Collaborative Water Governance and Social-Hydrological Justice:

The Case of the Upper Colorado River Endangered Fish Recovery Program

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Teaching Notes

Acknowledgements
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Curriculum Summary

Shared decision-making collaboratives, or collaborative governance initiatives, such as the Upper Colorado River Endangered Fish Recovery Program (UCREFRP) have become common in mountain west watersheds. Collaborative water governance aims to avoid costly litigation by increasing flexibility in administration and management to address ecological values. Collaboratives work across political and ecological scales to propose relevant policy solutions to socio-ecological issues, in this case balancing water needs across human stakeholders while protecting endangered fish species. However, it is important that future leaders in resource conservation recognize the inevitability of tradeoffs and the role of power in distributing the benefits of collaborative solutions to social and non-human stakeholders. The purpose of this case study is to encourage critical thinking about both the social and ecological outcomes of collaborative governance approaches. Students will have the opportunity to reconceptualize or adapt the UCREFRP outcomes to more equitably represent the needs of all organisms in the social-hydrological system (SHS). The SHS approach is comparable to the socio-ecological systems (SES) approach in that it focuses on the human-nature interface of complex natural resource problems, applies systems thinking to represent and analyze these problems these problems, and emphasizes interdisciplinary approaches to problem solving. This case study illustrates how social and hydrological processes as necessarily interconnected, where water's physical processes shape, and are shaped by, decisions made by the UCREFRP.

The case will provide an introductory-level explanation of water right administration for the purpose of the Colorado River context. In addition to incorporating scholarship on the assessment of collaborative governance processes, we draw on the literature and concept of ecological justice (that is, justice for all species) to explore power dynamics. Students will develop analytical skills in systems thinking and the conceptualization of feedbacks, scale, and interdependencies. This conceptual piece will be complemented with applied tools including a concept mapping, qualitative data analysis methodologies, and evaluative techniques to foster synthesis and assessment skills. In addition to developing a more holistic perspective on the relationship between a collaborative process and SHS outcomes, students will develop a sensitivity to the political nature of fish conservation and environmental governance. The module includes simplified data sources for students to use in assessments, such as interviews, key documents, and social theory frameworks. In addition to the socio-ecological case study approach, this curriculum follows a learning cycle to concretely promote active learning and engagement with the materials (see Box 1).

Introduction to Case Study

The Colorado River is the hardest working river in the West. It flows through seven states, two countries, provides water to approximately 40 million people, and irrigates nearly 4.5 million acres of farmland. Ten hydroelectric dams have the capacity to produce more than 4,200 megawatts of electricity: enough to power between three and four million average U.S. homes. But this progress was not achieved without altering the habitat and threatening the existence of four native fish species. Compounded with prolonged drought and increased seasonal water variability, four fish native to the Colorado River: the Colorado pikeminnow, the humpback chub, the bonytail chub, and the razorback sucker are now considered endangered by the federal government. The building of dams and reservoirs, alteration of water flow patterns, introduction of non-native species, diversion of water for irrigation and urban purposes, and destruction of plant life along river banks has affected the habitat and reproductive success of the rare fish. In this case, we focus more narrowly on the Colorado pikeminnow in the river's Colorado subbasin.

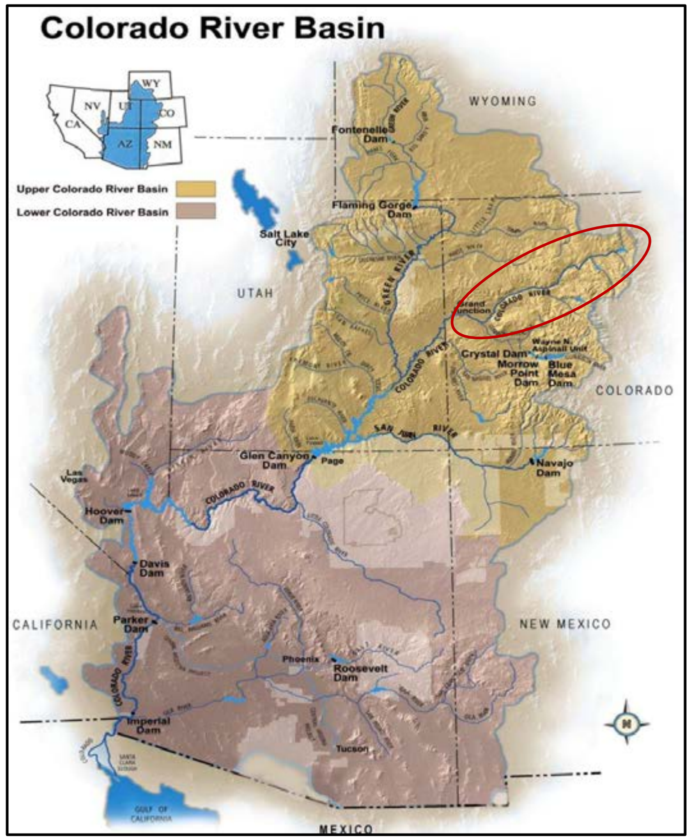


Figure 1. The Colorado River Basin with Colorado subbasin inside the red oval. Adapted from *Reclamation and Arizona: 1960s Photo Gallery* (Image 6, "The Colorado River Basin States"), U.S. Department of the Interior Bureau of Reclamation, https://www.usbr.gov/lc/phoenix/AZ100/1960/photogallery.html#top-of-page. Public Domain.

The listings of these fish under the Endangered Species Act (ESA) spurred years of failed litigation cases. Water users in Western Colorado sued the federal government for obstructing development on the Colorado subbasin. After years of failed litigation and under the auspices of stopping all diversions on the Colorado River, many saw the need for a new approach to management. If water users wanted to continue diverting water for agricultural production and municipal use, they would need to come up with a plan to address the needs of the endangered fish. Finally, a diverse set of stakeholders including farmers, ranchers, water managers, state water administrators, and representatives from U.S. Fish and Wildlife, the Bureau of Reclamation, and the Bureau of Land Management, to name a few, formed a basin-wide collaborative decision-making process to address the endangered fish listings. This collaborative, titled the Upper Colorado River Endangered Fish Recovery Program (UCREFRP), aims to restore native fish populations while maintaining current levels of water use for economic purposes. This collaborative effort in the Colorado subbasin focuses on a 15-mile stretch of river (see Figure 1, Colorado subbasin is highlighted with the red line) identified as critical habitat for the Colorado pikeminnow.

The collaborative was birthed from the complexities of the issue, and their efforts and diverse reflections on the process highlight this complexity. A farmer succinctly reflects on the decision-making process and justification for the UCREFRP collaborative processes: "*are we giving up water? It's almost more visceral than water rights, what are you giving up, what are you getting in return, are we getting enough? Is there any amount big enough to compensate us for what we're giving? ... the* [irrigation company] *board was somewhat reluctant to do it... given our role with the* [Bureau of] *reclamation we're* *not in complete control of our destiny. The service and reclamation, previous manager, I think put it correctly in this way: if this is inevitable how do we get something good out of what is demanded from us. I think the discussions parallel some of the discussions we're having currently. If we don't do this and can't help all get on board with this compliance, we have to get in compliance no matter if the fish recovery program is implemented or not."*

After almost three decades of collaborative work on the subbasin, participants have mixed opinions about the process. One irrigation company president shares: *"There were tradeoffs. In general it created a system that does work for everybody and there were benefits too in terms of modernization of systems that the government paid ... It enabled the farmers to modernize their irrigation systems without a huge cost to them, but at the same time use less water."*

A local rancher has a different perspective: *"that's a lot of federally mandated stuff. You know endangered fish recovery, these humpback suckers that all the people in Grand Junction caught the damn things back in the 1940s, threw them out on the bank because they aren't worth a shit for nothing. And put catfish in the river because catfish are good to catch, good for people to eat. Yeah, endangered fish is not very high on my list. That is probably one of the biggest waste of federal money. We're already digging ourselves into a black hole that there is no light at the end of the tunnel...*

I don't think we had to give up any water, all the federal projects are somewhat tied together. I think they use Green Mountain water to subsidize the River in order to keeping the damn endangered fish alive. I don't know. And still, if I catch one of them I'll throw the damn thing out on the bank over my shoulder and not tell anybody...They're out to protect species but nothing is protecting us."

Another rancher reflects opposite sentiments, *"any kind of retrofit or changes that needed to be made, the bureau has been great at that… If we need to make this more efficient operation we need a mini excavator. They pay for one, they buy one. Recovery has been truly great to work with. They realize that we're irrigators first and fish do come second but we tried not to act that way. I get along really well with all the recovery people."*

It is important to recognize that even collaboratives deemed to be "successful" will often have different stakeholders that hold diverse beliefs about whether or not the collaborative is successful, and whether or not the organization's definition of "success" is the right measure. Furthermore, while most stakeholders may see the collaborative as a success, it is important as researchers and as teachers that we ask (and prompt our students to ask): "successful for whom?" This is particularly important in this collaborative as human actors are generally satisfied with the distribution of water within the context of the collaborative--but non-human stakeholders, such as the Colorado pikeminnow, continue to struggle in population gains.

Introductory Video Links to Share with Students

- American Rivers. 2013. Colorado River: America's Most Endangered River. https://vimeo.com/67579458
- Ruth Powell Hutchins Water Center. 2015. Water in the Desert: The Grand Valley and Its Rivers. https://vimeo.com/106882559

Historical Background

- Quartarone, Fred. 1995. "Historical Accounts of Upper Colorado River Basin Endangered Fish." http://www.coloradoriverrecovery.org/general-information/general-publications/Historicalaccounts.pdf

The Learning Cycle

In addition to the resources provided by SESYNC, we have integrated the Beetles Learning Cycle (see Box 1) to promote an active learning environment. As described by the quote in Box 1, students learn better when they can relate new knowledge to previous knowledge and experiences. In addition, the learning cycle and this curriculum inspires student curiosities to arrive at new concepts and applications through a structured engagement and reflection process.

Education Level: Introductory interdisciplinary graduate students/upper level undergraduates.

Case Type/Method: Interrupted, Project-Based Learning case study using jigsaw, discussion, role-play scenario, and concept mapping.

Learning Goals Addressed: *SESYNC Learning Goals for Socio-ecological Synthesis addressed in this case study (see Table 1)*

1. Understand the structure and behavior of socio-ecological systems.
   a. Identify the environmental and social components of the system and their interactions.
   b. Identify feedbacks and explain the dynamics of an S-E system.
   c. Use tools and modeling approaches to understand dynamics of an S-E system.
2. Consider the importance of scale and context in addressing socio-ecological problems.
   a. Understand that ecological and social processes often vary across differing contexts, including space, time, and conditions (e.g. economic or political).
   b. Understand that ecological and social processes interact across different scales.
3. Co-develop research questions and conceptual models in inter- or trans-disciplinary teams.
   a. Identify disciplines and approaches relevant to the problem.
   b. Communicate across disciplinary boundaries.
   c. Understand the value of different knowledge sources and ways of knowing. Identify potential users of and applications for research findings.
4. Find, analyze, and synthesize existing data, ideas (e.g. frameworks or models), or methods.
   a. Identify data sources and appropriate tools, evaluate quality of data, and manage data.
   b. Understand the different kinds of data and research methods used by relevant disciplines in the natural and social sciences.
   c. Use geospatial and visualization tools.
   d. Integrate different types of data (interdisciplinary integration).

Structure of Teaching Notes

This case is divided into four modules that can be adapted individually or can build on one another throughout a semester. Each of the four modules in this case study include a module overview, and is further divided into Module Sessions. Modules 1-3 contain two sessions each; Module 4 contains one session. Each Session includes:

- A **Session overview** detailing learning objectives, activities, student learning outcomes and assessment;
- A list of **preparation materials** (usually conceptual and case-study related readings for students and instructors)
- A brief **lesson plan** outlining the order of events for the Session (such as lectures, activities, and discussion)
- A more detailed description of **activities**
- **Class materials** suggesting items and technology to support activities, as well as supporting documents and where to find them (such as student handouts)
- **Concepts and tools** of importance for the lectures or activities in that Session
- **Additional resources** (if available) to assist instructors
- **Detailed lecture notes** for instructors, presenting background information, key concepts, and references to accompany slides for several of the lectures (Boxes 2, 3, 4, 6, 7, and 8)
- **Detailed activity notes** for select activities (Box 5)
- **Suggested assessments** for select student learning outcomes

Lectures are labeled by their Module number, for example “Lecture 1.3” is the third lecture for Module 1. There are eight lectures for the entire case study. Slide PDF are included with supplementary materials for all lectures in the case study, labeled by their corresponding Lecture. PDFs can be converted to PowerPoint slides in Adobe Acrobat using the *export* function.

Activities are also labeled by Module, e.g. “Activity 2.C” is the third activity for Module 2. Optional activities, videos, discussion sessions, and homework assignments are included throughout the case, but are not labeled separately. Additional supplemental materials include student activity handouts, sign-up sheets, and homework assignments.

Appendices to the Teaching Notes include an answer key to the Module 1 team homework assignment and a reading associated with that assignment.

Table 1. Overview of Case Study Modules

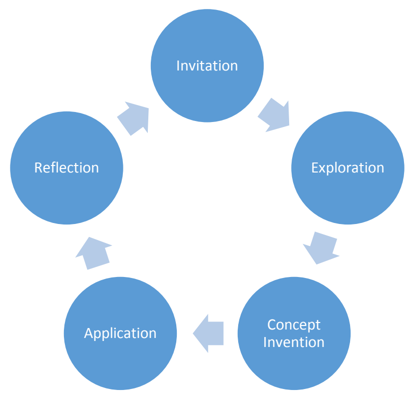
Module	S-E Learning Goals	Learning Objective	Specific Objectives	In-Class Time	Assignment	Activities
1: **Endangered Fish Scales: Visualizing the Intended Impacts of the Upper Colorado River Endangered Fish Recovery Program at Two Geographic Levels**	1, 1a, 2, 2b, 3	Recognize and analyze the problem, interventions, feedbacks, and relationships within a socio-hydrological system and apply a framework to a case	1. Adapt and apply a framework to model the logic of a collaborative initiative 2. Identify and describe key components of a collaborative program (targets, strategies, etc.) 3. Explain how collaborative environmental governance can be a potentially valuable process for addressing problems that span boundaries 4. Develop a conceptual model to describe a social-hydrological system as a function of the intended outcomes of a collaborative initiative	4 hours	Team homework assignment to prepare for jigsaw activity (1.C); final conceptual model and narrative assignment	Mapping activity (1.A); lectures 1.1, 1.2, and 1.3; introductory concept modeling activity (1.B); jigsaw concept modeling activity (1.C); discussion
2: **How Do We Evaluate a Natural Resource Collaborative?**	2a, 3b-c	Understand the how and why of natural resource collaborative assessment Prepare, present, and defend a stakeholder position, acknowledging importance of stakeholder dialogue and tradeoffs of assessment indicators	1. Identify relevant indicators of collaborative successes and challenges 2. Appreciate management complexity and the difficulty of meeting diverse value sets	3 hours	Essay assignment, stakeholder map and role-play scenario reflection	In-class stakeholder mapping activity (2.A); lecture 2.1; role-play scenario activity (2B); discussion

3: **Understanding Research Paradigms, Bathing in Qualitative Methods**	4a-b	Recognize, utilize and analyze data from diverse research paradigms with a focus on naturalist/interpretive-based methodologies	1. Synthesize quantitative and qualitative data from diverse sources 2. Understand and carry out qualitative methods of analysis; interview coding	3 hours	Interview coding	Toolkit activity (3.A); lectures 3.1, 3.2, 3.3; research paradigm group activity (3.B); video; interview coding activity (3C)
4: **Synthesizing Social Science and Conservation Conceptualizations of Justice in Collaborative Processes and Evaluation**	2a-b; 3a-c	Understand the value of different knowledge sources and ways of knowing in relation to collaboration, conservation, & environmental governance Identify relevant disciplines and approaches for moving the UCRERP forward	1. Synthesize divergent considerations of ethics and justice from social science and conservationist perspectives 2. Develop policy recommendations for improving UCREFRP assessment (i.e. identifying gaps, additions for enhancing equity across stakeholders, different indicators), Incorporating considerations of environmental and ecological justice	1.5 hours	Revision of essay from Module 2; development of policy recommendation	In-class peer-review activity (4.A); lecture 4.1; discussion

Box 1: The Learning Cycle

Content adapted from: The Lawrence Hall of Science. 2016. “The Beetles Learning Cycle Explained.” Berkeley, CA. http://beetlesproject.org/

“Learning is active and social. For deep learning to occur, instruction needs to access and connect to prior knowledge and give learners choices and responsibilities in their own learning experience.”
- The Lawrence Hall of Science, University of California Berkley



Invitation

The invitation stage is intended to engage students in the topic by getting them to contribute their won relevant prior knowledge. This kind of engagement is thought to decrease the tendency for shallow, rote learning of the content and increase the depth and “stickiness” of learning. The role of the instructor in this phase is to generate interest and excitement in the students about the topic. The instructor should set up the context and then introduce a challenge or a question to the students to pull them in. The instructor should encourage students to make observations, ask questions, and discuss their own relevant experiences and prior knowledge. Before delivering the case content, the instructor should be listening for how the students are engaging with the topic in order to help guide instruction.

Exploration

In this stage the instructor allows students to explore objects, phenomena, or ideas in an open-ended way in order to get students to start making sense of the topic and building common ground for developing new concepts together. The students should be able to work together in this phase independent of the instructor—that is, the instructor should only provide as much information as necessary to get the students on track to explore. While the students interact, the instructor should circulate and listen to interactions, ask probing questions, encourage students to wrestle with difficult concepts, help facilitate co-learning if necessary, and generally encourage curiosity.

Concept invention

Once students' interest in the topic has been focused through the previous phases, they are primed for making connections and constructing new meanings rooted in experience. This is the point at which the facilitator delivers new content to the students to facilitate learning. The instructor should recognize that the experiences and prior knowledge of students will shape the way content is processed and the new ideas and concepts that it generates, regardless of how that content is delivered to them. While providing formal definitions and vocabulary as needed to provide a foundation for learning about the topic, the instructor should also provide opportunities for students to explain concepts and definitions in their own words. Where possible, the instructor should try to use student experiences discussed in earlier phases in order to explain or exemplify concepts, or provide counterpoints. The instructor may also need to point out misconceptions, clarify fuzzy concepts, and acknowledge assumptions to help guide learning.

Application

The application phase allows student to take their vocabulary, knowledge, skills, etc. and apply them in a different context in order to cement their understanding of the concepts and ideas generated in previous phases. Through activities and discussion, students make new connections as they transfer knowledge from one situation to another and put their knowledge to use. To truly understand new concepts and ideas, the learner needs to apply them to a different context. The role of the instructor in this phase is to design and guide activities that allow for this authentic application of knowledge, evaluation students' learning progress, and provide feedback.

Reflection

This is a meta-cognitive stage intended to get students thinking about their own learning process. Students look back on their new knowledge, compare and contrast alternative explanations with their own, and elaborate on their emerging conceptual frameworks. The instructor's role is to design opportunities to prompt students to reflect on the activities and solidify connections between concepts (such as discussion, writing, drawing, or some other medium particular to the topic). Reflection of this sort improves is intended not only to reinforce the learning that has taken place during the case study or module, but to encourage students to be better, more active learners in the future.

Applying the learning cycle to this case study

This case study includes many complex concepts and context-specific details. The modules provide extensive background materials, readings, lecture slides, and lecture notes for instructors to familiarize themselves with the case and its concepts prior to implementing the case study in class. Our hope is that by adequately preparing instructors, they will be able to expand invitation and exploration activities, shorten the lectures or adapt content delivery to improve active learning, and otherwise adapt case content to promote the kind of deep and reflective learning outlined by the Beetles Learning Cycle. For more details on this learning framework, see the handout available here: http://beetlesproject.org/cms/wp-content/uploads/2015/12/The-Learning-Cycle-Explained.pdf

Collaborative Water Governance and Social-Hydrological Justice:

The Case of the Upper Colorado River Endangered Fish Recovery Program

Teaching Notes

Module 1
Endangered Fish Scales:
Visualizing the Intended Impacts of the Upper Colorado River Endangered Fish Recovery Program at Two Geographic Levels

Endangered Fish Scales: Visualizing the Intended Impacts of the Upper Colorado River Endangered Fish Recovery Program at Two Geographic Levels

Module Overview

Module 1 provides a general introduction to the collaborative initiative at the heart of the case, and consists of two, two-hour sessions. The purpose of Session 1.1 is to a) introduce students to the Upper Colorado River Endangered Fish Recovery Program (UCREFRP) as an example of long-term collaborative environmental governance, b) provide students with a tool for describing how the program is intended to impact conservation targets (specifically the Colorado pikeminnow), c) get students thinking about scale and complexity of a social-hydrological system, and d) lay the foundation for a more comprehensive modeling activity in Session 1.2. It is important to note that the UCREFRP is a large scale, long-term program encompassing multiple states and projects within its subbasins. Session 1.1 uses the full-scale UCREFRP as an entry point, but subsequent sessions and modules focus on efforts within the boundaries of the state of Colorado. The purpose of session 1.2 is to incorporate more detail into the concept models in order to describe how collaborative governance can alter elements of a social-hydrological system.

Since Module 1 is information-dense, instructors may wish to expand the duration of Session 1.1 and/or Session 1.2 to allow more time for the activities that encourage invitation, exploration, concept invention, application, and reflection (promoted by the learning cycle, see Box 1). This could help build a firmer foundation for the other case study modules.

Session 1.1: A conceptual model of the Upper Colorado River Endangered Fish Recovery Program

Table 2. Overview of Module 1, Session1.1

<table>
<tr><td colspan="4">Learning Goal 1: Students will apply a conceptual model to understand and describe the intended outcomes of the Upper Colorado River Endangered Fish Recovery Program.</td></tr>
<tr><th></th><th>Learning Objectives</th><th>Activities</th><th>Student Learning Outcomes and Assessment</th></tr>
<tr><td>Session 1.1:

A conceptual model of the Upper Colorado River Endangered Fish Recovery Program

2 hours</td><td>1. Describe key components of the UCREFRP and its goals
2. Demonstrate understanding of UCREFRP's intended outcomes regarding the Colorado pikeminnow using conceptual model</td><td>1. Activity 1.A (15 min)
2. Lecture 1.1: "The Big Picture: The Upper Colorado River Endangered Fish Recovery Program: an example of collaborative governance" (25 min)
3. Lecture 1.2: "A conceptual model for understanding the intended outcomes of UCREFRP" (10 min)
4. Activity 1.B: Conceptual model (30 min)
5. Small group or facilitated discussion (15 min)
6. Conclusion of Lecture 1.2: "Scaling down: a brief introduction to the Colorado pikeminnow" (15 min)
7. Homework overview (10 min)</td><td>SLOs:
1. Students will be introduced to the UCREFRP and will illustrate the logic of the program at the full Basin scale by developing a simple conceptual model.
2. Students will articulate the challenges imposed by scale when trying to develop a concept model.
3. Through homework, students will begin to develop a more comprehensive concept model at a smaller scale that demonstrates their comprehension of the logical links between program goals, strategies, actions, and desired conservation outcomes.

Assessment: The in-class concept models could be turned in for grading, but they may be more appropriate for a discussion of muddiest points. Student teams will use a jigsaw homework assignment to prepare for developing a more comprehensive model in the next class. Homework will be turned in for grading and feedback prior to the next class.</td></tr>
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Preparation Materials

Context-setting videos

- American Rivers. 2013. Colorado River: America's Most Endangered River. https://vimeo.com/67579458
- Ruth Powell Hutchins Water Center. 2015. Water in the Desert: The Grand Valley and Its Rivers. https://vimeo.com/106882559

Case study readings for students and instructors

Upper Colorado River Endangered Fish Recovery Program website: http://www.coloradoriverrecovery.org/ **EXPLORE THE PROGRAM WEBSITE (with guiding questions if desired)**

Final Programmatic Biological Opinion (PBO) Regional Director, Region 6 Fish and Wildlife Service. 1999. "Final Programmatic Biological Opinion for Bureau of Reclamation's Operations and Depletions, Other Depletions, and Funding and Implementation of Recovery Program Actions In the Upper Colorado River Above the Gunnison River." Denver, CO. Retrieved from http://www.coloradoriverrecovery.org/documents-publications/section-7-consultation/15mile/FinalPBO.pdf **READ PAGES 1-7 FOR BRIEF OVERVIEW OF LEGALLY DOCUMENTED HISTORY OF UPPER COLORADO RIVER ENDANGERED FISH RECOVERY PROGRAM**

NOTE: remind students to bring laptops to class if planning to use Draw IO web application to develop concept map (see Activity 1.B below)

Lesson Plan

Assumes that 1) case materials have already been provided to students and expectations made clear in previous class, and 2) students have read (and viewed) preparation materials. Suggested class materials are included below.

- Activity 1.A: Invitation Map Activity (15 min)
  - Small groups of students will examine maps of the Colorado River Basin and discuss the questions:
    - What do you know about this river basin? What do you observe on the map?
    - What does it remind you of? What questions do you have? (write these down)
  - Have students share back to the class.
- Lecture 1.1: "The Big Picture: The Upper Colorado River Endangered Fish Recovery Program: an example of collaborative governance" (25 min, see detailed lecture notes in Box 2)
  - Students should receive the Session 1.1 handout before class, which has definitions of concepts and focus questions to prepare them for the in-class activity
  - *Optional: Word bubble activity* (5 min)
    - *http://www.wordclouds.com/*
    - Before giving the definition slides, have students write 10 words on a pieces of paper to answer: What is collaborative water governance?
    - Get volunteer to input class responses into word bubble

        - Show word bubble at end of section in lecture on collaborative governance
- Lecture 1.2: "A conceptual model for understanding the intended outcomes of UCREFRP" (10 min, see detailed lecture notes in Box 2)
    - Challenges the students to visually depict the intent of the UCREFRP using a simple, hybridized logic/concept model
- Activity 1.B: Conceptual model (30 min)
- Small group or facilitated discussion (15 min)
- Conclusion of Lecture 1.2: "Scaling down: a brief introduction to the Colorado pikeminnow" (15 min)
- Homework overview (5-10 min)

Activities

***1.A Invitation Mapping Activity** (15 min)*

Layout large maps of the Colorado River Basin in different areas of the room (a projector can also be used, but paper maps are preferable for group work). Have students break out into equal number groups and circle around the maps. The goal is to have students connect with the river basin through prior knowledge and experiences.

***1.B Concept Model** (5 minute tutorial followed by 25 minutes of group work; see detailed lecture notes in Box 2 for background information about this activity)*

In small groups (2-3), students will develop a simple box and arrow diagram to describe the intended outcomes of UCREFRP at its largest scale. Students could do this by hand (colored sticky notes arranged on a wall would work well) or in a basic web application like Draw IO, which requires a brief tutorial:

<u>Introduce Draw IO as a tool for making concept maps</u>:

- Make enough copies of the Draw IO template for each team and label them: Team 1, Team 2, etc. Students can come up with team names if desired
- Send students the Draw IO template (see Session 1.1 Activity 1.B handout "UCREFRP Concept Modeling Guide for Students" and *class materials* below) before the in-class session
- Have them open the program on their computers and look over the handout to familiarize themselves with the Open Standards concepts and terminology
- Spend five minutes making sure students have successfully accessed the Draw IO template on their PC
- They will need to be signed into the email account to which you shared the template otherwise they won't be able to access it
- Give a short tutorial to introduce the program

Students should be able to refer back to both Lectures 1.1 and 1.2, so they should be either posted online before class or printed as PDFs. This is a very simple model using limited information at a large scale—the purpose is to get them thinking about scale, complexity, and the information needed to develop a more meaningful model in the next session.

This concept model (which is outlined in the Session 1.1 Activity 1.B handout, and further adapted in Session 1.2) borrows heavily from the Open Standards for the Practice of Conservation, which was developed by a consortium of international non-governmental organizations and foundations as a fairly standardized yet flexible framework to assist practitioners with effective conservation planning and adaptive management (see further discussion and resources in Box 2). We find it is better adapted to 'modeling' the logic of a collaborative governance intervention than a traditional social-ecological systems model. The following concepts are also defined in the Session 1.1 Activity 1.B student handout:

- **Scope**: Definition of the broad parameters or rough boundaries (geographic or thematic) for where or on what a project will focus.
- **Conservation Target**: An element of biodiversity at a project site, which can be a species, ecological community, or habitat/ecological system on which a project has chosen to focus.
- **Contributing Factor**: The indirect threats, opportunities, and other important variables that positively or negatively influence direct threats.
    - **Direct Threat**: Usually human activities, though they may be natural phenomena altered or exacerbated by human activities. For our in-class activity, we will use the broad primary threat discussed in the lecture (e.g. habitat modification), but for the homework you will identify more specific direct threats in the readings (e.g. creation of reservoirs or operation of dams).
    - **Indirect Threat**: The economic, cultural, societal, or institutional factors that are identified as drivers of direct threats to occur. Sometimes called a root cause or underlying cause. (e.g., logging policies, demand for fish, and human population growth)
    - **Opportunity**: A factor identified in a situation analysis that potentially has a positive effect on one or more targets, either directly or indirectly, and is often an entry point for conservation actions (e.g., demand for sustainably harvested timber, and established culture of conservation).
- **Key ecological attribute:** Aspects of a target's biology or ecology that help define a healthy target and that, if missing or altered, would lead to loss or extreme degradation of the target over time.
- **Stress**: The biophysical way in which a direct threat impacts a conservation target; they can be thought of impaired key ecological attributes.
- **Strategy**: A group of actions with a common focus that work together to reduce threats, capitalize on opportunities, and/or restore natural systems.
- **Activity:** A specific action or set of tasks included within an overall strategy

Activity 1.B only addresses scope, targets, threats, and strategies. <u>This is not intended to be a model of a social-hydrological system</u>, but rather a description of the UCREFRP at a large scale. Students will incorporate other Open Standards concepts into a more detailed concept model through the homework and Session 1.2.

<u>Questions to guide modeling activity</u> (answers to these questions are in the slides for Lecture 1.2)

- What is the scope of the UCREFRP?
- What are its primary conservation targets?
- What are the direct threats to those targets?

- What are its main strategies or program elements?
- What are the relationships between the elements of your model? (Draw arrows; be thoughtful about directionality of relationships)

Post-activity discussion

Students will be asked to reflect on the following questions:

- What does this model tell you?
- What parts of the model are missing?
- What information would we need to know about the conservation targets to make a better model?
- What about the threats? The strategies?
- What other information would improve this model?
- Would modeling this at a smaller scale make more sense? Why or why not?

They can remain in their small groups to discuss these questions and report out, or this can be conducted as a facilitated group discussion.

Resource for Activity 1.B

Foundations of Success. 2009. Using Conceptual Models to Document a Situation Analysis: An FOS How-To Guide. Foundations of Success, Bethesda, Maryland, USA. Download available here: http://www.fosonline.org/resource/using-conceptual-models-to-document-situation-analysis

Class Materials

- 3-4 maps of the Colorado River Basin for Activity 1.A
- Colored sticky notes and markers/ pens OR enough computers for a 1:2 or 3 ratio
- Session 1.1 handout “UCREFRP Concept Modeling Guide for Students” (describes in-class modeling activity and concept model components and terminology)
- Module 1 Team Homework Assignment handout
- Draw IO template for activity 1.B concept model (Figure 2; template example available here: https://drive.google.com/file/d/0BxJNSQEgg6tYRnBiTXdtRGZvTGM/view?usp=sharing)

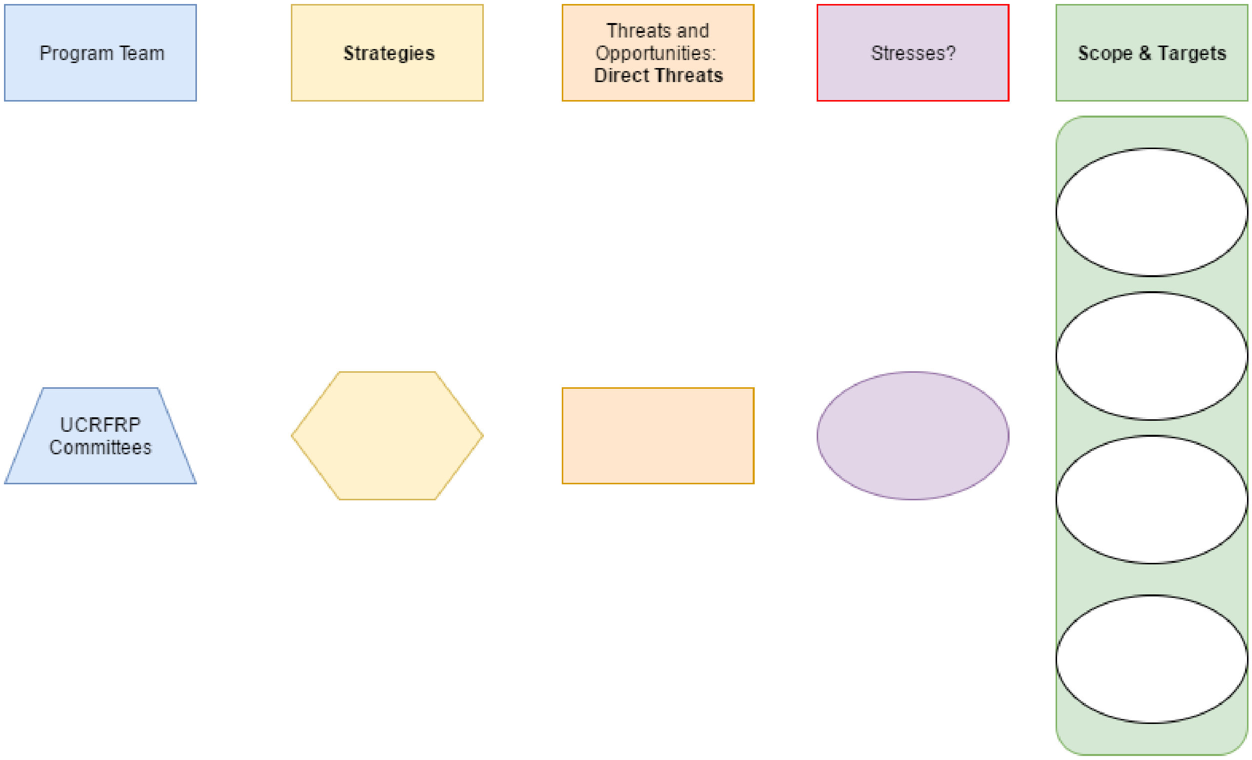

Figure 2. Sample Draw IO template for Activity 1.B

<u>Homework</u> (See Module 1 Team Homework Assignment in Student Handouts; Module 1 **Homework Answer Key** is available in Teaching Notes Appendix A)

During the last 10 minutes of class, students will be asked to break into groups of 3-6 (these can be pre-assigned). The purpose of the assignment is to prepare them for building a more comprehensive conceptual model at a smaller scale than the one built in class. The homework assignment will use a jigsaw approach in which students read different articles and answer different sets of questions to prepare them for Activity 1.C in Session 1.2. The homework has 3 components, each with its own readings and questions, so students should decide amongst themselves which members will complete which component. We recommend a minimum of 3 students per team. If the number of students in the class requires teams of four students, the fourth student could read the "additional references" for each homework component and contribute what they learn to help the other three students answer their set of questions. Keeping students in the same teams from Activity 1.B for the team homework is not required, but may yield a smoother process. Students will turn in answers to the guiding questions, and they are also encouraged to send their independently revised model sections (or questions about them) for feedback before the next class. They are not asked to combine answers or model sections as a team for the homework. Before the end of class in Session 1.1, check to ensure students' understanding of the change in scale from the UCREFRP basin-scale collaborative to the Colorado subbasin scale.

Homework Readings: (split between student team members per team homework handout)

Team Member 1:
U.S. Fish and Wildlife Service. 2002. Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado. Retrieved from https://www.fws.gov/southwest/sjrip/pdf/DOC_Recovery_Goals_Colorado_pikeminnow_2002.pdf
****READ EXECUTIVE SUMMARY, PAGES 22-33, AND APPENDIX A****

Final Programmatic Biological Opinion (PBO) Regional Director, Region 6 Fish and Wildlife Service. 1999. "Final Programmatic Biological Opinion for Bureau of Reclamation's Operations and Depletions, Other Depletions, and Funding and Implementation of Recovery Program Actions In the Upper Colorado River Above the Gunnison River." Denver, CO. Retrieved from http://www.coloradoriverrecovery.org/documents-publications/section-7-consultation/15mile/FinalPBO.pdf ****READ PAGES 36-37****

Additional resources:

Endangered fish fact sheet and non-native fish fact sheet available here: http://www.coloradoriverrecovery.org/general-information/general-publications/fish-fact-sheets.html

2015-2016 Highlights UCREFRP: Report
http://www.coloradoriverrecovery.org/general-information/general-publications/briefingbook/2016-Briefing_book.pdf

Team Member 2:

Bankert, Beck, Boone, D'Amico, and Sueltenfuss (2015). Colorado Headwaters Watershed Opportunities Map and Management Plan. ****READ ENTIRE INTRODUCTION: 1.1-1.7**** (Reading Available in Appendix of Case Study Teaching Notes)

Colorado Water Conservation Board (CWCB) (2015). Colorado Basin Implementation Plan.
https://www.colorado.gov/pacific/sites/default/files/CBIP-April-17-2015.pdf
****READ PAGES 12, 20-30, AND 34-38****

Additional resource:

Conservation Measures Partnership (2005). Taxonomy of Direct Threats. http://cmp-openstandards.org/using-os/tools/threats-taxonomy/

Team Member 3:
Best, Allen. 2016. "Phoning for Flows." Colorado Foundation for Water Education Magazine. https://www.yourwatercolorado.org/index.php?option=com_content&view=article&id=475:phoning-for-flows&catid=122. ****READ FULL ARTICLE****

Bankert, Beck, Boone, D'Amico, and Sueltenfuss (2015). Colorado Headwaters Watershed Opportunities Map and Management Plan. ****READ SECTIONS 1.4, AND 1.6**** (Reading Available in Appendix of Case Study Teaching Notes)

Final Programmatic Biological Opinion (PBO) Regional Director, Region 6 Fish and Wildlife Service. 1999. "Final Programmatic Biological Opinion for Bureau of Reclamation's Operations and Depletions, Other Depletions, and Funding and Implementation of Recovery Program Actions In the Upper Colorado River Above the Gunnison River." Denver, CO. http://www.coloradoriverrecovery.org/documents-publications/section-7-consultation/15mile/FinalPBO.pdf **READ PAGES 36-37**

Additional resource:

CWCB (2009). "Statewide Water Supply Initiative Factsheet." http://cwcbweblink.state.co.us/weblink/docview.aspx?id=113227&searchhandle=30039& dbid=0

Concepts and Tools

Tools: The activities in Session 1.1. and 1.2 adapt a conceptual framework and borrow terminology from Open Standards for the Practice of Conservation: http://cmp-openstandards.org/

If using software for developing concept models, we recommend Draw IO: https://www.draw.io/

Concepts: See Open Standards terminology outlined in Session 1.1 Activity 1.B handout "UCREFRP Concept Modeling Guide for Students."

Additional Resources for Instructors

Hopfl, K. (1994). Case study of the Endangered Fish Recovery Program of the Upper Colorado River. Retrieved from http://www.colorado.edu/conflict/full_text_search/AllCRCDocs/94-57.htm

****NOTE THAT THIS RESOURCE IS 1) DATED, AND 2) REFERS TO THE FULL GEOGRAPHIC EXTENT OF UCREFRP RATHER THAN THE SMALLER, COLORADO-ONLY EXTENT WE ARE FOCUSED ON FOR THE HOMEWORK AND SESSION 1.2; STILL PROVIDES GOOD CONTEXT****

2015-2016 Program Highlights Report for the UCREFRP http://www.coloradoriverrecovery.org/general-information/general-publications/briefingbook/2016-Briefing_book.pdf

Novak, J D, and a J Cañas. 2008. "The Theory Underlying Concept Maps and How to Construct and Use Them." *IHMC CmapTools*, 1–36. doi:Technical Report IHMC CmapTools 2006-01 Rev 2008-01.

Box 2. Module 1 Session 1.1 Detailed Lecture Notes for Instructors

***Lecture 1.1:* "The Big Picture: The Upper Colorado River Endangered Fish Recovery Program: an example of regional collaborative governance"**

Because the UCREFRP operates at such a large regional scale and undertakes many activities, the majority of this Case Study focuses on just one component of the Program, the Colorado subbasin and an area known as the 15-Mile Reach (introduced in the Team Homework Assignment readings). The purpose of Lecture 1.1 is to first contextualize UCREFRP as an example of a particular form of environmental governance, then briefly describe the program at its full regional scale. This is intended to help students (and instructors) understand the nested nature of UCREFRP, the context surrounding our Case Study, and the importance of considering scale and context in addressing socio-ecological problems. Collaboration and its evaluation are further elaborated in Lecture 2.1 (see Box 4 and Lecture 2.1 Slides), but instructors are free to rearrange content if they wish.

Introduction to Collaborative Governance and Management

Government refers to activities backed by formal authority and police power. *Governance* refers to activities backed by shared goals that may or may not derive from legal and formally prescribed responsibilities, and that do not necessarily rely on police powers to overcome defiance and attain compliance. It's creating the conditions for ordered rule and collective action or institutions of social coordination. Governance is the structures and processes by which people in societies make decisions and share power (Folke, Hahn, Olsson et al. 2005). Governance is more encompassing than just what a government does. It refers to the rules and norms that guide collective decision-making. It's not about one individual making a decision, but rather groups of individuals, organizations, or systems of organizations making decisions. It is a shared responsibility (Ansell & Gash, 2007).

Environmental Governance is "the set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes" (Lemos & Agrawal, 2006, p. 298).

Management (as differentiated from governance) involves operational decision-making to achieve specific conservation outcomes, whereas governance refers to the broader processes and institutions through which societies make decisions that affect the environment. But they're not mutually exclusive; management interventions also involve uncertainty, negotiation, deliberation, and sensitivity to social-ecological dynamics.

Cooperation and coordination among agencies and non-agency partners are often necessary for governing and managing natural resources or natural resource problems that cross jurisdictional boundaries, like wildlife, air quality, forest health, and water. *Collaboration* is more synthetic than cooperation or coordination, which tend to be applied to problems that require alignment of timing and protocols to achieve shared, clear-cut objectives, often over a short term period. Collaboration is a constructive process of exploring, deliberating on, and possibly implementing solutions to conflicts or shared problem situations (problem domain). Individuals, groups, or organizations that may be influenced by decisions made or actions taken pertaining to the problem domain, termed stakeholders, are generally interdependent and have the opportunity to participate in the process (Gray, 1989; Emerson, Nabatchi, & Balogh, 2011).

Collaborative environmental governance and management, on the other hand, constitute a particular approach to influencing public policy related to the environment (in contrast to, for example, litigation, public outreach campaigns, or the creation of market-based or behavioral incentives). *Collaborative governance initiatives* are "public policy or service oriented, cross-organizational systems involving a range of autonomous [entities] representing different interests and/or jurisdictions (as opposed to like-minded coalitions)" (Emerson & Gerlak, 2014, p. 769).

Since the early 1990s, collaborative approaches to influencing environmental policy, action, and outcomes have been on the rise in the United States, challenging traditional command-and-control natural resource regulatory frameworks. Several factors operating at different scales have contributed to reframing environmental governance and management to incorporate non-state actors. In the American West, these factors include increasing conflict regarding public lands management, shifting theoretical paradigms about ecological dynamics and human-environmental interactions, and a more general shift in thought regarding how best to manage for complexity in natural systems. Collaborative governance and management initiatives tend to emphasize 1) power-sharing among stakeholders (those impacted by or with the potential to impact an issue); 2) inclusive representation of stakeholders; and 3) iterative and long-term processes of engagement that promote co-development of solutions that couldn't be achieved alone.

UCREFRP Overview

The primary driver of collaboration behind the UCREFRP can be traced to declining fish health and the authority and responsibility of the U.S. Fish and Wildlife Service (USFWS) to enforce compliance with the Endangered Species Act (ESA). The UCREFRP emerged out of escalating conflict over water rights and the concern by water users that the government would link reduced stream flows to continued water development and force them to forego water use to secure instream flows. "Faced with the choice of litigating as an attempt to amend the ESA, halting water development, or negotiating a solution, the Colorado River Recovery Implementation Program (the original name for the UCREFRP) was formally accepted in 1987, preventing a federally mandated moratorium on water development" (Hopfl, 1994).

The primary goal is to remove four Colorado River fishes (razorback sucker, humpback and bonytail chub, and the Colorado pikeminnow) from ESA protection (i.e. delist) by 2023. The UCREFRP aims to recover these fish in the Colorado River and its tributaries in Colorado, Utah, and Wyoming while continuing to meet human needs and demands for water use and development in compliance with interstate compacts and applicable federal and state laws. The UCREFRP has five primary program elements: habitat management; habitat development and maintenance; native fish stocking; non-native species management; and research, monitoring, and data management. All of these factors are considered to be equally important recovery elements.

As of 2016 participants in the UCREFRP include the State of Colorado, the State of Wyoming, the State of Utah, the Bureau of Reclamation, the Colorado River Energy Distributors Association, the Colorado Water Congress, the National Park Service, The Nature Conservancy, the U.S. Fish and Wildlife Service, the Utah Water Users Association, the Western Area Power Administration, Western Resource Advocates, and the Wyoming Water Association.

UCREFRP Organization

Instructor note: this section may provide helpful context about the UCREFRP, particularly if collaborative governance structure is of interest, but can be cut if necessary.

The UCREFRP program is overseen by the Program Director's Office within the U.S. Fish and Wildlife Service. The program itself consists of five committees: Implementation, Management, Biology, Information and Education, and Water Acquisition. Each committee's membership includes multiple stakeholders, its own mission, and decision-making is consensus-based. For more details and lists of current membership for each of these committees, visit the committee page on the UCREFRP website: http://www.coloradoriverrecovery.org/committees/committees.html

The Implementation Committee reports to the Program Director's Office and oversees the UCREFRP, with specific oversight of the Management Committee. They review prioritized work plans generated by the lower committees (e.g. identifying habitat needs, reviewing instream flow recommendations, overseeing public education programs, recommending annual budgets, and ensuring that all recovery efforts are fully coordinated).

The Management Committee reports to the Implementation Committee and is tasked with ensuring coordination and effective management of the action-oriented committees "so that the highest priority needs of the fish are addressed" (Hopfl, 1994, para. 13). They oversee the research of the lower committees and report on this research to the Implementation Committee. They develop and update "the long term plan and the annual budget for the UCREFRP, promoting Congressional, public, and agency support for the program, ensuring funding is provided by Congress and all participating agencies, and handling any management issues that arise in the implementation of the UCREFRP" (Hopfl, 1994, para.13). Much of the prioritization, planning, and implementation of the UCREFRP program elements is undertaken by the remaining committees (Information and Education Committee, the Water Acquisition Committee, and the Biology Committee and its sub-committees). The program elements include instream flow identification and protection; habitat restoration; non-native fish management; propegation and stocking; research and monitoring; and information and education. These program elements are elaborated in the slides for lecture 1.1, and more detail can be found on the UCREFRP website's Program Elements page: http://www.coloradoriverrecovery.org/general-information/recovery-program-elements.html

Nested Scales of UCREFRP Efforts

Important instructor note*: this part of the lecture brings us from the big picture to the scale defined by our Case Study*

We have described the UCREFRP at its full program scale as an introduction, but the large scope of the program means that much of its potential for impact relies on the efforts of partnerships nested within the boundaries of the larger Program. For example, partners within the program have worked to cooperatively manage flows to protect endangered fish in different areas and subbasins within the larger program boundaries, including the Green, White, Duchesne, Gunnison, San Juan, Price, and Yampa Rivers. <u>Session 1.2 and subsequent modules will focus on the effort located specifically in the mainstem of Colorado subbasin, known as the 15-Mile Reach</u>. This part of the program exemplifies a public private partnership including representatives from the State, Bureau of Reclamation, Colorado River Energy Distributors Association, Colorado Water Congress, National Park Service, The Nature

Conservancy, U.S. Fish and Wildlife Service, Western Resource Advocates, and Western Area Power Administration.

References

Ansell, C., & Gash, A. (2008). Collaborative Governance in Theory and Practice. Journal of Public Administration Research and Theory, 18(4), 543–571. http://doi.org/10.1093/jopart/mum032

Emerson, K., & Gerlak, A. K. (2014). Adaptation in collaborative governance regimes. *Environmental Management*, 54(4), 768–781. http://doi.org/10.1007/s00267-014-0334-7

Emerson, K., Nabatchi, T., & Balogh, S. (2012). An Integrative Framework for Collaborative Governance. Journal of Public Administration Research and Theory, 22(1), 1–29. http://doi.org/10.1093/jopart/mur011

Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive Governance of Social-Ecological Systems. Annual Review of Environment and Resources, 30(1), 441–473. http://doi.org/10.1146/annurev.energy.30.050504.144511

Gray, B. (1989). Collaborating: Finding common ground for multiparty problems. Jossey-Bass San Francisco.

Hopfl, K. (1994). Case study of the Endangered Fish Recovery Program of the Upper Colorado River. http://www.colorado.edu/conflict/full_text_search/AllCRCDocs/94-57.htm

Lemos, M. C., & Agrawal, A. (2006). Environmental Governance. Annual Review of Environment and Resources, 31(1), 297–325. http://doi.org/10.1146/annurev.energy.31.042605.135621

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Box 2 Continued

In-Class Activity 1.B and Lecture 1.2: "A conceptual model for understanding the intended outcomes of UCREFRP"

Conceptual model of the UCREFRP at the regional scale

This lecture begins with an activity asking students to demonstrate big picture understanding of the UCREFRP's intended outcomes by creating a simple box-and-arrow diagram. This model borrows concepts and terminology from the Open Standards for the Practice of Conservation, but is much simpler and more descriptive, a bit like a logic model. We further adapt this framework in Session 1.2. Instructors teaching this module are encouraged to familiarize themselves with the framework and improve on our adaptation. Information can be found on the Open Standards website (http://cmp-openstandards.org/), and the following reference is also helpful:

Foundations of Success. 2009. Using Conceptual Models to Document a Situation Analysis: An FOS How-To Guide. Foundations of Success, Bethesda, Maryland, USA.

It's important to note that this reductive model is not meant to represent a social-hydrological or social-ecological system. The team homework assignment and Activity 1C in Session 1.2 give students an opportunity to expand this model to represent the role of the program within a broader social-hydrological system. In contrast, Activity 1.B serves as a simple tool for assessing students' basic understanding of the overall program. Students' models can be saved and emailed to the instructor for grading if desired, but we suggest using them instead as a point of discussion. A sample model created that can serve as an **answer key** in Draw IO **is included in the slides for Lecture 1.2**. Suggested post-activity discussion questions are:

- What does this model tell you?
- What parts of the model are missing?
- What information would we need to know about the conservation targets to make a better model?
- What about the threats? The strategies?
- What other information would improve this model?
- Would modeling this at a smaller scale make more sense? Why or why not?

The Colorado pikeminnow

To reduce complexity in the Session 1.2 in-class activity, we now narrow the scope of our case study to deal only with the Colorado pikeminnow. It is referred to by other colloquial names in the homework readings, so it may help to mention its aliases: squawfish, Colorado squawfish, whitefish, bigmouth whitefish, white salmon, and Colorado River salmon.

This lecture is intended to provide a general introduction to the Colorado pikeminnow and set the stage for the team homework assignment and Session 1.2 in-class activity. The following lecture notes provide background information for instructors unfamiliar with this species, but the actual lecture can be kept short by including less detail. At least one member of each student teams will have an opportunity to read in-depth about the fish, becoming the 'expert' in their team and educating others during the jigsaw activity.

Description

- Has a torpedo-like, elongated body reminiscent of a pike
- Its head is cone-shaped and flattish, constituting nearly a quarter of its overall body length.
- Its large mouth has long, hooked pharyngeal teeth, which are "teeth in the pharyngeal arch of the throat of cyprinids, suckers, and a number of other fish species otherwise lacking teeth. Many popular aquarium fish such as goldfish and loaches have these structures" (Wikipedia).
- Has a bright olive green back, gold or paler yellowish flanks, and silvery-white underneath.
- Young fish also have a dark spot on the caudal fin (tail fin).
- Breeding males are bronze-colored and heavily covered with tubercles while females are generally larger, lighter in color and with fewer tubercles.
- They are thought to have evolved more than 3 million years ago, and they can live up to 40 years.

Biology

- Young pikeminnows, up to 5 cm long, eat cladocerans, copepods, and chironomid larvae, then shift to insects at around 10 cm, gradually eating more fish as they mature.
- Once they achieve a length of about 30 cm, they feed almost entirely upon fish.
- The pikeminnow has ontogenetic separation of life history stage. The altricial young emerge from whitewater canyons, enter the drift as sac-fry and are transported downstream.
- Habitat for the young fish is predominantly alongshore backwaters and associated shorelines of more alluvial reaches of the turbulent and turbid rivers of the Colorado system. In contrast, adults reside in more well-defined channels, where they seek eddy habitats and prey on suckers and minnows.

<u>Reference</u>

Colorado pikeminnow. (2016, October 24). In *Wikipedia, The Free Encyclopedia*. Retrieved 17:55, October 24, 2016, from https://en.wikipedia.org/w/index.php?title=Colorado_pikeminnow&oldid=746001107

Distribution and Spatial Ecology

- The Colorado pikeminnow is endemic to the Colorado River Basin, where it was once widespread and abundant in warm water rivers.
- Wild populations are found only in the upper basin, and the species currently occupies only about 25% of its historic range basin-wide.
- Natural reproduction is currently known from the Green, Yampa, upper Colorado, Gunnison, and San Juan rivers.
- Although fish in the Green and upper Colorado River systems spawn at four primary locales, they are likely linked genetically, based on movement throughout the system and lack of genetic separation.
- Colorado pikeminnow are potamodromous (i.e. they undertake regular migrations in large freshwater systems) with adults making long-distance migrations of hundreds of kilometers to and from spawning areas, and thus requiring long sections of river with unimpeded passage.

- The species is adapted to warm rivers and requires uninterrupted passage and a hydrologic cycle characterized by large spring peaks of snowmelt runoff and lower, relatively stable base flows.
- Adults require pools, deep runs, and eddy habitats maintained by high spring flows. These high spring flows maintain channel and habitat diversity, flush sediments from spawning areas, rejuvenate food production, form gravel and cobble deposits used for spawning, and create backwater nursery habitats.
- Spawning occurs after spring runoff (around the summer solstice) at water temperatures typically between 18 and 23°C.
- After hatching and emerging from spawning substrate, larvae drift downstream to nursery backwaters that are restructured by high spring flows and maintained by relatively stable base flows.

<u>Reference</u>

U.S. Fish and Wildlife Service. 2002. Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado.

The Pikeminnow, Then and Now

- Once a common fish in the desert southwest and considered an epic catch
- Once an important food fish for Native Americans and early settlers
- Largest minnow in North America and on one of the largest in the world. Specimens up to 6 feet long and weighing up to 100 lbs have been reported
- The Colorado pikeminnow was the Colorado River's top predator in the early 1900s
- "Anglers reported catching voracious Colorado pikeminnow on everything from swallows and mice to earthworms and chunks of chicken or rabbit. Tim Merchant of Green River, Wyo., said his grandfather caught Colorado pikeminnow using chicken parts to bait multiple hooks on a clothesline. His grandfather tied the line to the bumper of his truck and waited. "When (the line) went tight, they'd just back the truck up and drag those fish out on the bank," Merchant said. "They were as big as a junior high school kid, 90 pounds. That's a big fish. "Anglers told of Colorado pikeminnow that were up to 5 feet long and 80 or more pounds; most recalled Colorado pikeminnow in the range of 20 to 40 pounds. Many of the seniors said they used Colorado pikeminnow for food, especially during the Depression. Humpback chub, bonytail, and razorback sucker also were consumed, but reportedly were bonier" (Program History, n.d.)
- While "catches in the 1960s ranged up to 60 cm for 11-year-old fish but, by the early 1990s, maximum sizes reached no more than 34 cm. Biologists now consider the average size of an adult pikeminnow to be between 4 and 9 pounds, and reports of the fish latterly exceeding 3 feet in length are now in question." (Wikipedia)
- Today, two wild populations of Colorado pikeminnow are found in the Upper Colorado River Basin – one in the upper Colorado River system and one in the Green River system.
- Listed as endangered by U.S. Fish and Wildlife Service in 1967; given full protection under the Endangered Species Act of 1973. Listed as endangered under Colorado law in 1976; status changed to threatened in 1998. Protected under Utah law since 1973. Currently listed as vulnerable by the IUCN.

- The population of adult Colorado pikeminnow in the Colorado River subbasin averages 612 individuals (1992 – 2014). The current USFWS criteria for downlisting this population is >700. Although the preliminary adult population estimate for 2014 (N=377) is the lowest on record, a record high number of young-of-year (YOY) pikeminnow were collected in the fall of 2015. The population in the Green River subbasin averaged 2,504 individuals (2001 – 2013)

References

Colorado pikeminnow. (2016, October 24). In *Wikipedia, The Free Encyclopedia*. Retrieved 17:55, October 24, 2016, from https://en.wikipedia.org/w/index.php?title=Colorado_pikeminnow&oldid=746001107

Colorado Pikeminnow Fish Facts (n.d.). Retrieved from http://www.coloradoriverrecovery.org/general-information/the-fish/colorado-pikeminnow.html

Program History: Historical Accounts of Upper Colorado River Basin Endangered Fish (n.d.). Retrieved from http://www.coloradoriverrecovery.org/general-information/program-history/program-history.html

The Endangered Species Act

- The purpose of the Endangered Species Act is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (16 U.S.C. 1531(b))
- Political costs of such power become extremely high when the needs of "a little known or uncharismatic creature" are pitted against vocal or politically powerful groups.
  ESA is particularly unpopular when applied to water resources, b/c compliance mandates may require holders of state-created water rights to reduce or even forego their established entitlements.
- The limits of ESA: "ESA has been widely regarded as an important catalyst, with the ability to convince states and local authorities to adjust to new reality of social support for environmental protection... [but] the ESA cannot easily force changes in state water law, or in the other areas of state and fed law that could help bolster the status of dwindling spp." (Doremus & Tarlock, 2003, p.285)
- Brief explanation of how ESA works: in order to carry out its mandate, ESA provides substantial latitude to provide enough instream flows to protect the wildlife therein, even if it means undercutting the rights of senior water appropriators. The U.S. Fish and Wildlife Service is the arm of the ESA dealing with terrestrial and freshwater species, while the National Marine Fisheries Service (NMFS, aka NOAA) handles marine and anadromous species); these two entities have the power to list a species as endangered or threatened based on scientific criteria. Once a listing happens, ESA section 9 bans "take" of that species, which means no capturing or killing, and no harm or injury through alteration of its environment. Section 4d allows the agency to impose regulations as they deem fit to protect and conserve the species in question, and Section 7 requires that they ensure that all other actions that they take themselves or that they sign off on do not put the species in jeopardy (basically reduce the chances of the species' survival and recovery). Under the same section, they can designate critical habitat, which

includes unspecified thresholds of water quality and quantity-- that means it's on the shoulders of the agency to specify those thresholds, even if good information is lacking. They are expected to err on the side of the species and denote what information was missing. When designating critical habitat, the agency in question obtains a list of species that may be in the area, then conducts a biological assessment to figure out if the proposed action will jeopardize any of threatened or endangered species; if it does, the applicable service (FWS or NMFS) issues a Biological Opinion. This formal statement includes an important element on incidental take, basically exempting actions that do their best to avoid jeopardy to the species from sanctioning under ESA Section 9.

Reference:

Doremus, H., & Tarlock, a D. (2003). Fish, farms, and the clash of cultures in the Klamath basin. Ecology Law Quarterly, 30(2), 279–350.

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Session 1.2: Refining the Concept Model: UCREFRP in the Upper Colorado River Subbasin

The purpose of this session is to incorporate more detail into the concept models in order to describe how collaborative governance can alter elements of a social-hydrological system. This session will begin with a brief presentation about the portion of the Upper Colorado River subbasin that lies within Colorado. This can be brief because each team should have at least one student who has familiarized themselves with this effort. Some time should be reserved to discuss 'muddiest points' and issues that came up in the homework assignment (particularly regarding institutional factors associated with water governance and how it fits into the model).

Table 3. Overview of Module 1, Session 1.2

Learning Goal 2: Students will expand their conceptual model to describe a social-hydrological system nested within the larger Recovery Program as defined by the effort known as the 15-Mile Reach.			
	Learning Objectives	**Activities**	**Student Learning Outcomes and Assessment**
Session 1.2: Refining the Concept Model: UCREFRP in the Upper Colorado River Subbasin 2 hours	1. Apply information gathered on a) ecological attributes of the pikeminnow and threats to its population viability and habitat; b) social, economic, institutional, and biophysical factors contributing to those treats; and c) the mechanisms of the 15-Mile Reach call to generate a more comprehensive concept model linking UCREFRP to its intended outcomes 2. If possible, identify ecosystem services generated by healthy and functioning conservation targets and possible human wellbeing targets	1. Invitation: Return to word cloud (5 min, optional) 2. Lecture 1.3: "Refining the Concept Model: UCREFRP in the Upper Colorado River Subbasin" (20 min) 3. Introduction to team activity: expanding the concept models to the social-hydrological system (10 min) 4. Activity 1.C: expanding the models to the S-H system (60 min) 5. Brief presentation and discussion of conceptual models (20 min) 6. Wrap up module 1, set stage for module 2 (5 min)	**SLO**: Students will apply the information they gathered through the homework assignment to a team jigsaw activity in which they expand their conceptual models to represent the broader social-hydrological system **Assessment**: Teams will briefly present progress on models in class, then they will incorporate feedback and complete the models as a team outside of class.

Preparation Materials

For students and instructors

See Homework Readings for Session 1.1

Lesson Plan

Assumes students have received feedback on submitted homework assignments before class.

- Optional invitation: display word cloud from previous class and ask students to journal for 5 minutes on:
    - Now that you know what you know, would you change any of the concepts or processes in the wordcloud? Why? What's missing?
- Lecture 1.3: "Refining the Concept Model: UCREFRP in the Upper Colorado River Subbasin" (See detailed lecture notes in Box 3; 20 min)
- Introduction to team activity: Expanding the conceptual models (10 min)
- Activity 1.C: expanding the concept model (60 min)
- Brief team report-outs (20 min)
- Module conclusion and homework overview (5 min)

Activities

1.C Concept Model Jigsaw (60 min)

In teams, have students open new Draw IO template. They will share and discuss answers to homework questions, starting with section 1, and begin adding components to the model. If possible, teams identify ecosystem services provided by healthy/functioning conservation targets that might translate to human wellbeing targets, and add these to the model. Once all the major components have been added to the model, teams can start connecting the different parts of model in Draw IO. Teams may not finish this process during the time allotted in class, in which case they should focus on getting all the important elements into the model first; they can work on pruning, arranging, and adding arrows outside of class. Questions are provided on the Session 1.2 activity handout "Expanding the Concept Models" to help guide students in selecting what to include in their final models. These questions will also frame the narrative for the final product. ***Note****: if instructor prefers a paper-based concept modeling activity, see Activity 1.B description and Class Materials in Session 1.1 above.*

Team Report-Outs (20 min)

Teams are asked to share links to their models in Draw IO with instructor so all can view on large screen. Each team will select one member to share progress highlights at the end of class. The following questions guide reporting:

- What are some of the dominant physical, biological, and human elements and processes affecting the Colorado pikeminnow's population and habitat within the Upper Colorado River subbasin?
- Were you able to identify any wellbeing targets?

- How is the HUP call ultimately intended to influence the targets?

Class Materials

- Session 1.2 Activity 1.C handout "Expanding the Concept Models"
- Copies of submitted Module 1 Team Homework Assignments with feedback from instructor
- Access to at least one computer per team

Homework

Students will need to work as a team outside of class to complete the UCREFRP social-hydrological concept model. The final model should be completed in Draw IO as neatly as possible. If a paper version was created instead, students should take pictures of the final version and create a digital version in PowerPoint or other software that allows them to create a detailed diagram. The final model should include those elements and relationships that the team feels are most appropriate for answering the set of questions provided in the 1.2 Activity 1.C handout. When they turn in the model it should be accompanied by answers to these questions:

1. What are the ecological (biological and physical) components of the system that directly or indirectly influence the conservation targets?
2. Besides the HUP call, what are the social, cultural, economic, and institutional elements within the boundaries of the system that directly or indirectly influence the conservation targets?
3. What are the mechanisms through which the above elements influence the conservation targets and their key ecological attributes?
4. What are the key laws and policies that directly or indirectly influence the conservation targets?
5. Without getting too far into the weeds, what are the property rights in the system regarding water resources, and how might they affect the conservation target?
6. What agencies/entities control how water moves through the system?
7. What other key stakeholder groups might directly or indirectly influence the conservation targets?
8. What are potential ecosystem services that could be generated by improving the condition of the conservation targets, and how might these translate to human wellbeing targets? (see explanation below)
9. Now that you have a more complete picture of the socio-hydrological system, how do the activities of the 15-Mile Reach HUP call affect 1) the conservation targets, and 2) other parts of the social-hydrological system?
10. What important elements of the system are not addressed by the HUP call?
11. Discuss some of the challenges or frustrations you faced while developing this model.
12. Discuss the potential value of representing a socio-hydrological system in this way. How might you use it for evaluating the efforts of the UCREFRP?

Concepts and Tools

Ecosystem services: the outputs of ecological processes that directly or indirectly contribute to social wellbeing. With regards to the conservation efforts of the UCREFRP, human wellbeing might be achieved through ecosystem services provided by healthy or functioning populations of pikeminnow and pikeminnow habitat. Possible categories of human wellbeing targets developed by the Millennium Ecosystem Assessment include:

- Necessary material for a "good life": including secure and adequate livelihoods, income and assets, food, shelter, access to goods, etc.
- Health: including being strong, feeling well, and having a healthy physical environment
- Good social relations: including social cohesion, mutual trust and respect, good gender and family relations, the ability to help others
- Security: including secure access to natural and other resources, safety of person and possessions, and living in a predictable and controllable environment with security from natural and human-made disasters
- Freedom and choice: including having control over what happens and being able to achieve what a person values doing or being

Additional Resources for Instructors

Bankert, Beck, Boone, D'Amico, and Sueltenfuss (2015). Colorado Headwaters Watershed Opportunities Map and Management Plan. (See Appendix 2)

Grading Rubric

Table 4. Suggested grading rubric for final conceptual model assignment

Category & Criteria (Weight)		LEVELS OF ACHIEVEMENT: 1 Beginning (50%)	2 Developing (75%)	3 Experienced (85%)	4 Exceptional (100%)	Score
System Model Diagram	Organized clearly and logically in a manner that is easy to understand (10%)	Diagram has no clear organizational system	The system model has an organization system, but it is difficult to understand	Diagram is mostly organized in a clear manner, with one or two areas that lack clarity	Diagram has clear, easy to follow organization system that demonstrates a thoughtfully planned system model diagram	
	Representation of components and relationships in the system (15%)	Components are not visually differentiated by type or category. Relationships between components not represented.	Components are poorly differentiated using a system that is unclear or simplistic. Relationships weakly represented.	Components are clearly differentiated using a uniform system. Relationships between elements are clearly represented using arrows or other designations, but the directionality or type of effect may be lacking.	Components are clearly differentiated using a uniform system. Relationships are represented in a way that makes clear the direction (which is element is the cause and which is the effect) and type of effect (e.g. increase, decrease).	
	Components included in the system (10%)	Only basic components are included, providing a superficial, simplistic representation of the system	While a more complex set of components s present, several important components of the system are missing.	A few important components are left out of a mostly-comprehensive set of components.	Components included in the system provide a comprehensive snapshot of the system. Bounds of system are clearly described in written portion of assignment.	
	Relationships included in the system (15%)	Relationships in the system are simplistic and the system lacks feedback loops.	Relationships in the system are mostly simplistic, with only one or two complex relationships present. Importance and certainty of relationships are not represented.	Causal relationships, feedback loops, and outcomes are generally represented, although 1-2 relationships may be simplified. Importance and certainty are generally represented.	Diagram clearly includes the complex relationships that exist in the system, including causal relationships and mechanisms, feedback loops, and outcomes. Importance and certainty of relationships are represented using a clear, graduated system with at least 3 levels.	
Written Narrative Describing the Model **Written Description of System Model**	Supports the system model diagram, providing a clear explanation of the model and justifying components and relationships included (20%)	Explanation of system model is unclear; does not justify components and relationships included	Explanation of the system model is simplistic, describing only basic casual relationships. Only some components and relationships are justified	Explanation of the system model is clear and thorough, and includes explanation of complex relationships. A few relationships are not described in appropriate depth. Most components and relationships are appropriately justified.	Explanation of the system model is clear and through, and all relationships are addressed. All components and relationships are appropriately justified.	

	Summary identifies key uncertainties and gaps in knowledge (5%)	No uncertainties are identified, or few uncertainties are listed without any explanation.	A few uncertainties are identified, but support for their inclusion is superficial	Several uncertainties present in the system are identified and supported with justification. One or two key uncertainties may be left out, or may not have appropriate justification.	Uncertainties present in the system are comprehensively identified and supported with clear justification.	
	Summary identifies potential areas of vulnerability in the system (5%)	No vulnerabilities are identified, or few are listed without any explanation	A few areas of vulnerability are identified, but support for their inclusion is superficial	Several vulnerabilities present in the system are identified and supported with justification. One or two key uncertainties may be left out, or may not have appropriate justification	Vulnerabilities present in the system are comprehensively identified and supported with clear justification	
Writing: Organization and Mechanics	Organized in a clear and logical manner (10%)	Writing lacks a clear sense of direction; there is a lack of structure, title, introduction and/or conclusion; No title page	Organization mostly ineffective and does not support the focus of the paper. Lacks introduction, topic sentences or conclusion. Title page missing relevant information	Structure moves reader through text without confusion, paragraphing and title page present. Clear introduction, topic sentences and conclusion.	Structure enhances central theme of the review; appropriate organizational structure and clear transitions. Clear introduction, topic sentences and supporting arguments, and strong conclusion. Logical flow; complete title page present	
	Correct grammar, spelling, punctuation and formatting (5%)	More than 5 spelling, grammar, or punctuation errors. Inappropriate font, size, formatting or word choice	Some spelling, grammar or punctuation errors. Some word choice errors, formatting errors, inappropriate font, size or margins	No spelling, grammatical or punctuation errors; minimal errors in word choice. Some inconsistency in presentation, white space, or other formatting errors	No spelling, grammatical or punctuation errors; word choice and syntax consistently appropriate. Fonts, sizes and presentation meet professional standards and enhance overall appearance	
Reflective Memo (individual)	Reflective Memo (5%)	Reflective memo incomplete (50%) or absent (0%)			Reflective memo completed thoroughly	

Box 3. Module 1 Session 1.2 Detailed Lecture Notes for Instructors

Lecture 1.3: Brief overview of the Colorado portion of the Upper Colorado River Subbasin

As of Session 1.1, we have reduced the scope of the UCREFRP program we are focusing on in our Case Study to the portion within Colorado that flows from headwaters in Rocky Mountain National Park to confluence with the Gunnison River in Grand Junction, CO and on to the border with Utah. The Upper Colorado River Basin encompasses about 17,800 square miles, of which about 10,000 are located in the state of Colorado.

The following summaries of and excerpts from one of the homework readings (Bankert, Beck, Boone, D'Amico, and Sueltenfuss, 2015) are intended for instructor background. For the sake of time, however, the lecture should be cut back to focus on those elements that were most unclear to students, as revealed through Module 1 team homework submissions.

Headwaters of the Upper Colorado River subbasin

The basin within Colorado is composed of two physiographic provinces: the Southern Rocky Mountains (SRM) and the Colorado Plateau (CP). The two provinces differ extensively in terms of land use, physical geography, biological communities, water chemistry, and so forth. The topography varies from mountainous regions in the Southern Rocky Mountains to high plateaus bordered by steep cliffs along valleys in the Colorado Plateau. Due to differences in altitude, the climate ranges from alpine conditions in the Southern Rocky Mountains to semiarid/arid conditions in the Colorado Plateau. Consequently, precipitation varies from 40 inches annually at high elevations in Southern Rocky Mountains to less than 10 inches annually in the Colorado Plateau. Differences account for shifts in both macroinvertebrate and fish communities based on their local habitat.

Aquatic communities

Major controlling factors that determine composition of biological communities in the two physiogeographic provinces are thermal profiles, velocity profiles, substrate composition, physiochemical conditions and physical habitat. Land use effects have further influenced shifts in community compositions. The SRM physiogeographic province is dominated by a coldwater fish assemblage, including trout, dace, sculpin and longnose sucker. Trout constitute the majority of the fish biomass in the SRM, and as such prey upon the native fishes (dace, sculpin, etc.). Other native fishes include mountain sucker, mountain whitefish, mottled sculpin and Colorado cutthroat trout. Fish communities in the SRM are of extreme recreational benefit to the region, with four major stream sections designated as "Gold Medal Trout water." The macroinvertebrate assemblage is dominated by specialist species such as caddisflies, mayflies, and stoneflies. Both the fish and macroinvertebrate assemblages in the SRM physiogeographic province rely on cold, clean water with coarse substrate. The CP physiogeographic province is dominated by a warmwater fish assemblage, including minnows, suckers, bass, carp, etc. Fish communities in the CP are of extreme conservation concern, including four federally endangered species; Colorado pikeminnow, humpback chub, razorback sucker, and bonytail chub. Other native species include flannelmouth sucker, bluehead sucker, speckled dace, and Kendall warm springs dace. The macroinvertebrate assemblage is dominated by aquatic worms, leeches, and dragonflies. Both fish and macroinvertebrate assemblages in the CP physiogeographic province tolerate warmer water with lower dissolved oxygen content and finer substrate types.

Land cover, use, and ownership

Wetlands are an integral component of the Rocky Mountain landscape. They provide a host of beneficial services, such as flood abatement, storm water retention, groundwater recharge, and water quality improvement. Wetlands are particularly important for wildlife because they are highly productive and diverse ecosystems, providing habitat for many species. For example, in many parts of the Rocky Mountain West, over 90% of wildlife species depend on wetlands or riparian areas at some point in their life. The relative importance of wetlands is underscored by the fact that they occupy a small fraction of the landscape. Though total acreage of wetlands in the Rocky Mountains is unknown, estimates exist on a state level. Estimates for Colorado place the extent at roughly 1 million acres or 1.5% of the land area. Historically, Colorado likely supported twice the wetland acreage that exists today. Up to 50% of Colorado's original wetlands have been drained, converted to farmland or urban development, or lost as a result of water diversion and storage.

Land cover within the eastern portion of the Colorado Headwaters is predominantly forested, shrub, and grasslands, with some pasture and smaller areas of developed land adjacent to the Colorado River. In the western portion of the watershed, the valleys become wider, with a result of increased developed land, cultivated crops, and pasture land. Forested and shrub land is predominantly located on hillsides. Land ownership is highly consistent with changes in terrain, similar to many high mountain watersheds in Colorado. Land at higher elevations or on steeper slopes is federally or state owned, while land in the valleys is generally privately owned. Because valleys are more expansive in the western portion of the watershed, there is more private ownership to the west in the lower elevations than in the eastern high elevations.

Extractive water uses

Spring snowmelt runoff provides a significant portion of the Colorado River's water supply. Many dams, canals, and other structures divert water from the Colorado River mainstem and its tributaries. However, only about 25% of the runoff is actually used within the Upper Colorado Basin in Colorado. Within the basin irrigation is by far the largest extractive use (>75%). Water storage, fisheries, municipal, and domestic uses lag behind irrigation but are nonetheless important water uses that may increase in demand in the future. Despite the socially-important beneficial uses supported by water storage, dams can negatively affect aquatic ecosystems by entraining sediment, altering thermal and flow regimes, altering nutrient cycling, and preventing longitudinal movement of fish. Surface water diversions are also put to beneficial use outside the Upper Colorado Basin. Around half a million acre-feet of water (5% of basin runoff) is removed from the Upper Colorado River Basin through trans-basin diversions every year (CWCB 2015b). Water is transported across the Rocky Mountains to Eastern Colorado to supply cities and farms. The largest trans-basin tunnels include Adams, Moffatt, and Roberts, although a total of 11 trans-basin diversions move water from Western to Eastern Colorado. Up to 70% of the basin runoff flows out of Colorado to satisfy interstate requirements under the Colorado River Compact. Future stressors of water supply include projected population increases, increased municipal and industrial needs, and climate change impacts on supply. For the seven counties in the Upper Colorado Basin, population is expected to double by 2050, compared to a 2008 baseline population. As a result of population increases and a growing energy industry in Colorado, annual municipal and industrial water demands will also double by 2050.

Water quality

Water quality is another constraint to ecosystem health that is exacerbated by dams, mining, and water extraction. The Clean Water Act 303(d) list shows streams listed in the Upper Colorado for heavy metals, temperature, sediment, and aquatic life. Furthermore, the Eagle Mine (located on the Eagle River, a major tributary in the SRM province) was designated as a superfund site in 1988. While a 2000 EPA report claimed that clean-up efforts had significantly reduced harmful effects to human and environmental health, the Upper Colorado River has an extensive history of mining and the detrimental and cumulative effects of mining on environmental health span beyond the clean-up of one former mine among thousands. Climate change remains a significant management hurdle to overcome, as expected streamflow changes in the Upper Colorado have been historically difficult to model. According to the Colorado Climate Change Vulnerability Study, under most climate scenarios we can expect to see less snowpack, earlier snowmelt, and more severe droughts. Overall, climate change will likely lead to lower streamflows and higher temperatures that will further degrade aquatic habitat. The combination of large amounts of water diverted from the channel and the uncertainty in the future amount of water in the basin will force new management practices to be adopted in the basin.

Governance of the Upper Colorado River subbasin

The Upper Colorado River Compact is an interstate agreement that delineates the amount of water that Colorado must deliver to the state of Utah. Important federal agencies include the Bureau of Reclamation, responsible for the funding and maintenance of much of the large water infrastructure on the mainstem. Bureau projects are particularly important when considering the health of the Colorado since their infrastructure needs to allow fish passage. Administratively, the water rights associated with these projects are tied to the land and cannot be taken out of agricultural use as defined in 30-year contracts between the bureau and water providers such as conservancy and irrigation districts.

Apart from some federally administered water rights, state water governance entities must follow the principles provided by the system of prior appropriation, the legal framework for water allocation in Colorado and the West. The principles of prior appropriation state ‘first in time, first in right’, meaning that the person that obtained a water right first has the right to use it to the exclusion of others during times of shortage. Diverted water must be continually put to a beneficial use such as municipal, industrial, and irrigation. Ownership is not tied to the land so that water can be transported to distant locations for use while rights can be sold and the purchaser would maintain the same ‘priority’ as the original owner. The water court, division engineer, and water plan must operate within this legal framework.

At the local level, the basin roundtable is a decision-making entity that represents diverse user groups including Municipal & Industrial (M&I), Agricultural, Environmental, and Recreational with both voting and nonvoting members working to address shortages in the headwaters region. Conservancy and irrigation districts provide water to these multiple users, maintain water infrastructure and may facilitate projects by administering and allocating external funding. These districts tend to have the most direct influence with water users on the ground. Understanding how water rights are administered, how infrastructure is managed, and who is making these decisions for whom is key to considering which areas have the most potential for conservation and restoration on the mainstem of the Colorado River.

Federal regulatory water rights are an avenue available to the federal government for water appropriation via federal environmental mandates like the Clean Water Act and the Endangered Species Act. These mandates allow the federal government to trump the usually dominant state water policy to "protect the quantity and quality of stream flows" by enjoining water diversions when these statutes are invoked (Doremus & Tarlock, 2003, p. 305). ESA provides U.S. Fish and Wildlife Service a very powerful (and heavy-handed) tool with the potential to disrupt water use and development. It is this power (and its potential repercussions) that ultimately drove the formation of the UCREFRP.

As we know, the UCREFRP, is a multi-agency arrangement that formed a collaborative governance process with the goal of delisting four fish from Endangered Species Act protection by 2023 (with the primary emphasis of this Case Study being the Colorado pikeminnow). The UCREFRP is an exemplary case of how water conflicts might deter expensive legislation and court battles through (potentially polycentric) collaborative water governance. The UCREFRP has considerable influence on how water is developed in the basin and the protections for sustainable river management processes. The success of the program is identified as one of the primary management issues on the Colorado mainstem and allows for the future use of Colorado River water in compliance with interstate compacts, treaties, and applicable federal and state law.

Importance of the 15-Mile Reach

The 15-Mile reach is located downstream of several large water diversions and upstream of the confluence with the Gunnison River. It provides critical spawning habitat for both the Colorado pikeminnow and the razorback sucker. It also provides a balance of temperature and available food sources that are optimal for adult Colorado pikeminnows. Low water flows in the late summer/early flow reduce habitat for the Colorado pikeminnow and razorback sucker; reduced spring runoff flows impairs the creation and maintenance of habitat. Because of this, many recovery actions are focused on the section of river known as the 15-Mile Reach.

The Historic User Pool Phone Call

To obtain group compliance with the Endangered Species Act via U.S. Fish and Wildlife’s Programmatic Biological Opinion, Grand Valley irrigators, federal authorities, Colorado River District and municipal reservoir operators, and others have developed innovative consensus-based management arrangements. Since 1995 water managers in the Colorado River Basin have conducted weekly Historic Users’ Pool (HUP) calls throughout the irrigation season in order to manage 10,825 acre-feet (AF) of water, including reservoir operations, to meet target flows for endangered fish in the “15-Mile Reach” of critical habitat in the Colorado River (CWI 2014). Over time, the call has come to address other considerations as well, such as stream conditions in Grand County and fishing conditions in the Frying Pan River downstream from Ruedi Reservoir. There has been some reduction in diversions from irrigation, and before 2002 the project’s irrigators diverted 285,217 acre feet annually. Since then, they draw 240,000 acre feet annually, leaving more water in the river for the fish with physical improvements financed by the UCRFRP.

Reference: Bankert, Beck, Boone, D’Amico, and Sueltenfuss (2015). *Colorado Headwaters Watershed Opportunities Map and Management Plan*. Unpublished manuscript, Colorado State University, Fort Collins, CO.

Collaborative Water Governance and Social-Hydrological Justice:

The Case of the Upper Colorado River Endangered Fish Recovery Program

Teaching Notes

Module 2
How and why do we evaluate a Natural Resource Collaborative?

How and why do we evaluate a Natural Resource Collaborative?

Module Overview

Students will be introduced to socio-ecological assessment of the natural resource collaboratives. This module emphasizes the importance of collaborative social processes and decision-making as a necessary skill set in contemporary resource management and governance. Students will consider the complexity of diverse perspectives, interests, values and power dynamics when measuring social and ecological outcomes. In practice, “participatory evaluations driven by collaborative participants themselves are needed to determine progress toward goals, provide feedback to guide future actions, and identify larger scale issues that impact specific efforts...can play an important role in illuminating these larger scale issues and are best used to address specific questions with broad import for policy-making and management” (Conley and Moote, 2003). Students will engage with the theoretical frameworks of participatory assessment as well as the practical implications of assessment indicators including potential policy outcomes.

Session 2.1: Introduction to socio-ecological assessment of collaboratives

Table 5. Overview of Module 2, Sessions 2.1

Learning Goal 1: Critical analysis of natural resource collaborative processes for both ecological and social outcomes			
Session Title	**Learning Objectives**	**Activities**	**Student Learning Outcomes and Assessment**
Session 2.1: **Introduction to socio-ecological evaluation of collaboratives** 1 hour, 30 min	1. Explain why collaborative assessment is needed and how it is accomplished 2. Identify relevant indicators of collaborative success 3. Analyze assessment indicators, the processes to develop indicators, and apply to UCREFRP case	1. Activity 2.A: Invitation stakeholder analysis worksheet and mapping (small groups develop stakeholder map) (25 min) 2. Lecture 2.1: “Introduction to Collaboration and its Evaluation” and recap of Lecture 1.2 (30 min) 3. Guided small group work: review main points from readings and collaborate on how to	**SLOs:** 1. Students will work first individually to identify different types of assessment, when they are appropriate, and case examples of assessment process 2. Students will generate both ecological and social assessment indicators relevant to UCREFRP stakeholder groups

		apply an assessment to the UCREFRP (30 min)	**Assessment:** An individual paper assignment summarizing and analyzing the assessment readings and applying to the UCREFRP, tying together modules 1 and 2. Due before first session of this module. Stakeholder Map that identifies UCREFRP Colorado participants and their anticipated preferred assessment indicators

Preparation Materials

Background readings on the evaluation of collaborative governance for students and instructors

Ansell, C., & Gash, A. (2008). Collaborative Governance in Theory and Practice. Journal of Public Administration Research and Theory, 18(4), 543–571. Retrieved from http://marphli.pbworks.com/w/file/fetch/55667103/Collaborative_governance_theory.pdf

Conley, Alexander, and Margaret a. Moote. 2003. "Evaluating Collaborative Natural Resource Management." *Society & Natural Resources* 16 (5): 371–86. Retrieved from http://library3.eri.nau.edu/gsdl/collect/erilibra/import/ConleyAndMoote.2003.EvaluatingCollaborativenaturalResourceManagement.pdf

Muñoz-Erickson, T a, B Aguilar-González, and T D Sisk. 2007. "Linking Ecosystem Health Indicators and Collaborative Management: A Systematic Framework to Evaluate Ecological and Social Outcomes." *Ecology and Society* 12 (2): 1–19. Retrieved from http://www.ecologyandsociety.org/vol12/iss2/art6/

Option: have students find one or two articles of their own

Case study readings for students and teachers

Brower, Ann, Chanel Reedy, and Jennifer Yelin-kefer. 2001. "Consensus versus Conservation in the Upper Colorado River Basin Recovery Implementation Program." *Society for Conservation Biology* 15 (4): 1001–7. Retrieved from http://onlinelibrary.wiley.com/doi/10.1046/j.1523-1739.2001.0150041001.x/full

U.S. Department of the Interior. 2015. "Implementing Innovative Solutions to Manage Water and Hydropower Resources While Recovering Endangered Species." ****FOCUS ON ACTIVITIES WITHIN THE STATE OF COLORADO AND PARTICULAR TO THE PIKEMINNOW**** Retrieved from: https://www.fws.gov/southwest/sjrip/pdf/20142015highlights.pdf

Lesson Plan

- Activity 2.A: Invitation – Scenario Preparation: small groups develop stakeholder map (25 min)
    - Break students into random groups of 3
    - They can use their new Draw.io skills or butcher paper
    - Use the Stakeholder Analysis Worksheet (Session 2.1, Activity 2.A Handout) to help with brainstorming a list of potential stakeholder groups, representative organizations or individuals, and potential data sources for learning more about the groups
    - Have them answer these questions with the map:
        - Identify the stakeholders with interests in the UCREFRP assessment process
        - Determine who should be included formally as stakeholder in participatory assessment indicator process
- Lecture 2.1: "Introduction to Collaboration and its Evaluation" (30 min)
    - Lecture 2.1 provides an overview of a close relative of collaborative governance and collaborative conservation, and discusses reasons and methods for evaluation. We recommend that instructors narrow this presentation to include only those components they wish to highlight. See detailed lecture notes for instructors in Box 4 and Lecture 2.1. slides.
- Guided small group work: review main points from readings and collaborate on how to apply an assessment to the UCREFRP (30 min)
    - Discuss main points from readings - share with class
    - Each group develops a list of potential assessment indicators for the UCREFRP
    - Make a list on the board or a projected word doc and discuss
    - Revise assessment indicators for UCREFRP stakeholders

Activities

2.A Scenario Preparation: Stakeholder Analysis Worksheet and Mapping *(see Session 2.1, Activity 2.A handout)*
This activity teaches students how to identify differences in UCREFRP stakeholders and their representative organizations. It also provides students with access to potential data sources for learning more about the groups. They will consider values and interests specific to each group and generate their preferences for assessment indicators to be used in the participatory development of assessment indicators scenario in the following session. Student may identify stakeholders that are not pre-defined for the scenario. This type of student-driven learning (see the Learning Cycle described in Box 1) can be encouraged by including these additional stakeholders. There is no narrative assignment attached to this due to the amount of other written assignments already given but this is an option if desired. Students will turn in their maps and a list of stakeholders they think should be included in the scenario.

Class Materials

- Specific materials or technology needed for the activities, like computers, software, index cards, etc.

- Butcher paper and pens for brainstorming and drawing stakeholder map
- Laptops if using Draw.io
- Stakeholder Analysis Worksheet (Student Handouts Module 2, Session 2.1, Activity 2.A)
- Students should bring copies of their essay assignment
- Stakeholder Role Sign-up Document (Student Handouts Module 2, Session 2.2 Supplemental)

Homework

Students will prepare for the Activity 2.B scenario in Session 2.2 by researching roles. See Session 2.2 Activity 2.B handout for roles, and Box 5 for homework details.

Concepts and Tools

Concepts: stakeholders; interests, values, preferences

Tools: participatory assessment, social and ecological assessment indicators

Box 4. Module 2 Session 2.1 Detailed Lecture Notes for Instructors

Lecture 2.1: Introduction to Collaboration and its Evaluation

The following excerpts are intended to provide ample background for instructors unfamiliar with collaborative governance or evaluation. The lecture can be shortened, lengthened or re-focused to accommodate course objectives. Slides for Lecture 2.1 are in the case study supplemental materials.

Huayhuaca, C. (2015). *Interactions among Collaborative Initiatives and Implications for Adaptive Capacity in a Complex Water Governance System*. Unpublished manuscript.

What is Collaboration? *(With some review from Lecture 1.1)*

Cooperation and coordination among agencies and non-agency partners are often necessary for governing and managing natural resources or natural resource problems that cross jurisdictional boundaries, like wildlife, air quality, forest health, and water. *Collaboration* is more synthetic than cooperation or coordination, which tend to be applied to problems that require alignment of timing and protocols to achieve shared, clear-cut objectives, often over a short term period. Collaboration is a constructive process of exploring, deliberating on, and possibly implementing solutions to conflicts or shared problem situations (problem domain). Individuals, groups, or organizations that may be influenced by decisions made or actions taken pertaining to the problem domain, termed stakeholders, are generally interdependent and have the opportunity to participate in the process.

Collaborative environmental governance and management, on the other hand, constitute a particular approach to influencing public policy related to the environment (in contrast to, for example, litigation, public outreach campaigns, or the creation of market-based or behavioral incentives). *Collaborative governance initiatives* are "public policy or service oriented, cross-organizational systems involving a range of autonomous [entities] representing different interests and/or jurisdictions (as opposed to like-minded coalitions)" (Emerson & Gerlak, 2014, p. 769).

Since the early 1990s, collaborative approaches to influencing environmental policy, action, and outcomes have been on the rise in the United States, challenging traditional command-and-control natural resource regulatory frameworks. Several factors operating at different scales have contributed to reframing environmental governance and management to incorporate non-state actors. In the American West, these factors include increasing conflict regarding public lands management, shifting theoretical paradigms about ecological dynamics and human-environmental interactions, and a more general shift in thought regarding how best to manage for complexity in natural systems. Collaborative governance and management initiatives tend to emphasize 1) power-sharing among stakeholders (those impacted by or with the potential to impact an issue); 2) inclusive representation of stakeholders; and 3) iterative and long-term processes of engagement that promote co-development of solutions that couldn't be achieved alone.

Collaborative conservation is a process or series of efforts to bring stakeholders who may hold diverse, adversarial or opposing views on an issue of concern together to work toward solutions to intractable problems that link the social well-being with environmental conditions or outcomes. It is generally thought of as a movement that emerged in the western United States after protracted conflict with the federal government over public lands management, though it shares roots with community-based natural resource management in international participatory development strategies. It draws on theories of Jeffersonian or participatory democracy, collaboration theory, alternative dispute resolution, environmental conflict resolution, New Federalism, second generation public policy, ecosystem management, and adaptive management. While it may have originated over public lands disputes, many examples of collaborative conservation focus on private lands, such as the Chama Peak Land Alliance of northern New Mexico and Southern Colorado, which has brought together former adversaries (ranchers and environmental lawyers) in an ongoing effort to address a variety of issues including large landscape conservation and oil and gas drilling on public lands.

By expanding participation to a broader base of stakeholders, collaboration is thought to improve the diversity and flow of critical information to solve place-based problems; to mobilize greater resources and expertise; to improve engagement and interest in stewardship on behalf of citizens; and to mitigate conflict and increase likelihood of acceptance regarding decisions on contentious resource issues. Collaborative governance and management approaches are also normatively popular concepts and proponents point to its potential for improving the equity and quality of decision-making and for strengthening civil society, particularly when participation involves private citizens. The UCREFRP case is larger in scale than many “grassroots” examples of collaboration, and it is also more formal due to the fact that there are clear lines of accountability drawn by the need to comply with the Endangered Species Act. In this case, proponents of collaboration might point to the UCREFRP as a preferable alternative to costly and divisive and to its potential for improving information sharing and trust among diverse water users and water providers.

What do Collaboratives do?

Collaboratives may undertake different functions, depending on the nature of the issue they are addressing, the resources available to the group, and the degree of autonomy or authority the initiative enjoys with regard to the resource.

Some authors have developed very broad typologies to infer the ‘function’ that a collaborative initiative serves, such as *action, coordination*, or *policy*, though this is so broad that it is unhelpful. More helpful typologies have grouped initiatives’ strategies by their institutional level of arrangements, with strategies such as monitoring, education, or restoration projects occurring at the operational (e.g. management) level; coordinating policies or programs at the collective level; and deliberation on and development of rules, regulations, and policies at the constitutional level. In a discussion of classifying forest collaboratives, Cheng & Sturtevant (2012) summarize eight process functions (situation assessment, goal setting, developing options, analyzing consequences, selecting preferred options, implementing, monitoring, and evaluating outcomes) and six collaborative attributes (structuring, governing and administering the group; securing participants' commitment; managing conflict; forging agreements; developing norms of trust and reciprocity; and attaining outcomes), all of which could be useful codes for interpreting the variety of strategies, actions, and outputs. In an analysis of a large sample of watershed groups, Koontz and Johnson (2004) identified 13 types of strategies, which they refer to as accomplishments, consisting of initiative development and maintenance; education and outreach; elevated public awareness; networking; developing plans; changes to existing policy; influencing policy (through advocacy); land acquisition; restoration projects; research, monitoring; issue identification and prioritization; designation of protected resources; and changes to land use practice.

Critiques of Collaboration

Collaboration has its detractors. The investment of time and capital required to undertake collaborative partnerships is high, and such cross-boundary power sharing compromises are prone to conflict and contestation. As such, collaborative governance and management examples have been scrutinized in the literature in an effort to determine whether, when, and how it works. A common refrain from both proponents and detractors is that there is still uncertainty about its outcomes due to a lack of consistent reporting and systematic measurement in order to support or refute claims about its effectiveness; *particularly* the relative effectiveness of policy interventions that incorporate collaboration contrasted with other approaches.

Some critics have pointed out the flaws of consensus-based approaches to conservation (e.g. reinforcement of the status quo and legitimization of entrenched power relationships), arguing instead for a participatory decision-making model rooted in argumentation and debate. Some critics express concerns that all too often social and ecological objectives cannot be reconciled and that a shotgun marriage between the two is unlikely to achieve desired results for either. They express skepticism regarding the feasibility of jointly addressing the needs of people and the environment at the same time. A poignant critique brings up the negative consequences of promoting win-win scenarios without adequately acknowledging the inevitable trade-offs between human well-being and ecological well-being. Complicated power dynamics are difficult to overcome and may prevent key stakeholders from participating, particularly those who have little power to begin with and much to lose from ceding that power in a collaborative process.

Advocacy groups for environmental causes are sometimes among those with much to lose. The Endangered Species Act (ESA) is an important federal prescriptive regulation for protecting biodiversity as a public good; enforcement of ESA takes shape through litigation and court cases, especially citizen suits brought by environmental groups (more information about ESA is provided the detailed lecture 1.2 notes, below). Environmental groups may be less inclined to participate in a collaborative initiative if they feel it erodes their ability to influence enforcement of ESA. While it is not known whether this has been an issue in the UCREFRP case, the important role played by the U.S. Fish and Wildlife Service (one of two federal agencies enabled to enforce ESA), and the alignment of goals between the UCREFRP and the USFWS would suggest that the interests of the four species of endangered fish are adequately represented. The social dynamics of collaborative governance, are complex, however, and this assumptions is explored in greater detail in subsequent modules of this case study.

Why evaluate collaboration?

- Evaluation typically involves comparing *actual* project or program outcomes with *desired* goals/objectives or outcomes.
- Measure success-buy-in from stakeholders-engage more participation in the project and process, funding support, buy-in from decision-makers
- Even its hardcore proponents recognize that effective evaluation can help determine whether and why collaboration is effective, in part to address critiques and in part to further institutionalize this governance approach.

Challenges

- Ecological trends or long term socioeconomic outcomes can be difficult to measure due to lack of baseline data, and/or lack of long-term monitoring programs that allow reliable comparisons over time between cases.
- Hard to make causal links between specific management activities and trends because it may be difficult to determine which variables caused the outcome (problem of attribution).
- Some variables are difficult to measure

The literature is rife with examples of why it is difficult to assess performance of collaborative governance and management interventions. Spatial and temporal scale pose great challenges, not the least of which is the plurality of perspectives and objectives that could be brought into the fold of consideration. Further, some goals undertaken by collaborative initiatives are not easily measured. While the need for long-term outcomes (especially environmental outcomes) and attention to slow variables is constantly advocated, the budget allocated to evaluation rarely accommodates longitudinal research designs. With long-term data lacking and expensive to obtain, most evaluations still focus on short-term or process indicators because they are more feasible to measure given the combination of 1) limited time and resources and 2) the priority placed on community-defined measures of success, which tend to be shorter term and exclusive of external stakeholders. It is also difficult to isolate variables and establish causality, and there is a high likelihood of biophysical, political and socio-economic shifts affecting longitudinal impacts and confounding attribution. In order to be contextually relevant, there must be ample and sensitive criteria and indicators; however the contextual nature of existing case studies makes them difficult to compare and scale up. M&E strategies often fail to recognize or account for the multiple or unintended outcomes and impacts that can result from an intervention, which may emanate from overly rigid evaluative techniques that are not well equipped to deal with emergent phenomena, such as the critique of logic models. In many cases, outcomes may be intangible or may go unreported, such as the strengthening of civil society resulting from the participatory process. Causal factors are difficult if not impossible to determine because of the "inverse relationship between the complexity of systems and our ability to make significant statements about their behavior" (Campbell et al., 2001, p. 4). Plummer and Armitage (2007) lament that contemporary evaluative techniques still languish in a modernist paradigm ill-suited for analysis of complex adaptive systems, and call for a complete overhaul of the way we think about evaluation (although the developmental evaluation framework developed by Patton, 2010, begins to address this critique by integrating complexity concepts with an eye toward improving programmatic innovation).

Basics of Evaluation

There are many different evaluation paradigms informed by many different schools of thought, from formative evaluation that takes place early in a program to inform its growth; summative evaluation that takes place at the end of a program or cycle within a program to assess its performance; and developmental evaluation, which is a flexible approach to informing program adaptation and response to uncertainty. Stem, Margoluis, Salafsky, & Brown (2005) present four broad purposes for monitoring and evaluation applied to conservation approaches:

- Basic research: for learning and knowledge gathering to better understand the components and dynamics of a system
- Accounting and certification: determining whether a program or organization is fulfilling its obligations to authoritative stakeholders (i.e. funders, agencies)
- Status assessment: appraising the condition or state of a system or a variable therein (e.g. a species), irrespective of any intervention intended to influence that variable
- Effectiveness measurement: linking appraisal of the system variable(s) to the discrete intervention designed and implemented to affect it, and making normative judgments about that intervention based on specific criteria. This kind of evaluation might happen before and/or after the implementation takes place (e.g. impact assessment), or it might be an iterative process of adaptive learning from adjustments and feedbacks (e.g. adaptive management).

M&E approaches outline the steps involved in undertaking M&E in a particular scenario (i.e. *how* is the intervention to be evaluated), whereas evaluative frameworks represent the processes and outcomes to be considered as part of an evaluation (that is, *what* is to be evaluated).

In accordance with its historical emergence from the gridlock of environmental regulation and litigation in the 1990s, early assessment of collaborative conservation focused on costs, efficiency, fairness, innovation and longevity relative to litigation (the assumption being that collaboration was preferable to litigation). More recently, typical evaluands include aspects of process such as inclusiveness of representation and decision-making methods, and outcomes. Thomas and Koontz (2011) argue for the application of logic modelling as an evaluative framework for assessing community based natural resource management, which includes assessment of a) inputs (such as human, financial and technical resources contributed by partnership members, external donors, or public officials); b) processes (which they equate with activities and workload, like preparing plans); c) intermediate outputs (the early products and services resulting from the process, like completed plans); d) end outputs (the final deliverables and products, like implemented projects proposed by the plan, or compliance monitoring); e) intermediate outcomes: indications of changes happening outside the process that may precede the ultimate desired outcome; and f) end outcomes (the ultimate goal for change that the initiative emerged to address). Logic models are intuitive and easily compartmentalized; however, they are sometimes criticized as overly reductive and weighted towards outcomes, which can miss some of the value of ‘getting there’, i.e. the process. As Innes and Booher (1999) emphasize, collaborative endeavors are not just about producing plans and coming to consensus, they are also potentially valuable as venues for multi-loop learning, experimentation and innovation, and change. Emerson & Nabatchi (2015) differentiate evaluation approaches for assessing *process performance* (that is, the extent to which the process used for collaboration achieves desired or unexpected outcomes) and *productivity performance* (pertaining to the actions undertaken through collaboration, their outcomes, and the adaptations the initiative experiences throughout its tenure). However, they emphasize that, in order to understand the overall picture of collaborative performance, it’s important to assess both process and productivity variables (and their interactions).

Emerson and Nabatchi (2015) elaborate an evaluative framework for the *productivity* collaborative initiatives. Here they develop a rather sophisticated *summative* evaluation framework that describes performance parameters at the three levels of productivity: **actions** and **outputs**, **outcomes**, and

adaptation (a kind of impact). They further differentiate between three nested units of analysis that describe a collaborative initiative: that of the **participating organization** (like one of its participating agencies or non-profits); the **collaborative initiative** itself; and the **target goals** of the initiative. That is, they suggest the evaluator be explicit about whether they are trying to assess what the participating entities are getting out of their involvement in a collaborative, what the initiative itself is achieving as a whole, and whether and what directional change is being experienced by the target of the initiative's goals (which may be social or ecological). I find this last unit of analysis, the target goals, most appropriate to frame social and ecological outcomes, since many authors insist that collaboration cannot be evaluated without reference to its goals.

Target goals refer to the public problem, condition, service or resource that is the focus of the collaborative effort-- perhaps a common pool or public goods problem, which are often at the root of collaborative governance initiatives (CGRs). One criterion that could be used to assess this parameter is the **equity of actions**, that is: to what extent do the *beneficiaries* of the targeted change feel that the distribution of costs, benefits, and risks is fair? This might take the form of access to a resource, or the geographic distribution of benefits, and thus requires establishing who the beneficiaries of the target goal are, and what that net benefit is anticipated or intended to be. You might capture this through documented reports and other data sources of where certain activities take place, perhaps in terms of schools targeted for education and outreach activities-- are they only hitting the affluent schools or the schools where kids of the collaborators' kids go to school? How much are they investing in different actions associated with different beneficiaries? If you could find them, you might ask the intended beneficiaries directly for their perception of the distribution of benefits, of CGR actions; or (less ideally but perhaps more feasibly), you might ask the collaborators to report their own perceptions. These are all examples of social aspects of the criterion, but it could also be used to assess **ecological** aspects; for example, I have thought it would be cool to look at the distribution of implemented projects of a collaborative and assess the degree to which it appears they were being strategic (i.e. attempting to take advantage of pre-existing treatments or make an impact at a landscape level).

Effectiveness of outcomes is another criterion that might be explored at this unit of analysis, that is, "the extent to which the CGR's actions produce their intended effect in accomplishing its target goals" (Emerson & Nabatchi, 2015, p. 732). This might be captured directly as immediate outcomes in directional changes, or indirectly as intermediate outcomes, measured as changes in conditions that should reduce the future severity or incidence of the problem, or increase the likelihood that improvements will happen down the road.

Finally, under certain circumstances, one might have the opportunity to ascertain the extent to which change has been accomplished by assessing the adaptive capacity of the social or ecological system (as bounded by the goals of the CGR) before and after a change of some sort. Thus as a watershed coordinator, you might gather as much baseline data as pertains to the interventions your watershed group is undertaking, knowing that someday down the road another flood will happen, at which point you may be able to achieve what Conley and Moote (2003) refer to as "the Holy Grail for many," that is, "an evaluation showing that collaborative efforts improve" both social and ecological system health (p. 380).

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Innes, J. E., & Booher, D. E. (1999). Consensus Building and Complex Adaptive Systems. Journal of the American Planning Association, 65(4), 412–423. http://doi.org/10.1080/01944369908976071

Koontz, T. M., & Johnson, E. M. (2004). One Size Does Not Fit All: Matching breadth of stakeholder participation to watershed group accomplishments. Policy Sciences, 37(2), 185–204. http://doi.org/10.1023/B:OLIC.0000048532.94150.07

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Thomas, C., & Koontz, T. (2011). Research Designs for Evaluating the Impact of Community-Based Management on Natural Resource Conservation. Journal of Natural Resources Policy Research, 3(2), 97–111. http://doi.org/10.1080/19390459.2011.557877

Stem, C., Margoluis, R., Salafsky, N., & Brown, M. (2005). Monitoring and Evaluation in Conservation: a Review of Trends and Approaches. Conservation Biology, 19(2), 295–309. http://doi.org/10.1111/j.1523-1739.2005.00594.x

Session 2.2: Participatory development of assessment indicators

Table 6. Overview of Module 2, Session 2.2

<table>
<tr><td colspan="4">Learning Goal 1: Critical analysis of natural resource collaborative processes for both ecological and social outcomes; Exposure to diverse values, ways of knowing and experiences; Development of applied negotiation and collaboration skills</td></tr>
<tr>
<td>Session 2.2:

Participatory development of assessment indicators

1 hour, 30 min</td>
<td>1. Prepare, present, and defend a stakeholder position, acknowledging the importance of stakeholder dialogue and tradeoffs of management alternatives.</td>
<td>1. Group preparation for Scenario Activity (15 min)
2. Activity 2B: participatory development of assessment indicators scenario (60 min)
3. Small group and facilitated class discussion/debrief on process (15 min)</td>
<td>SLOs:
1. Student groups will understand conceptually and practice collaborative participant buy-in to indicators as buy-in to collaborative outcomes
2. Students take on role of one stakeholder and identifying which indicators are most relevant to their stakeholder’s values and interests. Roles include farmer, rancher, water manager, state water administrator, USFS, BLM

Assessment:

Comprehension and depth of understanding will be collectively assessed during the scenario debrief. A reflection assignment will be turned in the following class session.</td>
</tr>
</table>

<u>Preparation Materials</u>

Students should have researched their scenario role following the handout instructions (see Session 2.2, Activity 2.B Handout)

<u>Lesson Plan</u>

- Group preparation for Activity 2.B (15 min)
    - Students with the same stakeholder roles (i.e. ranchers, USFW, USBR) will meet together to discuss their roles, values, interests, and preferred assessment indicators.
        - What are the primary goals, interests and values held by the stakeholder’s entity/organization?

  - What role does the entity play in the UCREFRP on the Colorado subbasin? What skills and/or resources do you contribute to the collaborative?
  - How has the entity historically participated in administration, management, or governance of the subbasin?
  - Based on the answers to the above questions, what are your preferred assessment indicators? (That is, what would you expect the entity's preferred assessment indicators might be?)
  - Which other stakeholders might you align with? Which might challenge your preferred assessment indicators?
- Activity 2.B: Participatory Development of Assessment Indicators Scenario (see Box 5 for detailed activity notes; 60 min)
- Small group and facilitated class discussion/debrief on process (15 min)

Activities

2.B Participatory Development of Assessment Indicators Scenario Activity *(See Session 2.2, Activity 2.B handout, "Participatory Development of Assessment Indicators" and instructor's version in Box 5 detailed activity notes)*

Students should come to class having researched a participant in the UCREFRP and prepared to participate in redefining assessment indicators to include as next steps in the Species Status Assessment to FWS. First, they will break out into groups of synonymous stakeholders to share their research and information on the affiliated entity, their interests, values, and preferred assessment indicators.

Then, UCREFRP's diverse stakeholders will meet to decide together what to evaluate, or assess, using a facilitated collaborative and inclusive process. Stakeholders will use data, facts, and a professional attitude. The goal is to collaboratively negotiate assessment indicators by identifying criteria and indicators that can be used to measure progress toward goals & possible outcomes.

At the end of negotiations, break students out into small reflection groups and have them discuss any combination of these questions and then share back to the larger group (see debrief questions in Box 5).

Class Materials

See Session 2.2 handout, "Participatory Development of Assessment Indicators"

Homework

Reflection assignment (also see Box 5 activity notes below): Students will respond to the following reflection questions after the in-class participatory development of assessment indicators scenario in the form of a short (6 - 8 paragraph) essay in which they address the following:

- Briefly summarize what happened in the scenario.
- Recommend potential approaches to improve on participatory assessment processes and support your suggestions with peer-reviewed research.

- Reflect on what you learned about assessment of ESA motivated collaborative projects and more generally about collaborative natural resource governance from participating in the scenario. What more do you want to learn?

Conceptual Readings: (note: due to the number of readings and the transition in topics, we suggest the instructor skip a class session before beginning Module 3)

For students
Creswell, John W., and Dana L. Miller. "Determining validity in qualitative inquiry." *Theory into practice* 39, no. 3 (2000): 124-130. Stable URL: http://www.jstor.org/stable/1477543

Jonsen, Karsten, and Karen A. Jehn. "Using triangulation to validate themes in qualitative studies." *Qualitative Research in Organizations and Management: An International Journal* 4, no. 2 (2009): 123-150. http://dx.doi.org/10.1108/17465640910978391

Krauss, S. E. (2005). Research paradigms and meaning making: A primer. The Qualitative Report, 10(4), 758-770. Retrieved from http://www.nova.edu/ssss/QR/QR10-4/krauss.pdf

Eigenbrode, S.D., O'rourke, M., Wulfhorst, J.D., Althoff, D.M., Goldberg, C.S., Merrill, K., Morse, W., Nielsen-Pincus, M., Stephens, J., Winowiecki, L. and Bosque-Pérez, N.A., 2007. Employing philosophical dialogue in collaborative science. *BioScience*, *57*(1), pp.55-64. http://dx.doi.org/10.1641/B570109.

Cote, Muriel, and Andrea J. Nightingale. 2012. "Resilience Thinking Meets Social Theory: Situating Social Change in Socio-Ecological Systems (SES) Research." Progress in Human Geography 36 (4): 475–89. DOI: https://doi.org/10.1177/0309132511425708.

For instructors
Note: Find books listed below at a university or public library

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry.* Thousand Oaks, CA: Sage.

Lofland, J., & Lofland, L. (1996). *Analyzing social settings (3rd ed.).* Belmont, CA: Wadsworth.

Guba, E. G., & Lincoln, Y. S. (1994). *Competing paradigms in qualitative research.* In K. Denzin & Y. S. Lincoln (Eds.), Handbook of qualitative research (pp. 105-117). Thousand Oaks, CA: Sage.

Box 5. Module 2 Session 2.2 Detailed Activity Notes for Instructors

Activity 2B: Participatory Development of Assessment Indicators
Scenario Activity: Instructor's Version

Goals:

- Student groups will understand conceptually and practice collaborative participant buy-in to indicators as buy-in to collaborative outcomes
- Students take on role of one stakeholder and identifying which indicators are most relevant to their stakeholder's values and interests. Roles include farmer, rancher, water manager, state water administrator, USFS, BLM
- Identify diversity of resource users, their values and interests
- Prepare, present, and defend a stakeholder position, acknowledging the importance of stakeholder dialogue and tradeoffs of management alternatives

Class before the scenario:

- 5 minutes: Introduce the scenario and hand out roles or have students sign up (See Module 2, Session 2.2, supplemental handout). Ask them to get into groups of people with similar roles

Scenario Day:

- 15-20 minutes: Students with the same stakeholder roles (i.e. USFWS, farmers, ranchers, Colorado Division of Water Resources) will meet together to discuss their interests and preferred assessment indicators. Decide what your objective is for the meeting (what do you want to walk out with) but also what your essential needs are that must be met. Where might you be willing to compromise? Consider what is your best alternative if an agreement is not reached among all stakeholders? Is there a different way that your needs can be met?
- They can answer these questions more specifically:
    - Students with the same stakeholder roles (i.e. ranchers, USFW, USBR) will meet together to discuss their roles, values, interests, and preferred assessment indicators.
    - What are the primary goals, interests and values held by the stakeholder's entity/organization?
    - What role does the entity play in the UCREFRP on the Colorado subbasin? What skills and/or resources do you contribute to the collaborative?
    - How has the entity historically participated in administration, management, or governance of the subbasin?
    - Based on the answers to the above questions, what are your preferred assessment indicators?
    - Which other stakeholders might you align with? Which might challenge your preferred assessment indicators?

- 60 minutes: Multi-stakeholder groups meet to discuss and negotiate with the goal of reaching an agreement that meets all stakeholders' needs. Specifically, during this time your goal as a

group is to 1) identify and understand the differing interests of different stakeholders, 2) identify overlapping and common values and interests among all stakeholders, and 3) identify potential opportunities for meeting achieving a win-win agreement that meets everyone's needs.
- 15 minutes: Debrief

In Class Debrief

- So what happened here?
- What positions were at odds with each other?
- What were the main issues in this negotiation?
- Although the positions differed, were there any underlying common values or interests that the stakeholder could agree on?
- Who held the most power in this negotiation? What was the source of their power?
- Who held the least power and why?
- How did these differences in power affect the discussion?
- What can a facilitator do to reduce differences in power and put participants on more equal footing?
- Were there any key stakeholders missing from this discussion? If so, who? What might be the consequences of not having them "in the room"?
- What aspects of this situation necessitated collaboration?
- Which dimensions of the discussion were the most controversial amongst stakeholders: economic, social, or ecological?
- What would the outcome have been if one party had been given sole decision-making authority?
- What was the biggest challenge in the process of collaborating and why?
- What outcomes were only possible through collaboration and why?
- Do you think collaboration and compromise are more likely or less likely with the intervention of the federal government and the ESA ruling? Explain why or why not in this social and environmental context.
- Reflect upon the essential aspects of successful participatory assessments.

Optional Modifications:

- Depending on class size and preference, you could leave out one of the environmental group stakeholders

"Participatory evaluations driven by collaborative efforts themselves are needed to determine progress toward goals, provide feedback to guide future actions, and identify larger scale issues that impact specific efforts...can play an important role in illuminating these larger scale issues and are best used to address specific questions with broad import for policy-making and management" (Conley and Moote, 2003).

Introduction (*recaps some previously highlighted material*)

UCREFRP began collaborative negotiations between diverse user groups in 1988 after over a decade of failed litigation cases reacting to the implementation of the Endangered Species Act in the Colorado

River Basin. The Act was amended to direct Federal Agencies to work with State and local agencies to resolve water resource issues in concert with conservation of endangered species. In 1984, the Department of the Interior, Colorado, Wyoming, Utah, water users, and environmental groups formed a coordinating committee to discuss a process to recover the endangered fishes while new and existing water development proceeds in the Upper Colorado River Basin in compliance with Federal and State law and interstate compacts. After 4 years of negotiations, the UCREFRP was developed.

The participants on the Colorado subbasin, from its headwaters in Rocky Mountain National Park to Grand Junction, Colorado have focused their energies on meeting target habitat flows set by the U.S. Fish and Wildlife Service for a critical river segment called the 15-Mile Reach. This segment is located downstream of several large diversions contributing to extremely low water during late summer and early fall, creating a reduction of off-channel, quiet pikeminnow spawning habitat. In addition, the building of dams and reservoirs, alteration of water flow patterns, introduction of non-native species, diversion of water for irrigation and urban purposes, and destruction of plant life along river banks has affected the habitat and reproductive success of the rare Colorado pikeminnow.

As the group approaches three decades of collaborative governance on the mainstem in Colorado, the population of adult Colorado pikeminnow in the Colorado River subbasin averages 612 individuals (1992 – 2014). The current USFWS criteria for downlisting this population is >700. Flows are managed in the subbasin to benefit all life stages of the pikeminnow, the product of a weekly management phone call where participant make decisions about how much water will flow in every tributary and the mainstem itself (Best 2016). This weekly management call includes federal and state agency representatives, environmental groups and irrigators drawing approximately 80 percent of the river's flow to irrigate 70,000 acres of peaches, pears and corn, but also alfalfa, winter wheat and exurban lawns, and in recent years, vineyards. In addition to water development continuing, fish passage is provided at all major migration barriers and the species is self-sustaining (not stocked). However, after more than 30 years, the pikeminnow populations are not eligible for downlisting.

UCREFRP participants in the Colorado subbasin are working with the U.S. Fish and Wildlife Service (FWS) to produce a Species Status Assessment which will assist in revision of the recovery plan and inform the Service on the status of the species and potential reclassification.

As a participant in the UCREFRP, you are being asked to participate in redefining assessment indicators to include as next steps in the Species Status Assessment to FWS. The UCREFRP's diverse stakeholders will meet to decide together what to evaluate, or assess, using a collaborative and inclusive process.

Process: Participatory development of assessment indicators

You will take on the role of one stakeholder, which you will research extensively before representing their interests and preferred assessment indicators at the planning meeting for the Species Status Assessment Report. Your goal is to collaboratively negotiate assessment indicators by identifying criteria and indicators that can be used to measure progress toward goals & possible outcomes. As a stakeholder, you will use data, facts, and a professional attitude. The resources provided for you below will help you as you develop your preferred assessment indicators. Feel free to research beyond these resources and to use resources from previous modules to define the most relevant indicators for your stakeholder role. Roles include farmer, rancher, water manager from the Colorado River District, state water administrator from the Colorado Division of Water Resources, FWS, The Nature Conservancy, and facilitator. Come to class prepared to play the role of your stakeholder—"in character."

Stakeholder Instructions

A. Farmer: Congratulations! You are a farmer. Your family has lived in Garfield County for the last four generations. You have some of the oldest water rights in region dating back to the late 1800's and use water to grow alfalfa, wheat, hay and onions. Your water rights are very valuable and you aren't sure if your son will take over the farming operations after you retire.

B. Rancher: Congratulations! You are part of a family that has been ranching in Mesa County for four generations. You own some of the oldest water rights in the county and plan to pass them on to your son once he graduates from college and takes over the family ranching operations. In addition to the 500 head calf/cattle operation, you irrigate 1200 acres and raise a lot of alfalfa, hay, and some small grains, barley and oats.

C. Water manager at the Colorado River District: Congratulations! You play a very important role in managing the storage, timed release, and flows on Colorado subbasin. You are the one with "the finger on the button" to release water based on the needs expressed in the weekly HUP call.

D. State water administrator from the Colorado Division of Water Resources: Congratulations! You play the crucial role of administering the state's water rights. Your authority is to regulate and distribute in accordance with the statutes and the priorities of the decreed water rights. It is your job to make sure water users follow the rules and regulations of the state's system of prior appropriation.

E. U.S. Fish and Wildlife Service (FWS): Congratulations! You are part of the federal agency that initiated the UCREFRP. Under the ESA, FWS is given the responsibility to issue jeopardy opinions, designate critical habitat, and promote the recovery of the Colorado pikeminnow. The FWS has the ultimate responsibility to decide whether or not the program is working, in the sense that the fish are recovering in the Colorado River and negative depletion impacts are being offset.

F. The Nature Conservancy Deputy Director, Colorado River Program: Congratulations! You are involved to ensure that the rare pikeminnow is recovered. Your main complaint is the huge amount of time progress towards that end is taking. Also you are hesitant when it comes to trust or faith in such a large bureaucratic project run by the FWS.

G. Western Resource Advocates Healthy Rivers Program Director: Congratulations! You are involved to ensure that the rare pikeminnow is recovered. Your main complaint is the huge amount of time progress towards that end is taking. Also you are hesitant when it comes to trust or faith in such a large bureaucratic project run by the FWS.

H. U.S. Bureau of Reclamation: Congratulations! You play the important role of funding parts of the UCREFRP through power revenues and other sources. Your agency has a long history of water development in the West. Take some time to research that history as well as your role in the UCREFRP.

I. Facilitator: Congratulations! You get to facilitate the development of assessment indicators amongst a diverse group of stakeholders. As the neutral third party facilitator in this discussion you have no vested interest in any particular outcome. You are part of a local private environmental mediation practice and were hired by the US Bureau of Reclamation. Your charge is to help stakeholders understand each other's perspectives and interests, thereby finding common ground, and identifying potential opportunities for collaboration and "mutual gains" solutions—agreements that benefit everyone, or at least leave no one worse off. To prepare for the scenario, consider how you will manage the dialog among the stakeholder in your group. You may want to propose some ground rules for interaction, for example.

Consider the following questions to prepare for your stakeholder role:

1. What are the primary goals, interests and values held by the stakeholder's entity/organization?
2. What role does the entity play in the UCREFRP on the Colorado subbasin? What skills and/or resources do you contribute to the collaborative?
3. How has the entity historically participated in administration, management, or governance of the subbasin?
4. Based on the answers to the above questions, what are your preferred assessment indicators?
5. Which other stakeholders might you align with? Which might challenge your preferred assessment indicators?

References and Resources

Use these links and articles to research your role and that of your agency, organization or affiliated group. They will also be helpful in responding to the above questions.

Articles:

Best, Allen. 2016. "Phoning for Flows." *Colorado Foundation for Water Education Magazine*. https://www.yourwatercolorado.org/index.php?option=com_content&view=article&id=475:phoning-for-flows&catid=122.

Brower, Ann, Chanel Reedy, and Jennifer Yelin-kefer. 2001. "Consensus versus Conservation in the Upper Colorado River Basin Recovery Implementation Program." *Society for Conservation Biology* 15 (4): 1001–7. DOI: 10.1046/j.1523-1739.2001.0150041001.

Hopfl, Karen. 1994. "Case Study of the Endangered Fish Recovery Program of the Upper Colorado River." Boulder, CO.

Loomis, J, and J Ballweber. 2012. "A Policy Analysis of the Collaborative Upper Colorado River Basin Endangered Fish Recovery Program: Cost Savings or Cost Shifting?" *Natural Resources Journal* 52 (2): 337–62. <Go to ISI>://WOS:000313388200004.

Mueller, Gordon. 2005. "Predatory Fish Removal and Native Fish Recovery in the Colorado River Mainstem." *Fisheries* 30 (9): 19–26. doi:10.1577/1548-8446(2005)30.

Tyus, Harold M., and James F. Saunders. 2000. "Nonnative Fish Control and Endangered Fish Recovery: Lessons from the Colorado River." *Fisheries* 25 (9): 17–24. doi:10.1577/1548-8446(2000)025<0017:NFCAEF>2.0.CO;2.

Websites:

Upper Colorado Endangered Fish Recovery Program Website: http://www.coloradoriverrecovery.org/index.html.

Program Documents and Publications: http://www.coloradoriverrecovery.org/documents-publications/documents-publications.html.

Links to Stakeholder's Websites: http://www.coloradoriverrecovery.org/links/links.html.

Colorado's Division of Water Resources: http://water.state.co.us/Home/Pages/default.aspx.

Quartarone, Fred. 1995. "**Historical Accounts of Upper Colorado River Basin Endangered Fish**." http://www.coloradoriverrecovery.org/general-information/general-publications/Historicalaccounts.pdf.

Assignment

Respond to these reflections questions after the in-class participatory development of assessment indicators scenario in the form of a short (6 - 8 paragraph) essay.

1. Briefly summarize what happened in the scenario.
2. Recommend potential approaches to improve on participatory assessment processes and support your suggestions with peer-reviewed research.
3. Reflect on what you learned about assessment of ESA motivated collaborative projects and more generally about collaborative natural resource governance from participating in the scenario. What more do you want to learn?

Collaborative Water Governance and Social-Hydrological Justice:

The Case of the Upper Colorado River Endangered Fish Recovery Program

Teaching Notes

Module 3
Understanding Research Paradigms, Bathing in Qualitative Methods

Understanding Research Paradigms, Bathing in Qualitative Methods

Module Overview

In this module, socio-ecological systems (SES) is used as a proxy for analysis of socio-hydrological systems (SHS). The purpose of this module is for students to a) think critically about the application of SES in analyzing collaborative governance by engaging in SES from a social science perspective, b) understand and relate integral concepts for research design (epistemology, ontology, research paradigms, research methods and methodologies), c) determine suitable research methods given a research paradigm or question, d) develop the capacity to engage in qualitative data analysis. Students will focus in on the driving social processes while recognizing that the 'social' in SES frameworks needs more fine-tune analysis and nuance than it is typically given.

Session 3.1: Social science perspective on socio-ecological complexity

In this session, students will contemplate different approaches to knowledge and science. They will also learn how to better incorporate social science paradigms into their understanding and use of socio-ecological systems thinking. The session consists of one lecture and one small group activity focused on what students should keep in mind as they make decisions about how to design socio-ecological research studies. It builds on Modules 1 and 2 by encouraging students to think about the importance of incorporating participant's perceptions of the UCREFRP's efforts and objectives into the assessment of the collaborative. Furthermore, it helps them begin to understand how to do so.

Table 7. Overview of Module 3, Session 3.1

<table>
<tr><td colspan="4">Learning Goal: Learn different ways of doing science and how to integrate a naturalist philosophy into interdisciplinary research agendas. Conceptualize how to use a naturalist philosophy to account for social complexity in SES.</td></tr>
<tr><td></td><td>Learning Objectives</td><td>Activities</td><td>Student Learning Outcomes and Assessment</td></tr>
<tr><td>Session 3.1:

A social science perspective on socio-ecological complexity

2 hours</td><td>1. Explore underlying epistemology, ontology, research paradigms as shaping how we do research/science
2. Recognize, utilize and analyze data from diverse research paradigms with a focus on naturalist-based methodologies</td><td>1. Lecture 3.1: Social critique of SES (15 min)

2. Activity 3.A: Invitation - Toolkit activity (35 min)

3. Lecture 3.2: Introduces students to relationships between epistemology, ontology, research paradigms, and methodologies (45 min)

4. Activity 3.B Research paradigm group activity (25 min)</td><td>SLOs:
1. Students will be able to critique SES approach from a social science perspective
2. Students will be able to identify the relationships between epistemology, ontology, research paradigms, research methods and methodologies
3. Students will be able to apply knowledge of these relationships to process of research design
4. Students will experience determining suitable research methods given a research paradigm or question

Assessment:

Responses to Toolkit Activity

Small in-class group activity: Students provided a research question and must discuss appropriate research paradigm and methodology for answering research question</td></tr>
</table>

Preparation Materials

Conceptual readings for students and instructors

See Homework Readings for Module 2, Session 2.2

Lesson Plan

- Lecture 3.1: Social critique of SES (see Box 6 for detailed lecture notes; 15 min)
    - Examines social critique of SES including:
        - Over simplifying conceptualizations of the social world that conceptualize institutions as coordinating mechanisms sustaining equilibrium, missing subtle changes and dynamic flexibilities
        - Overly generalizing onto diverse cultural contexts
        - Heterogeneous social networks of relations that shape management practices
        - Avoidance of politics and power relations
        - Over-emphasis on formal legal institutions and mechanisms
    - Start to think about how to address social complexity in socio-ecological systems
- Activity 3.A: Invitation - Toolkit Activity (45 min total)
    - Pairs interview each other, 10 minutes each person (20 min)
    - Reflection questions in groups of four (10 min)
        - What was the experience of the interviewer and respondent? Could you actively listen? How?
        - What underlying assumptions about science and research did the respondents have? Where did these assumptions come from?
        - What kind of knowledge is valid?
    - Class Discussion (15 min)
      Arrive at importance of understanding epistemologies and research paradigms:
      They influence the questions we ask, what is important to study, what can be known, and standards we use to judge validity
- Lecture 3.2: Addressing Social Complexity in SES: Qualitative methods and research paradigms (see Box 6 for detailed lecture notes; 35 min)
    - Introduces students to qualitative research methodologies to address social complexity
    - Examines relationships between epistemology, ontology, research paradigms, and methodologies
    - At the end of this lecture, students will engage in a small group activity developed to help them think about important considerations in designing research.
- Activity 3B: Research paradigm group activity (25 min)
    - The activity is designed in a way that encourages students to think about the importance of incorporating participant’s perceptions of the UCREFRP’s efforts and objectives into the assessment of the collaborative.
    - The small group activity can begin during class if there is time. Otherwise, the activity can be a group homework assignment.

Activities

3.A Invitation: Toolkit Activity *(Also see Session 3.1 Activity 3.A Handout)*

This activity is an introduction to the concepts of epistemology, ontology and the beginnings of thinking about research paradigms, research methods and methodologies. Students will pair up and interview each other for 10 minutes each using the questions in the toolkit activity (see in-class handout). If students do not have experience with research, 'science' can replace 'research' throughout the toolbox questions. The interview questions prompt students to start to recognize and think about different types of knowledge, worldviews, and ways of doing science. It is a precursor to practicing qualitative interview coding, softly setting the stage for thinking about naturalist and positivist research paradigms. Following the interviews, groups of 4 will reflect on the process of interviewing as well as the content of the responses. We will then funnel into a class discussion.

Reflection Questions:

- What was the experience of the interviewer and respondent? Could you actively listen? How?
- What underlying assumptions about science and research did the respondents have?

How might this shape the way the respondent works with other scientists?

3.B Small Group Activity: Considerations for Research Study Designs

Students are provided the following research questions: *What are the UCREFRP stakeholders' perceptions of the collaborative's strategies and goals for reducing threats and stresses to the Colorado pikeminnow? Do participants believe the collaborative outcomes have been or are successful?* Drawing from the lecture, they must answer the following questions related to the research question:

- Epistemology & Ontology: What kind of knowledge is valid? How can we make sense of stakeholder's realities and practices? What research paradigm would be useful for answering this research question (positivist, naturalist, or a combination)? (10 min)
- Methods: Draw up a short research brief containing: (a) the methods you could use (e.g. closed-ended questionnaires, depth-interviews); (b) the scale of your research (e.g. sample size) and (c) the mode of data collection (e.g. face-to-face, by post, by e-mail, by telephone). (10 min)

Questions for Post Activity Discussion

Once the small groups have had the opportunity to respond (whether in class or as homework), they must choose a spokesperson to report back on: (i) how your research brief grew out of your epistemological starting point(s); (ii) any difficulties you faced in agreeing on epistemological and ontological positions in relation to your proposed research; (iii) potential limitations to the research: e.g. in terms of validity, representativeness, etc. Together, the class can then discuss the value of incorporating stakeholder perceptions into program assessment. (15 min)

Activity Modifications

Depending on the course, the instructor should decide how much time is needed to focus on teaching socio-ecological systems and how much time is needed for focusing on the naturalist paradigm and qualitative research methods. An environmental social science class, for example, may need to spend more time on the former, while an ecology class may need to spend more time on the latter. In resources for teachers, there is another PowerPoint that focuses on the different research paradigms. It is important to note the language they use differs slightly than what is used here. That is, ‘interpretivism’ is used instead of the concept ‘naturalist’ paradigms; however, these phrases generally represent the same type of research paradigm.

Class Materials

- Copies of the Session 3.1 Activity 3.A handout, “Toolkit Activity”
- Session 3.1 activity handout “Research Paradigm Small Group Activity: Considerations for Research Study Designs”
- Pen & paper, or digital device

Homework

Finish in-class small group activity 3.B as homework if not completed during class time. Find books in your university or public library or purchase.

Charmaz, K. 2006. “Coding in Grounded Theory Practice.” In *Constructing Grounded Theory: A Practical Guide through Qualitative Coding*, 42–71. London: Sage Publications Ltd.

Read over stakeholder interview excerpts in Module 3 Session 3.2 Handouts “Selected Participant Interview Responses”

Concepts and Tools

Concepts: Socio-ecological Systems (SES) framework; social science critiques of SES framework; epistemology & ontology as drivers of research paradigms, research questions, and research methods; positivist and naturalist research paradigms; quantitative and qualitative methodology and research methods; validity & triangulation in qualitative methodology

Additional Resources for Instructors

Stinchcombe, A.L., 2005. *The logic of social research*. University of Chicago Press. Book Chapter 1: The Nature of Qualitative Research: Development and Perspectives

Box 6. Module 3 Session 3.1 Detailed Lecture Notes for Instructors

The purpose of Lecture 3.1 is to encourage students to begin thinking about how to address social complexity in the social-hydrological system through the incorporation of social science perspectives and methods that are helpful for understanding this complexity. This lecture introduces students to relationships between epistemology, ontology, research paradigms, research methods and methodologies. It also teaches students about ways to conduct qualitative social science research that are relevant for many socio-ecological issues. Students should be able to incorporate social science approaches to studying socio-ecological complexity. They should also learn how to recognize, utilize and analyze data from diverse research paradigms with a focus on naturalist-based methodologies.

Lecture 3.1: A social science perspective on socio-ecological complexity

This lecture builds on what students have begun to learn about the application of a socio-ecological systems (SES) approach to complex environmental problems and collaborative efforts to address them. It provides more detail about SES and its applicability for environmental issues, but it also introduces the students to social science critiques of reliance on an SES framework and the gaps that exist in research and practice when this approach fails to account for diverse and complex social and cultural factors (i.e. power) in understanding and addressing socio-ecological issues.

This lecture then, asks students to think about how we might better incorporate the social sciences and what they offer into the SES framework, to enrich our understanding of the UCREFRP in this case, and collaboratives in general. It prepares students to think about different ways of approaching research and how our approach to knowledge and research translates into the use of different research methods and tools to further our understanding and ability to assess the UCREFRP. It ends by encouraging students to think about how we conduct methodological inquiry, which is the focus of Lecture 3.2.

Lecture 3.2: Addressing social complexity in SES: Qualitative methods and research paradigms

Lecture 3.2 begins by inviting students to think about the underlying assumptions we make in the context of science and research. It asks them to think about those involved in the collaborative, as well as their own assumptions that influence their research being implemented into policy. It introduces students to qualitative methods for data collection and analysis--with a focus on interview data. The lecture also highlights the differences between qualitative and quantitative methods of data collection and analysis--in particular it identifies how the concept of 'validity' is constructed differently in qualitative research methods.

In addition, it pushes students to think about the connection between ontology, epistemology, research paradigms, methodology, and research methods. That is, students should be thinking about how theories of knowledge and reality lead to particular research paradigms and appropriate research tools within the context of those paradigms. In particular, the lecture emphasizes the difference between positivism and naturalism, as they exist on different ends of research paradigm continuum.

Finally, the lecture asks students to engage in an activity where they are asked to discuss epistemology, ontology, and research methods if their critical research questions in the context of the UCREFRP were: "What are the UCREFRP stakeholders perceptions' of the collaborative's strategies and goals for reducing threats and stresses to the Colorado pikeminnow? Do participants believe the collaborative outcomes have been or are successful?" This exercise is an extension of their capacity to take on different perspectives and ways of knowing, a skill they should have begun to develop in the stakeholder roleplay activity in Module 2.

Session 3.2: Concept Invention and Application

Analyzing the UCREFRP collaborative participant perceptions

In this session, students will learn how to qualitatively analyze sociological interview data to better understand stakeholder perceptions of a) the collaborative's strategies for reducing threats and stresses to the Colorado pikeminnow, and b) the collaborative's goals and outcomes. They will also learn how to better synthesize quantitative and qualitative data from diverse sources.

Table 8. Overview of Module 3, Session 3.2

Learning Goal: Use qualitative social science methods to identify and analyze stakeholder perceptions of collaborative governance outcomes			
	Learning Objectives	**Activities**	**Student Learning Outcomes and Assessment**
Session 3.2: Analyzing UCREFRP collaborative participant perceptions 1 hour	1. Conduct qualitative methods of analysis; interview coding 2. Identify stakeholder perceptions from primary data 3. Synthesize quantitative new qualitative data with other diverse data and data sources provided in Module 1	1. Video on stakeholders and brief reflection discussion (10 min) 2. Lecture 3.3: Instructs students on how to code qualitative interviews (10 min) 3. Activity 3.C: Students will begin coding interviews individually and then in pairs using coding sheets (40 min)	**SLOs:** 1. Students will learn how to analyze interview data through the process of qualitative coding 2. From the data analysis, students will learn how to summarize participant perceptions of the collaborative and its assessment 3. Students will learn how to situate findings from interviews with findings from program reports 4. Students will learn how to report and discuss their analysis and synthesis of the data **Assessment:** Students will code interviews and compare the findings from their data analysis to program reports. They will situate these in the context of the concept map from Module 1 by highlighting how different stakeholders understood and perceived the collaborative's strategies for reducing threats and stresses to the Colorado pikeminnow. Students will also

			highlight variability in stakeholders' perceptions of the goals and outcomes of the collaborative's strategies for reducing threats and stresses to the Colorado pikeminnow. Students will report these in a mock "results" and "discussion" section of a research article.

Preparation Materials

Conceptual readings for students

See Homework readings for Module 3, Session 3.1

Case study readings for students

Read over interview excerpts provided in Session 3.2 Activity 3.C Supplemental Handout "Selected Participant Interview Responses"

Lesson Plan

- Video on Grand Valley and the Colorado River: https://vimeo.com/106882559 (10 min)
    - Go over vocabulary prior to video: Irrigation district, U.S. Bureau of Reclamation, etc.
    - 2:17 - 3:41 stakeholders start talking
    - 10:47 - end of history segment
    - 12:06 - overview of current
    - 15:56 recreation segment
    - 19:42 Water future
- Lecture 3.3: Instructs students on how to code qualitative interviews (see Box 7 for detailed lecture notes; 10 min)
- Activity 3C: Coding Activity (50 min)
    - Individually read through interviews and code using codebook (20 min)
    - Work in pairs to discuss how coding, challenges, interesting things (20 min)
    - Answer reflection questions in pairs (10 min)
    - Concluding and pulling the pieces together (15 min)
        - Based on the interview questions, how would you define epistemology?
        - How would you define your epistemology or research paradigm?
        - How does our epistemologies shape the way we work with other scientists? What about how we teach science?

Activities

3.C Coding Activity

Students will begin coding interviews in small groups using coding sheets, focusing on answering the following questions:

- How do interview respondents perceive the UCREFRP and the collaborative strategies and goals for reducing threats and stresses to the Colorado pikeminnow?
- How is this different from the way that program reports define the UCREFRP and its strategies and goals?
- How do participants describe, define, and measure the success of the collaborative's outcomes?
- How does this differ from the way the program reports describe, define, and measure the success of the collaborative's outcomes in Module 1? Students will then report their findings in a 1-2 page mock "results" and "discussion" section of a research article.

Class Materials

- Session 3.2 Activity 3.C. handout "Coding UCREFRP Qualitative Interview Instructions"
- Session 3.2 Activity 3.C Supplemental handout "UCREFRP Selected Participant Interview Responses"
- Session 3.2 Activity 3.C Supplemental handout "Codebook for UCREFRP Interview Coding Activity"
- Session 3.2 Homework handout "Reporting Findings from Coding Exercise"
- Print-offs of Session 3.2 Activity 3.C Supplemental UCERFRP selected interview excerpts for coding
- Highlighters for hand coding, or access to Word for electronic coding/Coding Sheets

Homework

See Session 3.2 Homework handout "Reporting Findings from Coding Exercise" Start/Finish coding activity if not completed during class time; Begin/Complete their 1-2 page "results" and "discussion" report of findings.

Reading for students and instructors

Cheng, T., et al. *Accepted*. "Examining the Influence of Positionality in Evaluating Collaborative Progress in Natural Resource Management: Reflections of an Academic and a Practitioner." Society & Natural Resources (*Publication should be available online spring 2017 through your university library*)

Concepts and Tools

Concepts: Grounded theory data coding and analysis; researcher preconceptions

Tools: Qualitative coding; codebooks for qualitative coding

Additional Resources for Instructors

Note: Find books at your university or public library.

Charmaz, Kathy. Constructing Grounded Theory. Sage, 2014.

Rubin, Herbert J., and Irene S. Rubin. Qualitative interviewing: The art of hearing data. Sage, 2011.

Box 7. Module 3 Session 3.2 Detailed Lecture Notes for Instructors

Lecture 3.3: Qualitative Coding Methods for Identifying UCREFRP Collaborative Participant Perceptions

The final lecture in Module 3 is designed to teach students new skills in conducting qualitative research. The lecture begins by introducing the students to the process of qualitative coding as it is used for analyzing interview data. The lecture briefly defines and describes qualitative coding before moving to an example of qualitative coding of interviews from a disaster research study called "Youth Creating Disaster Recovery." This study provides students with an example of a codebook, which provides definitions for each code that is used in the analysis process. It also shows students what the coding process looks like in a qualitative data analysis software program, Atlas.ti. After walking the students through this example so they can see what it looks like when codes are applied to interview data, the remaining slides provide a deeper description of the process of coding, which includes both do's and dont's in coding, and discusses how to overcome some of the challenges that are a part of the coding process. At the end of the lecture, students will be ready to work on coding interview data from the UCREFRP to uncover different stakeholder perceptions of the collaborative and its goals, outcomes, successes, and failures.

Collaborative Water Governance and Social-Hydrological Justice:

The Case of the Upper Colorado River Endangered Fish Recovery Program

Teaching Notes

Module 4
Synthesizing Social Science and Conservation Conceptualizations of Justice in Collaborative Processes and Evaluation

Synthesizing Social Science and Conservation Conceptualizations of Justice In Collaborative Processes and Evaluation

Module Overview

The purpose of this final module is for students to be able to a) incorporate different types of knowledge in evaluating strategies, goals, and outcomes in collaboratives, and know the value of doing so b) identify relevant cross-disciplinary theories and methods for enhancing UCREFRP strategies, goals, and outcomes and for evaluating the collaborative itself c) communicate notions of justice across disciplinary boundaries, apply them as part of the evaluation of the UCREFRP and d) demonstrate the importance of incorporating justice in future assessments of collaboratives. The students will build on the knowledge they have developed in the first 3 modules, as they apply new knowledge about synthesizing social science and conservationist approaches to the UCREFRP strategies, goals, and outcomes. Students will also re-visit their assessment of the UCREFRP established in Module 2 based on new readings that introduce the students to concepts of environmental and ecological justice. The final product for this module will tie together everything learned in this short course. Students will revise their assessment evaluations of the UCREFRP from Module 2. Within the revisions, students will also move their knowledge beyond the UCREFRP and will include a list of policy recommendations that encourage future collaboratives to embrace a more holistic and equitable socio-ecological approach to planning and evaluating collaborative strategies, goals, and outcomes.

Session 4.1: Synthesizing Social Science and Conservation Conceptualizations of Justice in Collaborative Processes and Evaluation

Table 9. Overview of Module 4, Session 4.1

<table>
<tr><td colspan="4">Learning Goal 1: Identify the value of different knowledge sources and ways of knowing in relation to collaboration, conservation, and environmental governance and apply this to assessment evaluation</td></tr>
<tr><th>Session Title</th><th>Learning Objectives</th><th>Activities</th><th>Student Learning Outcomes and Assessment</th></tr>
<tr><td>Session 4.1:

Synthesizing Social Science and Conservation Conceptualizations of Justice in Collaborative Processes and Evaluation

1 hour, 30 min</td><td>1. Describe the value of different knowledge sources and ways of knowing in relation to collaboratives

2. Identify relevant disciplines and approaches in the context of the UCRERP

3. Communicate notions of justice across disciplinary boundaries and apply them to the UCREFRP and future collaboratives</td><td>1. Invitation: Class-level discussion on positionality (see lecture notes)
2. Lecture 4.1: Introduces students to tensions in how social scientists and conservationists approach socio-ecological relationships. Introduces students to concepts of environmental and ecological justice. Encourages use of multi-criteria assessment and a synthesis of social science and conservationist concerns (could be two 30-45 minute sessions or one 1.5 hour session)
3. Activity 4.A: In-class small group peer-revisions of collaborative evaluation developed in Module 2. Revision suggesting should incorporate knowledge from Modules 3 and 4 as applicable
4. Final assignment: (see assessment)</td><td>SLOs:

1. Students will be able to synthesize divergent considerations of ethics and justice from social science and conservationist perspectives

2. Students will be able to synthesize and apply concepts of environmental and ecological justice to collaborative assessment

Assessment:

Building on previous modules, students will revise their assessment evaluations to incorporate issues of environmental and ecological justice. In revising the evaluation, students will include a list of policy recommendations for developing a more holistic process of assessment.</td></tr>
</table>

Preparation Materials

Conceptual readings for students and teachers

Alrøe, H.F., Byrne, J. and Glover, L., 2006. Organic agriculture and ecological justice: Ethics and practice. *Global development of organic agriculture: Challenges and prospects*, pp.75-112. ****READ PAGES 84-89 ONLY**** http://orgprints.org/3877/1/3877.pdf

Chan, K. and Satterfield, T., 2014. *Justice, equity, and biodiversity* (Doctoral dissertation, University of British Columbia). https://open.library.ubc.ca/cIRcle/collections/facultyresearchandpublications/52383/items/1.0132712

Gerber, J.F., Rodríguez-Labajos, B., Yánez, I., Branco, V., Roman, P., Rosales, L. and Johnson, P., 2012. *Guide to multicriteria evaluation for environmental justice organisations* (No. 8, p. 45). EJOLT Report. ****READ PAGES 29-37 ONLY**** http://repub.eur.nl/pub/95585

Shoreman-Ouimet, E. and Kopnina, H., 2015. Reconciling ecological and social justice to promote biodiversity conservation. *Biological Conservation*, 184, pp.320-326. https://www.researchgate.net/profile/Eleanor_Shoreman-Ouimet/publication/271850527_Reconciling_Ecological_and_Social_Justice_to_Promote_Biodiversity_Conservation/links/54ed3b640cf28f3e65358191.pdf

Lesson Plan

- Lecture 4.1: "Synthesizing Social Science and Conservation Conceptualizations of Justice in Collaborative Processes and Evaluation" (Two 30-45 minute sessions or one 1.5 hour session; see Box 8 for detailed lecture notes)
    - This lecture introduces students to tensions across different approaches social scientists and conservationists use to study and understand socio-ecological issues and relationships.
    - This lecture also introduces students to the concepts of environmental and ecological justice.
    - The lecture further encourages use of multi-criteria assessment for evaluation collaboratives, and pushes students to synthesize social science and conservationist concerns
    - The small 4.A group activity can begin during class if there is time. Otherwise, the activity can be a group homework assignment.

Activities

4.A Small Group Activity: Peer Reviewing

Students will participate in a peer-review activity that can be done in class or as homework. The students will work in groups of 2-3 people to review their peer's Module 2 assessment assignment. They will be provided hand-out that guides them in their evaluation, but the primary focus will be on identifying areas where their peers can improve their assessments by incorporating information, concepts, and tools from Modules and 3 and 4.

Class Materials

- Session 4.1 Activity 4.A handout “Small Group Activity: Guidelines for Peer Reviewing”
- Session 4.1 handout "Final Assignment Instructions”
- Pen & Paper, or digital device

Homework

Read preparation materials prior to Session 4.1

Small-group peer-review assignment, if not completed in class (Session 4.1 Handout)

Final Assignment: (See session 4.1 homework handout “Final Assignment Instructions”)

- Submit revised assessment evaluations, including peer feedback and a list of policy recommendations for developing a more holistic process of assessment

Concepts and Tools

Concepts: Social scientist approaches to culture, conservation, & justice; conservationist approaches to culture, conservation, & justice; Environmental Ethics; Environmental Justice; Ecological Justice; Multi-Criteria Problems, Analysis, & Evaluation; Anthropocentrism; Ecocentrism

Additional Resources

For teachers, on peer review activity:

http://writing.colostate.edu/guides/teaching/peer/

https://teachingcenter.wustl.edu/resources/incorporating-writing/planning-and-guiding-in-class-peer-review/

Box 8. Module 4 Detailed Lecture Notes for Instructors

The purpose of lecture 4.1 in this module is to introduce students to tensions in how social scientists and conservationists approach socio-ecological issues, continuing to expand of their ability to identify and engage with different ways of knowing that they focused on in Module 3. The lecture is also designed to introduce students to the concepts of environmental and ecological justice. The lecture challenges students to think about how issues of environmental and ecological justice can and should be more fully incorporated into collaborative efforts, goals, outcomes, and evaluations. It further encourages the use of multi-criteria assessment for evaluation collaboratives, which the students studied in Module 2. Finally, this lecture will guide students in their efforts to address and synthesize social science and conservationist concerns in evaluating and measuring the success of collaborative programs focused on socio-ecological issues. Critical concepts that students will be introduced to within this lecture include: environmental ethics, environmental justice, ecological justice, multi-criteria problems, analysis, & evaluation, anthropocentrism, and ecocentrism.

Depending on the course, the instructor should decide how much time is needed to focus on teaching environmental justice and social scientist approaches versus ecological justice and conservationist approaches. An ecology class, for example, may need to spend more time on the former, while an environmental social science class ecology class may need to spend more time on the latter.

The final assignment should tie together all four learning modules. Building on previous modules, students will revise their assessment evaluations to incorporate what they have learned throughout all modules, incorporating suggestions from the peer review process and from their new knowledge of issues of environmental and ecological justice. In revising their assessments, students will include a list of policy recommendations for developing a more holistic process of assessment. These policy recommendations should contain suggestions for improving UCREFRP assessment (i.e. identifying gaps, additions for enhancing equity across stakeholders, different indicators), incorporating considerations of environmental and ecological justice.

Lecture 4.1: Synthesizing Social Science and Conservation Conceptualizations of Justice in Collaborative Processes and Evaluation

This module has only 1 lecture that can be taught over the course of one or two classes. The lecture begins by introducing students to the lecture goals and an overview of the lecture. In addition, it provides it opens the lecture up with an opportunity for a class discussion that reviews what they have learned in the previous two models. The professor can provide a brief review, or ask the class to discuss this together.

Before beginning the new lecture, the students will engage in a class-level discussion on their positionality. Positionality is often understood in sociology as “gender, race, class and other aspects of our identities which serve as markers of relational positions rather than essential qualities.” From this perspective, “knowledge is valid when it includes an acknowledgment of the knower’s specific position in any context, because changing contextual and relational factors are crucial for defining identities and our knowledge in any given situation.” (Maher and Tetreault 1993 p. 118). A variety of factors influence our positionality as people, as professionals, and as scientists (see slide image). Asking students to talk about their own position or standpoint and think critically about how that might influence their work is a way to encourage them to further contemplate different ways of knowing and attempts to synthesize ways of knowing.

To start the new material, slides 5 - 19 draw from the assigned readings, but are centralized around the discussion focused on in Shoreman-Ouimet and Kopnina (2015) comparing conservationist and social scientist approaches to biodiversity and conservation issues. The goal of this reading and the presentation of the materials on these slides is to get students thinking about what challenges there are to approaching socio-ecological issues within transdisciplinary or interdiscplinary teams, and how we can overcome these challenges and reach a point where different approaches can be utilized in a complementary way despite their differences. These slides also draw out definitions and conceptualizations of environmental and ecological justice from Alrøe et al. (2006), and Chan et al. (2014).

The second part of the lecture, beginning on slide 20 draws from Gerber et al. (2012)'s report that focuses on applying multicriteria evaluation to issues of environmental justice. This reading and section of the lecture is a nice addition to what students read on conducting assessments in Module 2--it builds on what they have learned to think about in assessing collaboratives by incorporating issues of environmental justice. While it focuses on environmental justice, it is certainly adaptable to thinking about issues of ecological justice as well. The report draws on case studies of developing oil in the Niger Delta and Ecuador as "multicriteria problems," understood as problems that (a) have a finite set of alternatives and (b) an existing set of different – and often conflicting – valuation criteria under which we evaluate each alternative (e.g. impacts on land use, travel costs, people affected). Thinking about the UCREFRP in this way builds on work the students did in Module 3, analyzing different stakeholder perceptions on the program, its goals, outcome, successes, and failures.

The lecture then goes on to highlight what must need to be taken into consideration in developing a mulitcriteria assessment for the cases (drawn from the same reading). It highlights the potential scenarios, potential stakeholders, factors that act as criteria for decision making (i.e. social, political, economic, environmental), and different indicators for evaluation each potential scenario (i.e. local economy, governance, social cohesion, international relations, etc.). This is critical for getting the students to expand how they have thought about the UCREFRP and collaboratives addressing socio-ecological problems in general up to this point. It should stimulate the students to think about things that either the UCREFRP may not have taken into consideration in practice, or, factors that they had overlooked when they conducted their assessment of the UCREFRP in Module 2.

The final slide on this case highlights the most critical takeaways for improving students' capacity to engage in socio-ecological collaborative efforts in the future. It highlights some of the components of conducting this type of analyses that Gerber et al. (2012) identify as critical for success. They include:

- The key is inclusive participation/deliberation
- From the beginning, an evaluation must include the participation of stakeholders
- A multicriteria approach must be able to acknowledge all positions, including the most radically opposed ones
  Important stakeholders must acknowledge the evaluation of the various scenarios
  The evaluation will lose legitimacy if stakeholders feel betrayed by the indicators used for assessment

- The assessment must be connected with local processes

At the end of the lecture, students will be given instructions for their peer review activity--which can be done in class or as homework. Their final assessment will be to revise their assessment from Module 2 to incorporate what they have learned in Modules 3 and 4, as well as what suggestions they received from the peer review assignment.

*****

END CASE STUDY

APPENDIX A

Module 1 Team Homework Answer Key
Section 1: Linking threats to conservation targets

First identify key ecological attributes of the Colorado pikeminnow.

<u>*Readings*</u>

U.S. Fish and Wildlife Service. 2002. Colorado pikeminnow (Ptychocheilus lucius) Recovery Goals: amendment and supplement to the Colorado Squawfish Recovery Plan. U.S. Fish and Wildlife Service, Mountain-Prairie Region (6), Denver, Colorado. See executive summary, pages 22-33, and Appendix A https://www.fws.gov/southwest/sjrip/pdf/DOC_Recovery_Goals_Colorado_pikeminnow_2002.pdf

Regional Director, Region 6 Fish and Wildlife Service. 1999. "Final Programmatic Biological Opinion for Bureau of Reclamation's Operations and Depletions, Other Depletions, and Funding and Implementation of Recovery Program Actions In the Upper Colorado River Above the Gunnison River." Denver, CO. Read pages 36-37
http://www.coloradoriverrecovery.org/documents-publications/section-7-consultation/15mile/FinalPBO.pdf

1. **What important spatial and temporal processes characterize the life cycle of the fish in general? (e.g. migration, seasonal flooding)**

    - *The Colorado pikeminnow is endemic to the Colorado River Basin, where it was once widespread and abundant in warm water rivers.*
    - *Wild populations are found only in the upper basin, and the species currently occupies only about 25% of its historic range basin-wide.*
    - *Natural reproduction is currently known from the Green, Yampa, upper Colorado, Gunnison, and San Juan rivers.*
    - *Although fish in the Green and upper Colorado River systems spawn at four primary locales, they are likely linked genetically, based on movement throughout the system and lack of genetic separation.*
    - *Colorado pikeminnow are potamodromous (i.e. they undertake regular migrations in large freshwater systems) with adults making long-distance migrations of hundreds of kilometers to and from spawning areas, and thus requiring long sections of river with unimpeded passage.*
    - *The species is adapted to warm rivers and requires uninterrupted passage and a hydrologic cycle characterized by large spring peaks of snowmelt runoff and lower, relatively stable base flows.*
2. **What are its general habitat requirements? (Including flow regimes and temperature)**
    a. **How do these differ at different life stages?**
        - *Adults require pools, deep runs, and eddy habitats maintained by high spring flows. These high spring flows maintain channel and habitat diversity, flush sediments from spawning areas, rejuvenate food production, form gravel and cobble deposits used for spawning, and create backwater nursery habitats.*

- *Spawning occurs after spring runoff (around the summer solstice) at water temperatures typically between 18 and 23°C.*
- *After hatching and emerging from spawning substrate, larvae drift downstream to nursery backwaters that are restructured by high spring flows and maintained by relatively stable base flows.*
- *The pikeminnow has ontogenetic separation of life history stage. The altricial young emerge from whitewater canyons, enter the drift as sac-fry and are transported downstream.*
- *Habitat for the young fish is predominantly alongshore backwaters and associated shorelines of more alluvial reaches of the turbulent and turbid rivers of the Colorado system. In contrast, adults reside in more well-defined channels, where they seek eddy habitats and prey on suckers and minnows.*

3. **What is the diet of the Colorado pikeminnow?**
    - *Young pikeminnows, up to 5 cm long, eat cladocerans, copepods, and chironomid larvae, then shift to insects at around 10 cm, gradually eating more fish as they mature.*
    - *Once they achieve a length of about 30 cm, they feed almost entirely upon fish.*
    - *See Appendix A.10 "Diet" on page A-13 of assigned reading Colorado pikeminnow Recovery Goals (2002)*

Then use your understanding of key ecological attributes of the endangered Colorado pikeminnow to link primary (aka direct) threats to conservation targets.

1. **What are the primary threats to the Colorado pikeminnow?**
    - *Streamflow regulation, habitat modification, competition with and predation by nonnative fish species, pesticides and pollutants*
2. **What are some specific examples of the threats to the Colorado pikeminnow associated with streamflow regulation and habitat modification?**
    - *Streamflow regulation and associated habitat modification*
        - *Dam construction, reservoir inundation of riverine habitats*
        - *(Leading to) changes in flow patterns, sediment loads, and water temperatures*
        - *Decreasing annual peak flows of the Colorado River in occupied pikeminnow habitat since 1950*
        - *Reduced magnitude of spring peak flows and increased the magnitude of summer-winter base flows*
        - *Decreased flows upstream of principal pikeminnow nursery habitat during spring*
        - *Increased flows in the same area during summer through winter due to regulations resulting from Flaming Gorge Dam operation*
3. **What non-native fish species are found within the Upper Colorado River subbasin?**
    - *Non-native species highlighted in the reading: Channel catfish (Ictalurus punctatus), northern pike, (Esox lucius), black bullhead (Ameiurus melas), green sunfish (Lepomis cyanellus), largemouth bass (Micropterus salmoides), black crappie (Pomoxis nigromaculatus), red shiner (Cyprinella lutrensis), fathead minnow (Pimephales promelas)…*
4. **How do streamflow regulation, habitat modification, and interactions with nonnative fish explicitly affect the conservation targets by placing stresses on their population viability and habitat?**

- *Streamflow regulations*
    - *Reduce high velocity flows that flush sediments from spawning cobbles*
    - *Reduce channel and habitat complexity*
    - *(Resulting in) losses in food production*
    - *Reduce availability and quality of backwater nursery habitat*
    - *Leads to the loss of flooded bottomlands during spring runoff, which historically served as feeding areas and thermal refugia during sexual development of Colorado pikeminnow*
- *Habitat modification*
    - *Loss of habitat due to reservoir inundation*
    - *Cold-water releases from dams have influenced warm-water native fish by causing slowed growth and reproductive failure*
    - *Dams reduce flow and create physical barriers to the movements of the Colorado pikeminnow, which have a spawning cycle requiring long-distance migration to and from spawning sites*
    - *Colorado pikeminnow can get stuck (entrained) in canal systems when water is diverted, potentially lowering their survival rate*
- *Nonnative species*
    - *Predation of young-of-year and yearling Colorado pikeminnow by black bullhead, green sunfish, largemouth bass, and black crappie*
    - *Predation of subadult and adult Colorado pikeminnow by channel catfish and northern pike*
    - *Competition with red shiner, green sunfish, and fathead minnow*

5. **What are some management strategies identified in the reading that may help address some of the threats associated with streamflow regulation, habitat modification, and nonnative species?**
    - Manage flows in terms of magnitude, frequency, duration, and timing to benefit the species: e.g. mimicking natural hydropgraph of spring peak flows and summer-winter base flows; enhancing habitat complexity; warm water releases
    - Reducing threat of nonnative fish by promoting high spring flows
    - Strategies for removal and control of nonnative fish
    - Stocking arrangements
6. **Where is the 15-Mile Reach and why is it important?**
    - *The 15 mile reach is a river reach that extends from the confluence Gunnison River upstream 15 miles to the Grand Valley Irrigation Company Diversion Dam near Palisade, Colorado. The subject water depletions occur above the confluence with the Gunnison River, but they affect flows in critical habitat from Rifle to Lake Powell.*
    - *"1) The 15-Mile Reach provides valuable spawning habitat for Colorado pikeminnow and razorback sucker. 2) The 15-Mile Reach provides an optimum balance between temperature and food availability for adult Colorado pikeminnow in the Colorado River. 3) The 15-Mile Reach provides an important refuge for endangered fishes should a catastrophic event cause a loss of populations in the Gunnison River or in the Colorado River below the Gunnison River confluence." (Region 6 Fish and Wildlife Service, 1999, p. 37). See pp. 36-37 for additional details on the importance of the 15-Mile Reach.*

APPENDIX A CONT'D
Module 1 Team Homework Answer Key
Section 2: Elaborating contributing factors

For the Upper Colorado River subbasin (within the state of Colorado), identify possible contributing factors for each of the direct (primary) threats to the Colorado pikeminnow.

Readings:

Bankert, Beck, Boone, D'Amico, and Sueltenfuss (2015). Colorado Headwaters Watershed Opportunities Map and Management Plan. Read Entire Introduction: 1.1-1.7 (Reading Available in Appendix of Case Study Teaching Notes)

Colorado Water Conservation Board (CWCB) (2015). Colorado Basin Implementation Plan. Read pages 12, 20-30, and 34-38. https://www.colorado.gov/pacific/sites/default/files/CBIP-April-17-2015.pdf

1. **What is the potential impact of climate change on streamflows and habitat conditions?**
    - *"Colorado has always been vulnerable to extreme weather and climate events as was evidenced in the droughts of 1930, 1954, 1977, 2002 and 2012. Many Colorado River Basin water providers and agricultural irrigators depended upon surface supply intakes that were severely impaired during the droughts of 1977, 2002 and 2012 due to low river and stream flows and irrigators lost production. Many Colorado River Basin utilities were forced to impose water restrictions. The CWCB and Department of Natural Resources (DNR) address statewide drought planning through the Colorado Drought Mitigation and Response Plan (DMRP). In 2010, the DMRP went through a comprehensive revision and was again updated in 2013. The updated plan provides a blueprint for how the state will monitor, mitigate and respond to drought. The plan consists of four components: monitoring, assessment, mitigation, and response. Monitoring is ongoing and accomplished, at a minimum, by regular meetings of the Water Availability Task Force (WATF The 2013 DMRP will also be used to incorporate drought planning into the Colorado Water Plan as it is developed over the next year (CWCB, 2014). The most serious anticipated impacts of climate change include shifts in timing and intensity of precipitation, streamflows, reductions in late-summer flows, decreases in runoff, increases in drought, and modest declines for Colorado's high-elevation snowpack (Avery, et.al., 2011). These effects will ripple into water supply reliability, impacting municipalities, wildlife, ecosystems, forests, recreation, industries including power generation, snowmaking, energy extraction/ production, and agriculture" (Excerpted from the 2015 Colorado River Basin Implementation Plan reading, p. 23)*
2. **How is population expected to impact water availability?**
    - *"Colorado's population is expected to nearly double by 2050 from approximately 5.1 million people to between 8.6 million and 10 million people. On average, statewide population projections from 2008 forward indicate an increase of about 1.4 million people every 15 years. The fastest growth on a percentage basis is anticipated to take place on the West Slope with growth in some areas in the Basin increasing by 240 percent during the next 35 years (CDM, 2011b). This population growth will drive a significant demand for additional water to meet future municipal and industrial (M&I) demands and self-supplied industrial*

(SSI) water uses including snowmaking, energy extraction and production, and other industrial needs…" (Excerpted from the 2015 Colorado River Basin Implementation Plan reading, p. 23)

3. **Briefly describe Colorado's system of water administration (Prior Appropriation), and summarize some of the key water rights in the Colorado River Basin.**
    - *Answers will vary widely, and this may require additional time in Lecture 1.3 to elaborate. See 2015 Basin Implementation Plan pp. 20-22 and Bankert et al. 2015 section 1.6 for details.*
4. **What is the relationship between water and the economy in the Colorado River Basin?**
    - *Summarized nicely on 2015 Basin Implementation Plan p. 27*
5. **What are some resource-related human values in the Upper Colorado River subbasin identified in Bankert et al., 2015, section 1.4?**
    - *"The public and various stakeholder organizations highly value recreation, agricultural tourism, and the environment, all of which contribute to the economy and social well-being in the Upper Colorado Basin. These values generally promote conservation and stewardship of river water, and stakeholders are largely resistant to future development projects for inter-basin transfers..." (Bankert et al., section 1.4)*
    - *See also pages 34-38 of the 2015 Colorado River Basin Implementation plan*
6. **Brainstorm some of the social, cultural, economic, and institutional factors that might directly affect the following, and how:**
    a. **The abundance and extent of nonnative fish populations**
        - *Example: nonnative fish stocked by wildlife managers to meet demands of sport fishermen*
    b. **The extent and connectivity of the Colorado pikeminnow's habitat**
        - *Example: dams and reservoirs constructed to provide storage for consumptive water uses (e.g. irrigation) and non-consumptive uses (e.g. recreation); these break up the long-distance migration route of the Colorado pikeminnow and alter flow regimes that degrade its habitat.*
    c. **Streamflows and flow regulation**
        - *Example: Colorado's complex system of water rights, and its doctrine of beneficial use, have historically had serious implications for the amount of water left in-stream for fish*
    - *A wide variety of answers may emerge from this question. Students may also bring their own experiences to bear on the question. Instructors should evaluate these based on their interpretation of the readings on pp. 22-33 of the USFWS (2002) reading above, as well as the Bankert et al. (2015) and Basin Implementation Plan readings. Instructors should allow flexibility for interpretation.*
7. **Can you identify opportunities that could have a positive effect (direct or indirect) on the conservation targets? (For example, are there social or economic values associated with the river identified in the readings that might coincide align with reducing threats to the targets?)**
    - *Again, Answers to this will derive from both the readings and students' own knowledge and experience; evaluation of homework answers should be informed by the readings, with flexibility to accommodate creative, out-of-the box answers.*

APPENDIX A CONT'D

Module 1 Team Homework Answer Key
Section 3: Linking strategy to threat

The 15-Mile Reach Historic Users Pool (HUP) phone call is an example of an effort nested within UCREFRP that is applying a strategy to manage streamflows. Describe the actions involved in this call, and think about how it is intended to impact the threats to conservation targets.

Readings

Best, Allen. 2016. "Phoning for Flows." Colorado Foundation for Water Education Magazine. https://www.yourwatercolorado.org/index.php?option=com_content&view=article&id=475:phoning-for-flows&catid=122. **Read entire article**

Bankert, Beck, Boone, D'Amico, and Sueltenfuss (2015). Colorado Headwaters Watershed Opportunities Map and Management Plan. **Read sections 1.4, and 1.6** (Reading Available in Appendix of Case Study Teaching Notes)

1. **Where is the 15-Mile Reach and why is it important to the efforts of UCREFRP?**

   The 15 mile reach is a river reach that extends from the confluence Gunnison River upstream 15 miles to the Grand Valley Irrigation Company Diversion Dam near Palisade, Colorado. The subject water depletions occur above the confluence with the Gunnison River, but they affect flows in critical habitat from Rifle to Lake Powell.

   "1) The 15-Mile Reach provides valuable spawning habitat for Colorado pikeminnow and razorback sucker. 2) The 15-Mile Reach provides an optimum balance between temperature and food availability for adult Colorado pikeminnow in the Colorado River. 3) The 15-Mile Reach provides an important refuge for endangered fishes should a catastrophic event cause a loss of populations in the Gunnison River or in the Colorado River below the Gunnison River confluence." (Region 6 Fish and Wildlife Service, 1999, p. 37). See pp. 36-37 for additional details on the importance of the 15-Mile Reach.

2. **What is the purpose of the HUP call?**
   - *"Meeting target habitat flows set by the U.S. Fish and Wildlife Service for a critical river segment called the 15-Mile Reach, which is directly upstream of Grand Junction, is the essential purpose of the Phone Call, although, since its inception in 1995, the agenda has broadened to other matters" (Best, 2009, para. 2).*
3. **Which of the direct threat(s) described in the in-class activity does this strategy address?**
   - Streamflow regulation, habitat modification; high spring flows can also reduce competition with nonnative fish by creating better, more complex habitat that promotes production of food sources (invertebrates)
4. **Who are some of the major water users and other stakeholders that might participate in** a **given weekly call?**
   - *As many as 30 water user representatives may participate in the call from all over the state, including water users on the front range of Colorado (where most of the population of the state resides).*

- *The U.S. Fish & Wildlife Service represent the interest of the endangered fish, and through federal regulatory water rights, they have ultimate say over how much water much water must be delivered downstream for the fish. The USFWS sets target flows to meet the needs of the fish downstream; this water comes from 6 upstream reservoirs (Granby, Williams Fork, Wolford, Dillon, Green Mountain, and Ruedi)*
- *The Bureau of Reclamation provides a lot of water infrastructure in the region, including two of the above dames: Ruedi and Green Mountain, which contributed 21% and 59% of the 2008 target flows (the rest coming from the other reservoirs in the system). A representative from the BoR also moderates the phone call.*
- *Major senior water right holders, including*
    - *Agriculturalists in the Grand Valley with very senior water rights, e.g. the Grand Valley Irrigation Company, Grand Valley Water Users Association*
    - *Senior rights upstream from the Shoshone plant, including those who divert water from the Colorado River to supply cities on the Front Range, such as the Colorado-Big Thompson water project*
    - *The Shoshone Hydroelectric Plant, operated by Xcel Energy*
- *Environmental groups interested in restoring flows to benefit the fish and natural systems, e.g. the The Nature Conservancy, Western Resource Advocates*
- *Whitewater rafters and boaters, e.g. Timberline Tours*
- *Anglers and fly fishing guides, e.g. Trout Unlimited, Colorado River District,*
- *Water conservancy districts, e.g. Northern Colorado Water Conservancy District, Colorado River District*
- *Water accountants, e.g. the State Engineer and/or Regional Engineers, within the Colorado Division of Water Resources*

5. How does water move in, out, and through the system?

- *This is complex and benefits from the instructor reading the Phoning for Flows article; we also recommend allocating some of Lecture 1.3 to this question prior to Activity 1.C*
- *Most of the Colorado River's flows begin as snowpack in its headwaters in and around Rocky Mountain National Park*
- *Dams, canals, other structures divert water from the mainstem and tributaries*
- *Much of the spring runoff flows out of the state to meet the Colorado River Compact of 1922, Rio Grande/ Colorado/ Tijuana Treaty of 1944 between the US and Mexico, and the Upper Colorado River Basin Compact of 1948: See http://cwcbweblink.state.co.us/weblink/docview.aspx?id=113227&searchhandle=30039&&dbid=0*
- *Only 25% of the runoff stays within the basin, and 75% of that is diverted for extractive uses, like irrigation, municipal/industrial use, domestic use*

6. How does the phone call alter those flows?

- *Reservoir operators provide 10,825 acre-feet of water to enhance habitat flows in the 15-Mile Reach while cooperating on other measures with federal entities to enhance flows to meet targets for endangered fish and create fish passages at dams.*
- *The weekly HUP calls take place throughout the irrigation season*
- *There has been some reduction in diversions from irrigation, and before 2002 the project's irrigators diverted 285,217 acre feet annually. Since then, they draw 240,000*

acre feet annually, leaving more water in the river for the fish with physical improvements financed by the recovery program

- *See Best (2009) reading for more details*

7. What are the biggest constraints associated with flow management?

- *This is largely open to student interpretation, but should include something related to water rights or legal compacts, and availability of water*

8. What is the process of interaction for participants on the call?

- *They share who's on the call that week*
- *A hydrologist reports modeled flows based on temperature and precipitation forecasts*
- *A meteorologist issues a 10-day weather forecast*
- *Gauge readings at points along the River are reported*
- *Reservoir operators report on levels and status of each reservoir*
- *They build consensus and make decisions about how much water will be released to flow in every tributary of the mainstem of the Colorado River*

****End Homework Answer Key****

APPENDIX B
READING

COLORADO HEADWATERS WATERSHED

OPPORTUNITIES MAP AND MANAGEMENT PLAN

Andrew Bankert

Whitney Beck

Karie Boone

Timothy D'Amico

Jeremy Sueltenfuss

Report Prepared for:

Sustaining River Hydroecosystems for Biota

Fall 2015

Table of Contents

Executive Summary

The Upper Colorado River, flowing from the headwaters in Rocky Mountain National Park to the confluence with the Gunnison River in Grand Junction, CO is an imperiled watershed with a diverse group of stakeholders and physical stressors that threaten the system's aquatic biota. Some of these physical stressors include flow depletions from agriculture and transbasin diversions, loss of connectivity due to flow depletions and the installation of dams and diversion structures, and water quality degradation due to mining, agriculture, and urbanization. The riparian wetlands are characterized by the draining of freshwater fens as well as areas inundated by high flows. The aquatic communities in the "Southern Rocky Mountain" portion of the watershed are dominated by coldwater salmonids, salmonfly (*Pteronarcys californica*), and other stoneflies, and the aquatic communities in the "Colorado Plateau" portion of the watershed are represented by a more diverse native fish assemblage, including the endangered Colorado pikeminnow (*Ptychocheilus lucius*). The stakeholders in the basin view recreation, agriculture, tourism, and the environment as important cultural values for the Colorado River. Diverse stakeholders at multiple decision-making levels manage water in the basin at the federal, state, and at the local basin roundtable. Water allocation and access are administrated through water rights and the prior appropriations doctrine, which states that the 'first in time' is 'first in right' to the water in the basin.

To develop a management plan, six key objectives are defined. These objectives include: (1) analyzing data on physical and ecological stressors, (2) analyzing historic and current flow patterns, (3) characterizing the water quality and land use in the basin, (4) identifying management gaps and proposing alternatives to address ecological and physical stressors, (5) analyzing wetlands management, and (6) creating an "opportunities" map where management can be improved in the basin. The flows in the basin are analyzed using historical data from USGS stream gages. The water quality and biota metrics are analyzed from the EPA's Environmental Monitoring and Assessment Program and the USGS National Water Quality Assessment. Wetland data is mapped from the National Wetland Inventory. These six objectives can be thought of within the legal and institutional context generally and the Upper Colorado River Endangered Fish Recovery Program (UCREFRP) more specifically. The UCREFRP is examined to better understand how management practices within the basin can be improved and the endangered Colorado pikeminnow population numbers increased.

Our analysis found that the flows in the "Southern Rocky Mountain" portion of the watershed are heavily impaired while the flows in the "Colorado Plateau" portion are only slightly smaller than historic flows. The water quality was found to be higher in the Upper Colorado than more urbanized basins, but segments of the Upper Colorado have been placed on the Colorado Clean Water Act section 303(d) due to aquatic life, heavy metals, sediment, and temperature. Macroinvertebrate health was negatively correlated to the EPA's water chemistry parameters, which were heavily affected by nearby land use. About half of the wetlands in the basin are on private land, and an opportunities map was created to identify the best restoration potential for wetlands and streams in the basin.

As a result of the analysis, recommendations were created to restore the timing and magnitude of flow through the basin. This can be accomplished by releases from dams as well as limits on diversions while still allowing an adequate amount of water to be used for municipal and agricultural uses. Management recommendations to improve water quality through adjusting land use and land management practices were made to support macroinvertebrate health. The opportunities map shows the areas of highest wetland restoration potential. Recommendations for the UCREFRP include mitigating power differentials through increased federal funding, linking success to fish population health, linking hydrology to aquatic biodiversity, implementing "process-based" restoration principles, and creating a committee to develop, facilitate, and evaluate social learning processes within the basin.

1. Introduction

1.1 Basin Overview

The Upper Colorado River flows from the headwaters in Rocky Mountain National Park to the confluence with the Gunnison River in Grand Junction, CO. This unique stretch of the Colorado is governed by diverse groups of stakeholders and management units that confront an imperiled system with many physical stressors that threaten the system's biotic composition. The main physical issue associated with restoring and sustaining aquatic biota in the Upper Colorado River is the amount of water available for the channels and floodplains. Although the river transports a large supply of water, a significant proportion leaves the basin due to trans-basin diversions to Colorado's Front Range and downstream delivery requirements under the Colorado River Compact (CWCB 2015). Of the remaining water, a large portion is diverted for agriculture. Future stressors of water supply include projected population increases, increased municipal and industrial needs, and climate change impacts on supply (CWCB 2010; Gordon and Klein 2015).

In addition to uncertainty in the water supply, several large dams have been built along the mainstem of the Colorado River in Colorado, including the Price-Stubb, Grand Valley, Windy Gap, Granby, and Shadow Mountain dams. These dams supply hydropower, water for irrigation, and infrastructure to pipe water across and under the continental divide to the Front Range. The dams additionally impact the instream flow, sediment regime, lateral connectivity, and longitudinal connectivity of the basin to varying degrees.

Riparian wetlands along the Colorado are a mix between groundwater fens draining into the river and floodplain wetlands sustained by high flows in the channel. Research in the late 2000s identified the driver of floodplain formation in the upper portions of the Colorado River as beavers, rather than high flood events (Westbrook et al. 2006). The backwater effects behind beaver dams led to sediment deposition that created a floodplain elevation above what could be sustained through flooding alone. Now that beavers are largely absent from the system, the river is quite incised and does not access the floodplain even under higher than average flows. As the river enters the lower portions of our interest area, the floodplain is largely inactive as a result of river regulation from dams and water extraction from diversions (Nilsson and Berggren 2000).

Aquatic communities have also been impacted by the dams and water management, including both fish and macroinvertebrates. The "Southern Rocky Mountain" (SRM) portion is dominated by coldwater salmonidae, while the lower "Colorado Plateau" contains a more diverse native fish assemblage, including the endangered Colorado pikeminnow (*Ptychocheilus lucius*) (Deacon & Mize 1997). With regard to macroinvertebrates, salmonfly (*Pteronarcys californica*) along with other stonefly populations, which are key indicators of water quality, are in decline due to lack of water (Kowalski 2014). Fish and macroinvertebrate communities are further affected by land use practices in the different physiogeographic provinces (SRM; mining, CP; agriculture) as well as increasing urbanization.

Water quality is another constraint to ecosystem health that is exacerbated by dams, mining, and water extraction. The Clean Water Act 303(d) list shows streams listed in the Upper Colorado for heavy metals, temperature, sediment, and aquatic life (CDPHE 2012). Furthermore, the Eagle Mine (located on the Eagle River, a major tributary in the SRM province) was designated as a superfund site in 1988. While a 2000 EPA report claimed that clean-up efforts had significantly reduced harmful effects to human and environmental health, the Upper Colorado River has an extensive history of mining and the detrimental and cumulative effects of mining on environmental health span beyond the clean-up of one former mine among thousands.

Climate change remains a significant management hurdle to overcome, as expected streamflow changes in the Upper Colorado have been historically difficult to model. According to the Colorado Climate Change Vulnerability Study, under most climate scenarios we can expect to see less snowpack, earlier snowmelt, and more severe droughts (Gordon and Klein 2015). Overall, climate change will likely lead to lower streamflows and higher temperatures that will further degrade aquatic habitat. The combination of large amounts of water diverted from the channel and the uncertainty in the future amount of water in the basin will force new management practices to be adopted in the basin.

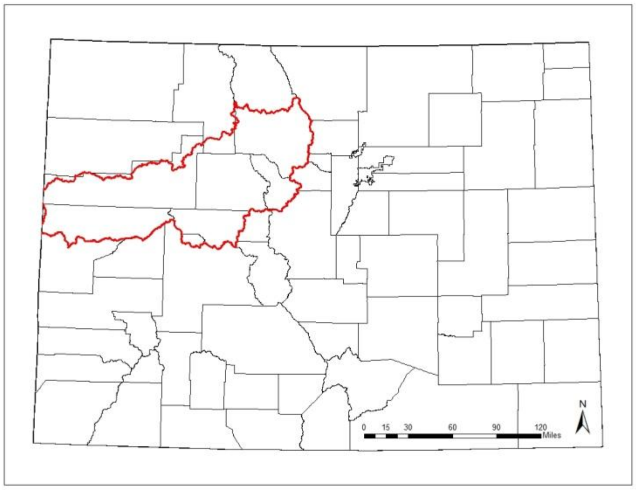


Figure 1: Colorado Headwaters Watershed boundary in Colorado (red). Black lines show Colorado counties (data from coloradoview.org)

1.2 Colorado Headwaters Watershed

The Upper Colorado River Basin encompasses about 17,800 square miles, of which about 10,000 are located in the state of Colorado (Figure 1). The Colorado subset of the basin is the primary focus of this report. The primary river, the Colorado River, originates in the mountains of central Colorado and flows approximately 230 miles southwest into Utah. The basin within Colorado is composed of two physiographic provinces: the Southern Rocky Mountains and the Colorado Plateau. The topography varies from mountainous regions in the Southern Rocky Mountains to high plateaus bordered by steep cliffs along valleys in the Colorado Plateau. Due to drastic differences in altitude, the climate ranges from alpine conditions in the Southern Rocky Mountains to semiarid/arid conditions in the Colorado Plateau. Consequently, precipitation varies from 40 inches annually at high elevations in Southern Rocky Mountains to less than 10 inches annually in the Colorado Plateau (Spahr et al 2000, Figure 2).

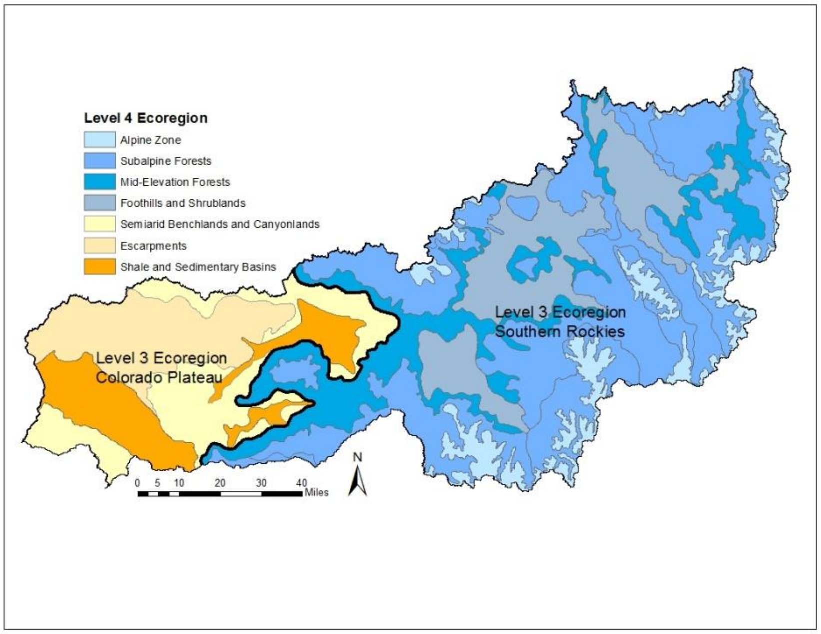


Figure 2: Level 3 and 4 ecoregions within the Colorado Headwaters. (Data from geodata.epa.gov).

The Southern Rocky Mountain Ecoregion, dominating the eastern portion of the Colorado Headwaters watershed, is characterized by steep subalpine and alpine zones surrounding high elevation valleys. Human activities in this high elevation zone include forestry, livestock grazing, mining, and tourism. The western part of the study area, the Colorado Plateau, is characterized by dry, low elevation basins and canyons with dominant human activities including oil and gas production, agriculture and livestock grazing, and recreation. Elevations in the Southern Rocky Mountain range from just under 5,000 ft. to over 14,000 ft.

1.3 Land Use and Ownership

Wetlands are an integral component of the Rocky Mountain landscape. They provide a host of beneficial services, such as flood abatement, storm water retention, groundwater recharge, and water quality improvement (Mitsch & Goselink 2007; Millennium Ecosystem Assessment 2005). Wetlands are particularly important for wildlife because they are highly productive and diverse ecosystems, providing habitat for many species. For example, in many parts of the Rocky Mountain West, over 90% of wildlife species depend on wetlands or riparian areas at some point in their life (McKinstry et al. 2004).

The relative importance of wetlands is underscored by the fact that they occupy a small fraction of the landscape. Though total acreage of wetlands in the Rocky Mountains is unknown, estimates exist on a state level. Estimates for Colorado place the extent at roughly 1 million acres or 1.5% of the land area (Dahl 1990). Historically, Colorado likely supported twice the wetland acreage that exists today. Up to 50% of Colorado's original wetlands have been drained, converted to farmland or urban development, or lost as a result of water diversion and storage.

Land cover (Figure 4) within the eastern portion of the Colorado Headwaters is predominantly forested, shrub, and grasslands, with some pasture and smaller areas of developed land adjacent to the Colorado River. In the western portion of the watershed, the valleys become wider, with a result of increased developed land, cultivated crops, and pasture land. Forested and shrub land is predominantly located on hillsides.

Land ownership is highly consistent with changes in terrain, similar to many high mountain watersheds in Colorado (Table 1, Figure 3). Land at higher elevations or on steeper slopes is federally or state owned, while land in the valleys is generally privately owned. Because valleys are more expansive in the western portion of the watershed, there is more private ownership to the west in the lower elevations than in the eastern high elevations.

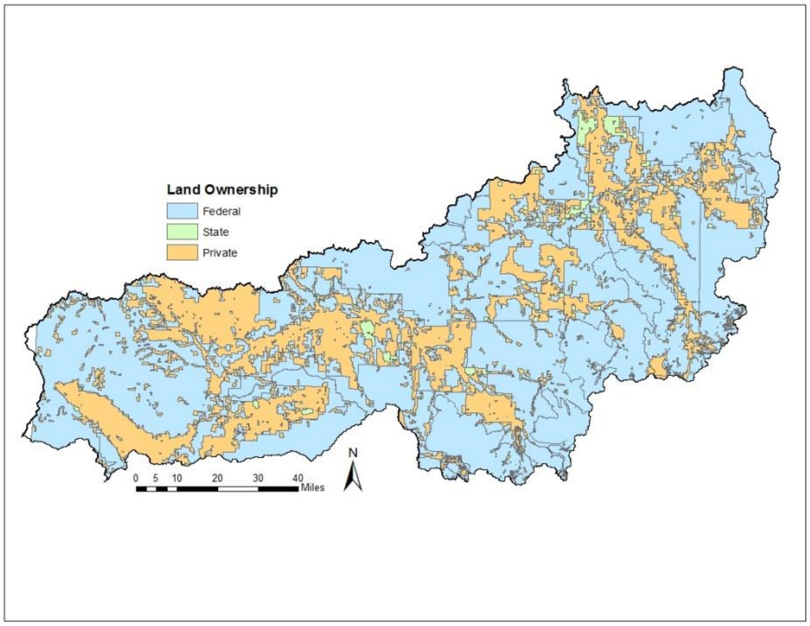


Figure 3 Land ownership within the Colorado Headwaters

Table 1: Land ownership within the Colorado Headwaters watershed.

Ownership	**Acres**
Federal	4,341,406
State	94,297
Private	1,846,796

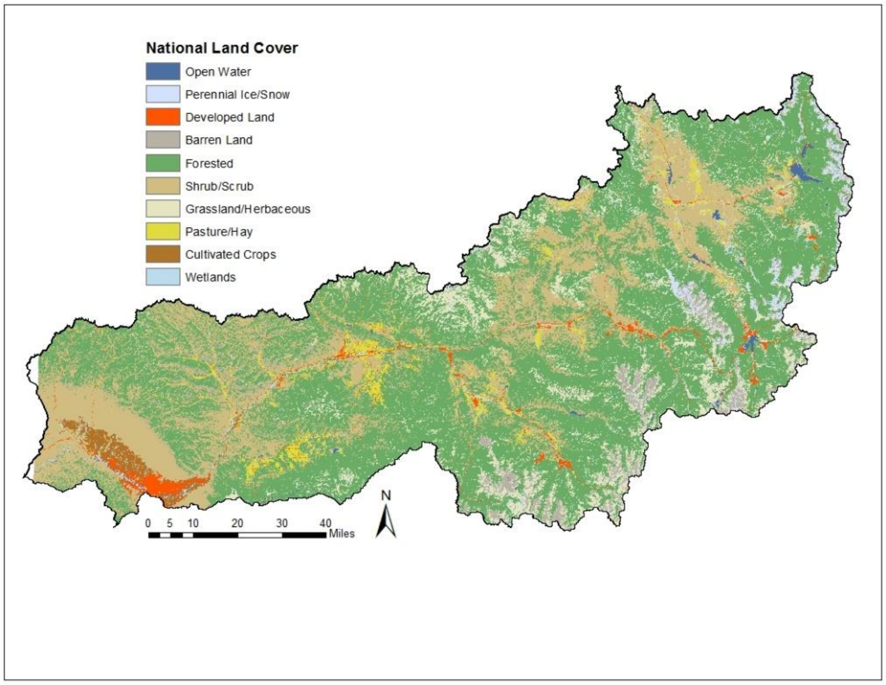


Figure 4: National Land Cover Data within the Colorado headwaters (data from coloradoview.org)

1.4 Water Extraction and Public Water Values

Spring snowmelt runoff provides a significant portion of the Colorado River's water supply. Many dams, canals, and other structures divert water from the Colorado River mainstem and its tributaries. However, only about 25% of the runoff is actually used within the Upper Colorado Basin in Colorado (CWCB 2015). Within the basin (Figure 5**)**, irrigation is by far the largest extractive use (>75%). Water storage, fisheries, municipal, and domestic uses lag behind irrigation but are nonetheless important water uses that may increase in demand in the future (CWCB 2009). Despite the socially-important beneficial uses supported by water storage, dams can negatively affect aquatic ecosystems by entraining sediment, altering thermal and flow regimes, altering nutrient cycling, and preventing longitudinal movement of fish (Lignon et al. 1995).

Surface water diversions are also put to beneficial use outside the Upper Colorado Basin. Around half a million acre-feet of water (5% of basin runoff) is removed from the Upper Colorado River Basin through trans-basin diversions every year (CWCB 2015b). Water is transported across the Rocky Mountains to Eastern Colorado to supply cities and farms (Figure 6**)**. The largest transbasin tunnels include Adams, Moffatt, and Roberts, although a total of 11 transbasin diversions move water from Western to Eastern Colorado (Table 2). Up to 70% of the basin runoff flows out of Colorado to satisfy interstate requirements under the Colorado River Compact (CWCB 2015b).

Future stressors of water supply include projected population increases (CWCB 2010), increased municipal and industrial needs (CWCB 2010), and climate change impacts on supply (Gordon and Klein 2015). For the seven counties in the Upper Colorado Basin, population is expected to double by 2050, compared to a 2008 baseline population (Appendix 1). As a result of population increases and a growing energy industry in Colorado, annual municipal and industrial water demands will also double by 2050 (CWCB 2010).

Expected climate-induced streamflow changes in the Upper Colorado have been historically difficult to model, with different studies producing conflicting results. Ficklin et al. (2012) divided the Upper

Colorado into sub-basins and modeled changes in each part of the hydrologic cycle. Despite only small decreases in precipitation under most scenarios, decreases in snow and increases in evapotranspiration will drive lower spring (-35% on average) and summer (-45% on average) streamflow. The Colorado Climate Change Vulnerability Study also determined that the Upper Colorado River Basin will likely experience a future with less snowpack, earlier snowmelt, and more severe droughts, as compared to historical conditions (Gordon and Klein 2015).

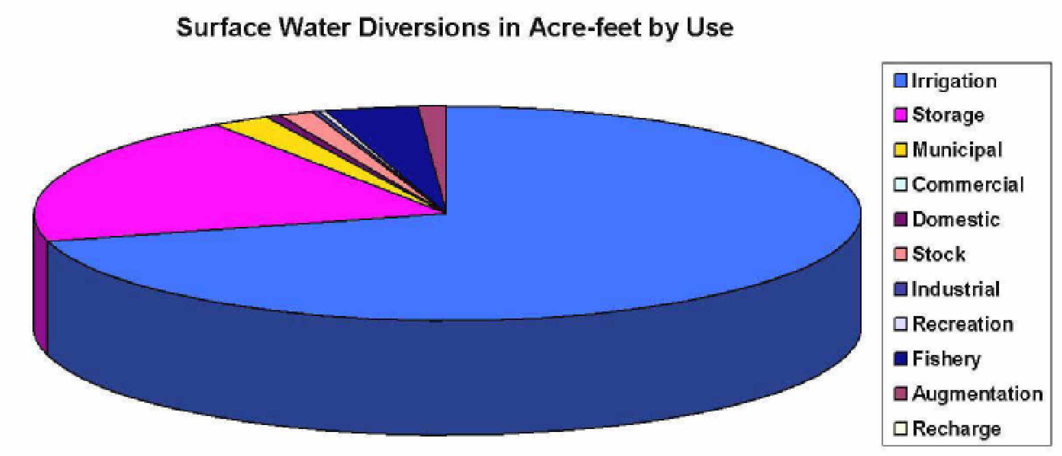


Figure 5: Surface water diversions (in acre-feet) are shown for each type of use within the Upper Colorado Basin (Source: CWCB 2009).

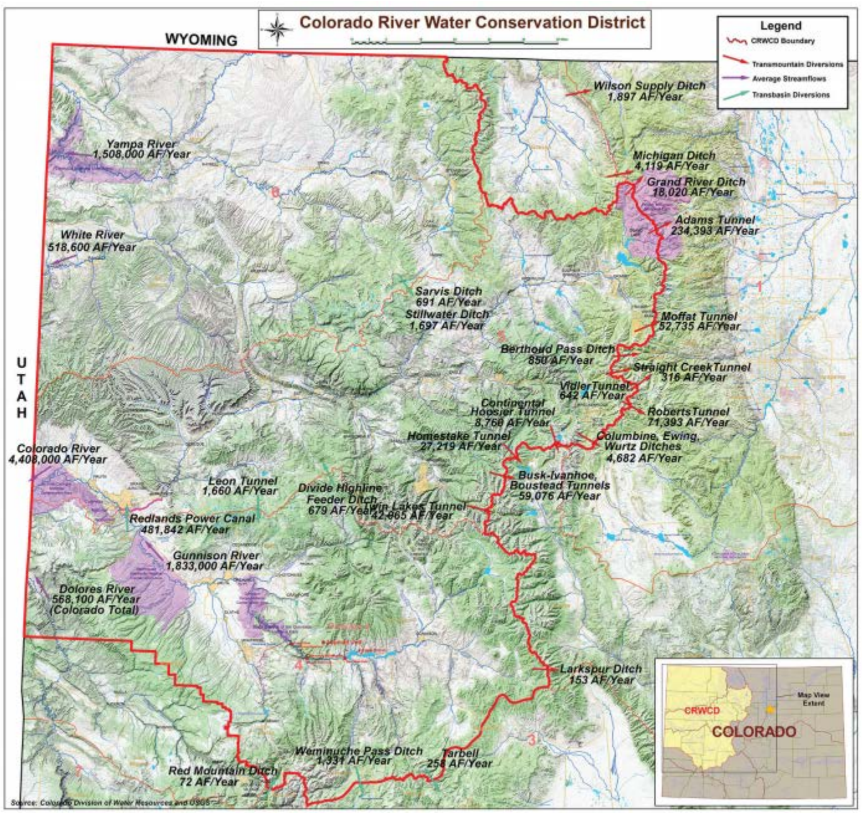


Figure 6: Each year, 450,000-600,000 acre feet are transported across the Rocky Mountains to Eastern Colorado to supply cities and farms. This map shows the transbasin and transmountain diversion points, with the three biggest tunnels located in the Upper Colorado Basin (Source: CBR 2015).

Transbasin Diversion	Diversion Amount (acre-feet)
Grand River Ditch	18,559
Adams Tunnel	247,735
Moffat Tunnel	51,726
Roberts Tunnel	93,645
Wurtz, Columbine, Ewing Ditches	4,830
Hoosier Pass Tunnel	10,770
Homestake Tunnel	26,914
Busk-Ivanhoe Tunnel	5,210
Boustead Tunnel	44,830
Twin lakes Tunnel	42,117
TOTAL	**546,336**

Table 2: Transbasin Diversions and the annual diversion amount from each diversion. (Source: Winchester)

The public and various stakeholder organizations highly value recreation, agricultural tourism, and the environment, all of which contribute to the economy and social well-being in the Upper Colorado Basin. These values generally promote conservation and stewardship of river water, and stakeholders are largely resistant to future development projects for inter-basin transfers. Figure 7 shows public responses regarding how the basin should meet future water needs, and demonstrates that people are largely supportive of conservation, increasing storage, increasing in-stream flows, and limiting future growth (CBR 2015).

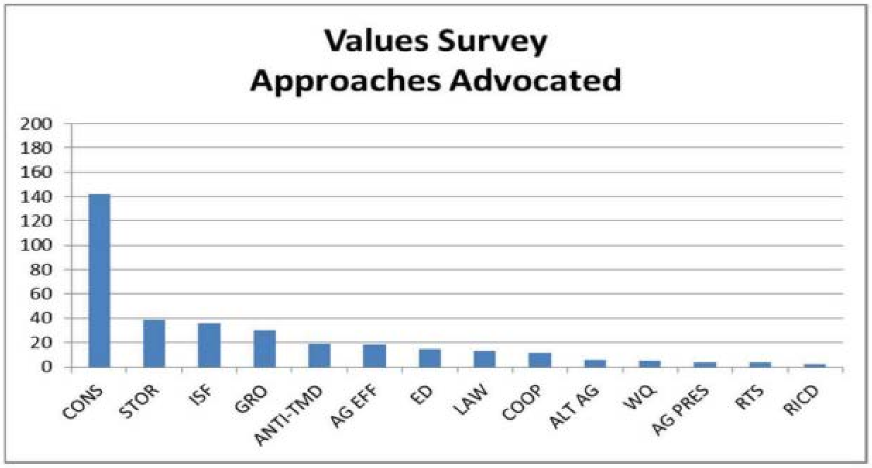


Figure 7: Over 200 adults in the Upper Colorado basin responded to a public values survey about the river. This figure shows free-form responses to the question: "what approaches do you favor for meeting future water needs"? CONS=conservation, STOR=increased storage, ISF=in-stream flows, GRO=limiting growth, ANTI-TMD=anti-transmountain diversions, AG EFF=ag efficiency, ED=public education, LAW=legal changes, COOP=cooperative approaches, ALT AG=non-permanent agricultural transfers, WQ=water quality, AG PRES=agricultural preservation, RTS=preserving water rights, RICD=recreational water rights. (Source: CBR 2015).

1.5 Biota

As a part of the National Water Quality Assessment (NAWQA) program, the United States Geological Survey (USGS) has committed to study water quality conditions across the nation. The USGS has been conducting studies in the Upper Colorado River basin (UCOL) focusing on the interactions of biota and contaminants since 1938 (Deacon & Stephens, 1996). Most of these studies have focused on macroinvertebrate and fish communities, but also include sediment, algal and trace element studies.

The UCOL can be divided into two sub-basins; the Southern Rocky Mountain (SRM) physiogeographic province and the Colorado Plateau (CP) physiogeographic province. The two physiogeographic provinces vary extensively, including but not limited to land use, physical geography, biological communities, water chemistry, etc. Due to the vast physiogeographic differences between the Southern Rocky Mountains (SRM) and the Colorado Plateau (CP), there will be obvious shifts in both macroinvertebrate and fish communities based on their local habitat. According to the USGS UCOL reports, the major controlling factors that determine composition of biological communities in the two physiogeographic provinces are thermal profiles, velocity profiles, substrate composition, physiochemical conditions and physical habitat (Deacon & Stephens, 1996). However, land use effects have further influenced shifts in community compositions.

The SRM physiogeographic province is dominated by a coldwater fish assemblage, including trout, dace, sculpin and Longnose Sucker. Trout constitute the majority of the fish biomass in the SRM, and as such prey upon the native fishes (dace, sculpin, etc.). Other native fishes include mountain sucker, mountain whitefish, mottled sculpin and Colorado cutthroat trout. Fish communities in the SRM are of extreme recreational benefit to the region, with four major stream sections designated as "Gold Medal Trout water". The macroinvertebrate assemblage is dominated by specialist species such as caddisflies, mayflies, and stoneflies. Both the fish and macroinvertebrate assemblages in the SRM physiogeographic province rely on cold, clean water with coarse substrate.

The CP physiogeographic province is dominated by a warmwater fish assemblage, including minnows, suckers, bass, carp, etc. Fish communities in the CP are of extreme conservation concern, including four federally endangered species; Colorado pikeminnow, humpback chub, razorback sucker, and bonytail chub. Other native species include flannelmouth sucker, bluehead sucker, speckled dace, and Kendall warm springs dace. The macroinvertebrate assemblage is dominated by aquatic worms, leeches, and dragonflies. Both fish and macroinvertebrate assemblages in the CP physiogeographic province tolerate warmer water with lower dissolved oxygen content and finer substrate types.

1.6 Colorado River Water Governance: Legal and Institutional Setting

Table 3 provides an overview of the governance framework within which water management decisions take place. The Upper Colorado River Compact is an interstate agreement that delineates the amount of water that Colorado must deliver to the state of Utah. Important federal agencies include the Bureau of Reclamation, responsible for the funding and maintenance of much of the large water infrastructure on the mainstem. Bureau projects are particularly important when considering the health of the Colorado since their infrastructure needs to allow fish passage. Administratively, the water rights associated with these projects are tied to the land and cannot be taken out of agricultural use as defined in 30-year contracts between the bureau and water providers such as conservancy and irrigation districts.

Apart from some federally administered water rights, state water governance entities must follow the principles provided by the system of prior appropriation, the legal framework for water allocation in Colorado and the West. The principles of prior appropriation states 'first in time, first in right', meaning that the person that obtained a water right first has the right to use it to the exclusion of others during times of shortage (Jones and Cech 2009). Diverted water must be continually put to a beneficial use such as municipal, industrial, and irrigation[1]. Ownership is not tied to the land so that water can be transported to distant locations for use while rights can be sold and the purchaser would maintain the same 'priority' as the original owner (Jones and Cech 2009). The water court, division engineer, and water plan must operate within this legal framework.

At the local level, the basin roundtable is a decision-making entity that represents diverse user groups including M&I, Agricultural, Environmental, and Recreational with both voting and nonvoting members working to address shortages in the headwaters region. Conservancy and irrigation districts provide water to these multiple users, maintain water infrastructure and may facilitate projects by administering and allocating external funding. These districts tend to have the most direct influence with water users on the ground. Understanding how water rights are administered, how infrastructure is managed, and who is making these decisions for whom is key to considering which areas have the most potential for conservation and restoration on the mainstem of the Colorado River.

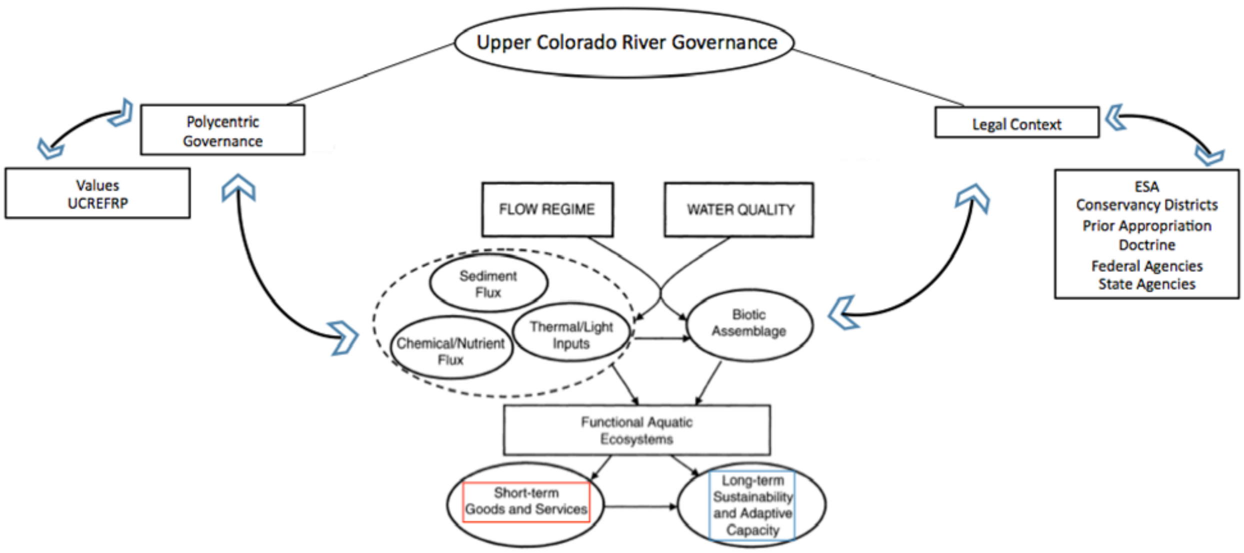
Finally, the focus of the institutional analysis will be on the Upper Colorado River Endangered Fish Recovery Program (UCREFRP), a multi-agency arrangement encompassing all the entities identified in Table 3. The Recovery Program formed a collaborative governance process with the goal of delisting four fish species - the humpback chub, bonytail chub, Colorado pikeminnow, and razorback sucker - from Endangered Species Act protection by 2023. The UCREFRP is an exemplary case of how water conflicts might deter expensive legislation and court battles through (potentially polycentric) collaborative water governance. The case has considerable influence on how water is developed in the basin and the protections for sustainable river management processes. The success of the program is identified as one of the primary management issues on the Colorado mainstem and allows for the future use of Colorado River water in compliance with interstate compacts, treaties, and applicable federal and state law (CWCB 2015).

[1] Beneficial use refers to the use, or purpose for making an appropriation of water, which is most often for an economic benefit.

Table 3: Overview of Key Governance Entities at Multiple Decision Making Scales		
Interbasin		
	Upper Colorado River Compact 1948	Establishes the af/year allotment for each upper basin state; managers insure that appropriate quantities flow out of the Upper Colorado to UT
Federal Agencies		
	USFW	Manages threatened and endangered species recovery programs and regulates actions impacting listed species under ESA; responsible for determining if a project exceeds the bounds of any programmatic biological opinions regarding further water development; coordinate NEPA compliance regarding a project's potential impacts to threatened and endangered fish and wildlife species; participation in Fish Recovery Program, restoration, monitoring and management
	Bureau of Reclamation	Partnerships with local ag water supply organizations to build and maintain water infrastructure: dams, power plants and canals; water wholesaler
State Governance		
	Water Court	Jurisdiction over all water right applications, due diligence, exchanges and augmentation plans, sets priority date and amount
	Division 5 Engineer	Administers water rights, insures senior right holders receive decreed quantity, employs water commissioners to get in field and insure water properly allocated
	State Water Plan	Basin Implementation Plans from each basin were developed into the statewide water plan that aims to fill the supply-demand gap while satisfying all beneficial uses
Local Governance		
	Colorado River Basin Roundtable	Representatives from diverse user groups including M&I, Agricultural, Environmental, Recreational work to address shortages in the

		headwaters area; gather data for SWSI; Look at the impacts of transbasin firming projects; Look at compact delivery impacts to existing and future in-basin water rights; Ensure endangered species' needs do not negatively impact future in-basin needs; Identify nonconsumptive needs for environmental and recreational flow and ultimately ensure adequate water supply for future needs
	Watershed Coalitions	Middle Colorado Watershed Council has carried out water quantity studies, organized clean-up days, and is developing a watershed plan
	Conservancy Districts	Colorado River District: water policy and planning agency; provide legal, technical, and political representation for their constituents in the CRB. They work with a diverse set of users but have a primary goal to keep water in agriculture and on the west slope (i.e., not diverted to east slope)
	Irrigation Districts and Companies	A public organization that supplies water to residents of the district through diversions, canals, laterals, pipes and other water transport systems primarily for the purpose of agricultural irrigation
Polycentric Governance?		
	Upper Colorado River Endangered Fish Recovery Program (UCREFRP)	A multi-agency arrangement formed to address ESA on 4 endangered fish in on the mainstem of the Colorado River; program includes provision of instream flows; habitat development and maintenance; native fish stocking; management of nonnative species and sportfishing; and research, monitoring, and data management

1.7 Conceptual Model



Model 1: This conceptual model ties together the positive feedbacks between the legal and institutional context with the hydroecological characteristics of the Colorado River mainstem

****SECTIONS 2-4 OMMITTED PER AUTHOR REQUEST****

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Appendix 1: *Expected population (top) and municipal water demand increases (bottom) by 2050 in the Colorado Basin by county. (CWCB 2010)*