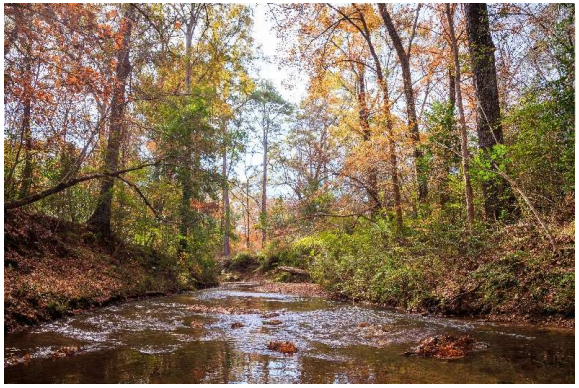

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Coastal Watershed Nutrient Load Modelling: Lavaca Bay

Michael Schramm – Research Specialist
2022-11-18

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Project Area

- Lavaca Bay Watershed
- 3,146 square miles
- 50% Pasture and rangeland
- 20% Cultivated crop
- 5% Developed residential/urbanized

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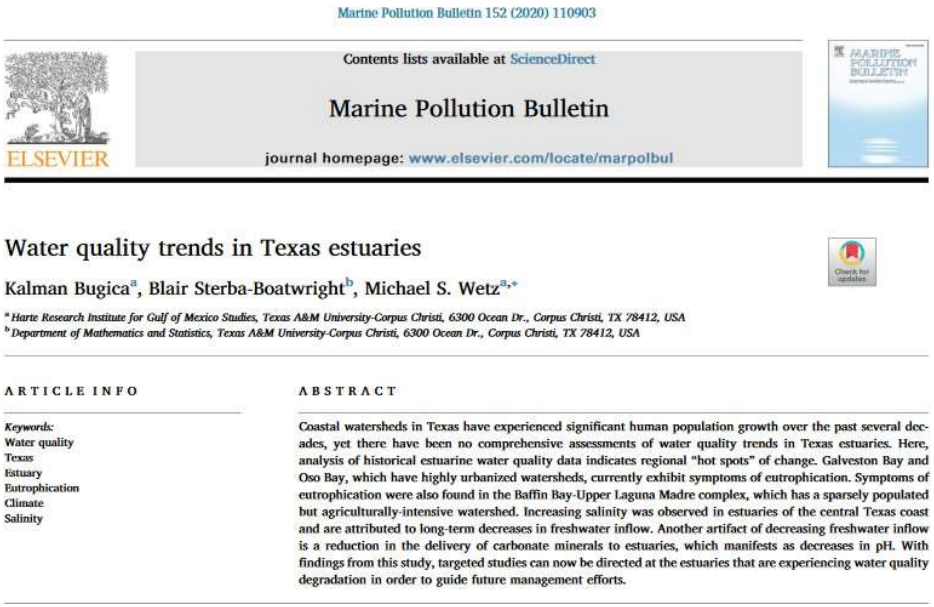
Background

- ⬆ TP and ⬆ Chlorophyll-a concentrations identified in Lavaca bay (Bugica, Sterba-Boatwright, and Wetz,2020).



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Water quality trends in Texas estuaries

Kalman Bugica[a], Blair Sterba-Boatwright[b], Michael S. Wetz[a,*]

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Keywords:
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Climate
Salinity

ABSTRACT

Coastal watersheds in Texas have experienced significant human population growth over the past several decades, yet there have been no comprehensive assessments of water quality trends in Texas estuaries. Here, analysis of historical estuarine water quality data indicates regional "hot spots" of change. Galveston Bay and Oso Bay, which have highly urbanized watersheds, currently exhibit symptoms of eutrophication. Symptoms of eutrophication were also found in the Baffin Bay-Upper Laguna Madre complex, which has a sparsely populated but agriculturally-intensive watershed. Increasing salinity was observed in estuaries of the central Texas coast and are attributed to long-term decreases in freshwater inflow. Another artifact of decreasing freshwater inflow is a reduction in the delivery of carbonate minerals to estuaries, which manifests as decreases in pH. With findings from this study, targeted studies can now be directed at the estuaries that are experiencing water quality degradation in order to guide future management efforts.

Project Objectives

- Goals
  - Quantify the nitrogen and phosphorus loads entering Lavaca Bay.
  - Identify changes over time.
  - Identify potential linkages between nutrient loads/discharge and nutrient concentrations in Lavaca Bay.
  - Engage interested stakeholders to evaluate data visualizations, reports and other project materials and future project directions

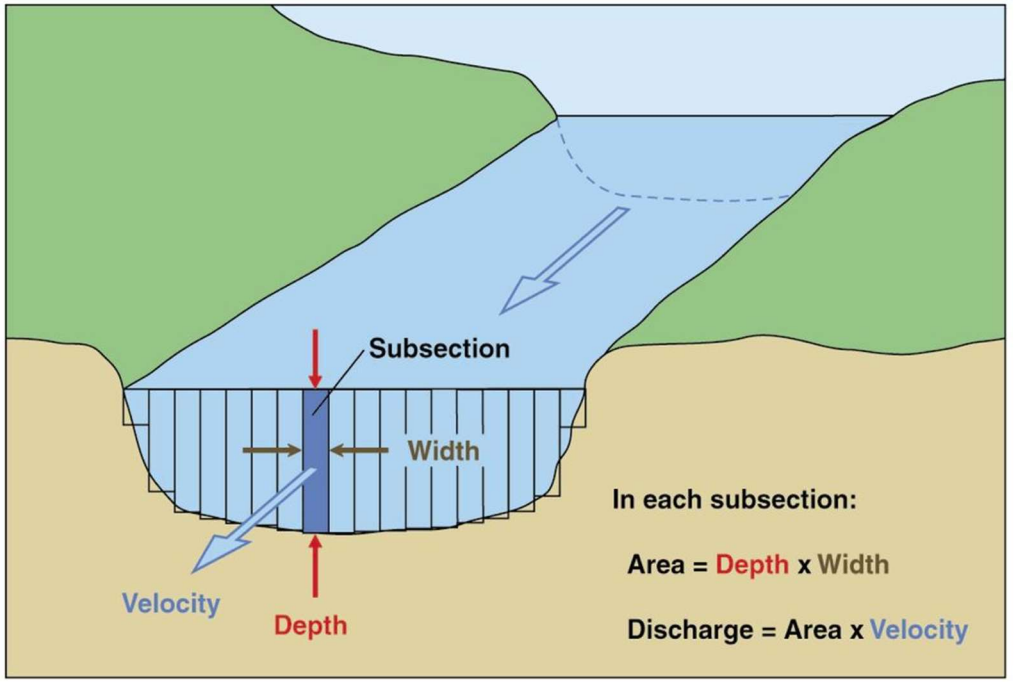
Key Terms

- Concentration – amount of pollutant dissolved in a given volume of water. Typically measured by lab analysis.

Key Terms

- Load – total mass of pollutant carried by the stream at a particular point.

Load = water volume over time x concentration

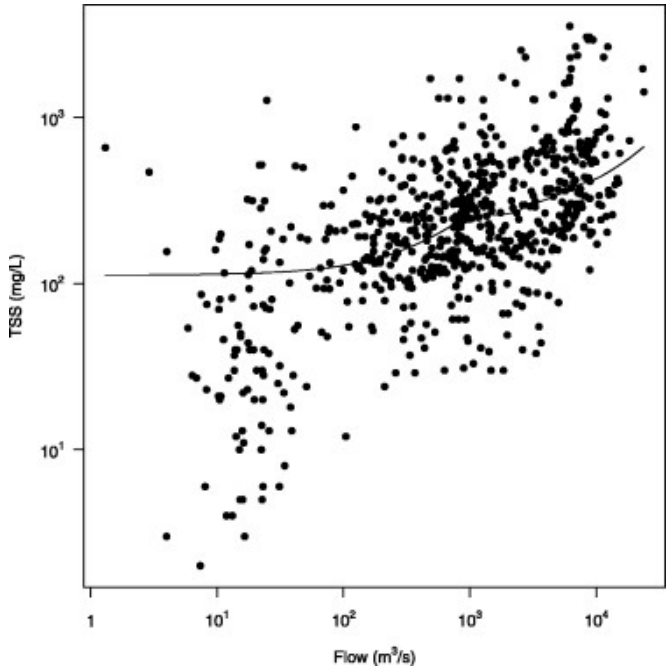


Why Quantify Nutrient Loads?

- To understand water quality changes within a river we want to know the concentration history.
- To understand progress of land-based management we want to know the flow-normalized loads (volume) history.
- To understand impact on estuaries and bays we need the load history.

(Robert Hirsch, USGS)

Why Models?



Load rating curve – Burdekin River Northeast Australia (Kuhnert et al. 2012)

- Flows can be measured/estimated continuously
- Nutrient concentrations are measured quarterly/monthly
- Need to "fill in the gaps"
- Data-driven models develop relationships between concentration, flow, and other variables (year and season)
- Other models try to mathematically represent the entire system (SWAT, QUAL2K, etc.)

Similar Projects

- Chesapeake Bay River Input Monitoring Program – USGS Quantifies nutrient and sediment loads in the nontidal rivers of the Chesapeake Bay Watershed.
- Gulf of Mexico Hypoxia Task Force – USGS, EPA, and others evaluate nitrate loads from the Mississippi River.
- Many individual projects/papers globally.

Goals for Advisory Committee

- Ask questions!
- Do you have concerns with the methodology/approach?
  - Do the figures and tables help you understand the data?
  - What data and info is most useful for your organization?
- Think about how to evolve the project going forward.
  - Do we need to focus on collecting more data, expand the project footprint, model more watersheds, etc.?

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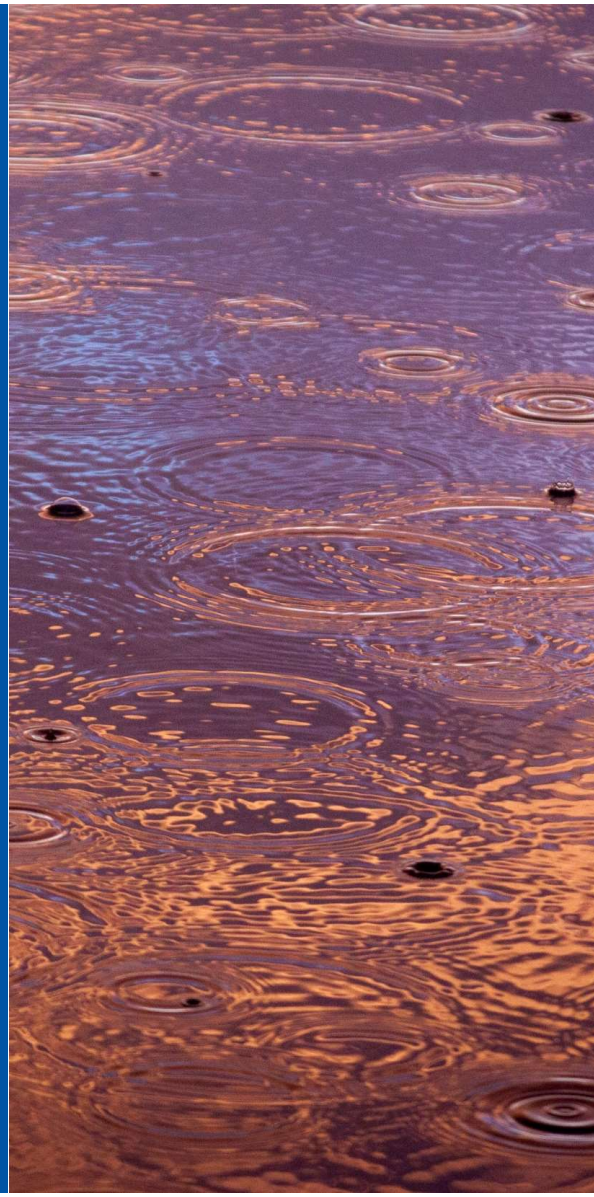
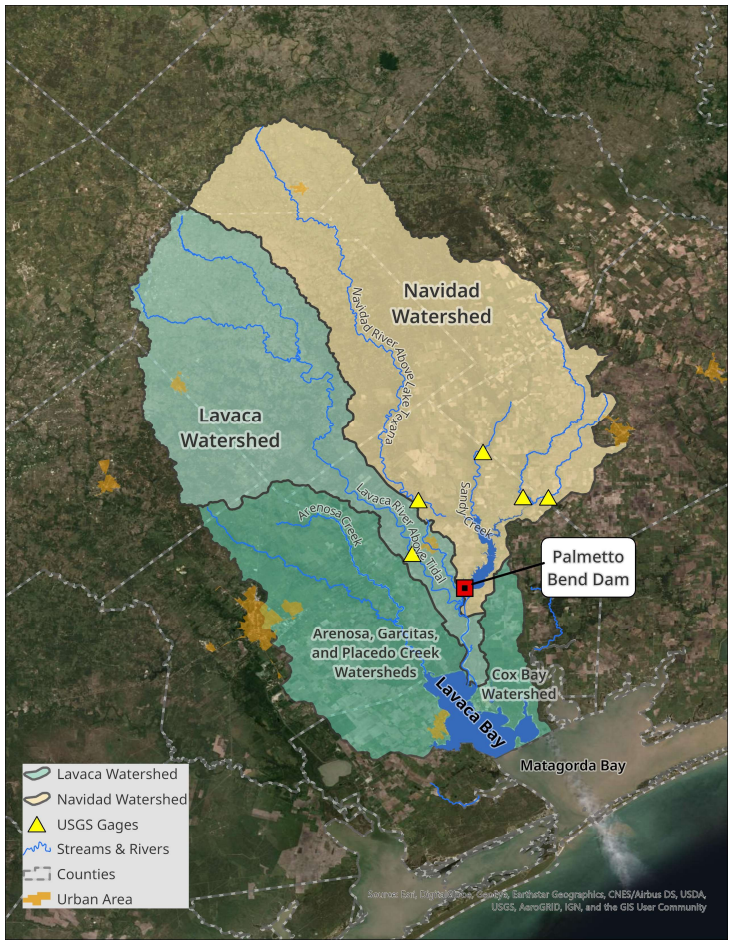
Technical Approach



Lavaca Bay Watersheds

- 1.3 million acre-feet annual discharge
- 65% from Lavaca/Navidad
  - Palmetto Bend Dam = 61% of Lavaca/Navidad discharge
  - Lavaca River nr Edna = 32% of discharge
  - Ungaged downstream runoff = 7%
- Minimal FW gaging or water quality data in Garcitas/Placedo/Cox



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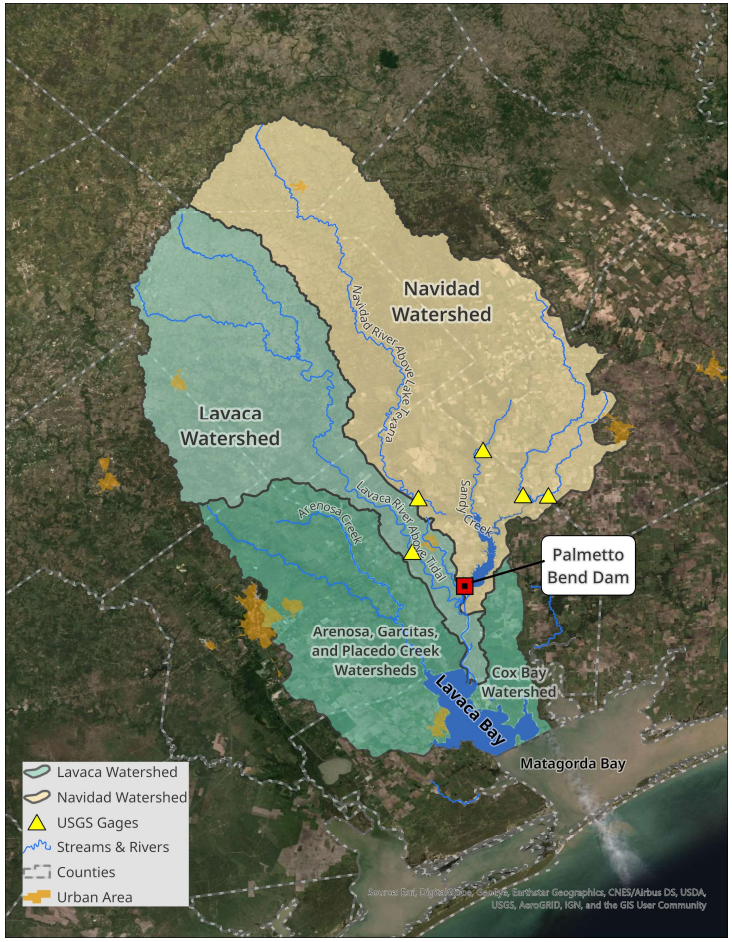
Site ID	Description	N
USGS-08164000	Lavaca River near Edna	NO_3: 74 TP: 80
Palmetto Bend Dam	Navidad River at Palmetto Bend Dam, Lake Texana	NO_3: 62 TP: 81
USGS-08164390	Navidad River at Strane Pk	NO_3: 59 TP: 77
USGS-08164450	Sandy Creek nr Ganado	NO_3: 56 TP: 75
USGS-08164503	West Mustang Creek nr Ganado	NO_3: 63 TP: 81
USGS-08164504	East Mustang Creek nr Louise	NO_3: 61 TP: 79



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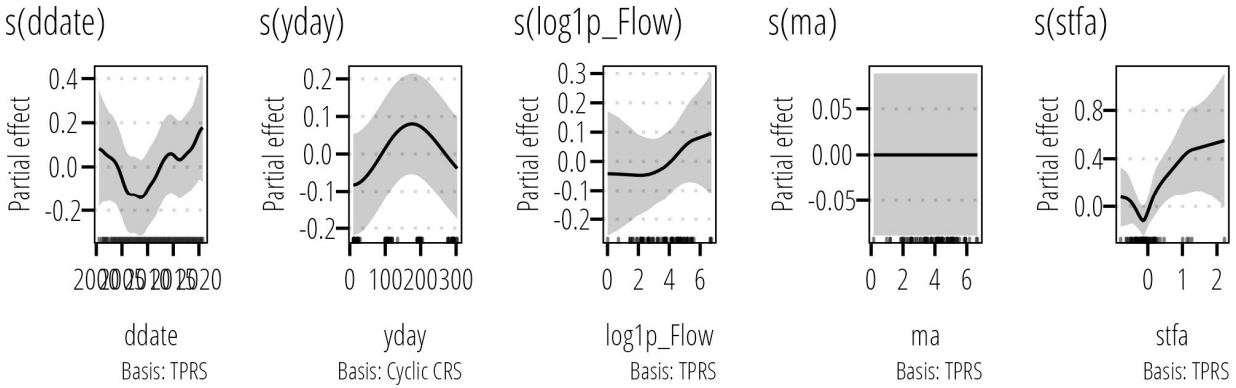
Load Estimation Models

- Focused on statistical models due to data availability
- Common approaches
  - LOADEST (USGS)
  - WRTDS (USGS)
  - Semi-parametric regression (Kuhnert et al. 2012; Robson and Dourdet 2015; McDowell et al. 2021)

Load Estimation Models

- Why semi-parametric regression (Generalized Additive Model or GAM)?
  - Flexibility to add different predictor variables
  - No previous assumptions about relationships between predictor variables required.



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What does a GAM look like?

$$Y = s(date) + s(day) + s(Flow) + s(ma) + s(fa)$$

- Y = Nitrate or Total Phosphorus Concentration
- Date = long-term trend
- Day = seasonal trend
- Flow = mean daily discharge (total inflow for Lake Texana)
- MA = exponential moving average of flow
- FA = Flow-anomaly

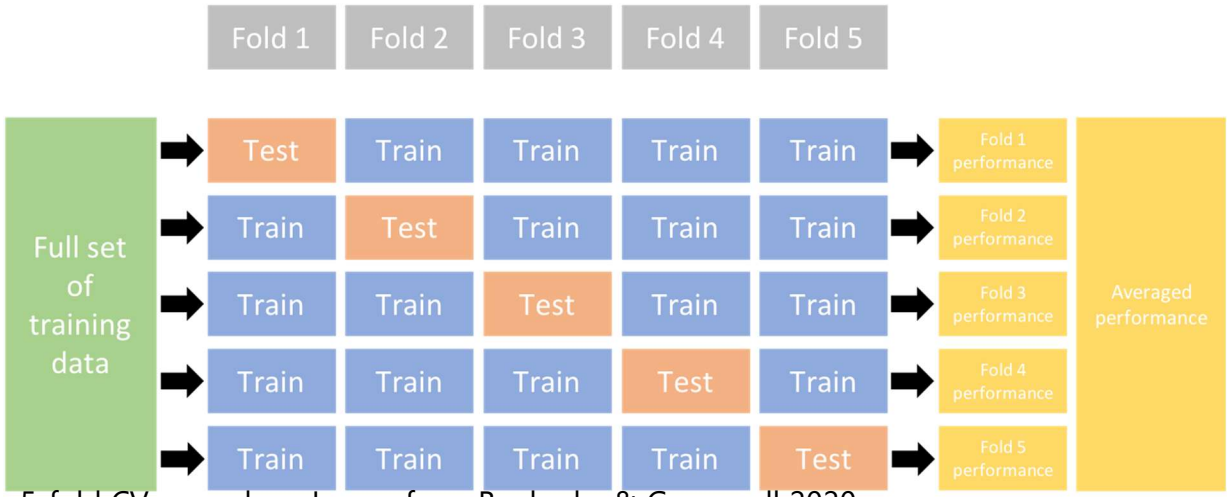
What does that mean?

Concentration is a function of

- (1) long term change
- (2) seasonal change
- (3) streamflow
- (4) previous streamflow events
- (5) how dry or wet it is relative to previous periods

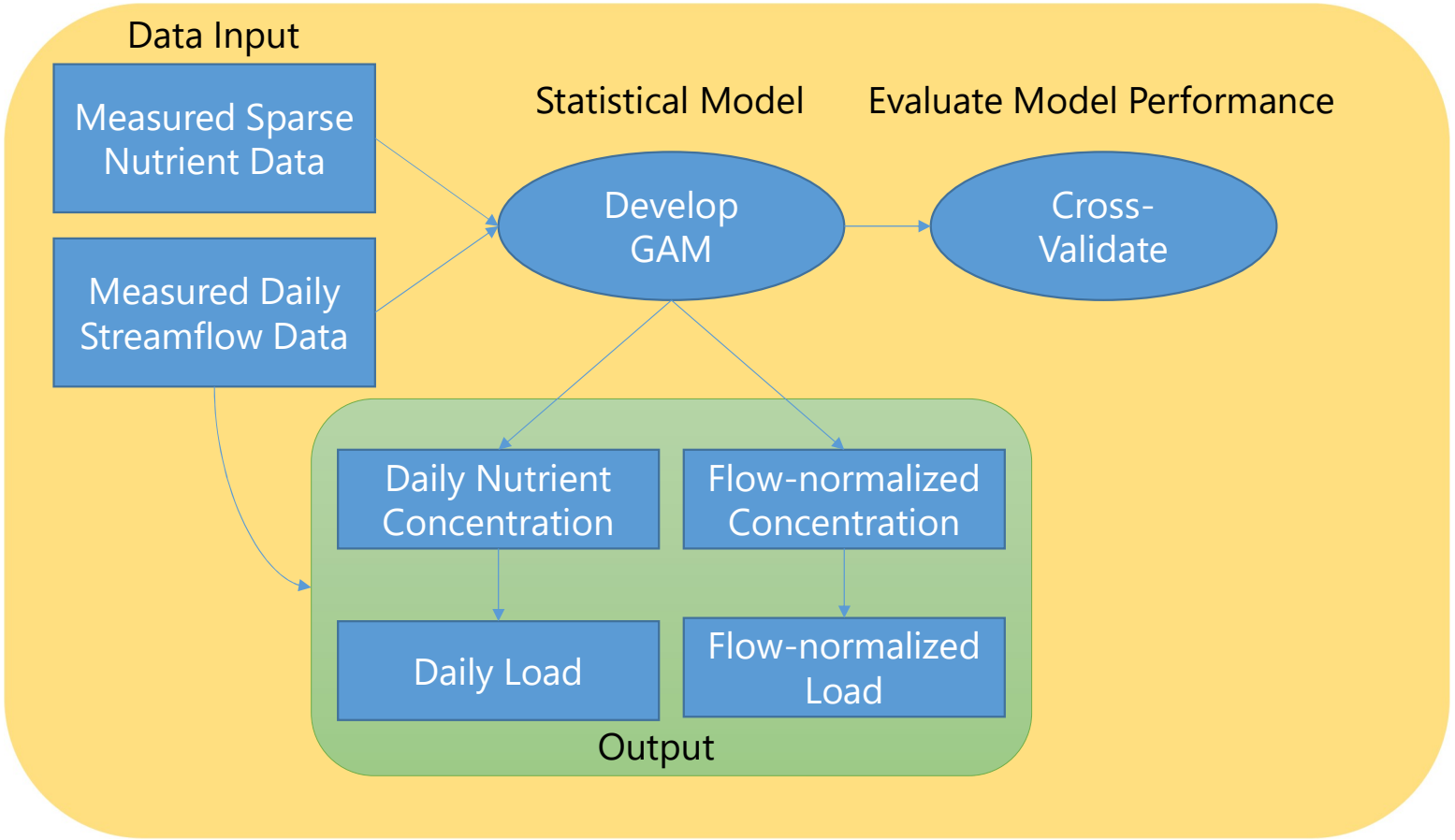
Validate Models

- Validation = Estimates of how well our method performs to **unknown data**
- Validation technique = Repeated 5-fold cross validation



5-fold CV procedure. Image from Boehmke & Greenwell 2020 (https://bradleyboehmke.github.io/HOML/)

Overview



Applied to each site

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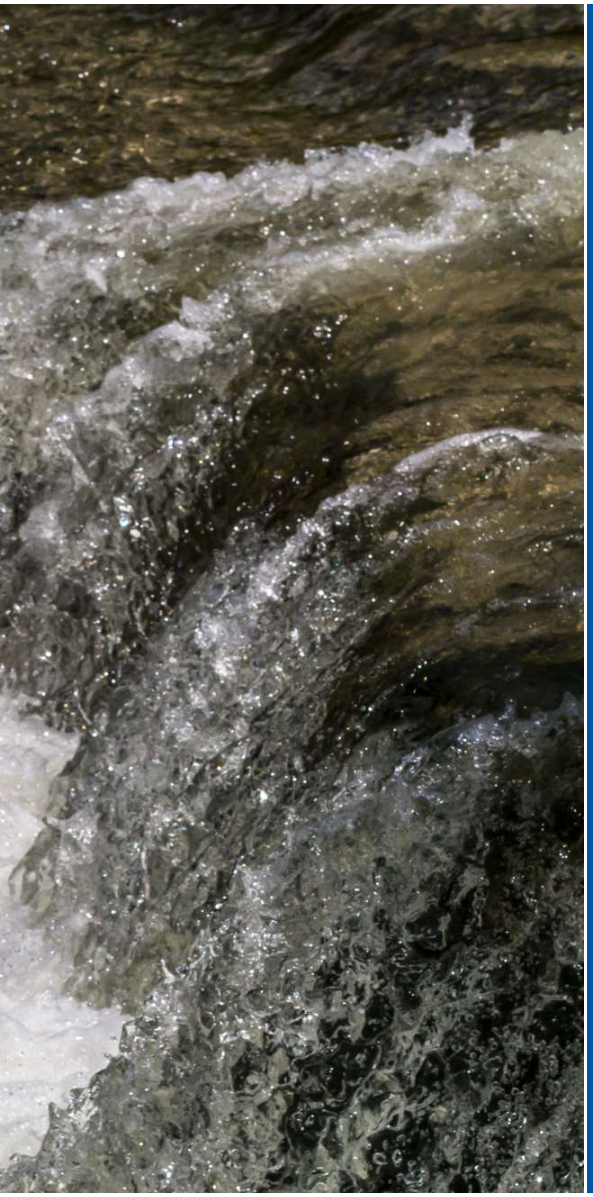


Results

Model Performance

Site ID	Description	Parameter	NSE	R^2	Percent Bias	Evaluation*
USGS-08164000	Lavaca River near Edna	NO_3	0.76	0.76	-7.8	Very Good
USGS-08164000	Lavaca River near Edna	TP	0.77	0.77	-7.5	Very Good
Palmetto Bend Dam	Navidad River at Palmetto Bend Dam, Lake Texana	NO_3	0.42	0.60	-43	Satisfactory/Not Satisfactory
Palmetto Bend Dam	Navidad River at Palmetto Bend Dam, Lake Texana	TP	0.88	0.96	-18	Very Good/Good

Moriasi, D. N., M. W. Gitau, N. Pai, and P. Daggupati. "Hydrologic and Water Quality Models: Performance Measures and Evaluation Criteria." *Transactions of the ASABE* 58, no. 6 (December 30, 2015): 1763–85. https://doi.org/10.13031/trans.58.10715.

Comparison with published results

Parameter	Annual Yield ($kg/km^2/yr$)	Approach	Time Period	Reference
TP	42.9 (CI=34.4, 54.0)	GAM	2000-2020	Current Project
TP	45.2	SPARROW	2012	Wise, Anning, and Miller (2019)
TP	42	SWAT	1977-2005	Omani, Srinivasan, and Lee (2014)
TP	20.81-91.58	SPARROW	2002	Rebich et al. (2011)
TP	28.9	LOADEST	1972-1993	Dunn (1996)

Wise, D. R., D. W. Anning, and O. W. Miller. 2019. "Spatially Referenced Models of Streamflow and Nitrogen, Phosphorus, and Suspended-Sediment Transport in Streams of the Southwestern United States." Scientific Investigations Report 2019-5106. Reston, Virginia: U.S. Geological Survey https://doi.org/10.3133/sir20195106

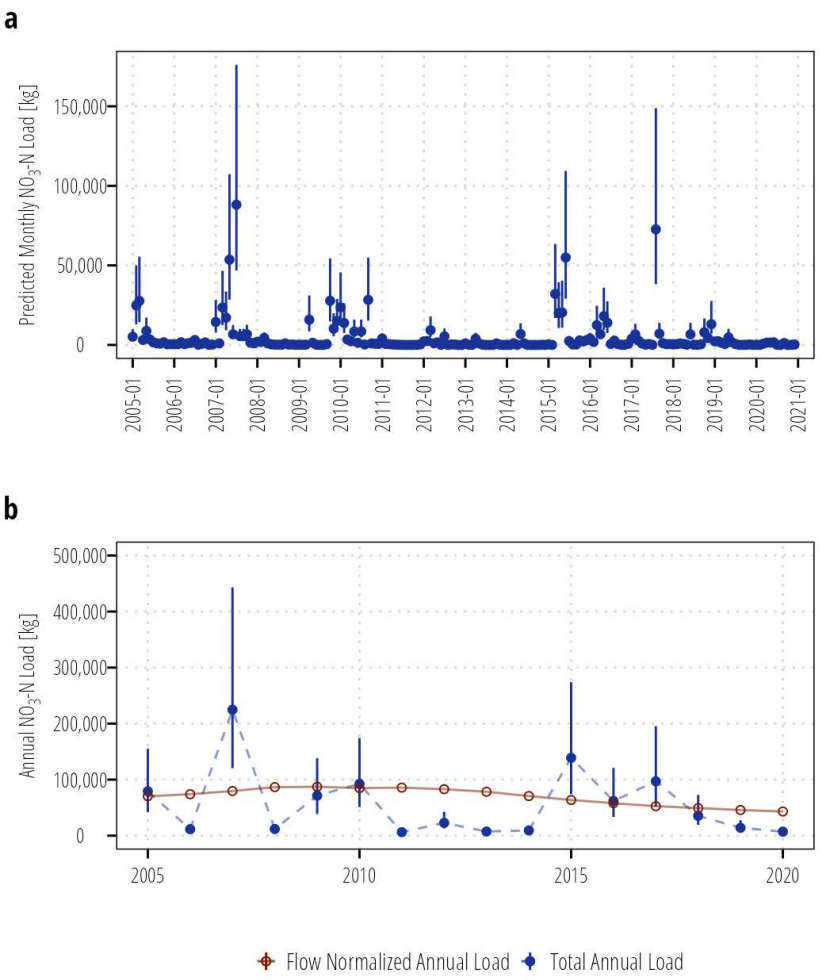
Omani, N., R. Srinivasan, and T. Lee. 2014. "Estimation of Sediment and Nutrient Loads to Bays from Gauged and Ungauged Watersheds." Applied Engineering in Agriculture, December, 869–87 https://doi.org/10.13031/aea.30.10162

Rebich, Richard A., Natalie A. Houston, Scott V. Mize, Daniel K. Pearson, Patricia B. Ging, and C. Evan Hornig. 2011. "Sources and Delivery of Nutrients to the Northwestern Gulf of Mexico from Streams in the South-Central United States1: Sources and Delivery of Nutrients to the Northwestern Gulf of Mexico From Streams in the South-Central United States." JAWRA Journal of the American Water Resources Association 47 (5): 1061–86. https://doi.org/10.1111/j.1752-1688.2011.00583.x

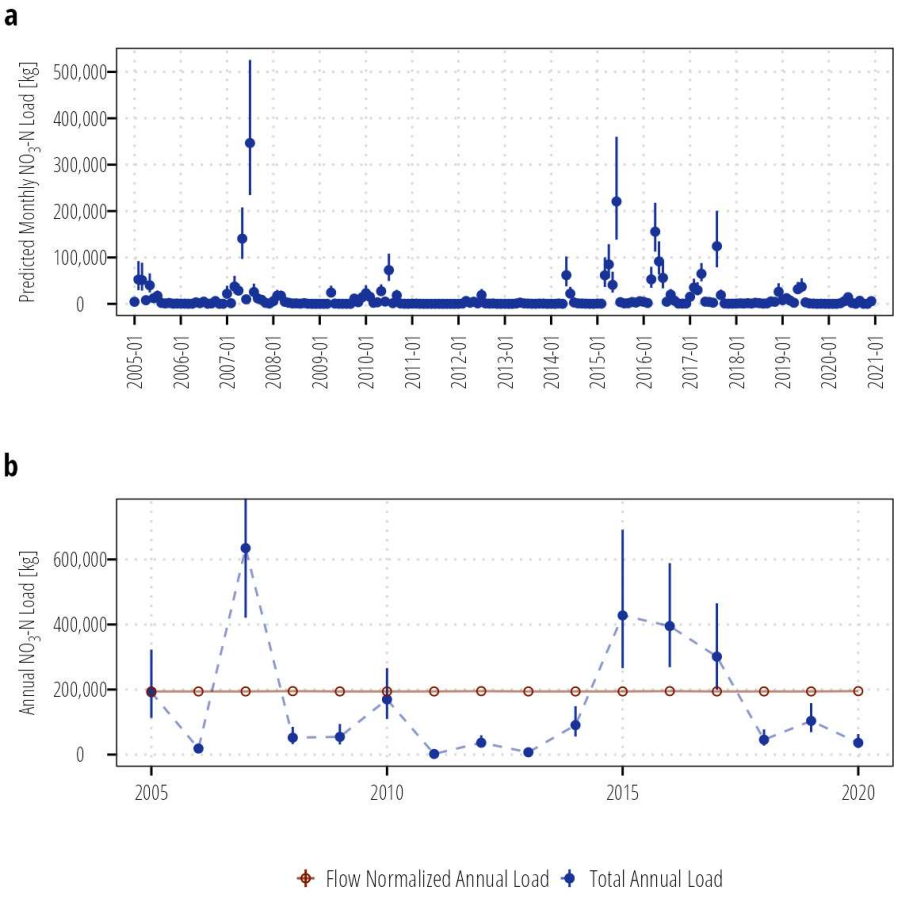
Dunn, David. 1996. "Trends in Nutrient Inflows to the Gulf of Mexico from Streams Draining the Conterminous United States, 1972-93." Water-Resources Investigations Report 96-4113. Austin, Texas: USGS. https://doi.org/10.3133/wri964113

Nitrate

Lavaca River



Navidad River



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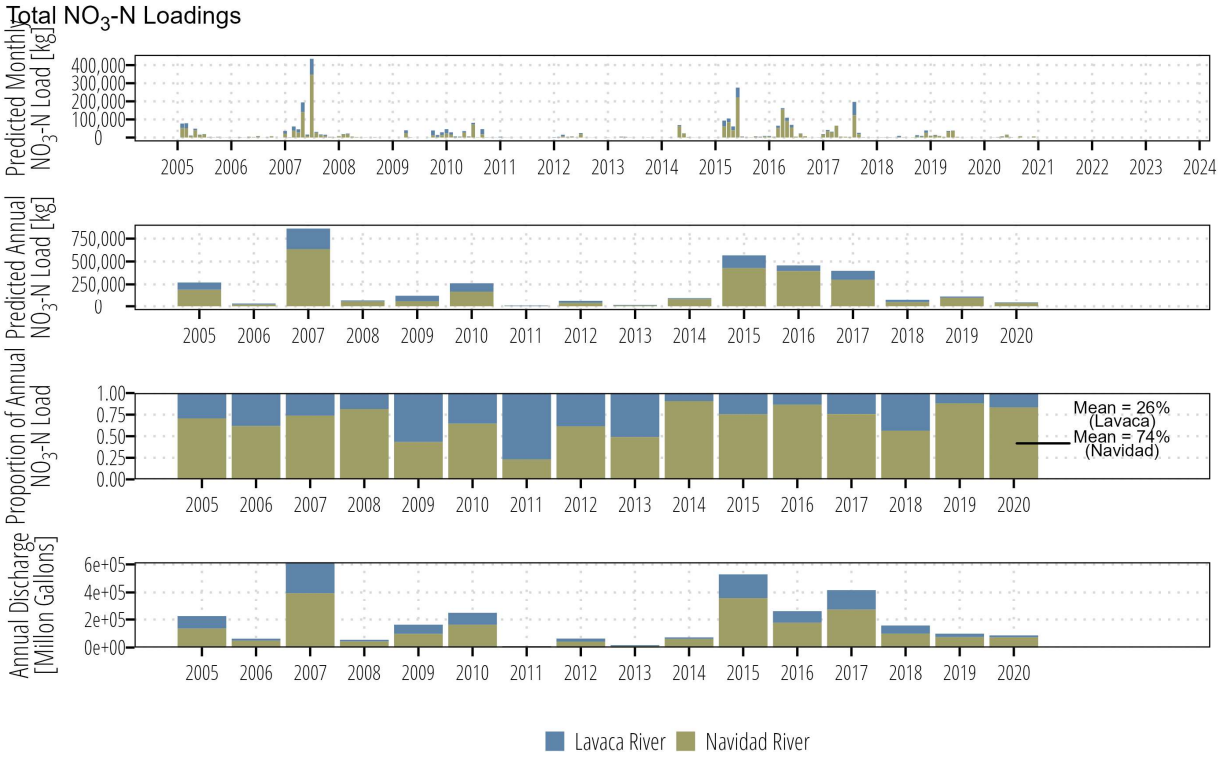

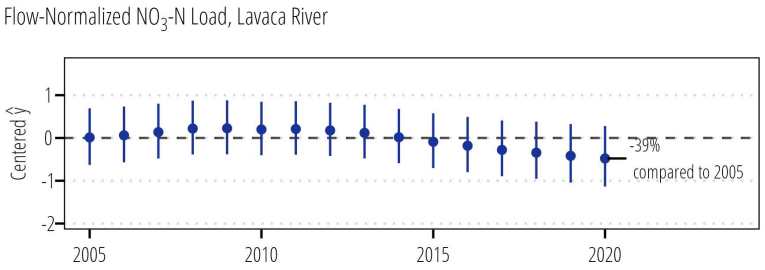

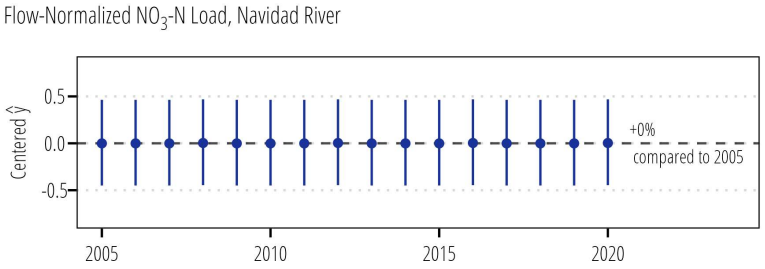

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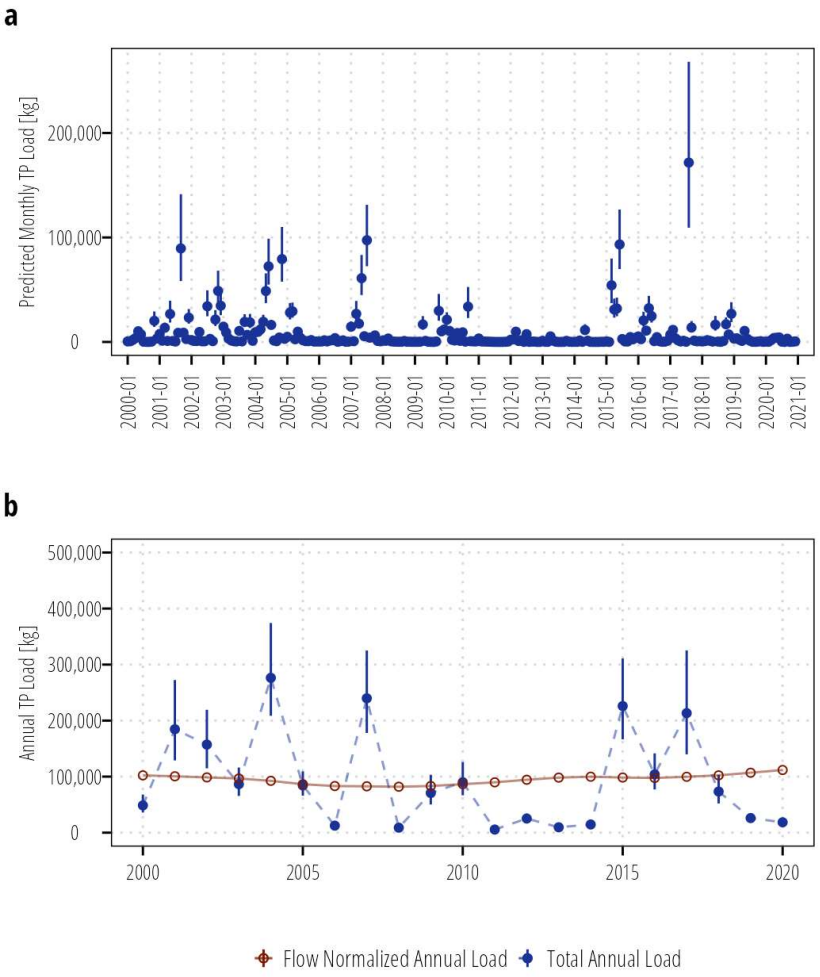
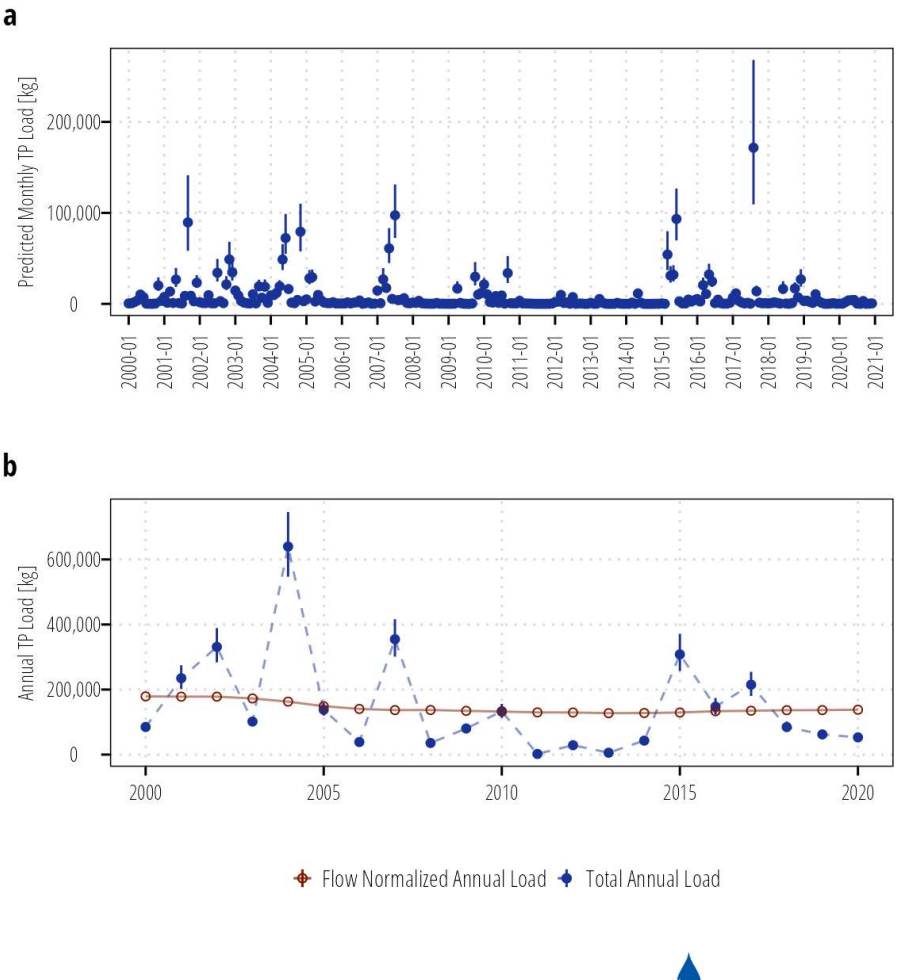
TP

Lavaca River



Navidad River



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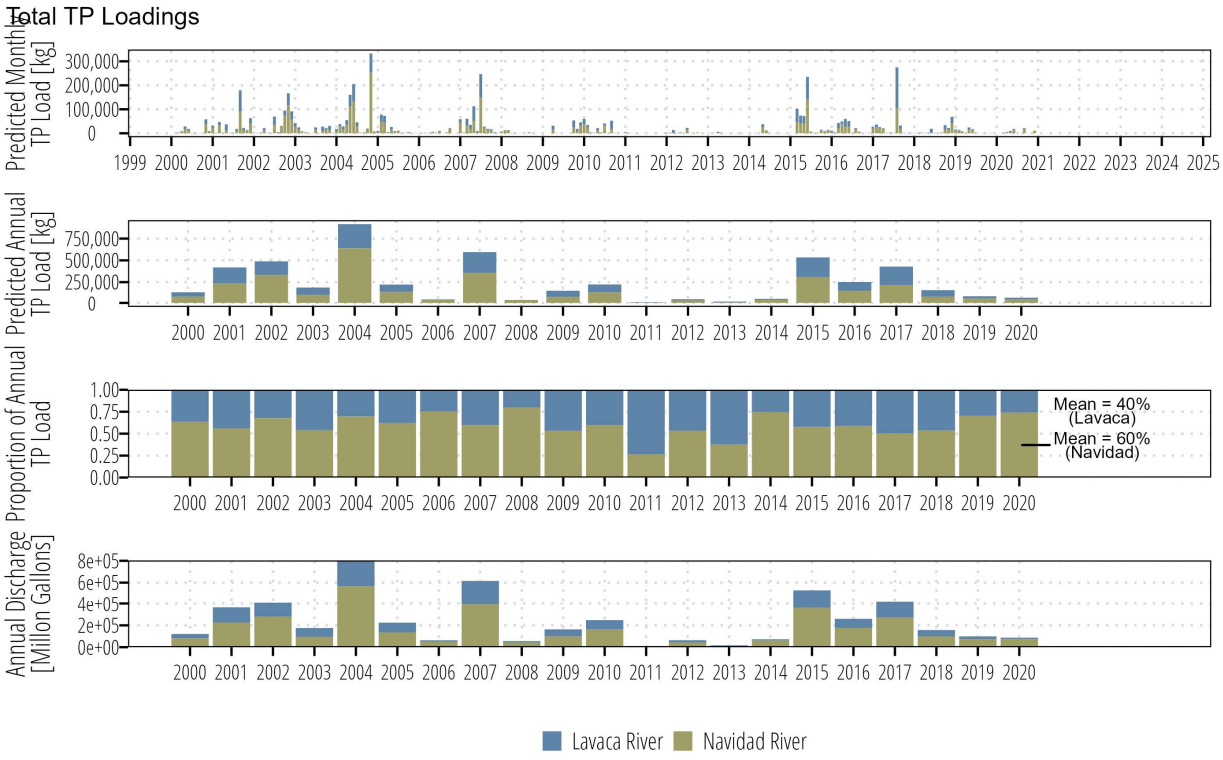

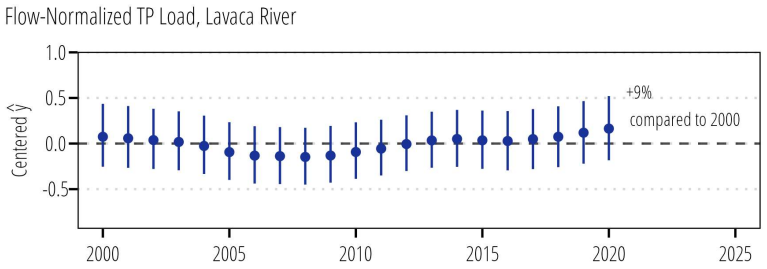

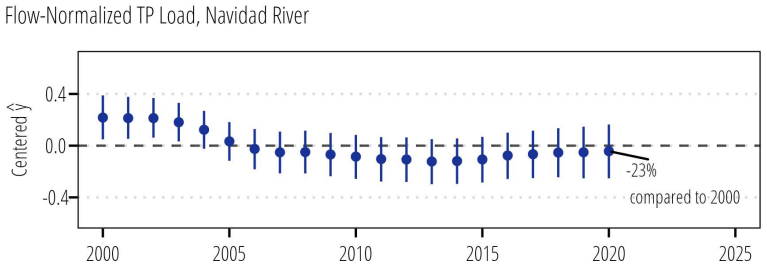

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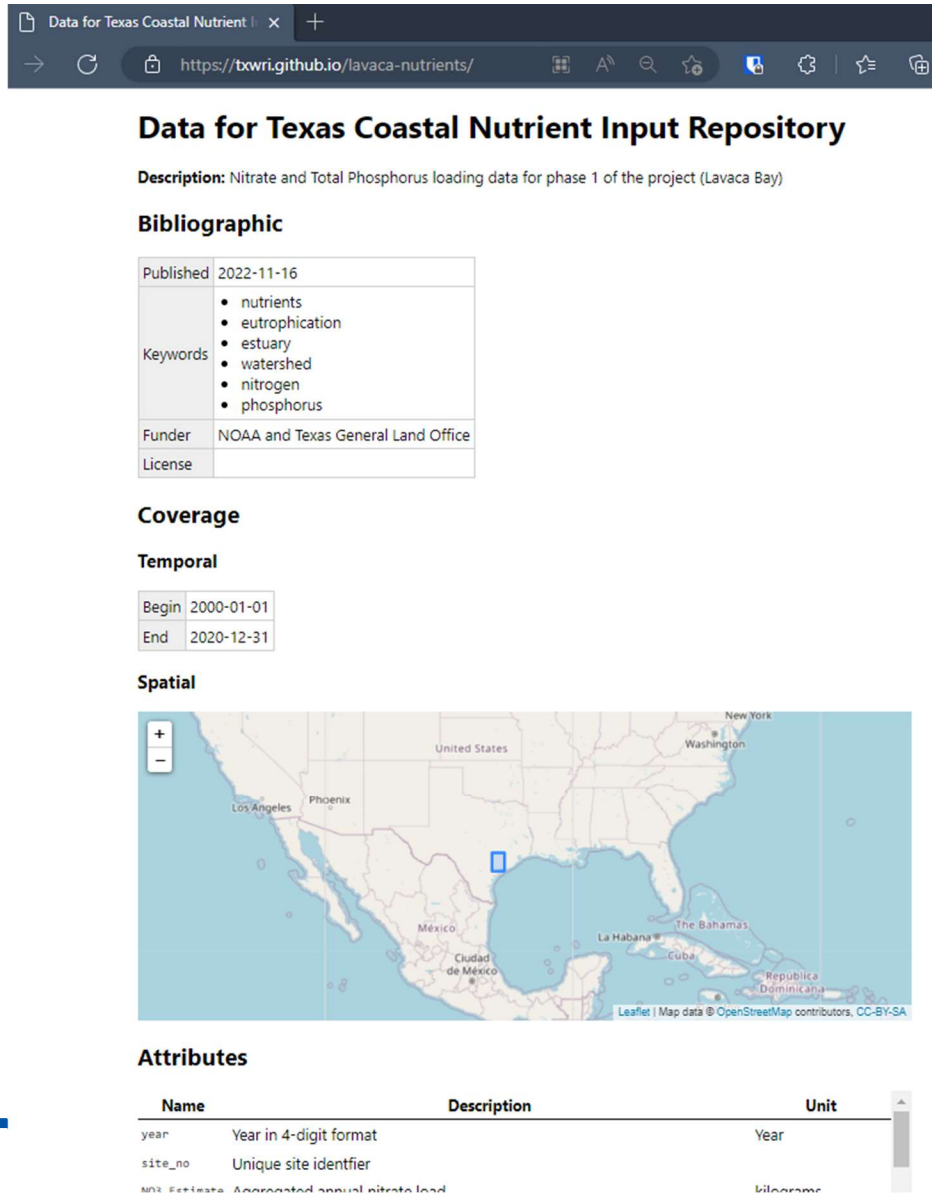
Discussion

- GAMs appear suitable for load estimation.
  - Nitrate model for Navidad may need modification (explore lake level, and meteorological predictors).
- Actual loads reflect flow variability as expected.
- We generally did not detect statistically significant trends in flow-normalized loads (exception, Navidad River TP).
  - This is probably a reflection of quarterly/monthly sampling designed to capture ambient water quality. High load events are event driven and will need flow/event biased sampling to statistically detect trends.

Data Sharing

- Project website: https://tcnir.twri.tamu.edu/
- Data downloads: https://txwri.github.io/lavaca-nutrients/
- Plans to submit to Water Data for Texas: https://www.waterdatafortexas.org/coastal



Next Steps

- Identify potential linkages between nutrient loads/discharge and nutrient concentrations in Lavaca Bay.
  - In-progress - utilizing methodology by Rebecca Murphy and others in the Chesapeake Bay.
- Develop formal data visualization and data summary products for review and sharing.
- Write and submit publications for peer-review.
- Prospects for continuing this project?
  - Additional monitoring; load estimates for Matagorda Bay; nothing?

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Thank You!

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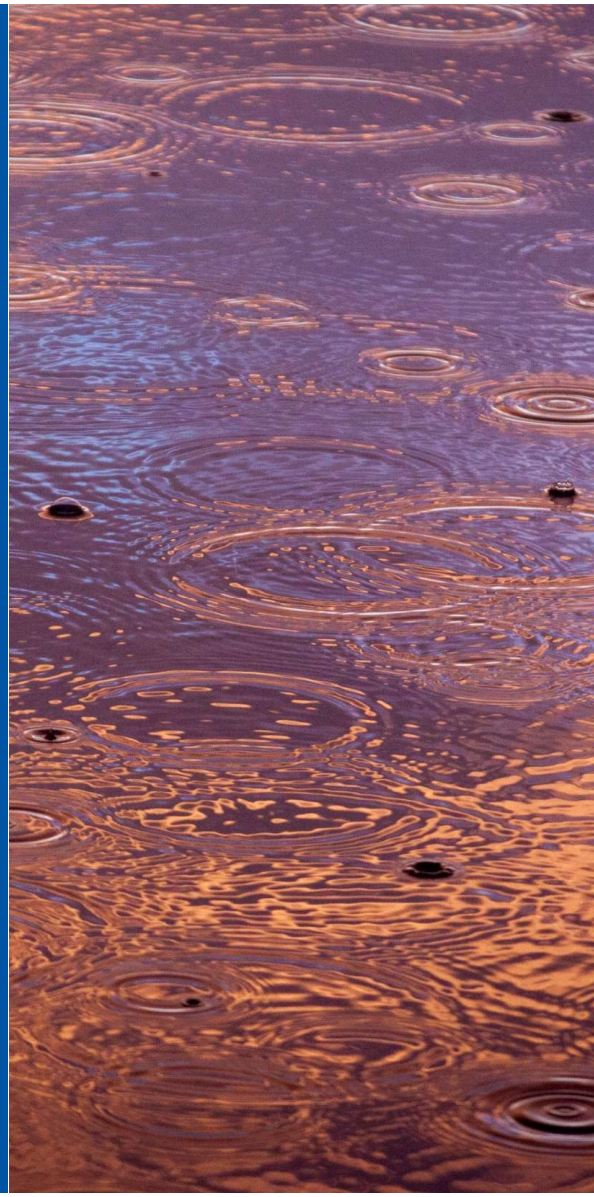
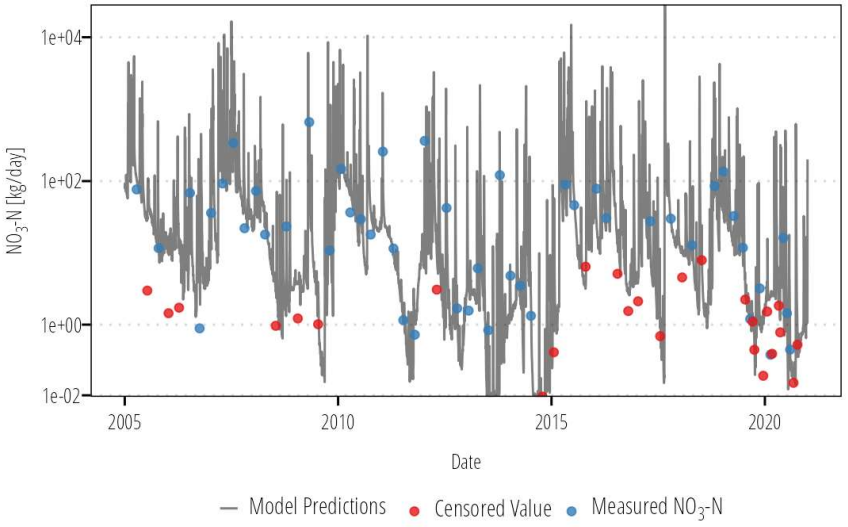
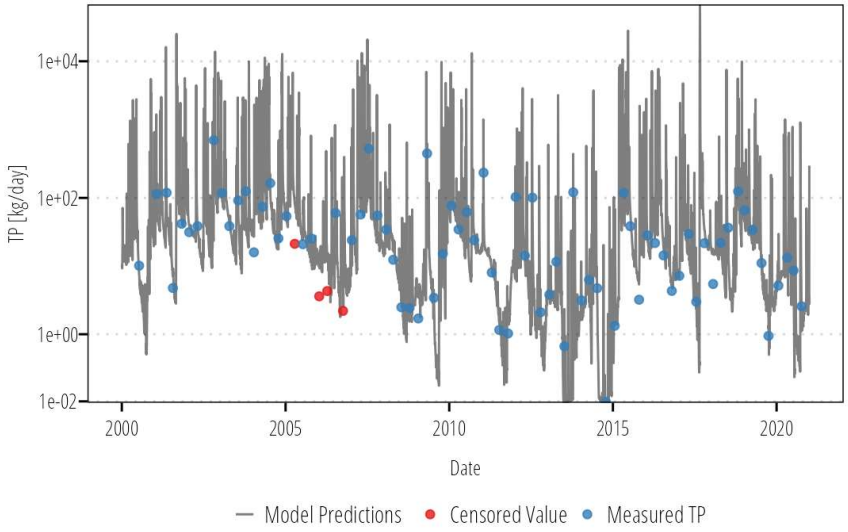
Extra Slides



Lavaca River Daily Total Loads





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Model Performance

Site ID	Description	Parameter	NSE	R2	Percent Bias	Evaluation*
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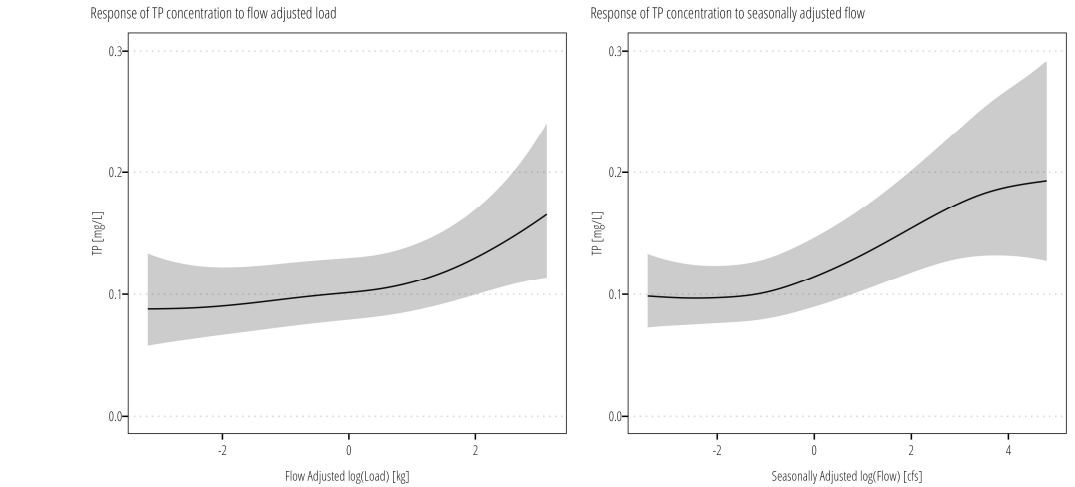
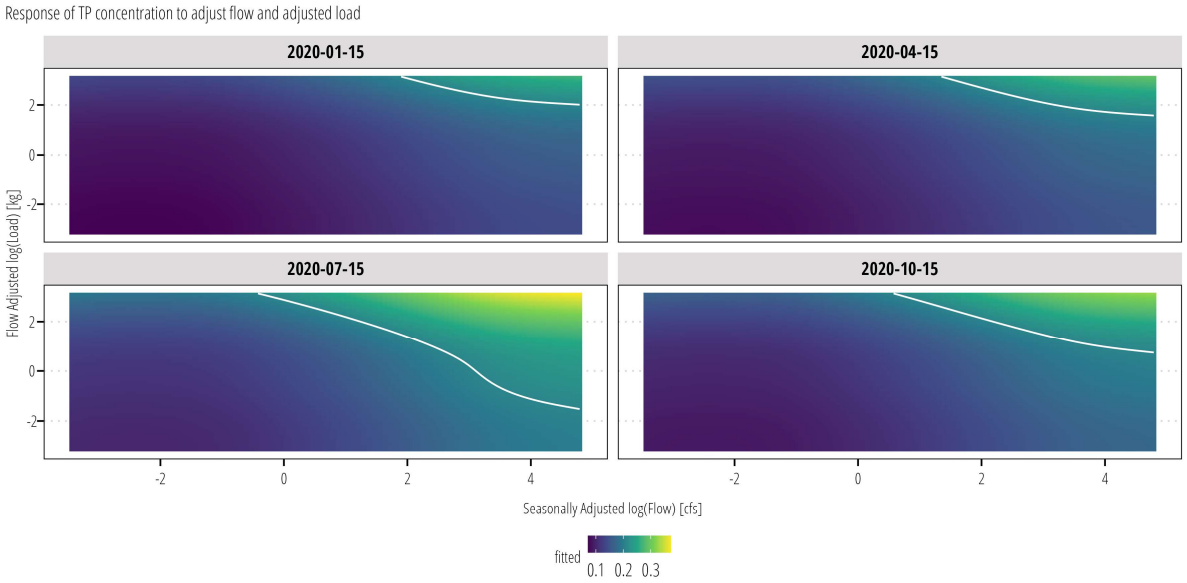
Palmetto Bend Dam	Navidad River at Palmetto Bend Dam, Lake Texana	NO_3	0.42	0.60	-43	Satisfactory/Not Satisfactory
USGS-08164390	Navidad River at Strane Pk	NO_3	0.59	0.69	-16	Good
USGS-08164450	Sandy Creek near Ganado	NO_3	0.45	0.46	-16	Satisfactory
USGS-08164503	W Mustang Creek near Ganado	NO_3	0.41	0.49	-13	Satisfactory
USGS-08164504	E Mustang Creek ne Louise	NO_3	0.38	0.54	-46	Satisfactory/Not Satisfactory

Model Performance continued

Site ID	Description	Parameter	NSE	R2	Percent Bias	Evaluation*
USGS-08164000	Lavaca River near Edna	TP	0.77	0.77	-7.5	Very Good
Palmetto Bend Dam	Navidad River at Palmetto Bend Dam, Lake Texana	TP	0.88	0.96	-18	Very Good/Good
USGS-08164390	Navidad River at Strane Pk	TP	0.95	0.98	-9.1	Very Good
USGS-08164450	Sandy Creek near Ganado	TP	0.78	0.81	-6.0	Very Good
USGS-08164503	W Mustang Creek near Ganado	TP	0.86	0.89	-6.5	Very Good
USGS-08164504	E Mustang Creek ne Louise	TP	0.85	0.85	-9.2	Very Good

Preliminary Lavaca Bay Model Results





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