

An Assessment of Little Bay Water Quality and Seagrass Monitoring Program

Mission-Aransas National Estuarine Research Reserve
The University of Texas at Austin Marine Science Institute
750 Channel View Drive
Port Aransas, Texas 78373

*Water Quality Monitoring: Dr. Ed Buskey, Rae Mooney, and Cammie Hyatt
Mission-Aransas National Estuarine Research Reserve
University of Texas at Austin Marine Science Institute*

*Seagrass Monitoring: Dr. Ken Dunton and Sara Wilson
University of Texas at Austin Marine Science Institute*

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Aransas County Navigation District
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INTRODUCTION

Little Bay is a small, semi-enclosed estuary located in the heart of Rockport, Texas. Estuaries are where freshwater from rivers and streams mixes with salt water from the oceans. Estuaries are extremely productive and valuable ecosystems that provide flood protection, filter nutrients and contaminants, and provide valuable habitats for wildlife, including nursery areas for many commercially and recreationally important fishes and invertebrates. Little Bay has been an important part of the Rockport community for many years. It not only provides the important ecological functions mentioned above, but it also supports the local tourism industry by providing opportunities for both residents and visitors to fish, kayak, boat, jet-ski, and watch birds.

For the last few years, there has been growing concern about the “health” of Little Bay. Many long-term residents and visitors have noted marked changes in the habitats and wildlife of Little Bay. They are worried about Little Bay’s ability to function properly and to continue to support the recreational activities which have made it such a popular destination for both residents and visitors. Various monitoring programs, including seagrass and water quality monitoring projects and water quality monitoring in the streams that flow into Little Bay, have been conducted to try and understand the recent decline in environmental quality. However, definitive explanations for the declines witnessed in Little Bay have not been found and further long-term monitoring efforts would be useful.

In 2012, the Mission-Aransas National Estuarine Research Reserve proposed the idea of establishing a quarterly “Report Card” to monitor the long-term health of Little Bay. Report cards are an effective way to portray the changing conditions of the estuary and have been used in several bays throughout the United States, including the heavily-impacted Chesapeake Bay system. The Little Bay Report Card includes measurements of water quality and is based on the following parameters: temperature, salinity, dissolved oxygen, turbidity, and chlorophyll. Water quality is compared to measurements taken in Aransas Bay. This comparison with Aransas Bay will be used to provide a “grade” for each parameter and will be factored into an annual score. Aransas Bay is generally regarded as a “healthy” bay with good water quality and productive habitats. Details on the Report Card measurements and “grades” can be found in Appendix A.

The information provided in this report includes an annual review of all water quality parameters, including nutrients, chlorophyll a, microplankton sampling, and seagrass extent monitoring in Little Bay and nearby Aransas Bay. The Mission-Aransas Reserve manages five data-logging stations throughout the Mission-Aransas Estuary and one in Little Bay. Each site contains a data logger that collects water quality information at 15 minute intervals throughout the year. The data for five stations, not including Little Bay, are available online at: www.nerrsdata.org. The microplankton samples were counted and analyzed by Cammie Hyatt, Mission-Aransas Reserve scientist. The seagrass monitoring was performed by Dr. Ken Dunton’s laboratory at the University of Texas Marine Science Institute. Dr. Dunton’s laboratory have extensive experience with seagrass monitoring on the Texas coast. Currently, they monitor seagrass within the Reserve, Corpus Christi Bay, and the upper and lower Laguna Madre.

WATER QUALITY PARAMETERS

Water quality parameter data, with the exception of the Secchi disk measurements, is collected using a YSI 6600 multiparameter sonde, programmed to collect data at 15 minute intervals. Data collected includes temperature, salinity, dissolved oxygen, chlorophyll a, and turbidity. Secchi disk depth is taken when the YSI sonde is replaced each month or every two weeks, depending on the season. Details on each parameter can be found in Appendix A. The data shown is from the past 2 years, April 2012 – March 2014. Displaying multiple years of data may provide a better understanding of the system since there is variability in the weather from year to year.

Unfortunately, in April 2013 the tube used to contain the YSI sonde at the Little Bay site broke off and therefore Research staff could not deploy the YSI in the water until it was repaired. Consequently, the YSI sonde was out of the water most of April – June 2013.

Temperature

There were no major differences in temperature between Little Bay and Aransas Bay during April 2012 through March 2014 (Figure 1). In general, the temperature was much colder during the 2013-2014 winter than the 2012-2013 winter and the winter of 2011-2012 was even warmer with January average temperatures of 18.2° C (data not shown), compared with 14.3 and 12.3° C during January of 2013 and 2014, respectively (Figure 1).

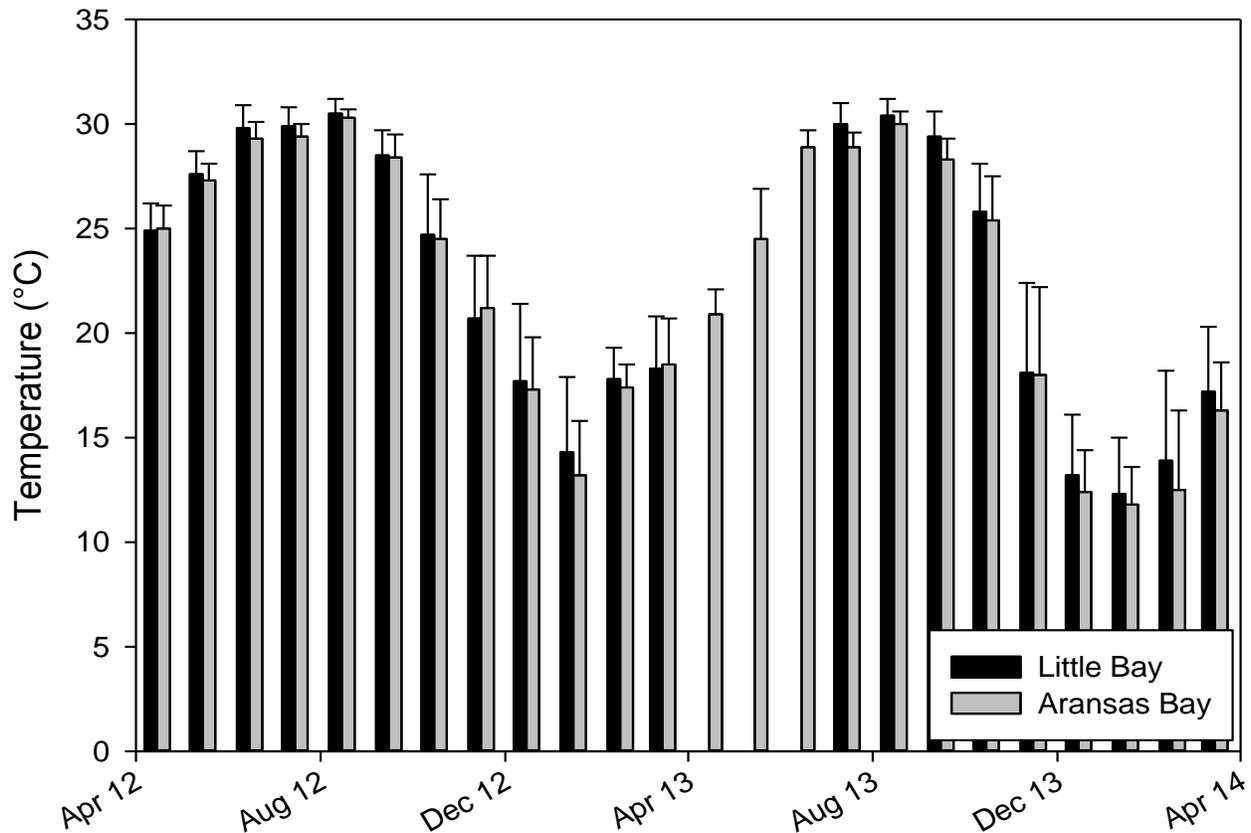


Figure 1. Temperature (°C) monthly averages in Little Bay (black bars) and Aransas Bay (grey bars) from April 2012 – March 2014

Salinity

During most of the study period the salinity was higher in Aransas Bay than Little Bay (Figure 2). This is most likely due to the Tule Creek waste water treatment plant outflow that provides some freshwater into Little Bay. In addition, the Little Bay watershed is urban and has many impervious surfaces that drain into the bay. Overall, the salinity was high in both bays during this time due to the drought that has been ongoing in South Texas since 2011 (Figure 2).

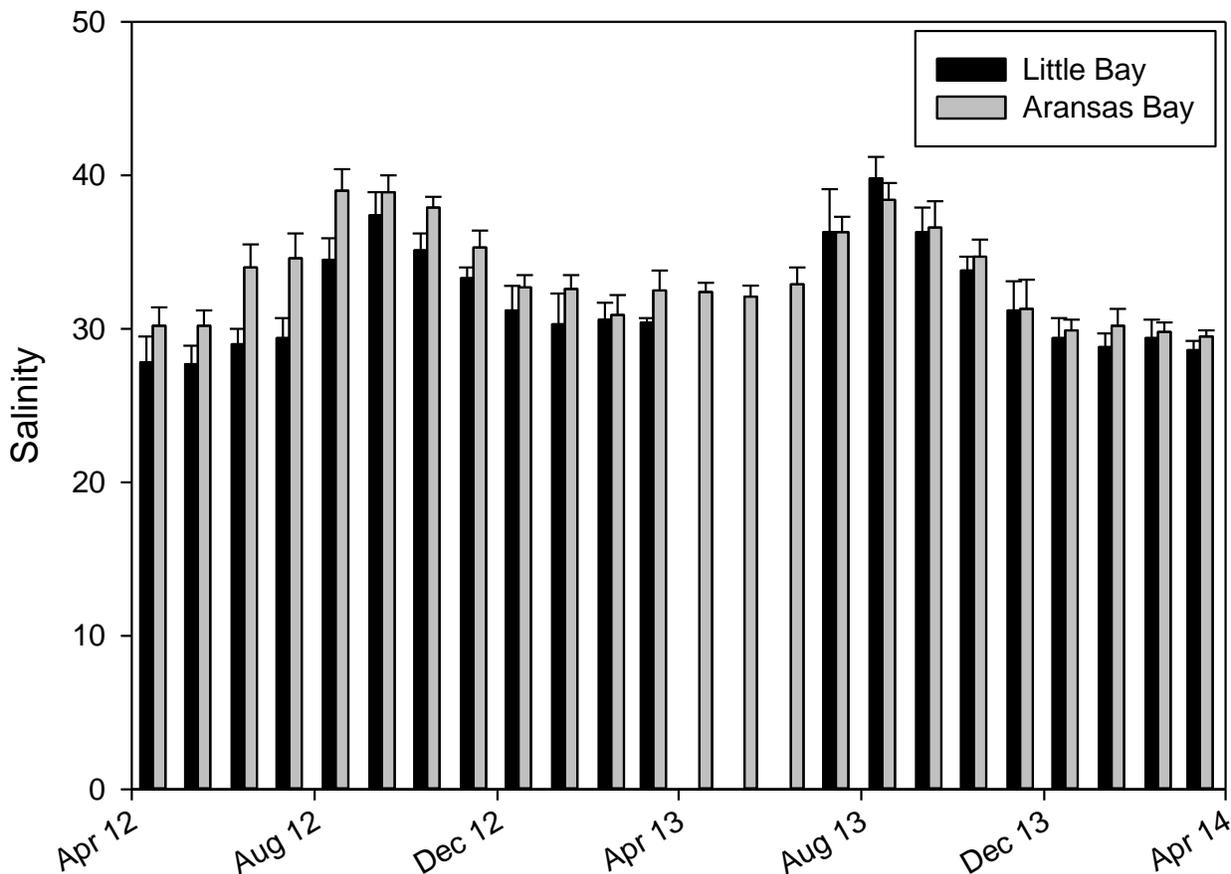


Figure 2. Salinity monthly averages in Little Bay (black bars) and Aransas Bay (grey bars) from April 2012 – March 2014.

Dissolved oxygen

Dissolved oxygen (DO) concentrations were mostly similar in Little Bay and Aransas Bay; however, there appears to be more variability in Little Bay (Figure 3). The Aransas Bay site is in an open bay and thus experiences wind mixing and little stratification. Stratification occurs when water masses with different salinities or temperatures converge to form layers that prevent mixing between the layers. In order for stratification to occur there needs to be low winds, otherwise wind would mix the layers together. The main problem with stratification is that oxygen will not mix from the air down to the bottom waters, causing hypoxia or low oxygen concentrations. The Little Bay site is located on a dock protected from the predominant SE wind. Protection from the predominant winds may allow for some stratification of the water column and lower DO concentrations at night, causing more variability. There was no hypoxia present during the study period (DO concentration < 2mg/L). Overall seasonal trends in both bays are evident, with higher dissolved oxygen concentrations in the winter with the cooler waters. Colder water has a greater capacity to hold more oxygen. When comparing sites, Little Bay had higher dissolved oxygen concentrations than Aransas Bay in the winter and Aransas Bay had higher than Little Bay in the summer.

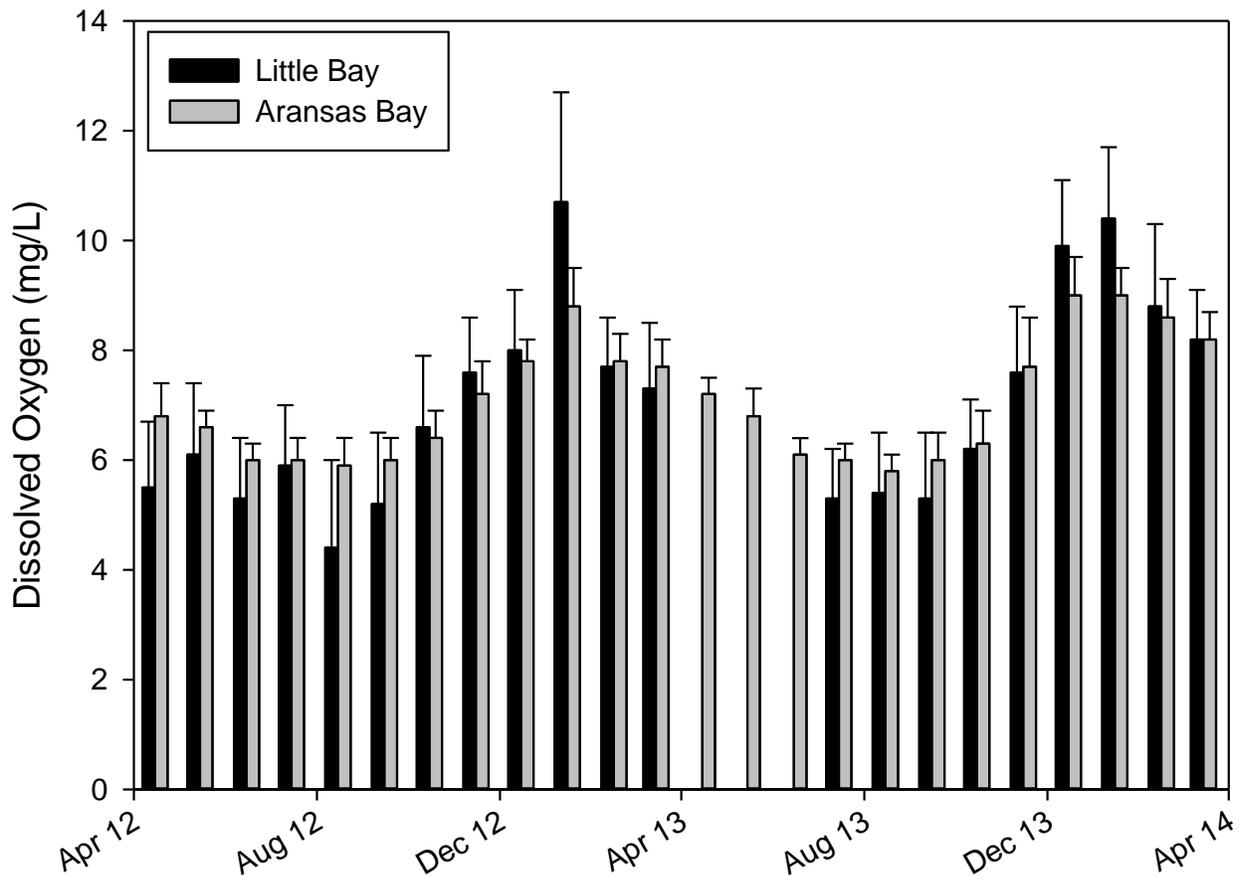


Figure 3. Dissolved oxygen concentration monthly averages in Little Bay (black bars) and Aransas Bay (grey bars) from April 2012 – March 2014.

Chlorophyll *a*

Chlorophyll *a* concentrations are measured because chlorophyll *a* is the major photosynthetic pigment in marine phytoplankton. It can be readily measured in seawater samples and used as an indicator of the amount of algae present in the water. Chlorophyll *a* concentrations measured by the YSI sonde *in-situ*, show much higher chlorophyll *a* in Little Bay than Aransas Bay (Figure 4). The measurements are highly variable, but that is most likely due to the concentrations going up during the daylight hours and wind mixing causing benthic (bottom) algae to become suspended. Also, the semi-enclosed nature of Little Bay makes it susceptible to algal blooms, whereas Aransas Bay is open to tidal flows which keep the water moving thus diluting the formation of blooms. In addition, nutrient inputs from Tule Creek and fertilizers from landscaping may add additional nutrients into Little Bay.

Note: The chlorophyll *a* measurements from the YSI sonde should not be used comparatively with the chlorophyll *a* concentrations determined by extraction from water samples since a direct correlation has not been established between *in situ* and extracted chlorophyll *a*, and extracted samples are based on water samples collected at a single day and time.

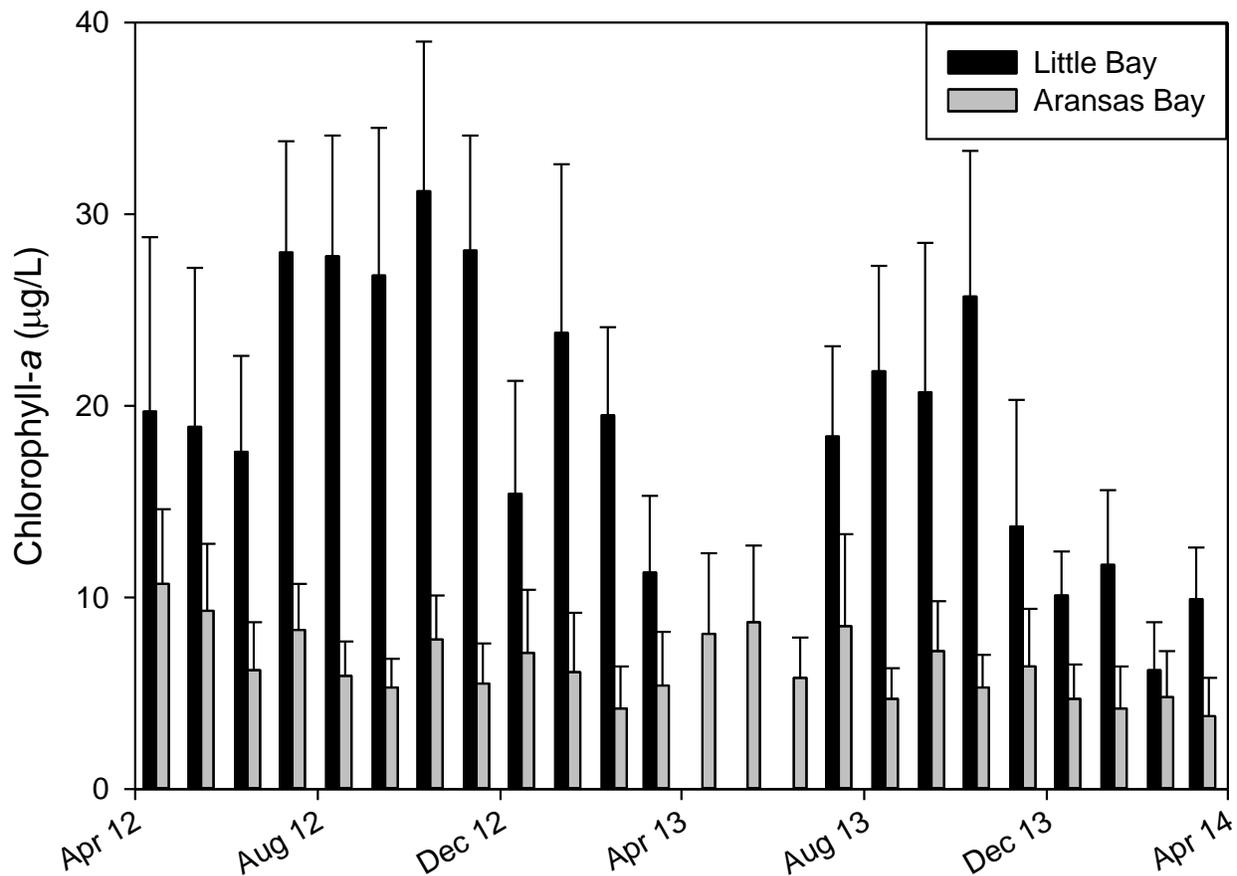


Figure 4. Chlorophyll-a concentration monthly averages (measured with YSI sonde) in Little Bay (black bars) and Aransas Bay (grey bars) from April 2012 – March 2014.

Turbidity

Turbidity levels were mostly higher in Aransas Bay than in Little Bay (Figure 5). This is likely due to the fact that Aransas Bay is a large open bay, whereas Little Bay is a smaller enclosed bay. Turbidity levels in Aransas Bay are highly variable due to the variability of the wind as well as the strong tidal currents that move through the Intracoastal Waterway. In addition, the Little Bay sonde location is on the southeast side of the bay protected from the predominant wind.

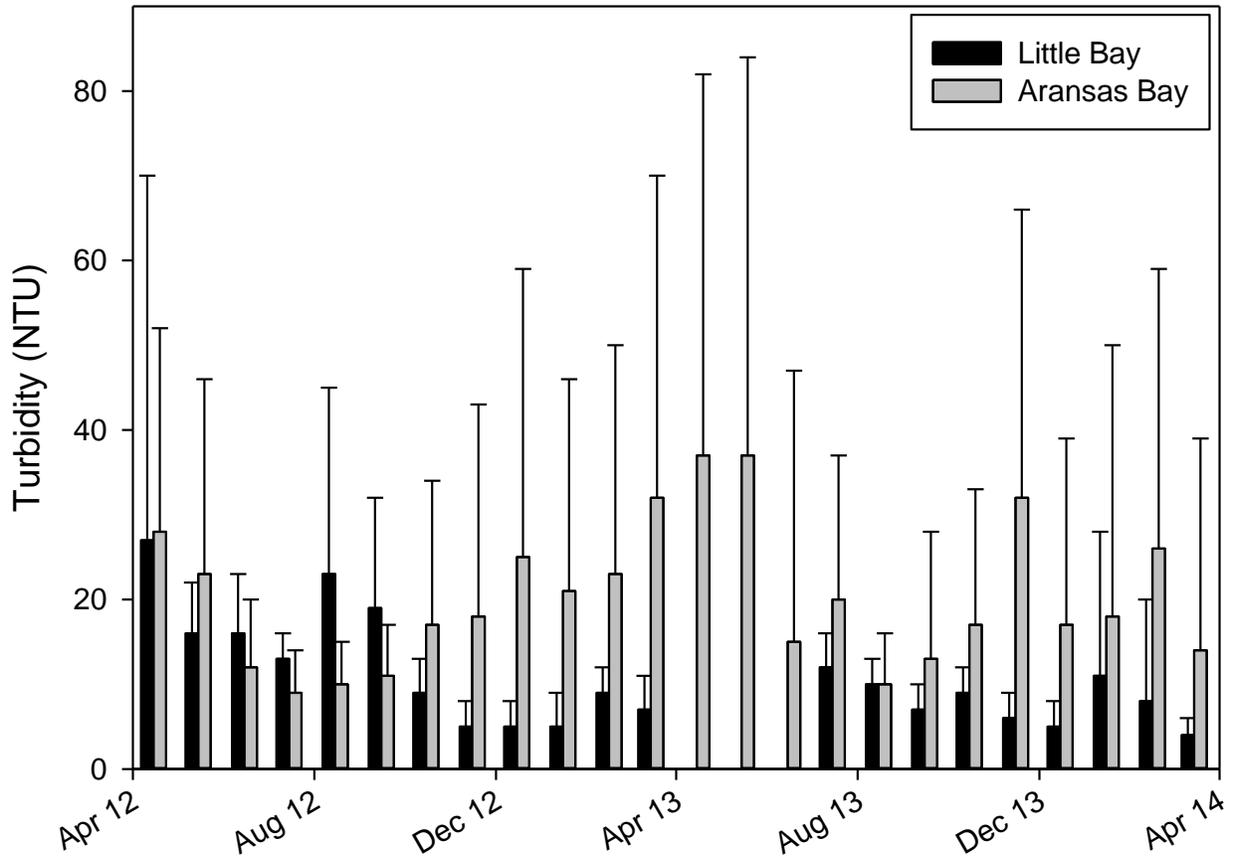


Figure 5. Turbidity level monthly average in Little Bay (black bars) and Aransas Bay (grey bars) from April 2012 – March 2014.

Secchi Disk Depth

Secchi disk measurements are made once or twice per month when the sondes are serviced. Secchi disk depth monthly averages were mostly higher in Aransas Bay compared with Little Bay (Figure 6). This means the water clarity was greater in Aransas Bay. These results are different from the turbidity results in Figure 5 with higher turbidity in Aransas Bay, but the chlorophyll *a* results in Figure 4 show higher concentrations in Little Bay. The Secchi disk depth and water clarity are influenced by both turbidity (sediments in the water column) and chlorophyll *a* concentrations (algae in the water column). In Little Bay, phytoplankton or algae in the water column may be inhibiting more light reaching the seafloor than suspended sediments. One concern for seagrass growth has been light levels and increased light attenuation due to suspended sediments or phytoplankton growth.

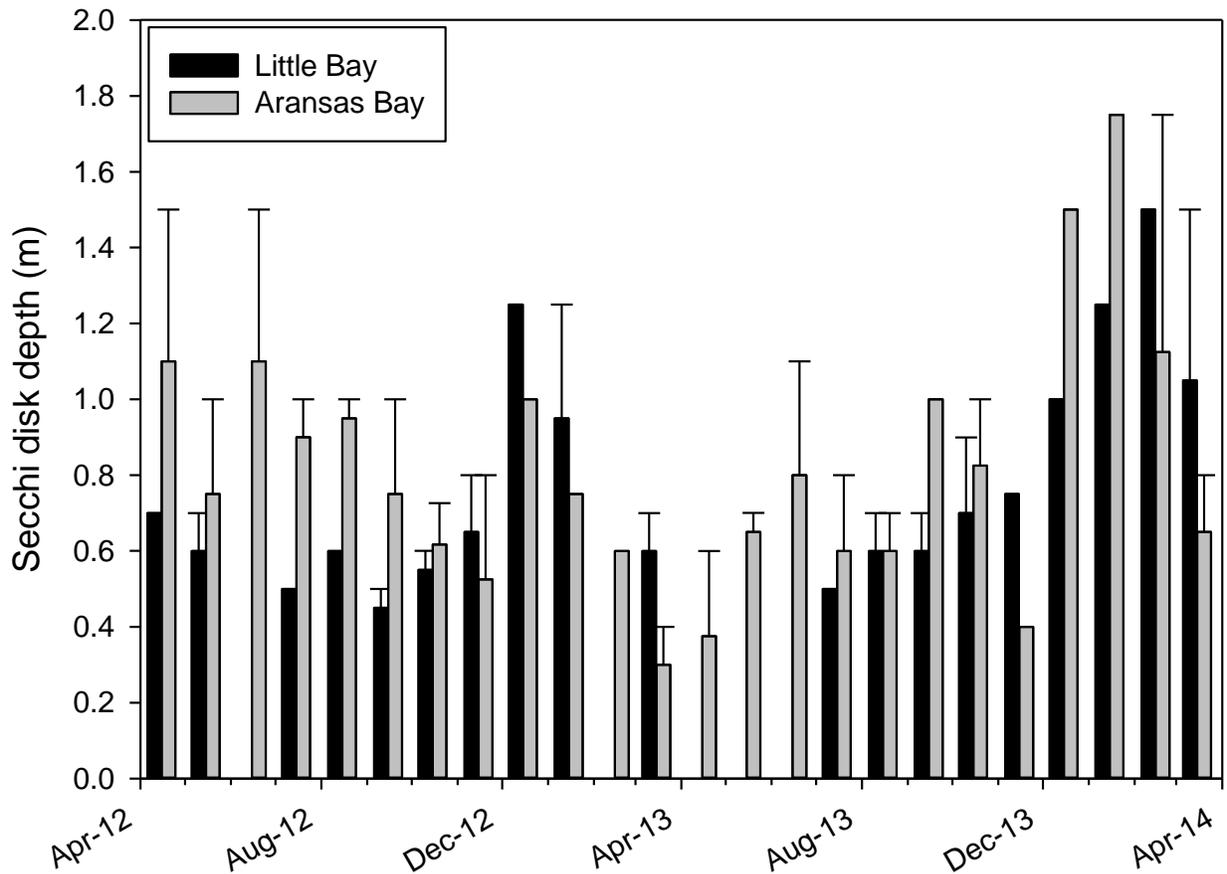


Figure 6. Secchi disk depth monthly averages in Little Bay (black bars) and Aransas Bay (grey bars) from April 2012 – March 2014.

CHLOROPHYLL A AND NUTRIENT CONCENTRATIONS

Beginning in March 2013, replicate water samples were collected once a month and brought back to the laboratory for analysis of chlorophyll *a* and nutrient concentrations. Nutrients that were analyzed include nitrate+nitrite, ammonium, phosphate, and silicate, all of which support the growth of phytoplankton in the water column. Replicate samples were averaged and standard error was calculated, which is displayed in the following graphs.

Chlorophyll *a* concentrations

For the most part, extracted chlorophyll *a* followed the same pattern as *in-situ* chlorophyll *a* sampled, every 15 minutes, by the YSI sondes with Little Bay having higher values than those of Aransas Bay (Figure 7). Chlorophyll *a* concentrations were especially high in Little Bay during December and January. This can be attributed to the enclosed nature of Little Bay and the same reasons previously mentioned. Which include additional nutrient inputs from Tule Creek, wind stirring up benthic algae, and excess fertilizers allowing growth of phytoplankton blooms.

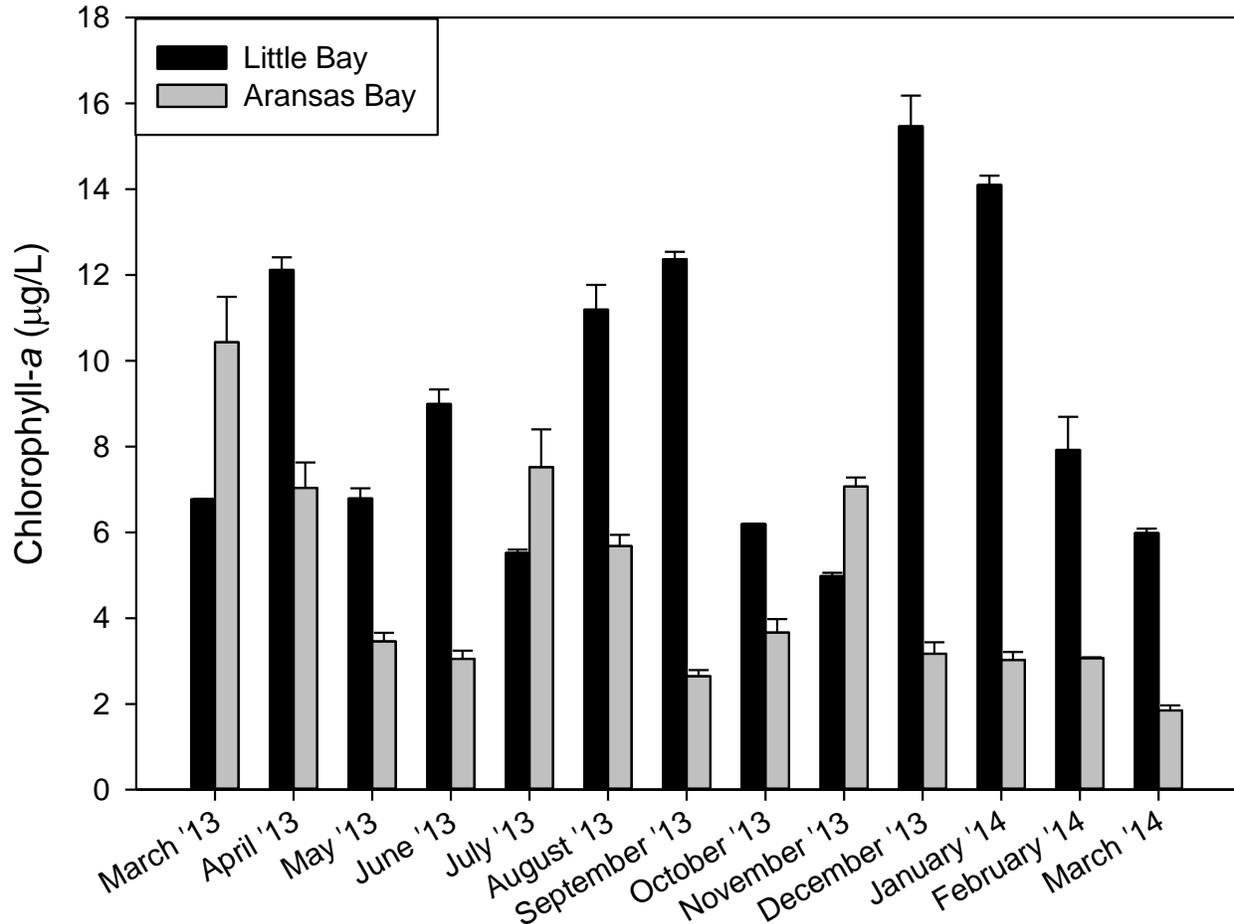


Figure 7. Chlorophyll-*a* concentrations (measured by extraction from water samples) in Little Bay (black bars) and Aransas Bay (grey bars) from March 2013 – March 2014.

Nitrate + nitrite concentrations

In general, there tends to be very low concentrations of nitrate+nitrite in both sites; however, there appears to be slightly higher levels in Little Bay during the summer whereas spring readings in Little Bay are typically similar to Aransas Bay (Figure 8). Fall and winter values are highly variable between the two sites which may be due to storm events. Nonetheless, the concentrations do not exceed 0.06 mg/L, which is very low.

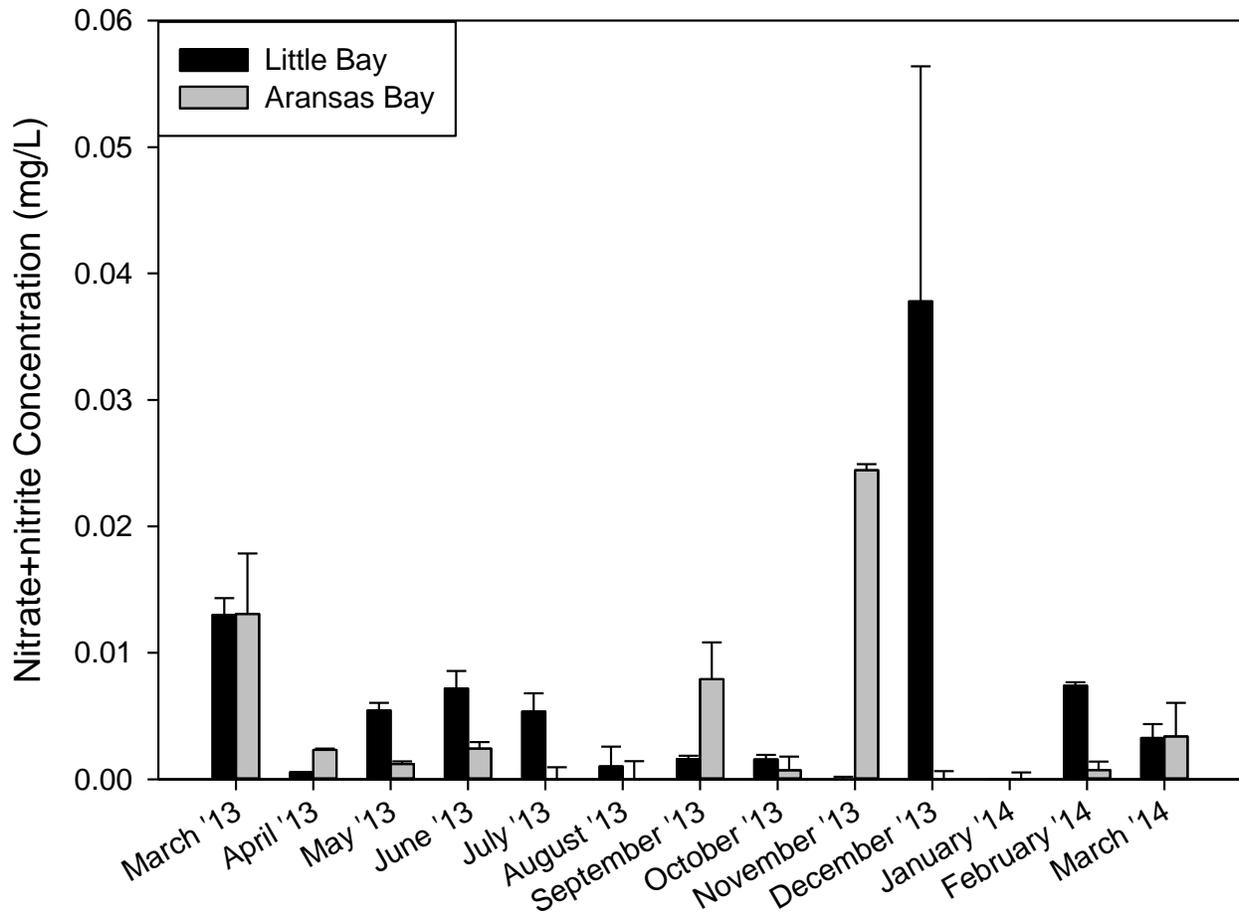


Figure 8. Nitrate+nitrite concentrations in Little Bay (black bars) and Aransas Bay (grey bars) from March 2013 – March 2014.

Ammonium concentrations

In general, there is very low ammonium concentrations in Little and Aransas bays (Figure 9). At times, Aransas Bay ammonium concentrations exceed Little Bay and vice versa. The concentrations are extremely low in both bays, not exceeding 0.025 mg/L.

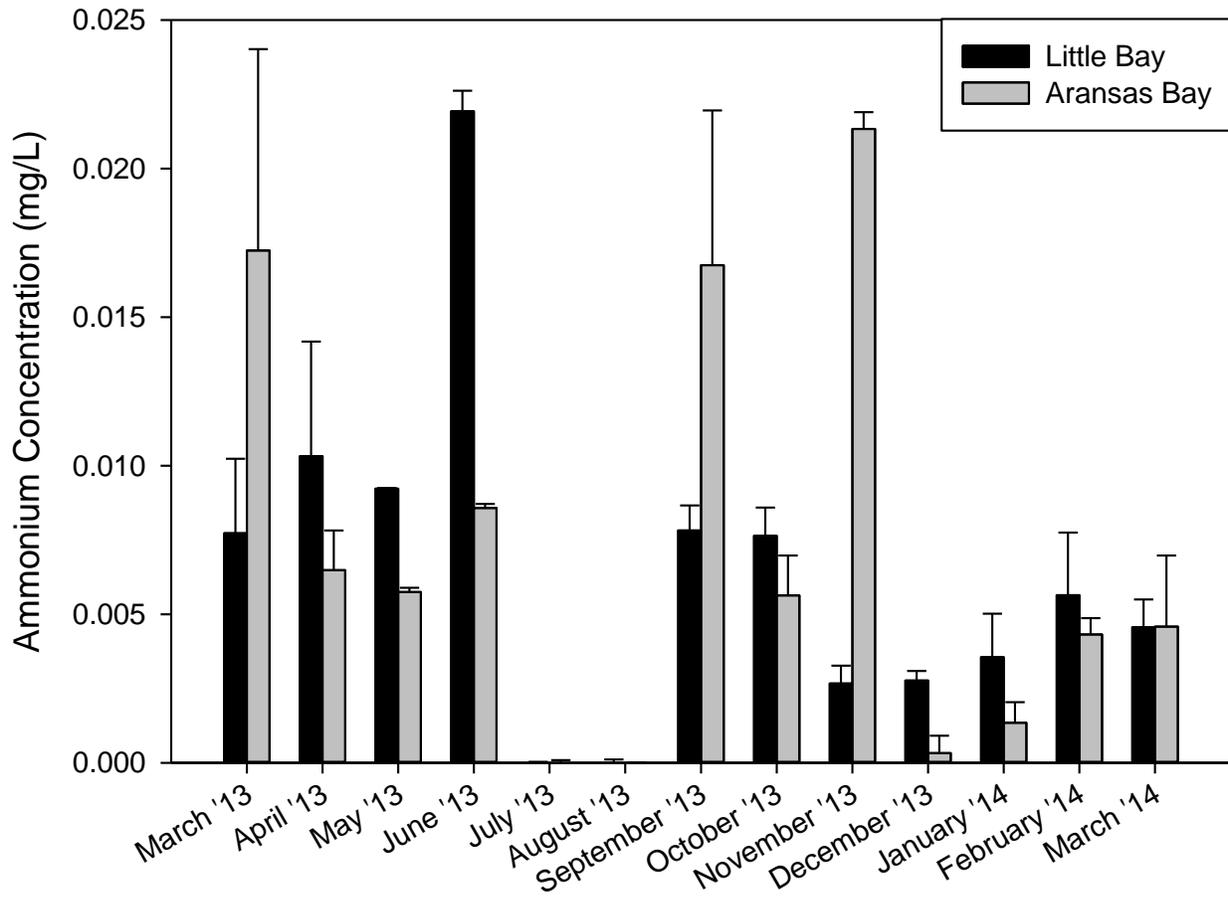


Figure 9. Ammonium concentrations in Little Bay (black bars) and Aransas Bay (grey bars) from March 2013 – March 2014.

Phosphate concentrations

With two exceptions, Little Bay has higher phosphate levels than Aransas Bay (Figure 10). This may be due in part to phosphates from fertilizers being transported via run-off from the surrounding areas. In general, phosphate concentrations are very low in both bays, not exceeding 0.05 mg/L.

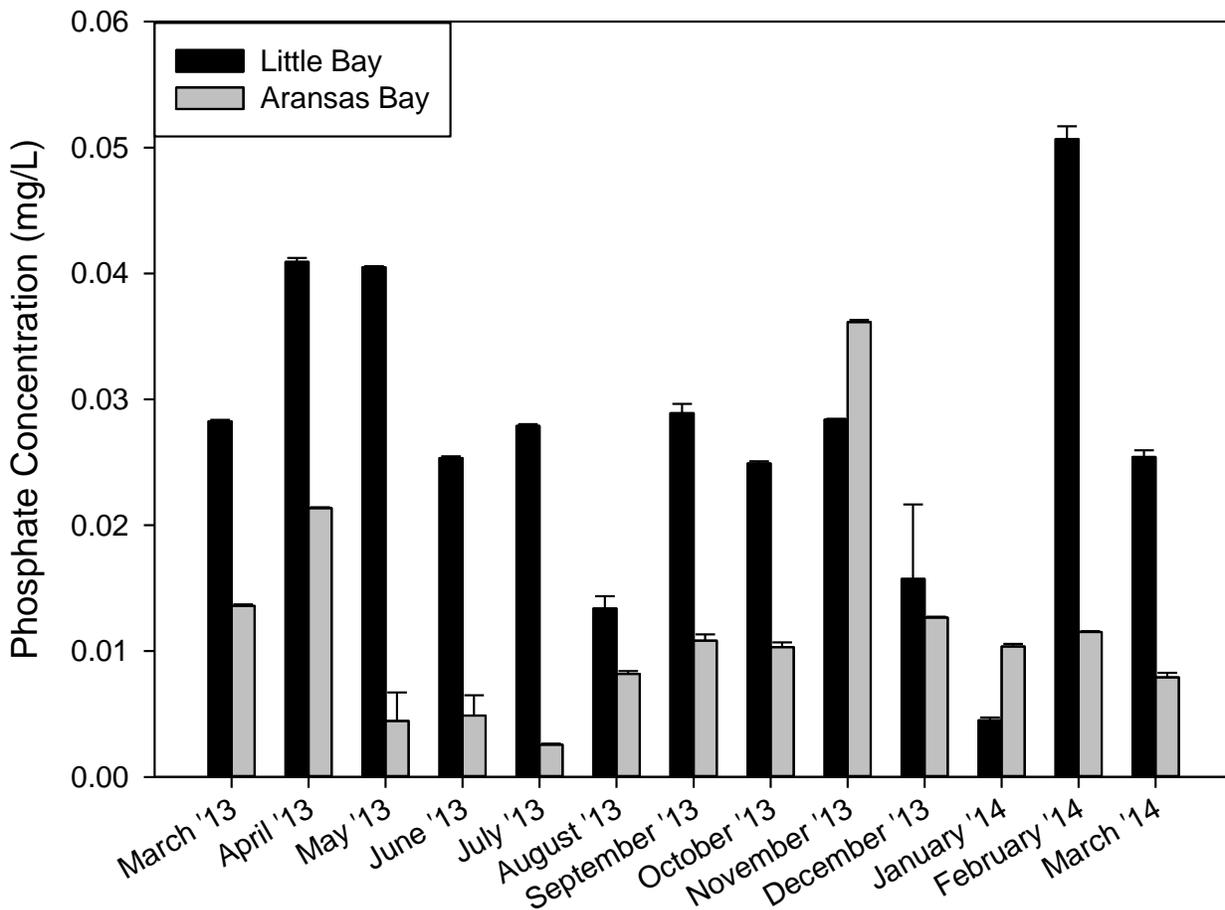


Figure 10. Phosphate concentrations in Little Bay (black bars) and Aransas Bay (grey bars) from March 2013 – March 2014.

Silicate concentrations

Silicate concentrations follow a similar pattern in Little and Aransas bays (Figure 11). Concentrations were highest in the fall of 2013 in both bays. In July of 2013, silicate concentrations were much higher in Little Bay than Aransas Bay. In November, December, and January, the silicate concentrations were higher in Aransas Bay than in Little Bay. The variations are likely due to small freshwater inflow events, with the main source of silicate from weathering rocks and clay soils. Large diatom blooms can deplete silicate concentrations in an estuary but the die-off of a large diatom bloom can also release silica into the water.

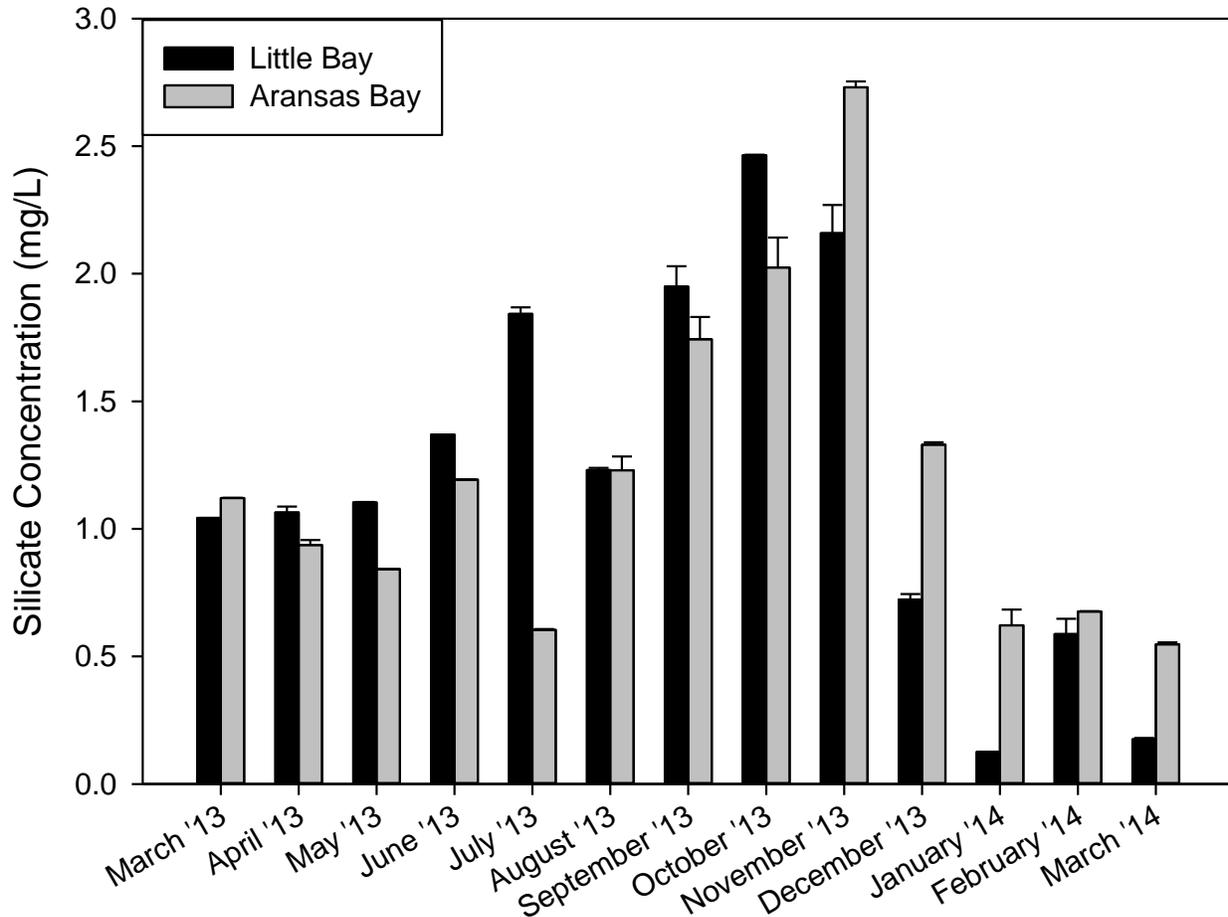


Figure 11. Silicate concentrations in Little Bay (black bars) and Aransas Bay (grey bars) from March 2013 – March 2014.

MICROPLANKTON SAMPLING

Microplankton are characterized as plankton that are from 20-200 μm in size. Most of these organisms are phytoplankton (autotrophs - algae) but some are heterotrophic protozoan, such as ciliates and heterotrophic dinoflagellates, which need to obtain carbon from other sources and cannot produce it themselves.

Water samples were collected once per month to count microplankton concentrations. Subsamples (1 ml of water) were taken from each bottle and settled overnight and then each cell was counted under a microscope and categorized into 6 major groups.

The major groups are:

Ciliates: Ciliates are protozoa that contain hair-like organelles called cilia that they use to feed, swim, attach to, and for sensation. Most ciliates are heterotrophs that feed on small algae (phytoplankton) and bacteria.

Tintinnids: Tintinnids are a type of ciliate which are characterized by their vase-shaped shell called a loricae. These organisms are very prevalent in marine waters.

Dinoflagellates: Dinoflagellates are protozoa that have whip-like organelles called flagella that they use mostly to swim and feed. Most dinoflagellates are photosynthetic, but many are mixotrophic, meaning that they can photosynthesize and also ingest prey. In addition to these, some dinoflagellates are obligate heterotrophs and rely on other plankton as food. An important dinoflagellate species in the Coastal Bend is the red tide, *Karenia brevis*, which causes harmful algal blooms.

Diatoms: Diatoms are typically the most abundant marine phytoplankton group. They are unicellular but can form colonies. Diatoms have a silica cell wall, making silicate an important nutrient for them.

Cryptophytes: Cryptophytes are a group of small algae or phytoplankton containing chloroplasts and two unequal flagella. They are a good food source for other microplankton and mesozooplankton.

Euglenoids: Euglenoids are one of the most well-known groups of flagellates. Most are unicellular and either contain chloroplasts or feed by phagocytosis (engulfing).

From March through November, 2013, Little Bay has proportionately more dinoflagellates than Aransas Bay, whereas Aransas Bay has more diatoms (Figure 12). However, December through March Little Bay experienced a very large Diatom bloom (Figure 12). There was also a drawdown of silicate during this bloom (Figure 11). Overall, Little Bay also contains more ciliates than Aransas Bay. Although both contain varying amounts of the different organisms mentioned above, Little Bay tends to be somewhat more diverse.

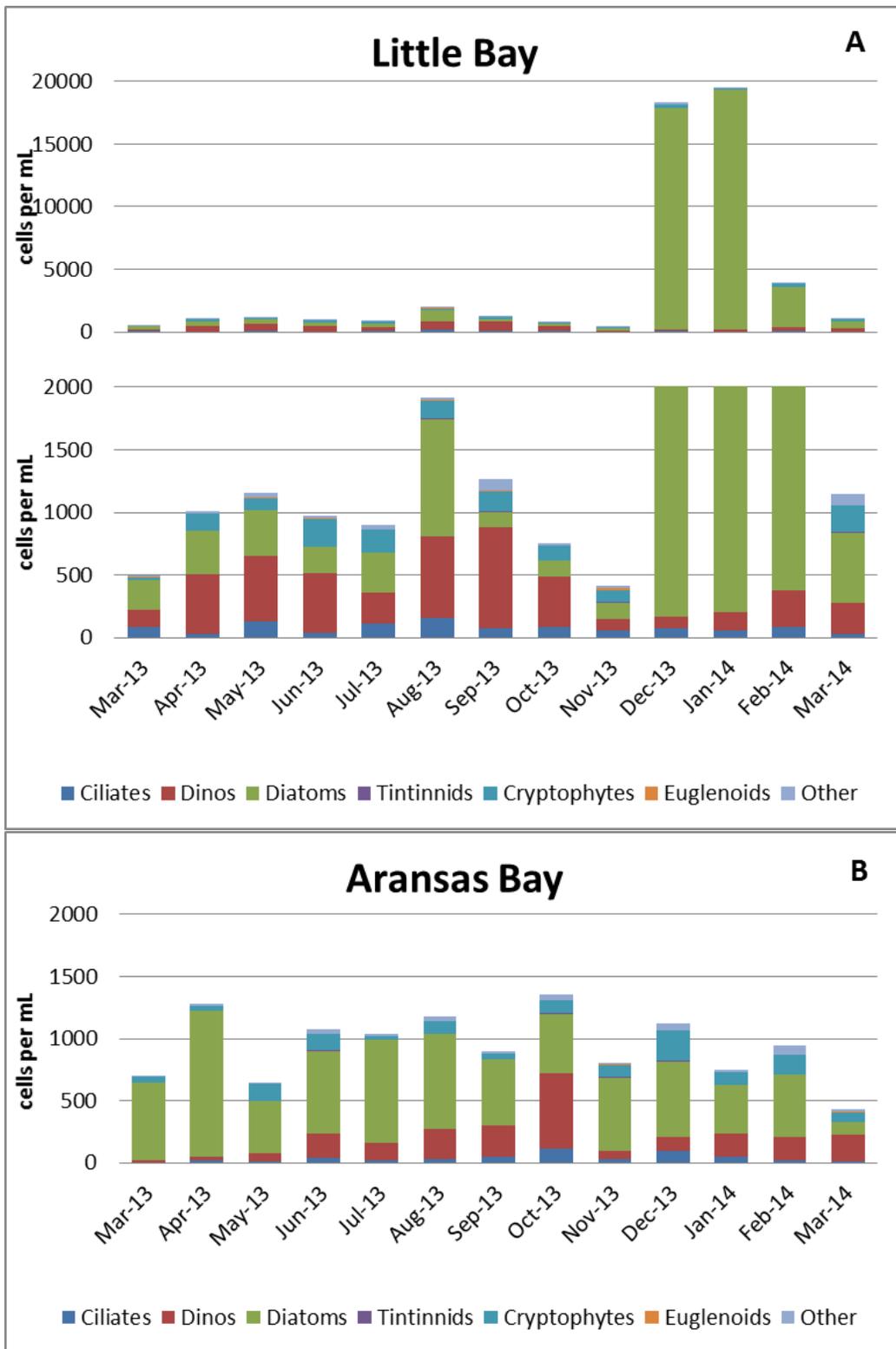


Figure 12. Microplankton cell counts in Little Bay (A) and Aransas Bay (B) from March 2013 – March 2014. The top panel of figure A has the full y-axis and the bottom panel is focused on the same range as Aransas Bay in order to see the details of the other microplankton groups. Dinoflagellates are abbreviated as *Dinos*.

SEAGRASS MONITORING

Seagrass and water quality sampling were conducted in Little Bay at 14 stations on October 31, 2012 and at 16 stations on November 4, 2013. Average station depth was taken with a meter stick and ranged from 78 cm in 2012 to 90 cm in 2013, with Secchi depths decreasing slightly from 57 cm in 2012 to 54 cm in 2013. Underwater light attenuation was measured with a lightmeter consisting of two LI-COR irradiance sensors mounted to a lowering frame. The light attenuation coefficient (k_d) increased slightly from 2012 (0.92) to 2013 (1.47), indicating lower water clarity in 2013, which was in agreement with Secchi depth measurements. A 1-L water sample was collected at each monitoring station and filtered in the laboratory to determine total suspended solid content. Total suspended solids varied little from 2012 (24.8 mg L⁻¹) to 2013 (25.1 mg L⁻¹), as did YSI 6920 sonde measurements of chlorophyll *a*, a measure of phytoplankton abundance (18.4 µg L⁻¹ in 2012, 18.3 µg L⁻¹ in 2013). Sonde salinity measurements were similar each year (34.3 in 2012, 32.2 in 2013), as were the dissolved oxygen (8.3 mg L⁻¹ in 2012, 8.0 mg L⁻¹ in 2013) and pH (7.9 in 2012, 8.1 in 2013) measurements (Table 1). It is important to note that the above parameters were measured on a single occasion each year, and may not be comparable with data from the deployed sondes, collected continuously at 15 minutes intervals. Water quality measurements (salinity, temperature, pH) from the Little Bay seagrass monitoring stations are similar to those from seagrass monitoring stations throughout Aransas and Redfish Bays. Water clarity (measured with Secchi depth, light attenuation, and chlorophyll *a* levels), however, was notably lower in Little Bay, likely due to the enclosed nature of Little Bay and wind mixing of benthic particulates and algae.

Seagrass was present at one station (LB21) in 2012. In 2013, LB21 still had seagrass, as did LB7 (moved south slightly) and another station containing seagrass (LB2) was added to the sampling program. The only seagrass species present in both years was shoal grass (*Halodule wrightii*), which increased in percent cover at LB21 from 6.3 % in 2012 (Figure 13 A) to 40.3 % in 2013 (Figure 13 B). Average seagrass canopy height was 4.9 cm in 2012 but increased to 6.6 cm in 2013. Shoal grass % C was similar between 2012 and 2013 (35.8 % and 34.9 %, respectively). Also similar was % N from 2012 and 2013 (2.4 % and 2.9 %, respectively). Average C:N ratios were 17.5 for 2012 and 14.5 for 2013, and were lower than C:N ratios of shoal grass from Aransas and Redfish Bays. Lower C:N ratios indicate that more N is available to seagrasses in Little Bay, likely due to inputs from Tule Creek.

Average $\delta^{15}\text{N}$ values ranged from 0.4 ‰ for 2012 to 3.6 ‰ for 2013. Higher $\delta^{15}\text{N}$ values were expected in Little Bay due to the wastewater treatment plant N inputs from Tule Creek, whereas in Aransas Bay there are no direct inputs of wastewater and the $\delta^{15}\text{N}$ values are ~1.7 ‰. Wastewater generally has a high (or enriched) $\delta^{15}\text{N}$ value because as bacteria cycle N at high rates, the $\delta^{15}\text{N}$ value of inorganic N becomes enriched as they utilize the 'lighter' (¹⁴N) N first and leave the 'heavy' (¹⁵N) behind. However, $\delta^{15}\text{N}$ of artificial fertilizers is ~0-3 ‰ because it is made from atmospheric N which has a $\delta^{15}\text{N}$ value of 0 ‰. There are also concerns and suggestions that in Little Bay some of the inorganic N may be coming from fertilizers from lawns or the golf course, therefore lowering the $\delta^{15}\text{N}$ values of available N. The increased $\delta^{15}\text{N}$ values in seagrass from 2012 – 2013 may indicate that during the drought, N inputs from the WWTP was the dominant form of N available for plants. Also, higher $\delta^{15}\text{N}$ values and slightly increased % N values in seagrasses in 2013 may indicate that greater anthropogenic N in the system helped to promote seagrass growth. Although there were low nitrate-nitrite and ammonium concentrations in Little Bay and Aransas Bay (Figure 8 and Figure 9), as N enters the system it is likely used up very quickly by phytoplankton,

recycled and maintained within the system. It must be noted that seagrass tissue sample sizes for Little Bay were quite small (n=1 in 2012, n=3 in 2013) due to the small extent of seagrass in the bay, and more samples must be gathered in future years to establish meaningful seagrass tissue baseline data. All seagrass parameters are reported in Table 2.

Table 1. Little Bay water quality parameters from 2012-2013.

	n	Depth (cm)	Secchi (cm)	K _d	TSS (mg L ⁻¹)	Chl <i>a</i> (µg L ⁻¹)	Salinity	D.O. (mg L ⁻¹)	pH
2012	1	78	57	0.92	24.8	18.4	34.3	8.3	7.9
2013	3	90	54	1.47	25.1	18.3	32.2	8.0	8.1

Table 2. Little Bay seagrass parameters from 2012-2013.

	n	Percent Cover (%) at LB21	Species	Avg. Canopy Height (cm)	% C	% N	C:N	δ ¹⁵ N
2012	1	6.3	<i>Halodule wrightii</i>	4.9	35.8	2.4	17.5	0.4
2013	3	40.3	<i>Halodule wrightii</i>	6.6	34.9	2.9	14.5	3.6

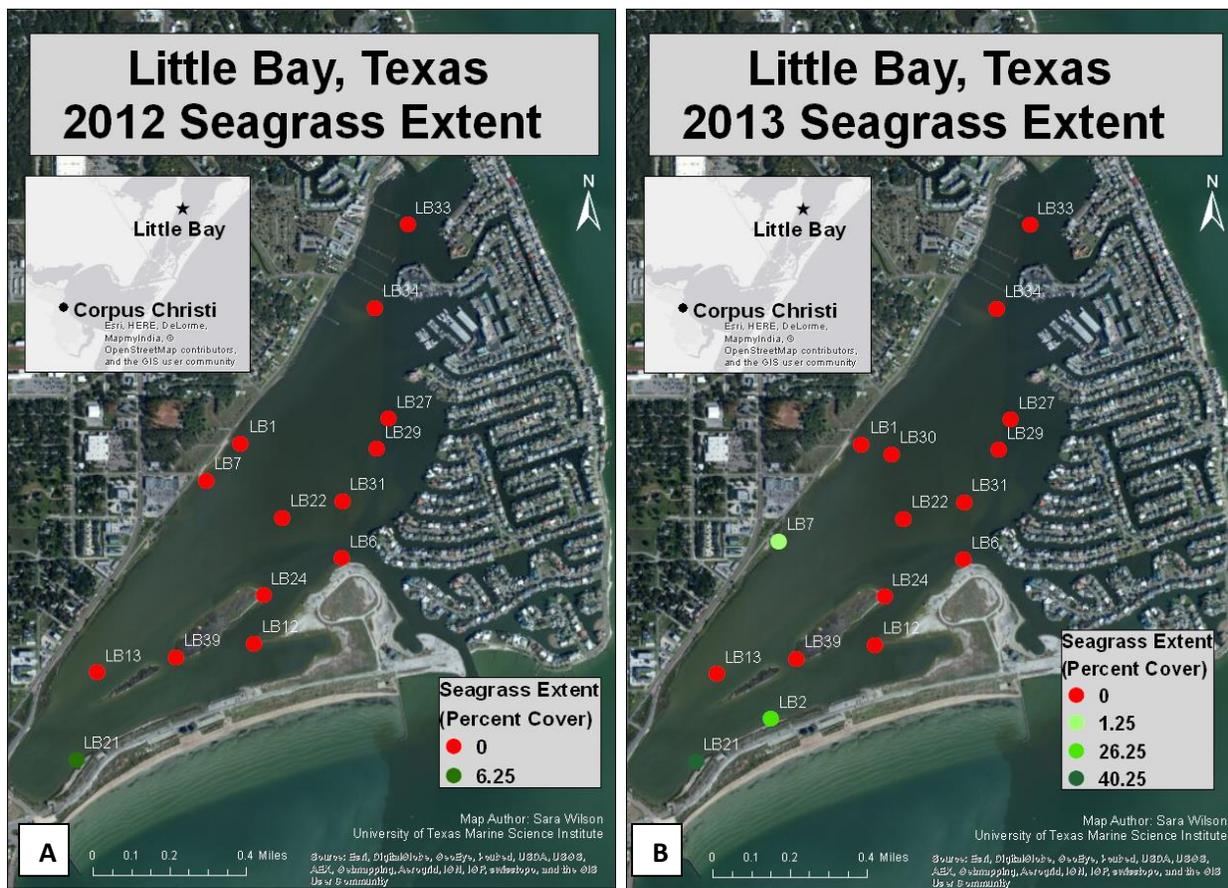


Figure 13. Little Bay seagrass extent in 2012 (A) and 2013 (B).

DISCUSSION

Water quality parameters in Little Bay and Aransas Bay sites were highly comparable. Small differences were seen between temperature, salinity, and dissolved oxygen in Little Bay and Aransas Bay. Previous studies by the Mission-Aransas Reserve have also seen little differences in dissolved oxygen and temperature (Dean and Buskey 2011). This study found little differences in salinity between the two sites. During this study period, the Coastal Bend has been experiencing a drought and therefore salinities at both sites were high (Figure 2). Three previous seagrass and water quality studies that measured salinity included the summers of 2007 and 2010, where the Coastal Bend experienced several tropical storms with large amounts of rainfall (Gill et al. 2007, Dunton and Wilson 2010, and Dean and Buskey 2011). During storm events, Little Bay experiences large amounts of direct freshwater inflows through Tule Creek and other storm water outflows, whereas Aransas Bay does not have any large rivers or creeks directly feeding into it and receives freshwater secondarily. In addition, Aransas Bay is continuously mixing with Gulf of Mexico water via the Ship Channel and the Lydia Ann Channel, keeping the salinity at more moderate levels. These previous studies indicated that low salinities may be responsible for the disappearance of seagrasses. Prior to anthropogenic changes to Little Bay, it was likely that following storm events the salinity of Little Bay did not remain low because the bay mixed with Aransas Bay more freely. Perhaps the recent drought and higher salinities in Little Bay have attributed to the increases in seagrasses shown in this report.

Large differences were seen in the turbidity and chlorophyll *a* concentrations. Turbidity measurements were much higher in Aransas Bay than Little Bay (Figure 5). This is likely due to Aransas Bay being a large open bay with frequent wind mixing, causing suspension of sediments. Little Bay, especially at the YSI sonde location, is more protected from the wind with less re-suspension of sediments. However, most of the time Secchi disk depth was greater in Aransas Bay, indicating greater water clarity on the days when these measurements were made (Figure 6). At the Little Bay seagrass sites, Secchi depth readings and light attenuation measurements were not at levels of concern for impeding seagrass growth. In addition, previous studies by the Mission-Aransas Reserve and Dr. Ken Dunton's laboratory also found that water clarity does not seem to impede seagrass growth in Little Bay (Dean and Buskey 2011, Dunton and Wilson 2010).

Chlorophyll *a* concentrations were much higher in Little Bay than Aransas Bay (Figure 4 & Figure 7). Monthly averages of *in-situ* chlorophyll *a* were consistently higher in Little Bay, whereas there were a few months of extracted chlorophyll *a* measurements that were higher in Aransas Bay than Little Bay (March, July and November 2013). Since Little Bay is small and enclosed, the chance of bloom formation is greater because there is not as much mixing with other water bodies, such as in Aransas Bay. Also, there is likely greater direct inputs of nutrients in Little Bay from Tule Creek, storm water inputs, and fertilizer runoff from landscaping. Secchi disk depth seems to have been more heavily influenced by chlorophyll *a* concentrations than turbidity, since Secchi disk depth was mostly greater in Aransas Bay. However, the Secchi disk depth was also only taken on days where the wind was low because the sites are accessed by boat when the weather is good.

Nutrient concentrations were generally low in both Little Bay and Aransas Bay. Mission-Aransas Reserve water quality data shows similar results, low nutrient concentrations, at other sites located in the Reserve boundary (data not shown). However, nutrient concentrations in the bay are not indicative of nutrient loading to the system. There is likely larger amounts of nutrients entering the system, but they are being

used up quickly by phytoplankton, macro algae, and seagrass. In Copano Bay, during storm events, rivers export large amounts of nutrients into the bay (Mooney and McClelland 2012). The source of the nutrients may be wastewater treatment plants, fertilizers, animal waste, or naturally occurring nutrients in the soil. The elevated nutrients can only be measured in the water column for a few days because they are quickly utilized by phytoplankton and bacteria (Bruesewitz et al. 2013, Mooney and McClelland 2012). In Little Bay, the amount of nutrient loading has been greatly reduced since the improvements of the wastewater treatment plant (WWTP) in October 2012 (Figure 14). Despite the improvements to the WWTP and the dramatic decreases in total nitrogen concentration, the WWTP effluent is still a point source of nutrients to the area. In addition, non-point source nutrient inputs such as runoff from land, including fertilizers, soils, and impervious surfaces can also contain high levels of nutrients that enter the waterways during storm events.

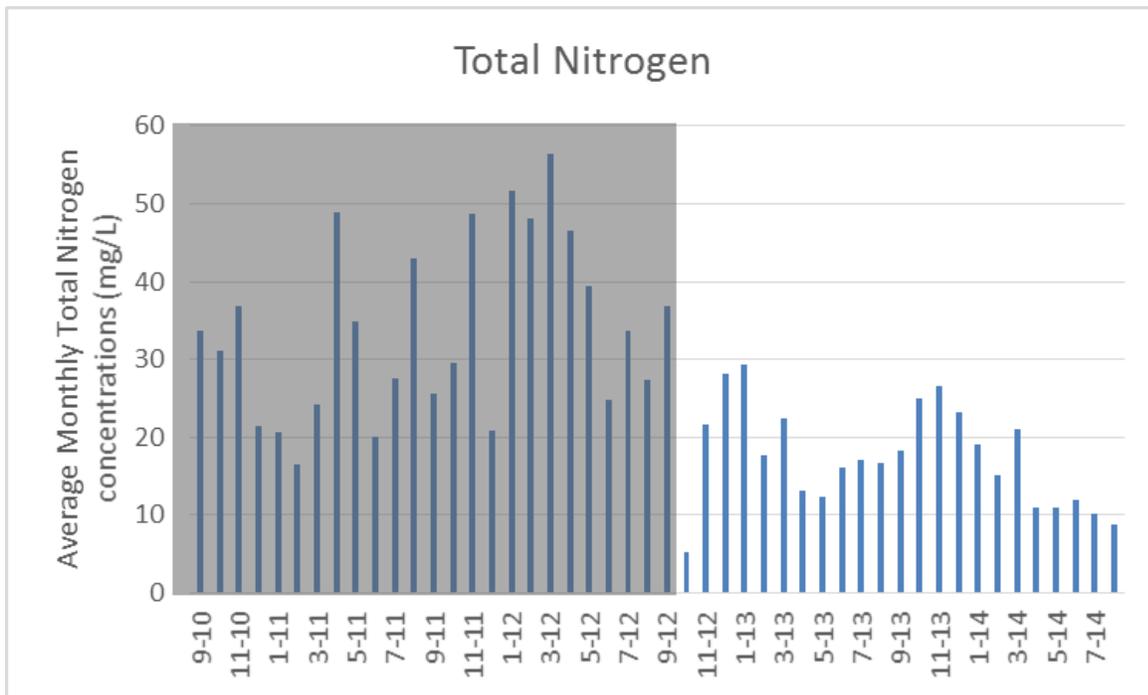


Figure 14. Average monthly total nitrogen concentrations (mg/L) from the wastewater treatment plant in Rockport. Area in grey was prior to the installation of the anoxic tank, October 2012. Data from Tom Rowe, Rockport.

Monthly microplankton samples show that there was more diversity of phytoplankton in Little Bay than in Aransas Bay. From March – November 2013, there were proportionately more dinoflagellates in Little Bay and proportionately more diatoms in Aransas Bay (Figure 12). More dinoflagellates in Little Bay, compared with Aransas Bay, could be due to larger nutrient inputs into the system.

There was a very large diatom bloom in Little Bay beginning in December 2013 and continuing through March 2014. The prevalence of diatoms may be limited by the amount of silicate in the water. Diatoms have a silica cell wall, therefore needing silica in order to grow. However, neither site appears to have a silica limitation for diatom growth, but there was an apparent drawdown on silicate in Little Bay during the bloom. The enclosed nature of Little Bay may enable a bloom to grow for longer periods of time than an open bay. If blooms continue for long periods of time, the amount of light reaching the sea floor in

Little Bay would be greatly reduced. This study did not include measuring light attenuation other than monthly measures of Secchi disk depth. Two recent studies in Little Bay measured light attenuation and found sufficient light to support seagrass growth (Dean and Buskey 2011 and Dunton and Wilson 2010). However, depending on the timing of these blooms, they could be blocking light during a critical time during spring when the seagrasses are beginning to regrow after winter.

Seagrass monitoring shows that seagrass extent appears to be improving over 2012-2013 summer seasons. When comparing years, seagrass was present at more sites in 2013, had increased percent cover and increased seagrass canopy height. As previously mentioned the ongoing drought, with little freshwater inputs into Little Bay, may have contributed to the increased percent cover of seagrasses. Continuous monitoring of Little Bay seagrass will determine whether this trend continues.

SUMMARY AND FUTURE RECOMMENDATIONS

The monitoring efforts described in this report, and those from a previous report (Dean and Buskey 2011) indicate that the water quality in Little Bay is generally good, and comparable in most aspects to the water in nearby Aransas Bay. Temperature, salinity and dissolved oxygen levels are consistently similar to those in the open bay. Inorganic nutrient levels are low in both locations, and there is no indication that excess free inorganic nutrients pose an environmental threat to Little Bay. However, there is clear evidence that water clarity is a major environmental issue in Little Bay, and this seems to be one likely contributor to the long term trend of decreasing seagrass cover in this area. The decrease in water clarity is evident from the consistently shallower Secchi depths in Little Bay compared to Aransas Bay, and the consistently higher level of chlorophyll *a* in Little Bay compared with Aransas Bay. Direct measures of turbidity from the YSI data sondes may appear to contradict this evidence, since they indicate that turbidity is generally higher in Aransas Bay than Little Bay, especially during winter and early spring. However, turbidity measures are more similar in the two locations during the major growth seasons for seagrasses during the late spring and summer. The higher chlorophyll *a* concentrations in Little Bay are of concern, and indicate that excess nutrients from Tule Creek are being rapidly taken up by phytoplankton, leading to additional phytoplankton biomass and reduced water clarity. It is interesting to note that the total nitrogen concentrations in the waters of the wastewater treatment plant have declined since the installation of the anoxic tank in October 2012. It may take some time before this reduced nutrient load results in a decrease in phytoplankton biomass in Little Bay since these nutrients are efficiently recycled in a system with reduced circulation with the open areas of Aransas Bay.

Given the above information, and working with the assumption that financial resources for continued monitoring may be limited, we would recommend that the most efficient use of resources would be to establish a group of volunteer “citizen scientists” to continue monthly measures of water clarity using Secchi disks, and to collect monthly water samples for chlorophyll *a* analysis. These relatively simple measures can be easily obtained by volunteers trained by the Mission-Aransas Reserve. If more resources were available, water samples could also be collected for analysis of inorganic nutrients and total suspended solids. Since seagrass surveys indicate that seagrass distributions are highly variable on a year-to-year basis, we would also recommend annual seagrass surveys, taken during the same month every year, until trends in seagrass distribution become apparent and predictable. We would recommend simplifying these surveys to include only measures of water depth, Secchi depth, percent cover of seagrass and average canopy height. Measures of percent carbon and nitrogen and of stable nitrogen isotopes could be eliminated without loss of important information about seagrass trends. We would also not recommend continuing analysis of microplankton populations, unless there are indications of issues with harmful algal blooms in Little Bay in the future.

The core issue in Little Bay seems to be reduced water clarity. Restoration efforts that may improve water clarity would include engineering solutions that improved water circulation between Little Bay and adjacent Aransas Bay, and establishment of oyster reefs within Little Bay. Increased oyster populations will feed on the abundant phytoplankton (chlorophyll *a*) in Little Bay and trap other fine suspended solids. Depending on their location, they could also reduce the re-suspension of sediments.

REFERENCES

- Bruesewitz D.A., W.S. Gardner, R.F. Mooney, L. Pollard, and E.J. Buskey. 2013. **Estuarine ecosystem function response to flood and drought in a shallow, semiarid estuary: Nitrogen cycling and ecosystem metabolism.** *Limnology and Oceanography* 58(6): 2293-2309.
- Dean, B. and E.J. Buskey. 2011. **Little Bay Water Quality Characterization Final Report.** CBBEP Contract Number 0922.
- Dunton, K.H. and C.J. Wilson. 2010. **An assessment of Little Bay Sediment and Water Quality in Relation to Indices of Seagrass Condition.** University of Texas Marine Science Institute Technical Report Number TR/10-001.
- Gill, M., K. Jackson, S. Morehead, and K. Dunton. 2007. **Little Bay Project Summary.** University of Texas Marine Science Institute unpublished report. 30 July 2007.
- Mooney, R.F. and J.W. McClelland. 2012. **Watershed Export Events and Ecosystem Responses in the Mission–Aransas National Estuarine Research Reserve, South Texas.** *Estuaries and Coasts* (2012) 35:1468–1485. DOI 10.1007/s12237-012-9537-4
- Smayda, T. J. 1983. **The phytoplankton of estuaries.** *In:* B. H. Ketchum (ed.). *Ecosystems of the World* 26: Estuaries and enclosed seas. Elsevier, New York, NY.

APPENDIX A: WATER QUALITY INDICATORS

Positive: Parameter indicates generally good or improving conditions relative to Aransas Bay.

Cautionary: Parameter indicates potentially deteriorating conditions relative to Aransas Bay; however, additional information or data are needed to fully assess the indicators response.

Negative: Parameter indicates poor or deteriorating conditions relative to Aransas Bay.

TEMPERATURE

Water temperature is an important indicator of the health of estuarine systems because of the direct relationship between water temperature and oxygen. As water temperature increases, the amount of oxygen that can be dissolved in the water decreases. Additionally, all plants and animals have a range of temperatures in which they thrive. Therefore, temperature determines what types of plants and animals are able to survive in the estuary. If the water in the estuary is outside the normal seasonal temperature range for which local organisms are adapted, it is most likely an indication that something is adversely affecting the health of the estuary. As a result, seasonal water temperature is an important indicator of habitat quality for many estuarine species.

SALINITY

Salinity refers to the amount of dissolved salts in seawater. Salinity levels in an estuary vary daily, seasonally, geographically, and with tidal cycles. Salinity levels in estuaries can rise on hot sunny days when evaporation removes fresh water and leaves behind the salt. Conversely, salinity is reduced by large amounts of rain and increasing freshwater inputs from rivers and creeks. Salinity gradients exist throughout an estuary, from the river mouth to the open ocean. Salinity levels are generally highest near the area where saltier water enters, and lowest upstream where freshwater flows into the estuary. Since salinity has major effects on physiological processes, salinity levels greatly influence the species of plants and animals that inhabit an area.

DISSOLVED OXYGEN

Dissolved oxygen (DO) refers to the oxygen that is available to aquatic organisms for respiration. Oxygen enters the water through two natural processes: diffusion from the atmosphere and photosynthesis by aquatic plants. The mixing of surface waters by wind and waves increases the rate at which oxygen from the air can be mixed into the water. Oxygen concentrations in estuarine waters undergo both daily and seasonal fluctuations due to changes in the tides, temperature, and plant photosynthesis. Oxygen levels typically peak during the daylight hours as plants are photosynthesizing and decrease at night when photosynthesis ceases and both plants and animals consume oxygen through respiration. Very high levels of DO, or supersaturation, can actually be harmful, causing capillaries in fish gills to rupture or tear. Low levels of DO are an even greater concern in estuaries when they create a condition known as hypoxia. Hypoxic conditions tend to support a lower diversity of species. Therefore, proper DO levels are critical to maintaining estuarine health.

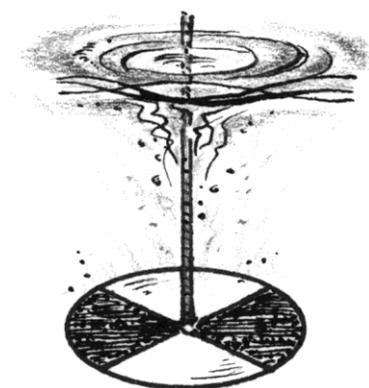
TURBIDITY

Turbidity is a reduction in the clarity of water due to the presence of particles suspended in the water column. Sediments, such as silt and clay, are generally transported into the estuary by river systems and

are responsible for high turbidity conditions, although phytoplankton or other organic material can also contribute significantly to turbidity. High turbidity limits the amount of light that can penetrate through the water, which can influence the vertical distribution and productivity of phytoplankton, seagrasses, and large algae (or macroalgae). This, in turn, affects other organisms that depend on these plants for food and oxygen. Scientists often consider turbidity of the water in connection with other factors to get a better understanding of its causes and consequences. For example, high levels of turbidity can indicate problems with shoreline erosion, or malfunctioning sewage treatment facilities.

SECCHI DISK DEPTH

The Secchi disk is a round disk, usually 20 centimeter in diameter with alternating quarters colored black and white (Figure 15), that is used to measure water clarity or turbidity. The disk is lowered into the water until it is no longer visible and the depth is used as a measure of transparency of the water.



secchi disk

Figure 15. Pictured is a drawing of a Secchi disk in the water. Drawing from <http://clean-water.uwex.edu/>.

CHLOROPHYLL A

Chlorophyll is a green-colored pigment that plants use to make their own food using the sun's energy and nutrients in a process known as photosynthesis. In the ocean and estuaries, microscopic plants, known as phytoplankton, are suspended in the water column and use chlorophyll to photosynthesize. By measuring the amount of chlorophyll in an estuary, scientists can quantify the levels of phytoplankton and estimate the photosynthetic activity in the water. Chlorophyll levels can vary seasonally, with higher levels measure in the sunny, summer months when phytoplankton are actively photosynthesizing. However, high chlorophyll levels can also indicate high levels of storm water runoff or other sources of excess nutrients entering the estuary. After a heavy rain, nutrient-loaded runoff from roads, farms, building sites, and poorly designed sewage treatment systems can enter the estuary and cause phytoplankton blooms, which ultimately can lead to depleted dissolved oxygen levels and even fish kills. Thus, chlorophyll measurement can be utilized as an indirect indicator of nutrient levels.

NITRATE

Nitrate and nitrite are the other two forms of naturally-occurring nitrogen found in water. In this report, the concentrations of nitrate and nitrite are combined and reported as nitrate because the concentrations

of nitrite are very small. (Nitrites are formed when ammonium is converted to nitrate through oxygenation.) Nitrogen is an essential nutrient for plant growth, but excessive amounts of nitrogen can cause algal blooms, which may lead to low dissolved oxygen levels. Nitrogen can enter the bay through several sources, such as phytoplankton decomposition, rain, fertilizer run-off, and wastewater treatment plant effluent. High nitrate levels in combination with high phosphate levels are largely responsible for eutrophication or algal blooms.

AMMONIUM

Ammonium is one of the three forms of naturally-occurring nitrogen found in water. Nitrogen is formed when organic matter, such as plants, decomposes. Nitrogen is an essential nutrient for plant growth, but excessive amounts of nitrogen can cause algal blooms, which may lead to low dissolved oxygen levels. Nitrogen can enter the bay through several sources, including phytoplankton decomposition, rain, fertilizer run-off, and wastewater treatment plant effluent. Ammonium is the form of nitrogen that is the easiest for plants and phytoplankton to use.

PHOSPHATE

In nature, phosphorus usually exists as part of a phosphate molecule (PO_4^{3-}). There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations. Phosphorus is a chemical that naturally attaches to sediment particles, and often, excess phosphorus and sediment pollution are linked. Phosphorus is an essential nutrient for plant and algae growth, but too much phosphorus can lead to algal blooms. Phosphorus can get into the bay through sources such as fertilizers and waste water effluent.

SILICATE

“Silicate” is a generic term for compounds that contain silicon, oxygen, and one or more metals. Silicate is common in water and is produced primarily from the weathering of silicate minerals. Silicate-based clays can cause higher turbidity levels and high presence of silicate in the water can create a milky appearance. Excess silicate in the water causes no harmful human health effects. Unlike the other major nutrients (phosphate, nitrate, or ammonium) that are needed by almost all plankton, silicate is an essential chemical requirement for very specific types of plankton, such as diatoms, radiolarians, and siliceous sponges. These organisms extract dissolved silicate from the water in order to produce hard skeletal structures. Once the plankton have perished, the skeletal material dissolves and as it settles through the water column, it enriches the waters with dissolved silica.