# Montana Water Center
# Montana State University

## Annual Technical Report
## 2019

## PRODUCTS

### PEER-REVIEWED ARTICLES, DISSERTATIONS AND THESES BY 104B FACULTY AND STUDENTS

| Project ID | Product |
|---|---|
| 2016MT308G | Miller, F. R., Ewing, S. A., Payn, R. A., Paces, J. B., Leuthold, S. J., & Custer, S. G. (2020). Sr and U isotopes reveal the influence of lithologic structure on groundwater contributions along a mountain headwater catchment (Hyalite Canyon, MT). *Journal of Hydrology*, 125653. |
| | Miller, F. R. (2018). *SR and U isotopes reveal interactions of surface water and groundwater along the mountain headwaters to intermountain basin transition (Hyalite Canyon and Gallatin Valley, MT)* (Doctoral dissertation, Montana State University-Bozeman, College of Agriculture). |
| 2016MT307B | Zambare, N., Lauchnor, E., Gerlach, R., & Pitts, B. (2018). Multi-scale Microscopy of Microbially Induced Calcium Carbonate Precipitation. *Microscopy and Microanalysis*, *24*(S1), 1328-1329. |
| | Zambare, N. M., Naser, N. Y., Gerlach, R., & Chang, C. B. (2020). Mineralogy of microbially induced calcium carbonate precipitates formed using single cell drop-based microfluidics. *Scientific reports*, *10*(1), 1-11. |
| | Zambare, N. M. (2020). *Microbially Induced Calcium Carbonate Precipitation: Meso-scale Optimization and Micro-scale Characterization* (Doctoral dissertation, Montana State University). |
| 2017MT311B | Snitker, Adam. 2019. LOCAL KNOWLEDGE AND CLIMATE INFORMATION: THE ROLE OF TRUST AND RISK IN AGRICULTURAL DECISIONS ABOUT DROUGHT. MS Thesis. |
| 2017MT312B | Simonin, M., Colman, B. P., Anderson, S. M., King, R. S., Ruis, M. T., Avellan, A., ... & Bernhardt, E. S. (2018). Engineered nanoparticles interact with nutrients to intensify eutrophication in a wetland ecosystem experiment. *Ecological Applications*, *28*(6), 1435-1449. |
| | Ward, C. S., Pan, J. F., Colman, B. P., Wang, Z., Gwin, C. A., Williams, T. C., ... & Hunt, D. E. (2019). Conserved microbial toxicity responses for acute and chronic silver nanoparticle treatments in wetland mesocosms. *Environmental science & technology*, *53*(6), 3268-3276. |
| 2018MT323B | Bunker, J., Nagisetty, R. M., & Crowley, J. (2021). sUAS Remote Sensing to Evaluate Geothermal Seep Interactions with the Yellowstone River, Montana, USA. Remote Sensing, 13(2), 163. |
| 2018MT325B | Monasmith, Ross, et al. "Photothermal floats for evaporation enhancement and waterfowl deterrence." *Mine Water and the Environment* 39.4 (2020): 716-723. |
| | Monasmith, Ross, and Katherine R. Zodrow. "Proper Adhesive Choice Increases Photothermal Float Durability in Mine Water Disposal Applications." *Mine Water and the Environment* 39.4 (2020): 724-734. |
| 2018MT324B | Worku, Fasil. 2019. "The Impact of Climate Change on Summer Low Flow of a Headwater Basin in Montana." Graduate student theses and dissertations. |

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| 2018MT322B | Bishop, N., Jones-Lepp, T., Margetts, M., Sykes, J., Alvarez, D., & Keil, D. E. (2020). Wastewater-based epidemiology pilot study to examine drug use in the Western United States. *Science of the Total Environment*, *745*, 140697. |
| | Margetts, M., Keshaviah, A., Hu, C., Troeger, V., Sykes, J., Bishop, N., ... & Keil, D. E. (2020). Using wastewater-based epidemiology with local indicators of opioid and illicit drug use to overcome data gaps in Montana. *medRxiv*. https://doi.org/10.1101/2020.04.18.20064113 |
| 2018MT327B | Robertson, Isaiah, "LIMITATIONS TO PHOTOSYNTHESIS IN SILVER BOW AND BLACKTAIL CREEKS" (2019). Graduate Theses & Non-Theses. 218. |
| 2019MT159B | Bray, Kimberly, "DECOUPLED DIEL SOLUTES: LINKING PRIMARY PRODUCTION AND NITRATE UPTAKE IN A MONTANE STREAM" (2020). *Graduate Student Theses, Dissertations, & Professional Papers*. 11678. https://scholarworks.umt.edu/etd/11678 |
| 2019MT155B | Thompson, Luke (2020). CASE STUDY OF WATER QUALITY SAMPLING AND SYSTEM PERFORMANCE FOR A VERTICAL FLOW AQUACULTURE TREATMENT WETLAND. Professional Paper. M.S. Environmental Engineering. Montana State University, Bozeman, MT. |
| 2019MT160B | Birrell, J. H., Shah, A. A., Hotaling, S., Giersch, J. J., Williamson, C. E., Jacobsen, D., & Woods, H. A. (2020). Insects in high-elevation streams: Life in extreme environments imperiled by climate change. *Global change biology*, *26*(12), 6667-6684. |

## INFORMATION TRANSFER PROGRAM

**RESEARCH PRESENTATIONS AND OUTREACH BY 104B FACULTY AND GRADUATE STUDENTS**

| Project ID | Product |
|---|---|
| 2016MT300B | Bobst, A. (2019). Hydrologic Effects of Beaver-Mimicry Stream Restoration. Lecture, Montana Tech, Butte, Montana. |
| 2016MT308G | Miller, F.R., Ewing, S.A. , Payn, R.A., Paces, J.B., Leuthold, S., Michalek, T., Custer, S. (2018) Sr and U isotopes reveal the influence of lithologic structure and weathering on surface-groundwater interaction along a mountain stream (Hyalite Canyon, MT). Oral presentation HS2.3.3, Isotope and Tracer Methods: Flow paths characterization, catchment response and transformation processes, Goldschmidt Conference, Boston MA, August 2018. |
| | Ewing, S. A. *[invited]* (2018) Geochemical tracers of mineral-water interactions from porewaters of the shallow subsurface to bedrock aquifers and rivers of Alaska and Montana. University of Alberta Department of Earth and Atmospheric Sciences, ATLAS seminar series, 5 October 2018. |
| | Payn, R.A., Ewing, S.A., Miller, F., Leuthold, S., Paces, J.B., Michalek, T., Custer, S.G. (2018) Using longitudinal synoptics of water quality along |

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| | Hyalite Creek and the Gallatin Valley to understand the distribution of groundwater sources to stream flow generation in the Gallatin River Watershed, Montana. Montana chapter, American Water Resources Association, West Yellowstone, MT, 18-19 October. |
| | Ewing, S.A. *[invited]* (2018) Geochemical tracers of mineral-water interactions from porewaters of the shallow subsurface to bedrock aquifers and rivers of Alaska and Montana. Chemistry Department seminar series, University of Montana. 19 Nov 2018. |
| | Ewing, S. A. (2019), *[Invited]* Evaluating sources and quality of water in Montana landscapes. Oral presentation at workshop, *Integrating science, technology & policy to address Montana's water management challenges*, University of Montana and Lubrecht Experimental Forest, Missoula, Montana, 14 May 2019. |
| | Ewing, S. A., Payn, R. A., Miller F., Leuthold, S., Paces, J. B., Hunt, A., Michalek, T., Gardner, P., Custer, S. G. (2019), Using weathering geochemistry to understand sources of streamflow across mountain-basin transitions of the upper Missouri Watershed. Oral presentation, annual meeting of the Universities Council on Water Resources and the National Institute of Water Resources, Snowbird, Utah, 11-13 June 2019. |
| 2016MT307B | Naser, N., Zambare, N., Chang, C. B., & Gerlach, R. (2018, October). Visualization of Microbially Induced Calcite Precipitation Using Droplet Microfluidics. In *2018 AIChE Annual Meeting*. AIChE. |
| 2017MT316B | Lauchnor, E. G., & Stoick, E. (2017, December). Heavy metal immobilization via microbially induced carbonate precipitation and co-precipitation. In *AGU Fall Meeting Abstracts* (Vol. 2017, pp. H21P-02). |
| | Lauchnor, E., Stoick, E., Zambare, N., Phillips, A., & Gerlach, R. (2018, August). Microbially driven calcium carbonate precipitation: Kinetics and remediation applications. In *ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY* (Vol. 256). 1155 16TH ST, NW, WASHINGTON, DC 20036 USA: AMER CHEMICAL SOC. |
| 2017MT318B | Maneta, M., Dobrowski, S., Holden, Z., Sala, A., Sapes, G., & Simeone, C. (2020, May). Hydrologic stress suppresses tree regeneration and destabilizes the lower treeline in the US Rocky Mountains. In *EGU General Assembly Conference Abstracts* (p. 21835). |
| 2017MT310B | Bailey, K., Hu, J., Korb, N., Kruse, C., & Harris, S. (2019, December). Ecophysiological comparison within a riparian area between two co-occurring woody species: juniper (encroached) and willow (naturally occurring). In *AGU Fall Meeting Abstracts* (Vol. 2019, pp. H33H-2013). |
| 2018MT323B | Crowley, J, Nagisetty, R., English, A., and Bunker, J.. "Insights into seasonal geothermal spring and river interactions". Presentation at MT AWRA 2019 conference in Red Lodge, MT. |
| 2018MT325B | K.R. Zodrow (2018), Passive Evaporation Enhancement of Acidic Mine Water. *American Water Resources Association, Montana Chapter Meeting.* October 17-19; West Yellowstone, MT. ***Oral Presentation.*** |

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| | K.R. Zodrow (2018), New Technologies for Acid Rock Drainage Treatment. *Invited lecture at Clemson University*. March 9; Clemson, SC. ***Oral Presentation.*** |
| | R. Monasmith and K.R. Zodrow (2018), Passive Evaporation Enhancement to Reduce Treatment and Storage Water Volumes. *American Water Resources Association, Montana Chapter Meeting*. October 17-19; West Yellowstone, MT. *3rd Place Student Poster.* ***Poster Presentation.*** |
| | R. Monasmith and K.R. Zodrow (2018), Harnessing sunlight to combat acid rock drainage: an evaluation of passive solar evaporation islands (PSEI). *Tech Expo*. April 25; Butte, Montana. ***Poster Presentation.*** |
| 2018MT320B | Hydrogeochemical Parameters Influence the Efficacy of Microbial Selenium Reduction in Contaminated Groundwater, American Geophysical Union, Fall Meeting 2019, abstract #H13B-04 |
| | Koepnick, H., Lauchnor, E., Peyton, B. 2019. Bioremediation of selenium in contaminated groundwater. (poster) Montana Section of the American Water Works Association & Montana Water Environment Association Joint Annual Conference, Billings, Montana. |
| 2018MT328B | Perkins, Kaitlin. 2020. *Characterizing sub-micron metal particles in a mine waste contaminated river to better understand potential exposure.* University of Montana. Graduate Student Conference. Oral Presentation. |
| | Perkins, Kaitlin. 2019. *Investigating the size, distribution, and associations of contaminants in the Upper Clark Fork River, Montana.* University of Montana. Graduate Student Conference. Oral Presentation |
| 2018MT322B | https://www.route-fifty.com/health-human-services/2020/05/test-covid-19-sewage/165177/ |
| 2019MT151B | Lahr, A. and L. Eby. February 2019. Reviewing the effects of beavers on aquatic ecosystems. Montana Chapter of the American Fisheries Society Annual Meeting. Billings, MT. Oral presentation. |
| 2019MT151B | Bobst A., A. Lahr, J. McEvoy. November 2020. Working with Beaver for Riparian Health: How University Research Supports Conservation and Management. Institute on Ecosystems Rough Cut Seminar. Oral presentation. |
| 2019MT151B | Lahr, A. and L. Eby. November 2019. Effects of beaver on aquatic ecosystems and questions for novel ecosystems. U.S.F.S. All Scientists Meeting, Region 1. November 2019. Missoula MT. Oral presentation. |
| 2019MT151B | Lolo National Forest outreach for region 1 and MT Beaver Working Group. Blog Spot. (1-pager available upon request) |
| 2019MT151B | Colman BP (2019) Remediation, restoration, and conservation of a watershed degraded by mining and extirpation of beavers, INSAKA Symposium, Johannesburg, SA, June 18-20 |
| 2019MT151B | Karjala, K, Colman BP (2020) "Being the Beaver: a Dive into Beaver Mimicry and Nutrient Cycling" University of Montana Conference on Undergraduate Research, April 24, Missoula, MT |

**MONTANA WATER CENTER TECHNICAL WORKING GROUP**

The Montana Water Center works with experts across the state and the Intermountain West to provide accurate, unbiased and accessible information on issues of vital importance for Montana's water future. In light of this mission, the Montana Water Center convened a technical working group in 2019-2020 to investigate the topic of irrigation efficiency and water conservation.

The working group comprised of a diverse set of stakeholders, including irrigators and irrigation managers, university scientists, agency scientists and managers, legislators, and non-governmental organizations and, through a series of webinars, workshops, and local watershed meetings, investigated how irrigation efficiency measures might best achieve the dual goals of improved on-farm production and maintenance of critical water supplies for downstream water users.

**To date the project has included the following information transfer aspects:**

**One 2-day workshop** attended by 60 technical working group members

**One 1-day workshop** attended by 25 technical working group members

**Four presentations** viewed by a combined total of 275 people and totaling 4 hours:

- Technical working group webinar, *The Hydrology of Irrigated Agriculture*
- Montana Water Summit presentation, *Irrigation Efficiency and Water Conservation*
- Montana Institute on Ecosystems Rough Cut Science Series presentation, *Evaluating Irrigation Efficiency*
- Montana Chapter of the American Water Resources Association presentation, *Evaluating Irrigation Efficiency*

**Two 15-minute recorded webinars and follow up discussions** with 12 key stakeholders and totaling 9 discussion hours.

**Technical Working Group synthesis publication**:

Lonsdale, W. R., Cross, W. F., Dalby, C. E., Meloy, S. E., Schwend, A. C., 2020. *Evaluating Irrigation Efficiency: Toward a Sustainable Water Future for Montana*, Montana University System Water Center, Montana State University, 42p., doi.org/10.15788/mwc202011

**All presentations, webinars, and the publication are publicly available on the Montana Water Center website**:

http://www.montanawatercenter.org/irrigation-efficiency-landing-page

**Project outcomes to date:**

- Text and graphics from Montana Water Center technical paper integrated into MT Natural Resources Conservation Service field staff internal guidance document on irrigation and water conservation.
- Invited presentations with MT watershed groups and Conservation Districts for 2021.
- Award of $20,000 in further funding to create decision support framework to help agencies, organizations, irrigation districts and others apply concepts from the technical paper in individual watersheds.

## STUDENT SUPPORT

Undergraduate students: 6
Master's students: 6
PhD students: 5

## NOTABLE ACHIEVEMENTS AND AWARDS

**Further Funding Awarded Based on 104b Faculty Seed Grants:**

(2016MT301B) Albertson, Lindsey and Poole, Geoffrey. 2020. Macroinvertebrate Ecosystem Engineers Mediate Whole-Stream Metabolism and Nutrient Uptake. National Science Foundation Grant. $1,666,841.00.

(2017MT311B) Yung, L., Metcalf, E., Jensco, K., Silverman, N., Sweet, M. and B. Bauer. 2016-2020. Improving the Efficacy of Climate Information for Water Use Decisions: Developing, Testing, and Institutionalizing New Tools for Producers. USDA Agriculture and Food Research Initiative Competitive Grants Program Water for Agriculture Challenge Area. $453,539

(2019MT151B) Eby and Hossack. Responses of Stream Communities to Beaver Dam Analogs in Sagebrush Systems. From USFS through CESU. $55,704.

(2019MT151B) Mitchell, Eby, and Hossack. Sage-grouse Synergies: Community Responses to Wetland Restoration in the Northern Great Plains, from USGS to the Cooperative Research Unit (CRU) $49,500

(2019MT151B) Colman BP, Malison RL, Eby L, Conserving biota by conserving water: the effects of beaver dam analogs on aquatic insect communities in headwater streams, WA Franke Freshwater Conservation Initiative, $39,444.

(2019MT152B) Sproles, E. and Palomaki, R. River Conditions Tool for Montana, from USFWS. $24,999. (2020-2022) Includes support for 2 undergraduate research assistants.

**104b Faculty Awarded Tenure:**
Jamie McEvoy, Department of Geography, Montana State University
Rob Payn, Department of Land, Resources and Environmental Science
Benjamin Colman, W.A. Franke College of Forestry and Conservation

**Awards:**
(2018MT325B) R. Monasmith and K.R. Zodrow (2018), Passive Evaporation Enhancement to Reduce Treatment and Storage Water Volumes. *American Water Resources Association,*

*Montana Chapter Meeting*. October 17-19; West Yellowstone, MT. ***3rd Place Student Poster***. *Poster Presentation.*

# Assessing The Costs And Benefits Of Beaver Dam Analogs To Create Resilience To Climate Change For Aquatic Ecosystems

**Project Type:** Annual Base Grant
**Project ID:** 2019MT151B

**Project Impact:**

We completed the BACI on three paired streams in Western MT and results varied by site with a year pre-treatment and a year post-treatment. Initial results of beaver mimicry on the Lolo National Forest resulted in increases in water residence time, base flows, habitat complexity, and temperature heterogeneity compared with the control site. Even though there was little change in residence time in the other paired sites, we observed increases in habitat complexity and temperature heterogeneity. There have not been persistent observable changes in either the concentration or quality of organic matter in BDA streams, but this may change as organic matter accumulates in the channel. The time frame is also short for a fish response but we are continuing our monitoring of several hundred fish to examine movement, growth and survival. We have secured funding for two additional MS students with one who started in spring of 2020 examining impacts on greenhouse gas fluxes and one starting in spring 2021 to study aquatic invertebrates. In Eastern MT, this seed grant allowed us to sample riparian vegetation, temperature, instream habitat, and biota before restoration at multiple sites. The restoration projects were delayed a year so there is no post-restoration data. We did further our collaborations with National Wildlife Federation, USGS and BLM. As part of that effort, we have been able to gain funding to start a PhD and MS student to start projects in the fall 2021 focused around the role of beaver and beaver mimicry in those ecosystems.

# Developing Cloud-based Tools To Predict Monthly Streamflow In Montana Using SnowCloudHydro

**Project Type:** Annual Base Grant
**Project ID:** 2019MT152B

**Project Impact:**

This funding successfully supported one PhD student, Ross Palomaki, during his first year at Montana State University. In his first month at MSU, Ross attended a hands-on workshop at Google HQ focused on Machine Learning and Artificial Intelligence with the intent of developing a better understanding of how these techniques could be applied to this USGS project. Our improved skills allowed us to retool our methodologies to develop SnowCloudHydro-Machine Learning (SCH-ML). This approach ingests a suite of hydroclimatic variables into a Random Forest algorithm to predict weekly streamflow at 135 stream gauges in Montana. The results were overall positive, with some sites underperforming. We are currently making modifications to improve model skill, and have hired an undergraduate student, Sam Neitlich, to help with the process. We anticipate submitting a manuscript to Frontiers – Earth Science's special issue  Advancement in Big Data Science in Hydroclimatology Research in the summer of 2021.

Sproles and Palomaki have presented this work to the Musselshell Watershed Coalition (April 2019 & 2021 forthcoming), the National Weather Service's Eastern Montana Hydrology Workshop (Fall 2019), and as a poster at the Fall Meeting of the American Geophysical Union (Dec 2020). We used SCH-ML to augment a successful grant proposal to the USFWS for a River Conditions Tool for Montana. SCH-ML is also a component of a proposal for the "Development of Integrated Forecasting System for Seasonal Water Availability in Uzbekistan (FORSIWA)" project. We plan to continue expanding the skill and scope of this project in the near future.

# Effects Of Changing Stream Temperatures On Montana Stonefly Communities

**Project Type:** Annual Base Grant
**Project ID:** 2019MT153B

**Project Impact:**

Climate change is altering mountain streams, resulting in warmer temperatures, depressed levels of oxygen, and lower flows. These changes present challenges to mountain-dwelling aquatic insects that depend on fast flows, cold temperatures, and high levels of oxygen. Insects may respond in multiple ways, including evolving, shifting ranges, or by exhibiting physiological and behavioral plasticity. We examined plasticity in respiratory phenotypes of giant salmonfly nymphs (Pteronarcys californica) in response to experimentally imposed combinations of dissolved oxygen, temperature, and flow. Stoneflies were collected from Rock Creek, Montana, and housed in the University of Montana's ECOR facility under controlled conditions. Two experiments were conducted: 1) temperature-oxygen interactions and 2) temperature-flow interactions. In both experiments, we measured survival and growth rates of nymphs over a 6-week experimental period and a set of performance phenotypes at the end (on survivors), including critical thermal maxima (CTMAX), gill morphology (light and scanning electron microscopy), and the oxygen-sensitivity of metabolic rate. In the temperature-oxygen experiment, both factors (and their interaction) had significant effects on growth and survival (lower in warmer, hypoxic treatments), and nymphs reared in hypoxia had higher CTMAX, indicating adaptive plasticity of gas delivery systems. Gill morphologies appeared to change across treatments, but analyses are ongoing. In the temperature-flow experiment, the no-flow treatment was more challenging than the flowing-water treatment to nymphs, especially at high temperatures. Together, these results indicate that hypoxia and low flows magnify the potential risks from warming temperatures, but that physiological plasticity in respiratory phenotypes may offset some risks.

# Aquatic Insect Ecosystem Engineering Creates Resource Hot Spots In Montana Streams

**Project Type:** Annual Base Grant
**Project ID:** 2019MT154B

**Project Impact:**

The fellowship research consisted of a field survey and controlled experiment where we investigated how aquatic insect ecosystem engineering by net-spinning caddisfly (Hydropsychidae) may have positive effects on stream community assembly and ecosystem function by creating hot-spots. In our field survey we documented that caddisfly engineering structures (retreats) were inhabited by a diversity of taxa (>25 taxa) along an environmental gradient. Density was 5.2 times higher on caddisfly retreats compared to bare rocks and this effect was greater at sites with higher flow and for beneficiary taxa that are smaller in body size. The results from the survey suggest that the facilitative effect of caddisflies is dependent on environmental conditions and functional traits. In our experiment we documented that caddisfly engineering increased invertebrate density by 2 times and had substantial effects on ecosystem functions relative to controls. Specifically, caddisflies increased local benthic particulate organic matter concentrations by 1.4 times and ecosystem metabolism by 1.6 times. Collectively, these findings from both a field survey and controlled experiment show that caddisflies concentrate invertebrate density and that the effects of caddisflies cascade to effect ecosystem functions related to carbon cycling. Given the ubiquity and high population densities of net-spinning caddisflies throughout Montana, our work suggests that caddisflies may play an important role in maintaining patterns of benthic ecosystem structure and function within Montana's rivers. The fellowship results are currently being prepared as manuscripts that will be submitted to peer reviewed journals.

# Optimization Of Two-stage Solids And Nutrient Removal Wetland Treatment System Operating At A Fish Hatchery In A Cold Climate

**Project Type:** Annual Base Grant
**Project ID:** 2019MT155B

**Project Impact:**

As fish hatcheries continue to operate and grow it is important to mitigate the nutrient impacts of their waste streams to prevent eutrophication of natural water bodies. In this study, the Ennis National Fish Hatchery's treatment wetland system is evaluated to determine its treatment efficacy and overall mitigation of nutrient loading on Blaine Spring Creek. Implementation and evaluation of three different influent sampling methods ultimately determined a sampling method that characterized the influent and mitigated variability in influent nutrient concentrations. Sampling and water quality analysis of treatment wetland influent and effluent characterized the treatment wetland efficacy. The treatment wetland removed 99% of TSS, 99% of COD, 88% of TN, and 88% of TP on average making the removal efficacy comparable if not consistently higher than nutrient removal of other aquaculture treatment wetlands. An estimation of the nutrient mass balance of the hatchery found that only 1-12% of nutrient loading was removed from the creek and that an improvement in the treatment wetland influent collection system would increase nutrient collection for treatment in the wetland and minimize the nutrient impact on the creek.

# The Influence Of Beavers On Amphibian Parasite Dispersal In Glacier National Park

**Project Type:** Annual Base Grant
**Project ID:** 2019MT156B

**Project Impact:**

In the summer of 2019, I filtered water to collect eDNA from 30 wetlands in Glacier National Park with funding from the Montana Water Center. The goal of this project was to understand how en-vironmental detection of chytrid fungus, a deadly fungus that infects amphibians, compares to swab detection of the fungus on individual amphibians in the same wetlands. After collecting our eDNA samples, we discovered that the protocol is flawed, and the reagent used to preserve DNA on the filter loses its effectiveness after a few months. Most of our samples failed to detect the fun-gus, so I am now working with the USGS and using data from their amphibian disease monitoring initiative to answer this question. I am also working with biologists across the US to further under-stand and improve the filtering protocol to preserve DNA for longer periods of time and to accu-rately detect chytrid fungus DNA in our samples.

# Dynamics Of Changing Water Availability And Water Rights Administration In The Upper Clark Fork River Basin, MT

**Project Type:** Annual Base Grant
**Project ID:** 2019MT157B

**Project Impact:**

Due to shifts in funding and Covid19, my research shifted from water availability and water rights in the Upper Clark Fork to social resilience to water-related vegetation transitions (eastern redcedar and cheatgrass). The eastern front of the United States' prairie grassland ecosystem is currently being invaded by eastern redcedar. These trees use a considerable amount of water and pose challenges for agriculture in an area already limited by water scarcity. Yet some areas along the frontier of this invasion appear to resilient to the change. I am part of an interdisciplinary team of social scientists working to understand the factors that influence social resilience to this vegetation transition. We are currently conducting a systematic literature review on how people's capacity to adapt has been conceptualized spatially and plan to use this information to inform future spatial analyses. Although the global pandemic has challenged our ability to engage with non-academic partners, we are finding new ways to cautiously collaborate with agencies, conservation groups, and tribal nations. We are preparing to administer surveys to agricultural producers and conservation professionals in the west this semester. For my dissertation, I will use the data from these surveys to understand how people's capacity to adapt to change is related to the structure of their social networks. In 2019, the Montana Water Center supported me to attend a week long workshop on agent based modelling, which will be critical in assessing the structure of social networks.

# Quantification Of Groundwater Flux At A Hydrothermal Feature In The Yellowstone River

**Project Type:** Annual Base Grant
**Project ID:** 2019MT158B

**Project Impact:**

The aim of this research was to evaluate geothermal seep interactions with the Yellowstone River in Montana, USA and to determine the utility of using combined thermal-optic sUAS systems in conjunction with in-situ measurements to study large river systems. Using vertically distributed temperature sensors, vertical fluid flux of hydrothermal features was determined. Vertical fluid flux appeared to be strongest during the spring, which agrees with other researchers' findings. Thermal infrared (TIR) orthomosaics were accurate in temperature ranges of tens of degrees but was not as accurate in ranges of several degrees. This allowed the characterization of geothermal features in and near the river throughout the year. Detection of geothermal features is made difficult during spring runoff due to increased river stage obscuring the thermal signature detectable by the thermal sensor. This study identified a key consideration for collecting sUAS based TIR data; rivers with an average width of 123% of the image ground cover area will be difficult to study given Federal Aviation Administration altitude restrictions. RGB-image orthomosaics were able to accurately estimate the river shoreline water surface elevation. However, the accuracy of water surface elevation estimate decreased dramatically in the mid-channel regions of the river.

## Primary Controls On Nitrate Use In Lotic Systems

**Project Type:** Annual Base Grant
**Project ID:** 2019MT159B

**Project Impact:**

Tight coupling of surface water diel dissolved oxygen (DO) and nitrate-N (NO3-N) signals reflects stoichiometric demand of carbon and nitrogen in stream ecosystems. However, DO and NO3-N can become decoupled due to alternative drivers of diel solutes, resulting in conflicting estimates of stoichiometric and modeled NO3-N uptake. In this study, Kimberly Bray measured benthic biomass, hydrology, and dissolved solutes in a montane stream located in western MT over a growing season (June-October 2019). Daily stream metabolism and NO3-N uptake were modeled using a single-station open-channel approach. Timing and amplitude of key diel signals were characterized quantitatively to assess decoupling of DO and NO3-N and investigate diel variation in hydrology. Miller Creek was heterotrophic, with ER ranging from -2.07 ± 0.37 to -5.53 ± 0.11 g O2¬ m-2 d-1 and GPP from 0.03 ± 0.04 to 0.82 ± 0.10 g O2¬ m-2 d-1. Statistical assessment with generalized additive models (GAMs) tied metabolism to localized channel conditions. Modeled NO3-N uptake (3.20 ± 1.50 to 12.14 ± 2.16 mg N m-2 d-1) agreed with stoichiometric estimates (0.42 ± 0.05 to 10.10 ± 3.5 mg N m-2 d-1) in magnitude, despite clear decoupling of diel DO and NO3-N signals. This research provides a model for calculating daily NO3-N uptake comparable to estimates from stoichiometry using a single-station approach, which can be applied in streams and rivers with diel DO and NO3-N decoupling.

# Variation In Oxygen, Temperature And Flow In Streams And How They Influence The Behavior Of The Giant Salmonfly, Pteronarcys Californica

**Project Type:** Annual Base Grant
**Project ID:** 2019MT160B

**Project Impact:**

Ectotherms often avoid abiotic stress by moving among microclimates. Such behaviors may allow populations to persist within refugia even when macro-conditions are stressful. Whether aquatic insects exploit locally available microclimates, however, has received little attention. For stream insects, life in water is shaped by the scarcity of oxygen. In principle, behavior may allow insects to mitigate oxygen shortages – by choosing local regions of lower temperature, higher dissolved oxygen, and higher flow velocity in ways that increase ratios of oxygen supply:demand. After sampling temperature, oxygen, and flow microclimates in two Montana streams, I found that temperature and oxygen do not vary strongly over small spatial scales. However, flows are highly heterogenous, often ranging from < .05 m/s within the substrate to > 1 m/s in the free-stream environment. Exploiting micro-variation in flow may, therefore, be the most reliable option for aquatic insects to mitigate oxygen shortages. I tested this hypothesis by examining the choice-preferences of giant stonefly nymphs, Pteronarcys californica, to experimental gradients in temperature, oxygen, and flow. In alignment with my predictions, P. californica nymphs show little ability to exploit laboratory gradients in temperature and oxygen; they made weak choices and only when presented with unrealistically large gradients. However, nymphs exploited high flows much more readily – choosing higher water velocities when temperatures are high or when oxygen levels were low. These behaviors may allow stoneflies, and other aquatic nymphs, to survive in streams during bouts of low-oxygen availability, which may increase in frequency due to climate change.