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LIFE SCIENCE AND BIOMEDICINE
NOVEL-RESULT

Response of macrobenthic communities to changes in water quality in a subtropical, microtidal estuary (Oso Bay, Texas)

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Abstract
The influence of nutrient loading and other anthropogenic stressors is thought to be greater in low inflow, microtidal estuaries, where there is limited water exchange. This 11-month study compared spatial changes in macrofaunal communities adjacent to regions that varied in land cover in Oso Bay, Texas, an estuarine secondary bay with inflow dominated by hypersaline discharge, in addition to discharge from multiple municipal wastewater treatment plants. Macrofauna communities changed in composition with distance away from a wastewater treatment plant in Oso Bay, with the western region of the bay containing different communities than the head and the inlet of the bay. Ostracods were numerically dominant close to the wastewater discharge point. Macrobenthic community composition is most highly correlated with silicate concentrations in the water column. Silicate is negatively correlated with salinity and dissolved oxygen, and positively correlated with nutrients within the bay. Results are relevant for environmental management purposes by demonstrating that point-source discharges can still have ecological effects in hydrologically altered estuaries.

Keywords: Nutrient enrichment; silicate; anthropogenic; ecological indicator; wastewater; ostracoda

Introduction

Coastal systems are increasingly subject to environmental degradation due to stressors of both natural and anthropogenic origin. One stressor, nutrient loading, contributes to algal blooms and subsequent decomposition that can limit dissolved oxygen in the water column (Pinckney et al., 2001). Macrobenthos are particularly sensitive to organic enrichment, making these communities useful for studying the influence of nutrient inputs on a system (Pearson & Rosenberg, 1978). Oso Bay, Texas, USA, is a shallow (mean 1 m), estuarine secondary bay in the northwestern Gulf of Mexico (Figure 1) experiencing rapid urbanization coincident with increased nutrient and organic matter inputs (Wang et al., 2018; Wetz et al., 2016). Microtidal, low-flow estuaries such as Oso Bay are believed to be more sensitive to anthropogenic influences than "classical" estuaries with strong riverine and/or tidal influences due to limited flushing (Bricker et al., 2007). This sensitivity makes management of these systems more challenging.

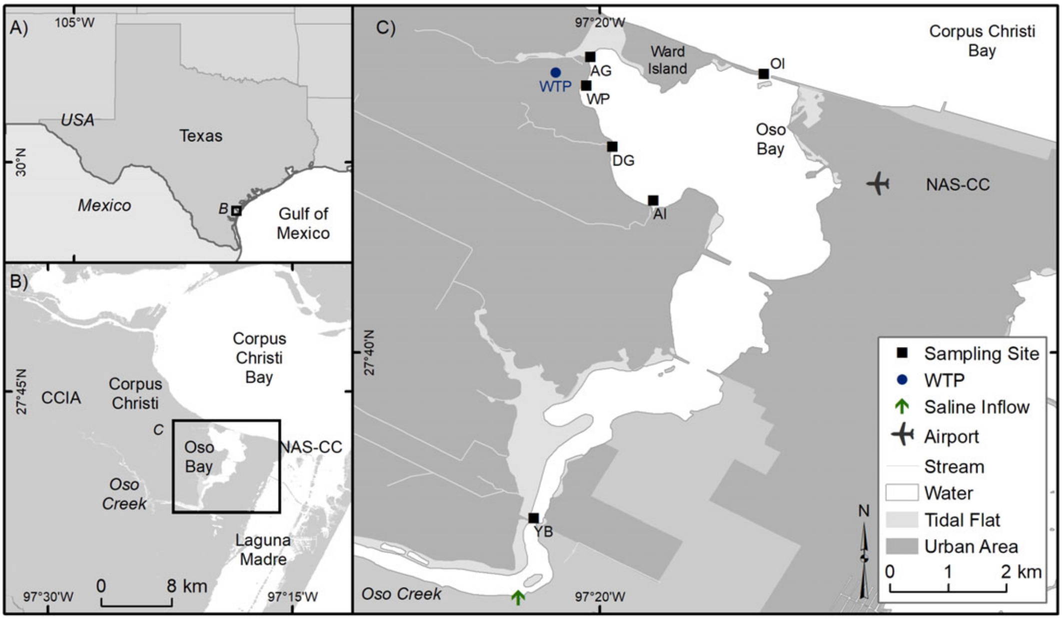

Figure 1. Sampling sites within Oso Bay. WTP = Wastewater treatment plant.

Objective

The aim of this 11-month study was to analyze spatial changes in estuarine macrobenthic communities adjacent to regions that varied in land cover. Oso Bay has multiple stressors, including its primary tributary, Oso Creek, being dominated by discharge of hypersaline cooling water from a power plant as well as discharge from multiple municipal wastewater treatment plants, while another wastewater treatment plant discharges directly into Oso Bay. This study focuses on spatial differences in land cover and the influence of nutrient inputs on macrobenthic communities to inform ongoing management activities by state (Texas Commission on Environmental Quality) and federal (U.S. Environmental Protection Agency) environmental management agencies.

Methods

Macrobenthic infaunal communities and sediment chlorophyll concentrations were collected using core samples monthly from February 2013 to January 2014 (de Santiago et al., 2020). Sediment grain size was sampled in January 2014. Water quality measurements (salinity, temperature, dissolved oxygen, pH) and water chemistry samples (SiO_4^{2-}, NH_4^+; $NO_2 + NO_3$, PO_4^{3-}, dissolved organic carbon [DOC], dissolved organic nitrogen [DON], total dissolved nitrogen [TDN]) were taken three to five days prior to benthic sampling (Wetz et al., 2016).

Sampling occurred at six sites within Oso Bay, including the head of Oso Bay below a hypersaline discharge point to Oso Creek (Yorktown Bridge, YB), and the mouth at Oso Bay inlet (OI), as well as four sites in the western region of the bay: an active golf course that uses reclaimed wastewater from for watering (AG), a defunct golf course (DG), a mix of agricultural land and impervious surface (AI), and a mixed residential area with outflow dominated by effluent from a municipal wastewater treatment plant (WP) (Figure 1). Multivariate statistical techniques (non-metric multidimensional scaling (nMDS), principal component analysis (PCA), Bio-Env; Clarke & Ainsworth, 1993) and Pearson's correlations were used to characterize macrobenthic community composition and water quality.

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Results

Macrobenthic communities are clustered into two groups: the four sites in the western region of the bay, and the stations at the inlet and head of the bay (Figure 2, Figure S1). The four sites in the western region were characterized by having high abundances of ostracods and oligochaetes but low abundances of bivalves and the polychaetes *Mediomastus californiensis*, *Brania* sp. and *Scoloplos* sp. (Suppl. Table 1). Mean ostracod abundance at WP was ≥50 times greater than at any other site.

Nutrient concentrations decreased and salinity increased with distance away from WP (Figure 3). Spatial variations in macrofaunal community structure are most highly correlated with silicate concentrations (r = 0.428, p = 0.001), followed by the combination of silicate, DOC and salinity (r = 0.407, p = 0.001; Bio-Env). Mean silicate concentrations were 2-11X higher at WP, AG and DG than AI, OI and YB (Figure S2, Table S2). Silicate is negatively correlated with salinity and dissolved oxygen and positively correlated with nutrients (NH_4^+; $NO_2 + NO_3$, PO_4^{3-}, DOC, DON, TDN; Table S3).

Discussion

Oso Bay has experienced rapid urbanization in recent decades coincident with shifts in water quality and symptoms of eutrophication (Bugica et al., 2020). Macrobenthos community composition corroborates with previous water quality results indicating impairment of the western region of the bay due to the effluent-based nutrient inputs at WP (Wang et al., 2018; Wetz et al., 2016). The macrobenthic community in the nutrient-rich western region of the bay was dominated by ostracods, known indicators of reduced water quality and sewage discharge (Rosenfeld & Ortal, 1983), and oligochaetes, commonly used as indicators of organic pollution (McLusky et al., 1980). Wastewater discharge can also be a significant source of silicate (Clark et al., 1992; Van Dokkum et al., 2004), which was highest in the western region of the bay and most strongly influenced macrobenthic community composition over space and time. Although the OI and YB sites are most separated in space, upstream hypersaline discharge appears to facilitate a macrobenthic community at YB that is similar to OI.

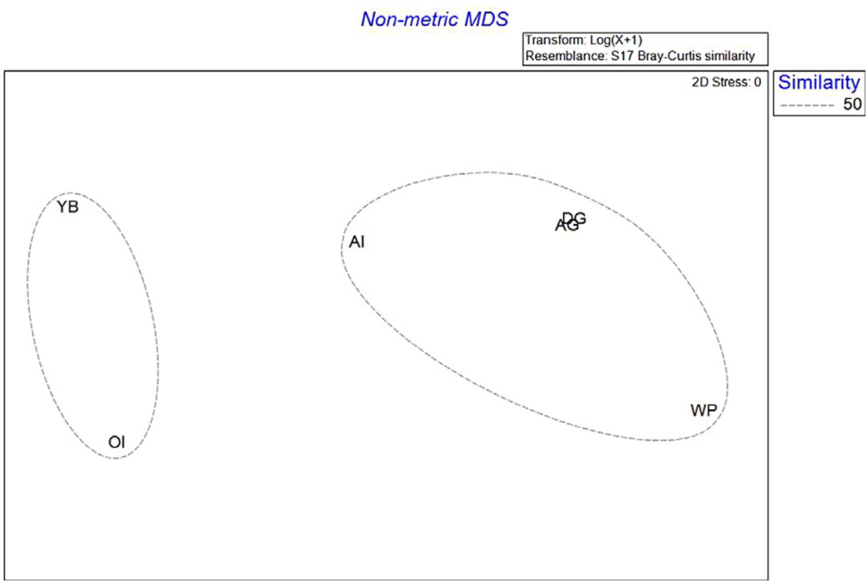

Figure 2. Non-metric multidimensional scaling plot of mean community composition at each station.

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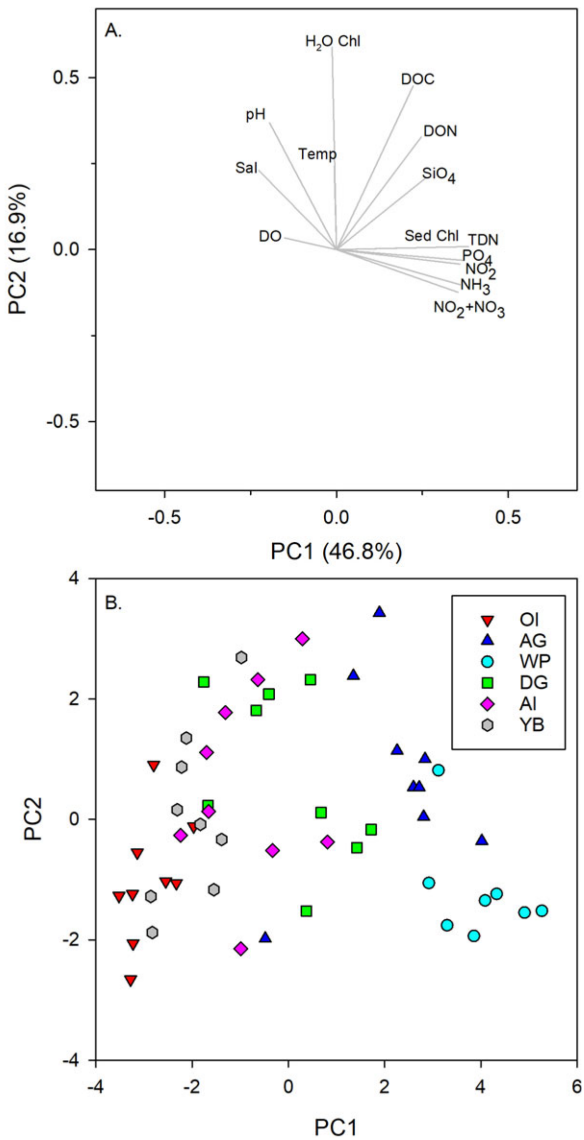

Figure 3. Principal components analysis of spatial variation in water quality and sediment chlorophyll. Variable vectors (top) and loading scores (bottom).

Conclusion

The dominant point source of nutrients and fresh water in the western region of Oso Bay (wastewater treatment plant) influences macrofaunal communities. Despite nutrient concentrations decreasing away from WP, macrobenthic communities remain more similar than those occurring at the head and inlet of the bay, likely due to relatively lower rates of water exchange in the western region. This correlation between macrofauna and water quality in Oso Bay indicates that macrobenthic communities are influenced by nutrient loading in shallow, microtidal estuaries, and can successfully be used as ecological indicators. The data that support the findings of this study are openly available in GRIIDC (de Santiago et al., 2020).

Acknowledgements. The authors thank two anonymous reviewers for constructive comments that improved the quality of this manuscript. We also thank Ken Hayes, Kelsey Fisher, Lynn Price and several others for collecting and analyzing water quality samples and Alex Nunez for management insights. We are grateful to Diana Sokoly for assistance with Oso Bay field sampling. Lastly, we thank the Gulf of Mexico Research Initiative Information and Data Cooperative for storing, and allowing open access of, the data that were generated in this study (de Santiago et al., 2020).

Author Contributions. JBP, KDS, and MSW conceived and designed the study. KDS and MSW conducted data collection. KDS and TAP performed statistical analyses. TAP and JBP wrote the article.

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Conflict of Interest. KDS, TAP, MSW and JBP declare none.

Supplementary Materials. To view supplementary material for this article, please visit http://dx.doi.org/10.1017/exp.2020.44.

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Peer Reviews

Reviewing editor: Dr. Arne Linlokken

Inland Norway University of Applied Sciences, Faculty of Applied Ecology, Agricultural Sciences and Biotechnology, Elverum, Norway, 2418

This article has been accepted because it is deemed to be scientifically sound, has the correct controls, has appropriate methodology and is statistically valid, and has been sent for additional statistical evaluation and met required revisions.

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Review 1: Response of macrobenthic communities to changes in water quality in a subtropical, microtidal estuary (Oso Bay, Texas)

Reviewer: Dr. Chet F Rakocinski

University of Southern Mississippi Gulf Coast Research Laboratory, Coastal Sciences, Ocean Springs , Mississippi, United States, 39564

Date of review: 01 August 2020

Conflict of interest statement. Reviewer declares none

Comments to the Author: This succinct article is well written with a clear take home message. It should prove interesting to other researchers and resource managers in the field of aquatic environmental science. Some suggestions for the authors to consider:

Abstract

- A connection should be made between the land cover and the stressors of concern
- what is the mechanistic connection between silicate as a proxy and other stressors shown to be correlated with silicate?

Introduction

-The role/connection of land cover is overlooked in the Introduction

Objective

-Connection between land cover and nutrients and other stressors is not made

-The temporal aspect of ‘spatiotemporal’ not addressed explicitly

Methods

-The temporal aspect of ‘spatiotemporal’ is not addressed explicitly, its only implied in the methods

- No details at all about the statistical analysis – at least should mention what was performed with which samples and in what context

Results

- No reference to the temporal dimension while using the term, ‘spatiotemporal’, except as implied in the NMDS graph of multiple points per station – was there a temporal pattern?

-Oligochaetes are known to be indicators of organic enrichment in low salinities

-No explicit connection to land cover is made

- Are correlations in table S3 adjusted for multiple testing error? (perhaps give threshold in legend); reviewer recognizes referring to P values as 'statistically significant' is out of favor, but the problem of multiple testing as an influence on P values remains

Discussion

-Oligochaetes are known to be indicators of organic enrichment in low salinities

-Lack of referral to any connection with land cover

-No discussion of temporal dimension for a study that lasted one year

Conclusion

-Role and promise of silicate as an indicator?

-Land cover?

-Temporal dimension?

Score Card

Presentation

4.7 /5

Is the article written in clear and proper English? (30%)	5/5
Is the data presented in the most useful manner? (40%)	5/5
Does the paper cite relevant and related articles appropriately? (30%)	4/5

Context

4.5 /5

Does the title suitably represent the article? (25%)	5/5
Does the abstract correctly embody the content of the article? (25%)	4/5
Does the introduction give appropriate context? (25%)	4/5
Is the objective of the experiment clearly defined? (25%)	5/5

Analysis

4.2 /5

Does the discussion adequately interpret the results presented? (40%)	4/5
Is the conclusion consistent with the results and discussion? (40%)	5/5
Are the limitations of the experiment as well as the contributions of the experiment clearly outlined? (20%)	3/5

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Review 2: Response of macrobenthic communities to changes in water quality in a subtropical, microtidal estuary (Oso Bay, Texas)

Reviewer: Dr. Robert Dunn[1,2]

[1]University of South Carolina, Georgetown, South Carolina, United States, 29440 [2]North Inlet-Winyah Bay National Estuarine Research Reserve

Date of review: 31 July 2020

Conflict of interest statement. Reviewer declares none.

Comments to the Author: This manuscript describes a set of benthic infauna samples and coincident water quality samples collected within Oso Bay, Texas, an impacted estuarine ecosystem with multiple point and non-point source discharge locations. The authors relate spatiotemporal changes in the community of benthic infauna with environmental parameters at 6 sites located across a gradient of water quality conditions.

I have just a few comments to improve the manuscript.

Introduction: Would be useful to describe why macrobenthos are particularly sensitive.

Objective: Clarify- a spatiotemporal gradient of [what type of] conditions? In addition, I suggest re-wording that the study focuses on spatial differences in benthic communities adjacent to regions which varied in land cover; differences in land cover themselves are not the focus of the manuscript.

Methods: A very brief description of the sampling methodology for benthic infauna would be useful. Could be as simple as "core samples"

Results: Overlaying the main community members on nMDS plot (Fig 2) would illustrate nicely why the communities at the saline sites differed from the 4 western sites.

Discussion: A sentence or two regarding the similarity of the upstream, hypersaline site and the site located at the inlet of Oso Bay would be a useful addition. E.g., does the inlet site reflect "natural" conditions, or is it also impacted? Given that the hypersaline discharge upstream acts as a source of salty water, is that leading to an artificial, pseudo-marine benthic community?

Score Card

Presentation

4.6 /5

Is the article written in clear and proper English? (30%)	5/5
Is the data presented in the most useful manner? (40%)	4/5
Does the paper cite relevant and related articles appropriately? (30%)	5/5

Context

4.8 /5

Does the title suitably represent the article? (25%)	5/5
Does the abstract correctly embody the content of the article? (25%)	5/5
Does the introduction give appropriate context? (25%)	4/5
Is the objective of the experiment clearly defined? (25%)	5/5

Analysis

4.6 /5

Does the discussion adequately interpret the results presented? (40%)	4/5
Is the conclusion consistent with the results and discussion? (40%)	5/5
Are the limitations of the experiment as well as the contributions of the experiment clearly outlined? (20%)	5/5

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