Pensacola and Perdido Bays Estuary Program Community Grant: Zooplankton Ecology and Water Quality Monitoring of Perdido Bay

Final Report

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Introduction

Zooplankton include microscopic organisms and the immature planktonic stages of larger organisms that are found in the water column and drift with water currents and tides. Zooplankton may feed on phytoplankton or other smaller zooplankton while serving as a food source for larger aquatic organisms. They are highly sensitive to their environment and impacts to that environment can be reflected in their populations, size, and community composition. Therefore, zooplankton are useful bioindicators of water quality and ecosystem health.

During stakeholder engagements (workshops and presentations), members of the community and local community science groups voiced concerns that the water quality within Perdido Bay is toxic to planktonic life. They had observed a decline in encrusting organisms and bivalves, many of which have a planktonic larval stage that would be susceptible to unfavorable water conditions. This stage is also easily captured and identified in zooplankton studies.

This project examined the zooplankton community and water quality parameters across Perdido Bay and its tributaries. This data will be useful to investigate and address stakeholder concerns and it has supplemented the long-term Perdido Bay water quality dataset as much of the regular monitoring of this system has not been reinitiated after pausing during the pandemic. This study is also helpful in the context of habit restoration. Current datasets are needed to create suitability models for restoration, especially current datasets that include benthic and water column data in addition to surface measurements. Understanding water clarity, salinity, and oxygen dynamics of the system are critical for assessing the suitability of large-scale habitat restoration such as the oyster restoration efforts currently occurring in the Pensacola Bay system.

Methods

Site Selection and sampling regime

Eighteen sampling sites were selected and included sites that have been monitored by the Bream Fishermen Association (BFA) and/or sampled by the University of West Florida (UWF), or are new sampling locations that were chosen to increase the spatial distribution of the study (Table 1, Figure 1). This sample design was chosen to increase the long-term monitoring dataset by utilizing existing stations, while the new stations allow for targeted sampling of additional areas of concern. In addition to the proposed 18 locations, two additional tributary water quality sites were added (PDO 19 Soldier Creek and PDO 20 Tee Lake). In total, there were 9 tributary/bayou sites, 5 open-water sites in the upper bay (north of the Lillian Bridge), and 6 sites in the middle bay segment (north of Innerarity Point and south of the Lillian Bridge).

Stations were sampled monthly from October 2022-April 2023 (funded by PPBEP) and monthly sampling was extended to include May-September 2023. This additional sampling was funded by UWF. Each monthly field collection typically took 2-3 full days to complete. This report contains water quality data for the extended sampling period and zooplankton community data for the PPBEP community grant period.

Table 1. Sampling locations.

Station ID	Description	Historical Sampling ID	Latitude	Longitude	Location
PDO1	Perdido River	UWF PER 1	30.461	-87.420	Tributary/Bayou
PDO2	Perdido River mouth	UWF PER 2; BFA 33010006	30.450	-87.389	Upper
PDO3	Perdido Bay at mouth of Eleven Mile Creek	UWF PER 7; BFA 330100A3	30.456	-87.376	Upper
PDO4	Eleven Mile Creek at Hwy 90 Bridge	BFA 33010013	30.497	-87.335	Tributary/Bayou
PDO5	Marcus Bayou at Blue Angel Pkwy	BFA 33010036	30.434	-87.324	Tributary/Bayou
PDO6	Perdido Bay off Millview	UWF PER 8; BFA 330100C6	30.425	-87.367	Upper
PDO7	Herron Bayou	UWF PER Herron Bayou	30.403	-87.375	Tributary/Bayou
PDO8	Manuel Bayou at Hwy 99 Bridge		30.361	-87.468	Tributary/Bayou
PDO9	Tarkiln Bay		30.351	-87.420	Middle
PDO10	Weekly Bayou Creek Bridge at 293/Bauer Rd	UWF PER Weekly Bayou; BFA 33010082	30.352	-87.403	Tributary/Bayou
PDO11	Bayou Garcon		30.322	-87.434	Tributary/Bayou
PDO12	Perdido Bay Innerarity	UWF PER 6; BFA 33010000	30.329	-87.491	Middle
PDO13	Perdido Bay at Arnica Bay mouth		30.316	-87.517	Middle
PDO14	Perdido Bay at Solider Creek mouth		30.335	-87.498	Middle
PDO15	Perdido Bay off Dupont Point	UWF PER5; BFA 33010D16	30.366	-87.451	Middle
PDO16	Perdido Bay off Spanish Cove		30.387	-87.450	Middle
PDO17	Perdido Bay at Lillian Bridge	UWF PER4; BFA 330100D3	30.404	-87.432	Upper
PDO18	Perdido Bay off Grassy Point	UWF PER 3	30.420	-87.403	Upper
PDO19	Soldier Creek		30.358	-87.497	Tributary/Bayou
PDO20	Tee Lake		30.457	-87.386	Tributary/Bayou

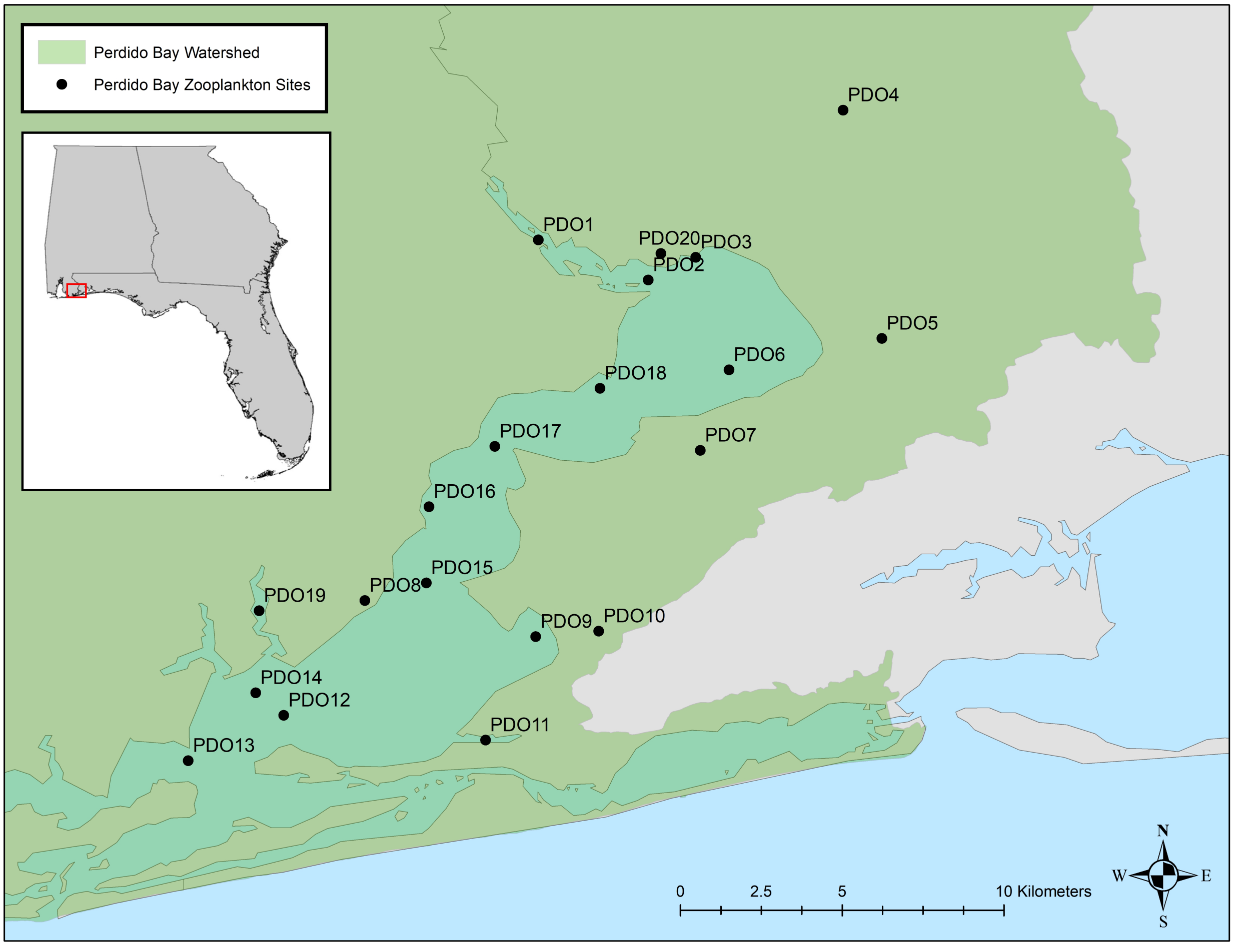


Figure 1. Sampling location map.

Field Collection

At each sampling location, profiles of ambient water condition (temperature, salinity, conductivity, dissolved oxygen, pH, and turbidity) were taken first at the surface and then in 1 m intervals until reaching the bottom. Water clarity was measured with a Secchi disk.

A surface grab sample was collected at each site and a bottom (~0.25 m above sediment) was taken with a van Dorn at sites where depth was ≥2 m. Whole water samples were collected for analysis of total suspended solids (TSS), total Kjeldhal nitrogen (TKN), and total phosphorus (TP). A volume of 60 ml of whole water was filtered through a GF/F filter. The filter was retained for chlorophyll-a analysis and the filtered water was collected for dissolved nutrient and color analysis. All samples were preserved on ice and taken to UWF. Samples were stored either refrigerated (TSS, TKN, and TP) or frozen (dissolved nutrients, chlorophyll-a, and color) until processed.

An integrated pole was used to sample the top 1 m of the water column (or entire water column if depth was ≤1 m) for zooplankton community composition. Bottom samples were taken using a van Dorn at sites with a depth ≥2 m. For each depth a total of 4 L of whole water was collected and preserved with Lugol's iodine solution. Samples were stored in the dark until they were processed.

Lab Processing

TKN and TP were analyzed by the UWF Wetlands Research Laboratory. TSS, ammonium, nitrate+nitrite, chlorophyll-a, and color were analyzed by Dr. Jane Caffrey's lab (Table 2). DIN was calculated (DIN = nitrate + nitrite + ammonium). Differences between sites and sampling months were tested with ANOVAs and Tukey post-hoc tests in JMP Pro 16.

Zooplankton whole water samples were filtered through a 41 µm Nitex mesh and concentrated to 20 ml. Subsamples were analyzed on an inverted microscope at 100x magnification. All surface samples and bottom samples where the difference between surface and bottom depth was greater than 1 m and stratification was indicated by water chemistry (salinity or dissolved oxygen) were analyzed. Species were identified to the lowest possible taxa and categorized into larger taxonomic groups. Abundances (number/L) were calculated based on organism counts, subsample volume, and total filtered volume.

Table 2. Water Quality Analysis Standard Methods used by Caffrey Lab.

Parameter	Reference
TSS	EPA method 160.2
Color	Florida Lakewatch SOP
NO3+NO2	Schnetger and Lehners 2014
NO2	Schnetger and Lehners 2014
DIP	Parsons et al. 1984
NH4+	Holmes et al. 1999
Chl a	Welshmeyer 1984

Results

Ambient Water Conditions

Water temperature ranged from 12-34.8 C over the study period (Figure 2). Differences observed were due to sampling month ($p<0.0001$) and not sampling location ($p=0.9810$). August was the warmest month sampled (mean 31.8 C) and November, January and February were the coldest (mean 16.2, 16.9, and 17.4 C, respectively).

The observed salinity range was 0.02-36.28 (PSU) (Figure 3). It varied by both station ($p<0.0001$) and month ($p<0.0001$). As expected, bottom measurements were generally higher than surface measurements, but stratification was frequently observed at deeper locations (e.g., PDO 1, PDO 17). Salinity generally declined across the sampling period, with highest salinity values observed in fall and lowest in summer.

Dissolved oxygen ranged from 0.12-11.19 mg/L (Figure 4). It varied by both station ($p<0.0001$) and month ($p<0.0001$). Lower oxygen concentrations were observed in bottom samples and PDO 10 frequently had very low dissolved oxygen. Temporal patterns in observed dissolved oxygen generally followed expected seasonal trends, with the lowest values in the summer and the highest values in the winter.

Generally, pH was stable across the study, although differences were observed related to location ($p<0.0001$) and month ($p<0.0001$). Higher pH values were observed in the middle and upper bay compared to the tributary/bayou locations (Figure 5). Lower pH values were recorded at PDO 10. June and July had significantly lower pH than the rest of the study period.

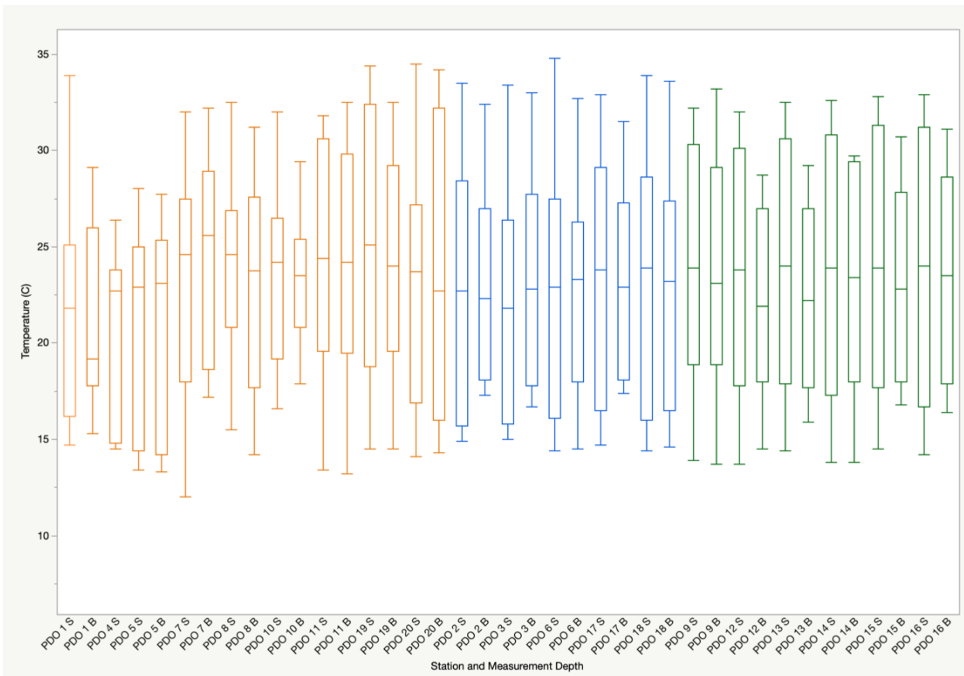


Figure 2. Temperature (C) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

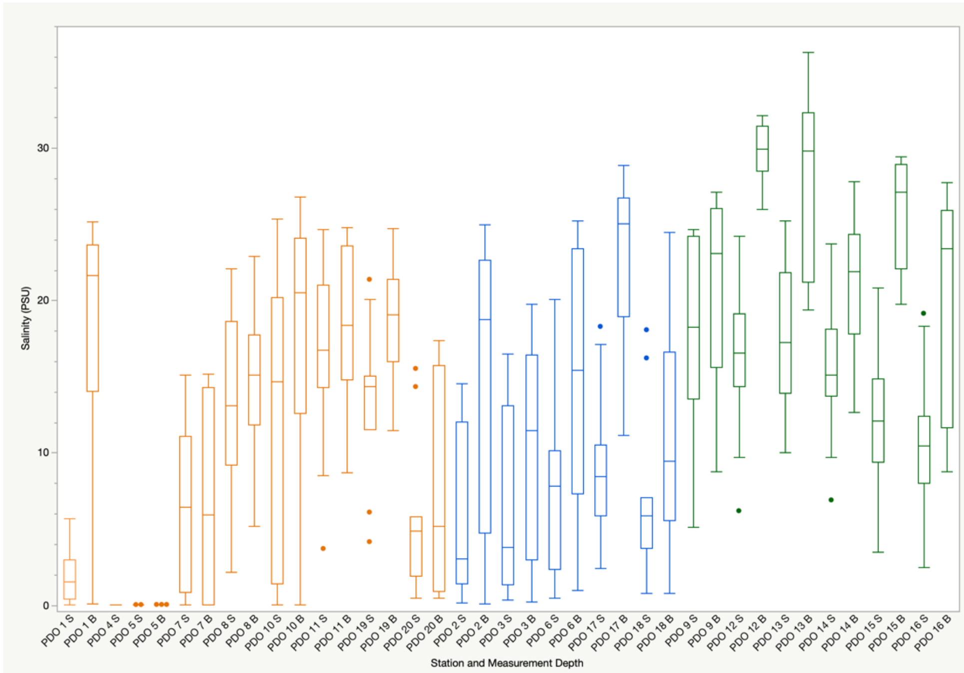


Figure 3. Salinity (PSU) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

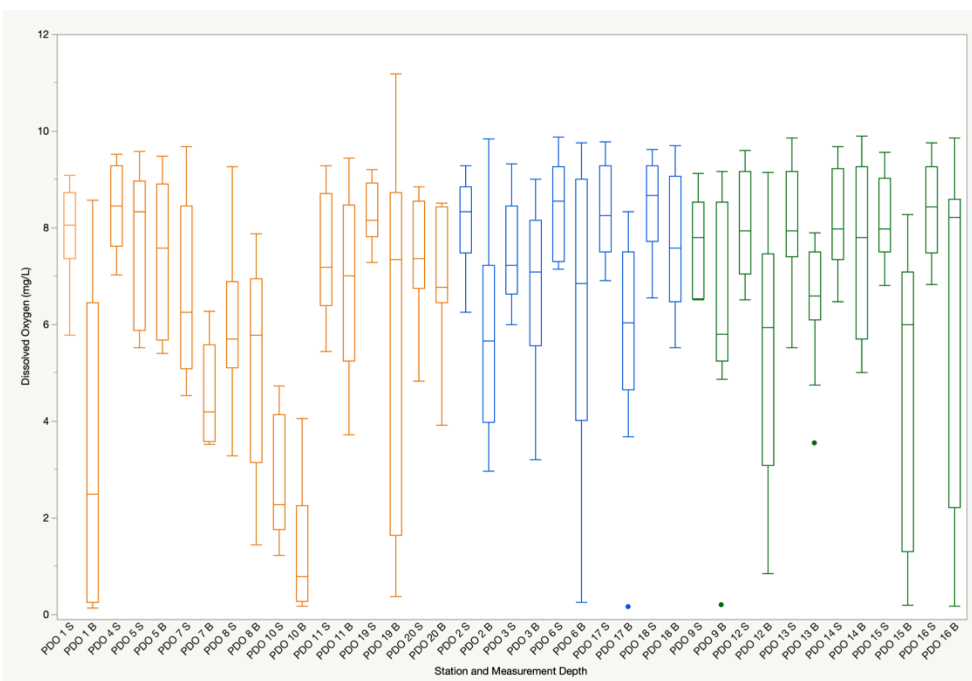


Figure 4. Dissolved oxygen (mg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

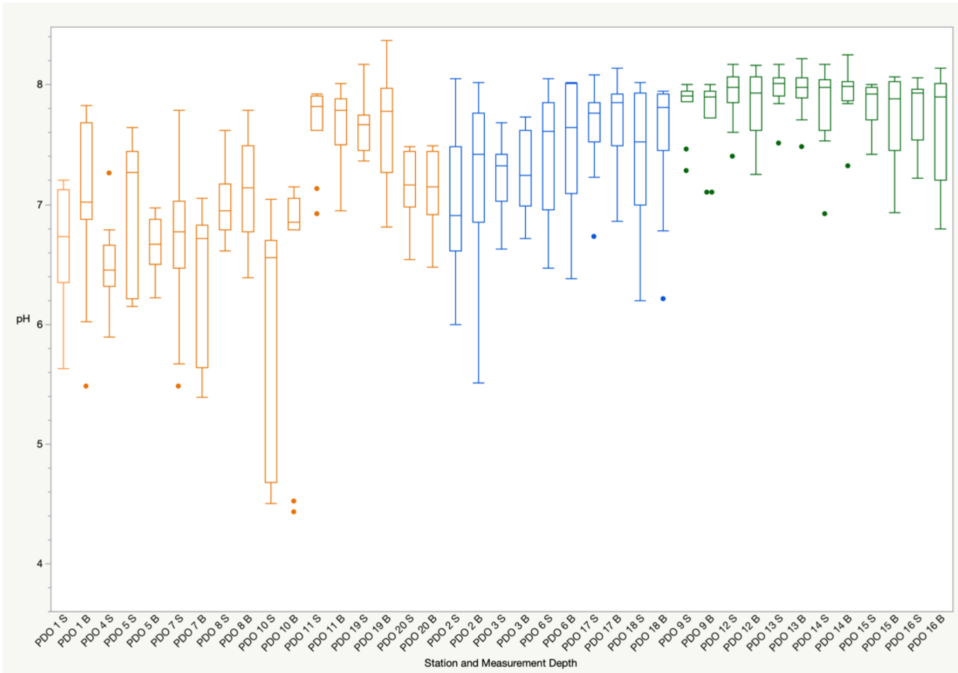


Figure 5. pH for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

Nutrients and Chlorophyll-a

Nitrogen concentration as measured by TKN (Figure 6) and DIN (nitrate + nitrite + ammonium) (Figure 7) was variable across the study area, but generally higher in tributary and upper bay sites and decreased with salinity. There were differences in both measurements over time (note TKN was only sampled during the PPBEP community grant period, October 22 – April 23), with the greatest differences generally observed between winter and spring.

Phosphorus varied over time ($p<0.0001$ for both TP and DIP) but there were no clear spatial trends. August had the highest observed DIP values (25. 4 µg/L) followed by January (7.8 µg/L) with all other months ranging on average between 1.6 and 4.0 µg/L. TP, which was only sampled during the PPBEP community grant period (October 22 – April 23), had a narrower range (103.8-116.2 µg/L), with highest concentrations occurring in October and March-April.

Chlorophyll-a varied by site ($p<0.0001$) with the highest average values (mean > 7 µg/L) occurring in Soldier Creek (PDO 19), and sites in the upper bay (PDO 2, PDO 6, PDO 18, PDO 17). The lowest chlorophyll values (mean <4 µg/L) were measured at many of the tributary and bayou locations (PDO 4, PDO 5, PDO 7, PDO 8, and PDO 11). Chlorophyll generally followed seasonal patterns with the highest values recorded during the summer.

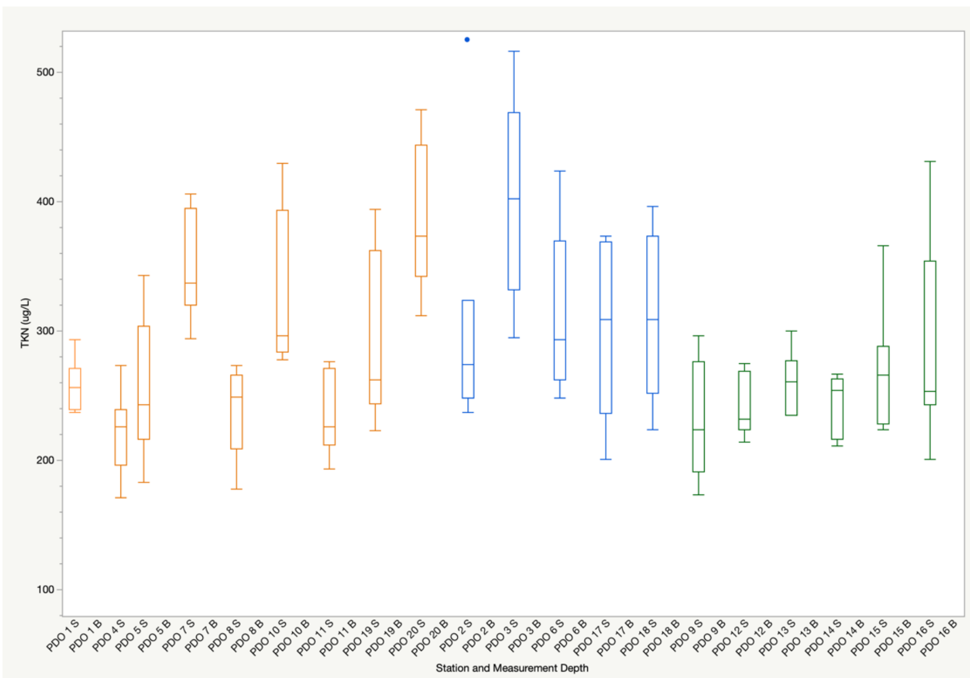


Figure 6. Surface total Kjeldhal nitrogen (TKN) (µg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). Samples collected October 2022-April 2023.

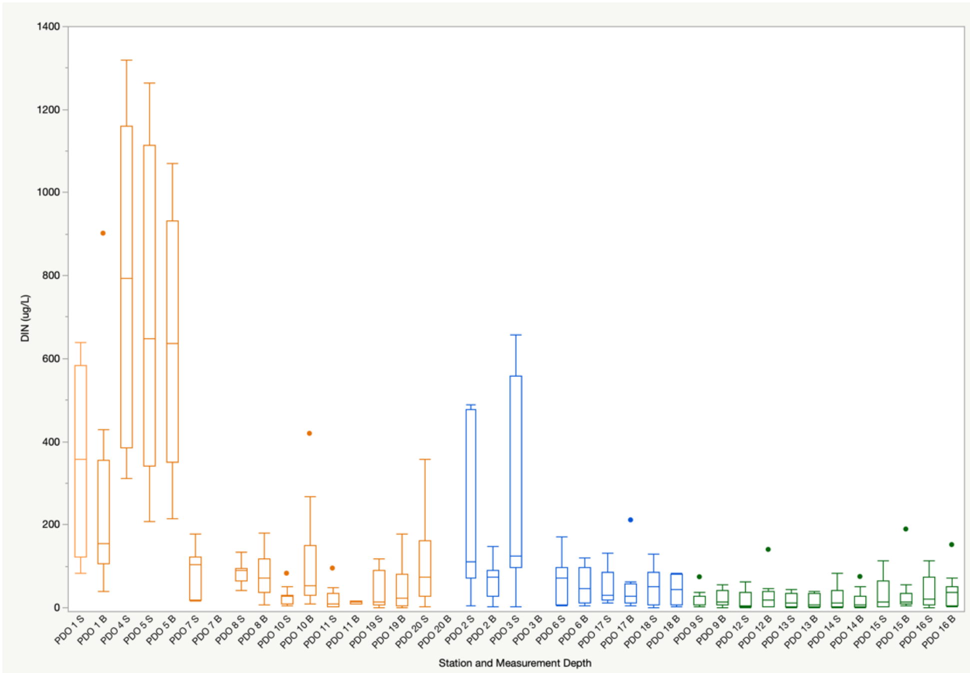


Figure 7. Dissolved inorganic nitrogen (DIN) (µg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

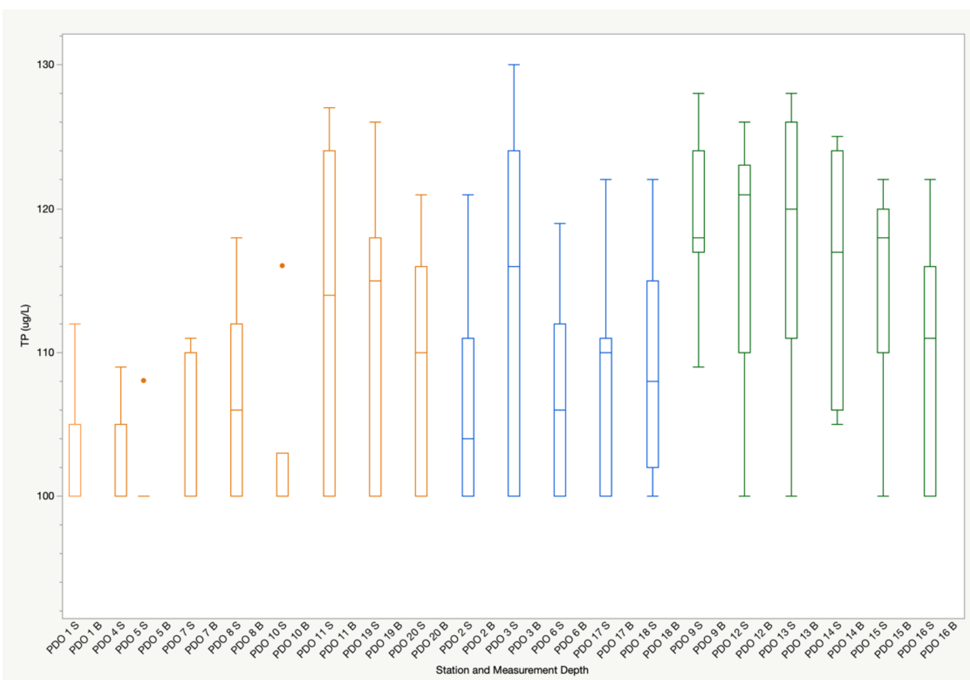


Figure 8. Surface total phosphorus (TP) (µg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). Samples collected October 2022-April 2023.

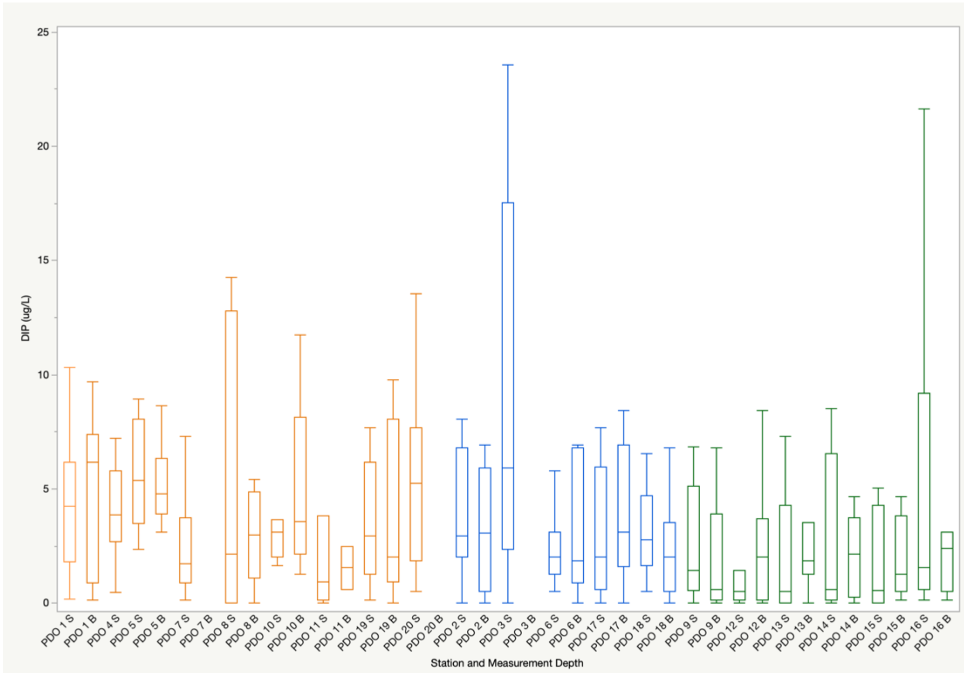


Figure 9. Dissolved inorganic phosphorus (DIP) (µg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

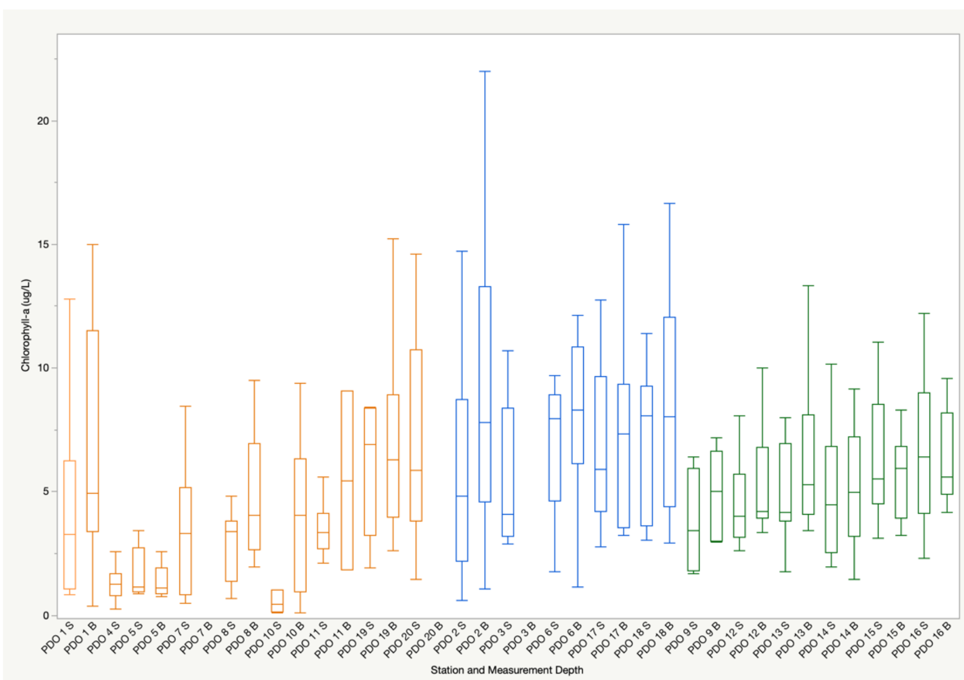


Figure 10. Chlorophyll-a (µg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

Water Clarity

Secchi disk readings were taken in the field as a measure of water clarity. One site, Eleven Mile Creek (PDO 4) was visible on bottom (VOB) 100% of the time. Several sites (PDO 7 and PDO 20) were often VOB. Station depth is an important factor and shallow sites were most likely to have VOB readings, although this was not true in all shallow locations for all sampling events. Secchi depth for all non-VOB measurements ranged from 0.5-3 m. Generally, Secchi disk measurements were higher (greater clarity) at middle bay locations.

Turbidity was variable but generally higher on bottom with respect to surface values at the same location (Figure 11). Turbidity varied by location ($p<0.0001$) with turbidity generally decreasing from north to south along the estuarine gradient. Turbidity also varied over time with higher values occurring in spring and summer and the lowest values occurring in the winter.

TSS roughly followed the same patterns observed in turbidity (Figure 12), with bottom samples having greater concentrations than surface samples and increasing in the late spring and summer. However spatial trends were less apparent.

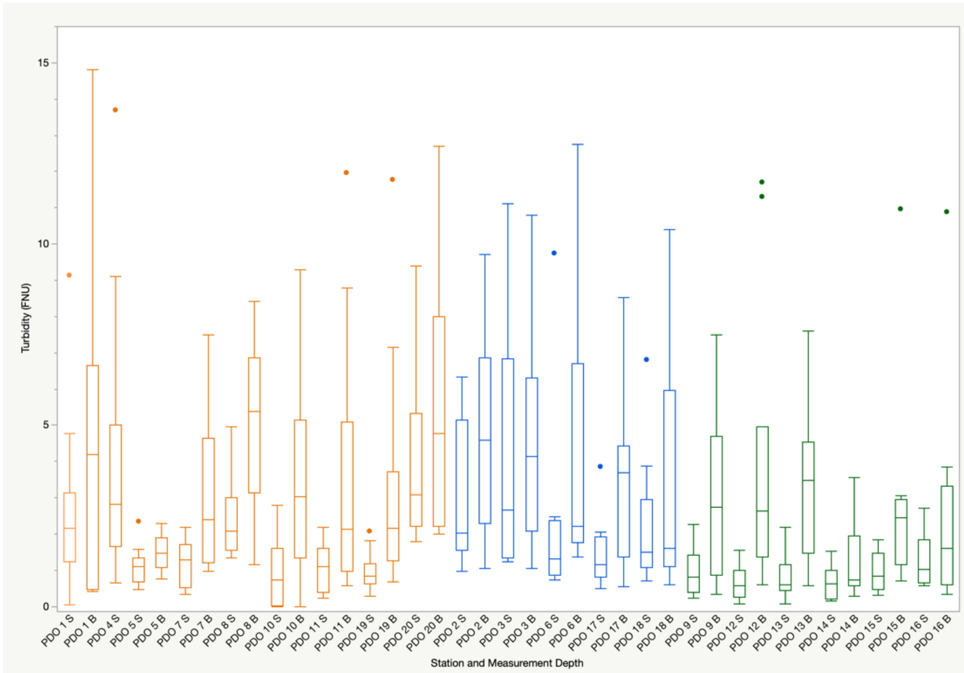


Figure 11. Turbidity (FNU) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-August 2023.

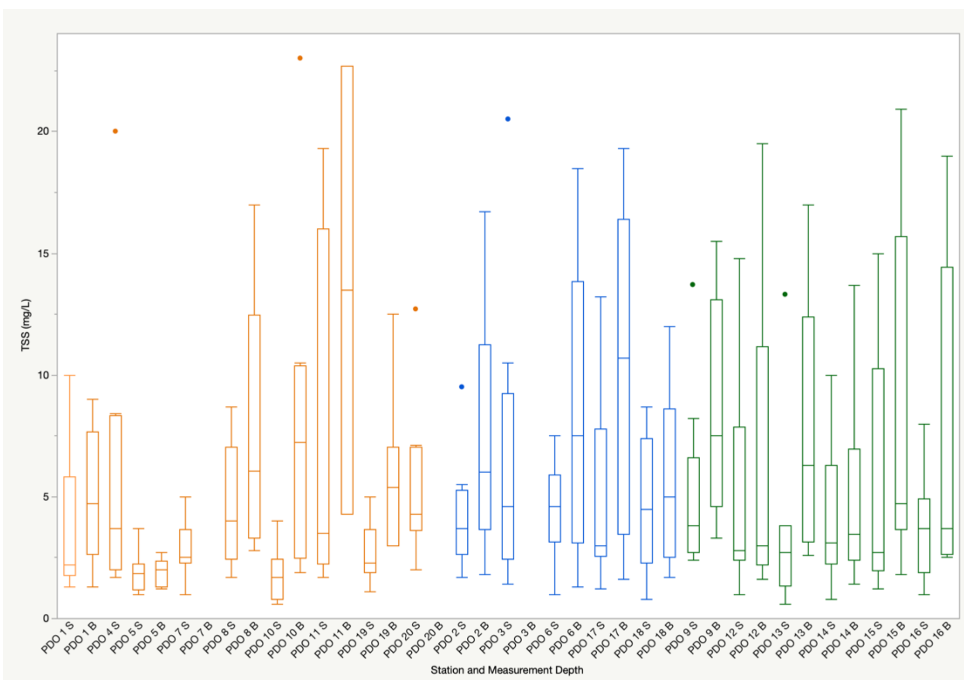


Figure 12. Total suspended solids (TSS) (mg/L) for tributary and bayou sites (orange), open-water upper bay sites (blue), and open-water middle bay sites (green). S indicates a surface measurement and B indicates a bottom measurement. Samples collected October 2022-June 2023.

Zooplankton

Zooplankton community composition was analyzed for all 18 surface samples. Dinoflagellates that were large enough to be retained in the filtering process were also included in zooplankton analysis (e.g., *Ceratium hircus, Ceratium tripos, and Dinophysis caudata)*. These taxa were often numerically abundant in open-water bay locations.

With some exceptions for short-term population increases in specific groups such as tintinnids or dinoflagellates, tributary and bayou stations tended to have lower abundances than open-water locations. Higher salinity locations generally had higher abundances than lower salinity locations (Figure 13). Overall, there were more taxonomic groups observed as salinity increased (Figure 14), but taxa within a specific group (e.g., rotifers) did not always follow this pattern. While rotifers were found at all locations, species diversity was higher in freshwater locations, which is typical of their species distributions across salinity gradients. Copepods were also found across the study area, and while overall abundance generally increased with salinity, species composition was reflective of the salinity tolerances of individual species.

Key taxa of interest to Perdido residents (e.g., bivalves, gastropods, and barnacles) were found at most locations sampled. Abundances increased with salinity and were also seasonal, with higher numbers occurring in the fall and then increasing again in the spring. It is important to note that during the planktonic stage, bivalves and gastropods cannot be reliably differentiated to lower taxonomic classifications (i.e., family, genus, or species). However, in some of the upper bay and tributary locations, at least some bivalve larvae had started to develop bissell threads. This indicates that at least in these instances, they were likely mussel (Mytilidae) and not oyster (Ostreidae) or infaunal clam (e.g., *Rangia*) larvae.

Community composition largely followed expected salinity gradients with rotifers representing a much higher percentage of the community in lower salinity sites (Figure 14). Cladocerans were more frequently observed in bay sites than the more freshwater tributary sites. The observed cladocerans were most often estuarine species. The lack of freshwater cladoceran species may be related to water velocity and the flashiness (pulses of high water volume and velocity) of some of the tributary creeks (e.g., PDO 4) and salinity of others (e.g., PDO 8 and PDO 19).

Across time, relative contribution of taxa to the overall community composition varied (Figures 15-17). For example, polychaetes were present across the study area and timeframe but comprised a higher percentage of the community in the fall and in the upper bay locations.

Bottom samples were analyzed for stations with a difference in sample depth greater than 1 m and whose ambient water parameters indicated stratification. Under similar water conditions with mixing, the zooplankton community should exhibit typical depth distributions and migrations. Where there is significant stratification and differences in water conditions, a layering of different zooplankton communities with respect to depth may be observed. Over the course of the study only one location, PDO 1, consistently met those criteria. Total observed abundances were higher in bottom samples than surface samples (Figure 18a). This was true for all taxa, but it was especially apparent for dinoflagellates (68.7 individuals/L compared to 5810.6 individuals/L). Rotifers and copepods had lower abundances in surface samples, but composed a higher percentage of the community composition when compared to bottom samples (Figure 18b).

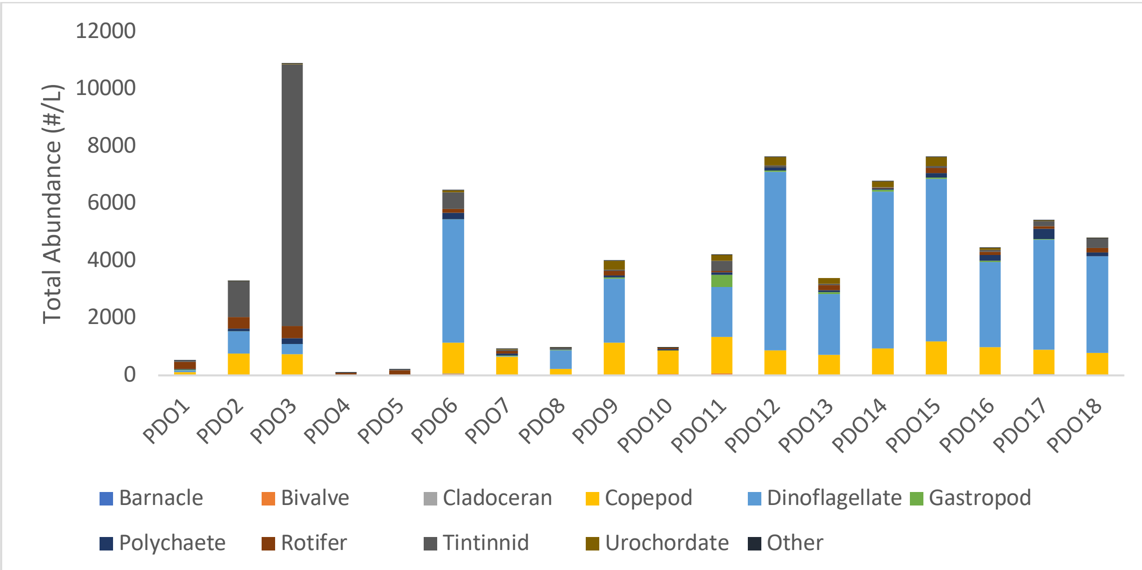


Figure 13. Total abundance of surface zooplankton by location, October 2022-April 2023.

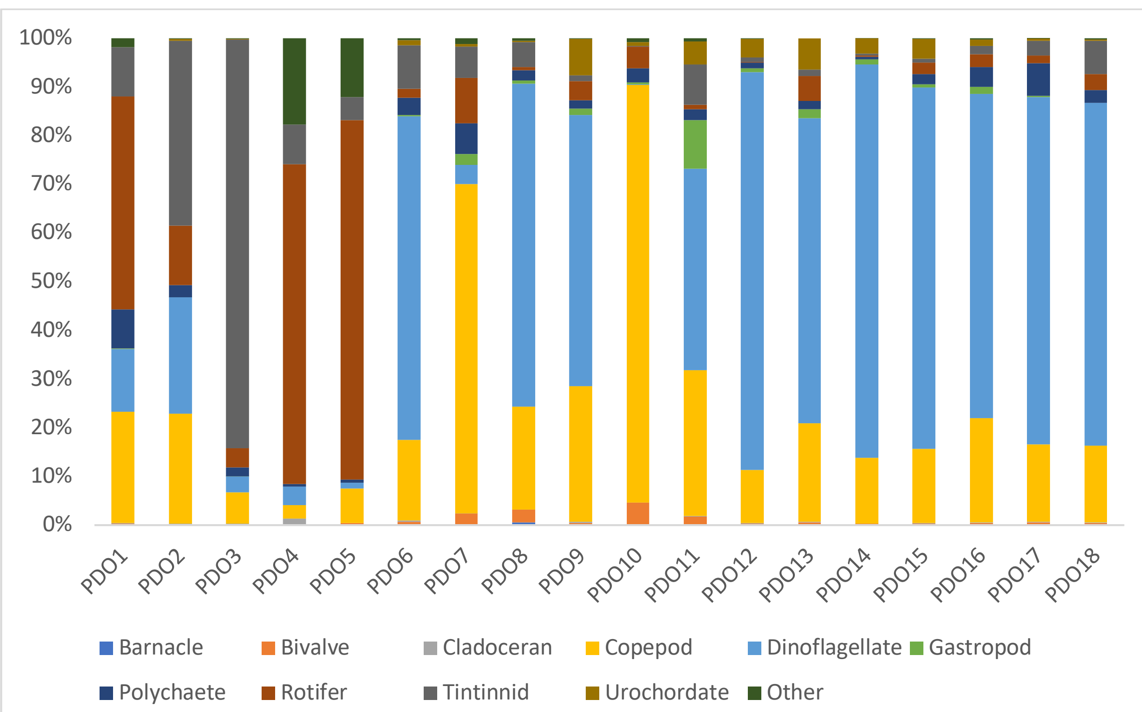


Figure 14. Community composition (%) of surface zooplankton by location, October 2022-April 2023.

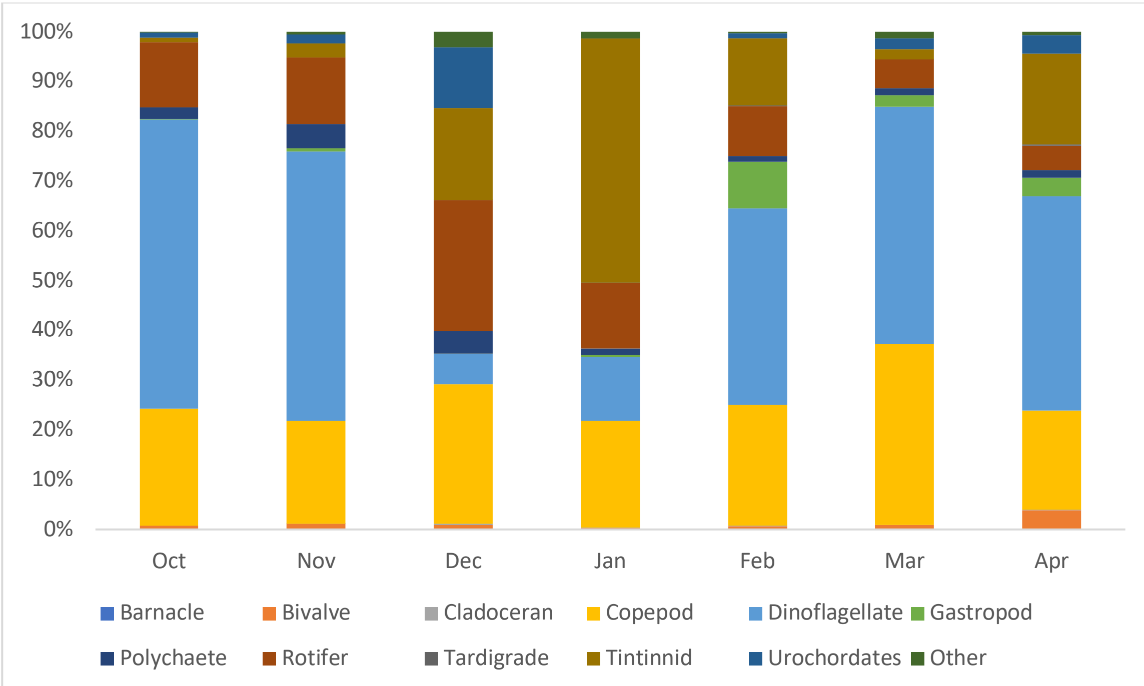


Figure 15. Monthly community composition (%) of surface zooplankton at tributary and bayou stations over the study period, October 2022-April 2023.

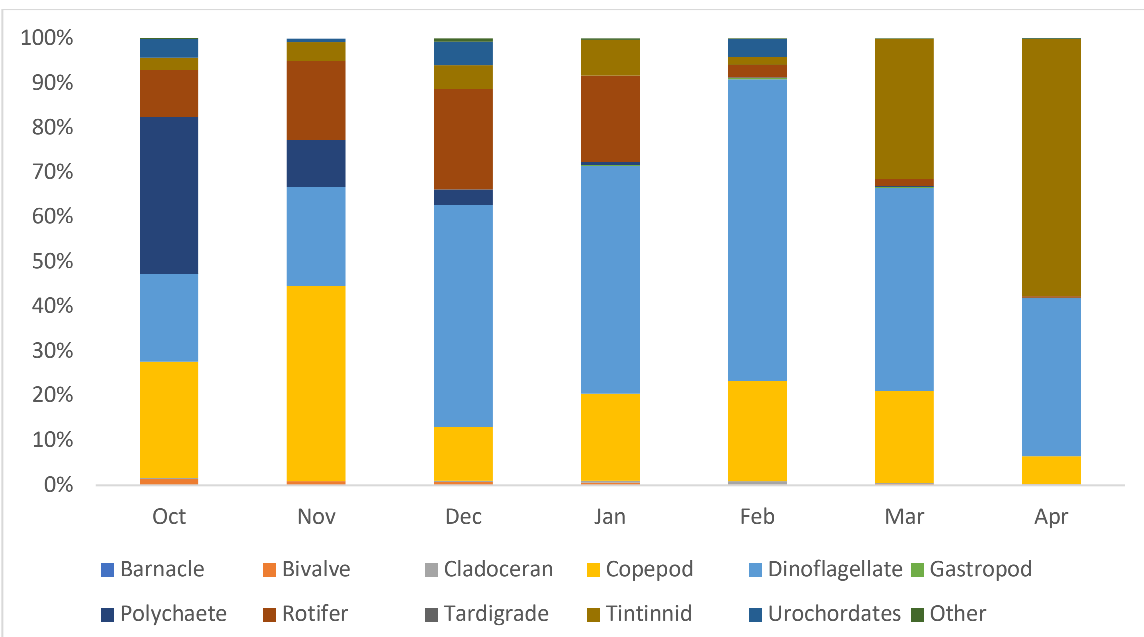


Figure 16. Monthly community composition (%) of surface zooplankton at open-water upper bay stations over the study period, October 2022-April 2023.

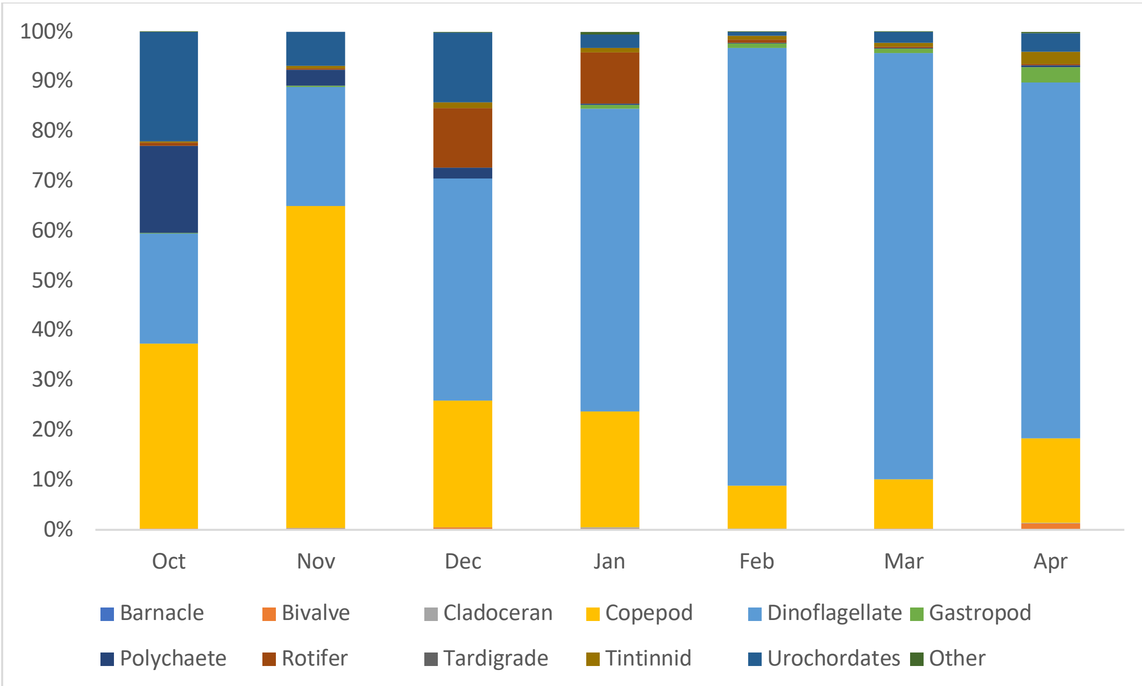
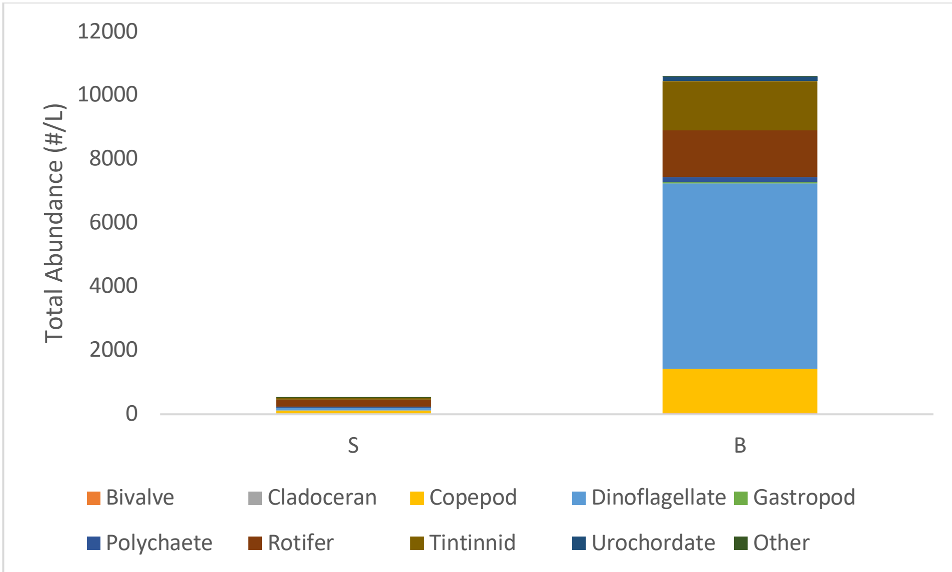
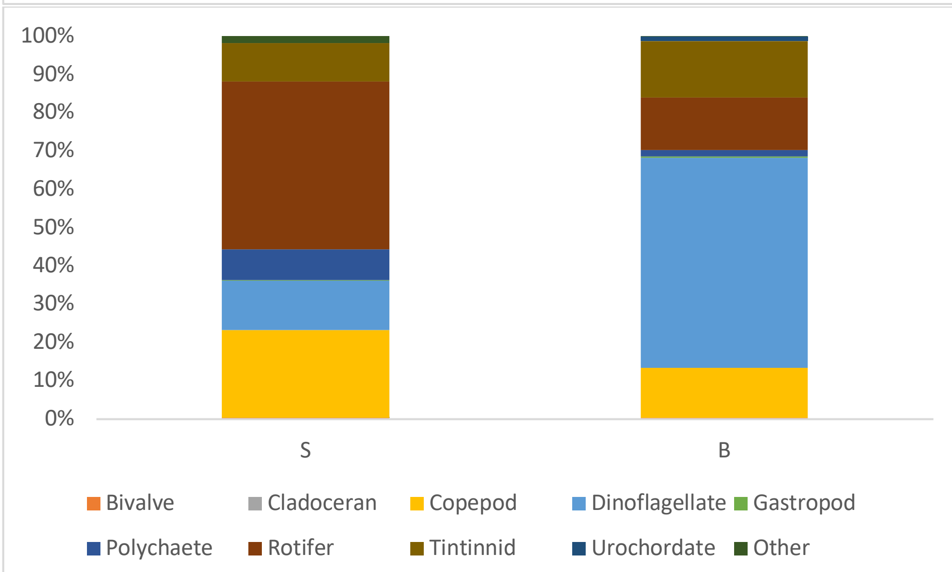


Figure 17. Monthly community composition (%) of surface zooplankton at open-water upper middle stations over the study period, October 2022-April 2023.



a.)



b.)

Figure 18. Surface and bottom zooplankton abundance (a) and community composition (b) for PDO 1, October 2022-April 2023.

Conclusions

Generally, water parameters followed expected trends based on typical estuarine gradients. With the exception of PDO 10 (Weekley Bayou Creek), all sampling locations had parameters that would support a typical zooplankton assemblage based on location within the estuarine gradient. Dissolved oxygen was at times quite low at this location. The pH was also approaching acidic conditions that could be harmful to estuarine organisms. Tarkiln Bayou (PDO 9), which is just outside the mouth of Weekley Bayou, did not display these same potential impairment concerns (low dissolved oxygen and pH). Despite, these less than ideal conditions, representatives of most of the common taxa observed throughout the study were detected at PDO 10.

A typical estuarine assemblage of zooplankton, which included larval bivalves, barnacles, and urochordates was observed and generally followed expected trends in taxonomic composition based on environmental conditions (e.g., flow, salinity, etc.) This would indicate that given adequate larval supply and settlement locations, adult encrusting organisms such as barnacles, mussels, and oysters, should be able to sustain populations in Perdido Bay in accordance with the estuarine gradient. The data on water parameters and zooplankton distribution can be utilized to better target areas that may support successful oyster and other restoration activities. The presence of zooplankton throughout the system in moderately high abundances, is indicative of a strong food chain base capable of supporting larger organisms, such as various fish species. Lower zooplankton abundances were detected in some upper bayou sites and creeks sites, however, in these areas that may experience considerable flow and pulses of freshwater, there is often a greater reliance on small ciliates, terrestrial food sources (such terrestrial insects), and benthic microorganisms (such as aquatic mites, aquatic insects, and vegetation associated cladocerans and copepods) to form the base of the food chain for larger organisms.

While the information in this study is informative and does fill some gaps in a data poor system, one year of sampling does not replace the need for consistent long-term monitoring.

Salinity remained quite high during much of the study period with brackish salinity extending into the upper bay for much of the year, but this snapshot may not be representative of years with greater rainfall. And the impacts of these higher or more frequent precipitation events will need to be understood to accurately assess areas that might be candidates for oyster restoration. A longer-term monitoring program is necessary to truly understand water quality and zooplankton dynamics, to assess trends in these parameters, and understand the impact of management actions.