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> Project Spotlight: Impact of Climate on Mercury Transport and Bioaccumulation along the Carson River-Lahontan Reservoir System

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The complex mechanisms that control mercury (Hg) transport and bioaccumulation in the Carson River-Lahontan Reservoir (CRLR) system make it difficult to predict what the system's response will be to climate change and how it will affect aquatic health. "One objective of this project is to establish the impact of projected climate on mercury transport through the Carson River-Lahontan Reservoir system," says Dr. Rosemary Carroll, who is the primary investigator (PI) for the project. "We are also trying to establish the significance of these changes in terms of timing and the total mass of each mercury species modeled, such as total mercury, total dissolved mercury, total methylmercury, and total dissolved methylmercury." The study uses tools developed specifically for the CRLR system to provide insight into the dominant mechanisms of Hg transport based on climate-induced changes to the hydrograph. In previous stages of the project, the PIs successfully modeled the geologic and geochemical controls on total and dissolved Hg transport through the CRLR system using a linked and modified version of the US EPA RIVMOD and WASP5/MERC4 numeric codes.

Another objective of this project is to establish the impacts of projected climate change on methylmercury (MeHg) bioaccumulation in the Lahontan Reservoir.



The Lahontan Reservoir.

"It is difficult to ascertain what influence a changing climate will have on Hg transport and bioaccumulation along the CRLR system," Carroll notes. "This study will provide insight into how significant changes in the dominant mechanisms of mercury transport could be and how these changes can be managed to better protect aquatic health." Output from the CRLR transport model serves as a boundary condition for a bioenergetics and mercury mass balance model (BMMBM) that was built to simulate Hg bioaccumulation in Sacramento blackfish (Orthodon microlepidotus), a filter feeding cyprinid found in the Lahontan Reservoir. Results from previous stages of this project suggest that peak dissolved MeHg loads coupled with periods of maximum plankton growth and maximum fish consumption rates are responsible for the large mercury burdens in the fish. (Continued on page 2)

RFPs

The National Competitive Grant [104 (g)] RFP for Fiscal Year 2015 is available on the NWRRI website (www.dri.edu/nwrri).

If you have questions about submitting a proposal, e-mail Amy Russell (Amy.Russell@dri.edu).

The US Bureau of Reclamation's (USBR) bias-corrected, spatially downscaled surface water projections provide 112 possible hydrographs along the Carson River. These hydrographs extend until 2099 and are based on the World Climate Research Programme Coupled Model Intercomparison Project 3 and a variable infiltration capacity hydrologic model. These hydrographs drive the CRLR Hg transport model and BMMBM, which are used to assess decadal shifts in system response and the significance of these shifts. Hypothetical management scenarios will be developed based on the system response and coded into the RIVMOD/WASP, and then the hydrographs will be rerun to test the approach's effectiveness.

Over the past year, Carroll has made coding modifications to the dissolved Hg from the original codes that she presented in her PhD thesis and soon she will be submitting an updated article to the journal *Ecological Modeling*. This project has also provided UNR graduate student Allison Flickinger with the opportunity to participate in multiple stages of research. "Allison has modified the coding for the RIVMOD/WASP to allow the transport code to run over 100 years at the daily time step and she has analyzed the USGS observed discharges from the

Gardnerville, Woodfords, and Carson City gages in order to determine a relationship between the upstream and downstream flows in the Carson River," Carroll explains. Flickinger has also performed a linear regression in the log-log scale for every month in order to compare the combined Gardnerville and Woodfords daily flows to the Carson City daily flows, which produced acceptable R-squared values for the regressions for all months except September and October. For these two months, regressions on a half-month time step resulted in higher R-squared values.

These regressions were applied to the combined upstream flows, which resulted in a set of modeled Carson City discharges. Comparing the modeled and observed daily flows showed a satisfactory normalized rootmean-square error (NRMSE) of 1.69 percent. The regressions were then applied to the upstream projections for 2000-2099 to create a set of projected flows at the Carson City gage site. By comparing the USBR projected flows from 1950–1999 to the observed flows, Flickinger found that there was a high level of bias. She then used the bias-correction method from Gangopadhyay and Pruitt (2011) and found the empirical cumulative distribution functions (ECDFs) for both the observed and the projected data from 1950-1999. The modeled data was corrected by finding the flow percentile based on the ECDF of the modeled data and using the flow of the corresponding percentile from the ECDF of observed data as the bias corrected flow.

A model was developed to predict the stage of the Lahontan Reservoir and the discharge from the Lahontan Dam so that these variables could be used as inputs to assess mercury transport. The model uses the



Dr. Rosemary Carroll on-site at the Lahontan Reservoir.

(Project Spotlight continued)

projected Fort Churchill flows as inputs along with an averaged Truckee Canal input. The outputs from the canal and the discharge from the dam were determined by release rules that ensure enough water is available for agriculture. The model was found to have an NRMSE of 12.63 percent for the reservoir stage and an NRMSE of 16.90 percent for the dam discharges. "The input files for each of the 112 hydrographs have been built and are currently being run using the mercury transport model on the Desert Research Institute grid, but simulation times are extensive and a single run can take up to several weeks to complete," Carroll says. "The output for each mercury species and the total mass transported is currently being analyzed, and then the decadal statistics will be used in order to determine whether changes to system are statistically significant."

Flickinger presented the transport results at the 2014 AGU Fall Meeting in San Francisco, California. For the next stage of this project, the researchers will use the MeHg output in the reservoir as a boundary condition in a model to estimate bioaccumulation in the reservoir's Sacramento blackfish. The outputs will then be processed and any significant changes from the baseline conditions will be addressed. Flickinger will also be defending her thesis for May graduation and she hopes to have her work published in a peer-reviewed journal at that time.

Reference:

Gangopadhyay, S. and T. Pruitt, 2011. West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections. Water and Environmental Resources Division, US Department of the Interior Bureau of Reclamation, Technical Memorandum No. 86-68210-2011-01.

Upcoming Events

NWRA 2015 Annual Conference Week; Reno, NV January 26-29: www.nvwra.org/2015-annual-conference

AWRA 2015 Spring Conference; Los Angeles, CA March 30-April 1: www.awra.org

NGWA Groundwater Summit; San Antonio, TX March 16-18: www.groundwatersummit.org

AGU Chapman Conference on California Drought; Irvine, CA April 20-22: chapman.agu.org/drought

AGU 2015 Joint Assembly; Montreal, Canada May 3-7: ja.agu.org/2015

AGU Chapman Conference on Evolution of the Asian Monsoon and its Impact on Landscape, Environment, and Society; Hong Kong SAR, China June 14-19: chapman.agu.org/monsoon

AWRA 2015 Summer Conference; New Orleans, LA June 15-17: www.awra.org

AGU Chapman Conference on The Width of Tropics; Santa Fe, NM July 26-31: chapman.agu.org/tropics

GSA 2015; Baltimore, MD November 1-4: www.geosociety.org/meetings/2015

ASA, CSSA, and SSSA 2015 Annual Meeting; Minneapolis, MN November 15-18: www.acsmeetings.org

AWRA 2015 Annual Water Resources Conference; Denver, CO November 16-19: www.awra.org

AGU 2015 Fall Meeting; San Francisco, CA December 14-18: meetings.agu.org/upcoming-meetings

PI Spotlight: Dr. Rosemary Carroll



Modeling mercury transport and fate has been a long-held interest for Dr. Rosemary Carroll. Both her MS and PhD research focused on mercury transport and fate modeling for the Carson River. To appropriately model this system, she had to extensively modify the codes describing hydraulics (RIVMOD) and water quality (WASP5, MERC4). She then conducted Monte Carlo simulations to examine uncertainty in the parameter values and in the model's ability to predict future system behavior. Her interest in

mercury transport modeling has also allowed her to continue to work collaboratively with Dr. John Warwick.

In her subsequent research at DRI, Carroll has focused on developing a coupled surfacesubsurface model (EPIC-MODFLOW) to describe hydrologic response in semipermanent and temporary wetlands to changing climatic conditions. She then translated this model to STELLA® and continues to look at climatic effects and prairie pothole wetlands. Much of Carroll's recent work has focused on evaluating climate-induced changes to stream and groundwater interactions and the ecohydrological impacts of vegetative succession. "Given that my past research had defined mercury transport in terms of specific flow regimes, it became apparent that it would be beneficial to understand how

climate change could affect hydrologic resources and influence water quality and ecological health," Carroll says.

If given the choice between a wet lab and the field, Carroll would rather work in the field. "Recently, I have been working about one day per week along the East River, which is a headwater catchment of the Colorado River," she explains. "The site is extraordinarily beautiful, I enjoy being outside, and I can often get to my research sites with skis. I have no complaints!" Another of Carroll's research interest includes working to improve water resources for populations that struggle with obtaining potable water, as well as working with the local/regional water planners to resolve issues with resource overuse, climate change, and water quality degradation. Currently, she is adding these topics to her work structure.

When asked what one of her favorite books was, Carroll couldn't decide on just one, but she did say that she is generally drawn to historical fiction and any book with great character development. "I also tend to lean toward books that place an emphasis on the landscape in the story," she adds. "Some of my favorite books include *Cutting for Stone* by Abraham Verghese, *The God of Animals* by Aryn Kyle, *The Book Thief* by Markus Zusak, *A Tale of Two Cities* by Charles Dickens, *Wuthering Heights* by Emily Brontë, *Pride and Prejudice* by Jane Austen, *Dancing at the Rascal Fair* by Ivan Doig, and *The Grapes of Wrath* by John Steinbeck."

"Given that my past research had defined mercury transport in terms of specific flow regimes, it became apparent that it would be beneficial to understand how climate change could affect hydrologic resources and influence water quality and ecological health."

Student Interview: Allison Flickinger

We asked graduate student Allison Flickinger about her current research and her plans for the future. Here's what she had to say:

What field are you currently studying and what sparked your interest in that field?

I'm studying hydrology. When I was growing up, I spent a lot of time on Minnesota's lakes and trips with my family were often to water-centric locations (the Headwaters of the Mississippi, Hoover Dam, and the Panama Canal), so it makes sense that I became interested in water research.

Which NIWR project are you working on and what research are you doing?

I'm working on the project titled "Impact of Climate on Mercury Transport and Bioaccumulation along the Carson River– Lahontan Reservoir System," which analyzes climate change and how it affects the transport and bioaccumulation of mercury in the Carson River and Lahontan Reservoir system.

What have you learned from working on this project?

I've learned a lot about working with large amounts of data and the intricacies of modeling.

Over the course of this project, what do you hope to learn more about?

I'll be starting to work with a bioenergetics and bioaccumulation model and I'm looking forward to learning about how the changes in mercury affect the fish in the reservoir.

What have you enjoyed most about working on this project?

I have enjoyed getting to see the Lahontan Reservoir and Dam because it is nice to be able to connect what I'm modeling with the real thing.



What are your goals for the next step in your career?

My goal after graduation is to get a job that uses my graduate education.

Do you have a favorite dish that you like to make and why is it your favorite?

I love to make lasagna because I use my mom's recipe. It's delicious and it makes a meal that is big enough to share with friends.

Cake or Pie?

Both! I have a bit of a sweet tooth.

"I have enjoyed getting to see the Lahontan Reservoir and Dam because it is nice to be able to connect what I'm modeling with the real thing." Success and the dedication to quality research have established the Division of Hydrologic Sciences (DHS) as the Nevada Water Resources Research Institute (NWRRI) under the Water Resources Research Act of 1984 (as amended). As the NWRRI, the continuing goals of DHS are to develop the water sciences knowledge and expertise that support Nevada's water needs, encourage our nation to manage water more responsibly, and train students to become productive professionals.

Desert Research Institute, the nonprofit research campus of the Nevada System of Higher Education, strives to be the world leader in environmental sciences through the application of knowledge and technologies to improve people's lives throughout Nevada and the world.

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