WRTDS Trends Study on New Jersey Rivers (1971-2011): Methods and Results

In cooperation with the New Jersey Department of Environmental Protection (NJDEP) and the Delaware River Basin Commission (DRBC)

Part 1: methods

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Purpose and Scope: Identify and quantify trends over water years 1971 - 2011

• Total nitrogen, filtered NO$_2$ + NO$_3$, and total phosphorus at 28 stations

• Specific conductance, filtered chloride, and total dissolved solids at 4 stations
Approaches

• Evaluate step trends between decades using seasonal rank sum test (used for data sets lacking discharge data)

• Evaluate trends in annual concentration and annual load, using Weighted Regressions on Time, Discharge and Season (WRTDS)
  • 1980 – 2011
  • 2000 – 2011
28 Stations from

- Ambient Surface-Water Monitoring program operated by the NJDEP in cooperation with the USGS
- USGS National Water Quality Assessment (NAWQA) program
- USGS in cooperation with DRBC and others

4 sites include major ions
Guiding ideas for WRTDS

• Describe the evolving behavior of the watershed using established methods in statistical smoothing. No mathematical straight-jacket!!

• Estimate both concentration & flux (averages as well as trends).

• Estimate the actual history but also a flow-normalized history.

• Resolve a serious bias in flux estimates.

• Be quantitative but also exploratory.
WRTDS: designed to deal with these issues (1)

- Data can be highly skewed
- Some data are censored
- Trends can be different across seasons
- Trends can be different across flows
- Trends can be non-linear or non-monotonic
WRTDS: designed to deal with these issues (2)

• We may want to evaluate trends in concentration or trends in flux

• Assessments of progress can be easily obscured by the random, but persistent, patterns of wet and dry years. I call this: “The thrill of victory, the agony of defeat”
Data requirements

• Requires a complete daily discharge record

• Streamflow can’t be too flashy (low intra-day variability)

• Works best with >100 samples

• Water quality samples should cover most of the discharge range

• For trends: 10 or more years of data

• For average flux: 5 or more years of data
How does WRTDS work?

It uses the data and a simple, highly-flexible smoothing model to decompose the data into 4 components.

1) Discharge related component
2) Seasonal component
3) Time trend
4) Random component
Locally Weighted Regression

For any location in time - discharge space (t and Q) we assume that concentration (c) follows this model

\[ \ln(c) = \beta_0 + \beta_1 \cdot t + \beta_2 \cdot \ln(Q) + \beta_3 \cdot \sin(2\pi t) + \beta_4 \cos(2\pi t) + \varepsilon \]

But the coefficients should be smoothly changing as we move through the space.

Use weighted regression at many points in that space. The weight on each sample is determined by its “relevance” to that particular point in the space.
An example of a WRTDS model

Note: it isn’t just increasing in the winter
Another way of viewing the model
Based on the WRTDS “surface”

- Compute estimates of concentration and flux: by day or season or year

- Integrate the surface over the probability distribution of flow to calculate a “Flow-Normalized Concentration” or “Flow-Normalized Flux”
Concentration trend 1980-2011 = 112% increase
Significant up trend
1980-2011 p-value < 0.02
Trend magnitude in Filtered Chloride Flow Normalized Concentration 1980 to 2011 Delaware River at Trenton NJ Water Year

Best estimate of change is a 112% increase
Another example

Let’s zoom in to the early and recent parts of the record

Discharge in ft$^3$/s

Toms River Total Nitrogen
Estimated Concentration Surface in Color

USGS
Flux trend 1980-2011 = 46% increase
Non-monotonic trend case

- Early years, clearly a point-source problem
- Middle years, a non-point problem
- Recently, much improved at high and low flows
Flux trend 1980 – 2011 = -26% or -0.85%/yr
Flux trend 1990 – 2011 = -48% or -2.3%/yr
Best estimate is a 48% decrease
An example of a regular published application of WRTDS: Chesapeake Bay Program

- Uses the multi-agency Non-Tidal Network of the Chesapeake Bay watershed
- Trends in loads of
  - nitrate plus nitrite
  - total nitrogen
  - orthophosphate
  - total phosphorus
  - suspended sediment
Total Nitrogen Yields and Trends: 2005-2014

Improving Trends = 44 of 81 (54%)
Degrading Trends = 22 of 81 (27%)
No Trend = 15 of 81 (19%)
Changes in Nitrogen per Acre Loads: 2005-2014

Example from the Susquehanna Watershed

EXPLANATION

- Green: Improving
- Orange: Degrading
- Gray: No Trend

Improving or degrading trends classified as likelihood estimates greater than or equal to 66%

*The number next to each bar represents the total percent change in total nitrogen yield over the specified time period.*
Changes in Total Nitrogen Yield:
2005-2014

Download figure: http://cbrim.er.usgs.gov/maps.html
These results are being used to:
- explain change
- enhance models
- measure progress
- inform strategies

It is built on a 3-decade effort with many partners.

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<th>Partners</th>
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<tr>
<td>US Environmental Protection Agency (US EPA)</td>
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<tr>
<td>Maryland Department of Natural Resources (MD DNR)</td>
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<td>Virginia Department of Environmental Quality (VA DEQ)</td>
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<td>Delaware Department of Natural Resources and Environmental Control (DNREC)</td>
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<td>New York State Department of Environmental Conservation (NYSDEC)</td>
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<td>Susquehanna River Basin Commission (SRBC)</td>
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<td>District Department of the Environment (DDOE)</td>
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References


• Hirsch and DeCicco, 2015, User Guide to Exploration and Graphics for RivEr Trends (EGRET) and dataRetrieval: R packages for Hydrologic Data, USGS Techniques and Methods, 4-A10.


• Many more papers (134 results for “WRTDS” in Google Scholar)

Software is the EGRET and EGRETci packages (in R) freely available from the Comprehensive R Archive Network (CRAN)

more than 2500 downloads of each in past 12 months