Modeling DOC quantity and quality in Tempe Town Lake: Time-series analysis of a 10-year data set

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Introduction

This urban, man-made lake receives water from multiple sources that vary over the course of the year. **Dissolved Organic Carbon (DOC)** concentration and **Oxygen saturation ($O_{2\text{-SAT}}$)** in the lake vary over time in response to climatic/meteorological events, ecosystem metabolism (C fixation and respiration), and anthropogenic activity.

What drives changes in DOC?

The answer to this question leads to two testable hypotheses:

H_1: Conditions preceding a storm and the magnitude of discharge during/following storm events are drivers of increases in DOC.

H_2: The relative contribution of autochthonous and allochthonous carbon is a function of rain and flow

Datasets

Field-collected and Measured Data (semi-weekly from 2010 to 2015 and bi-weekly from 2005-2010)

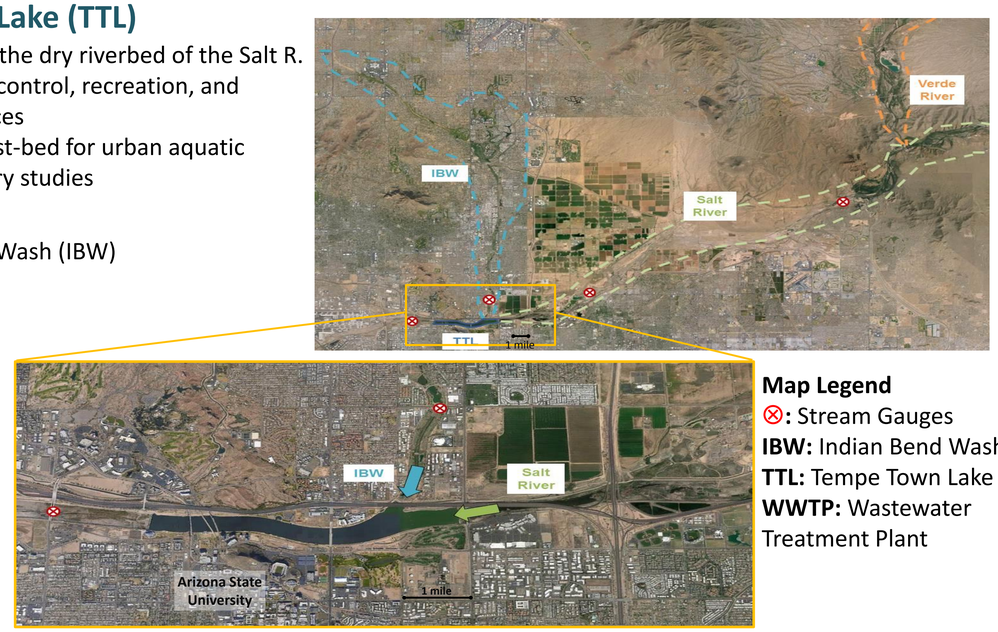
- **Conductivity, pH, Dissolved O_2, Temperature**: *in situ* measurements with calibrated hand-held meters
- **Dissolved Organic Carbon** (DOC): high-temperature combustion oxidation
- **Fluorescence index, Humification index, Freshness**: carbon composition via 3D fluorescence spectroscopy

Other Time-series Data

- City of Tempe **water quality** data (weekly; pH, T, clarity, O_2)
- USGS and Maricopa County Flood Control District **stream flow** data (daily averages)
- Maricopa County Flood Control District **rainfall** data (daily totals)

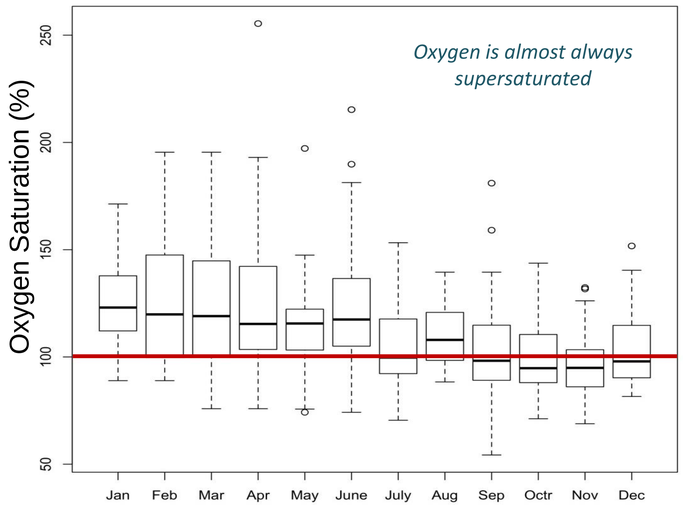
Tempe Town Lake (TTL)

- Constructed in the dry riverbed of the Salt R.
- Provides flood control, recreation, and aesthetic services
- An excellent test-bed for urban aquatic biogeochemistry studies
- Water sources
  - Indian Bend Wash (IBW)
  - Salt River
  - Verde River
  - storm water
  - rainfall

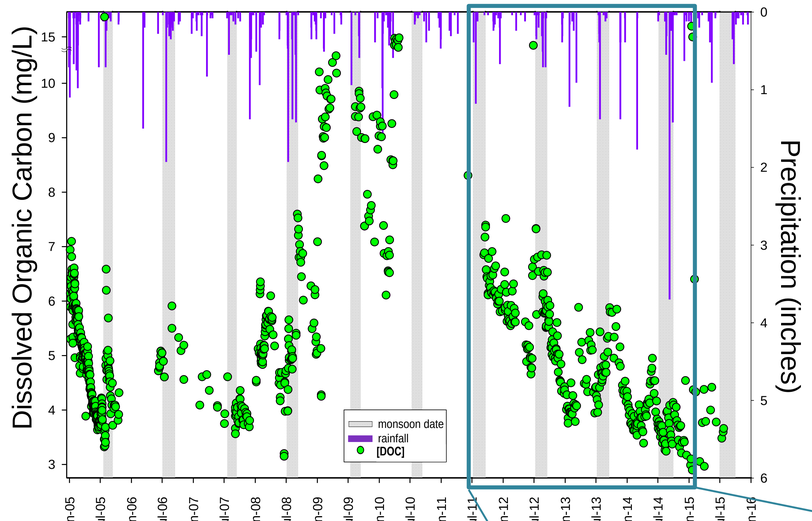


Map Legend
⊗: Stream Gauges
IBW: Indian Bend Wash
TTL: Tempe Town Lake
WWTP: Wastewater Treatment Plant

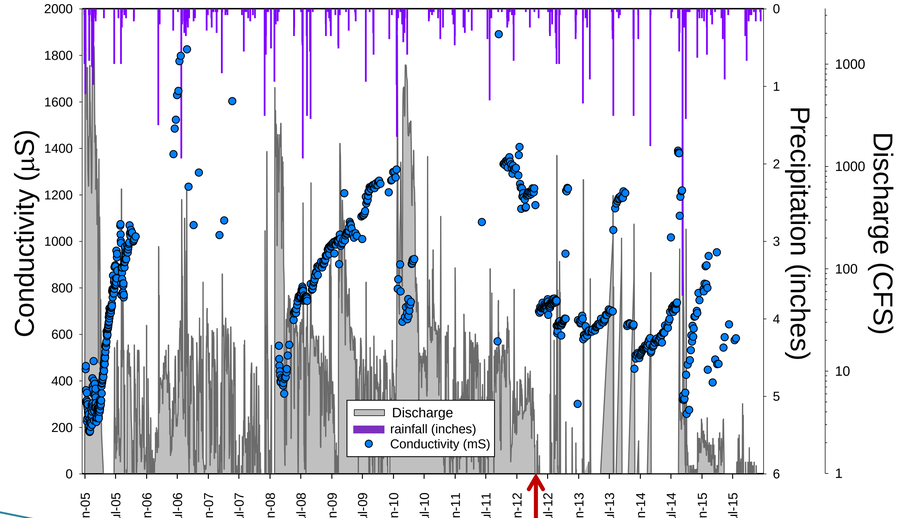
Time-series Data



Oxygen saturation by month in Tempe Town Lake from 2005 to 2015. The monthly mean is the horizontal line across each box (box boundaries are 25th and 75th percentiles, whiskers are the 10th and 90th percentiles, symbols are outliers). The red line is 100% saturation. Oxygen is only under-saturated during the fall (Sept-Dec), suggesting the lake is highly autotrophic (i.e., carbon fixation > respiration).



DOC concentration (green) and rainfall (purple lines) for Tempe Town Lake (2005-2015). Monsoons are highlighted by hashed bars. DOC exhibits strong seasonal and inter-annual variation. DOC is often elevated during river flow events (NB Jan. 2005, 2008, 2009-2010) and after monsoon storms; the blue box highlights the 'model-training data set'.



Conductivity (blue) and discharge (gray) for Tempe Town Lake (2005-2015). Conductivity is lowest during river flow events (Jan. 2005, 2008, 2009, and 2010). Treated effluent entering the lake from 2005-2012 maintained high conductivity; after Mesa WWTP effluent input ended (arrow) discharge decreased and conductivity began to exhibit seasonal and interannual variability as well as a clearer response to rainfall (purple drop lines).

ARIMA Model

Input Variables: Rain, $O_{2\ SAT}$, Flow, log flow, dry days, antecedent conditions

Each time series (DOC, FI , HIX, Freshness) was deseasonalized using Fourier decomposition. Deviation from the seasonal pattern was modelled as a combination of autoregressive and moving average parameters and included the six input variables. Best fits were based on AIC_c values.

Model Results

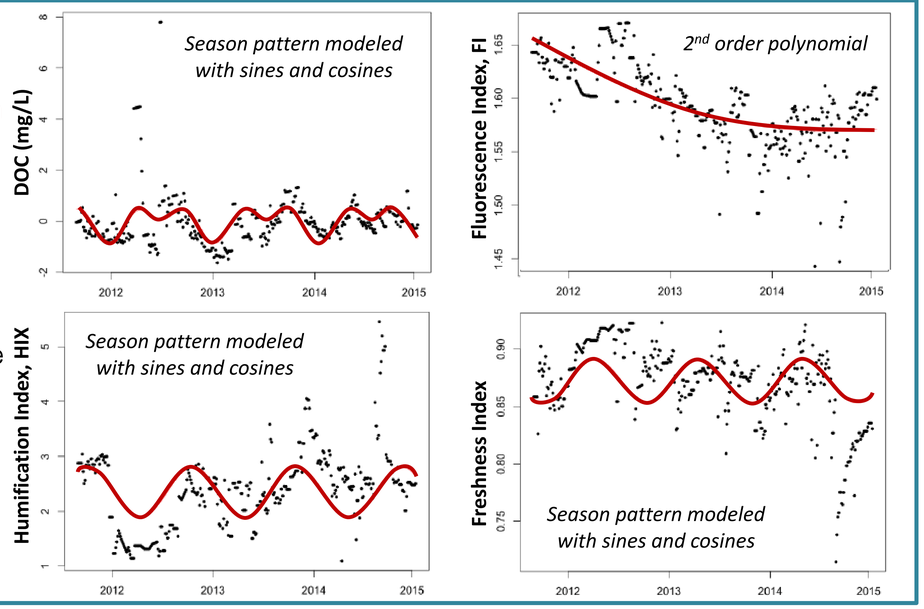
- **$O_{2\text{-SAT}}$ gave the best fit prediction for DOC concentration** (+, positive relationship)
- **External drivers (i.e., rain, flow, antecedent conditions) were important determinants of DOC composition:**
  - Rain (+) best predicted Fluorescence index, FI
  - logFlow (+) and Rain (–) best predicted Freshness
  - logFlow (–), drydays (–), and rain (+) best predicted Humification index, HIX

Interpretation

- **During dry periods algal growth generates fresh, autochthonous organic carbon (and oxygen)**
- **Dry periods allow carbon to build up on the landscape, subsequent rainfall delivers this terrestrial carbon to the lake.**

Our ongoing work compares findings for the last three years (2012-2015) to other periods in the time series, to test whether changes in lake management and climate have driven changes in DOC over longer time-scales.

Model fits for DOC, FI, HIX, and Freshness in Tempe Town Lake from Jul 2011-Jan 2015. The downward, generally linear trend in the DOC data (above) was removed before the interannual pattern was modeled. Best fits for composition indices were generally a function of rain and flow. DOC was predicted to be a function of $O_{2\ SAT}$, presumably through primary production.



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