Texas Coastal Nutrient Input Repository - Task 3 Report

Michael Schramm 1

1 Research Specialist, Texas Water Resources Institute, Texas A&M AgriLife Research

December 1, 2021

Texas Water Resources Institute

Texas A&M Agrilife

College Station, TX



This project was funded by a Texas Coastal Management Program grant approved by the Texas Land Commissioner, providing financial assistance under the Coastal Zone Management Act of 1972, as amended, awarded by the National Oceanic and Atmospheric Administration (NOAA), Oﬀice for Coastal Management, pursuant to NOAA Award No. NA21NOS4190136. The views expressed herein are those of the author(s) and do not necessarily reflect the views of NOAA, the U.S. Department of Commerce, or any of their subagencies.

Table of Contents

Table of Figures

Table of Tables

Abbreviations

# Introduction

A substantial proportion of coastal estuaries in the United States face excessive nutrient loading and exhibit symptoms of eutrophication (Bricker et al. 2008). Eutrophication leads to depletion of dissolved oxygen, degradation of habitat (Darby and Turner 2008) and increased risks of harmful algal blooms (Heisler et al. 2008).

There have been limited attempts at assessments of estuarine eutrophication along the Texas coastline. Notably, Bugica et al. (2020) provided evidence of regional eutrophication hot spots attributed to increases in coastal population, urbanization, and alterations of freshwater inflows along the Texas coast and is an important starting point for targeted regional studies. Bugica et al. (2020) assessed three sites in the Lavaca Bay and identified small but significant increases in Total Phosphorus (TP) and Orthophosphate (PO4-3) at two sites, Total Kjeldahl Nitrogen (TKN) at two sites, and chlorophyll-*a* at one site. Importantly, decreases in dissolved oxygen were not detected in the study. While there are indications that potential drivers of eutrophication are increasing in Lavaca Bay, the immediate symptoms of degraded dissolved oxygen are not evident. Significant decreases in pH at all sites assessed by Bugica et al. (2020) in Lavaca Bay also point to long-term decreases in freshwater inflow and a resulting increase in salinity. Long-term declines in the abundance of sensitive benthic fauna in Lavaca Bay have been linked to increases in salinity and reductions in freshwater inflows (Beseres Pollack et al. 2011; Palmer and Montagna 2015; Montagna et al. 2020).

The potential for negative impacts induced by eutrophication is a especially concerning given the significant declines already observed in benthic fauna abundance, biomass, and diversity within Lavaca Bay (Beseres Pollack et al. 2011). Underscoring this concern is the need for data that is adequate for evaluating changes over time in watershed nutrient loading. There is also a need to understand the effects of land management decisions on nutrient loading, relative to environmental drivers such as precipitation and discharge, and how it may contribute to or improve conditions related to eutrophication in Lavaca Bay. This work (1) quantifies Nitrate-Nitrogen (NO3-N) and TP loadings in the Lavaca Bay watershed and (2) assesses the relationship of eutrophication indicators in Lavaca Bay to changes in watershed discharge and loads.

# Methods

## Study Area

## Load Estimation

Regression based approaches are commonly used to estimate constituent concentration and fluxes based on continuously measured streamflow and sparsely measured constituent concentrations.  
Most regression-based approaches estimate daily concentration based on modeled relationships between concentration and discharge, season, and time (Cohn et al. 1992; Hirsch et al. 2010). These approaches have recently been extended to include antecedant discharge variables to improve model performance (Zhang and Ball 2017). We developed site-specific Generalized Additive Models (GAMs) relating NO3-N and TP to discharge and temporal covariates. GAMs are a semiparametric extension of generalized linear models where the linear predictor is represented as the sum of multiple unknown smooth functions and parametric linear predictors. We fit GAMs using the “mgcv” packages in R which makes available multiple types of smooth functions. Hastie and Tibshirani, 1990 In general, we used thin-plate regression splines which are piece-wise functions that are smoothly joined at multiple breakpoints (commonly callled knots). Wood 2006 To fit the spline function, users specify the maximum number of knots and the function is automatically estimated by minimizing the generalized cross-validation score. (wood 2006)

Wang et al. (2011); Kuhnert et al. (2012); Robson and Dourdet (2015); Hagemann et al. (2016); McDowell et al. (2021); Biagi et al. (2022) utilized variously specified GAMs to develop daily estimates of nutrient or sediment load based on temporal and flow-based variables. Although the underlying parameter estimation procedure of GAMs is substantially different than popular regression based approaches such as LOADEST (Cohn et al. 1992) or WRTDS (@ Hirsch et al. 2010), the functional form and model predictions tend to be similar (Beck and Murphy 2017). The main drivers for our selection of GAMs are the ability to model different error structures and the ease of including additional model covariates. Zhang and Ball (2017) demonstrated improvements in WRTDS results using antecedent flow variables. Inclusion of these model terms in WRTDS and LOADEST is generally difficult compared to GAMs which are a more general regression modelling approach. The generalized .

# Headings

## Second Level Heading

### Third Level Heading

First, second, and third level headings are defined by #, ##, and ### respectively.

# Tables

This is an example of an unformatted table and how we cross-reference that table ([Table](#tab:mtcars) ).

Table . this is the builtin mtcars data.

| mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |
| 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

The [flextable](https://davidgohel.github.io/flextable/) package provides additional formatting flexibility when exporting to Word (Table ).

Table . flextable formatted table.

| mpg | cyl | disp | hp | drat | wt | qsec | vs | am | gear | carb |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 21.0 | 6 | 160.0 | 110 | 3.90 | 2.620 | 16.46 | 0 | 1 | 4 | 4 |
| 21.0 | 6 | 160.0 | 110 | 3.90 | 2.875 | 17.02 | 0 | 1 | 4 | 4 |
| 22.8 | 4 | 108.0 | 93 | 3.85 | 2.320 | 18.61 | 1 | 1 | 4 | 1 |
| 21.4 | 6 | 258.0 | 110 | 3.08 | 3.215 | 19.44 | 1 | 0 | 3 | 1 |
| 18.7 | 8 | 360.0 | 175 | 3.15 | 3.440 | 17.02 | 0 | 0 | 3 | 2 |
| 18.1 | 6 | 225.0 | 105 | 2.76 | 3.460 | 20.22 | 1 | 0 | 3 | 1 |
| 14.3 | 8 | 360.0 | 245 | 3.21 | 3.570 | 15.84 | 0 | 0 | 3 | 4 |
| 24.4 | 4 | 146.7 | 62 | 3.69 | 3.190 | 20.00 | 1 | 0 | 4 | 2 |
| 22.8 | 4 | 140.8 | 95 | 3.92 | 3.150 | 22.90 | 1 | 0 | 4 | 2 |
| 19.2 | 6 | 167.6 | 123 | 3.92 | 3.440 | 18.30 | 1 | 0 | 4 | 4 |

# Figures

We can embed and cross-reference plots (Figure ).

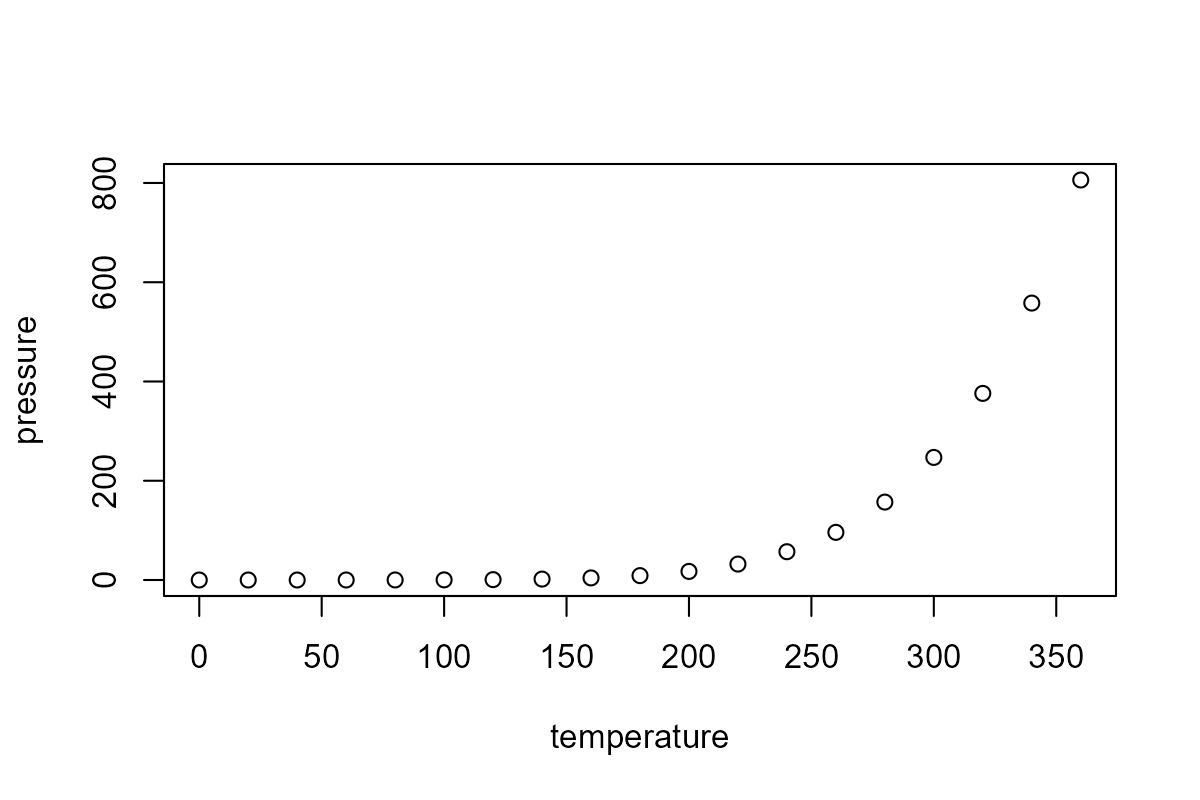


Figure . pressure dataset

# Landscape Section

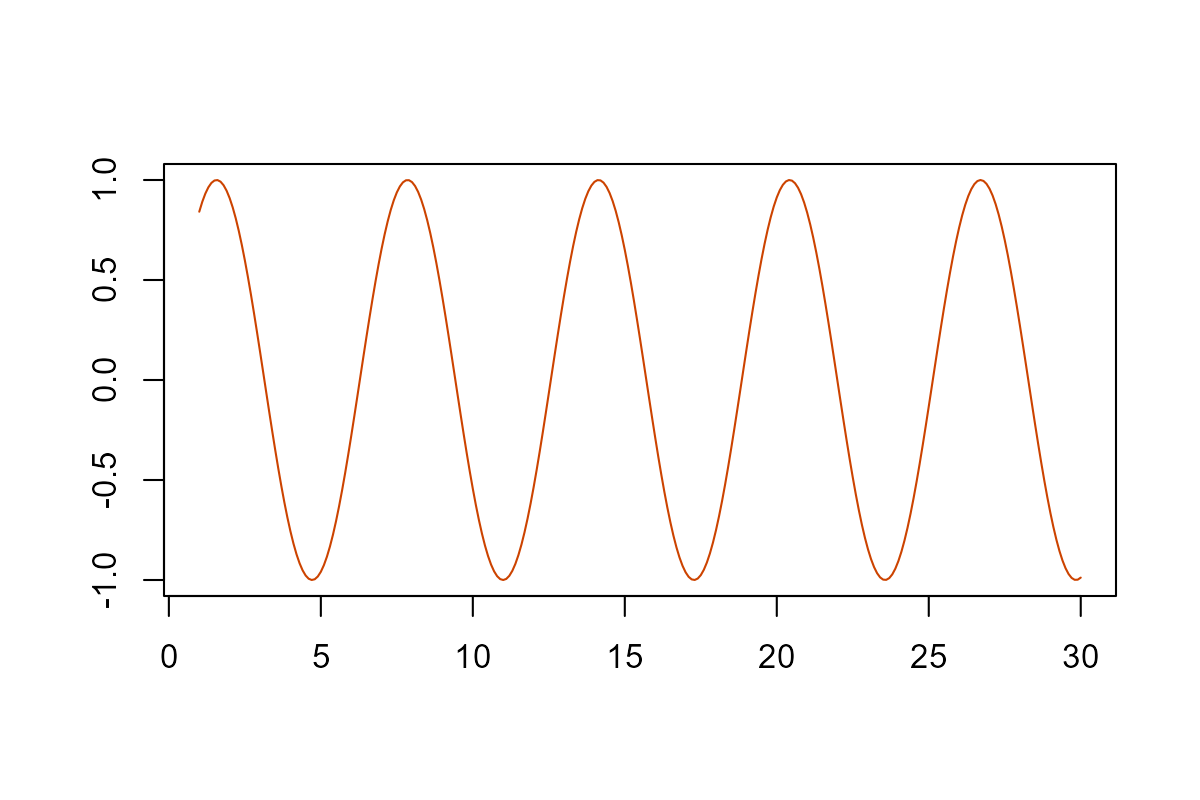


Figure . sin function

# Math

Wrap variables or math in a single $ to show math inline. For example, . Standalone equations are wrapped with $$.

If the equations need to be numbered and cross-referenced the format as:

\begin{equation}  
\left(\prod\_{i=1}^{n}y\_i\right)^{\frac{1}{n}} = \exp\left[\frac{1}{n}\sum\_{i=1}^n\log{y\_i}\right], \quad \textrm{when} \quad y\_1, y\_2, ..., y\_n > 0  
(\#eq:gmean)  
\end{equation}

Which renders as (Equation @ref(eq:gmean):

# References

In-text references and bibliography generation are handled automatically. It relies on creating a bibtex .bib file with your references. Software such as Zotero, Mendely, and even Google Scholar can generate the bibtex entries for you. The entries are stored in the bibliography.bib file inside the same directory as this .Rmd file. To make a in text citation, use the following syntax, [@helsel\_statistical\_2002] to generate the reference at the end of this sentence (**helsel\_statistical\_2002?**). Use a semicolon to include multiple references [@helsel\_statistical\_2002; @hirsch2010weighted] (**helsel\_statistical\_2002?**; **hirsch2010weighted?**). Or we might use @helsel\_statistical\_2002 without brackets to indicate (**helsel\_statistical\_2002?**) provide a fundamental overview of water quality statistics. The bibliography will populate automatically.

# Styling and fonts

This template uses Minion Pro for body fonts and Open Sans for headings following TWRI brand guidance and AgriLife brand guidance. I can’t bundle Minion Pro in this package because of licensing, but you can download and install both fonts from AgriLife (<https://agrilife.tamu.edu/wp-content/uploads/2021/03/AgriFonts.zip>). I recommend downloading and installing the fonts before knitting your documents. Note that Minion Pro won’t “embed” in Word documents because it is an OTF style font and currently Word only embeds TTF fonts. That means collaborators without the font installed on their system will see a different serif font on their system in Word. Once exported to pdf, both OTF and TTF fonts should be embedded correctly.

# Bibliography

Beck MW, Murphy RR. 2017. Numerical and qualitative contrasts of two statistical models for water quality change in tidal waters. JAWRA Journal of the American Water Resources Association. 53(1):197–219. doi:[10.1111/1752-1688.12489](https://doi.org/10.1111/1752-1688.12489). [accessed 2018 Jun 22]. <http://doi.wiley.com/10.1111/1752-1688.12489>.

Beseres Pollack J, Palmer T, Montagna P. 2011. Long-term trends in the response of benthic macrofauna to climate variability in the Lavaca-Colorado Estuary, Texas. Mar Ecol Prog Ser. 436:67–80. doi:[10.3354/meps09267](https://doi.org/10.3354/meps09267). [accessed 2022 Nov 11]. <http://www.int-res.com/abstracts/meps/v436/p67-80/>.

Biagi KM, Ross CA, Oswald CJ, Sorichetti RJ, Thomas JL, Wellen CC. 2022. Novel predictors related to hysteresis and baseflow improve predictions of watershed nutrient loads: An example from Ontario’s lower Great Lakes basin. Science of The Total Environment. 826:154023. doi:[10.1016/j.scitotenv.2022.154023](https://doi.org/10.1016/j.scitotenv.2022.154023). [accessed 2022 Apr 5]. <https://linkinghub.elsevier.com/retrieve/pii/S0048969722011159>.

Bricker SB, Longstaff B, Dennison W, Jones A, Boicourt K, Wicks C, Woerner J. 2008. Effects of nutrient enrichment in the nation’s estuaries: A decade of change. Harmful Algae. 8(1):21–32. doi:[10.1016/j.hal.2008.08.028](https://doi.org/10.1016/j.hal.2008.08.028). [accessed 2022 Apr 5]. <https://linkinghub.elsevier.com/retrieve/pii/S1568988308001182>.

Bugica K, Sterba-Boatwright B, Wetz MS. 2020. Water quality trends in Texas estuaries. Marine Pollution Bulletin. 152:110903. doi:[10.1016/j.marpolbul.2020.110903](https://doi.org/10.1016/j.marpolbul.2020.110903). [accessed 2020 Apr 8]. <https://linkinghub.elsevier.com/retrieve/pii/S0025326X20300217>.

Cohn TA, Caulder DL, Gilroy EJ, Zynjuk LD, Summers RM. 1992. The validity of a simple statistical model for estimating fluvial constituent loads: An Empirical study involving nutrient loads entering Chesapeake Bay. Water Resour Res. 28(9):2353–2363. doi:[10.1029/92WR01008](https://doi.org/10.1029/92WR01008). [accessed 2022 Apr 26]. <http://doi.wiley.com/10.1029/92WR01008>.

Darby F, Turner R. 2008. Effects of eutrophication on salt marsh root and rhizome biomass accumulation. Mar Ecol Prog Ser. 363:63–70. doi:[10.3354/meps07423](https://doi.org/10.3354/meps07423). [accessed 2022 Nov 11]. <http://www.int-res.com/abstracts/meps/v363/p63-70/>.

Hagemann M, Asce SM, Kim D, Park MH, Asce AM, Student PD. 2016. Estimating Nutrient and Organic Carbon Loads to Water-Supply Reservoir Using Semiparametric Models. J Environ Eng.:9.

Heisler J, Glibert PM, Burkholder JM, Anderson DM, Cochlan W, Dennison WC, Dortch Q, Gobler CJ, Heil CA, Humphries E, et al. 2008. Eutrophication and harmful algal blooms: A scientific consensus. Harmful Algae. 8(1):3–13. doi:[10.1016/j.hal.2008.08.006](https://doi.org/10.1016/j.hal.2008.08.006). [accessed 2022 Nov 11]. <https://linkinghub.elsevier.com/retrieve/pii/S1568988308001066>.

Hirsch RM, Moyer DL, Archfield SA. 2010. Weighted Regressions on Time, Discharge, and Season (WRTDS), with an Application to Chesapeake Bay River Inputs1: Weighted Regressions on Time, Discharge, and Season (WRTDS), With an Application to Chesapeake Bay River Inputs. JAWRA Journal of the American Water Resources Association. 46(5):857–880. doi:[10.1111/j.1752-1688.2010.00482.x](https://doi.org/10.1111/j.1752-1688.2010.00482.x). [accessed 2018 Jun 22]. <http://doi.wiley.com/10.1111/j.1752-1688.2010.00482.x>.

Kuhnert PM, Henderson BL, Lewis SE, Bainbridge ZT, Wilkinson SN, Brodie JE. 2012. Quantifying total suspended sediment export from the Burdekin River catchment using the loads regression estimator tool: REGRESSION ESTIMATOR TOOL FOR POLLUTANT LOADS. Water Resour Res. 48(4). doi:[10.1029/2011WR011080](https://doi.org/10.1029/2011WR011080). [accessed 2022 Jun 13]. <http://doi.wiley.com/10.1029/2011WR011080>.

McDowell RW, Simpson ZP, Ausseil AG, Etheridge Z, Law R. 2021. The implications of lag times between nitrate leaching losses and riverine loads for water quality policy. Sci Rep. 11(1):16450. doi:[10.1038/s41598-021-95302-1](https://doi.org/10.1038/s41598-021-95302-1). [accessed 2022 Apr 20]. <https://www.nature.com/articles/s41598-021-95302-1>.

Montagna PA, Cockett PM, Kurr EM, Trungale J. 2020. Assessment of the Relationship Between Freshwater Inflow and Biological Indicators in Lavaca Bay. Corpus Christi, Texas: Harte Research Institute, Texas A&M University-Corpus Christi Final Report to the Texas Water Development Board Report No.: Contract # 1800012268.

Palmer TA, Montagna PA. 2015. Impacts of droughts and low flows on estuarine water quality and benthic fauna. Hydrobiologia. 753(1):111–129. doi:[10.1007/s10750-015-2200-x](https://doi.org/10.1007/s10750-015-2200-x). [accessed 2022 Nov 11]. <http://link.springer.com/10.1007/s10750-015-2200-x>.

Robson BJ, Dourdet V. 2015. Prediction of sediment, particulate nutrient and dissolved nutrient concentrations in a dry tropical river to provide input to a mechanistic coastal water quality model. Environmental Modelling & Software. 63:97–108. doi:[10.1016/j.envsoft.2014.08.009](https://doi.org/10.1016/j.envsoft.2014.08.009). [accessed 2022 Apr 5]. <https://linkinghub.elsevier.com/retrieve/pii/S1364815214002333>.

Wang Y-G, Kuhnert P, Henderson B. 2011. Load estimation with uncertainties from opportunistic sampling data – A semiparametric approach. Journal of Hydrology. 396(1-2):148–157. doi:[10.1016/j.jhydrol.2010.11.003](https://doi.org/10.1016/j.jhydrol.2010.11.003). [accessed 2022 Sep 21]. <https://linkinghub.elsevier.com/retrieve/pii/S0022169410006773>.

Zhang Q, Ball WP. 2017. Improving riverine constituent concentration and flux estimation by accounting for antecedent discharge conditions. Journal of Hydrology. 547:387–402. doi:[10.1016/j.jhydrol.2016.12.052](https://doi.org/10.1016/j.jhydrol.2016.12.052). [accessed 2022 Jun 22]. <https://linkinghub.elsevier.com/retrieve/pii/S0022169416308502>.

# Appendix A

You can add more info, tables, and figures here.