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# Session 2A: Ecology, Biology, and Climate

Kentucky Water Resources Research Institute, University of Kentucky



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# SESSION 2A: ECOLOGY, BIOLOGY, AND CLIMATE

## Ecological Monitoring of WRP Easements in Western Kentucky

Karen Baumann, Christy Soldo, Luke Zuklic, Michael Flinn, and Howard Whiteman
Murray State University
(270) 809-3194
kbaumann1@murraystate.edu

Riparian wetlands improve the quality of our nation's streams, rivers, and lakes, and support diverse assemblages of plant and animal species. Each year, billions of dollars are spent on a variety of projects focused on restoring wetlands, such as the Wetlands Reserve Program (WRP). Our main objective for this study is to monitor water chemistry, hydrology, and community structure of macroinvertebrates and fish on easements enrolled in WRP and in surrounding wetlands in order to assess the effectiveness of restoration strategies. Our study sites include WRP easements of various ages (up to15 years), agricultural fields prone to flooding as control sites, and mature bottomland forests representing relatively undisturbed reference wetlands. Hydrological modification structures, such as levee breaks, ditch plugs, or shallow water areas, have been installed on each easement. We are using stovepipe cores and multi-habitat dip nets to sample macroinvertebrates, a backpack electrofisher to examine fish communities, ISCO automatic water samplers and YSI multi-parameter sondes to monitor water chemistry, and pressure transducers and GIS to determine easement hydrology. Preliminary results reveal higher species richness and diversity in restored and reference wetlands as compared to control sites. Because new easements are permanently enrolled, there is tremendous potential to quantify changes in physical and biological condition over time. Understanding how these easements respond to restoration will provide opportunities for future adaptive management practices.

# Discussion of Factors Influencing Ecosystem Productivity in the Greenup Pool of the Ohio River

Mindy Armstead, Austin Hoffman, Mandee Wilson, Cody Schumacher, Logan Beach, Kourtnie Farmer, and Rachel King
Natural Resources and the Environment
Marshall University
(304) 696-2923
m.armstead@marshall.edu

Marshall University is participating, with University of Kentucky and Murray State University, in a multistate research partnership to gain insight into the influence of food and energy production on aquatic ecosystems. Specifically, the research is investigating how food and energy production affect harmful algal bloom formation in the partner states with Marshall's research focused in the Ohio River. The NSF-EPSCoR research program, entitled Sensing and Educating the Nexus to Sustain Ecosystems (SENSE), has supported cyber-infrastructure development including the deployment of sensors monitoring real-time water quality parameters at Robert C Byrd and Greenup locks which bracket the Greenup pool of the Ohio River. Additionally, transect sampling in the Greenup pool is being utilized to demonstrate the extent to which real-time monitoring stations represent conditions throughout the pool.

After one year of high frequency data collection, and one series of 23 transect samples, trends in water quality and algal community dynamics are evident in the managed river system. High flows during the spring and fall of 2018 resulted in an atypical evaluation period and may have influenced findings. Primary productivity estimates were lower than expected with turbidity and flow potentially influencing algal productivity more than in typical flow years. Lower productivity in the Greenup Pool has implications for nutrient uptake in the eutrophic system. Real-time high frequency monitoring is ongoing and additional evaluations will be used to continue the development of productivity models for the managed river. With more than five million people utilizing the Ohio River as a drinking water source, management of the river to prevent algal blooms is a high priority and understanding the factors influencing algal productivity is an important first step in preventing bloom formation.

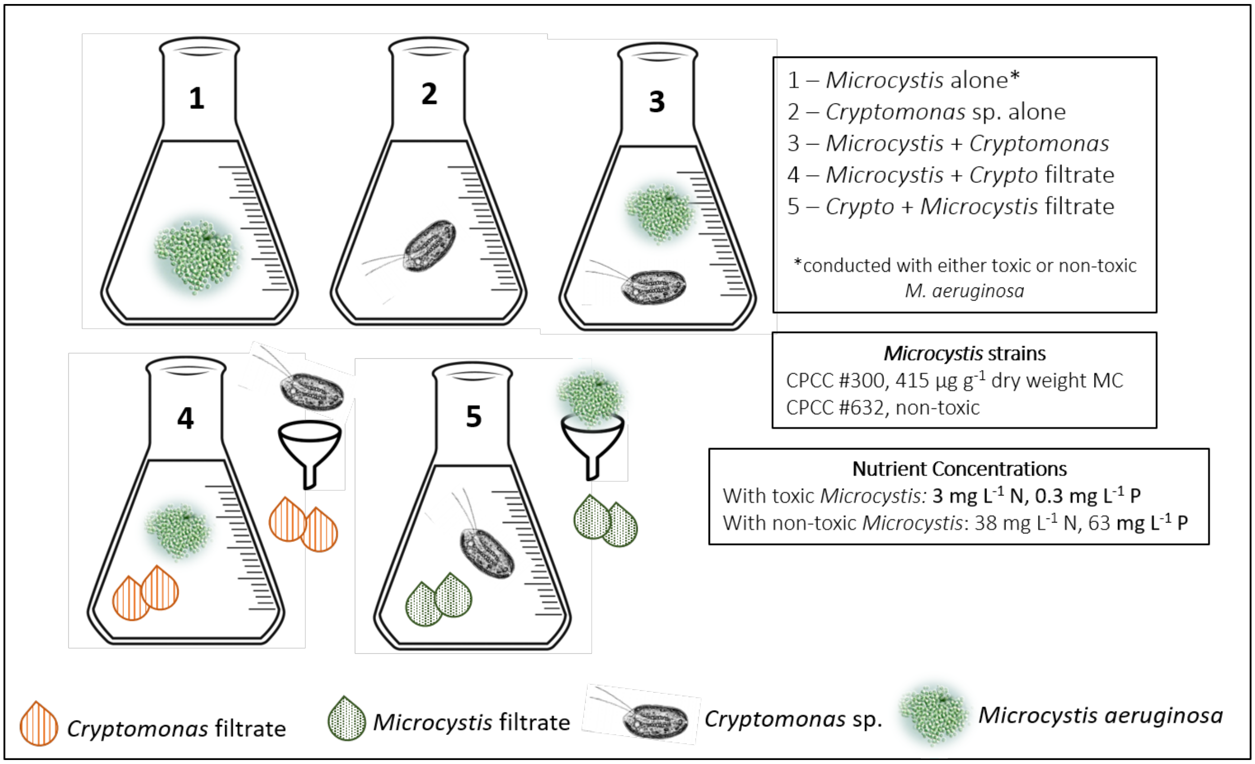
# Biotic Interactions Between a Bloom-Forming Cyanobacteria and a Planktonic Protist: Implications for Toxin Production

S.D. Princiotta, S.P. Hendricks, D.S. White
Hancock Biological Station
Murray State University
(270) 809 1729
sprinciotta@murraystate.edu

Freshwater ecosystems world-wide face threats of deterioration from toxin-producing cyanobacteria. Non-toxic cyanobacteria blooms also impair aquatic habitats for other organisms by reducing light availability and depleting dissolved oxygen during the decay processes. Multi-trophic interactions govern the formation and degradation of bloom conditions. Much attention on top-down controls of cyanobacteria blooms has focused on zooplankton, yet there is a growing body of literature dedicated to the roles of planktonic protists in "grazing the bloom." It has been suggested that phagotrophic protists can be effective grazers of cyanobacteria despite toxin production and colony formation. Many phagotrophic protists can function at more than one trophic level by combining photosynthesis with ingestion of particulate matter into a nutritional mode called mixotrophy. Here, we describe the biotic relationships between a mixotrophic protist (*Cryptomonas* sp.) and two strains of bloom-forming cyanobacteria (toxic and non-toxic *Microcystis aeruginosa*). Physical and allelopathic interactions were investigated between the protist and cyanobacteria under varying nutrient conditions in a full-factorial experimental design with each grown as a monoculture, grown in co-culture, and with addition of reciprocal filtrates. Cell abundance was determined by microscopic analysis over a period of 8 days, and production of microcystin-LR (MC-LR) was monitored both intra- and extracellularly by liquid chromatography (LC/MS/MS). Population growth rate was determined by slope of the linear regression of log-transformed cell abundance values plotted over time. The ability of *Cryptomonas* to ingest both forms of *M. aeruginosa* was assessed by disappearance of heat-killed, fluorescently labeled cyanobacteria.

Population growth rates of *Cryptomonas* in co-culture or with exudate from both strains of cyanobacteria were not different than when *Crytomonas* was grown alone. The relationship was maintained in both nutrient rich (38 mg $l^{-1}$ N, 63 mg $l^{-1}$ P) and poor (3 mg $l^{-1}$ N, 0.3 mg $l^{-1}$ P) media. However, in nutrient rich conditions, addition of non-toxic cyanobacterial filtrate led to an increase in population growth rate of *Cryptomonas* when compared with the co-culture treatment. Non-toxic *M. aeruginosa* exhibited the highest population growth rate in the presence of *Cryptomonas*. Conversely, population growth of toxic *M. aeruginosa* was significantly reduced in co-culture with the protist or its filtrate (under nutrient poor conditions). Despite evidence of competitive interactions, concentration of intracellular MC-LR was lowest when the *M. aeruginosa* was cultured with *Cryptomonas*. Finally, although abundance of fluorescently-labeled *M. aeruginosa* prepared from both toxic and non-toxic cultures declined in the presence of *Cryptomonas*, the highest protistan ingestion rates occurred during incubation with filtrate from toxic cyanobacteria.

Our work highlights the importance of considering biotic interactions among members of the plankton when studying algal bloom dynamics. The toxic strain of cyanobacteria was negatively affected by the presence of *Cryptomonas* and its derived filtrate, suggesting that the flagellate can either outcompete or ingest *M. aeruginosa* under nutrient poor conditions. Based on the disappearance of heat-killed *M. aeruginosa*, addition of cyanobacterial filtrate provides a nutritional supplement that supports increased feeding by *Cryptomonas* on toxic *Microcystis*. The study also calls into question the role of MC-LR because toxin-production was not likely a response to physical competitive interactions. Although more research is required to disentangle the effects of nutrients and toxicity on competitive interactions between members of the plankton, it should be noted that relationships between *Cryptomonas* and *Microcystis* varied with availability of N and P.



# The Use of Multiple Large and Detailed Databases to Evaluate the Impacts of Climate Change on Water Resources in the Ohio River Basin

Lynn Jarrett (retired)
Henryville, IN
(502) 558-4182
garylynnjarrett@gmail.com

Frejdyn Jarrett
Water Resources Program
University of New Mexico
frejdyn@unm.edu

Earth's atmosphere as we know it evolved as photochemical dissociation, or the breakup of water molecules by ultraviolet (UV) radiation, produced atmospheric $O_2$ levels of approximately 1-2% of current levels. At these levels $O_3$ (Ozone) could form to shield the Earth surface from UV radiation allowing microscopic plants to inadvertently oxygenate the atmosphere through the process of photosynthesis.

The scientific consensus for the last several decades is that the atmosphere of the modern Earth is largely created by and maintained by living organisms on the planet. The composition of the atmosphere is in chemical disequilibrium maintained primarily by the metabolic activities of photosynthesis and respiration and by various geochemical processes.

Beyond generating and maintaining the atmospheric it is widely believed that biological activity has produced catastrophic changes to the atmosphere such as snowball earth scenarios and fostering global fires over the last one billion years.

In the last several decades evidence indicates that another biologically produced event may be occurring. Increases in the atmospheric carbon dioxide ($CO_2$) concentration has been documented (Figure 1) by the National Oceanic and Atmospheric Administration's (NOAA) Earth System Research Laboratory (ESRL), (Dr. Pieter Tans, NOAA/ESRL (www.esrl.noaa.gov/gmd/ccgg/trends/) and Dr. Ralph Keeling, Scripps Institution of Oceanography (www.scrippsco2.ucsd.edu/).

In 1895 Arrhenius (1896) determined that dissolved $CO_2$ or carbonic acid trapped infra-red radiation in the atmosphere. He followed with a climate prediction based on greenhouse gases, suggesting that a 40% increase or decrease in the atmospheric abundance of the trace gas $CO_2$ might trigger the glacial advances and retreats.

In this study, multiple large national and regional water quality databases have been explored to determine if existing data can identify impacts that may potentially result from a changing atmosphere. Although, the signals from these databases are "noisy", numerous lines of evidence suggest that changes may be occurring (Figure 2).

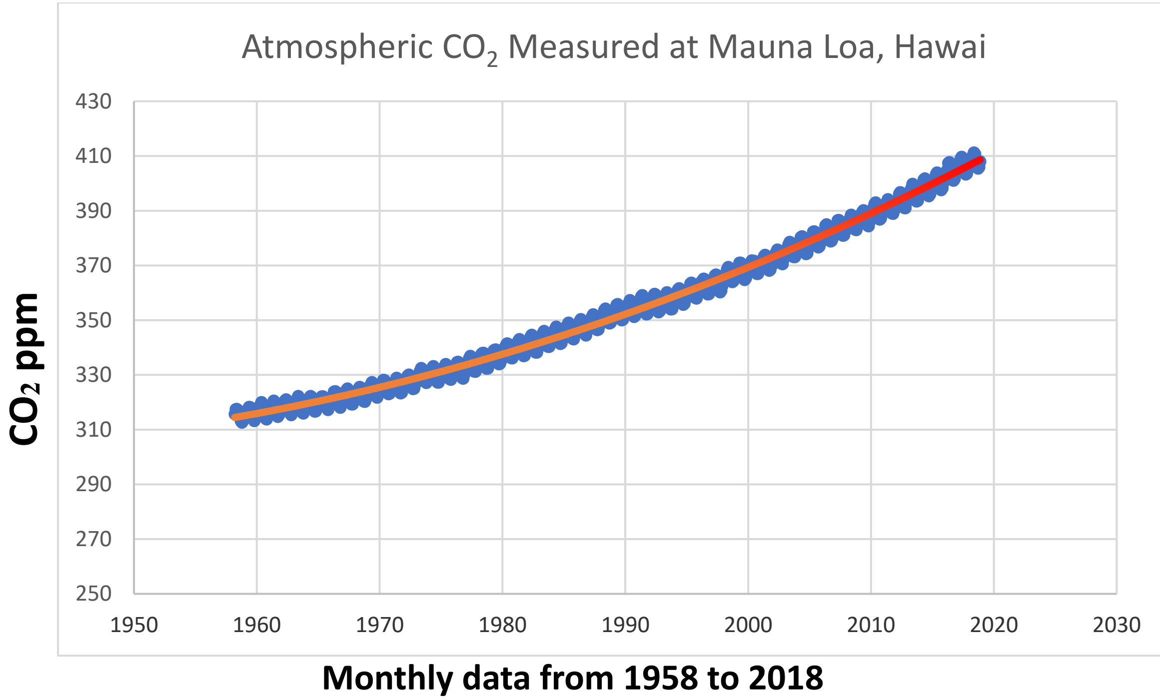



Figure 1. Presentation of monthly atmospheric $CO_2$ (ppm) at Mauna Loa, Hawaii between 1958 and 2018. A polynomial trend line is superimposed on the monthly cycles to emphasize the nonlinear increase in the measured greenhouse gas.

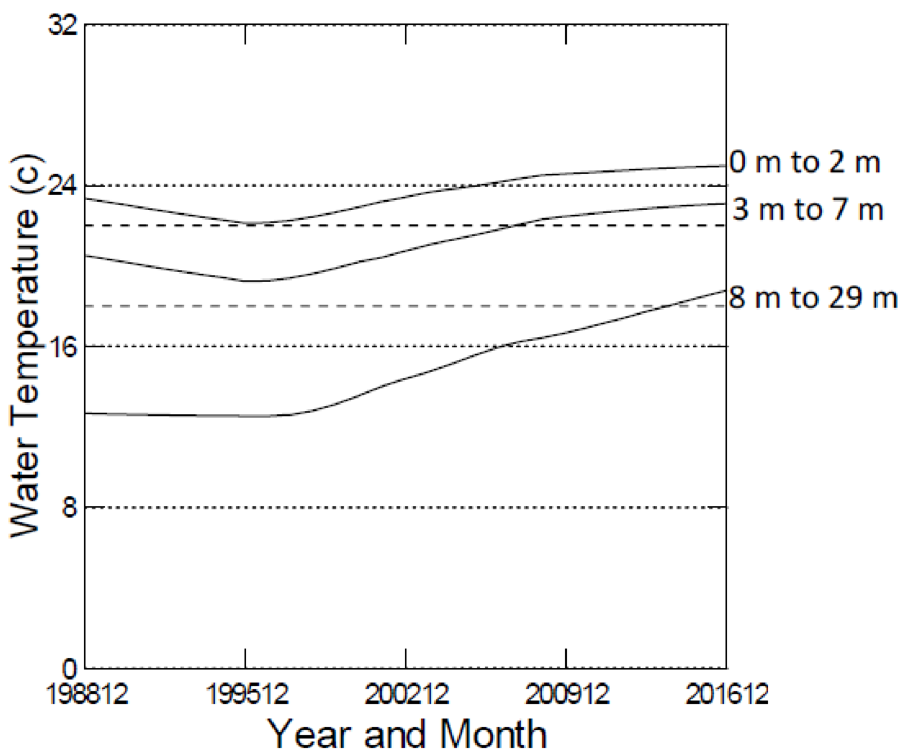



Figure 2. Water temperature trends at three different strata at Nolin Reservoir using forebay profiles and LOWESS smooths.

# Evaluating and Addressing Climate Awareness and Water in Kentucky*

Lauren Cagle[1] and Carmen Agouridis[2]
[1]Department of Writing, Rhetoric, & Digital Studies
[2]Department of Biosystems and Agricultural Engineering
University of Kentucky
lauren.cagle@uky.edu; carmen.agouridis@uky.edu

Our changing climate is a global issue with widely varying effects. In Kentucky, our future climate will have distinct effects because of industries, agricultural practices, and communities specific to the state. These effects will include changes to environmental precipitation patterns, which have the potential to negatively impacting freshwater availability, groundwater quality, and storm frequency and intensity, among other outcomes. As water is such an important everyday resource for people, changes to water cycles, availability, and water quality can influence perceptions of the environment and even raise climate awareness. For example, research suggests that individuals' beliefs about climate change can be correlated to their distance from a coastline, perhaps because of visible changes to the coastline functioning to raise climate awareness. Coastal dwellers are not the only ones whose experiences with water can affect their environmental perceptions; similarly, some evidence exists that local flooding risks are related to climate concern and can inform efforts to build community climate awareness. Moreover, Americans broadly consider water, even within the context of urban infrastructure, to be related to climate change; a 2013 survey found that 92% of Americans "want their community water provider to be a leader in preparing their community for climate change." Water issues in Kentucky thus present an opportunity to develop climate awareness about local climate effects in a non-coastal state. Raising public awareness around water and climate in Kentucky can be mutually reinforcing efforts.

The project seeks to increase climate awareness, particularly as it relates to Kentucky's water resources. Specific objectives are to 1) develop a consortium of Kentucky climate researchers and educators to promote collaboration and information sharing on climate awareness issues and the dissemination of said information to the state's population, 2) develop a website linking Kentucky's citizens, students, and teachers to the consortium and Kentucky-focused climate resources, 3) evaluate current levels of climate awareness in Kentucky's population (eastern, central, and western regions) with a focus on water resources, 4) develop a set of training materials, based on current awareness levels, for personnel who regularly interact with the public, such as Cooperative Extension Service agents and Kentucky Watershed Watch basin coordinators, and instructors (K-12 and adult learners), and 5) administer at least one workshop using the developed training materials.

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