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Did bacteria concentrations decrease following TMDL development?

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Total Maximum Daily Loads and *Escherichia coli* Trends in Texas Freshwater Streams

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Abstract

Fecal indicator bacteria are routinely used to assess surface water sanitary quality. The State of Texas uses Total Maximum Daily Loads to address water bodies that exceed the allowable fecal indicator bacteria criteria. The effectiveness of these processes in decreasing the fecal indicator bacteria concentrations has been debated due to the diversity and nature of fecal indicator bacteria sources. We assessed actual and flow-adjusted trends in measured *Escherichia coli* (*E. coli*) concentrations at 721 freshwater stream sites from 2001 through 2021. We also compared odds of statistical improvement of *E. coli* concentrations at sites before and after the adoption of Total Maximum Daily Loads (adopted from 2008 through 2014). Results indicate non-significant differences in the odds of statistically detected improvements in *E. coli* concentration between pre-Total Maximum Daily Load and post-Total Maximum Daily Load sites. Although the State of Texas and numerous watershed stakeholders have made efforts to address water quality impairments, these results join a body of evidence that water quality improvements are stagnating in the state. Furthermore, this study leverages water quality data used for state water quality standards assessment purposes and highlights that robust monitoring program design is needed to effectively assess the progress of water quality planning efforts.

Elevated fecal indicator bacteria (FIB) concentrations are responsible for approximately 40% of water quality impairments in the State of Texas (TCEQ 2019). *Escherichia coli* (*E. coli*) and enterococci are non-host specific bacteria typically present in the gut of warm-blooded animals and utilized as FIB to indicate the potential for recent fecal contamination of water

Metrics

Full text views: 482

Details

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water quality
trend test

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What has been done?

- 187 TMDLs
- $171M Ag Cost Share
- Urban stormwater, wastewater improvements*
- Municipal ordinances and design guidelines*

through 2018

*** unquantified!**

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Are we making progress?

320 impaired segments → 237 impaired segments (2010-2018)

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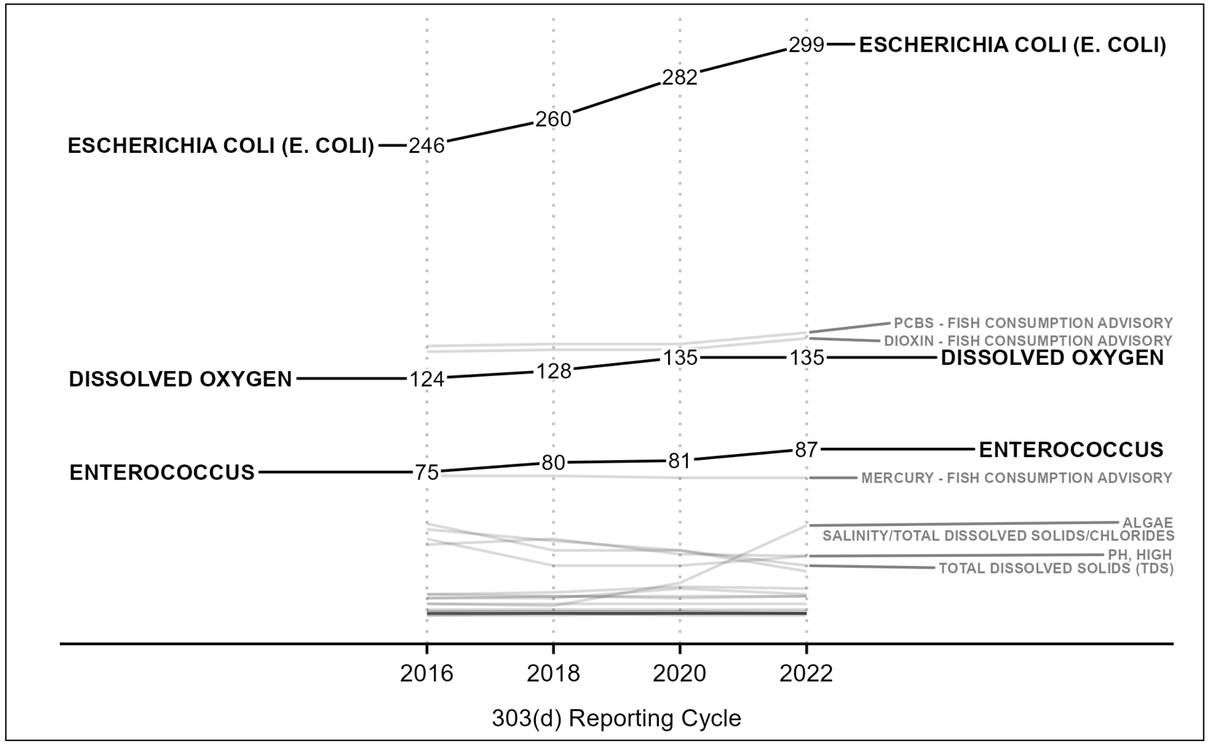
Are we making progress?



Number of impaired assessment units have increased

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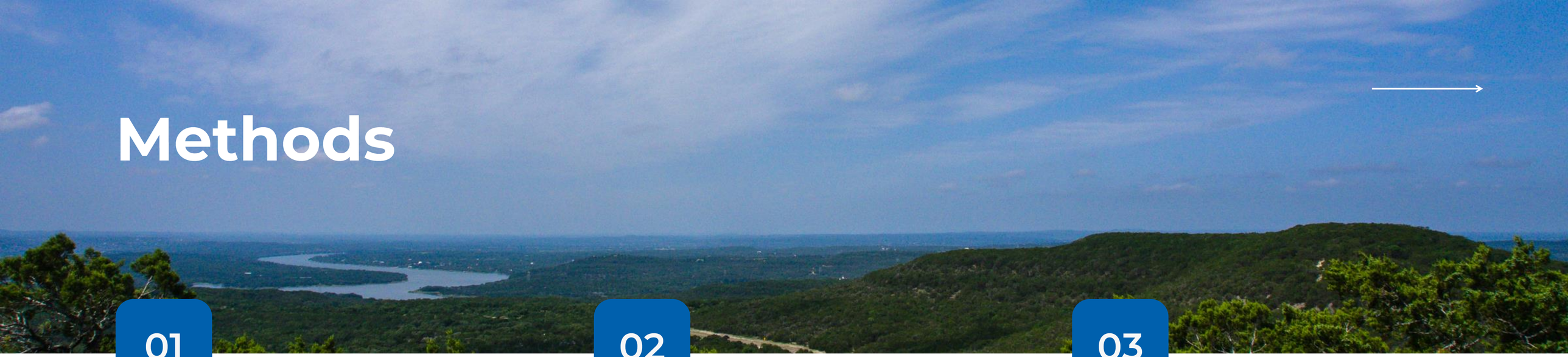
Are we making progress?

- Administrative listing and delisting are imperfect indicators
- Environmental improvement can be achieved without delisting
- Natural conditions can mask improvements from BMPs

Our Approach

Compare trends (slopes) in station specific *E. coli* concentrations:

- Stations after TMDLs
- Stations before TMDLs
- Stations without TMDLs
- Compare both raw trends and flow-normalized trends



Methods

01

Trend Analysis

- Mann-Kendall test on pre and post data sets.
- Mann Kendall test on seven-year period 2015-2021 for sites without a TMDL.
- Stations with a TMDL adopted after 2015 were excluded.

02

Flow normalization

- Mann-Kendall test was fit to the residuals of a semiparametric regression fit to the station's concentration discharge relationship.

03

Odds Ratios

- Estimated odds of water quality improvement based on the slope and p-value of the station specific Mann-Kendall test.
- Negative Slope and $p < 0.1$ were considered as stations with decreasing *E. coli*.

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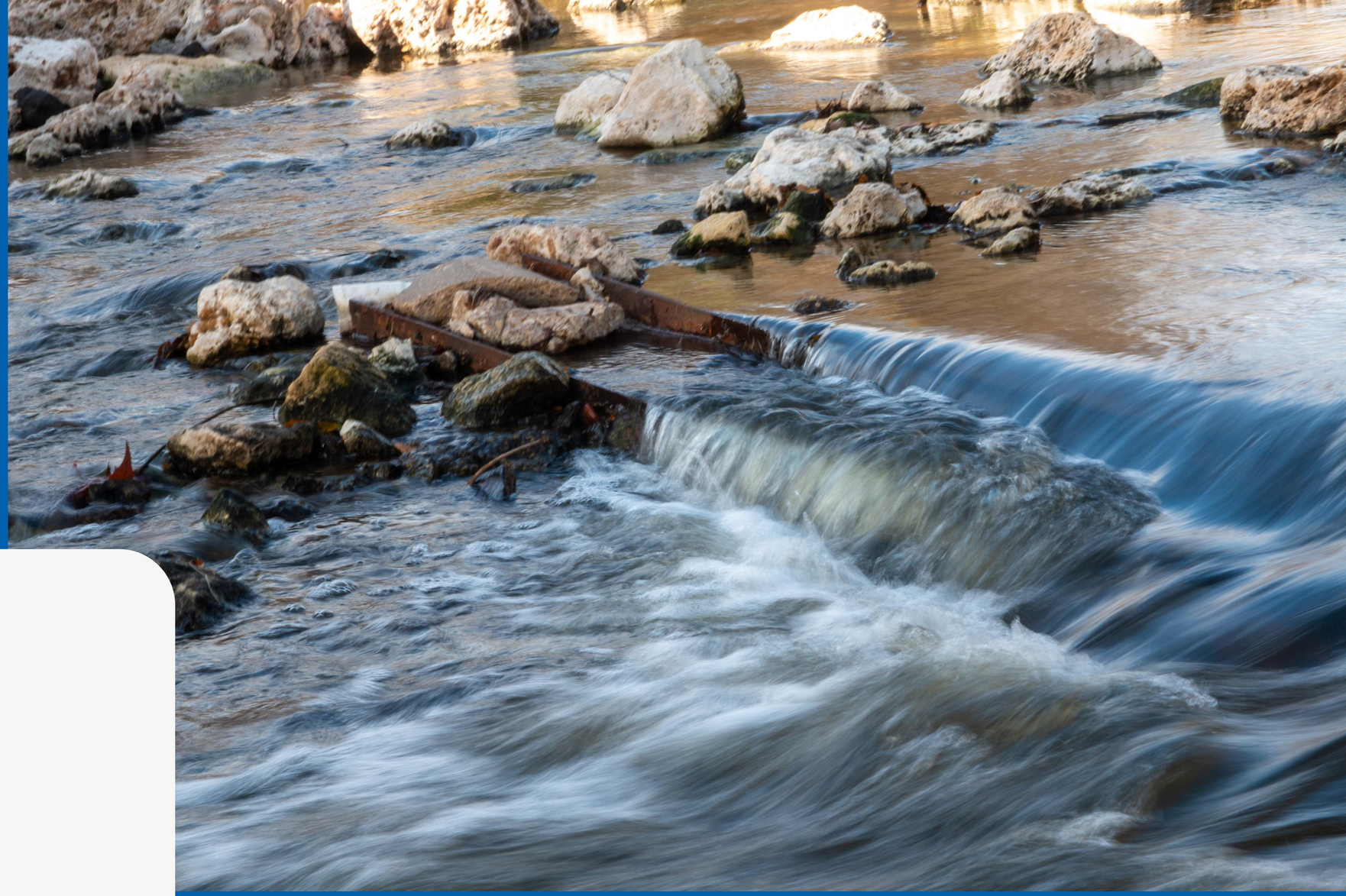


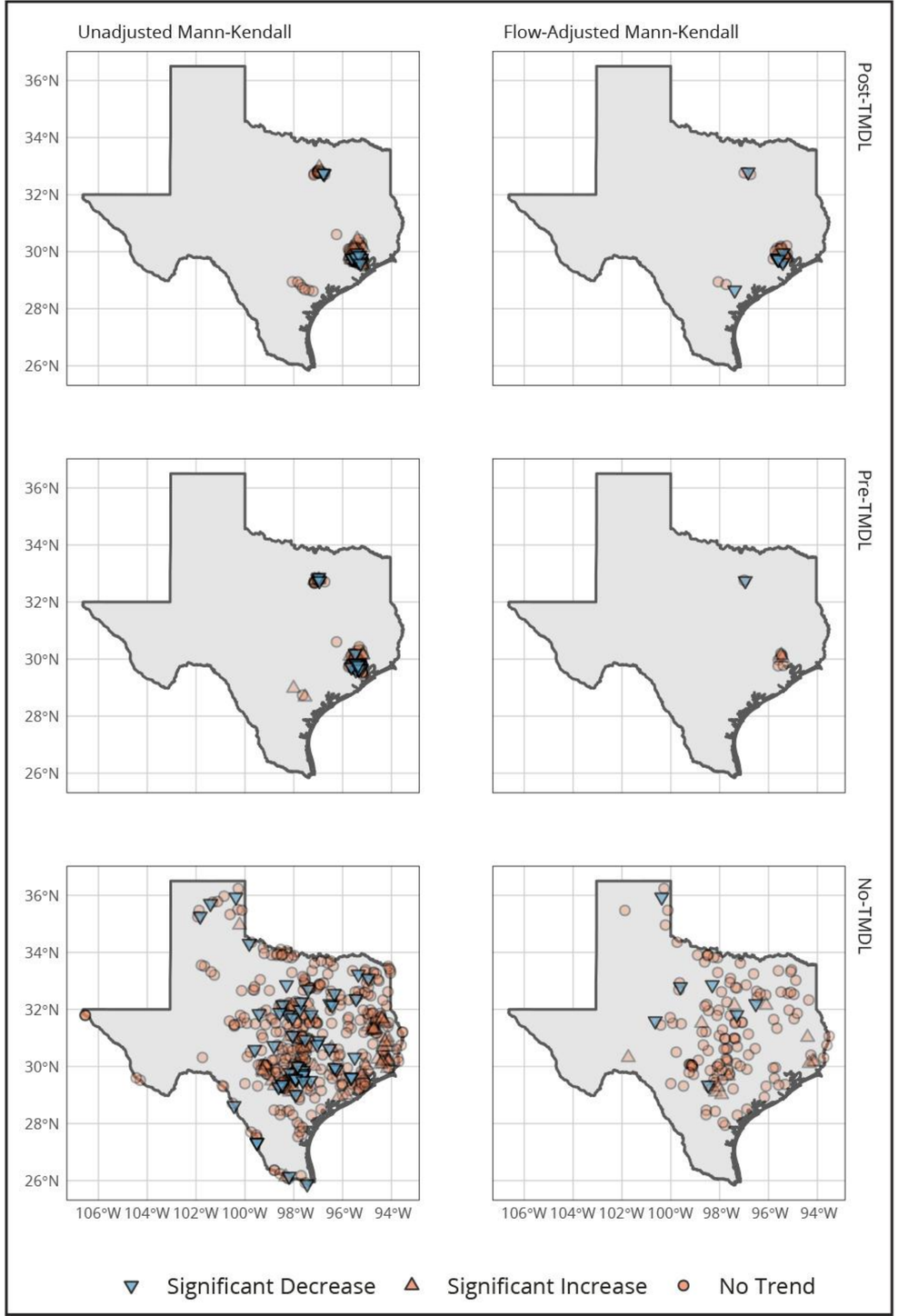
Results

Percent of Stations with Decreasing *E. coli*

Stations without TMDLs: 9.2% (n=552)

Stations before TMDLs: 11% (n=146)

Stations after TMDLs: 7.3% (n=164)



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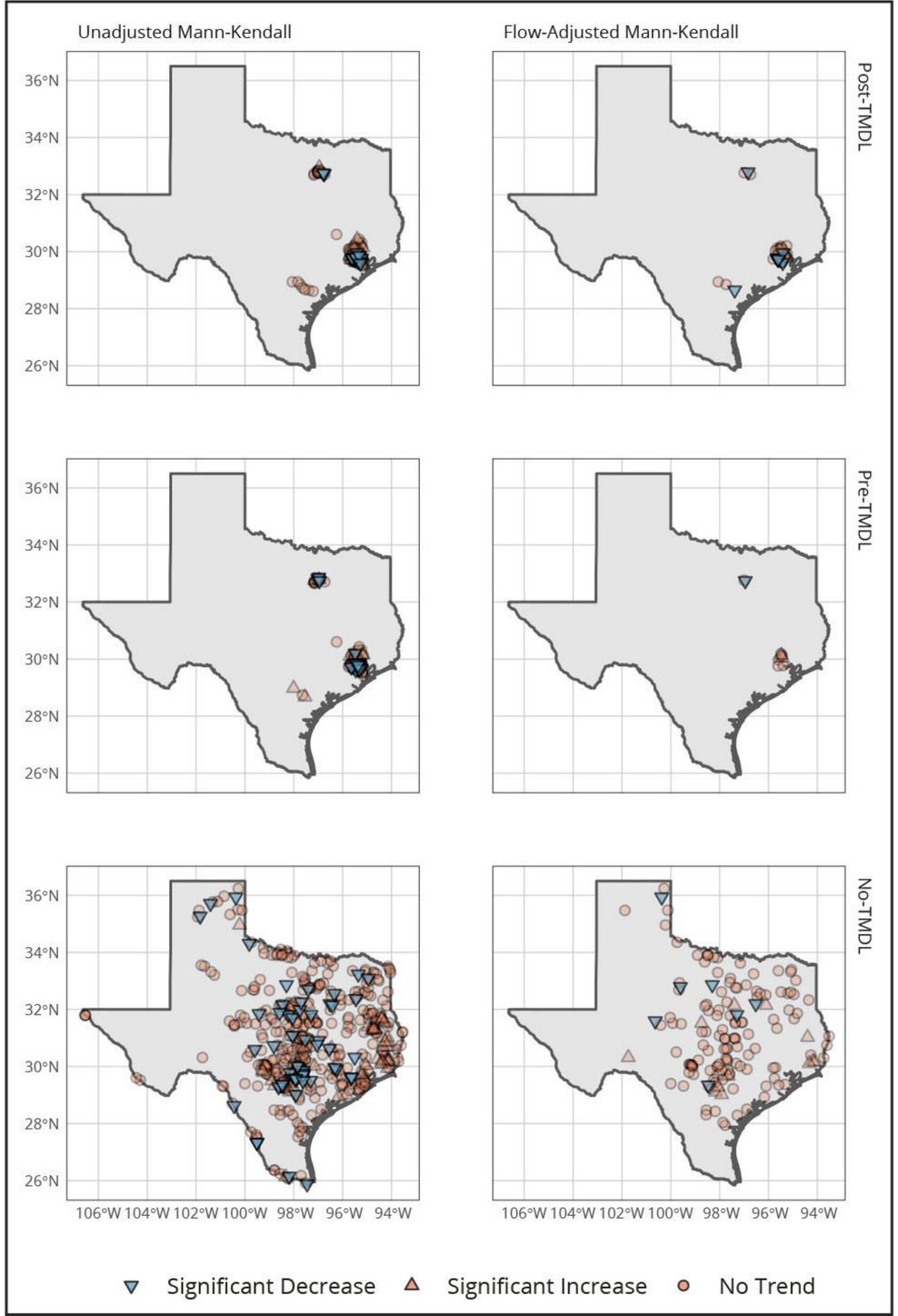
Percent of Stations with Decreasing Flow-Normalized *E. coli*

Stations without TMDLs: 4.7% (n=148)

Stations before TMDLs: 10% (n=10)

Stations after TMDLs: 17.4% (n=46)



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What are the differences in odds of *E. coli* decreasing at a station?

Station Type	Odds Ratio	95% CI	N
Post TMDL	1	-	164
Pre TMDL	1.56	[0.72 - 3.49]	146
No TMDL	1.29	[0.69 – 2.59]	552

For **Pre TMDL** stations, the odds of decreasing *E. coli* is 1.56 times that of a Post TMDL station, but the difference is **not significant** at the 95% confidence level.

For stations **without a TMDL**, the odds of decreasing *E. coli* is 1.29 times that of a Post TMDL station, but the difference is **not significant** at the 95% confidence level.

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What are the differences in odds of flow-normalized *E. coli* decreasing at a station?

Station Type	Odds Ratio	95% CI	N
Post TMDL	1	-	46
Pre TMDL	0.53	[0.03 - 3.45]	10
No TMDL	***0.24***	***[0.08 – 0.70]***	***148***

Compared to **Pre TMDL** stations, Post TMDL stations had 1.88 times the odds of decreasing flow normalized *E. coli*, but the difference is **not significant** at the 95% confidence level.

Compared to stations without a TMDL, **Post TMDL stations had 4.17 times the odds** of decreasing flow normalized *E. coli* (**significant** at 95% confidence level)

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There is not strong evidence that measured *E. coli* concentrations will decrease after a TMDL

WHY?

- Some uncontrollable sources:
  - Reported FIB naturalization in stream sediment/bank soils.
  - Wildlife
- Probable increases in population, urbanization, impervious surfaces in TMDL watersheds.
- We don't know if EQIP funding or related adoption of Agriculture BMPs increase in TMDL watersheds.
- Nonpoint sources are challenging – lots of work remain on BMP performance, scaling, and maintenance.

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Take away messages

Link water quality outcomes to actions.

We can and should evaluate water quality responses to programs, policies, and regulations.

Natural hydrologic conditions matter.

Hydrologic conditions masked some of the improvements achieved at individual stations.

Can we improve TMDL implementation?

No evidence that TMDLs are associated with improving H_2O quality.

What is associated with water quality improvement?

Can we collate data on watershed level funding, ordinances, projects, stakeholder involvement, etc. across the state?

What hinders improvement?

Are there natural or human influenced watershed characteristics that prevent improvement?

Other opportunities to measure success.

Can we more extensively use BST, QMRA, and other novel methods to inform progress in reducing human health risk in recreational water?

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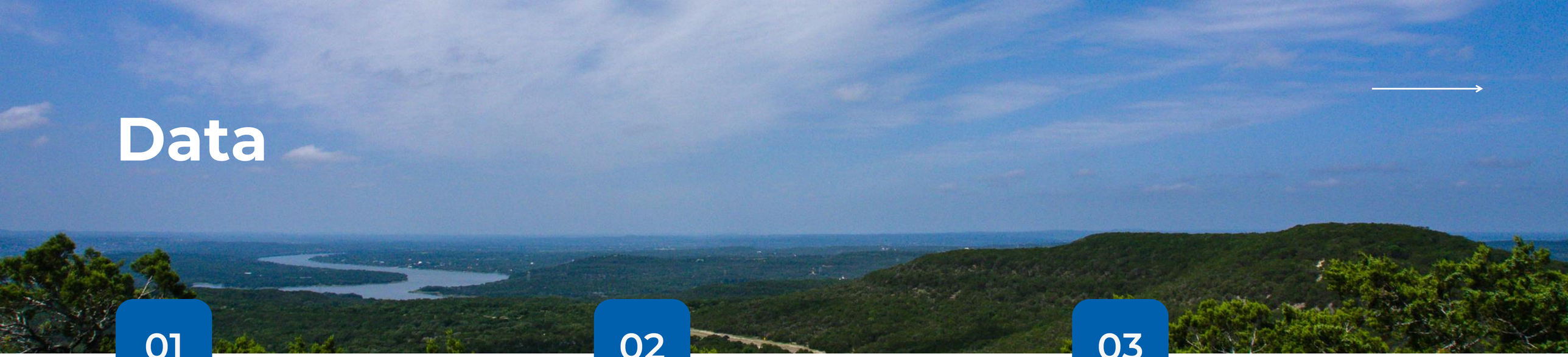
Extra Slides

Methods, Data, Study Limitations



Data

01

Station specific *E. coli*

- All *E. coli* data for SWQM stations 2001-2021.
- Split data by pre, post, and no TMDL.
- Discard data with <3 samples per year over seven years.

02

Streamflow

- SWQM stations linked to nearest mainstem USGS gage within 4 km.

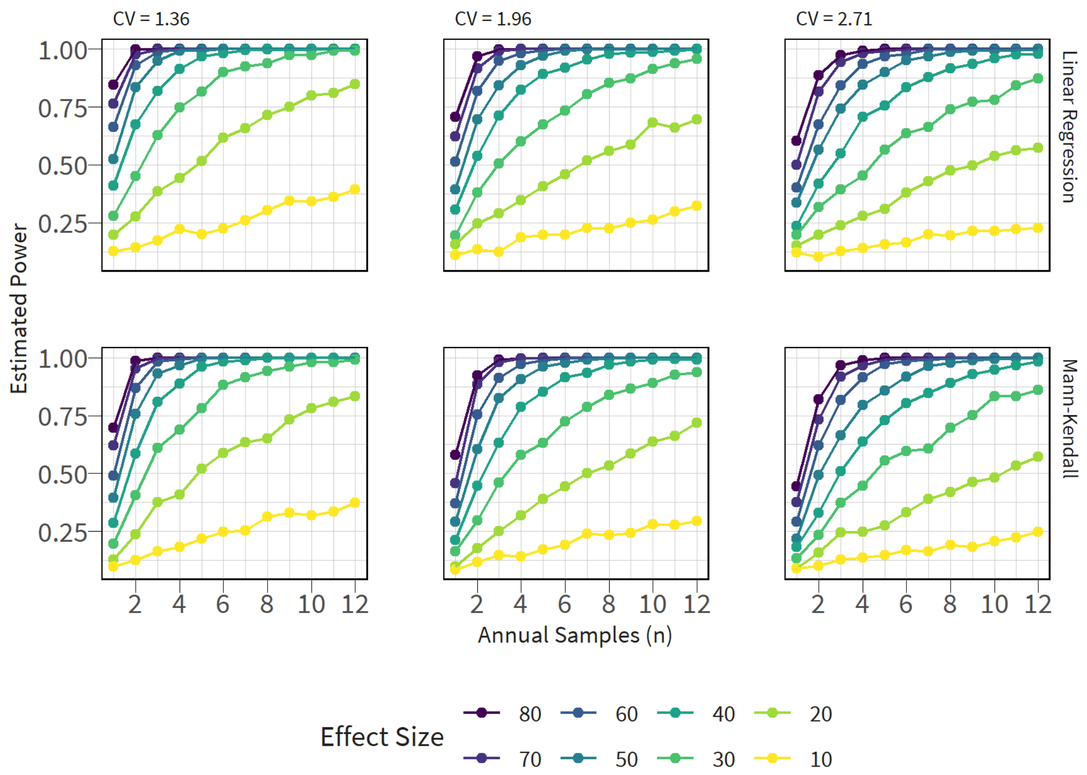
03

TMDLs

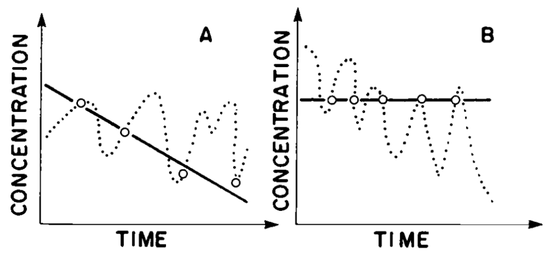
- Assessment units with bacteria TMDLs obtained from ATTAINS.
- Spatially linked to stations using NHDPlus.

Limitations

- Quarterly sampling is not sufficient for detecting small trends. See Schramm 2021.
- Sites with quarterly sampling are limited to detecting ~40% reductions.
- On average, sites needed 67-84% reductions to meet standards so this was considered adequate.



Schramm, M. 2021. Estimating statistical power for detecting long term trends in surface water Escherichia coli concentrations. Texas Water Journal. 12(1):140-150. https://doi.org/10.21423/twj.v12i1.7126



TYPE 1 Error

- Probability: α.
- No trend in population; trend detected in the time series.

TYPE 2 Error

- Probability: β.
- Trend in the population; no trend detected in the time series.

Figure 4. Illustration of Statistical Errors in Trend Detection, ○ = sample data.

Berryman, D., Bobée, B., Cluis, D. and Haemmerli, J. (1988), NONPARAMETRIC TESTS FOR TREND DETECTION IN WATER QUALITY TIME SERIES. JAWRA Journal of the American Water Resources Association, 24: 545-556. https://doi.org/10.1111/j.1752-1688.1988.tb00904.x

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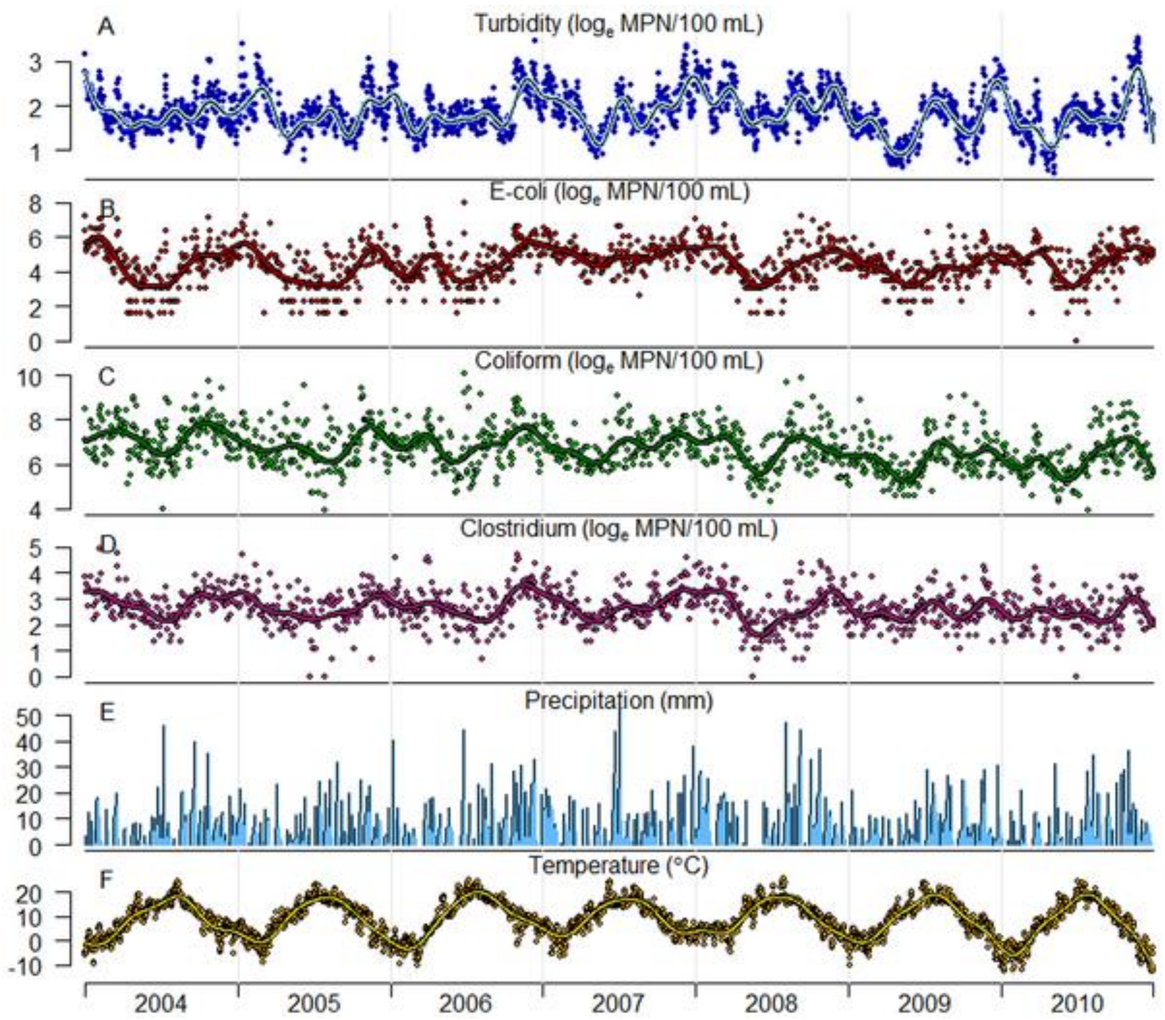
Limitations

- Trends are often non-linear and can be sensitive to values starting and ending values.
- This assess monotonic changes to provide single comparable endpoints
- Non-linear changes might be locally relevant.



Tornevi A, Bergstedt O, Forsberg B (2014) Precipitation Effects on Microbial Pollution in a River: Lag Structures and Seasonal Effect Modification. PLOS ONE 9(5): e98546. https://doi.org/10.1371/journal.pone.0098546
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0098546

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