2022 VIRTUAL MEETING OF THE ASSOCIATION OF MID-ATLANTIC AQUATIC BIOLOGISTS

AGENDA

DAY 1: WEDNESDAY, MARCH 30, 2022, 09:00 – 16:30 – PRESENTATIONS

09:00 **Welcome, AMAAB Business, Announcements**
Jenna Krug & Brian Henning, NJDEP - 2022 AMAAB President & Co-Chair/Jeopardy Host (jenna.krug@dep.nj.gov; brian.henning@dep.nj.gov)

09:10 **Potentially Toxigenic (PTOX) Cyanobacteria Observed in New Jersey During Multi-species Harmful Algal Bloom (HAB) Events**
Leah Anne Gibala-Smith, NJDEP, Bureau of Freshwater and Biological Monitoring (leah.gibala-smith@dep.nj.gov)

09:30 **Investigating the Effects of Harmful Cyanobacterial Blooms on the Vulnerability to Shell Disease of Northern red-bellied Turtles (*Pseudemys rubriventris*) in New Jersey**
Meiyin Wu, New Jersey Center for Water Science & Technology, Montclair State University (wum@montclair.edu)

09:50 **Assessing Harmful Algal Blooms at a Recreational Lake in Northern New Jersey Using Satellite Imagery**
David Hsu, New Jersey Center for Water Science & Technology, Montclair State University (hsut@mail.montclair.edu)

10:10 **Assessment of Digital Imaging Flow Cytometry in its Application of Harmful Algal Blooms Monitoring**
Melissa Mazzaro, New Jersey Center for Water Science & Technology, Montclair State University (mazzarom@montclair.edu)

10:30 - 10:50 **BREAK 20 minutes – JEOPARDY Round 1**

10:50 **Freshwater Probabilistic Monitoring Reporting Advances and Programmatic Integration at VDEQ – 40 min**
Emma Jones, VADEQ (emma.jones@deq.virginia.gov)

11:30 **Stream Fish Life History Strategies Explained by Environmental Stability**
Nathaniel Hitt, USGS Eastern Ecological Science Center (nhitt@usgs.gov)

11:50 **Using Environmental DNA for Surveillance and Monitoring of Aquatic Invasive Species**
Julie Lockwood, Rutgers University (julie.lockwood@rutgers.edu)

12:10 – 13:10 **LUNCH 1 HOUR**

13:10 **Creating Native vs Non-Native Fish Status in Virginia by HUC 8**
Brett Stern and Royce Steiner, VADEQ (royce.steiner@deq.virginia.gov; brett.stern@deq.virginia.gov)

13:30 **Spatial and Temporal Analyses of Perfluoroalkyl Substances (PFAS) in Smallmouth Bass Plasma from Sites in the Chesapeake Bay Watershed**
Vicki Blazer, USGS Eastern Ecological Science Center (vblazer@usgs.gov)

13:50 **Aquatic Life Use Assessments Using a Thermal Fish Index – 60 min**
Tim Wertz and Matt Shank, PADEP (twertz@pa.gov; mattheshan@pa.gov)

14:50 – 15:10 **BREAK 20 minutes – JEOPARDY Round 2**

15:10 **Making an Alphabet Soup of RBP's and SDM's: Using Multiple Tools to Inform Unionid Mussel Restoration**
Selina Cheng, Maryland DNR (selina.cheng@maryland.gov)

15:20 **Evaluating the Hydrology, Water-Quality, and Ecological Communities of Two Restored Urban-Suburban Streams in Northern Virginia**
Brendan Foster, USGS VA/WV Water Science Center (bfoster@usgs.gov)

15:30 **10 Years of Continuous Instream Monitoring in Susquehanna River Basin - StoryMap and Data Dashboard**
Luanne Steffy, Susquehanna River Basin Commission (lsteffy@srbc.net)

15:40 **Karst Terrain Promotes Thermal Resiliency in Headwater Streams**
Karmann Kessler, USGS Eastern Ecological Science Center (kkessler@usgs.gov)

15:50 **Developing a Chesapeake Bay Watershed-Wide View of Biological Status & Trends**
Kevin Krause, USGS Eastern Ecological Science Center (kkrause@usgs.gov)

16:00 **Comparing Salt Dilution and Acoustic Doppler Methods for Measuring Discharge in Remote Headwater Streams**
Karli Rogers, USGS Eastern Ecological Science Center (kmrogers@usgs.gov)

16:10 **Announcements/Business-Elections/Adjourn**

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DAY 2: March 31, 2022, 09:00 – 12:00 – WORKSHOPS

1. Trichoptera Identification

Facilitator: Andy Rasmussen (andrew.rasmussen@famu.edu) & Alex Orfinger (alexander1.orfinger@famu.edu), Florida A&M University

We will present a half-day online workshop on the taxonomic identification of larval Trichoptera (caddisflies). Attendees will be encouraged to ask questions and contribute to the discussion. The instructors will cover a wide range of topics including: Classification, Morphology and Identification, Taxonomic Resources, Identification of Polycentropodidae (Trumpet-Net Caddisflies), and Molecular Identification.

2. Stressor Identification Using CADDIS

Facilitator: Kate Schofield, USEPA Integrated Environmental Assessment Branch, Center for Public Health and Environmental Assessment (schofield.kate@epa.gov)

Thousands of waterbodies in the United States are listed as biologically impaired; for many of these waterbodies the cause of impairment is reported as "unknown." Before appropriate management actions can be developed and implemented, the causes of these impairments must be identified. CADDIS—the Causal Analysis/Diagnosis Decision Information System—is an on-line application designed to help users conduct these causal assessments. CADDIS provides a strength of evidence-based framework for stressor identification, along with information and tools (e.g., stressor summaries, analytical tools and examples, case studies) that can assist in identifying likely causes of biological impairment in streams and rivers. This workshop will provide an overview of CADDIS, including the Stressor Identification process and the supporting information and tools available on the CADDIS website. It will draw from regionally relevant examples to illustrate how CADDIS has been used and end with discussion of how future development of CADDIS can better address your key stressor identification needs. Go to epa.gov/caddis to learn more about Causal Analysis/Diagnosis Decision Information System (CADDIS).

3. Harmful Algal Blooms (HABs): Identification Using eDNA and Overview of a Statewide HABs Response Strategy

Facilitator: Christopher Main, DNREC (christopher.main@delaware.gov); Vic Poretti (victor.poretti@dep.nj.gov), Robert Schuster (robert.schuster@dep.nj.gov), Leah Gibala-Smith (leah.gibala-smith@dep.nj.gov), and Deidre Supple (deidre.supple@dep.nj.gov), NJDEP

Dr. Christopher Main from Delaware DNREC will cover the identification of HABs using eDNA while Bob Schuster and Vic Poretti will present details of NJDEP's marine and freshwater Harmful Algal Bloom (HAB) Response Strategies. Understanding freshwater Harmful Cyanobacteria Algal Blooms (HABs), their risks to human health, how to respond and monitor HABs, and proper response actions to protect human health during recreational activities. The session will include NJDEP's monitoring, analysis, and communication protocols as well as advanced technology being piloted. Email Jenna Krug at jenna.krug@dep.nj.gov with any questions.

4. An Introduction to Rendering Reports Using R

Facilitator: Lou Reynolds, USEPA (reynolds.louis@epa.gov)

This workshop will introduce the capabilities of R for publishing reports as html, pdf, and Word documents. The integration of data wrangling, analysis, visualization, and presentation is an important aspect of reproducible research. Written reports are an important, and many times, required way to present data. We will cover the basics and some more intermediate aspects of going from R code to documents – so it is helpful if you are familiar and comfortable with R. If you are already proficient and comfortable producing reports in R, this is not the course for you. It is important to have R, and R Studio, already installed on your computer. Questions about the course are welcome.

DAY 1 ABSTRACTS

Potentially Toxigenic (PTOX) Cyanobacteria Observed in New Jersey During Multi-species Harmful Algal Bloom (HAB) Events

Leah Anne Gibala-Smith, NJDEP BFBM (leah.gibala-smith@dep.nj.gov)

An overview of toxin production and cell densities observed in New Jersey during multi-species harmful algal bloom events will be presented. A brief overview of the Bureau of Freshwater and Biological Monitoring role as outlined in NJDEP's HAB Recreational Response Strategy will be reviewed as well.

Investigating the Effects of Harmful Cyanobacterial Blooms on the Vulnerability to Shell Disease of Northern red-bellied Turtles (*Pseudemys rubriventris*) in New Jersey

Meiyin Wu, New Jersey Center for Water Science & Technology, Montclair State University (wum@montclair.edu); Additional authors: Stephanie Getto, Molly Hillenbrand (MSU)

In 2019, an unknown shell disease was reported in Northern red-bellied turtles (Pseudemys rubriventris), a freshwater turtle species with a range that mainly includes southern New Jersey through North Carolina. This study investigates the effects of harmful cyanobacterial blooms on the vulnerability to shell disease of freshwater Northern red-bellied turtles (Pseudemys rubriventris) in New Jersey by characterizing and enumerating cyanobacteria in lake water and within the epizoic community with a goal to provide data-driven recommendations for P. rubriventris conservation. Phytoplankton community composition and cyanotoxin concentration were measured in two affected lakes (Daretown Lake and Elmer Lake) and one unaffected lake (Lake Fred) in Salem and Ocean counties, New Jersey. These measures were examined to determine whether the presence of potentially toxin-producing cyanobacteria had any effect on the occurrence of shell disease in these turtles. In addition to water samples, epizoic community was examined and cyanotoxins were measured from samples collected from turtle shells. Results indicate that cyanobacteria may increase the vulnerability of P. rubriventris to the shell disease. In general, cyanobacteria density and cyanotoxin concentrations were greater in water and epizoic samples collected from the affected lakes than the unaffected lake. Additionally, epizoic samples collected from turtles afflicted with shell disease were found to contain significantly greater cyanobacteria density than samples collected from healthy turtles, suggesting epizoic cyanobacteria growth may be the cause of shell diseases of P. rubriventris in New Jersey.

Assessing Harmful Algal Blooms at a Recreational Lake in Northern New Jersey Using Satellite Imagery

David Hsu, New Jersey Center for Water Science & Technology, Montclair State University (hsut@mail.montclair.edu); Additional authors: Anne Hurley, Yaritza Acosta-Caraballo, Mark Chopping, Meiyin Wu (MSU)

Harmful algal blooms (HABs) can lead to public health concerns, ecological stresses, and economic losses. Thus, it is important to routinely monitor the conditions of HABs in waterbodies. In addition to field investigations, remotely sensed satellite imagery has been utilized to assess HABs on a broader scale. Located on the border of New Jersey and New York, the Greenwood Lake has provided important freshwater resources for residents and visitors. However, it has also been well documented with ongoing HABs during summers and falls. The goal of this study was to apply two publicly available satellite imagery tools, including CyAN and Landsat, to estimate HABs at the Greenwood Lake. Water samples were collected at 15 sites along the shore of the Greenwood Lake on July 19, 2019 and transported to the Montclair State University's New Jersey Phytoplankton Lab for cyanobacteria identification and enumeration using a digital imaging flow cytometer. For satellite-derived estimates, CyAN provided a directly estimated cyanobacteria cell counts based on a cyanobacteria index algorithm. Landsat required an user-selected algorithm to derive the cell count estimates. We used a Normalized Difference Vegetation Index (NDVI) based on the spectral data of Landsat 8. Preliminary evaluations indicated positive correlations between in situ cyanobacteria cell counts and the corresponding estimated cell counts from the two satellite imagery using linear regressions. However, no significance was found. Due to the limitations of site selection and temporal coverage, future work should include additional sites away from the shore and increase sampling frequency to cover the entire HAB season to properly evaluate the applicability of the satellite remote sensing of HAB at the Greenwood Lake.

Assessment of Digital Imaging Flow Cytometry in its Application of Harmful Algal Blooms Monitoring

Melissa Mazzaro, New Jersey Center for Water Science & Technology, Montclair State University (mazzarom@montclair.edu); Additional authors: Meiyin Wu, Anne Hurley (MSU)

As harmful algal blooms (HABs) are becoming an increasing global threat to the health of people, animals, and aquatic ecosystems, finding ways to efficiently detect and manage blooms is critical. Traditional methods of identifying and enumerating phytoplankton cells involve light microscopy; however, this is a time-consuming and labor-intensive process. Meanwhile, digital imaging flow cytometry is a relatively novel and rapid method of enumerating and identifying particles within phytoplankton samples. Previous studies have documented comparable digital flow cytometry results to microscopy results; however, there are concerns relating to the underestimation of cells and misidentification of particles with their automated classification systems. Before digital imaging flow cytometry can be implemented into HAB monitoring protocols, a thorough and systematic comparison to light microscopy is needed using freshwater samples with a wide temporal and spatial range. This study investigates the accuracy and discrepancy of collected phytoplankton community data obtained by digital imaging flow cytometry and light microscopy methods. The results demonstrate that microscopy cell densities ($p < 0.001$) and natural unit densities ($p < 0.001$) for both phytoplankton and cyanobacteria were significantly higher than the results obtained by the digital imaging flow cytometry method. Additionally, taxa richness varied between the two methods, with microscopy detecting more phytoplankton taxa than digital imaging flow cytometry ($p = 0.016$). While digital imaging flow cytometry methods have potential in accurately enumerating and identifying phytoplankton, these findings demonstrate that improvements to digital imaging flow cytometry are needed before this method can be applied to routine HAB monitoring protocols.

Freshwater Probabilistic Monitoring Reporting Advances and Programmatic Integration at VDEQ– 40 min

Emma Jones, VADEQ (emma.jones@deq.virginia.gov); Additional authors: Jason Hill, Lucy Smith, and Mary Dail (VADEQ)

Virginia Department of Environmental Quality's (VADEQ) Freshwater Probabilistic Monitoring Program collects water quality, habitat, and benthic macroinvertebrate data to estimate aquatic ecosystem health, water chemistry and habitat to understand baseline conditions throughout the Commonwealth of Virginia. By embracing new mapping and automated analysis techniques, we can better explore the twenty year dataset at increasingly refined spatiotemporal scales, reporting on the condition of rivers and streams by basin, ecoregion, and stream size. By integrating these condition estimates across agency reporting and assessment tools, VADEQ can more readily understand monitoring data for TMDL and Permitting purposes.

Stream Fish Life History Strategies Explained by Environmental Stability

Nathaniel Hitt, USGS Eastern Ecological Science Center (nhitt@usgs.gov)

We show that predictors of environmental stability correspond to life history strategies of stream fishes in the mid-Atlantic region. The dataset included 51 fish species sampled during 2018-2019 from 20 streams intersecting the C&O Canal National Historical Park near the Potomac River in Maryland. We found that abundance of opportunistic strategists increased with low-permeability soils that produce flashy runoff dynamics and decreased with karst terrain where groundwater inputs can stabilize stream flow and temperature. Conversely, equilibrium strategists increased in karst terrain, indicating a response to stabilized environmental conditions. Our findings also indicate the utility of life history theory for understanding ecological responses to destabilized environmental conditions under global climate change.

Using Environmental DNA for Surveillance and Monitoring of Aquatic Invasive Species

Julie Lockwood, Rutgers University (julie.lockwood@rutgers.edu)

Environmental DNA is material, such as shed cells, waste products, exuviae, and reproductive secretions, that is continuously released into the environment by all living organisms. This DNA material can be collected within bulk samples of water and then assigned to species using standard molecular techniques. Our lab has been working with New Jersey Department of Environmental Protection, US Fish and Wildlife Service and other agencies to develop and deploy eDNA surveys for aquatic invasive species within the Raritan and Delaware river watersheds and coastal estuaries. In particular, we are surveying for Chinese pond mussels near their site of original introduction to ensure that they are eradicated and did not spread into nearby waterways. We are also in the initial phases of developing and deploying eDNA surveys for New Zealand mudsnail and non-native cnidarians. The mid-Atlantic is increasingly seeing new introductions of aquatic invasive species, and we argue that eDNA is a cost-effective tool for biosecurity surveillance and to inform management decisions.

Creating Native vs Non-Native Fish Status in Virginia by HUC 8
Brett Stern and Royce Steiner, VA DEQ (royce.steiner@deq.virginia.gov; brett.stern@deq.virginia.gov)
Previous native vs non-native status of Virginia fishes has been by major basin only, which typically span multiple habitat regimes and ecoregions. An interactive mapping application readily presented comprehensive data from multiple probabilistic surveys and historical records, allowing VDEQ to evaluate the native/nonnative status of the fish species of Virginia by HUC 8. The R shiny application has allowed VDEQ to efficiently identify population range extensions and correct misidentifications in the fish community database. With these database improvements, VDEQ's aims to create an Index of Biotic Integrity for fish communities in Virginia. The distribution of fishes native to Virginia will be used to calculate more accurate fish community metrics.

Spatial and Temporal Analyses of Perfluoroalkyl Substances (PFAS) in Smallmouth Bass Plasma from Sites in the Chesapeake Bay Watershed
Vicki Blazer, USGS Eastern Ecological Science Center (vblazer@usgs.gov); Additional authors: Heather L. Walsh and Cheyenne R. Smith
Fish kills of adult smallmouth bass in the Potomac drainage and young-of-year in the Susquehanna drainage, in conjunction with observations of intersex (testicular oocytes) in male bass, lead to an integrated monitoring of surface water contaminants and fish health indicators from 2013 to 2019. Blood and other tissues were collected during necropsies and plasma was obtained and replicate aliquots frozen. When questions began to be raised about the concentrations and potential effects of PFAS in Chesapeake Bay tributaries we initially utilized plasma from four sites (Antietam Creek, MD; South Branch Potomac River, WV; West Branch Mahantango Creek, PA and Pine Creek, PA) collected in 2018 to determine if 1) perfluorinated compounds were detectable in plasma from smallmouth bass in the region and 2) if concentrations varied with land use. Four compounds (PFDA, PFDoA, PFUnA, PFOS) were detected in every plasma sample and two others (PFNA, PFOSA) less frequently and at lower concentrations. Based on these initial findings we analyzed plasma from these four sites collected in 2017 and 2019 to determine if temporal trends occurred. We also used archived samples from other sites to determine spatial extent and further evaluate land-use influences and potential sources. Analyses are underway to examine associations with the numerous fish health indicators we have from these sites including prevalence of visible abnormalities, tissue parasite abundance, microscopic pathology including testicular oocytes, plasma vitellogenin, immune function endpoints and gene transcript abundance.

Aquatic Life Use Assessments Using a Thermal Fish Index – 60 min
Tim Wertz and Matt Shank, PA DEP (twertz@pa.gov; mattheshan@pa.gov)
The thermal fish index (TFI) is a valuable tool for monitoring and assessing fishes. The TFI is a multidisciplinary metric that can easily be applied to studies relating to: anthropogenic stress, waterbody condition, thermal effluents (316a), and global climate change. This simple, yet effective, metric can easily be incorporated in any program that uses assemblage-based methods for fish collection, or anyone working with fish assemblage data. An additional benefit includes a meaningful characterization of thermal class allowing the TFI to be easily understood and communicated across watershed, ecoregion or jurisdictional boundaries. This presentation will introduce the development of the TFI metric into an assessment method for making 303(d) and 305(b) listings in Pennsylvania and discuss real-world examples.

Making an Alphabet Soup of RBP's and SDM's: Using Multiple Tools to Inform Unionid Mussel Restoration

Selina Cheng, Maryland DNR (selina.cheng@maryland.gov)

Unionid mussels are among the most endangered animals in North America. They also play important roles in aquatic ecosystems, where they filter water, provide food for other animals, and act as indicators of ecosystem health. Their imperilment and ecological significance make their conservation and restoration urgent issues. Active conservation measures, such as captive propagation, are often used to augment or reintroduce mussel populations. However, a lack of knowledge about the life history and ecology of many mussel species can hamper the outcome of these efforts. To address these issues, we combine several types of data and tools to inform the restoration of Creeper (Strophitus undulatus), a geographically widespread mussel that is found in low abundance in Maryland. Specifically, we combine the use of rapid bioassessment protocol data (RBP) and species distribution modeling (SDM) using MaxEnt to 1) identify and evaluate candidate streams where restoration and survey activities are most appropriate, and 2) define a "habitat envelope" for potential restoration sites by examining the local ecological requirements at sites that currently support Creeper. The selected locations will be incorporated into a site restoration plan for Creeper. Combining a suite of readily available datasets and tools to inform restoration actions will help initiate best practices for mussel recovery and will ensure a successful outcome.

Evaluating the Hydrology, Water-Quality, and Ecological Communities of Two Restored Urban-Suburban Streams in Northern Virginia

Brendan Foster, USGS VA/WV Water Science Center (bfoster@usgs.gov)

The U.S. Geological Survey is conducting an intensive stream monitoring program of two restored small (< 1.3 mi2) urban-suburban streams in Reston, Virginia. In 2010, both stream channels were restored to stabilize the banks, preventing channel incision, mass wasting of the banks, and the attendant deleterious sediment effects. Restoration efforts will continue with the introduction of unionid mussels, planned for 2023. The monitoring program assesses the hydrology, water-quality, benthic macroinvertebrate communities, fish assemblages, and physical habitat throughout the two streams to evaluate changes over time. The monitoring program has completed its first year of data collection and will continue to collect these data for an additional year prior to the mussel introduction. Data collection will continue for two years during the introduction, and two years after the introduction to capture any lagged changes and to evaluate longer-term effects of the introduction on the streams and stream ecology.

10 Years of Continuous Instream Monitoring in Susquehanna River Basin - StoryMap and Data Dashboard

Luanne Steffy, Susquehanna River Basin Commission (lsteffy@srbc.net)

The Susquehanna River Basin Commission has been operating a large continuous instream monitoring (CIM) network for the past decade. The network originated in 2010 as a response to the natural gas boom in the basin but has evolved into a basin-wide network with a broader scope and a wide variety of applications. This brief talk will introduce a new StoryMap commemorating 10 years of CIM data collection and demonstrate the embedded data dashboard to regional partners and agencies.

Karst Terrain Promotes Thermal Resiliency in Headwater Streams
Karmann Kessler, USGS Eastern Ecological Science Center (kkessler@usgs.gov)
We demonstrate a statistical method to assess the thermal resiliency of streams from the relationship between air and water temperature data. We applied this method to data from 27 stream sites within the eastern panhandle of West Virginia (Potomac River basin) collected during summer 2021 by USGS and volunteers with the Sleepy Creek Watershed Association. Thermal sensitivity (slope of air-water linear regression) was primarily associated with karst terrain and secondarily associated with basin size. Streams in the Sleepy Creek watershed exhibited relatively low thermal resiliency (high linear regression slopes) in part due to the absence of karst groundwater inputs. Our results demonstrate the importance of karst terrain in promoting thermal resiliency in streams and suggest the importance of riparian vegetation for stream conservation outside of karst terrain.

Developing a Chesapeake Bay Watershed-Wide View of Biological Status & Trends
Kevin Krause, USGS Eastern Ecological Science Center (kkrause@usgs.gov)
Both benthic macroinvertebrates and fishes have long been used as key indicators of stream condition. Use of these indicators to measure progress in improving stream condition is of great interest to multiple stakeholder groups in the Chesapeake Bay Watershed. While efforts have addressed these needs at the single jurisdictional level (e.g., MBSS, SHEN NPS) further efforts are needed to track such site-specific changes in benthic macroinvertebrates and fish across the entire watershed. To fill this need, we seek to leverage long-term biological sampling data to quantify the status and trends among these two assemblages at the entire watershed scale. Data to support this work are available from benthic macroinvertebrate and fish sampling data compilation efforts which aggregated sampling data from federal, state, and local stream monitoring programs across the Chesapeake Bay watershed. Within these datasets, we are focusing on stream and river reaches that have been sampled repeatedly in five or more years. From these samples we are identifying key metrics that describe community composition or specific species that are both responsive to landscape drivers and instream stressors and are sufficient to estimate status over discrete time intervals and any trends that may be occurring. Results from these analyses will place results from jurisdictional studies within a broader regional context and extend the results of the recently completed predictive modeling efforts.

Comparing Salt Dilution and Acoustic Doppler Methods for Measuring Discharge in Remote Headwater Streams
Karli Rogers, USGS Eastern Ecological Science Center (kmrogers@usgs.gov)
Flow estimation is necessary for ecological and hydrological research in headwater streams, but conventional methods often lack utility in these environments during low streamflow conditions. Acoustic doppler velocimeters (ADV), such as the commonly used FlowTracker2, are reliable instruments but have limitations related to channel conditions (i.e., channel roughness, depth, velocity). Salt dilution is another method for collecting stream discharge that has been shown to perform well in headwater streams but is not widely used. Here, we compared the precision, feasibility, and efficiency of salt dilution and ADV as methods of measuring stream discharge in headwaters. Our analysis revealed (1) the precision of discharge measurements was similar between methods, (2) stream conditions were feasible for both methods but close to the limitations of FlowTracker2 (i.e., very shallow depths at most sites), and (3) salt dilution was substantially more efficient (i.e., less time required) than FlowTracker2. We conclude that salt dilution methods offer important benefits for ecohydrological research in headwater streams.