Expansion of Pro-Active Monitoring Capacity for Harmful Algal Blooms

Final Report

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Executive Summary

Harmful algal blooms (HABs) can lead to negative impacts on ecosystems, aquatic life and/or human health. On the Texas coast, rapid population growth is leading to growing prevalence of environmental stressors that may favor marine HABs. Routine monitoring can provide early warning of a HAB and lead to improved understanding of the environmental stressors that favor HABs, but monitoring is limited in Texas. This study established a routine HAB monitoring program in Port Bay and southern Copano Bay and engaged stakeholders for the purpose of sample acquisition and future expansion of a citizen scientist monitoring program. Results demonstrated that the study region had relatively low chlorophyll *a* concentration (an indicator of algal biomass), suggesting that conditions were not favorable at the time for attainment of algal biomass at bloom-levels. Several potential HAB species were documented during the study period but were found in low abundances that posed no obvious risk. It is recommended that additional sampling be conducted during spring and summer and over a multi-year period to fully characterize HAB presence and population dynamics as well as the conditions that influence them. In addition, given the presence of numerous shellfish harvesting beds in the area, a routine but more targeted sampling is recommended for the foreseeable future to mitigate potential risk to humans and the environment.

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Introduction

A harmful algal bloom (HAB) is broadly defined as the proliferation of a phytoplankton species that results in harmful effects on marine life, ecosystems and/or human health. Some HABs produce toxins that can: 1) cause mortality of marine life, 2) bioaccumulate in shellfish and cause negative health impacts in humans upon consumption, and/or 3) become aerosolized and cause negative human health impacts (in the case of the Gulf of Mexico "red tide" dinoflagellate, *Karenia brevis*). Not all HAB species are toxic however, as some cause marine life mortalities through depletion of oxygen in the water column, while others are simply a poor food source for fish and shellfish. Regardless of the mode of harmful action, marine HABs have been responsible for devastating negative impacts on local and regional economies. For example, one study estimated that the annual economic impacts of HABs in the United States was ~$83 million dollars in the year 2000 (~$143 million if estimated for 2022) (Hoagland et al. 2002), while a more recent study estimated that the impacts of a single red tide event that occurred in Florida in 2018 caused $317 million in economic loss to the tourism industry alone (Ferreira et al. 2022).

In the United States, estuarine and marine HAB frequency has increased over the past half century (Hallegraeff 1993; Anderson et al. 2012), attributed to a variety of factors including increased monitoring as well as increasing environmental stressors (Anderson et al. 2008; Heisler et al. 2008). Human activity in coastal watersheds, including land use change favoring urbanized and/or agricultural land cover, is a major driver of the increased nutrient loadings that can create an environment more favorable to HABs (Hopkinson and Vallino 1995; Bowen and Valiela 2001; Kaushal et al. 2008). Warming ocean waters and changing precipitation/hydrology patterns have also been implicated as an emerging driver of HAB formation (Hallegraeff 2010; Najjar et al. 2010; Wells et al. 2015; Tominack et al. 2020).

Negative impacts from several different species of HABs have been documented in Texas' marine waters. *Karenia brevis*, colloquially known as "red tide", produces brevetoxin that causes fish kills, shellfisheries closures, marine mammal and seabird mortality, and respiratory and digestive distress in humans (Kirkpatrick et al. 2004; Brand et al. 2012). A 2000 bloom was estimated to have caused between $22-25 million dollars in economic losses in Galveston County, while a 2011 bloom caused ~$10 million in losses due to oyster harvest closures (Evans and Jones 2001; https://www.fisheries.noaa.gov/west-coast/science-data/hitting-us-where-it-hurts-untold-story-harmful-algal-blooms). Magaña et al. (2003) reported that the frequency of *K. brevis* red tides on the Texas coast increased over the period of 1996-2000 compared to earlier years, and a recent study by Tominack et al. (2021) suggests that bloom frequency in one Texas estuary (Corpus Christi Bay) has indeed increased since the mid-1990's compared to an earlier period going back to the 1950's. Tominack et al. (2020) also found evidence that the increase in bloom frequency was tied to increasing salinity levels. A second HAB species that has had an impact on Texas coastal systems is *Dinophysis cf. ovum* (Campbell et al. 2010). In 2008, a bloom was observed in estuaries of the Texas Coastal Bend for the first time ever (Campbell et al. 2010; Swanson et al. 2010). This organism produces okadaic acid which can cause diarrhetic shellfish poisoning in humans upon consumption of contaminated shellfish. Okadaic acid was detected in relatively high concentrations in the tissue of important shellfish species during the 2008 bloom, leading to the temporary closure of shellfish beds from Corpus Christi Bay to Matagorda Bay (Deeds et al. 2010). Coincidentally, an "unusual" mortality event involving bottlenose dolphins was also noted during the bloom, and okadaic acid was detected in the gastrointestinal system of the dolphins (Fire et al. 2011). Since 2008, there have been several additional blooms that have led to shellfish closures. A third HAB species that is common to the Laguna Madre of Texas is *Aureoumbra lagunensis*, also known as the Texas “brown tide”. *A. lagunensis* is an estuarine-dependent HAB species that first bloomed in Baffin Bay and the Upper Laguna Madre in early 1990. The bloom lasted for 7 years (Buskey et al. 2001), and several additional long-lasting blooms have occurred in these systems since (unpubl. Texas Parks & Wildlife reports; Wetz et al. 2017). *A. lagunensis* does not produce a toxin, but blooms cause seagrass die-off by blocking light penetration to the bottom (Onuf 1996, 2000). Drivers of *A. lagunensis* blooms are complex, resulting from the combined effects of long residence times, high salinity, and excessive nutrient availability in Baffin Bay and Upper Laguna Madre (Buskey et al. 1997; Wetz et al. 2017; Cira and Wetz 2019). Finally, *Pyrodinium bahamense* is a ubiquitous dinoflagellate in many shallow tropical and subtropical marine ecosystems, including estuaries of the Coastal Bend of Texas (M.S. Wetz, unpubl. data). Although most strains are harmless, some strains have been known to produce saxitoxin that is harmful to humans when contaminated fish are ingested (Phlips et al. 2015). To date, there has been no evidence of *P. bahamense*-derived saxitoxin production in Texas. However, a large fish kill occurred in Baffin Bay in 2010 coincident with hypoxia as well as a *P. bahamense* bloom (unpubl. Texas Parks & Wildlife reports). *P. bahamense* has been implicated in low dissolved oxygen events that lead to fish kills elsewhere (e.g., Morrison and Greening 2011), and studies suggest that it is typically most competitive under relatively high nutrient conditions (Phlips et al. 2015) such as in Baffin Bay. Aside from these known bloom-forming taxa, several previously undetected HAB species have also been noted in Texas estuaries over the past decade, suggesting that additional monitoring is warranted.

HABs are a symptom of stressors such as increased nutrient loading and altered hydrology. On the Texas coast, rapid population growth is leading to growing prevalence of the aforementioned stressors that may favor HABs. One of the important lessons learned from stakeholders who have experience with previous HAB events in Texas and elsewhere is that more proactive, sustained HAB monitoring is sorely needed to provide early warning of a HAB to reduce: 1) economic loss to tourism and seafood-reliant industries from real or perceived health risks, 2) adverse human and marine life health impacts, and 3) negative publicity associated with HABs. In addition, monitoring data can lead to improved understanding of the environmental stressors that favor HABs, supporting development of policies and practices aimed at reducing the likelihood of HAB events. The goals of this project were to: 1) increase actionable, real-time estuarine HAB monitoring in southern Copano Bay that is home to Texas' first oyster farm, and 2) engage with relevant stakeholders to increase awareness of HABs and to lay the groundwork for future citizen science-based sampling.

Methods

Study area

Samples for water quality and phytoplankton identification were collected from southern Copano Bay every other week at five locations (Figure 1; Table 1). The sites had a depth ranging from 0.5 m to 2.5 m. Sample sites were reached by foot (CO2, CO3), or by kayak (CO1, CO4). CO1 is located just outside of the canals near a residential area while CO4 is at the mouth of Aransas River, near a highway bridge.

Sampling procedures and analysis

A YSI multiparameter sonde, which was calibrated prior to and after sampling, was used to measure salinity, temperature (ºC), DO (mg/L and %), and pH from just below the surface (0.1

m) at each site. Depth and transparency were measured using a Secchi disk. Whole water samples were collected from 0.1 m depth at each sampling location in amber Nalgene bottles and stored in a cooler filled with ice at 0ºC (for chlorophyll analysis) or at ambient temperature (for phytoplankton analysis) for transportation to processing facility.

Samples kept on ice during transportation were used to analyze chlorophyll-*a* concentration following EPA Method 445.0. Samples were first homogenized and then a known volume was filtered through Whatman GF/F filters, which were subsequently stored in a -20 ºC freezer before extraction at a later date. The extraction process required frozen filters to be placed into 10 mL of 90% acetone and vortexed prior to being placed back into a dark -20 ºC freezer to extract for 16-24 hours. Once the extraction process was complete, samples were vortexed and centrifuged prior to analysis on a Turner Designs Trilogy fluorometer.

Samples kept at ambient temperature were used to conduct qualitative live screen assessments of the phytoplankton genera or species present at each site. Quantitative phytoplankton counts were conducted by light microscopy according to the Utermohl method using Lugol’s as a fixative. Phytoplankton were identified down to genus level, or species when possible.

Results and Discussion

Chlorophyll a

Chlorophyll *a* was generally highest early in the time series (September-October 2023) and began to decrease in early November 2023 (Fig. 2). Decreasing water temperature (Fig. 3) and possibly light levels may explain this seasonal decrease, as phytoplankton growth is temperature and light-dependent (Eppley 1972; Pennock and Sharp 1994). Sites CO2 and CO4 had the highest chlorophyll *a* on average, at 1.7 ± 0.8 µg/L and 2.2 ± 1.2 µg/L, respectively, followed by CO1 and CO3 at 0.9 ± 0.7 µg/L and 1.1 ± 0.7 µg/L, respectively. Both CO2 and CO4 are located near freshwater sources, as indicated by the generally lower salinity levels at each, especially from early November onward (Fig. 4). Freshwater inflow has been shown to be a critical source of nutrients that support phytoplankton growth in local estuaries (Mooney and McClelland 2012). Overall, the chlorophyll *a* concentration observed during the study period are relatively low, suggesting that the study area is not being negatively affected by excessive nutrient inputs. However, additional sampling during spring and summer is recommended to fully characterize chlorophyll levels and the conditions that influence them.

Live Screens for HAB taxa

During the study period, several potentially harmful phytoplankton were observed. These include the dinoflagellates *Akashiwo sanguinea*, *Levanderina fissa*, *Margalefidinium polykrikoides*, and *Prorocentrum minimum*; the raphidophyte *Chattonellas sp.*; and the diatom *Pseudonitzschia sp.* (Table 2). However, abundances were consistently low when observed, while non-detects were common. At no time were abundances high enough to be considered bloom-level or to warrant a public health concern for any of the aforementioned taxa. Aside from these HAB taxa, previous sampling has detected the dinoflagellate HAB taxa *Karenia brevis* and *Dinophysis sp.* in Copano Bay (unpubl. TPWD reports), but these taxa were not observed during our period of study. Overall, findings from this limited sampling effort suggest that several HAB taxa are found in this region of Copano Bay, but that environmental conditions were not conducive to bloom formation. The relatively low chlorophyll concentrations suggest that nutrient levels may be low enough such that risk of HAB formation is relatively low. As with chlorophyll, additional sampling during spring and summer and over a several year period is recommended to fully characterize HAB presence and population dynamics as well as the conditions that influence them, especially freshwater inflow which may vary on interannual timescales in Copano Bay. In addition, given the presence of numerous shellfish harvesting beds in the area, a routine but more targeted sampling is recommended for the foreseeable future to mitigate potential risk to humans and the environment.

Stakeholder Engagement

An important component of this project was stakeholder engagement to increase potential for data acquisition via incorporation of citizen scientists and to increase awareness of HABs in the area. During the study, we collaborated with NOAA's Phytoplankton Monitoring Network (PMN) to collect samples at the Texas Oyster Ranch, owned by Brad Lomax. The PMN is a network of citizen scientists who monitor for HABs with oversight from NOAA scientists. Results were conveyed to Alex Nunez (Texas Parks and Wildlife Department) and Kirk Wiles (Department of State Health Services), who oversee the state's response to HAB events. Finally, we had preliminary discussions with a teacher at Rockport High School to gauge interest in organizing a student led HAB sampling effort in the future. Additional discussions will be required to bring this to fruition, and it is likely that we will need to connect the teacher with PMN given the lack of existing resources for sampling.

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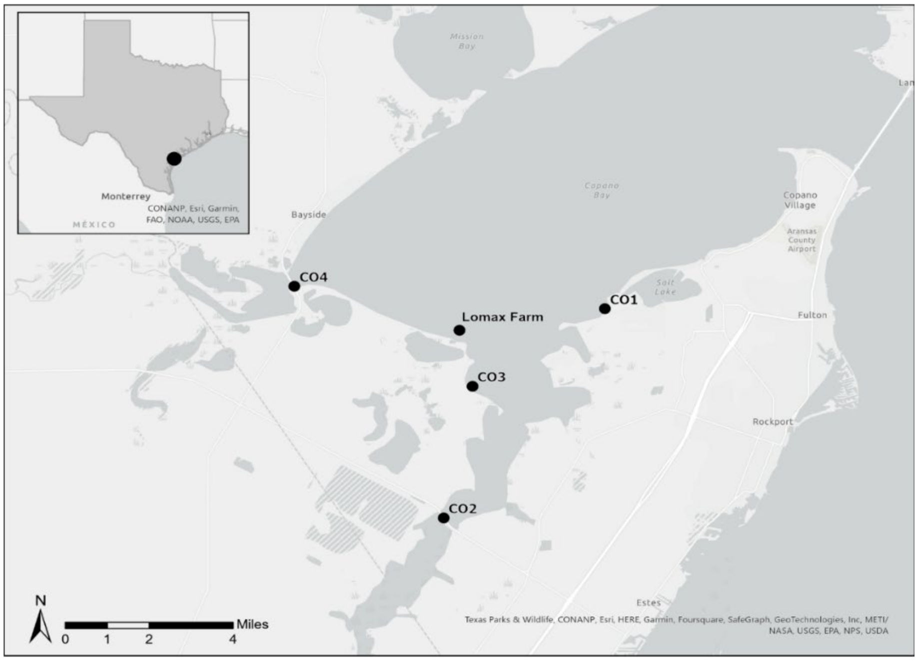
Fig. 1 Map of sampling sites in southern Copano Bay.



CONANP, Esri, Garmin, FAO, NOAA, USGS, EPA

Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, Foursquare, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

Fig. 2 Chlorophyll *a* concentration at each sampling site during sampling period.

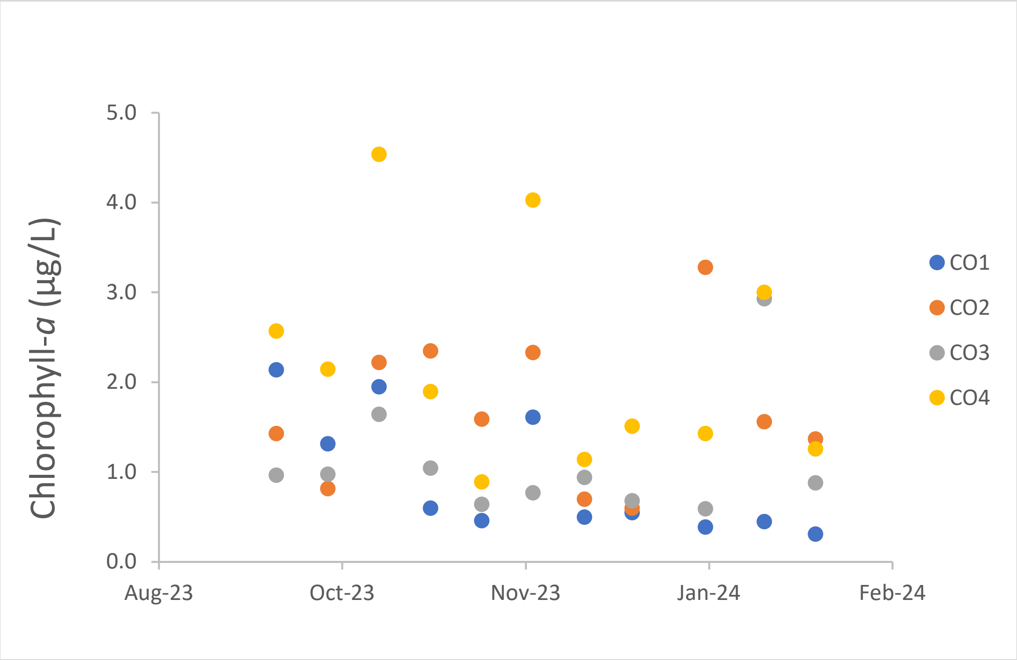


Fig. 3 Water temperature at each sampling site during sampling period.

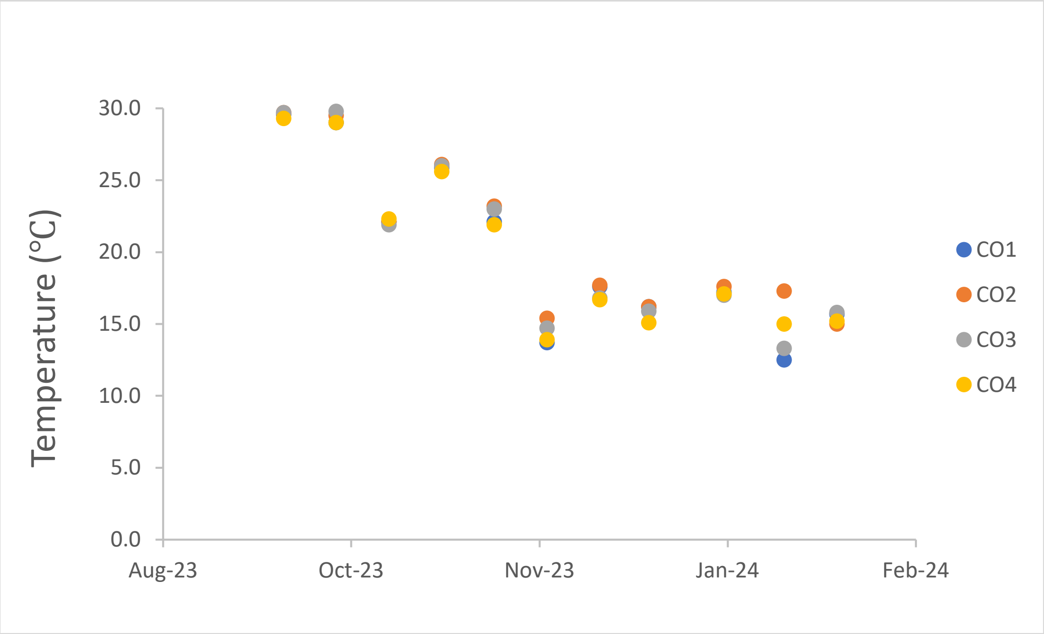


Fig. 4 Salinity at each sampling site during sampling period.

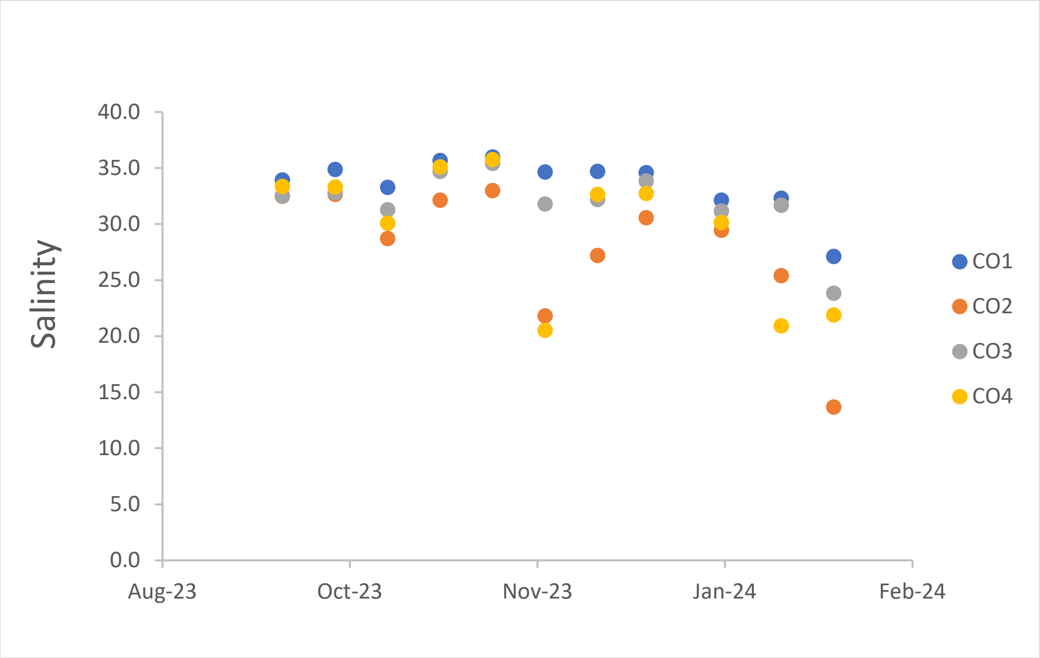


Table 1 List of sampling sites, their coordinates, and average depth recorded during sampling period.

Sampling ID	Latitude (N)	Longitude (W)	Average Depth (m)
CO1	28.06491º	-97.11270º	1.2
CO2	27.99567º	-97.16831º	1.8
CO3	28.03930º	-97.15836º	1
CO4	28.07237º	-97.21968º	1.2
Lomax Farm	28.05780º	-97.16286º	NR*

*NR = not recorded

Table 2 List of the HAB species observed in live screens during the sampling period.

Species Name	Species Type	Observations	Potential Harmful Impacts
Akashiwo sanguinea	dinoflagellate	More commonly observed during fall at CO1 and CO3.	Oxygen stress Toxin production
Chattonella spp.	raphidophyte	Observed once, in very low abundances, at CO4 in mid-October.	Toxin production
Levandarina fissa	dinoflagellate	Observed in very low abundance from mid-September to early November at CO2-CO4.	Oxygen stress
Margalefidinium polykrikoides	dinoflagellate	Observed in very low abundances in late September at CO1 and in late October at CO2.	Oxygen stress Toxin production
Pseudonitzschia spp.	diatom	Observed at CO1 and CO4 in October and December; higher abundances in late December.	Toxin production
Prorocentrum minimum	dinoflagellate	Observed in very low abundance in mid-September at CO2.	Toxin production