NR	NR	NR
14	SCL55	ERockWestEndCoquina	0.166	1.883	0.055	0.120	82.0	74	19.0	8.14	Medium	16	17	12	18	63	None	D	C	D	C
14	SCL62	ChateauSurMerLake	0.070	2.393	0.098	0.089	54.5	76	14.1	8.15	Low	22	9	17	15	63	None	D	D	D	C
16	SCL82	Pond Behind Jacaranda	0.032	1.765	0.091	0.167	51.6	78	2.4	8.01	Comm	23	11	18	12	64	None	D	F	NR	NR
17	SCL43	PalmLake	0.358	2.148	0.016	0.052	87.9	73	29.3	8.14	Low	8	27	11	20	66	None	D	C	C	C
17	SCL48	SLakeMurex	0.347	1.685	0.075	0.103	49.4	73	31.5	8.21	Medium	10	16	21	19	66	None	D	D	C	C
19	SCL15	PanamaCanal	0.159	1.633	0.024	0.063	117.8	70	19.2	8.12	Medium	17	24	6	23	70	None	C	F	D	D
20	SCL37	SmithLkBaileyTrct	0.505	2.020	0.082	0.093	24.7	65	25.0	8.00	Natural	5	14	26	26	71	None	C	C	D	C
21	SCL30	Pointe Santos	0.026	3.230	0.023	0.097	56.9	77	15.0	8.40	High	24	25	15	13	77	Declining	D	C	D	C
21	SCL31	BaileysPond	0.105	2.100	0.032	0.071	51.0	75	18.0	7.92	Comm	20	21	19	17	77	None	D	C	C	C
23	SCL36	SandPointe	0.144	3.183	0.093	0.143	21.7	69	22.2	8.31	High	18	10	27	24	79	Improving	C	F	F	F
24	SCL26	CasaYbel	0.169	1.918	0.018	0.071	50.3	71	16.9	7.95	High	14	26	20	22	82	None	C	D	D	D
25	SCL02	BeachRdVillasPnd	0.023	2.095	0.029	0.048	56.2	73	8.6	8.3	Medium	25	22	16	21	84	Declining	D	B	C	B
26	SCL64	TradewindsNLake	0.022	2.100	0.083	0.073	38.4	69	10.2	8.33	Medium	27	13	24	25	89	None	C	D	D	D
27	SCL11	GumboLimboEast	0.124	1.515	0.028	0.034	27.9	63	16.9	8.15	Medium	19	23	25	27	94	None	C	D	D	D

Figure 2. Boxplot of mean salinity values for the 25 lakes in this study for the period 2016 through 2023 taken for the Sanibel Communities for Clean Water project. Hurricane Ian immediately changed freshwater systems to marine systems.

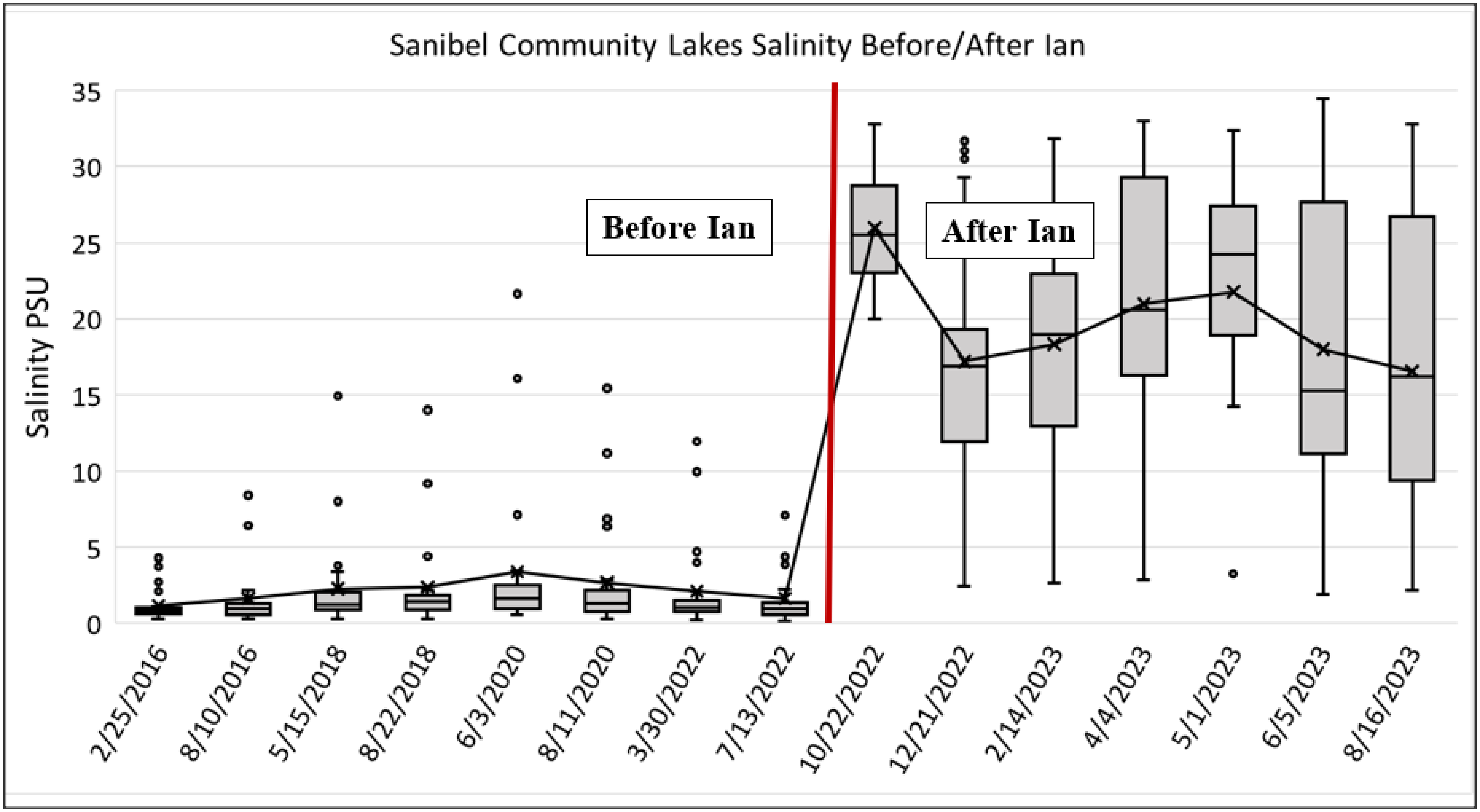


Figure 3. Time series of salinity in deep lakes verse shallow lakes and lakes which receive reclaimed water.

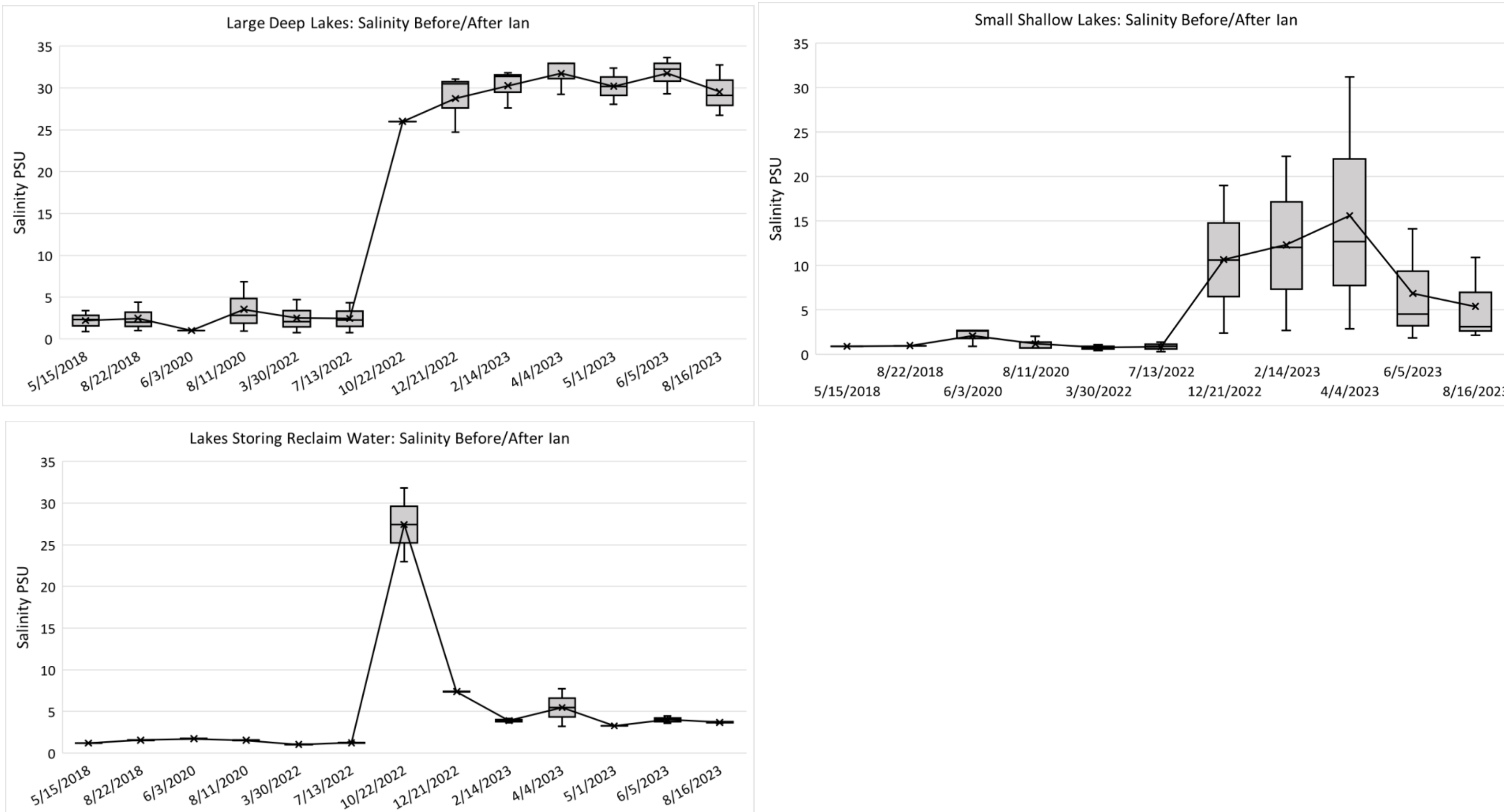


Figure 4. Time series for salinity at deep lakes. First graph is pooled data from all deep lakes in study. Individual deep lakes are also shown.

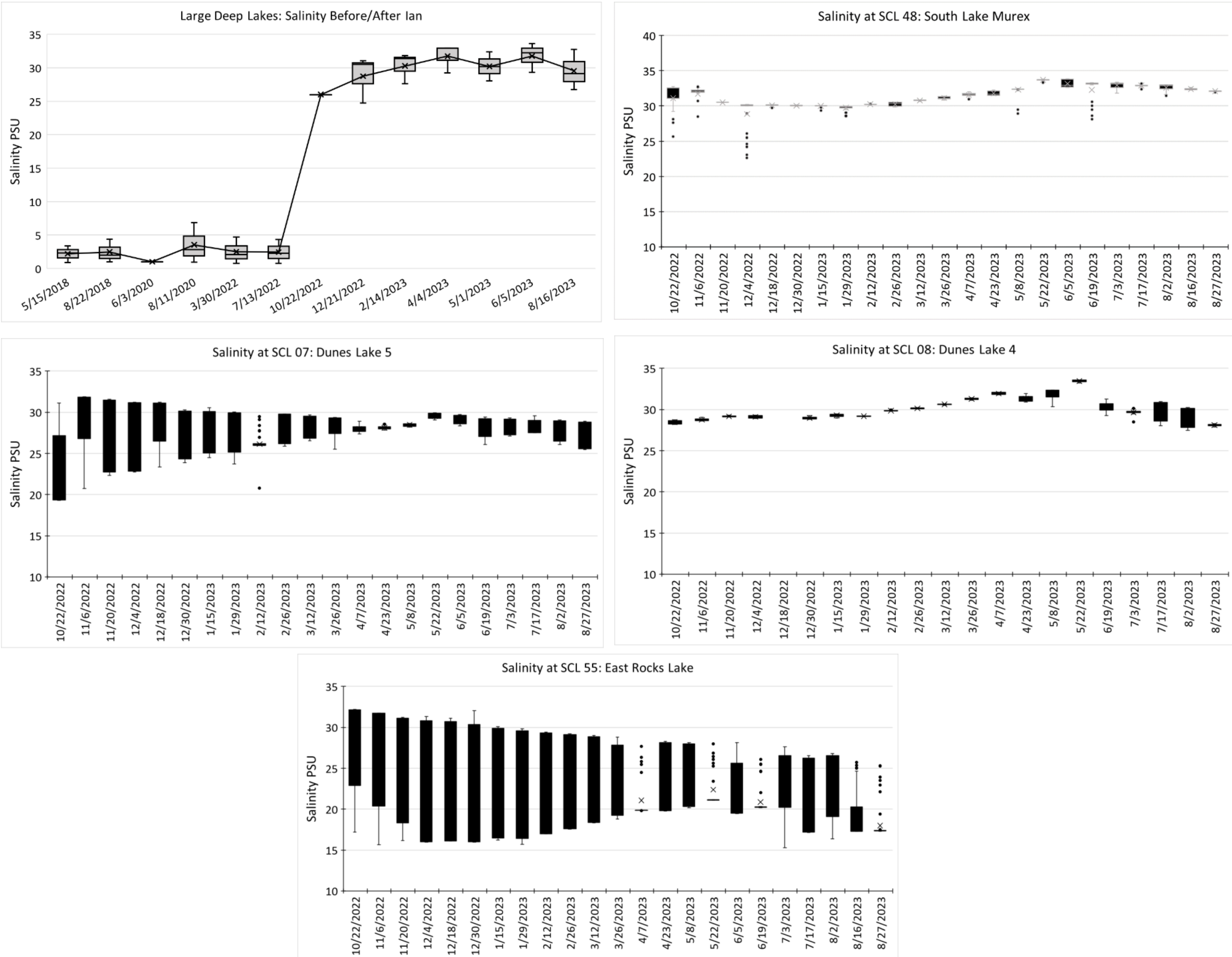


Figure 5. Shallow lake salinity time series. First plot is pooled data for all shallow lakes.

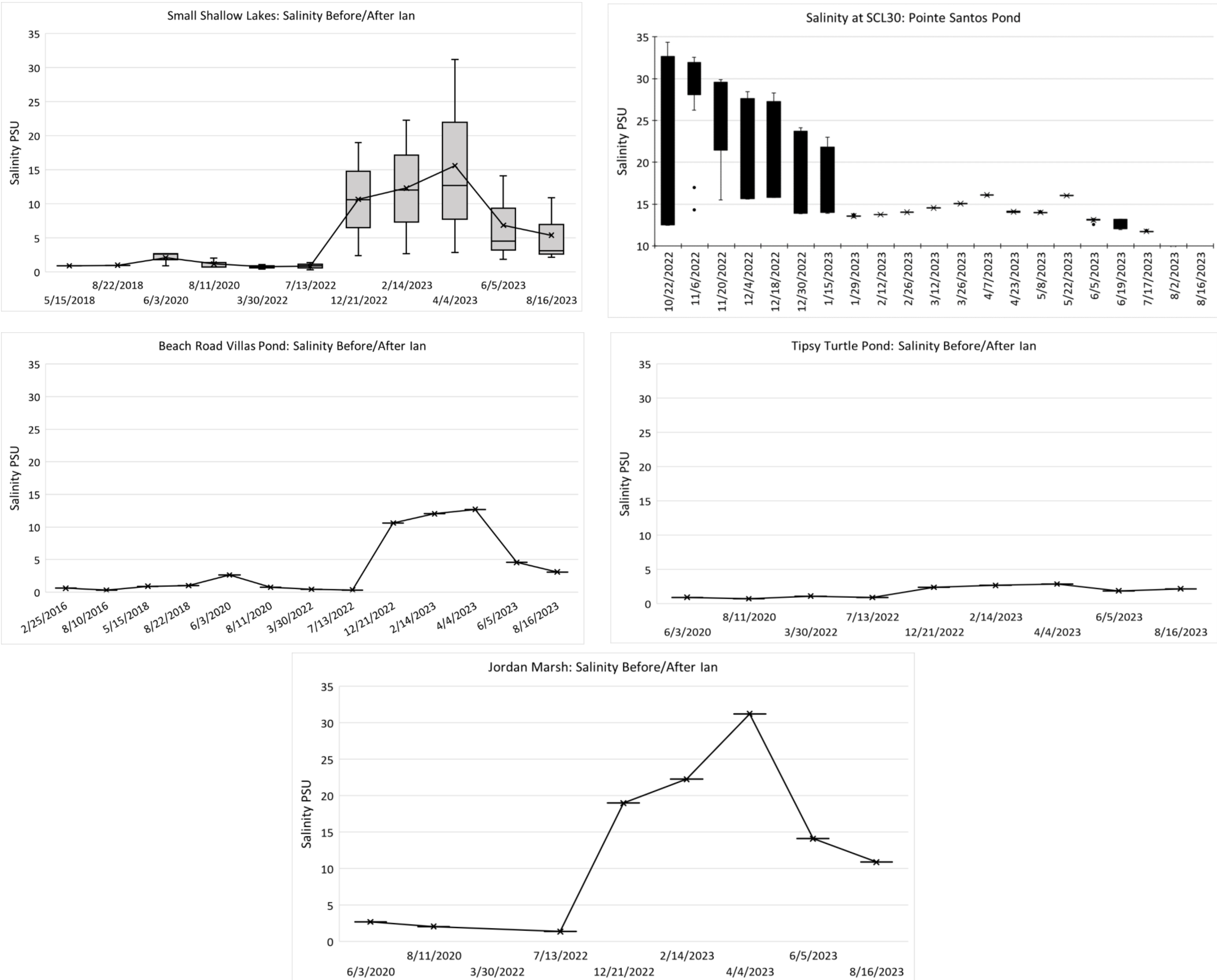
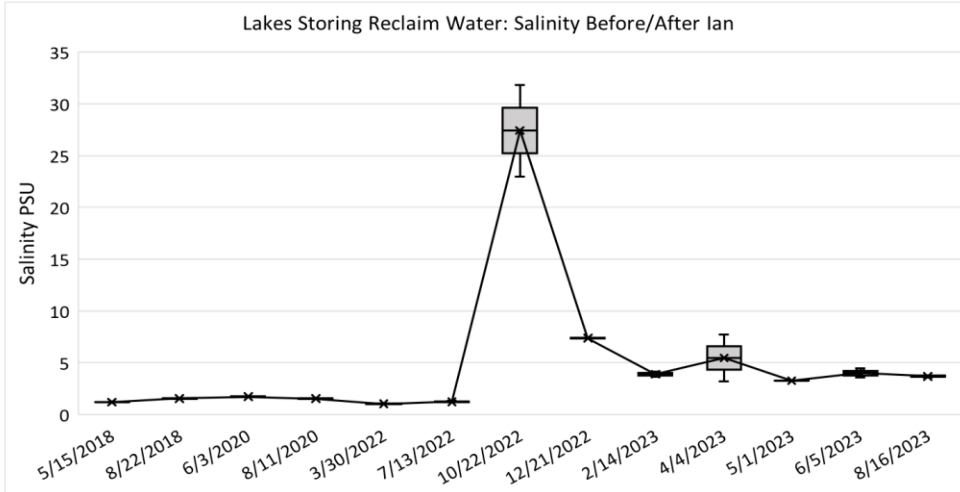
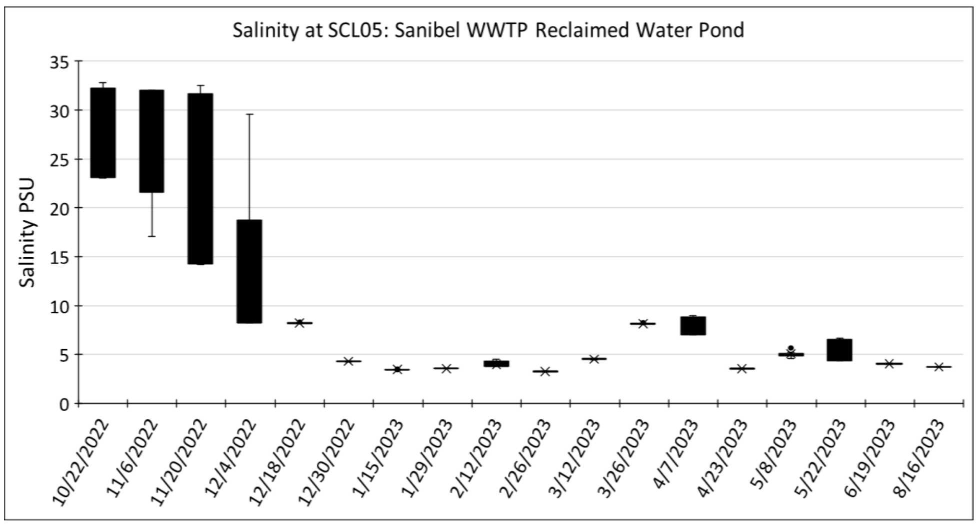


Figure 6. Salinity time series for lakes receiving reclaimed water.





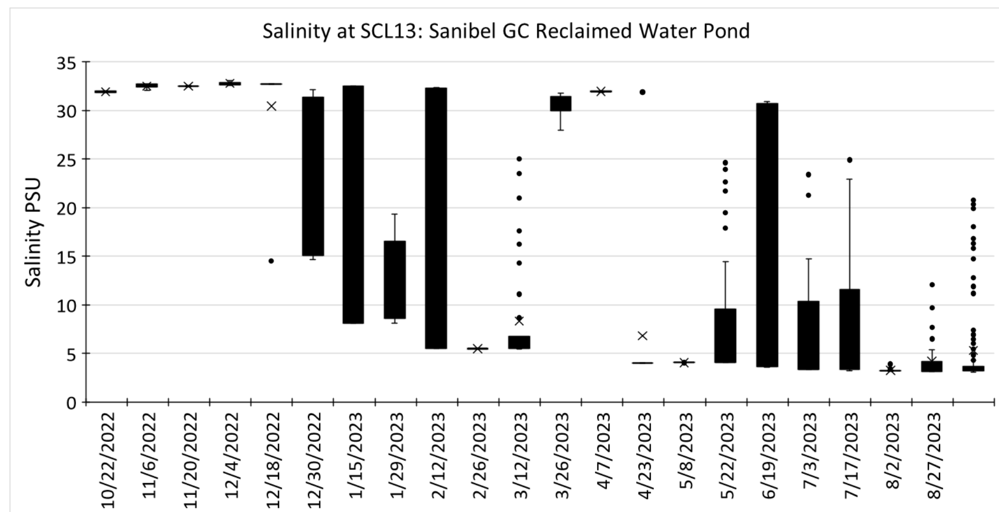


Figure 7. Time series of pH of the 25 monitored lakes values for before and after Ian.

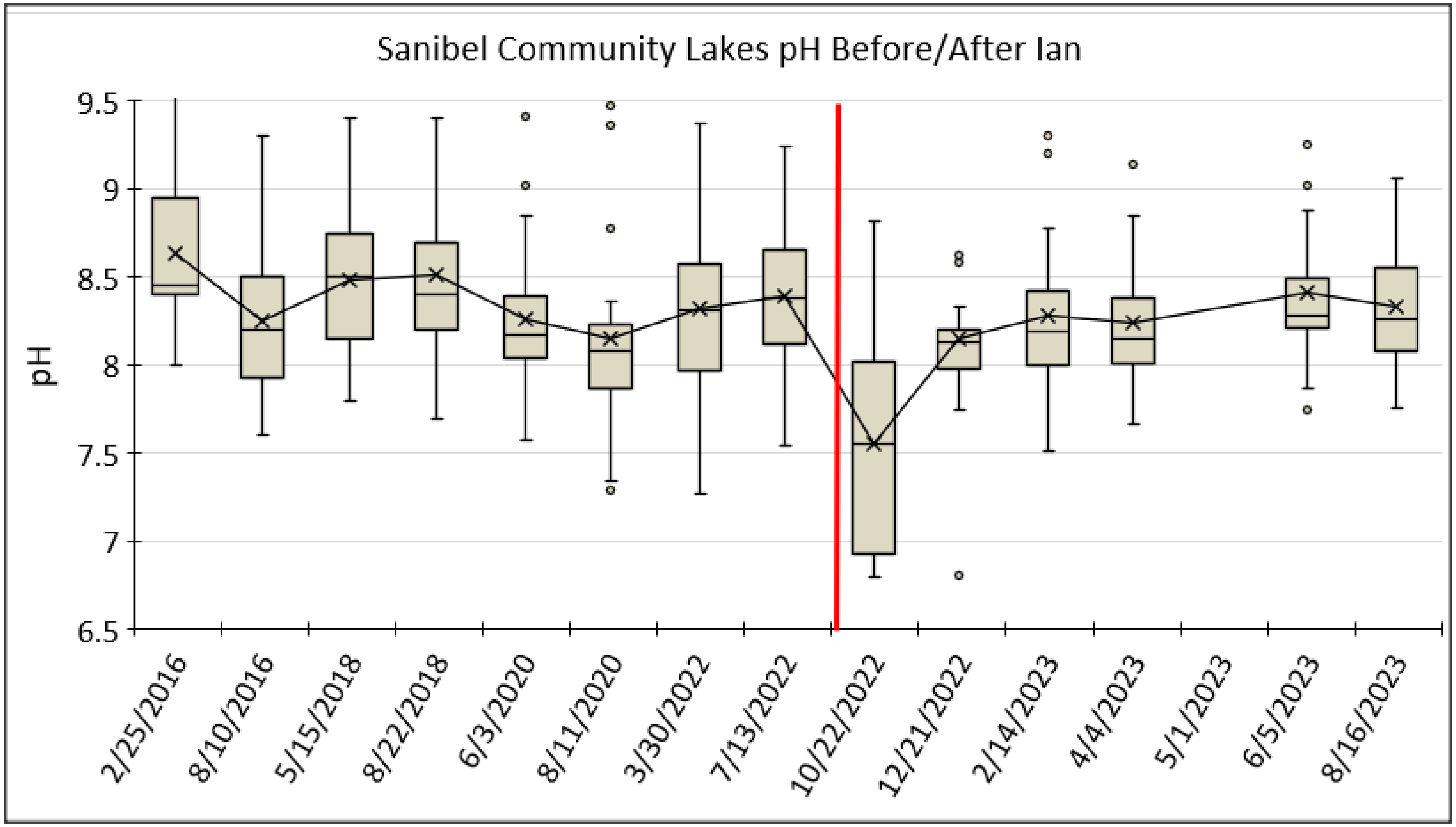


Figure 8. Boxplot of chlorophyll *a* concentration for the 25 lakes in this study for all periods sampled during the Sanibel Communities for Clean Water project.

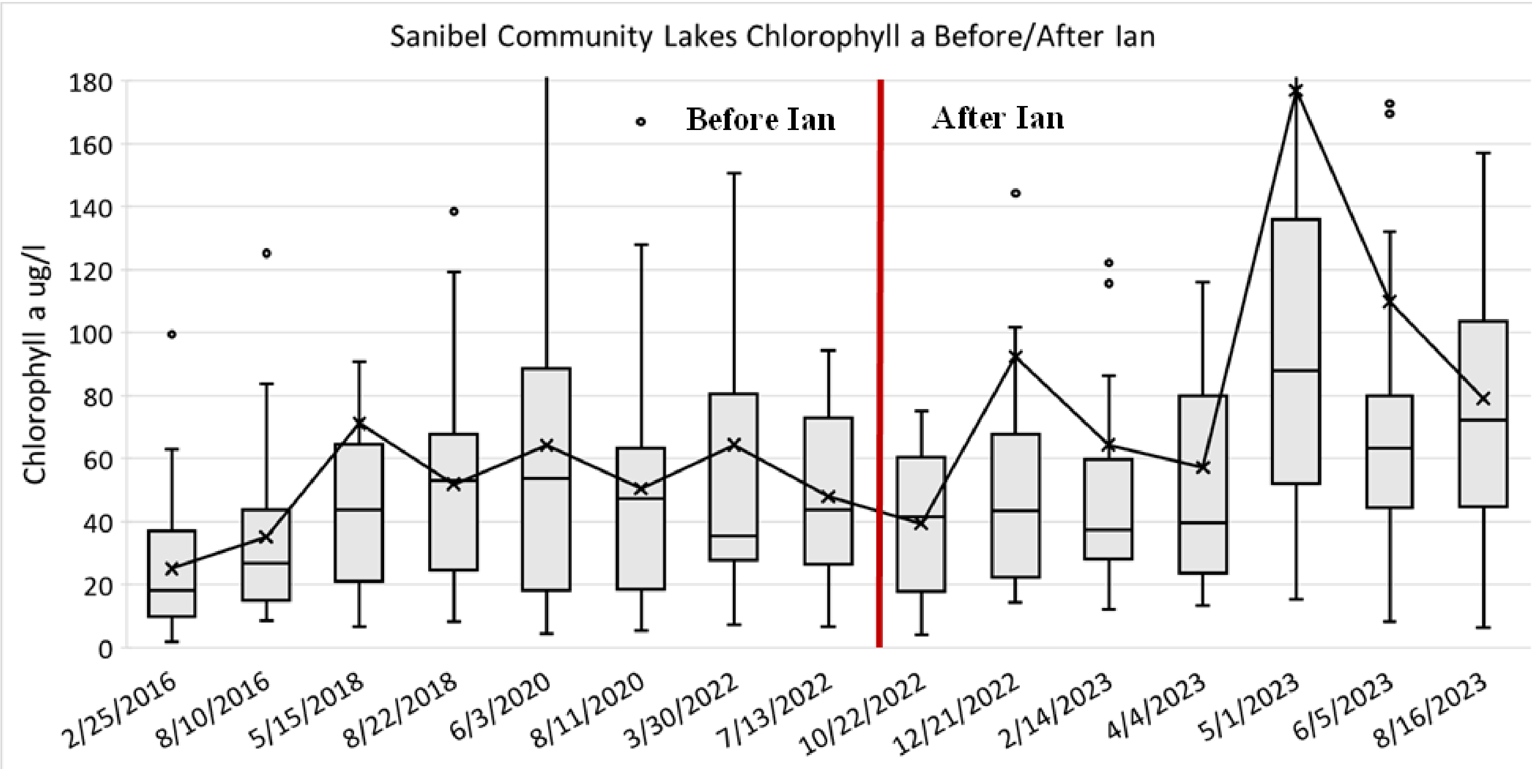


Figure 9. Boxplot of total phosphorus concentration for the 25 lakes in this study for all periods sampled during the Sanibel Communities for Clean Water project.

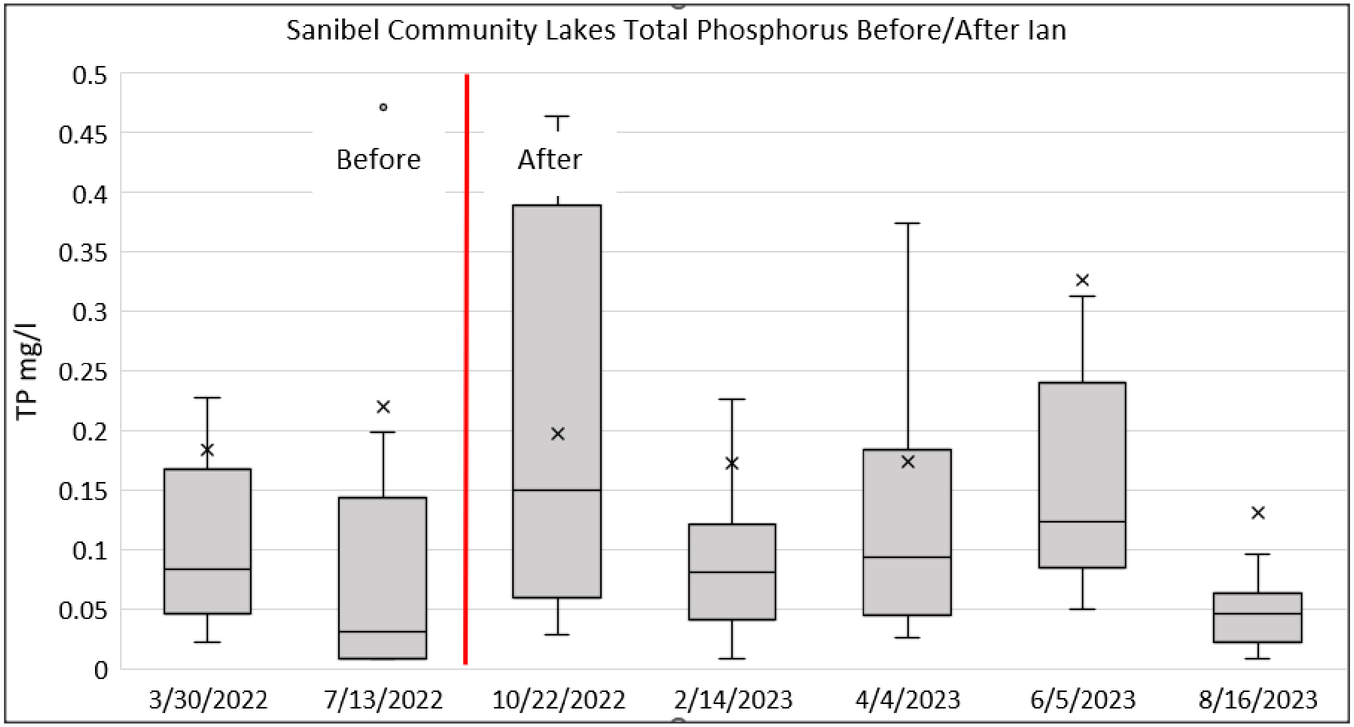


Figure 10. Boxplot of total nitrogen concentration for the 25 lakes in this study for all periods sampled during the Sanibel Communities for Clean Water project. Pooled data showed TN after the hurricane to be significantly lower.

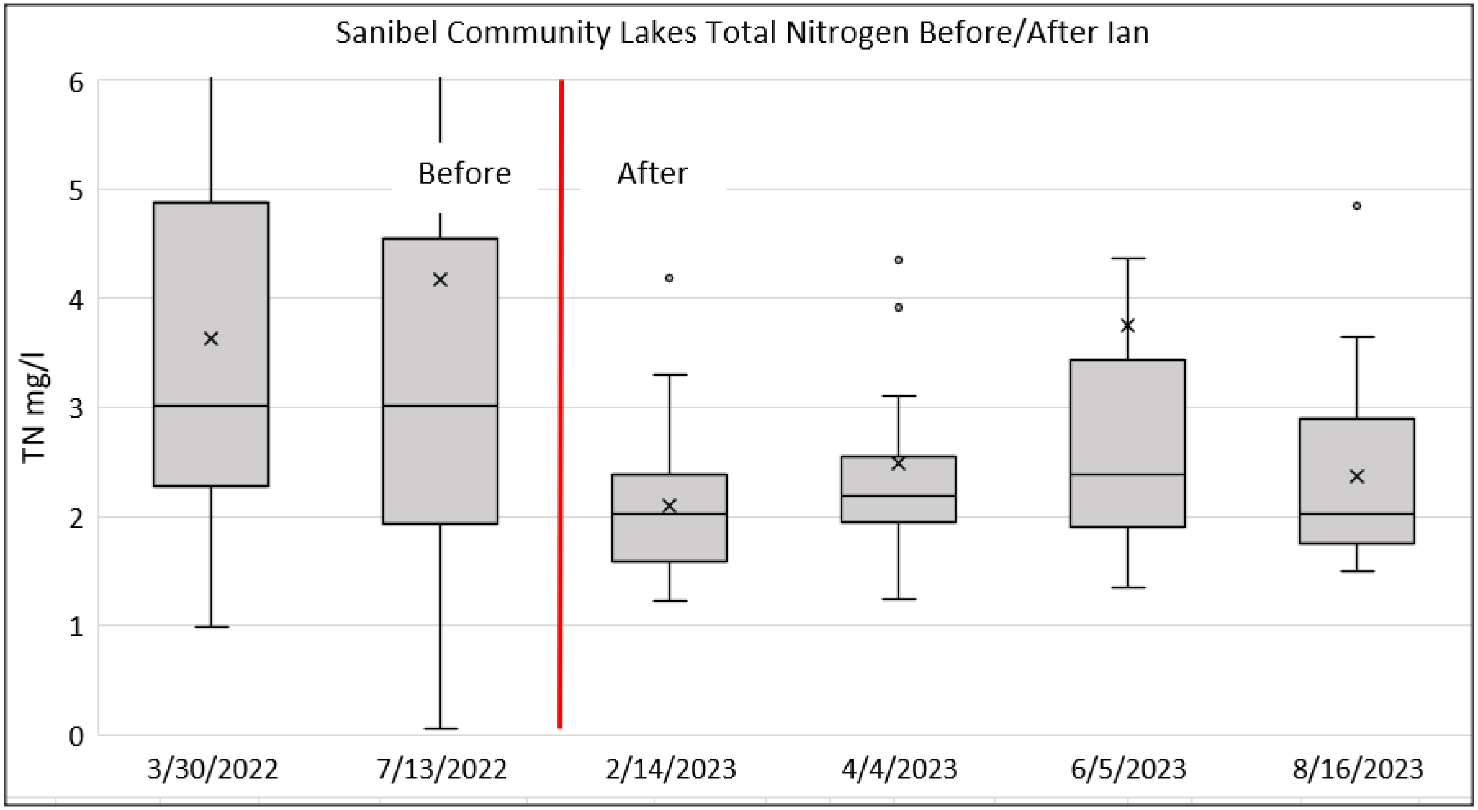


Figure 11. Boxplot of the trophic state index for the 25 lakes in this study for all periods sampled during the Sanibel Communities for Clean Water project. No significant difference could be found for TSI after the hurricane compared to before.

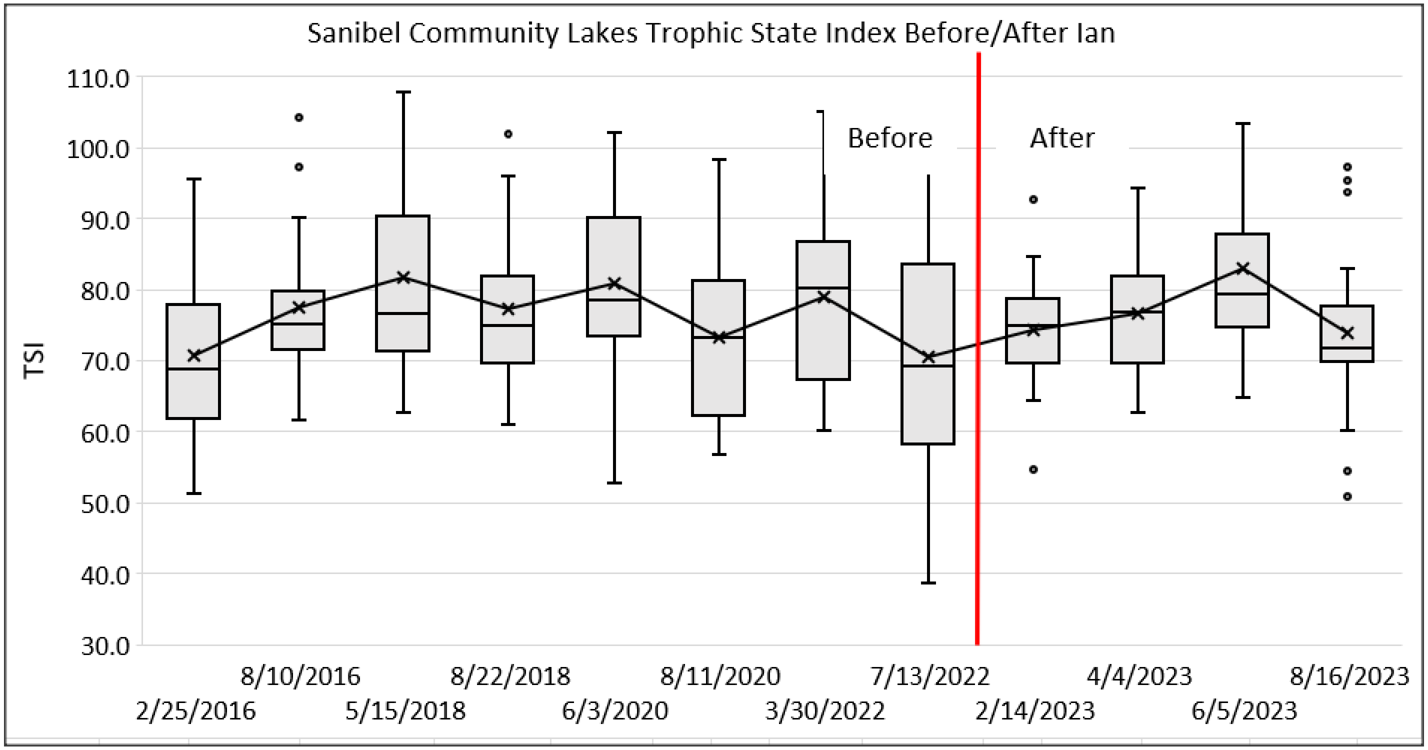


Figure 12. Boxplot of turbidity values for the 25 lakes in this study for all periods sampled during the Sanibel Communities for Clean Water project.

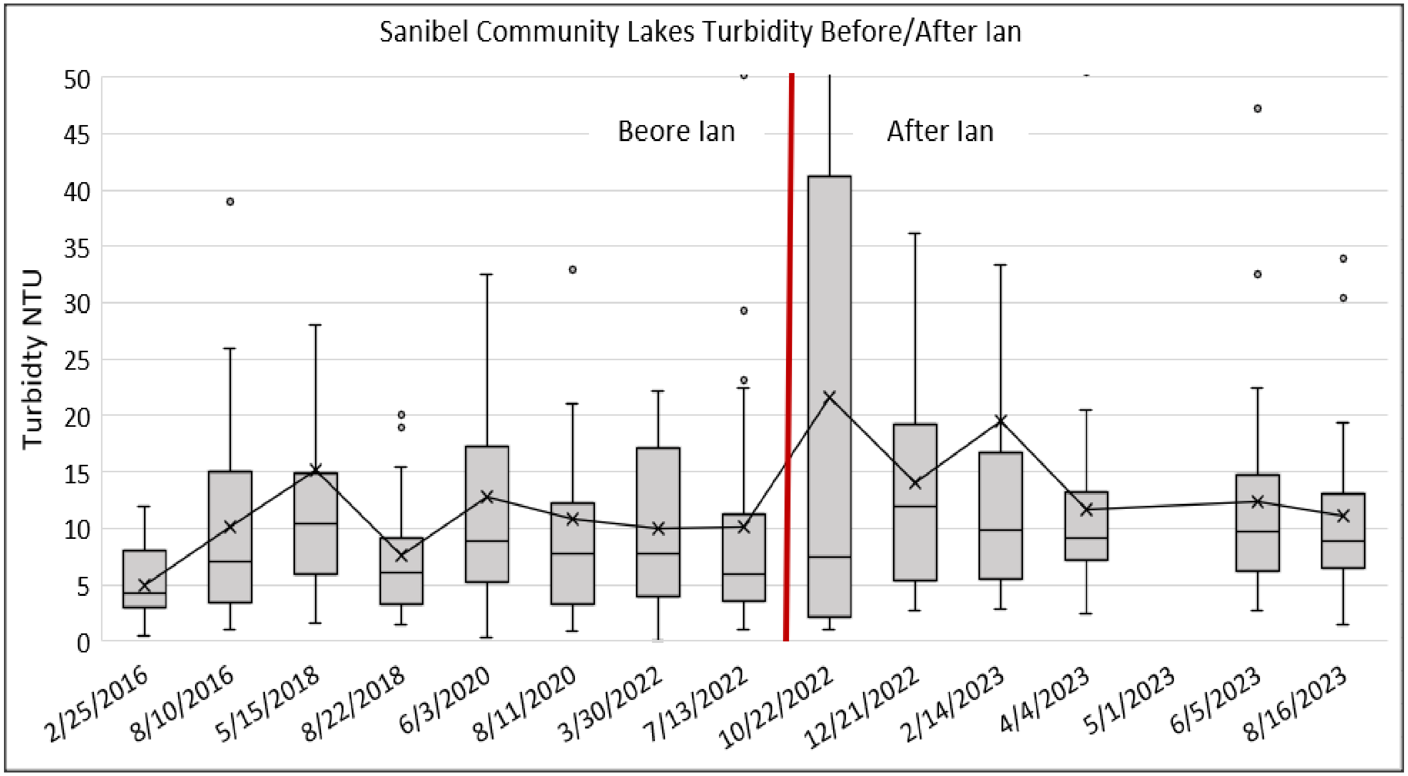


Figure 13. Boxplot of FDOM values for the 25 lakes in this study for all periods sampled during the Sanibel Communities for Clean Water project.

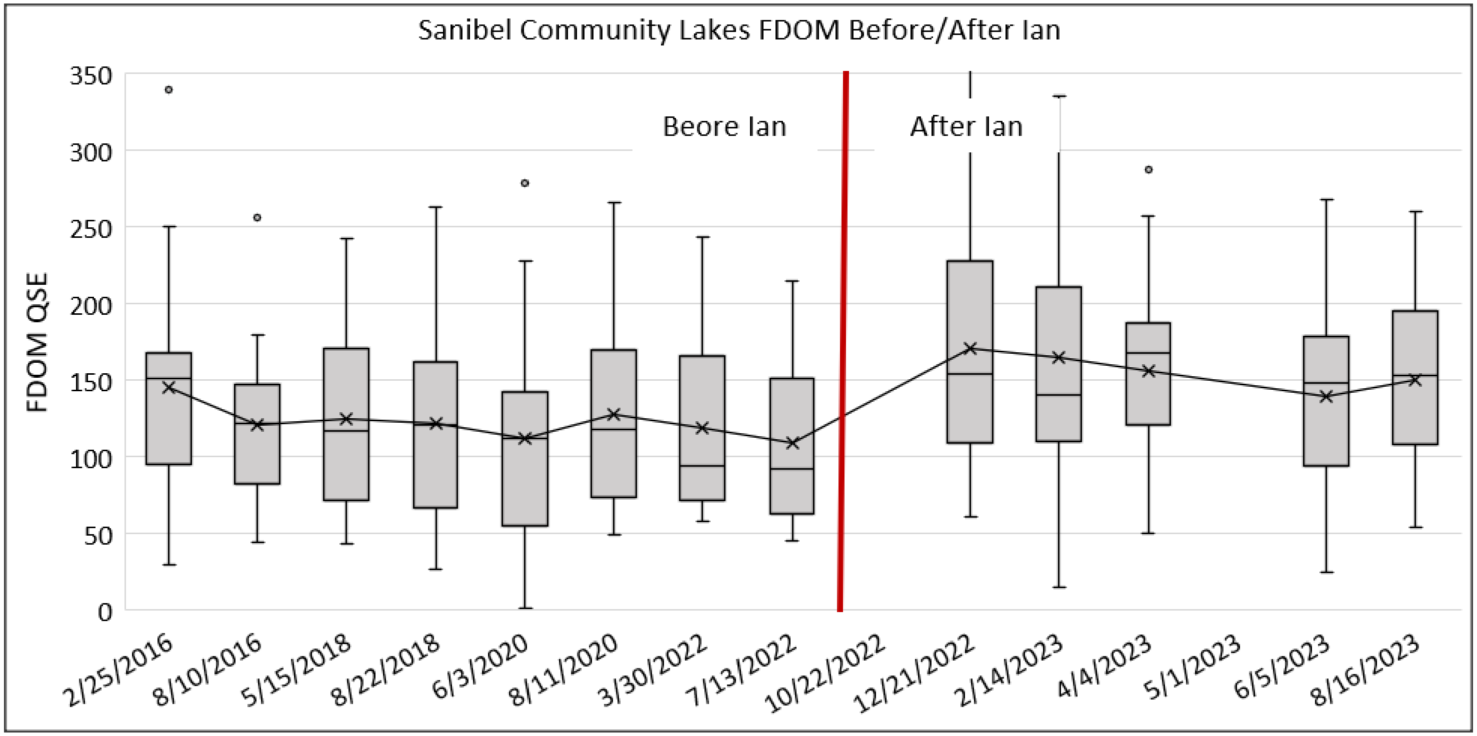


Figure 14. GIS interpolation of chlorophyll a concentration across lakes and ponds on Sanibel Island for this study period after hurricane Ian.

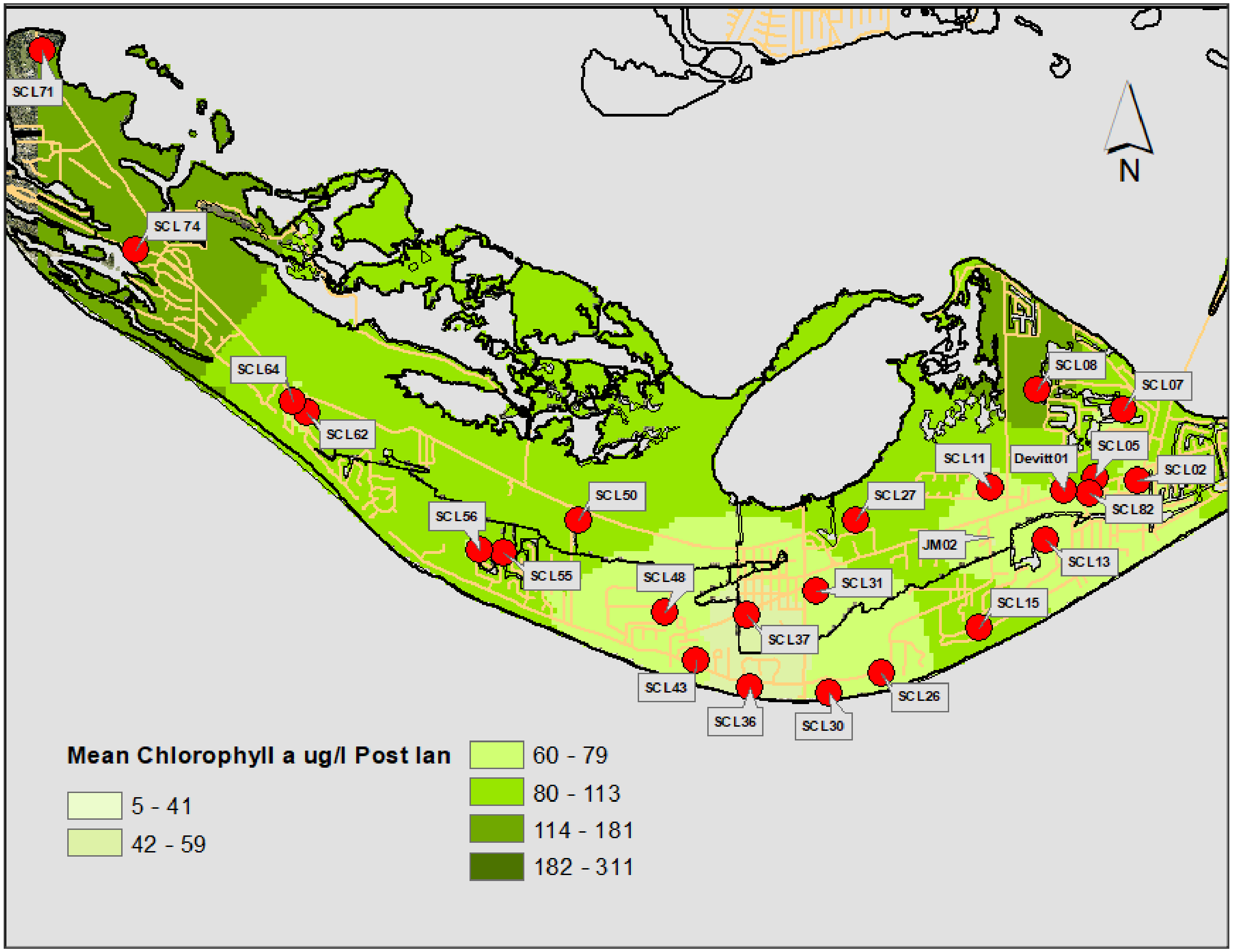


Figure 15. GIS interpolation of mean salinity across lakes and ponds on Sanibel Island for this study period after hurricane Ian.