High-Resolution Temporal Monitoring of an Arid, Urban Lake: Preliminary Results

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Introduction

Dryland lakes and rivers play an important role in arid ecosystems, with lakes and waterholes in particular acting as refugia for aquatic organisms during periods of low or intermittent flow (Sheldon et al 2009). Ecologically, they are also the site of complex dynamics, due to the extreme variation in resource availability; for example, dryland river systems in Australia are largely dependent on photosynthetic algae in shallow water during low-flow periods, but undergo booms in productivity in response to flood pulses (Bunn et al 2006).

Shallow urban lakes, by comparison, tend to have consistently high productivity, and are often eutrophic (Birch and McCaskie 1999), though there can be considerable variation in nutrient availability depending on climate (Mahapatra et al 1999).

What, then, of the arid urban lake? Which modality of primary production- extreme variability based on pulse events, or relatively consistent production due to anthrogenic nutrient addition- dominates such systems? And how sensitive is the urban arid lake ecosystem to pulse events in general, especially in the light of human-driven change? To answer these questions, field measurements are required.

Tempe Town Lake is an artificial lake located near the urban core of Tempe, AZ, derived from the damming of the Salt River. It was constructed in 1999 primarily for the use of recreation such as fishing and boating. Since 2005, it has been subject to long-term water quality monitoring by the Central Arizona-Phoenix Long-Term Ecological Research program, part of the national LTER network. It has been of interest due to being one of two lakes in the LTER network that are in an urban setting (the other being in Baltimore), and the only one located in an arid enviroment. Dissolved oxygen levels are generally above 5 mg/L, suggesting the lake is not eutrophic. The lake also trends alkaline, with an average pH around 8, likely due to its high productivity and carbonate-poor basement rock.

Tempe Town Lake hosts numerous special events over the course of the year, and is an important site for recreation, offering fishing, boating, and cycling and pedestrian paths along its perimeter (Tempe Tourism Office, 2018). It is also Arizona's second most-visited tourist attraction, and has generated a cumulative economic impact of over $1.5 billion dollars since its creation (City of Tempe, 2018). Consequently, information that can aid water quality management for Tempe Town Lake is highly desirable for the surrounding community.

For the past thirteen years, the pH, dissolved oxygen content, temperature, conductivity, dissolved organic carbon (DOC), and nitrogen content of the lake has been measured on a weekly basis for several years non-contiguously(Hartnett and Childers 2018). These measurements required water to be taken from the lake and brought back to the lab for analysis, which limited the temporal resolution of the dataset.

Recently, funding was obtained for equipping Tempe Town Lake with a data sonde, capable of detecting dissolved organic matter via fluorescence, that would allow *in situ* measurements at a much higher frequency than was previously possible. A major goal of this project is to determine if the parameters that can be measured by the sonde- in particular, colored dissolved organic matter (CDOM)- can be used as a proxy for DOC, which is not practical to measure *in situ*.

Additionally, the use of fluorescence may allow more nuanced characterization of the dissolved organic carbon, as this technique has been used previously to identify dissolved organic matter that's undergone multiple transformations (Jaffé et al 2008, Fellman et al 2010).

Methods

In order to investigate the dynamics of Tempe Town Lake at higher temporal resolution, a datasonde was procured.

The data sonde is a custom-built Eureka Manta 35+ water probe, featuring a Turner Designs fluorometer (Fig. 1). The sonde is equipped with sensors for temperature, pH, conductivity, dissolved oxygen, turbidity, CDOM/fCDOM, and chlorophyll A. The latter two are measured via fluorometer.

The fluorometer uses a bank of UV LEDS, emitting an excitation wavelength 340nm, which produces an emission centered around 470nm; these wavelengths are used in particular as they allow distinction between phytoplankton pigments (Watras et al 2011). It should be noted that since the fluorometer is single wavelength and limited to an excitation of 340 nm, it will not be able to determine fluorescence index, freshness index, or humidification index (Fellman et al 2010).

Temperature is measured via thermister, pH using a non-gel electrode, conductivity via four-electrode sensors, dissolved oxygen via optical sensor (which has the advantage of being lower maintenance compared to traditional Clark cell sensors), and turbidity via infrared sensor.

After calibration, the sonde was lowered into Tempe Town Lake on June 25, 2018 off a floating pier on the northeast side of the lake (Fig. 2) . The sonde was retrieved after an initial data-gathering period of three weeks, on July 16, 2018, and recalibrated before being returned to the lake for further data gathering. Sonde retrieval calibation occurred again on August 21, 2018. Technical issues prevented use of the sonde from that point through October 23, 2018, at which point the project resumed. Data retrieval and sonde calibration was conducted October 23, Observations were made by the sonde every thirty minutes, resulting in a detailed time series.

Discharge data was retrieved from USGS monitoring station 09512165 on the Salt River at Priest Drive, located only slightly upstream of Tempe Town Lake.

The resulting data was analyzed using simple regression tests, and a basic Fourier transform using Python to check for cyclical patterns.

Fig 1. Datasonde in the lab for calibration, with cell phone for scale.

Fig 2

Six months of data was collected, in two three-month increments.

Unsurprisingly, lake temperature showed a strong diurnal cycle, as did oxygen levels; oxygen lagged temperature, likely due to the time required for oxygen levels to reach saturation. What was more surprising was that the levels of CDOM appeared to cycle as well, especially during the summer (Fig 3). This diurnal cycle weakened during the winter, but was still detectable in Fourier analysis.

CDOM also appeared to correlate to temperature, though the correlation varied based on season– negatively correlated in the summer, and positively correlated in the winter (Fig 4). This suggests that whatever is causing the fluctuations in CDOM has an optimal temperature.

CDOM also changed as a function of discharge events, though, curiously, the magnitude of this change did not appear to correlate with the magnitude of the discharge event.

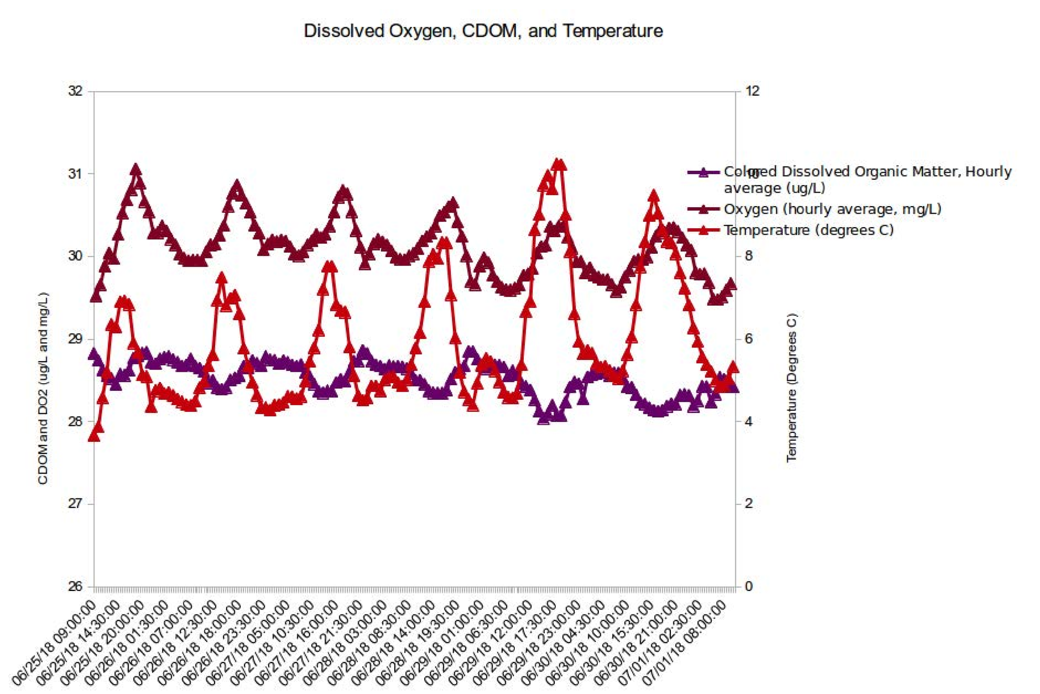
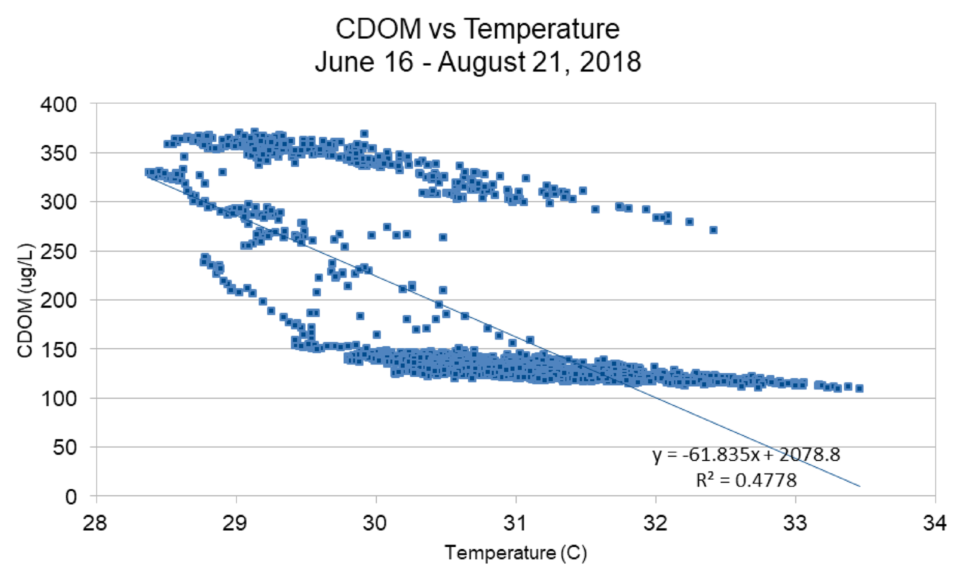
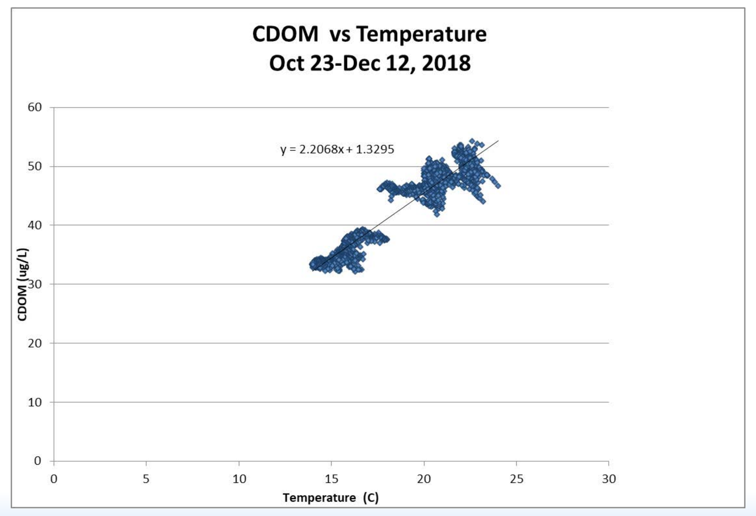


Fig 3. A one week snapshot of oxygen, temperature, and CDOM levels in the lake, starting on June 25 2018. All three parameters show a noticeable diurnal cycle, offset from each other.



Figs. 3 and 4. CDOM vs temperature.



The preliminary results from the datasonde demonstrate that there are indeed patterns in the behavior of Tempe Town Lake's biogeochemistry that require high-resolution monitoring. As more data becomes available as the seasons change, it is hoped that we will be able to further document these faster changes.

Additionally, there appears to be a correlation between temperature and the level of CDOM present in the lake, which may be driving the diurnal cycling. Understanding this relationship remains an important future goal for the project.

Looking further ahead, having a robust time series for Tempe Town Lake may make it possible to conduct more deeper analysis for critical slowing down and other transitions in the ecology of the lake.

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