

Colorado Water

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Front Cover: Bull moose sighting in Shadow Mountain Lake, Colorado. Photo by Eric Goranson

This Page: Leadville Fish Hatchery, Colorado. Photo by Mark Byzewski

Editorial

by Reagan Waskom, Director, Colorado Water Institute

Colorado's river complexes are home to a broad array of aquatic and terrestrial wildlife species. Included in this spectrum of biodiversity are threatened and endangered wildlife and plants, as well as potentially problematic invasive species. Associated floodplains harbor ecologically valuable wetland and riparian plant communities and wildlife. Colorado settlers began diverting stream flows and constructing dams in the second half of the 19th Century, long before society fully recognized the value and vulnerability of these ecosystems. Successful agriculture, industry, and cities in the semiarid West require water diversions that alter rivers primarily by withdrawing water from the stream, but also by altering pollutant and sediment loads, wood inputs, water temperature, and other physical factors. Such changes may affect plant and animal species that depend on rivers and the adjacent riparian habitat.


If left unmitigated, diversions and dams can impact native aquatic organisms by reducing usable habitat and isolating fish in small pools. High river flows create the structure of the stream—moving sediment down the river, creating and re-arranging riffles, pools and other habitat. High runoff flows in the spring also provide spawning cues to native fish and stimulate the germination of riparian plants. Alteration of the natural flow regimes may contribute to the success of invasive, nonnative fish and plant species. Phreatophytes such as tamarisk and Russian olive continue to spread in many riparian areas across the state.

As Colorado's population and thus demand for water increases, protection of our aquatic resources will become even more important and challenging. Through a combination of regulatory and voluntary water management enhancements, various groups across Colorado are currently enhancing streamflows with the goal of maintaining, restoring, or enhancing environmental resources in river systems. These may include activities such as re-timing diversions and reservoir releases. In some situations, releases from reservoirs used to meet water supply or power generation needs can be timed to provide needed flows for fish species, can be used to flush excess accumulated sediment and rebuild gravel bars and beaches, and can help restore riparian vegetation. In other cases, the most effective mechanism is the purchase and dedication of water rights to environmental purposes. Colorado water managers are currently engaged in a number of costly efforts to enhance water quality and quantity for threatened and endangered wildlife species, including the Platte River



Recovery Implementation Program, the Upper Colorado River Endangered Fish Recovery Program, the Upper Colorado River Wild & Scenic Stakeholder Group, and the Colorado Water Conservation Board (CWCB) Instream Flow Program, to name a few.

Voluntary flow enhancement has challenges in a state where the prior appropriation system effectively serves to protect the private property rights of water users. Water left in the stream for wildlife enhancement must be shepherded past intervening water rights to reach the intended downstream reach. The Colorado Instream Flow Program is responsible for the appropriation, acquisition, protection, and monitoring of instream flow and natural lake level water rights to help preserve and improve the natural environment. Since 1973, the CWCB has appropriated instream flow water rights on more than 1,500 stream segments covering more than 8,500 miles of stream and 477 natural lakes across the state.

Colorado's nine interstate compacts and two equitable apportionment decrees require us to deliver approximately two-thirds of the flow of our rivers to downstream states. The reality is that there simply isn't enough water to satisfy all of the competing demands, and wildlife and ecosystems often suffer the brunt of this shortage. CSU research faculty and their graduate students have been working on research related to aquatic ecology and restoration for more than five decades. Quantifying the habitat and flow requirements of various wildlife species is critically important if water managers are to have the information needed to reconcile the tradeoffs they face on a daily basis. This issue of *Colorado Water* features just a few of the many current projects on fish and wildlife at CSU. 

35 Years of Native Fish Ecology at the Larval Fish Laboratory

Kevin Bestgen, Larval Fish Laboratory, Department of Fish, Wildlife, and Conservation Biology, Colorado State University

CSU's Larval Fish Laboratory is celebrating 35 years of collaborative research and developments in the study of fishes, including taxonomic guides, field studies, and laboratory studies. These include projects that contribute to early life stage knowledge, control of invasive species, and recovery of endangered native species.

In 2013, the Larval Fish Laboratory (LFL) celebrated its first 35 years of work in the Department of Fish, Wildlife, and Conservation Biology (FWCB), Warner College of Natural Resources, at Colorado State University (CSU). The LFL was founded in 1978 by Darrel Snyder, co-founder of the Early Life History Section of the American Fisheries Society, and Clarence Carlson, now professor emeritus at CSU. The emphasis of the LFL at the outset was early life history of fishes, specializing in taxonomic guides for southwestern U.S. native and endangered fishes prepared by Snyder and capably illustrated by Lynn Bjork. Early life studies have remained an emphasis of the LFL through the years under the direction of Robert Muth from 1987-1997 and under Director Kevin Bestgen since then. In addition to ongoing taxonomic guide development in the Upper Colorado River and Rio Grande basins, identification of fishes from collaborative research is a focus (Sean Seal, Snyder, Diane Davis). As a result, our rapidly expanding fish collection has grown to over 130,000 lots and nearly four million specimens in more than 200 species.

Early life stages of fishes are difficult to identify because they are small, have few countable or easily recognizable morphological characteristics, and do not resemble larger and older juvenile or adult life stages (Figure 1). However, early life stages of fishes are sensitive to environmental and other perturbations, so understanding factors that affect their survival is key to fish management. Understanding species identity and distribution patterns also reveals locations of spawning or rearing areas and other habitat to protect. To aid species identification, we have recently developed computer interactive keys that have increased the reliability of species identifications by us and other researchers.

The scope of the LFL has also expanded greatly over time, including both field and laboratory studies on native fish ecology throughout the West. Field studies include

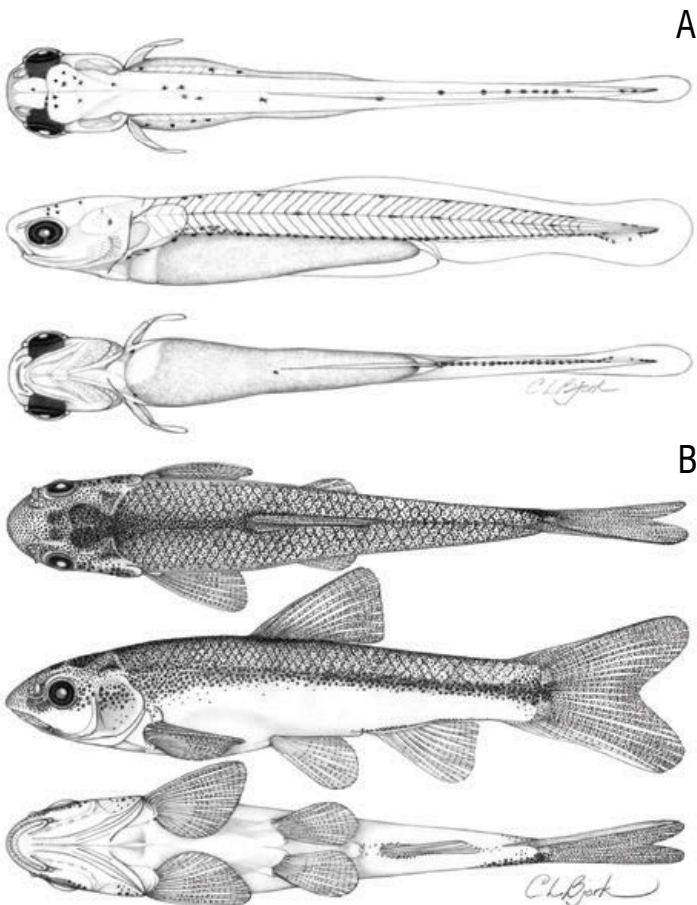


Figure 1. Flathead chub larvae 7 mm in length in three-view drawing, and flathead juvenile about 30 mm in length (B). Drawings by C. Lynn Bjork

Figure 2. Colorado pikeminnow head.
Photo by T. Wilcox



Figure 3. Electrofishing, mouth of Vermillion Creek, Green River drainage, Colorado. Photo by J. Hawkins

surveys of habitat and rare species in plains streams in the West (Tate Wilcox, Robert Compton, Matt Haworth, Bestgen), capture-recapture experiments using tagged fish (Koreen Zelasko, Ryan Fitzpatrick, Bestgen, Dr. Gary White), and reproduction, drift, and dispersal of early life stages of fish in large rivers of the upper Colorado River Basin, Colorado, Utah, and Wyoming (Zelasko, Wilcox, Seal, Angela Hill, Greg Fraser).

Tag-recapture data and statistical modeling was recently used to identify patterns of survival and movement of more than 150,000 razorback suckers (*Xyrauchen texanus*) stocked in the upper Colorado River Basin (Zelasko, Bestgen, and White)—wild fish were mostly eliminated before year 2000, so stocking was needed to bolster populations. Razorback sucker is federally listed as endangered in the Colorado River Basin, and along with humpback chub (*Gila cypha*), bonytail (*Gila elegans*), and Colorado pikeminnow (Figure 2, *Ptychocheilus lucius*), is the subject of a comprehensive and cooperative effort, the Upper Colorado River Endangered Fish Recovery Program (Recovery Program). We found that recently stocked razorback suckers had low survival rates, even though most were larger than 250 mm in length (10 in). After their first year of life, survival rates increased dramatically. Like many other Colorado River Basin fishes, razorback suckers are long-lived, with individuals documented in the wild at 50 years of age or older. Thus, once razorback suckers achieve adulthood, survival rates can be high. Recommendations to stock larger fish and in appropriate seasons led to



Figure 4. *Bear Creek cutthroat trout, Colorado.*
Photo by K. Rogers

increased survival of razorback suckers. Recovery goals for endangered fishes include widespread and abundant populations that persist without stocking or other assistance from management agencies.

Invasive fish investigations in the Upper Colorado River Basin are a long-standing emphasis for the LFL and include abundance and survival estimation and removal of large-bodied non-native piscivores and native fish response studies (John Hawkins, Cameron Walford, Andre Breton, Bestgen, Hill) in the Yampa and Green rivers, Colorado and Utah (Figure 3). We also conducted computer simulation modeling of effects of removals on predator population dynamics and recovery of native fishes (Breton, Hawkins, Dana Winkelman, Colorado Cooperative Fish and Wildlife Research Unit). We identified upstream epicenters for invasive northern pike (*Esox lucius*) and smallmouth bass (*Micropterus dolomieu*) that are important sources for sustaining downstream populations where native and endangered fishes reside.

Controlling negative effects of those invasive predators is important, because progress toward recovery of endangered fishes is impeded. For example, large northern pike present in the Yampa River, northwestern Colorado, are capable of capturing Colorado pikeminnow adults greater than 600 mm in length (24 in). Adult Colorado pikeminnow have historically reached lengths in excess of 1.5 m (5 ft) and weighed in excess of 20 kg (30+ lbs); individuals now average about 0.5 m in length and weigh about 1 kg. Controlling abundant invasive

species has been challenging because source populations are widespread and large bass and pike produce many thousands of offspring each year to replace those that are removed. For example, a 6 kg (about 10 lb) northern pike can produce 100,000 eggs annually. However, we have demonstrated success of removal efforts in some years. High removal rates of smallmouth bass, especially when combined with high spring flow levels in the Yampa River, result in order of magnitude increases in young native fishes. Thus, controlling source populations is a key to long-term success of control efforts for invasive fishes and recovery of native fishes.

The interactions of streamflow and fish ecology are tightly knit, so understanding those relationships is key to successful conservation of aquatic biota. This is especially true in mostly arid Colorado, where streamflows are often limited, are highly regulated by reservoir storage and diversions, and are in high demand to meet human needs. In the Colorado River Basin, we have participated in flow management studies designed to provide water in sufficient quantities and at the correct time to enhance survival of native fishes and provide for multiple other uses including recreation, power production, and agriculture. For example, flow and water temperature recommendations for the Green River downstream of Flaming Gorge Reservoir, Utah and Colorado, were designed to benefit endangered fishes. Our recent studies, in cooperation with Recovery Program partners including basin states, several federal agencies, water users, and environmental groups, showed that flow releases from Flaming Gorge Reservoir were too early in the year to




Figure 5. Larval Fish Laboratory staff. Front Row (left to right): Darrel Snyder, C. Lynn Bjork, Koreen Zelasko, Sean Seal. Back: Kevin Bestgen, Cameron Walford, John Hawkins. Photo by B. Wardell

benefit recruitment of early life history stages of reestablished razorback sucker. Shifts in timing and magnitude of those releases to inundate needed floodplain wetland habitat for early life stages of razorback suckers were recently implemented. In 2013, and for the first time in more than 40 years, juvenile razorback suckers (up to 150 mm, or 6 in) were produced in quantities such that they may add to adult populations and increase survival of the species in the future. This early success provides evidence that flow management and nonnative fish control can contribute to the long-term survival and recovery of endangered fishes in a region where water resources are limited and their allocation is often contentious.

Flow needs for fishes and other aquatic resources have also been conducted in streams east of the Continental Divide in Colorado. For example, timing of reproduction and recruitment of flathead chub (*Platygobio gracilis*) relative to flow patterns in Fountain Creek, a foothills stream near Colorado Springs, Colorado, was studied by LFL and FWCB graduate student Matt Haworth. Flathead chub is declining range-wide, and in Colorado, is listed as a Species of Special Concern by Colorado Parks and Wildlife. Those studies will aid management of Fountain Creek flows as they change in the future due to expanding human populations and increased need for municipal water. Closer to home, we recently collaborated with scientists from the City of Fort Collins, two federal agencies, and Colorado State University professors from three colleges to study streamflows, biota, and health of the Poudre River in Fort Collins.

Laboratory-based studies include native and invasive species interactions and ecotoxicology investigations, including effects of selenium and other toxicants on endangered fish larvae (Dan Beyers) and swimming and fish passage studies conducted in field-scale structures (Walford, Bestgen, Seal). We also recently completed an evaluation of the morphology of native cutthroat trout, including greenback cutthroat, the state fish of Colorado (Figure 4). We found that taxonomic arrangements of various subspecies of cutthroat trout in the southern Rocky Mountains may be different than what was historically postulated, and that additional taxa may deserve recognition. The rarity of many populations of cutthroat trout suggests that additional protections may be warranted to conserve them.

The LFL has built a reputation for excellence in conducting a variety of research, education, and outreach activities focused on early-life taxonomy, fish ecology, and native species conservation. Our current staff includes nine full-time personnel with a combined 164 years of service (Figure 5), in addition to 20 or more work-study, technician, graduate student, or post-doctoral researchers. Since 1990, we have hired more than 200 undergraduate students in the conduct of our research and service activities. The LFL looks forward to another 35 years of success! For more information on the Larval Fish Laboratory, go to warnercnr.colostate.edu/fwcb-research-outreach/research-centers/lfl. 

Large Wood in Front Range Rivers after the 2013 Flood Risk or Golden Opportunity?

Ellen Wohl, Geosciences, Colorado State University

Kurt Fausch and Kevin Bestgen, Fish, Wildlife, and Conservation Biology, Colorado State University

Brian Bledsoe and Mike Gooseff, Civil and Environmental Engineering, Colorado State University

Natalie Kramer, Geosciences, Colorado State University

A team of researchers from three departments at Colorado State University is working to develop a decision making framework for dealing with large wood in Front Range rivers. The goal of the group is to identify the many natural, recreational, and safety-related benefits and risks of large wood in streams and create tools for river managers.



Figure 1. Large wood in rivers is often perceived as not natural or undesirable by the general public, and can pose risks to human safety and infrastructure. However, it also provides important benefits to maintaining healthy river ecosystems.
Photo by Kurt Fausch

The September 2013 flood caused extensive erosion of river floodplains and damage to roads and infrastructure in and near rivers along Colorado's Front Range. It also toppled many large trees and moved them into river channels or onto floodplains. Although the general public and stormwater engineers often view these downed trees as "debris" that must be removed after a flood to ensure human health and safety, river scientists and managers know that large wood is a natural feature of these water courses and has important functions that help sustain rivers and the animals and plants that live in and along them (Figure 1). We formed a team of six scientists from three different departments at Colorado State

University to assess this tradeoff, working with stormwater engineers and natural resource managers in several locations (Figure 2), and are developing a risk analysis framework for managing large wood in Front Range rivers.

Most lowland rivers and streams in North America have little wood compared to pre-European settlement, because most large wood was removed starting in the late 1800s to improve navigation and flow conveyance for agriculture and other land uses. Likewise, streams in forested mountain regions often lack wood because trees were harvested from the riparian zone, and most large wood and boulders were removed from channels to allow

floating these saw logs downstream. During the last 50 years, most wood has been removed from Front Range rivers to prevent possible risk to human safety and possible damage to infrastructure like bridges and water diversions. For example, nearly all large trees that washed into the Cache la Poudre River during the 1983 flood (the largest peak flow before September 2013) were removed within about six months (Figure 3).

Large wood provides both physical and biological benefits for rivers, but it also poses risks for humans. Large trees and the log jams they create can slow the passage of floods and store sediment and smaller wood and leaves that would otherwise be

flushed quickly downstream (Figure 4). These dead leaves and wood can provide much of the food and living space that invertebrates in streams need to survive, especially in streams with primarily sandy beds like those along the Front Range.

In turn, these invertebrates provide much of the food needed by fish and other animals that live in and near streams. Log jams can also increase the amount of overbank flow onto the floodplain. In natural rivers, this is important for the creation

and maintenance of diverse habitat for birds, small mammals, reptiles, amphibians, and even fish that use aquatic habitats on these floodplains. Wood also can increase the amount of water forced into the gravel bed below the river and floodplain (termed hyporheic flow), which can also provide habitat for stream insects and lead to cooler stream temperatures and improved water quality. Finally, large wood and wood jams within river channels can increase the number of pools and create secondary channels and undercut banks. All of this increases habitat complexity and provides refuges for fish to hide from predators and find shelter from the flow, allowing them to feed more and grow faster.

Along with these advantages, large wood in Front Range rivers also poses risks. Wood jams can create higher water levels during floods, causing hazards where overbank flooding is not desirable. Wood can accumulate at bridges and diversions, causing increased flooding upstream and increased scour around piers and abutments, and large wood can also be washed downstream during floods and cause damage to other infrastructure. Large trees in the channel can create scour or deflect flow to the opposite bank and cause erosion. Large wood jams can also be hazardous to recreationists, by creating “strainers” that trap or snag boaters or tubers. In contrast, some wood jams may provide calmer water that allows boaters to reach shore and find rest, or avoid being drawn into dangerous conditions downstream.

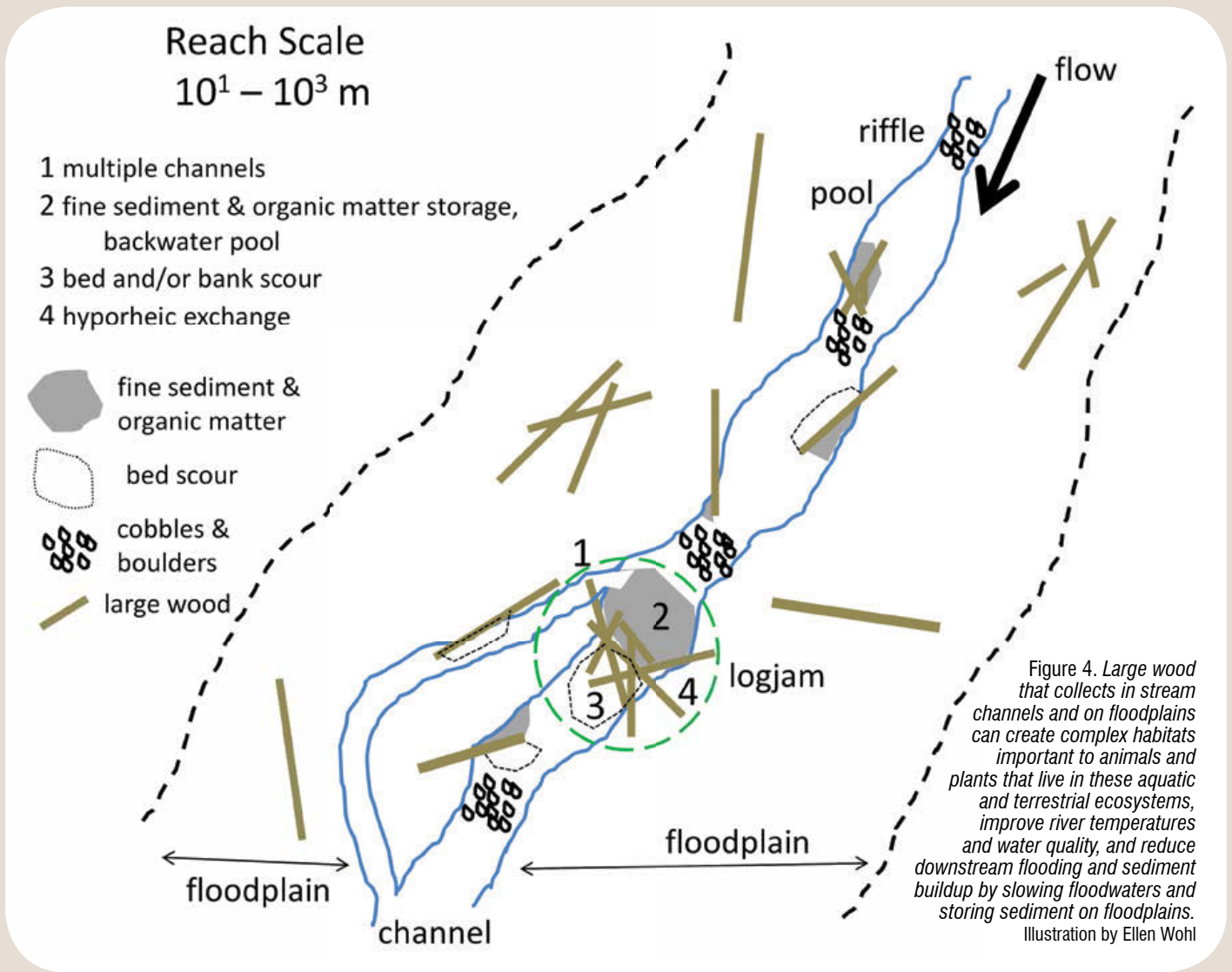
The goal of our working group is to create a decision framework for analyzing the benefits and risks of



Figure 2. Colorado State University faculty meet with river engineers and natural resources managers from the City of Fort Collins shortly after the September 2013 flood to discuss possibilities for managing large wood in the Cache la Poudre River. Photo by Kurt Fausch



Figure 3. After the 1983 flood, most large wood was quickly removed from the Cache la Poudre River, as shown here at Lyons Park in LaPorte, Colorado. Photo by Kurt Fausch



retaining (or placing) large wood in Front Range rivers, especially after floods like September 2013 flood that moved much wood into these rivers. To this end, we are creating a hierarchy of four tools to help river managers decide how to manage particular pieces of wood. These include:

1. A simple checklist to help make the initial decision of whether to remove wood immediately, or consider other options
2. If other options are considered, a Large Wood Structure Stability Analysis spreadsheet tool that provides

a quantitative assessment of how likely a piece of wood or large jam is to move downstream at different river flow levels

3. Decision criteria for assessing the risks and benefits of wood for aquatic and riparian habitat, recreationists, flooding, wood stability, downstream infrastructure, and unintended changes in the channel
4. A multi-criterion decision analysis that allows combining and reconciling multiple risk factors and tradeoffs in a quantitative way

Overall, many members of the public perceive that wood is not natural in

streams and feel that it should be removed. Likewise, many local and regional governments have sought to remove most wood from rivers, even when the risk to human life and property is minimal. However, wood is critical for the healthy functioning of river ecosystems, for providing habitat for many fish, amphibians, reptiles, birds, and mammals that live in rivers and riparian zones, and for creating aesthetic riverscapes that recreationists seek for enjoyment and to find solace. The goal of this project is to highlight these different benefits and risks and to find a way of supporting more informed and transparent decisions about large wood in rivers of the Front Range.

Boreal Toads

Conserving a High-Elevation Aquatic Species

Larissa Bailey, Department of Fish, Wildlife, and Conservation Biology, Colorado State University



Bailey, along with student researchers and other collaborators, is working to determine causes for population declines in boreal toads. Such research also aims to inform reintroduction and translocation efforts.

Approximately one third of the world's amphibian species are threatened, making them the most imperiled vertebrate taxa on the planet. Recent studies in the U.S. have indicated that on-average amphibian occurrence is declining at an average rate of 3.7 percent each year. If that rate remains unchanged, these species would disappear from approximately half of their current habitats in 20 years. The declines are even more drastic for species that are considered threatened, vulnerable, or endangered by the International Union for Conservation of Nature (IUCN). While habitat loss and alteration contribute to these declines in many areas, other studies suggest that disease, invasive species, and perhaps other unknown factors are related to declines in protected areas.

One amphibian species experiencing substantial declines in Colorado is the boreal toad (*Anaxyrus* [*Bufo*] *boreas*). Once considered common in the southern Rocky Mountains, dramatic population declines became apparent in the 1980s. In April 2012, the U.S. Fish and Wildlife Service found that there was substantial scientific information to pursue listing the remaining boreal toad populations in the southern Rocky Mountains (SRM), along with populations in Utah and parts of Idaho, as a distinct population segment; the final listing decision is scheduled for 2017. Many of the declines in boreal toads have been attributed the amphibian chytrid fungus (*Batrachochytrium dendrobatidis*, Bd), but the extent of the decline has not been quantified, and little is known about the persistence or dynamics of the

pathogen in high-elevation wetland habitats. Moreover, there are locations where factors other than disease (e.g., predation or competition from nonnative species) may compromise toad reproduction and recruitment, contributing to continued, but slower, population declines. Several graduate students and I, along with numerous collaborators, are working to fill these knowledge gaps and help management agencies determine optimal recovery actions to slow or reverse boreal toad declines.

The boreal toad is generally considered a subspecies of the western toad, and it can be distinguished from other toads by a lack of cranial crests between or behind the eyes. Adults have a light-colored stripe down the

Figure 1 (above). *Adult male boreal toad at a breeding site in Rocky Mountain National Park.*
Photo by Wendy Lanier



Figure 2. Breeding boreal toads and string of eggs at a breeding site in Rocky Mountain National Park. Photo by Anna Perez-Umphrey

middle of the back, and a dull white belly with unique spotting patterns (Figures 1 and 2). In Colorado, boreal toads are typically found at elevations between 2,500-3,800 meters (about 8,200-12,500 feet). Adults emerge from hibernation sites and migrate to breeding wetlands once the snow starts to melt and wetlands are ice free (mid-May to mid-June). Females stay at the wetland only long enough to breed and lay eggs—perhaps only a single night—and they won't breed again for 2-3 years. Eggs are laid in strings of two rows with between 4,000-12,000 eggs per clutch. Eggs hatch quickly (in 1-2 weeks) and tadpoles grow and mature during the summer, metamorphosing prior to winter snows. Little is known about the juvenile life-stage prior, but mortality is thought to be high. Individuals that make it to adulthood can live 9-15 years.

As a result of the observed boreal toad declines, an interagency recovery team was formed in 1994. The team consists of representatives from three state agencies (Colorado, Wyoming, and New Mexico) and six federal agencies and is primarily responsible for monitoring and setting research priorities for the SRM boreal toads.

The team has identified populations that are disease-free and doing relatively well, other populations that seem to lack the disease but continue to decline, and many populations that have declined after Bd was detected.

One Ph.D. student in our lab, Brittany Mosher, is using the data produced by the recovery team to jointly model amphibian and disease dynamics, with an emphasis on exploring factors that may influence disease occurrence and persistence at sites with and without toads. Her work also involves developing monitoring methods to detect Bd when toads are not captured. Such information regarding host-pathogen dynamics and factors influencing pathogen persistence will further our scientific understanding and inform future management decisions regarding where and when to perform translocations or reintroductions. In addition, Mosher's analyses will provide recommendations to improve monitoring efficiency for both amphibian and Bd presence.

Another graduate student in our lab, Wendy Lanier, is tackling factors that may inhibit toad recovery in the absence of Bd. Today management agencies face conflicting needs



Figure 3. Field enclosures for egg masses at a breeding site in Rocky Mountain National Park. Photo by Brittany Mosher



Figure 4. Rocky Mountain National Park personnel and volunteers searching for recently metamorphosed boreal toads at a reintroduction site in Rocky Mountain National Park. Photo by Larissa Bailey

of multiple threatened aquatic species. An example of a potential conundrum between endangered species management involves boreal toads and the Greenback cutthroat trout (*Oncorhynchus clarkii stomias*) in Rocky Mountain National Park (RMNP). In the 1990s, recovery efforts involved introducing the federally threatened trout species into high-alpine lakes that lacked non-native, invasive trout species. Some of these introductions occurred at sites that had boreal toads, and while the toads have persisted at these sites, no metamorph or juvenile recruitment had been documented in nearly a decade. Unlike many amphibian species, toads are generally considered unpalatable to fish due to their toxic skin secretions. Still, trout must engulf and taste their prey to determine if it is palatable and this process may injure tadpoles or inhibit their growth, even if the tadpoles are not consumed. Lanier is combining an extensive lab experiment with a field experiment and observational studies at wetlands with and without cutthroat trout to explore potential direct and indirect effects of trout on toad early life-history phases (e.g., hatching success and tadpole survival) (Figure 3). Her work will help determine criteria to

be used by management agencies in future reintroductions of both species.

The studies described above inform management agencies about criteria to consider in boreal toad reintroduction and translocation efforts. Despite ongoing use of this management tool, the success of these efforts is seldom quantified before the project is deemed completed or abandoned. I have worked with collaborators at Rocky Mountain National Park (Mary Kay Watry), U.S. Geological Survey (USGS, Erin Muths), and the Colorado Parks and Wildlife's Native Aquatic Species Research Facility to estimate survival of wild- and captive-bred eggs and reintroduced tadpoles. Our results suggest that eggs laid in the wild hatch at higher rates than eggs laid by captive toads, and that tadpoles released at later developmental stages have an increased probability of survival through metamorphosis (Figures 4, 5, and 6).

Finally, we are working with members of the boreal toad recovery team to revise the 2001 Boreal Toad Conservation Plan and Agreement. In collaboration with endangered species specialist Sarah Converse (USGS), we are using a formal decision-making framework to develop recovery



Figure 5. CSU students Staci Amburgey (master's student, Biology) and Jennifer Swanson (undergraduate student, Rangeland Ecology), apply a single elastomer mark to recently metamorphosed boreal toads at a reintroduction site in Rocky Mountain National Park. Photo by Larissa Bailey



Figure 6. Hatchery-reared boreal toad tadpoles being released at a reintroduction site in Rocky Mountain National Park. Photo by Larissa Bailey

objectives that reflect current stakeholder values and incorporate the large volume of demographic information that has been generated in the last decade, including those studies mentioned above. Models similar to those used in Mosher's research will be used to project the outcomes of potential management actions to the group's desired objectives, and thus form the basis for determining optimal management actions. The process will also identify key uncertainties that influence management decisions to target in future research.

Importantly, the projects described above and others have involved numerous graduate and undergraduate students. In addition to conducting valuable lab and field studies, these students gain valuable insight into how research findings are used in the management decision-making process.

Common Wastewater Contaminant Can Disrupt Fish Survival, Reproduction, and Population Dynamics

Dana Winkelman, Unit Leader, U.S. Geological Survey, Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University

Adam Schwindt, Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University

Research was conducted in simulated ponds on several generations of fathead minnows to determine if varying levels of a steroidal estrogen, a common wastewater effluent, would have an effect on fish. Lifetime exposure and early life exposure both had negative effects on survival and reproduction, as well as physiological effects.

Introduction

Freshwater ecosystems contain approximately 40 percent of global fish diversity, are highly threatened, and have current animal extinction rates (four percent) that are much higher than in the past. Stresses on freshwater ecosystems stem largely from increased water consumption and pollution associated with expanding human populations. Freshwater streams and rivers of semi-arid ecosystems, such as the Great Plains of the USA, are frequently dominated by wastewater effluent. For example, flow in the South Platte River downstream of Denver, Colorado, ranges from 69-100 percent wastewater effluent depending on the time of year. Projected decreases in stream flow due to climate change will likely exacerbate stresses on Great Plains rivers, as stream flow can be expected to become increasingly effluent dominated. Therefore, most fish populations in eastern Colorado will be exposed to wastewater effluent, and understanding how fish populations respond to effluent exposure is critical to management and conservation of fishes in these ecosystems.

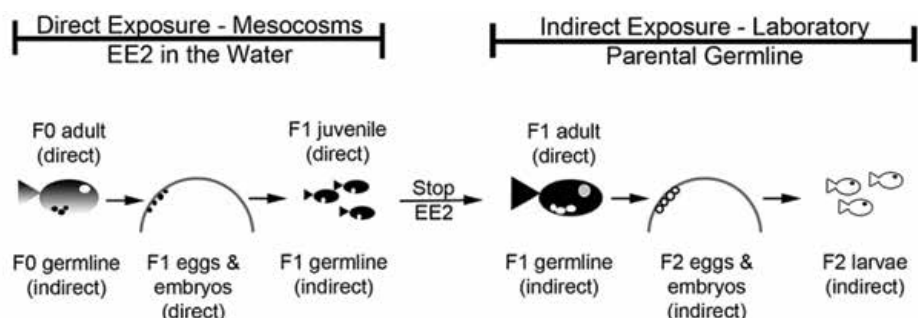
Wastewater effluent is a complex chemical mixture that can influence vertebrate physiology. Steroidal estrogens

are commonly found in wastewater effluent. These estrogens are either naturally produced by humans or ingested as birth control and excreted. Estrogens, as well as other pharmaceutical compounds, then enter aquatic systems following incomplete removal during wastewater treatment. Estrogens negatively affect fish reproduction, and investigators typically focus on physiological endpoints and use inferences based on these observations to speculate on population effects. However, few studies have directly measured population-level effects of estrogenic exposure. Direct evidence of estrogenic exposure on population responses will yield a better ecological measure of exposure and be more relevant to management and conservation. Additionally, most studies do not assess the population effects of long-term exposure (lifetime) or effects on offspring resulting from exposure to the parents (known as transgenerational effects). However, in most effluent-dominated systems, organisms could experience short-term to lifetime exposures, and the effects on reproduction and survival may persist even if exposure is reduced or stopped. Our research focused on how exposure to estrogenic compounds may influence population dynamics and persistence of Great Plains fishes.

Approach

We conducted our studies to evaluate if 17 α -ethinylestradiol (EE2), the synthetic estrogen in human birth control, reduces survival in multiple life stages and to evaluate if EE2 reduces reproductive output over multiple generations. We used fathead minnows (*Pimephales promelas*) in our experiments because they are ideal for population-level studies. They are indigenous to Great Plains streams and rivers, reach sexual maturity rapidly, and reproduce throughout the summer. We

Figure 1. A schematic of fathead minnow exposure history. Direct exposure to 1st generation adults and 2nd generation eggs, embryos, and juveniles occurred in the mesocosms. After the mesocosm experiment, exposures were stopped and fish were allowed to recover and reproduce (early life exposure). Fish were also continuously exposed after the mesocosm experiment, but they failed to produce offspring (life time exposure, not shown in figure).



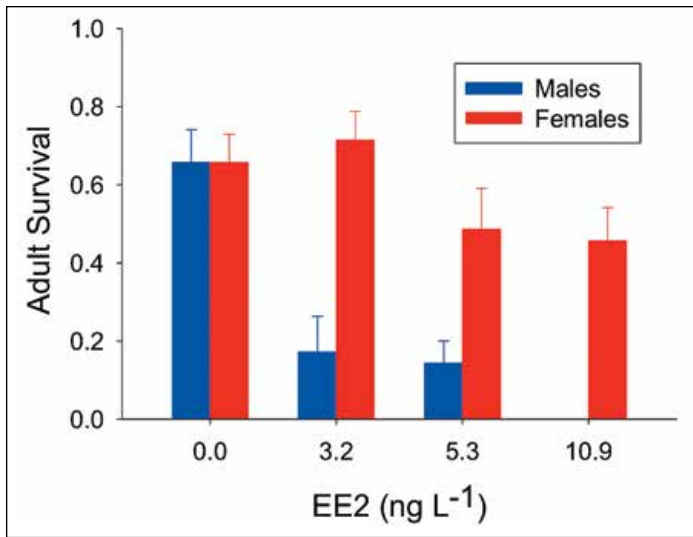


Figure 2. Effect of 17 α -ethinylestradiol (EE2) on adult (1st generation) fathead minnow survival. Male survival significantly declined relative to controls; no males survived the highest exposure level.

exposed fathead minnows to EE2, a potent estrogen in fish and a common contaminant in wastewater effluents. We conducted one experiment in outdoor mesocosms (simulated ponds) and exposed adult fish (first generation) to four concentrations of EE2 (0, 3.2, 5.3, and 10.9 ng/L) that cover the range of concentrations they might be exposed to in Great Plains streams. We then monitored reproduction and survival during the reproductive season (Figure 1).

After we finished the mesocosm experiment, we conducted a laboratory experiment using the fathead minnows hatched in the mesocosms (second generation). These fish were either allowed to recover and were only exposed early in their life (early-life exposure), or were continuously exposed throughout their life (lifetime exposure; Figure 1). We stopped exposing these fish when they reached maturity. They were then allowed to reproduce, and we assessed larval production and survival.

Adult Exposures (First Generation)

In the mesocosms, exposure of the first generation adults during the reproductive season caused dramatic declines in male survival and, to our understanding, no other studies report significant effects on adult survival at trace EE2 concentrations (Figure 2). The physiological mechanism causing reduced male survival in our study is unknown; however, it is likely due to the production of vitellogenin by exposed males. Vitellogenin is the protein used by females to produce eggs and is not produced by males unless they are exposed to an estrogen. Mortality for both males and females in the control mesocosms (unexposed) suggests other sources of mortality not associated with exposure to EE2 and highlights the importance of conducting experiments in realistic situations in which other

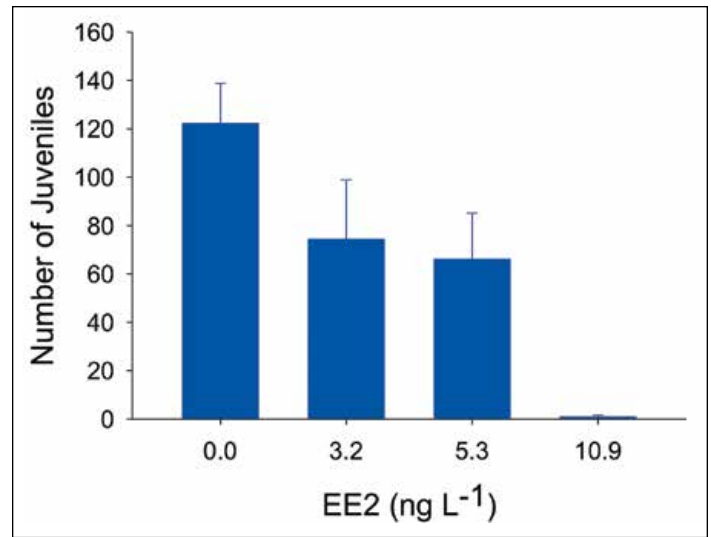


Figure 3. Effect of EE2 on the number of juvenile fathead minnows produced in the mesocosm experiment (2nd generation).

potential stressors are present (Figure 2). Fish in natural environments are exposed to multiple stressors in addition to chemical stressors, such as temperature, food abundance, and competition. Further studies to understand factors causing adult mortality are clearly needed and should be done in realistic settings.

Exposure of first generation adults also showed that they produced fewer juvenile fish; however, we did not observe statistically significant effects on reproductive output until our highest EE2 concentration (Figure 3). Our experimental results suggest that, even when male survival is low, reproductive output is sufficient to sustain reproduction at levels approaching that of unexposed fish.

Early-Life and Lifetime Exposures (Second Generation)

Individuals exposed to relatively low concentrations of EE2 early in life (mesocosms) and then transferred to clean water produced significantly fewer larvae (third generation) than unexposed fish (Figure 4). This was particularly true for fish exposed to higher EE2 concentrations, which produced almost no larvae (third generation; Figure 4). The lack of recovery suggests that timing of exposure may be important—if fish are exposed early in their life, it may have consequences for population recovery. The external appearance of second generation males changed dramatically after a lifetime exposure to EE2, and they began to resemble females (Figure 5). Changes in male appearance after exposure to an estrogen have been documented in other studies and are associated with disruption of reproductive behavior. Lifetime exposure of the second generation resulted in no surviving larvae (third generation) at any EE2 concentration (Figure 4). These reproductive failures resulting from early-life or lifetime

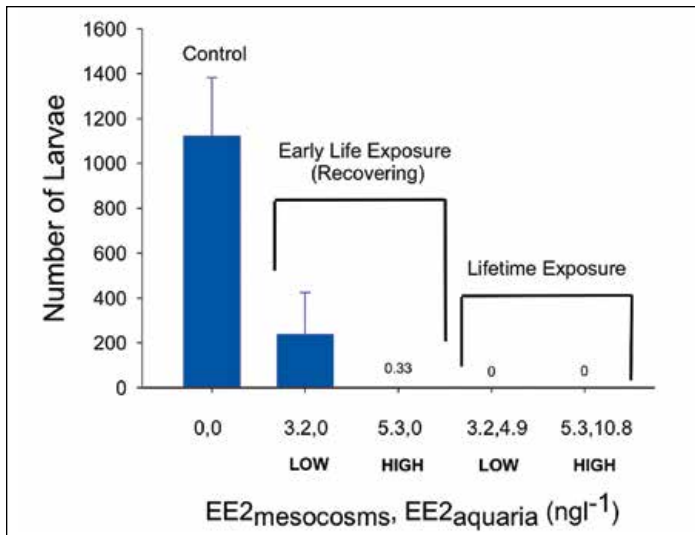


Figure 4. The number of larvae (3rd generation) produced by 2nd generation juveniles that were either allowed to recover from exposure or were continuously exposed throughout their lifetime.



Figure 5. The effect of 17 α -Ethinylestradiol (EE2) on male fathead minnow (*Pimephales promelas*) secondary sex characteristics. Panel A shows an unexposed male, Panel B shows a male that was exposed its entire life to 10.9 ng/L EE2, and Panel C shows an unexposed female for comparison.

exposures of EE2 could ultimately lead to population decline or failure.

Transgenerational Effects (Third Generation)

Embryos produced by second generation individuals (third generation) were never directly exposed to EE2. However, survival of third generation embryos was significantly reduced from controls (Figure 6). The surprising reduction in third generation embryo survival

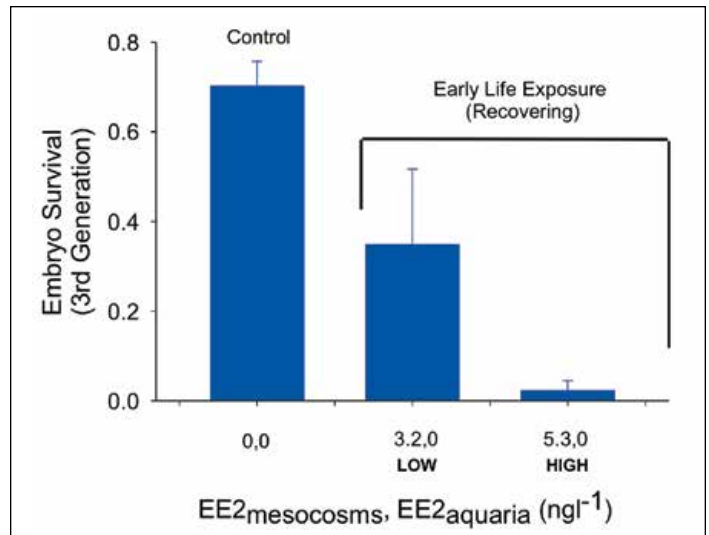


Figure 6. The effect of 17 α -Ethinylestradiol (EE2) exposure on 3rd generation embryo survival. Survival significantly declined relative to controls.

despite never directly experiencing EE2 suggests, at a minimum, parental effects, but could also result from changes in genetic activity known as epigenetic processes. Both possibilities, a physiological exposure from parents or epigenetic inheritance, indicate a transgenerational effect. The possibilities of transgenerational effects of EE2 exposure warrant further studies to determine if the effects are heritable, and predicting population dynamics will require understanding how these effects are transferred across generations.

Conclusions

Our results suggest that multiple mechanisms could contribute to population declines or failure, including: 1) reduced male survival, 2) reproductive failure, and 3) transfer of parental traits that limit offspring survival. Our studies confirm that EE2 exposure could reduce population growth rate and persistence, and that populations may have difficulty recovering even if estrogen exposures are stopped. Additionally, our results suggest that, even if fish migrate away from contaminated environments, populations may still experience declines because of the effects of early-life exposures. Considering that climate change and increasing human populations will likely exacerbate stresses on Colorado's Great Plains aquatic ecosystems, understanding the effects of contaminants on fish population dynamics is crucial to their management and conservation.

Acknowledgements

Our research was supported by Colorado Division of Parks and Wildlife and the Environmental Protection Agency. We would like to especially thank our collaborators Kristen Keteles, Alan Vajda, and Mark Murphy. Our more detailed description of our data has been previously published in *Journal of Applied Ecology*, 2014, 51:582-591.

Colorado Parks and Wildlife Hatcheries Stock Regional Waterways

Ken Kehmeier, Senior Aquatic Biologist,
Colorado Parks and Wildlife

Figure 1. Walleye brood fish are captured along the dams using gill nets. Courtesy of Colorado Parks and Wildlife

In 2014, Colorado Parks and Wildlife and collaborators collected, fertilized, and shipped over 100,000,000 walleye eggs to supply demands of over 725,000 fishing licenses.

Fisheries management predates all other wildlife management activities in Colorado. The first Colorado wildlife law passed in 1861, and it addressed overfishing: “It is unlawful to take trout by seine, net, basket, or trap.” The first wildlife official in Colorado was Colonel Wilson E. Sisty, who became the State Fish Commissioner in 1877.

With the state selling over 725,000 fishing licenses a year, many more regulations pertaining to fishing now exist to assist in providing a positive recreational experience for anglers. To assist in keeping fishing a successful outdoor experience, Colorado Parks and Wildlife (CPW) has 16 fish hatcheries that are responsible for 56 separate strains of fish and raise and stock over 90 million fish every year.

Two of those strains of fish that are raised are the walleye and saugeye (Walleye X Saugee hybrid), which in 2014 will be stocked in 80 lakes

around the state and traded to five other states for various fish we do not raise in our hatchery system. Every year around the middle of March, Parks and Wildlife fishery biologists, CPW staff, and volunteers gather at Cherry Creek, Chatfield, and Pueblo Reservoirs to collect walleye eggs for our hatchery requests. In 2014, over a 15-day period, 117,690,000 eggs were collected, fertilized, and shipped to our hatcheries in Wray and Pueblo. Of those millions of eggs, approximately 70 percent hatch and are stocked in those many lakes. Colorado has very few lakes where these species could reproduce naturally, and the survival of those eggs is very low, at less than one percent.

The spawning operation (act of expressing eggs from a female) starts early in the morning with boats leaving the marinas and moving toward the dams of the reservoir where gill nets (400 feet long and six feet deep) were placed parallel to

shore the night before (Figure 1). The nets are set in approximately eight feet of water, capitalizing on the walleyes’ desire to move into shallow water (less than three feet) early in the morning while it is still dark to spawn. The gill nets are an entanglement gear in which fish get caught, and biologists carefully pick them out. The fish are taken back to spawning facilities (a 30 foot barge) set up in the marina to handle the brood fish. Coming off the lake, all of the walleyes are sorted by gender, and biologists determine if females are “ripe” and will spawn that day or if they are “green” and not ready to spawn yet. Females not quite ready to spawn will be held in cages for up to three days to see if they will spawn. Once all the nets have been pulled, the crew set up to spawn and fertilize eggs.

If the operation is making the hybrid cross saugeye on a given day, a lot of preparation has taken place so this hybrid cross can be made. Colorado is



Figure 2. Colorado Parks and Wildlife fishery biologists spawn ripe females who produce approximately 125,000 eggs per pound of body weight. Courtesy of Colorado Parks and Wildlife



Figure 3. Walleye eggs are stirred to increase fertilization (nearest pan) and with bentonite clay (back pan) to break down egg adhesiveness so they can be water hardened and shipped to the hatchery. Courtesy of Colorado Parks and Wildlife

currently developing sauger fisheries along the Front Range, but until recently, we have traded for the male sauger milt (semen) with other states such as Nebraska or Kansas. Extended milt is shipped via overnight express to Colorado in small vials that contain milt and an extender that keep the milt alive. To extend the semen, biologists capture male sauger and

express the milt from the fish, taking all precautions to not expose it to water. The milt is combined with an extender (isotonic solution), which basically replicates the chemical environment that is found inside the male sauger. The extended milt is then shipped to Colorado and once in Colorado, the milt is oxygenated and checked to see that it still has



Figure 4. Walleye fry are transported back to the lake to be stocked in oxygen injected sealed bags. 100,000 fry are placed in each bag the bags are tempered to match the lake temperature before the fry are released. Courtesy of Colorado Parks and Wildlife

motility. Its viability is checked each day before it is used and the vials are re-oxygenated. If properly taken care of, the extended milt will be usable generally for about a week.


If pure walleye eggs are to be taken on that day, the crew will make sure to keep not only the females from the nets on the lake, but to also bring the males to the spawning barge. Male walleyes usually outnumber the females captured each morning as they move on to the shoreline and remain there hoping to mate with multiple females over the spawning season. Females will normally move in toward the shoreline when they are ripe or a few short days from being ripe (or ready to spawn).

The actual spawning of female walleyes is the same regardless of whether we are creating walleyes or saugeyes. To take or express the eggs from a female walleye, the biologist will apply hand pressure to the ventral portion of the body from about the midpoint or between the pectoral and pelvic fins back to the vent (Figure 2). The eggs will

flow freely from the vent of the fish and are confined in a dry, deep pan where they are held so they can be fertilized. Milt is then expressed from the male walleye—approximately 1.5 milliliters of extended milt is added to the pan. At this point, we add water to activate the milt and eggs. Once water is added, the milt is viable for about 90 seconds. After that point the milt is not longer viable and the egg becomes non receptive to being fertilized. The egg/milt/water is stirred with a goose feather for those 90 seconds to increase the chance of fertilization (Figure 3). In the wild, walleye eggs are adhesive by nature and once fertilized, they stick to rocky areas in the lake. This allows the eggs to stay in one place, and the normal wave action of the lake provides well-oxygenated water to the egg so it can develop and hatch. When we take the eggs for hatchery production, the adhesive nature of the eggs

causes problems—eggs will adhere to each other and create large clumps. These clumps have much lower hatching success because the oxygen content in the center of the clumps is not adequate for development and hatching. Biologists long ago found that a solution of water and bentonite clay will break down the adhering qualities of the egg and allow us to ship eggs to the hatchery that do not clump and will have increased survival. After the fertilization process is completed in the first 90 seconds, the bentonite clay solution is added to the pan, and the eggs are stirred for an additional 90 seconds to ensure the eggs are no longer adhesive. The bentonite and egg mixture is then rinsed numerous times until the water is clear and the eggs can be put into egg baskets to allow them to water harden prior to shipment to the hatchery. Water hardening is a process that eggs go through after coming in

contact with water. The egg absorbs water to fill out the shell, and that water provides not only protection for the developing embryo, but the shell also allows for exchange of water for life support systems needed by the egg to develop and hatch. An hour after the last egg is taken for the day, the eggs are siphoned into large coolers and driven by pickup to the hatchery.

Once at the hatchery, the eggs are put into hatching jars, and water slowly flows through the jar to keep the eggs gently rolling. Approximately 10 to 14 days after the eggs were taken at the lake, small (¼ inch long) walleye or saugeye fry hatch (Figure 4). After three more days, those fry are on their way to a lake to grow up and provide recreation for anglers. It takes about three years for those ¼ inch fry to grow up to 15 inches and become acceptable to anglers. 

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The CSU Water Center's New Look

Ajay More, Student Intern, CSU Water Center
Julie Kallenberger, Research and Outreach Coordinator, CSU Water Center
Emilie Abbott, Student Intern, CSU Water Center

“Design is so simple,
 that’s why it is so
 complicated.”

--Paul Rand

A logo is an embodiment of the organization it represents. Once a logo is chosen to be a symbol for an organization, it becomes so deeply intertwined with the organization that it is almost impossible to separate them.

When the Colorado State University (CSU) Water Center was revitalized in fall 2013, a logo was a top priority. The CSU Water Center commissioned students from the College of Liberal Arts at CSU to design the logo as a part of a class assignment. Two

classes, Art 356 and Art 456, with 15 students each, were chosen to design the logo. The students’ passion for design and their enthusiasm and interest were overwhelming. Students presented their designs with a short explanation of their design methodology and how their design fits with the CSU Water Center’s vision and mission.

Because of the high quality of all the designs and the various facets of water that they represented, it was very difficult to choose among the 30 designs. All of the logos were exhibited to the Executive Committee of the CSU Water Center for their input. After further discussion and evaluation of all submissions, the logo designed by Jessica “Jessa” Murphy



was selected as the new logo of the CSU Water Center.

Murphy is a senior in the College of Liberal Arts at CSU, pursuing a Bachelor of Fine Arts in Graphic Design. She has always had a passion for art and communications and aspires to use these passions to create

Above Photo: Jessa Murphy and her design of the CSU Water Center logo. Photo by Kim Hudson

artwork for print advertisements; she believes graphic design was the perfect major to accomplish this.


When Murphy set out to create her design for the Water Center, she conducted a search of common representations of water so that she could stay away from overused images in her own design. She began to reflect upon the many possible ways to draw a wave. The spiral design appealed to her because it looked not only like a wave, but also a current. The design's simplicity conveyed many ideas: "The power of water through currents and waves, how water power is used to generate electricity and fuel other industries, and the circular flowing motion that alluded to the water cycle were just

a few of the things that this image brought to my mind," Murphy said of the design.

In her work, Murphy enjoys collaging different mediums together in a project. She also favors a hand-drawn look in design as this makes a piece very personal to a designer. She tries to stay away from popular trends as much as possible, or at least add her own unique twist to what is well known. Murphy takes inspiration from the collages of Charley Harper and Eric Cale as well as the typographical creations of Jessica Hische.

After graduating with her Bachelor of Fine Arts, Murphy would like to employ her creativity working on a design team of a company, especially

an advertising agency, and eventually work her way up toward becoming art director. She hopes that her design and artwork will speak to people in an influential way and help companies and people achieve their goals. In her free time, she enjoys scuba diving and the many hiking and snowboarding opportunities Colorado has to offer.

Choosing a logo for the CSU Water Center took a lot of time and effort, as all of the designs were very creative and represented so many different aspects of water. With the selection of Murphy's design, the CSU Water Center's quest for a logo came to a successful conclusion. The logo will adorn the website, social media pages, and publications from the CSU Water Center. 



Professor Phil Risbeck teaches Jessa Murphy graphic design in his Art 456 course. Photo by Kim Hudson



Partnership Helps Protect Pikes Peak Watershed, Reduce Wildfire Risk

*Brian Woodward, Associate Public
and Media Relations Coordinator,
Colorado State Forest Service*



Located just 10 miles west of Colorado Springs and rising more than 14,000 feet, Pikes Peak is an unmistakable natural feature that draws thousands of visitors to central Colorado each year. However, few visitors think about the Pikes Peak Watershed and water supply system, a complex combination of natural streams, man made reservoirs, and lengthy tunnels and pipelines located amongst the thousands of acres of forestland that surround the impressive peak.

The first water supply infrastructure constructed in the Pikes Peak Watershed dates back to 1878, making the area an important source of fresh

water to the City of Colorado Springs for more than 100 years. Today, the 13,000 acres owned by Colorado Springs Utilities within the watershed supply 5.5 billion gallons of fresh water annually to the Utilities' customers. With a water delivery system of such grand proportions located in an area with a long history of intense wildfire, maintaining watershed health and excellent water quality does not come without proper forest management.

Since 1987, Colorado Springs Utilities has partnered with the Colorado State Forest Service (CSFS) to implement the Pikes Peak Watershed Forest Management Plan. The plan seeks to help maintain and improve the water

resources available on City-owned properties within the watershed. To learn more about the plan and the role the CSFS plays in protecting the watershed, we sat down with Andy Schlosberg, assistant district forester for the CSFS Woodland Park District. Schlosberg has managed implementation of the plan since 1992, when the total project budget was just \$30,000. Today, the district works with an annual project budget totaling nearly \$500,000 to help manage forestlands Colorado Springs Utilities owns and protects.

Above Photo: Garden of the Gods, a well-known collection of red rock formations located near the management area, with Pikes Peak in the distance. Courtesy of Kristy Muskopf



Masticated fuels on the ground result from the removal of standing fuels, which leaves a layer of mulch. Courtesy of Kristy Muskopf

CSFS: What are the primary goals of the Pikes Peak Forest Management Plan?

Schlosberg: The central goal of the plan is the protection of water quality. The supportive goals include the identification of wildfire hazard areas and reduction of wildfire risk, and improvement of forest health and water yield through proper forest management practices. We work with others to cooperatively manage adjacent public and private lands which may affect Pikes Peak Watershed health and maintain the high aesthetic qualities of the watershed for recreation and tourism.

What role can a state forestry organization play in protecting the health of a watershed and water supply system?

Healthy forests and healthy watersheds go hand in hand. Forests help maintain soil stability and reduce the flow of soil and debris into the water system. The CSFS provides the expertise necessary to restore forests to a healthy condition and reduce the likelihood of a catastrophic wildfire.

A well-managed forest will be less susceptible to loss of cover due to

insect and disease. A well-managed forest is also less susceptible to damage caused by fire. While insect and disease outbreaks and wildfire may still occur on these lands, the damage to the forest and watershed will be minimized.

What specific forest management activities have been conducted for the projects?

We've been evaluating the landscape and implementing forest restoration practices appropriate to the forest type. At higher elevations dominated by spruce, we use patch cutting of small openings with clumps of larger overstory trees, separating them to avoid blow-down. In the ponderosa forests of the lower elevation areas, we tend to thin from below to maintain a healthy tree density, leaving large, dominant trees with lots of open space and crown separation, along with some small patch cutting. This encourages new age classes to develop, which is important to the long-term health of the forest and the watershed.

So how is the reduction of hazardous fuels related to watershed health? What

effects can a wildfire have on a watershed?

When wildfire burns at high intensity, under extreme conditions, it can kill off the vegetation and root systems that hold soil and debris in place. This material can then flow into water storage systems, damaging water quality and fouling the distribution systems. Extreme fire behavior can also directly impact the infrastructure that supports the water system. By restoring forests to a more natural condition, the possibility of fire ignition is reduced. And if a fire does occur, forest restoration will help ensure that fire behaves in a more natural way. This means that the fire will not burn as hot, resulting in less damage to the soils and less mortality in the trees and vegetative ground cover.

With a management area of more than 13,000 acres, how are projects prioritized?

The first thing we consider in prioritizing treatment areas is public usage. The North Slope and Longs Ranch treatment areas of the watershed are much closer to the surrounding urban areas and see fairly heavy recreational use. For this reason, we are concerned that these areas are more likely to be impacted by wildfire and other human activity, and could have greater impacts on life and infrastructure in the event of a fire.

How have the projects evolved since you took the agreement over in 1992?

In the beginning, most of this work was accomplished by selling firewood contracts. This resulted in small projects, on the order of 10 to 40 acres, being accomplished over long time frames of two to four years each. But for the last 10 years or so, most of our treatment work has been done mechanically. This allows much larger projects, 100 to 300 acres, to

be completed within a single season. Currently we are at the point where most of the terrain accessible by heavy equipment has already come under management, and we are now beginning to do more work on steeper slopes by hand, the way we used to, with help from forestry contractors.

What is the next step for the agreement, how has it evolved?

Currently the plan is in its second incarnation. First drafted in 1986, the plan was updated again in 2010. The new version mainly incorporates updates to the forest structure occurring from our management activities, acknowledges new ideas and a better understanding of forest management—such as mixed conifer management—and looks at how the landowners' concepts of forest management and goals have changed, such as incorporating the use of prescribed fire and acknowledging increased recreational uses. Colorado Springs Utilities is committed to the management of their forested lands and to maintain their partnership with

CSFS, and we will probably be looking at a similar update in 2020.

Will the work for the plan ever be done?


Forest management work is never done, because trees are always growing. We still have many acres that have not been brought under management, and as the areas become more difficult to access, the time frame for achieving these goals extends out many years. If we should ever achieve the goal of reaching all these lands, it will then most likely be time to start re-entering some of our first project areas in order to maintain the conditions we previously worked to achieve.

If a private property owner wants to manage their own land to support the health of the watershed where they are located, where can they start?

The first step would be to contact your local CSFS district office or a qualified

forestry consultant! The landowner should start with a vision of what he or she wants the land to look like, and what kind of budget will be available. The landowner should also investigate grants/cost share programs and tax abatement opportunities available to help fund this type of important work. When you take a step back and consider the natural resources you can positively effect by developing and implementing a sound forest management plan on your property, I think most landowners will find that the results are well worth the effort.

For more information:

To learn more about the Colorado State Forest Service, the Pikes Peak Watershed Forest Management Plan, or tips on what you can do to improve the health of your forested property's water resources, visit csfs.colostate.edu or contact your local CSFS district office. 



In addition to being an important water storage system, North Catamount Reservoir is a highly popular recreation area located in the watershed.
Courtesy of Kristy Muskopf



COLORADO
CLIMATE
CENTER



Fish, Wildlife, and Climate

*Nolan Doesken and Wendy Ryan, Colorado Climate Center,
Department of Atmospheric Science, Colorado State University*

*Elk by the Alluvial Fan Picnic
Area, Rocky Mountain
National Park, CO.
Photo by Tim Jones*

What does climate have to do with fish and wildlife in Colorado? Depending on your point of view, either a lot or a little—but for sure, something. Many of Colorado’s fish and wildlife populations are more or less adapted to the various temperature and precipitation regimes we’ve experienced in recent decades. They also normally tolerate the escapades of Colorado’s daily weather fluctuations, storms, and temperature extremes, as well as the geographic, diurnal (day-night), seasonal and year-to-year variations in our climate (Figures 1-3). Some species, like pronghorn antelope, prefer the dry windswept open eastern plains or high open valleys. Others, like moose, require much wetter conditions with riparian vegetation and can handle cold temperatures and relatively deep snow. Species like mule deer and elk do well in the foothills and mountains, and some, like mountain lions, can survive over a wide range of conditions as long as there is a food source and are not too many people nearby.

Temperature and precipitation regimes help define the general range of many species. Fluctuations and extreme events (floods, drought, wildfire, deep snow, duration of snowcover, lack of snow, hail storms, and temperature extremes (hot or cold)) each influence habitat, water availability, and food supplies. This, in turn, contributes to changes in population, location, and health of fish and wildlife. And then there is us—the landscape-changing, resource-consuming human species—sometimes thoughtful and well-meaning, and sometimes oblivious to our heavy handed impacts to the land and water around us. Our populations continue to spread and increase in and near the mountains, while retracting and retreating across portions of the Great Plains.

Like climate, we directly and indirectly impact the fish and wildlife populations around us, often unknowingly. Some species live comfortable in our midst, while others flee to areas as remote as possible.

30 yr Normal Max Temperature: July Period: 1981-2010

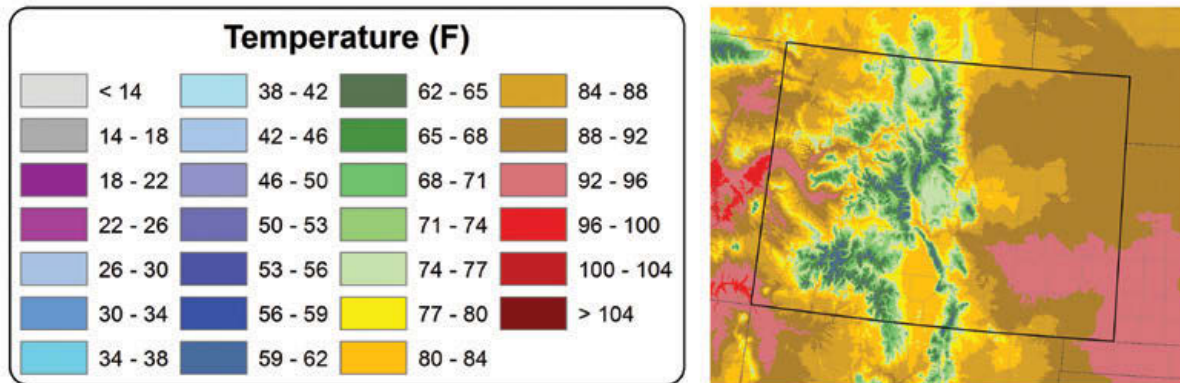


Figure 1. PRISM Climate Group 30-year average July temperature maximum in Colorado.

30 yr Normal Min Temperature: January Period: 1981-2010

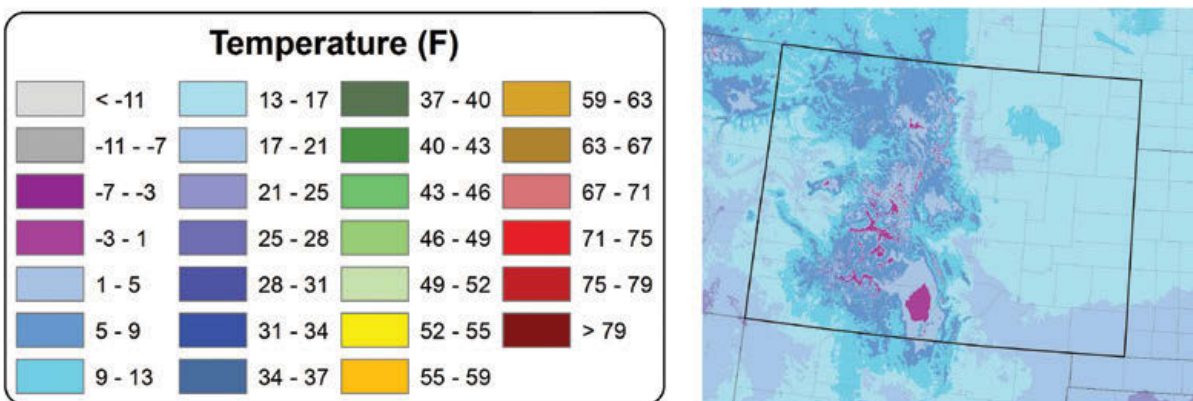


Figure 2. PRISM Climate Group 30-year average January minimum temperature in Colorado.

The Colorado Climate Center has been providing climate data and information for over 40 years to fish and wildlife researchers, state and federal resource managers, environmental groups, and other public and private concerns in Colorado. Climate data have been collected in various parts of the state back to the late 1800s, providing a rich resource for studying climate/wildlife interactions. Access to data has changed over the years. We originally relied on published federal data sources. Now data and information, even for remote mountain locations, is predominantly accessed via the Internet. Historically, temperature, precipitation, and snow water content were the most accessed climate variables. Now, more comprehensive data on things like snow depth, solar radiation, wind speed, and water temperature are measured and accessible.

Since we have the data to work with, do climate factors control the range and population of fish and wildlife species? Can trends in population of fish and wildlife be directly explained by trends in climate? As we dig into the data, we quickly find that these relationships are complex and dynamic. Historical data show incredible year-to-year variations, especially in precipitation and snow cover. A relationship to fish and wildlife populations appears at times, and at other times is vague. There has been a warming trend detected since the 1970s in many parts of Colorado, but it is still partially masked by the dramatic and year-to-year variations that are a natural part of our climate. We've had recent extreme attention-grabbing

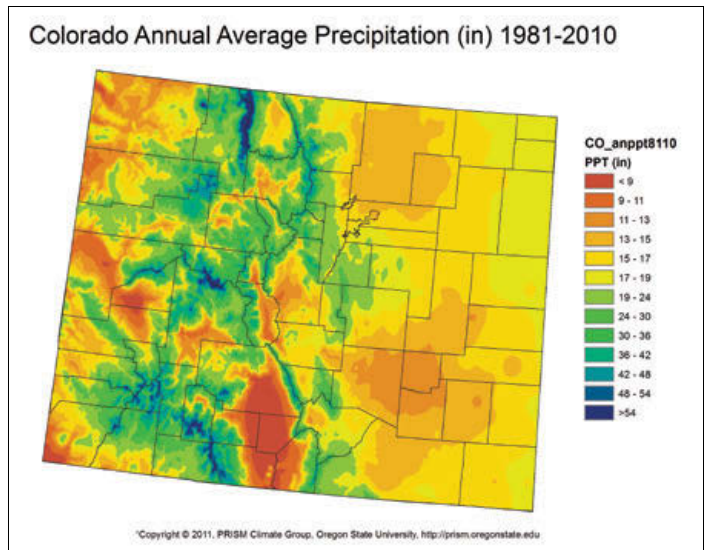


Figure 3. PRISM Climate Group 30-year average annual precipitation in Colorado.

floods and drought, but when we look back at historical data, we soon find that similar events have occurred in the past as well.

Climate change and its observed and potential impacts remain a great concern for resource managers in Colorado. How much and how fast will our climate change, what impacts will be felt, and what steps can be taken now to mitigate and adapt? These are easy and appropriate questions to ask but much harder to answer. We'll do our best to provide high quality climate information to help navigate these choppy waters. 🌀



Water and Wildlife Are Worth Fighting For

Private Lands Have Increasing Roles for Wildlife and People

Delwin Benson, Department of Fish, Wildlife, and Conservation Biology, Colorado State University

Even the words, “Whiskey is for drinking and water is for fighting” have a debatable derivation. However, the phrase represents the importance of a limited western resource increasing in demand.

Not debatable is that other states and Mexico join in the fights with agriculture, cities, energy development, recreation, and fish to keep hydrated from Colorado’s water.

Ecosystems are fueled by water in streams, under the ground, in the cells of plants and animals, and evaporating or transpiring into the atmosphere. Humans need water for physiology and aesthetics.

Similar to water, wildlife and humans have been tied together with a love/hate relationship since the beginning. My work, the upcoming Congress for Wildlife and Livelihoods on Private and Communal Lands, and your question is, how we can live on the lands and waters without evicting wildlife or ourselves?

The environmental and agricultural communities seem more inclined to point fingers at each other rather than finding meaningful solutions to our common interests, needs, and futures.

Colorado is proud of our mountain majesties that produce water, recreation, and other resources. Our public lands are valued by society, but the majority of land, about two-thirds in Colorado and nationally, is private, and the wildlife don’t know about boundaries except when land uses positively or negatively affect their habitats.

Around the world, landowners and interest groups are learning to live



with wildlife or have removed it from the landscapes. In highly populated Europe, some wildlife is abundant and shares landscapes that have been occupied by humans for centuries.

In Africa, wildlife and human interactions vary depending on human welfare and their ability to afford conservation practices. Wildlife are expanding on private lands of the south, eaten as bush meat in northern forests, sometimes tolerated among pastoral peoples, killed to protect crops and livestock, or are poached in the interests of local medicines or international uses of ivory and rhino horns for luxuries of the affluent who likely never saw the animals in the wild.

Regardless of the issues, it is locally and internationally valuable to have wildlife for tourism, hunting, managed food supplies, aesthetics, and their roles in ecological processes.

So how do we blend agriculture, wildlife and society together?

You are invited to join discussions about your interests, land uses, and nature conservation on private and communal lands during the **8th International Congress for Wildlife and Livelihoods on Private and Communal Lands: Livestock, Tourism, and Spirit September 7-12, 2014 in Estes Park Colorado.**

The Congress will discuss human and wildlife interactions from around the world with a major emphasis on interests, needs, and wildlife values of Colorado and the West.

Previous Congresses were held in Africa three times, Canada twice, France, and the first in New

Above Photos (clockwise): *Green Heron in Cottonwood Marsh, Boulder, CO.* Photo by Cathy Andersen. *Dove hunting in Illinois.* Courtesy of Max McGraw Wildlife Foundation. *Fox in Evergreen, CO.* Photo by Rob Lee

Mexico reflecting how wildlife and recreation contributes to agricultural management, conservation, economies, and healthy societies.

Our Congress emphasizes practical knowledge, skills, and attitudes with action outcomes to assist private and communal sectors internationally, in North America, and in Colorado before, during, and after the event. Sessions are planned with invited speakers of quality and substance, with related papers from around the world. Field trips are planned to Blue Valley Ranch, MacGregor Ranch, Sylvan Dale Ranch, and Rocky Mountain National Park. Small aircraft flights over lands involved with conservation issues and practices east and west of the Front Range and a workshop on chemical animal capture techniques are also planned.

Over 40 topics are being considered for the Congress, including:

- Collaborations across landscapes and jurisdictions by governments, businesses, and peoples
- Helping rural and urban persons to want wildlife and nature as part of their spirit and livelihoods
- Conservation legislation and policy to encourage wildlife management, nature conservation, endangered species protection, tourism, enterprises, and other human and landscape needs
- Energy development, climate change, and mitigations that promote wildlife and livelihoods
- Organizing, administering, and using Land Trusts or other payments for environmental services
- Urban, X-Urban, and Rural land and wildlife planning, development, and mitigations

- Forming and managing local to international private and communal Wildlife Associations
- Ethics of hunting and wildlife management techniques under different systems
- Role of NGOs to promote, and to evaluate conservation interests locally and internationally
- The role of institutions to educate future leaders and managers for private and communal sectors
- Preventing and mitigating invasive species, diseases, and conflicts between humans and wildlife
- The business of wildlife and nature conservation for state and national economies and workforces
- Release the spirit and strategies of thoughtful wildlife and nature conservation and human livelihoods

Wildlife Values Are High in Colorado—No Wonder the Congress is at Our Backdoor

Wildlife values in Colorado are fueled by water in competition or cooperation with all other uses. Decisions about how water is used among other land management decisions can ultimately help or hinder wildlife.

Wildlife-related recreation in Colorado from fishing, hunting, and wildlife-watching generated \$3.0 billion dollars from 2.3 million resident and nonresident users 16 years and older in 2011, according to the most recent surveys conducted by U.S. Department of the Interior Fish and Wildlife Service, U.S. Department of Commerce Economics and Statistics Administration, and U.S. Census Bureau.

The 919,000 hunters and anglers in Colorado are more accustomed

to seeking access to private lands with resident hunters using private lands exclusively (25 percent), and 41 percent use public land only. Non-residents (32 percent) use public land only, indicating an even higher value placed on private land access. Combining public and private access is also practiced by many.

Use of private lands would likely be higher if access were easier to negotiate. Some landowners don't want to be bothered by unwanted guests, while some landowners welcome visitors. Charging fees for access is on the increase.

The process of asking for permission gets more difficult as one's linkages to private lands become more limited due to most of society living in cities. Yet, the lure of interesting places, history, stories, and wildlife opportunities makes private land and wildlife initiatives prime for consideration.

For example, hunters and anglers know the value of private lands for their interests, and they pay license fees and excise taxes that help to support wildlife conservation on public and private lands. The 1.8 million wildlife watchers (observing, photographing, or feeding wildlife) in Colorado is an untapped resource to build linkages between rural and urban communities, to enhance wildlife and livelihoods, and to provide funding support for both public and private lands.

Landowners should activate nature and user plans in their holistic enterprise planning and management scheme just as logically as they consider more traditional agricultural products and uses. Some land and water resources and the families on the ground who operate them will be more valuable to plan with than others.

Landowners can start with what they have, such as ranch and farm practices that can be made interesting to city guests. Spare bedrooms and houses on the place can become bed and breakfast sites.

With a little more thought, planning, and work, wildlife that exists can be nurtured, used, and managed for viewers, hunters, anglers, and nature study. All that it takes to add nature conservation to land and water resources is a positive spirit and some thoughtful actions.

Actions are our desired outcomes or the Congress as well, not mere studies of problems. Sessions, titles, outcomes, and words should support: critical thinking, solutions, entrepreneurship, guidelines, best management practices, innovations,


results, applications, models, tools, impacts, future progress, recommendations, provocative debates, mitigations, examples, outcomes, successes, case studies, actions, behavioral change, etc.

Conclusions

- Society benefits from food, wildlife, and recreation produced on private and communal lands
- Landowners have wildlife on their lands, but may not have incentives for management
- Without the ecological contributions and spirit derived from nature, humans suffer
- Without human thoughts and actions, nature suffers
- Wildlife and society needs the collaborative spirit and actions

from private and communal partners along with governmental support and actions.

Your first action is to decide that you want to be part of our wildlife and livelihoods work, then go to the website, <http://tiny.cc/2014WildlifeCongress>, and submit abstracts for symposia, workshops, papers, or posters. If you only want to learn, then you can register with us and obtain your rooms at the YMCA of the Rockies outside of Rocky Mountain National Park on the same site. Spending early September in Colorado Rocky Mountains is a good way to start the autumn.

Delwin Benson is chairman of the 8th International Congress for Wildlife and Livelihoods on Private and Communal Lands: Livestock, Tourism, and Spirit, September 7-12, 2014, Estes Park Colorado. 



Congress for Wildlife and Livelihoods on Private and Communal Lands: *Livestock, Tourism and Spirit*

Please Join Us!
September 7-12, 2014
YMCA of the Rockies, Estes Park, Colorado



Register and reserve your rooms and board now through the website!
For the Daily Schedule and more information visit: tiny.cc/2014WildlifeCongress

Adapted from photos
by Mark Byzewski
and Eric Magnuson

What to Do With Water Data?

Patricia J. Rettig, Archivist, Colorado State University Libraries
Shea Swauger, Data Management Librarian, Colorado State University Libraries

Studies on the many aspects of water frequently involve data, whether numerical, textual, or photographic. Do you collect data as part of your work or research on water resources?

Do you have old field books piled up in an out-of-the-way corner? Do you have reams of paper containing important data that do not exist anywhere else? Do you have desk drawers full of floppy disks with presumably unreadable but important data files? Are your computer servers figuratively bulging at the seams with the voluminous data you have collected? Many people find themselves in one or more of these potentially daunting situations.

What are you doing to preserve all that unique data? Do you have a management plan for it? Are you going to archive it? If so, where? Could other people benefit from accessing your data? If so, how will you accomplish that? What are you going to do about your next project, for which you have yet to begin gathering data? Such questions do not necessarily have easy answers, but you can turn to the Colorado State University Libraries for help.

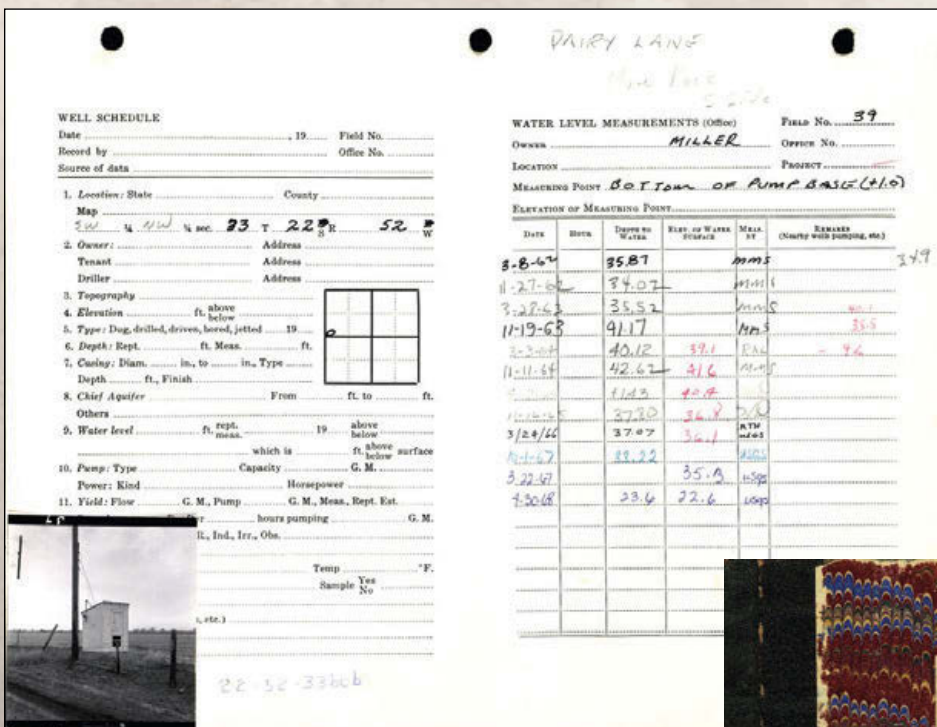
There are now two complementary services at CSU Libraries to help CSU faculty and researchers tackle long-term data needs. Archival services have been provided for historically important water records, including data, for over a decade via

the Water Resources Archive. More recently, data management services have been added in order to help manage, preserve, and make digital data accessible.

Combined, the two services can address data represented in your piles of papers, field books, and other physical formats, as well as digital versions of the same. For physical items, the Water Resources Archive has a proven track record of housing, preserving, and providing access to the multitude of formats. Management of digital data is both simpler and more complicated than that of physical formats, and it is perhaps more difficult to wrap your mind around.

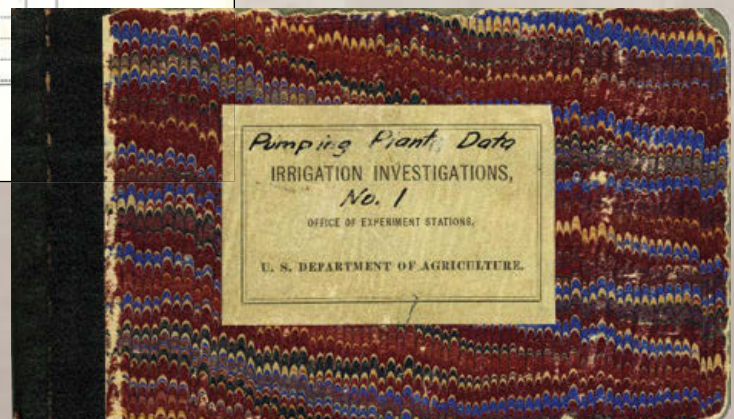
You may be somewhat familiar with the concept of archives—materials in boxes, boxes on shelves—but by now are wondering what exactly data management is. Data management is a growing practice that encompasses policies and procedures that make research data more accessible, usable, and preservable. It often involves sharing data, or making it publicly available, by depositing it into a digital repository.

Multiple major funding agencies now require that data management



Above Photo: Water level data manually collected from an observation well in Bent County, 1962-1968. CSU researchers maintained many binders full of such information until they turned it over to the Water Resources Archive for safekeeping.

Right Photo: The field books of William E. "Bill" Code (1891-1971), an irrigation engineer at the Agricultural Experiment Station, represent a wealth of original data related to groundwater, irrigation, and pumps. Many are now digitized and accessible through the Water Resources Archive. Photos from the Groundwater Data Collection, Water Resources Archive, CSU Libraries



plans accompany grant applications. Additionally, as more research becomes digitally based, data management has become more relevant to mainstream research workflows.

While funder mandates and data management plans can be time-intensive, there are some significant advantages to good data management and sharing. Sharing data has been shown to increase the impact of your research. One study found that researchers who shared their data were cited almost 10 percent more than their peers who did not. Sharing data also promotes research integrity, reproducibility, and verifiability, and allows new research questions to be asked through cross-disciplinary data reuse and meta-analysis. Additionally, placing your data in a repository increases its lifespan. One study found that without proper data


“Placing your data in a repository increases its lifespan.”

management, the chance of research data being accessible declines by 17 percent per year.

Data management and archiving can raise a lot of questions. Though the answers will not be the same for every situation, the archivists and librarians at Morgan Library are prepared to talk through questions and help people find solutions.

To further these efforts, this fall, CSU Libraries will present “Data Management and Water Resources” to CSU’s water faculty, researchers, and

graduate students. The presentation will cover some issues that researchers face with their data as well as services that the library offers to address those issues, including data management plans, metadata schemas, the digital repository, and data management best practices. The presentation will also cover archival services offered by the Water Resources Archive.

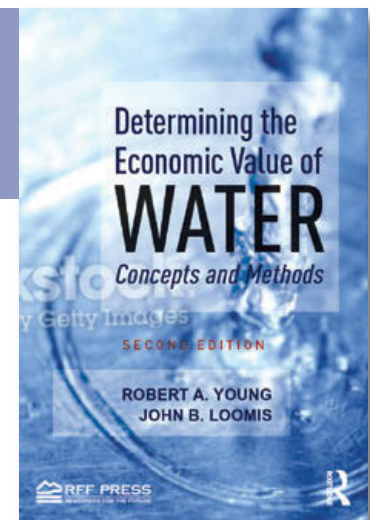
For more information about archival or data management services at the Libraries, contact the authors (970-491-1939 or Patricia.Rettig@ColoState.edu; 970-491-5785 or Shea.Swauger@colostate.edu) at any time. Alternatively, visit our websites for more information about the Water Resources Archive (lib.colostate.edu/water/) and data management (lib.colostate.edu/services/data-management). 

Determining the Economic Value of Water Concepts and Methods, Second Edition

By Robert A. Young and John B. Loomis

The book is a comprehensive resource for economic valuation of water including the theory, methods, and applications to water in its many uses from market (agriculture, industrial uses, and municipal uses) to non-market (water quality and recreation). A variety of valuation methods are reviewed including residual valuation, hedonic methods, and water markets. The strengths and weaknesses of each of these methods are discussed in detail. This volume also provides thorough exposition of the application of economic valuation methods and decision tools (e.g., benefit-cost analysis) to proposed water resources investments and policies.

The second edition represents a substantial update to the non market valuation methods and casts them within the context of valuation of water related ecosystem goods and services. The empirical examples in all chapters have been updated to the recent literature and include examples from all over the world. New topics include water use in biofuels and hydraulic fracking. More emphasis has been given to emerging water markets in the U.S. and around the world.



Order your copy today at
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New Book Details the Life of Explorer Zebulon Pike

Jared Orsi, History, Colorado State University

The biggest challenge of Colorado's rivers today is that there is too little water in them—or occasionally too much. At the dawn of the nineteenth century, the problem was that no one in the United States knew where they were.

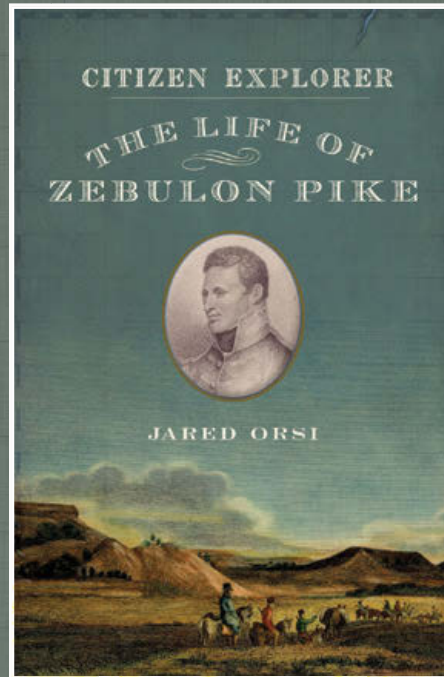
Zebulon Pike's orders were simple enough: find them. Ascend the Arkansas River to its headwaters. Locate the Red River and follow it to its mouth at the Mississippi.

But stir in some political intrigue, a couple of wild geographical ideas, and a faulty map, and Pike had an impossible task on his hands.

After departing the frontier town of St. Louis on July 15, 1806, he wrote detailed journals, compiled minute details in his traverse tables, and painstakingly mapped his entire route. Together these give us a good idea of where he went. Although I had read these documents repeatedly in preparing my recent biography of Pike, I never truly understood his route until I walked in his footsteps—that is, until I followed the rivers.

Pike first spotted the mountain that would come to bear his name on November 15, 1806. He called it the Grand Peak and detoured to climb it. Why?

At the time, Spain and the United States disputed the extent of the Louisiana Purchase, and many believed that watersheds should ultimately determine the boundaries. The view from the top of Pikes Peak, he believed, would enable him to see the Missouri, the Columbia, the Colorado, the Rio Grande, the Platte, and the Red, that is to take in the rivers that defined the geopolitical divisions of North America.



Here, he was deceived by a common geographical theory of the day that held that all the great western rivers flowed from a single so-called height of land somewhere in the Rocky Mountains. From Pike's November 24 camp at the confluence of Fountain Creek and the Arkansas River, in modern Pueblo, the Grand Peak looked like the height of land (Figure 1).

After spending several days unsuccessfully attempting to ascend the mountain, Pike gave up. He would tease out the geopolitical borders from the ground. But the rivers confused him near modern Cañon City. Several streams came together, and Pike wasn't sure which was the main branch. The scouting parties he sent out all reported their strands quickly dwindled. Believing he'd found the headwaters of the Arkansas, Pike turned north.

This was a curious thing to do. Before leaving St. Louis, Pike had almost certainly gotten a glimpse of the best map of the area, drawn

by the Prussian geographer the Baron Alexander von Humboldt. Humboldt had compiled the map from interviews and archival research during his recent travels in Spanish America. His map showed that the Red River, or Rio Rojo de Natchitoches, originated in the Rockies northeast of Taos, or south of where Pike was now camped (Figure 2).

When Pike looked up at the saw-toothed Sangre de Cristo Mountains blocking his path to the southwest, however, he determined them impossible to climb. Moreover, he had found a human trail heading north. Having seen no one since November 22, he wanted to ask directions.

The path led him to South Park before petering out. Crossing the Mosquito Range through Trout Creek Pass to the southwest, the party beheld a river running south. The Red? Pike thought so. The party rested on Christmas Day north of modern Salida and prepared for the homeward journey.

A few skeptics at the time and since have suggested that Pike was up to something more than just scouting western river geography. His commanding officer, General James Wilkinson, one of the arch rogues of early American history, had taken a loyalty oath to the King of Spain and had been a double agent since 1787. Moreover, by 1806, Wilkinson had entangled himself in the grandest of frontier conspiracies, Aaron Burr's murky plans to lead a private army to seize territory in northern New Spain and possibly the Louisiana Purchase. Burr would head the new nation with Wilkinson second in command. Although President Thomas Jefferson knew of and approved of



Figure 1. Pikes Peak from Zebulon Pike's November 24 campsite.
Photo by Jared Orsi

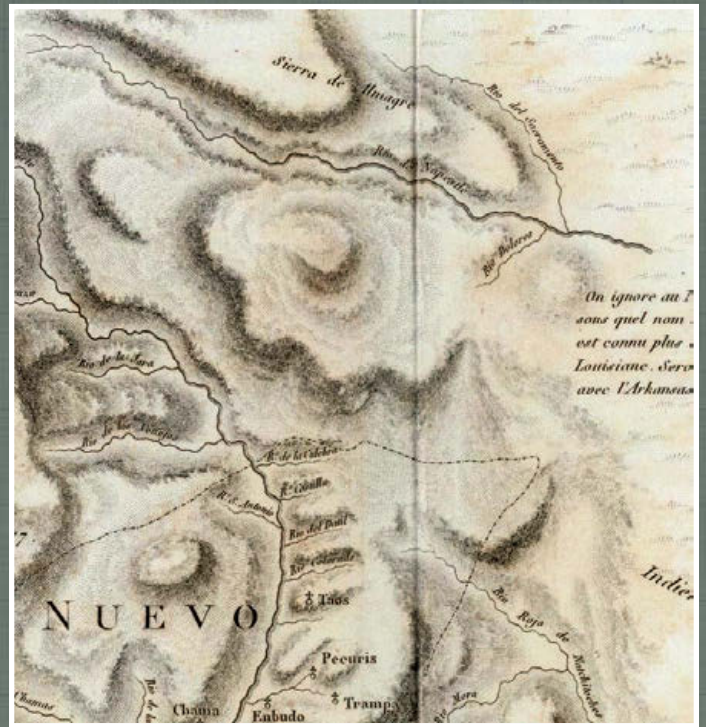


Figure 2. Portion of the Humboldt Map. Courtesy of David Rumsey Historic Map Collection, www.davidrumsey.com

Pike's expedition—a southwestern counterpart to the one the president had recently ordered Lewis and Clark to undertake to the northwest—it was Wilkinson who gave Pike his orders.

The business about the Arkansas and the Red, Pike's critics have alleged, was but a ruse to get him near his true destination, Santa Fe, where he was to gather intelligence about geography and Spanish military strength for Burr and Wilkinson.

If Pike had secret orders to reconnoiter Santa Fe, the view south on Christmas Day offered an inviting gap in the mountains, Poncha Pass (Figure 3). Any doubts he may have had would have been dashed by a glance to the southeast, where the heights of the northern Sangres loomed (Figure 4). If he was going over the mountains to Santa Fe, Poncha Pass was the place to try it. But he didn't. He continued downstream, exactly the behavior of a man who wanted to descend the Red River home.

The downstream path proved treacherous. The canyon narrowed. The horses stumbled over icy rocks

in the partly frozen streambed. There was no game to be found. Unable to escape via the steep ravines, the men had no option but to continue down this interminable gorge.

On January 5, 1807, Pike's 28th birthday, the party emerged from the chasm only to behold their own Arkansas River camp from which they had turned north in December. Thirty-six brutal days in the mountains had brought them in a very difficult circle.

“ On paper, several aspects of Pike's journey seem inexplicable. ”

If this was still the Arkansas, where was the Red? Surely Texas was not one of the places that crossed Pike's mind. But Texas was indeed where it was. The Red River did empty into the Mississippi, and eastward flowing streams did issue from the Rockies northeast of Taos. Humboldt's

mistake was connecting the two, unaware that the rivers from New Mexico bend northeastward to join the Arkansas, while the Red originates in Texas's Llano Estacado, three hundred miles from where Pike was looking.

Pike decided the Red must be to the southwest, on the yonder side of the Sangres, which he had deemed impossible to cross a month earlier. Now he would give it a try.

On January 17, the men got their boots wet crossing Grape Creek in the Wet Mountain Valley (Figure 5). John Sparks and Thomas Daugherty suffered frostbite so severe they could no longer walk, and Pike had to leave them behind. Others straggled onward, unable to proceed without the aid of walking sticks. Blizzards blinded the men and scattered the bison. Twice they went four days without food. Private John Brown grumbled and Pike upbraided him for his “mutinous” words.

Finally, on January 27, they made it over the mountains into the San Luis Valley, where Pike of course mistook



Figure 3. *Poncha Pass from near the Christmas Day camp.* Photo by Jared Orsi

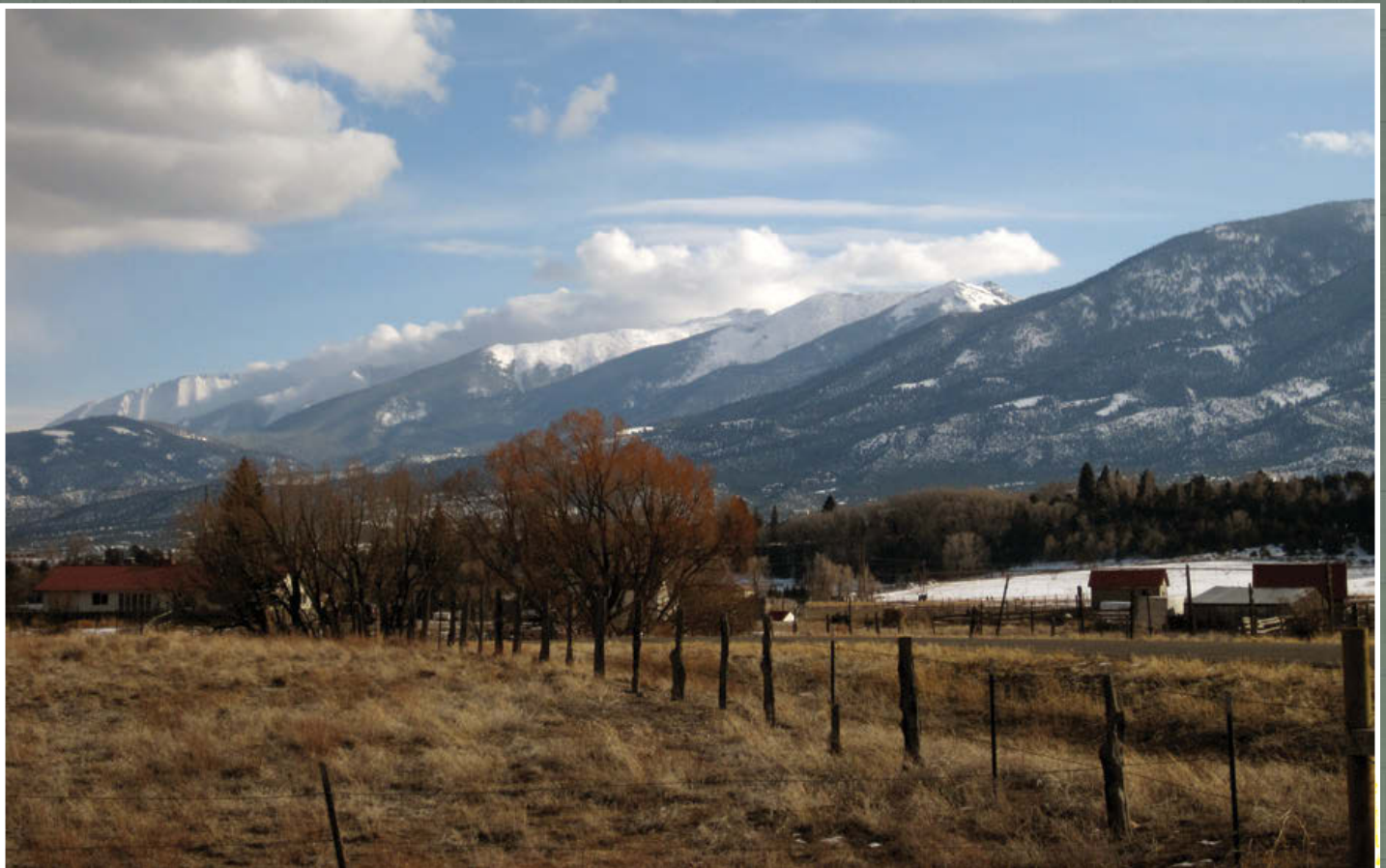


Figure 4. *Northern end of the Sangre de Cristo Mountains from near the Christmas Day camp.* Photo by Jared Orsi


the Rio Grande for the Red. Some have said Pike feigned geographical cluelessness, but there is reason to believe he was truly lost.

The party constructed a small stockade on the Rio Conejos, a tributary of the Rio Grande (Figure 6). At this time, the expedition's physician, John Robinson, left for Santa Fe, allegedly to collect a debt—more fodder for Pike's doubters—while Pike awaited the return of the rescuers he had sent to retrieve the men left behind.

If Pike and Robinson knew they were on the Rio Grande, the logical path to Santa Fe was downstream. Robinson, however, followed the Conejos upstream—the correct path for someone believing he was leaving the Red River and seeking Santa Fe to the southwest. As it turns out, going up the Conejos does lead to a good route to the New Mexican capital, but Pike and Robinson could not have had such nuanced understanding of local terrain.

Robinson's appearance in Santa Fe triggered a Spanish military expedition that located Pike. Spanish dragoons arrested him and took him to Santa Fe to explain himself to the governor. From there, a military escort guided him through northern Mexico and back to the United States.

On paper, several aspects of Pike's journey seem inexplicable. Why did he try to climb Pikes Peak? Why did he turn north from Cañon City? Did he really believe he was on the Red at Poncha Pass? And why did Robinson seek Santa Fe upstream? Knowledge of Colorado rivers, however, provides clues to help resolve these mysteries.

Jared Orsi's book, Citizen Explorer: The Life of Zebulon Pike (Oxford University Press, 2014), is available online. 

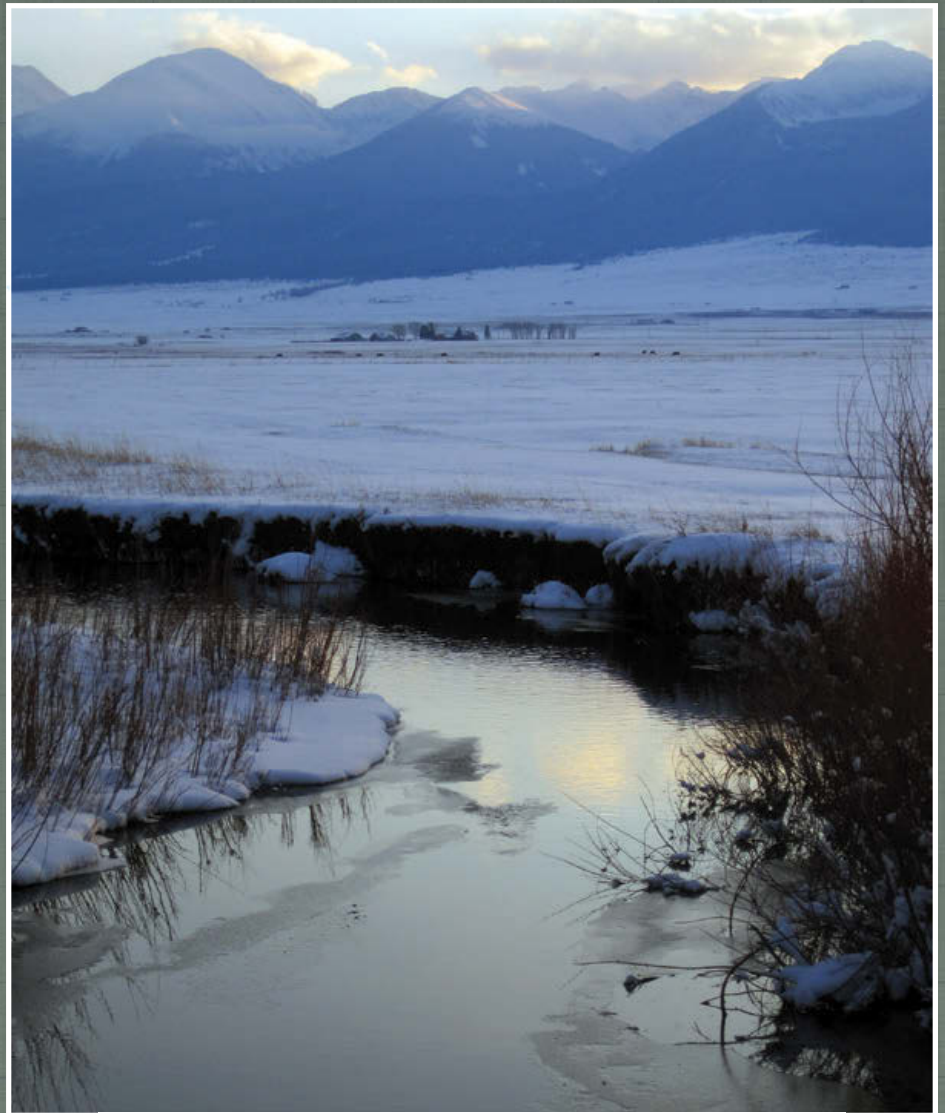


Figure 5. *Grape Creek near where Pike's men got their boots wet.* Photo by Jared Orsi



Figure 6. *On-site Reconstruction of the Pike Stockade.* Photo by Jared Orsi

Multi-Disciplinary Proposal Team

From Water Scarce to Water Source: The Governance of New Water in the Kenyan Drylands

Stacy Lynn, Natural Resource Ecology Laboratory, Colorado State University

Michele Betsill, Political Science, Colorado State University

Melinda Laituri, Ecosystem Science and Sustainability, Colorado State University

This project will look at the discovery of two large aquifers found to be sitting deep below the arid landscape of Turkana County, the driest county in Kenya, in 2013. This pilot study will allow the team to describe historical water use issues as framed by Turkana pastoralists, identify existing governance mechanisms and key actors involved in decision-making, measure the spatial and temporal distribution of water sources, and locate the community-identified social and ecological costs and benefits of water development. The team will then plan, write, and submit a large research proposal to the NSF Dynamics of Coupled Natural and Human Systems (CNH) program to build and expand on this pilot study.



Multi-Investigator Research Teams

Loss of Catchment Retention: Interactions Between Catchment Morphology, Residence Time, and Geochemical Processing Amidst a Changing Hydrologic Regime

Tim Covino, Ecosystem Science and Sustainability, Colorado State University

Ed Hall, Natural Resource Ecology Laboratory, Colorado State University

Ellen Wohl, Geosciences, Colorado State University

In this project, the team will explore mechanisms of catchment retention, including the storage of water and material in beaver-meadow complexes, to elucidate how these features control the timing, magnitude, and form of catchment fluxes of water, sediment, nutrients, and organic material. This research will combine geomorphology, hydrology, and microbiology to decipher interconnections and feedbacks between catchment morphology, hydrologic residence time, geochemical processing, and resultant catchment storage and flux dynamics.



How Carbongenic Nanoparticles (CNPs) Move Through Various Types of Porous Media Under Conditions That Replicate the Natural Environment

Yan Vivian Li, Design and Mechandising, Colorado State University

William E. Sanford, Geosciences, Colorado State University

Although nanoparticles are increasingly being added to the natural environment through fabrics and pharmaceuticals, not much is known about how these particles move and are accumulated. The objective of this project is to investigate how nanoparticles move through various types of porous media under conditions that replicate the natural environment. The research team seeks to optimize design and fabrication of carbongenic nanoparticles (CNPs), evaluate CNPs transport behaviors using laboratory column tests, and design complex 2-D models and field experiments to assess CNPs mobility in natural environments.



New Technology for Measuring Sap Flow and Transpiration in Agricultural and Native Ecosystems

Jay Ham, Soil and Crop Sciences, Colorado State University

Bill Bauerle, Horticulture and Landscape Architecture, Colorado State University

Grace Lloyd Miner, Ph.D. Student, Soil and Crop Sciences, Colorado State University

Gerard Kluitenberg, Agronomy, Kansas State University

Troy Ocheltree, Forest and Rangeland Stewardship, Colorado State University

The goal of this project is to develop new sap flow gauge technology for measuring transpiration from irrigated crops (e.g., corn and sunflower) and woody riverine plants (e.g., willow/Salix). The instrumentation takes advantage of new technology



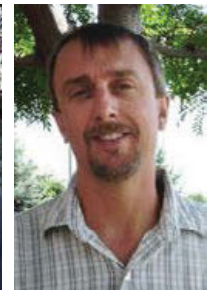
(3D printing, open-source electronics) to create a DIY design that is much lower in cost than current commercial instrumentation. Researchers will be able to deploy large numbers of the gauges to capture the spatial and temporal variation in consumptive use needed in water balance studies.

Rocky Mountain Streams Past and Present: The Influence of Forest Stand Age and Wood Deposition on Trout and Insect Biomass

Dana Winkelman, Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University

David Walters, Aquatic Systems, U.S. Geological Survey

This is a continuation of a National Science Foundation (NSF) funded project examining how wood deposition and retention in stream ecosystems influence hydrology, geomorphology, geochemistry, and animal biomass and production. The primary objectives of the NSF study are to quantify differences in wood deposition in streams with different management histories, quantify biogeochemical processes in those systems, estimate stream animal response occurring in jams and in adjacent stream segments without jams, and scale the site-specific measurements of biogeochemistry and stream animal response to entire watersheds.



The Water:Nitrogen Tradeoff: Optimizing the Use of Water to Fix Nitrogen and Reduce Agriculture's Carbon Footprint

Jessica Davis, Soil and Crop Sciences, Colorado State University

Jason Prapas, Engines and Energy Conversion Lab, Colorado State University

Heather Storteboom, Thin Air Nitrogen Solutions

Joshua Wenz, Graduate Student, Soil and Crop Sciences, Colorado State University

The goal of this project is to develop a process through which farmers can make their own nitrogen fertilizer using cyanobacteria to fix nitrogen, thus improving water use efficiency as compared to leguminous cover crops. Project objectives are to refine operational parameters to enhance cyanobacterial production and nitrogen fixation per unit of water, to monitor cyanotoxins to verify their absence from the cyanobacterial bio-fertilizer, and to communicate with farmers regarding cyanobacterial bio-fertilizer production and utilization.



When Water Rights Ebb into Energy Development: Unconventional Oil & Gas Development and Changes to Water Allocation in Northern Colorado

Stephanie Malin, Sociology, Colorado State University

This research will examine intersections between water rights and unconventional oil and gas development in northern Colorado. Specifically, Malin aims to interrogate ways in which northern Colorado agriculturalists, community leaders and stakeholders, industry participants, Colorado State University Extension personnel, and other mediating institutions and actors negotiate water rights amid expanding unconventional oil and gas development. She intends to analyze how leasing or selling water rights may empower Colorado communities and agriculturalists to participate in the industry boom.



Developing a Framework for Simulating the Fate and Transport of Salinity Species in the Lower Arkansas River Valley, Colorado

Ryan Bailey, Civil and Environmental Engineering, Colorado State University

The overall objective of the proposed project is to develop a framework for simulating the fate and transport of salinity species within the Lower Arkansas River Valley (LARV), which will offer an important contribution to the ongoing aim of identifying best-management practices (BMPs) that can remediate excessive salinity concentrations in the LARV and in other salt affected regions in Colorado. This overall objective will be accomplished by commencing the development of a salt fate and transport groundwater model that will account for the physical and chemical processes governing transport of individual salt ions and that can be applied at a variety of scales (field-scale to regional-scale), and performing a mass balance for individual salt ions at the soil profile scale, thereby enhancing understanding of the storage and movement of individual salt ions and providing additional data for preliminary model testing.



Uniting Water Related Research Expertise in Latin America at CSU

Ed Hall, Natural Resource Ecology Laboratory, Colorado State University

CSU has diverse expertise working with communities in Latin America to address water challenges. However, there is currently little to no coordination among these CSU researchers or research projects and no public face that highlights this university's diverse water related expertise and existing research collaborations in Latin American countries. Given the increasingly competitive nature of research funding, highlighting this range of expertise and facilitating collaboration among faculty researchers at CSU will provide a competitive edge to procuring funding to support water-related research in Latin America.



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Geologic sources and concentrations of selenium in the West-Central Denver Basin, including the Toll Gate Creek watershed, Aurora, Colorado, 2003-2007 - USGS Scientific Investigations Report: 2013-5099; Paschke, Suzanne S.; Walton-Day, Katie; Beck, Jennifer A.; Webbers, Ank; Dupree, Jean A.

Remediation scenarios for attenuating peak flows and reducing sediment transport in Fountain Creek, Colorado, 2013 - USGS Scientific Investigations Report: 2014-5019; Kohn, Michael S.; Fulton, John W.; Williams, Cory A.; Stogner, Robert W., Sr.

A review of environmental impacts of salts from produced waters on aquatic resources - International Journal of Coal Geology, 126: 157 – 161; Farag, Aida M.; Harper, David D.

Monitoring and research to describe geomorphic effects of the 2011 controlled flood on the Green River in the Canyon of Lodore, Dinosaur National Monument, Colorado and Utah - USGS Scientific Investigations Report: 2014-5022; Mueller, Erich R.; Grams, Paul E.; Schmidt, John C.; Hazel, Joseph E., Jr.; Kaplinski, Matt; Alexander, Jason A.; Kohl, Keith

Water Research Awards

Colorado State University (May 16, 2014 to July 15, 2014)

- Abt, Steven R**, Civil & Environmental Engineering, USDA-USFS-Rocky Mountain Research Station-CO, Bedload Transport in Gravel-Bed Rivers and Channel Change, \$91,742
- Andales, Allan A**, Soil & Crop Sciences, Colorado Water Conservation Board, Determination of Consumptive Water Use of Corn in the Arkansas Valley - Year 2 (Lysimeter), \$46,137
- Andales, Allan A**, Soil & Crop Sciences, USDA-Agricultural Research Service, Application of System Models to Evaluate and Extend Cropping Systems Studies at Different Great Plains/Northwest Locations, \$104,000
- Bagley, Calvin F**, CEMML, DOD-ARMY-Corps of Engineers, Wetland Planning Level Studies, Fort Wainwright, AK, \$245,440
- Bauder, Troy A**, Soil & Crop Sciences, Colorado Department of Agriculture, Training and Education for Agricultural Chemicals and Groundwater Protection, \$235,000
- Bestgen, Kevin R**, Fish, Wildlife & Conservation Biology, Colorado Division of Parks and Wildlife Anthropogenic Changes to Colorado's Eastern Plains Streams & Their Impact on Connectivity for Native Fishes, \$16,904
- Brummer, Joe E**, Soil & Crop Science, Colorado Water Conservation Board, Assessing the Agronomic Feasibility of Single-Season Irrigation Deficits on Hay as Part of a Western Slope Water Bank, \$49,512
- Caldwell, Elizabeth D**, CEMML, DOD-ARMY-Corps of Engineers, Safe Drinking Water Compliance Study US Army Garrison, Hawaii, \$52,000
- Caldwell, Elizabeth D**, CEMML, DOD-ARMY-Corps of Engineers, Stormwater Management Plan and Wastewater Compliance Study US Army Garrison, Hawaii, \$39,851
- Chavez, Jose L**, Civil & Environmental Engineering, USDA-Agricultural Research Service Estimating Evapotranspiration and Plant Water Stress with Remote Sensing, \$18,458
- Cooper, David J**, Forest & Rangeland Stewardship, University of Waterloo, Evaluating the Success of Fen Creation in the Post Oils Sands Landscape, \$126,784
- Cooper, David J**, Forest & Rangeland Stewardship, DOI-National Park Service, Impacts to Vegetation Communities Following Cessation of Irrigation within the Medano Ranch Area of Great Sand Dunes, \$7,520
- Doesken, Nolan J**, Atmospheric Science, Colorado Water Conservation Board, Improving Data Quality for an Enhanced Climate Data Delivery System for CoAgMet (Colorado Agricultural Meteorological) Network, \$50,000
- Gates, Timothy K**, Civil & Environmental Engineering, Colorado Water Conservation Board, Data Collection and Analysis in Support of Improved Water Management in the Arkansas River Basin, \$50,000
- Myrick, Christopher A**, Fish, Wildlife & Conservation Biology, DOI-USFWS-Fish & Wildlife Service, Improving Rock-Ramp Fishway Designs for Small-Bodied Plains Fishes, \$104,709
- Nissen, Scott J**, Bioagricultural Sciences & Pest Management, Colorado Department of Agriculture, Evaluation of Assessment Tools to Determine the Invasiveness of Aquatic Weeds in Colorado, \$10,350
- Norton, Andrew P**, Bioagricultural Sciences & Pest Management, City of Boulder Open Space & Mountain Parks, Effects of Russian Olive Removal on Soils and Understory Plant Communities in the Boulder Creek Floodplain, Boulder, \$5,000
- Norton, Andrew P**, Bioagricultural Sciences & Pest Management, Three Rivers Alliance, Environmental Impacts of Russian Olive on the South Fork of the Republican River, \$14,924
- Qian, Yaling**, Horticulture & Landscape Architecture, Denver Water Department, Soil Testing After 10 Years of Irrigation with Recycled Water, \$47,348
- Ramirez, Jorge A**, Civil & Environmental Engineering, National Science Foundation, WATER-IGERT: Integrated Water Atmosphere and Ecosystem Education and Research, \$482,568
- Ramirez, Jorge A**, Civil & Environmental Engineering, USDA-USFS-Rocky Mountain Research Station-CO, Application of the Variable Infiltration Capacity (VIC) Model to Estimate Water Yield and Assess Vulnerability of Wa? \$38,650
- Rathburn, Sara L**, Geosciences, DOI-National Park Service, Assessing the Annual Sediment Budget on a Reach of the Toklat River, Denali National Park, AK, \$68,266
- Rathburn, Sara L**, Geosciences, USDA-USFS-Rocky Mountain Research Station-CO, Mechanisms and Controls on Post-Fire Sediment Delivery: The High Park Burn in South Fork Cache la Poudre Basin, \$32,500
- van de Lindt, John W**, Civil & Environmental Engineering, North Dakota State University, Reducing Flood Vulnerability of Communities with Limited Road Access by Optimizing Bridge Elevation, \$57,000
- Warnock, Andrew C**, Education & Outreach Center, DOI-National Park Service, NPS Water Education Teacher Workshop, \$10,000
- Winkelman, Dana** Cooperative Fish & Wildlife Research, Colorado Division of Parks and Wildlife, Endocrine Disrupting Compounds Impact on Colorado's Eastern Plains Native Fishes, \$44,620

Calendar

August

20-22 Colorado Water Congress Summer Conference; Snowmass, CO

The high-energy summer conference is packed with great topical content. It's a don't-miss event for those who wish to stay informed about water issues in Colorado while engaging in numerous professional development activities.

www.cowatercongress.org/cwc_events/SummerConference.aspx

28 Documentary Film: *The Grand Valley and its Rivers*; Grand Junction, CO

The first public screening of a 30 minute documentary on the Grand Valley and its Rivers created by CMU's Water Center and Gen9 Productions. This film will explore the relationship of the Grand Valley to its rivers, how that relationship has changed over time, and what forces may affect the region's water future.

www.coloradomesa.edu/WaterCenter/Documentary.html

September

7-10 2014 RMSAWWA/RMWEA Joint Annual Conference; Albuquerque, NM

Joint annual conference of the Rocky Mountain Section of the American Water Works Association (RMSAWWA) and the Rocky Mountain Water Environment Association (RMWEA).

<http://bit.ly/1pdIsim>

7-10 29th Annual WaterReuse Symposium; Dallas, TX

Water professionals attend to learn about the latest innovations in water recycling and desalination, to network with colleagues, and to find solutions to critical water supply issues.

www.watereuse.org/symposium29

19 Colorado River District Annual Water Seminar; Grand Junction, CO

Growing the River: Is It All About Ag?

www.crwcd.org

24-25 4th Annual Natural Gas Symposium 2014; Denver, CO

CSU has built a reputation for hosting a balanced symposium discussing all sides of the natural gas issue while remaining an "honest broker" of information and education.

naturalgas.colostate.edu/symposium-2014/

October

7-9 2014 Sustaining Colorado Watersheds Conference; Avon, CO

Come Hell or High Water! This conference works to expand cooperation and collaboration throughout Colorado in natural resource conservation, protection, and enhancement by informing participants about new issues and innovative projects and through invaluable networking focusing on the spirit of community resiliency in the wake of the 2013 floods, wildfires, and other risks to our watersheds.

www.coloradowater.org/Conferences

November

5-6 4th Annual Upper Colorado River Basin Water Forum; Grand Junction, CO

Seeking a Resilient Future

www.coloradomesa.edu/watercenter/UpperColoradoRiverBasinWaterForum.html

14 *Reconciling Water Law and Economic Efficiency in Colorado Water Administration*; Colorado Springs, CO

Charles "Chuck" Howe will present on *Reconciling Water Law and Economic Efficiency in Colorado Water Administration*. This event is free and open to the public.

<http://bit.ly/1pxyilt>

16-20 International Water Conference; San Antonio, TX

Attendees come to learn unbiased details about the latest applications available in the industry, get educated on current technology and hold wide ranging discussions with their peers active in water treatment.

www.eswp.com/water/

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*Mountain goat near the
summit of Mt. Evans
Colorado.
Photo by Ron Booth*