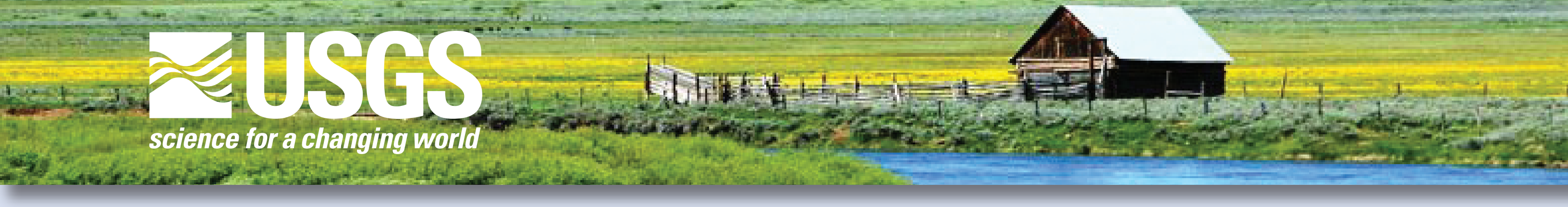

FORT COLLINS SCIENCE CENTER
Aquatic Systems Branch

Transdisciplinary Research to Address Water-Related Environmental Problems

Capabilities

The Aquatic Systems (AS) Branch at the Fort Collins Science Center (FORT) is a group of scientists dedicated to advancing interdisciplinary science and providing science support to solve water-related environmental issues. Natural resource managers have an increasing need for scientific information and stakeholders face enormous challenges of increasing and competing demands for water. Our scientists are leaders in ecological flows, riparian ecology, hydroscape ecology, ecosystem management, and contaminant biology. The AS Branch employs and develops state-of-the-science approaches in field investigations, laboratory experiments, remote sensing, simulation and predictive modeling, and decision support tools. We use the aquatic experimental laboratory, the greenhouse, the botanical garden and other advanced facilities to conduct unique research. Our scientists pursue research on the ground, in the rivers, and in the skies, generating and testing hypotheses and collecting quantitative information to support planning and design in natural resource management and aquatic restoration.

Photograph from Quan Dong, USGS.

Photograph from Robert Zuellig, USGS.

Ecological Flows

Ecological flow is a central theme of AS Branch studies, as our research examines how water flows affect populations, communities, ecosystems, and hydroscapes. Our studies elucidate the interactions among hydrologic, geomorphologic, biogeochemical, biological, and anthropogenic processes. Branch scientists identify and quantify the spatial and temporal attributes of water flow for ecological needs. Flow alternations by humans are a primary contributor to the degradation of aquatic ecosystems and the loss of freshwater biodiversity, and we provide innovative scientific methods and tools on flow-related ecological issues to decisionmakers, policymakers, and stakeholders.

Riparian Ecology

Riparian ecologists in the AS Branch study interactions among flow, channel change, and vegetation along rivers across the western United States and worldwide. Our work focuses on issues relevant to the management of water and public lands, including dam operation, climate change, invasive species, and ecological restoration. Investigations take place on a range of scales. For example, experimental studies in pots and growth chambers detect genetic, phenotypic, and species variations in response to environmental conditions, such as drought, frost, mycorrhizal inoculation, salinity, and carbon dioxide enrichment. Site-specific case studies examine processes and patterns of exotic species invasions, impacts of dams and consequences of climate change, while regional studies examine general patterns along environmental gradients, consequences of variation in water flow, and effects of human activities across the western United States.

Photograph from Quan Dong, USGS.

U.S. Department of the Interior
U.S. Geological Survey

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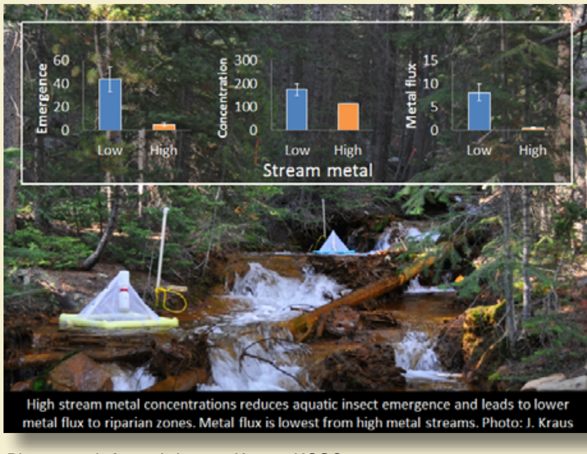


Photograph from Johanna Kraus, USGS.

Hydroscape Ecology

The interdisciplinary team of hydroscape ecology develops and advances a broad, landscape-scale perspective of ecological flows for aquatic ecosystems. A hydrologic landscape, hydroscape, is an environmental theater, where hydrologic, geomorphologic, biogeochemical, biological, and anthropogenic processes play to provide ecological services to the society. The construction of water control structures, water management and diversion, land conversion, and other social-economic activities have fragmented and domesticated hydroscapes. Decisionmakers are facing great challenges to manage and restore aquatic ecosystems, partially because of the lack of a landscape perspective. Our scientists develop innovative conceptual models and apply novel modeling and survey approaches to detect and quantify the ecological effects of anthropogenic alterations on hydrologic and geomorphic processes. We develop spatially explicit metrics and tools to address the ecological responses to hydrologic and geomorphic variations and the ecological flow needs at multiple scales.

Aquatic Ecology and Contaminants

The Aquatic Ecology and Contaminants Team investigates critical ecological processes operating in aquatic and riparian ecosystems and how these processes are affected by human activities. We address questions through a combination of field studies, laboratory experiments, and modeling, while working at multiple levels of biological organization from cells through ecosystems. Topics include land use and climate change effects on stream ecosystems and organisms, interactions between native and invasive fishes, the flux of contaminants through aquatic and riparian food webs, and contaminant effects on aquatic-riparian linkages.

Photograph from Quan Dong, USGS.

Decision Support Systems

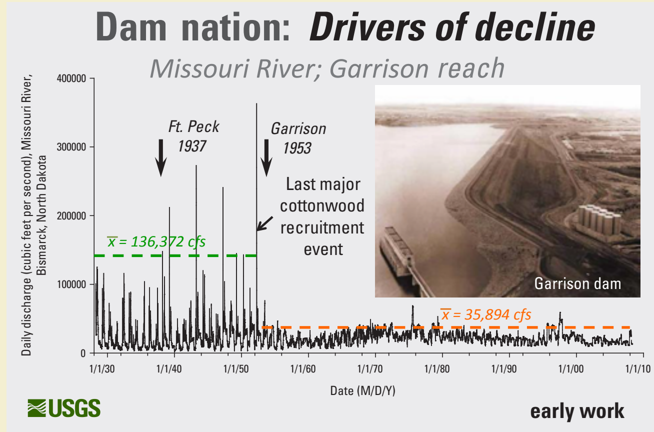
It is a difficult task to determine the desirable environmental targets for aquatic resource managers, because of a myriad of physical, hydrological, and biological processes affecting aquatic ecosystems and hydroscapes, the complexity of interactions and the multifaceted information, and substantial levels of uncertainty. Computer-based Decision Support Systems (DSS) can help integrate and communicate scientific information and analyses, and thus provide support tools for decisionmaking.

One primary focus of the AS Branch DSS development is to generate spatially explicit indices of habitat suitability for various flow scenarios. DSS integrates spatially explicit environmental data, alternative water flow scenarios, flow-specific hydrodynamic estimates of local habitats, estimates of physical-chemical conditions, and habitat suitability criteria for key taxa. Our decision support work creates and improves geospatial integration and representation of flow-dependent habitat suitability and the scoring systems for alternative flow regimes, based on continually improving flow data and statistics and quantitative understanding of site-specific relations between flow and desired environmental conditions. We also develop and apply Bayesian approaches to characterize uncertainties. Our tools promote understanding of the relations between aquatic species and habitats, serve adaptive management strategies, and evaluate the consequences of climate change and other uncertainties brought by anthropogenic effects.

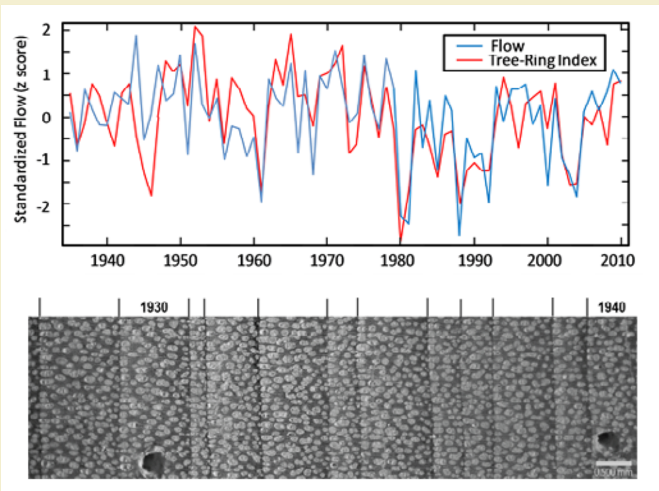
Selected Projects

Dams and Their Ecological Consequences

Scientists in the AS Branch have been studying the impacts of dams on riverscapes for more than two decades. Our scientists have written many reports on the effects of dams on recruitment of bottomland pioneer trees, such as cottonwood, along the Upper Missouri River and the Bill Williams River, and the effects of dams on channel geometry and vegetation throughout the Great Plains. Understanding the effects of dams and the relations between flow, sediment, and vegetation have allowed AS Branch scientists to provide valuable information for managing flow releases from dams to enhance native tree recruitment, or to remove exotic plant species that are encroaching on the channel along several rivers. Recently, AS Branch scientists are monitoring changes to flood plain vegetation along the Elwha River in Olympic National Park in response to the removal of two large dams. This study will provide lessons and guidance to the design and planning of future aquatic restoration efforts. We also study the ecological consequences of the experimental pulse flow in the Colorado River.



From Mike Scott, USGS.



From Jonathan Friedman, USGS.

Reconstructing Flood History from Tree Rings

Shifts in river flow regimes are a major threat to water supplies and riverine ecosystems. Understanding and predicting flow changes and their effects on vegetation are critical to effective river management. AS Branch scientists analyze rings of riparian trees relating tree growth and establishment to historical flow. We then use the tree rings to reconstruct the flow in past centuries. Flow reconstructions discover the frequency and magnitude of past droughts and floods—information that is essential for management of rivers and water supplies. We also use downscaled climate projections and watershed models to predict changes in flow and tree growth resulting from human-induced climate change. We have pioneered the use of cottonwood, a dominant riparian species, for tree ring analysis; this is a significant advance in arid regions where old trees of other species are otherwise scarce. Ongoing studies focus on rivers of the Upper Missouri Basin and the Tarim River, China.

Effects of Contaminants on Linked Aquatic and Terrestrial Food Webs

Most aquatic insects live in fresh water as larvae and move to land as flying adults to complete their life cycle. Although often ignored, the emergence of adults can transfer the effects of contamination from aquatic to terrestrial ecosystems as the adults are eaten by predators such as spiders, birds, and bats. Our scientists are investigating how contaminants move from streams, rivers, and lakes into riparian zones and how contamination alters the ecological linkages between these systems. Our investigations use large-scale field studies in various aquatic ecosystems, ranging from mountain headwater streams to the Great Lakes. We conduct complementary experiments at the new aquatic experimental laboratory at the Fort Collins Science Center to identify mechanisms underlying the patterns observed in these field studies. The mesocosm facility in our state-of-the-art laboratory is designed to replicate the coupled aquatic-riparian ecosystems. Our design is unique, because it can mimic a riparian boundary ecosystem whereas other facilities typically simulate either aquatic or terrestrial ecosystems, but not the boundary between the two. Results from these studies are helping managers to better evaluate water-quality criteria, to design and implement restoration plans for contaminated aquatic systems, and to assess the effectiveness of remedial actions.

Photograph from David Walters, USGS.

Climate Change and Trout

Cold-water fishes like trout, salmon, and charr are especially vulnerable to shifting conditions related to climate change; for example, warmer temperatures and more variable hydroclimate. Native cutthroat trout of the southern Rocky Mountains now only occupy a tiny fraction of their historic habitats because of stressors such as non-native fishes, habitat fragmentation, and detrimental land management practices. Using a combination of field and modeling approaches, we address how climate may influence native cutthroat trout and how conservation strategies can be tailored in a climate-smart approach to maximize conservation benefits under recent (late 20th–early 21st century) and projected climate conditions. One fundamental question we are addressing is how changes in thermal and hydrologic conditions may affect native cutthroat trout imbedded in mountain lake-stream networks. Our research includes modeling surface temperatures for mountain lakes at a regional scale, and examining how altered thermal and hydrologic regimes affect critical life history events, such as spawning migrations. Ultimately, we will integrate these ecological patterns into state-of-the-art decision support models and use these models as tools to aid in the conservation of native cutthroat trout populations.

Photograph from Jeremy Monroe, Freshwaters Illustrated.

Photograph from Leanne Hanson, USGS.

Using Unmanned Aircraft System Technology to Support Natural Resource Management

Unmanned Aircraft Systems (UAS) provide an affordable and safe method to collect high resolution imagery needed for the management of natural resources. Sensors on these airframes collect spatially explicit data for wildlife monitoring, vegetation analysis, habitat mapping, and erosion monitoring in areas where it has been previously difficult or impossible to obtain information. AS Branch research pilots are testing and integrating UAS technology to collect data in order to inform decisionmaking across Federal, State, and Tribal agencies. Our collaborations with other U.S. Geological Survey science centers, U.S. Fish and Wildlife Service, Bureau of Land Management, U.S. Department of Agriculture, Colorado Parks and Wildlife, and private landowners have demonstrated that this state-of-the-art technology is useful and has a place in natural resource management.

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