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Baseline

Baseline nutrient dynamics in shallow well mixed coastal lagoon with seasonal harmful algal blooms and hypoxia formation

Evan L. Turner[a,*], Bhanu Paudel[b], Paul A. Montagna[a]

[a] Harte Research Institute for Gulf of Mexico Studies, Texas A&M University–Corpus Christi, 6300 Ocean Drive, Unit 5869, Corpus Christi, TX 78412, USA
[b] Academy of Natural Sciences of Drexel University, 1900 Benjamin Franklin Parkway, Philadelphia, PA 19103, USA

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ABSTRACT

Weekly inorganic nutrient and chlorophyll-*a* concentrations were measured to establish baseline conditions in Corpus Christi Bay, Texas during seasonal hypoxia and harmful algal bloom (HAB) formation. Two fixed stations along the southern shoreline were sampled weekly for a continuous year at the same time each day. Weekly shoreline observations were found to be statistically similar to quarterly observations in the bay center, but with a greater power to detect seasonal trends. Dissolved Oxygen (DO) < 4 mg/L was measured in June, 2012 along the southern shoreline of Corpus Christi Bay, which places lower DO conditions west of previous estimates. During a bay-wide HAB event in November of 2011 no changes were observed in any of the nutrient or chlorophyll-*a* observations. This study documents a baseline of nutrients and chlorophyll-*a* in Corpus Christi Bay during a dry (average salinity > 36 PSU) year.

Studies over the previous decades have made direct linkages between human activities and excessive nutrient introductions into coastal waters and stimulating the production of increased organic matter (Nixon, 1995; de Jonge et al., 2002; Vitousek et al., 1997). Resultant eutrophication in coastal waters due to increased nutrient loading has been linked to oxygen depletion, harmful algal blooms, shifts in plankton community populations, and generally lower water quality (Cloern, 2001; Howarth and Marino, 2006; Rabalais and Nixon, 2002). However, every estuary is unique because of the interplay among site specific biogeochemical parameters, geomorphology, tides, and freshwater inflow. Coastal lagoons are a type of estuary defined as having either a narrow or nonexistent connection to the sea (Perillo, 1995). Coastal lagoons are often very shallow, productive, bordered by human development, and have long residence times, which raise the concern over future eutrophication through climate change (Lloret et al., 2008). Although eutrophication based impacts have been historically observed by Nixon (1995) in systems such as Moriches Bay in Long Island, New York, other coastal lagoons are often oligotrophic despite increased loadings over time (Boynton et al., 1996; Lloret et al., 2008). Estuaries are also prone to pulsed nutrient supply and rapidly changing nutrient dynamics that influences phytoplankton community biomass and structure in short timeframes (Pinckney et al., 1999). The frustration is in understanding the paradox of why some coastal lagoons have observed hypoxia and harmful algal blooms while having oligotrophic traits (Montagna and Froeschke, 2009). In order to model and predict organic matter production in coastal lagoons, and the possible effects of excessive organic material, time series baselines of nutrient input and organic biomass are required.

Corpus Christi Bay, Texas, is a coastal lagoon where seasonal hypoxia events are consistently observed in the southeastern region of the bay (Kim and Montagna, 2012; Montagna and Froeschke, 2009). Low nitrogen observations (below 1 μmol/L) coupled with high N:P ratios indicate the bay is nitrogen limited (Fig. 1) (Applebaum et al., 2005). Corpus Christi Bay, Texas is a shallow (<4 m), windy (average 18.5 km h^{-1}) coastal lagoon with average residence times greater than five months, and surrounded by large urban development (Ritter and Montagna, 1999). Corpus Christi Bay is the largest bay in the Nueces Estuary, which is connected to the Nueces Bay and fed by intermittent inflow from the Nueces River (Longley, 1994). However, a saltwater dam separates the outflow from the Nueces River to the Nueces Bay, particularly during dry periods with little rainfall. The only connection to the Gulf of Mexico is a narrow (250 m) ship channel through the barrier island, however large inlets exist to the neighboring Laguna Madre to the south and Aransas Bay to the north (Fig. 1).

Corpus Christi Bay is not considered oligotrophic or eutrophic as long term chlorophyll-*a* observations average above 5 μg/L, but rarely exceeds 20 μg/L in a 20-year quarterly time series of

* Corresponding author.
E-mail addresses: evan.turner@tamucc.edu (E.L. Turner), bhanu.paudel@drexel.edu (B. Paudel), paul.montagna@tamucc.edu (P.A. Montagna).

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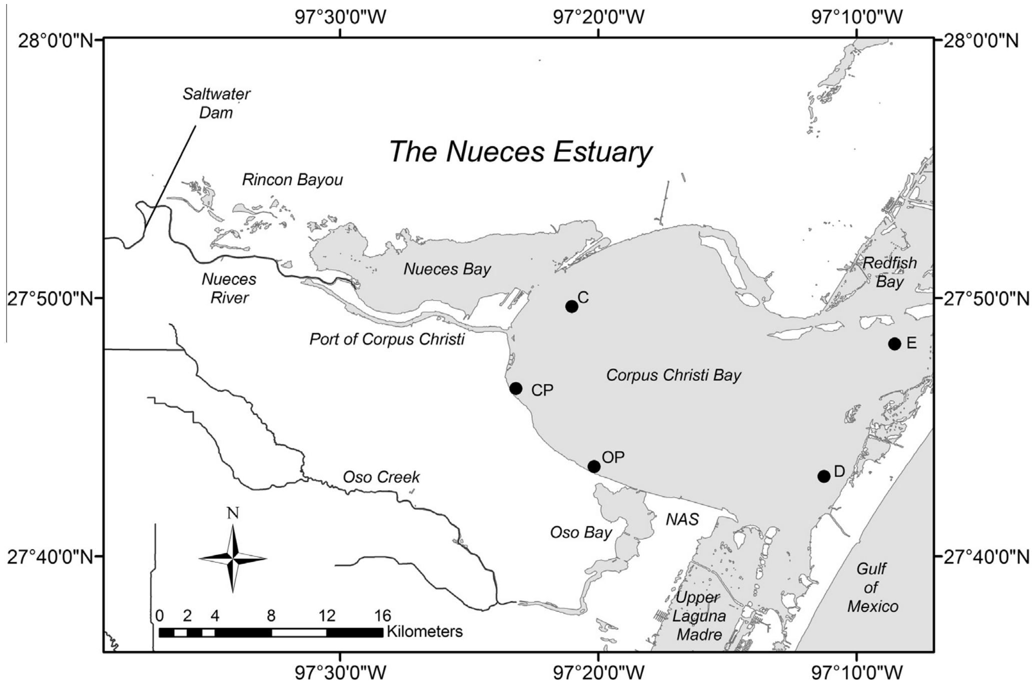

Fig. 1. The Nueces Estuary. Study Sites are Cole Park Pier (CP) and Oso Pier (OP). Both sites extend 100 m into Corpus Christi Bay. Previously established Montagna sample locates are C, D, and E.

observations (Montagna, Unpublished Data). Chlorophyll-*a*, inorganic nutrients, salinity, and benthic metrics are collected quarterly in three fixed locations in Corpus Christi Bay since the late 1980s (Fig. 1) (Montagna and Kalke, 1992; Ritter and Montagna, 1999). A hypothesis as to why low nutrients are consistently observed is because of fast denitrification rates in the area. Denitrification rates up to 90 μmol m^{-2} h^{-1} have been observed; however, denitrification and fixation vary inconsistently between seasons and spatially within the bay (Gardner et al., 2006). Additionally, An and Gardner (2002) previously found dissimilatory NO_3^- reduction to NH_4^+ (DNRA) is a significant process and likely preserving nitrogen as NH_4^+ in sediments. McCarthy et al. (2008) found a connection between hypoxia and denitrification in Corpus Christi Bay by observing the denitrification rates in some locations are significantly higher during periods of hypoxia. However, hypoxia still nearly always occurs seasonally in the south-eastern region of Corpus Christi Bay (Montagna and Froeschke, 2009).

Quantifying the nutrient input budget to Corpus Christi Bay is complex due to the combination of point and non-point sources. During periods of low flow nutrient input from the Nueces River can be blocked at the saltwater dam. Only a single study exists to quantify the budget of nitrogen loading to the Nueces Estuary, finding N from runoff is at 363×10^6 g N, input from point sources to be 1058×10^6 g N, atmospheric 377×10^6 g N, and the Nueces River 134×10^6 g N (Brock, 2001). A principle point source besides the Nueces River is a waste water treatment plant (WWTP) that releases effluent into Oso Bay, which in turn feeds into Corpus Christi Bay through an intermittent inlet.

The problem becomes to link brief periodic nutrient inflow to the temporal and spatial processes observed in Corpus Christi Bay. Because nutrient cycling in Corpus Christi bay is determined by seasonality and brief nutrient inputs, a solution is to collect nutrient and chlorophyll-*a* samples continuously throughout the year at higher frequency than the established quarterly observations. The purpose of this study is to investigate the effectiveness of weekly nutrient and chlorophyll-*a* observations as compared to the existing quarterly observations. The purpose of this work is to discover an optimal rate of sampling to capture most typical temporal nutrient cycling processes, create a baseline picture of biogeochemical indicators during a typical full year period, and to find possible relationships between these indicators and seasonal HAB's and hypoxia formation.

The strategy of long-term, frequent sampling has been applied to other coastal lagoons with some success. For example, Örnólfsdóttir et al. (2004) conducted seasonal phytoplankton biomass and community structure response assays during brief (1–2 day) nutrient pulses in Galveston Bay, Texas. The finding of this experiment is that brief, pulsed Nitrogen inputs have a role in increasing phytoplankton biomass in Galveston Bay. In Arcachon Bay, France a biweekly nutrient sampling strategy was employed for a full year to assay seasonal nutrient dynamic changes (Glé et al., 2008). Glé et al. (2008) found riverine nutrient input to be a driver of phytoplankton primary production; however, responses are dependent on the seasonal drivers such as temperature and light availability. Pulsed nutrient supply was also studied in the northern Hiroshima Bay, Japan (Yamamoto and Hatta, 2004). Heterogeneous pulsed nutrient input was found to be a factor to promote phytoplankton species diversity in this estuary system. Yamamoto and Hatta (2004) theorize that anthropogenic-based decreases of freshwater inflow may reduce the heterogeneity of nutrient pulses and alter species diversity. In all these studies the timing and duration of nutrient input was critical to phytoplankton growth and sometimes diversity.

In the current study, a year-long weekly survey in two fixed locations along the southern shoreline of Corpus Christi Bay is performed to examine the temporal cycling of nutrient dynamics. Additionally, the shoreline makes collections possible during bad weather (i.e., high winds that occur frequently in the bay) that would disrupt a frequent collection regime. This study will estimate the biomass of primary producers expressed as concentrations of chlorophyll-*a*. This technique applies well across many coastal systems and is relatively inexpensive to conduct (Brush et al., 2002). This data can later be combined with light attenuation