# Nevada Water Resources Research Institute Annual Technical Report FY 2017

# Introduction

Success and dedication to quality research has established the Division of Hydrologic Sciences as the recognized "Institute" under the Water Resources Research Act of 1984 (as amended). A total of 54 Institutes are located at colleges and universities in the 50 states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. The primary mission of the Nevada Water Resources Research Institute is to inform the scientists of Nevada.

# Research Program Introduction

Nevada is the most arid state in the United States and it is experiencing significant population growth and possible future climate change. With competing water demands for agricultural, domestic, industrial, and environmental uses, issues surrounding water supply and quality are becoming more complex, which increases the need to develop and disseminate sound science to support informed decision making.

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. Therefore, DHS has chosen to make a valuable contribution to water research and education in Nevada by judiciously distributing its Section 104 research funds among numerous subject areas. Projects must be of significant scientific merit (as determined by the review process) and relevant to Nevada's total water program to be considered worthy of funding.

To ensure collaboration and coordination among water-related entities throughout the state, DHS maintains a Statewide Advisory Council on Water Resources Research composed of leading water officials who may be called upon to assist in selecting the research projects that will be supported by Section 104 funds.

# Uptake of Pharmeceutical and Steroidal Compounds by Quagga Mussels in Lake Mead

## Basic Information

| | |
|---|---|
| **Title:** | Uptake of Pharmeceutical and Steroidal Compounds by Quagga Mussels in Lake Mead |
| **Project Number:** | 2016NV212B |
| **Start Date:** | 3/1/2017 |
| **End Date:** | 2/28/2019 |
| **Funding Source:** | 104B |
| **Congressional District:** | NV-01 |
| **Research Category:** | Water Quality |
| **Focus Categories:** | Water Quality, Toxic Substances, Invasive Species |
| **Descriptors:** | None |
| **Principal Investigators:** | Xuelian Bai, Kumud Acharya |

## Publications

There are no publications.

**TITLE: UPTAKE OF PHARMACEUTICAL AND STEROIDAL COMPOUNDS BY QUAGGA MUSSELS IN LAKE MEAD**

Annual Report

PIs: Xuelian Bai and Kumud Acharya

## Problem and research objectives

Municipal wastewater effluents contain untreated contaminants, such as naturally occurring and synthetic hormones as well as pharmaceuticals and personal care products (PPCPs). These unregulated contaminants have become a significant concern in the environment because of their potential effects on the health of wildlife and humans at trace levels. Conventional wastewater treatment plants (WWTPs) cannot remove organic contaminants completely and they are frequently found at levels of parts per trillion to parts per billion in wastewater effluents (Jones et al. 2005, Lubliner et al. 2010, Miao et al. 2004, Miao et al. 2002, Soulet et al. 2002). Previous studies have also reported the presence of these contaminants at significant levels in surface waters worldwide (Ellis 2006, Kolpin et al. 2002, Lin &Reinhard 2005, Stan &Heberer 1997, Ternes et al. 2002). Therefore, the long-term ecological and human health effects, as well as the exposure routes, of untreated contaminants in aquatic ecosystems need to be evaluated.

Many emerging contaminants are documented to cause adverse health effects, such as endocrine disruption, in wildlife and humans (Brian et al. 2005, Brian et al. 2007). Fish and other organisms downstream from WWTPs are chronically exposed to endocrine disrupting chemicals (EDCs) that may cause inappropriate sexual differentiation or development (Guillette et al. 1995, McLachlan 2001, Vajda et al. 2008). In addition to fish species, studies also reported the presence and uptake of EDCs in other aquatic species such as mollusks (Fernandes et al. 2011, Giusti &Joaquim-Justo 2013, Janer &Porte 2007, Scott 2012), mussels (Fernandes et al. 2010, Hallmann et al. 2016, Peck et al. 2007, Schwarz et al. 2017), algae (Bai &Acharya 2016, Bai &Acharya 2017, Maes et al. 2014, Zhang et al. 2014), and duckweed (Shi et al. 2010). Therefore, regulators and scientists attempt to identify the contaminants that can biomagnify in food chains and accumulate at harmful concentrations in higher trophic level organisms, including human beings. However, little information is available about the uptake of EDCs in bivalves, especially for synthetic chemicals that behave as xenoestrogens. The role that bivalves play in the accumulation and/or food web transfer of EDCs in aquatic ecosystems is still unclear.

Mussels have been used to indicate bioavailable concentrations of heavy metals and organic pollutants in aquatic environments. Mussels are efficient filter feeders that consume plankton and organic detritus, and they accumulate contaminants directly from the water column and from particulate matter (Richman &Somers 2005). The quagga mussel (*Dreissena bugensis*) is an invasive species that has spread through freshwaters across the United States, especially in the southwestern states. In southern Nevada, Lake Mead exhibits year-round warm temperatures, high calcium levels, and a lack of natural predators, all of which are strongly favorable conditions for the growth of quagga mussels. Additionally, Lake Mead represents an urban water supply reservoir that is used for drinking water, as well as recreation activities and a habitat for diverse wildlife species. Lake Mead is highly affected by anthropogenic activities through wastewater discharge from multiple WWTPs in the Las Vegas metropolitan area, where numerous untreated organic contaminants have been detected previously (Bai &Acharya 2017, Boyd &Furlong 2002, Rosen et al. 2010, Snyder &Benotti 2010). Many studies have reported that various aquatic organisms are undergoing endocrine disruption in Lake Mead and the adjacent Lower Colorado River (Bevans et al. 1996, Goodbred et al. 2015, Patino et al. 2003, Patino et al. 2015, Rosen et al. 2010). Therefore, quagga mussel can be an efficient biomonitor for water quality in this aquatic ecosystem.

The goal of this study was to understand the uptake of EDCs by quagga mussels in an aquatic ecosystem using both field monitoring and laboratory experiments. The objectives of this research were to: 1) measure ambient concentrations of a suite of EDCs in water samples and quagga mussels collected from different locations in Lake Mead, Nevada; and 2) determine the uptake processes of EDCs by quagga mussels under controlled laboratory conditions via direct exposure to EDCs in the water or via food chain (i.e., algae feeding). This research provides much-needed insights into the occurrence, exposure routes, and environmental risks of EDC accumulation in invertebrates.

## Methodology

### *1. Mussel and water sampling*

Quagga mussels were collected from three locations in the Lake Mead area: Lake Mead Marina, Las Vegas Bay, and Boulder Island (Table 1 and Figure 1). Mussels were collected at a 1 m depth from Lake Mead Marina and a 12 m depth from Las Vegas Bay and Boulder Island based on their availability at the different locations during the sampling season. The collected mussels were rinsed with lake water to remove debris, placed in ventilated containers filled with lake water, and then transported to the laboratory immediately. In the laboratory, adult mussels from each sampling site were rinsed with deionized (DI) water several times and deshelled immediately. Mussels larger than 12 mm were considered adults (Thaw 2013), and only adult mussels were selected for the following studies. Eventually, approximately 10 g (wet weight) of mussel tissue from each sampling site was obtained and kept frozen in a wide-mouth glass jar at -20 °C. The mussel tissue was then shipped overnight on ice to the EPA certified Weck Laboratories Inc. (City of Industry, CA) for trace organic chemical analysis. An additional batch of mussels was collected from Lake Mead Marina only and kept in an aquarium tank filled with lake water to acclimate to the laboratory conditions at room temperature for a week. The aquarium was aerated and fitted with sponge filters, and then exposed to 12 h of light and 12 h of darkness to maintain normal algal growth. These mussels were used for the following bench-scale exposure experiments.

Water was collected in duplicate simultaneously from the same sampling sites using 1 L amber glass bottles preserved with sodium azide (1 g/L) and ascorbic acid (50 mg/L). Water samples were kept on ice and transported to the laboratory immediately after collection. Water samples were kept at 4 °C in the laboratory until further chemical analysis performed. Additionally, bulk lake water was collected from Lake Mead Marina in 10 gallon carboys and filtered using a 35 μm mesh filter to remove plankton, sediments, and large pieces of algae (Thaw 2013). The filtered water was stored in aerated, lightly covered buckets in the laboratory for further experiments.

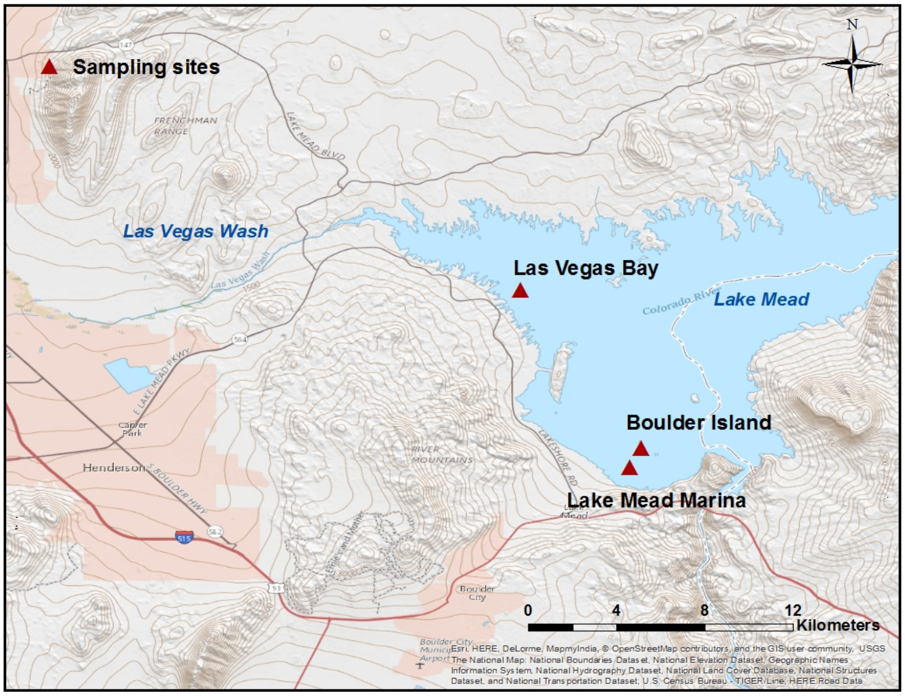



Figure 1. Map of sampling sites in Lake Mead, Nevada.

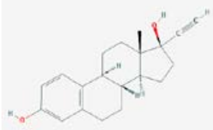
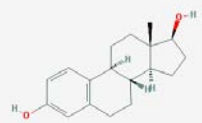
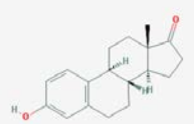
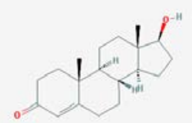
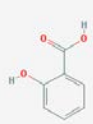
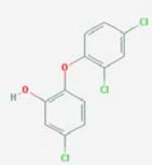
Table 1. Site description for water and quagga mussel sampling in Lake Mead.

| Site | Latitude (N) | Longitude (W) | Sample Date | Depth (m) |
|---|---|---|---|---|
| Lake Mead Marina | 36.029306 | -114.772056 | Jan-9-2017 | 1 |
| Boulder Island | 36.037153 | -114.767529 | Feb-14-2017 | 12 |
| Las Vegas Bay | 36.101688 | -114.816596 | Feb-14-2017 | 12 |

### *2. Bench-scale exposure experiments*

According to the field observations, the EDCs that were detected in the mussel tissue and all steroidal hormones were studied using a series of laboratory-based exposure experiments. Steroidal hormones are the most potent EDCs that accumulate in the mussel tissue and they can also cause adverse effects to other species within the food web. Although steroidal hormones were not frequently detected in the surface water or biomass, they are an important indicator of endocrine disruption in an aquatic ecosystem. For the exposure study, 30 adult mussels (size between 12 and 20 mm) were transferred from the aquarium tank to a 2 L beaker filled with the filtered, aerated lake water. Each beaker with 30 mussels was aerated and lightly covered with foil throughout the duration of the experiment (i.e., 7, 21, and 42 days) and kept at room temperature (~23 °C). During the experimental period, two studies were used to evaluate two potential exposure

Table 2. Properties of target EDCs used for laboratory-based experiments.

| Compound | Structure | Molecular Formula | Molecular Weight (g/mol) | Log *K*OW | Sw (mg/L) | Applied dose (ng/L) |
|---|---|---|---|---|---|---|
| | | | *Hormones* | | | |
| 17α-Ethinylestradiol |  | $C_{20}H_{24}O_2$ | 296.4 | 3.67 | 11.3 | 142 |
| 17β-Estradiol |  | $C_{18}H_{24}O_2$ | 272.4 | 4.01 | 3.6 | 92 |
| Estrone |  | $C_{18}H_{22}O_2$ | 270.4 | 3.13 | 30 | 130 |
| Testosterone |  | $C_{19}H_{28}O_2$ | 288.4 | 3.32 | 23.4 | 156 |
| | | | *Pharmaceuticals and personal care products* | | | |
| Bisphenol A |  | $C_{15}H_{16}O_2$ | 228.3 | 3.32 | 300 | 2163 |
| Salicylic Acid |  | $C_7H_6O_3$ | 138.1 | 2.26 | 2240 | 2082 |
| Triclosan |  | $C_{12}H_7Cl_3O_2$ | 289.5 | 4.76 | 10 | 127 |

pathways: direct water exposure and food chain exposure (i.e., via algae feeding). For the direct water exposure treatment, the lake water was spiked with 50 µL EDC stock solution to reach the desired initial concentrations (Table 2) in the beginning of the experiment. To keep the water fresh and clean in each beaker, 1 L of water with mussel feces was disposed twice a week, and 1 L of fresh lake water spiked with the EDCs at the initial doses was added to refill the beaker. A freshwater green alga species, *Nannochloris sp.*, was used as a food source to keep the mussels alive and healthy throughout the experiments. Algal cultivation followed previous methods (Bai &Acharya 2016, Bai &Acharya 2017), and approximately 0.01 g (dry weight) of the alga was applied to feed the mussels on a daily basis.

For the food chain exposure treatment, algal cells were spiked with 5 µL of the stock EDC solution and shaken well to bind the EDCs to the algal cells before they were fed to the mussels every day. Our previous findings showed that biosorption to algal cells was a major pathway for the uptake of hydrophobic compounds (Bai &Acharya 2016, Bai &Acharya 2017). The water changing process for this treatment followed the same process as the direct water exposure treatment, but no EDCs were spiked to the water to ensure that the EDCs applied were associated with the algal cells only. Five beakers were used for each treatment and for each experimental duration. For each treatment, at the end of the experiment (i.e., 7, 21, and 42 days), all 30 mussels from each beaker were collected and deshelled, and the tissue sampled from all five beakers was mixed together as one composite sample to obtain enough mass and to reduce the sample size. Each tissue sample (~ 10 g wet weight) was kept frozen at -20 °C in a wide-mouth glass jar until further analysis could be conducted. A control using filtered lake water without EDC spiking was used to identify the effects of the laboratory conditions and the EDCs on the mortality of the mussels. The results showed no mortality throughout the study period even with EDC spiking.

### 3. Chemical analysis

Standard chemicals of 17α-ethinylestradiol, 17β-estradiol, estrone, testosterone, bisphenol A, salicylic acid, and triclosan were purchased from Sigma-Aldrich (St. Louis, MO) with purity > 98%. The initial concentrations of the target EDCs were determined based on their reported levels in wastewater effluents and surface waters. The selected doses are approximately 5 times greater than the reported levels in wastewater effluents to ensure detection (Lubliner et al. 2010). The concentrations of the stock solution (in methanol) ranged from 3.7 to 86.5 mg/L. The physicochemical properties and initial doses of the compounds used in the study are summarized in Table 2. All analyses of the target compounds in the mussel and water samples were performed by Weck Laboratories Inc. as described elsewhere (Bai &Acharya 2017). Briefly, the analytical method for water samples followed the EPA standard method for pharmaceuticals and personal care products (i.e., EPA 1694M ESI-) and hormones (i.e., EPA 1694M-APCI) using liquid chromatography tandem mass spectrometry (LC-MS/MS) (U.S. EPA 2007), and an isotope spike was applied before sample pretreatment and extraction that was subject to the same analytical procedure. For the mussel tissue, the analytes were extracted using a quick, easy, cheap, effective, rugged, and safe (QuEChERS) method developed recently. The QuEChERS extraction procedure has been successfully used to determine pharmaceuticals in plants (Chuang et al. 2015) and fish

(Lopes et al. 2012). The mussel extracts were then analyzed for the target compounds using identical LC-MS/MS procedures to those used for the water samples.

**Principal findings and significance**

***1. EDCs in water samples***

The EDC concentrations in the water samples collected at the three study locations can be found in Table 3. Las Vegas Bay is the receiving waterway of municipal wastewater effluents. Boulder Island and Lake Mead Marina are further downstream of the Las Vegas Bay and expected to be less contaminated. However, these two locations are two of the most popular recreation sites at the lake, and recreational activities are considered the primary route for human exposure. Additionally, the nearby fisheries may also be influenced by these contaminants. Monitoring the contaminants using quagga mussels at these locations indicates the potential risks to other aquatic organisms, and even humans. The screening results showed that steroidal hormones were not found in any water samples. All of the PPCPs analyzed were detected in at least one of the sampling locations, except for iopromide. Bisphenol A, salicylic acid, and triclosan were found to be more abundant in the water samples compared with other analytes. The authors previously monitored over 200 wastewater organic contaminants in the urban watershed in Denver, Colorado, and reported that diclofenac, gemfibrozil, bisphenol A, and triclosan had median concentrations of 26.1, 32.3, 139, and 92.4 ng/L, respectively (Bai et al. 2018). The frequency of detection for diclofenac, gemfibrozil, bisphenol A, and triclosan was 40.1%, 42.5%, 50.9%, and 11.4%, respectively (Bai et al. 2018). Steroidal hormones were also found at low frequencies but relatively high concentrations at selected sampling sites in the Denver watershed: 17β-estradiol at 393 ng/L (11.4%), estrone at 112 ng/L (1.2%), and 17α-ethinylestradiol at 228 ng/L (9.6%). Additionally, triclosan has been detected at 2.6 and 8.0 ng/L in Lake Mead Marina and upstream of Las Vegas Bay, respectively (Bai &Acharya 2017). Similar monitoring studies have been done in Taihu Lake, China, where ibuprofen and diclofenac were detected at levels up to 65. 3 ng/L (Xie et al. 2015).

When comparing Lake Mead Marina and Boulder Island—which are the two adjacent sampling sites—the measured PPCPs appear to have higher concentrations in Boulder Island at 12 m depth (Table 3). This indicates that the contaminants are more persistent in the deeper water column, which may be because of low light exposure, low oxygen, and low microbial activities that inhibit the degradation of the contaminants. The persistence of EDCs in the deeper horizon may also cause a potential exposure risk for bottom-dwelling aquatic organisms. When comparing the Boulder Island and Las Vegas Bay sites sampled at the same depth (i.e., 12 m), more PPCPs were detected in the Las Vegas Bay water. Las Vegas Bay receives municipal wastewater effluent, surface runoff, and periodical flood water, all of which are sources of the contaminants measured. Conversely, the contaminants can undergo natural attenuation and dilution as water flows into Lake Mead, resulting in lower detections (Bai &Acharya 2017). In a previous study performed at the same locations by the U.S. Geological Survey (Rosen et al. 2010), the highest concentrations of hydrophobic organic contaminants were found at a depth of 8 m in Las Vegas Bay. Rosen et al. (2010) also suggested that contaminants were generally confined to within 6 m of the lake bottom during the winter and spring, when Las Vegas Wash water sank to the bottom because of temperature and density contrasts between the Las Vegas Wash and Lake Mead water. The results of this study further demonstrate that many EDCs are present in the southern Nevada watershed. Therefore, the ecological impacts of these contaminants need to be fully evaluated despite the trace levels detected and the vertical gradient of the contaminants needs to be monitored at different depths in the lake to assess the potential risks.

Table 3. Concentrations of EDCs measured in water (ng/L) and mussel (ng/g dry weight) samples in Lake Mead. MDL = method detection limit. ND= not detected.

| **Analyte** | **Lake Mead Marina**† | **Boulder Island**‡ | **Las Vegas Bay**‡ | **MDL** |
|---|---|---|---|---|
| | | **Water (ng/L)** | | |
| | | *Hormones* | | |
| 17α-Ethinylestradiol | ND | ND | ND | 0.56 |
| 17β-Estradiol | ND | ND | ND | 0.31 |
| Estrone | ND | ND | ND | 0.20 |
| Progesterone | ND | ND | ND | 0.17 |
| Testosterone | ND | ND | ND | 0.14 |
| | | *Pharmaceuticals and personal care products* | | |
| Bisphenol A | 1.2 | 30 | 22 | 0.27 |
| Diclofenac | 0.49 | ND | 1.5 | 0.26 |
| Gemfibrozil | ND | ND | 0.91 | 0.080 |
| Ibuprofen | ND | 0.55 | 1.5 | 0.39 |
| Iopromide | ND | ND | ND | 1.8 |
| Naproxen | ND | ND | 1.1 | 0.25 |
| Salicylic Acid | 17 | 28 | 36 | 0.86 |
| Triclosan | ND | 6.1 | 2.4 | 1.2 |
| | | **Mussel tissue (ng/g)** | | |
| | | *Hormones* | | |
| 17α-Ethinylestradiol | ND | ND | ND | 5.0 |
| 17β-Estradiol | ND | ND | ND | 5.0 |
| Estrone | ND | ND | ND | 5.0 |
| Progesterone | ND | ND | ND | 5.0 |
| Testosterone | 6.3 | 12 | 20 | 5.0 |
| | | *Pharmaceuticals and personal care products* | | |
| Bisphenol A | 47 | ND | ND | 5.0 |
| Diclofenac | ND | ND | ND | 5.0 |
| Gemfibrozil | ND | ND | ND | 5.0 |
| Ibuprofen | ND | ND | ND | 5.0 |
| Iopromide | ND | ND | ND | 25 |
| Naproxen | ND | ND | ND | 5.0 |
| Salicylic Acid | 430 | ND | ND | 250 |
| Triclosan | 24 | 28 | ND | 10 |

†Sample collected at 1 m. ‡ Sample collected at 12 m.

## 2. Uptake of EDCs by quagga mussels

### *2.1 Steroids*

For the quagga mussels collected from the field sites, testosterone was the only steroidal hormone that was detected (Table 3). Testosterone was not found in the water samples, but it was detected in the mussel tissue from all three sampling sites at various levels listed in order from high to low: Las Vegas Bay>Boulder Island>Lake Mead Marina (Table 3). Many studies have reported the occurrence of steroidal hormones in mollusks—mainly testosterone and 17β-estradiol—but the origins are still unknown. Fernandes et al. (2010) found that the naturally occurring testosterone along the mussel reproductive cycle ranges from 0.1-1.4 ng/g, which is much lower than the concentrations measured in this study (i.e., 6.3 to 20 ng/g in Table 3). Scott (2012) reviewed most of the existing studies on vertebrate sex steroids found in mollusks so far and he developed three hypotheses: a) vertebrate steroids are found in mollusks because of the limitations of analytical procedures; b) mollusks biosynthesize steroids themselves; and c) mollusks accumulate steroids from the environment. Steroidal hormones in aquatic environments can be from wastewater effluents and animal feeding operations. Moreover, species such as fish are demonstrated to release steroids in urine and feces. Therefore, mussels are continuously exposed to exogenous steroids throughout their life cycle and it is challenging to identify the origins of the steroids found in the mussel tissue. Furthermore, humans and animals usually release estrogens in biologically inactive conjugated forms (i.e., sulfate and glucuronide), which are also commonly found in aquatic environments (Bai et al. 2015, Bai et al. 2013). Interestingly, mollusks are known to be rich in the enzymes that hydrolyze the steroid conjugates, and therefore they are capable of taking up steroid conjugates from the environment and converting them to free steroids. All of these can be explanations for the occurrence of steroidal hormones in invertebrates. Although free steroids were not detected in the water samples in this study, free steroids and their conjugates might accumulate and transfer within the food web to cause adverse effects.

Testosterone was no longer detected in the mussels after they were exposed to EDCs under laboratory conditions for several weeks (Table 4). This is likely because the mussels may have released testosterone back to the water or esterified with fatty acids to stabilize the exogenous steroid. Similarly, Fernandes et al. (2010) stated that exposure to exogenous testosterone in the laboratory did not increase testosterone levels in the mussels and that the mussels likely excreted testosterone into the water. Mussels tend to esterify steroids with fatty acids and transform them into a more stable form that is resistant to metabolism (i.e., esterified steroids) (Scott 2012). Fatty acid esterification is a key mechanism that allows mussels to maintain their normal steroid levels following environmental exposure. This pathway may have occurred in this study, but esterified steroids were not measured in the mussel tissue.

Under laboratory conditions, the synthetic estrogen 17α-ethinylestradiol was detected at 7.4 ng/g after 42 days of exposure from the food chain (Table 4). 17α-ethinylestradiol detection in the mussel tissue suggests that exogenous estrogens can be taken up by aquatic invertebrate species from the environment because 17α-ethinylestradiol is a synthetic estrogen that cannot form endogenously. 17α-ethinylestradiol has been found in wild-caught mollusks at levels up to 80-130 ng/g of dry tissue weight (Liu et al. 2009, Lu et al. 2001). Naturally occurring estrogens were not detected in the mussel after 42 days of exposure, and therefore it appears that they either did not accumulate in the mussel or the estrogens were esterified and stabilized in the tissue. Of the naturally occurring estrogens, 17β-estradiol is the most frequently found in invertebrates, even though it was not detected in this study. Peck et al. (2007) reported that zebra mussels (*Dreissena polymorpha*)—which are freshwater bivalves—were susceptible to estrogen exposure, and when they were exposed to 5.5 ng/L of 17β-estradiol for 13 days, 17β-estradiol could accumulate in the mussel tissue at 840- and 580-fold in males and females, respectively. Additionally, testosterone and 17β-estradiol concentrations were found to increase dramatically over time in mollusks that were caged downstream of sewage treatment plants (Gust et al. 2010a, Gust et al. 2010b).

Table 4. Concentrations of selected EDCs measured in mussel tissue from laboratory-based exposure experiments (ng/g dry weight). MDL = method detection limit. ND= not detected.

| **Analyte** | **7 days** | | **21 days** | | **42 days** | |
|---|---|---|---|---|---|---|
| | Result | MDL | Result | MDL | Result | MDL |
| | | | **Direct water exposure** | | | |
| | | | *Hormones* | | | |
| 17α-Ethinylestradiol | ND | 0.67 | ND | 1.0 | ND | 0.55 |
| 17β-Estradiol | ND | 0.67 | ND | 1.0 | ND | 0.55 |
| Estrone | ND | 0.67 | ND | 1.0 | ND | 0.55 |
| Testosterone | ND | 0.67 | ND | 1.0 | ND | 0.55 |
| | | | *Pharmaceuticals and personal care products* | | | |
| Bisphenol A | ND | 0.56 | ND | 1.0 | 6.5 | 0.55 |
| Salicylic Acid | ND | 28 | ND | 51 | ND | 28 |
| Triclosan | 4.0 | 1.1 | ND | 2 | ND | 1.1 |
| | | | **Food chain exposure** | | | |
| | | | *Hormones* | | | |
| 17α-Ethinylestradiol | ND | 0.75 | ND | 0.62 | 7.4 | 0.65 |
| 17β-Estradiol | ND | 0.75 | ND | 0.62 | ND | 0.65 |
| Estrone | ND | 0.75 | ND | 0.62 | ND | 0.65 |
| Testosterone | ND | 0.75 | ND | 0.62 | ND | 0.65 |
| | | | *Pharmaceuticals and personal care products* | | | |
| Bisphenol A | 26 | 0.89 | ND | 0.62 | 6.5 | 0.65 |
| Salicylic Acid | 830 | 44 | ND | 31 | ND | 33 |
| Triclosan | ND | 1.8 | ND | 1.2 | ND | 1.3 |

### *2.2 PPCPs*

Bisphenol A, salicylic acid, and triclosan were found at relatively high levels in the mussel tissue based on the field observations (Table 3). Bisphenol A, salicylic acid, and triclosan can act as xenoestrogens because they have similar chemical structures to estrogens, and they may interfere with the endocrine systems of aquatic organisms. All of the contaminants detected are hydrophobic with log $K_{ow}$ values ranging from 2.26 to 4.76 (Table 2), so they tend to be associated with the biomass in the aquatic ecosystem. According to the field monitoring study in Taihu Lake, China, roxithromycin, propranolol, diclofenac, and 17β-estradiol were found in mussels (*Anodonta*) with bioaccumulation factors of 406, 234, 70, and 59 L/Kg, respectively (Xie et al. 2015). All these findings demonstrated the bioaccumulation potential of selected wastewater contaminants in mussels in aquatic environments.

After being exposed to EDCs for 7, 21, and 42 days in the laboratory, the mussels were able to accumulate selected EDCs at different levels. For both the direct water exposure and food chain exposure studies, bisphenol A and triclosan were found in the mussel tissue at levels lower than the field observations, and salicylic acid from the food chain exposure study was measured at a higher concentration compared with the field observation (Table 3 and 4). Moreover, bisphenol A and salicylic acid were measured at higher levels in the mussel tissue from the food chain exposure study compared with the direct water exposure study (Table 4), indicating that mussels may take up these compounds from the food source rather than directly from the water. Some mollusks are reported to be particularly susceptible to exposure to xenoestrogens such as bisphenol A, which can result in superfeminization of prosobranch snails (Jobling et al. 2003, Oehlmann et al. 2000). Triclosan was only detected after 7 days of exposure in the direct water exposure study (Table 4). This may be because triclosan is highly susceptible to light and it tends to photodegrade, and algae can increase its photodegradation rates (Bai &Acharya 2016, Bai &Acharya 2017). This results in the rapid dissipation of this compound in the aquatic environment and lower accumulation in the mussels. However, other studies have found triclosan in male common carp (*Cyprinus carpio*) from Las Vegas Bay to decrease sperm counts and induce vitellogenin (Jenkins et al. 2018, Leiker et al. 2009) . Nonetheless, xenoestrogens may play a role in the reproductive physiology of aquatic organisms, but the adverse effects to aquatic invertebrates following exposure to xenoestrogens and exogenous steroids need to be further evaluated.

**Information transfer activities**

The PIs have submitted a manuscript entitled "Uptake of endocrine disrupting chemicals by quagga mussels (*Dreissena bugensis*) in an urban-impacted aquatic ecosystem" to the peer-reviewed journal Environmental Science and Pollution Research and it is currently under review.

**Student support**

This project has supported one hourly student Rania Eddik from Nevada State College for 6 months. This project also supported PI Bai for one month, who is currently a postdoctoral fellow at DRI.

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# An 8000-Year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada

## Basic Information

| | |
|---|---|
| **Title:** | An 8000-Year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada |
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| **End Date:** | 2/28/2018 |
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| **Congressional District:** | NV-02 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Categories:** | Hydrology, Climatological Processes, Models |
| **Descriptors:** | None |
| **Principal Investigators:** | Steven Bacon, Rina Schumer |

## Publications

There are no publications.

## USGS/NIWR Final Project Summary

# An 8,000-year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada

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May 15, 2018

**Introduction**

Tree ring and other high-resolution paleoproxies that are resolved to annual time scales offer a means to extend the range of precipitation and temperature scenarios used in climate impact assessments. Deciphering patterns of background natural hydroclimate variability from underlying anthropogenic climate change is only possible from understanding the climate of the recent geologic past. The White Mountains within the Owens River Watershed in eastern California is the site of the ~8000-year long precipitation-sensitive Methuselah Walk bristlecone pine chronology (Hughes and Graumlich, 1996; Bale et al., 2011) and the ~5000-year long temperature-sensitive Sheep Mountain chronology (Salzer et al., 2014). It has been shown that the growth patterns of some annual tree-ring chronologies from moisture and temperature sensitive species show strong correlations with historical hydroclimate variability at watershed- to regional-scales (e.g., LaMarche, 1974). Depending on the type of tree species analyzed, tree-ring chronologies are commonly compared to a wide-range of instrumental records of the watershed's hydroclimatic system, such as precipitation, temperature, snow water equivalent (SWE), soil moisture, streamflow, lake water level, and drought indices. Ultimately, the goal of these analyses is to develop a hydroclimatic proxy dataset that could be used infer paleoclimatic change over the length of the tree-ring chronology studied. In turn the analyses could also be used to provide an extended perspective on the range in magnitude and duration of potential hydroclimatic variability that could be experienced under future climate change in eastern California and western Nevada.

**Research Objectives**

The goal of this 2-year study was to evaluate the sensitivity of the longest tree-ring records in North America from the White Mountains to different components of the hydrologic system using a coupled watershed runoff and lake surface evaporation model for the Owens River-Lake system along the south-eastern Sierra Nevada in California. All previous studies of streamflow and lake-level reconstructions from tree-ring records in the Sierra Nevada, as well as with the rest of the western U.S. are limited to precipitation sensitive chronologies of less than ~2000 years. This study used both temperature and precipitation sensitive tree-ring chronologies of less than ~5000 and ~8000 years, respectively, with a coupled watershed-lake water balance model to reconstruct past lake-level fluctuations of Owens Lake. The expected results will provide an annual resolved record of most of the Holocene (last ~8,000 years) hydroclimate variability in the Sierra Nevada that could be used to refine regional to global Holocene paleoclimate models, as well as provide perspective on the potential magnitude and duration of hydroclimate variability under future climate change.

**Methodology**

The principal activities during Year 1 research included the development of a calibrated watershed-lake water balance model and evaluation of the sensitivity of White Mountain tree-ring records using standard dendrochronological methods. The watershed-lake water balance model that was developed consists of four simplified hydrologic model components: (1) watershed runoff modified after McCabe and Markstrom (2007), (2) energy-balance and snow melt, (3) glacial ice accumulation, and (4) open water evaporation based on the Priestley-Taylor (1972) equation. The model domain consists of 800 x 800 m grid cells, of which each grid cell is considered an independent modeling unit in terms of physiographic elements, hydroclimatic conditions, and hydrologic processes (e.g., Hatchett et al., 2015; Barth et al., 2016). The Owens River watershed model domain consists of 12,969 grid cells. The monthly water-balance solution for each grid cell has been aggregated "lumped" at an annual time step in order to compare to Los Angeles Department of Water and Power measured runoff data for calibration. The climatic input variables of the model include 120-years of mean monthly minimum and maximum temperature, plus precipitation estimates for water years 1896–2015 from the 800-meter Parameter elevation Regression on Independent Slopes Model (PRISM) historical climate time-series dataset (Daly et al., 1994). Changes in solar insolation at each grid are also accounted for over the past ~8000 years using data of Berger and Loutre (1991).

Evaluation of the sensitivity of the White Mountain tree-ring chronologies to hydroclimate variability included comparisons of raw tree-ring width data and published precipitation and temperature indices deduced from tree-ring records with historical modeled components of the hydrologic system in the watershed using linear regression analysis. The historical modeled components at the site of the tree-ring chronologies or throughout the watershed include: annual precipitation, temperature, evapotranspiration, SWE, soil moisture, streamflow, and simulated Owens Lake water levels.

**Year 1 Results and Significance**

The watershed-lake water balance model was calibrated to measured runoff, observed seasonal snowpack extent, surveyed glacial ice extent, and measured open water evaporation. Preliminary historical model watershed runoff and lake-level simulations yielded interesting results that are providing insight to past hydroclimate variability of the region. The watershed-scale modeling approach of our study is similar in principle to the study of Saito et al. (2015) in the Sierra Nevada that also used a combined water balance and tree ring approach. Their study, however, did not include a lake evaporation element in the model and it simulated runoff over the last ~2000 years.

The Year 1 analysis of the precipitation- and temperature-sensitive tree-ring records with hydrologic model results have confirmed previous research of the White Mountains bristlecone pine tree-ring chronologies that traditional statistical techniques used in dendrochronological studies yield problematic correlations to observed precipitation and temperature. The combined effects of asymmetric growth habits and steep and snow dominated terrain, which exposes the trees to dynamic and antecedent environmental conditions, adds a level of complexity to inferring climate from ring-width data for this particular tree-ring chronology (e.g., Salzer et al., 2009; Tolwinski-Ward et al., 2015; Tran et al., 2017).

**Year 2 Results and Significance**

The primary goal of the Year 2 research was initially focused on investigating which component of the hydrologic system and at what geographical extent within the watershed the tree-rings are recording. Soon in to Year 2 research, it was determined to shift the focus and to evaluate the sensitive of tree-rings in a geologic context prior to performing the hydrologic modeling. The purpose of changing the Year 2 goal was to assess temporal correspondence between tree-ring records and the late Holocene (0–4000 years ago) lake-level record of Owens Lake, because the overall purpose of the study was to reconstruct Owens Lake water levels from the combination of tree-ring records and a watershed-lake hydrologic model. Success during Year 2 was measured by establishing significant temporal correspondence between tree-ring and lake-level records in the Owens River watershed. A brief summary of the analysis of tree-ring and Owens Lake water-level records is presented below, which was recently included in an accepted manuscript submitted to *Quaternary Research* (Bacon et al., *accepted*).

To assess the role of hydroclimate variability in controlling lake-level variations of Owens Lake, several tree-ring records of up to ~4000-yr long from the Owens River watershed were used to provide paleoclimatic proxy information. The tree-ring time series were aggregated into discrete time intervals that matched the ages of sand and mud units previously identified in the late Holocene sediment core OL97 (Smoot et al., 2000) and shoreline (Bacon et al., 2006) records of Owen Lake. Temperature-sensitive tree-ring chronologies from a site west of Owens Lake in the south-eastern Sierra Nevada were used for temperature information. This tree-ring record was developed from relic logs of foxtail pine (*P. balfouriana* Grev. and Balf.) with $^{14}C$ dates and reflects warm and cold intervals inferred from changes in timberline (Scuderi, 1987a,b), that also have corresponding temperature anomalies (Scuderi, 1993). An additional temperature-sensitive tree-ring chronology from bristlecone pine (*P. longaeva* Bailey) from the White Mountains was used and is based on the correlation of ring widths to summer (JAS) temperature meteorological data to estimate temperature anomalies relative to modern temperature (Salzer et al., 2014).

The same time-series aggregation also was performed for the precipitation-sensitive tree-ring chronologies developed from the Methuselah Walk bristlecone pine series from the White Mountains. These chronologies are based on either the correlation of ring widths to precipitation meteorological data (Hughes and Graumlich, 1996) or from analysis of carbon isotope ratios ($\delta^{13}C$) in cellulose that have been correlated to summer (JJA) precipitation meteorological data (Bale et al., 2011). The reported precipitation values of the tree-ring records were converted into percent-of-normal precipitation relative to the length of the records to provide a simple index with which to compare the precipitation anomalies to the timing of sand and mud deposition in sediment core OL97.

In summary, comparisons of the frequency of sand and mud deposition in sediment core OL97 to the tree-ring records and the Holocene glacial record of Bowerman and Clark (2011) in the Owens River watershed displayed a complex pattern of hydroclimate variability that ranged from wet/cold, wet/warm, dry/cold, to dry/warm. Data analysis revealed significant temporal correspondence between the magnitude of temperature and precipitation variability and the timing of sand and mud deposition in Owens Lake basin ($r^2 = 0.9985$; $p < 0.001$). The analysis demonstrated that sand deposition (i.e., lowstands) occurred mostly during periods with higher hydroclimate variability, whereas mud deposition (i.e., highstands) occurred primarily during times with lower hydroclimate variability. These relations link the hydrologic response of the Owens River-Lake system to two general patterns of hydroclimatic forcing during the late Holocene.

**Future Research**

The strong correspondence of the timing of lake-level variations of Owens Lake with tree-ring records demonstrated a link between the watershed and lake system, as well as showing that the tree-ring records were sensitive to hydroclimate variability at a watershed scale. The next step in future research will be to develop significant correlations of observed precipitation and temperature or other components of the hydrologic system (e.g., soil moisture, SWE, etc.) quantified by modeling of the Owens River-Lake system to the <5000 to 8000 year-long precipitation and temperature tree-ring records from the White Mountains. The accuracy of the modeled lake levels based on the tree-ring hydroclimatic reconstructions will be assessed by comparing to the Holocene shoreline record of Owens Lake (Bacon et al., 2006; Bacon et al., *accepted*), in combination with the paleotemperature depression record developed in the Sierra Nevada from glacial deposits (Bowerman and Clark, 2011).

The hydrologic modeling approach of this study could also be used to estimate the paleohydrologic surface conditions in closed basins of Nevada. With continued research, the results could possibly provide Holocene groundwater recharge estimates for these basins, which then could be used to provide a paleohydrologic context of groundwater recharge rates currently being used in groundwater modeling for water resources.

**Information Transfer Activities**

No conference presentations resulted during Year 1 or 2 research activities. Discussion of the project and preliminary results were highlighted in *Nevada Water News* (NWN, 2017). Year 2 research activities included analysis of tree-ring and lake-level records to identify temporal correspondence of hydroclimate variability that was included in a manuscript that was recently accepted in *Quaternary Research* (Bacon et al., *accepted*).

## Student Support

The project provided partial funding to the research of one Ph.D. student (S. Bacon) in the Graduate Program of Hydrologic Sciences at the University of Nevada, Reno. The student's Year 1 and 2 research activities have been summarized above.

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# Assessing Tree to Grass Water Use Ratios; Significance to Urban Water Conservation

## Basic Information

| | |
|---|---|
| **Title:** | Assessing Tree to Grass Water Use Ratios; Significance to Urban Water Conservation |
| **Project Number:** | 2016NV214B |
| **Start Date:** | 3/1/2017 |
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| **Funding Source:** | 104B |
| **Congressional District:** | NV-01 |
| **Research Category:** | Biological Sciences |
| **Focus Categories:** | Conservation, Water Use, Water Quality |
| **Descriptors:** | None |
| **Principal Investigators:** | Dale Devitt |

## Publications

There are no publications.

Annual Report May 15, 2018

Tree and Grass Water Use Ratios; Tradeoffs in the Urban Landscape

D.A. Devitt and T. Wynne, School of Life Sciences, UNLV

Water demand in the southwestern United States continues to rise, especially in the Las Vegas Valley, where the population now exceeds 2 million people. It is estimated that 60 percent of all the water used in the valley is used in the residential sector, with 70% of that water used outdoors to irrigate urban landscapes. These landscapes are dominated by trees and turfgrass and although much is known about the water use of turfgrass species, little is known about the water use of landscape trees and therefore little is known about the tradeoffs between grasses and trees in urban landscapes. We are conducting a tree to grass water use ratio study focusing on ten common landscape tree species grown in the valley (mesquite, ash (2), desert willow, oak, palo verde, vitex, locust, elm and crepe myrtle) and four turfgrass species (bermudagrass, bentgrass, tall fescue and ryegrass). We are estimating water use by closing hydrologic balances on the trees (basins) and turfgrass (lysimeters). We are also estimating transpiration of trees using Granier probes and estimating conductive tissue with a novel dye injection system. We will compare water use of all ten tree species with the four turfgrass species and develop models that incorporate reference ET and morphological characteristics such as tree height, canopy volume, basal canopy area, LAI and leaf area. Observations are ongoing.

Materials and Methods

- One hundred trees were planted 20 years ago, consisting of ten replicates of each of the ten species. Only a subset of 30 trees was chosen for the experiment, three replicates of each species.
- Bermudagrass “Tifway”, Tall Fescue “Monarch”, Ryegrass “Palmer Prelude”, and Bentgrass “Creeping” were planted in lysimeters.
- An Access tube (Dynamax Inc.) was installed in each grass lysimeter and each of the 30 trees basins used in the experiment. The access tubes allowed the Theta Probe PR2/6 (Dynamax Inc.) to measure soil moisture at six depths.
- To determine Evapotranspiration (ET) we used a hydrological balance approach; Evapotranspiration (ET) = Input-Output-Change in storage.
- Trees received water using a metered hose and grass was hand irrigated using a graduated cylinder.
- Reference ET (Penman Monteith) was estimated from meteorological data collected from a weather station.

- Thermal Dissipation Probes ten millimeters long TDP10 (Dynamax Inc.), were inserted in the trees in May 2016, to monitor sap flow in the trunk (one probe per tree). The probes connected to a data logger CR1000 (Campbell Scientific)
- Dye was injected into the trees to assess the amount of conductive tissue. Cores were taken and Photoshop (Adobe) was used to assess the stained area.

Results

- Reference ET 12 month total = 156.6cm

  Tall Fescue ET 12 month total=185.3 cm

  Low fertility Bermudagrass ET 12 month total=106cm

  Refer to Figure 1.
- ET on a basal canopy area basis typically peaked during summer months and declined in fall and winter months with distinct separation on a species basis. Refer to Figure 2.
- When comparing tree to bermudagrass ratios for Mesquite, Modesto Ash, and Crepe Myrtle, ratios above one occurred for all species but the highest values were primarily confined to the fall and winter period (Figure 3).
- When similar ratios were generated for tall fescue, fewer months had ratios above 1.0 with the highest ratios during January and February.
- With the exception of Crepe Myrtle, tree grass water use ratios on a yearly basis always reflected lower water use for trees compared to grasses. Indicating that larger areas of turfgrass would need to be removed to be equivalent to tree water use on a basal canopy area basis.
- Research is ongoing including the analysis of the Thermal Dissipation Probe data and core dye analysis. Because of high mortality with bentgrass and ryegrass during summer months, tree grass water use ratios will be confined to fall, winter, and spring periods for those grasses.

Information Transfer

Graduate student Tamara Wynne presented a poster at the American Society of Agronomy meetings in late fall of 2017. The research will terminate on June 1, 2018. Tamara will write her MS thesis based on this data set. We believe at least one quality publication will be generated from this research submitted in the fall of 2018.

Student support

Besides the graduate support for the research conducted by Tamara Wynne, two undergraduates in the School of Life Sciences have also been supported on this project.

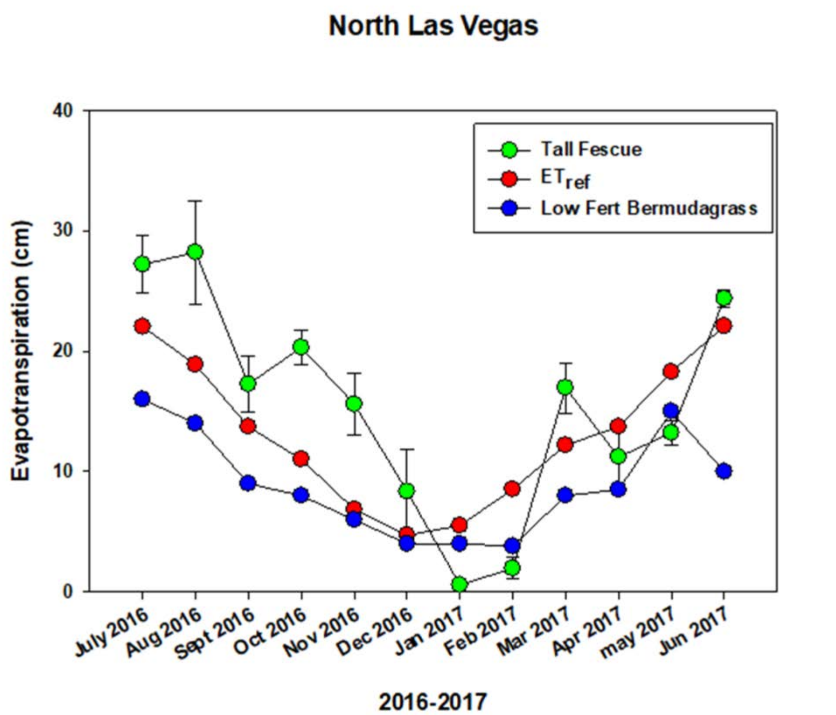


Figure 1. Evapotranspiration with time for tall fescue and, bermudagrass relative to reference evapotranspiration.

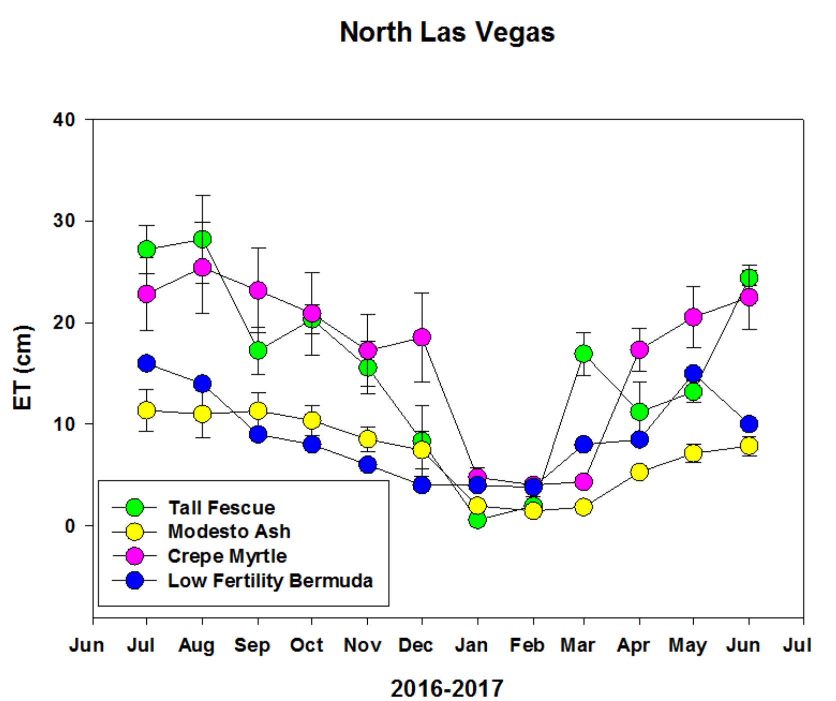


Figure 2. Evapotranspiration with time for tall fescue and bermudagrass compared to Modesto Ash and Crepe Myrtle.

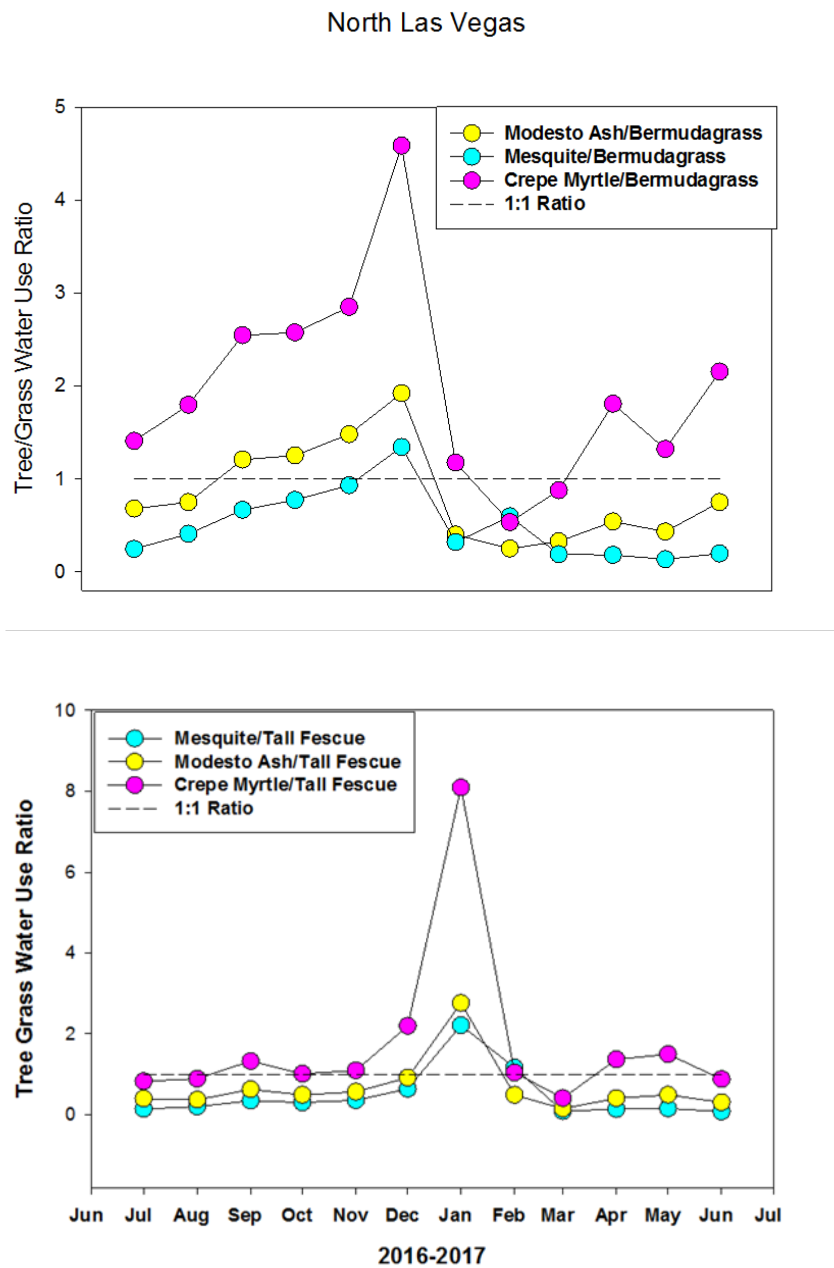


Figure 3. Tree to grass water use ratios with time comparing Modesto Ash, Mesquite and Crepe Myrtle to bermudagrass and tall fescue.

# Controls on Hydrologic Partitioning, Residence Time and Solute Export in a Snow-Dominated Watershed

## Basic Information

| | |
|---|---|
| **Title:** | Controls on Hydrologic Partitioning, Residence Time and Solute Export in a Snow-Dominated Watershed |
| **Project Number:** | 2016NV217G |
| **USGS Grant Number:** | |
| **Start Date:** | 9/1/2016 |
| **End Date:** | 8/31/2019 |
| **Funding Source:** | 104G |
| **Congressional District:** | NV-002 |
| **Research Category:** | Climate and Hydrologic Processes |
| **Focus Categories:** | Models, Solute Transport, Hydrology |
| **Descriptors:** | None |
| **Principal Investigators:** | Rosemary Woods-Hart Carroll, Rina Schumer, Christopher T Green |

## Publications

There are no publications.

**Controls on Hydrologic Partitioning, Residence Time and solute export from a snow-dominated watershed**

Rosemary W.H. Carroll and Rina Schumer

**Problems and Research Objectives**

The Colorado River is a major water source and economic engine for seven Western U.S. states. The majority of its water originates in snow-dominated headwaters. These headwater basins are considered especially vulnerable to climate change with implications for water resources and environmental management. This study will be the first to apply new methods for developing streamflow time-varying travel time distributions (TTDs) to a snow-dominated watershed of the East River, CO and, in particular, at a scale relevant for water management decisions (>100 $km^2$). Proposed work will develop TTDs describing the length of time water and solutes spend in the watershed under various hydrologic conditions using environmental tracers that capture a wide range of travel times. TTDs reflect integrated effects of watershed compartment connectivity and the degree of mixing of water of varying age since entering the watershed. These distributions affect water quality because many weathering processes and biogeochemical reactions are time-dependent. Time indicates catchment memory of past inputs and can be used as a proxy to understand hydrologic sensitivity to land use, climate change and other effects such as persistence of contamination. Implications of storage-dependence on water pathways and residence times in snow-dominated systems are not well understood, nor are the effects on both water delivery and water quality. We propose use of field observations with a combination of modeling approaches to quantify the principal controls on storage dependent thresholds and residence times as reflected by streamflow age distributions. Seasonal TTD moments will be compared to hydrograph characteristics (timing and volume) and export of principal ions, carbon, nutrients and heavy metals.

**Methodology**

Recent development of methods for computing time-variable TTDs incorporate multiple dynamics based on conservation equations for both mass and age (Botter *et al.,* 2011; Van Der Velde *et al.,* 2012; Harman 2015). Solving the conservation equation, requires an established relationship between the distribution of discharge ages and the distribution of stored water ages. This is captured in a so-called StorAge Selection (SaS) function that relates the way stored water of different ages is released to discharge. Separate SaS functions must be used for streamflow and ET outputs. We choose to use a method in which the SaS function relates the TTD to age ranked storage rather than absolute age (Harman 2015). This method does not contain *a priori* conceptual assumption, such as the number of “tanks” in a watershed and the degree of mixing, (Birkel *et al.,* 2010; McMillan *et al.,* 2012). While discharge age-ranked distributions can be estimated empirically using tracers, the functional form of the SaS function must be inferred. We will evaluate a variety of SaS functions simulating both invariant and transient storage conditions on stream flow output fluxes under a variety of hydrologic conditions. Functional responses will be developed for upper catchment tributaries and at the PH location where observed stream discharge and concentration data exist. The updated Python code written by (Harman 2015) has been obtained for hydrochemically-derived TTD development which contains an embedded optimization routine for nonlinear parameter estimation to minimize the weighted difference between the reference age-tracer concentrations and the TTD model estimates of age tracer concentrations. Appropriateness of selected SaS will also rely on a comparison to the observed power spectral density (Harman 2015; Kirchner and Neal 2013) and modeled particle paths generated from SLIM-FAST in an integrated hydrologic model and will consider alternative conceptual models for snowmelt, monsoonal rain and dry, or baseflow conditions.

Quantifying ages of groundwater contributions to stream discharge from shallow and deeper groundwater systems is imperative to understanding memory in the system. Springs and seeps occur in the Mancos Shale and talus slopes. Mapping springs will be done and correlated to geologic and hydrologic characteristics of the basin. Selected springs will be sampled twice annually (spring and fall) for discharge and geochemistry. Samples will be analyzed for stable isotopes, chloride, sulfate, nitrate and atmospheric tracers of groundwater age ($^3H$, $SF_6$). Access to private boreholes in the Mancos shale will provide age constraints of deeper groundwater while selected piezometers in the upper and lower floodplain will provide ages of shallow, alluvial groundwater. Groundwater and spring samples will be compared to age of baseflow using the novel technique recently published by Sanford *et al.* (2015) in which $SF_6$, Ar and N are collected hourly at a single location over a 12-hour period. The technique takes advantage of the temperature-dependence of Henry's Law constant of gases to estimate the mean gas residence time, and hence apparent age, of groundwater contribution to baseflow. This experiment will occur in the late summer within proximity of the PH sampling site. Data will help calibrate/verify TTD estimated mean travel times during baseflow conditions.

**Principal Findings and Significance**

Wok by Dr. Rosemary Carroll (PI) in joint effort with the Lawrence Berkeley National Laboratory Science Focus Area (SFA) performed end-member mixing analysis (EMMA) for the East River, CO using a suite of natural chemical and isotopic observations. EMMA is an initial step to elucidate source contributions to streamflow, associated flow paths and residence time. EMMA relies on principal component analysis to reduce the number of dimensions of variability (U-space) for use in hydrograph separation. The mixing model was developed for the furthest downstream and most heavily characterized stream gauge in the study site (PH). Potential tracers were identified from PH discharge as near linear (Mg, Ca, Sr, U. $SO_4$, DIC, $\delta^2H$ and $\delta^{18}O$) with alternative groupings evaluated. The best model was able to describe 97% of the tracer variance in 2-dimensions with low error and lack of residual structure. U-space positioning resulted in seasonal stream water source contributions of rain (9-16%), snow (48-74%) and groundwater (18-34%). EMMA developed for PH did not scale across 10 nested sub-catchments. Differences in mixing ratios are attributable to, (1) biogeochemical processes of sulfate reduction in the floodplain sediments; (2) source rock contributions from Mancos Shale and Morison Fm; (3) hydrologic partitioning induced by feedbacks within the critical zone; and (4) associated subsurface flow paths.

**Information Transfer**

Presentation of EMMA results at the Department of Energy PI meeting and to the SFA Watershed Function meeting occurred outside the reporting time period.

**Student support**

Work was funded in the fall of 2016. Work to date has focused on an international search to hire a Post-Doctoral Fellow. Dr. Zhufeng Fang began his contract on March 15, 2017 at the Desert Research Institute.

**References Cited**


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# Wastewater Reuse and Uptake of Contaminants of Emerging Concerns by Plants

## Basic Information

| | |
|---|---|
| **Title:** | Wastewater Reuse and Uptake of Contaminants of Emerging Concerns by Plants |
| **Project Number:** | 2017NV219B |
| **Start Date:** | 3/1/2017 |
| **End Date:** | 2/28/2019 |
| **Funding Source:** | 104B |
| **Congressional District:** | NV-03 |
| **Research Category:** | Water Quality |
| **Focus Categories:** | Water Quality, Toxic Substances, None |
| **Descriptors:** | None |
| **Principal Investigators:** | Kumud Acharya, Daniel Gerrity |

## Publications

There are no publications.

Annual Progress Report

Title: **Wastewater Reuse and Uptake of Contaminants of Emerging Concerns by Plants**
PI: Kumud Acharya, DRI and Daniel Gerrity, UNLV

## Problem and Research Objectives

Globally, agriculture consumes around 70% of world's fresh water reserve. Increased urbanization and population is putting additional demand on agricultural sector and more strain on water reserves. One viable option to reduce the strain is the use of reclaimed water for agricultural purpose. Irrigation with reclaimed water is practiced in Israel, California and many other places. There are challenges for using reclaimed water due to presence of low levels of emerging contaminants that may not be easily removed during treatment.

Wastewater treatment is not designed to remove trace organic compounds such as pharmaceuticals and endocrine disrupting compounds. Treated wastewater or reclaimed water thus may contain these trace organic contaminants (TOrCs). Therefore, plants irrigated with reclaimed water have a potential to uptake TOrCs. If these contaminants get translocated from the reclaimed water to the edible plant parts, they would enter the food chain. For example, California state requires a minimum of tertiary treatment before reclaimed water is used for agriculture.

The primary goal of the research is to evaluate the transport, persistence and accumulation of trace organic contaminants in plants irrigated with reclaimed water. This study demonstrates the potential of plant uptake of TOrCs when irrigated with ultra-filtered reclaimed wastewater.

## Methodology

Tomato and spinach plants were grown in greenhouse at University of Nevada Las Vegas from July to November 2017. In the greenhouse, temperature was maintained between $20^0$C–$23^0$C throughout the planting period. Plants were irrigated with ultra-filtered (UF) wastewater from Clark County Water Reclamation District (CCWRD) wastewater treatment plant. Plants were also irrigated with tap water and used as a negative control. For tomato plant, the roots, leaves, fruit and soil were analyzed for a range of TOrCs and ARGs. For spinach plant, only the leaves were analyzed for TOrCs. Tomato plants were grown for around 4 months and spinach plants were grown for 2 months before they were harvested.

Table 1. The list of TOrCs selected for the study along with their applications and concentrations in UF wastewater

| TOrCs | Applications | Concentration in UF wastewater (ug/L) |
|---|---|---|
| Atenolol | Beta blocker drug, used in cardiovascular diseases and hypertension | 0.187 |
| Benzotriazole | Effective corrosion inhibitor for copper and its alloys | 13.2 |
| Carbamazepine | Used to prevent and control seizures | 0.120 |
| DEET | Insect repellent | 0.257 |

| | | |
|---|---|---|
| Lidocaine | Medication used to numb tissue and perform nerve blocks | 0.437 |
| Meprobamate | Sedative used for anxiety, insomnia, tension, and nervousness. | 0.340 |
| Ranitidine | Antacid and antihistamine | 0.600 |
| Sucralose | Used as a replacement for other artificial or natural sweeteners | 47.667 |
| Sulfamethoxazole | Antibiotic against bacterial infections like urinary tract infections, bronchitis | 1.267 |
| TCEP | Common flame-retardant | 0.323 |
| Triclosan | Antibacterial and antifungal agent | 0.022 |
| Trimethoprim | Antibiotic used mainly in the treatment of bladder infections | 0.088 |
| Vancomycin | Used in treatment for skin infections, bloodstream infections, bone and joint infections, and meningitis | 0.500 |

Principle Findings and Significance

For trace organic analysis of spinach plants irrigated with UF wastewater, only sucralose was detected in spinach leaves (Figure 1). In tomato plants, sucralose was detected in soil, root and leaves but was not detected in tomato fruit (Figure 1). Figure 1 shows that the concentration of sucralose in leaves was higher for tomato plant than spinach. This may be explained by longer irrigation period of tomato plants than that of spinach. In tomato plant, sucralose existed higher in the leaves compared to root and soil.

Figure 2 shows the distribution of other TOrCs observed in tomato plant. Like sucralose, most of carbamazepine, lidocaine and meprobamate was detected in the leaves, whereas sulfamethoxazole and benzotriazole were found mostly in the roots.

Soil concentration factors (SCF) were determined for all TOrCs by normalizing concentrations found in soil to the concentrations in UF wastewater (Eq.1, Figure 3a). Higher SCF indicates higher potential of the compound to be found in the soil.

Similarly, root and leaf concentration factors (RCF and LCF) were calculated using concentrations measured in root and leaves, respectively (Eqs. 2 and 3, Figures 3b and 3c). Lidocaine and Carbamazepine had the highest LCF signifying that these compounds have highest tendency to be found in the leaves of a plant.

SCF = Concentration in soil / Concentration in reclaimed water (Eq. 1)

RCF = Concentration in plant root / Concentration in reclaimed water (Eq. 2)

LCF = Concentration in plant leaves / Concentration in reclaimed water (Eq. 3)

Currently, analysis is being conducted to understand the rationale behind different partition pattern observed for different TOrCs.

Information Transfer Activities

Results obtained so far are preliminary and have not been presented. On completion of data collection and analysis, they will be presented to a technical conference.

Student/other Support

The project currently provides support to a doctorate researcher (Harshad Oswal) for data collection and analysis.

Publications

The result will be published in peer-reviewed journals when all data have been collected and analyzed.

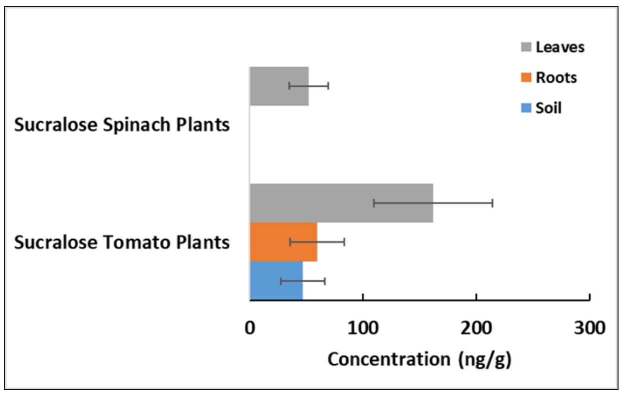



Figure 1: Concentration of sucralose in spinach and tomato plant tissues

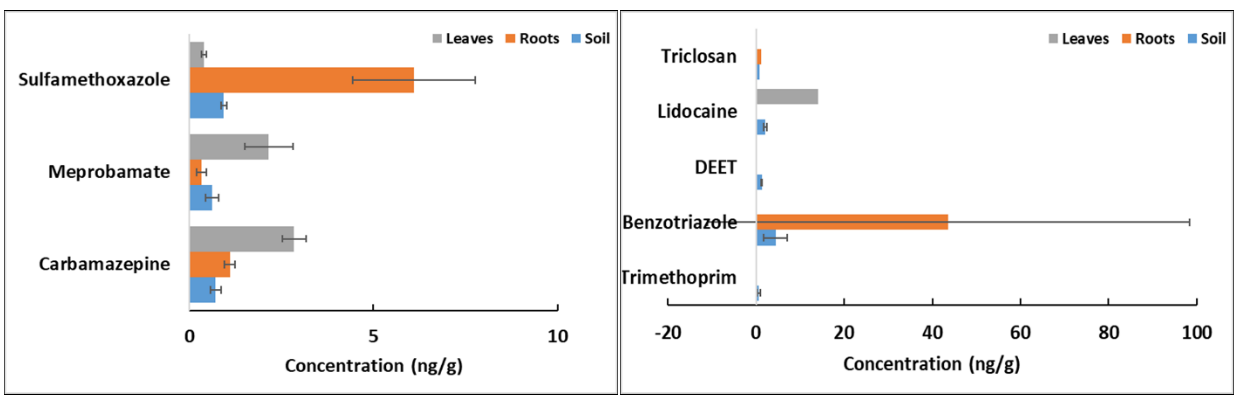



Figure 2: Concentration of TOrCs in soil, root and leaves of tomato plants

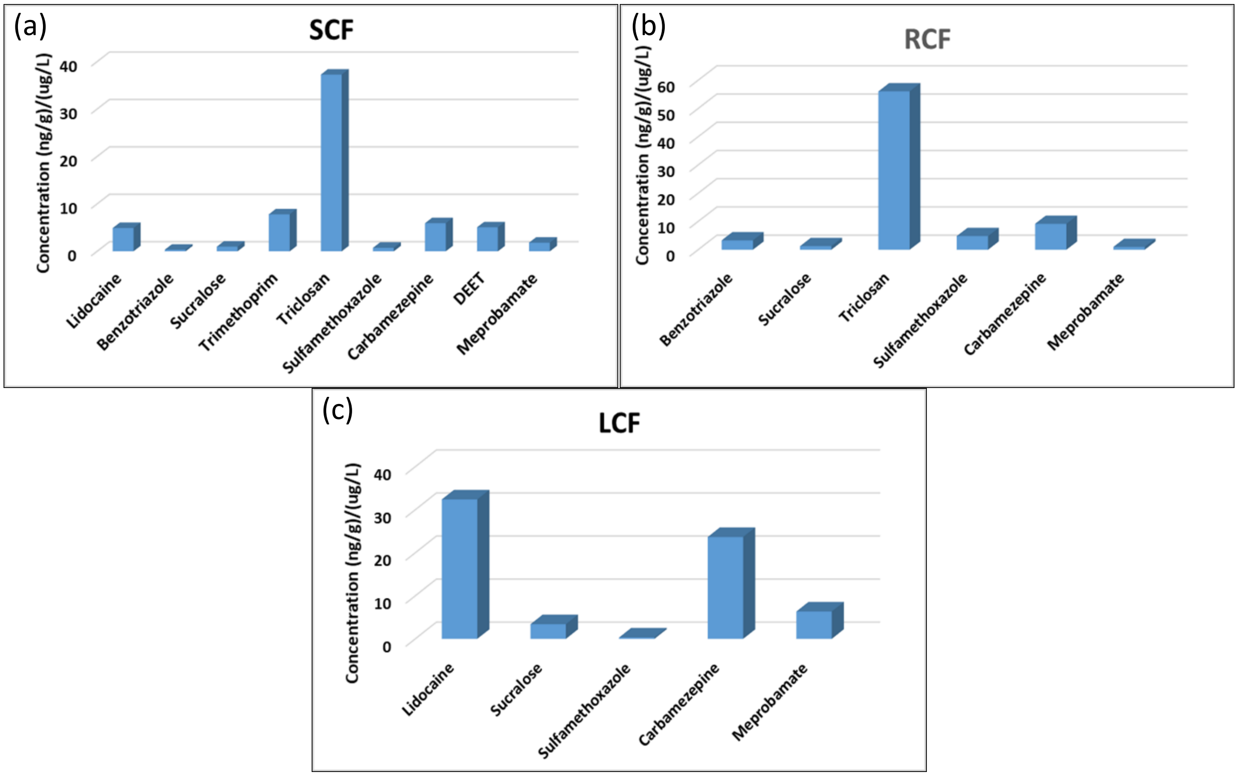



Figure 3: (a) Soil Concentration Factor; (b) Root Concentration Fact; (c) Leaf Concentration Factor

# Information Transfer Program Introduction

GreenPower Mission Statement: To support Nevada's preK-12 educators in science-based, environmental education by providing the tools, resources, and knowledge they need.

What is a Green box? Developed for K-12 educators, Green Boxes introduce environmentally focused topics that emphasize sustainable practices and natural resource conservation. Each Green Box is centered around a "green" topic written for either a particular grade or range of grade levels. Every box contains the material and curriculum needed to engage students in hands-on activities with real-life applications that are both informative and fun! Best of all, our program is completely free for educators to use. We have a large list of titles available and more coming online all the time.

Who Creates Green boxes? Green Boxes are made by educators for educators. Once created, each box is then vetted through our Advisory Green Box Committee, which is comprised of education and environmental experts. Upon committee approval, the Green Boxes then make their way to GreenPower schools.

What Does a Greenbox Contain? Curriculum aligned to Nevada State, Common Core, and Next Generation Science Standards. Enough content for 1 to 2 weeks of instruction, complete with hands-on-activities and projects. Most materials needed for activities (both consumables and non-consumables). A flash drive with curriculum and supplemental materials.

In addition to the Greenpower/GreenBox program, DRI maintains a current website and publishes a quarterly newsletter.

# Greenbox

## Basic Information

| | |
|---|---|
| **Title:** | Greenbox |
| **Project Number:** | 2016NV215B |
| **Start Date:** | 3/1/2017 |
| **End Date:** | 2/28/2019 |
| **Funding Source:** | 104B |
| **Congressional District:** | NV-03 |
| **Research Category:** | Not Applicable |
| **Focus Categories:** | Education, None, None |
| **Descriptors:** | None |
| **Principal Investigators:** | Amelia Gulling |

## Publications

There are no publications.

# Soil Erosion by Water in Southern Nevada

**Introduction:** Erosion is the process that moves earth materials such as soil and rocks by water or wind. Erosion occurs naturally and helped shaping many of our most remarkable landscapes (Figure 1). Erosion, however, can also be detrimental. For example, erosion can carry away fertile soil away (Figure 2) causing a range of issues from loss of productivity, to reduction of ecosystem services and eventually desertification. Soil erosion by water after a fire can cause damage to our infrastructure and communities (Figure 3).

The goal of this project is to develop a Green Box that teaches Elementary School children of Grades 2-3 about erosion, what it is, how it works and why it is important. The project has a special focus on soil erosion by water after a fire, an important issue in watersheds of Southern Nevada.

**Figure 1. Erosion created the Grand Canyon as rocks were taken away by the river (image source: ThingLink.com)**

**Figure 2. An example of soil erosion of farm land (image source: Soil-Net.com)**

**Figure 3. Floodwaters and eroded soil after the Carpenter I fire at the intersection of Grand Teton and Grand Canyon Road, Las Vegas, August 31, 2013. (image source: A. Healy/Fox5).**

### Tasks:

- <u>Part I - Developing a Green Box:</u> In Part I of this project PI Berli will design a Green Box on soil erosion by water in Southern Nevada along with a K-12 educator who will develop the lessons based on Berli's expertise. GreenPower staff along with the K-12 educator will make sure the lessons are aligned to the Next Generation Science Standards for the specific grades. This Green Box will be geared towards Grades 2-3.
- <u>Part II - Teacher Training:</u> For Part II of this project PI Berli will give a 30 minute presentation on soil erosion by water in Southern Nevada at a GreenPower teacher training to be held at DRI's Las Vegas campus.

### Budget and Budget Justification:

The proposed budget (enclosed) includes 25% of one month of PI Berli's salary. This time will be used by the PI for participating in the Green Box development as the science expert as well as to present the Water Erosion

Green Box at a teacher training. The GreenPower staff time and Green Box are funded through other grants and gifts. The budget also includes $5,000 to cover the supplies that will be included in the Green Box once the list is developed by the Green Box Administrator. The Green Box Administrator will do the purchasing of these supplies.

## Drought in the Southwest

**Seshadri Rajagopal, Mackenzie Peterson**

The hydroclimate of the southwestern United States which centers on southern Nevada and includes Arizona and parts of southern California are generally arid. Low annual precipitation, year-round warm climate over much of the southwest U.S. are due in part to a quasi-permanent subtropical high-pressure ridge over the region (Sheppard et al., 2002). Despite knowing some of the causes of aridity in the southwest U.S., the problem of defining what is meant by drought is longstanding and has never been resolved to the satisfaction of all (Redmond, 2002). In this module prepared primarily for middle school students, we will focus on developing lessons that address the following questions,

- What is a drought?
    - Define a meteorological drought, e.g. Standardized Precipitation Index
    - Define an agricultural drought, e.g. Palmer Moisture Anomaly Index
    - Define a hydrologic drought, e.g. Total Water Deficit
    - Define a regional drought, e.g. Drought Severity Index
- Why is the southwest U.S. prone to drought?
    - Explain the Hadley circulation
    - Rain Shadow effect
- How do we monitor drought?
    - National drought monitor http://droughtmonitor.unl.edu/
    - Develop exercise to monitor drought index
- How does drought change in the future in the southwest U.S.?
    - What do models predict?
    - What are student's expectations?

These lessons will be prepared along with presentations for teacher training. The PI will work with the GreenPower staff to ensure that Next Generation Science Standards are met, particularly for the Earth and Space Science discipline in the practice of asking questions and defining problems, analyzing and interpreting data, obtaining, evaluating and communicating information.

**References:**

Sheppard P.R., Comrie A.C., Packin G.D., Angersbach K.,Hughes M.K., 2002, The climate of the US Southwest, CLIMATE RESEARCH, Vol. 21: 219–238 Redmond K., 2002, The depiction of drought, BAMS.

# NWRRI Website & Newsletter

## Basic Information

| | |
|---|---|
| **Title:** | NWRRI Website & Newsletter |
| **Project Number:** | 2016NV216B |
| **Start Date:** | 3/1/2017 |
| **End Date:** | 2/28/2018 |
| **Funding Source:** | 104B |
| **Congressional District:** | NV-03 |
| **Research Category:** | Not Applicable |
| **Focus Categories:** | None, None, None |
| **Descriptors:** | None |
| **Principal Investigators:** | James Thomas |

## Publications

There are no publications.

NWRRI - Desert Research Institute

April 3, 2017

Volume 3, Issue 3

Desert Research Institute

Nevada Water Resources Research Institute

# Nevada Water News



## RFPs

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

For current RFP information, visit the NWRRI website (www.dri.edu/nwrri).

## Director's Letter

We have wrapped up another year at *Nevada Water News* and I'm very impressed by the unique and varied projects that our researchers have undertaken. From evaluating the presence of emerging contaminates in Lake Mead, to assessing urban water use, to analyzing groundwater basins and paleo-hydroclimatic data, these projects are exploring innovative solutions to conserve Nevada's valuable water resources. I'm also proud that these projects have provided hands-on research opportunities for a variety of students to learn skills that will prepare them for careers in the field of water resources research.

The newly funded NWRRI project "Wastewater Reuse and Uptake of Emerging Contaminants by Plants" led by Drs. Kumud Acharya and Daniel Gerrity continues this innovative research. This project will evaluate the use of reclaimed water for agricultural irrigation. The benefit of using reclaimed water for agricultural irrigation is that it could help conserve valuable drinking water supplies. However, little is known about the potential uptake of emerging contaminants by edible plants. This project will irrigate tomato and spinach plants with potable water and reclaimed water at several treatment stages in a greenhouse environment to evaluate the transport, persistence, and accumulation of emerging contaminants in edible plants.

In addition to the exceptional research that DRI faculty are conducting, DRI also supports advancements in water resources management and conservation statewide by partnering with programs such as WaterStart. WaterStart is a public-private, not-for-profit, joint venture that works to bring new water research, technology, and economic development opportunities to Nevada. Nevada's climate provides unique opportunities for studying

*(Director's Letter continued)*

sustainable water management and finding solutions for conserving this valuable natural resource. WaterStart connects world-renowned experts with partner organizations to provide water innovation services to management agencies, policy makers, and technology companies to support economic growth in Nevada's water sector. The goals of WaterStart are to support existing businesses and grow new business opportunities in Nevada through the group's unique capabilities and expertise, as well as to build an operational infrastructure and educate and train a highly skilled workforce.

I look forward to seeing what new research comes from our continuing projects and programs and what new advancements in resource conservation our researchers continue to make.

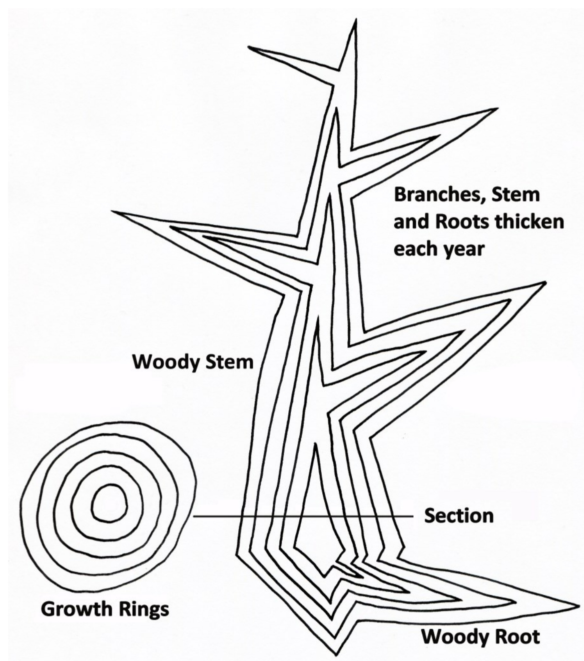
Sincerely,

Jim Thomas ■

# *An 8,000-year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada*

Climate impact assessments allow researchers to understand and anticipate the effects of climate change on the environment. However, being able to conduct accurate assessments requires understanding how and why climate changes have occurred. To do this, researchers need to be able to differentiate natural climate variability from human-induced climate changes. "Deciphering patterns of natural hydroclimate variability from underlying anthropogenic climate change is only possible by understanding the climate of the recent geologic past," explains Steven Bacon, the principal investigator of the project. "The goal of this study is to evaluate the sensitivity of the longest tree-ring record in North America, the Methuselah Walk bristlecone pine chronology from the White Mountains, to different components of the hydrologic system using a coupled watershed runoff and lake surface evaporation model for the Owens River-Lake system in California." This study is also part of Bacon's PhD research and includes collaboration with his PhD advisor Dr. Rina Schumer of DRI, as well as Dr. Adam Csank of the University of Nevada, Reno.

The researchers will evaluate the sensitivity of the Methuselah Walk chronology by comparing historical ring widths to a variety of hydrologic outputs from the coupled water balance and lake evaporation model. The hope is to make confident correlations in order to develop an 8,000-year record of the southern Sierra Nevada hydroclimate, which will include the precipitation and temperature fluctuations in the region over that time period. "LaMarche (1974) demonstrated that the growth patterns of some annual tree-ring chronologies from moisture- and temperature-sensitive species show strong correlations with historical hydroclimate variability at watershed to regional scales," Bacon says. "Depending on the type of tree species analyzed,




A new layer of wood is added each growing season, which creates a growth ring. By analyzing the tree-ring chronologies of precipitation- and temperature-sensitive trees, researchers can evaluate changes in the hydroclimate.

*(Project Spotlight continued)*

tree-ring chronologies are commonly compared to a wide range of instrumental records of the watershed's hydroclimatic system, such as precipitation, temperature, snow water equivalent, soil moisture, streamflow, lake water level, and drought indices. Ultimately, the goal of these analyses is to develop a hydroclimatic proxy dataset that could be used to infer paleoclimatic change over the length of the tree-ring chronology."

Combining the precipitation- and temperature-sensitive tree-ring chronologies from the White Mountains will potentially allow the researchers to reconstruct the hydrologic system of the Sierra Nevada region. "The coupled watershed runoff and lake surface evaporation model we will use has three primary model parameters: precipitation, temperature, and solar insolation. If we can demonstrate strong correlations between the White Mountain tree-ring chronologies and the historical modeled components of the hydrologic system in the watershed, then we could in turn use the associated precipitation and temperature reconstructions as input parameters in the coupled water balance model," Bacon says. "The accuracy of the modeled lake levels based on the tree-ring hydroclimatic reconstructions will be assessed by comparing them with the Holocene shoreline record of Owens Lake in combination with the paleotemperature depression record developed in the Sierra Nevada from glacial deposits."

The research for this study will also incorporate some novel techniques. This project will combine precipitation- and temperature-sensitive tree-ring chronologies to reconstruct a hydrologic system. The resultant chronology will be approximately 6,000 years longer than similar records in the western United States and potentially have the longest tree-ring-based reconstruction of runoff and lake-level fluctuations in North America. "Tree-ring and other high-resolution paleoproxies that are resolved to annual time scales allow the range of precipitation and temperature scenarios used in climate impact assessments to be extended," Bacon explains, "which could provide an extended perspective on the range in magnitude and duration of potential hydroclimatic variability that could be experienced under future climate change in eastern California and western Nevada."

Great Basin bristlecone pines are a long-lived species found in California, Nevada, and Utah. The Methuselah Walk bristlecone pine chronology from the White Mountains in Inyo County, California, is the longest tree-ring record in North America.

*(Continued on next page)*

***"If we can demonstrate strong correlations between the White Mountain tree-ring chronologies and the historical modeled components of the hydrologic system in the watershed, then we could in turn use the associated precipitation and temperature reconstructions as input parameters in the coupled water balance model." – Steven Bacon***

*(Project Spotlight continued)*

Additionally, this project will use variable estimates of solar insolation values over time in the evaporation component of the water balance model. "The total energy received by the Earth from the Sun changes with time, so the change in the magnitude of paleo-solar insolation needs to be included in a paleoclimate water balance model to accurately estimate evaporation from the water surface and evapotranspiration from the land surface," Bacon says. "Fortunately, previous work has computed the positions of Earth's orbit and rotation for the last 10 million years for paleoclimatic research. The resolution of this dataset is monthly insolation values for intervals of 10 degrees of latitude at 1,000-year time steps."

Although the project is still in its early stages, it has already produced some interesting results. "Our preliminary analysis and model results have confirmed that traditional statistical techniques yield problematic correlations to observed precipitation and temperature, which have also been found in previous dendrochronologic research of the White Mountain bristlecone pine tree-ring chronologies conducted by Hughes and Graumlich (1996) and Salzer *et al.* (2014)," Bacon explains. "These results are likely related to the bristlecone's harsh, upper montane to alpine mountainous environment and its short growing season and complex physiology. As a result, our ongoing research has primarily focused on finding which component of the hydrologic system and at what extent within the watershed the tree rings are recording."

The modeling techniques that the researchers are developing for this study could also benefit future watershed studies. "Although the watershed-scale modeling approach we are using is relatively similar in principle to the study of Saito *et al.* (2015) in the Sierra Nevada," Bacon says, "this project also includes lake surface evaporation and perennial snow/glacier accumulation elements that are calibrated to the shoreline record of Owens Lake and the glacial record in the watershed." If the researchers observe confident correlations between the observed precipitation and temperature and the other hydrologic system components, then they will be able to estimate precipitation and temperature in the southern Sierra Nevada region for up to 8,000 years. The model could then be used to estimate the paleohydrologic surface conditions in closed Nevada basins. "With additional research, the results could possibly provide Holocene groundwater recharge estimates for these basins," he adds, "which could then be used to provide a paleohydrologic context of modern groundwater recharge rates used for water resources management." ■

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## Upcoming Events

2017 UNR/NWRA Dinner Forum
April 19, 2017
Sparks, NV
www.nvwra.org/2017unr-nwradinnerforum

2017 Spring AWRA Specialty Conference
Connecting the Dots: The Emerging Science of Aquatic System Connectivity
April 30-May 3, 2017
Snowbird, UT
www.awra.org/meetings/Snowbird2017/

Truckee River Tour
May 4 & 5, 2017
Reno, NV
www.nvwra.org/truckee-river-tour

Long Canyon Mine Tour
May 9 & 10, 2017
Elko, NV
www.nvwra.org/2017-long-canyon-mine-tour

*(Continued on page 7)*

# *PI Spotlight: Steven Bacon*

Steven Bacon first became interested in water resources research while he was working on his master's degree in geology at Humboldt State University in California. "The watershed hydrology and fluvial processes classes that I was taking for my degree initially sparked my interest in the field," Bacon says. "I also used to perform geologic hazard assessments for dams and related water conveyance facilities along the western Sierra Nevada, which exposed me to the engineering aspect of water resources." His interest in water resources research has also inspired him to pursue a PhD in hydrology at the University of Nevada, Reno.

The NWRRI project "An 8,000-year Paleoperspective of Hydroclimate Variability in the Southern Sierra Nevada" is part of Bacon's PhD research, and it has given him a new understanding of the complex dynamics of hydrologic systems. "Developing a watershed runoff and lake evaporation model for paleoclimatic research that is process based and calibrated by Holocene and late Pleistocene shoreline and glacial geomorphic records has been fascinating," Bacon says. "In developing this model, I have learned a lot about the complexity of hydrologic systems in snowmelt-dominated arid and semiarid basins."

In addition to conducting hydrologic modeling of the Southwest to evaluate hydroclimate variability, Bacon's recent research includes geomorphic mapping of alluvial, fluvial, and lacustrine depositional environments; characterizing alluvial fan environments for flood hazard assessments; conducting analyses of sequence stratigraphy and soils; and geomorphic-based terrain modeling of dust emission hazards in desert regions. As he continues in his research, Bacon hopes to incorporate more of his geological expertise in future water resources studies. "Because I have a background in geomorphology and engineering geology, it would be interesting to use some the governing principles of process geomorphology to better understand the connection between surface water and both unconfined and confined groundwater systems," he adds.

When it comes to working in the lab or being out in the field, Bacon's preference is for fieldwork. "It's a chance to be where the air is fresh, the light is natural, and dirt is underfoot," he says. If he had six months with no obligations or financial constraints, Bacon would spend the time traveling with his family to multiple countries so that they could visit the mountains to play in the snow and tropical beaches to relax in the sun. When asked what he would want to have with him if he were shipwrecked on a desert island, Bacon answered, "I would want a machete and a fire starter. I've seen the movie *Cast Away*, and if Tom Hanks had these two items with him, he would have had more time to relax on the beach and figure out how to brew coconut beer." ■

***"Developing a watershed runoff and lake evaporation model for paleoclimatic research that is process based and calibrated by Holocene and late Pleistocene shoreline and glacial geomorphic records has been fascinating. In developing this model, I have learned a lot about the complexity of hydrologic systems in snowmelt-dominated arid and semiarid basins." – Steven Bacon***

# Postdoc Interview: Kelly Gleason

We asked Maki Postdoctoral Fellow Dr. Kelly Gleason about her current research and her continuing research plans. Here's what she had to say:

**1) What sparked your interest in water resources research?**

I became interested in water resources research because it is the primary mechanism by which climate influences ecosystems and society. Water is the conduit that connects upland montane headwater ecosystems to lowland natural resource users and policy makers.

**2) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?**

In the semiarid western United States, most annual precipitation falls as snow, although rising temperatures are reducing snowpack storage. I find snow hydrology particularly interesting because the biophysical interactions of water, climate, and ecosystem disturbances have profound consequences on water resource availability across multiple scales in space and time.

**3) What kinds of research are you currently working on and what have you learned so far from this research?**

Currently, I'm researching snow and ice processes in mountain environments, disturbance hydroclimatology, and water-climate-forest interactions using a suite of tools, including integrated hydroclimate modeling, surface energy balance modeling, remote sensing of land cover change, spatiotemporal statistics, and geoanalytics.

My primary research is focused on how forest fires affect snow hydrology and subsequent water resources across the Colorado River Basin. Burned forests shed black carbon, burned debris, and other light absorbing impurities that deposit in the snowpack during winter and concentrate on the snow surface during snowmelt. By increasing the transmission of sunlight through the canopy, decreasing the emission of longwave radiation by the canopy, and reducing snow surface shortwave albedo, forest fire disturbance accelerates snowmelt rates and advances the date of snow disappearance for many years following a fire.

**4) What do you hope to learn more about from the research you are doing?**

I hope to learn more about the combined effects of light absorbing impurities (i.e., black carbon, dust, and burned woody debris) on snow hydrology and water resources across the western United States and beyond under past, current, and future climate conditions.

**5) Do you have a preference for lab work or fieldwork, and if so, why?**

As a snow hydrologist and physical geographer, I use a combination of fieldwork, lab work, numerical modeling, and remote sensing to investigate the interactions of water, climate, and ecosystems. This provides me with a good seasonal balance of working in the field during the winter and conducting analyses in the lab during the summer.

*(Continued on next page)*

***"My goal in water resources research is to develop a world-class eco-hydro-climatology research group that investigates mechanistic biophysical drivers of earth surface processes and water resource availability in snow-dominated ecosystems." – Kelly Gleason***

*(Postdoc Interview continued)*

**6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?**

I am broadly interested in interactions and feedback of water, climate, and ecosystems under a changing climate system and across multiple scales in space and time. My goal in water resources research is to develop a world-class eco-hydro-climatology research group that investigates mechanistic biophysical drivers of earth surface processes and water resource availability in snow-dominated ecosystems.

**7) If you had six months with no obligations or financial constraints, what would you do with the time?**

I would hike the Pacific Crest Trail with skis.

**8) Cake or Pie?**

Sweet potato pie. ■

## Events continued

2017 GSA Cordilleran Section: 113th Annual Meeting
May 23-25, 2017
Honolulu, Hawai'i
www.geosociety.org/Sections/cord/2017mtg/

SeriesSEE Workshop
June 19, 2017
Reno, NV
www.nvwra.org/seriessee

Well Regulations Workshop
June 19, 2017
Reno, NV
www.nvwra.org/2016-wellregs-workshop

Well Design, Construction & Rehab Workshop
June 20, 2017
Reno, NV
www.nvwra.org/well-design

Well Rehabilitation Workshop
June 21, 2017
Reno, NV
www.nvwra.org/well-rehab

Borehole Geophysical Logging Workshops
June 22 & 23, 2017
Reno, NV
www.nvwra.org/2017borehole-geophysical-logging-workshop

2017 AWRA Summer Specialty Conference
Climate Change Solutions
June 25-28, 2017
Tysons, VA
www.awra.org/meetings/Tysons2017/

2017 AWRA International Conference
September 10 & 11, 2017
Tel Aviv, Israel
www.awra.org/meetings/Israel2017/

AEG 2017 Annual Meeting
September 10-16, 2017
Colorado Springs, CO
aegweb.site-ym.com/events/EventDetails.aspx?id=593893&group=

Pressing Water Quality Issues in Nevada Workshop
September 26, 2017
Reno, NV
www.nvwra.org/waterquality

NWRA Fall Symposium
September 27 & 28, 2017
Reno, NV
www.nvwra.org/2017fallsymposium

2017 ASA, CSSA, and SSSA International Annual Meeting
Managing Global Resources for a Secure Future
October 22-25, 2017
Tampa, FL
www.acsmeetings.org/

GSA 2017
October 22-25
Seattle, WA
community.geosociety.org/gsa2017/home

2017 Annual AWRA Conference
November 5-9, 2017
Portland, OR
www.awra.org/meetings/Portland2017/

AGU Fall Meeting
December 11-15, 2017
New Orleans, LA
fallmeeting.agu.org/2017/

*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.*

DRI Desert Research Institute | Nevada Water Resources Research Institute

www.dri.edu/nwrri

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Newsletter written and compiled by Nicole Damon

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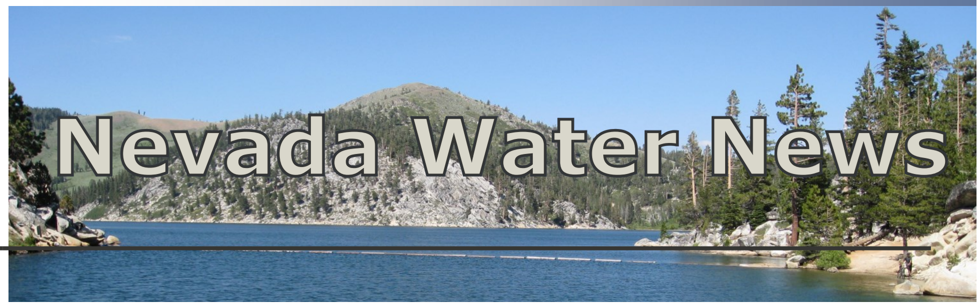
Desert Research Institute

Nevada Water Resources Research Institute




# Director's Letter

Greetings! As the new interim Director of the Division of Hydrologic Sciences (DHS) at Desert Research Institute, I'm pleased to be heading the Nevada Water Resources Research Institute (NWRRI).

Because Nevada is the most arid state in the United States, the research that DHS is conducting as the NWRRI provides valuable insights into managing and conserving Nevada's precious water resources. This research includes monitoring sensitive ecosystems—such as the research being done at Devils Hole that is featured in this issue—and finding innovative ways to conserve, restore, and repurpose valuable water resources.

This research is all the more important not only because of the past 16 years of ongoing drought that Nevada has experienced, but also because of the unknown effects that climate change could have on arid regions in the future. Desert Research Institute is taking an active role in conducting cutting-edge water resources research and providing opportunities for students to gain experience participating in these projects, which will train future generations of scientists.

I'm excited to learn more about the hydrologic research that DHS will be conducting in the coming years and how our researchers and students will be working to find the best ways to manage and conserve water resources in Nevada and throughout the United States and the world.

Sincerely,

Kumud Acharya ■

**Inside this issue:**



## RFPs

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

For current RFP information, visit the NWRRI website (www.dri.edu/nwrri).

# *The Effects of Ecosystem Changes on the Devils Hole Pupfish Population*

Devils Hole is a unique aquatic environment located in the Mohave Desert that is home to the endangered Devils Hole pupfish. “The pupfish live in a system that’s right on the edge of survivability in terms of both (high) water temperature and (low) dissolved oxygen,” says Dr. Mark Hausner, who has been researching the Devils Hole aquatic ecosystem for nine years. “It also has a seasonal cycle of food availability.” This delicate environment has undergone significant changes since it was first threatened by groundwater pumping in the late 1960s, which caused a sharp drop in the water level of Devils Hole. “Groundwater pumping for a ranching operation in Ash Meadows dropped the water level in the system by almost a meter, which almost completely dewatered the shallow shelf in Devils Hole,” Hausner explains. “Although the water level began to rise once the groundwater pumping stopped in 1974, it never returned to the pre-pumping level.”

Devils Hole was formed by a fissure in the rock connected to a groundwater aquifer and a series of ceiling collapses that created a water-filled cave that has a submerged shallow shelf (Riggs and Deacon, 2004). This shallow shelf is where the pupfish feed and spawn. A decrease in the water level over the shallow shelf also affects the water temperature, which in turn affects the survivability of pupfish eggs and juvenile fish, and consequently the overall pupfish population. “The Devils Hole pupfish population has an annual cycle, with spring lows and autumn highs,” Hausner says. “The fish live just 10-14 months and although they spawn year-round, larvae only grow to adulthood when two conditions are met: the water is cool enough and there’s enough food. This recruitment window occurs primarily in the spring, which causes a population increase from spring to fall.”

Devils Hole as seen from above. The equipment shown is used to measure the water level.

In addition to water level changes, there have been other long-term environmental changes within Devils Hole. “Over the years, the dominant algae has shifted from green algae to cyanobacteria, one of the main species of ostracod that the pupfish prey on is no longer found in the system, and there has been an increasing abundance of riffle beetles and predaceous flatworms,” Hausner says. “Although it’s difficult to attribute the population decline to one particular change, the sum total of changes in the system appear to be moving toward a less friendly habitat.”

The changes that have occurred in Devils Hole raise concerns about the potential effects of climate change on its ecosystem. Devils Hole is already experiencing higher water temperatures earlier in the year, which shortens the period of ideal water temperature and food availability on the shallow shelf. “Modeling shows that the current recruitment window is approximately ten percent shorter than the historical window, and simulations based on long-term climate projections point toward a continued shortening through the end of this century,” Hausner explains. “That’s what we’ve seen for the annual climate projections, but there has also been an increase in the

*(Research Spotlight continued)*

day-to-day climate variability, which is something that we'll be looking at in the future."

Although recent increases in the pupfish population seem encouraging, Hausner cautions that it's too early to determine what this signifies for the long-term. Although the spring population count increased from 80 fish in 2015 to 115 fish in 2016, it is still much lower than the spring counts of 220 fish in the late 1980s and early 1990s. The 2016 fall count of 144 fish also showed an increase, but it was still much lower than the fall counts from 30 years ago that averaged 400 to 500 fish. "We can't say for sure if the population will continue to rise," says Hausner. "We're learning more about the system all the time, but we don't have a lot of information about the ecosystem from the late 80s to early 90s, when it was relatively stable. We are getting better at managing the ecosystem, but we don't yet know if that's enough for the pupfish to survive."

The effects of human-induced changes to Devils Hole show the importance of proactive research, monitoring, and planning, especially for endangered populations. "In the simplest possible terms, humans 'broke' Devils Hole by mining the groundwater that the ecosystem depends on," Hausner says. "From my perspective, that means we have the responsibility to try to remedy the problems we caused."

A variety of management practices have been implemented at Devils Hole to encourage a more hospitable environment for the pupfish. Cover packets were installed on the shallow shelf to provide additional shade and protect juvenile fish from being eaten by adult fish. Material deposited from overland flows onto the shallow shelf is occasionally removed to maintain the depth of the shallow shelf, which is necessary to prevent increases in peak water temperatures that damage pupfish eggs and interfere with recruitment. Ongoing ecosystem monitoring is also integral to developing effective management plans. "In 2009, a long-term ecosystem monitoring plan (LTEMP) was finalized for Devils Hole to provide regular, systematically collected observations of a number of different ecosystem parameters," Hausner explains. "Having this baseline dataset for comparison when something happens is a valuable resource."

The Devils Hole pupfish depend on the shallow shelf in Devils Hole for both feeding and spawning (photo by Olin Feuerbacher/U.S. Fish and Wildlife Service).

One of the more controversial management practice is the supplemental feeding program, which began in 2006. "The spring 2006 survey was just 38 fish and by December of that year, the few observable fish appeared to National Park Service (NPS) staff to be emaciated," Hausner explains. "The NPS staff were worried about a possible extinction, so they began providing additional food over the winter months. In the long term, the goal is to stop the supplemental feeding, but not until managers are confident that the fish can survive without it."

Another conservation effort is the establishment of a refuge population at the Ash Meadows Fish Conservation Facility (AMFCF), which is operated by the U.S. Fish and Wildlife Service. The AMFCF is a full-scale replica of the uppermost six meters of Devils

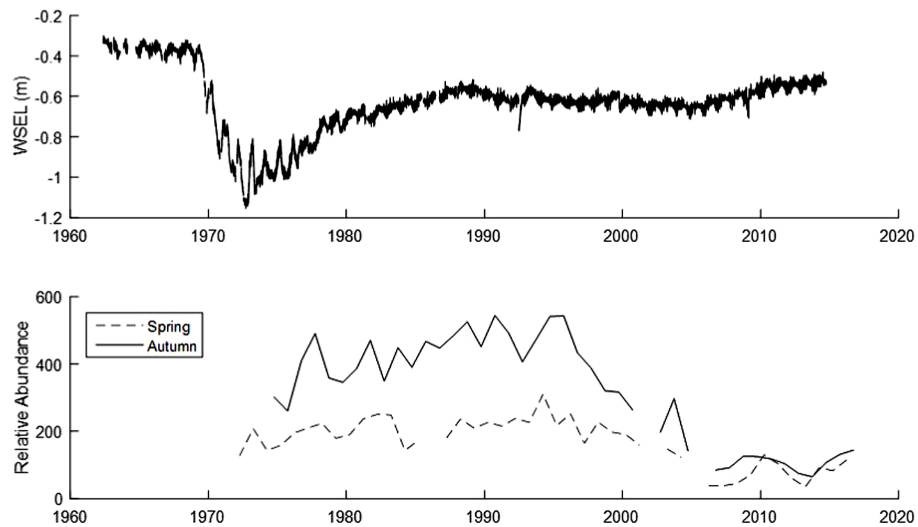
*(Research Spotlight continued)*

Hole made up of a 100,000 gallon tank and aquaria for rearing juvenile pupfish and invertebrates. The conservation facility supports a backup population of 50-100 Devils Hole pupfish. Pupfish eggs are collected from Devils Hole each winter, when they are likely to be viable but unlikely to survive until adulthood. The eggs are then transferred to the refuge tank, which helps maintain genetic diversity at the facility. “The facility also houses hybrid pupfish that are used for research purposes in a separate building,” Hausner adds. “These are Devils Hole pupfish hybridized with Ash Meadows Amargosa pupfish in a previously established refuge. Researching the behavior and physiology of the hybrid pupfish, as well as various aquiculture techniques, has helped inform a number of management actions in Devils Hole, such as the use of cover packets and the formulation of the supplemental food.”

Monitoring practices not only allow researchers to learn more about the pupfish, but they could also provide insight into the potential effects of climate change on arid environments in general. “Environmentally, the Devils Hole pupfish is like a canary in a coal mine,” Hausner says. “Devils Hole is thought to be the smallest complete habitat for any vertebrate species in the world. Therefore, this limited habitat will respond quickly to stressors.” The stressors that Devils Hole is it is currently experiencing—climate change, drastic temperature fluctuations, and shifting communities—are anticipated to be global environmental stressors in the future. “Ash Meadows National Wildlife Refuge (which surrounds Devils Hole) is just 23,000 acres, but it is home to three other endangered species of fish: the Ash Meadows Amargosa pupfish, Warm Springs pupfish, and Ash Meadows speckled dace,” Hausner says. “The other two pupfish species are the closest relatives to the Devils Hole pupfish and they will likely respond to the same stresses in similar ways. The more we understand the response of the Devils Hole ecosystem to stress, the better we’ll be able to manage and mitigate the impacts of those stresses on other endangered species.”

<u>**Reference:**</u>

Riggs, A.C., and J.E. Deacon, 2004. “Connectivity in Desert Aquatic Ecosystems: The Devils Hole Story.” In *Conference Proceedings, 2002, Spring-Fed Wetlands: Important Scientific and Cultural Resources of the Intermountain Region, May 7–9,2002,* edited by D.W. Sada and S.E. Sharpe. DHS Publication No. 41210. Desert Research Institute. https://www.dri.edu/images/stories/conferences_and_workshops/spring-fed-wetlands/spring-fed-wetlands-riggs-deacon.pdf.




The top plot shows the change in the water surface elevation (WSEL) over time. The bottom plot shows the spring (dashed line) and fall (solid line) pupfish population surveys. Although the population has increased since 2013 (when the spring survey counted just 35 fish), the current numbers are still far less than they were 25-30 years ago.

***“Devils Hole is thought to be the smallest complete habitat for any vertebrate species in the world. Therefore, this limited habitat will respond quickly to stressors. [...] The more we understand the response of the Devils Hole ecosystem to stress, the better we’ll be able to manage and mitigate the impacts of those stresses on other endangered species.”***
***– Mark Hausner***

# *Postdoc Interview: Tihomir Kostadinov*

We asked postdoctoral fellow Dr. Tihomir Kostadinov about his current research and his continuing research plans. Here's what he had to say:

**1) What sparked your interest in water resources research?**

I have been interested in Earth and life sciences since I was very young. In college, I majored in biology with an emphasis in botany and I took an oceanography class, which I found fascinating and it sparked my interest in science related to water resources. I also took a GIS class, which I enjoyed. I went on to do ocean color remote sensing for my MA and PhD degrees, so I've been an oceanographer for a while. Later, at the University of Richmond, I had a collaborator who was interested in snow, so I branched out into snow remote sensing, which is what I am currently doing at DRI. Overall, I'm fascinated by the multiple critical roles water plays in climate and life on our planet.

**2) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?**

Water on Earth and electromagnetic energy from the Sun are the two most important factors for sustaining life on our planet. Water is crucial for climate formation and freshwater on land is vital for humanity's existence. I am fascinated by all the intricate relationships between life and the Earth's systems that involve water, from the hydrologic cycle to the carbon cycle to climate feedbacks. When it comes to arid systems such as Nevada, I find it fascinating that such a variety of life calls this area home despite the extreme lack of precipitation (except this year!), especially in the growing season. It is also fascinating how dependent arid regions are on wintertime snowfall. Accurately quantifying the hydrologic cycle in such places, for example by using innovative techniques for the remote sensing of snow, is one of my key interests and that is what brought me here.

**3) What kinds of research are you currently working on and what have you learned so far from this research?**

I am currently working on remote sensing of snow in the Sierra Nevada. Specifically, I am focusing my efforts on multi-platform data sets that have been collected over the Sierra Nevada and the Sagehen Creek watershed in particular. These include airborne hyperspectral imager overflights; light detection and ranging (LIDAR) data, which is essentially radar with lasers instead of radio frequencies; and ground-based distributed temperature observations, which have all been collected over the last few years. These multi-platform contemporaneous observations offer a unique opportunity to develop new methods to improve our capabilities to quantify snow in complex, forested terrain from space. Snowpack acts differently under forest canopies, which also make the snow hard to see with optical satellites. What I have learned so far is that although the same physical principles apply to ocean color and land/cryosphere remote sensing, the challenges facing the two fields, the terminology, and the approaches

*(Postdoc Interview continued)*

used are substantially different. I have also seen how valuable hyperspectral satellite sensors (i.e., imagers that measure at many finely resolved light wavelength channels to provide a fully resolved spectrum) can be for remote sensing. A fully resolved spectrum contains more information about the environment compared with most of the current satellite imagers that only measure a few wavelength channels. This underscores the importance of using hyperspectral instruments in future satellite missions.

**4) What do you hope to learn more about from the research you are doing?**

I hope to learn more about the principles and techniques of land remote sensing, particularly in relation to the cryosphere and vegetation. I am also looking forward to learning more about using LIDAR data. One of my goals is to establish new scientific collaborations to become a better and more versatile scientific programmer and analyst. I am also looking forward to doing more fieldwork with different instruments.

**5) Do you have a preference for lab work or fieldwork, and if so, why?**

I enjoy fieldwork, especially when there are lots of real-time measurements to collect. I also believe it is very important to actually spend time in the systems we are studying and get hands-on experience conducting measurements. I've done fieldwork both on research vessels at sea and on land in the mountains of the western United States, and I have enjoyed both. That said, I do enjoy lab work as well, which in my case is primarily modeling and analyses. I particularly enjoy solving challenging technical issues and programming tasks that are mathematical in nature, producing maps/visualizations of data, and calibrating and testing the field instruments.

**6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?**

I'm an interdisciplinary scientist and I'm interested in many aspects of Earth science, but particularly remote sensing, oceanography (and water in general), planetary habitability, and the physical basis and controls on climate and climate change. I am interested in the Milankovitch cycles of Earth's orbital parameters and their effect on climate (i.e., the astronomical theory of climate). I also have an interest in positional astronomy and solar energy. I definitely aim to incorporate more of my interests in my future career as I have done in the past (e.g., branching out from ocean color to snow remote sensing).

**7) What is one of your favorite movies or books and why?**

I like a lot of books that deal with the relationship between humans and the natural environment. Here's four outstanding examples: *How to Find a Habitable Planet* by James Kasting; *The Omnivore's Dilemma* by Michael Pollan; *Guns, Germs, and Steel* by Jared Diamond; and *Sapiens* by Yuval Noah Harari.

***"Water is crucial for climate formation and freshwater on land is vital for humanity's existence. I am fascinated by all the intricate relationships between life and the Earth's systems that involve water, from the hydrologic cycle to the carbon cycle to climate feedbacks." – Tihomir Kostadinov***

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

I like to make a dish called *banitsa*, which is layers of phyllo dough with a mix of feta cheese, plain yogurt, and eggs layered between the dough that is then baked. It's a staple dish from Bulgaria (where I'm from) and the surrounding regions. I've grown up on it and always liked it. ■

## Upcoming Events

2017 Legislative Updates with Nevada State Engineer, Jason King, P.E.
July 26, 2017
Reno, NV
www.nvwra.org/2017legislativeupdates

2017 AWRA International Conference
September 10 & 11, 2017
Tel Aviv, Israel
www.awra.org/meetings/Israel2017/

AEG 2017 Annual Meeting
September 10-16, 2017
Colorado Springs, CO
aegweb.site-ym.com/events/EventDetails.aspx?id=593893&group=

Environmental Geochemistry Workshop
September 25, 2017
Reno, NV
www.nvwra.org/geochemistry

Pressing Water Quality Issues in Nevada Workshop
September 26, 2017
Reno, NV
www.nvwra.org/waterquality

NWRA Fall Symposium
September 27 & 28, 2017
Reno, NV
www.nvwra.org/2017fallsymposium

Independence Lake & Perazzo Meadows Tour
September 29, 2017
Independence Lake, California (depart from Reno)
www.nvwra.org/2017-independence-lake-tour

2017 ASA, CSSA, and SSSA International Annual Meeting
Managing Global Resources for a Secure Future
October 22-25, 2017
Tampa, FL
www.acsmeetings.org/

GSA 2017
October 22-25
Seattle, WA
www.geosociety.org/meetings/2017/

2017 Annual AWRA Conference
November 5-9, 2017
Portland, OR
www.awra.org/meetings/Portland2017/

AGU Fall Meeting
December 11-15, 2017
New Orleans, LA
fallmeeting.agu.org/2017/

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DRI Desert Research Institute | Nevada Water Resources Research Institute

www.dri.edu/nwrri

For more information about the NWRRI, contact:

*Amy Russell, Business Manager*
*702-862-5471*
*Amy.Russell@dri.edu*

*Kumud Acharya, Director*
*702-862-5371*
*Kumud.Acharya@dri.edu*



Newsletter written and compiled by Nicole Damon

NWRRI - Desert Research Institute

October 2, 2017

Volume 4, Issue 1

Desert Research Institute
Nevada Water Resources Research Institute


**Inside this issue:**



## RFPs

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

For current RFP information, visit the NWRRI website (www.dri.edu/nwrri).

# *Program Spotlight: WaterStart*

Fresh water is vital to economic development and maintaining quality of life, but the potential effects of climate change on the availability of this resource are a global concern. Finding ways to preserve valuable water resources is crucial for sustaining growing populations, particularly in arid and semiarid regions such as Nevada. Therefore, in addition to the water resources research that Desert Research Institute (DRI) is conducting, the institute supports advancements in water resources management and conservation statewide through its partnership with WaterStart.

WaterStart, housed at DRI, is a public-private, not-for-profit, joint venture that was established in 2013 through the Nevada Governor's Office of Economic Development (GOED) to bring new water research, technology, and economic development opportunities to Nevada.


Syrinix is one of the water tech innovation companies that has been brought to Nevada through the WaterStart program. Syrinix provides intelligent pipeline monitoring systems, such as the system pictured above, that generate valuable flow data for optimized decision making and risk management. Photo courtesy of the Las Vegas Valley Water District.

Nevada's climate provides unique opportunities for developing new technologies and industries around the conservation and preservation of water resources. "Nevada is one of the driest states in the country and innovation is key to the long-term, sustainable management of

*(Program Spotlight continued)*

its water resources," explains Dr. Kumud Acharya, who is the Executive Director of the Division of Hydrologic Sciences at DRI as well as the former Chief Technology Officer of WaterStart. "Therefore, it makes sense for Nevada to lead water technology innovation activities."

WaterStart leverages the expertise of Nevada's academic, public, and private sector institutions to create new economic opportunities in water technologies in the state. The institute's connections with the University of Nevada, Reno (UNR), and the University of Nevada, Las Vegas (UNLV), provide WaterStart with access to cutting-edge water resources research. "DRI has more hydrologists than any other academic institution in the United States," Acharya says. "Currently, DRI, UNR, and UNLV produce a wealth of innovations in water technology that can provide opportunities for further developments." The Southern Nevada Water Authority (SNWA), which is one of the leading early adopters of innovative water technologies in the nation, is also part of the WaterStart network.

***"Our goal is to build a global water technology innovation hub in Nevada by attracting, partnering with, and servicing national and international water-related businesses, which will accelerate workforce and economic development across the state."***

***– Nate Allen***

The WaterStart network includes other public and private sector institutions, such as MGM International; the Truckee Meadows Water Authority; Winnemucca Farms, Inc.; GOED; the Department of Employment, Training, and Rehabilitation; the Las Vegas Global Economic Alliance; and the Economic Development Authority of Western Nevada. This diverse network maximizes the expertise of multiple sectors and opens channels for further economic opportunities for water technology innovations in the state. "Our goal is to build a global water technology innovation hub in Nevada by attracting, partnering with, and servicing national and international water-related businesses, which will accelerate workforce and economic development across the state," explains Nate Allen, the Executive Director of WaterStart. "We also hope that the partnerships between WaterStart and industry will increase funding for NSHE institutions through their support of the commercialization of new water technologies."

Desert Research Institute and WaterStart will work to bring technology companies to Nevada by targeting companies that meet their partners' technology needs. The selected companies are then provided with matching funds through the program's commercialization fund to conduct pilot studies at one of the partner facilities. This network of strategic partnerships also allows for close collaboration with first adopters so that new technologies can be scaled for use much more quickly. "In addition to reaching out directly to new tech companies, we organize workshops and invite tech companies to pitch their products, and we regularly attend national and international water expos to look for new innovative water

Echologics pipeline monitoring systems precisely identify and locate emerging leaks so that repairs can be made before more significant failures occur. Photo courtesy of the Las Vegas Valley Water District.

*(Program Spotlight continued)*

tech companies," Allen adds. "So far, we have brought about a dozen companies to the state, and they have started creating new jobs and contributing to the local economy."

More information about WaterStart and the water technology innovations the program is currently seeking can be found at waterstart.com. ■

# *Postdoc Interview: John Umek*

We asked postdoctoral fellow Dr. John Umek about his current research and his continuing research plans. Here's what he had to say:

**1) What sparked your interest in water resources research?**

When I was growing up, I spent a lot of time camping, hunting, and fishing, which developed my passion for the outdoors. In college, I took a wide range of classes, but aquatic ecology sparked my interest more than any other biology class. From that point on, I knew my career path was pretty much set.

**2) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?**

The most interesting aspect of water research in the West is how it provides a unique oasis for multiple types of organisms. My master's degree focused on tracking the movement of native Lahontan cutthroat trout in central Nevada using radio telemetry and microsatellite genetics. It was interesting to see how a threatened endemic fish uses river sections for movement, reproduction, and habitat preference on a small spatial scale. Additionally, the staff work I did at the University of Nevada, Reno, and my dissertation looked at food webs and numerous species in Walker Lake, Lake Mead, and Lake Tahoe to model the biotic and abiotic factors that influence aquatic ecosystems. It was fascinating to document the differences between these Great Basin lakes.


**3) What kinds of research are you currently working on and what have you learned so far from this research?**

I am currently working with Dr. Don Sada to create innovative methods for integrating aquatic biology and hydrogeology to address groundwater issues in the arid West. One of my long-term goals is to try to determine the biodiversity patterns of benthic invertebrates in springs on a large geographical scale. It has been interesting to see the amount of biodiversity, differences in community structure, and number of rare species in such small desert springs. The effects of even slight changes to the systems can have large-scale consequences to the spring ecosystem. It has also been very interesting to study new aquatic environments and see areas of the Great Basin

*(Postdoc Interview continued)*

that I haven't seen before.

**4) What do you hope to learn more about from the research you are doing?**

I hope to gain a better understanding of the anthropogenic impacts, such as climate change and water use, on our water resources and their effects on benthic invertebrate communities in particular. I would also like to learn more about food web structures and changes within particular ecosystems over time, which could provide a critical foundation for understanding predator-prey dynamics and resource competition in systems that haven't yet been studied thoroughly enough compared with their use and importance. Assessing limnological characteristics and processes based on their effects on benthic invertebrates will hopefully help define the ecosystem structure and population dynamics within these ecosystems. This information will also help characterize healthy and unhealthy river and lake ecosystems, as well as determine proper courses of action to conserve water quality and native fishes, invertebrates, and plant communities.

**5) Do you have a preference for lab work or fieldwork, and if so, why?**

I prefer working in the field over lab work. Both lentic and lotic ecosystems present their own challenges, but once I'm on the water, I find the work very enjoyable. However, I will admit that on occasion, I do enjoy identifying benthic invertebrates in the lab and extending my taxonomic knowledge.

**6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?**

My other main research interest includes understanding the impacts of invasive species on aquatic ecosystems. Invasive species are a common problem and one of the largest threats to biodiversity in aquatic ecosystems. Unfortunately, I believe that a lot of the aquatic ecosystems I'm studying now (and will study in the future) will have invasive species, so this is an aspect that I'd like to incorporate into my research. I would also like to be involved with large-scale watershed projects in the future. Participating in the Walker Lake project gave me a thorough understanding of the importance of working with multiple collaborators to address the numerous aspects associated with water research.

**7) What is one of your favorite movies or books and why?**

One of my favorite books is *Undaunted Courage* by Stephen E. Ambrose. It's a fascinating account of the Lewis and Clark expedition. Not only is the book an incredible story, but it also includes a lot of naturalistic observations ranging from the Great Plains to the West Coast.

**8) Cake or Pie?**

Cake; I still haven't found anything better than a piece of carrot cake. ■

> ***"One of my long-term goals is to try to determine the biodiversity patterns of benthic invertebrates in springs on a large geographical scale. It has been interesting to see the amount of biodiversity, differences in community structure, and number of rare species in such small desert springs."***
>
> ***– John Umek***

# Upcoming Events

2017 ASA, CSSA, and SSSA International Annual Meeting:
Managing Global Resources for a Secure Future
October 22-25, 2017
Tampa, FL
www.acsmeetings.org/

GSA 2017
October 22-25
Seattle, WA
community.geosociety.org/gsa2017/home

2017 Annual AWRA Conference
November 5-9, 2017
Portland, OR
www.awra.org/meetings/Portland2017/

NGWA Groundwater Summit 2017
December 4-7, 2017
Nashville, TN
groundwatersummit.com/

AGU Fall Meeting
December 11-15, 2017
New Orleans, LA
fallmeeting.agu.org/2017/

2018 Ocean Sciences Meeting February 11-16, 2018
Portland, OR
osm.agu.org/2018/

NWRA 2018 Annual Conference
February 26-March 1, 2018
www.nvwra.org/2018-annual-conference-program

NWRA 2018 Conference Tour of the Nevada National Security Site
February 26, 2018
Las Vegas, NV
www.nvwra.org/2018-conference-tour

Water Rights in Nevada Class
February 26, 2018
Las Vegas, NV
www.nvwra.org/2018-water-rights-seminar

NGWA Groundwater Issues and Science Affecting Policy and Management in the Southwest
February 26 & 27, 2018
Albuquerque, NM
www.ngwa.org/Events-Education/conferences/Pages/5034feb18.aspx

Advanced Water Rights in Nevada Class
February 27, 2018
Las Vegas, NV
www.nvwra.org/2018-adv-water-rights-seminar

2018 Nevada Well Drilling Regulations & Forms Class and Water Well Drilling Exam Tutorial
February 27, 2018
Las Vegas, NV
www.nvwra.org/2018-wellregs-workshop

2018 Groundwater Workshop
February 27, 2018
Las Vegas, NV
www.nvwra.org/2018-usgs

2018 AWRA Spring Specialty Conference: GIS & Water Resources X
April 22-25, 2018
Orlando, FL
www.awra.org/meetings/Orlando2018/index.html

North American Forest Soils Conference: International Symposium on Forest Soils
June 10-16, 2018
Quebec City, Quebec, Canada
www.cef-cfr.ca/index.php?n=Colloque.NAFSC-ISFS2018

Water Rights in Nevada Class
June 11, 2018
Reno, NV
www.nvwra.org/2018-june-water-rights

Advanced Water Rights in Nevada Class
June 12, 2018
Reno, NV
www.nvwra.org/2018-june-advanced-water-rights

Nevada Well Drilling Regulations & Forms Class and Water Well Drilling Exam Tutorial
June 12, 2018
Reno, NV
www.nvwra.org/2018june-wellregs

AGU Chapman Conference
September 25-27, 2018
Washington, D.C.
chapman.agu.org/congo-hydrologic-research/

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Newsletter written and compiled by Nicole Damon.

NWRRI - Desert Research Institute

January 2, 2018

Volume 4, Issue 2

Desert Research Institute | Nevada Water Resources Research Institute

# Nevada Water News

**Inside this issue:**



## RFPs

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

For current RFP information, visit the NWRRI website (www.dri.edu/nwrri).

## *Wastewater Reuse and Uptake of Emerging Contaminants by Plants*

As one of the driest states in the United States, finding ways to preserve and extend Nevada's limited water resources is vitally important for sustaining the region's growing population. Solley (1993) showed that agricultural irrigation accounts for up to 81 percent of daily freshwater usage. Because water used for agricultural irrigation isn't required to comply with drinking water standards, using reclaimed water to irrigate crops could help conserve valuable drinking water resources.

However, there are concerns about using reclaimed water for irrigation, particularly for food crops because their uptake of contaminants isn't completely understood. "Municipal

**Spinach plants are being grown in greenhouses at UNLV and irrigated with reclaimed water to assess CEC uptake in leafy plants.**

*(Project Spotlight continued)*

wastewater combined with storm water runoff can be a source of emerging pollutants such as pharmaceuticals and personal care products (PPCPs), especially in urban areas," explains Dr. Kumud Acharya, the co-PI of this research project that also includes Dr. Daniel Gerrity of the University of Nevada, Las Vegas (UNLV). "It is common for sewage waste to have residues of prescription pharmaceuticals, antimicrobial products, and hormones and many existing wastewater treatment plants are not designed to remove trace concentrations of these chemicals."

***"Through this research, we hope to determine if plants have different capacities to uptake and accumulate CECs, and if accumulation varies within the different structures of the plants. We also hope to determine if the uptake of CECs by plants is a compound- and concentration-dependent process."***

***– Kumud Acharya***

In a study funded by the United States Department of Agriculture (USDA) National Institute of Food and Agriculture (NIFA), Wu et al. (2014) reported detection frequencies for 19 target contaminants of emerging concern (CECs) of 64 percent for vegetables irrigated with treated wastewater and 91 percent for vegetables irrigated with fortified water. "Because this is an emerging research field, more studies are needed to understand the uptake rates and pathways of CECs in food crops irrigated with reclaimed water," Acharya says.

**Tomato plants are also being grown to assess the uptake of CECs in fruit plants. The results will be compared with those obtained for the spinach plants.**

In order to fill this knowledge gap, the goal of this project is to evaluate the uptake and bioaccumulation of CECs in food crops. The researchers are growing both tomatoes and spinach in a climate-controlled greenhouse located on the UNLV campus, and the plants are being irrigated with both tap water and reclaimed water at different stages of treatment, which was obtained from the Clark County Water Reclamation District (CCWRD) in Las Vegas, Nevada. "We chose tomatoes and spinach as the food crops for the study because they encompass both leafy and fruit varieties of crops," Acharya explains. "Tomatoes and spinach are also often consumed raw, which would increase potential human exposure to CECs."

The data from this project will be combined with the data collected for the associated project "Plant Uptake of Contaminants of Emerging Concern in

*(Project Spotlight continued)*

Agroecosystems Irrigated with Reclaimed Water" being conducted for the USDA Agriculture and Food Research Initiative (AFRI), and then used to characterize the potential human exposure to chemical and microbiological contaminants through food crops irrigated with reclaimed water. Currently, the researchers are still in the process of collecting samples. Harshad Oswal, a PhD student at UNLV, is in charge of the project experiments, such as collecting wastewater, planting and harvesting the plants, and taking samples and analyzing the samples for CECs. Providing opportunities for students to expand their research skills is also an important aspect of the projects supported by the NWRRI program. "Harshad is being trained and developing many new skills in researching emerging contaminants, which is a rapidly growing new research field," Acharya says.

Once the plants are ready to be harvested, samples of the plants and soils will be collected and analyzed for the target CECs to evaluate potential human exposure. "Through this research, we hope to determine if plants have different capacities to uptake and accumulate CECs, and if accumulation varies within the different structures of the plants," Acharya explains. "We also hope to determine if the uptake of CECs by plants is a compound- and concentration-dependent process. For example, if uptake is a function of the CEC, the water source, or the pretreatment processes." ■

**References**

Wu, X.Q., J.L. Conkle, F. Ernst, and J. Gan, 2014. Treated Wastewater Irrigation: Uptake of Pharmaceutical and Personal Care Products by Common Vegetables under Field Conditions. *Environmental Science & Technology* 48, 11,286-11,293.

Solley, W.B., 1993. Water-use Trends and Distribution in the United States, 1950-85. *HortScience* 28, 283-285.

# *Postdoc Interview: Zhufeng Fang*

We asked postdoctoral fellow Dr. Zhufeng Fang about his current research and his continuing research plans. Here's what he had to say:

**1) What sparked your interest in water resources research?**

I was born in northeast China, so growing up near the overwhelming beauty of the Changbai Mountains and the Amur River cultivated my obsession with nature. Over time, this obsession developed into an impulse to understand the natural environment. And when I learned that many Chinese river and groundwater systems were contaminated, this impulse further prompted me to choose water science as my specialty.

**2) What do you find most interesting about water resources research, particularly working in an arid/semiarid environment such as Nevada?**

Working in an arid/semiarid region is amazing because sources of water will appear seemingly from nowhere. I currently live near the Truckee River and walk by it every day on my way to and from work. Looking out at the river, I often think about how my work at DRI can contribute to making the river cleaner and healthier, which will allow more people to enjoy it as well.

**3) What kinds of research are you currently working on and what have you learned**

*(Postdoc Interview continued)*

**so far from this research?**

I'm currently working on modeling the transit time distribution of precipitation and snowmelt. The goal of this work is to understand the significance of seasonal snowmelt, as well as the precipitation types and intensities of a snow-dominated, alpine watershed. My previous research was on subsurface flow and groundwater research, so this ongoing surface hydrologic study is a new area of research for me.

So far, I have learned a lot about surface hydrology, such as how rain and snow are formed and how they enter the surface water system, how hydrochemicals with different ages partition and travel from the precipitation to the outflow, and how the different snowmelt rates before and during the spring snowmelt season control the dynamics of catchment storage, stream flow transit time distribution, and young water percentage in the outflow.

**4) What do you hope to learn more about from the research you are doing?**

I hope to learn more about snow hydrology, which it is very important for my current and future research projects at DRI. Although this area of research is still pretty new to me, I already find it very interesting and it's definitely worth learning so

that I can incorporate it into my expertise and research background.

**5) Do you have a preference for lab work or fieldwork, and if so, why?**

I started doing scientific research in the lab at Nanjing University back in 2005. I built a big glass box, filled it with fine sand, planted soybeans, designed a mini irrigating system, and set up high-density electrical resistivity tomography (ERT) monitoring system to simulate rainfall infiltration processes and investigate the effect of vegetation on the spatial and temporal distribution of soil water content. This early work taught me so many things about hydrology and inspired me to pursue higher-level water research, so my answer at this point is definitely lab work. However, I will welcome any opportunity to work in the field because it is something new for me to explore.

**6) What are some of your other research interests? Do you have any goals for incorporating those interests into your work as you continue in your career?**

Mathematics is my top research interest besides hydrology and I have already incorporated a lot mathematics into my research, such as principal component analysis, wavelet coherence analysis, Bayesian updating, and

*(Postdoc Interview continued)*

the stochastic process. Because hydrologic research—especially the modeling work I am doing now—has a fairly close relationship with mathematics, there are plenty of opportunities for me explore this interest.

Another one of my research interests is botany, and I'm sure that I will be able to combine hydrology and botany in future research, such as exploring variations in root water uptake in desert and forest plants. I am also very interested in astronomy, so hopefully one day I can incorporate the Big Bang into my hydrologic research (just kidding!).

**7) If you could go on vacation anywhere in the world, where would you want to go, why would you want to go there, and what would you want to do there?**

I have travelled to 41 countries and regions over the past twelve years, but there are still places I dream of visiting. Given this vacation, I would want to go to Greenland. I've wanted to explore the Arctic since childhood. Imagine being surrounded by giant icebergs, traveling or fishing by canoe, and watching polar bears and whales (as long as they don't make me their dinner) with a cup of hot coffee in your hand—what a wonderful vacation!

**8) Coke or Pepsi?**

Coke! ■

***"I currently live near the Truckee River and walk by it every day on my way to and from work. Looking out at the river, I often think about how my work at DRI can contribute to making the river cleaner and healthier, which will allow more people to enjoy it as well."***

***– Zhufeng Fang***

## Upcoming Events

2018 Ocean Sciences Meeting
February 11-16, 2018
Portland, OR
osm.agu.org/2018/

2018 UNR/NWRA Dinner Forum
February 15, 2018
Reno, NV
www.nvwra.org/2018unr-nwradinnerforum

Groundwater Issues and Science Affecting Policy and Management in the Southwest
February 26-27, 2018
Albuquerque, New Mexico
www.ngwa.org/Events-Education/conferences/Pages/5034feb18.aspx

NWRA 2018 Annual Conference
February 26-March 1, 2018
www.nvwra.org/2018-annual-conference-week

2018 NGWA Groundwater Fly-in and Water Resources Congressional Summit
March 6-7, 2018
Washington, D.C.
www.ngwa.org/Events-Education/conferences/Pages/5090mar18.aspx

2018 Lower Colorado River Science Symposium
March 8, 2018,
Southern Nevada Water Authority, Molasky Building
100 N. City Parkway, Las Vegas, NV 89106
Contact: todd.tietjen@snwa.com

2018 AWRA Spring Specialty Conference: GIS & Water Resources X
April 22-25, 2018
Orlando, FL
www.awra.org/meetings/Orlando2018/index.html

*(Continued on page 6)*

# Events Continued

2018 GSA Combined Cordilleran & Rocky Mountain Meeting
May 14-17, 2018
Flagstaff, AZ
www.geosociety.org/GSA/Events/Section_Meetings/GSA/Sections/rm/2018mtg/home.aspx

North American Forest Soils Conference: International Symposium on Forest Soils
June 10-16, 2018
Quebec City, Quebec, Canada
www.cef-cfr.ca/index.php?n=Colloque.NAFSC-ISFS2018

Water Rights in Nevada Class
June 11, 2018
Reno, NV
www.nvwra.org/2018-june-water-rights

Aquifer Testing Workshop
June 11, 2018
Reno, NV
www.nvwra.org/2018-june-aquifer-testing-workshop

Advanced Water Rights in Nevada Class
June 12, 2018
Reno, NV
www.nvwra.org/2018-june-advanced-water-rights

Nevada Well Drilling Regulations & Forms Class and Water Well Drilling Exam Tutorial
June 12, 2018
Reno, NV
www.nvwra.org/2018june-wellregs

The New MODFLOW Course: Theory and Hands-on Applications
June 19-22, 2018
Las Vegas, Nevada
www.ngwa.org/Events-Education/shortcourses/Pages/258jun18.aspx

AWRA Summer Conference: The Science, Management, and Governance of Transboundary Groundwater
July 9-11, 2018
Fort Worth, TX
www.awra.org/meetings/FortWorth2018/index.html

AGU Chapman Conference: Hydrologic Research in the Congo Basin
September 25-27, 2018
Washington, D.C.
chapman.agu.org/congo-hydrologic-research/

2018 ASA and CSSA Meeting: Enhancing Productivity in a Changing Climate
November 4-7, 2018
Baltimore, MD
www.acsmeetings.org/

2018 GSA Annual Meeting
November 4-7, 2018
Indianapolis, Indiana
www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2018.aspx

2018 AWRA Annual Conference
November 4-8, 2018
Baltimore, MD
www.awra.org/meetings/Baltimore2018/index.html

2018 Fall Meeting
December 10-14, 2018
Washington, D.C.
fallmeeting.agu.org/2017/

2018-2019 SSSA International Soils Meeting: Soils Across Latitudes
January 6-9, 2019
San Diego, CA
www.sacmeetings.org/

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*Kumud Acharya, Director*
*702-862-5371*
*Kumud.Acharya@dri.edu*

Banner photo: Winter scene with snow in Red Rock Canyon National Conservation Area by Caleb Steele calebfsteele - https://unsplash.com/photos/PTsDbfXgpxc, CC0, https://commons.wikimedia.org/w/index.php?curid=61894887

Events list, page 6: Lake Tahoe winter scene by Samir Mahendra from San Francisco, USA - Flickr, CC BY 2.0, https://commons.wikimedia.org/w/index.php?curid=1084962

Newsletter written and compiled by Nicole Damon.

# USGS Summer Intern Program

None.

| Student Support | | | | | |
|---|---|---|---|---|---|
| **Category** | **Section 104 Base Grant** | **Section 104 NCGP Award** | **NIWR-USGS Internship** | **Supplemental Awards** | **Total** |
| **Undergraduate** | 3 | 0 | 0 | 0 | 3 |
| **Masters** | 1 | 0 | 0 | 0 | 1 |
| **Ph.D.** | 2 | 0 | 0 | 0 | 2 |
| **Post-Doc.** | 1 | 1 | 0 | 0 | 2 |
| **Total** | 7 | 1 | 0 | 0 | 8 |

# Notable Awards and Achievements

None to report

# Publications from Prior Years

1. 2013NV194B ("Optimization of ozone-biological activated carbon treatment for potable reuse applications") - Dissertations - Selvy, Ashley, 2015, "Impacts of Ozone Dose and Empty Bed Contact Time on Total Organic Carbon Removal through Ozone-Biological Activated Carbon Treatment," M.S. Thesis, Department of Civil & Environmental Engineering and Construction, Howard R. Hughes College of Engineering, University of Nevada Las Vegas, Las Vegas, Nevada, 98 pages.
2. 2013NV194B ("Optimization of ozone-biological activated carbon treatment for potable reuse applications") - Dissertations - Aquino, Mayara, 2017, "Impacts of Ozone Dose and Empty Bed Contact Time on Bulk Organic Removal and Disinfection Byproduct Mitigation in Ozone-BIofiltration Systems," M.S. Thesis, Department of Civil & Environmental Engineering and Construction, Howard R. Hughes College of Engineering, University of Nevada Las Vegas, Las Vegas, Nevada, 128 pages.
3. 2013NV195B ("Estimation of Atmospheric Wet and Dry Deposition of Nutrients to Lake Tahoe Snowpack") - Articles in Refereed Scientific Journals - Pearson, C., Schumer, R., Trustman, B. D., Rittger, K., Johnson, D. W., Obrist, D., 2015: Nutrient and Mercury Deposition and Storage in an Alpine Snowpack of the Sierra Nevada, USA, Biogeosciences, 12, 3665-3680, Published, doi: 10.5194/bg-12-3665-2015.
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